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N. L. Phillips

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N. L. Phillips

NIWA
Private Bag 14901
Wellington

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EXECUTIVE SUMMARY

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The fishery developed in Bay of Plenty in 1994 as a result of the development of the orange roughy fishery. Reported catches increased up to 1800 t in the 1997 fishing year, but have decreased considerably since. Seamount features are mostly fished in three main areas (Mercury-Colville, White Island, and North Colville) within CDL 1. The Mercury-Colville fishery is the main area fished. Other areas (which are relatively new) include White Island fishery and the North Colville fishery, but catch is small in comparison.

Black cardinalfish is caught as either a target species or as bycatch from the orange roughy fishery. There has been an increased amount of target fishing since 1996–97, but the amount of black cardinalfish caught while targeting orange roughy decreased during the same period.

In the Mercury-Colville and North Colville areas, fishing was initially in the summer but latter changed to winter. Little pattern could be seen in most recent years. However, the season for White Island lasts from February to July.

Several standardised CPUE indices were calculated. The regression analysis was applied to four datasets; all vessels involved in the QMA fishery; all vessels involved the Mercury-Colville fishery; vessels that fished for 3 or more consecutive years; and vessels that fished for 3 or more consecutive years and targeted black cardinalfish.

All of the standardised indices derived from these series were similar, showing a substantial decline over the period examined.

These conclusions should be treated with caution as the catch rates were highly variable, with a small number of available data for each year surveyed, and the data set was unbalanced. Given these constraints, the resulting indices may have a limited application for monitoring abundance of black cardinal fish in CDL 1.

1. INTRODUCTION

Black cardinalfish (*Epigonus telescopus*) occur throughout the New Zealand Economic Exclusive Zone (EEZ) at depths of 300–1100 m. They are most commonly found in mobile schools up to 150 m off the bottom over hills and rough ground. It is the only species of cardinalfish that reaches a marketable size and is found in commercial concentrations. Black cardinalfish have been caught since 1981, initially as a bycatch of target trawling for other high value species. However, the QMA 1 fishery did not develop until the mid 1990s as a result of bycatch from new orange roughy fisheries in the area, and subsequently developed into a target fishery (Clark 2001; Field et al. 1997). The main depth range of schools (600–900 m) overlaps the upper end of the depth range of orange roughy and the lower end of alfonsino and bluenose.

Black cardinalfish was introduced into the Quota Management System (QMS) on 1 October 1998. The fishery is managed in 10 stocks or Quota Management Areas (QMA) (Figure 1). Most of the reported landings for black cardinalfish are from QMA areas 1, 2, and 3. The TACC for QMA 1 was set at 1200 t.

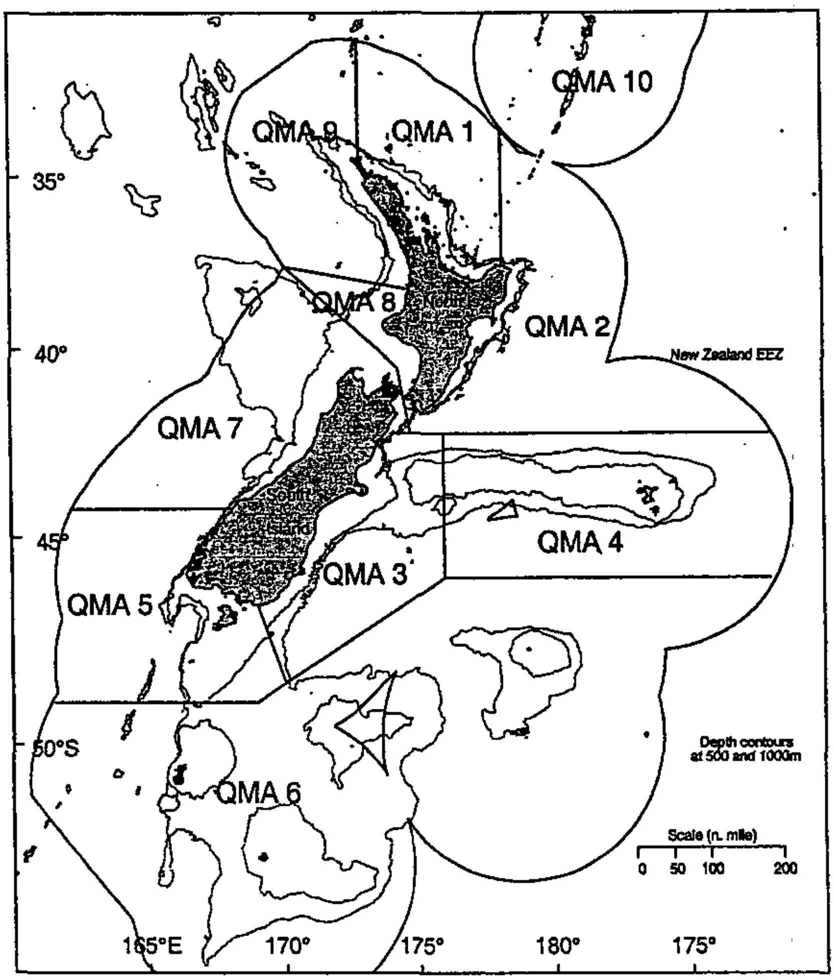

Figure 1: Quota Management Areas (QMA) for black cardinal fish in the New Zealand Economic Exclusive Zone (EEZ).

A standardised CPUE analysis was reported by Field & Clark (2001) for cardinalfish from QMA 2. Their results showed a substantial decline in the index from 1989–90 to 1993–94 (16% of the 1989–90 peak), and the index has fluctuated between 10 and 23% of the peak values since.

There has been no previous CPUE analysis for black cardinalfish in QMA 1. The research in this report was part of a study conducted by NIWA for the Ministry of Fisheries under contract MOF 2001–03G. The objectives reported in this document are as follows.

1. To carry out a descriptive analysis of commercial catch and effort data from the fishery for cardinalfish in QMA 1 with the inclusion of data up the end of the 2000–01 fishing year.

2. To investigate the use of standardised and unstandardised analyses of commercial catch and effort data as a relative abundance index for cardinalfish in QMA 1.

2. METHODS

2.1 Data selection and variable description

The data set comprises commercial catch and effort data from all vessels making tows targeting or catching black cardinalfish (reported either as the general cardinalfish code, CDL, or the specific black cardinalfish code EPT) from the 1989–90 to 2000–01 fishing years. The data were extracted from Trawl Catch Effort and Processing Returns (TCEPR) and Catch, Effort, Landing Returns (CELR) from the Ministry of Fisheries catch and effort database in March 2002.

The data included information on where vessels fished, what and how much was caught, and vessel characteristics. Table 1 lists the variables extracted and derived variables used in the descriptive and CPUE analyses.

Most of the variables are self explanatory, but some require further definition. *Area* separates the main fishing grounds within the QMA 1 fishery (see Figure 3 for locations). *Knoll* is the known seamount feature where the tow started. If the start position of the tow was more than 5 n. miles from the location of the known seamount, then *knoll* was set to unknown.

For this study it was decided to only use TCEPR records for the following reasons.

1. The fishery and recording of catches of black cardinalfish did not develop until the mid 1990s, resulting in "best estimates" for reported and QMR landings.
2. Black cardinalfish tended to be discarded before 1994. The amount of discarding is unknown (Field et al. 1997).
3. Recording of catches after 1994 are likely to be relatively accurate as by this time black cardinalfish had been proposed as a potential quota species and fishers would be attempting to establish a catch history in the fishery.
4. As CELR forms do not contain tow-by-tow records, but only the number of tows, CPUE derived from these records could only be quantified as 'catch per average tow' or 'catch per day'. Fortunately, only a small proportion of catch is recorded on CELR records (20%). Consequently, these data were omitted from the descriptive and CPUE analyses.
5. Most of the estimated catch (80% plus in 6 of the 8 years) since the 1994 fishing year is recorded on TCEPR records (Table 2), thus allowing many more variables for inclusion in the CPUE analysis.
6. Examination of data for CDL 2 by Field & Clark (2001) revealed that the geographical distribution of catches is largely related to seamount features

which require detailed locality data to analyse at an appropriate scale. These data are available only from TCEPR data.

Table 1: Description of variables used in the descriptive and CPUE analysis. Variables in bold are categorical, and variables with * are derived.

Variable	Description
Year	Fishing year (1 October – 31 September the following year)
Vessel	Anonymous vessel identification number
Start date	Date at the start of the tow
Start time	Time at the start of the tow
Start longitude	Longitude at the start of the tow
Start latitude	Latitude at the start of the tow
Wingspread	Wingspread in metres of the net at the start of the tow
Headline height	Headline height in metres of the net at the start of the tow
Bottom depth	Depth in metres of the bottom at the start of the tow
Groundrope depth	Depth in metres of the ground rope at the start of the tow
Target species	Species of fish targeted
Total catch	Estimated catch in tonnes of target and bycatch species for the tow
CDL catch	Estimated catch in tonnes of cardinalfish
*Tow duration**	Duration of the tow in hours
*Fishing day**	Number of days since the start of the fishing year
Month*	Month of the fishing year
*Vessel experience**	Number of years the vessel has been operating in the fishery
Fishery*	The main fishing grounds within the fishstock
Knoll*	Name of the seamount where the tow occurred
*CPUE**	Catch-per-unit-effort (catch per tow)

2.2 Data grooming

Catch and effort data often contain many errors, most in the form of missing data, invalid codes, or implausible values. Data for all areas were checked for such errors before the analysis.

Individual tow records were checked to see if the tows occurred within the area boundaries within the defined period. Tow records outside the defined areal boundaries or time period were not investigated or otherwise validated, and hence were deleted.

All the variables for each record were checked for valid codes and values, and all variables were range checked. Variables with invalid codes or out of range values were visually compared with records from the same vessel on or around the time and date of the tow in question. Obvious transcription errors and recording errors were corrected if possible. If no correction could be applied and the data were still considered highly improbable or had an invalid code, then the values were set to missing.

Less than 1% of tows catching and/or targeting cardinalfish reported using midwater trawl gear. These records were removed from the analysis. Records that listed nationality as Australian were also removed before the CPUE analysis.

For the CPUE analysis, a number of records that were included in the descriptive analysis were removed if there were missing values for *Vessel speed, wingspread, headland height, groundrope depth, vessel, vessel nationality, start longitude/latitude, CDL catch.* This resulted in 98 records (4% of the total data set) removed from the dataset.

2.3 Descriptive analysis

The catch and effort data were summarised to provide descriptive statistics showing how the QMA 1 fishery has operated over the past 8 years. The data were examined for the whole QMA 1 fishery and by each fishery. Summary statistics were:

- estimated catch by month and fishing year
- estimated catch by target species
- estimated catch by nationality by fishing year
- mean catch by day and duration by fishing year
- mean trawl headline height/ wingspread
- mean vessel tonnage, length, power
- distribution of catch rate and summary statistics by individual fisheries/seamounts

2.4 Unstandardised CPUE analysis

Unstandardised CPUE identifies gross changes of catch rates that may reflect changes in abundance, or changes in spatial and temporal distribution of catch effort. Unstandardised CPUE was calculated for QMA 1 and for the Mercury-Colville fishery as tonnes per tow as per Field & Clark (2001).

Unstandardised CPUE indices were calculated for:

- QMA 1 fishery:
  - o All vessels,
  - o Vessels that caught 70% of the black cardinalfish catch for all years combined (denoted 70% vessels),
  - o Vessels that were involved in the fishery for 3 or more consecutive years (denoted 3+ vessels) targeting black cardinalfish and orange roughy, and target black cardinalfish only,

- Mercury-Colville fishery:
  - o All vessels,
  - o 70% vessels and
  - o 3+ vessels targeting black cardinalfish and orange roughy, and target black cardinalfish only.

2.5 Standardised CPUE analysis

Estimates of relative year effects were obtained from a stepwise multiple regression method, where the data were modelled using a combined lognormal/binomial model (Vignaux 1994). In summary, this approach fits the data as two parts. The lognormal component is used to fit log-transformed non-zero CPUE data, while the binomial component models the proportion of non-zero tows. Combined CPUE indices are then calculated from the lognormal and binomial indices.

A forward stepwise multiple regression-fitting algorithm was employed (Chambers & Hastie 1991; Venables & Ripley 1994). The algorithm generates a final regression model iteratively. The reduction in residual deviance (denoted r^2) is calculated for each single term addition to the base model. The term that results in the greatest reduction in the residual deviance is added to the base model, where the change is more than 1%. The algorithm then repeats this process, updating the base model, until no more terms can be added.

Year was treated as a categorical value so that the regression coefficients of each year can vary independently. The relative year effects calculated from the regression coefficients represent the change in CPUE over time, all other effects having been taken into account. Therefore it represents a possible index of abundance. *Year* was standardised to the year with the most records. This reduces the standard error for all other years.

The stepwise algorithm also considered first order interaction terms. At each step, all first order interactions between variables selected up to that point were evaluated. As earlier, terms that resulted in a reduction of more than 1% in residual deviance were added to the model, and terms less than 1% increase in null deviance were deleted. As the primary interest in the model is an estimate of relative year effects, possible interactions with *year* were not evaluated. Also, to reduce model complexity, interactions with *vessel* were not considered. However, *year/vessel* and *vessel/area* interactions were examined to see if they were selected by the automatic stepwise algorithm.

Alternative stopping rules to the 1% change in residual deviance were briefly investigated, but are not reported here. Less conservative stopping rules tended to result in models more terms (most of which were first order interaction terms which had little meaning), but little change in the estimated relative year effects was found.

Catch per tow was chosen as the measure of CPUE because cardinalfish aggregate in schools that are generally caught by trawling briefly across the tops of hills and rough ground. This resulted in higher catch rates for short duration tows and lower catch rates for long duration tows (Figure 2). In these situations the length of the tow in time or distance is not a relevant measure of effort (Field & Clark 2001).

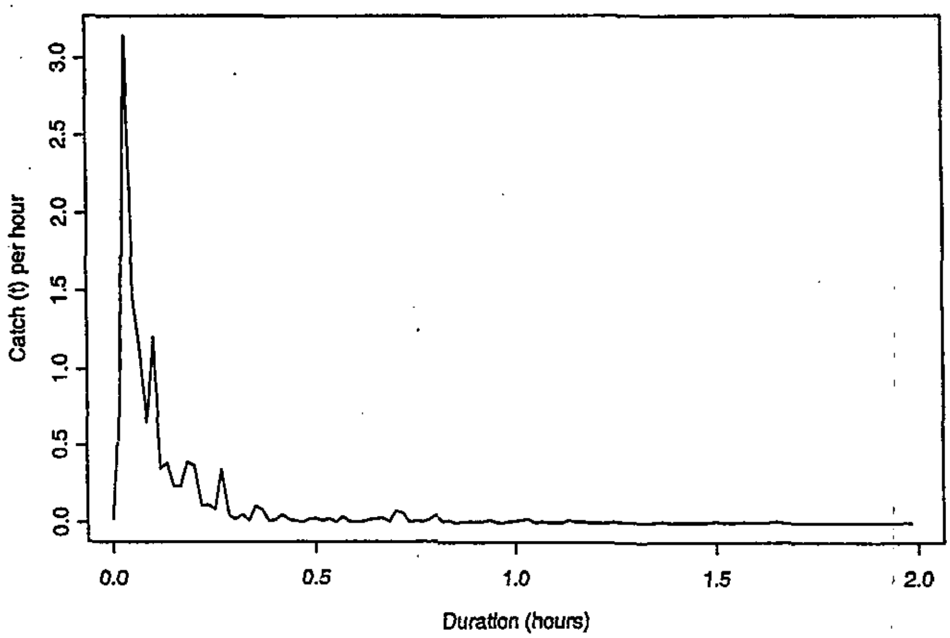

Figure 2: Relationship between black cardinalfish catch rate (t/hr) and duration of the tow. Note, the data have been smoothed using a kernel smoother.

Vessel effects were incorporated into the CPUE standardisation to allow for likely differences in fishing power between vessels. Vessels that were not involved in the fishery for consecutive years, or only participated for a couple of years provide little information to the standardisations (Knuckey et al. 1998) and can result in model overfitting (Francis 2001). CPUE analysis was investigated for vessels involved in the fishery and for 3 or more consecutive years (denoted 3+ vessels). A comparison was also made for all vessels involved in the fishery. Table C1 (Appendix C) lists the number of tows by vessel for each fishing year.

The 1993–94 fishing year (first year of the fishery) was excluded as there were very few records present, and the TCEPR catch represented only 27% of the QMR returns.

For this study, tows from the total QMA 1 and Mercury-Colville fisheries were considered. In summary, the following indices were estimated and compared:

- Mercury-Colville fishery
    - All vessels (target black cardinalfish and orange roughy)
    - 3+ vessels (target black cardinalfish and orange roughy)
    - 3+ vessels (target black cardinalfish only)

- QMA 1 fishery
    - All vessels (target black cardinalfish and orange roughy)

3. RESULTS

3.1 Descriptive analysis

3.1.1 QMA 1 fishery

Annual reported catches of black cardinalfish in QMA 1 were small, and fluctuated before the 1994–95 fishing year (Table 2) as it was not a quota species and tended to be discarded or not reported. After 1994, landings increased and peaked in 1996–97 at 2000 t (QMR landings). Catches have subsequently declined, with 213 t reported from the QMR landings for 2000–01 which is considerably lower than the TACC of 1200 t.

Most catch before 1993–94 was reported on CELR forms, which accounted for less than 40% of the QMR reported landings. Recording on TCEPR forms increased to over 80% of the QMR reported landing since 1994–95.

Table 2: Annual catch (t) reported from the QMA 1 fishery from TCEPR, CELR (estimated and landed) and QMR. The estimated catch from the TCEPRs is also presented as a percentage of the total Quota Management Returns (QMR) catch. Note all values rounded to the nearest tonne, so "0" indicates catches less than 0.5 t and "-" indicates zero catch and blank cells indicate no data available.

	Estimated catch					TCEPR as
Fishing year	TCEPR	CELR	Total	Landed catch	QMR	percent QMR
1989–90		4	4	597	613	0
1990–91		87	87	233	233	0
1991–92		2	2	6	7	0
1992–93		1	1	21	23	0
1993–94	98	2	100	365	364	27
1994–95	965	1	966	1 056	1 162	83
1995–96	1 263	26	1 289	1 410	1 418	89
1996–97	1 856	-	1 856	2 143	2 001	93
1997–98	988	-	988	1 094	995	99
1998–99	620	4	624	663	663#	94*
1999–00	850	4	854	985	980	87
2000–01	213	2	215	293	294	72

Based on landed catch as QMR return was based on 1 months data (K. Duckworth, Ministry of Fisheries, pers. com)
* TCEPR as percent of landed catch

The fishery is largely based on hill features and is divided into threemain areas (Figure 3); the Bay of Plenty (denoted White Island fishery), Colville Ridge (denoted as the Mercury-Colville fishery) and north Colville ridge (denoted as North Colville fishery). The distribution and targeting of black cardinalfish is similar to that of orange roughy (Figure 3).

The distribution of trawl shots and catch rates of black cardinalfish (target/catch black cardinalfish and or orange roughy are shown in Figures 4–6. Very little catch occurred in 1993–94 and this was concentrated in the Mercury-Colville fishery as a result of orange roughy bycatch. Increased targeting occurred from 1994–95, with catches still concentrated in the Mercury-Colville area. This fishery has dominated throughout the entire time series. From 1997–98, catch rates have been recorded in other areas for both targeted and non-targeted black cardinalfish, although catch rates have been lower in comparison with those of the Mercury-Colville fishery.

Three areas account for a high proportion of black cardinalfish catch and effort in QMA 1. The Mercury-Colville fishery accounted for 86% (range 53–100% by year) of the total catch (Table 3). Other areas that recorded catch included the White Island fishery (range 0–46% catch by year) and North Colville fishery (range 0–11% catch by year). Other areas within the QMA 1 fishery resulted in less than 2% of the catch by year.

