EXECUTIVE SUMMARY

Langley, A.D. (2002). Analysis of catch and effort data from the TRE 7 fishery.

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This report documents the results of CPUE analyses for the TRE 7 fishery. The analyses are essentially an update of analyses done in 1999.

A pseudo-standardised analysis of catch and effort data from the 1974–97 period was updated with the inclusion of data from the 1997–98 to 2000–01 fishing years. The analysis was based on catch and effort data aggregated by vessel class (small pair trawlers, large pair trawlers, and single trawlers) and month for the peak trevally fishing season (December–March).

The annual indices derived from the pseudo-standardised CPUE analysis were consistent with previously determined. The indices reveal an increase in the catch rate of trevally during the late 1970s to reach a peak in 1980–81. The indices declined from 1980–81 to 1986–87, increased in 1987–88, and remained relatively constant at this level subsequently.

Two separate standardised CPUE analyses were also conducted based on data sets from the target trevally fishery and the trevally bycatch from the snapper (SNA 8) target fishery. Both models reveal similar trends in the catch rate of trevally with respect to the main variables included in the model (vessel, statistical area, month, number of trawls, and snapper catch). The annual indices derived from the two standardised analyses suggested an overall decline in the catch rate of trevally from 1989–90 to 2000–01. However, there is a poor correlation between the two sets of annual indices, with years of high and low catch rates differing between the two models.

The target trevally index is considered to be the more reliable of the two standardised CPUE indices due to the greater proportion of the total TRE 7 catch incorporated in the target trevally data set. There are also a number of systematic trends in the trevally catch and effort data from the snapper target fishery data that could potentially bias the CPUE indices derived from the snapper bycatch model. However, the trevally target indices reveal a high degree of inter-annual variability and, in the absence of other indices of abundance for the TRE 7 fishery, it is unknown whether they reliably monitor abundance.

Potential biases in the annual indices derived from the pseudo-standardised analysis are identified. These are mainly attributable to changes in the relative level of target fishing for trevally over the period included in the analysis. Recent data from the fishery reveals that there was an increase in the proportion of the trevally single trawl catch taken by the target fishery and an increase in the proportion of days fished that targeted trevally. It is considered that the annual indices derived from the pseudo-standardised analysis are less reliable than the indices derived from the standardised CPUE models.

1. INTRODUCTION

The TRE 7 fishstock supports an important inshore trawl fishery for trevally, principally off the northern west coast of the North Island. The species is targeted by trawl vessels and also represents a significant bycatch of the snapper trawl fishery (SNA 8).

The TRE 7 fishery developed from the early 1940s with relatively small landings taken principally as a bycatch of the snapper fishery (Francis et al. 1999). Landings increased during the 1960s and were about 2000–3000 t from 1971 to 1983. A TACC of 1800 t was introduced in 1986–87 and was increased to the current level of 2153 t in 1990–91 (Annala et al. 2001). Annual catches have been about the level of the TACC since 1992–93. A detailed summary of the catch history from TRE 7 was provided by Francis et al. (1999).

Catch and effort data from the TRE 7 fishery were analysed by Francis et al. (1999). The CPUE analysis included data from 1974 to 1997 derived from three data formats. Catch and effort data were summarised by vessel class (small pair trawlers, large pair trawlers, and single trawlers) and aggregated by month for the peak trevally fishing season (December–March). A "pseudo-standardised" CPUE analysis was conducted using these data sets and a standardised CPUE analysis was conducted on catch and effort data from the trevally and snapper target single trawl fisheries for 1989–97 (Francis et al. 1999).

The pseudo-standardised CPUE analysis conducted by Francis et al. (1999) showed no long-term trends in catch rate. Similarly, the year indices derived from the standardised CPUE analyses showed little contrast over the 8 years from 1989–90 to 1996–97. The annual indices derived from the single trawl pseudo-standardised analysis and the indices from the trevally target CPUE analysis were incorporated in a stock assessment of the TRE 7 fishery (Hanchet 1999).

This report updates the analysis of CPUE data conducted by Francis et al. (1999) with the inclusion of data from the 1997–98 to 2000–01 fishing years. The work summarised in this report was conducted as a requirement of objective 1 of the Ministry of Fisheries research project TRE2001/02, Stock assessment of trevally in TRE 7. The specific project objective was *to update the standardised and unstandardised CPUE analyses for TRE 7*.

2. METHODS

2.2 Standardised CPUE analysis

2.2.1 CPUE data set

The initial data set was restricted to catch and effort records from the trevally and snapper bottom trawl fishery operating within TRE 7 from 1989–90 to 2000–01.

About 50% of the trawl records from the two fisheries were recorded in Catch Effort Landing Return (CELR) format. CELRs record the summarised catch and effort data for each day of fishing in a statistical area (for a given target species and fishing method). The remainder of the catch and effort data were recorded in Trawl Catch Effort Processing Return (TCEPR) format that records catch and effort data for individual trawls. To incorporate both sets of data in the CPUE data set, TCEPR records were amalgamated to a format consistent with the CELR data. A single record was derived for each vessel-day of fishing within a statistical area and the total number of trawls, total duration of fishing, and total catch of trevally and snapper was determined.

Separate CPUE data sets were derived for the two fisheries. The trevally target CPUE data set included all records where trevally was targeted and caught and the snapper bycatch CPUE data set included all records where snapper was targeted and trevally was caught. The CPUE data sets were restricted to catch and effort records from statistical areas 040–042 and 045–047. This area accounts for most of the catch from the TRE 7 fishery (Francis et al. 1999).

The variables included in the two CPUE data sets are given in Table 1.

The initial data set for both fisheries combined included a total of 18 303 aggregated daily catch and effort records. The range of values for each of the variables in the CPUE data set was examined and obvious outliers were excluded from the data set. The accepted range for each of the variables is given in Table 2. About 7% of all CPUE records and 18% of the trevally catch were excluded by these criteria.

The trawl fleet generally operated in both the target trevally fishery and the target snapper fishery between 1989–90 and 2000–01. A core group of vessels was defined from the combined CPUE data set, with qualifying vessels participating in the fishery for at least three years and completing at least 50 days of fishing (targeting either trevally or snapper). The core group of 37 vessels accounted for 87% of the groomed CPUE records and 89% of the corresponding trevally catch. The final data set included 5263 target trevally records and 5817 snapper bycatch CPUE records.

2.2.2 Data summary

The 39 core vessels in the combined CPUE data set were in the fishery for between three years and 12 years from 1989–90 to 2000–01 (Figure 1). Of the 39 vessels, 15 were in the fishery for at least 8 years, while four vessels were present in every year. Most of the core vessels completed 100–700 days of fishing during the study period (Figure 1).

Trevally target fishery

Most of the CPUE records from the target trevally fishery were reported by vessels in the 15–30 m length range (Figure 2). The size of vessels participating in the fishery remained relatively constant from 1991–92 to 2000–01, although the vessels in the fishery during the two preceding years were generally smaller and less powerful.

For each day of fishing, the vessels generally conducted 2–4 target trawls with a total trawl duration of about 5–12 hours (Figure 2). The total number of trawls conducted per day was relatively constant over the study period, while there was a general decline in fishing duration from 1992–93 to 1998–99 followed by an increase in the two most recent years.

The median daily catch of trevally from the target fishery was relatively constant between 1989–90 and 1993–94 at about 500–600 kg, increased markedly to 1200 kg in 1994–95, and was maintained at about 300–400 kg from 1995–96 to 2000–01 (Figure 2).

From 1989–90 to 2000–01, the distribution of target trevally fishing effort between statistical areas was variable. In 1989–90 and 1990–91, the fishery was concentrated in the North Taranaki Bight (statistical area 041). In the subsequent years, this area accounted for a smaller proportion of the total fishing effort and there was an increase in the level of effort in statistical areas 047 (Ninety Mile Beach) and 042 (Table 3). From 1994–95 to 1998–99, a significant proportion of the target trevally fishing effort occurred in statistical area 042. Statistical areas 040 and 046 accounted for a relatively low proportion of the total fishing effort from 1989–90 to 2000–01 (Table 3).

Most of the target trevally fishing was conducted during the November–April period, with a seasonal peak in fishing effort during January–March (Table 4). The monthly distribution of fishing effort varied between years, although there was no systematic trend in the seasonal distribution of effort between 1989–90 and 2000–2001.

From 1989–90 to 2000–2001, about 15–20 core vessels operated in the target trevally fishery annually (Table 5). However, the level of target fishing effort and catch increased steadily. The trevally target catch generally increased from about 200 t in 1989–90 to about 600 t in 2000–2001. The level of fishing effort in the target fishery, expressed as the annual number of trawls and total trawl duration, followed a similar trend to the target catch. The average catch per trawl and average catch per hour of trawling remained relatively constant throughout 1989–90 to 2000–01 (Table 5).

