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M. R. Dunn

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M. R. Dunn

NIWA
Private Bag 14901
Wellington

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EXECUTIVE SUMMARY

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This report updates descriptive analyses of commercial catch and effort data for all the main black cardinalfish fisheries in the New Zealand Exclusive Economic Zone (EEZ) to the end of the 2004–05 fishing year. It also includes a description of one fishery outside the EEZ, on the northern Challenger Plateau and southern Lord Howe Rise. The distribution, catch, effort, and catch rate trends are described for each of nine identified sub-area fisheries, and standardised catch per unit effort (CPUE) indices determined for the fishery in Quota Management Area 2.

The largest sub-area fishery in 2004–05 was at Tuaheni, followed by Mercury-Colville, North Challenger and Lord Howe, and Ritchie and Rockgarden. Unstandardised catch rates were relatively low for most areas and at an historical low for five of the nine sub-areas. Catch rates were relatively high only for Tuaheni and Wairarapa.

The standardised CPUE indices suggested catch rates in QMA 2 were relatively low in 2004–05. However, there was evidence of bias in the catch and effort data caused by the entry of black cardinalfish into the Quota Management System in 1998, and the indices described only a relatively small proportion (less than one third) of the catch.

1. INTRODUCTION

Black cardinalfish (*Epigonus telescopus*, Risso 1810) are the only commercially exploited species of cardinalfish in New Zealand waters (MFish Science Group 2006). Black cardinalfish are a deep-water shoaling species, and their biology is poorly known (Dunn 2005).

The exploitation of black cardinalfish within the New Zealand EEZ started as a bycatch in the early 1980s, with a targeted fishery developing from the mid 1990s (Field et al. 1997, Dunn 2005). The species came into the Quota Management System (QMS) on 1 October 1998, and Total Allowable Commercial Catches (TACCs) were set for Quota Management Areas (QMAs) 2–8 (Figure 1). In the following year, TACCs were set for QMAs 1 and 9. No TACC has been set for QMA 10. None of the TACCs have been changed since their introduction (MFish Science Group 2006). There have been no scientific studies to determine the number or boundaries of black cardinalfish stocks in New Zealand waters.

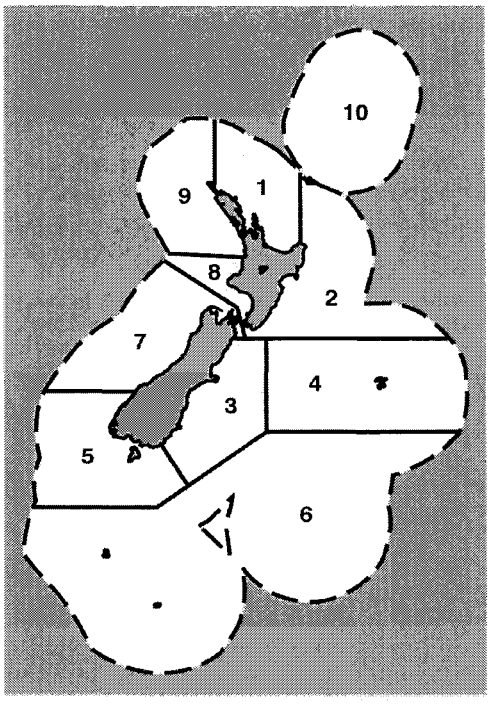

Figure 1: Location of Quota Management Areas (QMAs) for black cardinalfish within the New Zealand EEZ.

There are no fishery independent biomass indices for black cardinalfish, and therefore stock assessments have used commercial catch per unit effort (CPUE). An assessment of the largest stock, in QMA 2, was rejected because the model biomass trajectory did not fit the CPUE index well (Field & Clark 2001, MFish Science Group 2006). Phillips (2002) analysed CPUE from QMA 1, the second largest fishery, and concluded CPUE was not a reliable indicator of stock abundance. There have been no other studies to determine the status of New Zealand black cardinalfish stocks, and consequently the status of the stocks remains poorly known.

Catch and effort statistics for the black cardinalfish fisheries were most recently described by Dunn (2005) for the fishing years 1979–80 to 2002–03 (New Zealand fishing years run from 1 October to 30 September). This did not include the calculation or evaluation of standardised CPUE indices.

The work described in this report was carried out under Ministry of Fisheries (MFish) project CDL200501 objective 1: "To provide a descriptive analysis of the commercial catch and effort data from black cardinalfish fisheries, with the inclusion of data up to the end of the 2004–05 fishing year" and objective 2: "To carry out both unstandardised and standardised catch per unit effort analyses with the inclusion of data up to the end of the 2004–05 fishing year for the CDL 2 fishery".

2. METHODS

2.1 Data sources

All records where black cardinalfish was specified as targeted and/or caught on Trawl Catch Effort Processing Returns (TCEPR) or Catch, Effort and Landing Returns (CELR) were extracted from the Ministry of Fisheries (MFish) Catch Effort Database. This included the "high-seas" versions of both form types, as used by vessels fishing outside of the New Zealand EEZ. This data set covered the fishing years 1990–91 to 2004–05, with 16 643 TCEPR and 1081 CELR records. The TCEPR forms gave tow-by-tow information, with location and estimated catch for each trawl. The CELR forms provided daily catch records with effort estimated as the number and total duration of tows in the day. CELR forms tended to be used by smaller inshore vessels, and larger deepwater vessels (over 28 m in length) were required to complete TCEPR forms. In addition, details of the corresponding vessel specifications were provided by MFish, and included a time series of records of vessel length, power and tonnage.

Records were selected where any cardinalfish species was caught or targeted. These were specified as the 3-letter species codes CDL, EPD, EPL, EPR, EPT, and HOW. The species code expected for commercial catches of black cardinalfish (*Epigonus telescopus*) is CDL, but the meaning of this code has varied over time. Before 01/10/1991 and after 15/07/1999 the code refers to *E. telescopus*, but between those dates it refers to *Epigonus* spp. (Anon. 2003). Because *E. telescopus* is the only commercial species, this should have caused little or no bias (Dunn 2005).

2.2 Data grooming

Error checks were performed for the following data fields:

- Bottom depth (where more than 1300 m or less than 200 m)
- Effort depth (with respect to *bottom depth*)
- Position (for location, and where large differences in start and finish position)
- Trawl speed (where more than 8 kt or less than 1.5 kt)
- Duration (where more than 8 hours)
- Target species
- Vessel nationality (if none ever recorded then assumed to be Domestic)
- Vessel length and power
- Time of day
- Fishing gear

Missing or erroneous values were replaced with imputed average values. For example: where depth was missing it was replaced with the mean depth from all other tows recorded within 1 n.mile of that tow position; where tow length calculated using given positions was greater than 30 n.mile, and speed calculated from distance and duration was greater than 8 knots, the tow positions were replaced with the median values for that vessel and day (this would allocate the vessel to roughly the right area). Records containing errors that could not be

corrected were excluded from further analyses. A total of 11 259 of the 16 643 TCEPR records were edited (Table 1).

Table 1: Number of TCEPR records (N) by the type or types of edit(s) made.

Type of edit	N	Type of edit	N
None	5 384	Position + Nationality	235
Depth	88	Depth + Nationality + Position	14
Nation	10 425	Speed + Duration	13
Depth + Nationality	377	Speed + Duration + Nationality	46
Position	48	Speed + Duration + Nationality + Depth	5
Depth + Position	2	Target Species + Nationality	6

Each tow was classified as either a *hill* tow, *near-hill* tow, or *flat* tow, depending on the distance between the start position and each of 840 known underwater features, of which most were hills (elevations of 95–5070 m; O. Anderson, NIWA, pers.comm.). Each tow was also classified as either a *short* tow, with duration of 30 minutes or less, or a *long* tow. A duration of 30 minutes or less has previously been used to define tows on hills when targeting orange roughy (Francis 2001, Anderson 2005), and would be typical of tows targeting specific aggregations of fish. Correspondingly, most tows on hills were shorter than 30 minutes duration, and most hills on flat areas were longer (Figure 2). The classification of tows is summarised in Table 2.

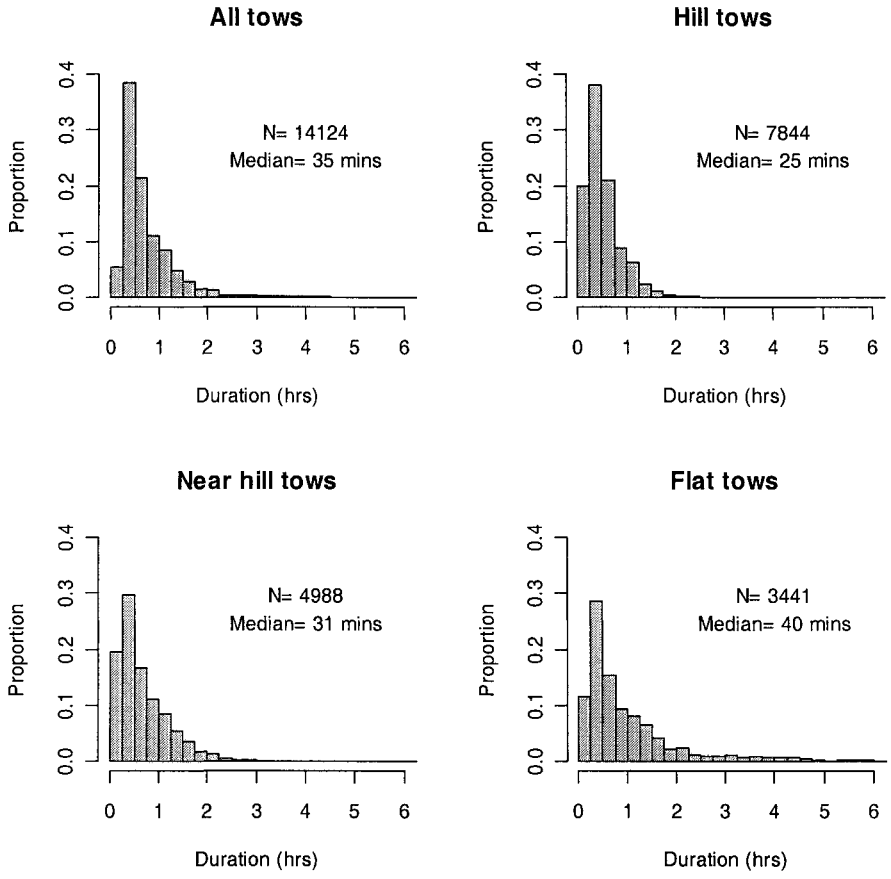

Figure 2: Frequency of tows catching or targeting CDL by tow duration, and by distance to known features, following Table 1.

A known but unquantified source of mortality for black cardinalfish has been the discarding at sea of this species whilst target fishing for higher value species (MFish 2006). This study has not incorporated any adjustments to catch levels for these discards.

Table 2: Tow classification system used.

Tow duration	Distance between tow start position and feature		
	<1.5 n.mile	1.5 to <5 n.mile	5 n.mile and over
30 minutes or less	Hill short	Near hill short	Flat short
Over 30 minutes	Hill long	Near hill long	Flat long

2.3 Definition of fishery areas

In addition to MFish QMAs, this description of the fishery also uses areas described by Dunn (2005), which were:

1. Kaikoura. The area between 172.9° E and 175.2° E, and between 41.7° S and 43.1° S. Catches from this area are included in QMA 2 and QMA 3.
2. Wairarapa. The area between 175.1° E and 177.3° E, and between 40.65° S and 42° S. Catches from this areas are included in QMA 2.
3. East Coast. Catches from this area are included in QMA 2.
    a. Ritchie Hill and the Rockgarden. The area bounded by points at 178.2° E 39.2° S, 177.8° E 40.2° S, 178.5° E 40.2°S and 178.9° E 39.2° S.
    b. Tuaheni High. The area between 178.35° E and 179° E, and between 38.6° S and 39.1° S.
    c. East Cape. The area between 178.4° E and 180°, and between 37.2° S and 38.2° S.
4. Bay of Plenty. Catches from this area are included in QMA 1.
    a. North Colville. The area between 177.3° E and 177.7° E, and between 34.8° S and 35.2° S.
    b. Mercury-Colville. The area between 176.4° E and 177° E, and between 36° S and 36.7° S.
    c. White Island. The area between 177° E and 177.6° E, and between 36.75° S and 37.4° S.
5. North Challenger and Lord Howe. The area between 164° E and 169° E, and between 35° S and 38.5° S. This area is outside the New Zealand Exclusive Economic Zone (EEZ).

2.4 Standardised catch per unit effort (CPUE)

Only *hill short* and *near-hill short* tows were used for standardised CPUE analyses. Long tows were excluded from the analysis data set because black cardinalfish were known to form distinct and dense acoustic marks, and it seemed unlikely that these would be targeted by longer tows. There were few short tows on the flat, and consequently these records were also excluded.

In order to adequately estimate predictor effect in the model, a continuity rule was applied for the predictors *vessel*, *target species,* and *sub-area* (*sub-area* being the specific nearest hill or feature). For each level of each predictor, at least 10 tows must have been completed in 3 or more years. For example, data were restricted to records associated with vessels that completed at least 10 tows per year in each of at least 3 fishing years.

The standardised CPUE analyses were carried out by fitting a generalised linear model to CPUE, using the stepwise multiple regression technique described by Francis (2001). The units of CPUE used were kg per tow. Since there was a non-trivial proportion of zero catch tows in the data set, the model for the CPUE was split into two parts (1) a normal model for the natural log of the non-zero tows, with a normal error distribution and identity link function, and (2) a binomial model which estimates the probability of a non-zero catch, with a binomial response and logit link function. The combined model estimates catch rates from all tows (including those with zero catch) by combining results from the normal and binomial models. The coefficient of variation (c.v.) of the estimates from the combined model were calculated using a bootstrap procedure (Francis 2001).

The predictor variable *fishing year* was forced into the model, and other variables tested for inclusion (Table 3). A stepwise forward procedure was used to select predictor variables, and they were entered into the model in the order which gave the maximum decrease in the Aikake Information Criterion (AIC). Because it is possible that CPUE trends were different for each *sub-area*, *tow type,* and *target species*, interactions between these variables and *fishing year* were also tested for inclusion in the model. Predictor variables were accepted into the final model if they explained at least 0.5% of the deviance and their predicted effects were sensible.

Table 3: Predictor variables used included in the standardised CPUE analysis.

Variable	Type	Comment	Variable	Type	Comment
Fishing year	Categorical	Forced into the model	Bottom depth	3rd order polynomial	–
Vessel	Categorical	Vessel key	Target species	Categorical	–
Sub-area	Categorical	i.e., hill	Duration	3rd order polynomial	–
Tow type	Categorical	Hill short or Near-hill short	Distance	3rd order polynomial	From speed and duration
Month	Categorical	–	Kw	3rd order polynomial	Vessel engine power
Fishing day	3rd order polynomial	Day of the fishing year	Tonnes	3rd order polynomial	Gross tonnage of vessel
Time	3rd order polynomial	Time of day tow was shot	Edits	Categorical	Type of data edit made

3. RESULTS

3.1 Overall fishery

In recent years, when the species code CDL was to be used specifically for black cardinalfish, the catches recorded to other cardinalfish species codes were found to be very small (Table 4). If this was the case in the period 1/10/1991 to 15/07/1999 (which seems a reasonable assumption), any bias caused by changes in the meaning of the species code CDL over time has been small. Some catches of EPT were recorded in 1994 (1.6 t), but this was actually during the period when CDL should have been used for all cardinalfish species. It seems likely that commercial catches of cardinalfish species other than black cardinalfish have been minimal, and in subsequent analyses only catches recorded as CDL have been used, and will be referred to as *black cardinalfish.*

Table 4: Total estimated catch (t) of cardinalfish by species code and form type for the period 1999–00 to 2004–05. The present meaning of the species codes are CDL, *Epigonus telescopus*; EPD, *Epigonus denticulatus;* EPL, *Epigonus lenimen;* EPR, *Epigonus robustus;* EPT, *Epigonus telescopus* (intended for research use only); HOW, *Howella brodiei.*

Form type	CDL	EPD	EPL	EPR	EPT	HOW
TCEPR	13 547.0	0	1.3	2.6	0	0
CELR	129.5	0	0.1	0	0	0
Total	13 676.5	0	1.4	2.6	0	0

Almost all catches have been made from trawls (Table 5). Except for 1991–92 and 1992–93, over 95% of the estimated catches were reported from bottom trawls.

Table 5: Estimated catches (t) of black cardinalfish by fishing method and by form type from 1990–91 to 2004–05.

	TCEPR		CELR				
Fishing year	Bottom trawl	Midwater trawl	Bottom trawl	Midwater trawl	Setnets	Lines	Other
1990–91	2 888.9	45.7	1 246.7	25.4	3.3	0.9	0.1
1991–92	1 219.2	247.8	163.5	1.4	0.3	2.8	0
1992–93	1 865.0	145.9	148.3	0.8	<1	0.8	0
1993–94	3 662.7	63.1	128.2	46.1	0.1	1.2	12.7
1994–95	3 213.2	73.3	225.4	0	<1	0.7	0
1995–96	3 152.2	16.6	271.4	0	0	1	0
1996–97	3 995.6	52.5	287.2	0	0	0.1	0
1997–98	2 275.6	58.5	61	2.5	0	0.2	0
1998–99	2 201.4	56.4	67.8	0.2	0	0.3	3.6
1999–00	3 031.8	32.2	90.9	5.1	0	0.4	0
2000–01	2 253.8	1.2	0	6.6	0	0.3	0
2001–02	2 326.8	55.4	0.2	0.7	0	0.9	0
2002–03	2 670.8	57.1	4.8	0.9	0	0.3	2.2
2003–04	1 653.3	78.1	<1	<1	0	0.1	0
2004–05	1 343.7	42.9	14.2	1.2	0	0.6	0

For 1990–91 to 2004–05, the TCEPR data set described about 93% of the estimated catches, and about 85% of the reported catches (Table 6). Some of the discrepancy between the estimated and reported landings may be because only the top five most abundant species are required to be recorded on TCEPR forms, and in some cases black cardinalfish may have been caught, but were not amongst the top five. Nevertheless, because the TCEPR data describe at least two-thirds of the catch in all years they should be representative of the fishery. All subsequent analyses therefore use only the more detailed TCEPR data, unless specified.

Table 6: Estimated catch of black cardinalfish by form type (TCEPR or CELR), and the reported catch reproduced from the Fisheries Plenary Report (to the nearest t, MFish 2006) for 1990–91 to 2004–05.

Fishing year	TCEPR	CELR	Proportion TCEPR	Reported catch	TCEPR as proportion of reported catch
1990–91	2 934.6	1 276.3	0.70	4 311	0.68
1991–92	1 467.0	168.1	0.90	1 838	0.80
1992–93	2 010.8	149.9	0.93	2 366	0.85
1993–94	3 725.8	188.2	0.95	3 801	0.98
1994–95	3 286.5	226.1	0.94	3 710	0.89
1995–96	3 168.7	272.5	0.92	4 490	0.71
1996–97	4 048.1	287.3	0.93	4 567	0.89
1997–98	2 334.1	63.7	0.97	2 743	0.85
1998–99	2 257.8	71.9	0.97	1 921	1.18
1999–00	3 064.0	96.4	0.97	4 377	0.70
2000–01	2 254.9	6.9	1.00	2 213	1.02
2001–02	2 382.1	1.8	1.00	2 839	0.84
2002–03	2 727.9	8.2	1.00	2 996	0.91
2003–04	1 731.4	0.2	1.00	1 785	0.97
2004–05	1 386.6	16.0	0.99	1 683	0.82

Estimated catches of black cardinalfish have fluctuated, but overall show a slow decline, and catches in the most recent year, 2004–05, were the lowest since 1990–91 (Table 7). The absolute values and trends in estimated catches were generally similar to the reported catches for the largest fisheries, which have been in QMAs 1, 2, & 3 (except for QMA 1 in 1998–99, Tables 7 & 8). The correspondence between estimated and reported catches was poorer for fisheries in other areas. In 2004–05, only about 40% of the TACC was caught, and the TACC has never been restrictive (Table 7).