Table 3: Percentage of estimated catch by fishery and fishing year. See Figure 3 and text for definitions of each fishery. Note all values rounded to the nearest percentage, so "0" indicates catches less than 0.5 % and "-" indicates zero catch or no data available.

	Fishery			
	Mercury-Colville	White Is	North Colville	Other
1993–94	100.0	0.0	-	0.0
1994–95	99.1	0.0	0.9	-
1995–96	99.8	-	0.0	0.2
1996–97	99.8	0.0	0.0	0.2
1997–98	83.3	14.6	0.1	2.0
1998–99	53.4	46.0	0.5	0.1
1999–00	63.0	25.7	10.9	0.4
2000–01	91.1	4.5	3.3	1.1

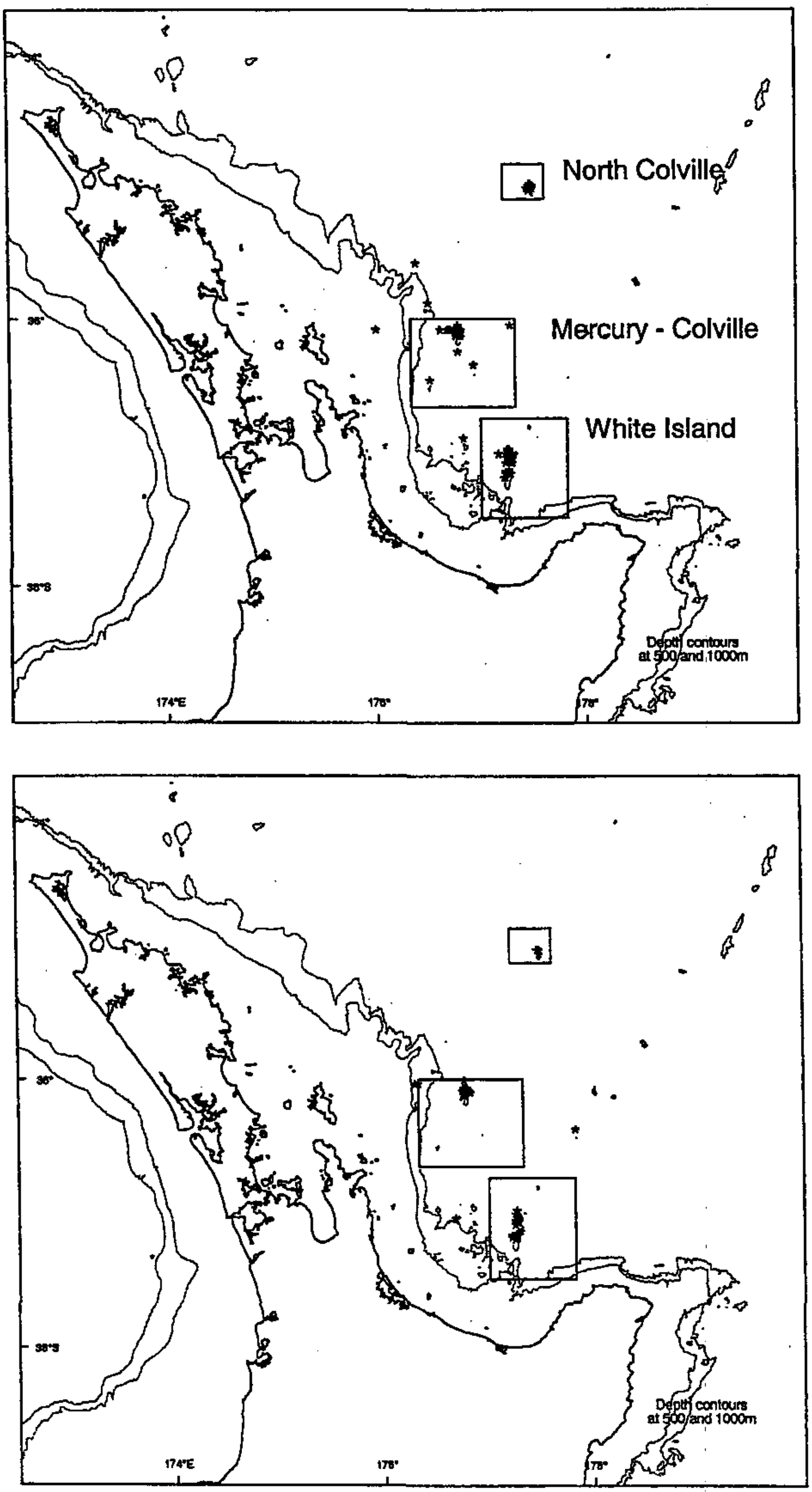

Figure 3: Location of tows targeting cardinalfish (top) and orange roughy (bottom) with a catch of cardinalfish greater than 500 kg from 1993–94 to the 2000–01 fishing year. The boxes indices indicate separate fisheries examined in this report.

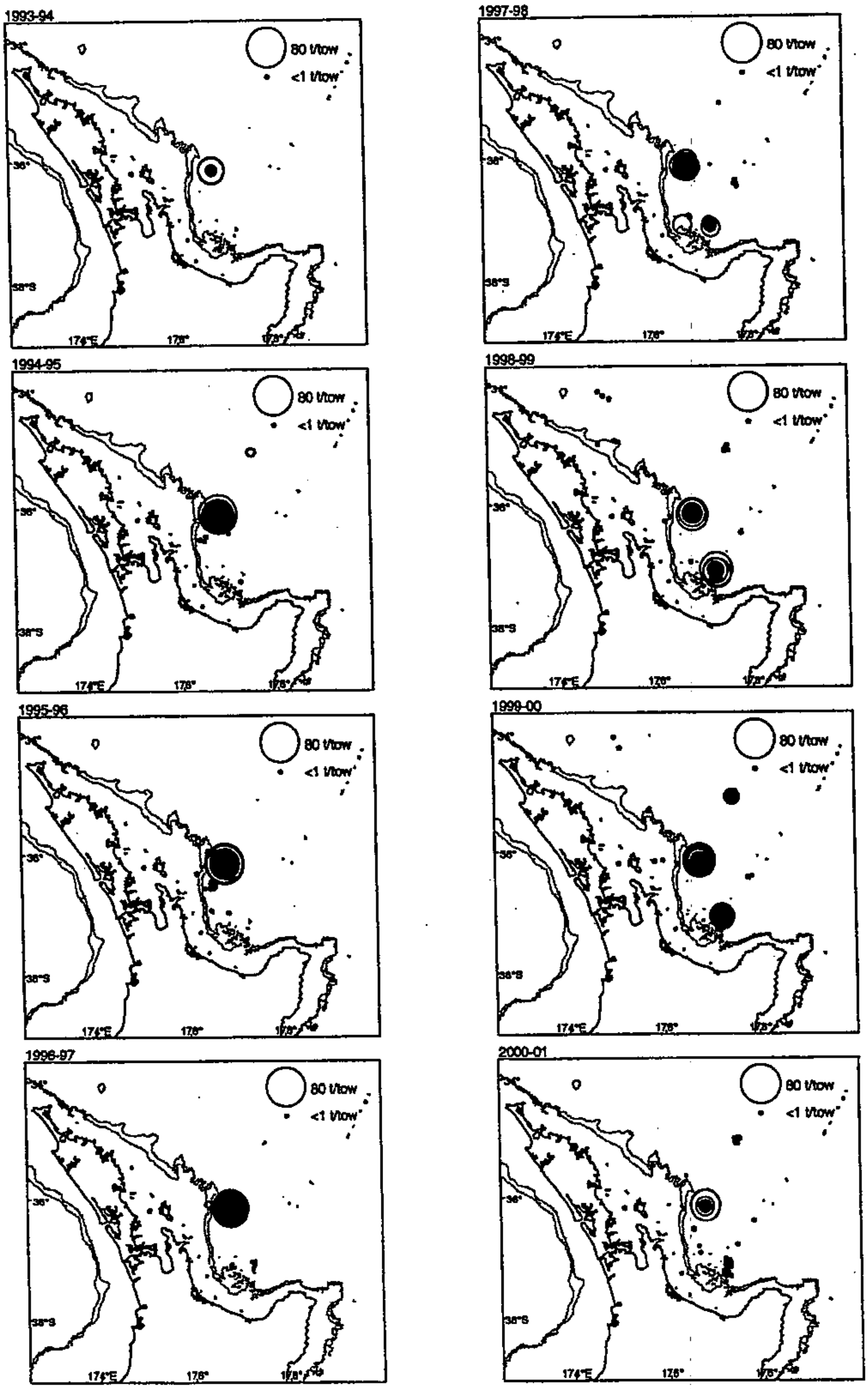

Figure 4: Unstandardised catch rates (t per tow) of cardinalfish for all tows in QMA 1 from 1993–94 to 2000–01.

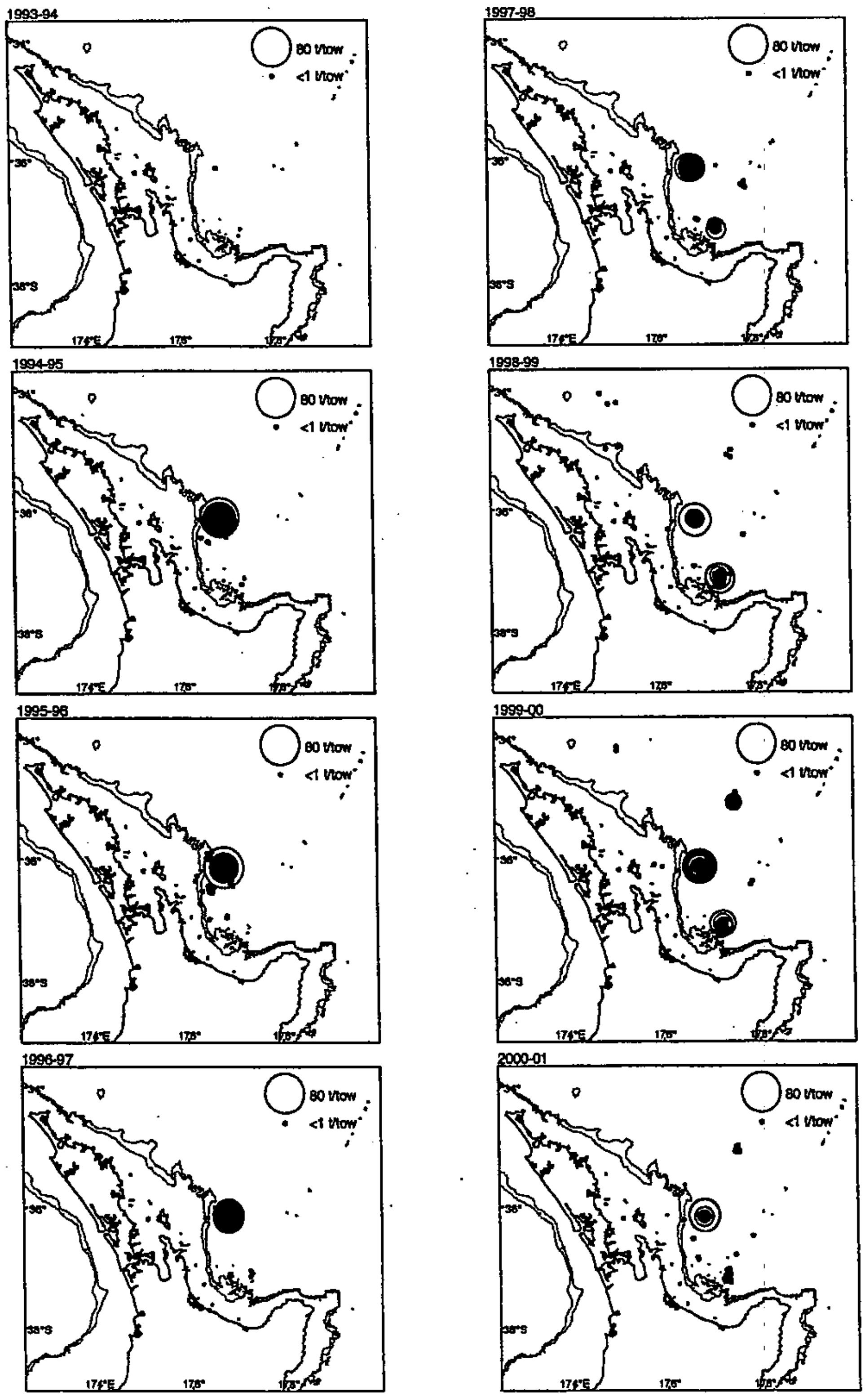

Figure 5: Unstandardised catch rates (t per tow) of cardinalfish for all tows that targeted black cardinalfish in QMA 1 from 1993–94 to 2000–01.

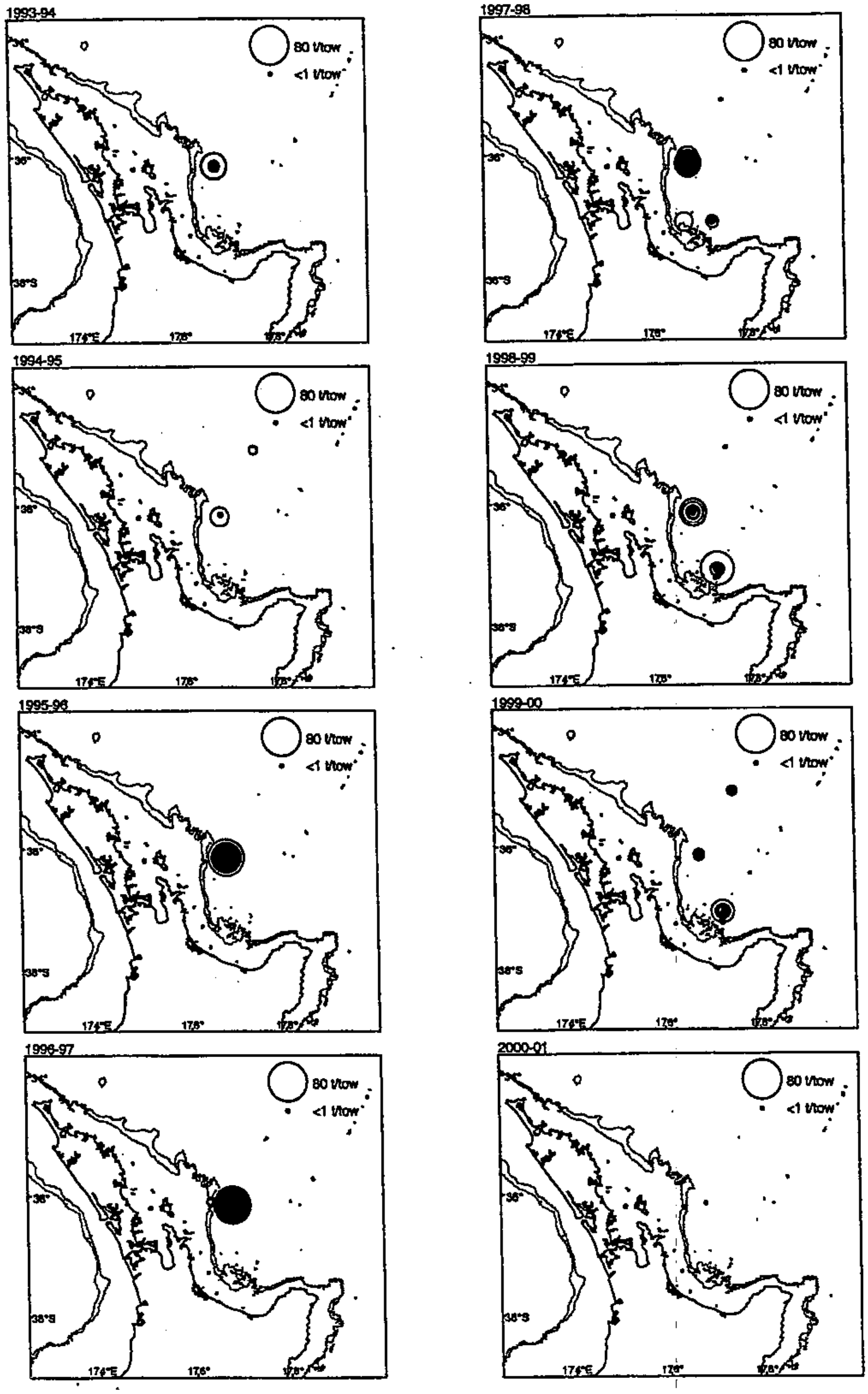

Figure 6: Unstandardised catch rates (t per tow) of cardinalfish for all tows that targeted orange roughy in QMA 1 from 1993–94 to 2000–01.

Monthly patterns of catch and effort are presented in Figure 7. In 1993–94, most catch and effort occurred in the spring/summer period while targeting black cardinalfish. This continued in the 1994–95 fishing year, but there was more targeting of orange roughy especially in August/September. Both catch and effort increased in the winter of the 1995–96 fishing year, mostly targeting orange roughy, but effort was still high during the summer. In 1996–97, effort was more evenly spread across the year apart form October/November, but higher catches were recorded for the winter. From 1997–98 both catch and effort decreased, but there are been slightly higher levels of catch for the winter months, which tend to correspond to the spawning period (Annala et al. 2001). There was no seasonal pattern in 2000–01 due to the low levels of catch and effort.

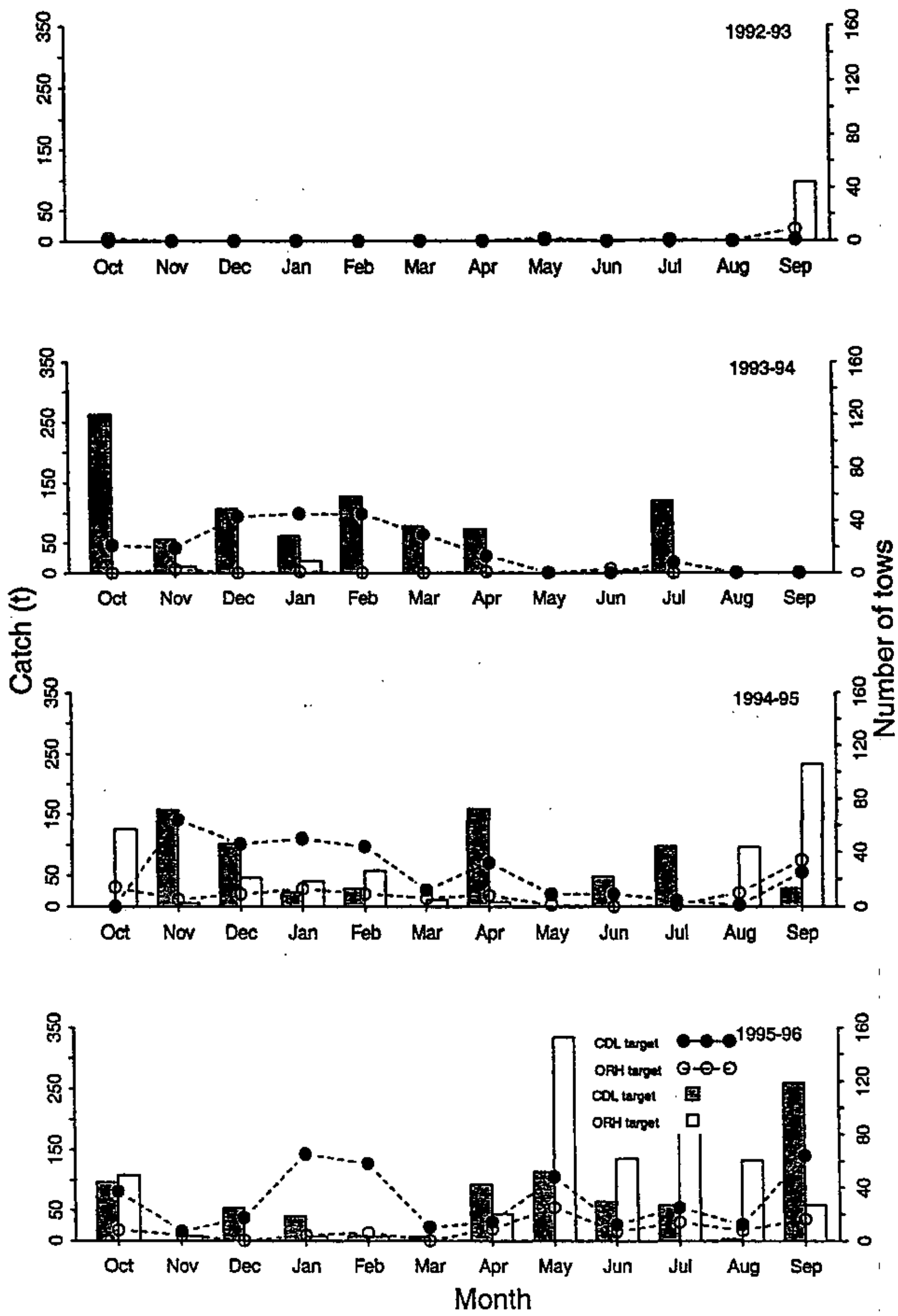

Figure 7: Black cardinalfish catch (bars) and effort (number of tows – lines) by target species (CDL, black cardinalfish; ORH, orange roughy) by month and year.

