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Stock structure of kahawai, *Arripis trutta*

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CPUE analysis and updated assessment for the west coast South Island orange roughy fishery (ORH 7B) to 2005–06

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EXECUTIVE SUMMARY

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This report updates the descriptive analysis of catch and effort data for ORH 7B, and the standardised CPUE analysis.

The ORH 7B fishery developed in the Cook Canyon in 1985. Reported annual landings have ranged from 95 t to 1760 t. The TACC was reduced from 1708 t to 430 t in the 1995–96 fishing year following several years from 1992 to 1995 when the TACC was not achieved. The TACC was reduced again to 110 t in the 2001–02 fishing year, where it has stayed since. Catch rates, both catch per tow and catch per hour, have remained low, with their mean values over the last three years being less than 10% of their values at the start of the fishery. The mean distance towed in the last three years is more than three times the initial level.

Up until 1996–97 about 70% of the estimated catch was recorded on TCEPR forms. In 1997–98 this decreased to 20% and now nearly all the catch is recorded on CELR forms. Because of this change in the fleet composition, and associated difficulties with vessel linkage across years, it was decided to split the standardised CPUE analysis into two series: (i) using TCEPR data from 1985–86 to 1996–97, and (ii) using CELR data from 1990–91 to 2005–06.

The standardised analysis for the TCEPR data used catch per tow in a linear regression model. Indices from this model show a steep decline after the first two years, followed by a more gradual decline and a slight increase in catch rates for the last two years. In the last two years the index is about 22% of the value in the first two years.

The standardised analysis for the CELR data used daily catch in a linear regression model. Indices from this model show a steep decline for the first four years, followed by an increase to a peak in 1995–96, and subsequent low catch rates after then. In the last two years the index is about 22% of the value in the first two years.

The updated assessment model shows the stock slowly rebuilding since the mid 1990s, which is inconsistent with trends in catch rates. This is likely to be due to the assumption concerning recruitment in the model.

1. INTRODUCTION

1.1 Overview

This report updates the unstandardised and standardised catch per unit effort analyses for the orange roughy fishery on the west coast South Island (ORH 7B). The previous catch effort analysis of this fishery by McKenzie (2005) up to the 2002–03 fishing year is updated with the inclusion of data up to the end of the 2005–2006 fishing year.

The work was carried out for Ministry of Fisheries project ORH200602 (Orange roughy stock assessment). It covers the west coast South Island stock (ORH 7B), Objective 2 (update the unstandardised and standardised catch per unit effort analyses).

The standardised indices are used to update one of the assessment models from the previous assessment (McKenzie 2005). This was additional work asked for by the Deep Water Working Group.

1.2 Description of the fishery

Quota Management Area ORH 7B covers an area off the west coast of the South Island from near Westport to south of Jackson Head. Orange roughy occur throughout the QMA which includes domestic fishing return areas 033, 034, 705, and 706 (Figure 1). The fishery is centred on an area near the Cook Canyon, which is a trench running out from the coast in roughly an east-west direction. Fishing also occurs to the south around the Moeraki Canyon.

The fishery developed from May 1985, with a rapid increase in the following year when aggregations of spawning orange roughy were targeted in winter. Most of the catch is taken in the winter, particularly in June and July. Reported landings have ranged from 95 to 1760 t per year (Table 1, Figure 2).

Catches in 1993 to 1995 were well below the TACC of 1708 t. The TACC was reduced to 430 t for the 1996 fishing year, but was only reached only in the 1996 and 1997 fishing years. The TACC was further reduced in the 2001 fishing year to 110 t.

No non-commercial or Maori customary fisheries for orange roughy are known in this area.

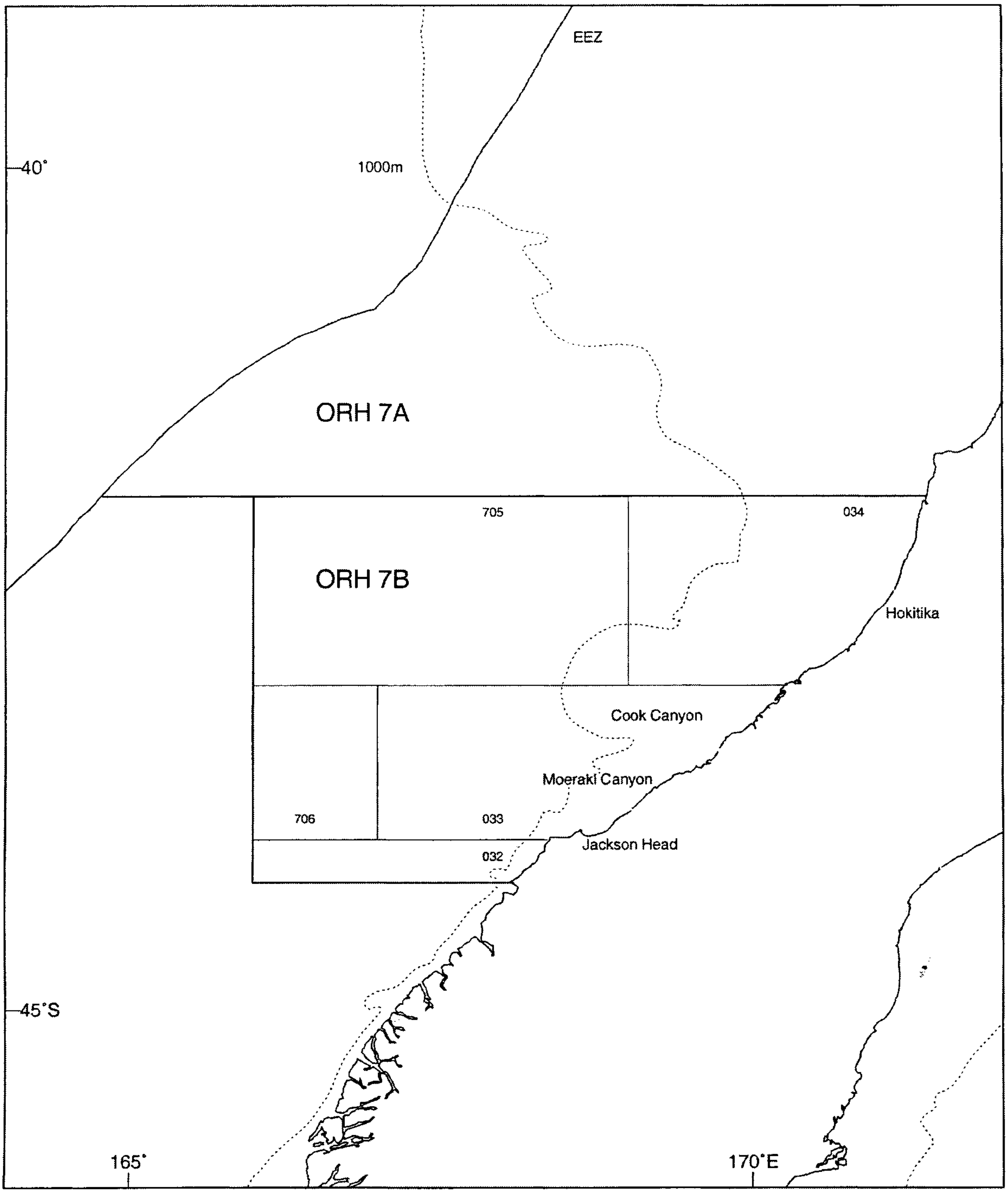

Figure 1: Location of the west coast South Island orange roughy fishery showing domestic fishing return areas.

Table 1: Reported catches, TACCs, and estimated catch totals from TCEPR and CELR data for ORH 7B. Blanks indicate no data.

Fishing year	Reported landings (t)	TACC (t)	TCEPR catch (t)	CELR catch (t)	Total estimated catch (t)	Estimated catch/reported landings (%)
1983–84†	2					
1984–85†	282					
1985–86†	1 763	1 558	1 071	473	1 544	88
1986–87†	1 446	1 558	827	423	1 250	86
1987–88‡	1 413	1 558	911	339	1 250	88
1988–89‡	1 750	1 708	827		827	47
1989–90‡	1 711	1 708	871	411	1 282	75
1990–91‡	1 683	1 708	904	753	1 657	98
1991–92‡	1 604	1 708	905	696	1 601	100
1992–93‡	1 139	1 708	589	539	1 128	99
1993–94‡	701	1 708	481	179	660	94
1994–95‡	290	1 708	185	135	320	110
1995–96‡	446	430	150	125	275	62
1996–97‡	425	430	197	47	244	57
1997–98‡	330	430	39	131	170	52
1998–99‡	405	430	40	320	359	89
1999-2000‡	284	430	85	142	227	80
2000–2001‡	161	430	47	105	152	94
2001–2002‡	95	110	23	60	82	86
2002–2003‡	90	110	13	75	88	87
2003–2004‡	118	110	3	115	118	100
2004–2005‡	106	110	1	100	102	95
2005–2006‡	73	110	0	73	73	100

† FSUdata
‡ QMS data

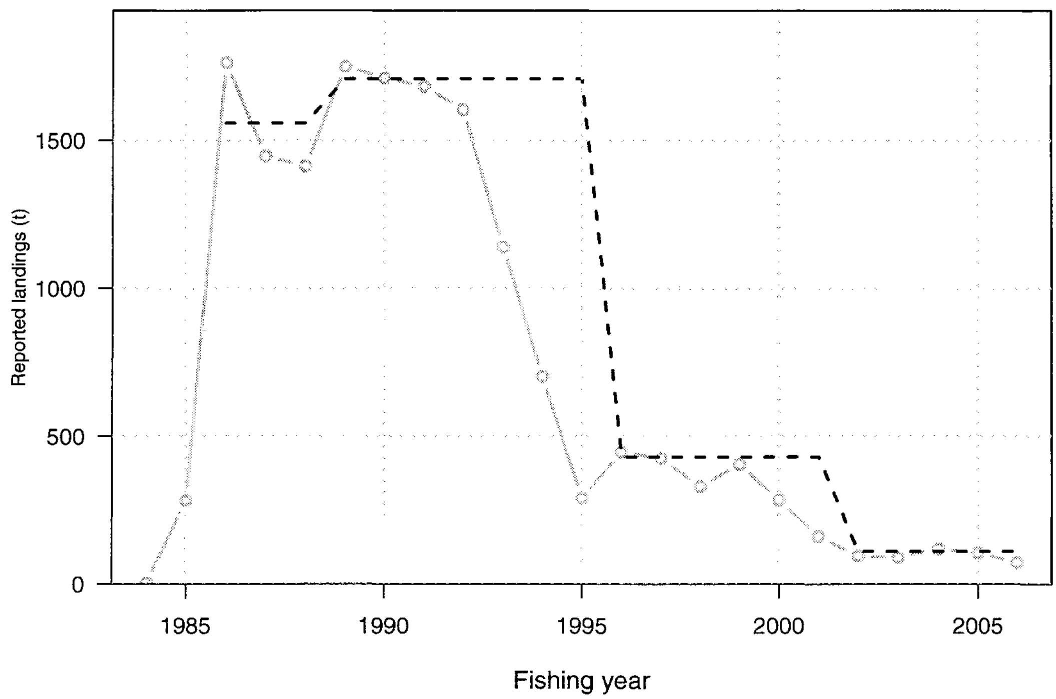

Figure 2: Reported landings (circles joined by solid lines) and the TACC (dashed line).

1.3 Literature review

The initial development of the fishery and early research results were described by Armstrong & Tracey (1986). Several research surveys were carried out in the area in the 1980s (Tracey 1985, Armstrong & Tracey 1987, Tracey et al. 1990) and provided data on distribution and biology of orange roughy in the Cook Canyon area, but no time series of surveys has been developed to assess changes in relative abundance.

2. REVIEW OF THE FISHERY

2.1 Data sources

Catch and effort data from the west coast South Island fishery are recorded on either trawl-catch-effort-processing-returns (TCEPR) or catch-effort-landing-return (CELR) forms. The TCEPR forms give tow-by-tow information, with location and estimated catch for each trawl. The CELR forms provide daily catch records with effort estimated as the number and total duration of tows in the day. CELR forms tend to be used by smaller inshore vessels. Larger deepwater vessels are required to complete TCEPR forms.

The west coast South Island fishery was defined as the area between latitudes 42° and 44.25° S, and longitudes 166° and 171.5° E. This area includes domestic fishing return areas 033, 034, 705, 706, and the northern part of 032 (see Figure 1). Tows (TCEPR) or daily catch records (CELR) within this area that targeted or caught orange roughy were extracted for the 2001 fishing year through to 2006[1]. Only data from 1986 onwards were retained as landings and effort was minimal before then (Table 1).

To combine data from both TCEPR and CELR forms, tow-by-tow data from TCEPR were condensed into a daily format. All tows by a vessel on a day in a statistical area were combined and the catches from individual tows summed. This gave a total daily catch record comparable with CELR data.

The data from 2003 to 2006 were combined with groomed data from 1986 to 2002 (summarised by Field 1999, O'Driscoll 2001, McKenzie 2005).

2.2 Catch effort data

A total of 8814 tows from 3159 vessel days were present in the groomed data (Table 2). Almost all tows targeted orange roughy.

The TACC was reduced to 110 t in 2001–02 and associated with this was a drop in the number of vessel days and tows in 2001–02 (Table 2, Figure 2). In recent year's catch rates, both catch per tow and catch per hour, have remained low, with their mean values in the last three years less than 10% of their values at the start of the fishery. The mean distance towed in the last three years is more than three times the initial level.

[1] Throughout the document year is the fishing year, where the number is based on the calendar year in the latter part of the fishing year, e.g. 2005 denotes the 1 October 2004 – 30 September 2005 fishing year.

Table 2: Summary of groomed data from TCEPR and CELR forms. "*" denotes TCEPR data only.

