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R. G. Blackwell

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EXECUTIVE SUMMARY

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A target rubyfish fishery developed during 1989–90, but has since declined. Rubyfish landings from this fishery represent only 3% of the 1997–98 total rubyfish landings of 308 t, and most rubyfish are taken as minor bycatch in the trawl fisheries for alfonsino, gemfish, and hoki.

This report briefly describes the target rubyfish fishery from 1988–89 to 1997–98. Insufficient data are available to analyse catch/day data for the 1988–89 fishing year. Standardised CPUE indices of catch/day for rubyfish derived from a loglinear (LNL) model showed a decline from 1989–90 to 1992–93, followed by fluctuating catch values. The fishery is relatively small and operates over a wide area fromEast Cape to Palliser Banks in QMA 2, and catch rates of the 10 vessels in the fishery varied widely between months, fishing grounds, and fishing years. The standardised CPUE (catch/tow) indices from 1991–92 to 1997–98 were more variable than the catch/day indices, but also indicated a decline in CPUE from 1991–92 to 1997–98. Insufficient data were available to analyse catch/tow data before the 1991–92 fishing year.

These indices should be considered as very approximate indications of a decline in abundance of rubyfish. The fishery appears to have progressed between fishing grounds (generally from south to north). It is possible that larger declines may have occurred on individual grounds, as the level of fish movement between grounds is not known. These apparent changes in the relative abundance of rubyfish may be confounded with changes in the fishing patterns of the few vessels active in the fishery. Although the target rubyfish fishery declined after 1996–97, standardised CPUE varied widely between vessels, grounds, and fishing years. These constraints, together with the little data currently available, appear to preclude the use of target CPUE data for future estimation of changes in rubyfish abundance.

1. INTRODUCTION

Rubyfish have been reported from South Africa, southern Australia, and from fisheries in the Indian and southeast Atlantic oceans. Although rubyfish occur in the subtropical waters of northern and central New Zealand from 50 to 800 m, most commercial landings are taken in QMA 2, between 200 and 400 m (Paul 1997).

Landings reported since 1982–83 have been taken from the Bay of Plenty, off the east and west coasts of Northland, the Taranaki Bight, off Westland, and off the east coast of the North Island. Over 80% of the total New Zealand landings are taken in QMA 2, where rubyfish is associated with the seamounts and drop-offs that occur between 300 and 600 m off the east coast, North Island (Annala *et al.* 1999). The major fishing grounds in QMA 2 are shown in Figure 1.

In QMA 2, a small target fishery developed and landings peaked in 1995–96 at 595 t (Table 1). This fishery subsequently declined and now represents 3% of the 1997–98 QMA 2 landings of rubyfish. Most rubyfish is now taken in association with the target fisheries for gemfish and hoki. Rubyfish are also taken as bycatch of other target trawl fisheries in QMA 2 (Blackwell 1999), including alfonsino, bluenose, cardinal fish, and tarakihi (Blackwell, unpublished results).

Although a preliminary stock assessment was completed by Paul (1997), little biological information is available for rubyfish. This report reviews and updates the target fishery and presents standardised CPUE indices for rubyfish.

1.1 Objectives

This report addresses activity two of objective 3 for project INS9801:

> To develop standardised CPUE indices for the midwater trawl fishery for rubyfish in QMA 2.

1.2 Previous research

Paul (1997) described the early development of the rubyfish target fishery, and noted difficulties associated with determining accurate data coverage in this fishery. He calculated a non-standardised CPUE series from TCEPR data, which declined from 6 to 3 t/tow between 1991–92 and 1994–95.

Paul (1997) used Method 4 of Annala *et al.* (1999) $MCY = cY_{av}$ to derive an initial estimate of MCY of 382 t. This was based on a value of $c = 0.6$, and a period of stable landings between 1990–91 and 1994–95 when catches varied between 558 and 699 t.

2. METHODS

2.1 Data

All catch effort data from 1988–89 to 1997–98 from the Ministry of Fisheries Trawl Catch Effort and Processing Return (TCEPR) and Catch Effort Landing Return (CELR) databases were extracted where the fishing method = trawling, area = RBY 2, and target species = rubyfish. These data are estimated catch per day (CELR) or per tow (TCEPR), and only a maximum of five species (often fewer) are recorded in each estimated catch record. The data included zero catch records (where no rubyfish was caught). This does not necessarily mean that nothing was caught, but that RBY was not in the top five species estimated in the catch record. All data were checked for errors and outliers, using the following constraints:

- net depth less than or equal to bottom depth
- bottom depth in range 50 – 800 m
- wingspread less than 100 m
- total catch less than 60 000 kg

Outliers were altered if the cause of the anomaly was apparent, or the record was removed from the database. The records removed by the above constraints represented 60 t of rubyfish during 1988–89 to 1997–98.

Catch per tow. Tow by tow data are available only from the TCEPR database. Although few records were excluded by the above constraints, a number of duplicate records were removed from the TCEPR data, providing a total of 282 tow data records after grooming. These were assigned to a fishing ground as defined by Stocker & Blackwell (1991) on the basis of start position, and summarised by fishing day.

Catch per day. The daily catch records from the CELR database provided most of the catch and effort data in this fishery up to 1990–91. Statistical area, the only location variable available on the CELR database, was used in this analysis. The duplicate records present in the CELR data were removed, and the corrected data were combined with the summarised daily catch data from the TCEPR database to provide a total of 222 daily catch records after grooming.

2.2 Models

Lognormal linear (LNL) model. This model was described by Doonan (1991) and Vignaux (1992). As a log transformation was applied to the data to approximate linearity, a small arbitrary constant (c) was added to the CPUE to avoid taking the logarithm of zero. The analysis may be sensitive to the value of c chosen (Vignaux 1992). A sensitivity analysis was carried out to determine the effects of a range of c values on the model.

A stepwise procedure similar to that used by Doonan (1991) was used to calculate the LNL model, using PROC GLM, a general linear modelling procedure of the SAS statistical software (SAS 1989). Variables were added to the model until less than 1% improvement was seen in R^2 following the addition of each additional variable. As the data sets were small, each additional variable was also examined to determine if inclusion in the model was statistically significant at the 5% level. If a variable failed to either explain 1% of variation or was not statistically

significant, then it was excluded from the model. If the fishing year variable did not enter the model, this was forcibly included to derive annual indices.

Combined model. The percentage of tows with zero catch of rubyfish in both the catch/day and the catch/tow databases examined in this project did not exceed the 10% threshold (Doonan *et al.* 1995). Where zero catch exceeds this threshold, the data generally require separate analysis of the LNL and binomial components of CPUE, as described by Coburn et al. (1999).

3. RESULTS

3.1 Analysis of raw CPUE data

From 1990–91 to 1997–98, between 60 and 80% of the total New Zealand rubyfish landings were reported from QMA 2 (Table 1). A target rubyfish trawl fishery developed in 1989–90 and estimated catch peaked in 1992–93 (Table 2), but declined, particularly after 1994–95. The estimated catch varied between 82 and 125% of the reported catch data, probably as a result of errors in estimated catches by fishers. Although the target rubyfish fishery has declined, rubyfish were also taken as bycatch of gemfish from 1993–94 to 1997–98, alfonsino from 1992–93 to 1996–97, and the hoki trawl fishery after 1995–96 (Table 2).

Most target rubyfish were taken by midwater trawling (Table 3), and the minor amount of bottom trawl fishing was not included in the LNL analysis. The midwater trawl fishery involved only 10 vessels between 1989–90 and 1997–98, and of these only five fished for more than three years. Both the number of tows (Table 4) and mean raw CPUE (catch/day) (Table 5) varied widely between vessels and statistical area. Although mean catch was not strongly associated with vessel size (Figure 2), vessels fell into two distinct groups: 20–30 m and 40–43 m.