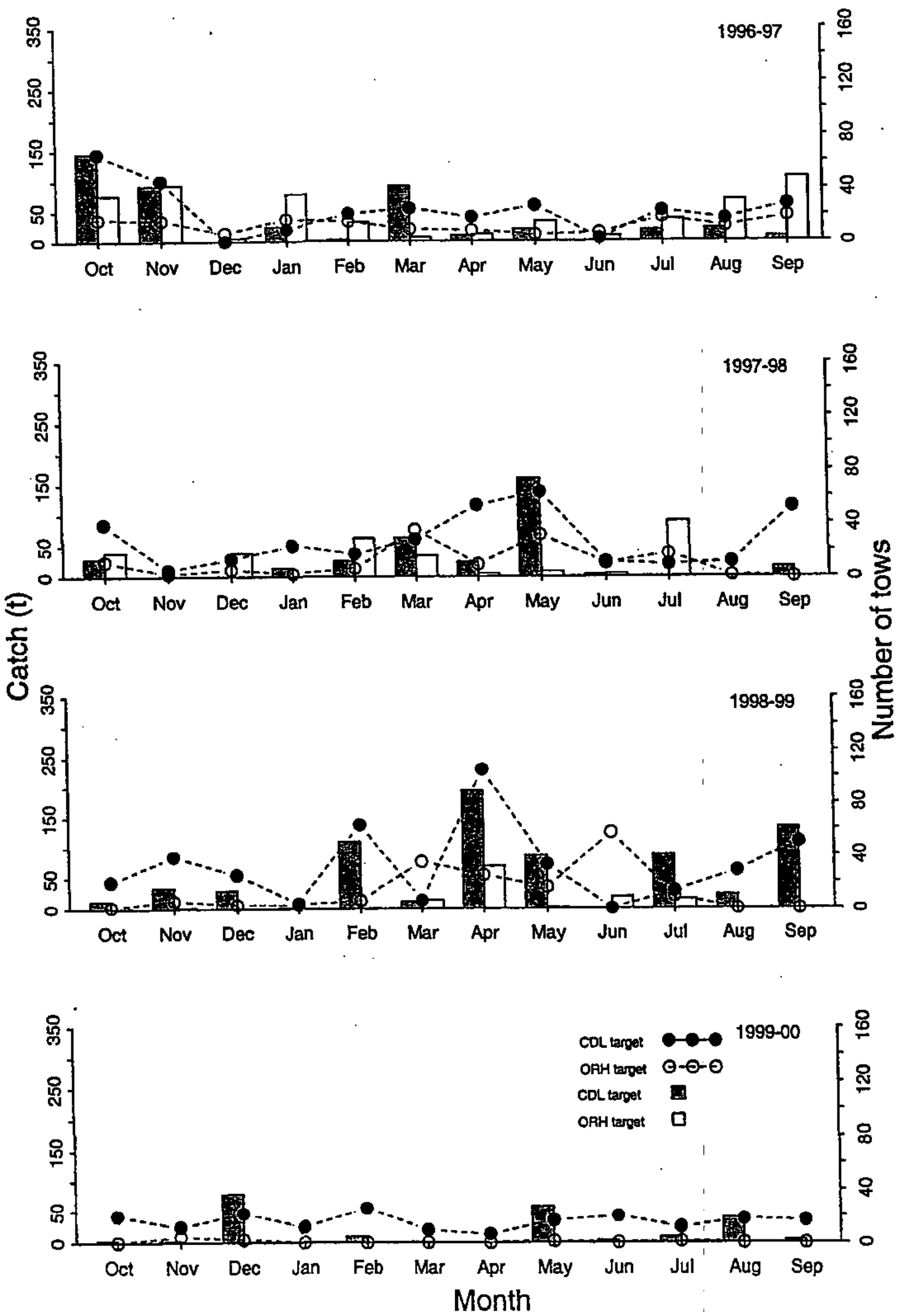

Figure 7: *Continued.*

The black cardinalfish catch is primary taken as a combination of target fishing and as bycatch of orange roughy (Table 4). It is also a minor bycatch species of other target fisheries including bluenose, alfonsino, and rubyfish, but the proportions are small in comparison. Since 1996–97, target fishing has increased, and the bycatch of orange roughy has decreased.

Table 4: Percentage catch of black cardinal fish by target species and fishing year. Note all values rounded to the nearest percentage, so "0" indicates catches less than 0.5%, "-" indicates zero percent.

	Bluenose	Alfonsino	Cardinalfish	Orange roughy	Rubyfish
1993–94	-	-	0	100	-
1994–95	-	4	92	4	0
1995–96	-	0	51	49	-
1996–97	-	-	43	57	-
1997–98	0	-	44	56	-
1998–99	-	-	54	46	-
1999–00	-	-	86	14	-
2000–01	-	0	99	1	-

Most vessels (80%) catching black cardinalfish are New Zealand registered vessels (Table 5). The number of vessels in the fishery peaked in 1995–96 at eight, and has decreased steadily since. In the 2000–01 fishing year, an Australian-registered vessel entered the fishery. This appears to be an error in the database.

Table 5: Number of unique vessels targeting and/or catching black cardinalfish by registered nationality for each fishing year.

	Nationality		
	New Zealand	Australia	Unknown
1993–94	2	0	0
1994–95	6	0	0
1995–96	8	0	1
1996–97	7	0	0
1997–98	5	0	1
1998–99	5	0	1
1999–00	4	0	0
2000–01	3	1	1
All years	12	1	2

Between the 1993–94 and the 2000–01 fishing years, 13 unique vessels have operated in the QMA 1 fishery (Table 6); of these 10 have targeted black cardinalfish. These vessels have accounted for 75% of the tows and 59% of the catch.

Five vessels have been involved in the fishery for 3 or more consecutive years, taking 95% of the catch and accounting for 92% of the tows. Vessels that targeted black cardinalfish and were involved in the fishery for 3 or more consecutive years accounted for 58% of the catch and 69% of the tows.

Table 6: Summary of catch and effort for all vessels (NZ registered only), vessels that caught 70% of the black cardinalfish for all years combined (70% vessels), and vessels involved in the fishery for 3 or more consecutive years (3+ vessels) for all tows and for tows targeting black cardinalfish in the QMA 1 fishery.

		All tows					Targeted CDL				
Vessel selection	Fishing year	Catch (t)	No. vessels	No tows	t/tow	Zero tows (%)	Catch (t)	No. vessels	No tows	t/tow	Zero tows (%)
All vessels	1993–94	98	2	16	6.2	13	0	1	2	0.0	100
	1994–95	965	6	239	4.0	34	887	4	223	4.0	36
	1995–96	1 263	9	408	3.1	41	644	9	296	2.2	56
	1996–97	1 853	7	470	3.9	46	795	4	369	2.2	59
	1997–98	988	5	430	2.3	39	432	5	282	1.5	60
	1998–99	620	5	453	1.4	44	336	4	324	1.0	62
	1999–00	849	4	547	1.6	30	727	4	386	1.9	42
	2000–01	213	4	190	1.1	44	211	4	181	1.2	46
	All years	6 849	13	2 753	2.5	39	4 032	10	2 063	2.0	52
70% vessels	1993–94	98	1	14	7.0	14	0	1	2	0.0	100
	1994–95	881	1	204	4.3	30	864	1	196	4.4	31
	1995–96	1 069	2	210	5.1	21	552	2	129	4.3	34
	1996–97	1 409	2	397	3.6	49	676	2	335	2.0	58
	1997–98	751	2	345	2.2	39	384	2	238	1.6	56
	1998–99	489	2	286	1.7	39	211	2	177	1.2	63
	1999–00	170	2	210	0.8	30	82	2	93	0.9	67
	2000–01	61	2	25	2.4	64	61	2	24	2.5	67
	All years	4 928	2	1 691	2.9	37	2 830	2	1 194	2.4	52
3+ vessels	1993–94	98	1	14	7.0	14	0	1	2	0.0	100
	1994–95	901	2	209	4.3	31	884	2	201	4.4	32
	1995–96	1 088	4	247	4.4	28	560	4	159	3.5	43
	1996–97	1 720	5	456	3.8	48	795	4	369	2.2	59
	1997–98	988	5	430	2.3	39	432	5	282	1.5	60
	1998–99	620	4	445	1.4	45	336	4	324	1.0	62
	1999–00	849	4	547	1.6	30	727	4	386	1.9	42
	2000–01	213	4	190	1.1	44	211	4	181	1.2	46
	All years	6 477	5	2 538	2.6	38	3 945	5	1 904	2.1	51

Changes in vessel, net characteristics, and catch rates are shown in Figure 8. Vessels have increased in size and power since 1996–97. Mean vessel length has increased from 31 m to 33 m since 1996–97. During this period, vessel power also increased from about 750 to 1100 kW and tonnage from 280 to 350 t. Headline height and wingspread have remained consistent over this period with means of 7 and 20 m respectively. Fishing duration has also remained consistent (mean of 30 min), apart from the 1998–99 fishing year when the mean duration was close to 1 hr. About 50% of tows were during daylight (50% of tows were between 8 am and 8 pm). The catch per tow has from a mean of 6 t/tow in 1993–94 to 1 t/tow in 2000–01.

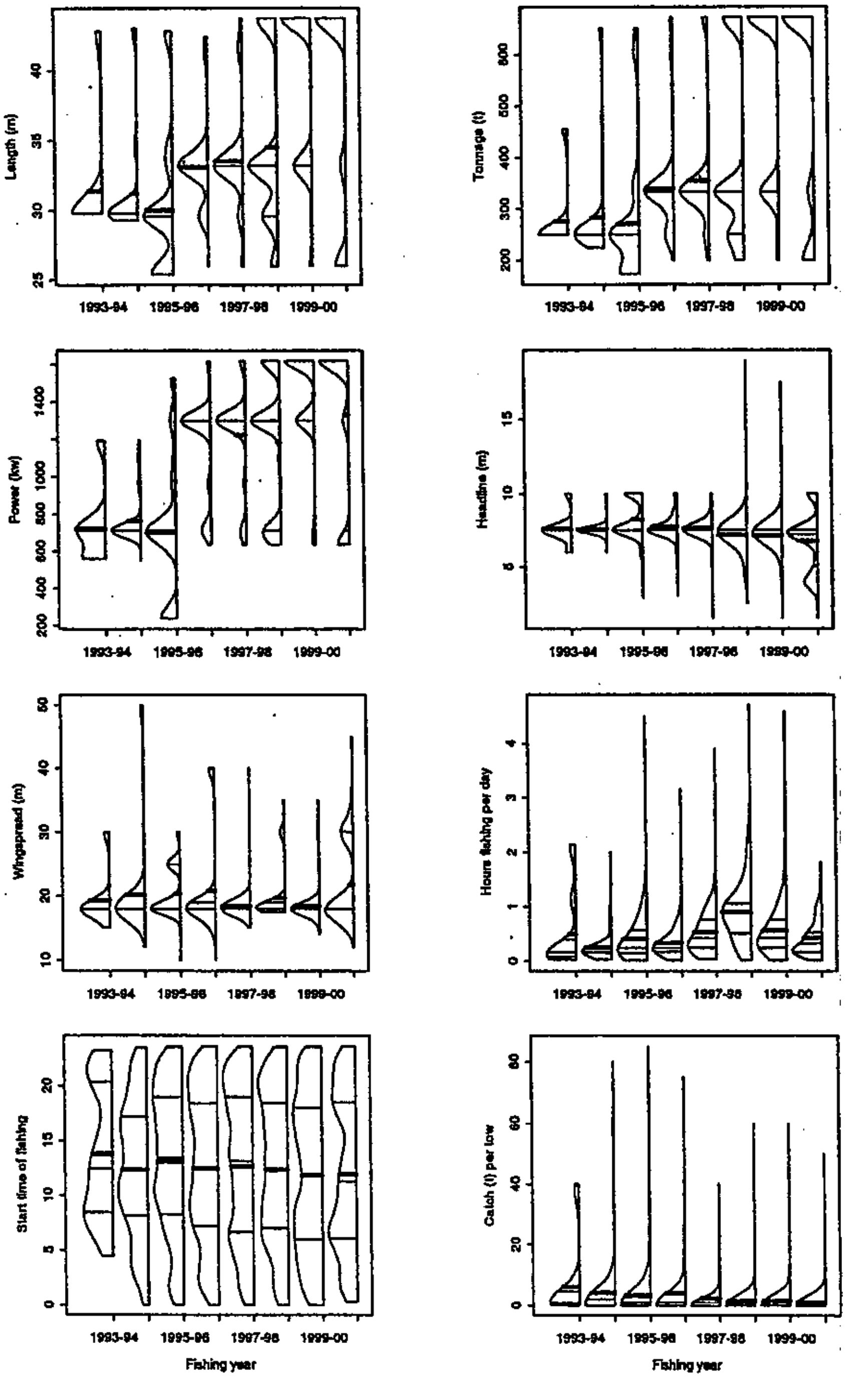

Figure 8: Distribution plots for vessel and fishing characteristics for all vessels. Horizontal lines indicate the upper, median, and lower quartiles, and the bold horizontal line indicates the mean.

3.1.2 Mercury-Colville fishery

The fishery developed in 1993–94 and there was a rapid increase in catch up to the 1996–97 fishing year with 1840 t from the Mercury-Colville fishery, but catches have decreased to 194 t in 2000–01 (Table 7).

The Mercury-Colville fishery consists of several knolls (see Figure 9 for names and locations). Most tows (96%) and catch (range 96–100% by year) are on the Colville Knolls, with a small amount on Mercury Knoll (3% tows) (Table 7). On the Colville Knolls, there has been a rapid increase in catch up to the 1996-97 fishing year. Other knolls have remained steady with annual take of up to 2 t. Effort (number of tows) also shows a similar picture for the Colville Knolls. There was a steady increase up to the 1996–97 fishing year, and a subsequent decrease.

Table 7: Catch (t) and effort (number of tows) Mercury-Colville fishery by knoll from the 1993–94 to the 2000–01 fishing year and the percentage catch from the Colville Knolls. All values are rounded to the nearest tonne, therefore "0" indicates catch less than 0.5 t, and "-" indicates no catch. "Not known" is catch from unknown hills or where tow start locations were more than 5 n. miles from a known hill.

	Colville Knolls		Other knolls		Unknown		Colville knoll	Mercury-Colville
	Catch	N. tows	Catch	N. tows	Catch	N. tows	Catch (%)	fishery catch (t)
1993–94	98	13	0	1	-	-	100	98
1994–95	956	230	0	4	0	2	100	956
1995–96	1255	340	2	42	4	3	100	1 261
1996–97	1842	445	-		8	3	100	1 849
1997–98	795	283	2	2	28	1	96	823
1998–99	331	147	0	1	0	1	100	331
1999–00	535	175	0	1	-	0	100	535
2000–01	191	104	0	2	3	3	98	194

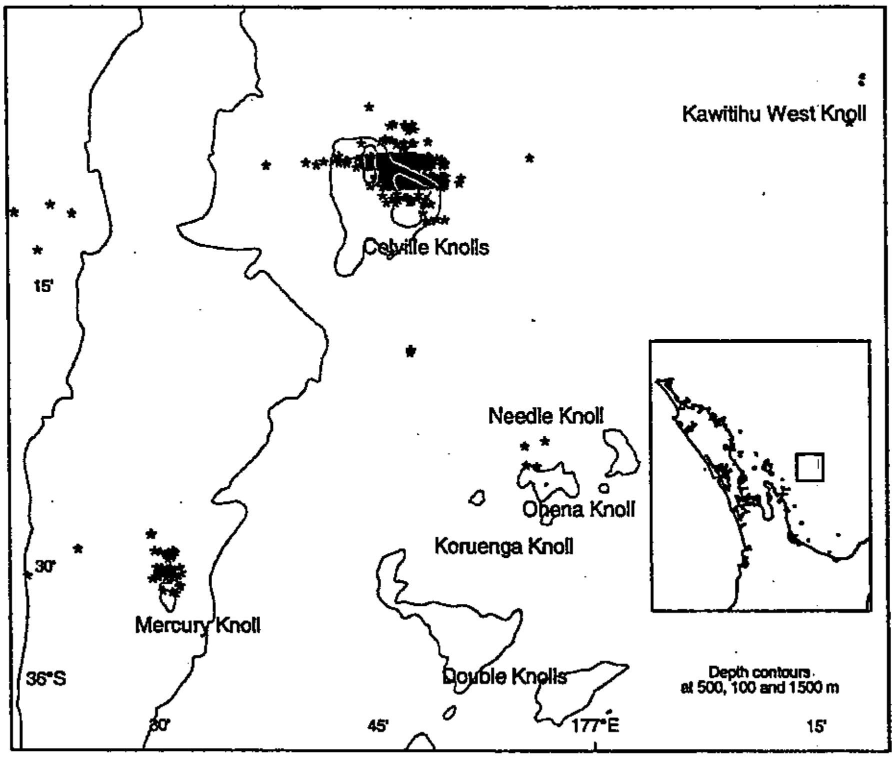

Figure 9: Positions of known knolls, and tows targeting black cardinalfish (*) and orange roughy (+) in the Mercury-Colville fishery from the 1993–94 to the 2000–01 fishing years.

Monthly patterns of catch and effort are presented in Figure 10. In the 1994–95 fishing year, most catch occurred in spring/summer, with effort mainly concentrated in the summer. Both catches and effort increased slightly in the winter of the 1995–96 fishing year, and catch were lower during the summer. In 1996–97, effort peaked in October/November, but catches tended to be low. High catches were recorded in the winter, especially for the target fisheries. From 1998–99, both catch and effort decreased, but slightly higher levels of catch occurred in the winter.

Most catch is taken by either target fishing, or as a bycatch of orange roughy (Table 8). In 1994–95, 93% of black cardinalfish was taken as target species. From 1995–96 to 1998–99, nearly half was taken as bycatch of the developing orange roughy fishery. Since 1999–2000 most catch has been taken as target fishing, probably as a result of declining catch rates of orange roughy.

Most catch (both target and non-target) comes from the Colville Knolls (Table 9). This has been consistent for all years. There has been catch from other knolls, but the catch has been small in comparison.

