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EXECUTIVE SUMMARY

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A standardised CPUE analysis was conducted of catch and effort data from the BAR 1 fishery for the 1989–90 to 1999–2000 period. The analysis was based on data from the main BAR 1 fishery which operates within Canterbury Bight and Pegasus Bay. The fishery comprises inshore trawl vessels catching barracouta as either a target species or as a bycatch to the red cod trawl fishery.

Two separate analysis were conducted: one based on data from the target trawl fishery and the other based on data from the barracouta bycatch of the red cod fishery. The dependent variable of both CPUE models was the natural logarithm of the total catch of barracouta for each day of fishing by an individual vessel. The significant predictor variables included in the two CPUE models were comparable: unique vessel index, number of trawls, month, and fishing year, and the fishing duration variable was also included in the analysis of the target CPUE.

The annual indices derived from the two models were comparable. The indices were relatively constant between 1989–90 and 1991–92 and subsequently increased to a peak in 1996–97 and 1997–98, at about 150% the level of the 1989–90 year. Catch rates subsequently declined in 1997–98 and 1998–99 to the level of the base year and remained at this level in 1999–2000.

The CPUE indices were compared with barracouta biomass estimates derived from the series of winter and summer trawl surveys conducted off the east coast of the South Island. The CPUE indices were also compared with a series of CPUE indices derived from the BAR 5 trawl fishery. There was no clear correlation between the CPUE indices and estimates of barracouta biomass from the trawl surveys. The CPUE indices were negatively correlated with a series of CPUE indices derived from the BAR 5 trawl fishery.

The appropriateness of the BAR 1 CPUE indices as indices of stock abundance were considered in discussions with commercial operators in the BAR 1 fishery. We recommend the CPUE indices from the two fisheries are used to monitor the relative abundance of recruited barracouta (fish over 70 cm fork length) within the Canterbury Bight/Pegasus Bay area. However, due to the apparent inter-annual variation in the distribution of barracouta, these indices may not adequately monitor the abundance of the entire barracouta stock.

1. INTRODUCTION

The BAR 1 fishery management area supports an important trawl fishery, principally conducted by inshore trawl vessels operating off the east coast of the South Island. Barracouta are caught in conjunction with other species, principally red cod, in the mixed trawl fishery operating in Pegasus Bay and Canterbury Bight (Langley & Walker, unpublished results). The inshore fleet is mainly based in Lyttelton, Timaru, and Dunedin and the catch is processed in local processing facilities. Barracouta are also caught by larger trawl vessels targeting middle depth species, principally arrow squid and jack mackerel.

The annual reported catch from the BAR 1 fishery fluctuated around 7000 to 9500 tonnes between 1989–90 and 1993–94, slightly below the corresponding TACC of 9960 tonnes. Catches increased over the subsequent years to reach a peak of 12 000 tonnes in 1996–97 and catches declined slightly to about 9000–10 000 tonnes in 1998–99 and 1999–2000. In 1997–98, the TACC for BAR 1 was increased to 11 000 tonnes in line with the increased level of catch in the previous year (Annala et al. 2001).

The BAR 1 fishery is managed separately from the other main barracouta fisheries in Southland (BAR 5) and off the west coast of the South Island (BAR 7). However, there is evidence to suggest barracouta from the Southland area and off the eastern coast of mainland New Zealand areas represent the same stock (Hurst & Bagley 1989).

The BAR 5 fishery has been monitored by a time series of trawl surveys (Hurst et al. 1990, Hurst & Bagley 1997) and CPUE indices (Harley et al. 1999). Trawl surveys were conducted within the Pegasus Bay/Canterbury Bight area from 1991 to 2000 (Beentjes & Stevenson 2000, 2001). However, the resulting biomass indices from both winter and summer trawl surveys were highly variable between years and not considered to be a reliable indicator of stock abundance.

The work summarised in this report was conducted as a requirement of objective 3 of the Ministry of Fisheries research project BAR2000/01, Stock assessment of barracouta. The specific project objective was *to complete a characterisation of the barracouta fishery in BAR 1 and determine the feasibility of deriving a relative abundance index from catch and effort data.* This report provides an analysis of the catch and effort data from the BAR 1 fishery and investigates the potential to use these data as a relative abundance index for the fishery.

2. METHODS

2.1 CPUE dataset

The initial data set was restricted to catch and effort records from the barracouta bottom trawl fishery operating within statistical areas 018, 020, 022, and 024 from 1989–90 to 1999–2000. This area accounts for most of the catch from the BAR 1 fishery with most of the catch taken by the target barracouta fishery or as a bycatch of the red cod fishery (Langley & Walker, unpublished results). During the earlier years of the study period, most of the catch was taken by the target barracouta fishery; subsequently, an increased proportion of the BAR 1 catch was taken by the red cod target fishery.

Separate CPUE data sets were derived for the two fisheries. The barracouta target CPUE dataset included all records where barracouta was targeted and caught, and the red cod bycatch CPUE data set included all records where red cod was targeted and barracouta was caught.

Most (85%) 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 was 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 determined for each vessel day of fishing within a statistical area and the total number of trawls, total duration of fishing, and total catch of barracouta was determined.

The variables included in the two CPUE datasets are presented in Table 1.

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

Variable	Type	Description
$CPUE_t$	Continuous	CPUE measured in kilogrammes of barracouta 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.
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)
Vessel length	Continuous	Overall length of the vessel (m)

The initial data set for both fisheries combined included 25 323 catch and effort records. The range of values for each of the variables in the CPUE dataset was examined and obvious outliers were excluded. The accepted range for each of the variables is presented in Table 2. About 10% of all CPUE records were excluded by these criteria.

In addition, records from large (over 43 m overall length) trawl vessels were excluded from the CPUE dataset. These vessels accounted for a small proportion of the trawl records (4%) and operated in a different area from the smaller vessels since the larger vessels are excluded from within 12 n. miles of the coast and from the greater Canterbury Bight area. These vessels also targeted barracouta in association with fishing for other species, principally squid and jack mackerel and used both midwater and bottom trawl gear (Langley & Walker, unpublished results).

Table 2: Range checks performed on the barracouta CPUE data set for barracouta target and red cod bycatch records for vessels under 43 m in length.

Variable	Target species	
	Barracouta	Red cod
$CPUE_t$	1–15 000	1–8 000
Duration	1–18	1–18
Trawls	1–7	1–7
Duration/trawls	0.5–7	0.5–7
$CPUE_t$/*Duration*	1–1 500	1–1 000

For the fleet of smaller trawl vessels (less than 43 m overall length), individual vessels generally operated in both the target barracouta fishery and the target red cod fishery from 1989–90 to 1999–2000. 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 100 days of fishing (targeting either barracouta or red cod). The core group of 42 vessels accounted for 85% of the groomed CPUE records. The final data set included 4462 target barracouta records and 14 337 red cod bycatch CPUE records.

2.2 Data summary

The 42 core vessels in the combined CPUE data set were in the fishery for between 3 and 11 years during 1989–90 to 1999–2000 (Figure 1): 21 vessels were in the fishery for at least 8 years and 6 vessels were present in every year. Most of the core vessels completed 100–600 days of fishing during the study period (Figure 1).

Almost all of the fishing trips conducted by the core vessels were short (1–3 days). Usually, either red cod or barracouta was the declared target species for every day of the trip and there were few instances occurred both species were declared as the target species during a trip. From 1989–90 to 1995–96, there was a general increase in the proportion of vessels reporting red cod as the target species when barracouta was caught (Figure 2). In subsequent years, most vessels reported red cod as the principal target species.

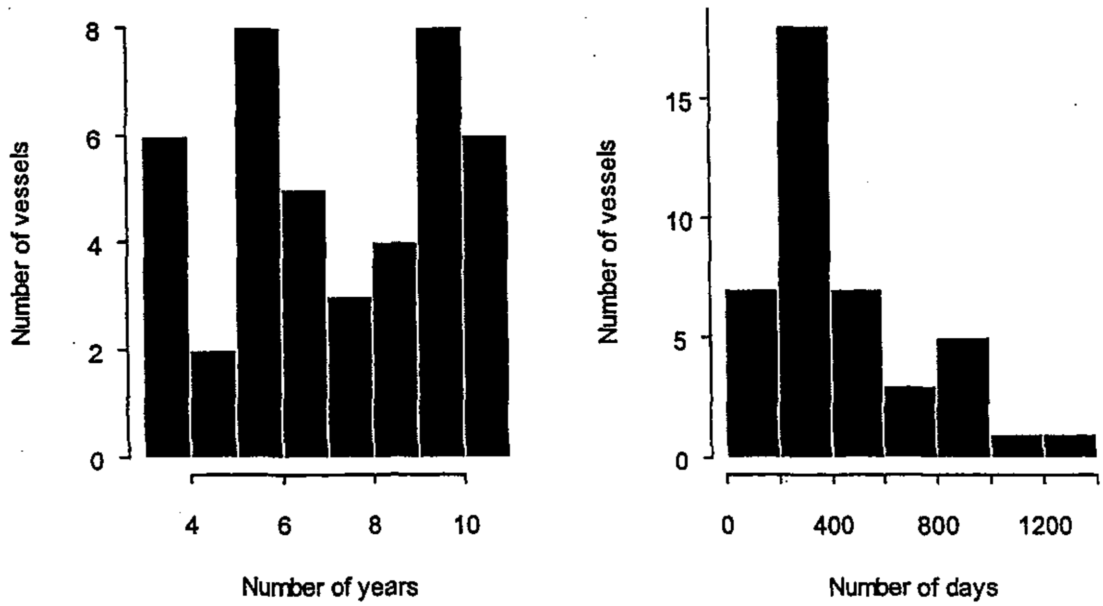

Figure 1: Histograms of the number of years fished (left) and total number of days fished (right) by individual vessels for core vessels in the barracouta CPUE data set (barracouta and red cod target combined).