CPUE (Catch/day). The mean raw CPUE (total catch/no. of days) increased from 1989–90 (Table 6) and peaked at 9.3 t/day in 1991–92. It declined to 4.8 in 1993–94, rose again to 7.6 t/day in 1994–95, and declined to 1.6 t/day in 1997–98. Raw CPUE in 1997–98 represented 17% of the peak CPUE reported in 1991–92.

The highest catch rates (Figure 3), generally occurred in the more northern statistical areas (*see* Figure 1), though target rubyfish fishing also occurred in statistical areas 13 and 14. Fishing effort appeared to shift to the northern areas between 1991–92 and 1995–96 (Table 7), although insufficient data were available in subsequent fishing years to determine trends. A plot of raw CPUE indices against the number of shots/day did not show any obvious pattern (Figure 4).

CPUE (Catch/tow). Mean raw CPUE (total catch/no. of tows) from the TCEPR database (Table 8) followed a generally similar trend to the raw CPUE (catch/day) described above. Raw CPUE in 1997–98 represented 18% of the peak CPUE reported in 1991–92.

3.2 Regression models of CPUE (catch/day)

The variables vessel ID, number of shots, fishing year, and fishing time entered the LNL model in order (Table 9), and explained 38% of the variation in the data. Although month of fishing and statistical area explained more than 1% of the variation (R^2), they were not statistically significant, and were not included in the model. The model was not very sensitive to the levels of c used in the analysis, and annual indices for each level of c were similar (Appendix 1). However, from the residual plots (Appendix 1), the addition of constant c = 10 reduced the skewness of the data and these transformed data were used to derive the fishing year coefficients.

Annual abundance indices (Table 9) generally declined from 1989–90 to 1997–98. They show a steeper decline but less year-to-year variability than the raw CPUE values (Figure 5).

3.3 Regression models of CPUE (catch/tow)

The variables ground, vessel ID and fishing year entered the LNL main effects model in order (Table 10), and explained 20% of the variation in the data. The decrease in the fishing ground coefficients (Figure 6) from the northern to the southern grounds was consistent with trends in the raw CPUE.

The model was not very sensitive to the levels of c used in the analysis and annual indices were similar for the levels of c used in the analysis (Appendix 2). Examination of the residual plots (Appendix 2) indicated that the addition of constant c = 10 reduced the skewness of the data, and these transformed data were used to derive fishing year coefficients (Table 10). These showed a similar decline but less year-to-year variability than the raw CPUE values (Figure 7).

4. DISCUSSION

Analysis of estimated catch data from the TCEPR and CELR databases indicated that rubyfish landings were generally a good fit with the reported (QMS) catch data. The differences between estimated catch and reported catch data reflect errors in estimation of the weight of rubyfish when it was reported as one of the top five species caught per day or per tow. A zero estimated catch of rubyfish means that rubyfish was not reported as one of the top five species, rather than necessarily representing a zero catch of rubyfish.

Based on a review of this estimated catch data, the rubyfish target midwater fishery was very small, and the catch rate varied widely between vessels, fishing years, and fishing grounds. No fishing ground was fished in all years between 1988–89 and 1997–98. The general trend in both raw CPUE series was one of decline, from 1989–90 to 1997–98. The raw CPUE (catch/day) reported in 1997–98 represented only 17% of the peak year (1991–92). A similar decline also occurred in raw CPUE (catch/tow) where the 1997–98 data represented 18% of the peak year of fishing (1990–91).

The analysis was limited to tows where rubyfish was declared as the target species. The decline in standardised CPUE (catch/day) indices from 1989–90 to 1997–98 was similar to, but less variable than, the decline in raw CPUE. The slight increase in these indices that occurred during 1993–94 and 1994–95 was also present in the raw CPUE data. The CPUE (catch/tow) data indicated a steeper decline in abundance had occurred, particularly after 1994–95, and these

trends were similar to the patterns in the raw CPUE and consistent with Paul (1997), who found raw CPUE varied between fishing grounds. Paul (1997) noted the uncertainty associated with determination of the target species in the data used for analysis.

These indices should be taken as a very approximate indication of a decline in the abundance of rubyfish in RBY 2. Because there has been a progression of the fishery between grounds (generally from north to south), it is difficult to be confident that an overall abundance index is valid. It is possible that smaller or larger declines have occurred in individual grounds and that little fish movement occurs between grounds. The trends may also be confounded by changes in vessel ownership during this period. Fishing activity has become centred on the port of Napier and may be influenced by logistic constraints. The relative importance of the categorical vessel variable in the LNL analysis of both CPUE series may reflect the high turnover of vessels in this fishery, and possibly be related to skipper experience. The reduction in target fishing after 1994–95 may be related to the small market for rubyfish, and that rubyfish does not seem to be a preferred species in the midwater trawl fishery in QMA 2. More recent landings may also be limited by the amount of quota available for target fishing (C. Robinson, commercial fisher, pers. comm.). These factors, together with the few records available from this target fishery, appear to preclude the use of these CPUE series for future estimation of changes in rubyfish abundance.

5. ACKNOWLEDGMENTS

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Table 1: Reported landings (t) of rubyfish by QMA and fishing year, 1990–91 to 1997–98

QMA	1	2	3	4	5	6	7	8	9	10	Total
1990–91	66	159	5	3	0	0	9	0	3	0	245
1991–92	147	390	0	0	0	0	20	1	6	0	564
1992–93	90	491	0	0	0	0	31	0	0	0	612
1993–94	116	379	3	0	0	0	72	0	5	0	575
1994–95	43	500	3	12	0	0	13	0	10	0	581
1995–96	106	595	2	0	0	0	9	0	23	0	735
1996–97	128	297	2	1	<1	0	14	<1	21	<1	463
1997–98	50	308	<1	1	0	0	6	<1	13	<1	380

(Source: Annala *et al.* 1999)

Table 2: Estimated landings (t) of rubyfish by bottom and midwater trawl from RBY 2, by target species, total reported landings (t), and estimated landings as percentage of total reported landings, 1988–89 to 1997–98. BNS, bluenose; BYX, alfonsino;CDL, cardinal fish;HOK, hoki; LIN, ling; ORH, orange roughy, RBY, ruby fish; SKI, gemish; Other, all other target species where RBY 2 landings were reported.

	Target species											
	BNS	BYX	CDL	HOK	LIN	ORH	RBY	SKI	Other	Estimated landings	Reported landings	Percent
Fishing year												
1988–89	0	1	0	0	1	0	0	1	0	3		
1989–90	4	40	0	3	0	0	55	19	4	125		
1990–91	10	17	2	4	0	4	85	17	3	141	159	89
1991–92	96	54	0	1	0	0	269	62	11	493	390	126
1992–93	14	71	0	7	0	0	349	66	6	514	491	105
1993–94	0	43	2	8	0	0	217	189	4	462	379	122
1994–95	0	160	5	2	1	1	243	210	1	624	500	125
1995–96	0	88	1	76	0	1	99	396	16	678	595	114
1996–97	0	33	0	36	1	6	46	115	5	243	297	82
1997–98	3	19	1	47	0	0	10	168	14	262	308	85

Table 3: Estimated landings of RBY 2 in target trawl fishery, and number of days fished, by method, 1988–89 to 1997–98: BT, bottom trawling; MW, midwater trawling; Total, all trawling

Method	BT		MW		Total	
Fishing year	No. days	Weight (t)	No. days	Weight (t)	No. days	Weight (t)
1989–90	3	0	7	55	7	55
1990–91	10	9	13	75	22	85
1991–92	7	16	27	253	43	269
1992–93	18	67	58	282	125	349
1993–94	3	4	44	214	48	217
1994–95	11	8	31	235	39	243
1995–96	6	8	20	91	28	99
1996–97	1	1	16	45	17	46
1997–98	1	0	6	9	6	10