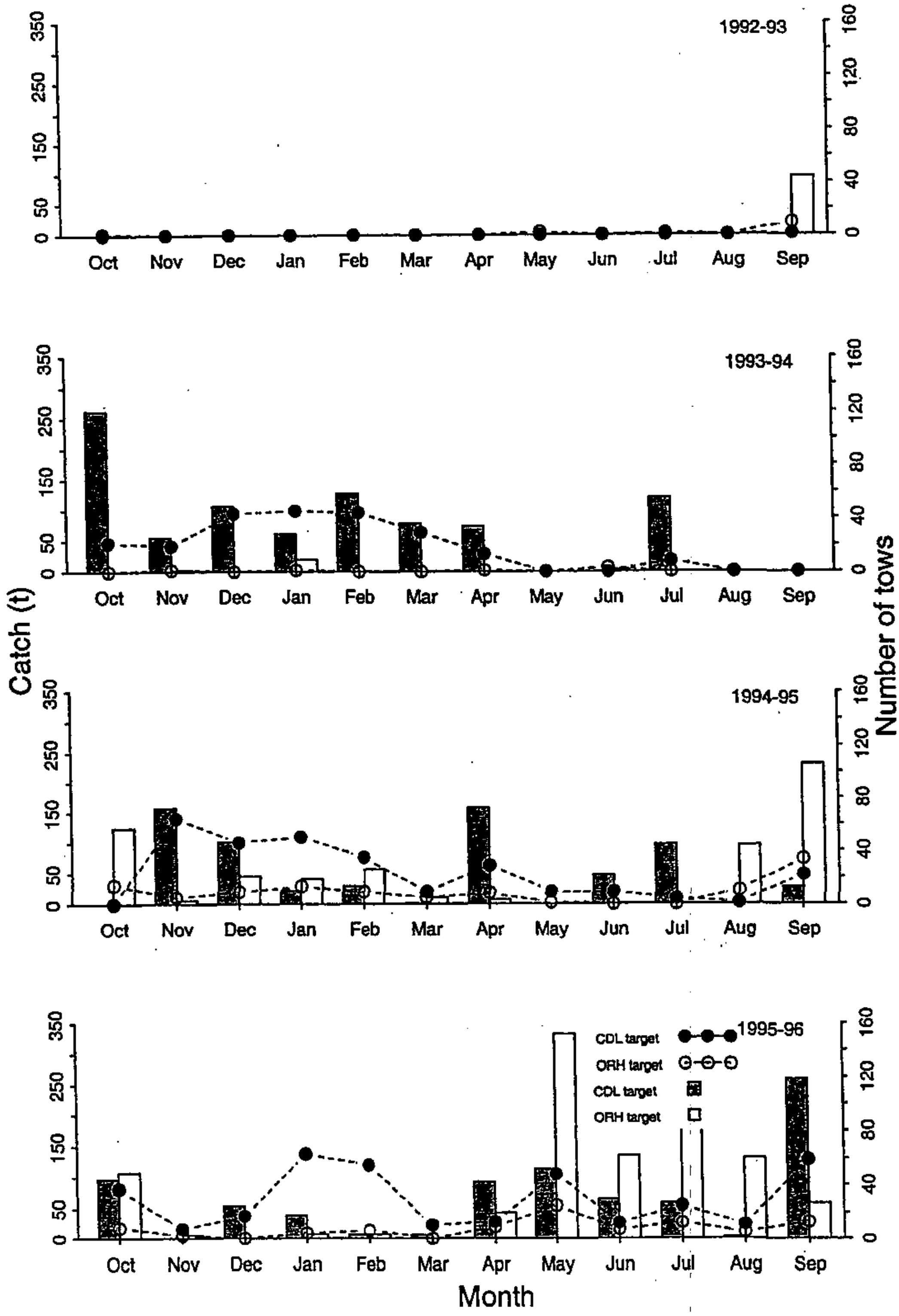

Figure 10: Black cardinalfish catch (bars) and effort (number of tows – lines) by target species (CDL, black cardinalfish, ORH, orange roughy) by month and year for the Mercury-Colville fishery.

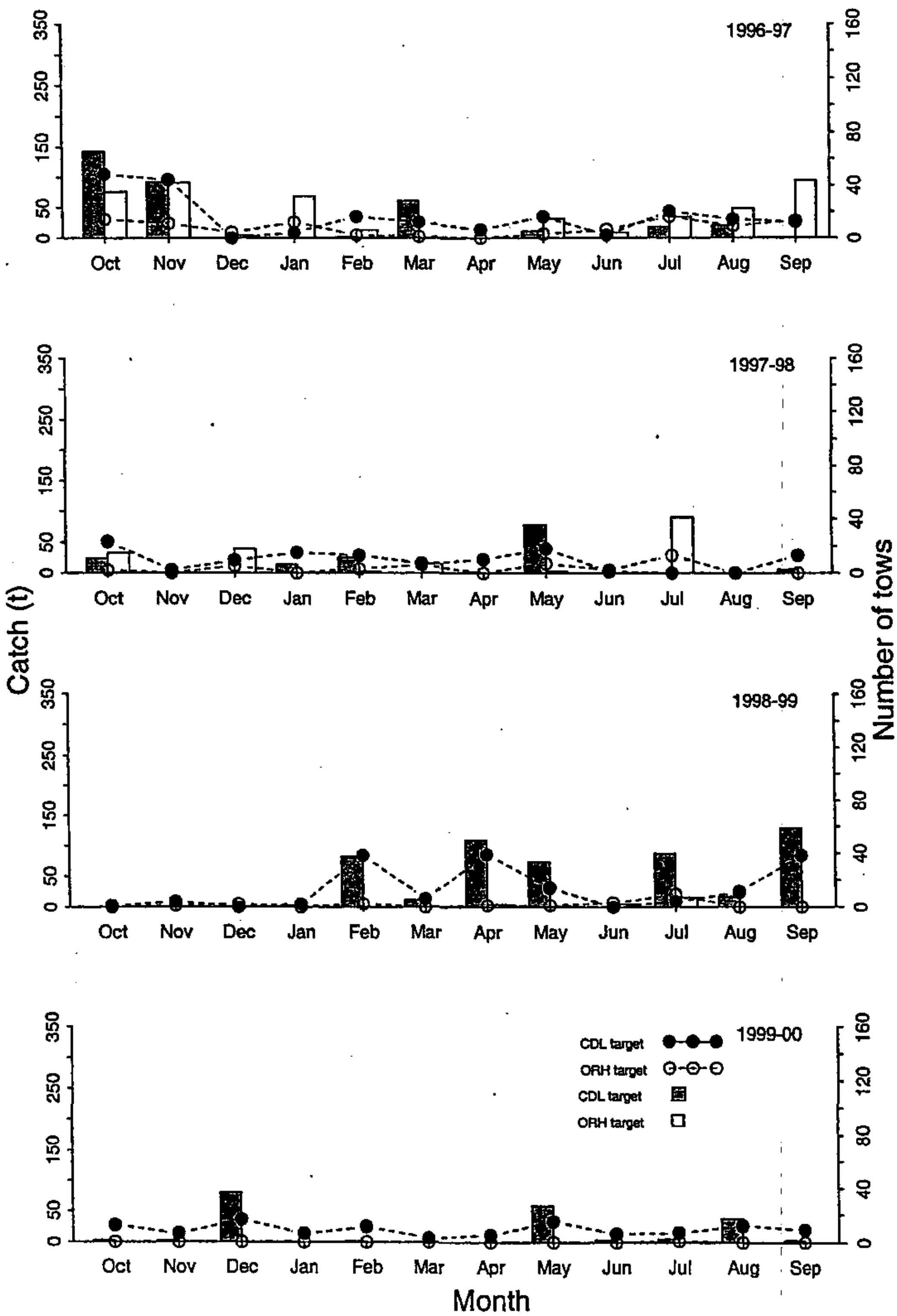

Figure 10: *Continued.*

Table 8: Percentage catch of black cardinalfish by target species by fishing year from the Mercury-Colville fishery.

			Target species
	Black cardinalfish	Orange roughy	Other
1993–94	0.0	100.0	0.0
1994–95	92.7	2.6	4.6
1995–96	51.0	49.0	0.0
1996–97	43.0	57.0	0.0
1997–98	42.3	57.7	0.0
1998–99	45.0	55.0	0.0
1999–00	95.3	4.7	0.0
2000–01	99.5	0.5	0.0

Table 9: Catch (t) of black cardinalfish by target species by knoll in the Mercury-Colville fishery, "Not known" is catch where tow start locations were over 5 n. miles from a known hill. All catches rounded to the nearest tonne; therefore "0" indicates catch less than 0.5 t, and "-" indicates no catch.

	Colville knolls			Other knolls			Not known		
	CDL	ORH	Other	CDL	ORH	Other	CDL	ORH	Other
1993–94	0	98	-	-	0	-	-	-	-
1994–95	887	25	44	0	-	-	0	-	-
1995–96	637	618	-	2	0	-	4	-	-
1996–97	792	1050	-	-	-	-	3	4	-
1997–98	348	447	0	1	-	-	-	28	-
1998–99	149	182	-	-	0	-	0	-	-
1999–00	510	25	-	-	0	-	-	-	-
2000–01	190	1	-	0	-	-	3	-	-

Between the 1993–94 and the 2000–01 fishing years, 13 unique vessels have operated in the Mercury-Colville fishery (Table 10), of which 10 have targeted black cardinalfish. Two vessels caught 72% of the total catch for the fishery. The five vessels that have been involved in the fishery for 3 or more consecutive years caught 94% of the catch (83% of the QMA 1 fishery) and these vessels accounted for 89% of the tows (58% of the QMA 1 fishery). Four of those vessels targeted black cardinalfish, and accounted for 56% of the catch and 69% of the tows.

Table 10: Summary of catch and effort for all vessels and vessels involved in the fishery for 3 or more consecutive years (3+ vessels) for all tows and for tows targeting black cardinalfish in the Mercury –Colville fishery.

		All tows					Target CDL				
		Catch (t)	N. tows	N. vessels	t/tow	Zero tows (%)	Catch (t)	N. tows	N. vessels	t/tow	Zero tows (%)
All vessels	1993–94	98	14	2	7.0	7		1	1	0.0	100
	1994–95	956	236	6	4.1	34	887	222	4	4.0	36
	1995–96	1 261	386	9	3.3	40	642	278	9	2.3	55
	1996–97	1 849	448	7	4.1	47	795	357	4	2.2	59
	1997–98	823	286	5	2.9	44	348	194	5	1.8	65
	1998–99	331	149	3	2.2	50	149	111	3	1.3	68
	1999–00	535	176	4	3.0	41	510	157	4	3.3	46
	2000–01	194	109	3	1.8	46	193	108	3	1.8	46
	All years	6 047	1 804	13	3.4	42	3 524	1 428	10	2.5	54
3+ years	1993–94	98	12	1	8.1	8	0	1	1	0.0	100
	1994–95	892	207	2	4.3	31	884	201	2	4.4	32
	1995–96	1 086	234	4	4.6	26	557	133	3	4.2	36
	1996–97	1 719	436	5	3.9	48	795	357	4	2.2	59
	1997–98	823	286	5	2.9	44	337	190	4	1.8	65
	1998–99	331	149	3	2.2	50	149	111	3	1.3	68
	1999–00	535	176	4	3.0	41	495	156	3	3.2	46
	2000–01	194	109	3	1.8	46	189	91	2	2.1	45
	All years	5 678	1 609	5	3.5	41	3 406	1240	4	2.8	51

Changes in vessel, net characteristics, and catch rates are shown in Figure 11. Vessels have increased in size and power since 1996–97. Mean vessel length has increased from 31 to 33 m since 1996–97. Vessel power also increased from about 750 to 1100 kW during the same period and tonnage from 280 to 350 t. Headline height and wingspread have remained consistent with means of 7 and 20 m respectively. Fishing duration has also remained consistent (mean of 30 min), apart from the 1998–99 fishing year where the mean duration was close to 1 hr. Most tows occurred during daylight. The catch per tow has decreased over the time series from a mean of 6 t/tow in 1993–94 to 1 t/tow in 2000–01.

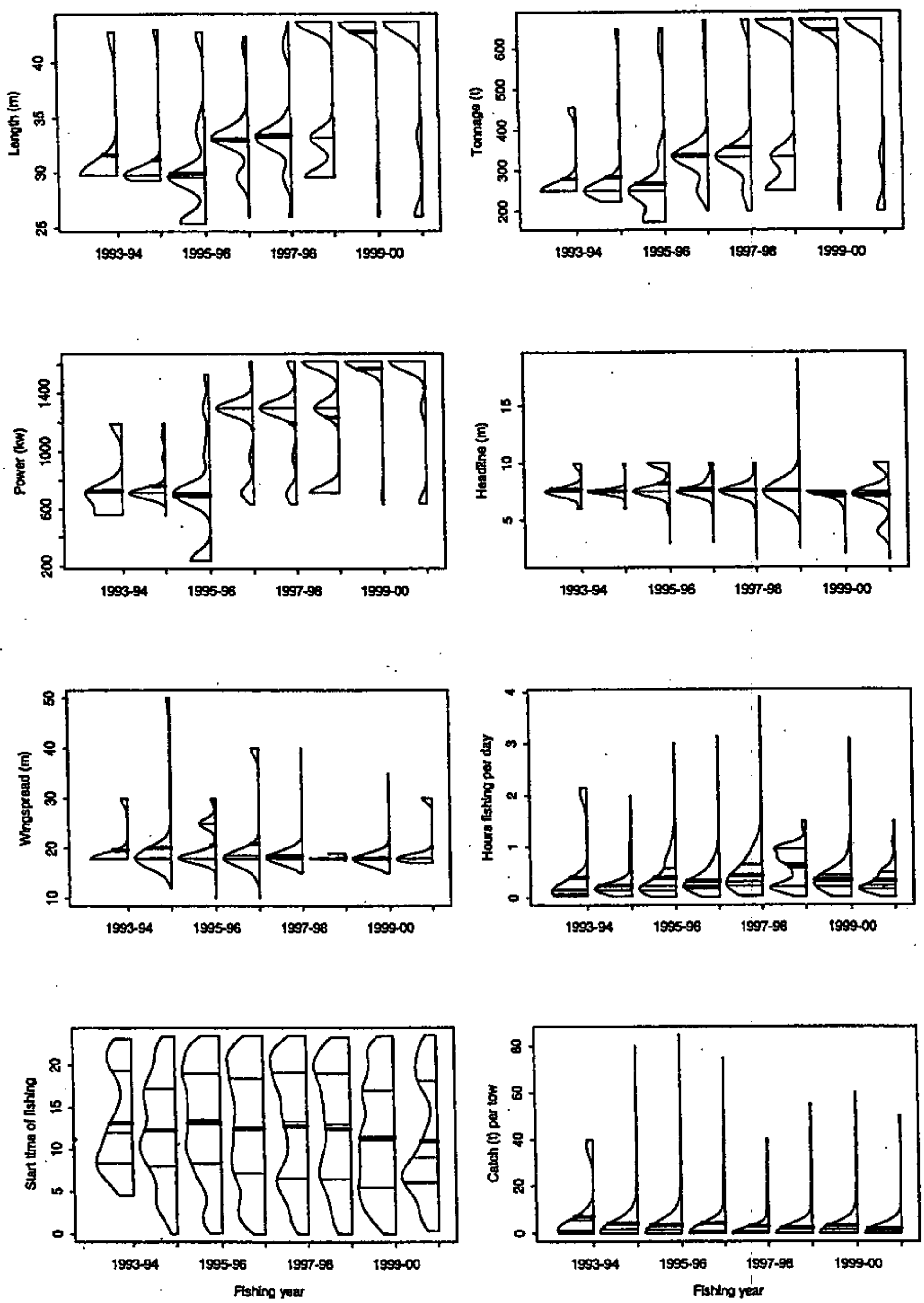

Figure 11: Distribution plots for vessel and fishing characteristics for all vessels. Horizontal lines indicate the upper quartile, median, lower quartile, and the bold horizontal line indicates the mean.

3.1.3 White Island fishery

The White Island fishery did not develop until the 1997–98 fishing year (Table 11) although it appears that some exploratory fishing occurred before this. The fishery peaked in the following year with a catch of 286 t, but catches have decreased rapidly since.

The White Island fishery consists of several knolls (see Figure 12 for names and locations). Most tows (60%) and catch (range 67–100% by year) were on the Waiotahi knoll (Tables 12 & 13). There were some fishing on the Nukuhou Knoll (34% tows, and 16–31 % of catch by year), but very little fishing on other knolls.

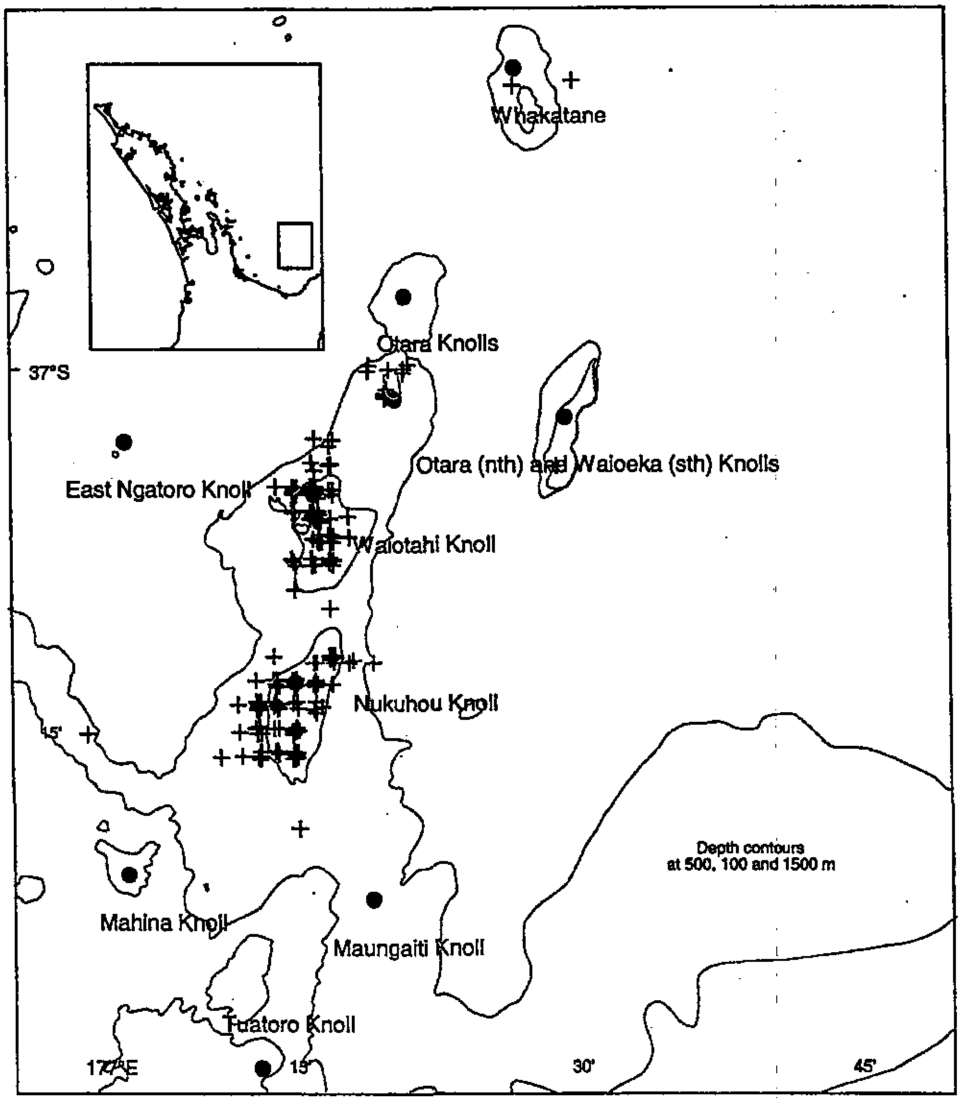

Figure 12: Positions of known knolls and tows targeting black cardinalfish (*) and orange roughy (+) in the White Island box from the 1993–94 to the 2000–01 fishing year.

Table 11: Percentage of catch of black cardinalfish by knoll and fishing year from the White Island fishery.

