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New Zealand Fisheries Assessment Research Document 95/19

Assessment of the ORH 7B orange roughy fishery for the 1995–96 fishing year

M.R. Clark and K.D. Field

NIWA
P O Box 14-901
Kilbirnie
Wellington

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N.Z. Fisheries Assessment Research Document 95/19. 15 p.

1. EXECUTIVE SUMMARY

1. The fishery in ORH 7B developed off the Cook Canyon in 1985. A TAC was set at about 1500 t to constrain the fishery until more information on stock size became available. It was increased to 1700 t in 1988 as a result of QAA decisions. The TACC has not been caught in the last two fishing years.

2. There has been limited stock assessment research. An assessment made in 1988 used methods to calculate biomass that are no longer considered appropriate. Yield estimates have not been made in recent years.

3. The fishery assessment carried out here incorporates updated landings from 1993–94, analysis of commercial CPUE data from 1985–86 to 1993–94, and results of stock reduction analysis.

4. Unstandardised (average catch per tow) and standardised (year effects) CPUE indices both show substantial decreases over the period of the fishery. The indices in 1993–94 were 11% and 2% of 1985–86 levels for the respective analyses.

5. Virgin biomass was estimated from stock reduction analysis on the two sets of CPUE data at between 10 000 t and 15 000 t. Mid-year biomass in 1994–95 was 4–15% of virgin levels.

6. Yield estimates have been calculated. Both Maximum Constant Yield (MCY) and Current Annual Yield (CAY) are of the order of 100–200 t.

7. Current catch levels, and the level of the TACC, are not sustainable, and will not allow the stock to move towards a size that will support the Maximum Sustainable Yield (MSY).

2. INTRODUCTION

2.1 Overview

This document updates the stock assessment of orange roughy in Quota Management Area ORH 7B, which covers an area off the west coast of the South Island from near Westport to south of Jackson Head.

The assessment incorporates analyses of commercial catch and effort data from the fishery between 1985–86 and 1993–94. Biomass and yield estimates are calculated using stock reduction analysis.

2.2 Description of the fishery

Orange roughy occur throughout the QMA (which includes domestic fishery return areas 032 (northern part), 033, 034 (southern part), 705, and 706). The fishery centres 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 months (Table 1), particularly in June and July.

Table 1: Reported orange roughy catch for ORH 7B (rounded to nearest 10 t) by 3-month periods from 1984–85 to 1993–94 (–, no catch; * less than 5 t).

Year	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May
1984–85	250	–	–	30
1985–86	1 020	520	30	90
1986–87	1 230	180	*	40
1987–88	1 310	–	–	*
1988–89	1 170	10	–	30
1989–90	1 360	–	10	10
1990–91	1 120	310	50	60
1991–92	1 540	10	–	*
1992–93	1 120	70	–	20
1993–94	570	80	30	*

2.3 Literature Review

The initial development of the fishery, and early research results, were described by Armstrong & Tracey (1986). Specific trawl survey results were given by Tracey (1985), Armstrong & Tracey (1987), and Tracey *et al.* (1990). Data from other research and commercial trips are available in Clark & Tracey (1988a), and unpublished voyage reports (JO386, JO589, TAN9103, TAN9307). Robertson (1986), Robertston *et al.* (1988), and Clark & Tracey (1988b) carried out early stock assessments for ORH 7B, and also gave additional background information.

3. REVIEW OF THE FISHERY

3.1 Total Allowable Catches and landings data

Total Allowable Catches (TACs) and reported landings for ORH 7B from 1983–84 to 1993–94 fishing years are shown in Table 2. From the development of the fishery in the 1985–86 year through until 1991–92, the TAC was almost always fully taken. However, in 1992–93 and 1993–94 reported landings were 67% and 41% respectively of the TAC.

Over the years there has been a shift in timing of the main catches (Table 3). Up to and including 1988, most of the catch was taken in June. In 1989, catches in June and July were about equal, but since then July has been the main fishing month.

3.2 Maori and recreational fishing patterns

There is no known recreational or traditional Maori catch of orange roughy.