Table 4: RBY 2 target trawl fishery: Length (m) overall (LOA), gross registered weight (GRW), and number of tows by vessel and fishing year, 1988–89 to 1997–98

Source: CELR and TCEPR databases

Range LOA : 1 = 1–19 2 = 20–29 3 = 30–50
Range GRW: 1 = 1–49 2 = 50–99 3 = 100–199 4 = 200+

			Fishing year									
Vessel	LOA	GRW	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98
1	2	2						17				
2	1	2				2						
3	1	2		12	6	13	3					
4	3	4							8			
5	1	2					4	2	2			
6	2	3		2	3					5		
7	2	3			17	33	86	36	24	24	17	3
8	2	3					4	1		1		
9	2	4								2		
10	3	4						11	8	2	5	5
Total			0	14	26	48	97	67	42	34	22	8

Table 5: RBY 2 target trawl fishery: mean raw CPUE (t/day) by vessel and statistical area

Vessel	Statistical area							
	12	13	14	15	201	203	204	Overall
1		0.0	0.0					0.0
2		7.0						7.0
3		5.0	4.9					4.9
4	7.5							7.5
5	0.5	0.6						0.6
6	5.0		6.3	12.0				6.6
7	18.7	7.7	4.6	5.8			4.7	5.6
8			0.				2.4	0.5
9				0.5				0.5
10	4.1	14.6	9.3	2.0	35.0	0.5	0.1	9.5

Table 6: RBY 2 target trawl fishery: raw CPUE (tonnes per day), and the proportion of zero catch by day from 1988–89 to 1997–98, from the CELR and TCEPR databases

Fishing year	Number of days	Estimated RBY catch (t)	CPUE (t/day) Mean	*s.e.*	Number of zero catch days	Percentage of zero catch (days)	Percentage of RBY 2 landings (QMS)
1989–90	7	55	7.9	4.9	0	0	0
1990–91	13	75	5.8	1.4	1	4	47
1991–92	27	252	9.3	1.8	3	11	65
1992–93	58	282	4.9	0.8	6	10	57
1993–94	44	214	4.8	1.3	0	0	56
1994–95	31	235	7.6	1.6	1	3	47
1995–96	20	91	4.5	1.5	2	10	15
1996–97	16	45	2.8	0.9	2	12	15
1997–98	6	9	1.6	0.6	0	0	3
	222	1 258			15		

Table 7: RBY 2 target midwater trawl fishery. Estimated catch (t) by fishing year and statistical area, 1988–89 to 1997–98

	Statistical area						
Fishing year	12	13	14	15	201	204	Total
1989–90	0	0	43	12	0	0	55
1990–91	0	0	64	0	0	12	75
1991–92	0	207	13	0	0	32	252
1992–93	0	166	59	0	0	57	282
1993–94	0	142	71	0	0	0	214
1994–95	70	84	47	0	35	0	235
1995–96	56	4	19	12	0	0	91
1996–97	0	11	35	0	0	0	45
1997–98	1	4	5	0	0	0	9

Table 8: RBY 2 target trawl fishery: raw CPUE (tonnes per tow), and the proportion of zero catch tows from 1988–89 to 1997–98, from the TCEPR database

Fishing year	Number of tows	RBY weight (t)	CPUE (t/tow) Mean	*s.e.*	Number of zero catch tows	Percentage of zero catch (tows)
1989–90	0	0	0		0	0
1990–91	3	12	3.9	2.9	0	0
1991–92	33	216	6.5	1.3	3	9
1992–93	90	281	3.1	0.5	9	10
1993–94	50	213	4.3	1.2	0	0
1994–95	42	235	5.6	1.2	1	2
1995–96	34	91	2.7	0.5	5	15
1996–97	22	45	2.0	0.6	3	14
1997–98	8	9	1.2	0.5	0	0
	282	1 102			21	

Table 9: RBY 2 target trawl fishery: LNL analysis of CPUE (catch/day+10) from 1989–90 to 1997–98

	R^2 at iteration					
Iteration	1	2	3	4	5	
Variables						
Vessel ID	**0.19**					
Number of shots	0.06	**0.31**				
Fishing year	0.04	0.23	**0.36**			
Fishing time	0.01	0.19	0.32	**0.38**		
Month	0.03	0.25	0.36			*
Statistical area	0.06	0.23	0.36	0.39		*
Wingspread	0.01	0.18	0.28	0.36	0.38	*
Net height	0.01	0.18	0.28	0.36	0.37	*
Length	0.01	0.18	0.28	0.36	0.37	*
Breadth	0.02	0.18	0.28	0.36	0.37	*
Draught	0.01	0.18	0.28	0.36	0.37	*
Tonnage	0.01	0.18	0.28	0.36	0.37	*
Power	0.01	0.18	0.28	0.36	0.37	*
L*B*D	0.01	0.18	0.28	0.36	0.37	*
% increase in R^2	18.9	12.4	5.1	1.30	0.10	

Note: Month not significant $F_{(10,221)}$=1.66: p> 0.05)
Note: Statistical area not significant $F_{(6,221)}$=1.67: p> 0.05)
Note: * indicates variable is not significant at 5% level

Main effects model: Log(CPUE kg/day+10) = Vessel ID, number of shots, fishing year, fishing time

Annual indices for the fitted model of log(catch/day+10)

	Index	*s.e.*
1989–90	8.71	3.49
1990–91	7.40	3.07
1991–92	4.27	2.36
1992–93	1.79	2.23
1993–94	4.06	2.20
1994–95	4.57	2.24
1995–96	1.30	2.37
1996–97	1.28	2.37
1997–98	1.00	

Table 10: RBY 2 target trawl fishery: LNL analysis of CPUE (kg/tow+10) from TCEPR data, 1991–92 to 1997–98.

	R^2 at iteration				
Iteration	1	2	3	4	5
Variables					
Ground	**0.14**				
Vessel ID	0.09	**0.18**			
Fishing year	0.05	0.16	**0.20**		
Speed	0.02	0.15	0.19	0.21	*
Month	0.05	0.17	0.17	0.20	*
Start time	0.00	0.15	0.19	0.20	*
Fishing time	0.00	0.15	0.18	0.20	*
Bottom depth	0.04	0.16	0.18	0.20	*
Net depth	0.04	0.16	0.18	0.20	*
Wingspread	0.00	0.15	0.18	0.20	*
Length	0.01	0.15	0.18	0.20	*
Breadth	0.01	0.15	0.18	0.20	*
Draught	0.01	0.15	0.18	0.20	*
Tonnage	0.00	0.15	0.18	0.20	*
Power	0.01	0.15	0.18	0.20	*
L*B*D	0.01	0.15	0.18	0.20	*
% increase in R^2	14.5	3.5	2.1	0.9	

Main effects model: Log(CPUE kg/day+10) = Ground, vessel ID, fishing year

Note: * indicates variable is not significant at 5% level

Annual indices for the fitted model of CPUE log (catch/tow +10)

Fishing year	CPUE index	*s.e.*
1991–92	4.97	2.29
1992–93	3.48	2.19
1993–94	4.77	2.17
1994–95	4.05	2.16
1995–96	2.71	2.27
1996–97	2.53	2.29
1997–98	1.00	

