ISSN 1175-1584

MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

Alfonsino (*Beryx splendens*) abundance indices from standardised catch per unit effort (CPUE) analysis for the east coast North Island (BYX 2) midwater trawl fishery, 1989–90 to 1997–98

R. G. Blackwell

New Zealand Fisheries Assessment Report 2000/53
December 2000

Alfonsino (*Beryx splendens*) abundance indices from standardised catch per unit effort (CPUE) analysis for the east coast North Island (BYX 2) midwater trawl fishery, 1989–90 to 1997–98

R. G. Blackwell

NIWA
PO Box 893
Nelson

New Zealand Fisheries Assessment Report 2000/53
December 2000

Published by Ministry of Fisheries
Wellington
2000

ISSN 1175-1584

Citation: Blackwell, R.G. 2000:
Alfonsino (*Beryx splendens*) abundance indices from standardised catch per unit effort (CPUE) analysis for the east coast North Island (BYX 2) midwater trawl fishery, 1989–90 to 1997–98.
New Zealand Fisheries Assessment Report 2000/53. 40 p.

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

EXECUTIVE SUMMARY

Blackwell, R.G. 2000: Alfonsino (*Beryx splendens*) abundance indices from standardised catch per unit effort (CPUE) analysis for the east coast North Island (BYX 2) midwater trawl fishery 1989–90 to 1997–98.

New Zealand Fisheries Assessment Report 2000/53. **40 p.**

Most of the 1368–1868 t of alfonsino landed in BYX 2 between 1989–90 and 1997–98 was taken in the small target fishery that involved only 27 vessels. Alfonsino is also taken as bycatch of gemfish, hoki, and other target fisheries in QMA 2.

This report compares two standardised CPUE indices from the target midwater trawl fishery during the fishing years 1989–90 to 1997–98, using loglinear (LNL) and gamma log link (GLL) models. Data for the 1988–89 fishing year were excluded from analysis due to poor quality and low quantity. The CPUE (catch/day) estimator, which is based on CELR and TCEPR data, includes the searching time and exploratory fishing components that characterise this fishery. This is compared to an alternative estimator of CPUE (catch/tow) derived from TCEPR tow-by-tow data.

An initial examination of the data determined a high turnover of vessels in this fishery, and a high level of vessel movements between fishing grounds and statistical areas. None of the vessels involved in the fishery fished for the entire time period, and most remained only for a short time in the fishery. An alternative CPUE analysis was also completed for the main vessels in this fishery. Data were grouped into four fishing grounds (Madden, Palliser, Ritchie, Other) in this analysis.

For the CPUE (catch/day) estimator, the variability in the LNL model for all vessels was mainly explained by the number of shots, categorical vessel ID, month of fishing, and fishing year. The standardised CPUE indices declined steeply from 1989–90 to 1991–92, then stabilised from 1993–94 to 1997–98. The indices showed less year to year variability than the raw CPUE values, and indices for the GLL all-vessel model followed a similar trend. Indices for the main-vessels analysis from both the LNL and GLL models were slightly higher, but followed a similar trend to the indices for the all-vessel data for these models.

For the CPUE (catch/tow) estimator, the raw data were variable with little trend, and fishing year was forced into the LNL and GLL regression models to derive annual indices. Both the LNL and GLL all-vessel indices displayed little trend, and showed less year to year variability than the raw CPUE values. The LNL statistical area indices were higher for the northern areas, although insufficient data were available to determine a difference in CPUE indices for the main-vessel analysis. Much of the variability in this fishery appeared to be associated with vessel-level changes in fishing pattern, as removal of the categorical vessel ID parameter resulted in a reduction in the explanatory power of the model. Annual indices for the main vessels were generally similar to, but slightly higher than, the all-vessels data.

The catch/day estimator appears to explain more of the variability in the data, and from the regression diagnostics, be a better fit to the data, than the catch/tow models, although trends were similar between the all-vessel and main-vessel models for both estimators. The catch/tow estimator may underestimate alfonsino abundance by not adequately including the searching time

and prospect fishing characteristic of this alfonsino fishery. The main differences between these two estimators appear to relate to fishing during 1989–90 and 1990–91, and both CPUE indices are relatively flat for the remainder of the review period.

It is recommended that the catch/day series derived from the main-vessel analysis be used to describe CPUE trends in the fishery. These indices suggest that the fishery may have completed the fishing down phase of development and remained relatively stable since 1991–92. As a strong vessel effect occurs in all models, these trends in standardised CPUE indices may also be influenced by the changes in fishing patterns of the few vessels involved in this fishery.

1. INTRODUCTION

Although alfonsino (*Beryx splendens*) is widely distributed throughout the New Zealand EEZ from 25 to 1200 m, the fishery is mostly confined to QMAs 2 & 3. A domestic fishery developed in 1981 on the seamounts and drop-offs that occur between 300 and 600 m off the east coast, North Island. Before 1983, alfonsino was virtually unfished (Horn 1988). A small target trawl fishery developed in 1983, and catch has been regulated in all except this first year of the fishery (Horn 1988). Major fishing grounds in QMA 2 (Figure 1) include the East Cape Ridge in area 201, Ranfurly Bank in area 11, Tolaga Bank in area 12, Tuaheni High in area 13, Paoanui Ridge and Ritchie Banks in area 204, the Motukura Banks and the North and South Maddens in area 14, the Kaiwhata and Palliser Banks in area 15, and the Cook Strait canyon in area 16. In more recent years, effort has shifted to the Madden Canyons and the Motukura Banks (Langley 1995). The 1997–98 landings of 1652 t of alfonsino in QMA 2 represent 57% of the total New Zealand landings of 2881 t (Table 1).

Over 72% of the estimated landings of alfonsino, from 1988–89 to 1997–98 were taken in target fishing (Table 2), although an increasing amount is taken as bycatch in gemfish and hoki target fishing (Blackwell, unpublished results). Alfonsino is also taken as bycatch of the hoki, gemfish, and orange roughy fisheries in QMA 2. Landings of alfonsino also include about 1% of the red bream, *Beryx decadactylus* (Annala *et al.* 1999).

This report presents standardised CPUE estimators of catch/day and catch/tow for the target BYX 2 midwater trawl fishery for all 27 vessels in the fishery from 1989–90 to 1997–98. These data were then compared to the CPUE estimators based on an analysis of the seven main vessels in the fishery during this period. In this latter analysis, fishing grounds were grouped into four areas: Madden, Palliser, Ritchie and Other.

1.1 Objectives

This report addresses Objective 3 of Ministry of Fisheries Project INS9801:

> To develop standardised CPUE indices for the midwater trawl fishery for alfonsino in BYX 2.

Following the presentation of these data at the 2000 Inshore Working Group meeting, further analysis of the main catch vessels only, with revised groupings of fishing grounds, was requested by the Ministry of Fisheries under this objective. These additional analyses for catch/day and catch/tow are also presented in this report.

1.2 Previous research

Alfonsino are considered to be a long-lived, moderately slow growing species (Horn & Massey 1989). Horn (1988) summarised the biology of alfonsino in BYX 2, and noted that stock relationships are poorly understood as the New Zealand stocks of this species may form part of a larger South Pacific stock. Full recruitment into the commercial fishery occurs at 5 years (Horn & Massey 1989) although catch curve analysis (Horn 1988) indicated a steep decline in abundance with increasing age. The age composition varies among grounds (Horn 1988) and alfonsino may undergo age-specific migration. M cannot be estimated by catch curve analysis as parts of the population may not be available for sampling, but was estimated at 0.20–0.23, using a maximum age of 20 years (Horn & Massey 1989).

Horn (1988) considered alfonsino to be densely aggregated but patchy in distribution, and developed a non-standardised CPUE index based on catch per fishing day which accounted for the searching time and prospect fishing characteristic of this target fishery. Alfonsino occur in dense aggregations on the bottom during the day which are not visible on the echo sounder. They form into large schools at dusk, and migrate up into midwater during the night to feed (Horn 1988).

Horn (1988) found this index had declined by 67% between 1983–84 and 1986–87, and estimated a CAY of 505 t based on 1983–84 landings of 1530 t. Stocker & Blackwell (1991) used this non-standardised CPUE index and estimates of B_0 (15 500 to 21 000 t) to estimate MCY at 980–1330 t. A standardised CPUE index of catch per tow was developed by Langley (1995) to review the effects of changes in fishing practice in the alfonsino fishery on bluenose bycatch. As this index did not include searching time and prospect fishing, and underestimated alfonsino abundance, Langley (1995) recommended that this index should not be used for relative biomass estimation.

This report compares these two indices of standardised CPUE (catch/day and catch/tow) from the target alfonsino midwater trawl fishery using data from all vessels, and also for the main vessels in this fishery, from 1989–90 to 1997–98.

2. METHODS

2.1 Preparation of data

All catch and effort data from 1988–89 to 1997–98 from the Ministry of Fisheries Trawl Catch Effort and Processing Return (TCEPR) and Catch Effort Landing Return (CELR) databases were extracted where the fishing method = midwater trawling, fishstock = BYX 2, and target species = alfonsino. Here, "midwater" refers to the net type, rather than the location of the tow, and a midwater net may in fact be used to fish a school close to the bottom. The data, including zero records of alfonsino, were checked for errors and outliers. As estimated catch data were used, a "zero" record does not necessarily mean zero catch, but indicates that alfonsino was not included in the top five species reported in the top part of the TCEPR and CELR forms. The following constraints were used:

- net depth less than or equal to bottom depth
- bottom depth in range 50–1000 m
- wingspread less than 100 m

Outliers were altered if the cause of the anomaly was apparent, or the record was removed.

Catch per day

All vessels. The catch/day dataset combined tow-by-tow data from the TCEPR database with daily catch data from the CELR database. Both databases contained considerable numbers of duplicate records for each fishing day and tow which were removed before error checking. For the TCEPR data, fishing grounds were defined by start position (Ryan & Stocker (1991), and these data were summarised by daily catch and fishing ground for each vessel. For the CELR data, statistical area was the only available location variable, and this was used for the initial data analysis. The TCEPR and CELR daily catch data were merged to provide a total of 1702 records for all vessels.

Main vessels. Although the fleet consisted of 27 vessels, very few fished for the duration of the review period. To remove those vessels that fished infrequently, the following selection criteria were adopted (I. Doonan, NIWA, pers. comm.). Vessels were included in the analysis if they had fished for three years or more between 1989–90 and 1997–98, and completed 15 or more tows in each of three or more fishing years. The catch and effort data for all years were analysed for those vessels that satisfied this effort criterion. For this analysis, data were summarised into four categories based on the major fishing grounds: Ritchie, Kaiwhata/Palliser, Motukura/Maddens (North Madden, Madden, South Madden, Motukura), and Other (all other grounds). Due to data limitations, the Motukura/Maddens category included CELR data from the Motukura Banks and the Madden Canyon in statistical area 14. The TCEPR data from these two fishing grounds were combined for data continuity. The Kaiwhata/Palliser category included CELR data from Kaiwhata and Palliser Banks in statistical area 15, and TCEPR from these areas. These data represented 1320 daily catch records.

Catch per tow

All vessels. The corrected TCEPR tow-by-tow dataset contained 3284 records after error checking. Not all of these were errors, as some records were excluded because they did not comply with the above constraints. Each record was assigned to a fishing ground on the basis of start position. To provide a basis for comparison, the data for Motukura and Madden Banks, and for Kaiwhata and Palliser Banks, were combined, as described above.

Main vessels. The main vessel TCEPR dataset contained 2807 records after error checking, and records were assigned to one of the four fishing ground categories defined above.

2.2 Models

Lognormal linear (LNL) model. This model was described by Doonan (1991) and Vignaux (1992). A log transformation was applied to the data to approximate linearity, after adding a small arbitrary constant (c) to the CPUE to avoid taking the logarithm of zero. The analysis may be sensitive to the value of c chosen (Vignaux 1992), because the statistical distribution of the data may be distorted, so the assumptions of normality and equality of variances may be compromised. A sensitivity analysis determined the effects of a range of c values on the model.

A stepwise procedure similar to that used by Doonan (1991) was used to calculate the LNL model, using PROC GLM, a general linear modelling procedure of the SAS statistical software (SAS 1989). Variables were 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. If the fishing year variable did not enter the model, this was forcibly included to derive annual indices.

Gamma log link (GLL) model. The gamma log-link model (Vignaux 1994) attempts to minimise the residual deviance by changing the parameters of the linear model. The expected and observed values are compared in untransformed space, so zero values can be left in the model and no arbitrary constant is required: PROC GENMOD, a generalised linear modelling procedure of the SAS statistical software (SAS 1989), was used. Variables were added to the model until less than 1% improvement was seen in D (residual deviance of the model) following the inclusion of each additional variable. If the fishing year variable did not enter the model, this was forcibly included to derive annual indices.

The percentage of zero tows in the datasets examined in this project did not exceed the 10% threshold (Doonan *et al.* 1995) that generally requires separate analysis of the LNL and binomial components of CPUE.

RESULTS

3.1 Analysis of raw CPUE data

Alfonsino catches in BYX 2 have slightly exceeded the TAC for 8 of the last 10 years. Catches have increased slightly between 1988–89 and 1997–98, and the average catch for this period was 1629 t (*see* Table 1). Alfonsino supports a target midwater and bottom trawl fishery in QMA 2, and is also taken as bycatch in a number of other fisheries (Table 2). Estimated landings in the target fishery have decreased since 1992–93 and alfonsino bycatch in the trawl fisheries for hoki and gemfish has increased. Data from the 1988–89 fishing year were excluded from analysis due to poor quality and low quantity (*see* Table 2).

Alfonsino target fishing was generally carried out by midwater trawling (Table 3). Fishing effort varied widely among the 26 vessels in this fishery, although no vessels fished for the complete time period. Effort data (number of tows) for the seven vessels that satisfied the selection criteria are given in the upper portion of Table 4. The mean catch rate (t/day) varied widely (Table 5) among statistical areas for vessels in both "main" and "other" fishing effort categories. High catch rates were generally associated with larger fishing vessels.

Catch per day

Catch and effort data for the target fishery (all vessels) are given in Table 6. Raw CPUE for all vessels (mean and *s.e.* from individual vessel catch/day data) varied between 4.8 t/day in 1993–94 and 6.6 t/day in 1990–91. The mean raw CPUE (t/day) for all vessels varied among fishing years and statistical areas (Figures 2 and 3) and month of fishing (Figure 4). Mean catch (t/day) appeared to increase with the number of shots per day (Figure 5), presumably because fishers continued to fish each area until the catch rates fell before moving off to a new fishing ground.

Catch and effort data (Table 7) for the "main catch" vessels (where 15 or more tows were completed in each of three or more fishing years) are provided for all fishing years 1989–90 to 1997–98, including years when effort was below the 15 tow threshold. The mean raw CPUE for these vessels (Figure 6) was very similar to, but higher than, the all-vessel data. It varied among fishing grounds and showed no trends (Figure 7).

Catch per tow

Means and *s.e.* for raw CPUE (t/tow) from the TCEPR database (all vessels) peaked in 1990–91 at 3.1 t/tow, and then slowly decreased to 2.1 t/tow in 1997–98 (Table 8). Data for the main vessels are given in Table 9.

The mean and C.I. for the raw CPUE (t/tow) for the main vessels (Figure 8), was similar to, but generally slightly higher than the all-vessels mean data. Mean CPUE initially increased, then declined, and these trends varied slightly among fishing grounds (Figure 9).

3.2 Regression models of CPUE (catch/day)

LNL model

The data are poorly structured, as no vessel fished in every fishing year, and some fishing grounds and statistical areas were unfished during this period. Statistical advice (D. Gilbert, NIWA) indicated that analysis of the interaction terms was likely to result in over-parameterisation and provide misleading results. The results from the main effects analysis only are presented in this report.