Snapper bycatch

From 1989–90 to 1995–96, the snapper bycatch CPUE dataset was dominated by core vessels in the 15–20 m length range (overall length). From 1996–97, there was an increase in the fishing effort by the larger and more powerful vessels in the fleet (Figure 3).

During most fishing days, the vessels conducted two to four trawls of a total fishing duration of 5–12 hours. From 1994–95 to 2000–01, daily median fishing duration steadily declined from 9 hours to 7 hours (Figure 3).

The daily catch of trevally reported from the snapper target fishery was relatively low between 1989–90 and 2000–01 (Figure 3). The level of snapper catch was more variable, with higher catches in 1989–90 to 1991–92 and 1996–97 to 1998–99.

From 1989–90 to 2000–01, the target snapper fishery was concentrated within statistical areas 042 and 045 (Table 6). However, the distribution of fishing effort between areas varied over the study period. In 1989–90, a high proportion of the fishing effort occurred in statistical area 047 (Ninety Mile Beach) although the level of fishing effort in this area was low during the subsequent year. From 1990–91 to 2000–01, there was a general decline in the level of fishing effort in statistical areas 041 and 042, while the proportion of fishing effort in 046 and 047 increased (Table 6). Negligible targeting for snapper occurred in statistical area 040.

Most (70–80%) of the snapper target fishing effort occurs during October to March (Table 7). However, from 1989–90 to 2000–01 there was a general increase in the proportion of fishing effort during November–December and a corresponding decline in fishing effort in February.

The snapper core vessel fleet comprised about 15–22 vessels annually (Table 8). The annual TRE 7 bycatch from the fishery increased from about 100 t in 1989–90 to 400 t in 1998–99 and declined to about 180 t in the two subsequent years. From 1989–90 to 1992–93 there was a large increase in the number of snapper target trawls and total trawl duration. The level of fishing effort remained relatively stable from 1993–94 to 1998–99, but declined in 1999–2000 and 2000–01 (Table 8).

The catch rate of trevally (catch per trawl and catch per hour) was relatively stable between 1989–90 and 1995–96, increased to reach a peak in 1998–99, and then declined slightly in the two subsequent years (Table 8). From 1996–97, there was a slight decline in the proportion of snapper target fishing days with no associated trevally bycatch.

2.2.3 CPUE analysis

A standardised CPUE analysis was conducted for both the trevally target fishery and snapper bycatch fishery based on the methods of Vignaux (1992, 1994). For both CPUE analyses, the natural logarithm of the trevally catch (kilograms) from one day of fishing was used as the CPUE estimate (dependent variable) in the model. The two effort variables (total number of trawls and the total fishing duration) were introduced as potential predictor variables in the CPUE models. This enabled the model to determine the most appropriate relationship between the daily trevally catch and the number of trawls and/or fishing duration.

For each model option, the relevant CPUE estimate (the dependent variable) was tested against the predictor variables summarised in Table 1. All continuous variables were offered to the model as third order polynomial functions. The variable *vessel* was included as a categoric variable to account for differences in the relative fishing success between the individual vessels.

The CPUE estimate was regressed against each of the predictor variables to determine which explained the most variability in CPUE. This selected variable was then included in the model and the CPUE regressed against the selected variable and each of the other predictor variables to determine the next most powerful variable. The stepwise regression was continued until the remaining variables contributed no significant explanatory power to the model (less than a 0.5% increase in the R^2 value).

Annual indices and the associated standard errors were determined following Francis et al. (1999).

For each model option, the model fit was investigated through an examination of the model residuals and quantile-quantile plots (Chambers et al. 1983). The predicted relationship between CPUE and each of the main variables included in model was also examined.

2.3 Pseudo-standardised CPUE analysis

Francis et al. (1999) conducted a CPUE analysis of the TRE 7 fishery using all the available catch and effort data from the 1974–97 period. The analysis included catch and effort (days fished) data aggregated by month for the main fishing season (December–March) for three separate vessel classes:

?? single trawlers 16–22.9 m long and 150–350 kW power,
?? small pair trawlers 18–22.9 m long,
?? large pair trawlers 23 m long and over.

The CPUE data set was updated to include aggregated catch and effort data from the single trawl vessels from the 1997–98 to 2000–01 fishing years (Appendix 1).

The updated CPUE data set was analysed using a generalised linear model following the procedure of Francis et al. (1999). Monthly aggregate CPUE values were treated as replicate estimates of CPUE for the fishing season. The monthly CPUE were $\log_{10}$ transformed and regressed against the predictor variables fishing year, vessel class, and the interaction term between the two variables. Each monthly CPUE value was weighted by the number of fishing days in the month. The model enabled a year index to be calculated for the time-series based on the coefficients for the individual fishing year and single trawl vessel class.

3. RESULTS

3.1 Standardised CPUE models

3.1.1 Trevally target model

The trevally target CPUE model included the categorical variable *vessel* at the first iteration, followed by the *trawls* variable as a third order polynomial function (Table 9). The categorical variables *month, fishing year,* and *stat area* were included at the third, fourth, and fifth iterations, respectively. The continuous variable *snapper catch* was the final variable included in the model. The six variables explained 43% of the variation in the logarithm of daily trevally catch (Table 9).

The CPUE model predicted a steady increase in daily trevally catch with an increase in the number of *trawls* conducted, to a maximum of four trawls per day (Figure 4). Catches were predicted to remain relatively constant with increased fishing effort.

The individual *vessel* coefficients from the CPUE model reveal a high level of variation in the fishing success among the vessels in the target trevally fleet (Figure 4). *Month* coefficients were low during May–September, increased during spring to reach a peak in December–January, and subsequently declined during late summer–autumn (February–April) (Figure 4).

Highest catch rates were achieved in *stat area* 040 (Figure 4). Catch rates from the remaining statistical areas were comparable, although catch rates from the northern area of the fishery (statistical areas 045, 046, and 047) were slightly higher (Figure 4).

The CPUE model predicts an increase in trevally catch rate with increasing snapper bycatch, up to a maximum snapper catch of 1000 kg. The relationship is poorly determined for higher values due, in part, to the small number of records with a snapper bycatch exceeding 1000 kg (Figure 4).

The annual indices from the trevally target CPUE model were variable between 1989–90 and 2000–01. The annual indices were high in 1989–90, 1990–91, and 1994–95, while the indices for 1992–93, 1998–99, and 1999–2000 were low (Table 10 and Figure 4). The high indices at the start of the time series and low indices at the end of the series suggest an overall decline in the catch rate of trevally between 1989–90 and 2000–01. However, there is no systematic trend in the annual indices and the 1989–90 and 1990–91 indices have a higher standard error.

3.1.2 Snapper bycatch model

The snapper bycatch CPUE model included the same predictive variables as the target trevally CPUE model in almost the same order (Table 11). However, the six variables explained less of the variation in the logarithm of daily trevally catch compared to the target trevally model (29% compared to 43%).

The parameterisation of the *trawls, month, stat area*, and *snapper catch* variables for the snapper bycatch model were comparable to the trevally target CPUE model (Figure 5). There was also a significant correlation between the corresponding vessel coefficients derived from the two models (Figure 6). However, the annual indices derived from the snapper bycatch CPUE model were less variable than those from the trevally target model. The indices indicated the bycatch rate of trevally was constant between 1990–91 and 1999–2000, with a higher catch rate in 1989–90 and a lower index for 2000–01 (Table 12).

The residuals from both CPUE models approximated a normal distribution (Figure 7).

3.2 Pseudo-standardised index

The annual indices derived from the pseudo-standardised CPUE analysis were consistent with indices determined by Francis et al. (1999). The indices reveal an increase in the catch rate of trevally during the late 1970s to reach a peak in 1980–81(Figure 8 and Table 13). The indices declined from 1980–81 to 1986–87, increased in 1987–88, and remained relatively constant at this level throughout the subsequent period.

4. DISCUSSION

A comparison of the annual indices derived from the three CPUE analyses reveals considerable differences in the resulting trends in catch rates from the TRE 7 fishery during recent years. The annual indices from the pseudo-standardised analysis are relatively constant between 1989–90 and 2000–01 (Figure 9). The annual indices derived from the two standardised analyses are more variable, in particular the indices from the target trevally model, and suggest an overall decline in catch rates from 1989–90 to 2000–01. However, there is a poor correlation between the two sets of annual indices, with years of high and low catch rates differing between the two models (Figure 9).