Table 7: Estimated catches (to the nearest tonne) of black cardinalfish by QMA from TCEPR forms. The Total Allowable Commercial Catch (TACC) is shown in the last row, and came into effect on 1 October 1998 (the 1998–99 fishing year). ET includes all TCEPR catches which could not be allocated to a QMA.

Fishing year	1	2	3	4	5	6	7	8	9	10	ET	Total
1990–91	0	2 354	524	5	2	0	<1	0	0	0	48	2 934
1991–92	0	1 241	184	14	<1	0	15	0	0	0	11	1 467
1992–93	0	1 362	399	<1	0	0	1	<1	0	0	248	2 011
1993–94	98	2 368	140	3	3	0	39	0	0	3	1 071	3 726
1994–95	1 078	1 882	49	1	0	0	18	6	0	0	251	3 286
1995–96	1 284	1 536	21	4	8	0	30	0	<1	6	279	3 169
1996–97	1 872	1 621	41	8	0	0	26	0	0	0	480	4 048
1997–98	1 088	1 024	41	13	0	1	25	0	<1	<1	142	2 334
1998–99	621	1 057	160	32	0	0	20	0	<1	<1	367	2 258
1999–00	859	1 820	187	19	0	<1	14	0	9	2	154	3 064
2000–01	214	1 061	91	28	58	0	<1	0	18	0	785	2 255
2001–02	374	1 614	137	13	12	0	<1	0	3	0	228	2 382
2002–03	529	1 711	169	64	2	0	25	0	2	0	226	2 728
2003–04	454	947	90	126	21	0	<1	0	4	0	89	1 731
2004–05	198	926	41	34	<1	<1	2	0	9	0	176	1 387
TACC	1 200	2 223	196	5	2	1	39	0	4	–	–	3 760

Table 8: Estimated catches from TCEPR forms (Table 6) as a proportion of the reported catches by QMA given in Table 2 on page 87 of MFish (2006). MFish (2006) give no catches for QMA 10.

Fishing year	1	2	3	4	5	6	7	8	9	ET
1990–91	0.00	0.68	0.88	4.69	0.53	-	0.18	0.00	-	-
1991–92	0.00	0.75	1.26	4.86	0.74	0.00	1.37	-	-	0.64
1992–93	0.00	0.88	0.77	0.30	0.00	-	0.62	-	-	0.92
1993–94	0.27	1.03	0.51	0.32	0.55	-	6.47	-	-	1.29
1994–95	0.93	0.85	0.97	0.16	0.00	0.00	0.35	-	0.00	1.09
1995–96	0.91	0.59	0.37	1.11	0.84	-	1.17	-	-	0.82
1996–97	0.94	0.85	0.41	1.09	-	-	0.95	-	-	0.92
1997–98	1.09	0.87	1.01	0.04	-	-	0.33	-	0.01	0.35
1998–99	25.86	0.83	0.89	0.79	-	0.00	1.23	0.00	0.10	0.94
1999–00	0.88	0.84	0.87	0.53	0.00	0.00	0.53	-	9.35	0.16
2000–01	0.73	0.93	0.92	0.81	0.78	0.00	0.01	-	6.05	1.38
2001–02	0.82	0.95	0.94	0.46	0.69	0.00	0.11	-	0.68	0.47
2002-03	0.91	0.93	0.98	0.80	0.18	0.00	0.94	-	0.42	0.82
2003-04	0.94	0.98	0.94	0.85	0.78	0.00	0.06	-	0.72	1.53
2004-05	0.74	0.84	0.95	0.70	0.01	0.70	0.79	-	9.38	0.86

The areas fished in the last two years are similar to those fished in previous years, with no large and new fisheries having developed (Figure 3) (Dunn 2005) although there were some relatively large catches on the north Chatham Rise, just to the east of the 180° hills in 2003-04.

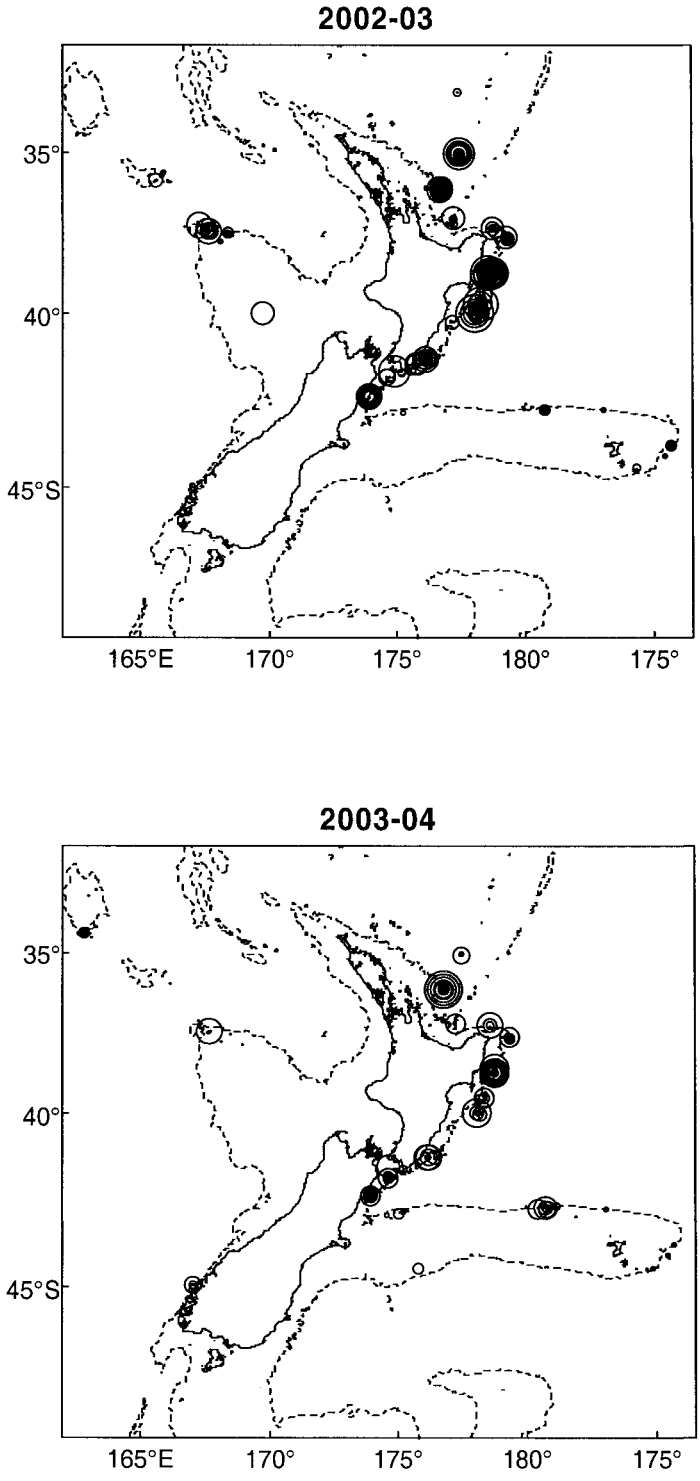

Figure 3: Unstandardised estimated catch rates (t/tow) of black cardinalfish by fishing year, for tows from all trawls by fishing year, with circle area proportional to catch rate (maximum = 71 t/tow), with the 1 000 m isobath shown by the broken line.

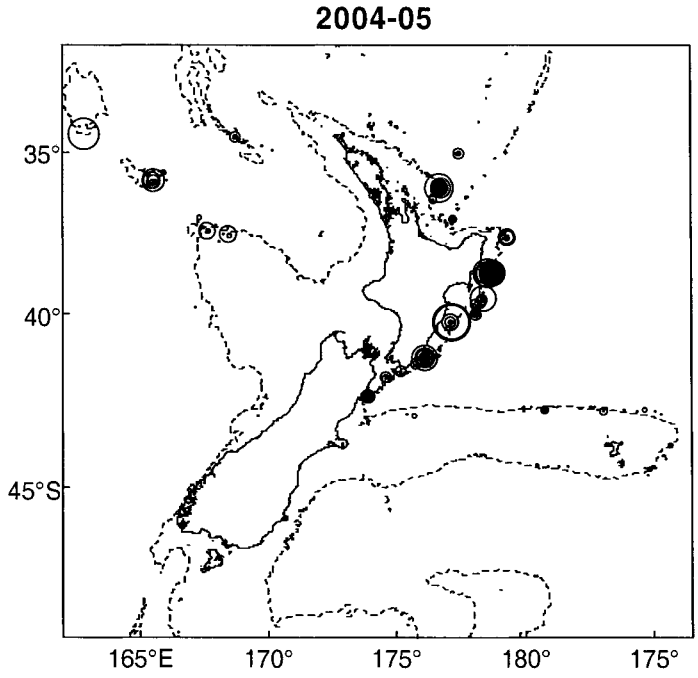

Figure 3 (cont.): Unstandardised estimated catch rates (t/tow) of black cardinalfish by fishing year, for tows from all trawls by fishing year, with circle area proportional to catch rate (maximum = 71 t/tow), with the 1000 m isobath shown by the broken line.

Estimated catches in the Kaikoura, Wairarapa, and Bay of Plenty areas declined over the last three fishing years (Table 9). Estimated catches for East Coast remained much the same in the last two fishing years, but these catches were about half those for the two previous years. The areas defined by Dunn (2005) include just over 98% of the total estimated catch from 1990–91 to 2004–05.

Table 9: Estimated catches (t) of black cardinalfish by fishery area (t) and fishing year from TCEPR records.

Fishing year	Kaikoura	Wairarapa	East Coast	Bay of Plenty	Other EEZ	North Challenger and Lord Howe	Other ET
1990–91	522	69	2 285	0	9	NA	49
1991–92	180	208	1 031	0	37	10	0
1992–93	464	245	1 088	0	22	175	17
1993–94	162	384	1 982	98	30	1062	8
1994–95	118	270	1 544	1 078	25	207	44
1995–96	21	82	1 446	1 284	61	244	30
1996–97	72	347	1 245	1 872	33	451	29
1997–98	39	29	986	1 087	50	142	0
1998–99	155	127	913	621	74	316	51
1999–00	207	161	1 630	858	53	152	2
2000–01	84	196	863	214	112	485	300
2001–02	168	163	1 399	374	50	159	69
2002-03	182	266	1 429	529	95	224	2
2003-04	129	167	730	453	163	42	47
2004-05	51	123	788	198	50	118	57

The relatively large catch (163 t) from other areas of the EEZ in 2003–04 was mostly from the Chatham Rise, in the area just to the east of 180° (Figure 3). Catches were relatively low in recent years from the North Challenger and Lord Howe.

About 80% of the estimated catch of black cardinalfish in recent years has been from tows recording black cardinalfish as the target species, reaching a maximum of 82% in 2004–05 (Table 10). This is in contrast to the mid 1990s, when about 60% of the estimated catch was taken in the target fishery. This suggests black cardinalfish have been less frequently taken as a bycatch in recent years, or alternatively that targeting has increased.

Table 10: Estimated catch (to the nearest t) of black cardinalfish by target species and fishing year, with the % of black cardinalfish caught in the target fishery.

Fishing year	Bluenose	Alfonsino	Black cardinalfish	Hoki	Orange roughy	Oreos	Other	% target fishery
1990–91	2	41	2 083	275	461	73	<1	71
1991–92	<1	246	734	67	419	<1	0	50
1992–93	<1	222	742	227	818	0	3	37
1993–94	0	166	1 273	34	2 221	30	2	34
1994–95	3	273	1 984	3	1 018	3	3	60
1995–96	0	115	1 795	40	1 170	48	0	57
1996–97	25	139	2 154	157	1 487	66	0	53
1997–98	<1	46	1 362	53	854	19	0	58
1998–99	<1	48	1 332	197	675	0	6	59
1999–00	31	18	2 100	271	642	<1	1	69
2000–01	14	44	1 429	221	546	<1	<1	63
2001–02	0	22	1 950	163	246	0	<1	82
2002-03	1	69	2 231	277	149	<1	<1	82
2003-04	19	106	1 318	153	135	<1	0	76
2004-05	6	24	1 140	90	124	1	2	82

Table 11: Estimated catch, and effort statistics including catch rate, by fishing year, for all tows catching black cardinalfish.

Fishing year	No. vessels	No. tows	Catch (t)	% tows target CDL	% CDL target tows zero catch	Median duration	Tonnes per tow
1990–91	18	589	2 935.7	65	54	50	5.41
1991–92	19	405	1 467.0	42	62	44	4.29
1992–93	32	552	2 010.8	37	56	40	3.65
1993–94	39	1 045	3 726.3	37	62	40	3.31
1994–95	35	896	3 286.5	64	46	35	3.49
1995–96	37	1 234	3 168.7	77	51	32	1.90
1996–97	34	1 306	4 048.1	73	57	27	2.27
1997–98	33	1 124	2 334.1	65	55	32	1.87
1998–99	42	1 460	2 257.8	63	62	47	1.46
1999–00	42	1 687	3 064.1	64	52	33	1.93
2000–01	34	1 131	2 254.9	66	49	25	1.92
2001–02	30	1 180	2 382.1	70	53	22	2.37
2002-03	32	1 680	2 730.6	73	52	20	1.82
2003-04	34	1 067	1 731.6	59	58	20	2.09
2004-05	30	1 287	1 387.4	66	59	20	1.35

In 2004–05, the overall number of tows catching black cardinlfish was close to the average over the last 10 years, but the estimated catch was relatively low, and consequently the

unstandardised catch rate was low, in fact the lowest on record (Table 11). The percentage of tows catching black cardinalfish which targeted the species has remained fairly constant, as has the percentage of targeted tows which failed to catch any black cardinalfish.

The median duration of tows catching black cardinalfish has roughly halved since the early 1990s (Table 11). This move towards shorter tows has been consistent on the hills, near hills, and flat areas, although the overall proportion of effort in each of these areaa has remained much the same (Figure 4). This change in tow duration could be associated with increased targeting of specific high density acoustic marks.

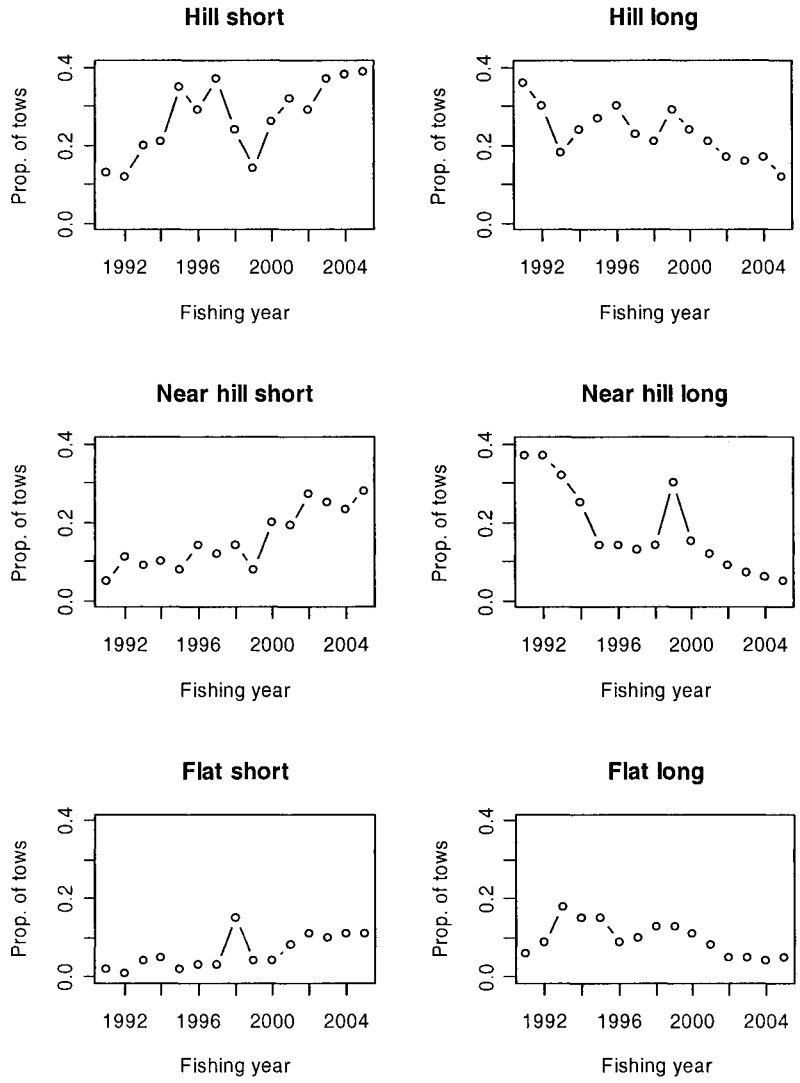

Figure 4: The proportion of tows catching black cardinalfish by tow duration and area fished (see Section 2.2 for definitions), and by fishing year (shown labelled as year ending, i.e., 1992 means 1991–92).

The hills have been the focus for the black cardinalfish fishery, with about 80% of the catch in 2004–05 taken on or near hill features, and most catches taken in short tows on the hills (Figure 5).

The proportion of the estimated catch of black cardinalfish taken in each tow type has shown similar trends to effort (Figure 5), with little change between the proportion of hill, near-hill, and flat tows, but an increase in the proportion of the catch taken from short tows.

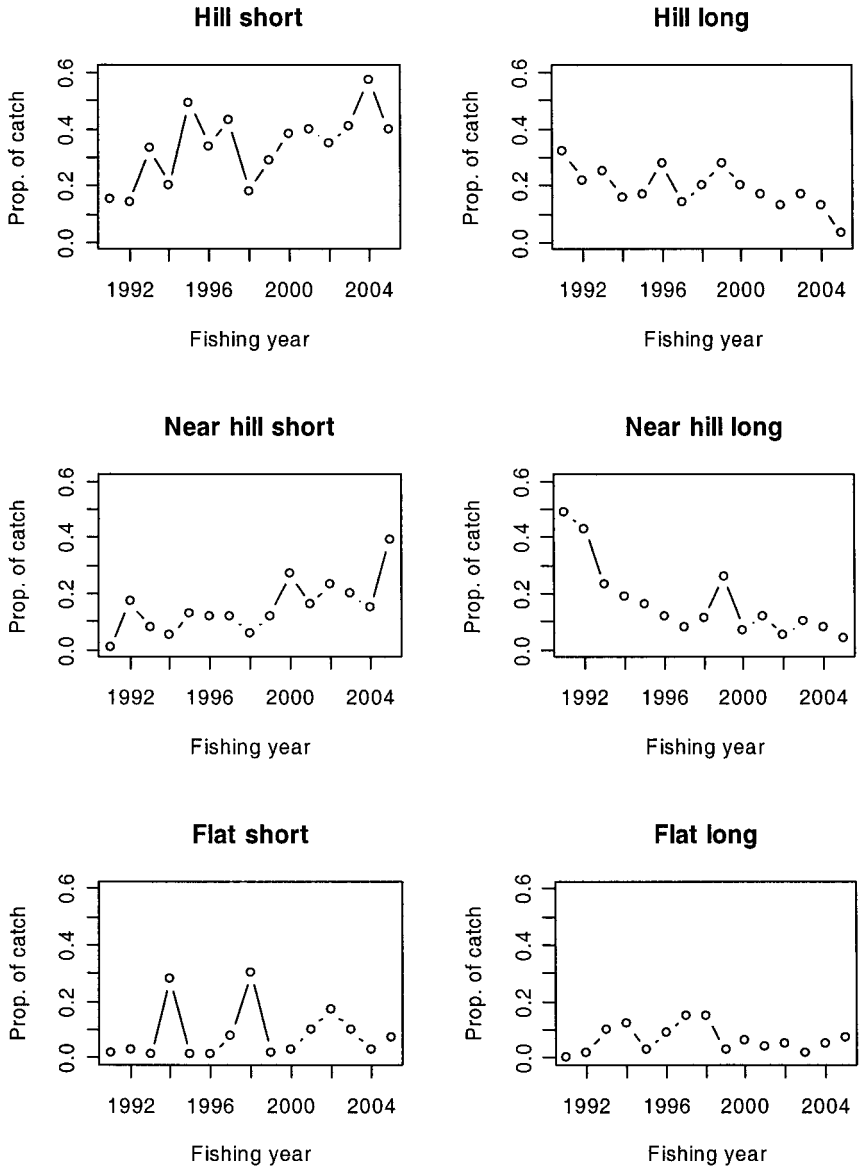

Figure 5: The proportion of black cardinalfish catch by tow duration and area fished (see Section 2.2 for defintions), and by fishing year (shown labelled as year ending, i.e., 1992 means 1991–92).