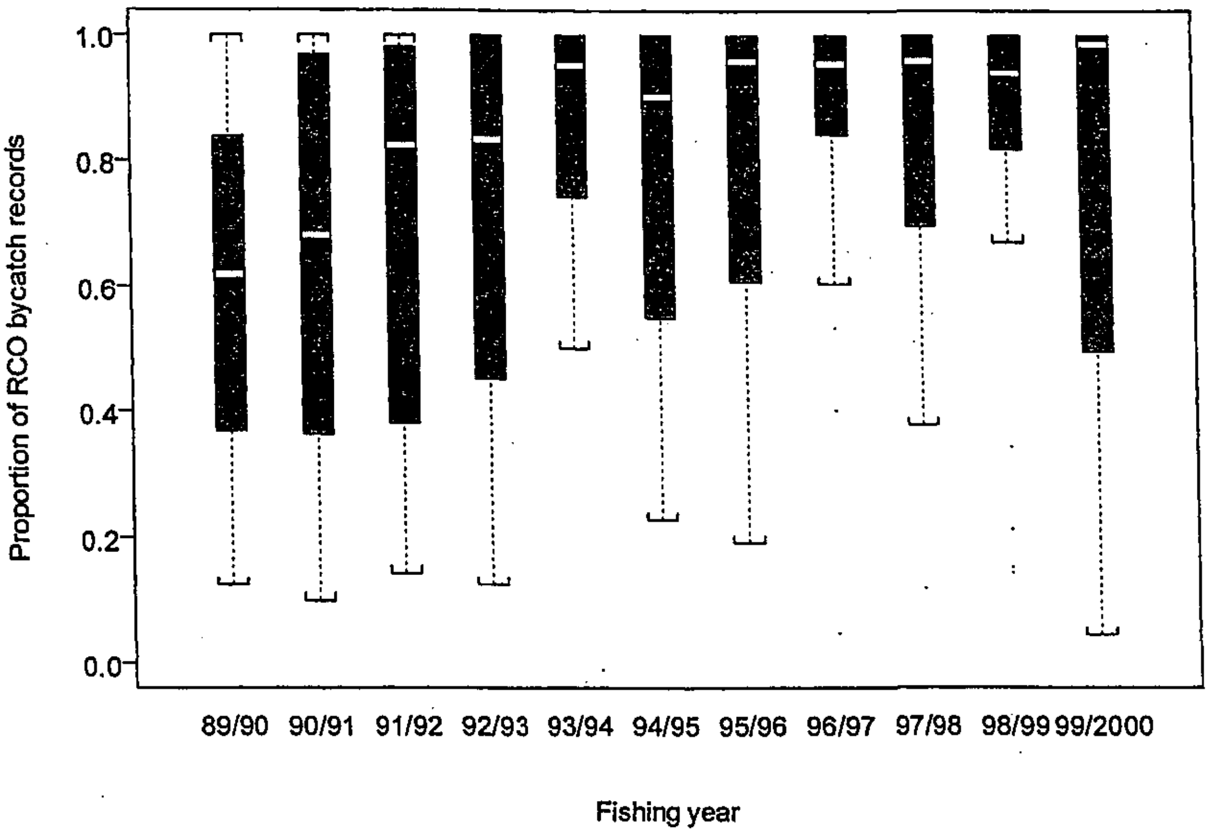

Figure 2: The proportion of records where barracouta was caught as bycatch of the red cod fishery by fishing year. The entire data set is all records by the core vessels that caught BAR 1 where barracouta or red cod were the target species. The boxes denote the inter-quartile range of the data with the bar representing the median value and the whiskers represent 1.5 times the inter-quartile range.

2.2.1 Barracouta target fishery

Most of the CPUE records from the target barracouta fishery were conducted by vessels in the 15–25 m length range (Figure 3). The size of vessels participating in the fishery remained relatively constant from 1989–90 to 1999–2000.

For each day of fishing, the vessels generally conducted 1–3 target trawls with a combined trawl duration of 5–10 hours (Figure 3). The total number of trawls conducted per day was relatively constant over the study period, but fishing duration was more variable. The total trawl duration declined between 1990–91 and 1992–93, subsequently increased to a peak in 1996–97, and declined slightly in the more recent years (Figure 3).

The median daily catch of barracouta from the target fishery was relatively constant between 1989–90 and 1993–94, increased to a peak in 1996–97, and remained at the higher level in subsequent years.

Most (62%) of the target barracouta fishing was within statistical area 022 (Table 3). However, between 1989–90 and 1994–95 there was a general decline in the proportion of target trawls conducted within 022 and a corresponding increase in the proportion of fishing effort within statistical area 018 and to a lesser extent statistical areas 020 and 024 (Table 3). In the subsequent years, the distribution of target fishing effort increased within statistical area 022, while the proportion of trawls conducted in statistical areas 020 and 024 declined. From 1994–95 to 1999–2000, about 30% of the target fishing effort was conducted in statistical area 018 (Table 3).

Most of the target barracouta fishing was conducted from October to June, with limited fishing conducted in the remainder of the fishing year (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 1999–2000 (Table 4).

From 1989–90 to 1999–2000, about 20 core vessels operated in the target barracouta fishery annually (Table 5). However, the level of target fishing effort and catch varied considerably. The barracouta target catch was highest in 1990–91 at about 1300 t and declined to 284 t in 1993–94. The target catch increased to 700 t in the subsequent year and was maintained around 600–800 t for the remainder of the period. 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 that of the target catch (Table 5). The average catch per trawl and average catch per hour of trawling remained relatively constant between 1989–90 and 1999–2000 (Table 5).