The decline in the annual indices from the target trevally CPUE model is largely attributable to the high indices from the 1989–90 and 1990–91 years. Both indices have a high associated standard error compared to the remainder of the time series. The indices for these years were also derived from catch and effort data skewed to include the smaller trawl vessels operating within the southern region of the fishery (statistical area 041) (see Table 3 and Figure 2).

The high inter-annual variation observed in the indices derived from the target trevally standardised analysis and, to a lesser extent, the snapper bycatch analysis may be attributable to other important factors that are not incorporated in either CPUE model. The prevailing environmental conditions may influence the catch rate of trevally through increasing the availability of the species and/or influencing the efficiency of the fishing operation. This scale of inter-annual variability is not apparent from the indices derived from the pseudo-standardised analysis. This may be due to the aggregation of catch and effort data from all vessels fishing in a given month and/or the lack of inclusion of any other explanatory variables in the model.

The aggregated nature of the pseudo-standardised data set provides no opportunity to explore potential changes in the distribution of catch and effort throughout the time period. Francis et al. (1999) were relatively confident that the pseudo-standardised indices were monitoring TRE 7 abundance, largely based on the application of these same data to determine CPUE indices for the SNA 8 fishery. However, the analysis assumes that the relative level of target fishing between the snapper and trevally fishery remained constant throughout the entire study period. This is despite differences in the levels of total annual catch from the SNA 8 and TRE 7 fisheries, particularly during the mid 1970s and early 1980s when the catch from the SNA 8 fishery peaked and then declined. In contrast, catches from the TRE 7 fishery reached a peak in the early 1980s and then declined.

Since 1986–87, catches from the two fisheries have been constrained by the respective TACCs, with the TACC for the TRE 7 fishery at a higher level than the SNA 8 TACC (Annala et al. 2001). The higher TACC for TRE 7 may have resulted in a higher degree of target fishing for trevally compared to the historical (pre QMS) distribution of catch.

There was also an apparent increase in the level of directed target fishing for trevally during recent years. Between 1989–90 and 2000–01, there was a general increase in the proportion of the trevally single trawl catch taken by the target fishery (from about 65% to 85%) and an increase in the proportion of trevally target days fished from 40% to 60%. This may be attributable to a change in the relative abundance of the two species or a shift in the seasonal distribution of the operation of the fishery. The annual indices derived from the pseudo-standardised analysis are potentially highly sensitive to changes in the relative level of target fishing. Given the observed increase in the target fishery in recent years and uncertainty regarding the historical catch and effort time series, the annual indices derived from the pseudo-standardised analysis should be considered to be less reliable than the more recent CPUE indices.

Despite differences in the model data sets and, to some extent, the fitting procedure, the annual indices derived from the two standardised CPUE analyses were relatively similar to the indices determined by Francis et al. (1999) for the two fisheries. Both models reveal similar trends in the catch rate of trevally with respect to the main variables included in the model, although the annual indices are slightly different. Given the similarities observed between the two models, it may be appropriate to combine the two data sets in the future with the inclusion of target species as an additional explanatory variable. However, given the larger proportion of the total TRE 7 catch incorporated in the target trevally data set, it is considered that the annual indices derived from the corresponding model are more likely to be indicative of annual trends in trevally abundance.

There have also been a number of systematic trends in the trevally catch and effort data from the snapper target fishery data that could potentially bias the CPUE indices derived from the snapper bycatch model. These trends include an increase in larger, more powerful vessels in the fishery, a decline in trawl duration, and a shift in the seasonal distribution of fishing effort. By comparison, there were fewer apparent trends in the distribution of the target trevally data set over the same period, particularly for the significant variables included in the CPUE model.

Only limited data are available from the TRE 7 fishery and no other series of abundance indices that could be used to validate the annual indices from the CPUE models. Length and age frequency data are available from four years of sampling from the TRE 7 bottom trawl fishery (Langley 2002). However, there is no strong contrast in these data and, in isolation, they do not indicate any strong change in the abundance of trevally over the limited period sampled.

Nevertheless, the catch sampling data will be incorporated in a stock assessment model for TRE 7 in conjunction with the CPUE indices considered to be most reliably monitoring trevally abundance. The catch sampling data were principally collected from the target trevally fishery. Given potential differences in the selectivity-at-age of trevally between the target and snapper bycatch fisheries, it is considered most appropriate to index the observed age frequency data with the CPUE indices derived from the target fishery.

5. ACKNOWLEDGMENTS

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Table 1: Types and descriptions of the variables used to model CPUE.

Variable	Type	Description
CPUE	Continuous	CPUE measured in kilograms of trevally caught per day.
Fishing Year	Categorical	Fishing year
Month	Categorical	Month of year
Duration	Continuous	Total duration of trawling (h)
Trawls	Continuous	Total number of trawls conducted.
Trawl duration	Continuous	Average trawl duration (h)
Vessel	Categorical	Unique vessel code
Stat area	Categorical	Sub area fished
Form type	Categorical	Type of form recording catch and effort data (CELR or TCEPR)
SNA catch	Continuous	The total catch of snapper from the day of fishing
Vessel length	Continuous	Overall length of the vessel (m)

Table 2: Range checks performed on the trevally CPUE data set for trevally target and snapper bycatch records.

Variable	Target species	
	Trevally	Snapper
CPUE	1–10 000	1–10 000
Duration	0.5–20	0.5–20
Trawls	1–10	1–10
Duration/trawls	0.5–5	0.5–5
Stat area	040–042, 045–047	040–042, 045–047
SNA catch	< 5000	< 5000

Table 3: Percentage distribution of target trevally CPUE records by statistical area and fishing year and the total number of records in the dataset.

Statistical area	Fishing year											
	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
040	0.5	8.7	19.5	5.8	8.5	5.9	3.0	3.6	4.5	3.2	6.5	8.3
041	58.2	53.2	28.7	22.9	17.5	15.3	25.1	27.3	19.6	26.3	18.8	15.1
042	5.3	14.7	11.9	11.5	16.0	32.5	29.6	27.5	30.3	38.3	19.9	24.1
045	13.8	13.8	20.3	29.0	28.4	20.0	13.5	9.9	12.7	14.1	18.8	24.1
046	7.4	6.9	5.7	12.1	7.3	6.9	10.2	6.3	11.5	8.6	12.6	15.3
047	14.8	2.8	13.8	18.7	22.4	19.4	18.6	25.4	21.4	9.6	23.3	13.0
Number of records	189	218	261	497	331	320	371	527	780	596	658	515

Table 4: **Percentage distribution of target trevally CPUE records by month and fishing year and the total number of records in the dataset.**

Month	Fishing year											
	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Oct	6.3	7.8	3.8	8.7	11.2	6.6	1.3	2.7	2.4	5.0	5.5	2.1
Nov	21.7	7.8	3.8	7.0	12.4	5.0	3.0	1.3	2.1	14.9	7.8	9.1
Dec	9.0	5.0	10.7	9.5	12.1	5.3	10.2	3.8	4.5	12.2	7.6	15.5
Jan	11.1	17.9	13.4	21.5	25.1	42.5	21.0	21.4	13.8	20.5	15.0	16.5
Feb	5.3	13.8	18.8	16.5	10.6	17.8	19.9	19.4	15.1	20.3	20.2	18.3
Mar	9.0	11.5	13.0	18.1	8.2	9.1	11.6	18.8	10.8	13.6	16.0	21.6
Apr	7.9	3.2	13.4	6.4	13.6	3.8	4.9	9.1	9.6	8.2	16.6	10.5
May	6.3	6.9	2.7	1.2	3.3	4.1	8.9	4.0	12.4	3.0	7.9	1.4
Jun	5.3	5.0	3.1	1.0	2.1	2.5	0.3	3.4	6.0	1.2	2.4	1.7
Jul	7.4	6.4	7.3	2.8	0.6	1.3	0.3	4.0	9.9	0.5	0.5	1.0
Aug	4.8	8.3	4.6	2.0	0.0	0.0	6.2	3.0	6.4	0.0	0.3	0.0
Sep	5.8	6.4	5.4	5.2	0.9	2.2	12.4	9.1	6.9	0.5	0.3	2.3
Number of records	189	218	261	497	331	320	371	527	780	596	658	515

Table 5: **Summary of catch and effort records from the trevally target CPUE data set (non-zero trevally catch) by fishing year, including the trevally (TRE) catch (tonnes), the number of records, the number of core vessels, the total number of trawls and trawl duration (hours), and the total catch per trawl (kg) and catch per hour (kg).**

	Fishing year											
	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
TRE catch	187.0	259.4	336.1	552.7	428.8	660.9	350.0	620.7	744.2	489.0	600.2	584.5
Number of records	189	218	261	497	331	320	371	527	780	596	658	515
Number of vessels	12	14	15	21	19	15	16	19	25	19	16	12
Number of trawls	512	572	755	1 674	1 090	991	958	1 440	1 998	1 614	1 862	1 240
Trawl duration	1 502	1 633	2 220	4 716	2 716	2 912	3 014	4 346	6 013	4 374	5 599	4 021
Catch per trawl (kg)	365	453	445	330	393	667	365	431	372	303	322	471
Catch per hour (kg)	125	159	151	117	158	227	116	143	124	112	107	145

Table 6: Percentage distribution of the snapper bycatch CPUE records by statistical area and fishing year and the total number of records in the dataset.