The catches taken on or near hills and in short tows have come from about 10 specific and discrete areas, focused on and around known hills or groups of hills off the east coast of the North Island, in the Bay of Plenty, and on the north Challenger Plateau (Figures 6 & 7).

The fishery for orange roughy has been the most valuable deepwater trawl fishery in New Zealand waters, and the areas where black cardinalfish have been caught are also the site of targeted orange roughy fishing (Anderson & Dunn 2006). Although the TACC has not limited catches for black cardinalfish, the TACCs for orange roughy have been limiting in QMA 2 since 2000–01.

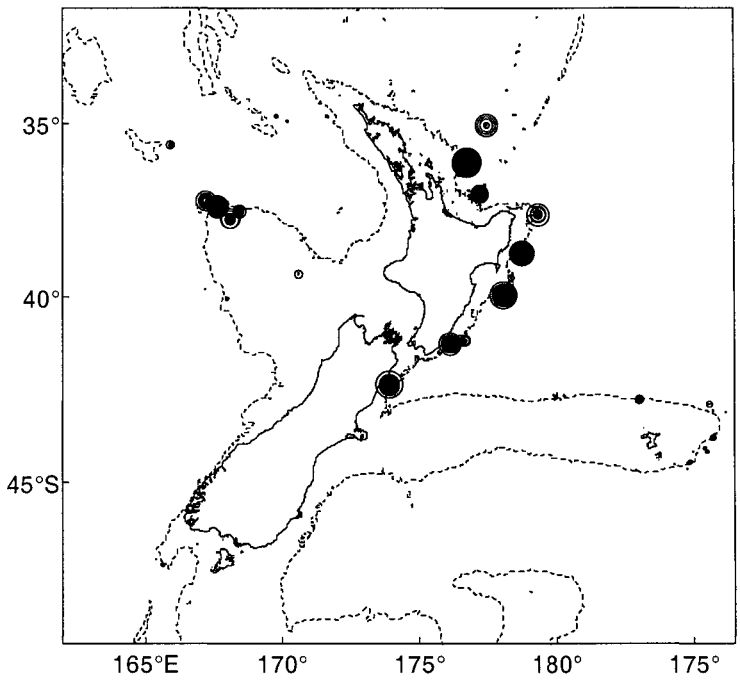

Figure 6: Catch rate of black cardinalfish of tow type *hill short*, for the fishing years 1990–91 to 2004–05 inclusive. Catch rate proportional to circle size, maximum 85 t/tow.

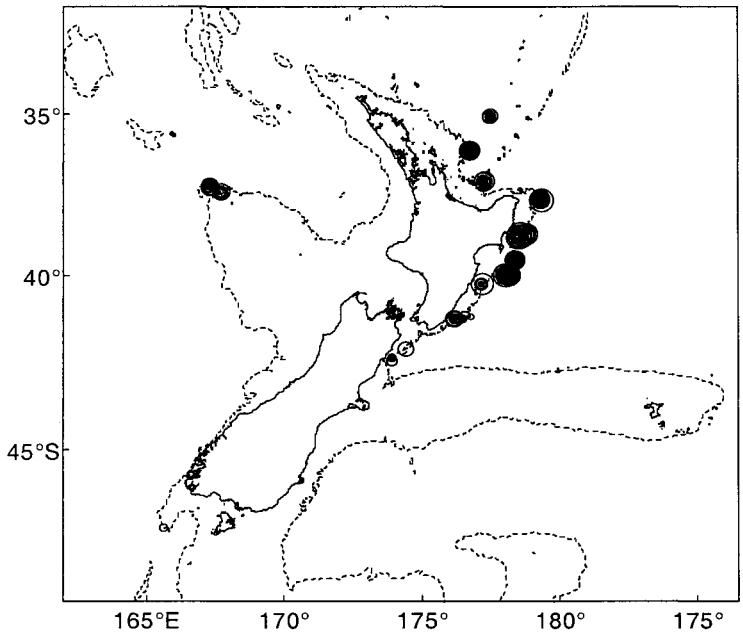

Figure 7: Catch rate of black cardinalfish of tow type *near hill short*, for the fishing years 1990–91 to 2004–05 inclusive. Catch rate proportional to circle size, maximum 90 t/tow.

In QMA 2 (referred to as the Mid-East Coast orange roughy fishery) the orange roughy catches were usually taken steadily from October until April, then relatively large catches were made in May and June, and in recent years (2000–01 and from 2002–03) the TACC has then been taken by the end of June, and fishing has stopped during the last two or three months of the fishing year (Figure 8). The same general pattern of catches has been observed for the black cardinalfish fishery in QMA 2, even though the TACC for this species was never reached.

This suggests the black cardinalfish fishery in QMA 2 was effectively limited by the orange roughy TACC. The exception was 2002–03, when some black cardinalfish catches were taken after the orange roughy TACC was reached. In 2002–03 the orange roughy catch did not increase in this period, suggesting that black cardinalfish were targeted.

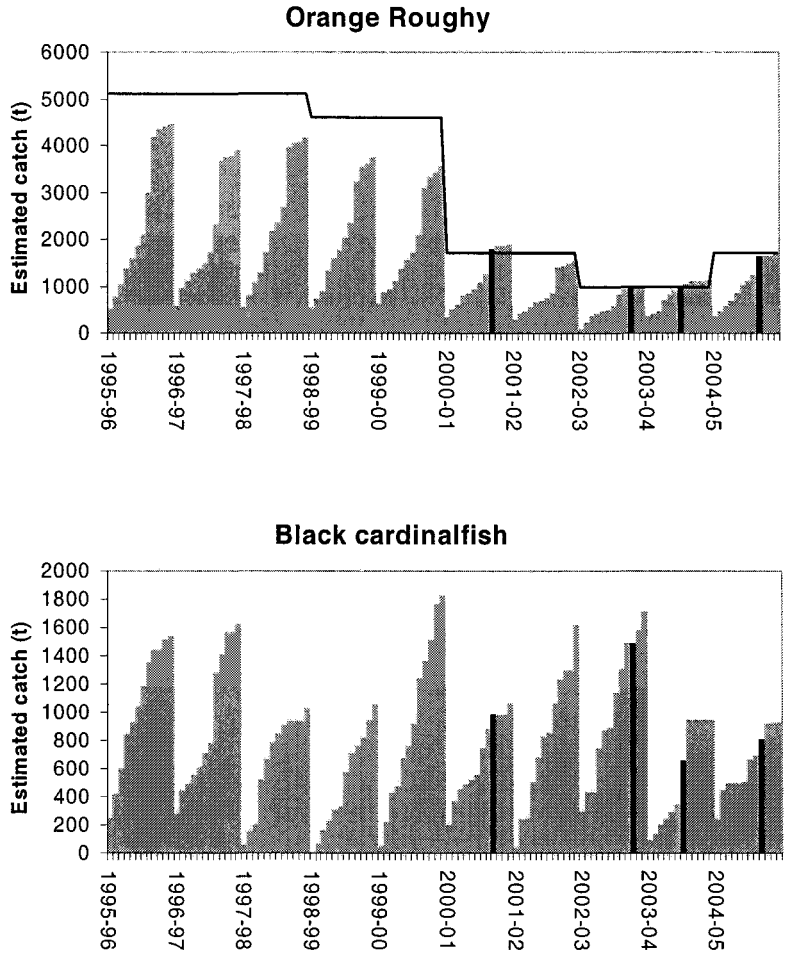

Figure 8: Cumulative catch (bars) in each fishing year for orange roughy and black cardinalfish in QMA 2, showing the TACC for orange roughy (solid line in upper panel), and the month in which the cumulative catch came within 5% of the TACC each year is shown as a dark bar.

The following sections are an update of Dunn (2005), but focusing on the status of the fishery in the last two years. More details of the fishery before then were given by Dunn (2005).

3.3 Kaikoura

In the previous fishery description (Dunn 2005), the Kaikoura fishery was largely a bycatch in the hoki fishery. There was very little targeting of black cardinalfish, but catches and bycatch rates of black cardinalfish in fisheries targeting other species had been increasing.

Catches of black cardinalfish have decreased since 2002–03, with the catch in 2004–05 the lowest since 1997–98. There has been little change in the structure of the fishery over the last 3 years: most black cardinalfish were still caught as a bycatch in the hoki fishery (Table 12), and the fishery took place in the same areas (Figure 9) and depths (Figure 10) as before.

Table 12: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the Kaikoura fishery.

Fishing year	Alfonsino	Cardinalfish	Hoki	Oreos	Orange roughy	Smooth oreo
1990–91	0	277.4	148.4	0	23.8	72.9
1991–92	0	57.2	51.4	0	70.8	0.5
1992–93	1.8	0.9	213	0	247.9	0
1993–94	0.8	4	4.4	30	122.4	0
1994–95	33.7	0	2.8	2.5	79.1	0
1995–96	0	0	20.5	0	0.3	0
1996–97	0	21.5	50.3	0.2	0	0
1997–98	0	0	39.2	0	0	0
1998–99	0	0	140.7	0	14	0
1999–2000	0	32.7	174.1	0	0	0
2000–01	0	0	84.1	0	0	0
2001–02	0	24	144.1	0	0	0
2002–03	0	0.4	181.6	0	0	0
2003–04	0	12.4	116.6	0	0.1	0
2004–05	0	1.9	49.4	0	0	0

Table 13: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the Kaikoura fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1990–91	5	84	277.4	0.48	3.3
1991–92	2	19	57.2	0.68	3.0
1992–93	2	7	0.9	0.57	–
1993–94	2	5	4	0.4	–
1994–95	2	4	0	1	–
1995–96	2	7	0	0.71	–
1996–97	4	14	21.5	0.36	1.5
1997–98	2	6	0	1	–
1998–99	2	2	0	1	–
1999–2000	3	14	32.7	0.5	2.3
2000–01	0	–	–	–	–
2001–02	2	3	24	0.67	–
2002–03	1	1	0.4	0	–
2003–04	2	2	12.4	0	–
2004–05	3	8	1.9	0.62	–

Most of the catch was still taken between November and April, but relatively large catches have also been reported in recent years for August, September, and October, with some catch also taken in May (Figure 11).

The peak in catch and catch rate at depths of 200–400 m may be an artefact where gear depth was reported as bottom depth during midwater fishing, but this was not resolved (Figure 10).

There were insufficient data to calculate unstandardised CPUE for the black cardinalfish target fishery, and targeted effort remains very low (Table 13).

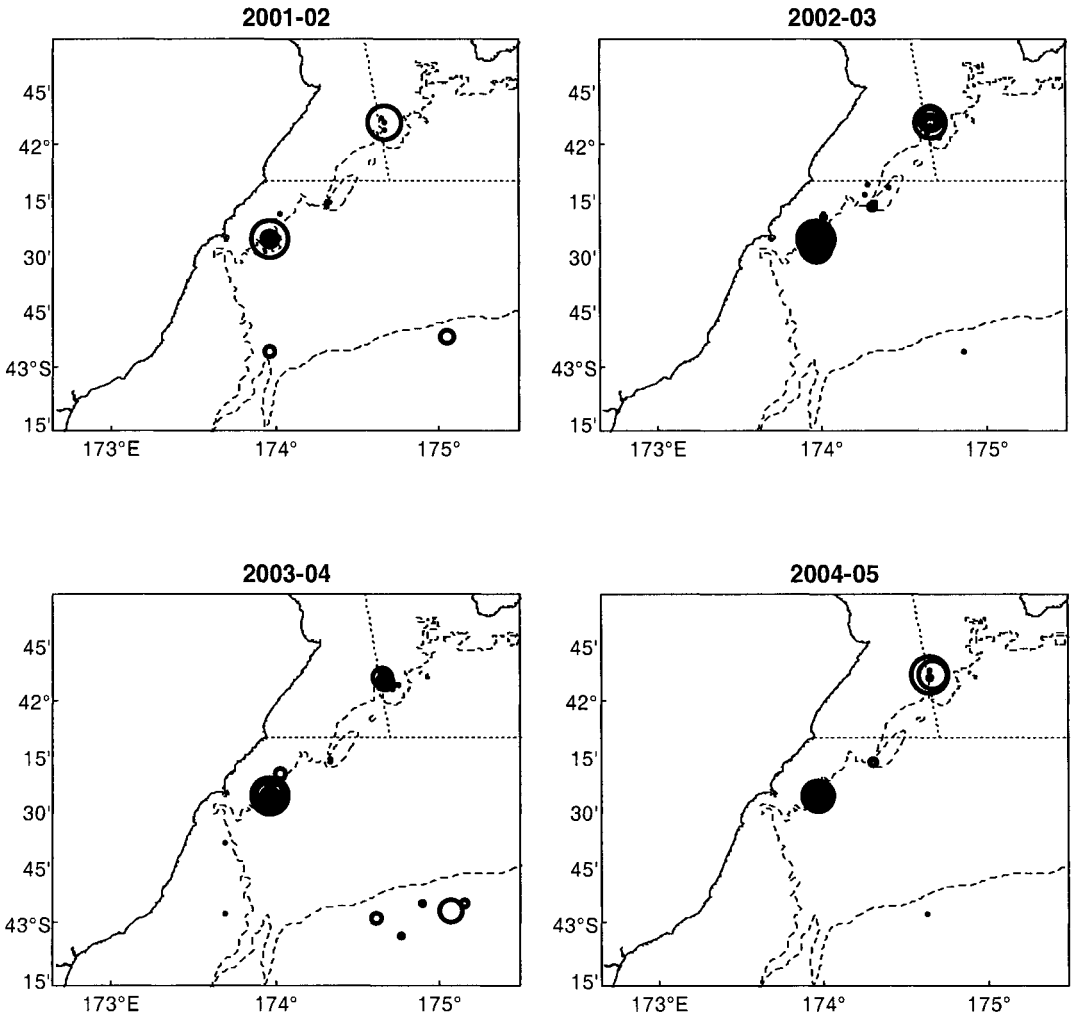

Figure 9: Estimated trawl catch rate (t/tow) of black cardinalfish by fishing position and fishing year for the Kaikoura fishery, for all tows catching black cardinalfish. Catch rate proportional to circle area (maximum 85 t/tow).

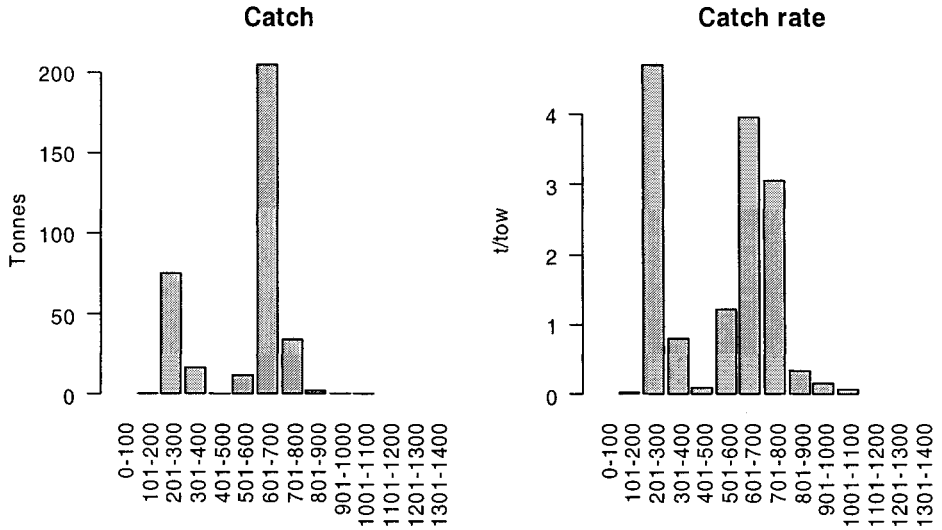

Figure 10: Total estimated catch (left panel) and catch rates (right panel) by depth class for the Kaikoura fishery, for all tows catching black cardinalfish, over the period 2002–03 to 2004–05.

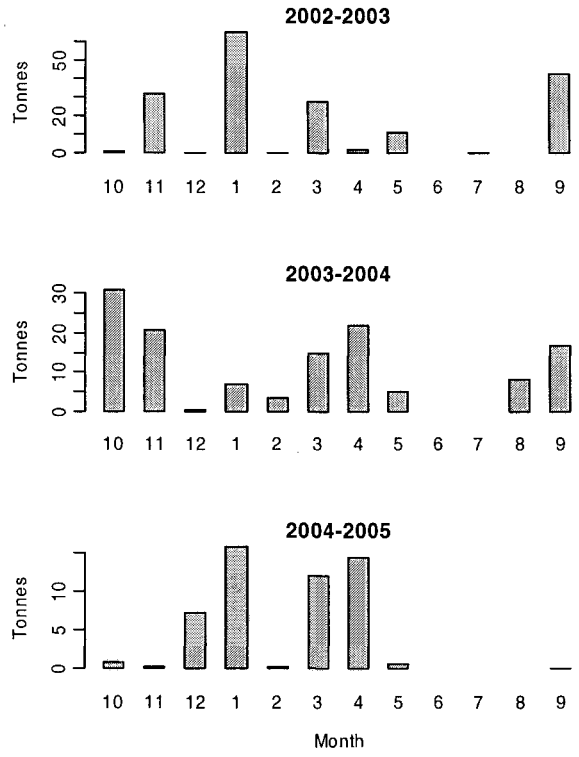

Figure 11: Estimated catch by month and fishing year, for all tows catching black cardinalfish in the Kaikoura fishery.

3.4 Wairarapa

In the previous fishery description (Dunn 2005), the Wairarapa fishery was largely a bycatch in the alfonsino fishery and later a target fishery. It was focused on three main areas, at depths of 400–900 m, and throughout the year but with relatively low catches in July and August. The estimated catch, and the proportion of the estimated catch taken in the target fishery, had both been increasing, reaching a maximum in 2002–03. Catch rates had been variable, but were relatively high in 2002–03.

Table 14: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the Wairarapa fishery.

Fishing year	Bluenose	Alfonsino	Cardinalfish	Capro dory	Hoki	Oreos	Orange roughy	Warehou
1990–91	2.3	0.2	1.6	0	15	0	50.1	0
1991–92	0	28.7	62	0	5.3	0	112	0
1992–93	0	99.7	125.3	0	0	0	20.2	0
1993–94	0	78.4	130.9	0	22.8	0	151.7	0
1994–95	0	173.7	63.1	0	0.1	0	33	0
1995–96	0	2.3	50.3	0	4.9	0	24.3	0
1996–97	25	20.1	209.1	0	64.3	2.1	6.3	0
1997–98	0	2.2	18.6	0	3.8	0	4.8	0
1998–99	0	0	107.8	0	8.7	0	5.1	5.8
1999–2000	31	0	112.2	0	12.7	0	5.2	0
2000–01	10	42	94.4	0	47.2	0	2.9	0
2001–02	0	18.6	128	0.2	15.7	0	0.5	0
2002–03	0	32	228.9	0	5.4	0	0	0
2003–04	0	3.5	152.5	0	5.4	0	5.2	0
2004–05	0	9.5	76.8	0	36.2	0	0.5	0

Table 15: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the Wairarapa fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1989–90	1	5	0	1	–
1990–91	6	28	1.6	0.71	0.1
1991–92	5	36	62	0.75	1.7
1992–93	8	55	125.3	0.64	2.3
1993–94	6	107	130.9	0.82	1.2
1994–95	5	39	63.1	0.82	1.6
1995–96	7	84	50.3	0.57	0.6
1996–97	9	90	209.1	0.63	2.3
1997–98	6	31	18.6	0.52	0.6
1998–99	9	57	107.8	0.47	1.9
1999–2000	11	72	112.2	0.54	1.6
2000–01	9	83	94.4	0.54	1.1
2001–02	9	85	128	0.66	1.5
2002–03	7	103	228.9	0.48	2.2
2003–04	7	54	152.5	0.67	2.8
2004–05	7	47	76.8	0.77	1.6

Most black cardinalfish were still caught in the target fishery (Table 14). Catches of black cardinalfish declined after the peak in 2002–03, and in 2004–05 were the lowest since 1997–98 (Table 14).