Table 2: Reported landings (t) of orange roughy and TACs (t) for ORH 7B from 1983–84 to 1993–94

Fishing year	Reported landings	TAC
1983–84*	2	–
1984–85*	282	–
1985–86*	1 763	1 558
1986–87*	1 446	1 558
1987–88†	1 413	1 558
1988–89†	1 750	1 708
1989–90†	1 711	1 708
1990–91†	1 683	1 708
1991–92†	1 604	1 708
1992–93†	1 139	1 708
1993–94†	701	1 708

* FSU data
† QMS data

Table 3: Percentage of total annual catch reported in June and July, 1985–86 to 1993–94

Year	June	July
1986	49	9
1987	75	7
1988	75	23
1989	46	40
1990	17	72
1991	27	49
1992	24	69
1993	21	67
1994	16	56

4. RESEARCH

4.1 Stock structure

Orange roughy in this fishery are thought to be a single stock. Results from mitochondrial DNA studies indicate that fish from neighbouring fishing grounds of the Challenger Plateau and Puysegur Bank are distinct from the Cook Canyon.

Spawning occurs in the Cook Canyon area at about the same time (late June, early July) as on the Challenger Plateau and the Puysegur Bank. The distances between the Cook Canyon and Challenger and Puysegur grounds are 330 km and 520 km respectively.

Orange roughy from the Cook Canyon are larger than those on the Challenger Plateau: the modal peak is 1–2 cm larger for both sexes.

4.2 Resource surveys

Research surveys have been carried out in the area since 1983. Two cruises by GRV *James Cook* in February and December 1983 involved collection of trawl and hydrological data, and trawling was also carried out in October that year by F.V. *Arrow* under charter to MAF. In 1985 there was exploratory and research fishing by commercial vessels, as well as a biomass survey by F.V. *Arrow* on charter. Further bathymetric and trawling work was carried out on *James Cook* in February 1986, and there was another trawl survey by *Arrow* in July. Biological data were collected during a commercial trip by *Ocean Ranger* in June 1988.

These surveys have provided a wide range of data on distribution, relative abundance, and biology of orange roughy in the Cook Canyon region. However, data for stock assessment purposes are limited. Surveys using *Arrow* in 1985 and 1986 were both stratified random trawl surveys, but the first occurred before spawning distribution was well known, and the 1986 survey took place after spawning had finished and some dispersal was likely to have occurred. No time series of surveys has been developed to measure changes in relative abundance.

4.3 Catch per unit effort

4.3.1 Unstandardised catch rates

Profiles of unstandardised seasonal catch rate for ORH 7B are shown in Figure 1. The profile is a line of smoothed medians (medians calculated for five consecutive data points) of the average tonnes per tow caught by a vessel in a day's fishing (N.B., smoothing was done with the 'S' function "smooth", Becker *et al.* 1988). Except for 1985–86 and 1986–87 there has been very little fishing effort in ORH 7B outside the winter spawning period (June-July). In the early years of the fishery, effort during the spawning period was concentrated in June. However, by 1987–88 catch rates during June had declined and effort was extended into July. By 1992–93, catch rates throughout the spawning period had declined, and effort was at twice 1989–90 levels.

In line with the decline in catch rates and increase in effort, the geographical distribution of effort also underwent a major change in 1992–93. Effort which had previously been concentrated on a very small area in the Cook Canyon at the intersection of statistical areas 033, 034, and 705 began to spread out into all three areas (Figure 2).

4.3.2 Unstandardised CPUE analysis

Unstandardised mean catch per tow is summarised by 3 month period in Table 4. Catch rates were highest during the winter months (June-August) when fish are aggregated for spawning. These winter catch rates were relatively stable until 1990–91, after which they decreased to about one-third of their previous level in 1993-94.

Table 4: Unstandardised mean catch (t) per tow by 3-month periods

Year	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May
1984–85	3.0	–	–	0.6
1985–86	8.4	3.2	2.1	1.0
1986–87	4.4	1.2	0.7	1.5
1987–88	3.2	–	–	0.2
1988–89	3.1	0.3	–	0.4
1989–90	3.6	–	1.5	0.6
1990–91	4.3	6.3	4.6	1.8
1991–92	2.3	0.3	–	0.1
1992–93	1.7	0.6	–	0.4
1993–94	0.9	1.5	0.6	0.1

4.3.3 Standardised CPUE analysis

A standardised CPUE analysis of commercial data for the orange roughy fishery in ORH 7B was carried out using the multiple regression technique described by Field (1992).