	E. Ngatoro	Mahina	Maungaiti	Nukuhou	Otara/Waioeka	Otara	Waiotahi	Whakatane	Not known	Total catch (t)
1993–94	-	-	-	100.0	-	-	-	-	-	0
1994–95	-	-	-	-	-	-	-	-	-	-
1995–96	-	-	-	-	-	-	-	-	-	-
1996–97	-	-	-	-	-	-	100.0	-	-	0
1997–98	-	-	-	16.7	-	-	83.3	-	-	144
1998–99	0.1	0.1	0.0	31.0	-	-	68.8	0.0	0.0	286
1999–00	1.4	-	-	6.7	0.1	0.1	91.8	0.0	0.0	219
2000–01	0.2	-	-	30.9	-	-	66.8	0.0	2.1	10

Table 12: Summary of effort (number of tows) by knoll in the White Island area by fishing year.

	Nukuhou	Waiotahi	Other knolls	Not known
1993–94	1	0	0	0
1994–95	1	0	0	0
1995–96	0	0	0	0
1996–97	0	9	0	0
1997–98	7	127	0	0
1998–99	120	149	7	1
1999–00	128	127	17	2
2000–01	21	32	2	1

Monthly patterns of catch are presented in Figure 13. From 1997–98 most catch (mean 56%, range 23–87% of the catch by year) and effort has bin in February–May.

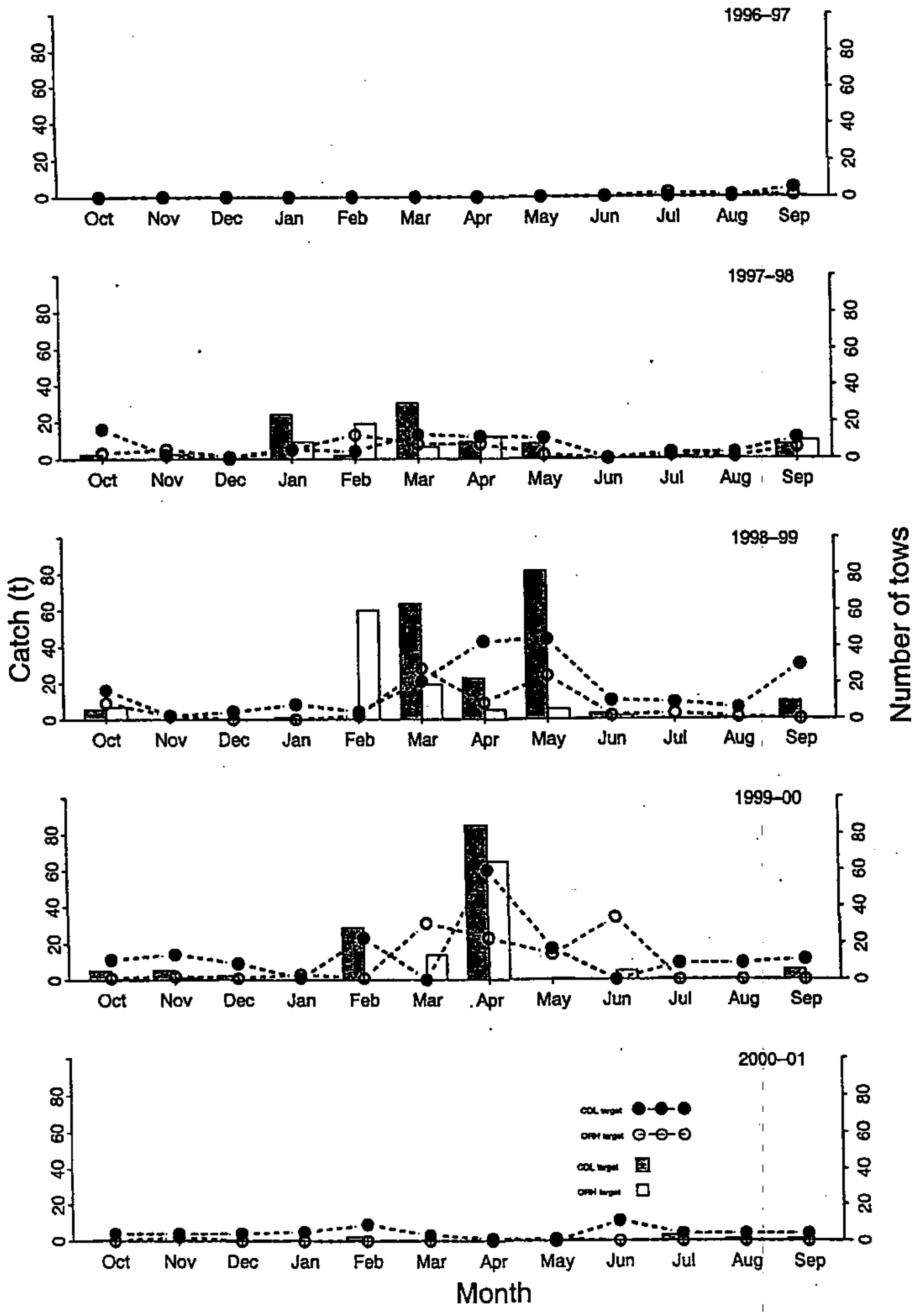

Figure 13: Black cardinalfish catch (bars) and effort (number of tows – lines) by target species (CDL, black cardinalfish, ORH, orange roughy) by month and year for the White Island fishery.

Most catch is taken by either target fishing or as a bycatch of orange roughy (Table 13). In 1996–97, most black cardinalfish was taken as bycatch of orange roughy (62% of the catch). This has steadily decreased since then, and there has been an increase in the amount of catch taken as target species.

Table 13: Percentage of catch of black cardinalfish by target species and fishing year from the White Island fishery.

	CDL	ORH
1993–94	-	100
1994–95	-	-
1995–96	-	-
1996–97	38	62
1997–98	58	42
1998–99	66	34
1999–00	61	39
2000–01	94	6

Most targeting of black cardinalfish is on Waiotahi (39–66% of black cardinalfish catch by year) and Nukuhou (35–61%) knolls (Table 14). There has been a steady increase in the targeted catch from Waiotahi over the last 5 years and a decrease of black cardinalfish catch as bycatch from the orange roughy fishery.

Table 14: Percentage of catch of black cardinalfish by target species by knoll and fishing years from the White Island fishery. "Other" is from other knolls (including unknown) in the White Island box.

	Waiotahi		Nukuhou		Other	
	CDL	ORH	CDL	ORH	CDL	ORH
1993–94	-	-	-	100	-	-
1994–95	-	-	-	-	-	-
1995–96	-	-	-	-	-	-
1996–97	38.5	61.5	-	-	-	-
1997–98	41.4	41.9	16.7	-	-	-
1998–99	38.1	30.7	27.3	3.7	0.2	0.0
1999–00	57.0	34.7	2.6	4.1	1.4	0.1
2000–01	66.8	-	25.0	5.9	2.3	-

Seven vessels been involved in fishery since 1993–94, catching 10% of the QMA 1 catch; these vessels account for 27% of tows in QMA 1. Catch rates peaked in 1997–98 and have steadily decreased since (Table 15).

Table 15: Summary of catch and effort for all vessels involved in the White Island fishery.

	Catch (t)	N. tows	N. vessels	t/tow	Zero tows (%)
1993–94	0	1	1	0.0	0.0
1994–95	0	1	1	0.0	100.0
1995–96	-	-	-	-	-
1996–97	0	9	3	0.0	44.4
1997–98	144	134	5	1.1	26.1
1998–99	286	277	5	1.0	40.4
1999–00	219	274	4	0.8	27.4
2000–01	10	56	4	0.2	41.1
All years	659	752	7	0.9	33.2

Changes in vessel, net characteristics, and catch rates are shown in Figure 14. There has been a slight increase in the mean vessel characteristics as a result of one or two larger vessels entering the fishery. Headline height has decreased over the time series from a mean of 8 m in 1996–97 to 5.5 m in 2000–01. Mean wingspread remained steady up to 1999–2000 at about 18 m, but increased to 26 m in 2000–01.

Fishing duration has also remained consistent (30 min), apart from the 1998–99 fishing year when the duration was close to 1 hr. Fifty percent of tows occurred between 8 am and 8 pm. The mean catch per tow has varied from 200–1000 kg per tow.

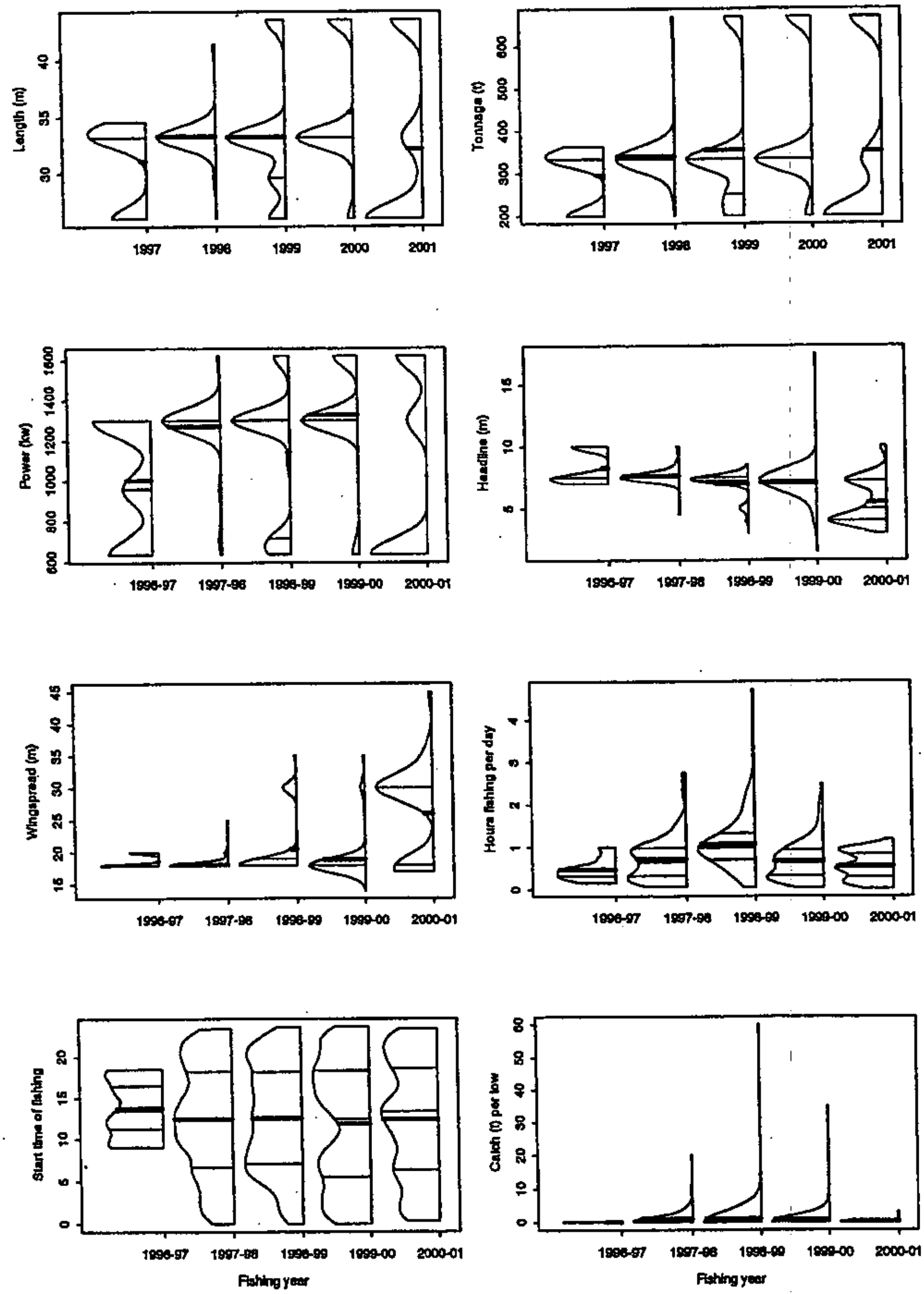

Figure 14: Distribution plots for vessel and fishing characteristics for all vessels. Horizontal lines indicate the upper quartile, median, lower quartile, and the bold horizontal line indicates the mean.

3.2 CPUE analysis

3.2.1 Unstandardised CPUE

Unstandardised CPUE is presented in Table 16 and Figure 15 for the QMA 1 and the Mercury-Colville fishery for all vessels, 3+ vessels, and 70% vessels.

For the 3+ vessels and the all vessels data sets the resulting indices are similar for the different targeting types. There is a decline in the index from about 4–5 t per tow in 1994–95, to 1–2 t per tow in 2000–01. The 70% vessels differ from the other core vessels in that there is a large increase in the index for 2000–01 that appears to a result of a single vessel present in the fishery for that year.

Table 16: Comparison of unstandardised CPUE for QMA 1 and Mercury-Colville fishery by vessel selection and tow type.

CDL 1

	All tows			Successful target CDL			Target CDL		
	All vessels	70% vessels	3+ Vessels	All vessels	70% vessels	3+ Vessels	All vessels	70% vessels	3+ Vessels
1993–94	6.16	6.97	6.97				0.00	0.00	0.00
1994–95	4.04	4.32	4.31	6.24	6.40	6.50	3.98	4.41	4.40
1995–96	3.09	5.09	4.40	4.99	6.49	6.15	2.18	4.28	3.52
1996–97	3.94	3.55	3.77	5.23	4.83	5.23	2.16	2.02	2.16
1997–98	2.30	2.18	2.30	3.79	3.66	3.79	1.53	1.61	1.53
1998–99	1.37	1.71	1.39	2.71	3.19	2.71	1.04	1.19	1.04
1999–00	1.55	0.81	1.55	3.26	2.63	3.26	1.88	0.88	1.88
2000–01	1.12	2.44	1.12	2.18	7.59	2.18	1.17	2.53	1.17

Mercury-Colville fishery

	All tows			Successful target CDL			Target CDL		
	All vessels	70% vessels	3+ Vessels	All vessels	70% vessels	3+ Vessels	All vessels	70% vessels	3+ Vessels
1993–94	7.03	8.13	8.13				0.00	0.00	0.00
1994–95	4.05	4.31	4.31	6.24	6.39	6.50	3.99	4.41	4.39
1995–96	3.27	5.21	4.64	5.14	6.55	6.34	2.31	4.40	3.74
1996–97	4.13	3.64	3.94	5.37	4.96	5.37	2.23	2.07	2.22
1997–98	2.88	2.80	2.88	5.12	4.93	5.12	1.80	1.87	1.79
1998–99	2.22	3.14	2.22	4.13	6.50	4.13	1.34	1.91	1.34
1999–00	3.04	0.50	3.04	6.00		5.99	3.25	0.00	3.24
2000–01	1.78	6.05	1.78	3.33	15.12	3.33	1.79	6.05	1.79

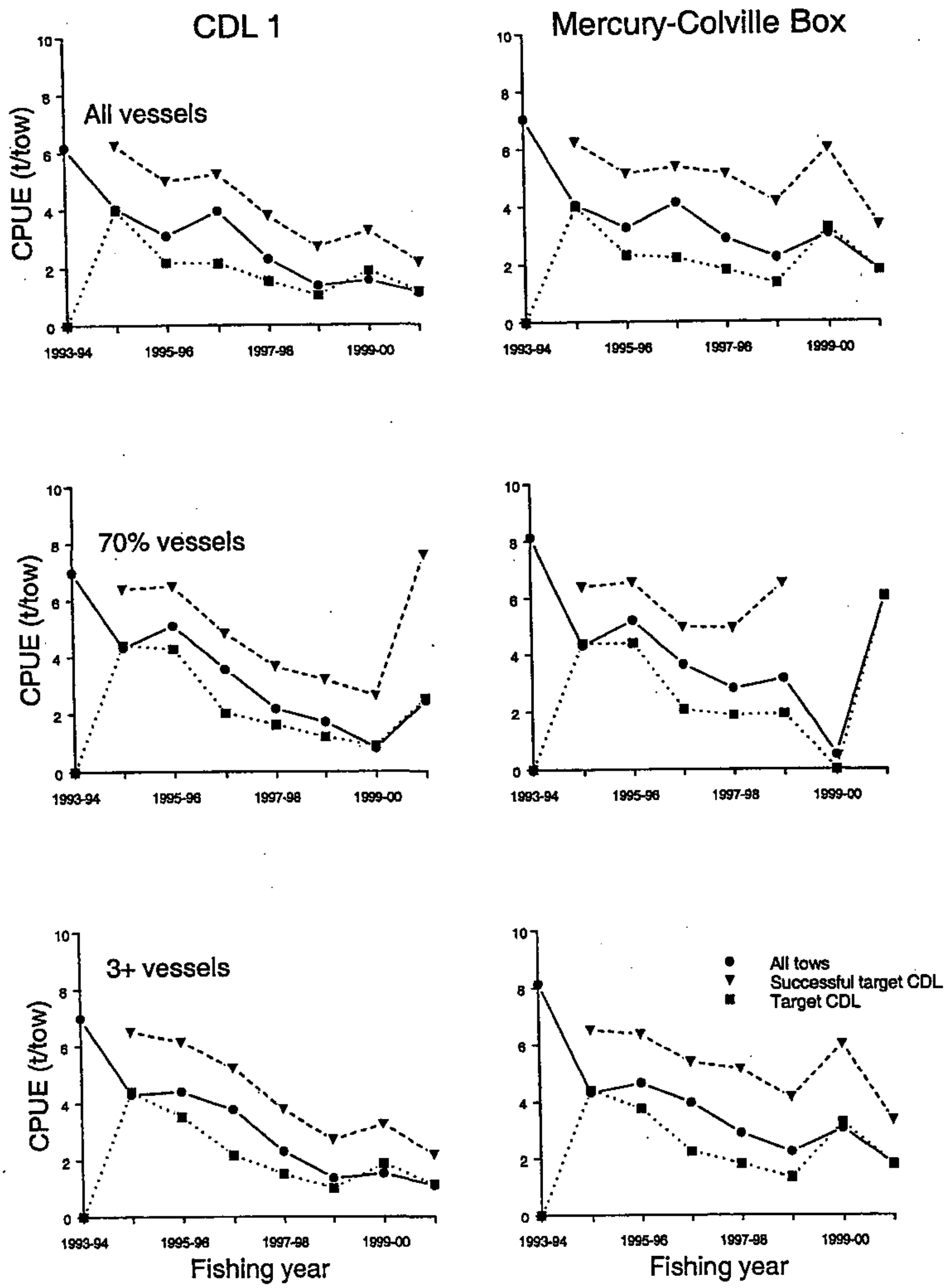

Figure 15: Unstandardised CPUE (t/tow) of black cardinalfish in QMA 1and for the Mercury-Colville fishery for all vessels, 70% vessels and 3+ vessels for all tows (target black cardinalfish and non target tows), targeted cardinal fish tows (including zero catch), and successful target tows (targeted tows that caught black cardinalfish).

3.2.2 Standardised CPUE

QMA 1 fishery

For the QMA 1 fishery (all vessels), four variables were selected with a total R^2 of 30% by the binomial model, with *target species* explaining 22% of the residual deviance (Table 17). For the lognormal component of the combined model, five predictor variables were selected by the model (including year) and explained 16% of R^2. *Fishery* explained 9% of the deviance.

Table 17: Selected variables and corresponding R^2 from the stepwise multiple regression algorithm QMA 1 fishery for all vessels.

Binomial		Lognormal	
Selected variable	R^2	Selected variable	R^2
Target species	22.38	*Fishery*	8.83
Vessel	25.58	*Month*	11.21
Month	26.56	*Year*	13.22
*Vessel*Month*	30.02	*Vessel*	15.04
		Target species	16.21

The standardised year effects for CDL 1-all vessels are presented in Figure 16 and are listed in Table A1. The combined index is flat up to 1997–98, then declined for the next 3 years to 15% of the 1997–98 fishing year.