The targeted effort more than halved, and the proportion of target tows with zero catch conversely increased, with over three-quarters of the target tows producing no catch in 2004–05 (Table 15). Catch rates were relatively high for the last three fishing years (Table 15).

Over the last three fishing years the fishery has been focused on one main feature (Figure 12), a seamount with a surface depth of 500 m, and an elevation of just over 500 m. Effort and catch rates in an area to the south of this (called "south" by Dunn 2005) and also on the bank to the east (called "offshore" by Dunn 2005) have both declined.

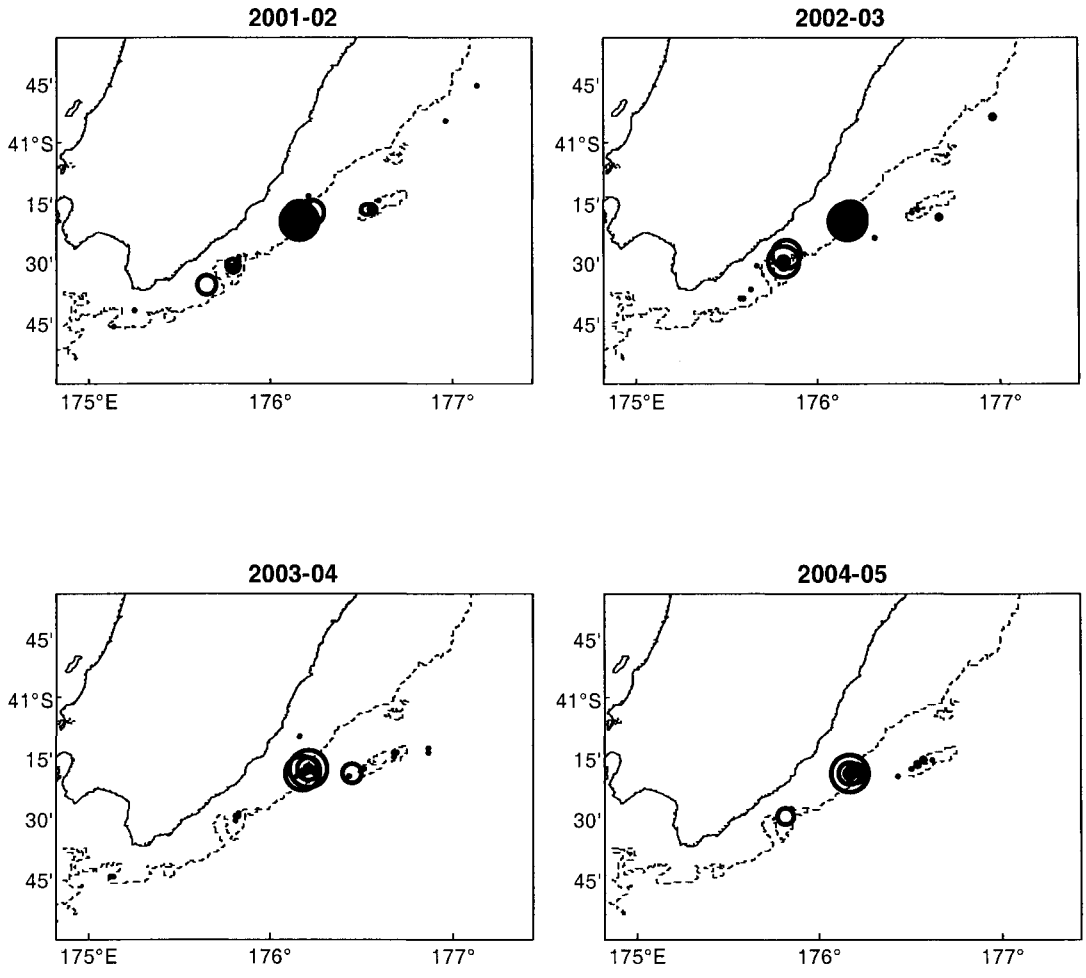

Figure 12: Estimated trawl catch rate (t/tow) of black cardinalfish by fishing position and fishing year for the Wairarapa fishery, for tows targeting black cardinalfish. Catch rate proportional to circle area (maximum 85 t/tow).

The fishery is still focused at depths of 400–700 m, with a peak in catches at 500–600 m (Figure 13).

In earlier years the fishery took place throughout the year, with low catches in July and August (Dunn 2005). Since 2002–03 the fishery has been more active during the summer months, with the greatest catch taken between October and April (Figure 14).

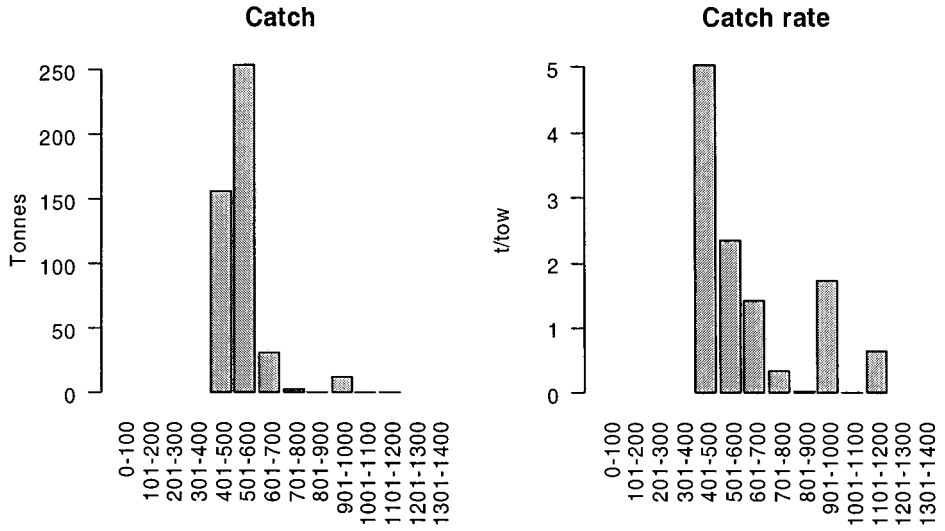

Figure 13: Total estimated catch (left panel) and catch rates (right panel) by depth class for the Wairarapa fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

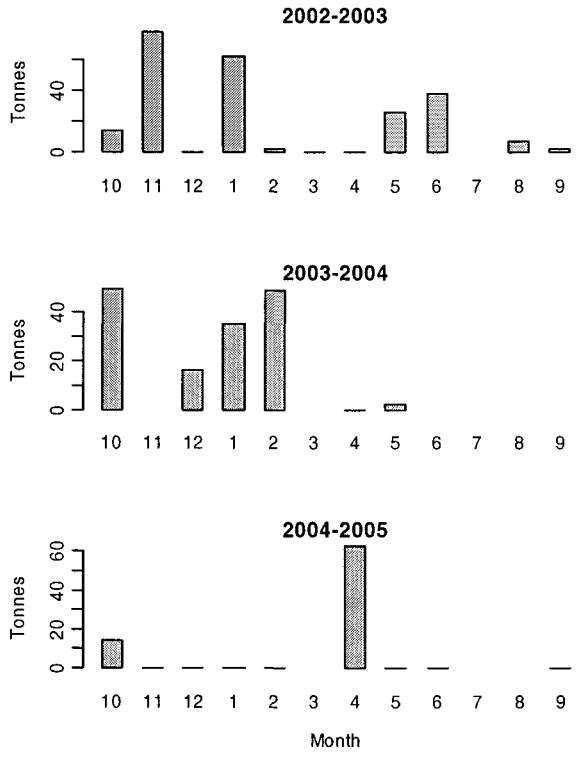

Figure 14: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the Wairarapa fishery.

3.5 East Coast

The East Coast fishery has provided the greatest catches, and was split into three areas by Dunn (2005). These were, from north to south, East Cape, Tuaheni, and Ritchie and Rockgarden.

Of the three areas, the largest catches were made in Tuaheni, and the smallest in East Cape (Dunn 2005). The catches from the target fishery at East Cape were increasing, greatest between January and April, and greatest at a depth of 600–699 m. The catches from the fishery at Ritchie and Rockgarden showed no clear trend, and were slightly deeper, with most at a depth of 700–799 m, and largest between November and May. The catches at Tuaheni were increasing, in recent years largely a winter fishery (between April and November), and were taken over a wider depth range than the other areas.

In the last three fishing years, the catches of black cardinalfish from East Cape were still mostly taken from the target fishery (Table 16). The trend of increasing catches reversed, with catches in 2004–05 only about 30 t, and catch rates were also relatively low (Table 17).

Table 16: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the East Cape fishery.

Fishing year	Alfonsino	Cardinalfish	Capro dory	Oreos	Orange roughy
1993–94	0	34.2	0.2	0	254.8
1994–95	0.1	174.2	0	0	408.6
1995–96	70.3	320.9	0	0	322.1
1996–97	0	81.2	0	0	50.9
1997–98	0	162.4	0	10	27.6
1998–99	0	127.9	0	0	78.6
1999–2000	0.3	95.5	0	0	93.7
2000–01	0	6.2	0	0	0.2
2001–02	0	22.6	0	0	3.1
2002–03	0	122.2	0	0	34.1
2003–04	0	42.5	0	0	50.8
2004–05	0	29.1	0	0	0.4

Table 17: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the East Cape fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1993–94	3	18	34.2	0.44	1.9
1994–95	5	71	174.2	0.48	2.5
1995–96	11	204	320.9	0.46	1.6
1996–97	9	68	81.2	0.62	1.2
1997–98	8	85	162.4	0.53	1.9
1998–99	11	81	127.9	0.64	1.6
1999–2000	8	99	95.5	0.66	1.0
2000–01	7	27	6.2	0.56	0.2
2001–02	6	24	22.6	0.54	0.9
2002–03	7	76	122.2	0.51	1.6
2003–04	5	28	42.5	0.54	1.5
2004–05	8	54	29.1	0.57	0.5

The fishery at Tuaheni has continued to be almost entirely a target fishery (Table 18), and has provided the largest catches, although catches decreased over the last two years following a peak in 2002–03 (Table 19). Although catches have decreased, catch rates remained relatively good.

Table 18: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the Tuaheni fishery.

Fishing year	Bluenose	Alfonsino	Black cardinalfish	Hoki	Oreos	Orange roughy
1990–91	0	0	1 658.6	109.5	0	15
1991–92	0	1	407.3	0	0	60
1992–93	0	0	328.6	0	0	18.4
1993–94	0	1	431.3	0	0	616.6
1994–95	0	0	579.1	0	0	99.9
1995–96	0	0	366.1	0	26.1	72.7
1996–97	0.2	19.6	447.8	11.5	63.5	141
1997–98	0	9.2	8.8	0	0	2.3
1998–99	0	0	198.4	0	0	62.1
1999–2000	0	0.2	441.5	16	0	201.1
2000–01	0	0	346	53.5	0	0.1
2001–02	0	0.2	495.1	0	0	0
2002–03	0	0.1	777.5	0	0	0
2003–04	0	26	469.6	0	0	0.2
2004–05	0	0	502.1	0	0	3.6

Table 19: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the Tuaheni fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1990–91	6	219	1 658.6	0.49	7.6
1991–92	5	48	407.3	0.58	8.5
1992–93	9	55	328.6	0.45	6
1993–94	6	99	431.3	0.51	4.4
1994–95	8	93	579.1	0.42	6.2
1995–96	9	154	366.1	0.48	2.4
1996–97	9	183	447.8	0.53	2.4
1997–98	8	47	8.8	0.72	0.2
1998–99	10	105	198.4	0.70	1.9
1999–2000	11	150	441.5	0.61	2.9
2000–01	10	136	346	0.38	2.5
2001–02	11	143	495.1	0.48	3.5
2002–03	10	275	777.5	0.54	2.8
2003–04	9	134	469.6	0.53	3.5
2004–05	10	214	502.1	0.65	2.3

In Ritchie and Rockgarden, most catches were still made in the target fishery (Table 20), and the catches declined from a peak of 860 t in 2002–03 to just 67 t in 2004–05 (Table 21). Effort also substantially reduced over the last three fishing years, and catch rates decreased to the lowest on record in 2004–05 (Table 21).

The areas fished in the last three years are similar to those described by Dunn (2005). The area to the north and west of the main fishery in East Cape (the East Cape Hills) was fished

only in 2002–03 (Figure 15). Relatively high catches were taken at the eastern end of Tuaheni during the last three years (Figure 15).

The catches at East Cape have continued to be taken at a similar depth range, largely at 601–700 m, but in the last three fishing years fewer catches were made at depths between 801–900 m, and the second peak in catches at 1101–1199 m present in early years is now absent (Figure 16). In Tuaheni the catches in the last three fishing years were taken over a wider depth range than before (Dunn 2005), and the catch rates were high over an especially wide depth range, from 400 to 1000 m (Figure 17). The catches at Ritchie and Rockgarden have become relatively shallow during the last three years, and were focused at 401–700 m rather than 700–799 m previously (Dunn 2005), with catch rates now highest at the shallow end of this range (Figure 18).

Table 20: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the Ritchie and Rockgarden fishery.

Fishing year	Bluenose	Alfonsino	Black cardinalfish	Hoki	Oreos	Orange roughy
1990–91	0	40	100.3	0	0	360.1
1991–92	0.2	203.2	186	0	0	159
1992–93	0	115.1	207.2	0	0	333.8
1993–94	0	79	60.8	0	0	357.9
1994–95	3.1	23.9	29.9	0	0	169
1995–96	0	1.1	147.5	0	0	69.5
1996–97	0	83.8	231.4	0	0	50.6
1997–98	0.1	33	600.2	0	9.3	104.6
1998–99	0	0.3	234.8	0	0	151
1999–2000	0	4.8	506.5	1.7	0	178.8
2000–01	4	0.8	363	8.5	0	36.5
2001–02	0	1.8	862.8	1	0	10.2
2002–03	0.3	20	406.5	0.7	0	1
2003–04	0	0.5	102	0	0	0.6
2004–05	0.6	2.1	66.7	0	0	11.7

Table 21: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the Ritchie and Rockgarden fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1989–1990	1	1	0	1	0
1990–91	7	53	100.3	0.79	1.9
1991–92	8	67	186	0.61	2.8
1992–93	8	69	207.2	0.62	3
1993–94	9	52	60.8	0.75	1.2
1994–95	8	34	29.9	0.56	0.9
1995–96	9	95	147.5	0.45	1.6
1996–97	8	91	231.4	0.46	2.5
1997–98	12	200	600.2	0.46	3
1998–99	14	202	234.8	0.52	1.2
1999–2000	14	204	506.5	0.5	2.5
2000–01	11	170	363	0.49	2.1
2001–02	8	285	862.8	0.47	3
2002–03	9	252	406.5	0.48	1.6
2003–04	9	57	102	0.39	1.8
2004–05	10	81	66.7	0.57	0.8

The catches from East Cape in 2002–03 were greatest between January and April, as in previous years (Dunn 2005). In 2004–05 catches were also made in May, and in 2004–05 catches were later again, and greatest in June and July (Figure 19). As in the previous few years, the catches in Tuaheni were largely during the winter, from April until November (Figure 20). In Ritchie and Rockgarden the catches had no clear seasonal pattern (Figure 21).

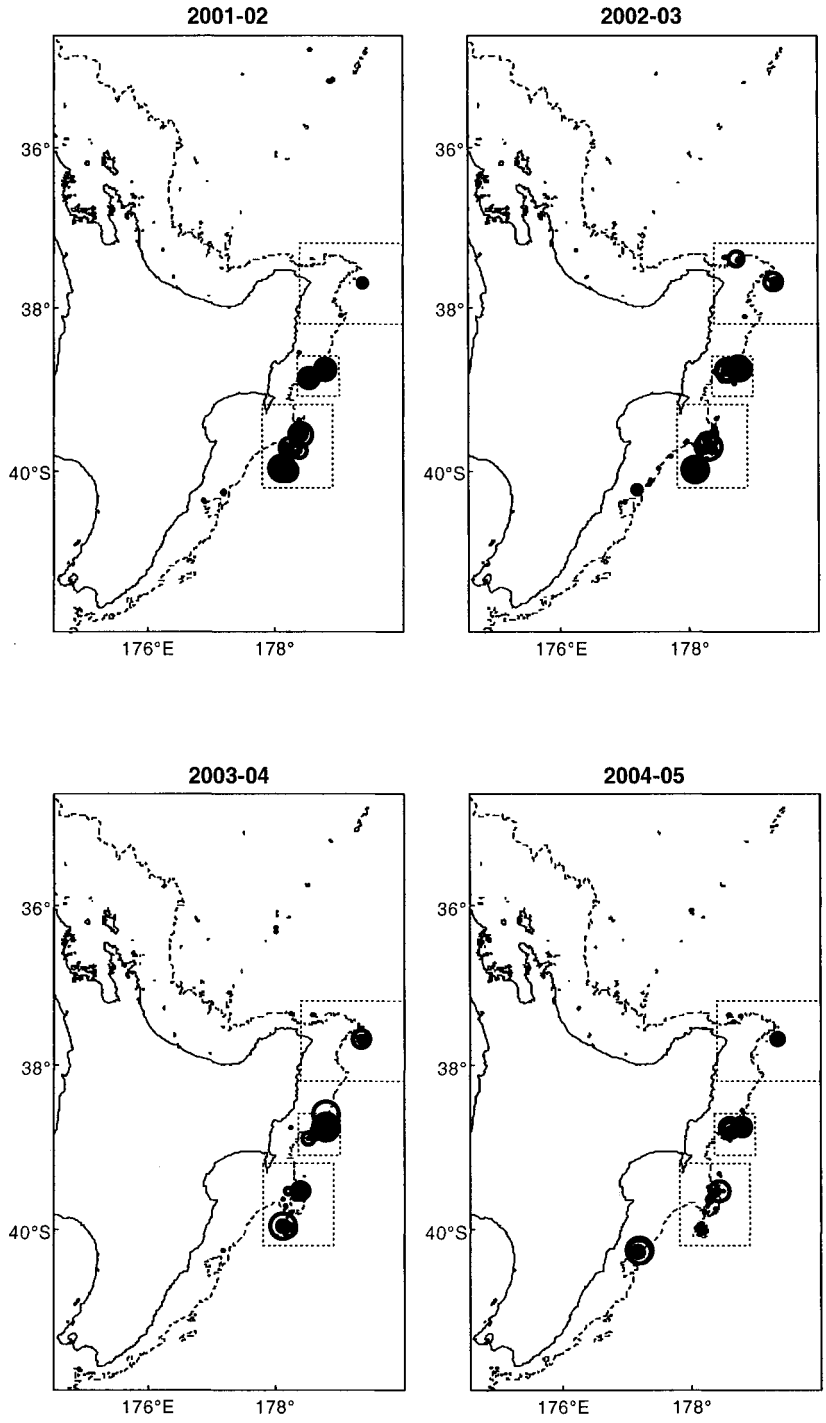

Figure 15: Estimated trawl catch rate (t/tow) of black cardinalfish by fishing position and fishing year for the East Coast fishery, for tows targeting black cardinalfish. Areas shown in boxes are (from north to south) East Cape, Tuaheni, and Ritchie and Rockgarden. Catch rate proportional to circle area (maximum 76 t/tow).