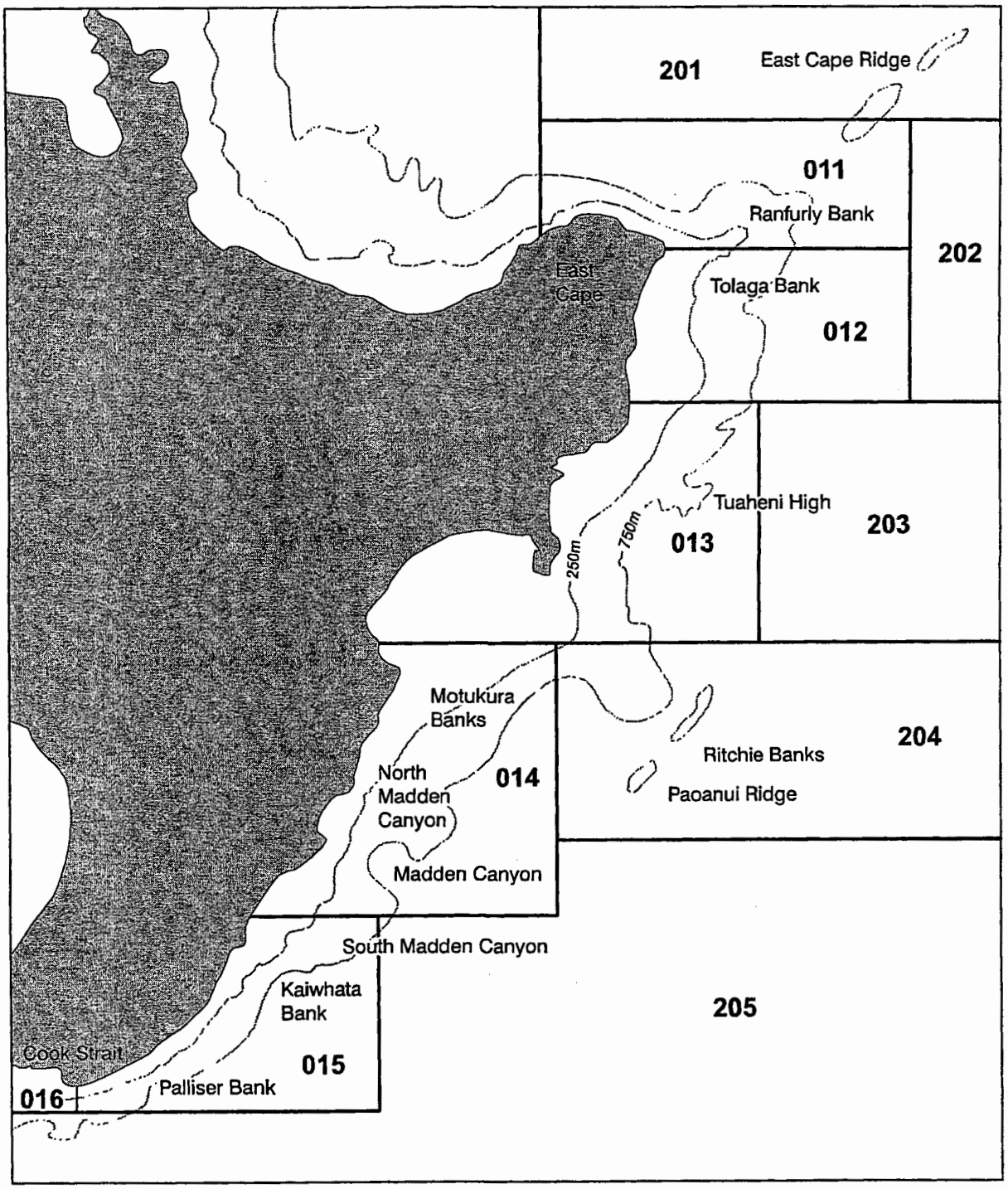


Figure 1: The rubyfish fishery in QMA 2 showing major fishing grounds and statistical reporting areas 11–16, 201–205. The 250 m and 750 m depth contours are also shown.

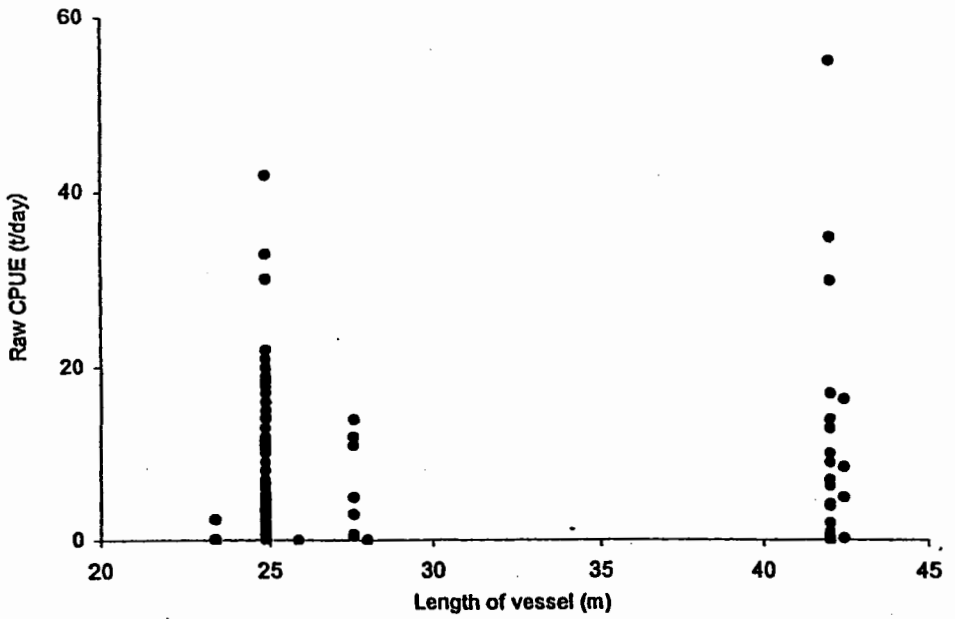


Figure 2: RBY 2 target trawl fisheryL mean raw CPUE (t/day) by vessel length, 1990–91 to 1997–98

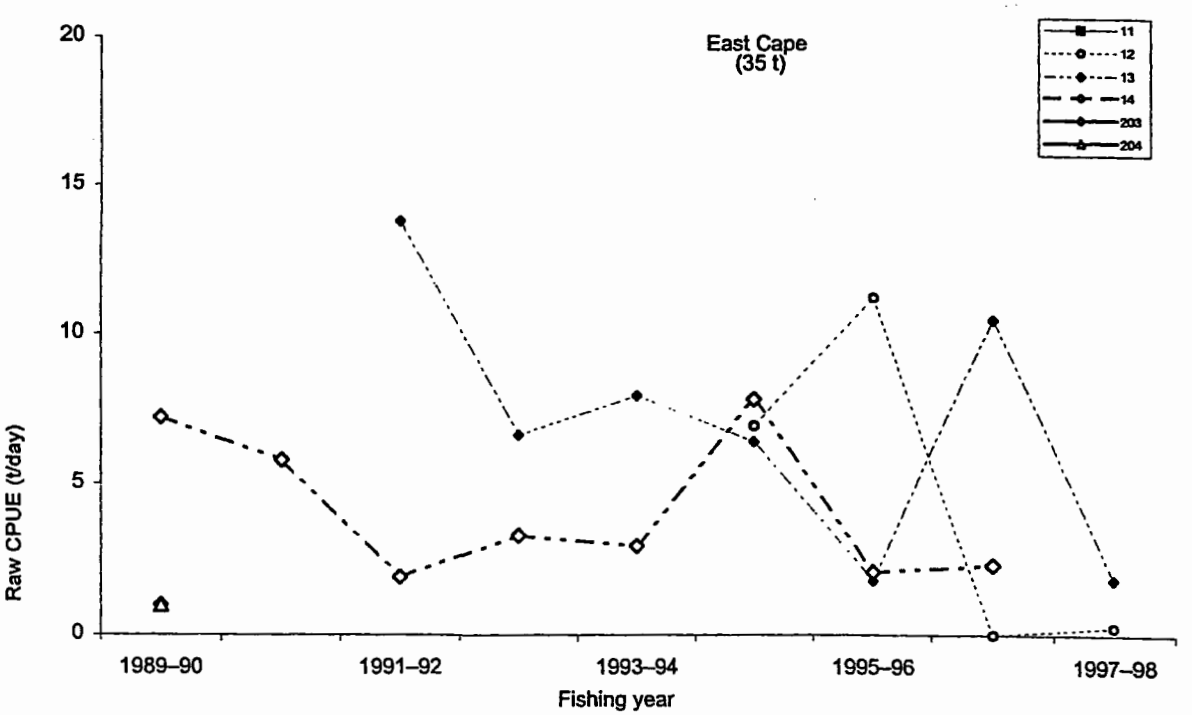


Figure 3: RBY 2 target trawl fishery; mean raw CPUE (t/day) by statistical area and fishing year