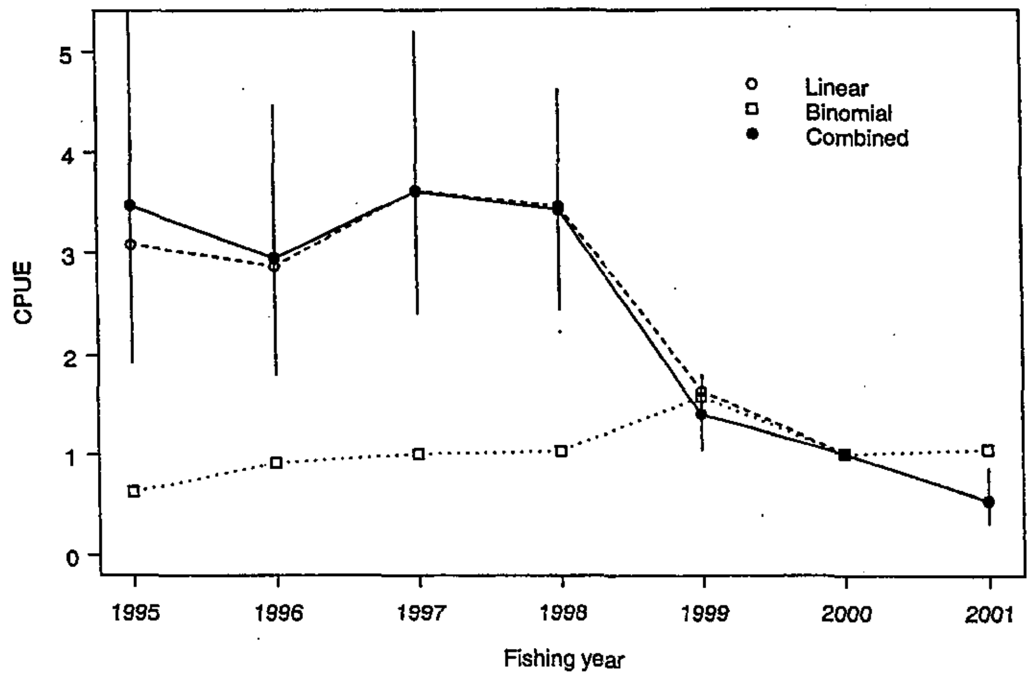

Figure 16: Standardised indices for the different models for the QMA 1 fishery all vessels. Note. 1995 denotes the 1994–95 fishing year. 95% Confidence intervals are given for the combined model.

The effects of the selected variables are shown in Figure 17. Nine vessels were incorporated in the model, but one had a higher than expected catch rate when compared to the other vessels. This vessel was in the fishery for only one year. As expected, catch rates from the Mercury-Colville fishery and from vessels that target black cardinalfish were higher. Expected catch rates tended to fluctuate from month to month, with no clear seasonal trend.

Diagnostic plots are presented in Figure 18. They indicate a reasonable pattern in the residuals, but the Q-Q plot indicates a deviation from the normal distribution of the residuals at either end, suggesting that very small and large values of catch rate are not well predicated in the model.

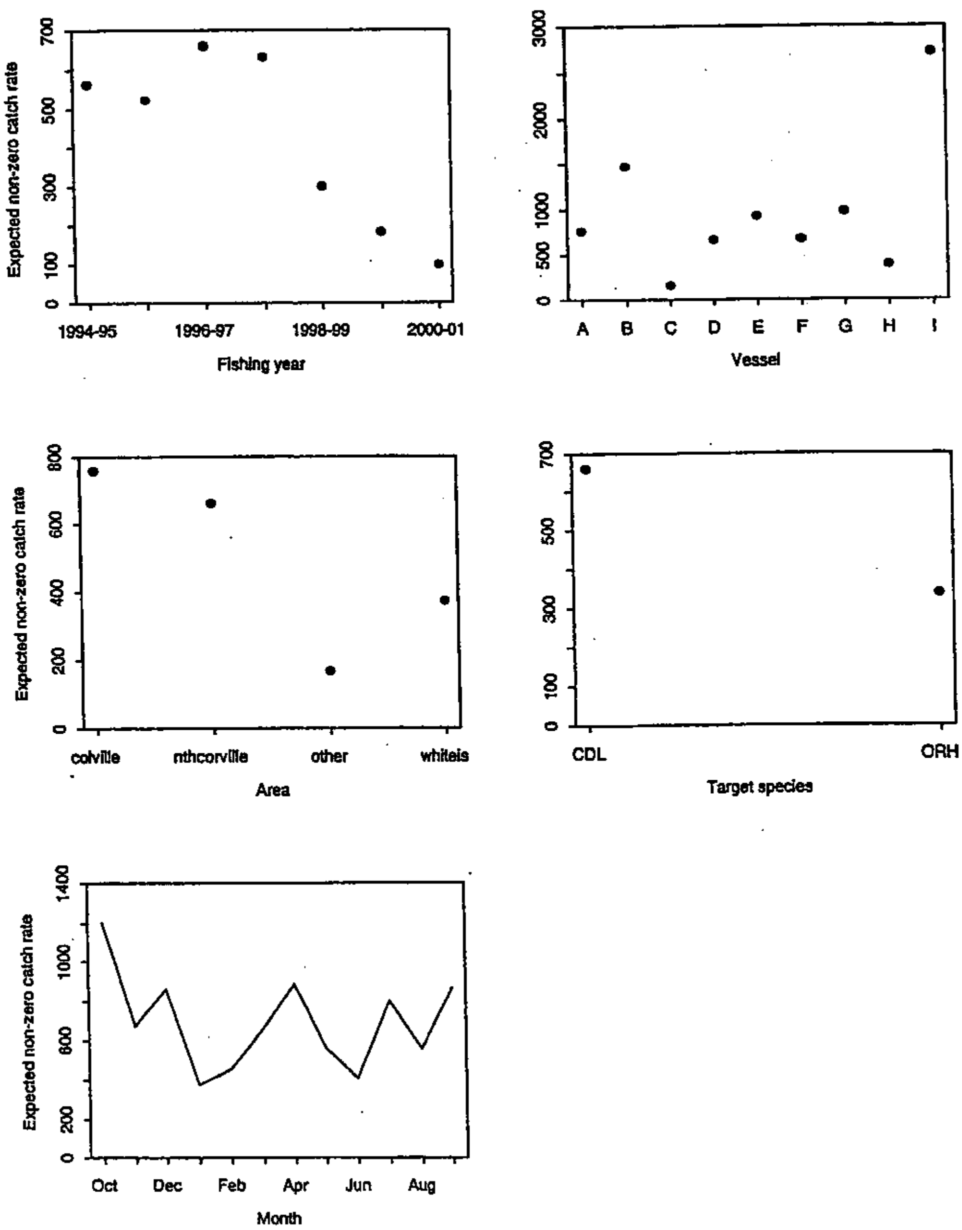

Figure 17: Expected variable effects for variables selected into the CPUE model for the QMA 1 fishery-all vessels.

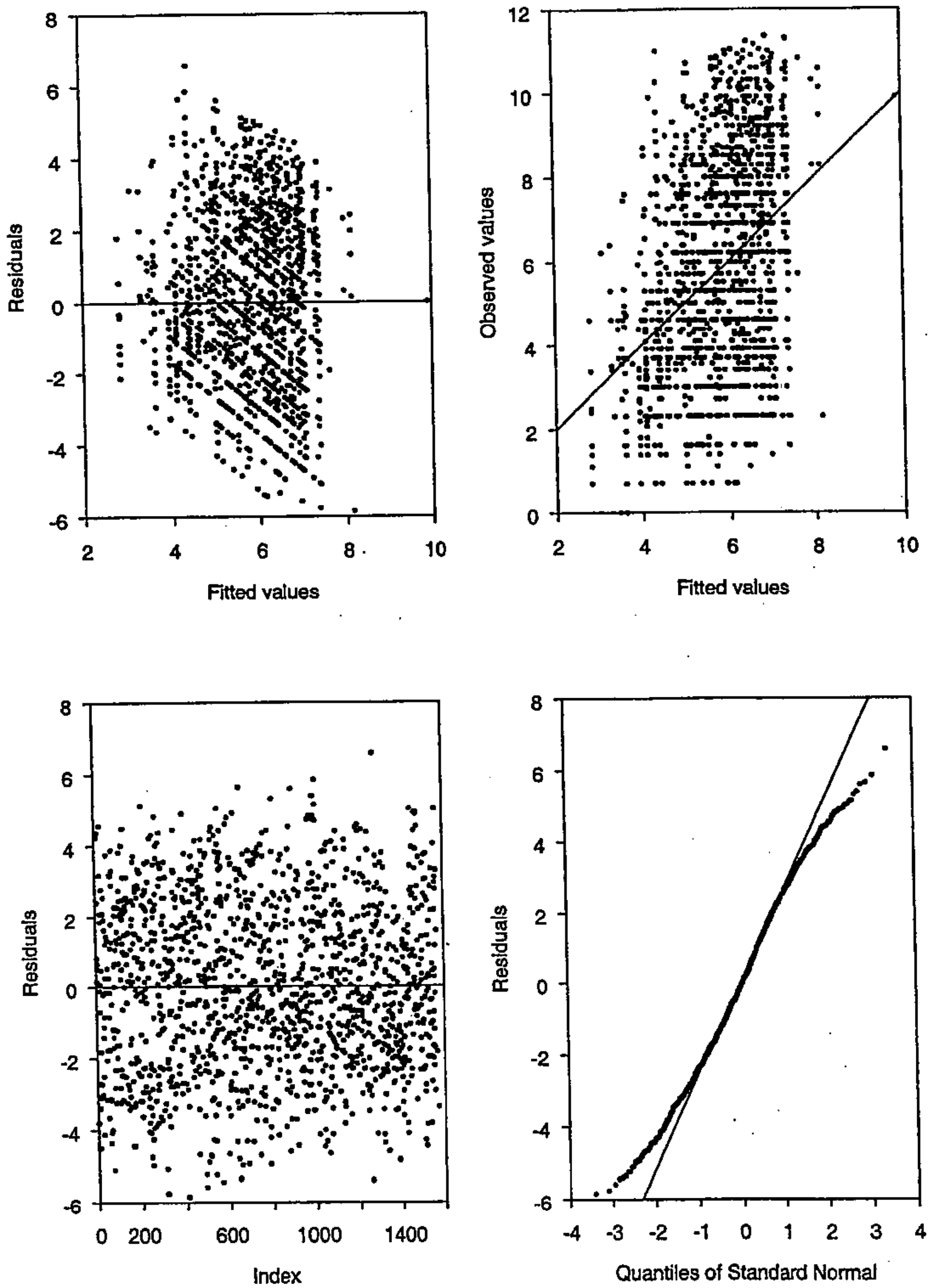

Figure 18: Diagnostic plots (log scale) of the lognormal model for QMA 1 fishery, all vessels. Top left figure shows fitted values versus residuals, top right, fitted values versus observed values, bottom left, normal quartile -quartile plot of the residuals.

Mercury-Colville fishery

All vessels

For the Mercury-Colville fishery (all vessels), four variables were selected with a total R^2 of 29% by the binomial model, with *target species* explaining 19% of the deviance (Table 18). For the lognormal component of the combined model, six predictor variables were selected, including year with a total R^2 of 15%. *Month* explained most (4%) of the deviance.

Table 18: Selected variables and corresponding R^2 from the stepwise multiple regression algorithm Mercury-Colville fishery for all vessels.

Binomial		Lognormal	
Selected variable	R^2	Selected variable	R^2
Target species	18.93	*Month*	3.89
Vessel	23.51	*Vessel*	6.18
Month	24.94	*Year*	7.92
*Vessel*month*	28.67	*Duration*	8.99
		*Month*Duration*	13.62
		Knoll	14.66

The standardised year effects are presented in Figure 19 and in Table A2. The binomial index increased up to the 1988–99 fishing year and then declined. Both the lognormal and combined indices are similar and tend to be variable but show a downward trend.

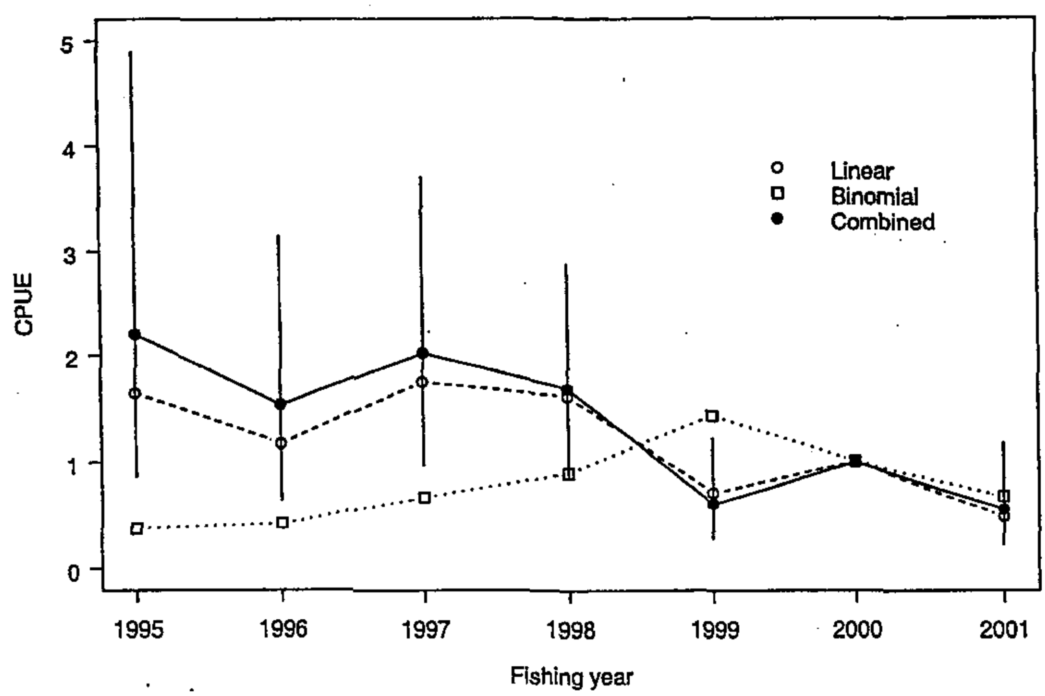

Figure 19: Standardised indices for the different models for Mercury-Colville fishery all vessels. 95% confidence intervals are also presented for the combined index only.

The effects of the selected variables are shown in Figure 20. There were nine vessels incorporated in the model, but one had a large expected catch rate when compared to other vessels. This vessel was in the fishery for only one year. Expected catch rates tend to fluctuate from month to month, with no clear seasonal trend. The catch rate was higher for tows under 30 minutes, although there is a slight increase for tows of 1.5–2 hr. The Mercury and Needle knolls had lower than expected catch rates when compared to the other knolls. However, many of the other knolls tend to have only one or two tows associated with them, so the catch rates tended to be higher.

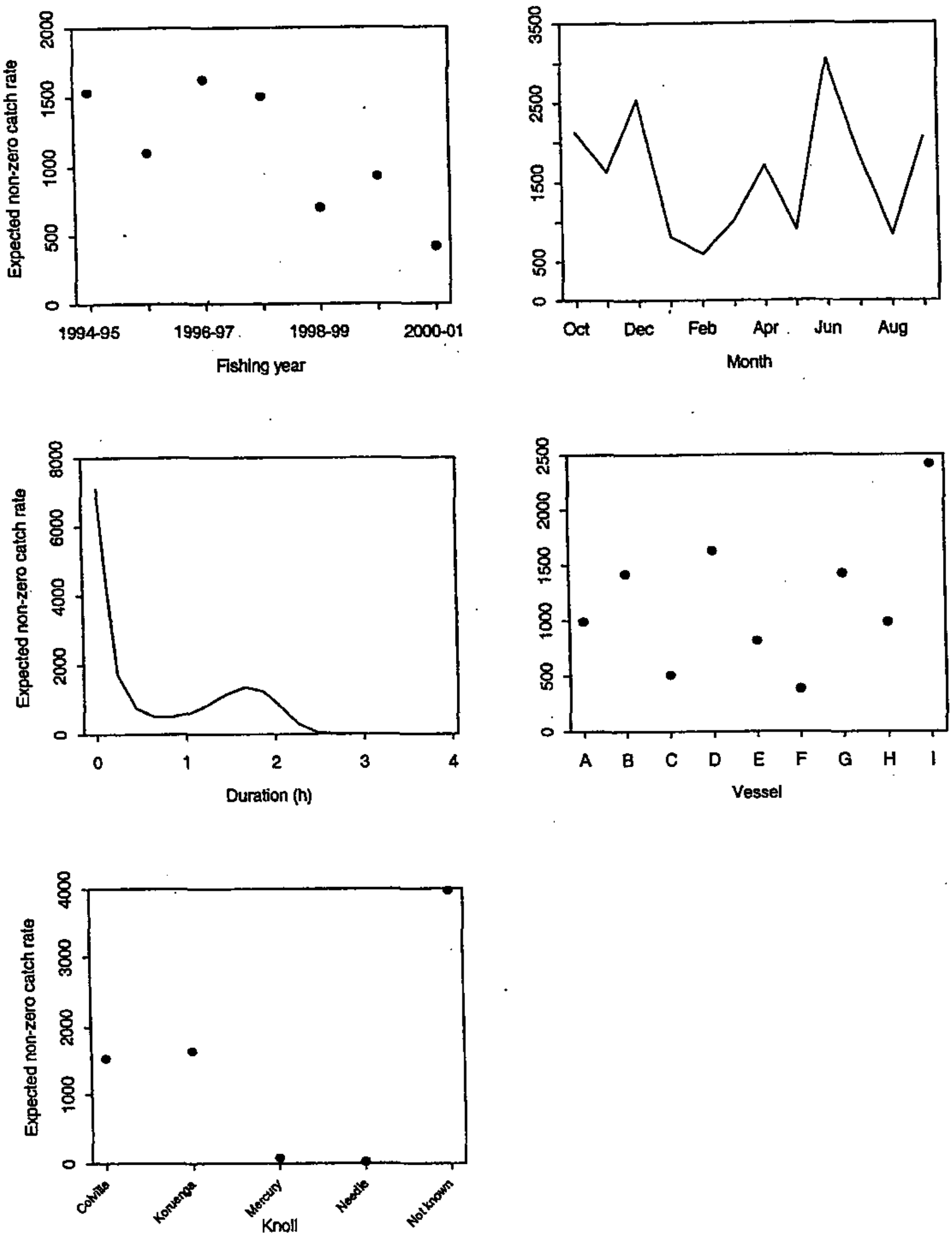

Figure 20: Expected variable effects for variables selected into the CPUE model for the Mercury-Colville fishery-all vessels.

Diagnostic plots (Figure 21) indicate a reasonable pattern in the residuals, but the Q-Q plot indicates a deviation from the normal distribution of the residuals. Again, the model does not seem to predict small and large levels of catch rate.