All vessels. The variables number of shots, vessel ID, month, and fishing year entered the LNL main effects model in order (Table 10), and this model explained 27% of the variation in the data. The month indices (Figure 10) were lowest in December to February and peaked in April-May (Figure 11), and were generally consistent with the raw CPUE.

From the sensitivity analysis (Appendix 1) the trends in annual indices and residual plots are similar for the three levels of c used in the analysis, although the analysis may be influenced by the high catch rates of some of the larger vessels in this fishery. Annual indices (Figure 11) sharply decreased from 1989–90 to 1991–92, then remained relatively constant from 1992–93 to 1997–98. This was generally consistent with trends in raw CPUE, although the slight increases during 1990–91, 1995–96, and 1996–97 were not seen in the standardised indices.

The analysis was repeated with catch and effort allocated to fishing ground as defined for the main vessel analysis. Fishing ground did not enter this alternative model and explained only 0.66% of variation, which was very similar to the 0.67% of variance explained by statistical area in the main effects model (Table 10). Indices for the statistical area model were used in subsequent analysis.

Main vessels. From the LNL analysis of the seven main vessels in this fishery (Table 11), the variables number of shots, vessel ID, *month, and fishing* year entered the main effects model, and this model explained 25% of variation in the data. The annual indices (Figure 11) were similar to, but slightly higher than, the indices for the all-vessels analysis. Regression diagnostics (Appendix 1) indicated that trends in both models were *similar.*

GLL model

All vessels. The variables vessel ID, number of shots, month, and fishing year entered the GLL model in order (Table 12). Annual indices for the GLL model decreased from 1989–90 to 1990–91, then remained stable from 1991–92 to 1997–98 (Figure 12). Trends in GLL model indices were generally similar to, but slightly less variable than, the LNL indices.

Main vessels. The variables number of shots, vessel ID, month, and fishing year entered the model (Table 13), and the annual indices (Figure 12) were generally similar to, but slightly higher than, the indices for the all-vessels analysis.

3.3 Regression models of CPUE (catch per tow)

LNL model

All vessels. Variables vessel ID, month, and statistical area entered the LNL all-vessels model, and fishing year was forced into the model to derive annual indices. This model explained only 12% of the variability in the data (Table 14). The regression diagnostics (Appendix 2) indicated the model was a relatively poor fit to the data, but trends in annual indices were not sensitive to the levels of c used in the analysis. The analysis may be influenced by high catch rates by some of the larger vessels in this fishery. CPUE indices was higher in northern areas (Figure 13), and varied slightly between month of fishing (Figure 14). The annual indices (Figure 15) were flat, with little contrast between 1989–90 and 1997–98. These trends were generally consistent with trends in the raw CPUE.

Main vessels. The variables vessel ID and month of fishing entered the model (Table 15), and fishing year was forced into the model to derive annual indices. This model explained only 10% of variability and regression diagnostics (Appendix 2) indicated the model was a poor fit to the data. No differences were seen between fishing grounds, although this may relate to variability in CPUE among the six vessels that satisfied the selection criteria. Trends in annual indices were similar for the levels of c used in the analysis, and the annual indices were similar to, but more variable than, the indices for the all-vessel data (Figure 15).

GLL model

All vessels. The variables vessel ID and month entered the model of catch/tow (Table 16), and fishing year was forced into the model to derive annual indices. These annual indices (Figure 16) showed little contrast and were generally similar to, but less variable than, the trends in the LNL indices.

For the main vessel analysis (Table 17), the variables vessel ID and month of fishing entered the model, and fishing year was forced into the model to derive annual indices. These indices were slightly higher than the indices from the all-vessel analysis (Figure 16).

4. DISCUSSION

Alfonsino is considered to be a relatively long-lived slow growing species which is patchily distributed in high density aggregations associated with seamounts and drop-offs of the east coast North Island (Annala *et al.* 1999). Before 1981 alfonsino was considered virtually unfished, and a small target midwater trawl fishery developed during 1981 (Annala *et al.* 1999). Most alfonsino landings taken during 1989–90 to 1997–98 have been associated with this target fishery, although the proportion of total BYX 2 landings has decreased from 85% in 1992–93, to 52% in 1997–98. This reflects the increasing importance of alfonsino bycatch in several other target fisheries including hoki (Blackwell unpubl. results).

Previous analyses of alfonsino have used a non-standardised CPUE index of catch/day which appears to have fallen by at least 50% (42–92%) between 1983–84 and 1987–88 on each of the major grounds (Horn 1989). Stocker & Blackwell (1991) found a similar (48%) decrease (from 9.3 t/day to 4.8 t/day) had occurred between 1982–83 and 1989–90, although some differences occurred in the method of averaging the rate of decline across all fishing grounds. The raw CPUE estimate of 5.5 t/day derived for 1989–90 in the present study was higher than the 4.8 t/day reported by Stocker & Blackwell (1991) for 1989–90. This difference may relate to the different extraction methods used for these two analyses, or to new data added since the previous analysis.

This report presents a new standardised CPUE series based on the catch/day estimator of Horn (1989), derived from loglinear and gamma log link models, and compares these series with data derived from the standardised CPUE catch/tow estimator developed by Langley (1995). The regression diagnostics indicated these models were a relatively poor fit to the data, which appears to be due in part to the small size of the fishery, and to the high level of variability in catch and effort among the 26 vessels involved. Although most vessels fished for only one or two years, no vessel was present for the entire survey period. Removal of the categorical vessel variable decreased the predictive power of these models, which suggested that this variable included other factors, such as skipper experience, rather than merely the physical features of the vessel. An alternative analysis reviewed changes in CPUE for these estimators for the seven main vessels, that contributed most of the fishing effort in the fishery during this period.

Variability in the CPUE (catch/day) was associated with the number of shots per day, categorical vessel ID, month of fishing, and fishing ground, and the LNL model explained 27% of variability in the all-vessel data and 25% of variability in the main-vessel data. Although a lower seasonal availability of alfonsino during winter is suggested from the analysis, fishers advised that most vessels in this fishery shift effort from alfonsino to hoki in this period (C. Robinson, Pacific Trawling Ltd, Napier, pers. comm.). Trends in annual indices for the seven main vessels were similar to, but slightly higher than, those for all-vessels, and similar trends occurred for the GLL analysis for both the main-vessel and all-vessel datasets. These series generally indicated that CPUE had fallen during 1989–90 and 1991–92, then remained relatively stable until 1997–98. These trends were generally consistent with, but less variable than, the trends in raw CPUE.

Annual indices for the CPUE (catch/tow) estimator were flat, with little contrast, for both the LNL and GLL models. Fishing year was forced into these models to derive annual indices, and these models explained a very low level (10–12%) of data variability. The annual indices were generally consistent with the trends in CPUE (catch/day) after 1991–92. Although variables vessel ID, month, statistical area, and fishing year entered the LNL all-vessels model, statistical area did not enter the main-vessels LNL model or the GLL models. However, as data from only six main-catch vessels were available, insufficient data may be available to determine trends, given the high vessel-level variability in catch and effort. Data from the GLL models of catch/tow were similar for the all-vessel and main-vessel data, and generally followed the trends for the LNL main-vessel analysis. The annual indices were generally similar to trends in raw CPUE.

This analysis and review of the regression diagnostics indicates that the catch/day estimator explains more data variability and provides a better fit to the data than the catch/tow estimator. Langley (1995) found little change in standardised CPUE (catch/tow) indices between 1990–91 and 1993–94, but recommended that this index should not be used to describe changes in relative abundance. The catch/tow estimator substantially underestimated fishing effort by excluding searching time and exploratory fishing components of this fishery (Horn & Massey 1989, Langley 1995).

The alfonsino fishery is relatively small and catch and effort data are poorly structured. Effort varied widely among fishing vessels and some statistical areas and fishing grounds were unfished in some fishing years. No fishing vessel consistently fished during the entire survey period, and these data limitations precluded analysis of the interaction terms between these variables. Although annual indices derived from the LNL and GLL models are similar, the LNL model may be more suitable than the GLL model for the analysis of such data (D. Gilbert, NIWA, pers. comm.).

It is concluded that the standardised CPUE index of catch/day for the main vessels in the fishery from 1989–90 to 1997–98 best reflect changes in the relative abundance of alfonsino. These data are consistent with a fishery that is generally stable, with little contrast, particularly after 1991–92. This fishery may now have completed the fishing down phase of development (Horn 1988, Stocker & Blackwell 1991) and entered a period of relative stability.

5. ACKNOWLEDGMENTS

This research was carried out for the Ministry of Fisheries under project INS9801. Thanks to Kim Duckworth (Ministry of Fisheries) for extraction of the raw data and to Ian Doonan and David Gilbert (NIWA) for statistical advice. Thanks also to Malcom Francis who reviewed this document and to Peter McMillan and Stuart Hanchett (NIWA) for comments on an earlier version of this manuscript.

6. REFERENCES

Annala, J.H., Sullivan, K.J. & C.J. O'Brien (Comps.) 1999: Report from the Fishery Assessment Plenary, April 1999: stock assessments and yield estimates. 430 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I. 1991: Orange roughy fishery assessment, CPUE analysis – linear regression, NE Chatham Rise 1991. New Zealand Fisheries Assessment Research Document 91/9. 48 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J., P.J. McMillan, R.P. Coburn, A.C. Hart, & P.L. Cordue 1995: Assessment of smooth oreo for 1995. New Zealand Fisheries Assessment Research Document 95/12. 31 p. (Unpublished report held in NIWA library, Wellington.)

Horn, P.L. 1988: Alfonsino. New Zealand Fisheries Assessment Research Document 88/7. 21p. (Unpublished report held in NIWA library, Wellington.)

Horn, P.L. & Massey, B.R. 1989: Biology and abundance of alfonsino and bluenose off the lower east coast North Island, New Zealand. *New Zealand Fisheries Technical Report No 15*. 32p.

Langley, A.D. 1995: Analysis of commercial catch and effort data from the QMA 2 alfonsino-bluenose trawl fishery 1989-94. New Zealand Fisheries Assessment Research Document 95/18. 12 p. (Unpublished report held in NIWA library, Wellington.)

Ryan, M. & Stocker, M. 1991: Biomass and yield estimates for bluenose in QMA 2 for the 1991-92 fishing year. New Zealand Fisheries Assessment Research Document 91/8. 15 p. (Unpublished report held in NIWA library, Wellington.)

SAS 1989: SAS/STAT User's Guide, Version 6, Fourth Edition, Volumes 1 & 2. SAS Institute Inc., Cary, N.C. 846 pp.

Stocker, M. & Blackwell, R.G. 1991: Biomass and yield estimates for alfonsino in BYX 2 for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 91/12. 9 p. (Unpublished report held in NIWA library, Wellington.)

Vignaux, M. 1992: Catch per unit effort (CPUE) analysis of the hoki fishery. New Zealand Fisheries Assessment Research Document 92/14. 31p. (Unpublished report held in NIWA library, Wellington.)

Vignaux, M. 1994: Catch per unit of effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. New Zealand Fisheries Assessment Research Document 94/11. 29 p. (Unpublished report held in NIWA library, Wellington.)

Table 1: Reported landings (t) of alfonsino by fishstock and annual TACs (t) from 1985–86 to 1997–98

Fishstock	BYX 1		BYX 2		BYX 3		BYX 7		BYX 8		BYX 10		All BYX	
QMA(s)	1 & 9		2		3,5 & 6		7		8		10		1–10	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1985–86*	11	-	1 454	-	3	-	1	-	0	-	0	10	1 469	-
1986–87Υ	3	10	1 387	1 510	75	220	4	30	1	20	0	10	1 470	1 800
1987–88Υ	8	27	1 252	1 511	101	1 000	2	30	1	20	0	10	1 364	2 598
1988–89Υ	6	27	1 588	1 630	64	1 000	4	30	0	20	1	10	1 663	2 717
1989–90Υ	24	31	1 496	1 274	147	1 007	21	80	<1	20	0	10	1 688	2 422
1990–91Υ	17	31	1 459	1 274	202	1 007	26	81	0	20	0	10	1 664	2 423
1991–92Υ	7	31	1 368	1 499	264	1 007	2	81	<1	20	<1	10	1 641#	2 648
1992–93Υ	6	31	1 649	1 504	113	1 007	12	81	<1	20	<1	10	1 780#	2 653
1993–94Υ	7	31	1 688	1 569	275	1 007	31	81	<1	20	0	10	2 001#	2 718
1994–95Υ	11	31	1 670	1 569	482	1 010	59	81	<1	20	0	10	2 223#	2 721
1995–96Υ	11	31	1 868	1 569	961	1 010	66	81	<1	20	0	10	2 906#	2 721
1996–97Υ	39	31	1 854	1 575	983	1 010	77	81	<1	20	0	10	2 953#	2 727
1997–98Υ	14	31	1 652	1 575	1148	1 010	67	81	<1	20	0	10	2 881#	2 727

- FSU data.
- Υ QMS data.

Table 2: Estimated landings of bottom trawl and mid-water trawl caught BYX 2, by target species, QMR total landings and percentage of QMR total landings analysed, 1988–89 to 1997–98

	Target species										Reported landings	
	BNS	BYX	CDL	HOK	LIN	ORH	RBY	SKI	Other	Total	QMR	Percent
Fishing year												
1988–89	0	217	1	0	2	5	0	1	2	228	1 588	14
1989–90	208	1 263	11	0	1	11	1	23	0	1 518	1 496	100
1990–91	249	976	46	57	1	23	32	7	21	1 411	1 459	97
1991–92	60	1 209	10	46	0	35	19	5	1	1 385	1 368	100
1992–93	86	1 311	17	66	0	16	51	10	10	1 557	1 649	94
1993–94	0	1 262	57	45	10	145	23	115	2	1 659	1 688	98
1994–95	14	1 054	123	29	0	150	19	69	0	1 458	1 670	87
1995–96	1	925	157	203	0	19	5	212	7	1 529	1 868	82
1996–97	13	810	68	357	1	24	4	146	27	1 450	1 854	78
1997–98	13	688	46	329	0	16	1	135	16	1 244	1 652	75
Total		9 715								13 439	16 292	82

Table 3: Alfonsino target trawl fishery: Estimated landings and number of days fished for BYX 2, by trawl method, 1989–90 to 1997–98. BT, bottom trawl; MW, midwater trawl

Method	BT		MW		Total	
Fishing year	*No. days*	*BYX weight (t)*	No. days	BYX weight (t)	No. days	BYX weight (t)
1989–90	12	16	228	1 247	240	1 263
1990–91	15	45	140	931	155	976
1991–92	6	14	214	1 195	220	1 209
1992–93	8	5	250	1 306	258	1 311
1993–94	25	64	251	1 198	276	1 262
1994–95	58	109	196	945	254	1 054
1995–96	24	75	149	850	173	925
1996–97	33	142	115	668	148	810
1997–98	21	33	132	655	153	688

Table 4: BYX 2 target trawl fishery: length overall (LOA), gross registered weight (GRW), and number of tows by vessel and fishing year, 1989–90 to 1997–98, from the TCEPR and CELR databases

LOA: 1=0–25, 2=26–30, 3=31–35, 4=36–40, 5=41+.