Table 5 shows the proportion of the reported landings for ORH 7B which is also reported as estimated catch on the catch-effort database and was therefore available for the analysis. Between 1983–84 and 1987–88 data were collected by the Fisheries Statistics Unit (FSU). During this time almost all catches were reported with individual tow information. In 1988–89 the QMS took over collection of catch-effort data, and during this transition year only 47% of reported landings were captured on the catch-effort database. Since 1989–90 nearly half the catch on the catch-effort database has been reported without tow information. For this reason, all tow-by-tow data were summarised into day format, i.e., CPUE = (total catch / total tows) by statistical area by vessel by day.

As in the ORH 2A fishery (Field *et al* 1994) the first year in this fishery was characterised by large losses of fish due to burst and unretrieved nets. As reported landings do not record these fish, the CPUE index would not accurately represent abundance for this year. For this reason the Working Group chose to not include 1984—85 in the standardised model.

Table 5: **Percentage of reported landings (t) in ORH 7B that is also reported as estimated catch on the catch-effort database, and percentage of this estimated catch which has information on individual tows. FSU, Fisheries Statistics Unit; QMS, Quota Monitoring System**

Year	System	Reported landings (t)	% on database	% with tow information
1983–84	FSU	2	100	100
1984–85	FSU	282	91	99
1985–86	FSU	1 763	89	99
1986–87	FSU	1 446	90	98
1987–88	FSU	1 413	89	99
1988–89	FSU & QMS	1 750	47	100
1989–90	QMS	1 711	80	66
1990–91	QMS	1 683	101	55
1991–92	QMS	1 604	100	56
1992–93	QMS	1 139	102	51
1993–94	QMS	701	94	74

For the purposes of this analysis ORH 7B was defined as statistical areas 033, 034, 705, and 706. The analysis was run for the spawning period fishery (1 June to 30 July) from 1986 to 1994. Records of all New Zealand vessels that had fished for at least 14 days between 1986 and 1994 (i.e., had at least 14 records) and where orange roughy was the target were included in the analysis. This resulted in a dataset of 1117 records for 15 vessels.

Fishing year, season, and vessel were included as categorical variables and regressed against a CPUE of log(mean tonnes per tow per vessel-day). Although in the data catches were reported from three statistical areas, historically the fishery has been concentrated in a very small area centred on the intersection of areas 033, 034, and 705. It was therefore not appropriate to include area as a variable in the model. Season was categorised into fixed periods of 5 days each, beginning on 1 June. In exploratory analyses, vessel variables such as volume had almost no explanatory power, even though the data showed major differences in the fishing effectiveness of different vessels. For this reason individual vessel was used as a factor. The data for 1988–89 were retained in the final analysis, because the results were the same whether or not the data were included.

Results from this regression analysis which were used to choose the best predictor variable at each iteration are shown in Table 6. At the first iteration, year explained the most variability in CPUE. Season improved R^2 by 56%, and the addition of the vessel factor by a further 16%. Using the three variables year, season, and vessel in the model explained 29% of the variability in CPUE (Table 6).

The season coefficients from the regression are shown in Figure 3. As expected for this spawning period fishery, there was a sharp increase and decline in the season effect around a peak in late June. A frequency histogram of the vessel coefficients (Figure 4) showed that fishing effectiveness of a few vessels was markedly different from most of the fleet. The relative year effects for each year included in the analysis are shown in Table 7 and Figure 5. The relative year effect showed a sharp decline between 1986 and 1988, and by 1994 the index had dropped to 2% of its 1986 peak value.

Table 6: **Choice of variables in stepwise regression against spawning log (mean catch per tow). Each entry shows the R^2 that would be achieved by including the given variable into that iteration**

	R^2 at Iteration		
Variable	**1**	**2**	**3**
Year	0.16		
Season	0.02	0.25	
Vessel	0.09	0.20	0.29

Table 7: **Relative year effects for regression of spawning log (mean catch per tow). *n* = number of records i.e., vessel-days; 2 s.e = two standard errors**

Year	***n***	**Relative year effect**	**2 s.e.**
1986	33	1.00	–
1987	64	0.48	0.17
1988	107	0.19	0.06
1989	77	0.14	0.05
1990	93	0.13	0.04
1991	120	0.19	0.06
1992	194	0.09	0.03
1993	207	0.05	0.02
1994	227	0.02	0.01

4.4 Estimation of biomass

A deterministic stock reduction analysis technique (*after* Francis 1990) was used to estimate virgin (B_0) and current (B_{1995}, mid-season 1994–95) biomass. Biological parameters were the same as those used for Chatham Rise (ORH 3B) orange roughy (*see* Doonan 1994, Francis *et al.* 1995) (Table 8). Note that any small differences in the von Bertalanffy and length weight parameters between the stocks have very little effect on the resulting biomass estimates. Catches before 1994–95 were taken from Table 2, and catches in 1994–95 were assumed equal to those in 1993–94 (i.e., 700 t). In keeping with previous orange roughy assessments the maximum exploitation rate (E_{max}) is assumed to be 0.67 (Francis *et al.* 1995). It was assumed that there was no overrun of reported catch.