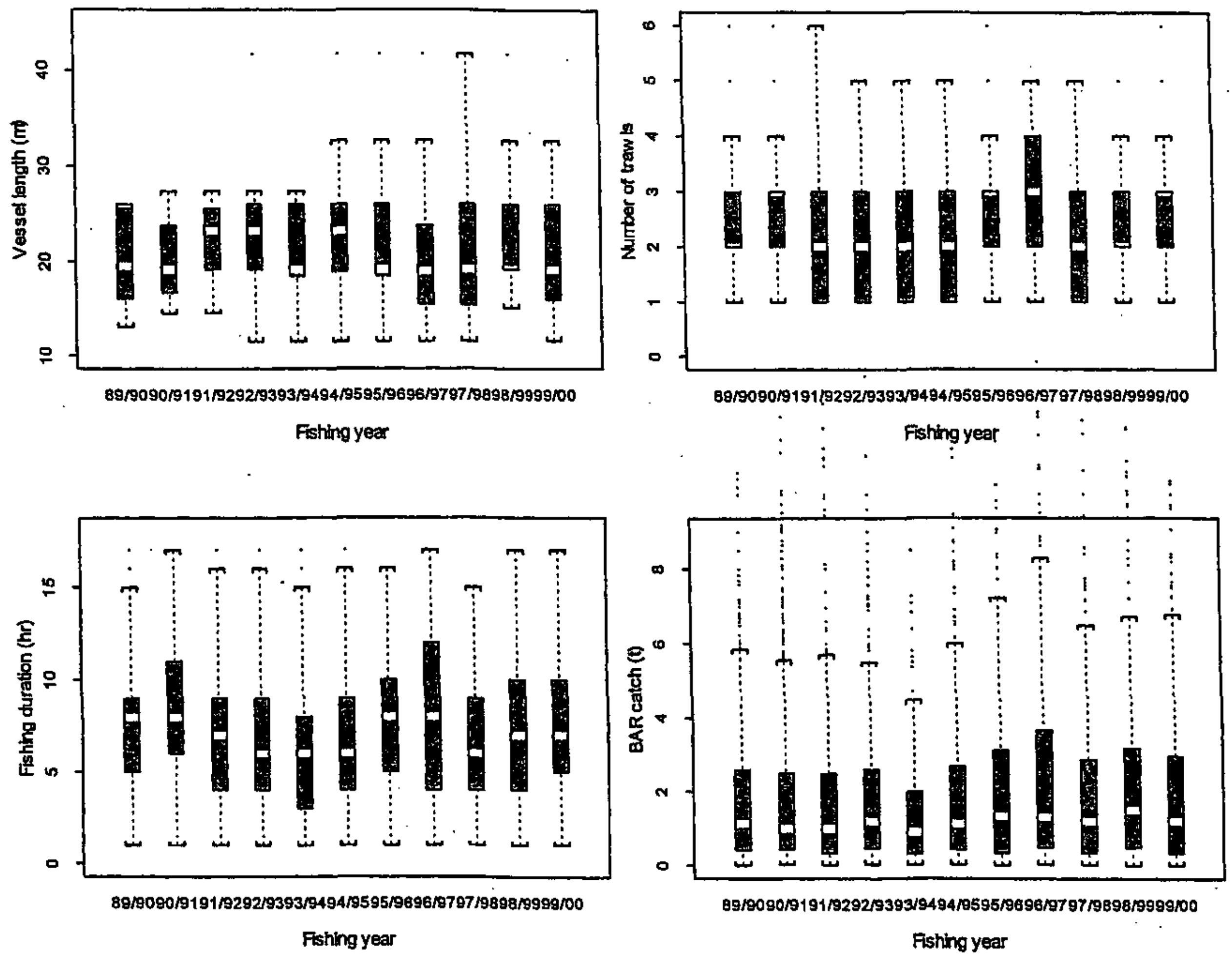

Figure 3: Annual trend in the main variables included in the barracouta target CPUE data set; vessel length (m), number of trawls per record, total duration of fishing per record (hours), and barracouta catch (t). The boxes denote the inter-quartile range of the data with the bar representing the median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

Table 3: Percentage distribution of target barracouta 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	1999/2000
018	8	8	19	19	24	31	28	32	27	8	29
020	8	8	13	8	11	10	4	7	5	7	8
022	79	69	57	53	53	43	61	54	61	79	55
024	5	14	11	20	12	15	7	7	7	6	8
Number of records	490	704	510	563	187	356	323	278	306	384	361

Table 4: Percentage distribution of target barracouta 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	1999/2000
Oct	2	14	11	6	14	10	13	13	19	9	10
Nov	5	9	9	9	22	15	19	19	24	3	14
Dec	3	11	7	6	13	7	7	18	19	1	6
Jan	9	18	12	14	21	11	7	19	5	8	15
Feb	8	10	12	20	7	5	12	5	1	8	18
Mar	12	8	20	13	3	11	12	3	4	14	6
Apr	15	8	12	7	5	19	9	10	5	15	3
May	22	12	5	11	4	10	11	9	4	16	7
Jun	11	4	3	10	1	9	2	3	6	13	7
Jul	3	1	1	2	3	0	1	0	6	5	6
Aug	3	3	5	2	0	0	3	0	3	2	3
Sep	4	2	3	2	6	1	6	2	6	6	4
Number of records	490	704	510	563	187	356	323	278	306	384	361

Table 5: **Summary of catch and effort records from the barracouta target CPUE data set by fishing year, including the barracouta (BAR) catch (tonnes), the number of records, the number of 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	1999/2000
BAR catch	936.9	1 323.6	918.8	1073.9	284.5	709.8	699.5	714.9	611.3	848.0	747.3
Number of records	490	704	510	563	187	356	323	278	306	384	361
Number of vessels	19	23	23	24	18	21	21	23	19	17	14
Number of trawls	1 179	1 822	1 050	1 123	384	785	854	723	711	892	941
Trawl duration	3 687	5 955	3 556	3 763	1 188	2 432	2 561	2 236	2 071	2 781	2 743
Catch per trawl (kg)	795	726	875	956	741	904	819	989	860	951	794
Catch per hour (kg)	254	222	258	285	239	292	273	320	295	305	272

2.2.2 Red cod bycatch

The red cod bycatch CPUE dataset was dominated by core vessels in the 15–20 m length range (overall length), with vessel size remaining relatively constant from 1989–90 to 1999–2000 (Figure 4). During most fishing days, the vessels conducted 2–4 trawls of a total fishing duration of 5–12 hours. Fishing duration remained relatively constant during the study period although there was an increase in the daily number of trawls conducted in 1997–98 to 1999–2000 (Figure 4).

The daily catch of barracouta reported from the red cod target fishery was relatively low between 1989–90 and 1994–95, but steadily increased in the subsequent years to reach a peak in 1997–98 (Figure 4). The level of barracouta bycatch declined slightly in 1998–99 and 1999–2000.

Most (70%) of the red cod target CPUE records in BAR 1 were conducted within statistical area 22, with about 20% of the records from statistical area 020 (Table 6). The remainder of the trawls were conducted in statistical areas 018 and 024. The areal distribution of fishing effort between statistical areas remained relatively constant from 1989–90 to 1999–2000.

There was a persistent seasonal trend in the distribution of the red cod bycatch trawl records. The monthly proportion of red cod bycatch trawls increased between October and December, remained at a high level from December to May, and declined in the subsequent months (Table 7). A small proportion of the total red cod bycatch trawls were recorded from August to September.

The red cod core vessel fleet comprised about 25–35 vessels annually (Table 8). These vessels accounted for an annual BAR 1 bycatch of 500–600 t between 1989–90 and 1992–93. The level of bycatch steadily increased from 1993–94 to reach a peak of about 2500 t in 1997–98 before declining to about 1200 t in 1998–99 and 1999–2000 (Table 8). From 1989–90 to 1997–98, there was an increase in the number of fishing days on which barracouta was reported as a bycatch of the red cod fishery and a corresponding increase in both the number of trawls and hours fished (Table 8). The level of red cod target fishing effort declined in 1998–99 and 1999–2000. The catch rate of barracouta (catch per trawl and catch per hour) increased steadily between 1991–92 and 1997–98 and declined slightly in the two subsequent years (Table 8).