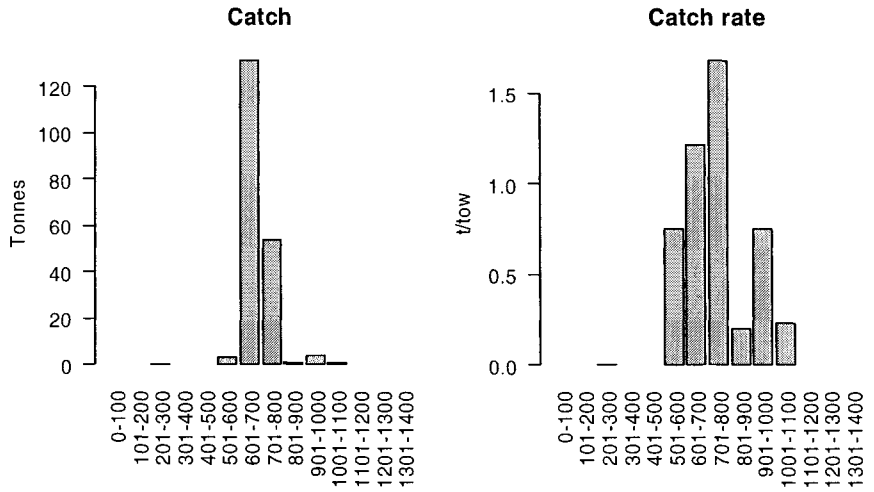

Figure 16: Total estimated catch (left panel) and catch rates (right panel) by depth class for the East Cape fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

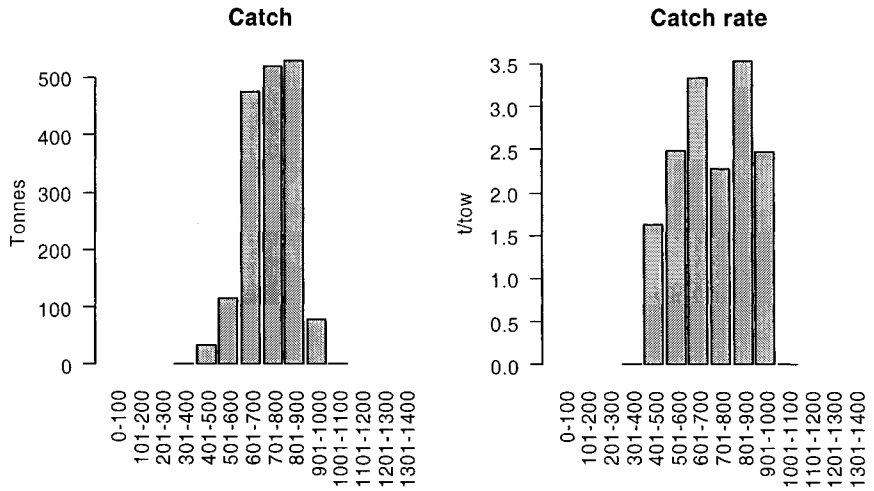

Figure 17: Total estimated catch (left panel) and catch rates (right panel) by depth class for the Tuaheni fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

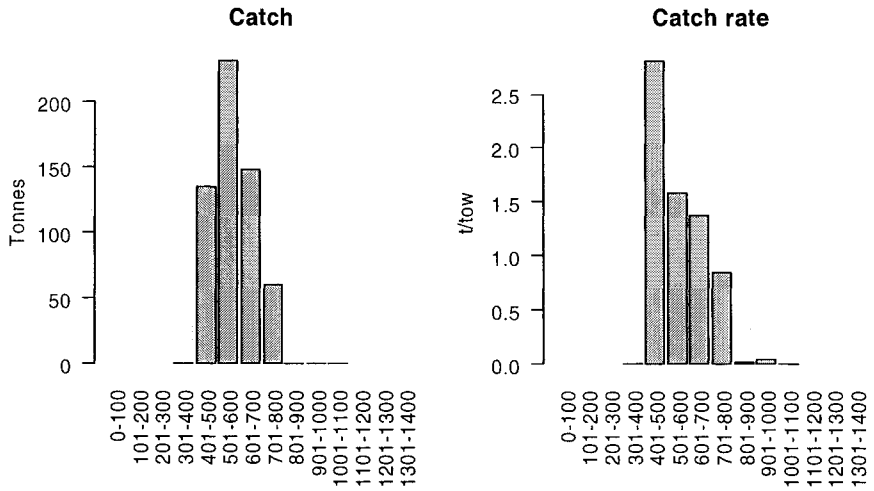

Figure 18: Total estimated catch (left panel) and catch rates (right panel) by depth class for the Ritchie and Rockgarden fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

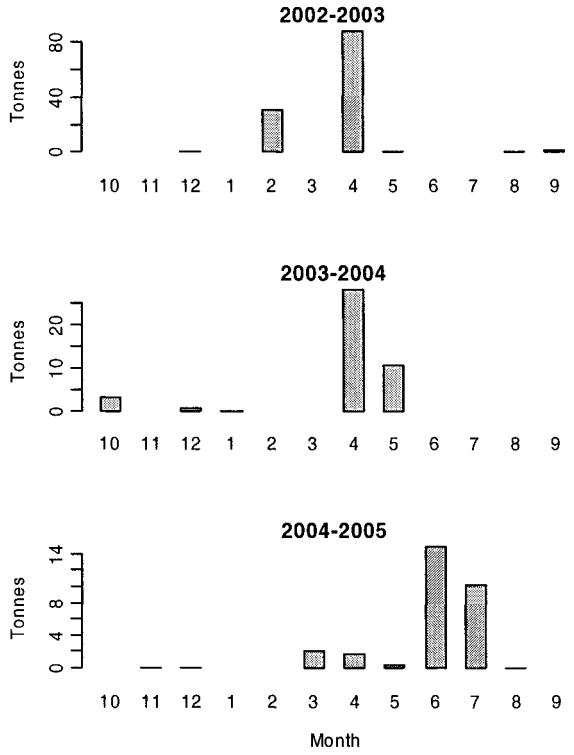

Figure 19: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the East Cape fishery.

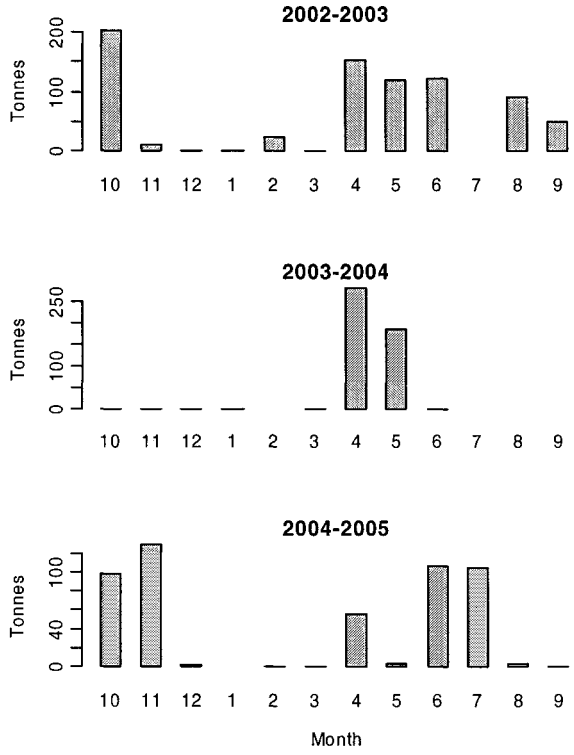

Figure 20: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the Tuaheni fishery.

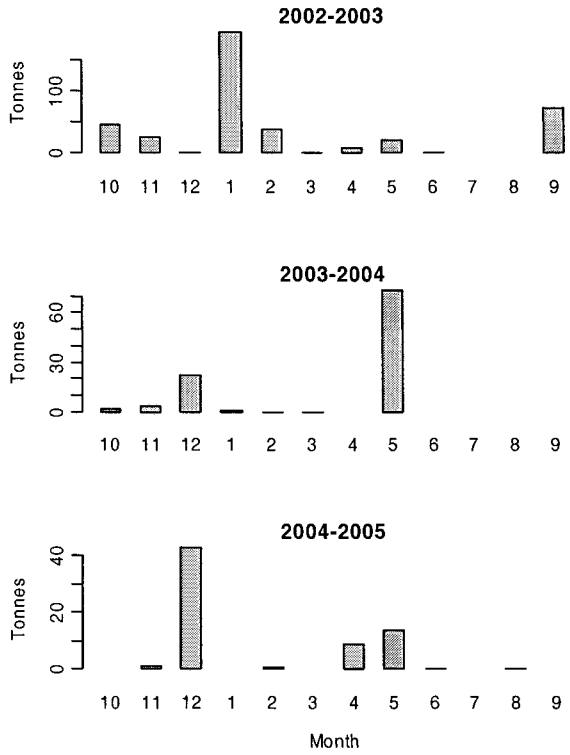

Figure 21: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the Ritchie and Rockgarden fishery.

In 2002–03 and 2004–05, good catches of black cardinalfish were made from a feature to the south of Ritchie and Rockgarden (see Figure 15). In 2004–05 the catch from this feature was about 170 t.

3.6 Bay of Plenty

The Bay of Plenty fisheries were the most recent to develop. Dunn (2005) described three distinct areas: Mercury-Colville, White Island, and North Colville.

Of the three areas, the largest catches have been made in Mercury-Colville (Dunn 2005). The catches and catch rate from the largely target fishery at Mercury-Colville were relatively low, mostly taken between February and August, and mainly at depths of 700–799 m. The catches at White Island were low, although increasing after only 9 t were caught in 2000–01, mainly taken between January and May, and at depths of 600–999 m. The catches at North Colville were low until a relatively large catch in 2002–03, taken at depths of 800–999 m, and there was no clear seasonal pattern.

In the last three fishing years, the catches of black cardinalfish in Mercury-Colville from the orange roughy target fishery declined further, such that the black cardinalfish catches were almost entirely from the target fishery (Table 22). Effort has been variable, but was relatively high in 2004–05, but in 2004–05 catches had declined and were the lowest recorded (Table 23).

The catches of black cardinalfish from White Island over the last three fishing years have largely been from targeted fishing (Table 24), however, in 2004–05 only 4 t were caught from 30 tows, giving the lowest catch rate since the start of the fishery (Table 25).

Table 22: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the Mercury-Colville fishery.

Fishing year	Bluenose	Alfonsino	Black cardinalfish	Orange roughy	Ruby fish
1993–94	0	0	0	98.5	0
1994–95	0	41.5	999.9	25.2	2.5
1995–96	0	0	647.3	626.8	0
1996–97	0	0	796.7	1 062.8	0
1997–98	0.2	0	400.8	445.2	0
1998–99	0	0	147.3	182	0
1999–2000	0	0	509.2	25.3	0
2000–01	0	0	193.8	1	0
2001–02	0	0	239.9	101.8	0
2002–03	0	0	242.5	32.3	0
2003–04	0	0	397.8	0.1	0
2004–05	0	0	171.4	0.2	0

Table 23: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the Mercury-Colville fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1993–94	1	1	0	1	0
1994–95	4	233	999.9	0.35	4.3
1995–96	9	280	647.3	0.56	2.3
1996–97	4	372	796.7	0.59	2.1
1997–98	5	204	400.8	0.66	2
1998–99	3	112	147.3	0.7	1.3
1999–2000	4	158	509.2	0.46	3.2
2000–01	3	110	193.8	0.46	1.8
2001–02	4	131	239.9	0.6	1.8
2002–03	7	162	242.5	0.59	1.5
2003–04	4	128	397.8	0.7	3.1
2004–05	3	180	171.4	0.53	1

Table 24: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the White Island fishery.

Fishing year	Black cardinalfish	Orange roughy
1996–97	0.1	1.2
1997–98	84.9	105.4
1998–99	187.5	98.4
1999–2000	135.5	85.2
2000–01	9.1	0.6
2001–02	16.8	1.2
2002–03	47.8	4.4
2003–04	26.8	2.3
2004–05	4.2	4

Table 25: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the White Island fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1994–95	1	1	0	1	0
1995–96	0	0	0	0	0
1996–97	2	5	0.1	0.8	0
1997–98	5	91	84.9	0.45	0.9
1998–99	4	205	187.5	0.58	0.9
1999–2000	4	167	135.5	0.46	0.8
2000–01	4	54	9.1	0.43	0.2
2001–02	5	46	16.8	0.43	0.4
2002–03	6	51	47.8	0.41	0.9
2003–04	3	52	26.8	0.73	0.5
2004–05	4	30	4.2	0.6	0.1

The catches of black cardinalfish from North Colville have largely been from a target fishery (Table 26), and decreased rapidly after the large catch in 2002–03 (Table 27). Effort remained much the same in the last two fishing years at just over 40 tows, but catch rates in 2004–05 declined to the same level as 2001–02, and were the lowest recorded.

Table 26: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the North Colville fishery.

Fishing year	Black cardinalfish	Orange roughy
1994–95	0	9
1995–96	0	0
1996–97	0	0.6
1997–98	0	1
1998–99	0.1	2.7
1999–2000	87.5	10.7
2000–01	5.1	0
2001–02	4.2	4
2002–03	190.9	4.8
2003–04	21	0.4
2004–05	9.4	0

Table 27: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the North Colville fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1998–99	1	5	0.1	0.6	–
1999–2000	2	51	87.5	0.18	1.7
2000–01	1	10	5.1	0.7	0.5
2001–02	1	17	4.2	0.59	0.2
2002–03	2	124	190.9	0.43	1.5
2003–04	1	46	21	0.65	0.5
2004–05	2	43	9.4	0.58	0.2

The areas fished in the last three years are similar to those described by Dunn (2005), and focused on one or more specific features within each area (Figure 22).

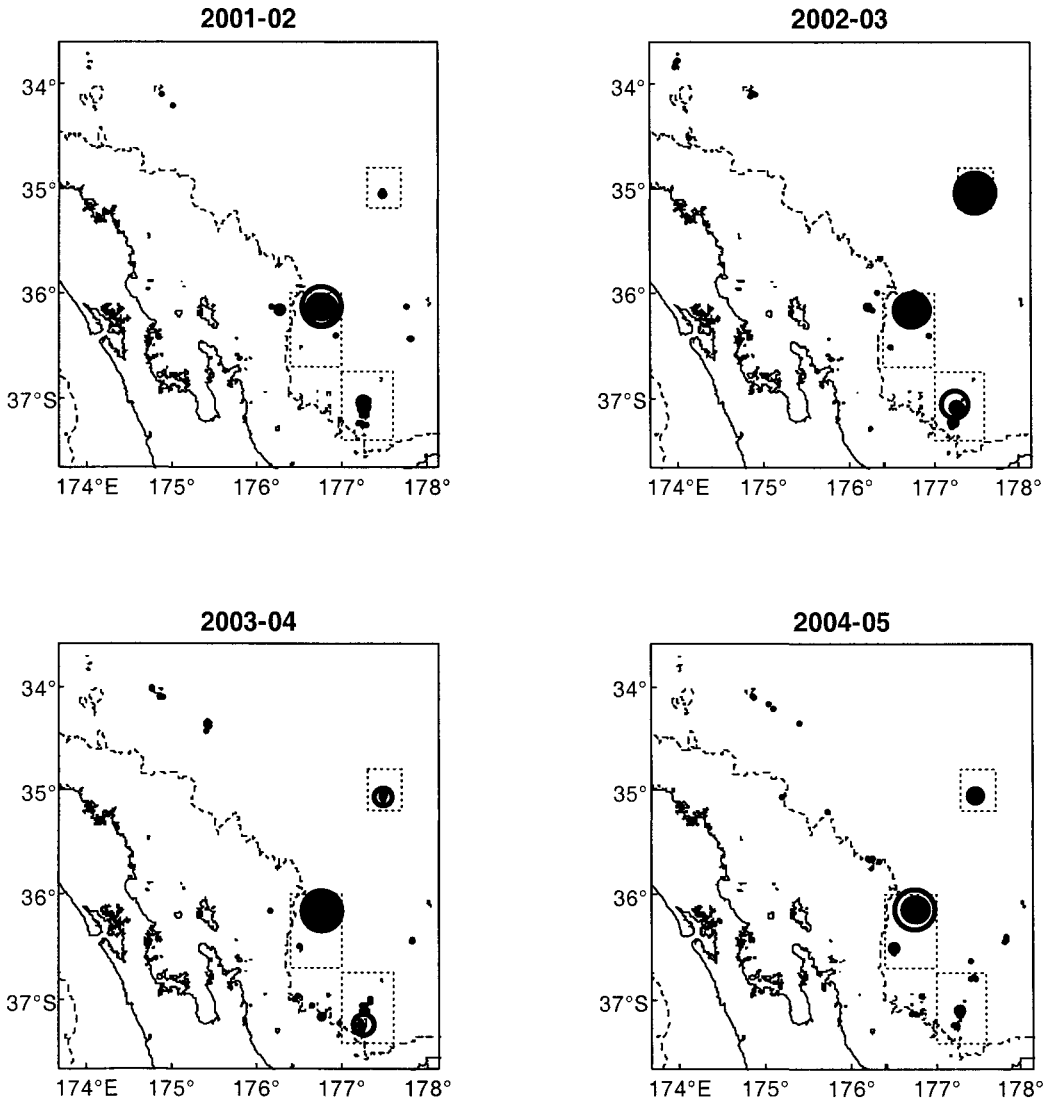

Figure 22: Estimated trawl catch rate (t/tow) of black cardinalfish by fishing position and fishing year for the Bay of Plenty fishery, for tows targeting black cardinalfish. Areas shown in boxes are (from north to south) North Colville, Mercury-Colville and White Island. Catch rate proportional to circle area (maximum 70 t/tow).

The catches at Mercury Colville have continued to be taken at a similar depth range, almost entirely at 701–800 m (Figure 23). The relatively high catch rate recorded at 401–500 m was from a single tow at 475 m, in February 2005.

The catches at White Island over the last three fishing years were almost entirely taken at 701–800 m (Figure 24). In previous years the catches have been more evenly taken over a wider depth range, from 600–999 m (Dunn 2005).

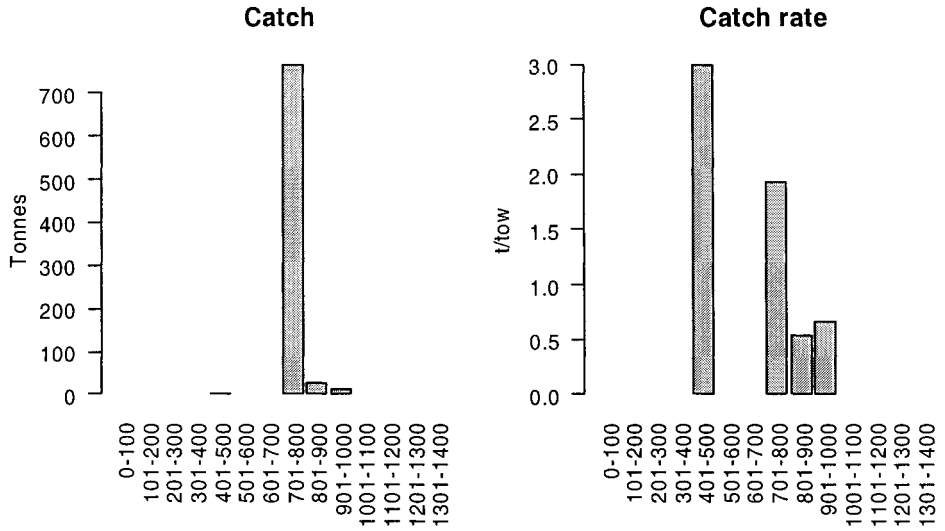

Figure 23: Total estimated catch (left panel) and catch rates (right panel) by depth class for the Mercury-Colville fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

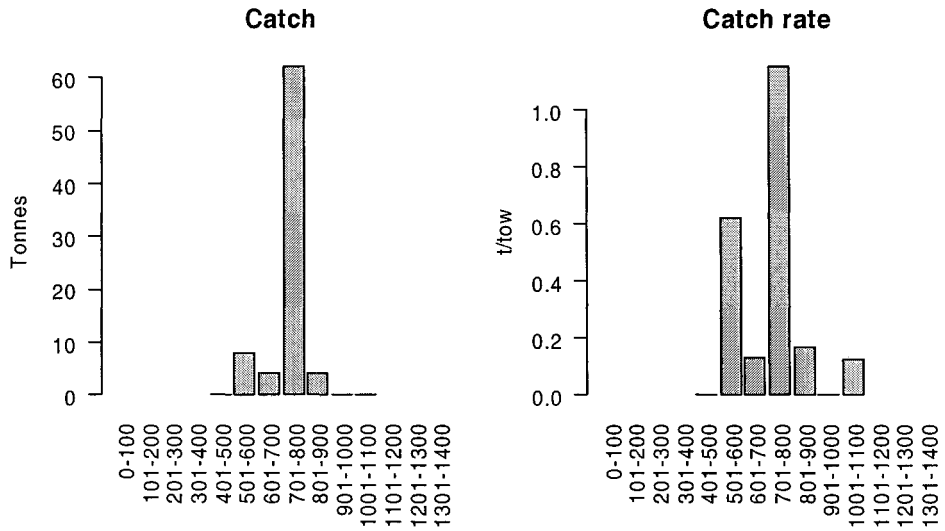

Figure 24: Total estimated catch (left panel) and catch rates (right panel) by depth class for the White Island fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

The peak catches and catch rate at North Colville over the last three fishing years were at the same depths as recorded for previous years, at 801–999 m (Figure 25) (Dunn 2005).