Table 8: Biological parameters used in this assessment

Parameter	Symbol	Male	Female	Both sexes
Natural mortality	M	–	–	0.045 yr^{-1}
Age at recruitment	A_r	33 yr	34 yr	
Gradual recruitment	S_r	9 yr	8 yr	
Age at maturity	A_m	33 yr	34 yr	
Gradual maturity	S_m	9 yr	8 yr	
von Bertalanffy parameters	L_∞	36.4 cm	38.0 cm	
	K	0.070 yr^{-1}	0.061 yr^{-1}	
	t_0	–0.4	–0.6	
Length-weight parameters	a			0.0921
	b			2.71
Recruitment variability	σ_R			1.1
Recruitment steepness				0.75

The biomass estimates used in the stock reduction analysis, and results of the runs, are given in Table 9. All estimates were used as indices of relative abundance. They were assumed to have a coefficient of variation of 30%, and this was constant across all years. Model structure considers both sexes separately, and has natural mortality occurring before fishing mortality because most of the catch occurs in June-July, which is towards the end of the fishing year. Confidence intervals for B_0 were derived from bootstrap analysis (Cordue & Francis 1994). Population trajectories for standardised and unstandardised CPUE and scaled index values are given in Figure 6.

Table 9: Summary of stock reduction results: indices used, and biomass estimates

	Unstandardised CPUE	Standardised CPUE
Indices:		
1986	8.4	1.00
1987	4.4	0.48
1988	3.2	0.19
1989	3.1	0.14
1990	3.6	0.13
1991	3.2	0.19
1992	2.3	0.09
1993	1.7	0.05
1994	0.9	0.02
Estimates:		
B_0 (t)	13 400	11 800
B_0 (95% confidence interval)	11 800 – 15 800	–
B_{1995}	2 020	500
B_{1995}/B_0 (%)	15	4
Exploitation rates:		
1991–2	0.35	0.54
1992–3	0.33	0.64
1993–4	0.27	0.67

Values of B_0 are similar from both CPUE datasets (*see* Table 9). The 95% confidence interval range from the unstandardised analysis is 11 800 – 15 800 t, and the mid-season biomass in 1994–95 is estimated to be 15% of virgin levels.

Results from the standardised analysis are less certain. The standardised CPUE indices show a level of decline which conflicts with the catch history. This means that the estimate of B_0 is dependent on the maximum exploitation rate assigned to the model. With an E_{max} of 0.67, the lowest estimate of B_0 consistent with the catch history is 11 800 t (an E_{max} value greater than 1 was required for a fit to the model which was consistent with both the CPUE indices *and* the catch history). As B_0 was constrained by E_{max} it was not appropriate to calculate a 95% confidence interval. The standardised CPUE analysis estimates mid-season biomass in 1994–95 to be only 4% of virgin levels, with very high estimates of exploitation rates for recent years (constrained by E_{max}).

Given the uncertainty in the standardised analysis, results from the unstandardised analysis only are used in the following yield sections.

4.6 Yield estimates

4.6.1 Estimation of Maximum Constant Yield (MCY)

Using the method of Francis (1992) the maximum constant catch that can be taken indefinitely (without reducing the population below 20% B_0 more than 10% of the time) from a population with biological parameters as in Table 8 is 210 t, with 95% confidence interval of 180—240 t.