GRW: 1=0–100, 2=101–150, 3=151–200,4=201+

			Fishing year								
	LOA	GRW	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98
Main vessels											
1	1	2	88		42	22	144	166	88	120	78
2	1	1	30	17	15	11					
3	3	4	40	27	44			25	48		
4	2	3		54	50	158	158	83	92	148	129
5	2	3				62	124	40			
6	5	4					6	44	28	5	19
7	5	4	38	198	216	148	67			6	32
Other vessels											
1	1	1		2							
2	2	1					2				
3	2	2	174			2					
4	1	1			16	8					
5	5	4	46								
6	2	4				1					
7*	3	4									
8	1	1		2	1	4	3				
9	2	4					3	2			
10	1	1		2	20	1					
11	3	4		2	20	1					
12	2	3	3	4							
13	1	1					14				
14	2	4						7			
15	5	4									51
16	1	1			4						
17	3	4							7		
18	5	4							7		
19	4	4						2	18		
20	4	4								6	8

* fished only in 1988–89 and excluded from analysis

Table 5: BYX 2 target trawl fishery: Mean raw CPUE (t/day) by vessel and statistical area, 1989–90 to 1997–98

	Statistical area							
	12	13	14	15	16	203	204	206
Main vessels								
1	2.8	4.0	4.1	4.0			4.37	
2		3.2	3.4					
3		6.6	20.0	3.5			5.8	
4	0.1	6.4	5.9	3.5		13.5	5.8	6.6
5	2.6		1.4	2.8			4.7	
6		7.8	5.0				14.2	
7		7.2	3.4	8.3	28.1		9.1	
Other vessels								
1				0.2			0.1	
2				1.7				
3		1.4	4.8	4.7			1.5	
4		2.1	1.1	0.5				
5							8.5	
6				0.1				
7*								
8				1.3	0.0			
9		4.3	0.0	3.5			0.0	
10			1.0	0.1				
11		4.3	0.1	5.7			2.3	
12		1.0	2.2	3.5				
13		2.5	1.3					
14	18.0	3.5	6.6	3.6			1.0	
15				2.2			4.8	
16			0.1		0.0			
17			0.0				3.3	
18							6.1	
19	1.0		4.3				7.4	
20			10.3				5.5	

* fished only in 1998–99 and excluded from analysis

Table 6: BYX 2 target trawl fishery: Raw CPUE (tonnes (t) per day) and the percentage of zero catch, all vessels, 1989–90 to 1997–98. Source: TCEPR and CELR databases

Fishing year	Number of days	BYX weight (t)	Mean CPUE (t/day)	*s.e.*	Number of zero catch days	Percentage of zero catch
1989–90	228	1 247	5.5	0.3	10	4.4
1990–91	140	931	6.6	0.5	2	1.4
1991–92	214	1 195	5.6	0.4	19	8.9
1992–93	250	1 306	5.2	0.4	13	5.2
1993–94	251	1 198	4.8	0.4	21	8.4
1994–95	196	945	4.8	0.5	13	6.6
1995–96	149	850	5.7	0.5	9	6.0
1996–97	115	668	5.8	0.5	9	7.8
1997–98	132	655	5.0	0.5	16	12.1
	1 702	9 156			112	6.6

Table 7: BYX 2 target trawl fishery: Raw CPUE (tonnes (t) per day) and the percentage of zero catch, main vessels, 1989–90 to 1997–98. Source: TCEPR and CELR databases

Fishing year	Number of days	BYX weight (t)	Mean CPUE (t/day)	*s.e.*	Number of zero catch days	Percentage of zero catch
1989–90	95	565	5.9	0.5	6	6.3
1990–91	130	917	7.0	0.5	1	0.7
1991–92	160	1 095	6.8	0.5	13	8.1
1992–93	208	1 161	5.6	0.4	10	4.8
1993–94	230	1 119	4.9	0.4	17	7.4
1994–95	160	805	5.0	0.6	12	7.5
1995–96	113	700	6.2	0.6	7	6.2
1996–97	113	658	5.8	0.5	9	8.0
1997–98	110	559	5.1	0.5	15	13.6
	1 319	7 579			90	6.8

Table 8: BYX 2 target trawl fishery: Raw CPUE (tonnes (t) per tow) and the percentage of zero catch tows, all vessels, 1989–90 to 1997–98. Source: TCEPR database

Fishing year	Number of tows	BYX weight (t)	Mean CPUE (t/tow)	*s.e.*	Number of zero catch tows	Percentage of zero catch tows
1989–90	280	642	2.3	0.2	16	5.7
1990–91	258	797	3.1	0.2	4	1.5
1991–92	386	1 097	2.8	0.2	15	3.9
1992–93	476	1 276	2.7	0.2	18	3.8
1993–94	534	1 194	2.2	0.1	35	6.5
1994–95	396	914	2.3	0.2	24	6.0
1995–96	332	850	2.6	0.2	16	4.8
1996–97	285	668	2.3	0.1	15	5.3
1997–98	317	655	2.1	0.1	23	7.3
	3 284	8 170			166	

Table 9: BYX 2 target trawl fishery: Raw CPUE (tonnes (t) per tow) and the percentage of zero catch tows, main vessels, 1989–90 to 1997–98. Source: TCEPR database

Fishing year	Number of tows	BYX weight (t)	Mean CPUE (t/tow)	*s.e.*	Number of zero catch tows	Percentage of zero catch tows
1989–90	157	347	2.2	0.2	13	8.3
1990–91	258	797	3.1	0.2	4	1.5
1991–92	352	1 048	3.0	0.2	13	3.7
1992–93	390	1 146	2.9	0.2	16	4.1
1993–94	499	1 120	2.2	0.1	30	6.0
1994–95	358	804	2.2	0.2	23	6.4
1995–96	256	701	2.7	0.2	14	5.5
1996–97	279	658	2.3	0.1	15	5.4
1997–98	255	558	2.1	0.2	21	8.2
	2 804	7 179			149	5.3

Table 10: BYX 2 target trawl fishery: LNL analysis of CPUE (kg/day) from 1989–90 to 1997–98

LNL main effects model of CPUE (kg/day+1), all vessels

Boldface *indicates* variable has been included in the model

	R^2 at iteration				
Iteration	1	2	3	4	5
Variables					
No. shots	**0.15**				
Vessel ID	0.13	**0.25**			
Month	0.02	0.17	**0.26**		
Fishing year	0.02	0.17	0.26	**0.27**	
Statistical area	0.03	0.16	0.25	0.27	0.28
Fishing time	0.02	0.15	0.25	0.26	0.28
Net height	0.00	0.15	0.25	0.26	0.27
Wingspread	0.00	0.16	0.25	0.26	0.27
Quarter	0.01	0.16	0.25	0.26	0.27
Length	0.04	0.17	0.25	0.26	0.27
Breadth	0.04	0.17	0.25	0.26	0.27
Draught	0.05	0.18	0.25	0.26	0.27
Tonnage	0.01	0.15	0.25	0.26	0.27
Power	0.02	0.16	0.25	0.26	0.27
L*B*D	0.03	0.17	0.25	0.26	0.27
% increase in R^2	14.9	9.8	1.5	1.2	0.7

Main effects model: Log(CPUE kg/day+1) = No. of shots, vessel ID, month, fishing year

Annual indices for the LNL model of CPUE (kg/day+1) all vessels

	Main effect	
Fishing year	model	*s.e.*
1989–90	3.22	1.35
1990–91	2.09	1.30
1991–92	1.13	1.26
1992–93	1.45	1.26
1993–94	1.10	1.26
1994–95	1.52	1.27
1995–96	1.50	1.29
1996–97	1.03	1.29
1997–98	1.00	

Table 11: BYX 2 target trawl fishery: LNL analysis of CPUE (kg/day), main vessels, 1989–90 to 1997–98

LNL main effects model of CPUE (kg/day+1), main vessels

				R^2 at iteration	
Iteration	1	2	3	4	5
Variables					
Number of shots	**0.15**				
Vessel ID	0.06	**0.21**			
Month	0.04	0.19	**0.23**		
Fishing year	0.03	0.18	0.22	**0.25**	
Fishing ground	0.03	0.17	0.22	0.24	0.25
Fishing time	0.02	0.16	0.21	0.24	0.25
Net height	0.00	0.16	0.21	0.23	0.25
Wingspread	0.00	0.19	0.22	0.24	0.25
Quarter	0.02	0.18	0.22	0.24	0.25
Length	0.04	0.17	0.22	0.24	0.25
Breadth	0.03	0.17	0.22	0.24	0.25
Draught	0.04	0.18	0.22	0.24	0.25
Tonnage	0.01	0.16	0.22	0.24	0.25
Power	0.02	0.18	0.22	0.24	0.25
L*B*D	0.04	0.18	0.22	0.24	0.25
% increase in R^2	15.7	5.8	2.0	1.7	0.3

Main effects model: Log (CPUE kg/day+1) = Number of shots, vessel ID, month, fishing year

Annual indices for the LNL model of CPUE (kg/day+1), main vessels

Fishing year	Main effect model	*s.e.*
1989–90	3.56	1.36
1990–91	2.13	1.31
1991–92	1.16	1.29
1992–93	1.58	1.27
1993–94	1.06	1.26
1994–95	1.47	1.27
1995–96	1.54	1.29
1996–97	1.35	1.28
1997–98	1.00	

Table 12: BYX 2 target trawl fishery: GLL analysis of CPUE (kg/day), all vessels, 1989–90 to 1997–98

	Deviance at iteration				
Iteration	1	2	3	4	5
Variables					
Vessel ID	**2251.14**				
Number of shots	2351.89	**2033.03**			
Month	2512.61	2201.83	**1978.68**		
Fishing year	2574.06	2239.34	2012.96	**1948.82**	
Fishing time	2559.84	2193.12	2023.84	1967.62	1939.83
Statistical area	2524.87	2243.02	2027.19	1972.68	1942.35
Wingspread	2557.97	2240.82	2014.05	1961.62	1930.16
Net height	2587.21	2248.83	2029.93	1975.78	1944.84
Length	2456.44	2219.93	1998.83	1978.68	1948.82
Breadth	2422.32	2251.14	1998.83	1978.68	1948.82
Draught	2482.95	2251.14	1998.83	1978.68	1948.82
Tonnage	2525.94	2251.14	1998.83	1978.68	1948.82
Power	2478.80	2251.14	1998.83	1978.68	1948.82
L*B*D	2468.81	2251.14	1998.83	1978.68	1948.82
% decrease in deviance		9.68	2.67	1.50	0.46

GLL model: Log(CPUE kg/day) = Vessel ID, number of shots, month, fishing year

Annual indices for the GLL model of CPUE (kg/day), all vessels

Fishing year	Main effect model	*s.e.*
1989–90	1.87	1.18
1990–91	1.01	1.16
1991–92	1.01	1.14
1992–93	0.99	1.13
1993–94	0.91	1.14
1994–95	0.88	1.13
1995–96	1.06	1.16
1996–97	1.07	1.14
1997–98	1.00	

Table 13: BYX 2 target trawl fishery: GLL analysis of CPUE (kg/day), main vessels, 1989–90 to 1997–98

	Deviance at iteration				
Iteration	1	2	3	4	5
Variables					
No. of shots	**1793.06**				
Vessel ID	1796.85	**1597.53**			
Month	1890.71	1688.11	**1549.51**		
Fishing year	1957.50	1753.68	1571.52	**1510.86**	
Fishing ground	1938.82	1756.69	1585.11	1539.84	1499.52
Fishing time	1956.04	1787.77	1593.58	1543.78	1506.54
Net height	1978.17	1790.99	1596.26	1548.63	1509.19
Wingspread	1931.77	1686.85	1591.17	1544.47	1506.95
Quarter	1915.48	1709.71	1565.07	1549.51	1510.86
Length	1871.65	1705.85	1597.53	1549.51	1510.87
Breadth	1843.09	1690.74	1597.53	1549.51	1510.87
Draught	1899.68	1713.67	1597.53	1549.51	1510.87
Tonnage	1893.45	1715.79	1597.53	1549.51	1510.87
Power	1858.45	1683.46	1597.53	1549.51	1510.87
L*B*D	1869.26	1691.18	1597.53	1549.51	1510.87
% decrease in deviance		10.90	3.00	2.49	0.75

GLL model: Log(CPUE kg/day) = No. of shots, vessel ID, month, fishing year

Annual indices for the GLL model of CPUE (kg/day), main vessels

	Main effect	
Fishing year	model	*s.e.*
1989–90	2.15	1.18
1990–91	1.15	1.16
1991–92	1.04	1.15
1992–93	1.00	1.14
1993–94	0.91	1.14
1994–95	0.90	1.14
1995–96	1.10	1.16
1996–97	1.08	1.15
1997–98	1.00	

Table 14: BYX 2 target trawl fishery: LNL analysis of CPUE (kg/tow), all vessels, 1989–90 to 1997–98

Main effects model of CPUE (kg/tow+1), all vessels

	R^2 at iteration			
Iteration	1	2	3	4
Variables				
Vessel ID	**0.07**			
Month	0.04	**0.09**		
Statistical area	0.02	0.08	**0.11**	
Fishing year	0.02	0.08	0.10	**0.12**
Start time	0.01	0.07	0.10	0.12
Wingspread	0.02	0.08	0.09	0.11
Speed	0.15	0.08	0.09	0.11
Fishing time	0.00	0.07	0.09	0.11
Bottom depth	0.00	0.07	0.09	0.11
Net depth	0.00	0.07	0.09	0.11
Net height	0.00	0.07	0.09	0.11
Length	0.03	0.07	0.09	0.11
Breadth	0.04	0.07	0.09	0.11
Draught	0.04	0.07	0.09	0.11
Power	0.03	0.07	0.09	0.11
Tonnage	0.01	0.07	0.09	0.11
L*B*D	0.03	0.07	0.09	0.11
% increase in R^2	7.41	2.21	1.42	0.56

Main effects model: Log(CPUE kg/tow+1) = Vessel ID, month, statistical area, fishing year

Annual indices for the LNL model of CPUE (kg/tow+1), all vessels

	Main effect	
Fishing year	model	*s.e.*
1989–90	0.81	1.27
1990–91	1.24	1.23
1991–92	0.71	1.20
1992–93	1.09	1.19
1993–94	1.06	1.18
1994–95	0.91	1.19
1995–96	1.08	1.20
1996–97	1.36	1.19
1997–98	1.00	

Table 15: BYX 2 target trawl fishery: LNL analysis of CPUE (kg/tow), main vessels, 1989–90 to 1997–98

Main effects model of CPUE (kg/tow+1), main vessels

	R^2 at iteration		
Iteration	1	2	3
Variables			
Vessel ID	**0.07**		
Month	0.04	**0.10**	
Fishing year	0.03	0.08	**0.10**
Start time	0.01	0.08	0.11
Wingspread	0.05	0.07	0.10
Fishing ground	0.03	0.08	0.10
Speed	0.01	0.07	0.10
Fishing time	0.00	0.07	0.10
Bottom depth	0.00	0.08	0.10
Net depth	0.00	0.08	0.11
Net height	0.00	0.08	0.10
Length	0.05	0.07	0.10
Breadth	0.06	0.07	0.10
Draught	0.04	0.07	0.10
Power	0.05	0.07	0.10
Tonnage	0.04	0.07	0.10
L*B*D	0.05	0.07	0.10
% increase in R^2	7.37	2.35	0.56

Main effects model: Log(CPUE kg/tow+1) = Vessel ID, month, fishing year

Annual indices for the LNL model of CPUE (kg/tow+1), main vessels

	Main effect	
Fishing year	model	*s.e.*
1989–90	0.85	1.22
1990–91	1.50	1.19
1991–92	0.88	1.17
1992–93	1.24	1.15
1993–94	1.11	1.15
1994–95	1.01	1.14
1995–96	1.14	1.17
1996–97	1.47	1.16
1997–98	1.00	

Table 16: BYX 2 target trawl fishery: GLL analysis of CPUE (kg/tow), all vessels, 1989–90 to 1997–98