The catches at Mercury-Colville have previously been taken throughout the year (Dunn 2005), and this pattern has continued, although most catches were taken between February and September (Figure 26). Catches of over 50 t were made in four months in 2003–04, but in 2004–05 this occurred only in February, when 74 t was caught in three tows.

The catches at White Island have a similar seasonal pattern to previous years, with catches largely taken between January and May, although in each year most of the catch has been taken in a single month, and the timing that month has been variable (Figure 27).

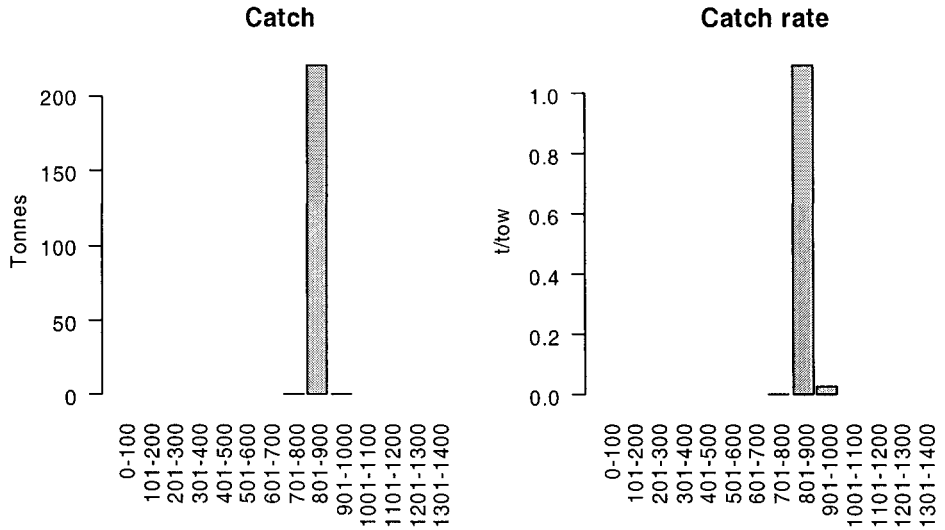

Figure 25: Total estimated catch (left panel) and catch rates (right panel) by depth class for the North Colville fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

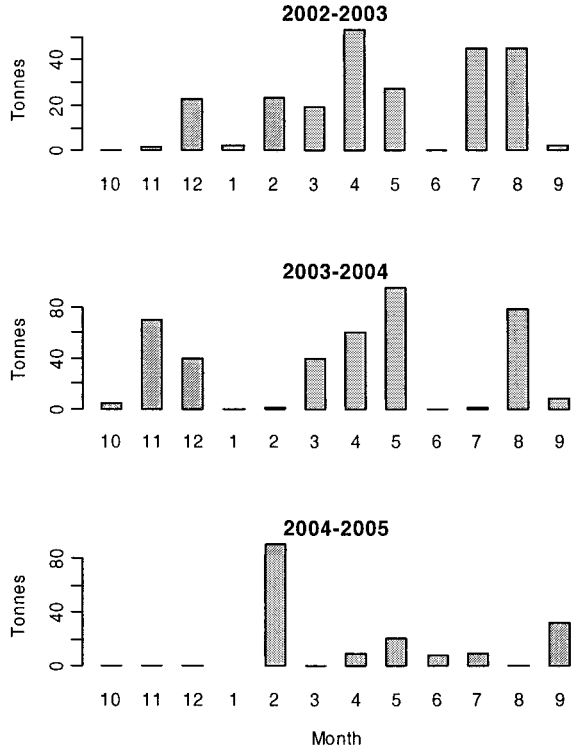

Figure 26: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the Mercury-Colville fishery.

In North Colville there has been no clear seasonal pattern to catches, with large catches previously taken in March, August, November, and December (Dunn 2005). In the last three fishing years large catches have again been made in March and August, but also in July and September (Figure 28).

Almost all catches in the Bay of Plenty have come from these three fisheries, with less than 5 t per year taken outside these areas.

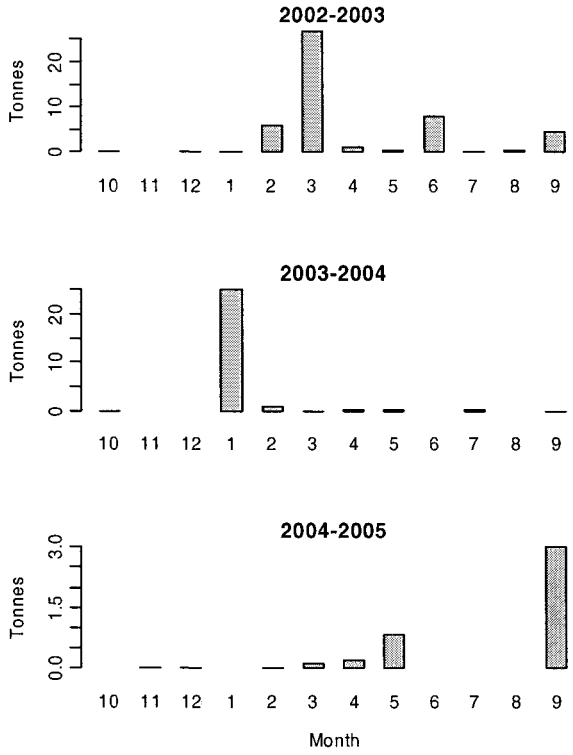

Figure 27: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the White Island fishery.

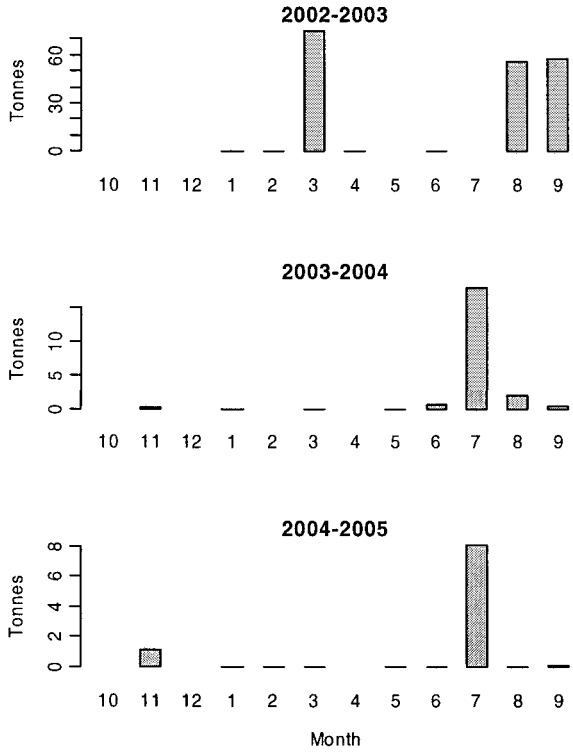

Figure 28: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the North Colville fishery.

3.7 North Challenger and Lord Howe

The North Challenger and Lord Howe fishery is just outside the New Zealand EEZ, where black cardinalfish have been caught in targeted tows since the early 1990s (Dunn 2005). The fishery described by Dunn (2005) took place in two main areas, one on the southern edge of Lord Howe Rise, and the other at the northern edge of the Challenger Plateau. Catches were taken between 600–1199 m, with greatest catches in the target fishery a little shallower than in the orange roughy bycatch fishery. Catches were seasonal, and almost entirely taken between January and May. There were no clear trends in catches or catch rates.

In the last three fishing years, most catches were reported from the target fishery (Table 28), effort and catches were relatively low, and catch rates were relatively high in 2003–04 and low in 2004–05 (Table 29).

Table 28: Estimated trawl catches (t) of black cardinalfish by target species and fishing year, for the North Challenger and Lord Howe fishery.

Fishing year	Alfonsino	Black cardinalfish	Orange roughy	Other*
1991–92	0	0	10.3	0
1992–93	0	0.3	174.3	0.1
1993–94	5.4	503.8	551.4	2.2
1994–95	0.3	97.8	109.1	0
1995–96	40	200.9	3.2	0
1996–97	2.8	333.2	115	0
1997–98	0.2	74.1	67.2	0
1998–99	1	293.7	21.5	0
1999–2000	8.4	138.1	5	0.1
2000–01	0	357.3	127.8	0
2001–02	0	133.3	25.8	0
2002–03	2	200.7	21.7	0
2003–04	0	40.1	2.2	0
2004–05	0	103.4	15	0

* Other includes bluenose, prawns, hoki, stargazer, and warehou.

Table 29: Number of vessels, tows, estimated catch, proportion of tows which had a zero catch of cardinalfish, and catch rate (t/tow; only calculated if there was 10 or more tows), by fishing year, for tows targeting cardinalfish in the North Challenger and Lord Howe fishery.

Fishing year	No. vessels	No. tows	Catch (t)	Prop. tows with zero catch	t/tow
1992–93	2	15	0.3	0.8	0
1993–94	9	83	503.8	0.49	6.1
1994–95	4	53	97.8	0.45	1.8
1995–96	2	66	200.9	0.53	3
1996–97	4	91	333.2	0.6	3.7
1997–98	3	27	74.1	0.52	2.7
1998–99	6	97	293.7	0.68	3
1999–2000	6	93	138.1	0.66	1.5
2000–01	3	89	357.3	0.64	4
2001–02	5	57	133.3	0.68	2.3
2002–03	6	83	200.7	0.59	2.4
2003–04	3	12	40.1	0.42	3.3
2004–05	4	62	103.4	0.68	1.7

In the last three fishing years the fishery has occurred in the same two areas (Figure 29), and most of the catch was still taken at depths of 701–800 m (Figure 30), although highest catch rates were slightly deeper than before, 901–1000 m in the last three years compared to 800–899 m before (Dunn 2005).

The seasonality of the fishery has also remained the same, with large catches taken between January and May, and peak catches consistently taken in March (Figure 31).

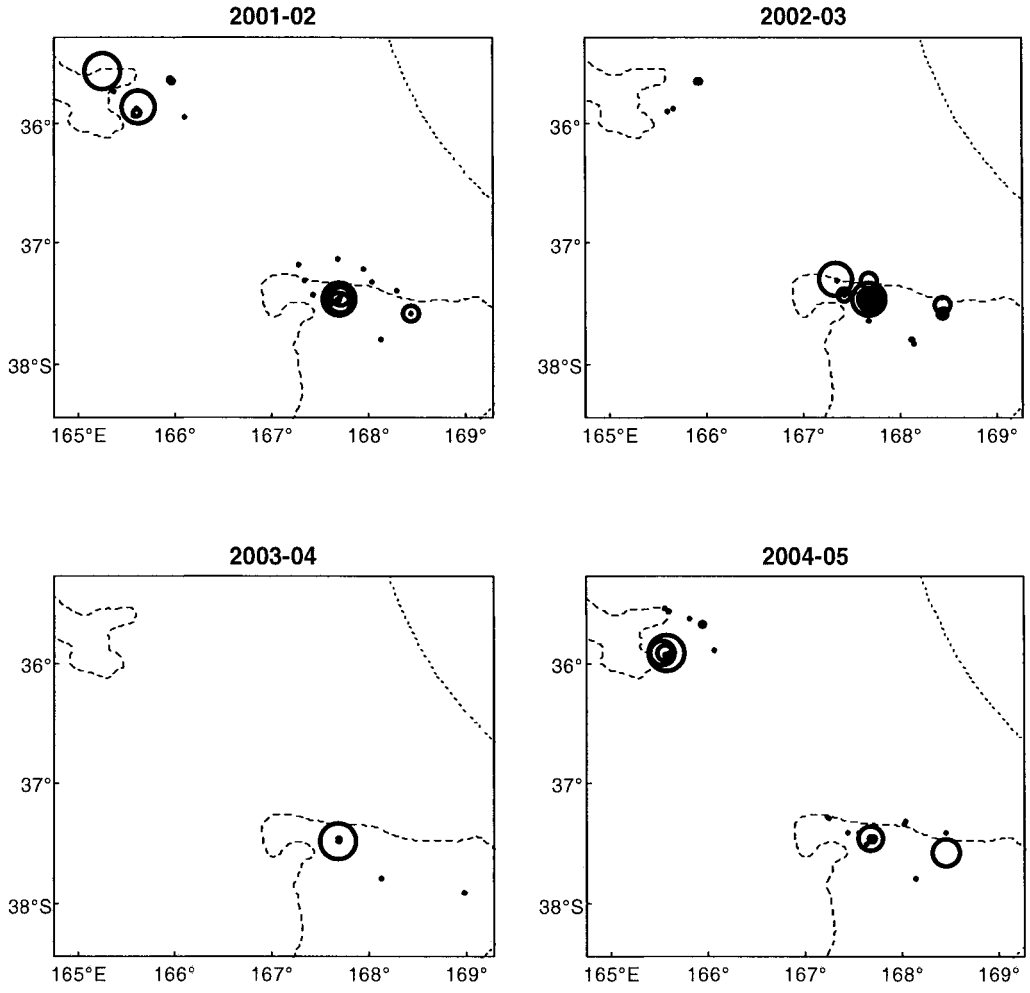

Figure 29: Estimated trawl catch rate (t/tow) of black cardinalfish by fishing position and fishing year for the North Challenger and Lord Howe fishery, for tows targeting black cardinalfish. Catch rate proportional to circle area (maximum 40 t/tow).

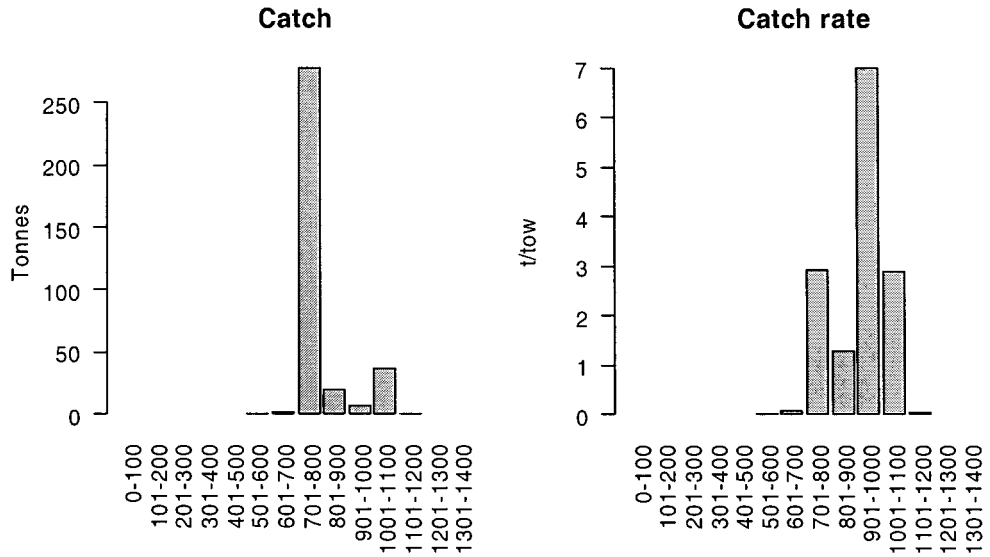

Figure 30: Total estimated catch (left panel) and catch rates (right panel) by depth class for the North Challenger and Lord Howe fishery, for tows targeting black cardinalfish, 2002–03 to 2004–05.

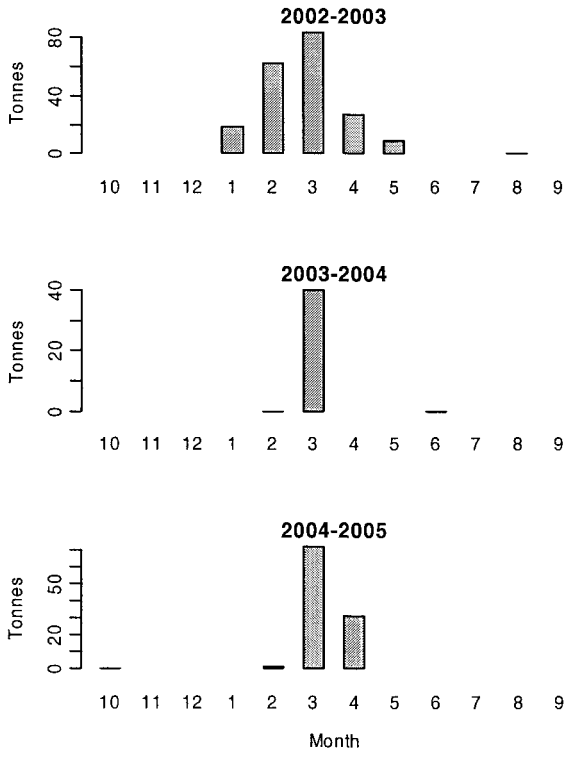

Figure 31: Estimated catch by month and fishing year, for tows targeting black cardinalfish in the North Challenger and Lord Howe fishery.

4. CPUE ANALYSES FOR QMA 2

Four standardised CPUE indices are presented:

- Short tows targeting cardinalfish.
- All tows targeting cardinalfish.
- All tows targeting cardinalfish on or near Tuaheni hill.
- All tows targeting cardinalfish on or near Tuaheni hill, shortened time series.

There were insufficient data to complete analyses for any specific hills other than Tuaheni. The following sections (4.1 to 4.4) show the results of each model, with a summary given in Section 4.5.

4.1 Index for short tows targeting cardinalfish

After data grooming and applying the data selection criteria, eight vessels were included in the data set, with good overlap between vessels (Table 30). Data were also restricted to a number of specific features, to allow a sub-area effect to be estimated (Table 31).

The dependent variable was log(t/tow), and the final binomial model explained 5.2% of the deviance (Table 32), and the non-zero catch (normal) model 11.9% of the deviance (Table 33). None of the interactions tested were included in either model.

The fit of the model was reasonable (Figure 32). Whilst most of the data fitted the model, the small departures towards the ends of the normal model quantile plot indicated the model did not describe all of the extremes of the catch rate. Alternative transformations of the predictand were tried, but did not improve the fit.

Table 30: Tows by vessel key and fishing year as used in the standardised CPUE analysis, after application of the data selection criteria.

Fishing year	3763	1195	321	5663	4849	8601	5250	12600
1990–91	–	3	1	13	–	–	–	–
1991–92	–	–	–	26	24	–	–	–
1992–93	1	3	5	10	21	–	–	–
1993–94	31	5	10	23	–	–	1	–
1994–95	7	13	6	25	2	2	–	–
1995–96	–	122	1	46	3	16	–	–
1996–97	3	56	2	38	10	4	7	–
1997–98	–	31	5	5	1	5	2	–
1998–99	–	12	11	–	3	10	8	14
1999–2000	10	26	17	30	3	11	33	8
2000–01	–	1	32	57	11	11	13	16
2001–02	–	15	16	93	13	31	34	32
2002–03	11	21	–	185	13	30	19	29
2003–04	–	2	–	32	16	29	1	17
2004–05	–	–	–	35	64	4	18	54

The model indicated just over a two-fold difference in success rate between vessels, and roughly five-fold difference in subsequent non-zero catch rate between vessels, with one performing especially well and two particularly poorly (Figure 33).

Fishing success peaked in the latter half of the fishing year, around day 270 (equivalent to late

June), and non-zero catch rate was greatest at the start of the year, with a smaller increase around July (Figure 33).

Non-zero catch rates were relatively high for three of the six sub-areas (Figure 33), which included the Ritchie and Rockgarden (H574) and Tuaheni (H542) sub-areas, and the most southerly feature in the Wairarapa sub-area (H310: the name of this feature isn't known, but it is the heavily fished feature shown in Figure 6). Fishing success increased with tow distance, and non-zero catch rates were highest for relatively short and longer tows.