However, the mid-season $B_{1994\text{-}95}$ was estimated at 15% of B_0 (*see* Table 9). This is below the 20% B_0 at which the long-term MCY is considered safely sustainable, and therefore the MCY for this stock in its current state is less than the long-term MCY. Following the suggestion of Francis (1992) the MCY has been scaled down by the amount the current biomass is below 20% B_0, i.e., 15/20.

$$\begin{aligned} MCY &= 0.0154 * B_0 * (15/20) \\ &= 160 \text{ t} \end{aligned}$$

4.6.2 Estimation of Current Annual Yield (CAY)

Using the method of Francis (1992) with biological parameters of Table 8, the CAY exploitation rate (E_{CAY}) equals 0.069. This was applied to beginning of season biomass (less natural mortality) for 1995–96. The catch in 1994–95 was assumed to be 700 t, the same as in 1993–94.

$$CAY = 150 \text{ t } (95\% \text{ c.i.} = 50 - 310 \text{ t})$$

Long-term equilibrium biomass under a CAY fishing strategy is at 29% of B_0, and the mean catch (MAY) is 280 t (2.1% of B_0).

5. MANAGEMENT IMPLICATIONS

There are very strong signals of stock decline in this fishery. Reported catches in the last two fishing years have been 67% and 41% of the TACC. CPUE has also shown a marked decline.

Both sets of CPUE data show similar trends: a steep decline between the first 2 years of fishing, a further drop the following year, then a slight rally before a continued decline over the last 4 years. Neither data set gives a very good fit to the population model, and CPUE might not be tracking abundance accurately. While there is uncertainty about the estimates of virgin and current biomass, they give a clear indication that virgin biomass was not large — of the order of 10–20 000 t. Current biomass is estimated to be less than 20% of B_0.

Current catch levels are not sustainable, even in the short term. The current TACC and catch will not allow the stock to move towards a size that will support the MSY. Under the assumption of B_0 = 13 400 t, the maximum catch that will allow the stock to increase in 1995–96 is about 430 t.

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Figure 1: Unstandardised catch rate (tonnes per tow) by year for orange roughy caught in ORH 7B. The line is of smoothed medians (medians calculated for five consecutive data points) of the average tonnes per tow caught by a vessel in a days fishing.