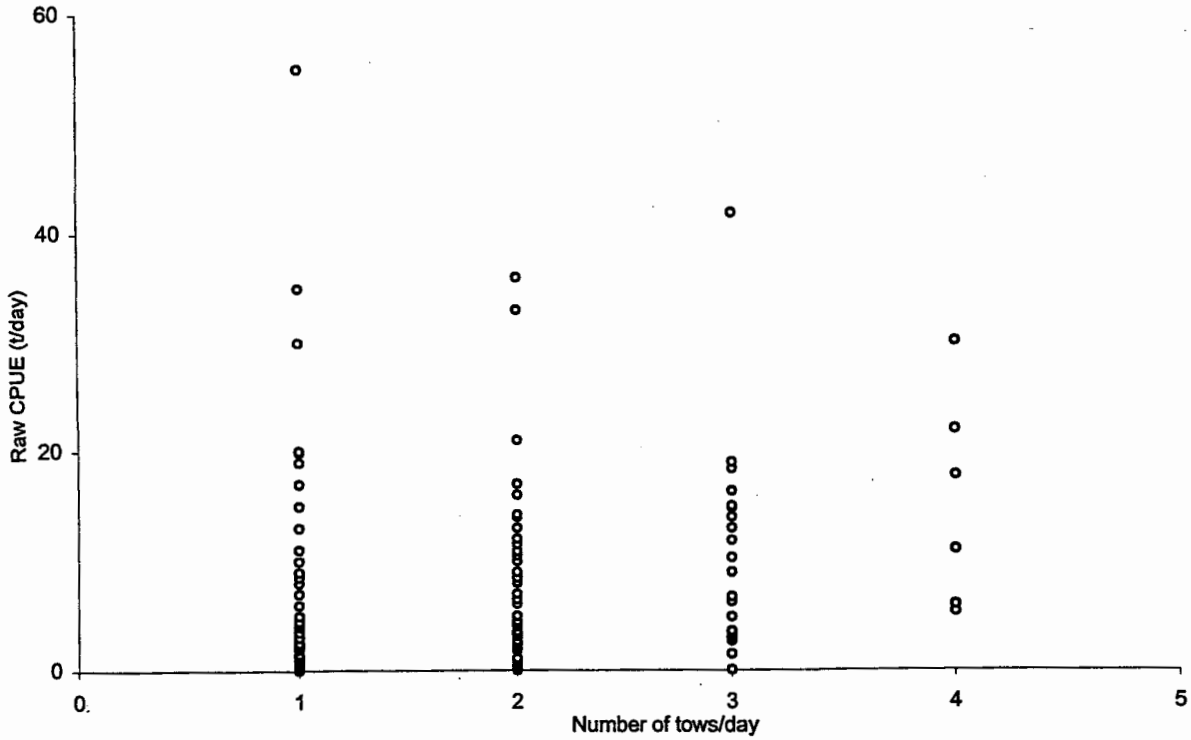


Figure 4: RBY 2 target trawl fishery: raw CPUE (t/day) by number of tows/day, from 1989–90 to 1997–98

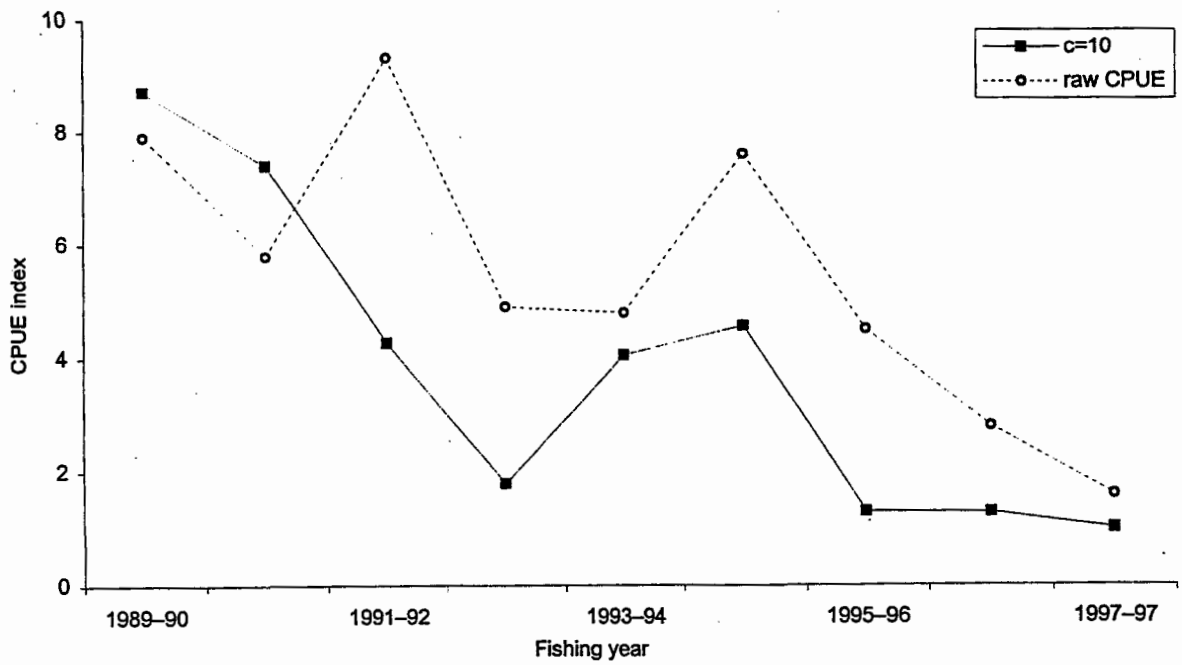


Figure 5: RBY 2 target trawl fisher: annual abundance indices for the fitted model of CPUE (t/day), and raw CPUE indices, 1989–90 to 1997–98