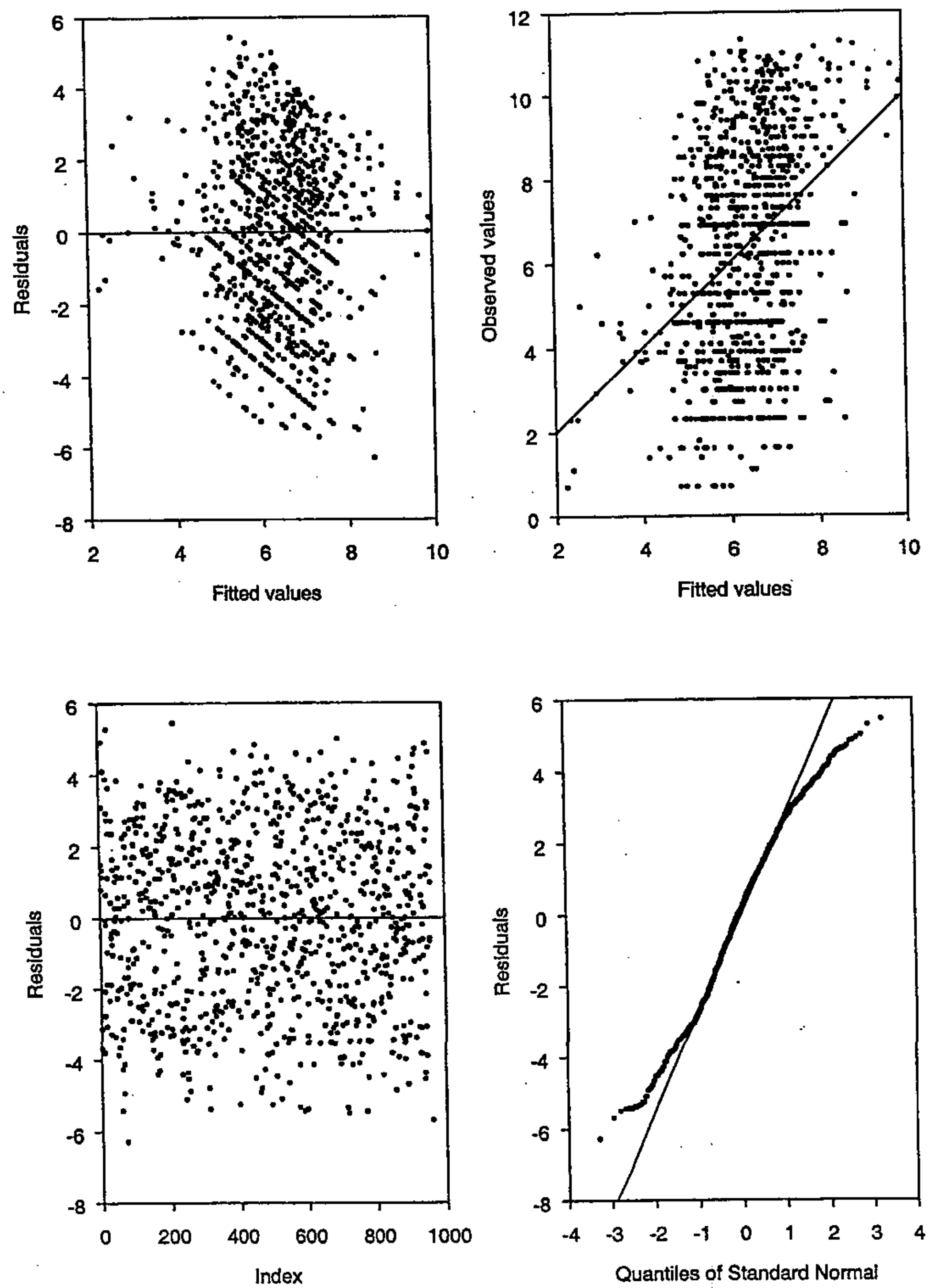

Figure 21: Diagnostic plots (log scale) of the lognormal model for Mercury-Colville fishery, all vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot of the residuals.

3+ vessels

For the Mercury-Colville fishery (3+ vessels), three predictor variables were selected (plus one interaction effect) for the binomial model with a total R^2 of 28%, with *target species* explaining 18% of the deviance (Table 19). For the lognormal component, four predictor variables were selected (plus 1 interaction effect) with a total R^2 of 12% with *month* explaining most of the deviance.

Table 19: Selected variables and corresponding R^2 from the stepwise multiple regression algorithm Mercury-Colville fishery for all vessels.

Binomial		Lognormal	
Selected variable	*R2*	Selected variable	*R2*
Target species	18.05	*Month*	3.94
Vessel draught	22.75	*Year*	5.91
Month	24.65	*Knoll*	6.91
*Month*Vessel draught*	27.61	*Duration*	8.45
		*Month*Duration*	12.34

The standardised year effects for all vessels are shown in Figure 22 and listed in Table A3. The binomial index increases up to the 1988–99 fishing year and then declines. Both the lognormal and combined index are similar, and tend to be variable and show a slight declining trend.

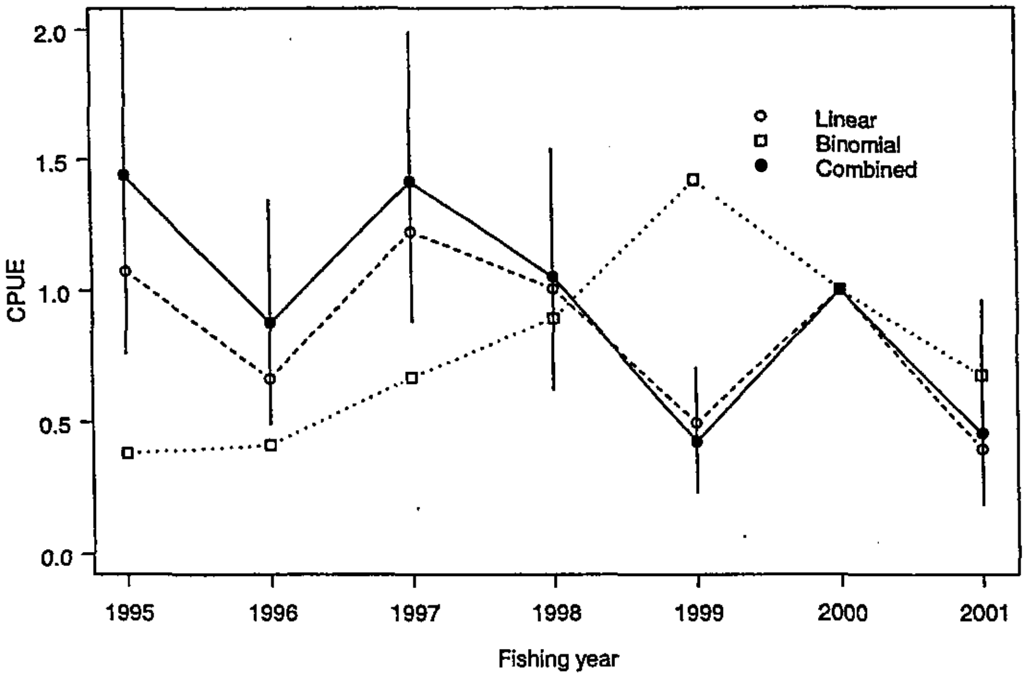

Figure 22: Standardised indices and 95% confidence intervals (combined indices only) for the different models for Mercury-Colville fishery, 3+ vessels.

Diagnostic plots (Figure 23) indicate a reasonable pattern in the residuals, but once again the Q-Q plot indicates a deviation from the normal distribution of the residuals for small and large level of catch rate.

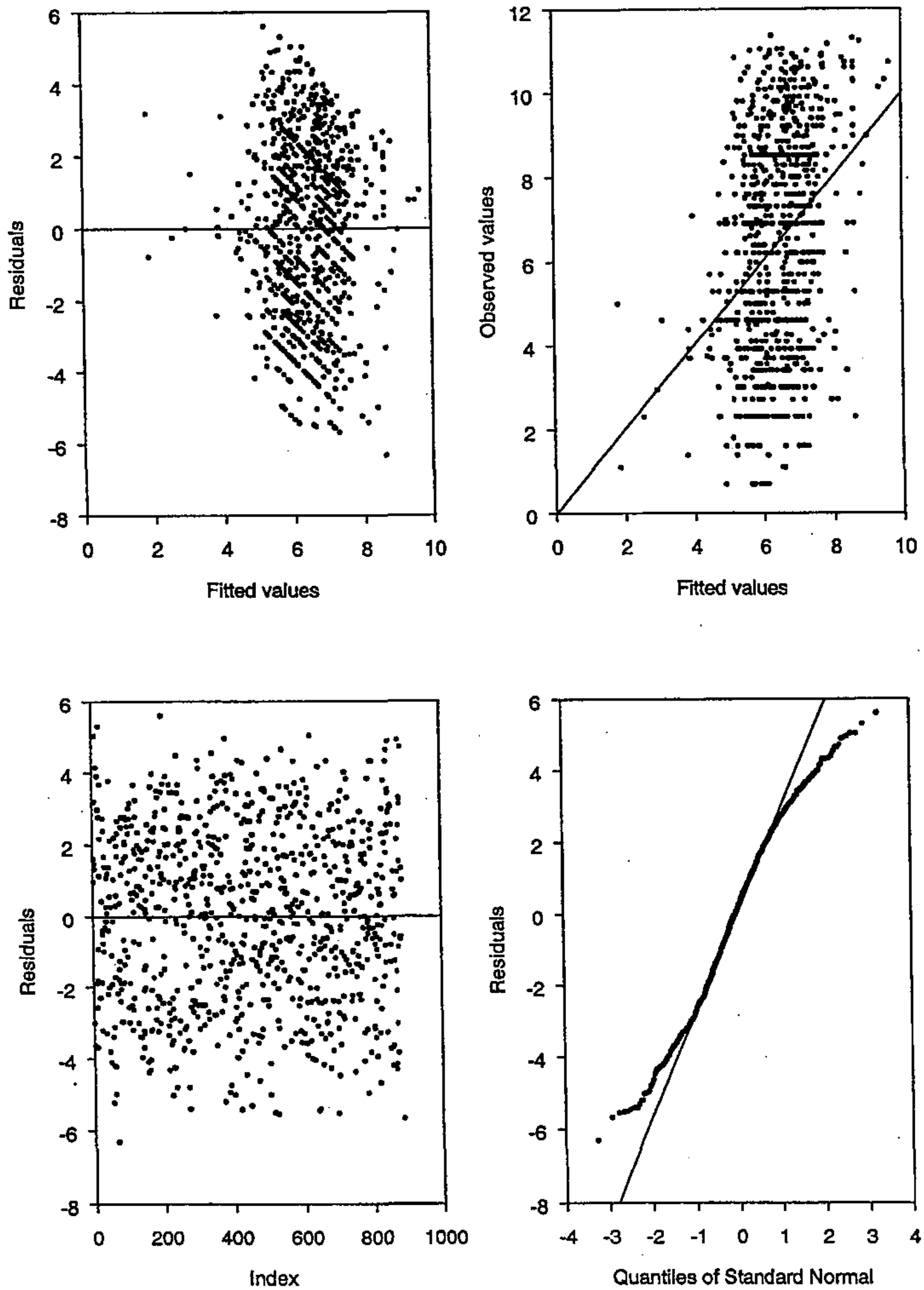

Figure 23: Diagnostic plots (log scale) of the lognormal model for Mercury-Colville fishery 3+ vessels. . Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot of the residuals.

The effects of the selected variables are shown in Figure 24. Expected catch rates tended to fluctuate from month to month, with no clear seasonal trend. The catch rate was higher for tows under 30 minutes, although there is a slight increase for tows of 1.5–2 hrs. Mercury and Colville knolls have lower than expected catch rates when compared to the other knolls, but these knolls tend to have only one or two tows associated with them

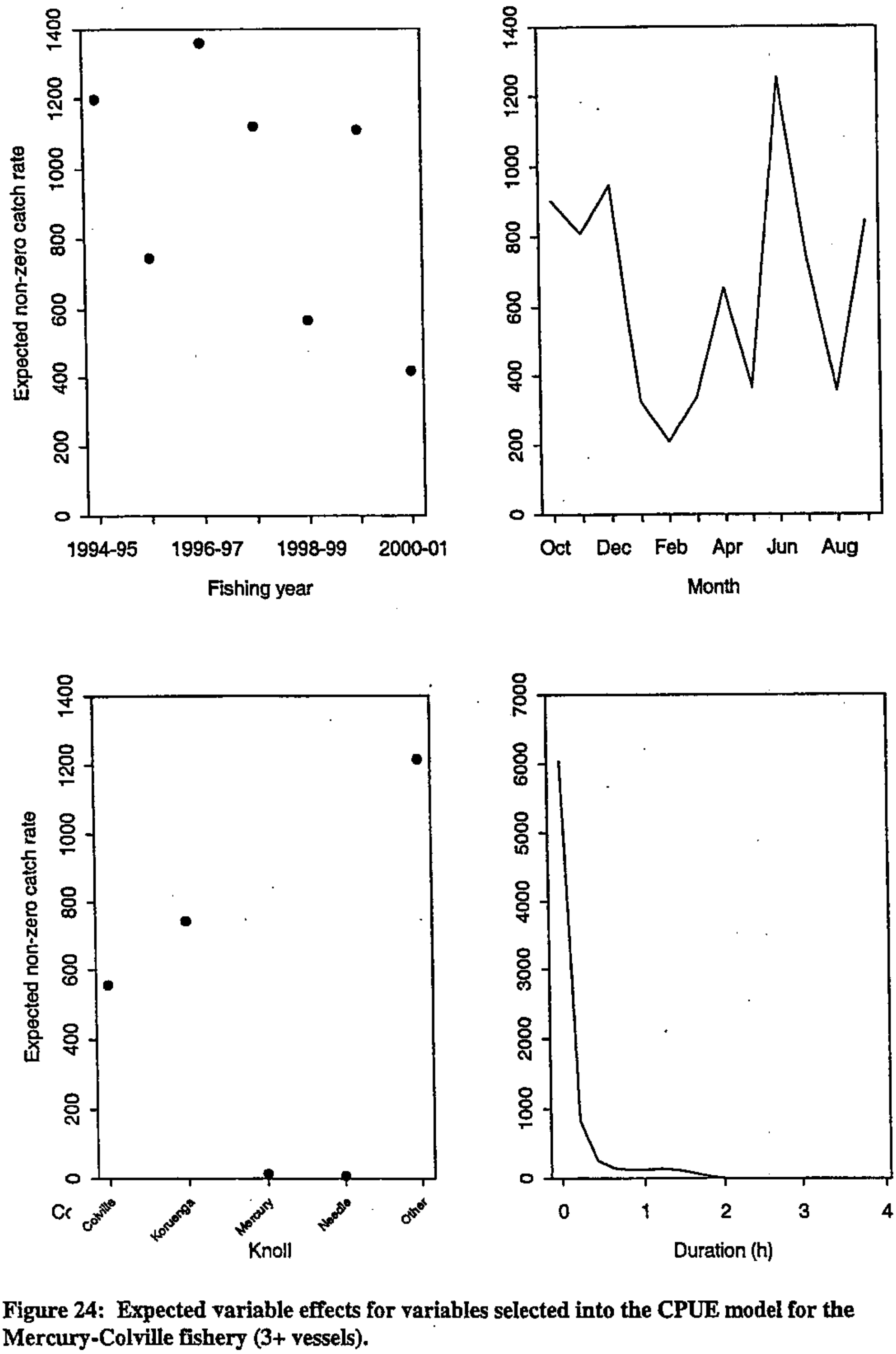

Figure 24: Expected variable effects for variables selected into the CPUE model for the Mercury-Colville fishery (3+ vessels).

Target 3+ vessels

For the Mercury-Colville target fishery (3+ vessels), four predictor variables were selected for the binomial model. These variables explained 9% of the R^2, with *vessel* explaining most (5%) of the deviance (Table 20). For the lognormal component of the combined model four predictor variables were selected (plus three interaction terms) with a total R^2 of 17%. *Month* explained most of the deviance with an R^2 of 4%.

Table 20: Selected variables and corresponding R^2 from the stepwise multiple regression algorithm Mercury-Colville target fishery, 3+ vessels.

Binomial		Lognormal	
Selected variable	R^2	Selected variable	R^2
Vessel	4.77	*Month*	3.54
Month	7.09	*Year*	4.94
Year	8.59	*Headline*	5.97
Wingspread	9.14	*Headline*Month*	10.52
		Start time	11.14
		*Month*Start time*	15.99
		Headline Start time*	17.00

The standardised year effects for all vessels are shown in Figure 25 and are listed in Appendix A, Table A4. The binomial index increased up to 1997–98 and declined until 2000–01. Both the lognormal and combined indices are similar and show a gradual decline from 1994–95 to 1998–99. There was a sharp rise from 1998–99 to 1999–2000 followed by a steep decline in 2000–01. There has been an 87% decrease in the index from 1994–95 to 2000–01, although most of this is attributable to the change in the last year and the 95% confidence intervals are wide.

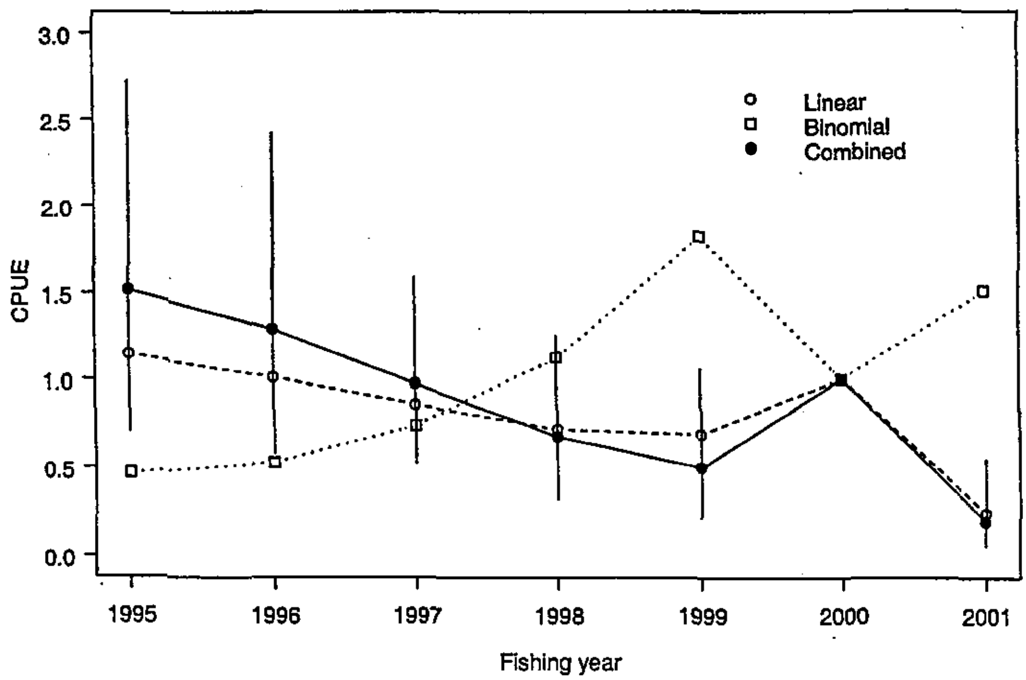

Figure 25: Standardised indices for the different models for Mercury-Colville black cardinalfish target fishery, 3+ vessels.

The diagnostic plots (Figure 26) indicate a reasonable pattern in the residuals, but the Q-Q plot indicates a deviation from the normal distribution of the residuals for high and low values of catch rate.