Statistical area	Fishing year											
	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
040	0.4	1.0	0.5	0.2	0.3	0.4	0.9	0.2	0.1	0.0	0.3	0.2
041	15.3	33.7	12.5	18.9	13.9	15.1	16.4	16.0	14.0	4.6	3.4	10.6
042	31.9	28.5	37.1	38.6	39.4	33.1	32.0	26.9	25.6	26.4	24.5	33.1
045	16.1	31.6	44.0	29.9	32.5	29.3	30.3	31.2	35.1	41.4	38.2	31.5
046	3.2	0.5	0.5	2.0	2.4	3.8	7.9	5.8	8.4	8.7	12.5	10.2
047	33.1	4.7	5.4	10.4	11.4	18.4	12.6	20.0	16.7	18.8	21.1	14.3
Number of records	248	193	391	645	581	523	585	520	700	606	327	498

Table 7: Percentage distribution of the snapper bycatch CPUE records by month and fishing year and the total number of records in the dataset.

Month	Fishing year											
	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Oct	12.5	25.4	17.1	10.7	16.2	12.6	10.4	10.0	15.9	7.3	16.5	3.4
Nov	10.5	13.0	23.5	16.4	19.4	12.8	24.6	20.0	22.4	25.2	15.3	19.5
Dec	8.5	6.7	17.9	11.3	13.6	14.7	14.7	18.7	19.4	17.5	17.7	15.7
Jan	11.3	17.6	9.5	8.7	9.5	11.7	10.8	4.8	9.3	16.2	11.0	17.9
Feb	15.7	12.4	7.4	10.5	8.1	9.0	6.2	3.7	6.3	9.1	2.4	8.0
Mar	12.9	7.3	3.6	12.7	6.9	1.7	6.2	3.5	7.0	10.2	1.2	8.4
Apr	6.9	6.2	2.0	6.5	5.9	7.8	8.5	3.7	3.0	5.8	4.0	4.8
May	4.0	2.6	4.6	5.0	4.8	9.2	6.2	10.2	4.3	4.6	4.6	5.6
Jun	1.2	0.0	2.3	5.0	6.4	4.0	3.6	4.2	3.0	1.0	8.0	3.0
Jul	2.4	0.0	0.8	5.4	4.8	3.1	3.4	6.0	3.3	0.2	7.0	1.8
Aug	2.0	1.6	2.8	3.3	2.4	5.0	0.7	3.5	2.3	1.0	7.3	3.2
Sep	12.1	7.3	8.4	4.5	2.1	8.4	4.8	11.9	3.9	2.0	4.9	8.6
Number of records	248	193	391	645	581	523	585	520	700	606	327	498

Table 8: Summary of catch and effort records from the the snapper bycatch CPUE data set (non-zero trevally catch) by fishing year, including the trevally (TRE) catch (tonnes), the number of records, the number of core vessels, the total number of trawls and trawl duration (hours), and the total catch per trawl (kg) and catch per hour (kg). The percentage of snapper target records with no trevally associated catch is also presented.

	Fishing year											
	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
TRE catch	126.2	84.2	151.5	326.8	339.5	242.9	261.1	292.5	386.6	423.8	164.3	189.1
Number of records	248	193	391	645	581	523	585	520	700	606	327	498
Number of vessels	14	16	17	20	20	20	24	22	22	19	15	12
Number of trawls	806	676	1 350	2 298	2 166	1 845	1 746	1 501	2 052	1 778	821	1 123
Trawl duration	2 123	1 694	3 451	5 989	5 669	4 830	4 986	4 179	5 631	4 552	2 519	3 531
Catch per trawl (kg)	157	125	112	142	157	132	150	195	188	238	200	168
Catch per hour (kg)	59	50	44	55	60	50	52	70	69	93	65	54
Percent zero TRE	30.3	47.8	36.5	29.6	30.7	37.6	35.9	39.4	24.2	18.8	28.1	28.7

Table 9: Variables included in the stepwise regression of the trevally target CPUE model in order of importance.

Iteration	Variable	% R^2 at iteration
1	*Vessel*	21.3
2	*Trawls*	33.5
3	*Month*	38.3
4	*Fishing Year*	41.0
5	*Stat Area*	42.5
6	*SNA catch*	43.0

Table 10: Year indices with standard deviation and regression coefficients for the trevally target CPUE model; *n*, number of records. The bounds represent the 95% confidence interval.

Fishing year	*n*	Regression coefficient	Standard error	Canonical Index	Year index	Lower bound	Upper bound
1989–90	189	0.00	0.090	0.479	1.61	1.35	1.93
1990–91	218	0.17	0.080	0.652	1.92	1.64	2.25
1991–92	261	-0.49	0.076	-0.011	0.99	0.85	1.15
1992–93	497	-0.87	0.057	-0.390	0.68	0.61	0.76
1993–94	331	-0.62	0.069	-0.142	0.87	0.76	0.99
1994–95	320	-0.06	0.067	0.420	1.52	1.33	1.74
1995–96	371	-0.53	0.063	-0.053	0.95	0.84	1.07
1996–97	527	-0.41	0.053	0.072	1.07	0.97	1.19
1997–98	780	-0.56	0.047	-0.086	0.92	0.84	1.01
1998–99	596	-0.90	0.054	-0.419	0.66	0.59	0.73
1999–2000	658	-0.83	0.054	-0.347	0.71	0.64	0.79
2000–01	515	-0.65	0.060	-0.174	0.84	0.75	0.94

Table 11: Variables included in the stepwise regression of the snapper bycatch CPUE model in order of importance.

Iteration	Variable	% R^2 at iteration
1	*Vessel*	8.3
2	*Trawls*	17.1
3	*Month*	24.4
4	*Stat Area*	26.4
5	*Fishing Year*	27.9
6	*SNA catch*	29.0

Table 12: Year indices with standard deviation and regression coefficients for the snapper bycatch CPUE model; *n*, number of records. The bounds represent the 95% confidence interval.

Fishing year	*n*	Regression coefficient	Standard error	Canonical Index	Year index	Lower bound	Upper bound
1989–90	248	0.000	0.077	0.347	1.42	1.22	1.64
1990–91	193	-0.272	0.086	0.075	1.08	0.91	1.28
1991–92	391	-0.212	0.063	0.136	1.15	1.01	1.30
1992–93	645	-0.424	0.051	-0.077	0.93	0.84	1.02
1993–94	581	-0.303	0.053	0.045	1.05	0.94	1.16
1994–95	523	-0.456	0.054	-0.108	0.90	0.81	1.00
1995–96	585	-0.421	0.052	-0.074	0.93	0.84	1.03
1996–97	520	-0.319	0.054	0.029	1.03	0.93	1.14
1997–98	700	-0.461	0.048	-0.113	0.89	0.81	0.98
1998–99	606	-0.150	0.054	0.198	1.22	1.10	1.35
1999–2000	327	-0.323	0.070	0.025	1.03	0.89	1.18
2000–01	498	-0.829	0.059	-0.482	0.62	0.55	0.69

Table 13: Pseudo-standardised single trawl coefficients (log 10), the associated standard error, the annual indices, and the number of days fished by single trawl vessels included in the data set.