	Deviance at iteration		
Iteration	1	2	3
Variables			
Vessel ID	**4388.92**		
Month	4617.02	**4255.40**	
Fishing year	4879.95	4381.75	**4245.23**
Wing spread	4763.41	4344.80	4216.92
Statistical area	4809.10	4369.42	4237.81
Speed	4784.67	4306.11	4255.46
Start time	4886.31	4383.66	4249.32
Fishing time	4910.54	4371.86	4236.65
Bottom depth	4902.22	4388.88	4255.42
Net depth	4900.16	4372.10	4246.84
Net height	4901.74	4367.94	4243.95
Length	4781.54	4380.23	4255.40
Breadth	4681.96	4380.23	4255.40
Draught	4828.43	4380.23	4255.40
Power	4775.57	4380.23	4255.40
Tonnage	4749.71	4380.23	4255.40
LBD	4774.71	4380.23	4255.40
% decrease in deviance		3.04	0.24

GLL model: Log(CPUE kg/tow) = Vessel ID, month, fishing year

Annual indices for the GLL model of CPUE (kg/tow), all vessels

	Main effect	
Fishing year	model	*s.e.*
1989–90	1.10	1.145
1990–91	0.97	1.12
1991–92	0.82	1.11
1992–93	0.92	1.10
1993–94	0.92	1.01
1994–95	0.90	1.10
1995–96	0.96	1.10
1996–97	1.05	1.10
1997–98	1.00	

Table 17: BYX 2 target trawl fishery: GLL analysis of CPUE (kg/tow), from 1989–90 to 1997–98, main vessels

	Deviance at iteration		
Iteration	1	2	3
Variables			
Vessel ID	**3705.19**		
Month	3861.61	**3578.78**	
Fishing year	4078.33	3696.73	**3567.67**
Wing spread	3889.67	3684.53	3560.37
Speed	3977.00	3705.67	3577.91
Start time	4083.10	3684.46	3557.57
Fishing ground	4030.75	3684.88	3571.04
Fishing time	4116.16	3705.16	3578.75
Bottom depth	4114.76	3683.18	3566.16
Net depth	4113.79	3678.52	3562.84
Net height	4116.16	3704.06	3577.55
Length	3973.92	3705.18	3578.78
Breadth	3842.79	3705.18	3578.78
Draught	4030.56	3705.18	3578.78
Power	3870.90	3705.18	3578.78
Tonnage	3902.43	3705.18	3578.78
LBD	3963.67	3705.18	3578.78
% decrease in deviance		3.41	0.31

GLL model: Log(CPUE kg/tow) = Vessel ID, month, fishing year

Annual indices for the GLL model of CPUE (kg/tow)

	Main effect	
Fishing year	model	*s.e.*
1989–90	1.09	1.15
1990–91	1.00	1.19
1991–92	0.86	1.11
1992–93	0.95	1.03
1993–94	0.90	1.01
1994–95	0.92	1.10
1995–96	0.99	1.11
1996–97	1.09	1.10
1997–98	1.00	

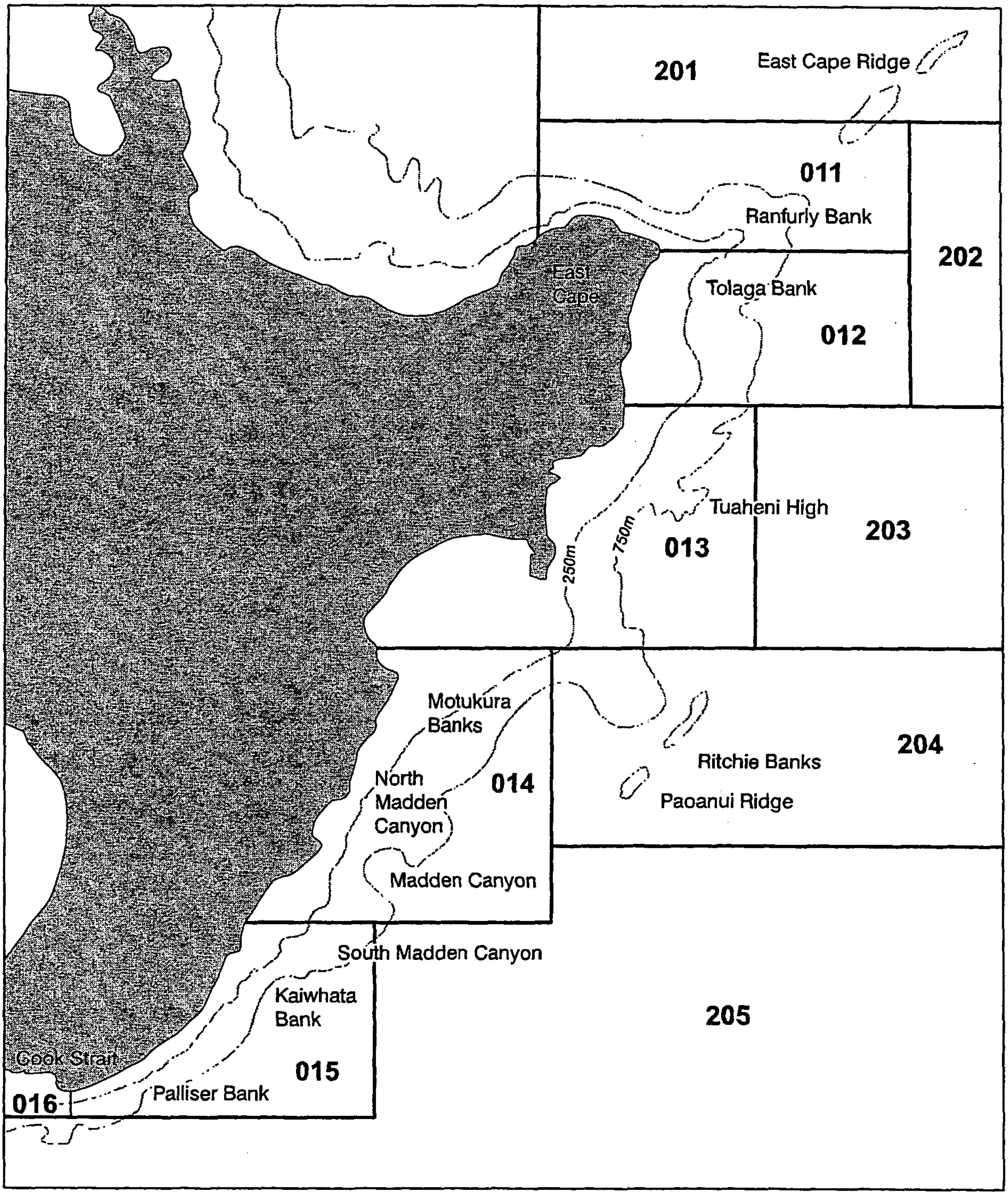


Figure 1: The alfonsino fishery in QMA 2 showing major fishing grounds and statistical reporting areas 11–16, 201–205. The 250 m and 750 m depth contours are also shown.

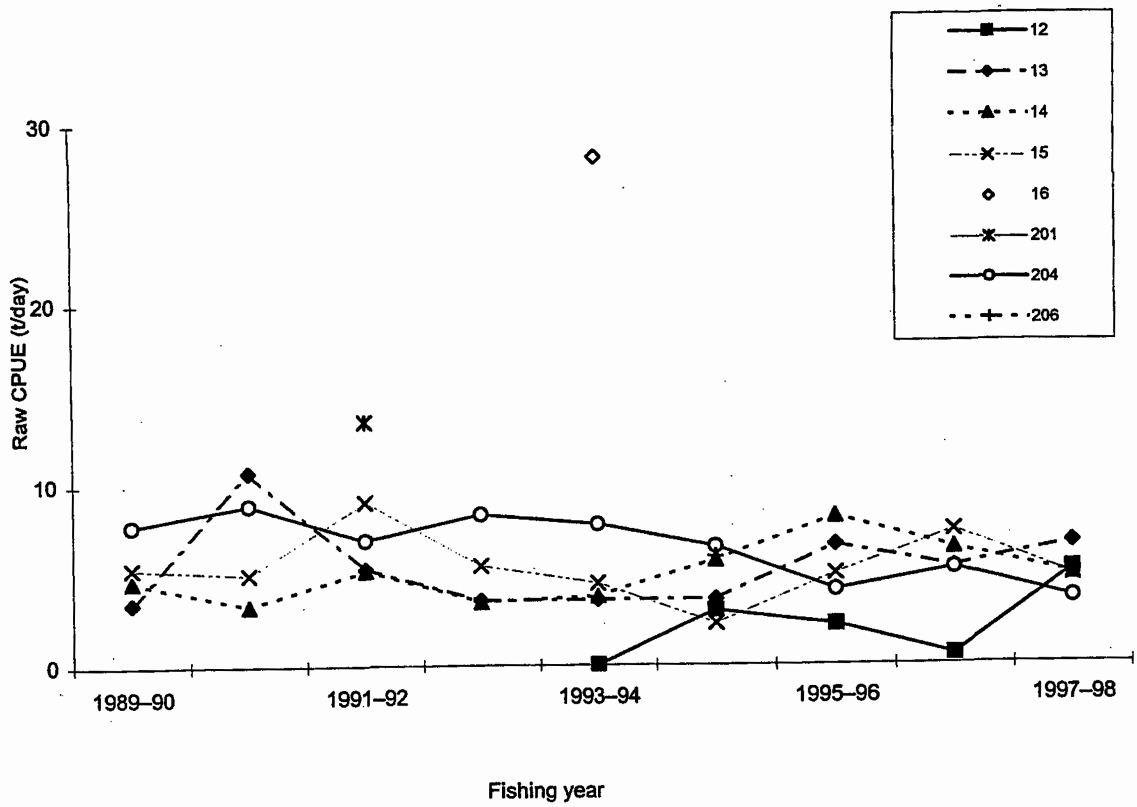


Figure 2: BYX 2 target trawl fishery: mean raw CPUE (t/day), by statistical area and fishing year, all vessels, 1989–90 to 1997–98.

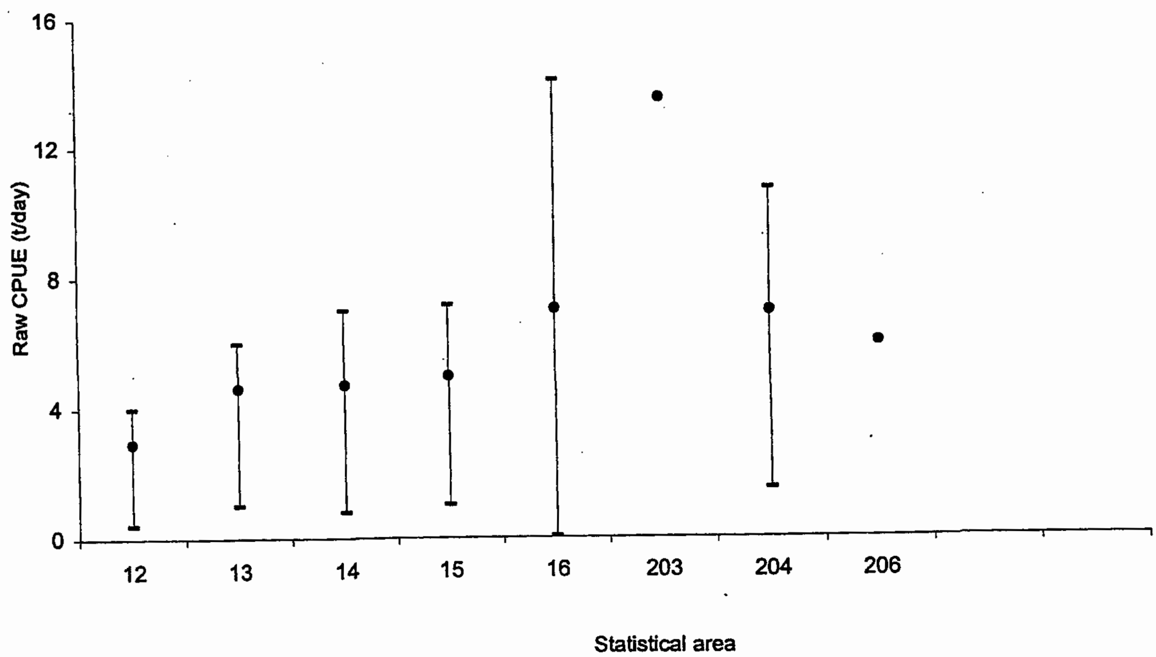


Figure 3: BYX 2 target trawl fishery: mean and quartiles of raw CPUE (t/day), by statistical area, all vessels, 1989–90 to 1997–98.

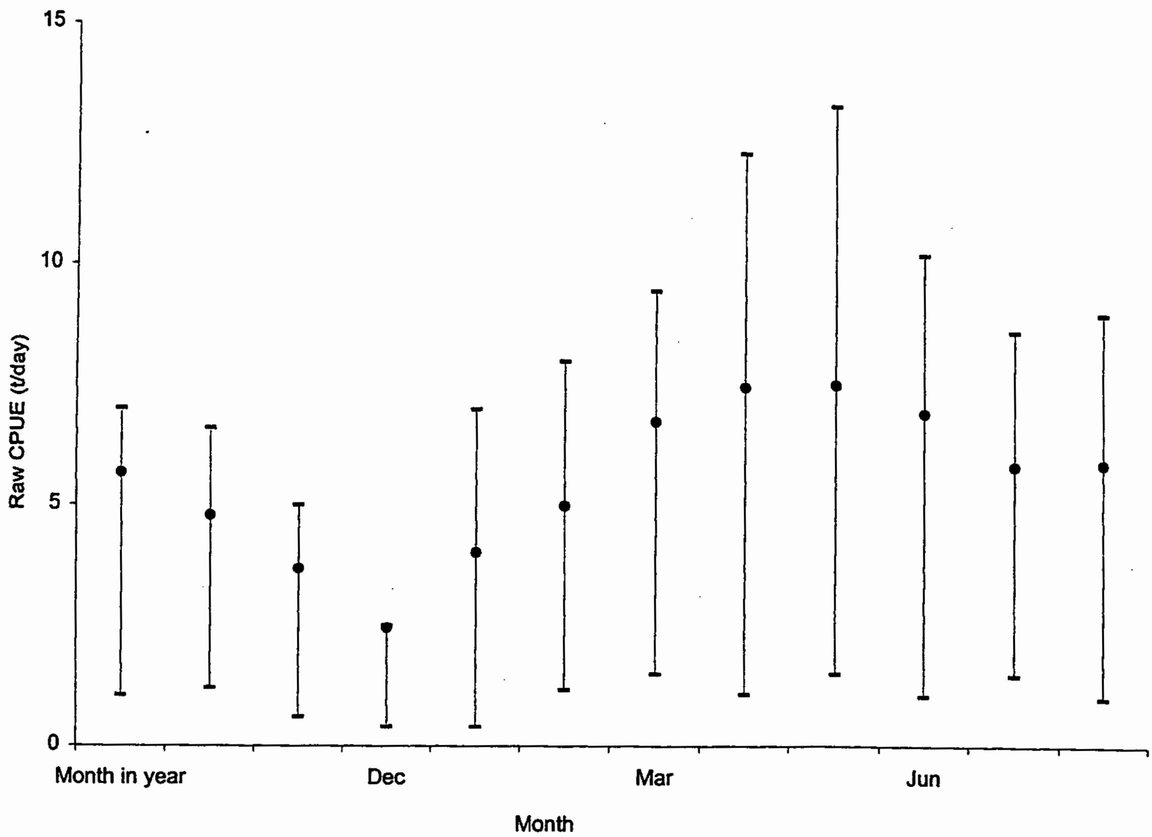


Figure 4: BYX 2 target trawl fishery: mean and quartiles of raw CPUE (t/day) by month in fishing year, all vessels, 1989–90 to 1997–98.