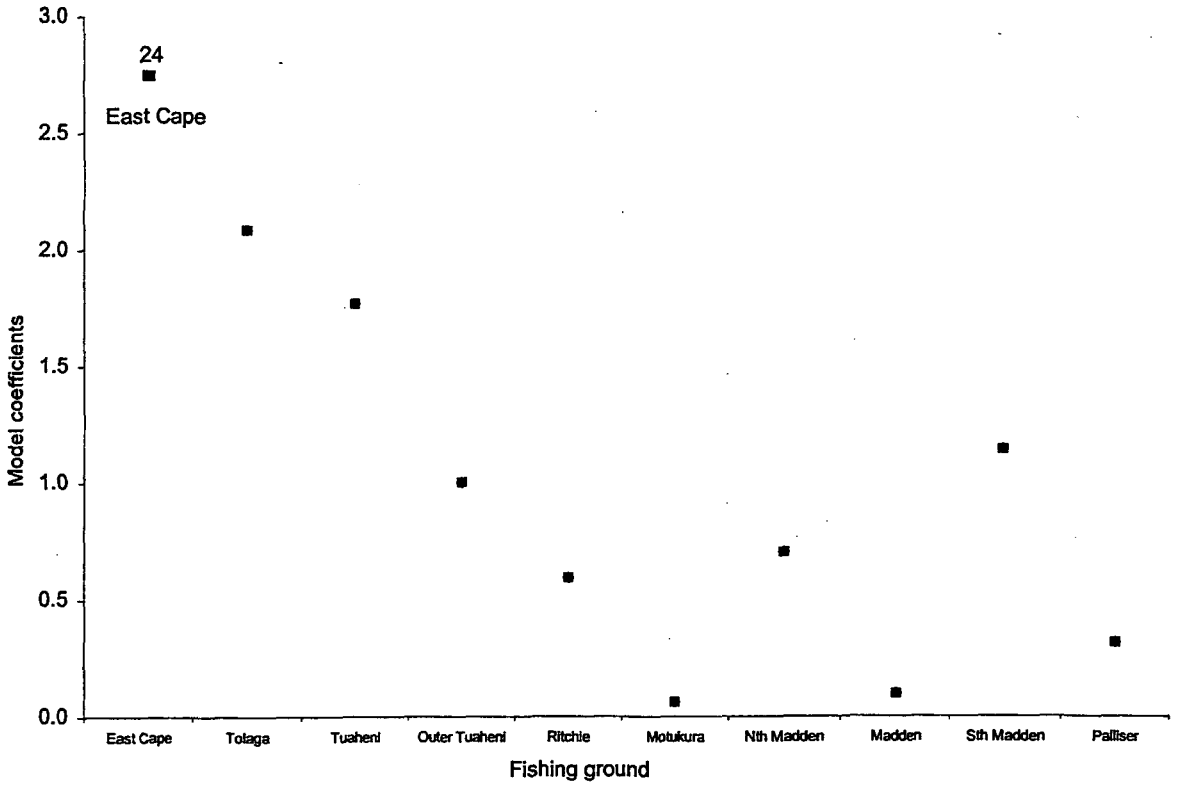


Figure 6: RBY 2 target trawl fishery: fishing ground coefficients for the fitted model of CPUE (t/day), 1991–92 to 1997–98

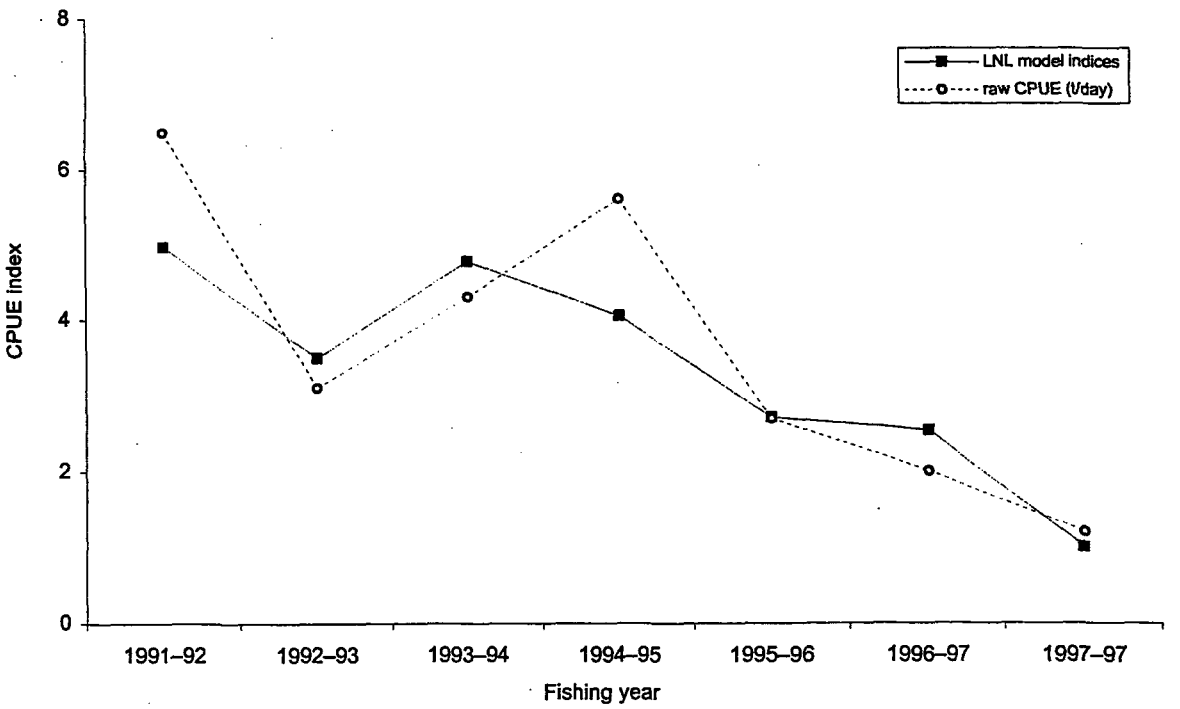
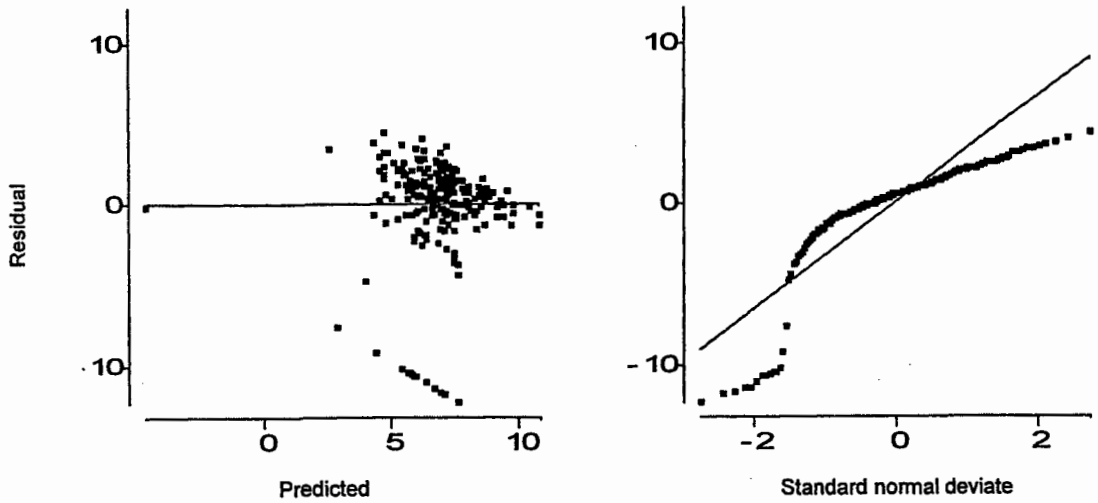
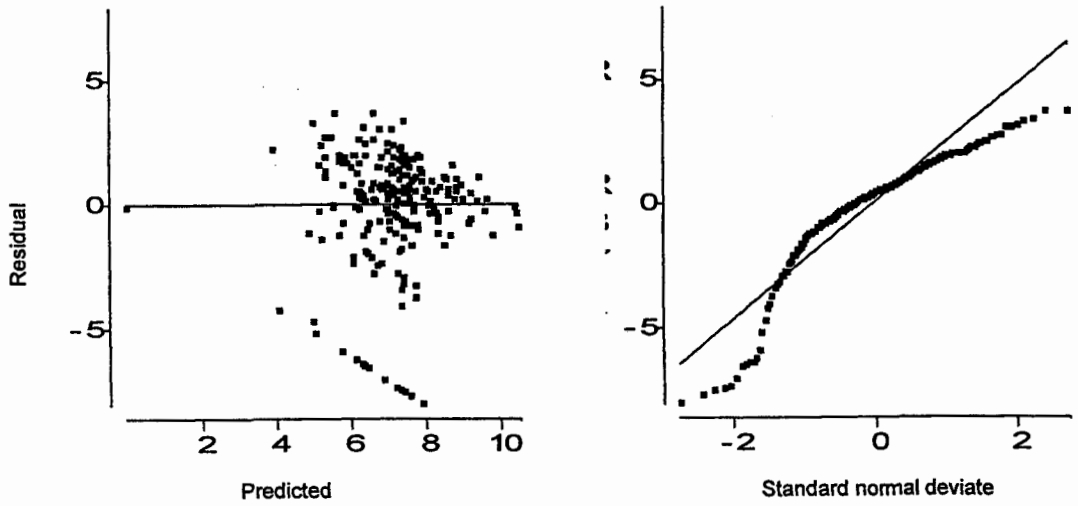