Fishing year	Number of days	Coefficient	Standard error	Index
1977–78	51	2.40	0.26	251
1978–79	111	2.56	0.18	363
1979–80	61	2.77	0.23	589
1980–81	172	3.05	0.14	1122
1981–82	256	3.00	0.12	1000
1982–83	276	2.97	0.11	933
1983–84	408	2.70	0.10	501
1984–85	188	2.86	0.14	724
1985–86	260	2.77	0.12	589
1986–87	110	2.50	0.18	316
1987–88	137	2.95	0.16	891
1988–89	140	2.87	0.16	741
1989–90	237	2.92	0.12	832
1990–91	255	2.90	0.12	794
1991–92	211	2.88	0.13	759
1992–93	193	2.75	0.14	562
1993–94	215	2.96	0.11	912
1994–95	161	2.84	0.15	692
1995–96	249	2.89	0.12	776
1996–97	197	2.79	0.13	617
1997–98	200	2.82	0.13	661
1998–99	359	2.86	0.10	724
1999–2000	242	2.85	0.12	708
2000–01	166	2.94	0.15	871

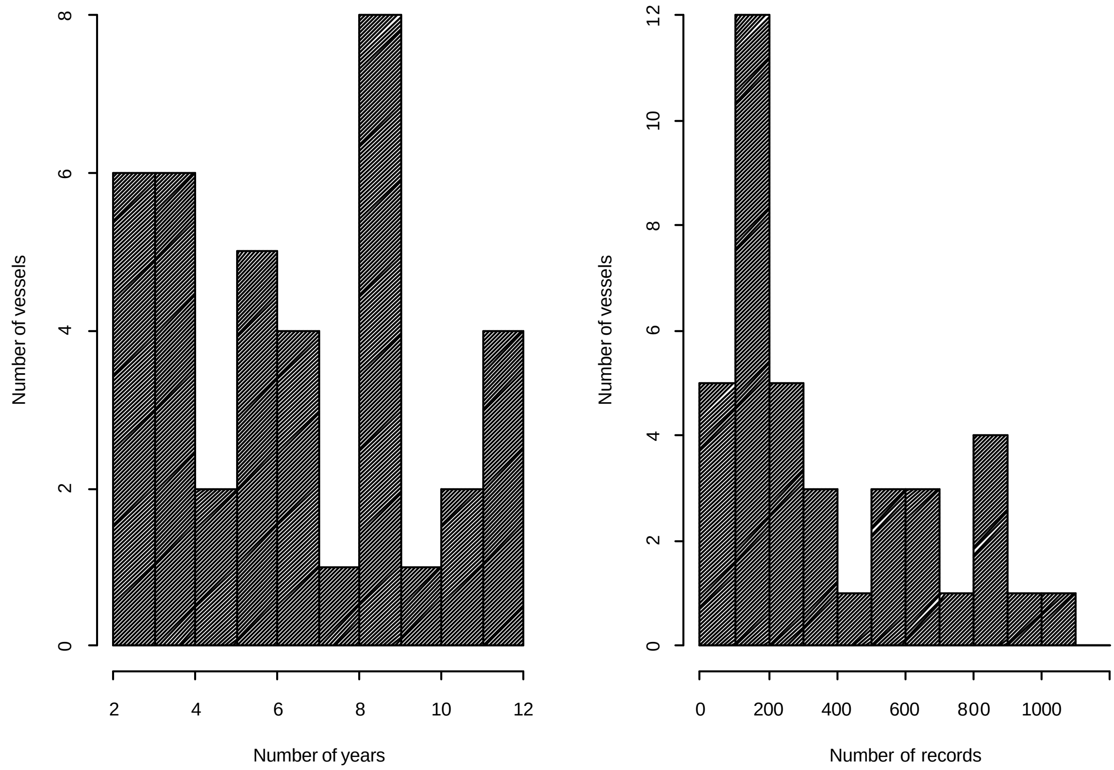

Figure 1: Histograms of the number of years fished (left) and total number of records (right) by individual vessels for core vessels in the trevally CPUE data set (trevally and snapper target combined).

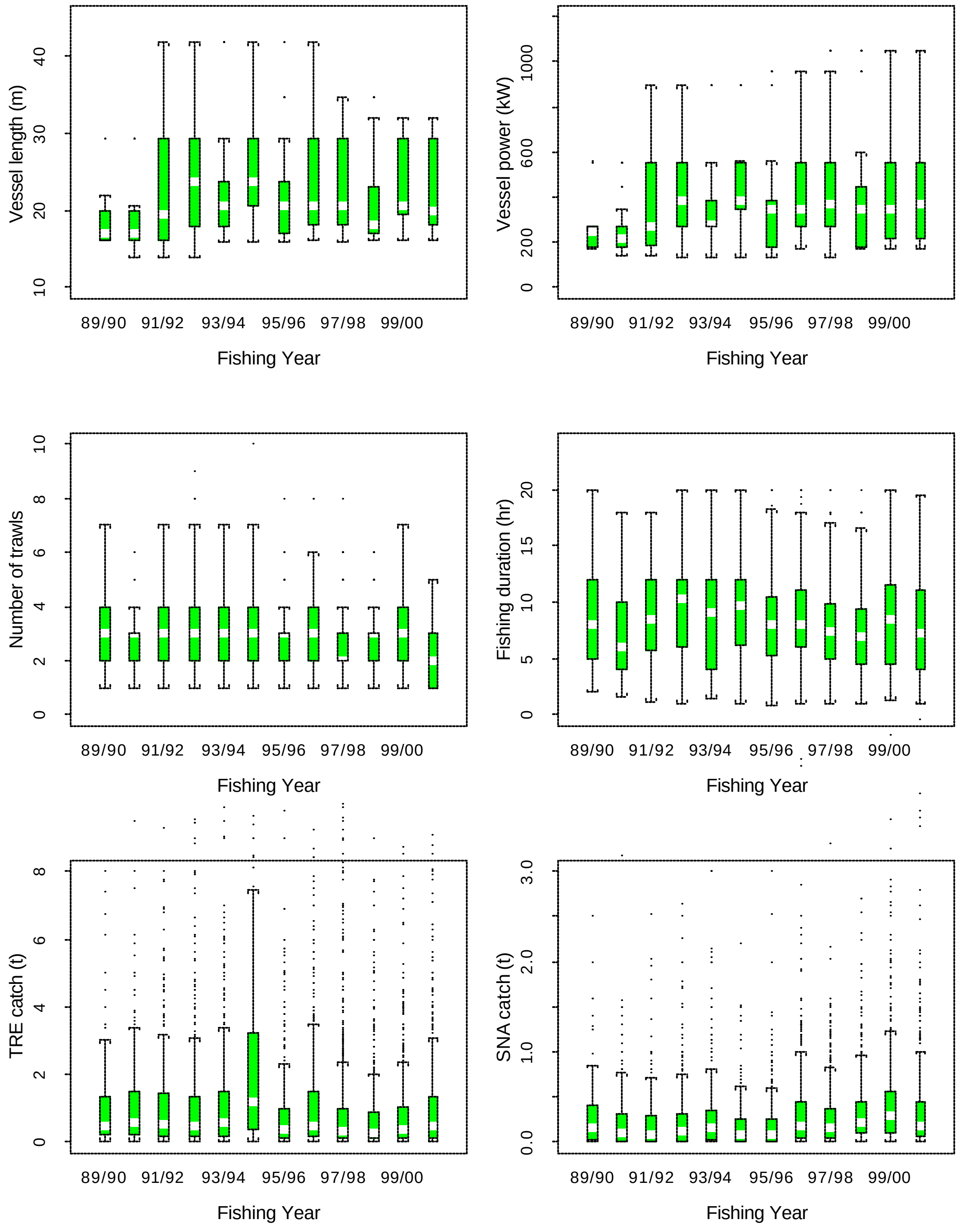

Figure 2: **Annual trend in the main variables included in the trevally target CPUE data set; vessel length and power, number of trawls per record, total duration of fishing per record (hours), trevally catch (t), and snapper catch (t). The boxes denote the inter-quartile range of the data with the white bar representing the median value; the whiskers represent 1.5 times the inter-quartile range.**