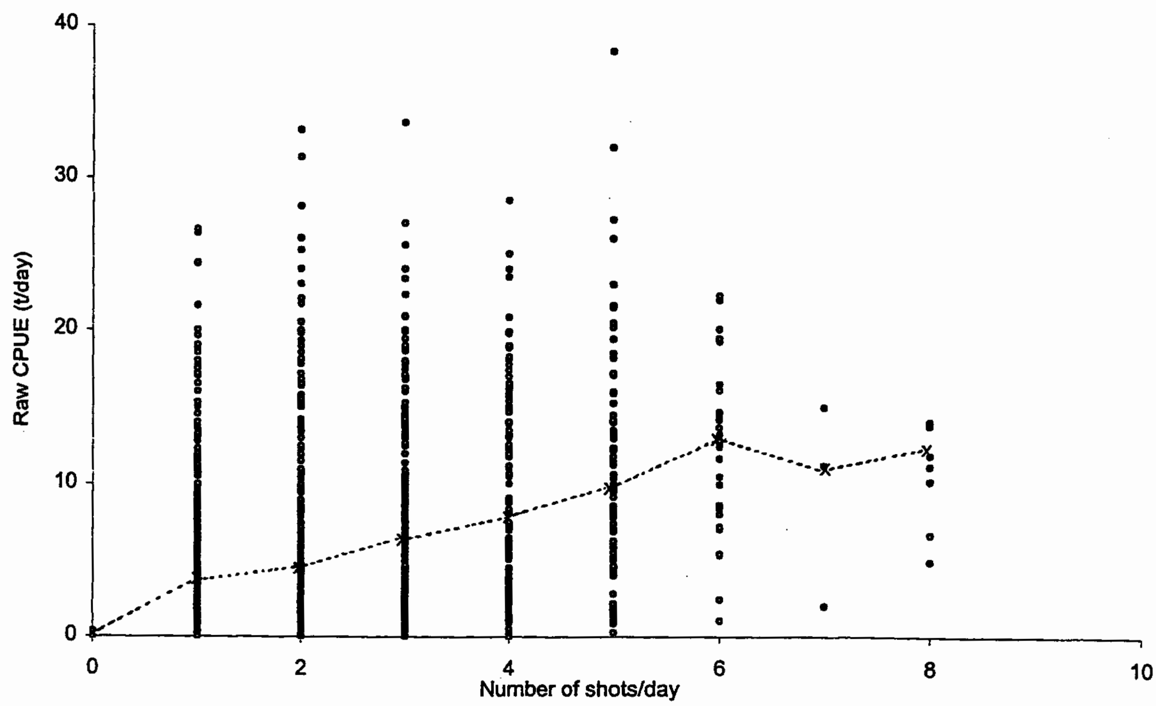


Figure 5: BYX 2 target trawl fishery: raw CPUE (t/day) and number of shots/day, and mean CPUE/shot (x), all vessels, 1989–90 to 1997–98.

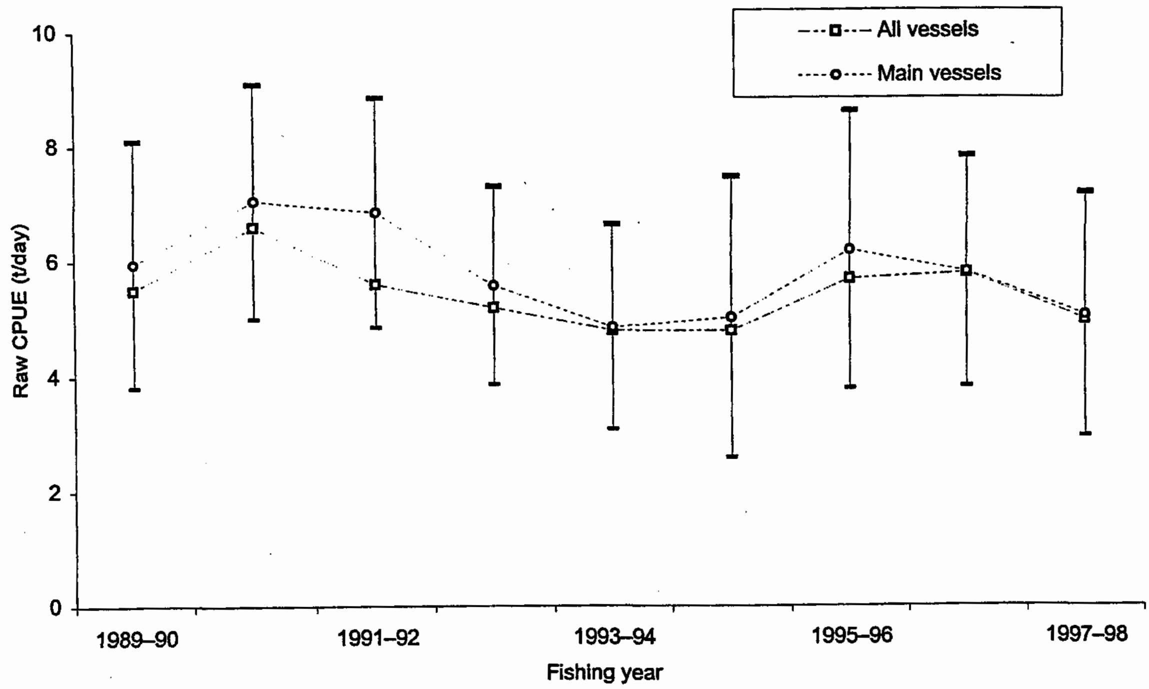


Figure 6: BYX 2 target trawl fishery: mean and C.I. For raw CPUE (t/day) main vessels, and mean raw CPUE, all vessels, 1989–90 to 1997–98.

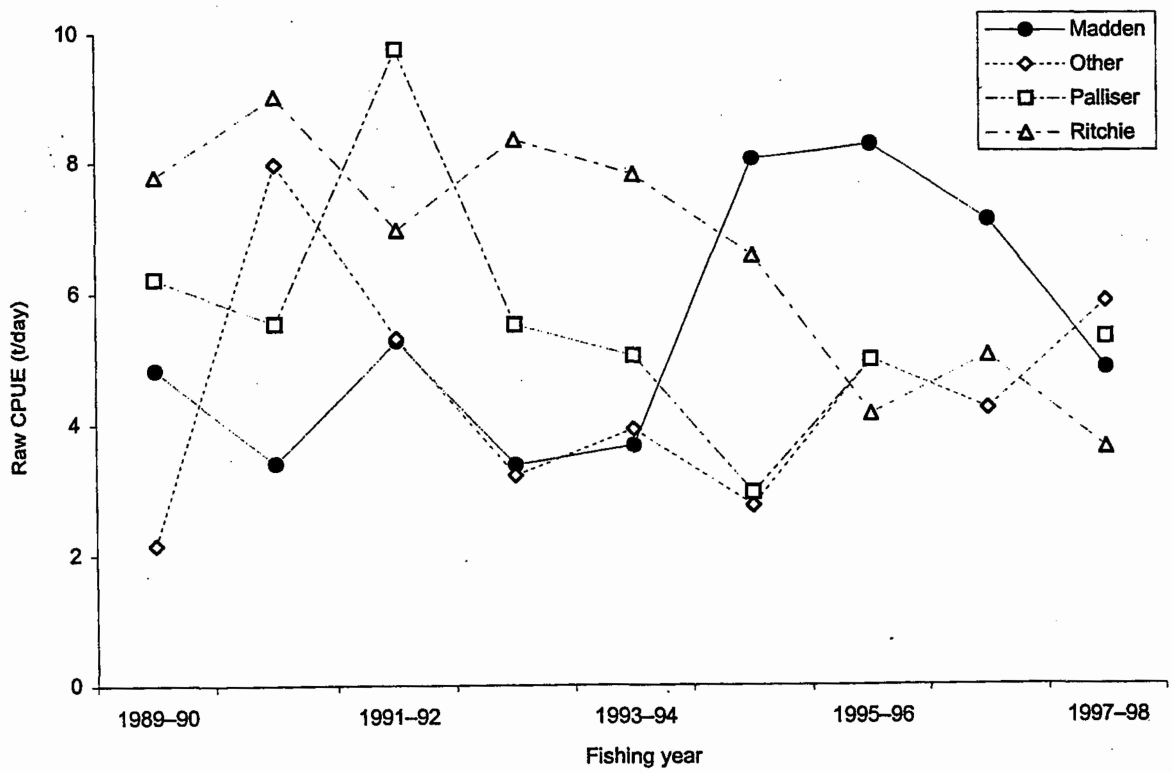


Figure 7: BYX 2 target trawl fishery: mean raw CPUE (t/day) by major fishing grounds, main vessels, 1989–90 to 1997–98.

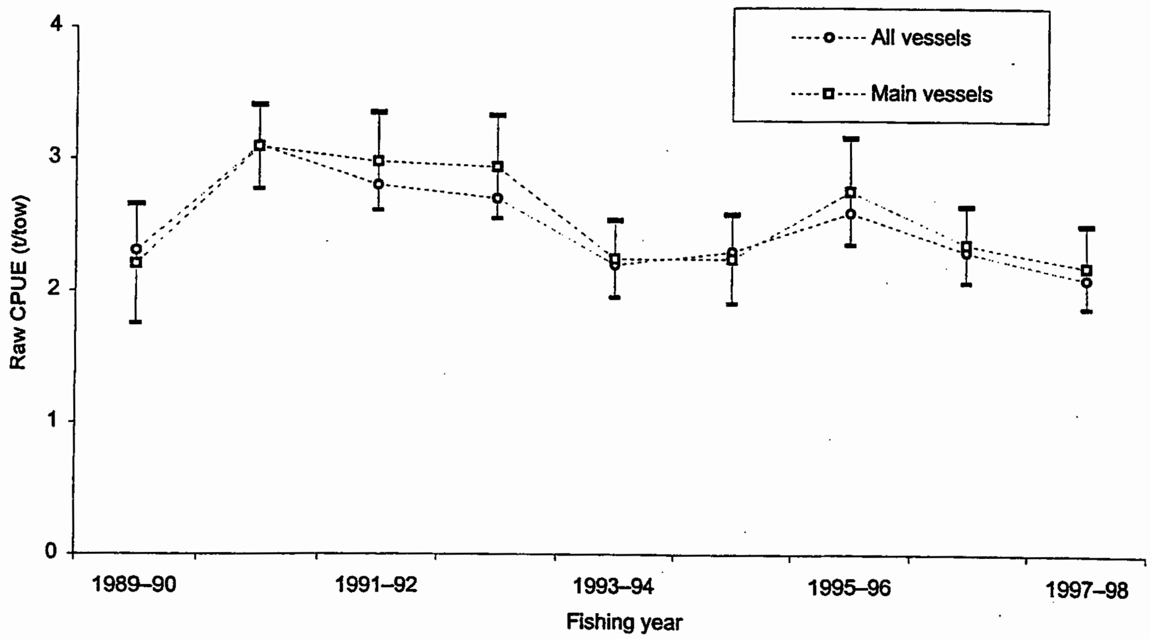


Figure 8: BYX 2 target trawl fishery: mean C.I. for raw CPUE (t/tow) main vessels and mean raw CPUE, all vessels, 1989–90 to 1997–98.

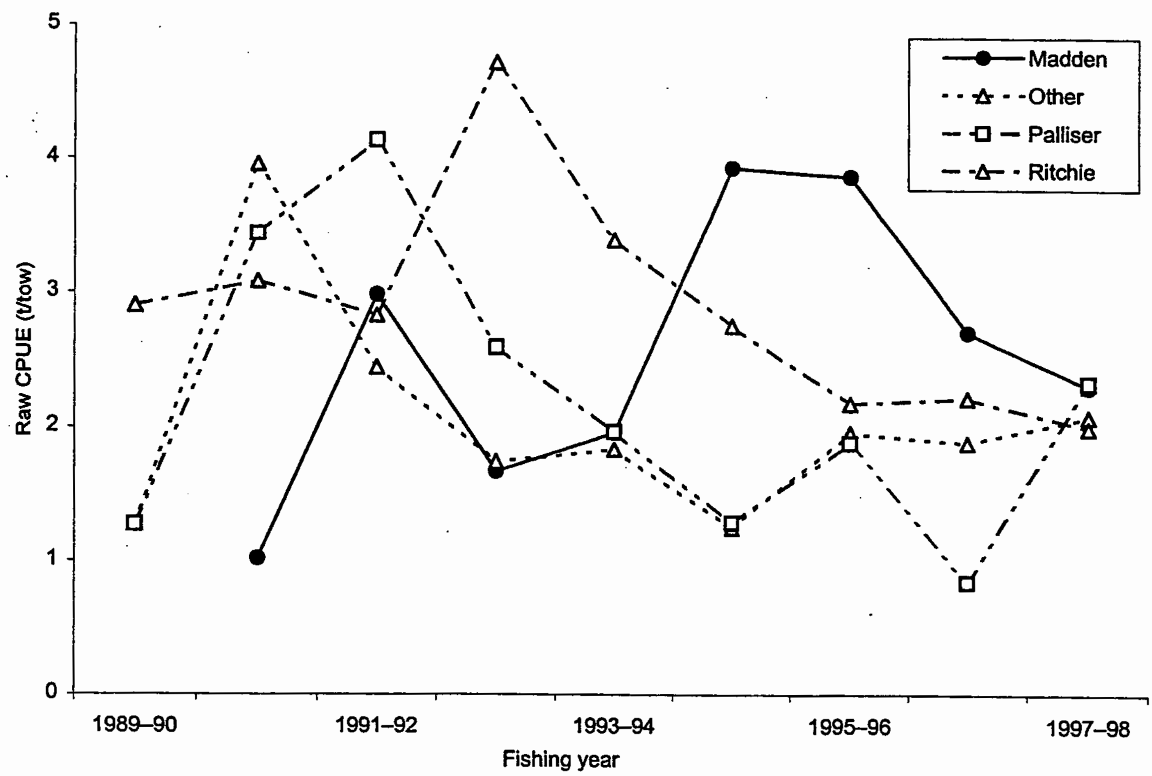


Figure 9: BYX 2 target trawl fishery: mean raw CPUE (t/tow) by major fishing grounds, main vessels, 1989–90 to 1997–98.

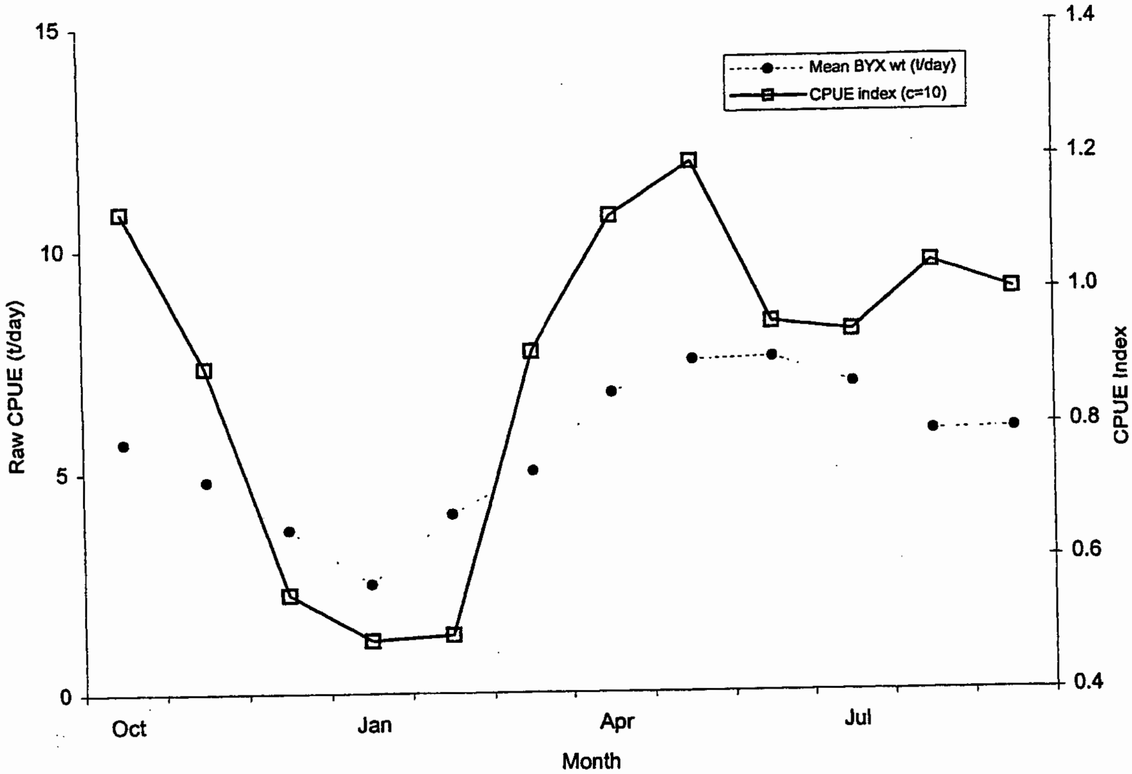


Figure 10: BYX 2 target trawl fishery: mean and C.I. for CPUE (t/day) by month, and monthly CPUE indices, all vessels 1989–90 to 1997–98, c=10.