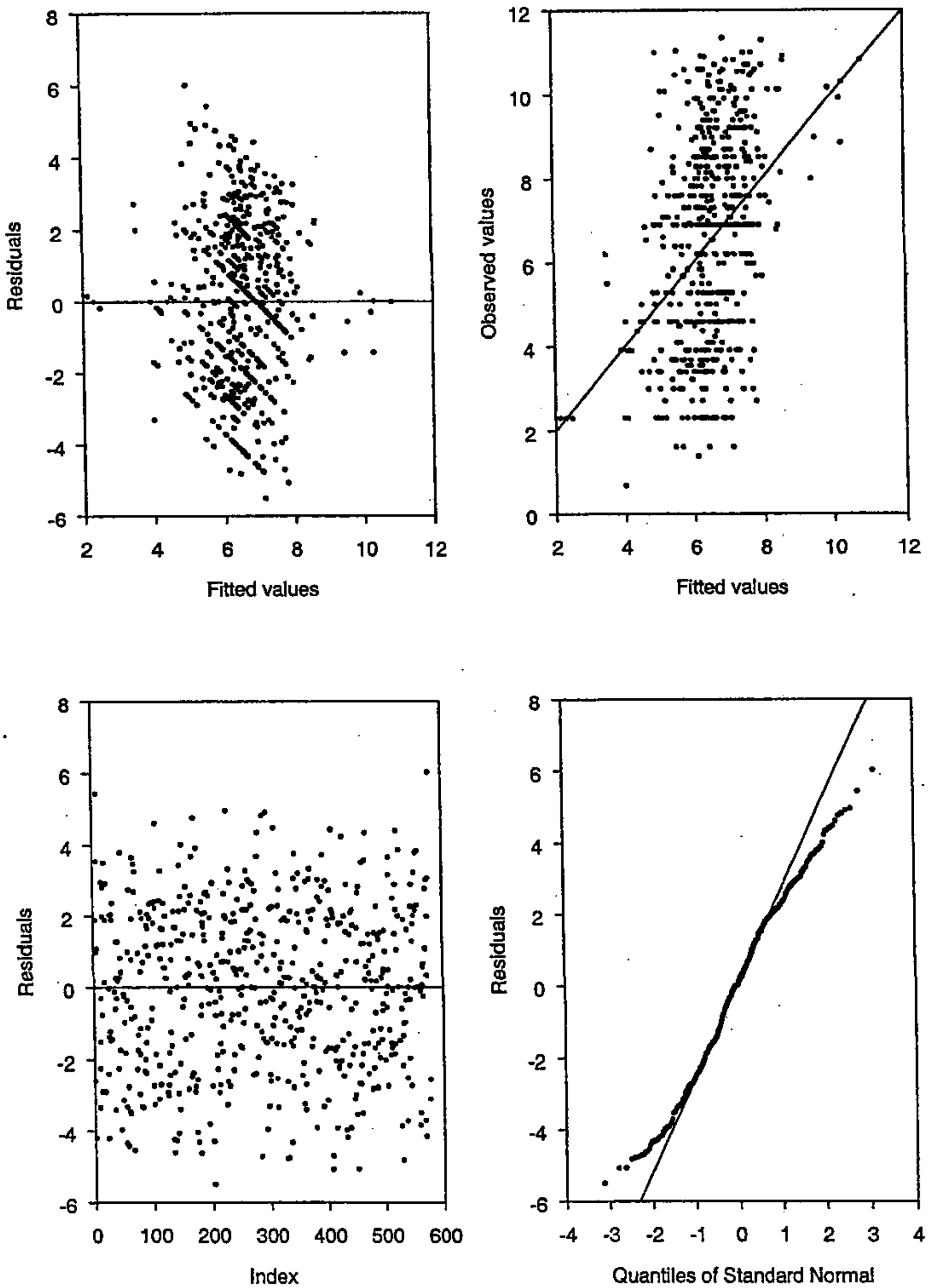

Figure 26: Diagnostic plots (log scale) of the lognormal model for Mercury-Colville target fishery, 3+ vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot of the residuals.

The effects of the selected variables are shown in Figure 27. Expected catch rates tended to fluctuate from month to month, but there is a higher catch rate for June–July. There were higher catch rates where a headline height is 4.5–6 m. There appears to be a diurnal trend in the catch rates for the fishery, with higher catch rates in the late evening and late morning.

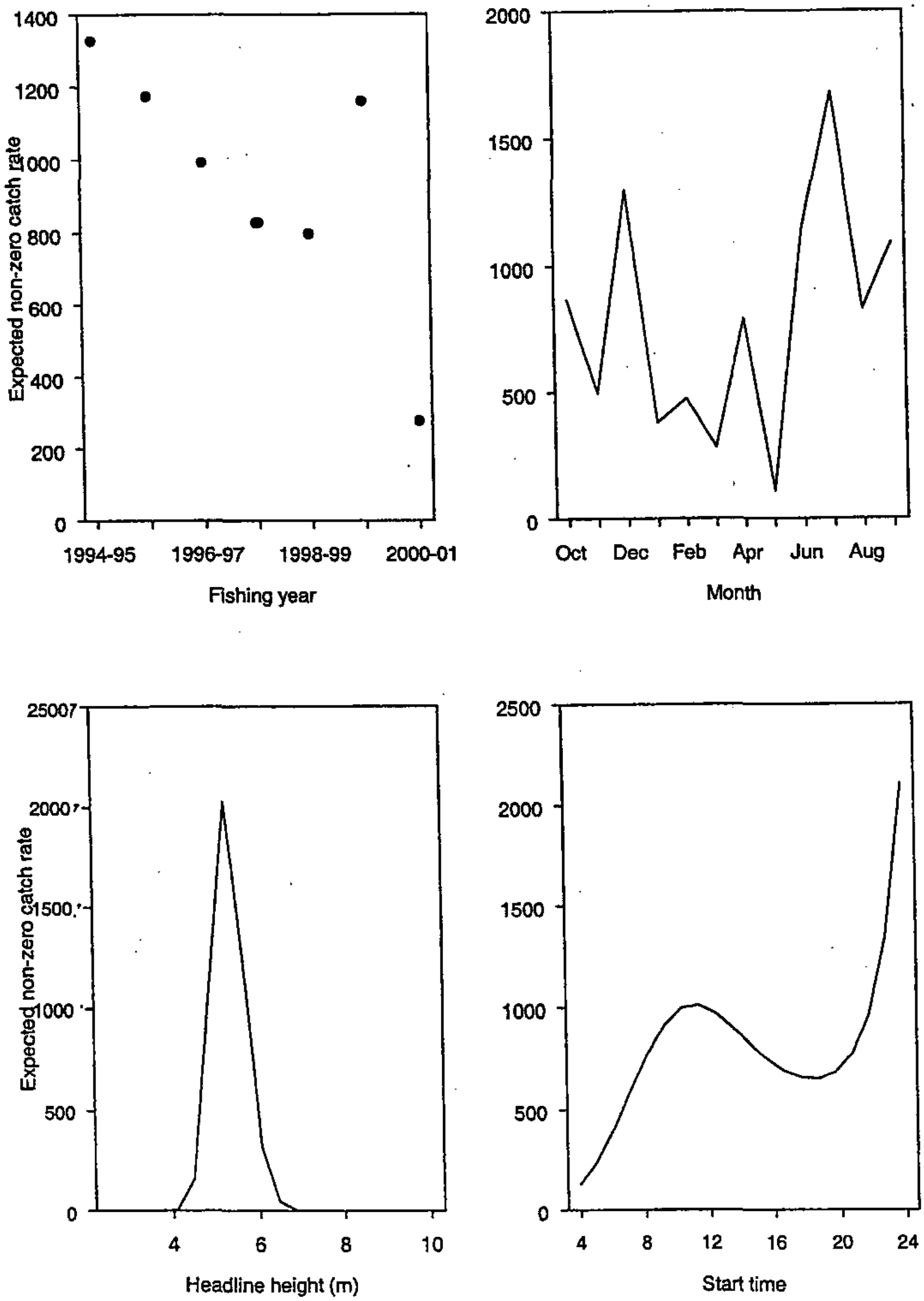

Figure 27: Expected variable effects for variables selected into the CPUE model for the Mercury-Colville target fishery (3+ vessels).

4. DISCUSSION

Dunn et al, (2000) noted that calculation of CPUE indices does not necessarily result in an index which is related to abundance. They cautioned against the use of CPUE indices in stock assessment models until several aspects of the analysis had been evaluated and the CPUE indices themselves had been validated by fishery independent data. They recommended that CPUE analysis included discussion of:

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

Definition of the relationship between CPUE and fish abundance

As black cardinalfish tend to aggregate, fishing behaviour is to start fishing once a suitable aggregation is found. This could result in hyperstability (when CPUE remains high while the population is declining) due to the distribution of the population and fishers. The catch rates from the top 5% of tows are about 40 tonnes per tow, suggesting that this is well below trawl saturation. It is also not a high catch rate in absolute terms, and it is unlikely that CPUE is artificially high as a result of targeting a clumped population.

Assessment of data adequacy

The data used in this analysis have been carefully groomed to remove as many errors as possible. Some are bound to remain, and these may have some effect on the resulting CPUE indices. However, when using large datasets there may not be much effect on the final CPUE estimates, (e.g., Dunn & Harley 1999).

There are some concerns over the amount of data available for the analysis. There are only about 400 records per year for the QMA 1 fishery (all vessels). The number of records is further reduced when considering target-only tows, core vessels, or specific fisheries. This may result in insufficient contrast in the catch rates to detect real changes in abundance.

A number of tows (9%) lasted over 1 hour. It is unlikely that this could occur while towing on hill features. It is possible that the tows could be midwater trawls and misreporting of tow method has occurred. It was discounted that these tows are towing along the bottom along flat areas (e.g., flat tows as defined by Francis (2001)) as the bottom depths around the known seamount features would be too great to catch black cardinalfish.

There may also be a problem with reporting of catch before 1998 (when black cardinalfish became a quota species). It is possible that not all catches have been recorded and discarding may have occurred.

Model fitting and validation

Model fitting and model validation are considered by comparing the explanatory variables, the amount of variation explained, the diagnostic plots, and the results of the different models used in the analysis.

Month appeared to be an important predictor as it was selected in most models. Expected catch rates tended to fluctuate from month to month, with no clear seasonal trend. This suggests that the model has not detected a real month effect as a result of not enough data, or has interpreted some other pattern in catch rates as having been caused by month. There are many ways in which this could happen. For example, suppose that **catchability** in the fishery was exceptionally high in one year. The model should react to this by increasing the coefficient for that year. However, the model might also increase the coefficients associated with months where most fishing occurred in that year (Francis 2001), i.e., changes in catch rates are potentially obscured by the parameterisation of other variables. This sort of misinterpretation is called aliasing and is most probably a result of an unbalanced data set.

Target species an important variable selected for the QMA 1 fishery (all vessels). There appears to be a problem in the lognormal model where target species explains very little of the residual deviance compared to the binomial model. This is probably a result of the meaning of target species. Paul & Bradford (2000) noted that target species is used by fishers in several ways: the single species targeted, the main of several species targeted, the species for which most quota is still held, the main species actually caught – whether it was targeted or not, the species which legalises a subsequent bycatch trade, or simply just a logical species for that area and fishery.

The *month*duration* interaction was selected by the Mercury-Colville model (all vessels and 3+ vessels). This interaction suggests that there is a change of duration by month. However, the tows occur on fixed features, so this interaction may not be valid. This too may be a result of the unbalanced data set.

The models considered have a very large number of parameters. It is therefore, of some, concern that it is possible to explain only a relatively small fraction of the overall deviance (up to 30% for binomial models and 17% for lognormal). However, the inability to explain a substantial fraction of the variability in the data when conducting catch-effort standardisations is not particularly unusual (e.g., Punt et al. 2000; Vignaux 1994). This is probably a result of the inability to identify and include all the key variables that determine catch rates. For example, individual skippers' experience was not available, even though the number of years the vessel has been in the fishery was included. However, there were almost certainly different skippers over the time period. Other effects on catching ability such as improvements in net and bottom rig design, and electronic equipment could not be quantified and may result in an increase in overall deviance.

The analysis was also performed with a less conservative stopping rule (0.5%) as a sensitivity. This resulted in an increase in the number of parameters selected (and an increase in deviance explained), but many of the resulting interaction terms did not appear to be valid.

As recommended by Dunn et al. (2000), subsets of vessels that had fished in the various fisheries were analysed. In each vessel subset, similar variables were selected to the all vessels data set, suggesting the model did not appear to be overly sensitive to the vessel selection used. The resulting CPUE trends were also similar.

The diagnostic plots from the regression analyses were all similar. In general, the models developed for each of the fisheries were unable to capture the extremes in catch rate observed in the fishery, and tended to underestimate the lower and upper extremes of the catch rates. This appears to be a common problem for many CPUE analyses and probably reflects the sometimes patchy nature of fish and fisheries.

Evaluation of the CPUE index

An important step in assessing the feasibility of CPUE as an index of abundance is to determine whether annual changes in CPUE reflect the abundance of black cardinalfish by comparing the CPUE indices to fishery independent data. Unfortunately, there has been very little research on abundance of black cardinalfish in CDL 1.

There have been three trawl surveys (1995, 1998, 2000) in the Mercury-Colville fishery, but they were optimised for orange roughy abundance. A comparison of the standardised indices and estimated biomass indices for black cardinalfish from the surveys are presented in Figure B1 (Appendix B). The biomass indices show a sharp decline similar to that of the orange roughy trend (M.R. Clark & R.I.C.C. Francis, NIWA, unpublished results). The decline in the research index is steep, but adds support to the decline in abundance shown by the CPUE indices for the QMA 1 fishery (all vessels) and the Mercury-Colville fishery (all vessels and 3+ vessels).

5. CONCLUSIONS

The fishery initially developed in 1994–95 as a result of bycatch of the orange roughy fishery. Current information concerning the black cardinalfish fishery in QMA 1is limited as a result of the short timescale of the fishery, and the short time black cardinalfish has been included in the QMS.

Trends in unstandardised and standardised year effects tend to be similar for the different vessel groupings (all vessels, 3+ vessels and 70% vessels) analysed and show a substantial decline over the time period investigated.

There were considerable changes in the annual distribution of the data records over the study period with respect to a number of the significant variables included in the CPUE model, particularly *vessel, month, knoll, fishery*. The unbalanced nature of these data sets means that parameterisation of the variables in the model may obscure annual changes in standardised catch rates.

Overall, the CPUE models used in this study appear to have a limited application for monitoring the abundance of black cardinalfish in CDL 1. This is due to the high variation in catch rates from the fishery, and the small number of annual catch and effort records available for the fishery.

The TACC was only 25% caught, and this may be indicative of a decline in catch rates and possibly also in stock size. These trends suggest that this fishery should be monitored carefully.

6. ACKNOWLEDGMENTS

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Appendix A

Table A1: Standardised CPUE indices and 95% confidence intervals for the QMA 1 fishery (all vessels).

	Binomial		Lognormal		Combined	
Fishing year	Index	CI	Index	CI	Index	CI
1994–95	0.62	0.33–1.19	3.08	1.54–6.16	3.47	1.93–5.83
1995–96	0.91	0.51–1.64	2.87	1.55–5.32	2.94	1.81–4.47
1996–97	1.00	0.64–1.58	3.61	2.14–6.09	3.61	2.40–5.19
1997–98	1.03	0.67–1.60	3.46	2.20–5.45	3.42	2.44–4.62
1998–99	1.58	1.07–2.33	1.64	1.07–2.52	1.40	1.05–1.80
1999–00	1.00	na	1.00	na	1.00	na
2000–01	1.04	0.61–1.80	0.54	0.28–1.07	0.53	0.31–0.86

Table A2: Standardised CPUE indices and 95% confidence intervals for the Mercury-Colville fishery (all vessels).

	Binomial		Lognormal		Combined	
Fishing year	Index	CI	Index	CI	Index	CI
1994–95	0.37	0.15–0.94	1.63	0.56–4.77	2.20	0.86–4.89
1995–96	0.42	0.17–1.04	1.16	0.42–3.19	1.52	0.64–3.15
1996–97	0.67	0.30–1.47	1.74	0.69–4.41	2.02	0.96–3.70
1997–98	0.89	0.41–1.95	1.60	0.64–3.99	1.67	0.85–2.87
1998–99	1.42	0.75–2.68	0.71	0.25–2.04	0.61	0.28–1.21
1999–00	1.00	na	1.00	na	1.00	na
2000–01	0.68	0.29–1.57	0.48	0.16–1.43	0.55	0.23–1.16

Table A3: Standardised CPUE indices and 95% confidence intervals (CI) for the Mercury-Colville fishery (3+ vessels).

	Binomial		Lognormal		Combined	
	Index	CI	Index	CI	Index	CI
1994–95	0.38	0.15–0.97	1.07	0.50–2.33	1.44	0.76–2.36
1995–96	0.41	0.16–1.02	0.66	0.32–1.36	0.88	0.49–1.35
1996–97	0.67	0.30–1.47	1.22	0.63–2.37	1.41	0.88–1.99
1997–98	0.89	0.41–1.95	1.00	0.47–2.14	1.05	0.62–1.54
1998–99	1.42	0.75–2.68	0.50	0.21–1.19	0.42	0.23–0.71
1999–00	1.00	na	1.00	na	1.00	na
2000–01	0.67	0.29–1.56	0.39	0.13–1.18	0.45	0.18–0.96

Table A4: Standardised CPUE indices and 95% confidence intervals for the Mercury-Colville black cardinalfish target fishery (3+ vessels).

	Binomial		Lognormal		Combined	
	Index	CI	Index	CI	Index	CI
1994–95	0.47	0.18–1.21	1.14	0.44–2.98	1.52	0.71–2.72
1995–96	0.53	0.21–1.30	1.01	0.37–2.76	1.29	0.58–2.42
1996–97	0.74	0.35–1.56	0.86	0.36–2.01	0.97	0.52–1.59
1997–98	1.12	0.53–2.37	0.71	0.25–2.04	0.68	0.32–1.25
1998–99	1.82	1.01–3.31	0.69	0.22–2.19	0.50	0.21–1.06
1999–00	1.00	na	1.00	na	1.00	0.00–0.00
2000–01	1.51	0.78–2.94	0.24	0.05–1.04	0.19	0.06–0.55

Appendix B

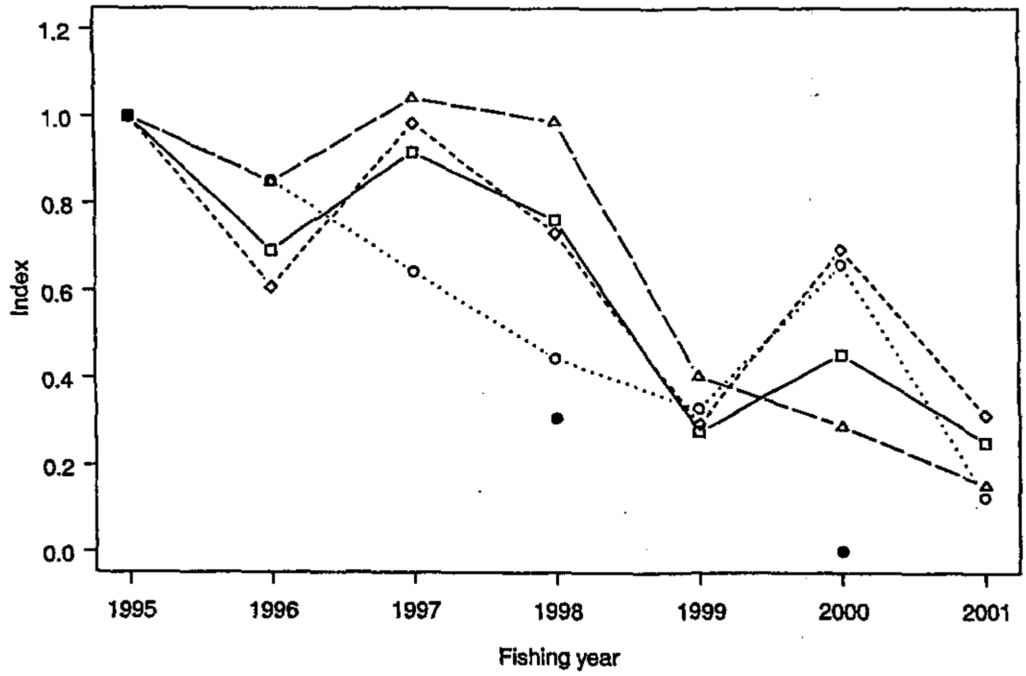

Figure B1: Comparison of biomass indices (solid circles) to standardised CPUE indices for CDL 1, all vessels (triangle), Mercury-Colville fishery, all vessels (squares), 3+ vessels (diamonds), target 3+ vessels (hollow circles). All indices have been standardised to the initial year.

Appendix C

Table C1: Summary of the number of tows for all vessels fishing in the QMA 1 fishery targeting or catching black cardinalfish.

Vessel								Fishing year
	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01
A		1						
B			106					
C		14	15			8		
D				7				
E	14	204	179	98	49	98	14	3
F			29	4	17	45	23	46
G	2	7						
H		8	14					
I		5	8	34	22			
J			4					
K			22	7				
L			31	299	296	188	196	22
M				21	46	114	314	119