Fishing year	Number of vessel days	Number of tows	Total recorded estimated catch (t)	Mean daily catch rate (t/tow)	Mean daily catch rate (t/hr)	Mean tow speed* (kt)	Mean tow duration* (h)	Mean tow length* (nm)
1985–86	138	357	1544	4.5	2.9	2.5	1.7	4.4
1986–87	132	405	1250	4.0	2.7	2.6	1.8	4.3
1987–88	132	420	1250	3.4	2.3	2.8	1.6	4.6
1988–89	133	368	827	2.5	1.6	2.9	1.7	5.0
1989–90	123	356	1282	4.5	5.6	2.8	1.6	4.4
1990–91	208	632	1657	2.8	3.3	2.9	1.6	4.8
1991–92	238	810	1601	2.0	1.4	2.9	1.9	5.1
1992–93	258	784	1128	1.5	2.3	3.0	1.7	5.0
1993–94	298	708	660	1.1	0.9	2.8	2.3	6.5
1994–95	162	361	320	0.9	1.6	3.0	2.0	5.4
1995–96	66	150	275	2.2	1.7	2.9	2.1	6.4
1996–97	90	182	244	1.3	7.5	2.9	3.0	8.6
1997–98	96	228	170	0.7	0.3	2.8	2.6	7.0
1998–99	188	566	359	0.6	0.2	2.6	2.6	6.5
1999–2000	213	647	259	0.4	0.1	3.6	4.3	13.5
2000–01	177	431	152	0.3	0.1	3.5	3.2	10.4
2001–02	120	276	82	0.3	0.1	3.8	3.5	12.3
2002–03	89	231	88	0.4	0.2	3.8	3.6	12.2
2003–04	90	252	118	0.4	0.2	3.6	3.8	14.0
2004–05	121	393	102	0.3	0.1	4.2	4.6	14.2
2005–06	87	257	73	0.3	0.2	4.4	3.7	15.3

2.3 Seasonal and spatial distribution of catch and effort

Historically most effort (Table 3, Figure 3) and catch (Table 4, Figure 4) in the west coast South Island fishery has been concentrated in the winter spawning period (June and July) with a much smaller, secondary peak in catch and effort in September and October. Since 1998, catch has tended to be more spread throughout the year and less of it has been recorded on TCEPR forms (Figure 5 and Figure 6).

The geographical distribution of effort has changed over the course of the fishery (Figure 7). Initially effort was concentrated in a very small area in the Cook Canyon at the intersection of statistical areas 033, 034, and 705. Effort became more dispersed in 1993 as fishers ranged widely in an attempt to catch the available quota and has remained widespread.

Catch rate plots (Figure 8) show high catch rates in the Cook Canyon in the early years of the fishery. Catch rates have decreased as the fishery dispersed, but relatively high catches were taken in the Moeraki Canyon to the south in 1993 and 1994. Catch rates have been low throughout ORH 7B in 1997–2006, with very few catches over 5 t.

Table 3: Monthly distribution of effort (number of tows) in the west coast South Island orange roughy fishery.

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1985–86	129	4	0	9	2	0	24	45	104	4	8	28
1986–87	111	14	0	0	1	0	2	1	238	2	33	3
1987–88	0	0	0	2	0	0	0	23	359	30	6	0
1988–89	0	0	0	0	0	0	0	43	229	11	51	34
1989–90	0	0	4	0	0	0	21	0	204	77	50	0
1990–91	88	26	3	22	2	0	12	77	228	115	4	55
1991–92	26	16	0	0	0	3	0	24	416	285	39	1
1992–93	72	0	0	0	0	0	0	43	185	436	15	33
1993–94	28	15	5	27	9	11	5	7	206	367	22	6
1994–95	2	21	15	13	2	13	1	35	76	149	24	10
1995–96	11	4	0	0	0	1	0	2	53	79	0	0
1996–97	6	1	0	2	0	0	0	7	127	39	0	0
1997–98	14	2	3	3	0	7	8	3	77	47	1	63
1998–99	33	28	12	48	11	42	25	25	128	76	0	138
1999–2000	22	23	12	15	4	10	79	65	208	96	16	97
2000–01	1	21	7	0	4	4	15	44	183	60	21	71
2001–02	1	6	0	16	0	21	14	17	44	65	20	72
2002–03	10	0	3	6	0	11	15	43	81	4	15	43
2003–04	12	8	28	24	5	4	21	48	88	2	1	11
2004–05	20	4	0	4	7	28	5	49	116	84	19	57
2005–06	0	0	12	12	0	5	32	25	74	68	24	5

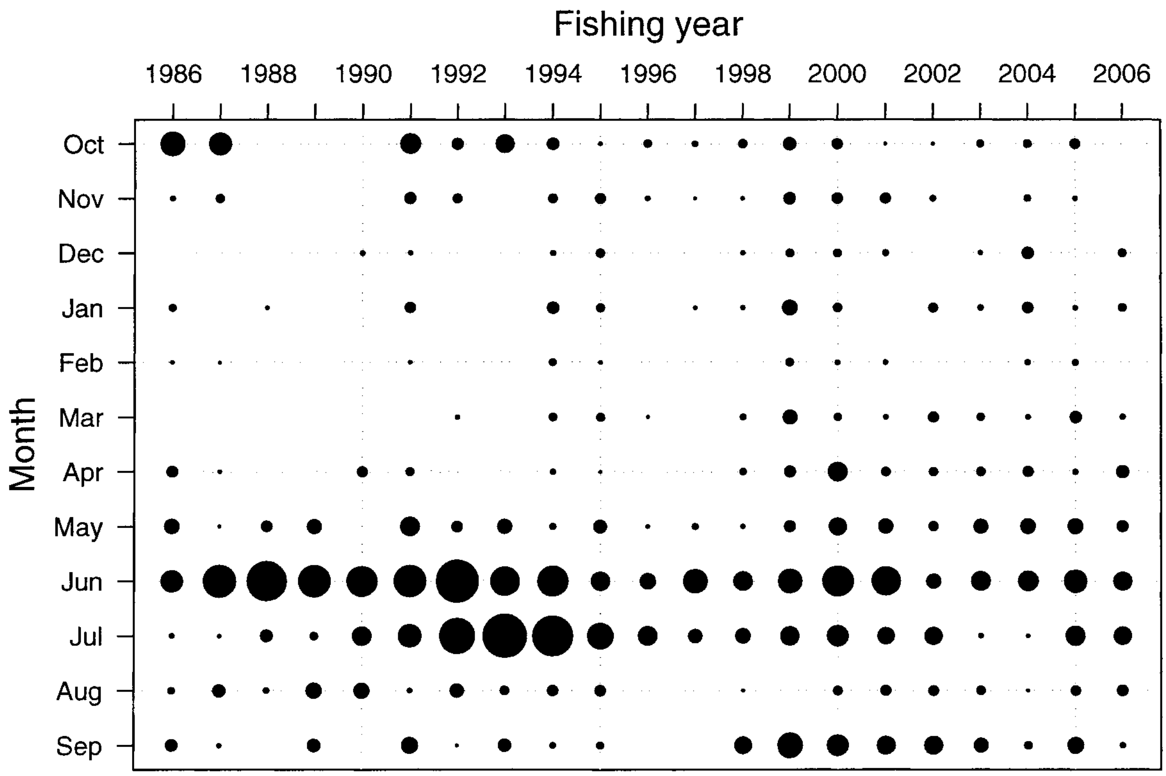

Figure 3: Monthly distribution of effort (number of tows) in the west coast South Island orange roughy fishery (see Table 3). The area of the circles is proportional to the number of tows; the largest circle represents 436 tows.

Table 4: Monthly distribution of estimated catch (t) in the west coast South Island orange roughy fishery. Blanks indicate months when there was no effort (see Table 3).

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1985–86	419	1		15	1		22	68	855	91	9	64
1986–87	144	0			1		0	0	994	19	44	48
1987–88				0				78	888	210	75	
1988–89								85	535	116	81	9
1989–90			6				14		248	827	188	
1990–91	184	34	12	30	1		3	62	474	734	12	111
1991–92	6	6				0		3	659	879	48	0
1992–93	30							17	494	531	19	36
1993–94	33	7	10	5	13	1	1	2	106	375	86	22
1994–95	0	43	10	3	2	5	0	8	76	164	3	3
1995–96	2	0				2		0	156	114		
1996–97	2	0		2				5	203	33		
1997–98	20	0	0	0		1	1	0	28	57	0	62
1998–99	45	31	7	22	2	10	10	3	94	68		69
1999–2000	7	12	7	4	0	1	27	13	91	57	3	38
2000–01	0	13	1		0	1	3	13	55	28	15	23
2001–02	0	1		5		11	3	4	16	24	4	15
2002–03	2		0	4		5	6	12	41	4	3	12
2003–04	2	3	13	11	2	2	6	12	54	0	0	13
2004–05	4	0		1	1	5	1	6	26	31	6	20
2005–06			8	1		1	5	4	22	25	6	1

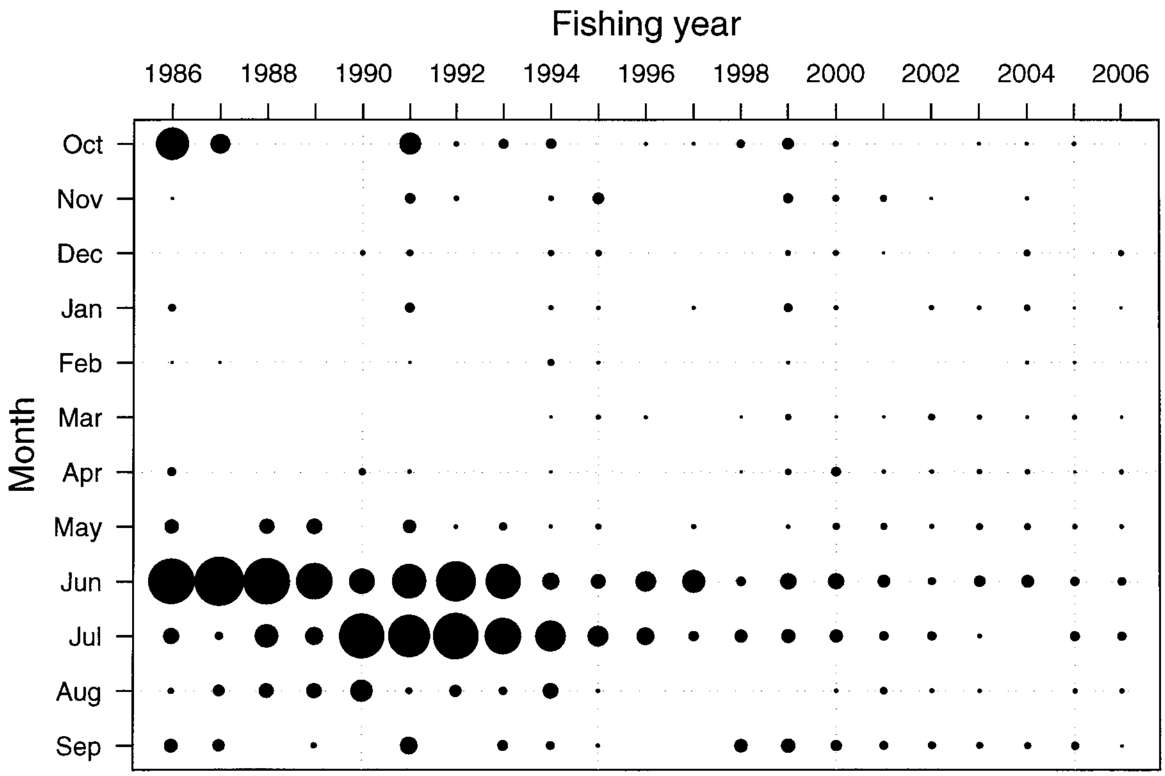

Figure 4: Monthly distribution of estimated catch (t) in the west coast South Island orange roughy fishery (see Table 4). The area of the circles is proportional to the number of tows; the largest circle represents 994 tons. No circles indicate months where there was no effort.

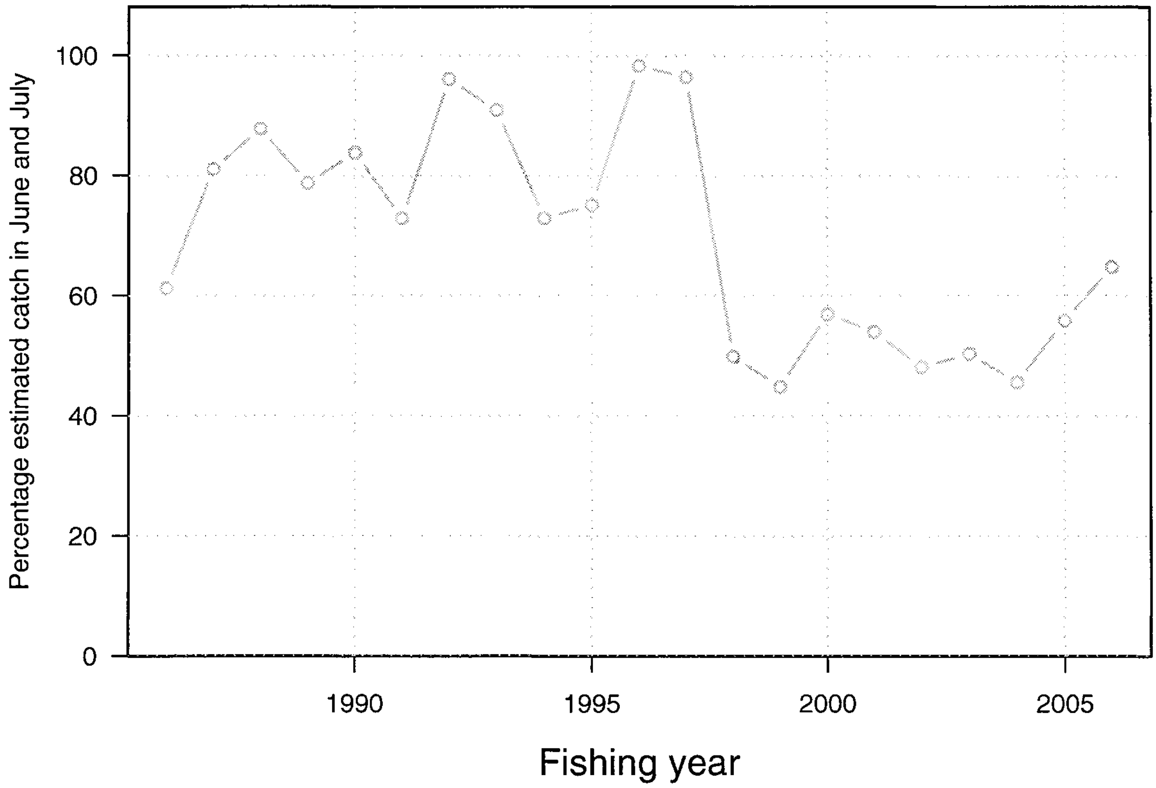

Figure 5: Percentage of the estimated catch taken in June and July.