Table 31: Tows by sub-area (hill) and fishing year as used in the standardised CPUE analysis, after application of the data selection criteria.

Fishing year	H257	H271	H280	H310	H542	H574
1990–91	–	1	14	–	2	–
1991–92	–	–	46	4	–	–
1992–93	–	2	28	6	4	–
1993–94	5	10	29	13	13	–
1994–95	5	8	16	14	11	1
1995–96	94	16	24	13	41	–
1996–97	16	15	12	35	41	1
1997–98	27	1	13	4	4	–
1998–99	17	3	14	6	17	1
1999–2000	23	3	39	15	33	25
2000–01	11	5	63	21	35	6
2001–02	20	15	98	36	37	28
2002–03	45	33	95	46	72	17
2003–04	17	10	24	8	29	9
2004–05	24	30	33	13	70	5

Table 32: Predictor and percentage of deviance explained for the final binomial model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	2 104	0.9	0.9
Vessel key	2	7	2 082	2.5	1.7
Fishing day	3	3	2 046	4.6	2.0
Tow distance	4	3	2 040	5.2	0.6

Table 33: Predictor and percentage of deviance explained for the final normal model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	3 456	3.8	3.8
Vessel key	2	7	3 441	7.7	3.9
Sub-area	3	5	3 433	10.0	2.3
Fishing day	4	3	3 430	11.1	1.0
Tow distance	5	3	3 430	11.9	0.8

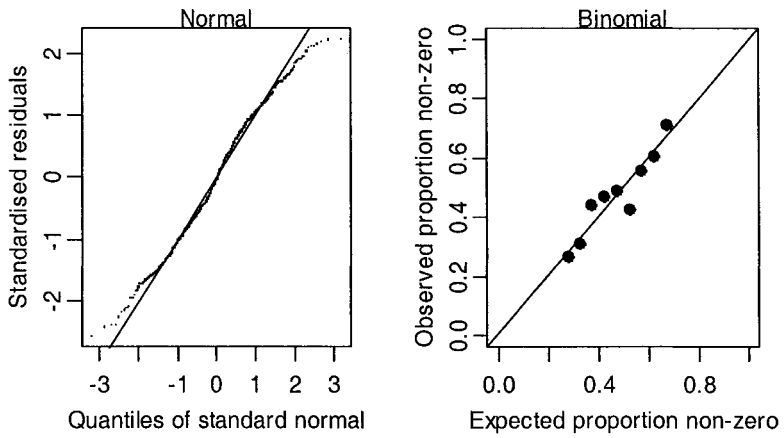

Figure 32: Residuals (left panel) and normal quantile plot (right panel) for the fit of the final CPUE model.

4.2 Index for all tows targeting cardinalfish

Unlike the previous index, this included records with tows longer than 30 minutes. The dependent variable used was log(t/hour), rather than t/tow, and so *tow duration* and *tow distance* (closely correlated with tow duration) were removed as potential predictors. The tow duration component of the *tow type* variable was removed, so that *tow type* had only the levels hill, near hill, and flat.

After data grooming and applying the data selection criteria, 13 vessels were included in the data set, with reasonable overlap between vessels (Table 34). Data were also restricted to a number of specific features, to allow a sub-area effect to be estimated (Table 35). These were the same six features that were included in the previous index.

Table 34: Tows by vessel key and fishing year as used in the standardised CPUE analysis, after application of the data selection criteria.

	Vessel key												
Fishing year	3926	804	1195	3763	11338	321	333	4849	8601	5663	5250	5262	12600
1990–91	85	7	118	–	–	1	30	–	–	–	–	–	–
1991–92	21	4	40	–	–	–	3	31	–	–	–	–	–
1992–93	21	32	20	1	–	17	–	38	–	–	–	–	–
1993–94	74	69	15	52	–	31	–	–	–	–	–	–	–
1994–95	–	23	16	–	–	21	–	9	9	48	–	–	–
1995–96	–	22	199	–	–	42	–	10	52	78	–	–	–
1996–97	–	–	115	5	47	45	–	73	21	71	16	–	–
1997–98	–	22	115	–	39	11	–	–	11	19	–	–	–
1998–99	–	–	49	–	40	60	–	43	25	9	33	16	30
1999–00	–	1	80	18	70	75	–	7	16	81	30	6	11
2000–01	–	–	2	–	2	89	–	28	28	156	8	6	21
2001–02	–	–	21	–	1	74	9	31	55	189	60	9	47
2002–03	–	–	43	24	–	–	6	89	50	344	20	6	59
2003–04	–	–	4	–	–	–	20	70	42	62	–	17	21
2004–05	–	–	–	4	–	–	24	77	8	54	40	22	77

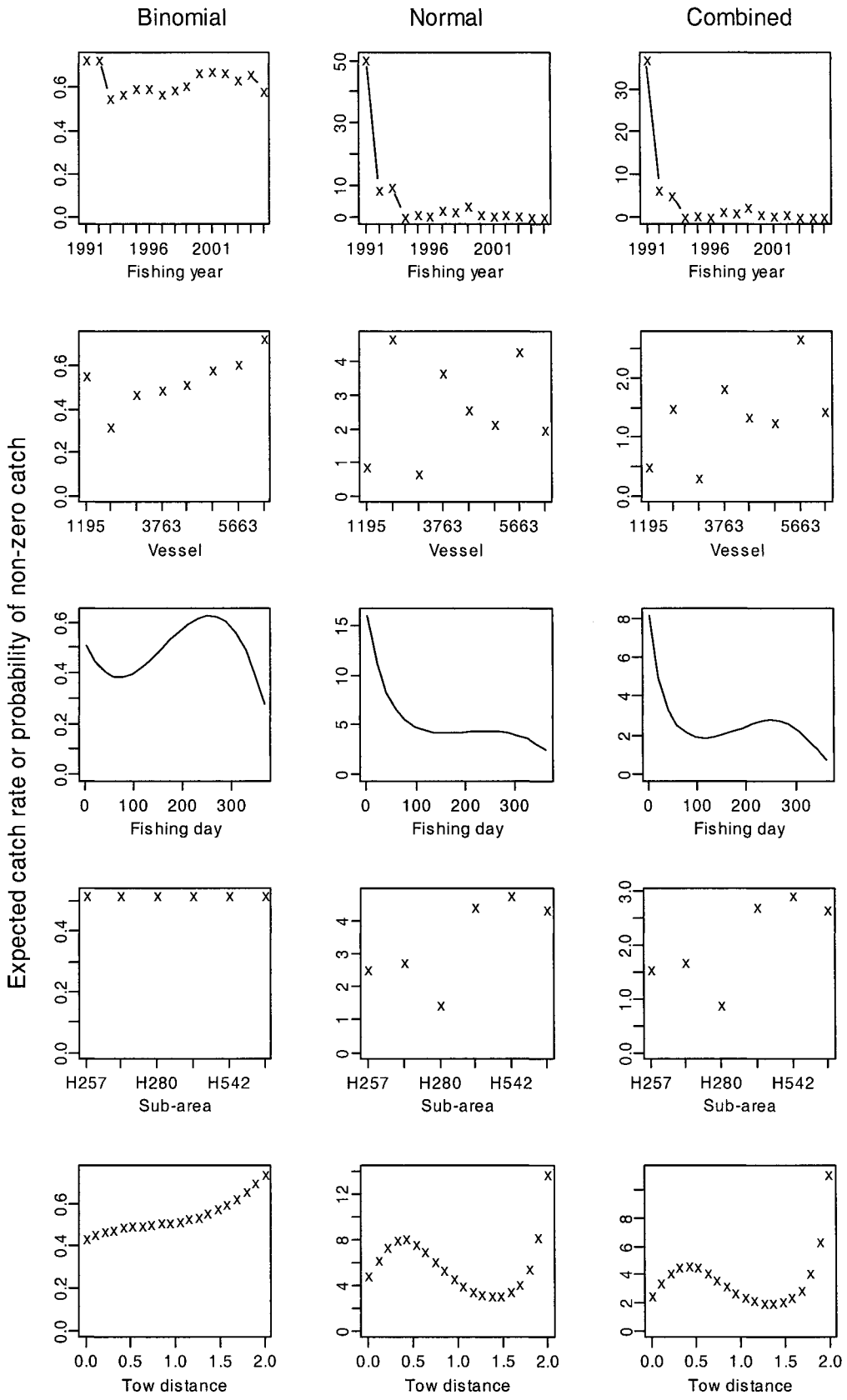

Figure 33: Model predictions by *Fishing year* (labelled as year ending, i.e., 1991 means 1990–91) and *Vessel*, for the binomial, normal and combined model, made with all other predictors set to the median (fixed) values.

Table 35: Tows by sub-area (hill) and fishing year as used in the standardised CPUE analysis, after application of the data selection criteria.

	Hill					
Fishing year	H257	H271	H280	H310	H542	H574
1990–91	–	2	40	12	217	11
1991–92	–	1	63	10	47	2
1992–93	–	4	61	32	52	6
1993–94	12	18	48	89	83	1
1994–95	13	28	31	29	65	2
1995–96	173	35	70	45	120	4
1996–97	57	19	52	80	166	33
1997–98	48	12	94	20	34	76
1998–99	55	14	140	47	92	46
1999–2000	55	11	145	60	139	53
2000–01	20	16	116	58	121	50
2001–02	20	24	171	70	120	102
2002–03	58	59	164	90	216	76
2003–04	23	12	34	34	123	22
2004–05	39	65	47	36	150	29

The final binomial model explained 4% of the deviance (Table 36), and the non-zero catch (normal) model 13.3% of the deviance (Table 37). None of the interactions tested were included in either model.

Table 36: Predictor and percentage of deviance explained for the final binomial model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	6 292	0.8	0.8
Vessel key	2	7	6 204	2.6	1.8
Month	3	3	6 135	4.0	1.4

Table 37: Predictor and percentage of deviance explained for the final normal model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	11 028	2.8	2.8
Vessel key	2	12	10 897	9.5	6.7
Month	3	11	10 875	11.4	1.8
Sub-area	4	5	10 863	12.8	0.6
Bottom depth	5	3	10 855	13.3	0.6

Whilst most of the data fitted the model, the small departures towards the ends of the normal model quantile plot indicated the model did not describe all of the extremes of the catch rate, particularly for small catches (Figure 34). Alternative transformations of the predictand were tried, but did not improve the fit.

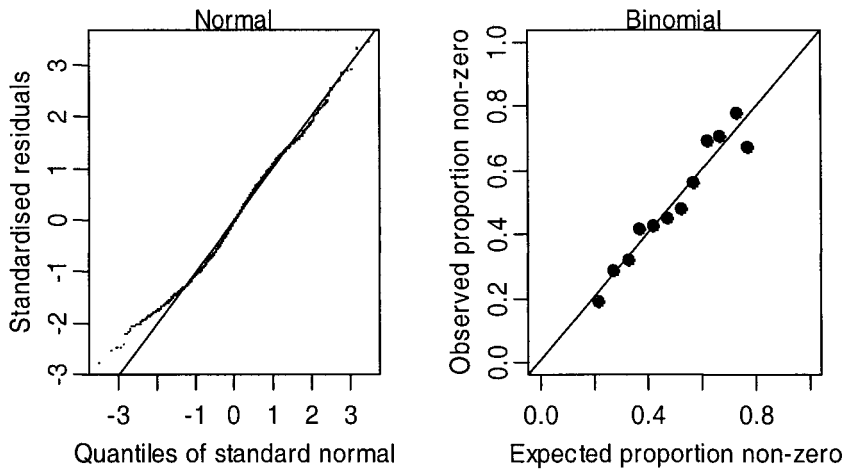

Figure 34: Residuals (left panel) and normal quantile plot (right panel) for the fit of the final CPUE model.

The model indicated a roughly two-fold difference in success rate between vessels with one vessel doing particularly well, and a more than ten-fold difference in subsequent non-zero catch rate, with three vessels performing relatively well (Figure 35).

Fishing success peaked in the latter half of the fishing year, around May and June, and non-zero catch rate was much greater in July (Figure 35). Non-zero catch rates were relatively high for four of the six features (Figure 35), which were in the Ritchie and Rockgarden sub-area (H574), two in the Tuaheni sub-area (H542 and H271), and the last in the East Cape sub-area (H257). Unlike the previous index, the catch rate on the feature in the Wairarapa sub-area (H310) was relatively low. Non-zero catch rate increased towards the shallow end of the depth range (Figure 35).

4.3 Index for Tuaheni

This index includes only tows made on or near the Tuaheni hill. As a result there was less data available. The dependent variable used was log(t/hour), and so *tow duration* and *tow distance* were removed as potential predictors. The tow duration component of the *tow type* variable was removed, so that *tow type* only had the levels hill, near hill and flat.

After data grooming and applying the data selection criteria, eight vessels were included in the data set, with reasonable overlap between vessels (Table 38).

The final binomial model explained 5.2% of the deviance (Table 39), and the non-zero catch (normal) model 19.3% of the deviance (Table 40). None of the interactions tested were included in either model.

Whilst most of the data fitted the model, the small departures towards the ends of the normal model quantile plot indicated the model did not describe all of the extremes of the catch rate (Figure 36). Alternative transformations of the predictand were tried, but did not improve the fit.

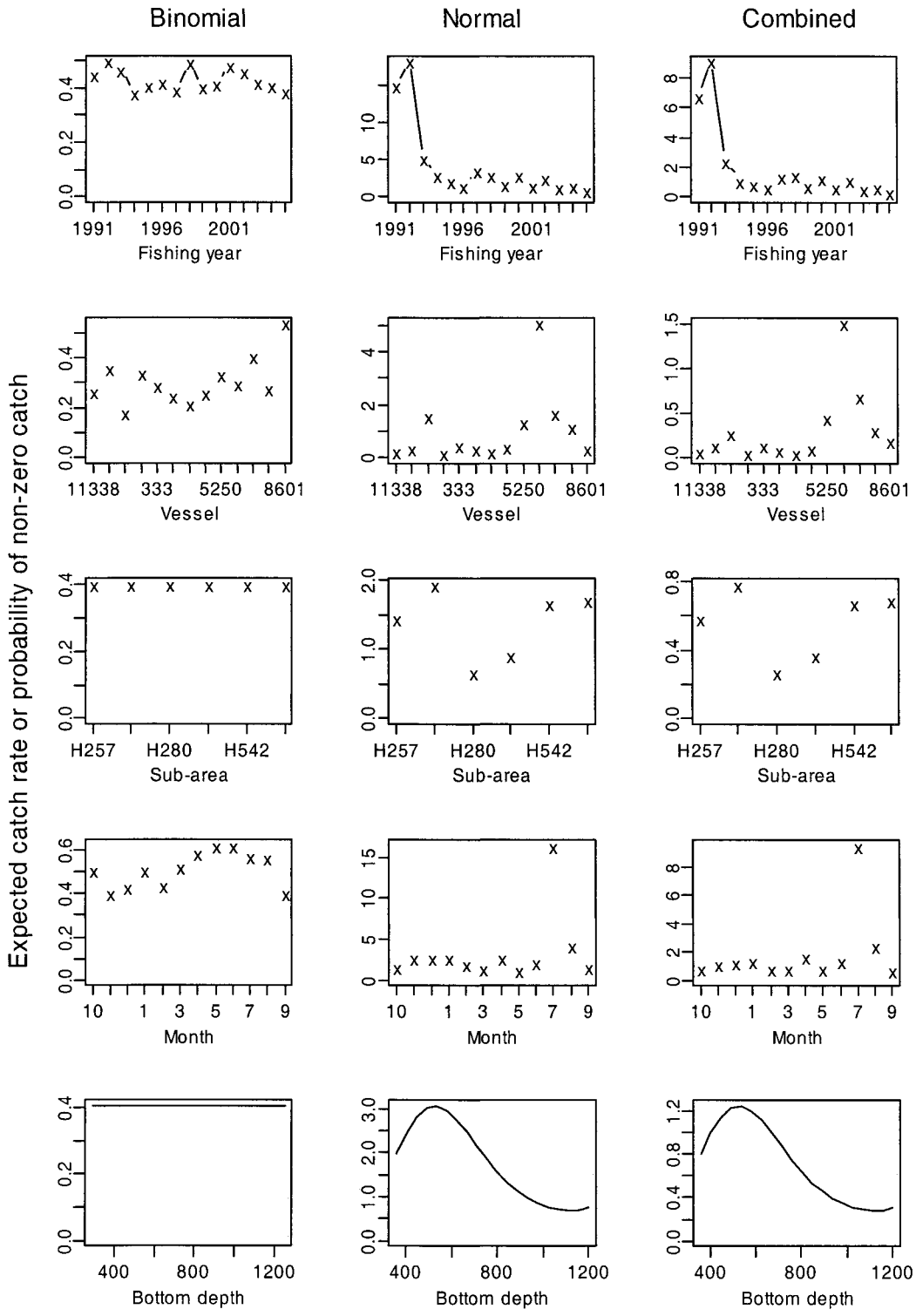

Figure 35: Model predictions by *Fishing year* (labelled as year ending, i.e., 1991 means 1990–91) and *Vessel*, for the binomial, normal and combined model, made with all other predictors set to the median (fixed) values.

Table 38: Tows by vessel key and fishing year as used in the standardised CPUE analysis, after application of the data selection criteria.

Fishing year	3926	1195	333	321	8601	5663	4849	12600
1990–91	69	98	29	–	–	–	–	–
1991–92	12	20	3	–	–	–	–	–
1992–93	18	7	–	–	–	–	5	–
1993–94	5	3	–	15	–	–	–	–
1994–95	–	10	–	17	4	8	–	–
1995–96	–	46	–	28	8	21	9	–
1996–97	–	42	–	15	2	16	72	–
1997–98	–	9	–	1	–	–	–	–
1998–99	–	2	–	23	9	–	10	13
1999–00	–	6	–	49	14	2	3	4
2000–01	–	1	–	57	12	13	7	15
2001–02	–	2	6	44	17	4	3	29
2002–03	–	19	6	–	15	46	72	45
2003–04	–	2	19	–	6	8	63	12
2004–05	–	–	17	–	3	19	59	20

Table 39: Predictor and percentage of deviance explained for the final binomial model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	1 892	1.6	1.6
Fishing day	2	3	1 880	2.6	1.0
Vessel key	3	7	1 855	4.7	2.1
Bottom depth	4	3	1 852	5.2	0.6

Table 40: Predictor and percentage of deviance explained for the final normal model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	3 601	10.4	10.4
Vessel key	2	7	3 574	15.5	5.1
Month	3	11	3 572	18.4	2.9
Bottom depth	4	3	3 570	19.3	0.9

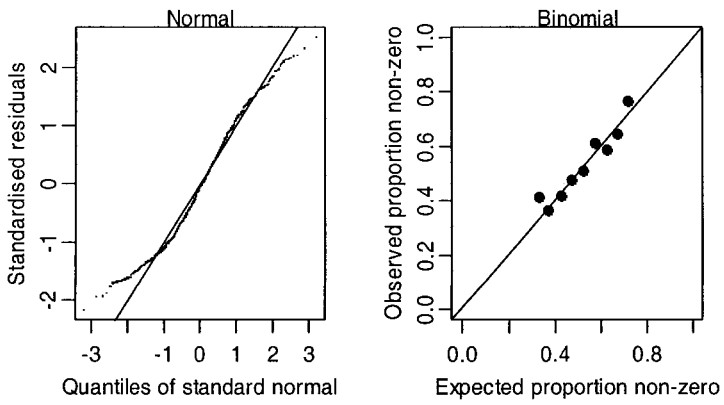

Figure 36: Residuals (left panel) and normal quantile plot (right panel) for the fit of the final CPUE model.

The model indicated a roughly three-fold difference in success rate between vessels, with one doing particularly well, and a more than ten-fold difference in subsequent non-zero catch rate, with two vessels performing especially well (Figure 37).

Fishing success peaked in the second half of the year, around day 250, consistent with early June (Figure 37). Non-zero catch rates peaked in July and August. Both fishing success and subsequent non-zero catch rates peaked at around 800 m bottom depth.

4.4 Short index for Tuaheni

This index used the same data as the previous index, except that the year range was truncated to 1994–95 to 2004–05. This was to try and avoid the steep decline in standardised catch rates at the start of the time series (see summary of analyses in Section 5.5).