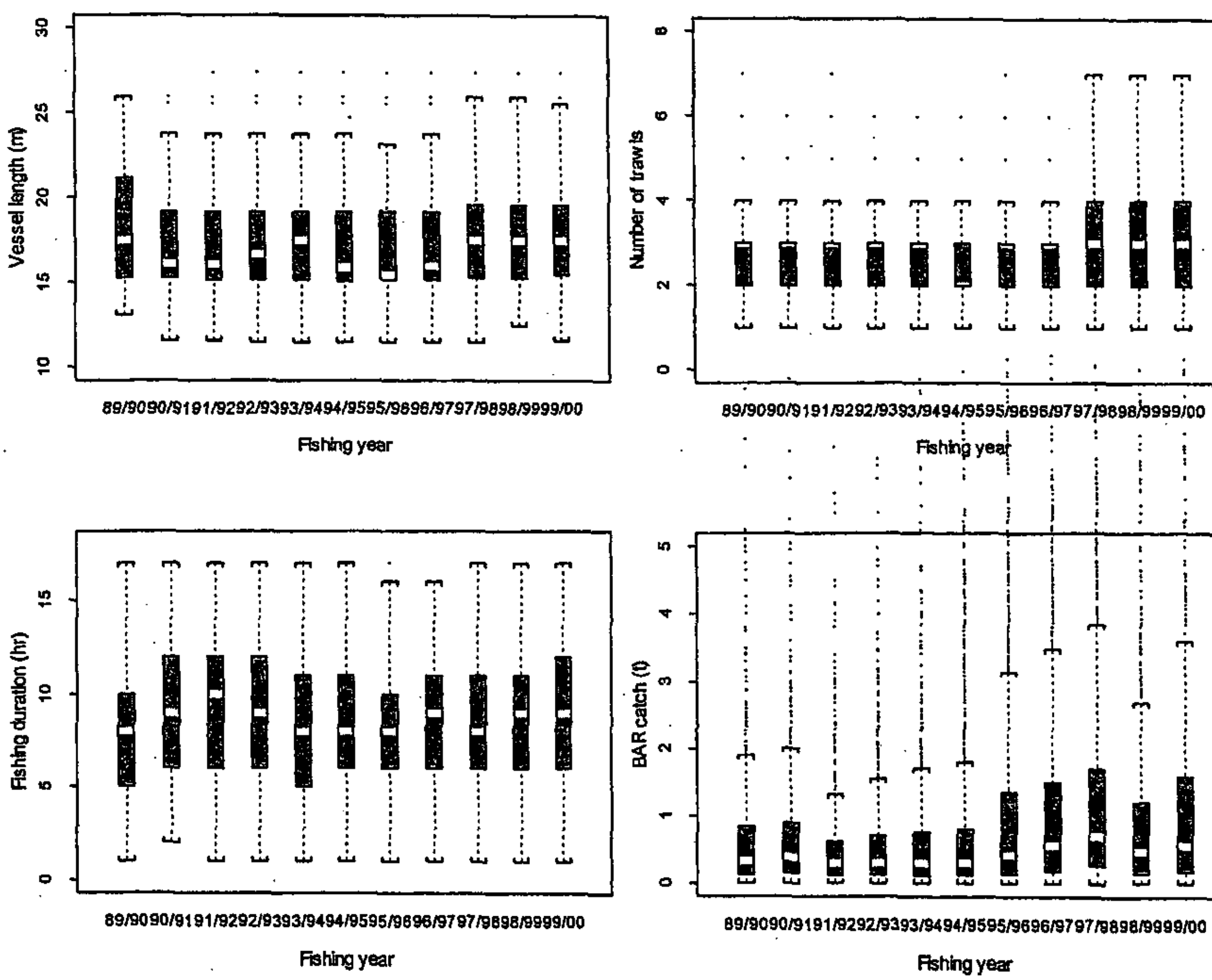

Figure 4: Annual trend in the main variables included in the red cod bycatch CPUE data set; vessel length (m), number of trawls per record, total duration of fishing per record (hours), and barracouta catch (t). The boxes denote the inter-quartile range of the data with the bar representing the median value and the whiskers represent 1.5 times the inter-quartile range.

Table 6: Percentage distribution of red cod 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	1999/2000
018	2	4	4	5	10	9	6	5	6	3	3
020	32	20	22	21	18	27	21	17	27	18	20
022	64	68	68	70	68	59	69	71	62	71	74
024	2	8	6	4	4	5	3	7	4	8	3
Number of records	640	900	999	1 137	1 162	1 613	1 689	1 811	1 927	1 308	1 151

Table 7: Percentage distribution of red cod 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	1999/2000
Oct	2	3	5	3	3	5	6	6	6	8	6
Nov	13	13	4	7	8	13	13	11	8	14	9
Dec	9	4	9	8	14	10	8	11	8	9	9
Jan	10	10	16	10	13	15	15	11	16	16	9
Feb	8	11	11	15	12	17	11	11	13	13	11
Mar	8	7	7	12	10	10	10	11	15	11	12
Apr	9	12	12	16	13	8	10	14	10	10	12
May	15	17	12	8	11	13	13	12	9	8	16
Jun	13	9	13	12	6	4	6	7	8	5	6
Jul	7	7	5	4	5	4	5	3	3	2	5
Aug	3	5	3	3	3	1	2	2	2	1	2
Sep	4	3	4	1	2	1	1	1	2	2	3
Number of records	640	900	999	1 137	1 162	1 613	1 689	1 811	1 927	1 308	1 151

Table 8: **Summary of catch and effort records from the red cod bycatch CPUE data set by fishing year, including the barracouta (BAR) catch (tonnes), the number of records, the number of 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	1999/2000
BAR catch	476.7	617.1	551.9	686.1	750.7	1198.5	1719.7	1983.2	2360.2	1220.1	1288.6
Number of records	640	900	999	1 137	1 162	1 613	1 689	1 811	1 927	1 308	1 151
Number of vessels	21	26	27	29	26	34	33	34	32	26	23
Number of trawls	1 616	2 329	2 660	2 802	3 061	4 076	4 250	4 863	5 338	3 720	3 418
Trawl duration	5 174	7 925	9 321	10 111	9 653	13 673	13 691	15 192	15 815	11 084	10 552
Catch per trawl (kg)	295	265	207	245	245	294	405	408	442	328	377
Catch per hour (kg)	92	78	59	68	78	88	126	131	149	110	122

2.3 CPUE Analysis

A standardised CPUE analysis was conducted for both the barracouta target fishery and red cod barracouta bycatch fishery based on the methods of Vignaux (1992, 1994). For both CPUE analyses, the natural logarithm of the barracouta catch (kilogrammes) from one day of fishing was used as the CPUE estimate (dependent variable) in the model. An examination of unstandardised catch rates from both the barracouta target and red cod bycatch fisheries revealed a decline in catch rates (catch per hour) with increasing daily fishing duration (Figure 5). Consequently, daily catch per hour was rejected as an appropriate CPUE estimate and instead 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 barracouta 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 power 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 1% increase in the R^2 value).

Annual indices were determined relative to a base year of 1989–90. The standard deviation of the annual indices was determined following Francis (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.

2.4 Operator Interviews

The results of the CPUE analysis were discussed with a number of key participants in the BAR 1 commercial fishery. Recent trends in CPUE were compared with observations from the commercial fishery concerning trends in the abundance of barracouta. The discussions were also used to identify any changes in the operation of the BAR 1 fishery that may influence the catch rate of barracouta.

The results of these interviews were documented in a separate report (Langley & Walker, unpublished results).

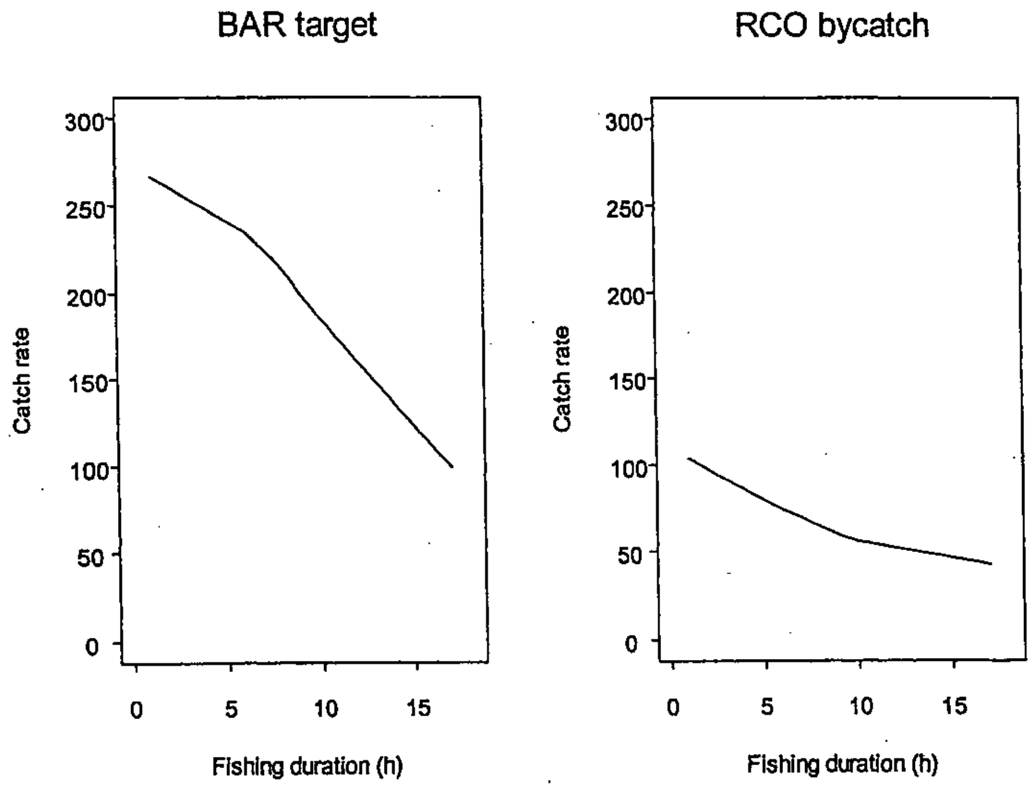

Figure 5: Relationship between barracouta catch rate (kilogramme per hour) and trawl duration for the barracouta target (left) and red cod bycatch (right) fisheries. The lines represent the locally weighted regression fit to the data.

3. RESULTS

3.1 Barracouta target CPUE model

The barracouta 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 variable *month* and the continuous variable *duration* were included at the third and fourth iterations, respectively. The categorical variable *fishing year* was the final variable included in the model. The five variables explained 30% of the variation in the logarithm of daily barracouta catch (Table 9).

Most of the individual *vessel* coefficients from the CPUE model were within a relatively narrow range, suggesting similar fishing power among the vessels in the target barracouta fleet (Figure 6). *Month* coefficients were relatively constant for the January–July period, declined markedly in August–September, and steadily increased between September and December (Figure 6).

The CPUE model predicted a steady increase in daily barracouta catch with an increase in the number of *trawls* conducted, while catches were also predicted to increase with increasing fishing *duration* up to a maximum at about 8 hours per day (Figure 6). Predicted target catches declined slightly for days exceeding a fishing *duration* of 8 hours.

The annual indices from the CPUE model were relatively constant from 1989–90 to 1991–92, but increased steadily between 1991–92 and 1996–97 to about 50% above the level of the 1989–90 base year. The indices declined slightly in 1997–98 and subsequently declined to the level of the base year in 1998–99 and 1999–2000 (Table 10).