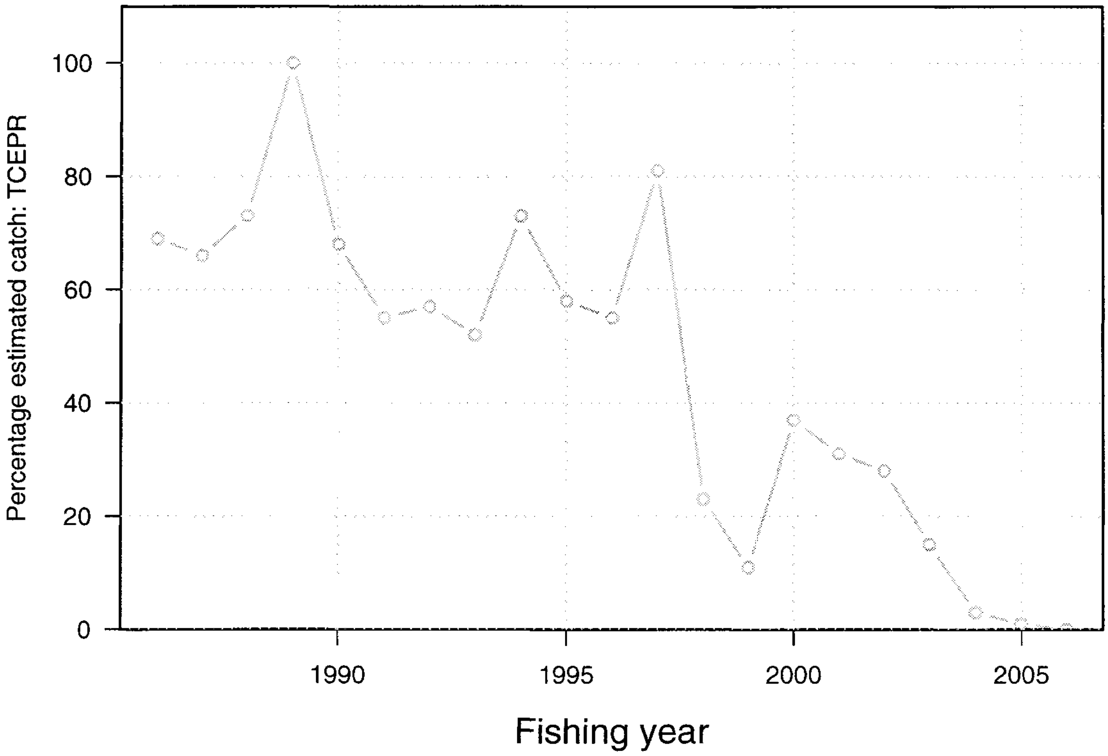

Figure 6: Percentage of the estimated catch recorded under TCEPR forms.

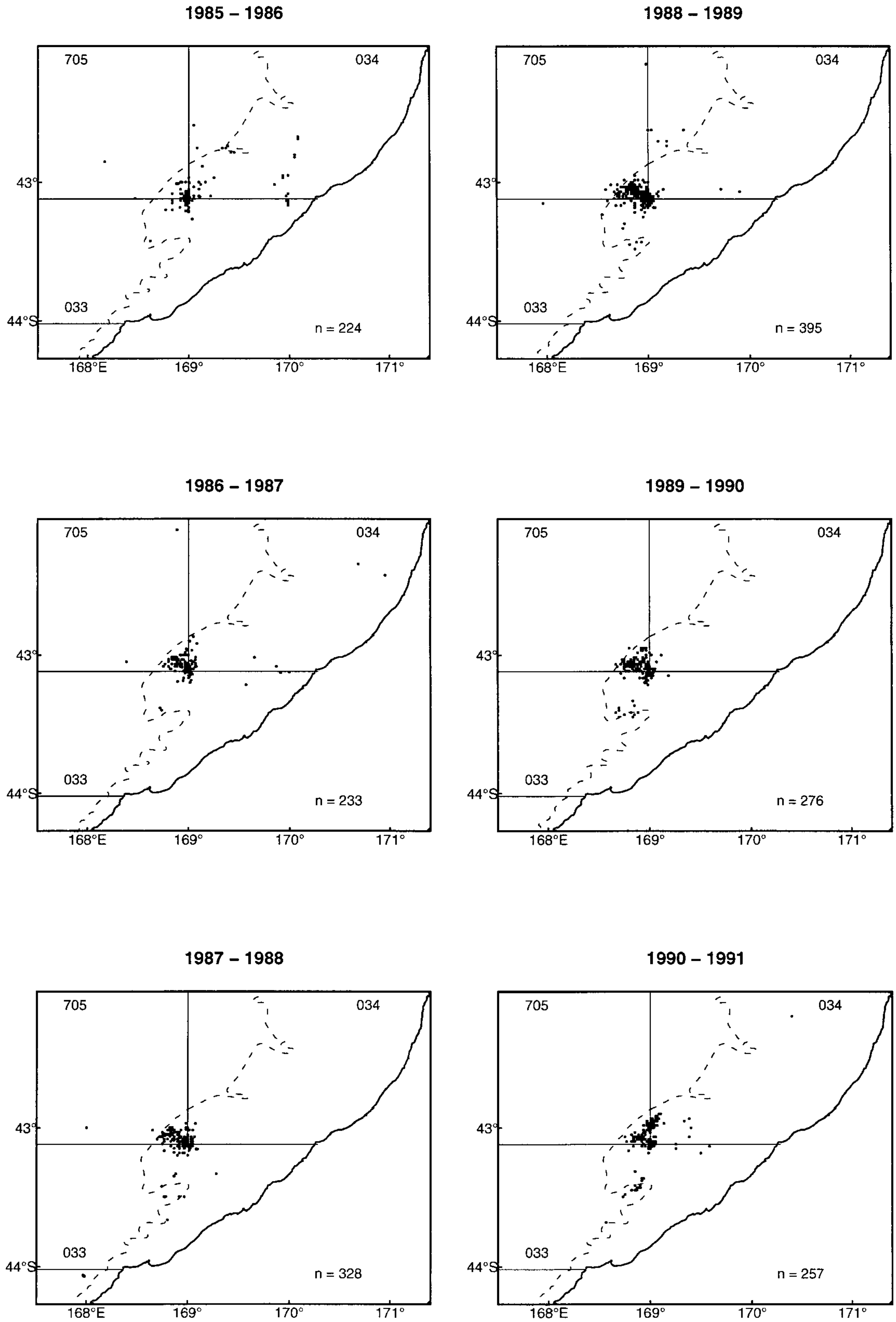

Figure 7: Positions of tows which targeted or caught orange roughy in the west coast South Island fishery, 1985–86 to 1990–91. TCEPR data only. Dotted line is 1000 m isobath.

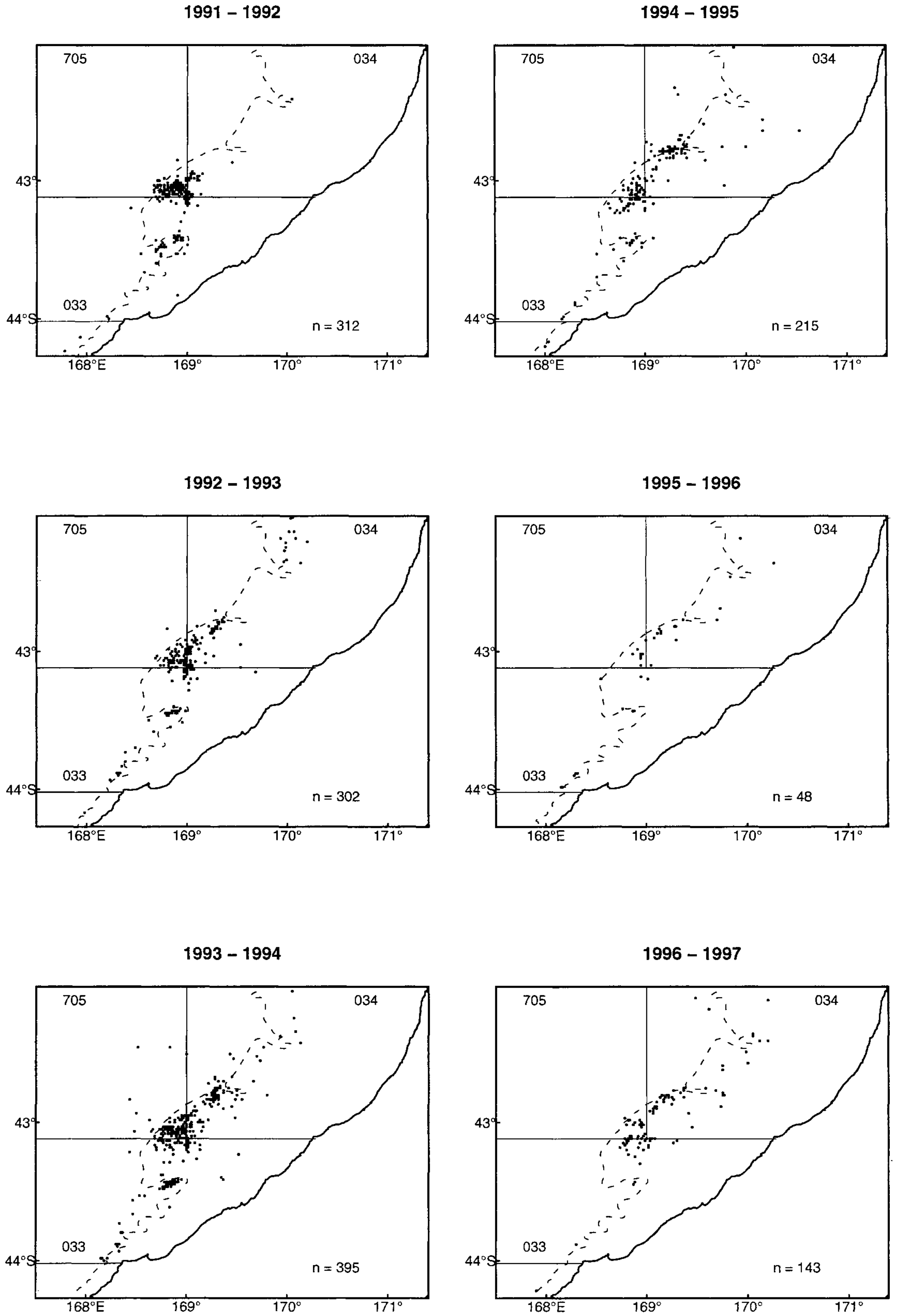

Figure 7 cntd: Positions of tows which targeted or caught orange roughy in the west coast South Island fishery, 1991–92 to 1996–97. TCEPR data only. Dotted line is 1000 m isobath.

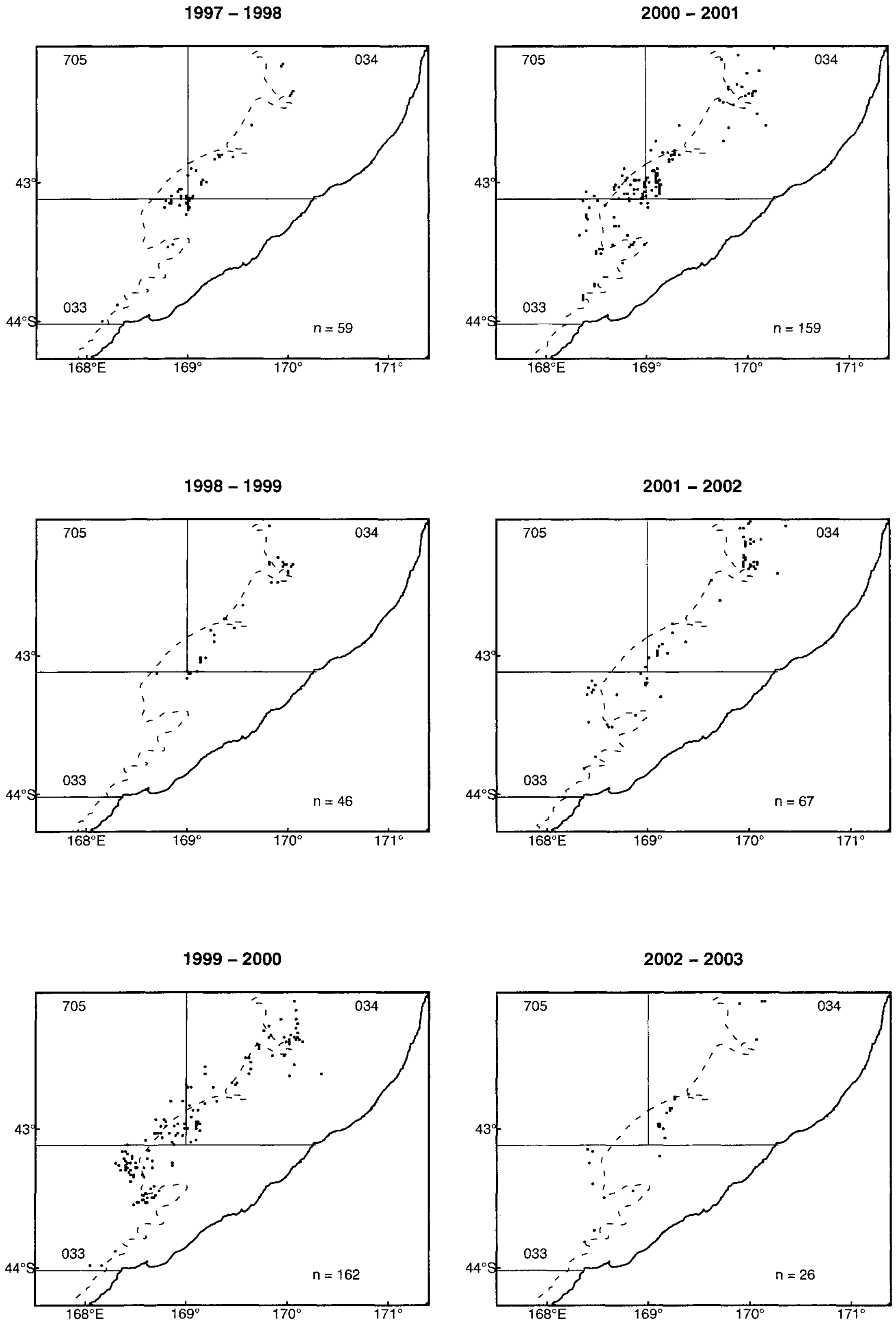

Figure 7 cntd: Positions of tows which targeted or caught orange roughy in the west coast South Island fishery, 1997–98 to 2002–03. TCEPR data only. Dotted line is 1000 m isobath.