Figure 7: RBY 2 target trawl fishery: annual abundance indices for the fitted model of CPUE (t/tow), and raw indices(t/tow), 1991–92 to 1997–98

Appendix 1: Regression diagnostics for CPUE (catch/day)

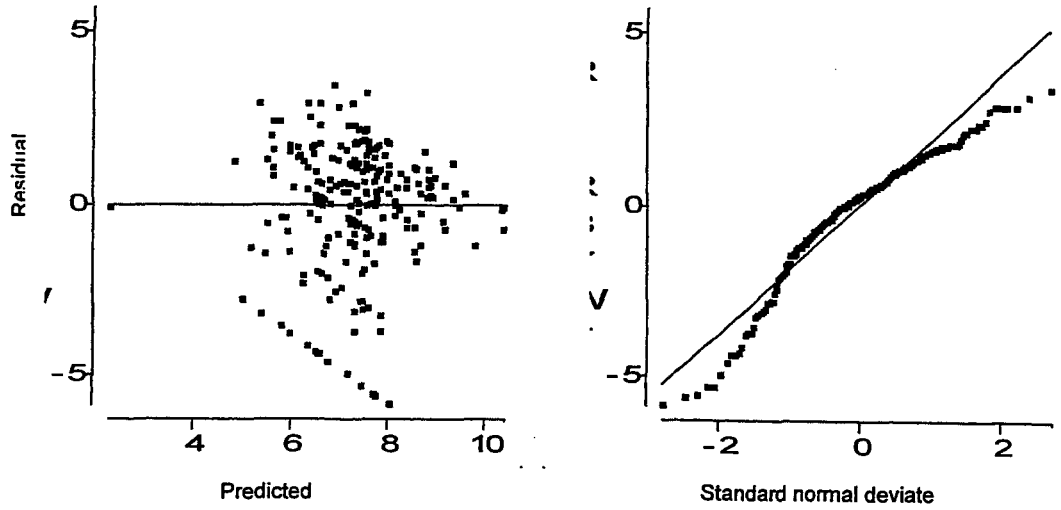


Rubyfish target trawl fishery: plot of residual * predicted values for the LNL model log (RBY kg/day+0.01)= vessel ID, no. of shots, fishing year



Rubyfish target trawl fishery: plot of residual * predicted values for the LNL model log (RBY kg/day+1)= vessel ID, no. of shots, fishing year

Appendix 1 – *continued*



Rubyfish target trawl fishery: plot of residual * predicted values for the LNL model log (RBY kg/day+10)= vessel ID, no. of shots, fishing year

Sensitivity analysis

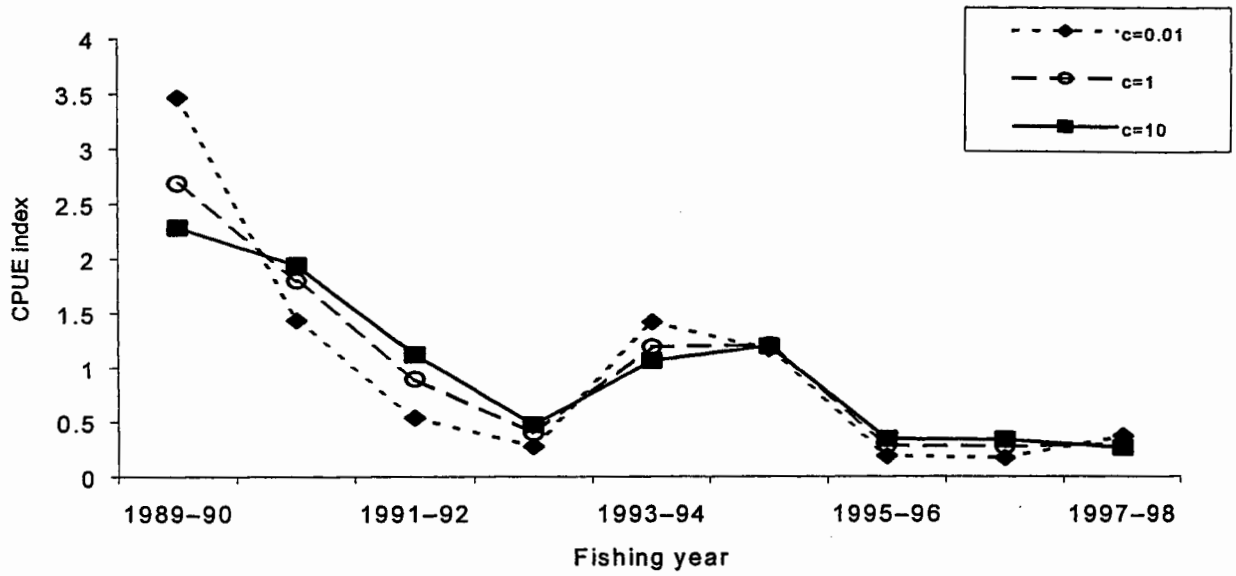
Comparison of three levels of the constant (c) for the fitted model of CPUE (kg/day)

Constant	R^2
0.01	0.27
1	0.34
10	0.38

Annual indices for levels of (c) for the fitted model

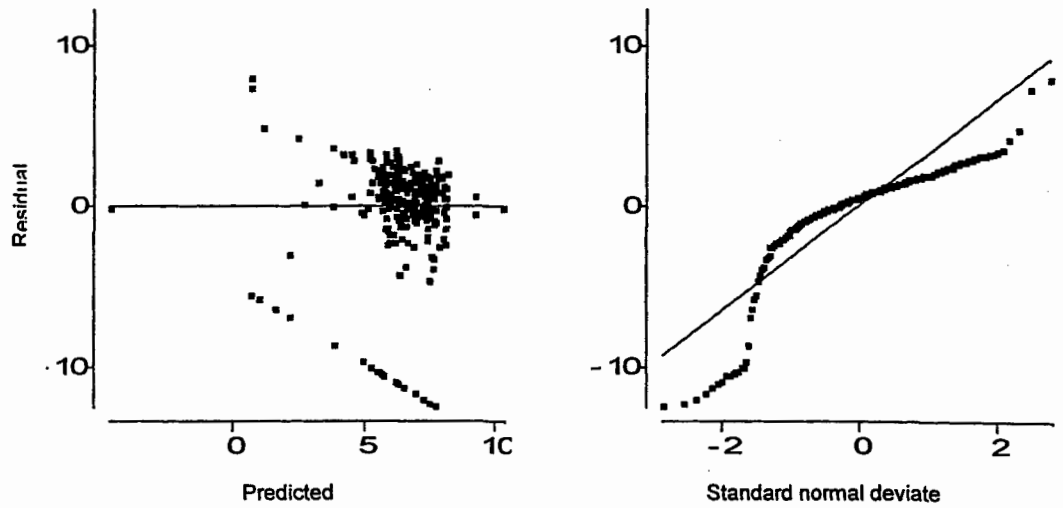
	c=0.01	c=1	c=10
1989–90	9.44	9.12	8.71
1990–91	3.90	6.11	7.40
1991–92	1.45	3.03	4.27
1992–93	0.74	1.34	1.79
1993–94	3.86	4.04	4.06
1994–95	3.18	4.09	4.57
1995–96	0.50	0.95	1.30
1996–97	0.46	0.92	1.28
1997–98	1.00	1.00	1.00