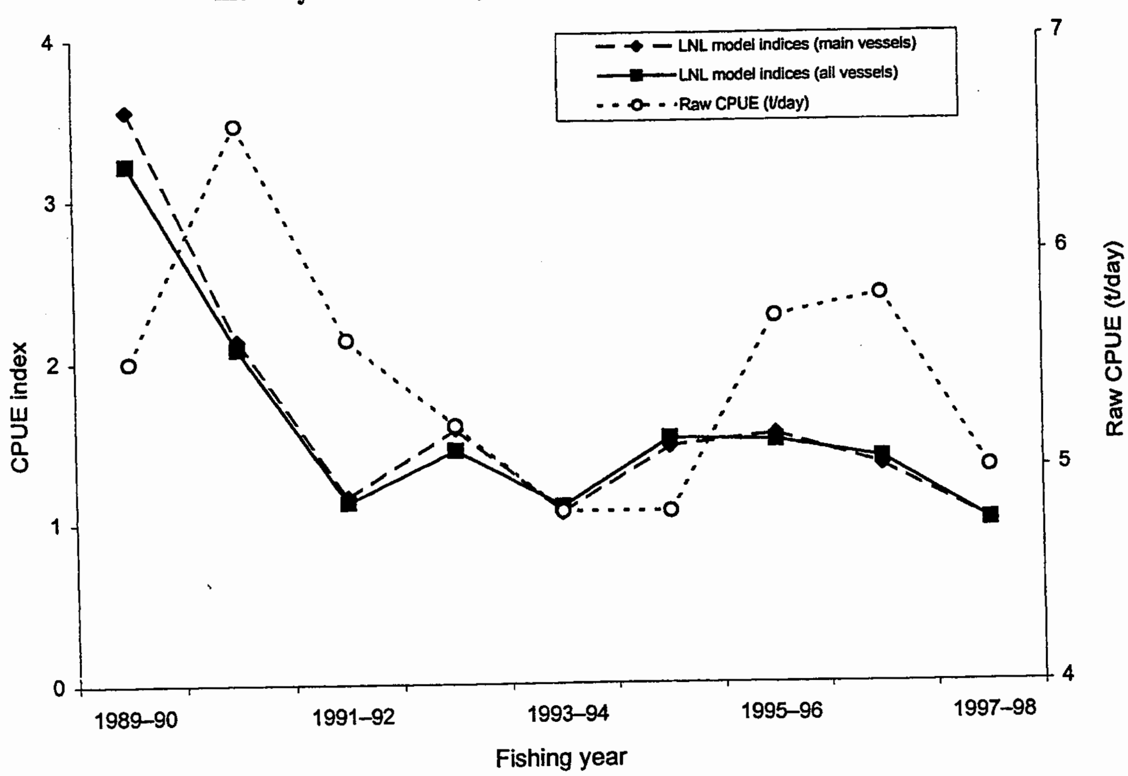


Figure 11: BYX 2 target trawl fishery: year indices, CPUE (catch/day) from the LNL main effects models, all vessels (stat. areas), and main vessels (main fishing grounds), and raw CPUE (t/day), 1989–90 to 1997–98.

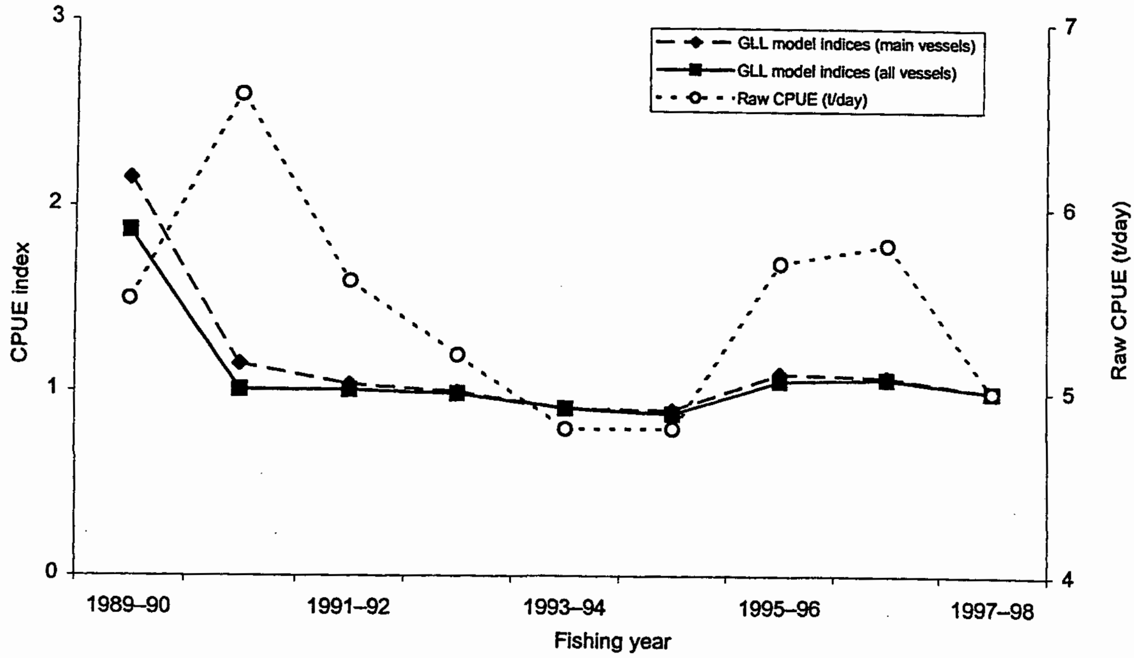


Figure 12: BYX 2 target trawl fishery: annual CPUE indices from the GLL models of catch/day, all vessels and main vessels, and raw CPUE (t/day), from 1989–90 to 1997–98.

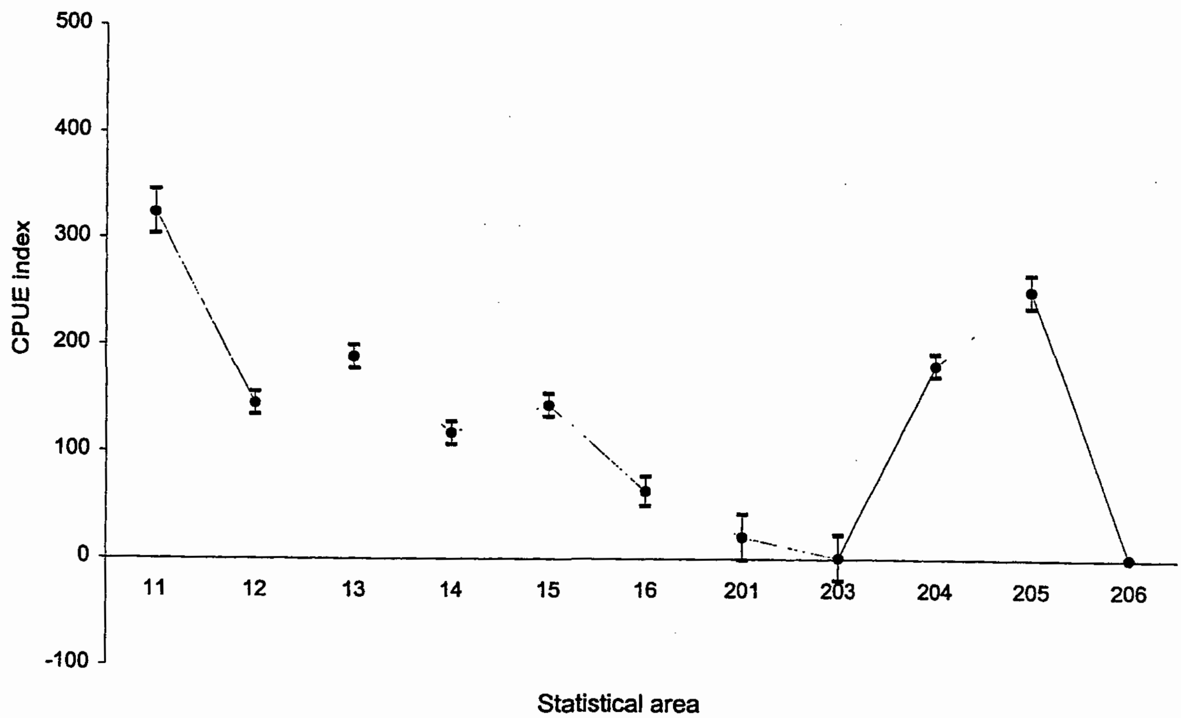


Figure 13: BYX 2 target trawl fishery: statistical area indices from the LNL model of catch/tow (all vessels), from 1989–90 to 1997–98.

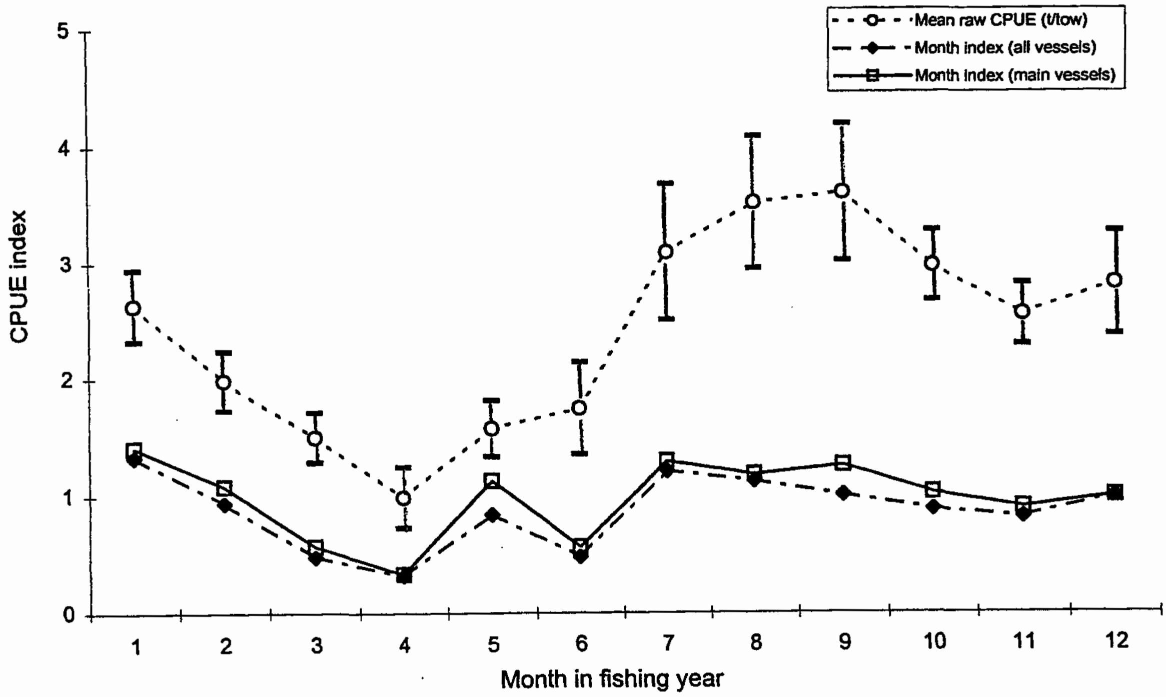


Figure 14: BYX 2 target trawl fishery: month indices from the LNL all vessel, and main vessel models of CPUE (catch/tow) , mean and C.I. for raw CPUE (t/tow), from 1989–90 to 1997–98.

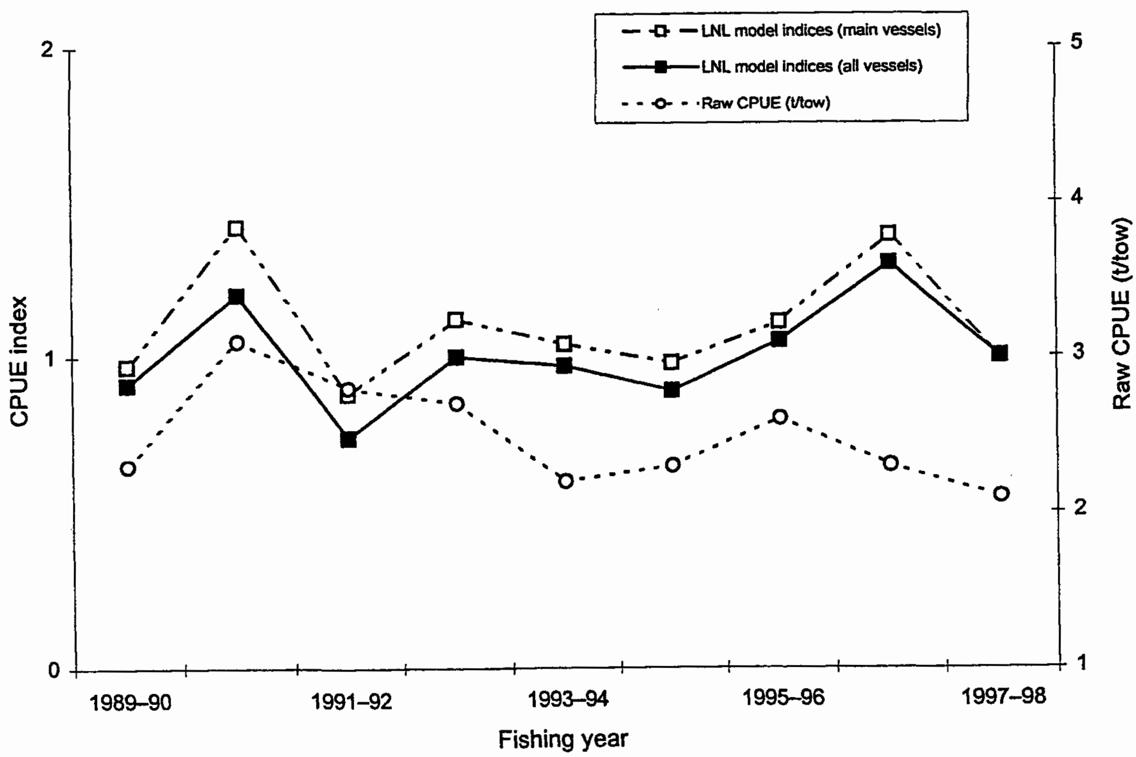


Figure 15: BYX 2 target trawl fishery: annual indices from the LNL all vessel, and main ain vessel models of CPUE (catch/tow), mean and C.I. For raw CPUE (t/tow), from 1989–90 to 1997–98.