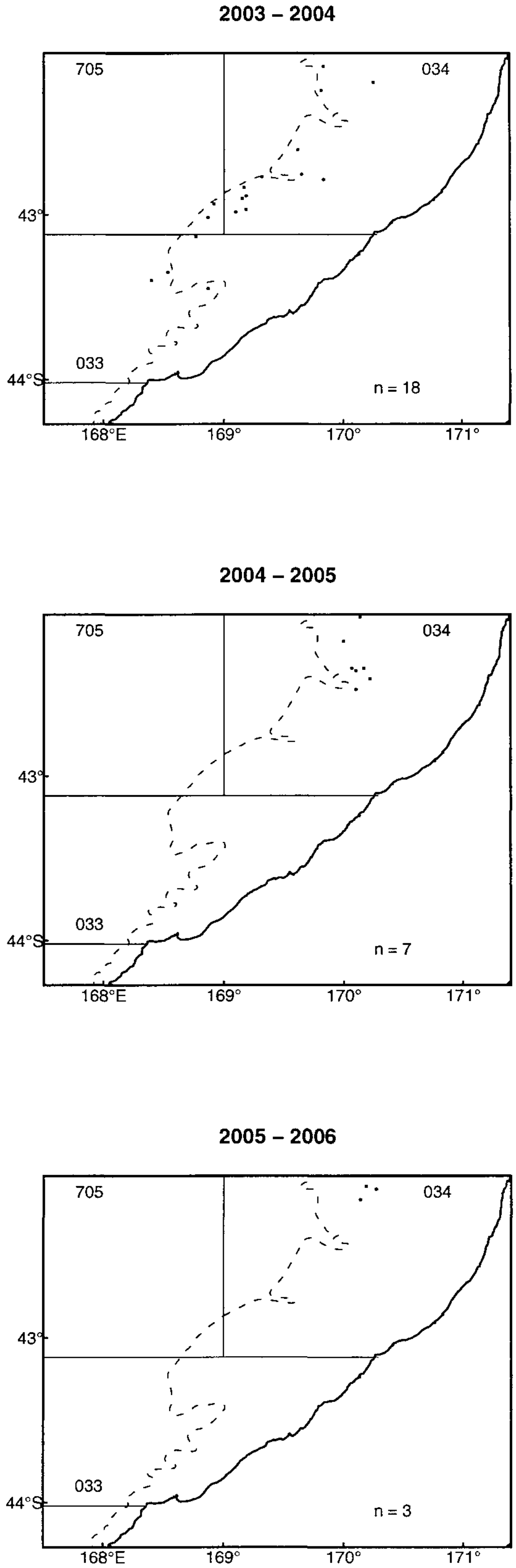

Figure 7 cntd: Positions of tows which targeted or caught orange roughy in the west coast South Island fishery, 2003–04 to 2005–06. TCEPR data only. Dotted line is 1000 m isobath.

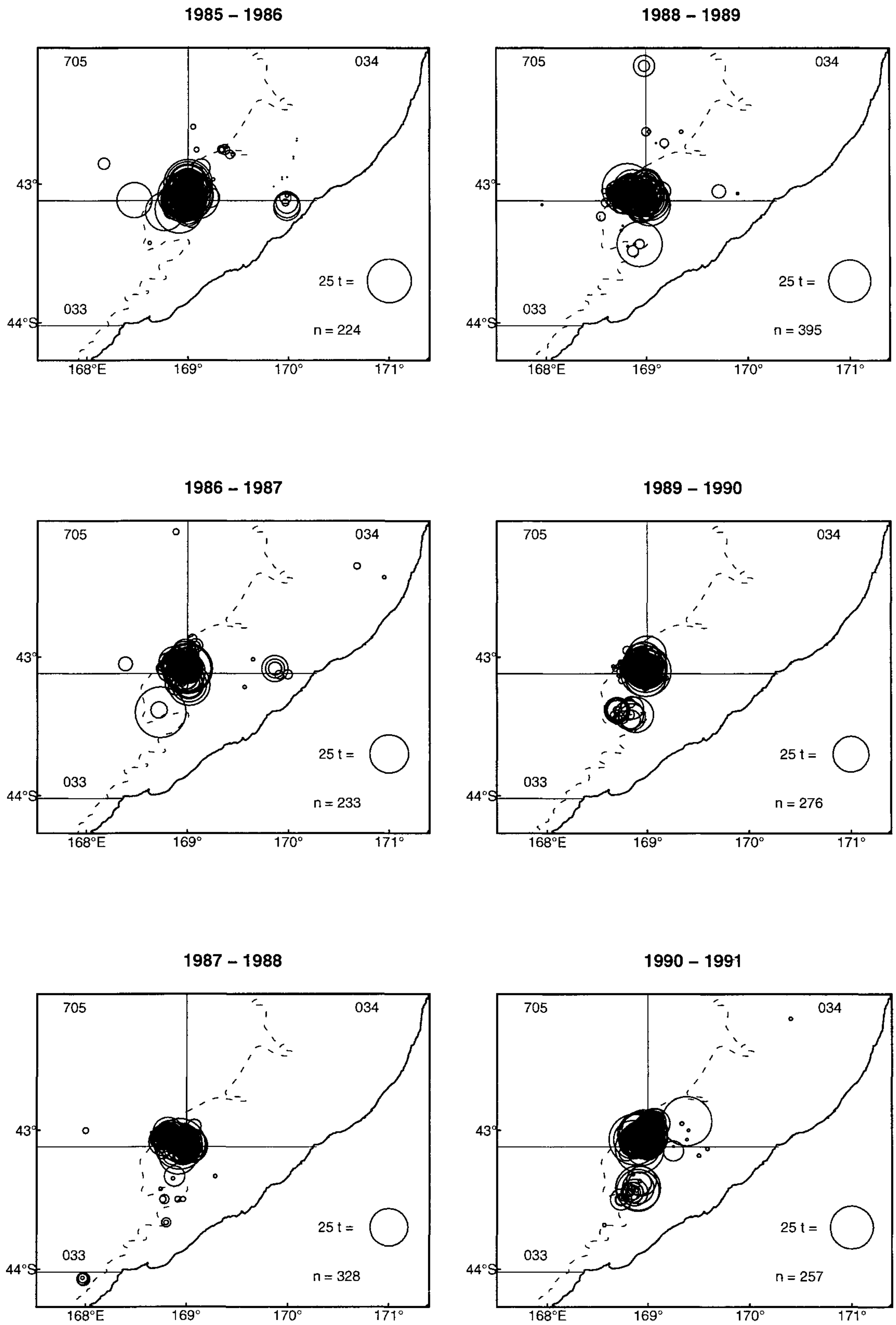

Figure 8: Unstandardised catch rates of tows which targeted or caught orange roughy in the west coast South Island fishery, 1985–86 to 1990–91. Circle area is proportional to t/tow. TCEPR data

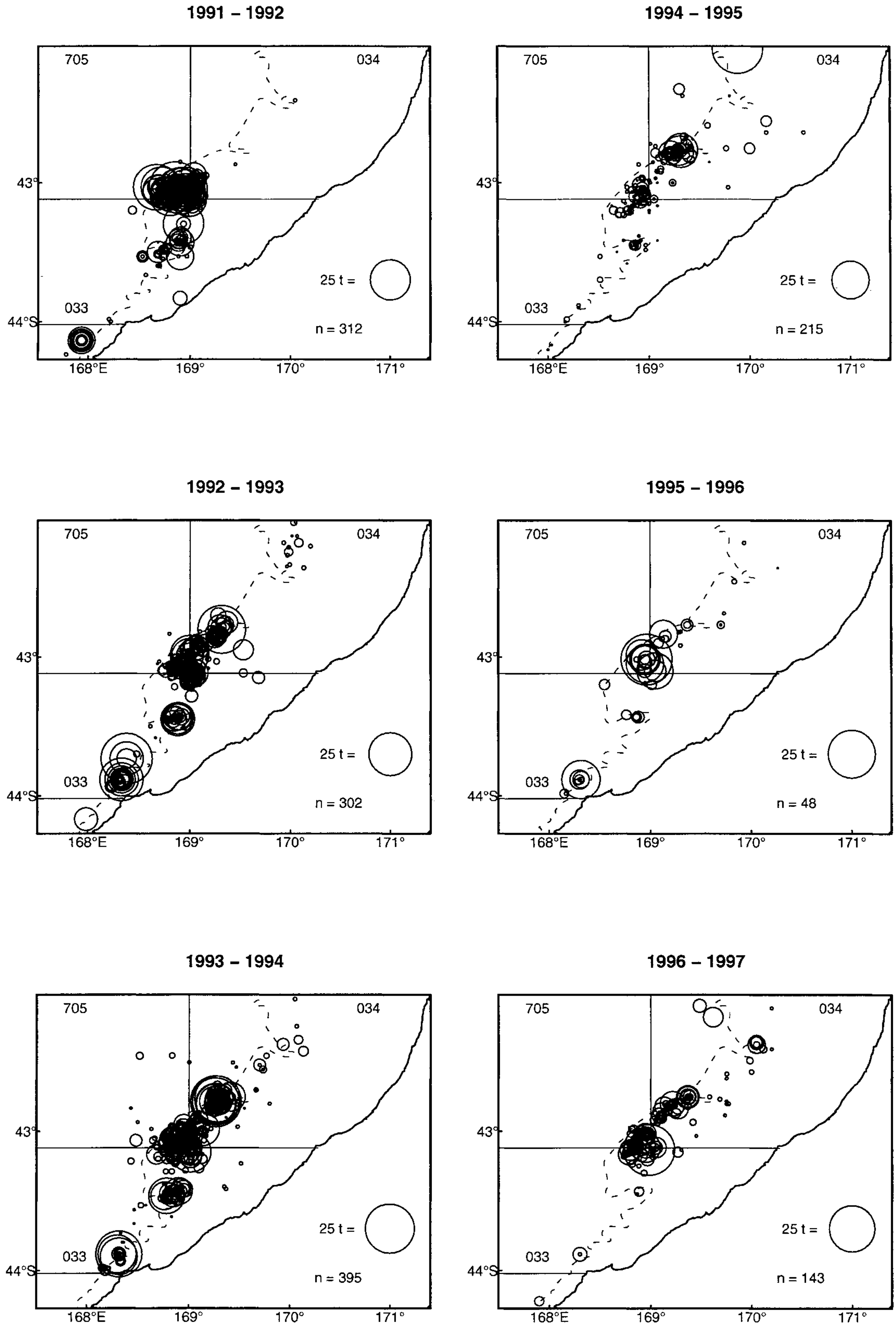

Figure 8 cntd: Unstandardised catch rates of tows which targeted or caught orange roughy in the west coast South Island fishery, 1991–92 to 1996–97. Circle area is proportional to t/tow. TCEPR data only. Dotted line is 1000 m isobath.

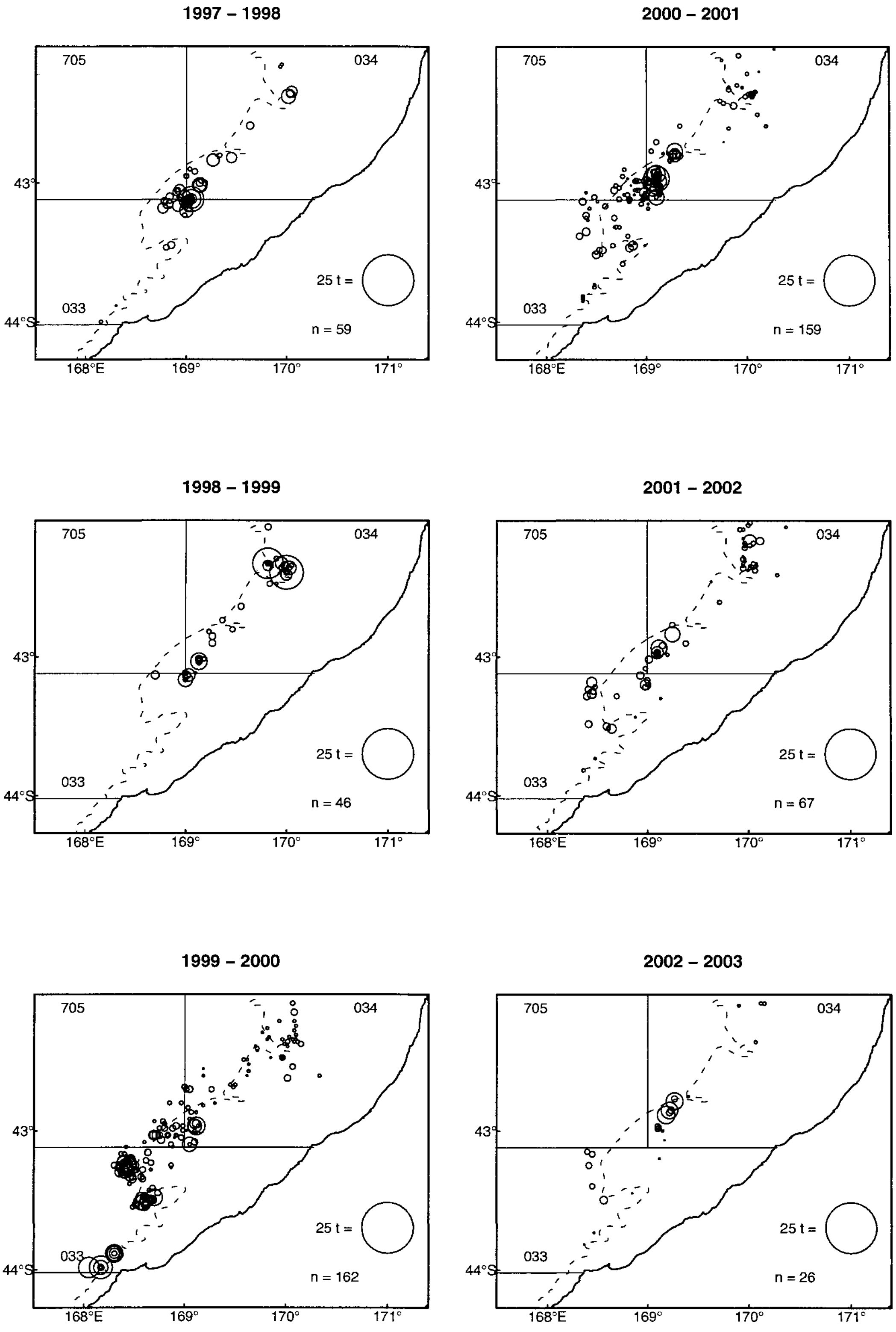

Figure 8 cntd: Unstandardised catch rates of tows which targeted or caught orange roughy in the west coast South Island fishery, 1997–98 to 2002–03. Circle area is proportional to t/tow. TCEPR data only. Dotted line is 1000 m isobath.