The CPUE model residuals had a reasonably good fit to the data set (Figure 7). However, there was a contraction in the range of the positive residuals at the upper range of the predicted values.

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

Variable	% R^2 at iteration						
	1	2	3	4	5	6	7
Vessel	14.21						
Trawls	5.60	25.69					
Month	4.58	16.42	28.27				
Duration	7.70	25.36	26.88	29.42			
Fishing year	0.48	15.01	26.34	28.88	30.09		
Stat area	1.85	14.25	25.76	28.30	29.46	30.13	
Form type	0.59	15.16	25.69	28.27	29.42	30.10	
% Improvement		80.8	10.0	4.1	2.3	NS	

Table 10: Year indices with standard deviation and regression coefficients for the barracouta target CPUE model; *n*, number of records.

Fishing year	*n*	Regression coefficient	Year index	S.D.
1989–90	490	0.000	1.000	0.061
1990–91	704	-0.016	0.984	0.050
1991–92	510	-0.060	0.942	0.055
1992–93	563	0.136	1.145	0.051
1993–94	187	0.075	1.078	0.081
1994–95	356	0.200	1.222	0.061
1995–96	323	0.185	1.204	0.065
1996–97	278	0.434	1.543	0.071
1997–98	306	0.333	1.395	0.067
1998–99	384	-0.005	0.995	0.061
1999–2000	361	0.119	1.127	0.066

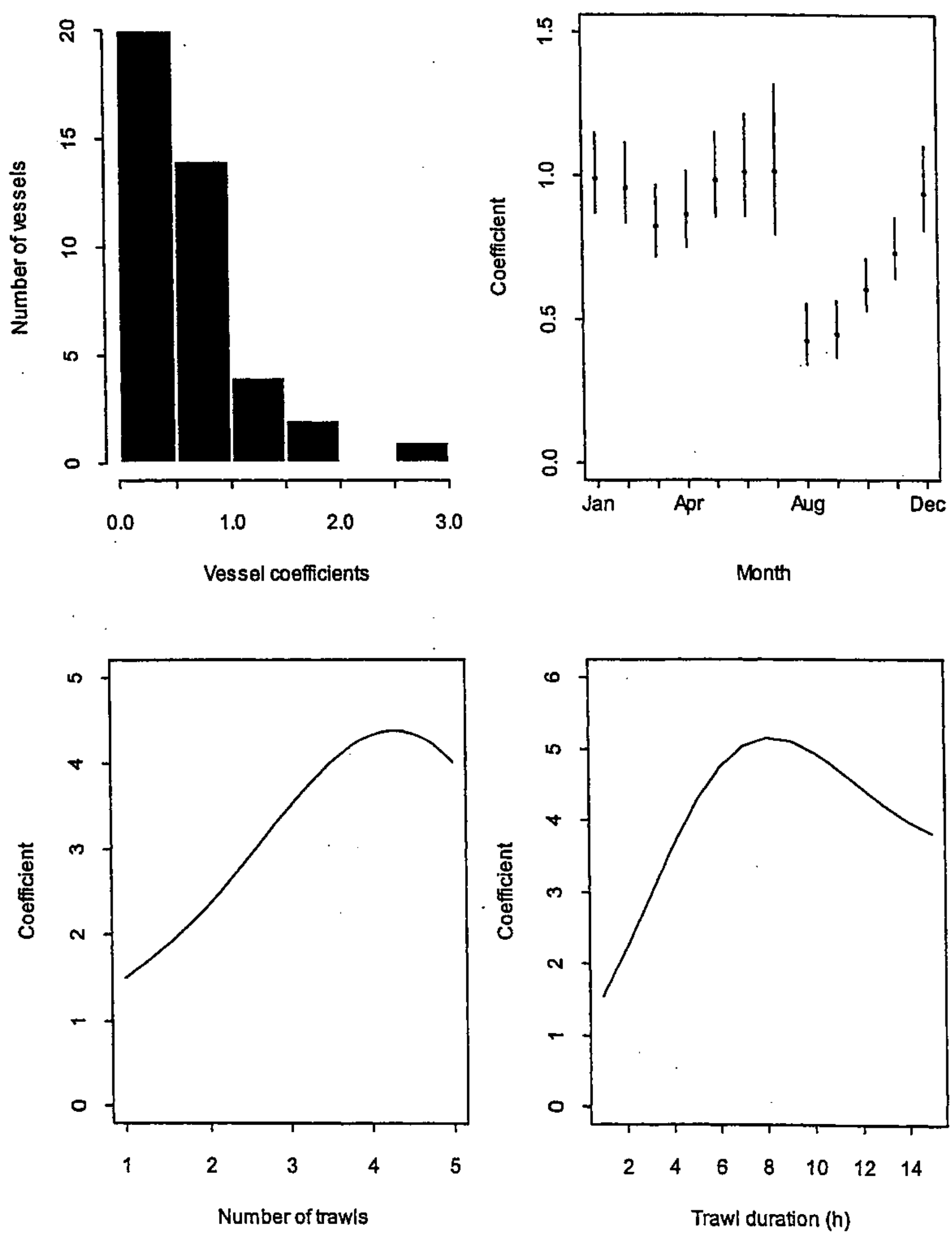

Figure 6: Summary of the exponentiated coefficients from the target barracouta BAR 1 CPUE model.

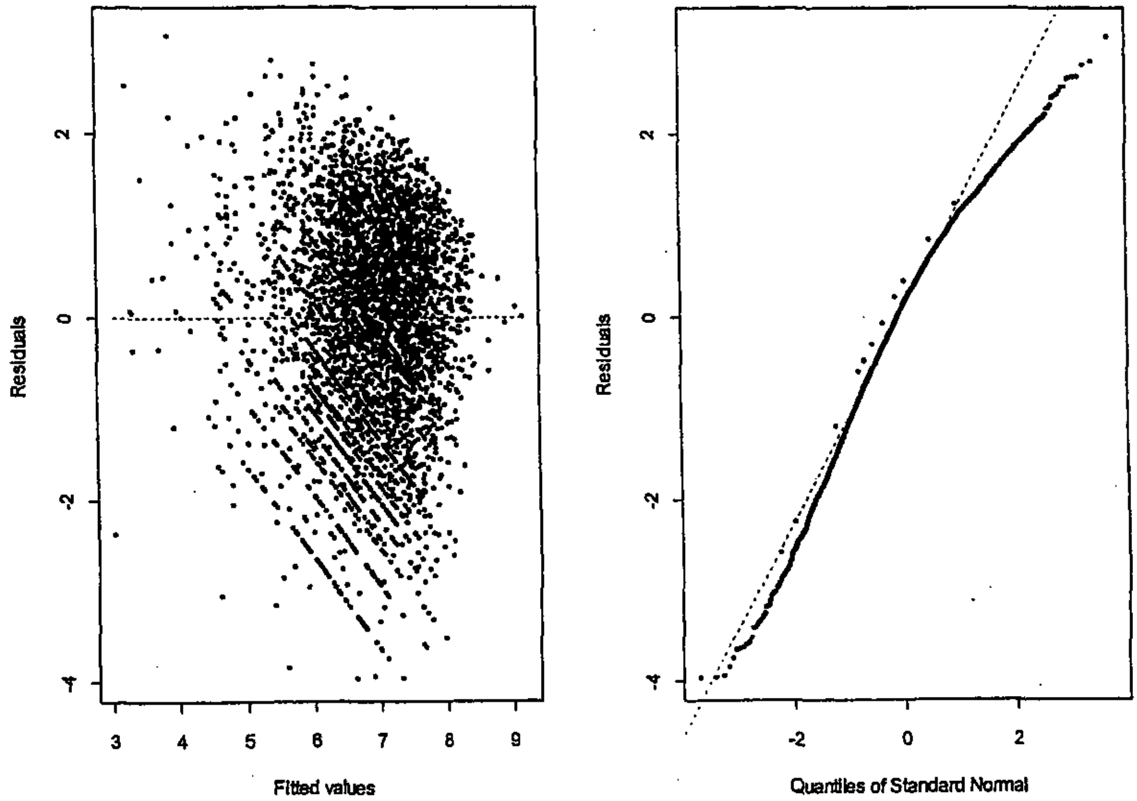

Figure 7: Relationship between fitted values and residuals from the target barracouta CPUE model (left) and quantile-quantile plot of the model residuals versus a standard normal distribution (right).

3.2 Red cod bycatch CPUE model

The red cod bycatch CPUE model included the categorical variable *vessel* at the first iteration (Table 11). The *trawls* variable was included at the next iteration, followed by the categorical variables *fishing year* and *month* at the third and fourth iterations. The four significant variables accounted for 33% of the variation in the logarithm of barracouta bycatch (Table 11).