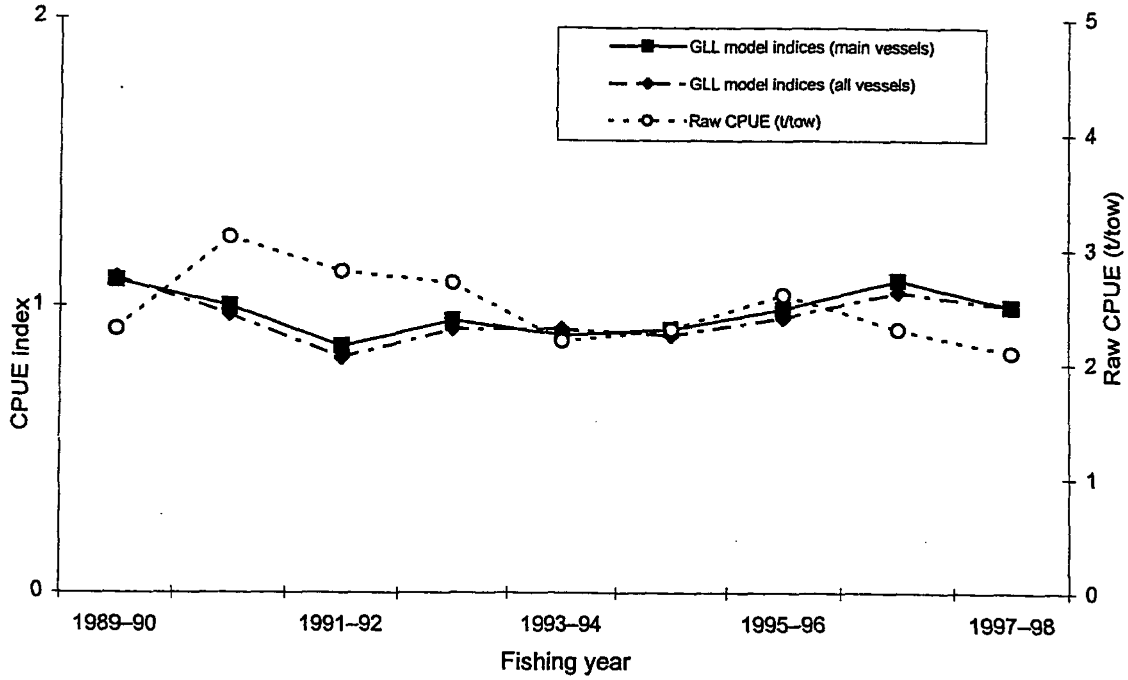
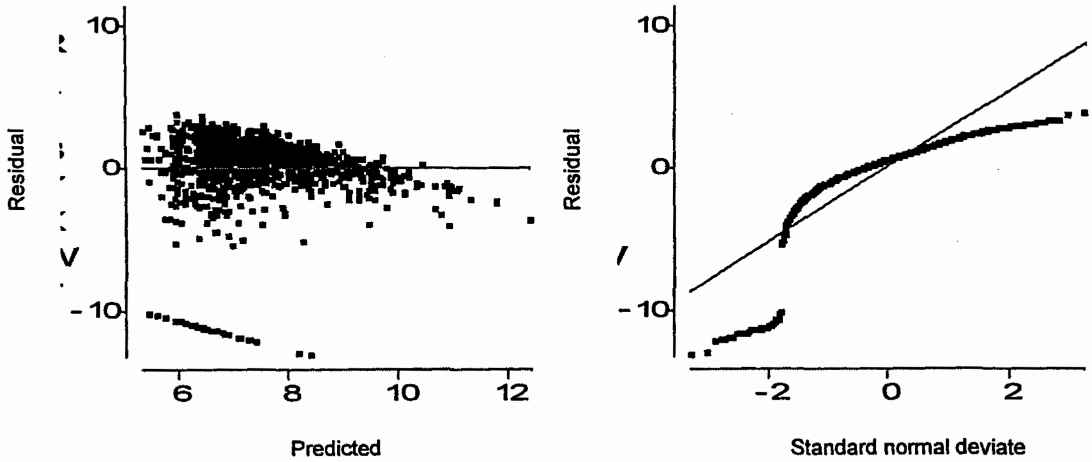
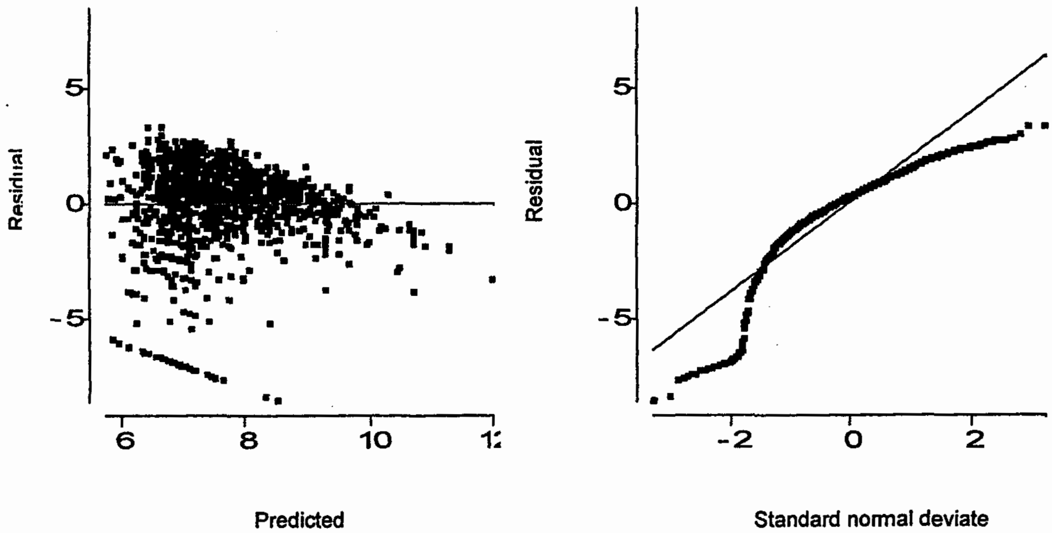


Figure 16: BYX 2 target trawl fishery: annual CPUE indices from the GLL models of catch/tow, all vessels and main vessels, and raw CPUE (t/tow), from 1989–90 to 1997–98.

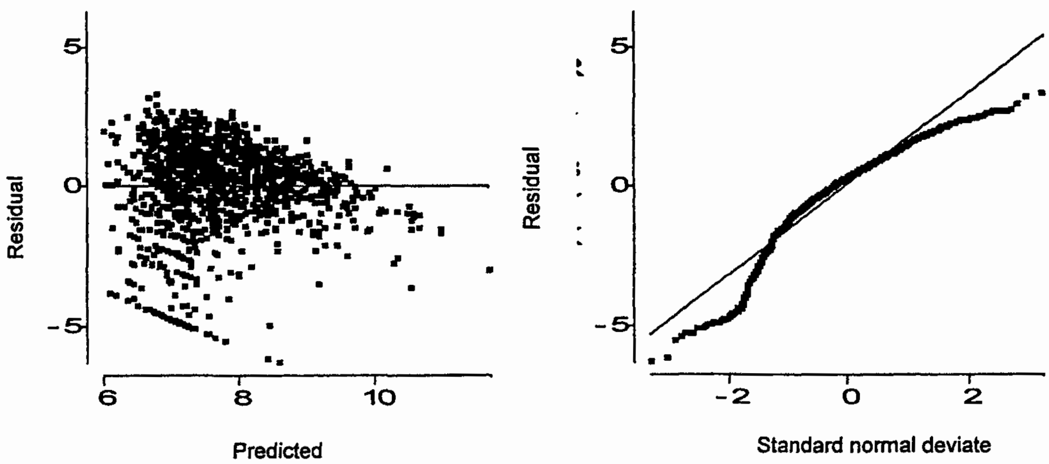
Appendix 1: Regression diagnostics for CPUE (catch/day)



BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (all vessels), log (wt+0.01) = no. of shots, vessel ID, month, fishing year.

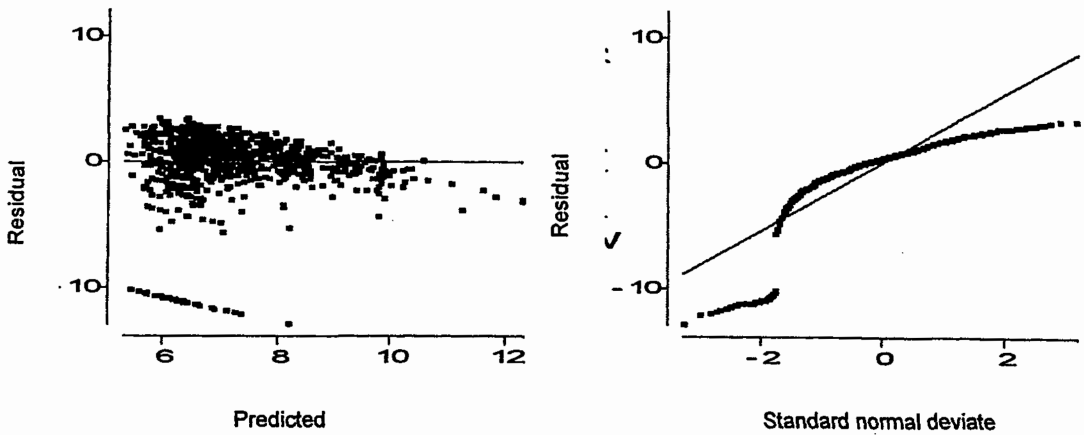


BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (all vessels), log (wt+1) = no. of shots, vessel ID, month, fishing year.

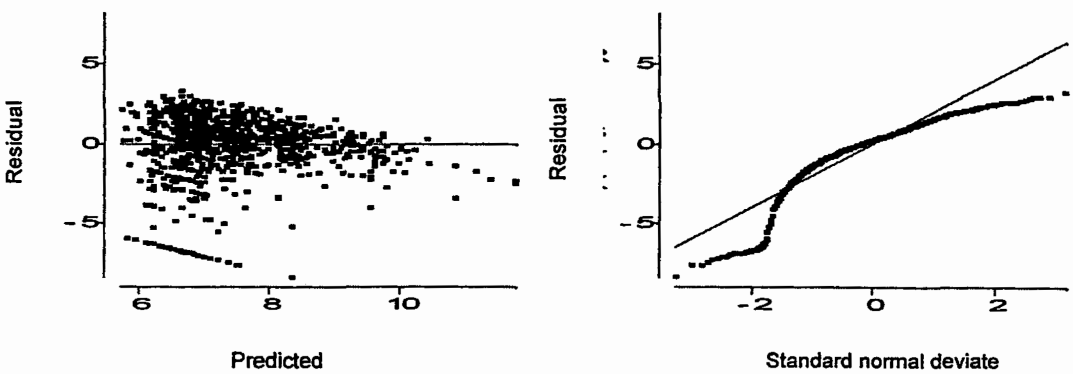


BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (all vessels), log (wt+10) = no. of shots, vessel ID, month, fishing year.

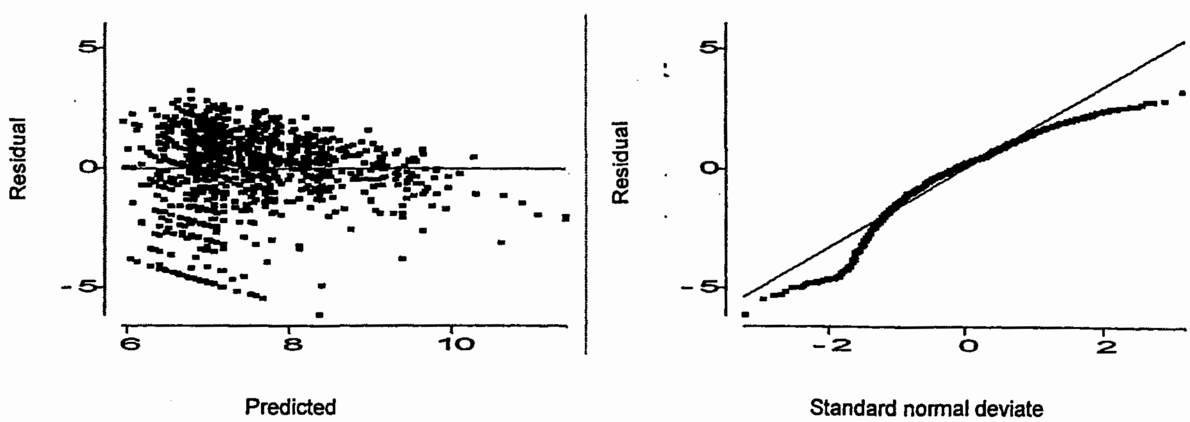
Appendix 1: – *continued*



BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (main vessels), log (wt+0.01) = no. of shots, vessel ID, month, fishing year.



BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (main vessels), log (wt+1) = no. of shots, vessel ID, month, fishing year.



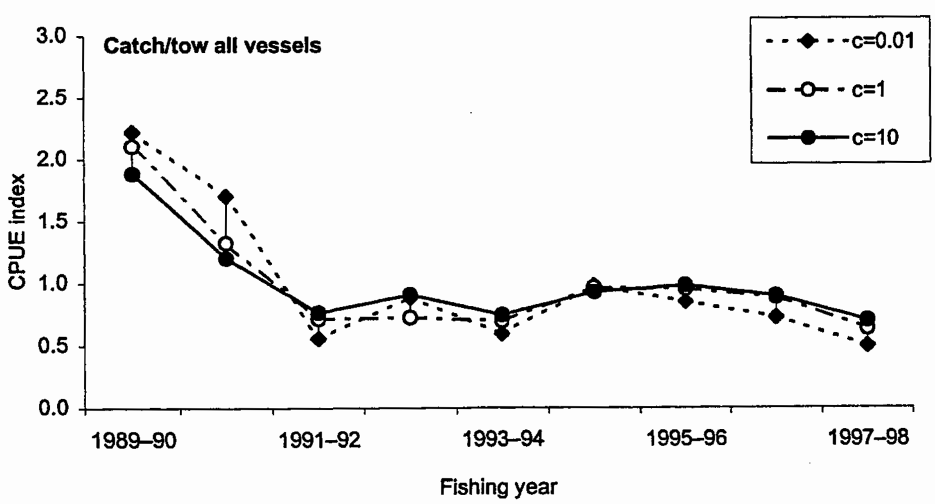
BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (main vessels), log (wt+10) = no. of shots, vessel ID, month, fishing year.

Appendix 1: – *continued*

Sensitivity analysis: log (catch/day+c), all vessels, 1989–90 to 1997–98

Comparison of annual indices and R^2 for levels of the constant (c)

Constant	c=0.01	c=1	c=10
R^2	0.21	0.27	0.31
Fishing year			
1989–90	4.46	3.22	2.69
1990–91	3.42	2.09	1.72
1991–92	1.12	1.13	1.091
1992–93	1.78	1.14	1.299
1993–94	1.19	1.10	1.062
1994–95	1.96	1.52	1.325
1995–96	1.71	1.50	1.401
1996–97	1.45	1.39	1.278
1997–98	1.00	1.00	1

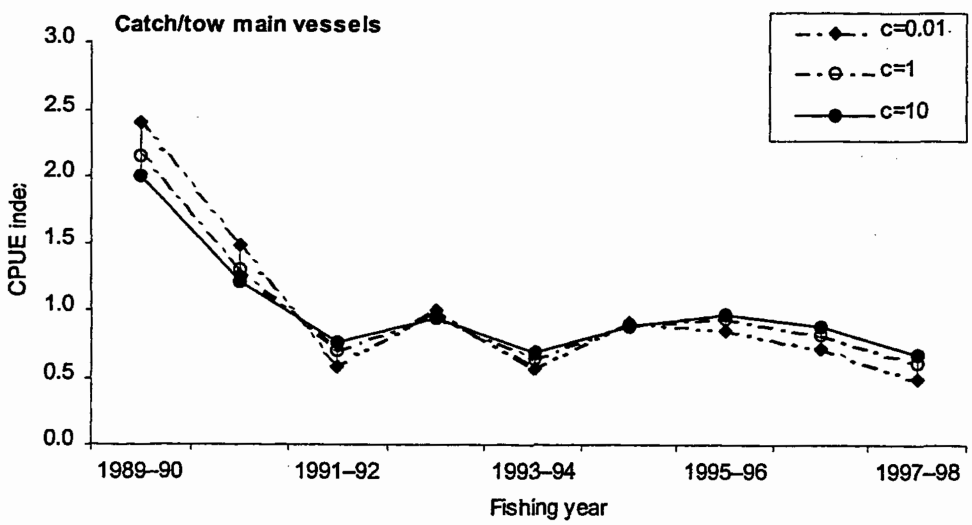


Scaled annual CPUE indices for reviewed levels of constant (c), all vessels, by fishing year 1989–90 to 1997–98.