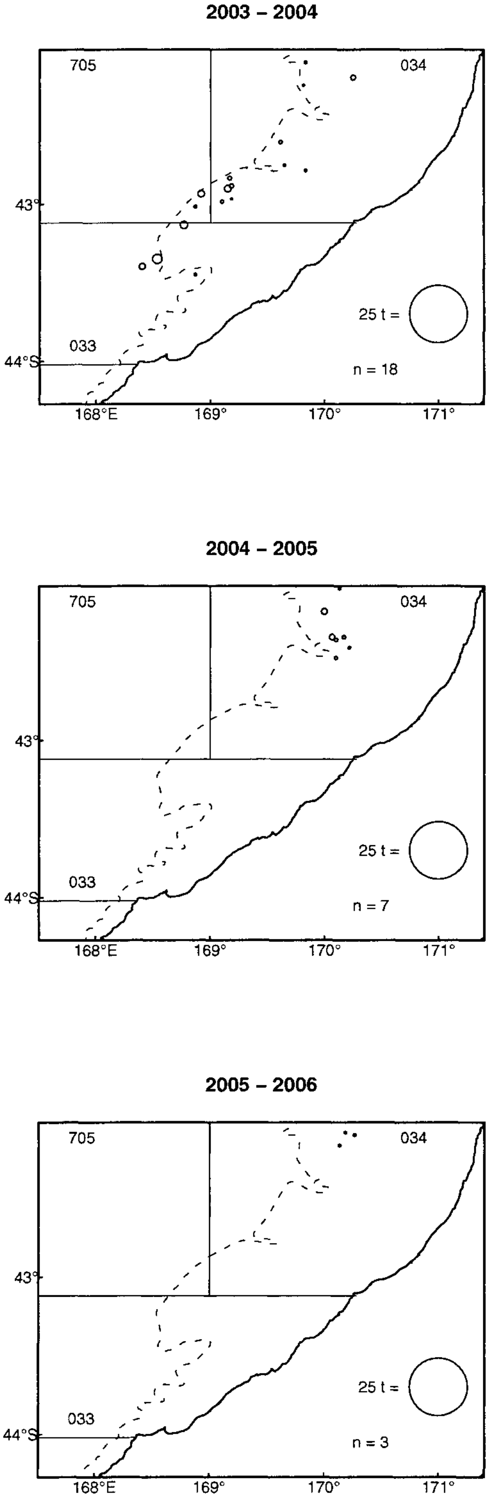

Figure 8 cntd: Unstandardised catch rates of tows which targeted or caught orange roughy in the west coast South Island fishery, 2003–04 to 2005–06. Circle area is proportional to t/tow. TCEPR data only. Dotted line is 1000 m isobath.

3. STANDARDISED CATCH PER UNIT EFFORT (CPUE) ANALYSES

Up until 1997 about 70% of the estimated catch was recorded on TCEPR forms. In 1998 this decreased to 20% and now nearly all the catch is recorded on CELR form (see Figure 6). Because of this change in the fleet composition, and associated perceived difficulties with vessel linkage across years, it was decided by the Deepwater Working Group to split the standardised CPUE analysis into two series: (i) using TCEPR data from 1986 to 1997, and (ii) using CELR data from 1991 to 2006. In addition, in order to increase vessel linkage across years, it was decided to use all months of data, not just from the winter fishery (June-July) as had been done for previous standardisations (O'Driscoll 2001, McKenzie 2005).

For both series standardised catch per unit effort (CPUE) analyses were carried out using Generalised Linear Models (GLMs), based on the procedure explained by Vignaux (1994), and as modified by Francis (2001). The aim behind this type of analysis is to remove the effect of changes in fishing patterns and conditions (e.g., the type of vessel used, when fishing was done, fishing techniques used) on the catch rate, leaving a component that is presumed to be proportional to the biomass of fish present.

A step 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 Akaike Information Criterion (AIC). Predictor variables were accepted into the model only if they explained at least 0.5% of the deviance.

3.1 Standardised CPUE analysis for TCEPR data (1986–97)

3.1.1 Input data

For the TCEPR data set the vessels were restricted to those that had fished at least two years with 30 non-zero tows. This restriction resulted in an input data set consisting of 2414 tow records from 8 vessels (from an original 29), and represented 64% of the recorded catch from 1986 to 2006. Overlap between selected vessels is good, and two vessels fished for more than nine years (Table 5, Figure 9). However, in 1996 there is a total of only 37 tows, so the year effect for 1996 may be poorly estimated.

Table 5: Number of non-zero TCEPR tows by vessel (rows) and fishing year (columns), for vessels selected to go into the standardised CPUE analysis. The vessels labels are arbitrary.

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	67	85	73	0	0	0	0	0	0	0	0	0
2	0	30	33	43	0	0	0	0	3	0	0	0
3	29	7	27	72	60	15	0	0	0	0	0	0
4	17	0	0	27	9	37	3	32	0	0	0	0
5	0	0	79	155	139	110	109	105	53	7	18	19
6	40	28	0	13	28	60	44	64	47	0	19	85
7	0	0	0	0	0	16	75	29	99	91	0	0
8	0	0	0	0	0	0	0	0	139	74	0	0

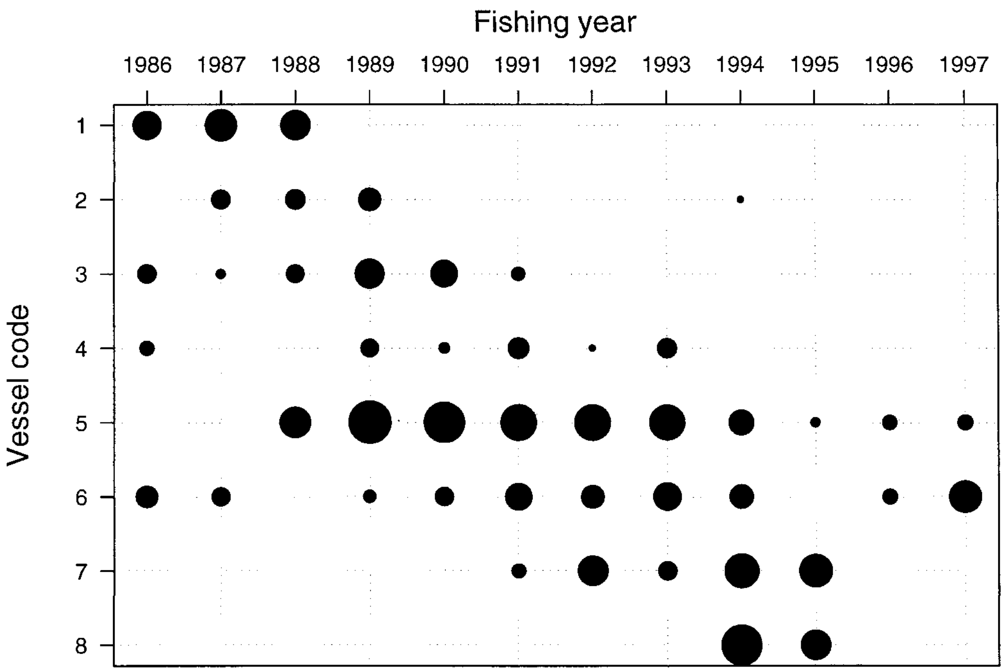

Figure 9: Graphical representation of number of non-zero TCEPR tows by fishing vessel and year, for vessels selected to go into the standardised CPUE analysis (see Table 6). The area of a circle is proportional to the number of tows; the largest circle represents 155 tows.

3.1.2 Methods

In the standardised CPUE analysis catch rate (the dependent variable) was modelled as log(catch per tow). For about 8% of the tows the estimated catch was zero and these were ignored in the standardised analysis as typically this proportion of zero tows makes very little difference to the resultant standardised CPUE indices. Furthermore, due to the way catch is recorded and estimated not all these will be actual zero tows, but the extent to which they are is unknown.

Variables used as possible predictors of catch rate were fishing year, month, vessel, tow duration, tow speed, tow depth, and distance class (Table 6). The distance bin categorical variable is derived from projecting tow positions along a diagonal line (Figure 10), then dividing the projected distances into distance bins (Figure 11).

Table 6: Variable entered into the standardised CPUE analysis for the TCEPR data. Duration, speed, and depth were offered to the model as third-degree polynomials.

Variable offered	Type	Description
fishing year	categorical	Fishing year: 1995 = 1 Oct 94 – 31 Sep 95
month	categorical	Month (Oct, Nov, Dec, etc)
vessel	categorical	Each vessel was an independent variable
duration	continuous	Tow duration
speed	continuous	Speed of vessel
depth	continuous	Bottom depth
distance bin	categorical	Projected distance from fishing centre (see Figure 11)

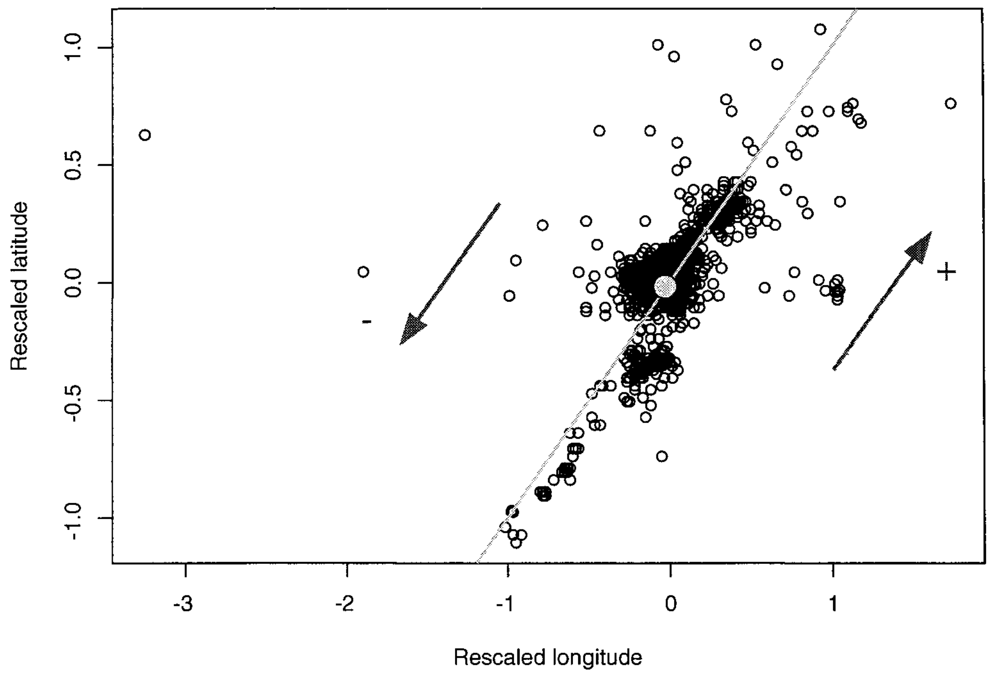

Figure 10: Projecting the TCEPR data tow position on to a line. The longitude and latitude values are rescaled so that they are zero at the centre of the cluster of the points (shown by a solid circle). The direction for positive and negative projected distances is shown by the arrows.

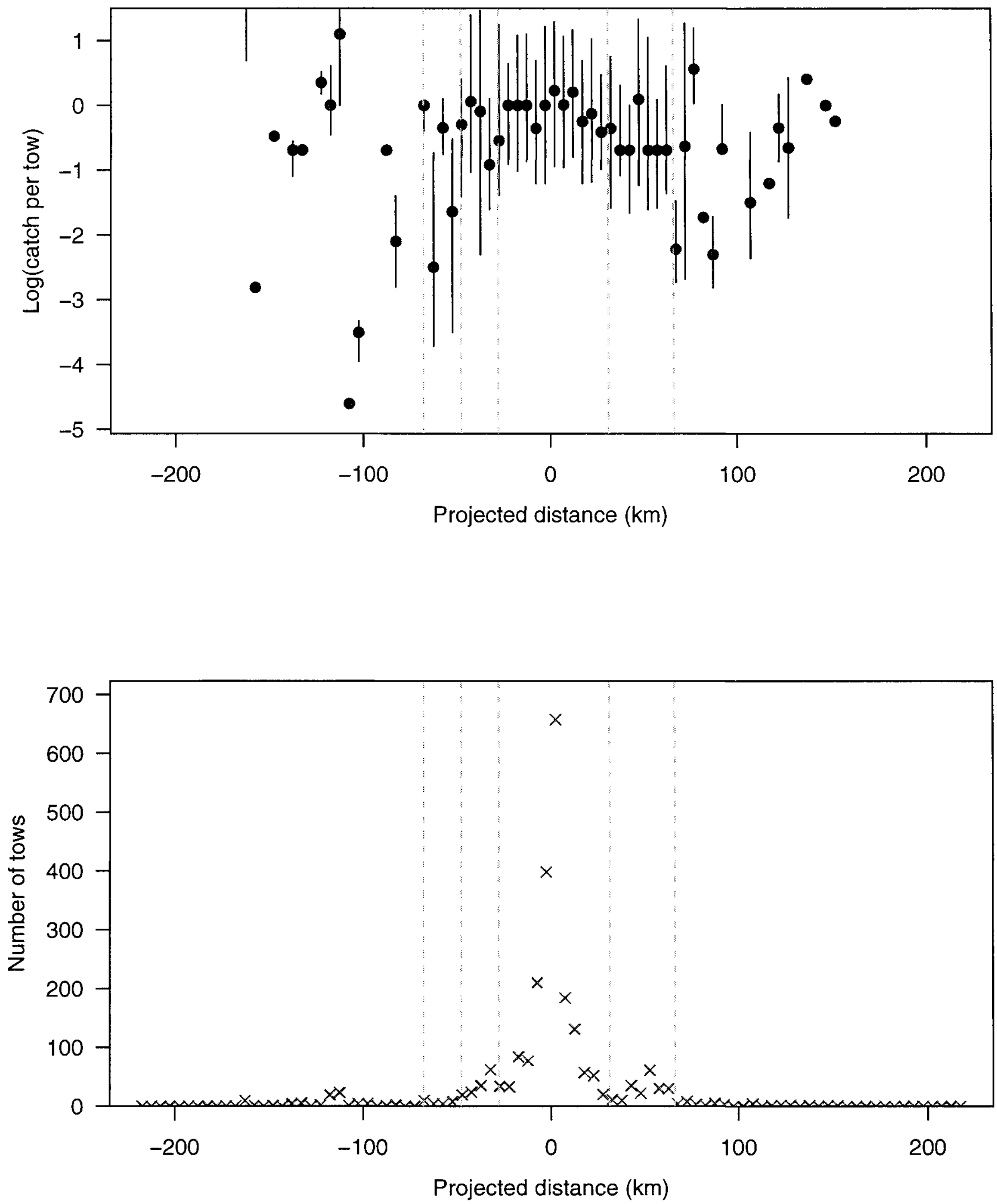

Figure 11: Pictorial representation of the projected distance bins with respect to the log of the catch rate (top graph) and number of tows (bottom graph). The locations of the bins is shown by the vertical dashed lines, with the leftmost bin bounded at -220 km and the rightmost bin at 220 km. Median catch rates are found for each 5 km bin and the number of tows is summed for each 5 km bin. For the top graph the lower and upper quartiles are shown for each bin as the end points of the vertical line segments.