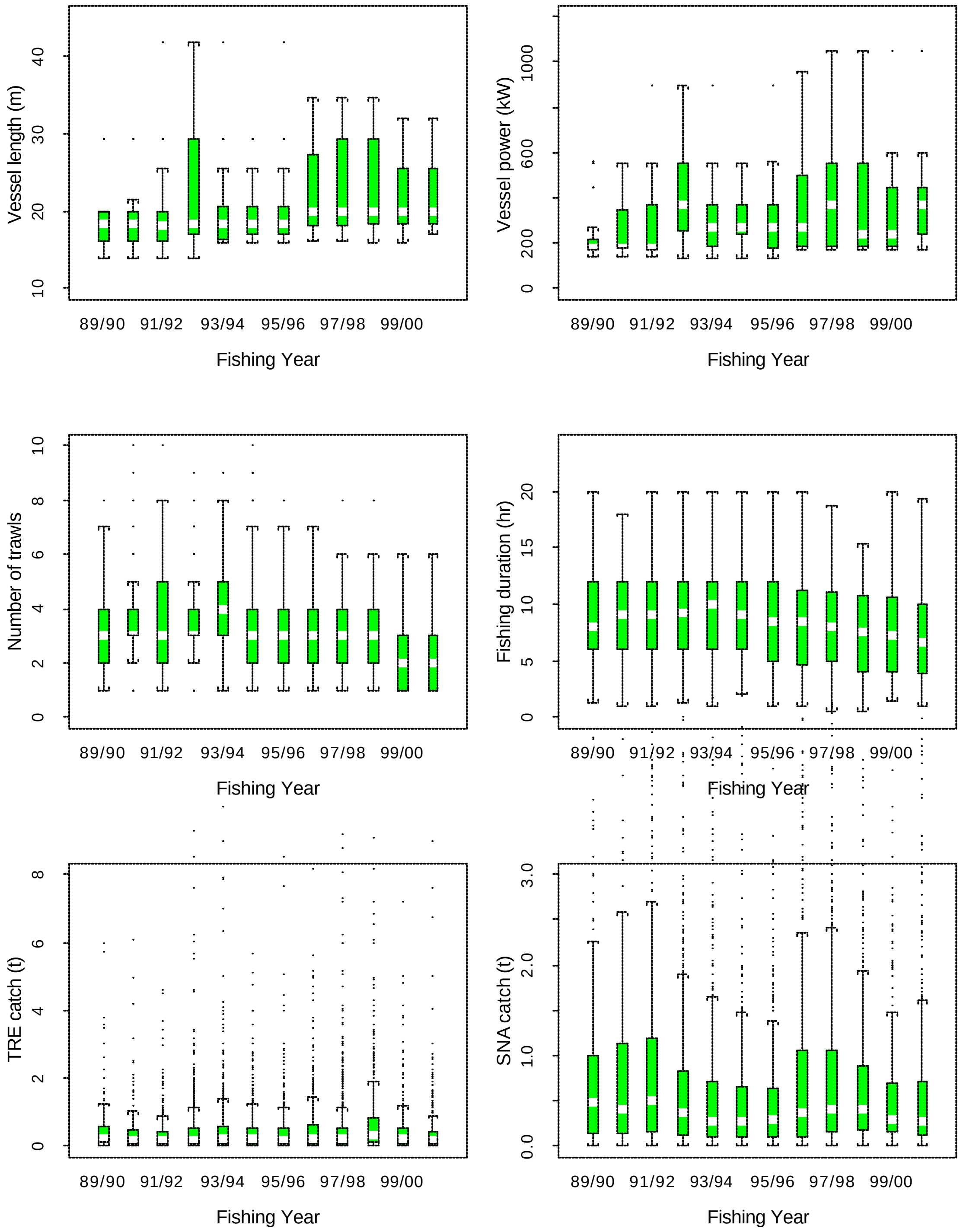

Figure 3: Annual trend in the main variables included in the snapper bycatch CPUE data set; vessel length and power, number of trawls per record, total duration of fishing per record (hours), trevally catch (t), and snapper catch (t). The boxes denote the inter-quartile range of the data with the white bar representing the median value; the whiskers represent 1.5 times the inter-quartile range.

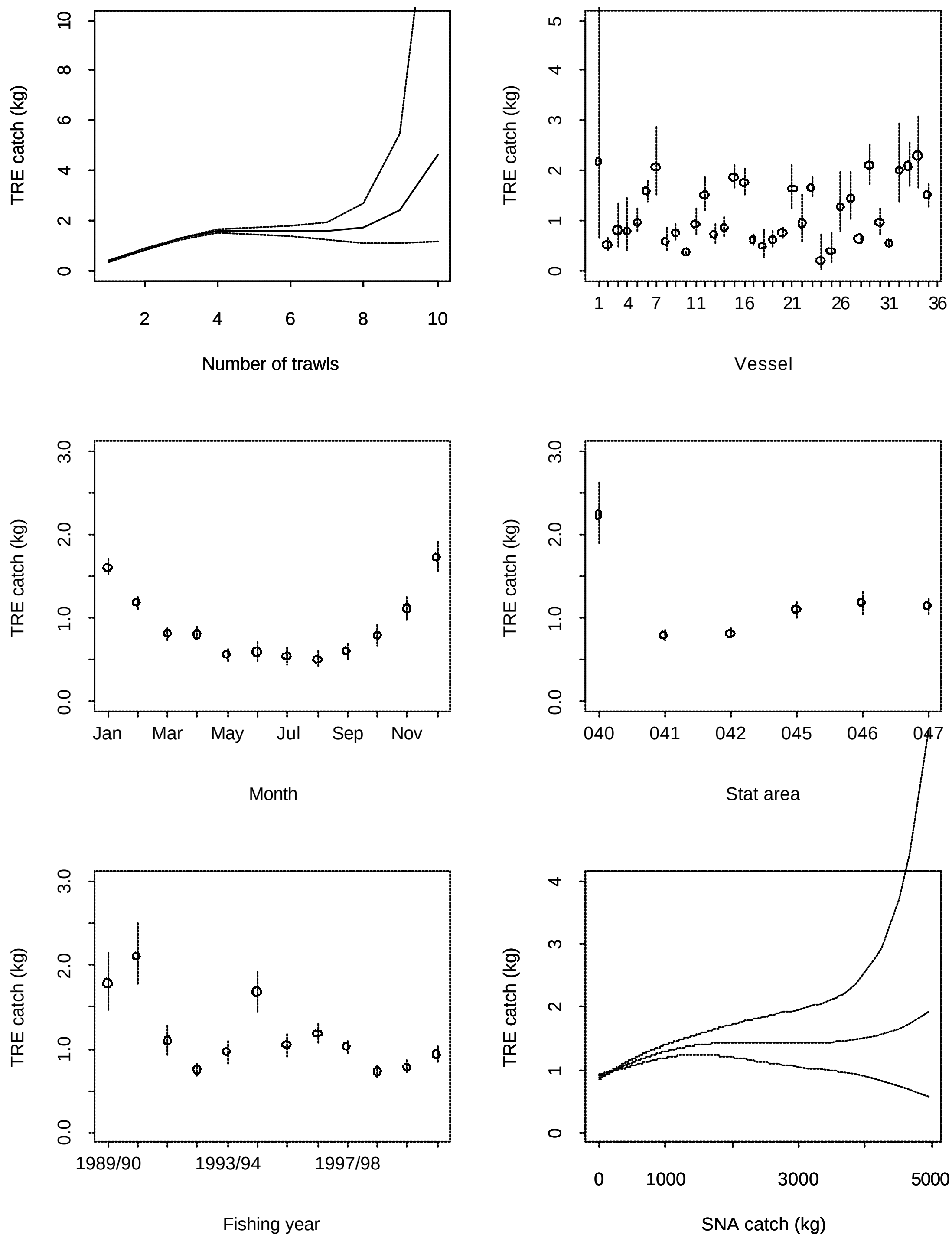

Figure 4: Predicted trevally catch (and 95% confidence intervals) for each of the significant variables included in the trevally target stardardised CPUE model.