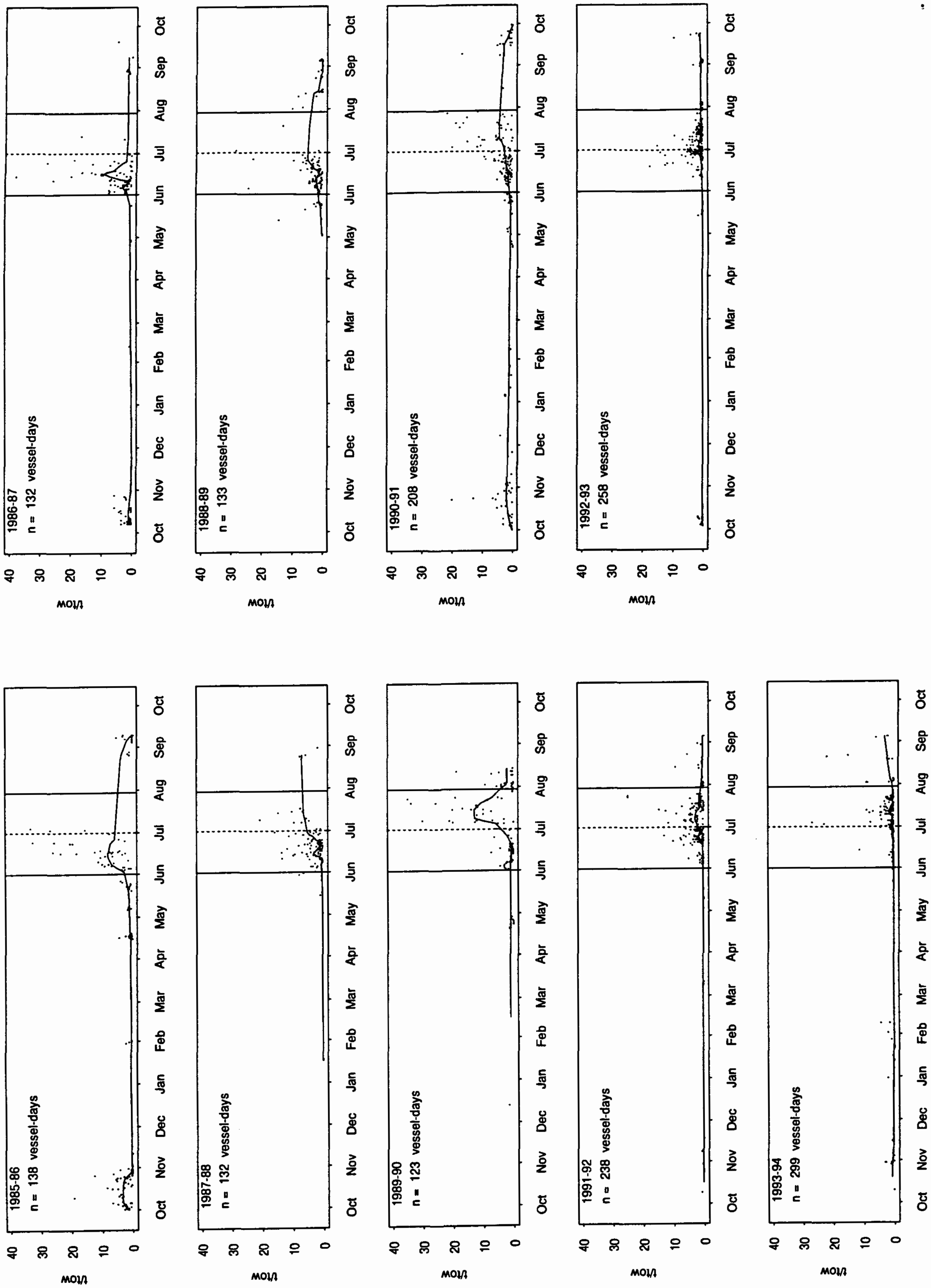

Figure 2: Geographical distribution of orange roughy caught in ORH 7B during the spawning period (1 June - 30 July) and reported with tow position. Dotted line is the 1000 m depth contour.