3.1.3 Results for TCEPR data (1986–97)

Variables selected by the regression model were fishing year, month, vessel, and distance (Table 7). The month effects are consistent with the raw data, with a peak in catch rates in June (Figure 12). The February month effect seems anomalously high, but it is based on just six tows. The distance bin effects differ from what one may expect from the raw data for which there was a peak in catch rate for the bin centred on a projected distance of zero. However, the distance bins effects are after the month effects are removed, and these two are highly correlated (e.g., high catch rates in June take place in the bin centred on a projected distance of zero). Overall the model explained 23% of the variability in CPUE, and the diagnostic plot suggests a good fit for the model (Figure 13).

The standardised year effects showed a pattern of steep decline from the initial years of the fishery, followed by a more gradual decline, with an increase in the last two years (Table 8, Figure 14). In the last two years the index is about 22% of the value in the first two years.

Table 7: Variables included in the final model for the TCEPR data (0.5% additional deviance explained).

	Dof	AIC	Percentage deviance explained	Additional % deviance explained
Fishing year	10	8879	11.8	11.8
Month	11	8689	19.2	7.4
Vessel	7	8616	22.1	2.9
Distance class	5	8592	23.1	1.1

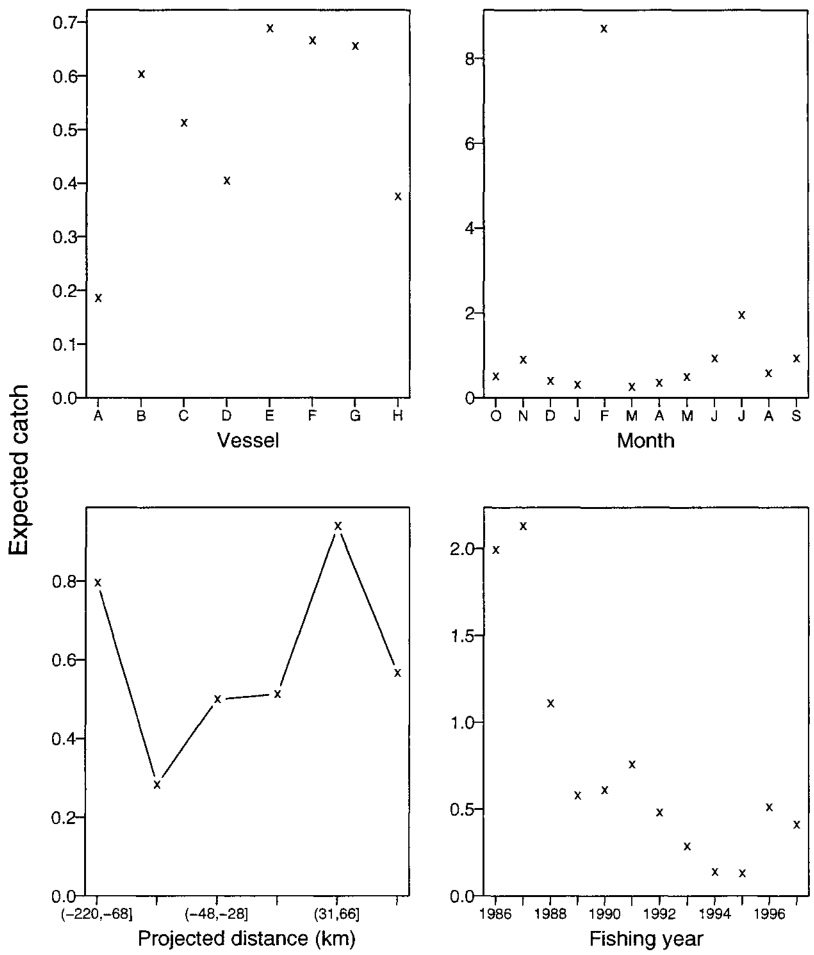

Figure 12: Vessel, month, projected distance class, and year effects for the fitted model.

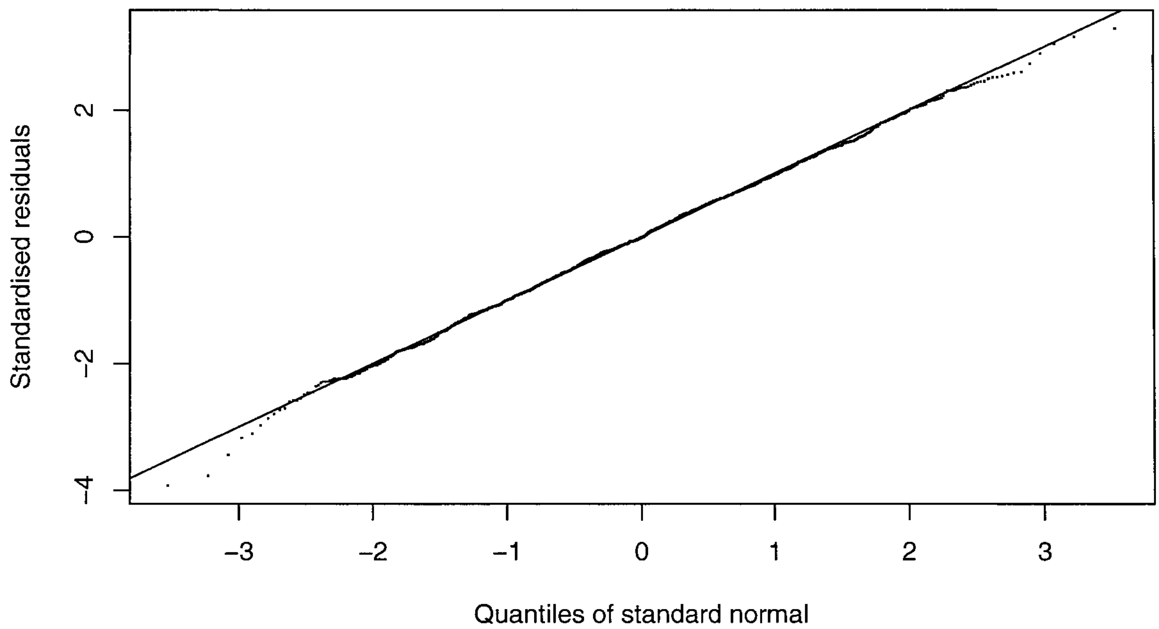

Figure 13: Diagnostics plot for the model for the TCEPR data. The sorted standardised residuals are plotted (y-axis) against the corresponding quantiles of the standard normal distribution (x-axis).

Table 8: Standardised CPUE indices (relative year effect) for the TCEPR data with number of tows from 1986 to 1997. nobs, no. of observations

year	nobs	standardised CPUE	c.v.
1986	153	1.99	0.20
1987	150	2.13	0.23
1988	212	1.11	0.26
1989	310	0.58	0.22
1990	236	0.61	0.22
1991	238	0.76	0.23
1992	231	0.48	0.23
1993	230	0.29	0.23
1994	341	0.14	0.25
1995	172	0.13	0.27
1996	37	0.51	0.33
1997	104	0.41	0.26

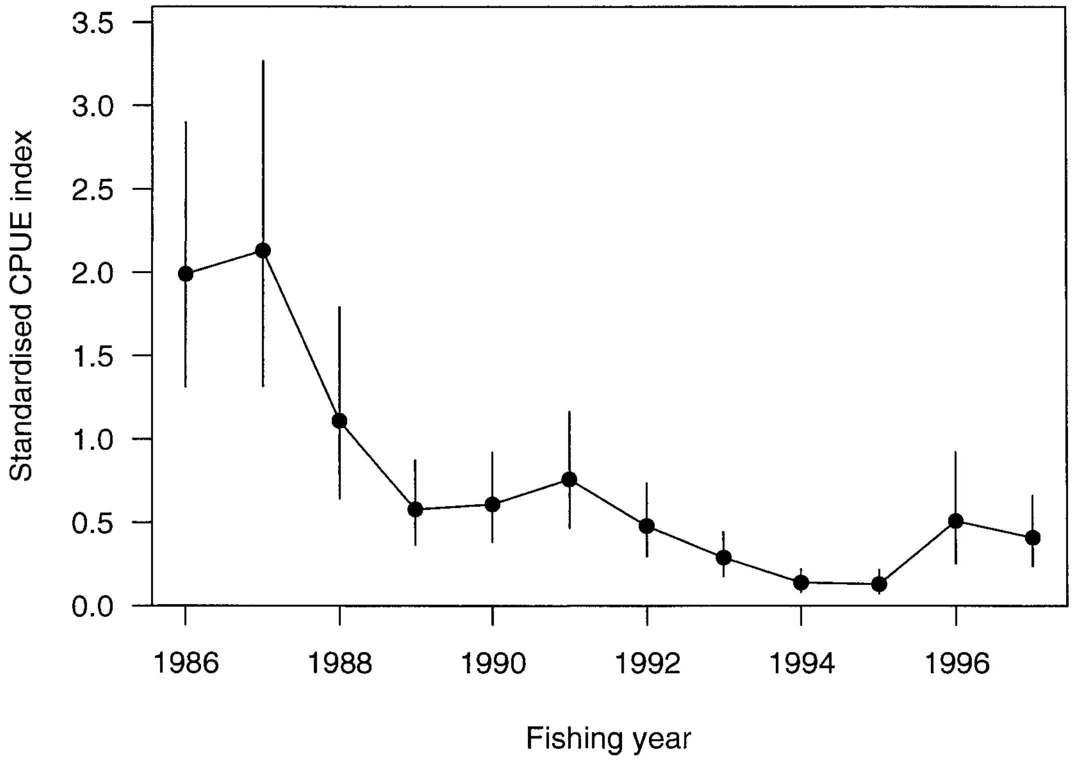

Figure 14: Standardised CPUE index for the TCEPR data (see Table 8). The error bars represent the 95% confidence intervals.

3.2 Standardised CPUE analysis for CELR data (1991–2006)

3.2.1 Input data

For the CELR data set the vessels were restricted to those that had fished at least 20 days and for two or more years. This data set consisted of 1318 daily records (4415 tows) from 10 vessels (from an original 13), and represented 46% of the catch from 1991 to 2006. Overlap between selected vessels is generally good, and two vessels fished for more than eight years (Table 9, Figure 15). However, in 1996 and 1997 there are only 29 and 19 daily records respectively, so the year effects for these years may be poorly estimated.

Table 9: Number of non-zero CELR daily records by vessel (rows) and fishing year (columns), for vessels selected to go into the standardised CPUE analysis. The vessels labels are arbitrary.

	91	92	93	94	95	96	97	98	99	2000	2001	2002	2003	2004	2005	2006
1	36	26	32	25	0	0	0	0	0	0	0	0	0	0	0	0
2	3	6	10	4	0	0	0	0	0	0	0	0	0	0	0	0
3	26	27	35	14	17	26	19	37	48	0	0	0	0	0	0	0
4	22	18	23	0	0	0	0	10	22	40	0	0	0	0	0	0
5	9	10	5	9	0	0	0	0	0	2	18	12	0	0	0	0
6	16	22	21	31	29	3	0	5	37	70	67	34	52	39	43	40
7	0	0	0	0	0	0	0	0	2	19	0	14	6	1	36	17
8	0	0	0	0	0	0	0	0	0	0	3	4	1	13	10	2
9	0	0	0	0	0	0	0	0	4	0	0	9	0	10	10	15
10	0	0	0	0	0	0	0	0	0	0	0	0	8	12	15	7

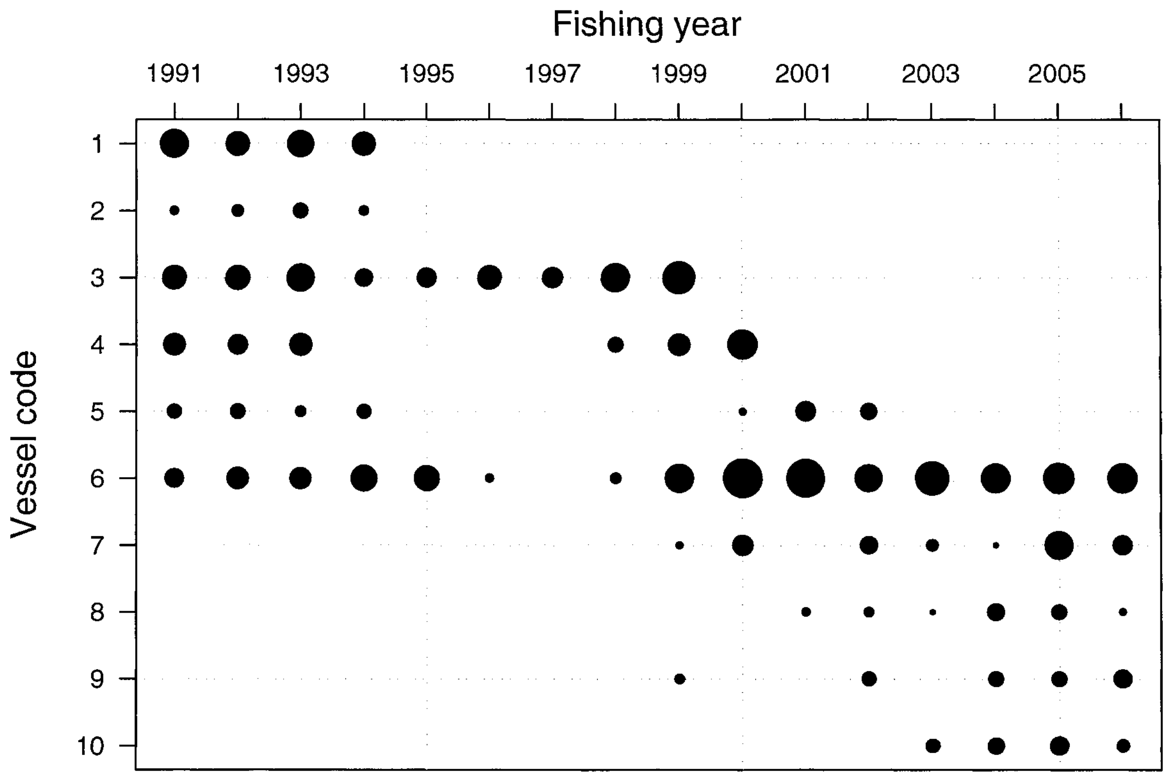

Figure 15: Graphical representation of number of non-zero CELR daily records by fishing vessel and year, for vessels selected to go into the standardised CPUE analysis (Table 9). The area of a circle is proportional to the number of tows; the largest circle represents 70 daily records.