The *vessel* coefficients derived from the CPUE model indicate the fishery was dominated by vessels with relatively low bycatch rates of barracouta (Figure 8). The *month* coefficients indicate that the bycatch of barracouta was relatively high between December and February. Catch rates were moderate between March and July, declined to the lowest level in August and September, and recovered in October–November (Figure 8).

The CPUE model predicted the daily barracouta bycatch to increase steadily with an increase in the number of trawls conducted during the day. However, the predicted increase in catch attenuated for days exceeding three trawls (Figure 9). The fishing duration was not included as a significant variable, but the variable was strongly correlated with the daily number of trawls.

The annual indices from the red cod bycatch CPUE model were relatively constant from 1989–90 to 1994–95 (Table 12). In the subsequent three years, the indices increased markedly to peak in 1997–98 at 1.7 times the level of the 1989–90 base year. The indices declined in the following year and the 1998–99 and 1999–2000 indices were around the level of the base year.

An examination of the residuals from the CPUE model indicated a relatively good fit to the red cod bycatch data (Figure 9).

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

Variable	% R^2 at iteration						
	1	2	3	4	5	6	7
Vessel	22.00						
Trawls	4.44	29.36					
Fishing year	3.94	23.97	31.42				
Month	3.44	23.89	31.35	33.08			
Duration	13.30	27.62	29.92	31.65	33.35		
Stat area	0.50	22.22	29.81	31.59	33.28		
Form type	2.91	22.33	29.68	31.42	33.08		
% Improvement		33.5	7.0	5.3	NS		

Table 12: Year indices with standard deviation and regression coefficients for the red cod bycatch CPUE model; *n*, number of records.

Fishing year	*n*	Regression coefficient	Year index	S.D.
1989–90	640	0.000	1.000	0.044
1990–91	900	0.225	1.252	0.037
1991–92	999	-0.001	0.999	0.036
1992–93	1 137	0.119	1.127	0.034
1993–94	1 162	-0.022	0.978	0.033
1994–95	1 613	0.091	1.096	0.029
1995–96	1 689	0.350	1.420	0.028
1996–97	1 811	0.430	1.538	0.027
1997–98	1 927	0.538	1.713	0.027
1998–99	1 308	0.092	1.097	0.032
1999–2000	1 151	0.119	1.127	0.034

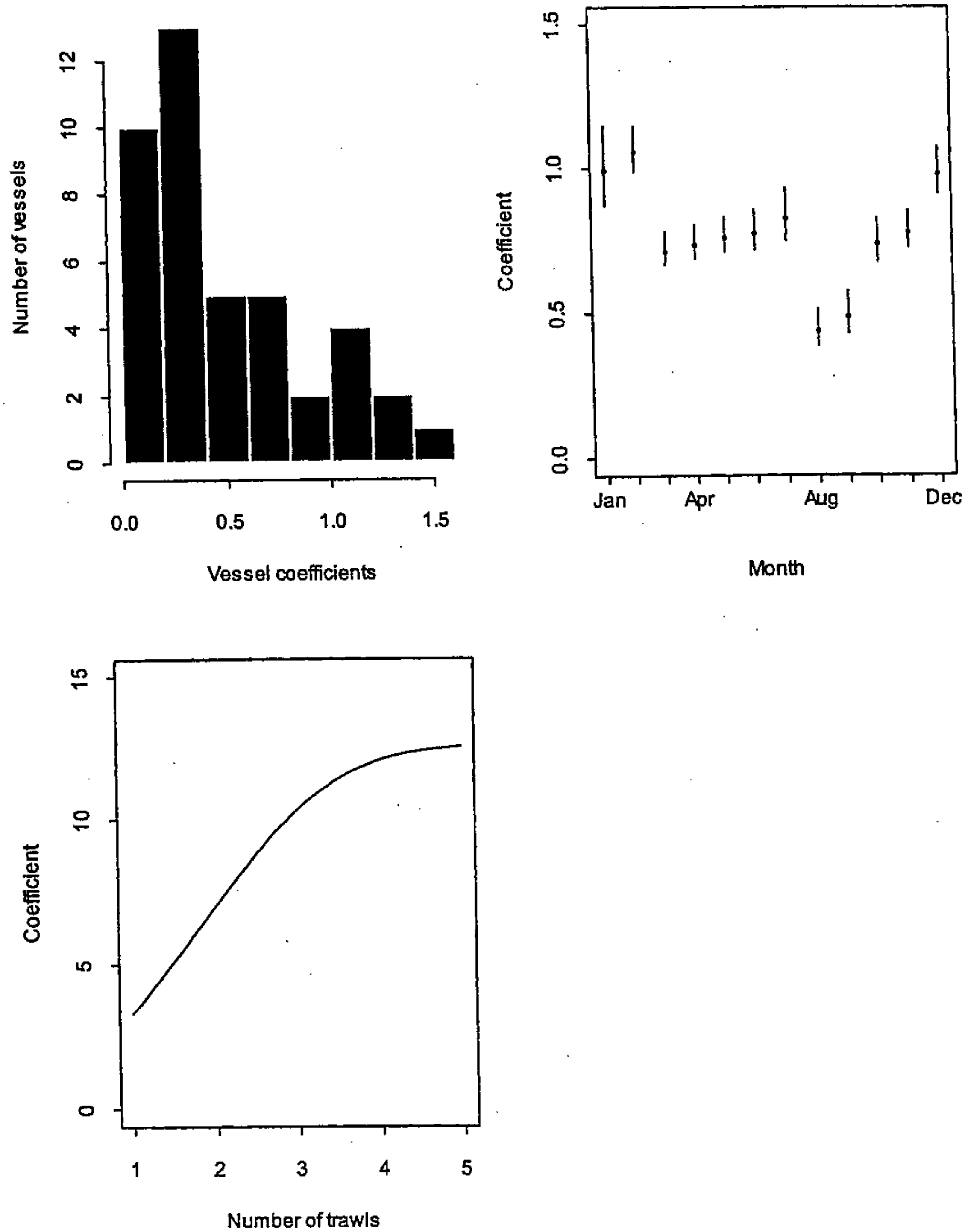

Figure 8: Summary of the exponentiated coefficients from the red cod bycatch BAR 1 CPUE model.

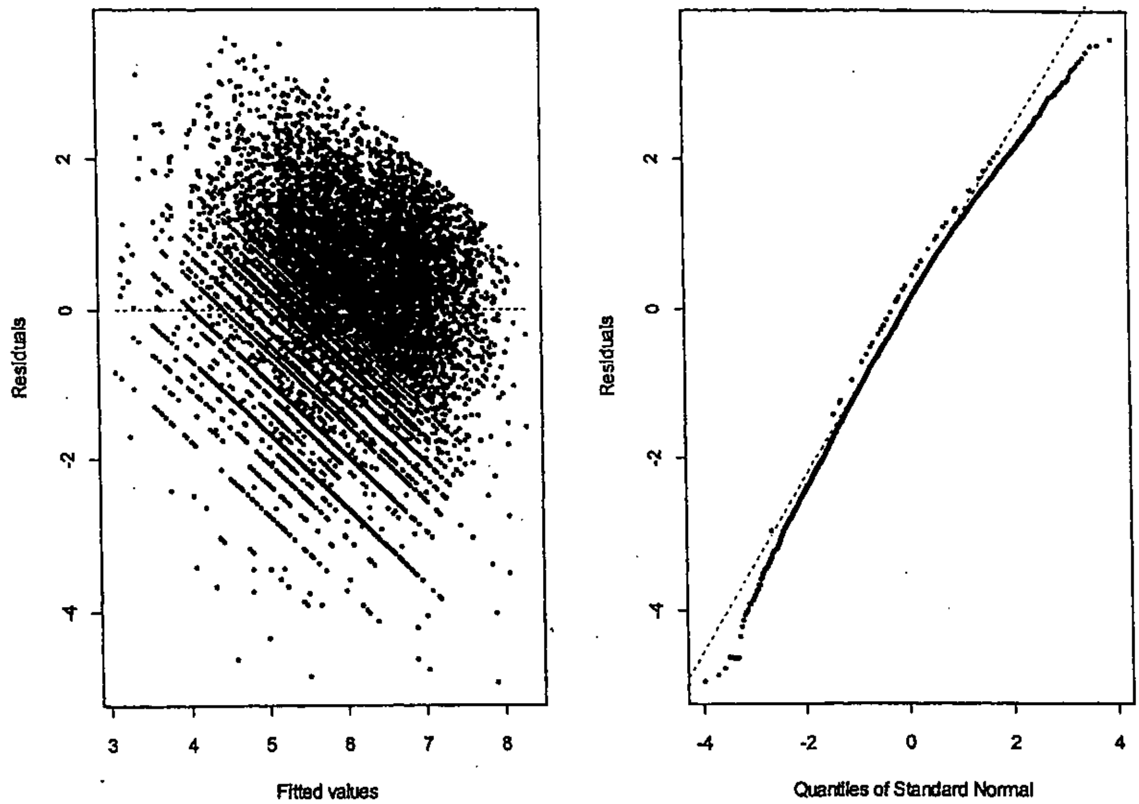

Figure 9: Relationship between fitted values and residuals from the red cod bycatch BAR 1 CPUE model (left) and quantile-quantile plot of the model residuals versus a standard normal distribution (right).