After data grooming and applying the data selection criteria, six vessels were included in the data set, with few tows, but good overlap between vessels (Table 41).

Table 41: Tows by vessel key and fishing year as used in the standardised CPUE analysis, after application of the data selection criteria.

	Vessel key					
Fishing year	1195	321	8601	5663	4849	12600
1994–95	10	17	4	8	–	–
1995–96	46	28	8	21	9	–
1996–97	42	15	2	16	72	–
1997–98	9	1	–	–	–	–
1998–99	2	23	9	–	10	13
1999–00	6	49	14	2	3	4
2000–01	1	57	12	13	7	15
2001–02	2	44	17	4	3	29
2002–03	19	–	15	46	72	45
2003–04	2	–	6	8	63	12
2004–05	–	–	3	19	59	20

The final binomial model explained 5.6% of the deviance (Table 42), and the non-zero catch (normal) model 13.6% of the deviance (Table 43). None of the interactions tested were included in either model.

Table 42: Predictor and percentage of deviance explained for the final binomial model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	1 425	2.1	2.1
Fishing day	2	3	1 409	3.7	1.5
Vessel key	3	5	1 391	5.6	1.9

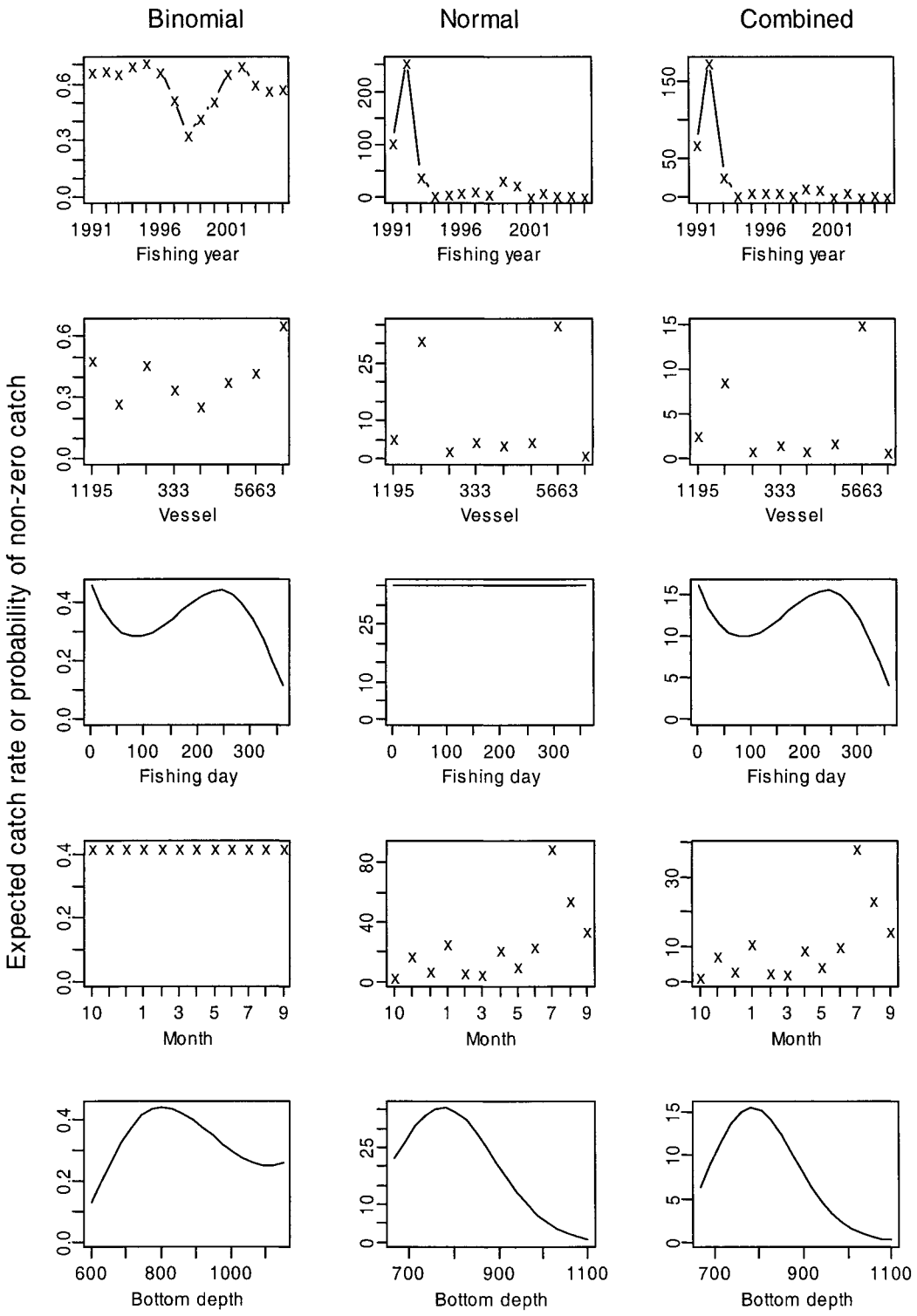

Figure 37: Model predictions by *Fishing year* (labelled as year ending, i.e., 1991 means 1990–91) and *Vessel*, for the binomial, normal and combined model, made with all other predictors set to the median (fixed) values. *Fishing day* was not included in the normal model, and *Month* not included in the binomial model, and so have no effect on catch rate or probability of non-zero catch rate respectively.

Table 43: Predictor and percentage of deviance explained for the final normal model fit. Df, degrees of freedom; AIC, Aikake Information Criterion; % dev. expl., % of deviance explained; Add % dev. expl., additional % deviance explained.

Predictor	Step	Df	AIC	% dev. expl.	Add % dev. expl.
Fishing year	1	13	2 782	2.5	2.5
Vessel key	2	5	2 755	9.0	6.6
Month	3	11	2 750	13.6	4.6

Whilst most of the data fitted the model, the departures towards the ends of the normal model quantile plot indicated the model did not describe all of the extremes of the catch rate (Figure 38). Alternative transformations of the predictand were tried, but did not improve the fit.

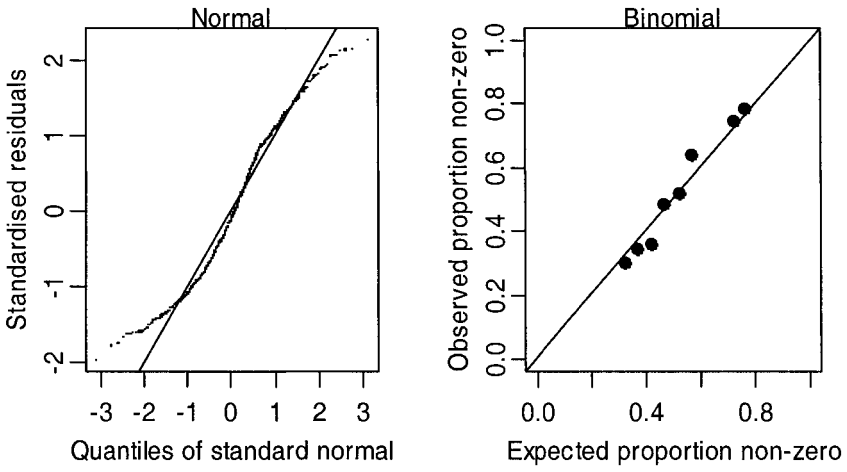

Figure 38: Residuals (left panel) and normal quantile plot (right panel) for the fit of the final CPUE model.

The model indicated a roughly three-fold difference in success rate between vessels, with one doing particularly well, and a roughly sixty-fold difference in subsequent non-zero catch rate, with one vessel performing especially well (Figure 39).

Fishing success peaked in the second half of the year, around day 260, consistent with mid-June, and non-zero catch rates peaked in July, and were relatively high in August and September (Figure 39).

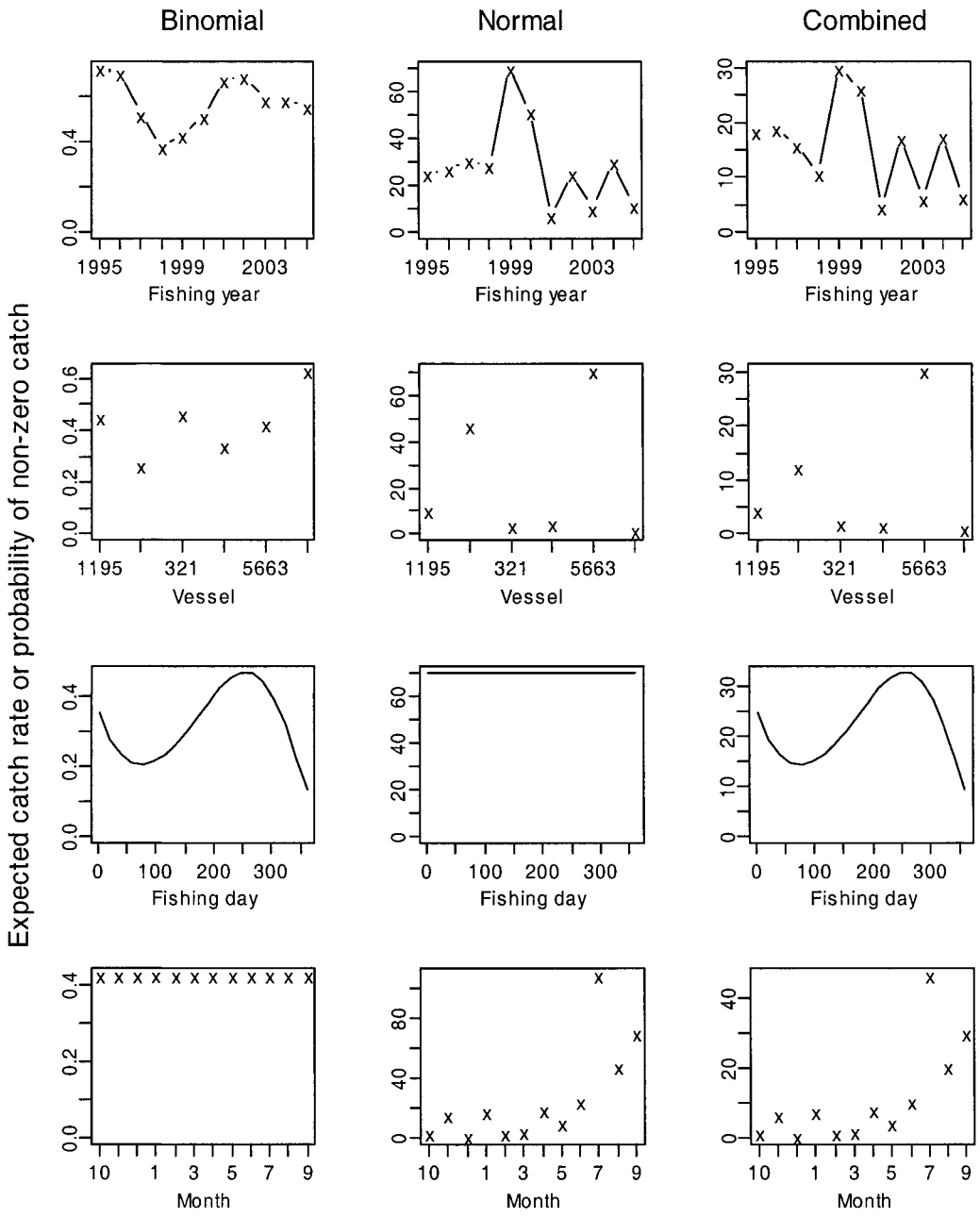

Figure 39: Model predictions by *Fishing year* (labelled as year ending, i.e., 1991 means 1990–91) and *Vessel*, for the binomial, normal and combined model, made with all other predictors set to the median (fixed) values. *Fishing day* was not included in the normal model, and *Month* not included in the binomial model, and so have no effect on catch rate or probability of non-zero catch rate respectively.

4.5 Summary of standardised CPUE analyses

The year effects for the four indices are summarised in Table 44. The indices for the whole area, and for the longer Tuaheni series, all indicated a rapid decline in CPUE in the first few years. This was avoided in the shortened Tuaheni index. These indices also indicated that recent catch rates were relatively low. This is not consistent with the unstandardised catch rates for the main fishery, which has been at Tuaheni (see Section 3.5).

Table 44: Year effects for the four alternative standardised CPUE indices.

Fishing year	Short tows, target	All tows, target	Tuaheni	Tuaheni short
1990–91	1.000	0.739	0.401	–
1991–92	0.186	1.000	1.000	–
1992–93	0.149	0.268	0.160	–
1993–94	0.009	0.119	0.027	–
1994–95	0.021	0.097	0.042	0.61
1995–96	0.016	0.072	0.041	0.63
1996–97	0.044	0.151	0.041	0.53
1997–98	0.037	0.157	0.020	0.35
1998–99	0.072	0.076	0.086	1.00
1999–2000	0.029	0.133	0.074	0.87
2000–01	0.019	0.074	0.012	0.15
2001–02	0.005	0.128	0.046	0.57
2002–03	0.015	0.060	0.016	0.20
2003–04	0.010	0.068	0.023	0.58
2004–05	0.010	0.038	0.014	0.22

The large initial decline and recent decline in the CPUE indices are caused by a combination of predictors. There have been changes in the seasonality of the fishery. Catch rates between June and September, and especially in July, were usually predicted to be high, and catch rates between October and May predicted to be low. In the first few years on the index, the fishery largely took place between October and May, therefore in months with a relatively low predicted catch rate (Table 45).

Table 45: Number of tows targeting cardinalfish by fishing year and month for QMA2.

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1990–91	52	1	19	36	11	2	40	45	6	–	6	23
1991–92	44	4	6	8	18	10	4	4	–	1	–	–
1992–93	9	3	1	17	25	55	9	4	–	–	2	4
1993–94	59	23	49	13	2	12	14	21	28	2	11	7
1994–95	14	25	22	11	4	13	3	11	6	2	2	13
1995–96	111	22	34	11	34	54	73	35	10	–	14	4
1996–97	12	20	41	13	16	43	18	124	53	20	6	23
1997–98	48	12	15	12	24	14	33	28	3	–	–	28
1998–99	34	2	1	3	15	24	72	43	16	5	22	67
1999–2000	42	26	32	10	59	28	22	73	25	42	12	24
2000–01	5	58	21	8	14	36	80	45	39	2	–	31
2001–02	76	12	60	9	80	74	11	38	56	12	1	67
2002–03	70	46	50	36	88	1	111	130	58	–	25	25
2003–04	16	32	9	30	9	6	46	88	–	–	–	–
2004–05	1	7	27	24	9	6	61	71	59	35	2	4

The vessel predictor is also having an effect, as the vessels with the lower predicted catch rates were more active in the early years of the fishery. If the month and vessel predictors were excluded from the final models, then the CPUE indices for the recent years were relatively high instead of relatively low, and would be more consistent with the unstandardised CPUE. Because of these temporal changes in the vessel composition and seasonality of the fishery, when the first four years of data were excluded such that the vessel and seasonal composition was more consistent, the large initial decline in the CPUE index did not occur.

The CPUE indices presented here included a relatively small proportion of the fishery (less than one-third of the estimated catch), largely because much of the catch was taken whilst targeting other species, and because of the data selection criteria (Table 46). The most representative index was that targeting cardinalfish and using tows of all duration (described in Section 4.2).

Table 46: The proportion of QMA 2 estimated catch included in each CPUE index, following application of the data selection criteria.

Fishing year	Target short tows	Target all tows	Tuaheni, target all tows	Tuaheni short
1990–91	0.02	0.54	0.52	–
1991–92	0.06	0.39	0.22	–
1992–93	0.07	0.19	0.06	–
1993–94	0.03	0.17	0.03	–
1994–95	0.07	0.16	0.07	0.07
1995–96	0.09	0.21	0.11	0.11
1996–97	0.09	0.23	0.08	0.08
1997–98	0.04	0.24	0.003	0.003
1998–99	0.06	0.21	0.06	0.06
1999–2000	0.16	0.33	0.06	0.06
2000–01	0.14	0.34	0.12	0.12
2001–02	0.30	0.60	0.16	0.15
2002–03	0.24	0.53	0.21	0.20
2003–04	0.15	0.43	0.22	0.21
2004–05	0.35	0.43	0.19	0.17
Overall	0.11	0.32	0.13	0.10

The explanatory power of models for the whole area was relatively low (under 20%), with the greatest deviance explained by the longer Tuaheni index. This index, and also the shorter index, showed a decrease in fishing success around the time the species came into the QMS (1998).

All models predicted an increase in fishing success and/or catch rates around June or July. This may indicate an increase in abundance at this time, possibly associated with the formation of fish aggregations for spawning.

The target all tows index predicted standardised catch rates in 2004–05 that were relatively low, at about 4% of the maximum, 14% of the level in 1992–93, or 50% of the 1998–99 value. The long Tuaheni index predicted catch rates in 2004–05 that were 14% of the maximum, and 16% of the 1998–99 value. The short Tuaheni index predicted catch rates in 2004–05 that were 22% of the 1998–99 value (which was also the maximum).

5. DISCUSSION

The main fishing areas, as identified by Dunn (2005), are still yielding catches of black cardinalfish. Reduced catches and catch rates, however, suggest that the black cardinalfish stocks have been fished down.

The standardised CPUE indices did not have a very high explanatory power, but the effects were consistent with the descriptive analyses of the fishery. A change in the fishing success around 1998 is consistent with a bias in catch reporting associated with the introduction of

black cardinalfish into the QMS that year. This was not clear from analyses of unstandardised catch rates (Dunn 2005), and suggests some bias in catch rates is likely from this data set. Previous reports have concluded that catch per unit effort was not a reliable index of abundance for black cardinalfish (Field & Clark 2001, Phillips 2002).

The initial steep decline in standardised CPUE indices was largely due to changes in the vessel composition and season fished. Ignoring this period, the indices suggest that 2004–05 catch rates were relatively low, at around one-third of the catch rates 10 years earlier.

Basic information, such as stock boundaries, spawning locations and timing, the distribution of nursery grounds, validated growth rates, longevity and age at maturation, and recruitment patterns, is still lacking for black cardinalfish. These data are required to help correctly evaluate stock status and vulnerability. The analyses of commercial catch data has suggested that spawning aggregations may be targeted on the east coast of the North Island in June and July.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Anderson, O.; Dunn, M.R. (2006). Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B and 7B to the end of the 2003-04 fishing year. *New Zealand Fisheries Assessment Report 2006/20.* 59 p.

Anon (2003). Ministry of Fisheries Catch Effort Library v1.01.

Anderson, O.F. (2005). CPUE analysis and stock assessment of the South Chatham Rise orange roughy fishery for 2003–04. *New Zealand Fisheries Assessment Report 2005/7.* 33 p.

Dunn, M.R. (2005). Descriptive analysis of catch and effort data from New Zealand black cardinalfish (*Epigonus telescopus*) fisheries for the fishing years 1979–80 to 2002–03. *New Zealand Fisheries Assessment Report 2005/32.* 47 p.

Field, K.D.; Clark, M.R. (2001). Catch-per-unit-effort (CPUE) analysis and stock assessment for black cardinalfish (*Epigonus telescopus*) in QMA 2. *New Zealand Fisheries Assessment Report 2001/23.* 22 p.

Field, K.D.; Tracey, D.M.; Clark, M.R. (1997). A summary of information on, and assessment of the fishery for, black cardinalfish, *Epigonus telescopus* (Risso, 1810) (Percoidei: Apogonidae). New Zealand Fisheries Assessment Research Document 97/22. 6 p. (Unpublished report held in NIWA library, Wellington.)

Francis, R.I.C.C. (2001). Orange roughy CPUE on the South and East Chatham Rise. *New Zealand Fisheries Assessment Report 2001/26.* 30 p.

Ministry of Fisheries, Science Group (Comps.) (2006): Report from the Fishery Assessment Plenary, May 2006: stock assessments and yield estimates. 875 p. (Unpublished report held in NIWA library, Wellington.)

Phillips, N.L. (2002). Descriptive and catch-per-unit-effort (CPUE) analyses for black cardinalfish (*Epigonus telescopus*) in QMA 1. *New Zealand Fisheries Assessment Report 2002/55.* 54 p.