3.2.2 Methods

Catch rate (the dependent variable) was modelled as log(mean daily catch). There were a small number of daily records where the catch rate was zero (less than 1%) and these were ignored in the standardised analysis.

Variables used as possible predictors for the catch rate were fishing year, month, vessel, statistical area, and daily total tow duration (Table 10). Other variables, such as tow speed and depth, which are commonly included in CPUE analyses, are not recorded on CELR forms.

Table 10: Variables entered into the standardised CPUE analysis for the CELR data. Duration (daily) is the daily total tow duration, and was offered to the model as a linear term.

Variable offered	Type	Description
fishing year	categorical	Fishing year: 1995 = 1 Oct 94 – 31 Sep 95
month	categorical	Month (Oct, Nov, Dec, etc)
vessel	categorical	Each vessel was an independent variable
area	categorical	Statistical area
duration (daily)	continous	Daily total hours of towing

3.2.3 Results for CELR data (1991–2006)

Variables selected by the regression model were fishing year, month, duration (daily), and vessel (Table 11). The month effects are consistent with the raw data, with a peak in catch rates in June (Figure 16). The daily catch increased as the daily tow duration increased. Overall, the model explained 36% of the variability in CPUE, and the diagnostic plot suggests a good fit for the model, though the data has slightly fewer days with low catch rates then assumed by the model (Figure 17).

The standardised year effects showed a pattern of steep decline for the first four years of the fishery, followed by an increase to a peak in 1996, and subsequent low catch rates after then (Table 12, Figure 18). In the last two years the index is about 22% of the value in the first two years.

Table 11: Variables included in the final model for the CELR data (0.5% additional deviance explained).

	Dof	AIC	Percentage deviance explained	Additional % deviance explained
Year	14	4338	21.4	21.4
Month	11	4237	28.4	7.0
Duration	1	4156	32.8	4.4
Vessel	9	4119	35.5	2.8

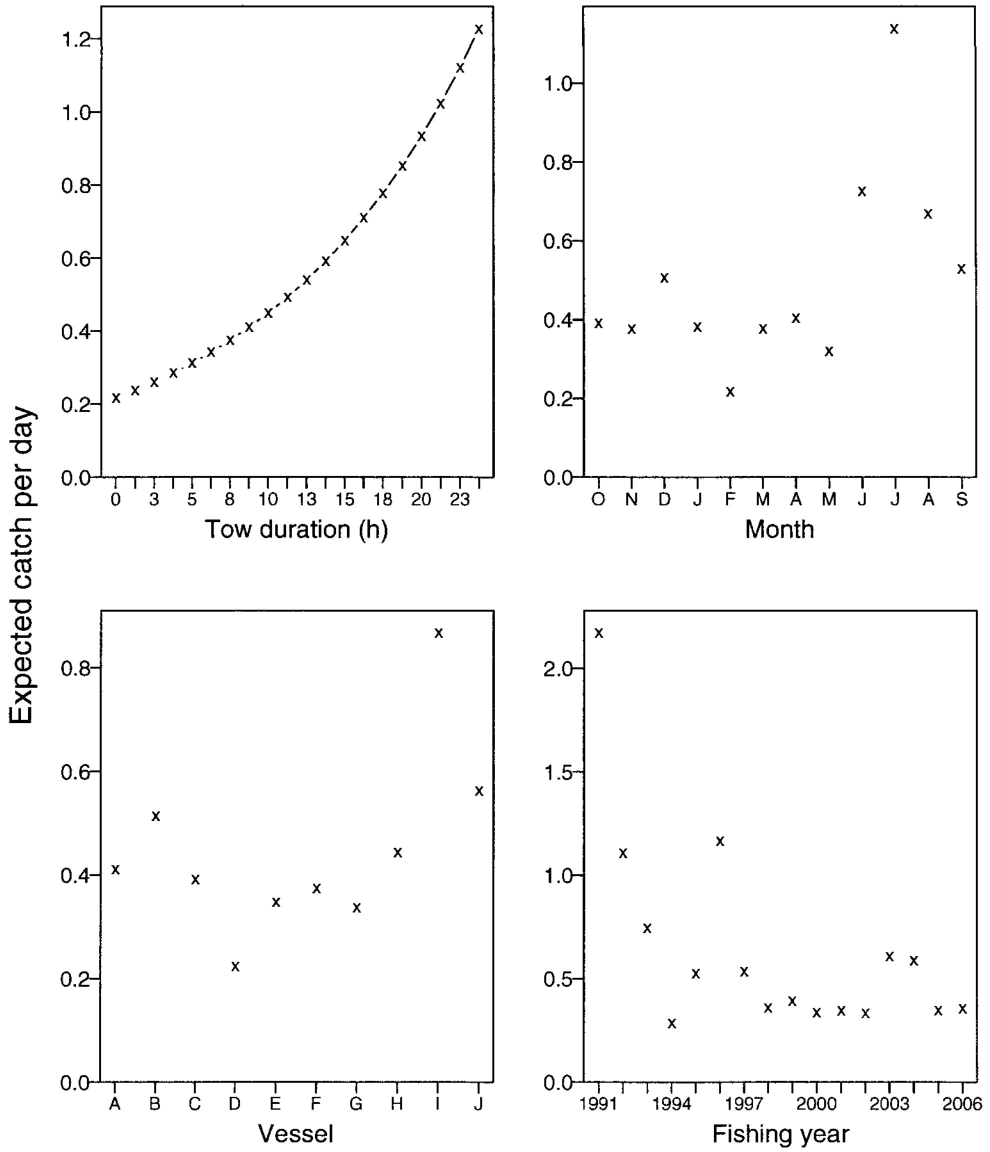

Figure 16: Tow duration (daily total), month, vessel, and year effects for the fitted model for the CELR data.

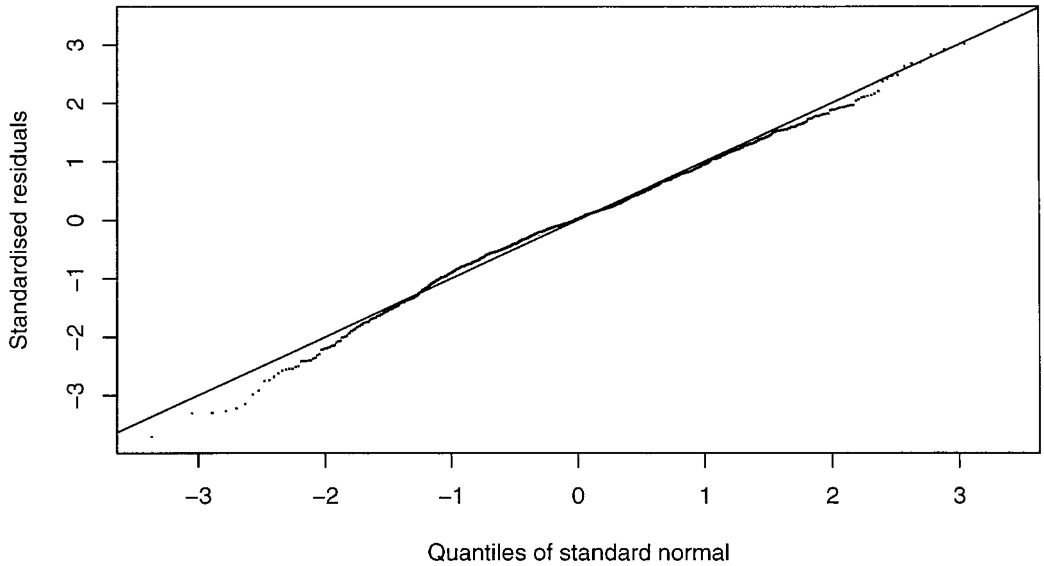

Figure 17: Diagnostics plot for the model for the CELR data. The sorted standardised residuals are plotted (y-axis) against the corresponding quantiles of the standard normal distribution (x-axis).

Table 12: Standardised CPUE indices (relative year effect) for the CELR data with number of daily records from 1991 to 2006. nobs, number of observations.

year	nobs	standardised CPUE	c.v.
1991	110	2.17	0.27
1992	108	1.11	0.27
1993	126	0.74	0.27
1994	81	0.28	0.28
1995	46	0.53	0.30
1996	29	1.16	0.33
1997	19	0.53	0.38
1998	52	0.36	0.30
1999	112	0.39	0.28
2000	131	0.34	0.27
2001	88	0.34	0.28
2002	73	0.33	0.28
2003	67	0.61	0.26
2004	75	0.59	0.25
2005	114	0.35	0.24
2006	80	0.36	0.26

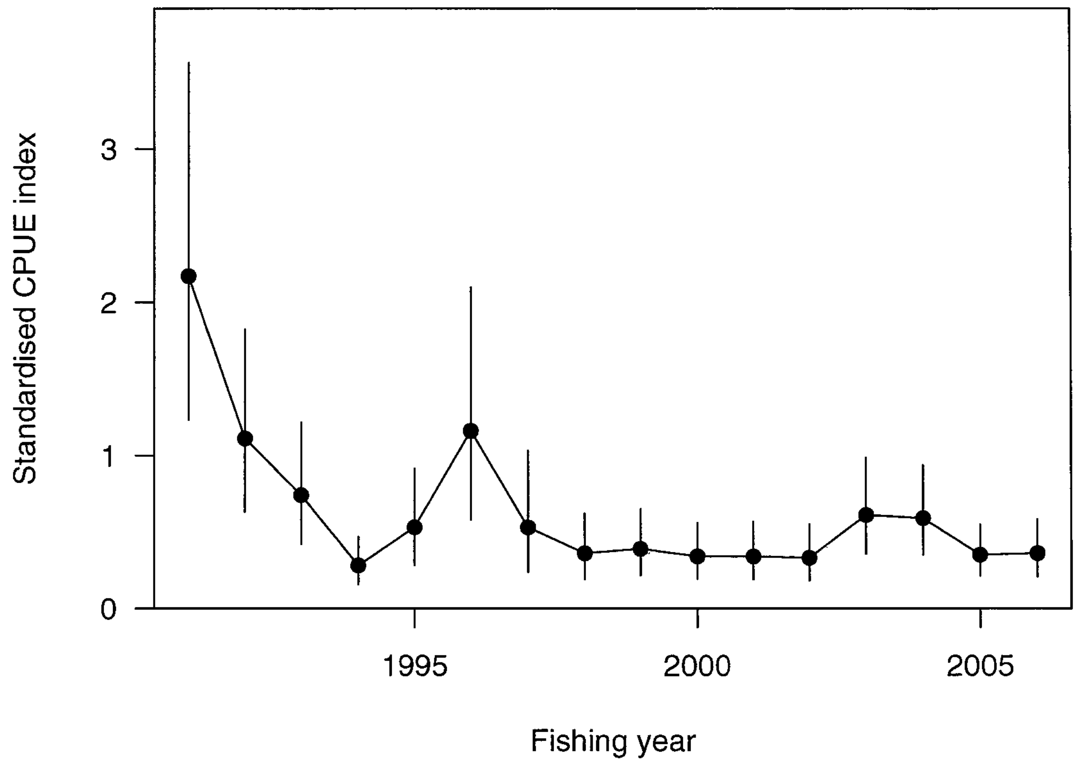

Figure 18: Standardised CPUE index for the CELR data (see Table 12). The error bars represent the 95% confidence intervals.

3.3 Discussion

Although the two series cover different fishing years, they do overlap for seven years (1991–97), and it is instructive to overlay the two series (Figure 19). In the overlap years the two series display the same pattern of changes, though the series based on the CELR data is higher at the start (1991) and lower at the end (1997). In both series there is a peak in 1996, the year in which the TACC was dropped to 430 t from 1708 t (Table 1), so the peak may be a consequence of a contraction of effort to tows with higher catch rates (associated with certain locations and times).

In the previous CPUE standardisation (McKenzie 2005) the TCEPR data were collapsed into a daily format and combined with the CELR data. Only data from the peak months of fishing (June-July) were used and a standardised series was generated that covered 1986 to 2003. However, it was decided by the Deep Water Working Group to split the series into two on the basis that the fleet composition had changed with larger vessels moving out, and associated perceived difficulties with vessel overlap between the earlier and later vessel fleets. For stock assessment purposes, each of the series is assigned a separate estimated relativity constant that scales the indices into biomass indices, and because of this the estimated model biomass trajectory is less certain then it would be if a single series was used for the entire time period. For the two series in question here there is a substantial amount of overlap (1991–97) and the CELR series is missing only the first five years from the fishery, so this is less of a problem then it could be. Nonetheless, it is suggested that in future standardisations a more formal analysis be made as to what degree of vessel overlap is acceptable for a single series to be used, as opposed to using non-explicit intuitive criteria. Furthermore, a data set worth considering for future standardisations is that consisting of the combined TCEPR and CELR data and using all months of data. This data set may have sufficient vessel overlap (under some criterion) to enable a single series to be used covering all year (Appendix A1).

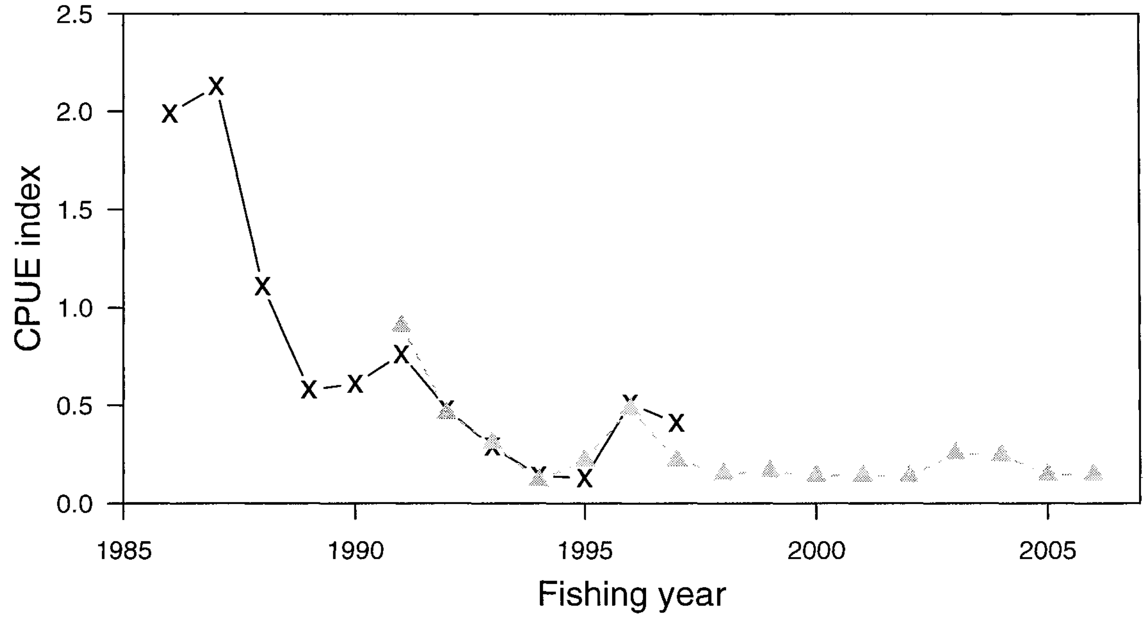

Figure 19: The CPUE indices based on: (i) TCEPR data (solid line and crosses) covering 1986 to 1997, and (ii) CELR data (triangles and dashed line) covering 1991 to 2006. The CELR index has been scaled so that it has the same mean value as the TCEPR index in the years that they overlap.