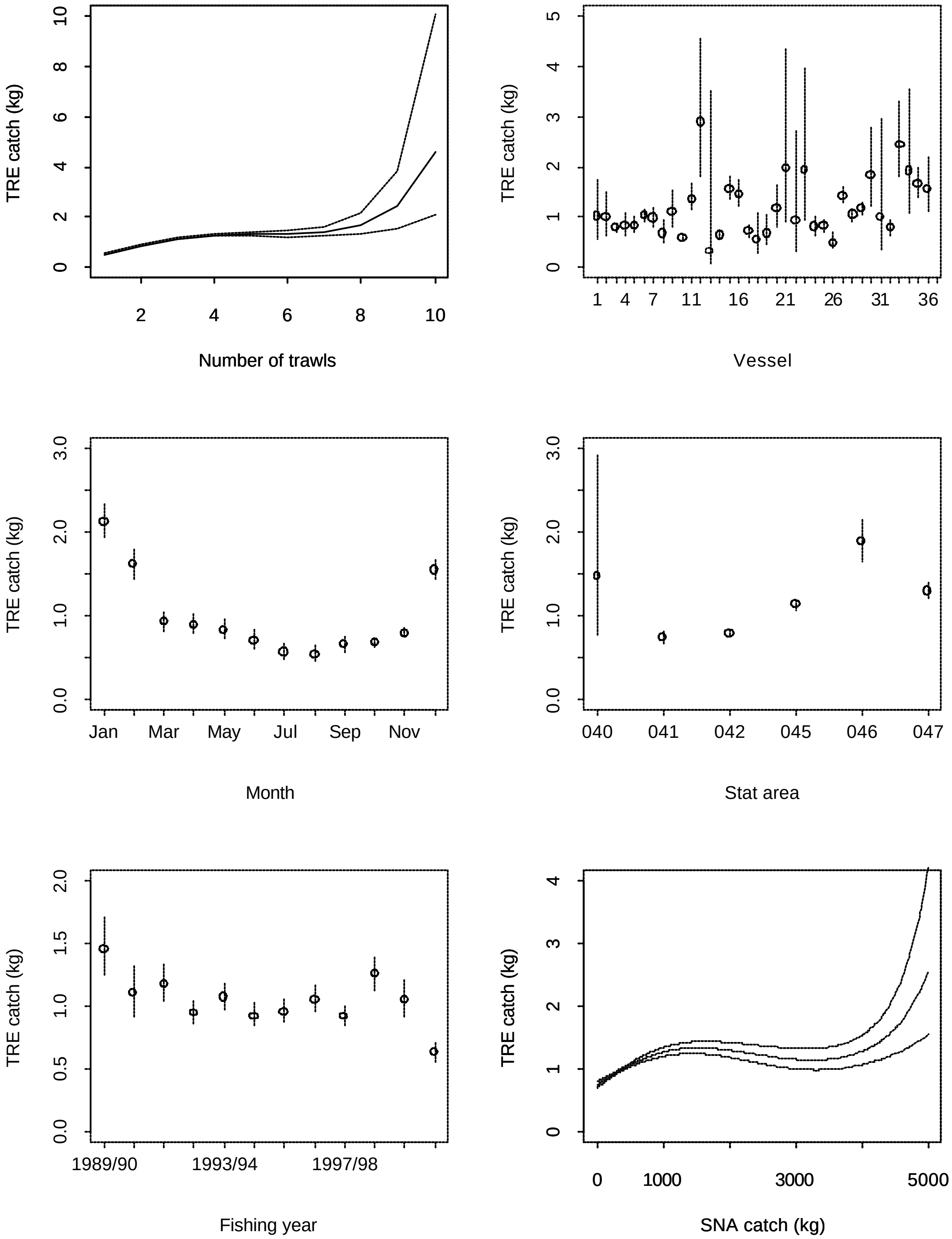

Figure 5: Predicted trevally catch (and 95% confidence intervals) for each of the significant variables included in the snapper bycatch stardardised CPUE model.

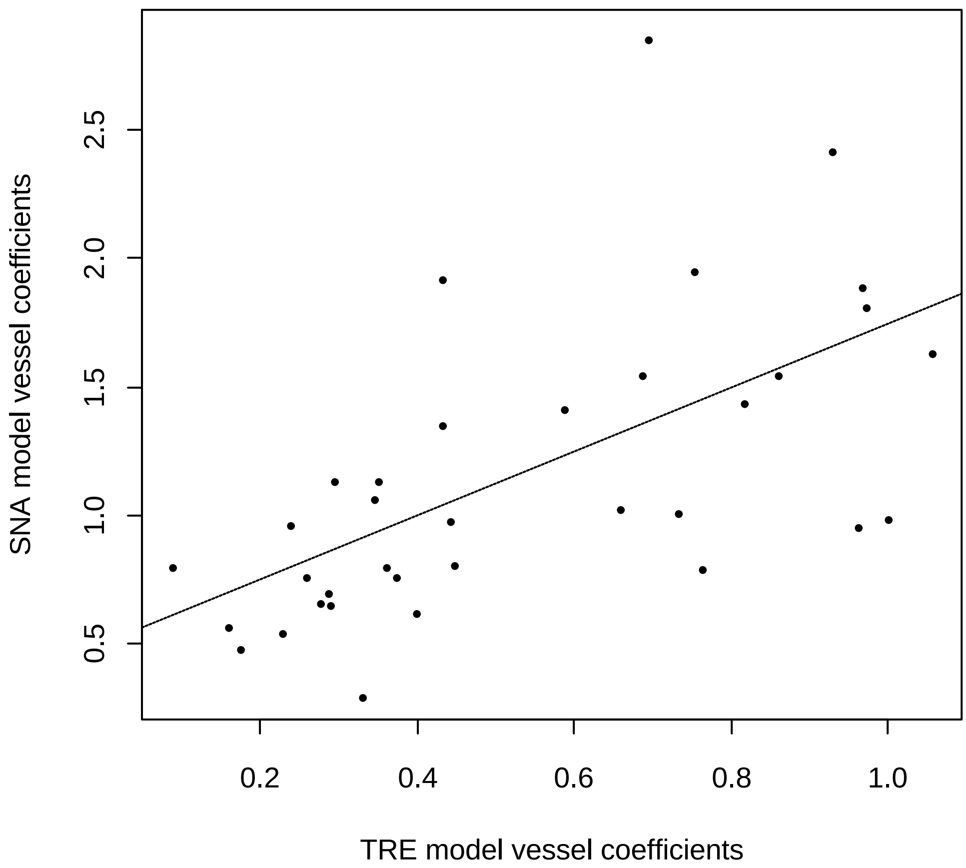

Figure 6: Comparison of the vessel coefficients derived from the TRE target and SNA bycatch CPUE models. The line represents the least squares fit to the data.

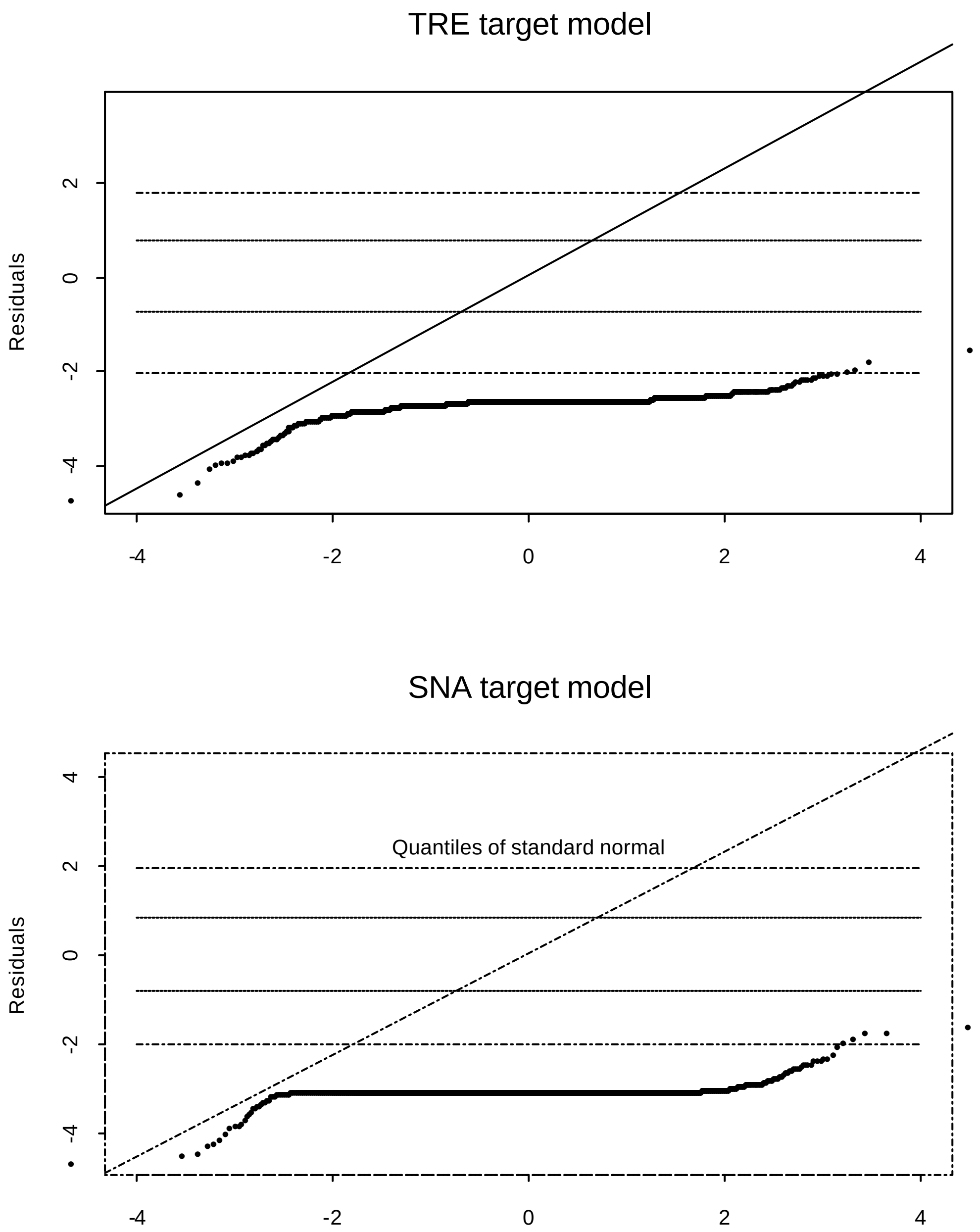

Figure 7: Quantile-quantile plots for the trevally target (top) and snapper bycatch (bottom) standardised CPUE models. The dashed lines represent the 5%, 25%, 75%, and 95% quantiles of the model residuals.