3.3 Summary

A comparison of the individual vessel coefficients from the barracouta target and red cod bycatch CPUE models revealed a strong correlation between the two sets of indices (correlation coefficient = 0.762, p < 1%) (Figure 10). Vessels in the fleet that achieved high catch rates of barracouta in the target fishery also had a high bycatch of barracouta from the red cod trawl fishery. There was also a strong positive correlation between vessel length and the vessel coefficients derived from both the target barracouta (correlation coefficient = 0.826, p < 1%) and red cod bycatch (correlation coefficient = 0.522, p < 1%) CPUE models (Figure 10).

The trends in annual indices from the barracouta target and red cod bycatch CPUE models are generally comparable (Figure 11). The two sets of indices were around the level of the 1989–90 base year for 1989–90 to 1991–92 and increased to a peak in 1996–97 and 1997–98, about 150% the level of the base year. Catch rates subsequently declined in 1997–98 and 1998–99 to the level of the base year and remained at this level in 1999–2000 (Figure 11). Annual indices from the red cod bycatch CPUE model were determined with a higher level of precision than the indices from the barracouta target model due to the larger number of records included in the former data set.

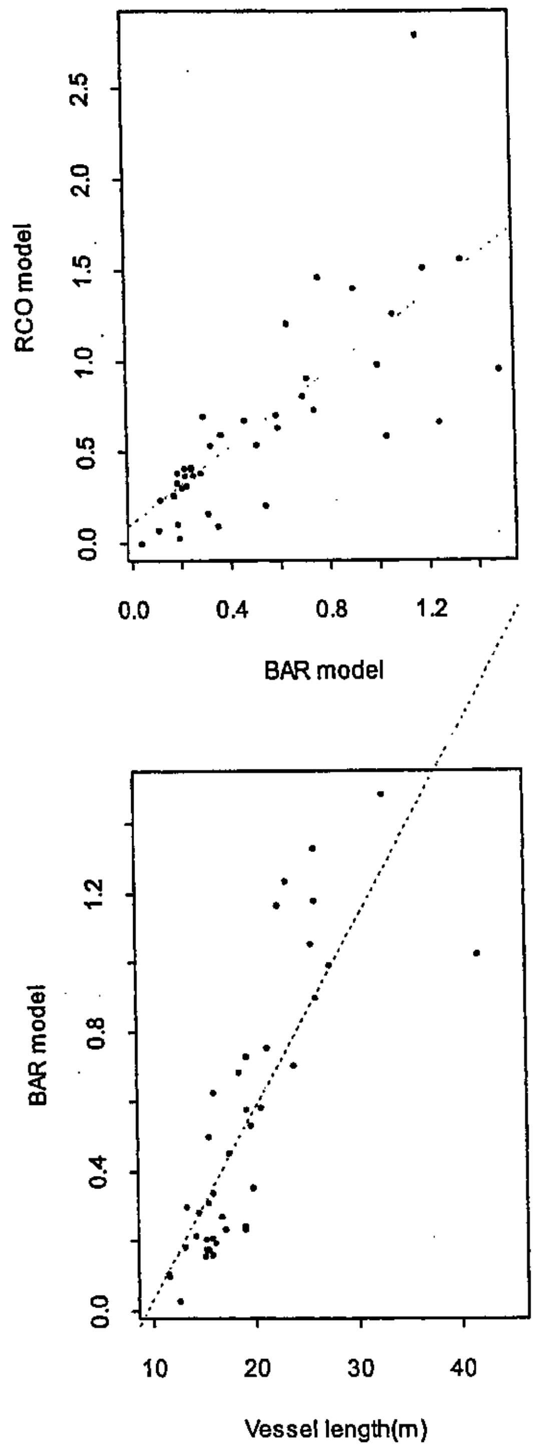

Figure 10: Relationship between vessel coefficients derived from the target barracouta and red cod bycatch BAR 1 CPUE models (top) and the relationship between vessel length (m) and vessel coefficients derived from the target barracouta CPUE model (bottom). The line represents the least squares fit to the data.

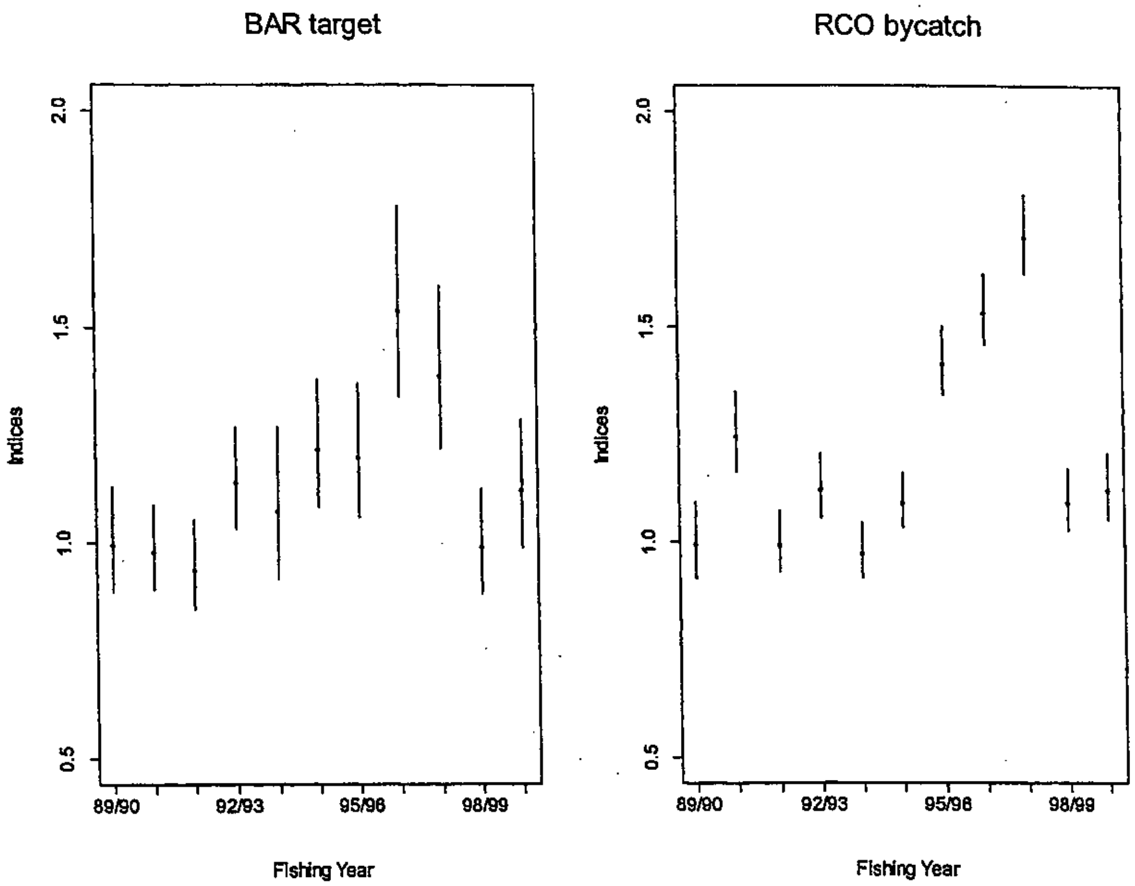

Figure 11: Annual indices derived from the target barracouta (left) and red cod bycatch (right) BAR 1 CPUE models. The confidence intervals represent +/- 2 standard error.

4. DISCUSSION

The southeast South Island target barracouta and target red cod inshore trawl fisheries account for a substantial proportion of the total annual BAR 1 catch. The two fisheries are inherently linked with the main inshore trawl fleet targeting both species. The declaration of the target species is largely an artefact of the current reporting regime that requires the vessel master to specify a single target species for the fishing day or trawl. However, the southeast South Island fishery is largely considered to be a mixed trawl fishery based on a suite of species dominated by red cod and barracouta.

The factors determining the declaration of the target species for an individual fishing trip were investigated through discussions with operators in the BAR 1 commercial fishery (Langley & Walker, unpublished results). Conflicting comments were received on concerning the ability to specifically target barracouta in the Canterbury Bight/Pegasus Bay area. Some fishers considered that barracouta schools were identifiable on the echosounder and could be targeted in certain areas at specific times of the year, while others stated that the barracouta generally occurred in mixed schools with other species and could not be targeted exclusively.