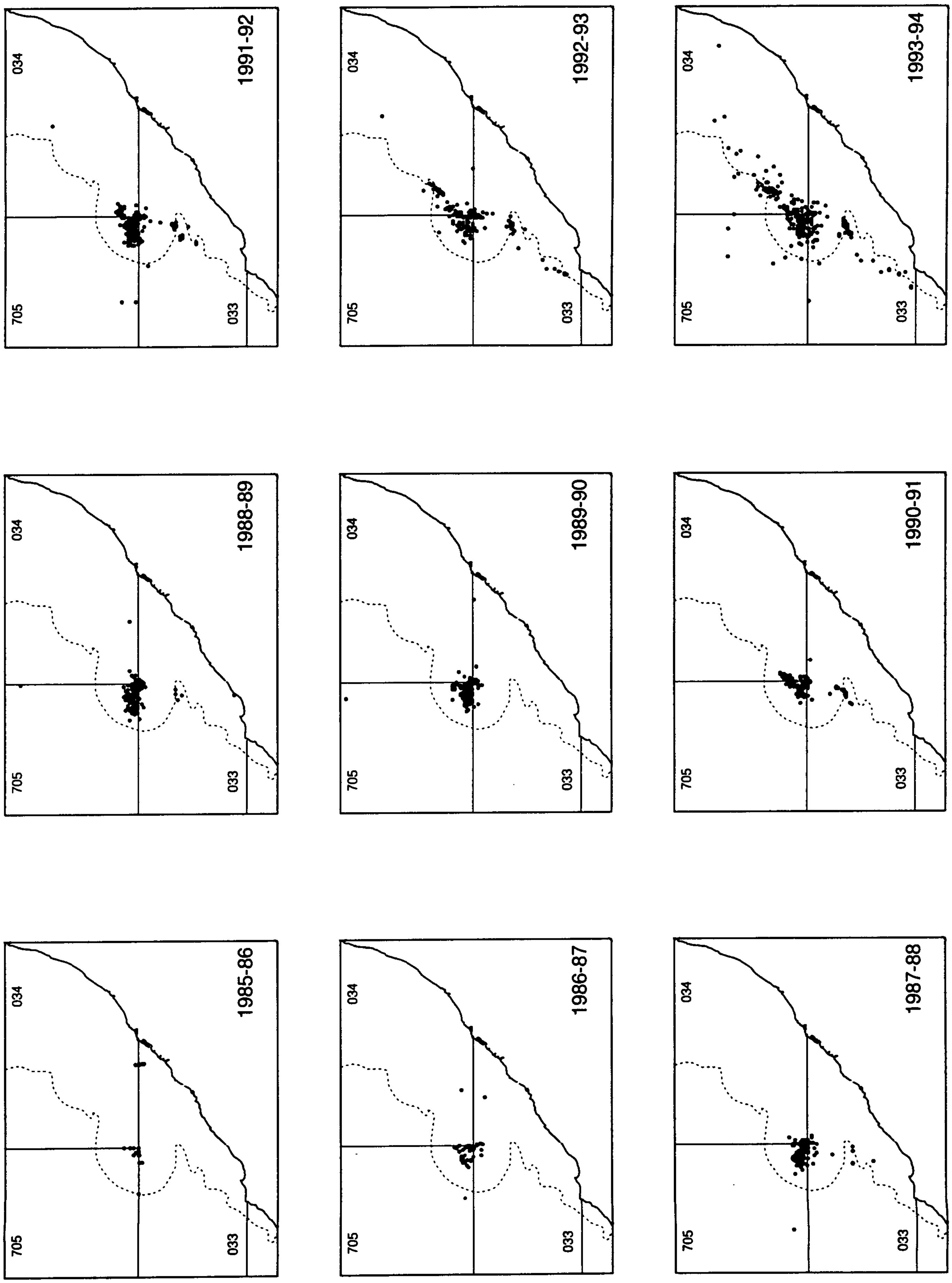

Figure 3: Relative season effects for the standardised regression of spawning period CPUE in ORH 7B.

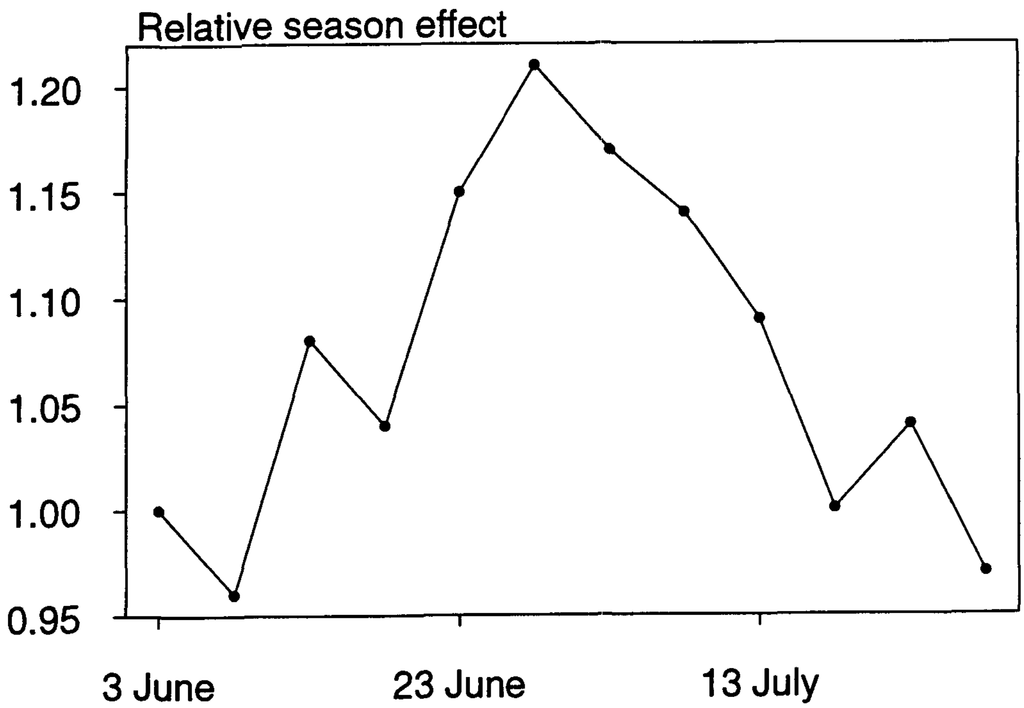

Figure 4: Frequency histogram of relative vessel effects for the standardised regression of spawning period CPUE in ORH 7B.