Quantiles of standard normal

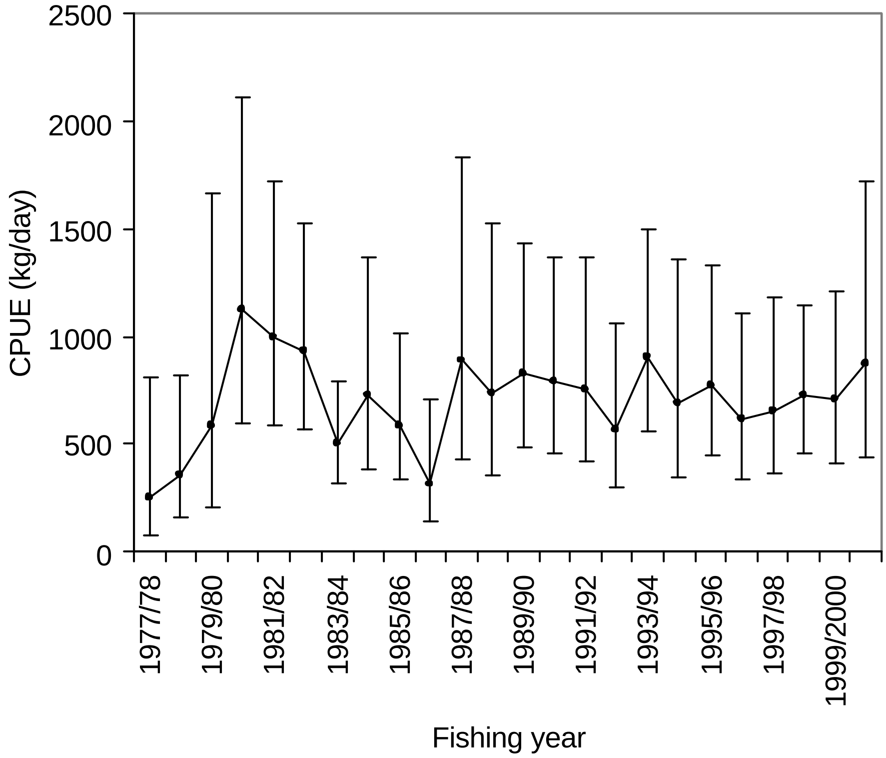

Figure 8: Trevally pseudo-standardised single trawl CPUE indices and 95% confidence intervals.

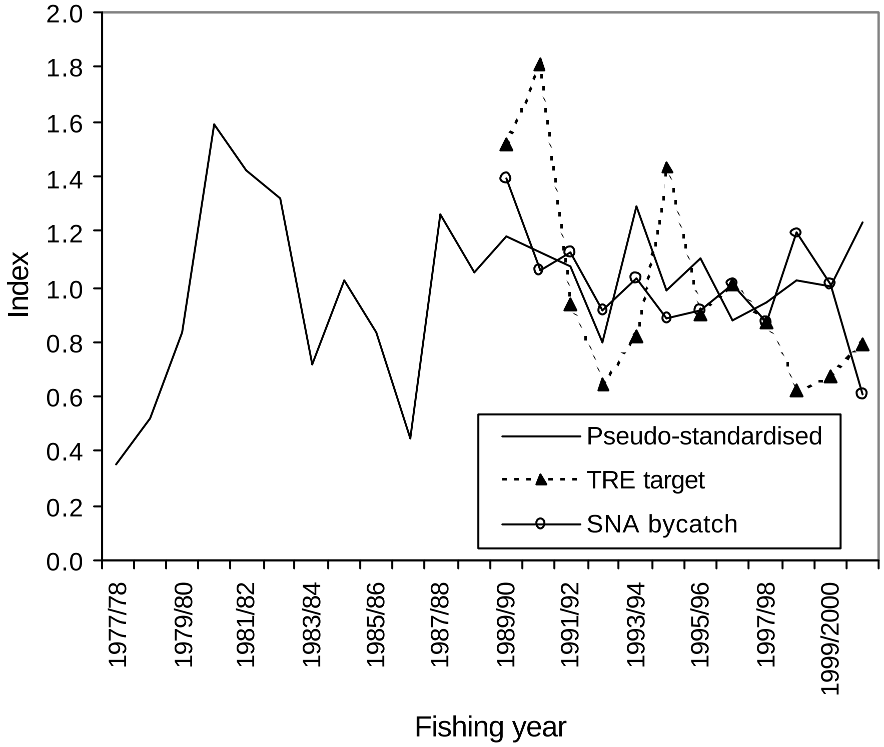

Figure 9: Comparison of the annual CPUE indices derived from the psuedo -standardised analysis and the target trevally and snapper bycatch standardised CPUE models.

Appendix 1. Monthly catch and effort data included in the single trawl pseudo-standardised CPUE analysis (after Francis et al. 1999)

Fyear	Month	Catch (kg)	Days	CPUE	Fyear	Month	Catch (kg)	Days	CPUE
1977/78	Dec	4 180	4	1 045	1989/90	Dec	59 583	58	1 027
	Jan	665	7	95		Jan	85 224	73	1 167
	Feb	7 023	24	293		Feb	36 854	59	625
	Mar	3 369	16	211		Mar	24 378	47	519
1978/79	Dec	6 484	17	381	1990/91	Dec	73 338	78	940
	Jan	15 232	50	305		Jan	112 409	95	1 183
	Feb	15 422	30	514		Feb	25 517	47	543
	Mar	3 955	14	283		Mar	10 686	35	305
1979/80	Dec	7 044	15	470	1991/92	Dec	43 459	63	690
	Jan	18 440	24	768		Jan	89 990	77	1 169
	Feb	8 723	12	727		Feb	17 298	42	412
	Mar	3 508	10	351		Mar	21 297	29	734
1980/81	Dec	49 671	48	1 035	1992/93	Dec	16 130	32	504
	Jan	102 279	54	1 894		Jan	32 655	36	907
	Feb	46 303	40	1 158		Feb	20 667	39	530
	Mar	13 582	30	453		Mar	42 240	86	491
1981/82	Dec	145 139	134	1 083	1993/94	Dec	35 382	52	680
	Jan	66 616	59	1 129		Jan	74 473	68	1 095
	Feb	35 642	37	963		Feb	45 351	48	945
	Mar	13 549	26	521		Mar	45 318	47	964
1982/83	Dec	67 901	75	905	1994/95	Dec	14 236	42	339
	Jan	104 233	69	1 511		Jan	56 256	58	970
	Feb	96 116	72	1 335		Feb	29 692	40	742
	Mar	22 333	60	372		Mar	19 955	21	950
1983/84	Dec	110 996	111	1 000	1995/96	Dec	37 390	60	623
	Jan	104 851	129	813		Jan	63 295	73	867
	Feb	20 795	82	254		Feb	76 622	65	1 179
	Mar	17 525	86	204		Mar	25 431	51	499
1984/85	Dec	57 963	72	805	1996/97	Dec	34 612	47	736
	Jan	115 444	66	1 749		Jan	60 830	60	1 014
	Feb	6 350	20	318		Feb	27 482	49	561
	Mar	4 286	30	143		Mar	11 682	41	285
1985/86	Dec	31 229	77	406	1997/98	Dec	60 259	61	988
	Jan	59 300	62	956		Jan	41 348	61	678
	Feb	65 299	69	946		Feb	38 050	45	846
	Mar	16 272	52	313		Mar	7 422	33	225
1986/87	Dec	10 499	26	404	1998/99	Dec	106 044	91	1 165
	Jan	13 482	27	499		Jan	104 621	112	934
	Feb	5 202	17	306		Feb	41 445	85	488
	Mar	8 081	40	202		Mar	29 366	71	414
1987/88	Dec	26 907	31	868	1999/2000	Dec	65 600	61	1 075
	Jan	7 809	19	411		Jan	68 525	65	1 054
	Feb	58 314	51	1 143		Feb	29 236	70	418
	Mar	34 829	36	967		Mar	24 475	46	532
1988/89	Jan	30 996	39	795	2000/01	Dec	72 951	42	1 737
	Feb	42 498	65	654		Jan	44 494	38	1 171
	Mar	31 238	36	868		Feb	24 885	45	553
						Mar	22 385	41	546