The discussions with operators in the fishery revealed that the declaration of the target species was dependent on a number of factors, including composition of the catch, relative value of the species caught, the availability of quota of the principal species, and the bycatch trade-off regime. During 1989–90 to 1995–96 there was a decline in the proportion of target barracouta trawls relative to the proportion of red cod target trawls that had a bycatch of barracouta. This corresponded to a period of increased catches from the southeast South Island red cod fishery (RCO 3), with high catches maintained between 1994–95 and 1998–99 (Annala et al. 2001). The increased effort in the fishery yielded an increase in barracouta bycatch (see Table 8). The annual catches from the BAR 1 fishery exceeded the TACC between 1994–95 and 1997–98, and consequently BAR 1 quota was likely to be limited during this period and less likely to be declared as the target species of the fishing trip.

Given the mixed nature of the southeast South Island inshore trawl fishery, the BAR 1 CPUE indices derived from the target barracouta and red cod fisheries are not independent. Rather, the two data sets are strongly influenced by the factors that influence the declaration of the target species of the fishing trip. Despite a change in the level of declared targeting of barracouta during the study period, both sets of indices show comparable trends in the relative catch rate of barracouta. The CPUE indices reveal an increase in catch rates from about 1991–92 to 1997–98 and then a reduction in catch rates in 1998–99 to 1999–2000. The timing and the extent of the increase in standardised catch rates varies between the two models, with the increase in the bycatch of barracouta not occurring until 1995–96. This was the first year that BAR 1 quota was limited and the lack of available quota may have meant that more of the larger catches of barracouta were reported as bycatch of the target red cod fishery.

In future, it may be appropriate to update the CPUE analysis using an amalgamated data set and including target species as an additional predictor variable. An examination of the coefficients from the two current models revealed strong similarities in the parameterisation of the two models, indicating that an amalgamation of the data sets is justified. The CPUE model could be further improved by the inclusion of the catch of the associated species, principally red cod, as a potential predictor variable(s) in the model.

Trawl surveys of the inshore southeast coast fishery were conducted between 1990–91 and 1999–2000 (Beentjes & Stevenson 2000, 2001). The trawl surveys represent two separate series, with five winter surveys (May–June) conducted before 1996–97 and four subsequent surveys conducted in summer (December–January). The trawl surveys yielded relative biomass estimates for barracouta of moderate precision (coefficients of variation 20–30%) (Beentjes & Stevenson 2000, 2001).

The termination of the winter trawl survey time-series prevented a comparison with the CPUE indices during the period of greatest contrast in the relative abundance of barracouta, i.e., the increase from 1991–92 to 1997–98 and subsequent decline. However, there was an apparent positive correlation between the two sets of indices for 1990–91 to 1995–96, with the exception of the low trawl survey biomass estimate from 1993–94 (Figure 12). Nevertheless, the correlation was not significant given the small number of observations (corr. coef. = 0.539, df = 4).

There is no apparent correlation between the four summer trawls surveys and the CPUE indices from 1996–97 to 1999–2000 (Figure 12). The barracouta target CPUE indices were at a peak in 1996–97 and declined in 1998–99 and 1999–2000, although the trawl survey indices remained high. The inconsistency between the two sets of indices may relate to the seasonal availability of barracouta to the trawl survey. Monthly coefficients for the target BAR 1 CPUE index revealed that the catch rate of barracouta is relatively constant throughout December–July, indicating no change in the availability of barracouta to the fishing fleet during this period. Most of the trawl survey barracouta catch comprised relatively small fish (less than 60 cm F.L.) (Beentjes & Stevenson 2000, 2001), but the length composition of the inshore trawl fishery is unknown.

The target BAR 1 CPUE indices are negatively correlated (corr. coef. = -0.707, $p < 5\%$) with CPUE indices derived from the BAR 5 for 1989–90 to 1997–98 (Harley et al. 1999). This observation is consistent with other evidence, which suggests that the BAR 5 and the east coast of the South Island areas are linked (Langley & Bentley, unpublished results).

In general, the recent trends in BAR 1 CPUE indices are consistent with comments received from the participants in the commercial fishery. A number of the fishers interviewed noted that the abundance of the large barracouta (over 70 cm fork length) preferred by the processors had declined in the last two years, while the abundance of smaller barracouta had increased. Barracouta in the smaller size classes are generally avoided due to the low port price. Most interviewees also noted that the abundance of the larger barracouta was strongly influenced by water temperature and the distribution and abundance of the main food source (squid, anchovies, and krill).

The discussions with participants in the fishery also concentrated on identifying any significant changes in the operation of the BAR 1 fishery that may have influenced the catch rate of barracouta. This included a consideration of any changes in the configuration of the main BAR 1 fleet and changes in targeting behaviour. Most fishers noted that the configuration of the core fleet, including fishing gear, had remained relatively constant throughout the period of the CPUE analysis. However, the level of catch and, therefore, catch rate is likely to be influenced by economic factors, principally the port price of barracouta.

The high price differential between small and large barracouta means that larger fish are preferentially targeted, while the economic return for catching and landing smaller barracouta is marginal. Changes in the relative price differential between the large and small barracouta could potentially influence the CPUE index.

There is no information on the length composition of the catch landed by the BAR 1 inshore trawl fishery in the Canterbury Bight/Pegasus Bay area. However, given the results of discussions with commercial operators, there is a strong preference for fish in the larger length classes (over 70 cm fork length). On this basis, the CPUE indices derived for the BAR 1 fishery should be considered as indices of relative abundance for the larger length size classes of barracouta only. The length of recruitment to the commercial fishery may account, at least in part, for the observed differences between the CPUE indices and the trawl survey relative biomass estimates of barracouta from the east coast South Island trawl survey. The trawl survey abundance estimates principally derived from fish in the 20–65 cm length range, with only a few surveys catching a significant number of fish in the larger length range.

Overall, the annual indices derived from the CPUE models appear to monitor trends in the abundance of recruited barracouta in the Canterbury Bight/Pegasus Bay fishery. However, a recent review of the stock structure of barracouta suggested that the fish resident off the east coast of the South Island may be a component of a single stock whose distribution extends along the entire eastern coast of mainland New Zealand and includes Southland (BAR 5) (Langley & Bentley, unpublished results).There also appears to be considerable inter-annual variation in the distribution of barracouta between the Southland and east coast South Island areas. Consequently, the CPUE indices derived for Canterbury Bight/Pegasus Bay fishery may not adequately monitor the abundance of the entire barracouta stock.

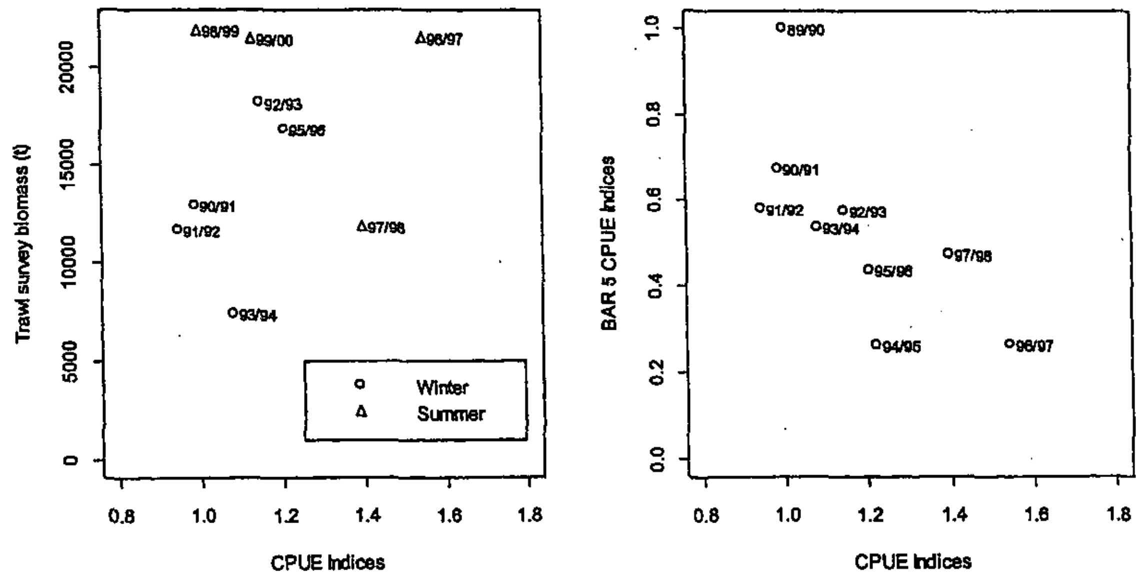

Figure 12: Relationship between the target BAR 1 CPUE indices and winter and summer ECSI trawl survey indices (left) (Beentjes & Stevenson 2000, 2001) and CPUE from BAR 5 fishery (Harley et al. 1999) (right).

5. ACKNOWLEDGMENTS

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