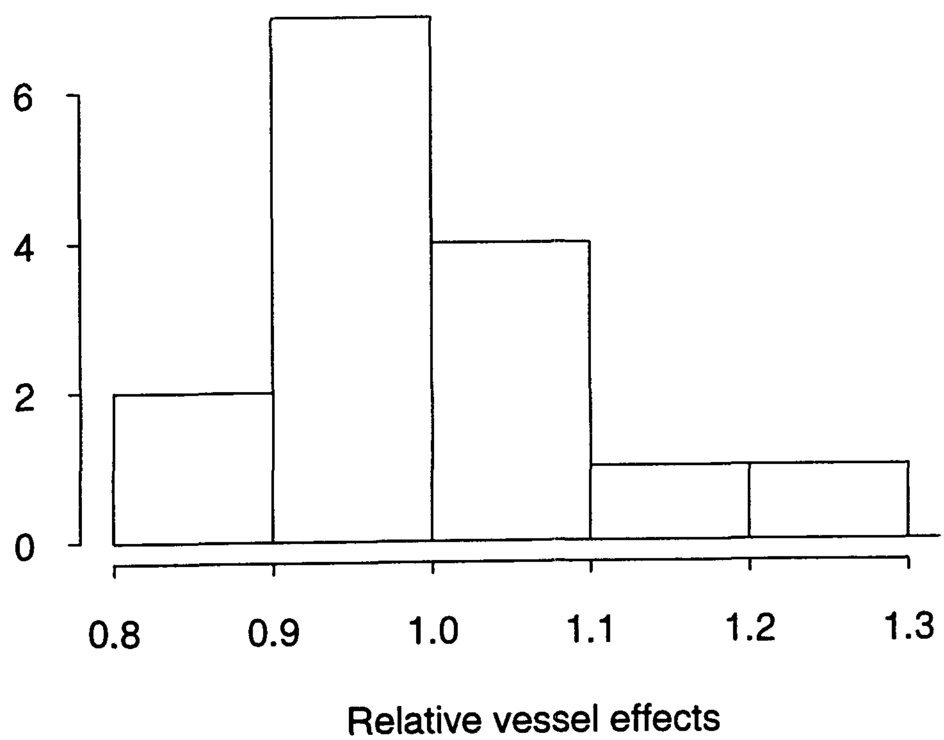

Figure 5: Relative year effects for the standardised regression of spawning period CPUE in ORH 7B with error bars representing two standard errors.

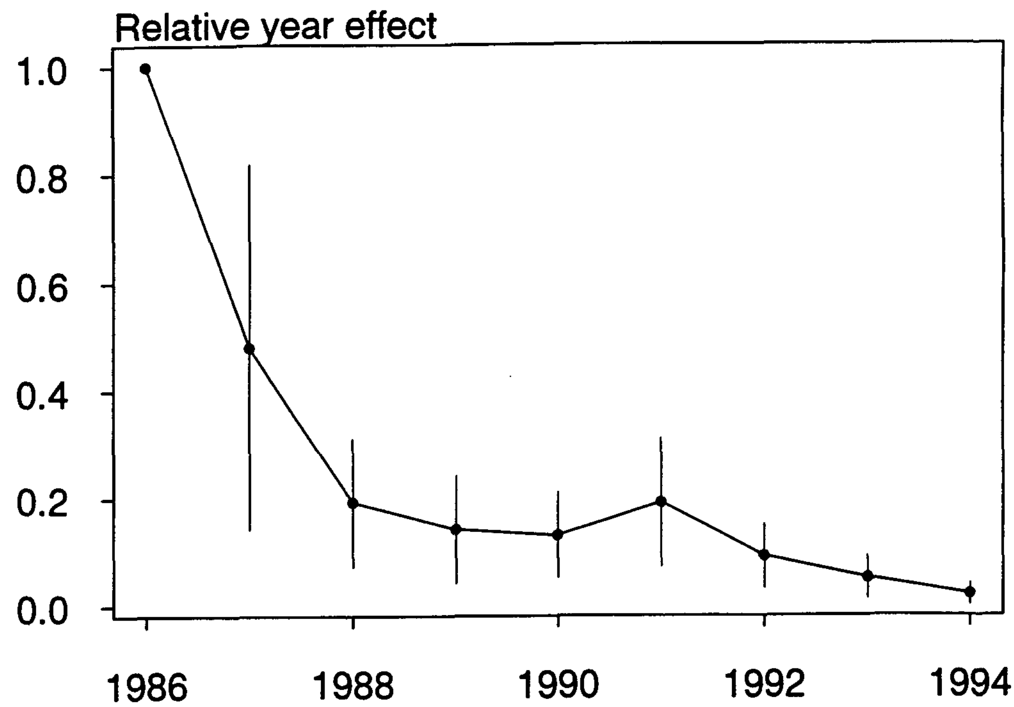

Figure 6: Estimates of biomass for ORH 7B from the deterministic stock reduction analysis. Solid line is estimated biomass, points are CPUE indices converted to absolute estimates by dividing by the estimated catchability.