4. UPDATED ASSESSMENT MODEL

4.1 Introduction

The previous assessment of this stock was by McKenzie (2005) in which two alternative assessments were examined. In the first (Beta1) it was assumed that the CPUE was proportional to biomass. In the second (EstBeta) it was assumed that the relationship between CPUE and the biomass could be non-linear with CPUE proportional to the biomass to the power of β. The estimated status of the stock depended strongly on which alternative assessment is used. If CPUE is assumed to be directly proportional to biomass (Beta1), then the current biomass was estimated to be 17% B_0 with a 95% confidence interval of 14–23% B_0. When this assumption was relaxed (EstBeta) the current biomass is much higher at 45% B_0, with a 95% confidence interval of 18–69% B_0. The model results, in both cases, indicated the stock has been slowly rebuilding since the mid 1990s.

The Deep Water Working Group decided it would be worthwhile to update the Beta1 assessment, incorporating the two new standardised CPUE series. In what follows, the assumptions of the previous assessment are briefly reviewed and model run results for the updated assessment are presented. As part of the assessment update two changes are made to the assessment model: (i) the growth curve is changed from the previous assessment, which was split by sex, to a common growth curve for both sexes, and (ii) maturity isn't explicitly included as part of the model partition, but instead is based on an ogive. Both of these changes have minimal impact on model results. For the previous assessment the only observational data were a standardised CPUE index covering 1986–2003. For the updated assessment two standardised CPUE indices are used based on different data set: (i) TCEPR data from 1986–1997, and (ii) CELR data from 1991–2006. Separate relativity constants (q values) are used for these in the model.

4.2 Model set up

The standardised CPUE indices were incorporated into an age-based Bayesian stock assessment with deterministic recruitment to estimate stock size. The stock was considered to reside in a single area, with no partition by sex or maturity. Age groups were 1–70 years, with a plus group of 70+.

There is a single time step in the model, in which the order of processes is ageing, recruitment, maturation, and mortality (natural and fishing). Each fish is aged by one year at the start of the time step, and fish are recruited into the model at age one year, with equal year class strengths over the years 1983–2006. Recruitment numbers followed a Beverton-Holt relationship. Mortality was "instantaneous", i.e., half the natural mortality was applied, then all of the fishing mortality, then half the natural mortality. Only mature fish were taken by the fishing fleet, and, as with other orange roughy stock assessments, a maximum fishing pressure of 0.67 was permitted (Francis et al. 1995). These and other model biological parameters are summarised in Table 13.

The proportion of the fish that are mature is given by a logistic ogive as a function of their age, estimated from otolith data (Ministry of Fisheries, Science Group (comps.) 2006, p. 385). As there is no information on vulnerability, the fishery selectivity is set equal to the maturity ogive. Catches taken in the model are as given in Table 1, with no overruns included, and for 2007 the catch for 2006 is assumed (73 t).

Five free parameters are estimated in the model: (i) the virgin biomass, (ii) relativity constants for both CPUE series for scaling them to biomasses, and (iii) process error for both CPUE series (Table 14). The relativity constants are treated as nuisance parameters, with their solutions calculated analytically.

Table 13: Model parameters. Biological parameters (natural mortality, length-at-age) are those estimated for the northwest Chatham Rise (ORH 3B) orange roughy fishery (Ministry of Fisheries, Science Group (comps.) 2006, p. 385) where fish size is similar to orange roughy in ORH 7B. The length-weight parameters are from the previous assessment (McKenzie 2005).

Parameter	Symbol	Both sexes
Year class strengths (1983-2006)	YCS	1
Proportion of recruited fish	p_m , p_f	0.5
Recruitment variability	σ_R	1.1
Recruitment steepness	h	0.75
von Bertalanffy parameters	L_∞	37.28
	k	0.059 yr^{-1}
	t_0	-0.264 yr
Length-weight parameters	a	9.91e-05
$[W(kg) = aL(cm)^b]$	b	2.70
Natural mortality	M	0.045 yr^{-1}
Maximum fishing pressure	U_{max}	0.67

Table 14: Free parameters for the model. The CPUE series based on the TCEPR and CELR data are denoted as the "early", and "late" CPUE series.

Free parameters	Prior	Number of parameters
B_0	uniform-log	1
relativity constant (q-early CPUE)	uniform-log	1
relativity constant (q-late CPUE)	uniform-log	1
process error (early CPUE)	uniform	1
process error (late CPUE)	uniform	1

4.3 Results

Three models runs were conducted: (i) including both CPUE series, (ii) including only the early CPUE series (TCEPR data), and (iii) including only the late CPUE series (CELR data). There was very little difference between model results with virgin biomass estimated at 12 900 t, and current biomass as 27% of virgin biomass (Table 15). While the fit to the early CPUE series is reasonable, the biomass trajectory is flatter then the late CPUE series, and in particular for most of the last seven years lies above the CPUE indices (Figure 20).

As in the previous assessment, the model results show the stock slowly rebuilding since the mid 1990s (Figure 20), which is inconsistent with trends in catch rates and tow duration (Table 2). This is likely to be due to a combination of high recruitment (near virgin recruitment levels) and low recent catches. Because of the poor fit to the recent CPUE indices the stock assessment was not accepted by the Deep Water Working Group.

Table 15: Summary of model runs. The less the likelihood the better the model fit. Biomass is mid-year biomass. U_{2007},

	Both CPUE	Only early CPUE	Only late CPUE
B_0	12900	12900	12900
$B_{current}$	3490	3460	3440
$B_{current}(\%B_0)$	27	27	27
U_{2007}	0.02	0.02	0.02
U_{max}	0.36	0.37	0.37
early process error	0.37	0.37	–
late process error	0.39	–	0.39
q early CPUE	1.4E-04	1.4E-04	–
q late CPUE	2.4E-04	–	2.5E-4
likelihoods			
early CPUE	-3.92	-3.93	–
late CPUE	-4.29	–	-4.31

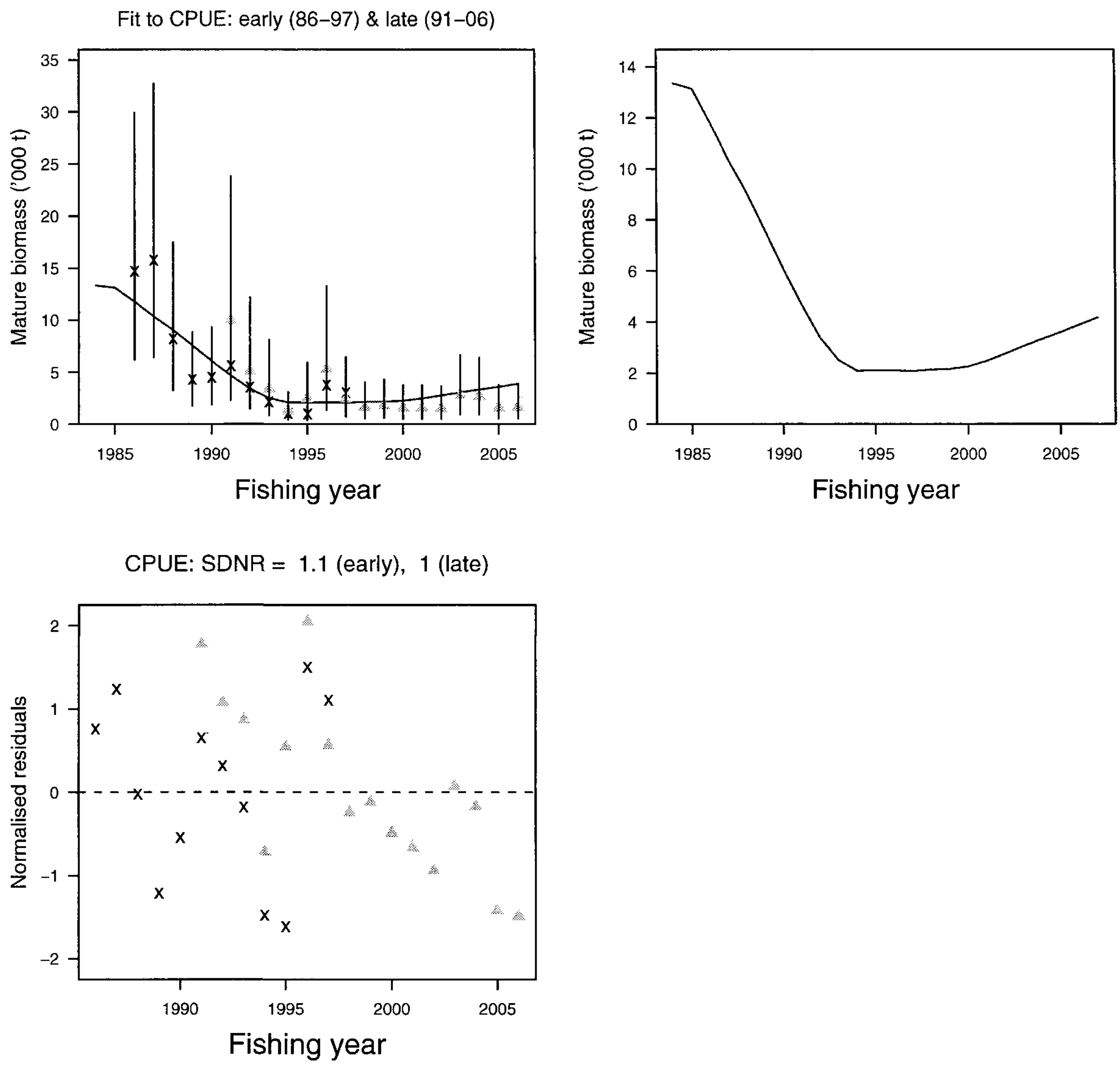

Figure 20: Fits for the model run with both the early and late CPUE series in it. The vertical lines for the CPUE indices indicate 95% confidence intervals (including process error). Shown in the title for the residuals plot is the standard deviation of the normalised residuals (SDNR).

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APPENDIX A1: ALTERNATIVE DATA SET FOR FUTURE STANDARDISATIONS

Table A1: Annual effort by 22 core vessels. Daily records were selected from all months of the year. Core vessels were those that had fished more than 20 days in this period and in at least two years. Fishing year 86 is 1985–86 fishing season, etc. The vessels are coded by arbitrary numbers.

	Fishing Year																				
Vessel	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
1	40	33	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	14	2	23	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	14	11	17	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
4	13	2	14	26	25	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	0	0	15	4	15	2	15	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	20	57	53	39	38	55	35	5	10	13	15	0	3	0	0	0	0	0	0
7	0	0	0	0	6	36	26	32	25	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	21	9	1	1	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	3	6	10	4	0	0	0	0	0	0	0	0	0	0	0	0
10	15	12	0	4	14	25	19	26	26	0	12	45	5	0	0	11	0	0	0	0	0
11	0	0	0	0	0	11	39	17	57	54	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	13	26	27	35	14	17	26	19	37	48	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	77	45	0	0	14	19	6	2	0	0	0	0	0
14	0	0	0	0	0	22	18	23	0	0	0	0	10	22	40	0	0	0	0	0	0
15	0	0	0	0	5	9	10	5	9	0	0	0	0	0	2	18	12	0	0	0	0
16	0	0	0	0	0	16	22	21	31	29	3	0	5	37	70	67	34	52	39	43	40
17	0	0	0	0	0	0	0	0	0	4	0	6	0	0	0	24	7	5	2	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	46	16	11	7	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	2	19	0	14	6	1	36	17
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	1	13	10	2
21	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	9	0	10	10	15
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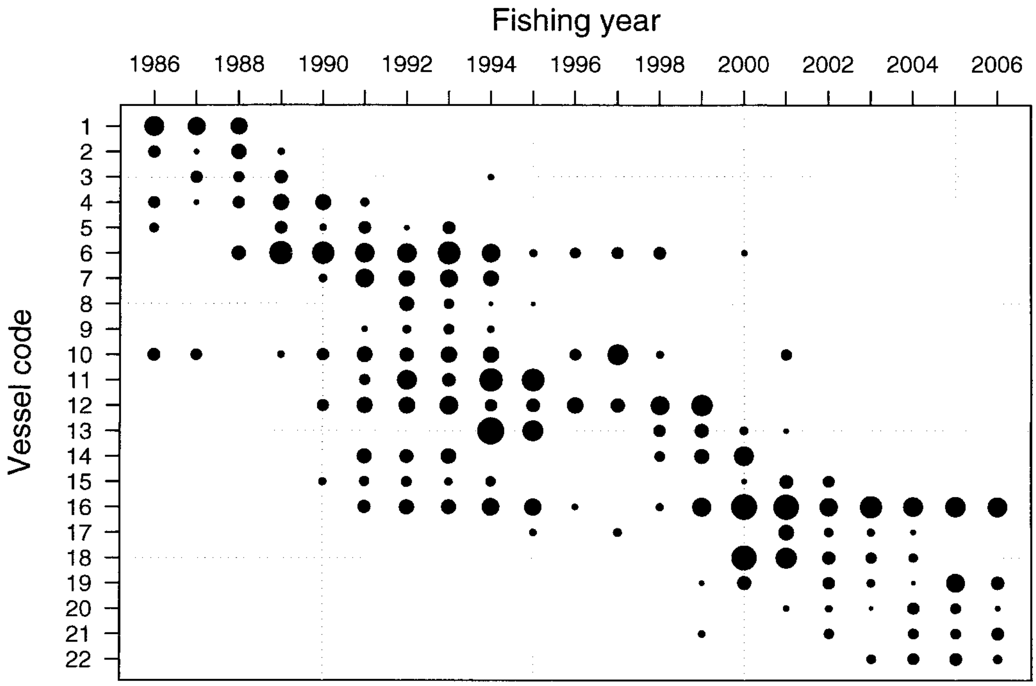

Figure A1: Tows by year and vessel code. The area of a circle is proportional to the number of tows; the largest circle represents 77 tows.