Appendix 1 – *continued*

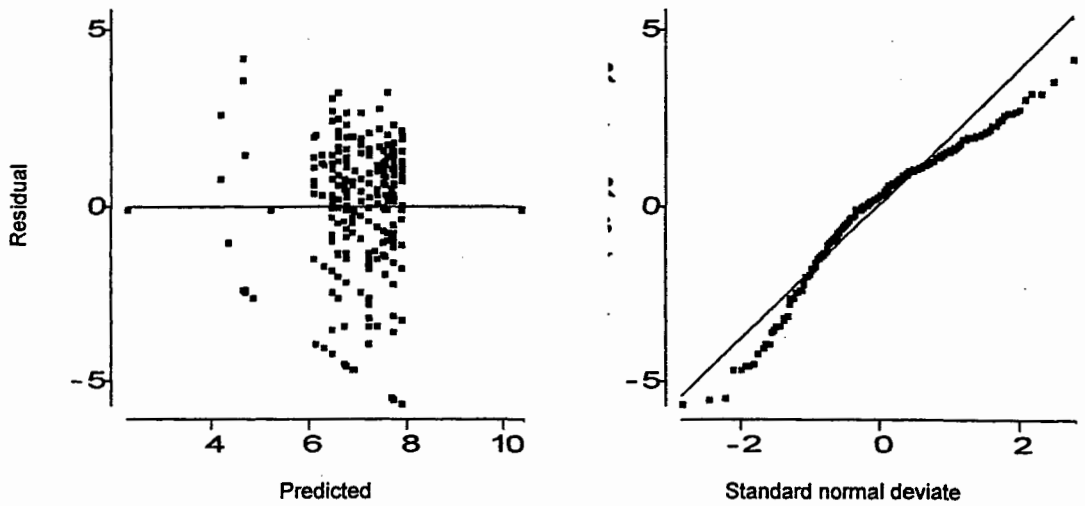


Scaled annual CPUE indices for reviewed levels of constant (c), by fishing year, 1989–90 to 1997–98

Appendix 2: Regression diagnostics for CPUE (kg/tow)

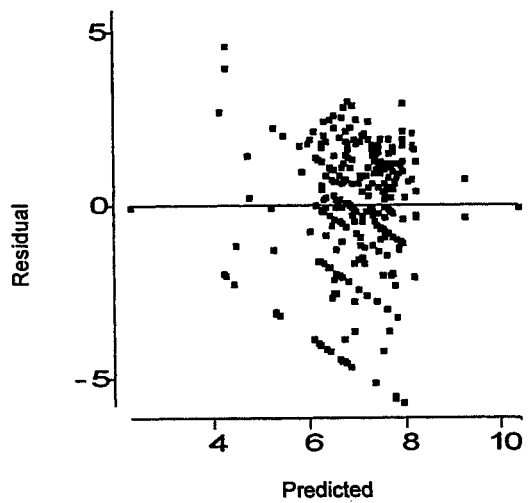


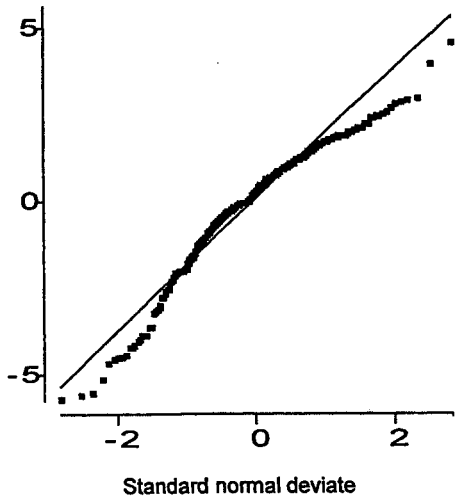
Rubyfish target trawl fishery: plot of residual * predicted values for the LNL model log (RBY kg/tow+0.01)= Ground, vessel ID, fishing year



Rubyfish target trawl fishery: plot of residual * predicted values for the LNL model log (RBY kg/tow+1)= Ground, vessel ID, fishing year

Appendix 2 – *continued*





Rubyfish target trawl fishery: plot of residual * predicted values for the LNL model log (RBY kg/tow+10)= Ground, vessel ID, fishing year

Sensitivity analysis

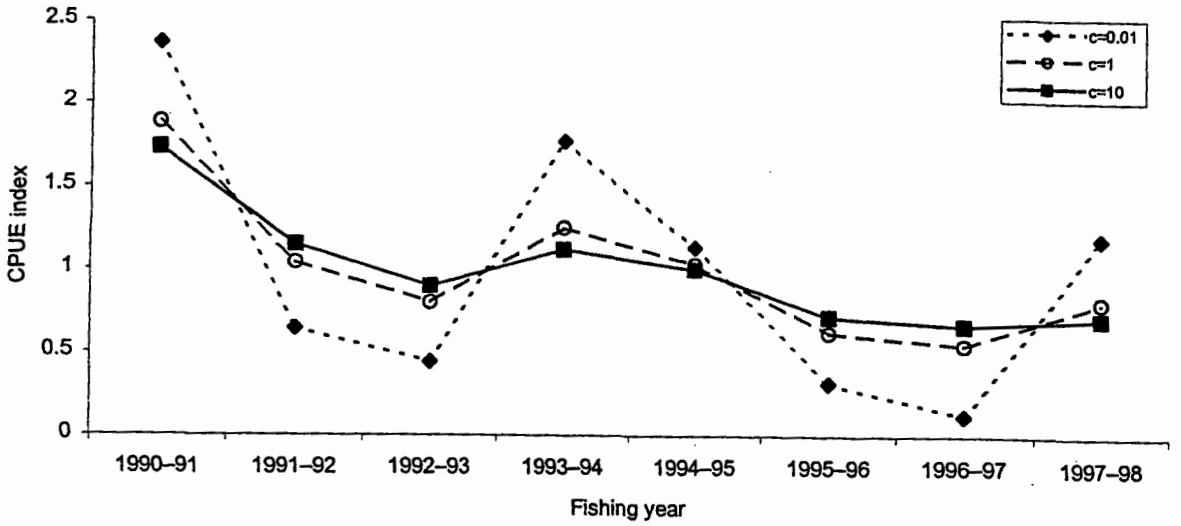
Comparison of three levels of the constant (c) for the fitted model of CPUE (kg/tow)

Constant	R^2
0.01	0.21
1	0.21
10	0.20

Annual indices for levels of (c) for the fitted model

	c=0.01	c=1	c=10
1990–91	7.14	10.12	11.21
1991–92	1.71	3.59	4.97
1992–93	1.44	2.67	3.49
1993–94	4.36	4.66	4.77
1994–95	2.57	3.56	1.05
1995–96	1.30	2.14	2.72
1996–97	1.11	1.96	2.53
1997–98	1.00	1.00	1.00

Appendix 2: – *continued*



Scaled annual CPUE indices for reviewed levels of constant (c), by fishing year, 1989–90 to 1997–98