Sensitivity analysis: log (catch/day+c), main vessels, 1989–90 to 1997–98

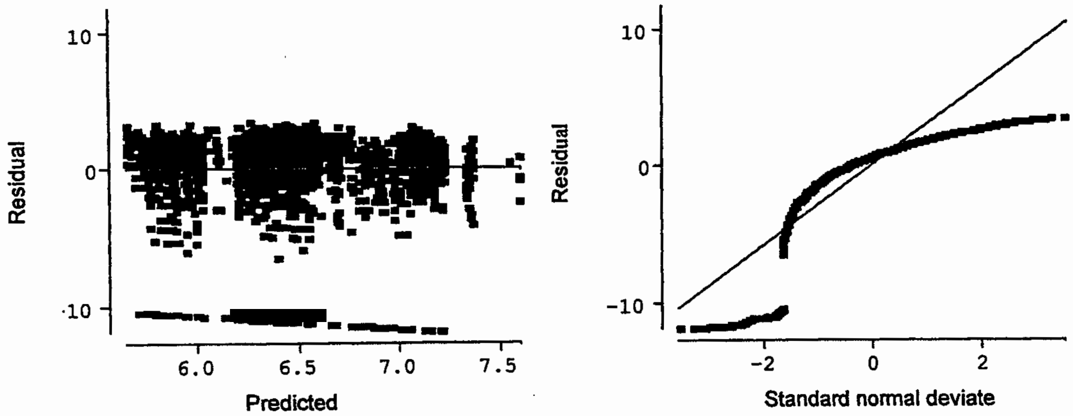
Comparison of annual indices and R^2 for levels of the constant (c)

Constant	c=0.01	c=1	c=10
R^2	0.25	0.25	0.29
Fishing year			
1989–90	4.96	3.56	2.96
1990–91	3.05	2.13	1.78
1991–92	1.21	1.16	1.13
1992–93	2.05	1.58	1.39
1993–94	1.18	1.06	1.03
1994–95	1.91	1.47	1.31
1995–96	1.74	1.54	1.45
1996–97	1.46	1.35	1.30
1997–98	1.00	1.00	1.00

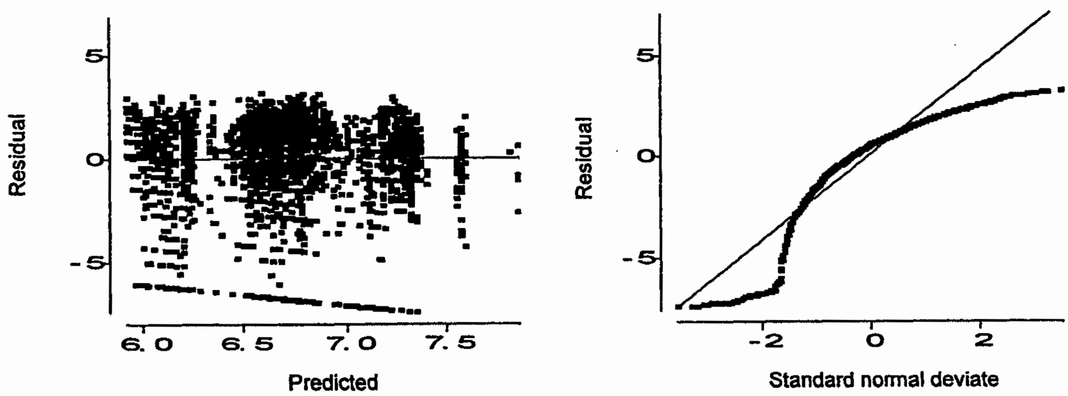


Scaled annual CPUE indices for reviewed levels of constant (c), main vessels, by fishing year 1989–90 to 1997–98.

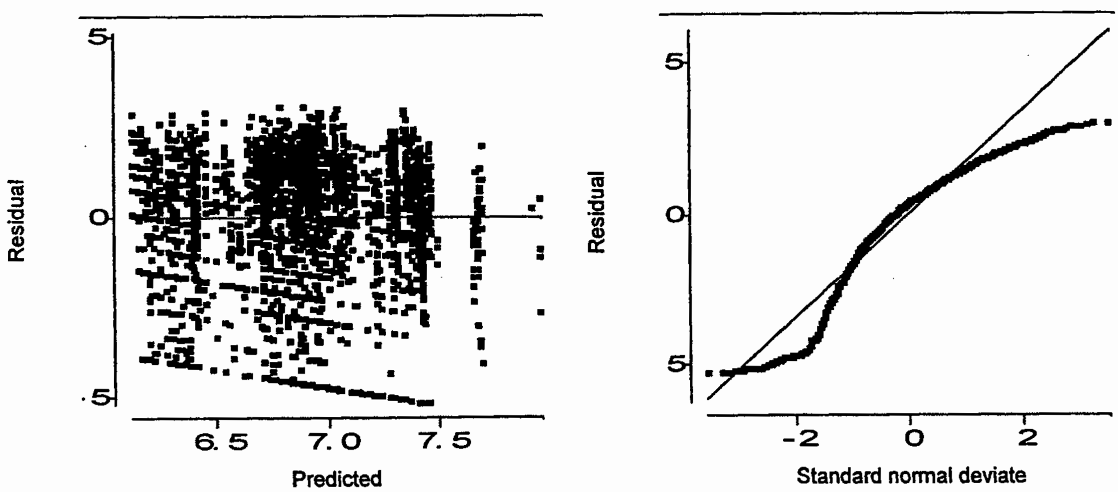
Appendix 2: Regression diagnostics for CPUE (catch/tow)



BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (all vessels), log (wt+0.01) = vessel ID, month, statistical area, fishing year

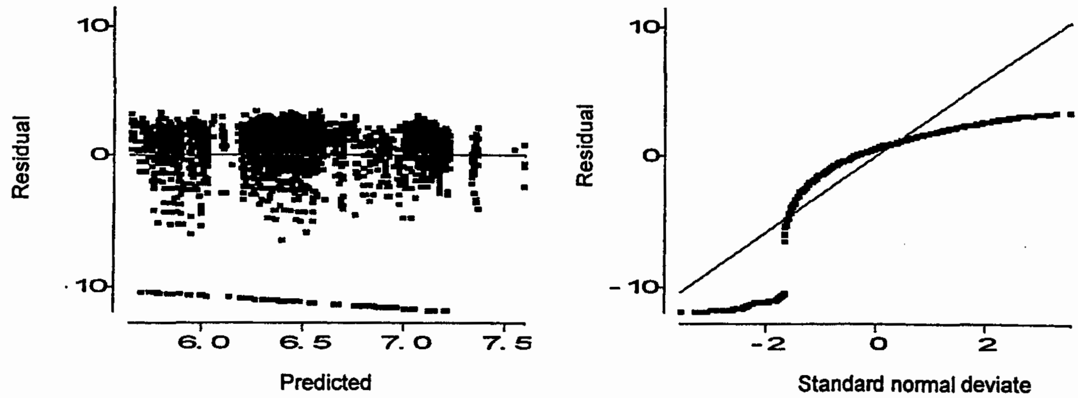


BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (all vessels), log (wt+1) = vessel ID, month, statistical area, fishing year

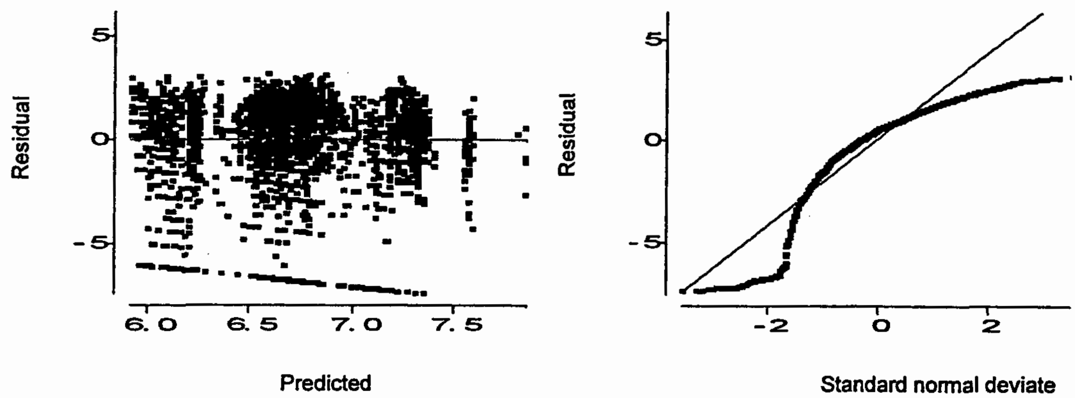


BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (all vessels), log (wt+10) = vessel ID, month, statistical area, fishing year

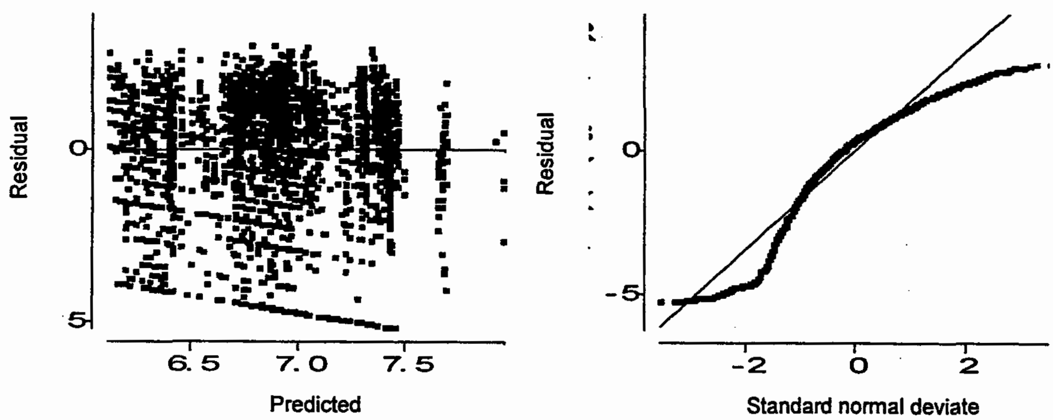
Appendix 2: – *continued*



BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (main vessels), log (wt+0.01) = vessel ID, month, fishing year



BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (main vessels, log (wt+1) = vessel ID, month, fishing year



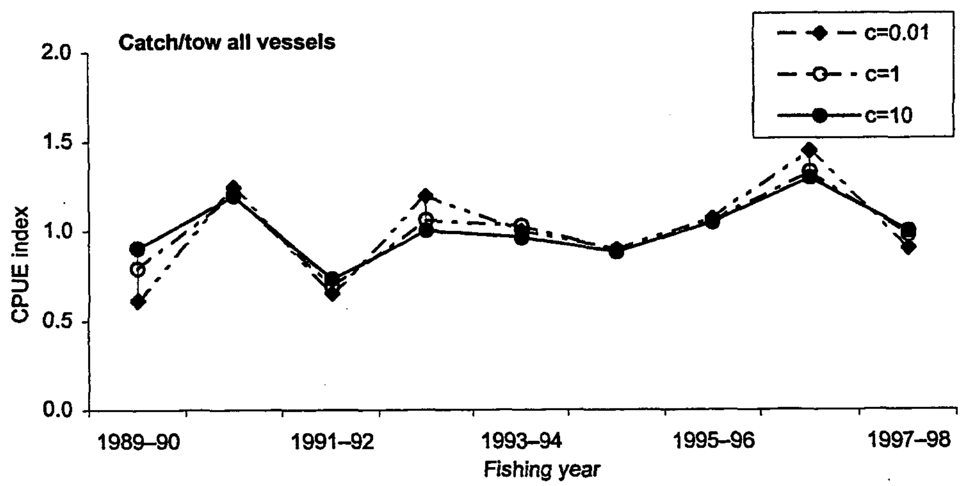
BYX 2 target midwater trawl fishery: plot of residual*predicted values for the LNL model (main vessels), log (wt+10)= vessel ID, month, fishing year

Appendix 2: – *continued*

Sensitivity analysis: log (catch/tow+c), all vessels, 1989–90 to 1997–98

Comparison of annual indices and R^2 for levels of the constant (c)

Constant	c=0.01	c=1	c=10
R^2	0.08	0.12	0.13
Fishing year			
1989–90	0.68	0.81	0.91
1990–91	1.38	1.24	1.20
1991–92	0.72	0.71	0.74
1992–93	1.33	1.09	1.01
1993–94	1.11	1.06	0.97
1994–95	0.99	0.91	0.89
1995–96	1.18	1.08	1.05
1996–97	1.60	1.36	1.30
1997–98	1.00	1.00	1.00



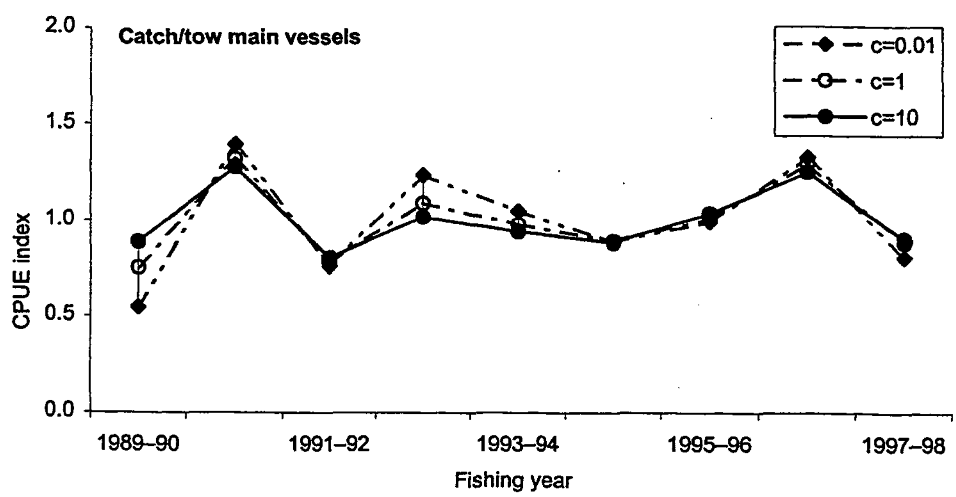
Scaled annual CPUE indices for reviewed levels of constant (c), all vessels, by fishing year1989–90 to 1997–98

Appendix 2: – *continued*

Sensitivity analysis: log (catch/tow+c), main vessels, 1989–90 to 1997–98

Comparison of annual indices and R^2 for levels of the constant (c)

Constant	c=0.01	c=1	c=10
R^2	0.08	0.11	0.12
Fishing year			
1989–90	0.68	0.85	0.98
1990–91	1.72	1.50	1.42
1991–92	0.94	0.88	0.89
1992–93	1.53	1.24	1.13
1993–94	1.30	1.11	1.04
1994–95	1.09	1.01	0.98
1995–96	1.23	1.14	1.15
1996–97	1.64	1.47	1.39
1997–98	1.00	1.00	1.00



Scaled annual CPUE indices for reviewed levels of constant (c), main vessels, by fishing year1989–90 to 1997–98