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Assessment of the ORH 7A orange roughy fishery for the 1996–97 fishing year

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1. EXECUTIVE SUMMARY

1. The ORH 7A fishery developed in the southwestern region of the Challenger Plateau in 1981. Catches are taken inside the EEZ and on the Westpac Bank about 25 n. miles outside the EEZ. Reported catches have varied from 1600 t to 12 200 t per year, following changes in the TACC as the fishery developed and became fully exploited. The current TACC is 1900 t for ORH 7A and the Westpac Bank.

2. This fishery assessment incorporates updated landings from 1994–95, analysis of commercial CPUE data from 1982–83 to 1994–95, and results of stock reduction analyses.

3. Unstandardised (average catch per tow in winter months) and standardised (year effects) CPUE indices both show substantial decreases over the period of the fishery. The indices in 1994–95 were 22% and 2% of peak levels for the respective analyses.

4. Virgin biomass was estimated from stock reduction analysis on the two sets of CPUE data at between 90 700 t and 132 000 t. Current biomass, $B_{mid1995-96}$, was 13–41% of virgin levels, but is not considered well estimated. The model estimates that stock size is currently increasing slowly, but this is not reflected in the CPUE data.

5. Yield estimates have been calculated. MCY is estimated to be 860–1930 t, and CAY is 930–3680 t.

6. The uncertainty in estimates of biomass and yield mean that the fishery needs to be carefully monitored.

2. INTRODUCTION

2.1 Overview

This document updates the stock assessment of the orange roughy fishstock on the Challenger Plateau (ORH 7A, Figure 1). The assessment incorporates a standardised analysis of commercial catch and effort data from the fishery between 1982–83 and 1994–95. Biomass and yield estimates are calculated using stock reduction analysis.

2.2 Description of the fishery

The fishery is centred in the southwestern region of the Challenger Plateau, about 200 n. miles west-north-west of Cape Farewell. The fishery developed in late 1981, and rapidly expanded as spawning concentrations of fish were located. Reported catches have varied from 1600 to 12 200 t per year, after several changes in the TACC (Table 1). Since 1989–90 the bulk of the landings have been in the winter months when the fishery targets aggregations of spawning fish.

A fishery developed outside the EEZ in 1987. Westpac Bank, the main area fished, is about 25 n. miles outside the EEZ boundary, and 40 n. miles from the centre of fishing inside the zone. Peak catches of 3 500 t were taken in 1988–89 (*see* Table 1). Catches have declined since then, partly on account of an agreement between New Zealand and Australia to restrict fishing in the area, and because catches by New Zealand vessels count against ORH 7A quota inside the EEZ. The accuracy of reported catches outside the EEZ by foreign vessels is uncertain.

2.3 Literature Review

Most papers relevant to the Challenger orange roughy fishery were outlined in previous stock assessment reports (*see* Clark 1991, 1992). The history of the fishery and changes in the stock during the 1980s were described by Clark & Tracey (1994). Unstandardised CPUE has been regularly updated (Annala 1993, 1994, 1995). The stock assessment was substantially updated in 1995 with the use of revised a stock reduction model and the same life history parameters used for Chatham Rise orange roughy (Doonan 1994).

3. REVIEW OF THE FISHERY

3.1 Total Allowable Catches and landings data

Total Allowable Catches (TACs), reported landings, and total estimated catches (adjusted by the estimated overrun, detailed discussions of overrun are given in Clark 1991 and Francis *et al.* 1993) for ORH7A from 1980–81 to 1994–95 fishing years are shown in Table 1. The TAC was considerably reduced in 1989–90 following evidence the stock had been overexploited and had declined to relatively low levels (Clark 1991). Since 1990–91 the TAC has been held at 1900 t.

3.2 Maori and recreational fishing patterns

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

Table 1: Reported catches (t), estimated overrun, total estimated catch (t, i.e., adjusted for overrun) and TACs (t) from 1980–81 to 1994–1995

Fishing year	Inside EEZ	Outside EEZ	Total catch	% overrun	Total estimated catch	TAC
1980–81†	1	32	33	30	43	–
1981–82†	3 539	709	4 248	30	5 522	–
1982–83†	4 535	7 304	11 839	30	15 410	–
1983–84†	6 332	3 195	9 527	30	12 385	4 950
1984–85†	5 043	74	5 117	30	6 652	4 950
1985–86†	7 711	42	7 753	30	10 079	6 190
1986–87†	10 555	937	11 492	30	14 940	10 000
1987–88‡	10 086	2 095	12 181	30	15 835	12 000
1988–89‡	6 791	3 450	10 241	25	12 801	12 000
1989–90‡	3 709	600 *	4 309 *	20	5 171	2 500
1990–91‡	1 340	17	1 357	15	1 560	1 900
1991–92‡	1 894	17	1 911	10	2 102	1 900
1992–93‡	1 412	675	2 087	10	2 296	1 900
1993–94‡	1 594	138	1 732	5	1 819	1 900
1994–95‡	1 554	82	1 636	5	1 718	1 900

† FSU data

‡ QMS data

* Minimum value because of unreported catches by foreign vessels fishing outside the EEZ.

4. RESEARCH

4.1 Stock structure

There are no new data which would alter the stock boundaries given in previous assessment documents.

Orange roughy on the Challenger Plateau are regarded as a single separate stock. Size structure, parasite composition, flesh mercury levels, and mitochondrial DNA studies show differences to other major fisheries within the EEZ. Spawning occurs in July, at a similar time to fish on the Chatham Rise, Puysegur Bank, Ritchie Banks, Cook Canyon, and Lord Howe Rise (Clark 1990).

4.2 Resource surveys

Trawl surveys to investigate the distribution and abundance of orange roughy on the Challenger Plateau were carried out, with a number of chartered commercial vessels, each year from 1983 to 1990. Survey design was standardised from 1987. The 1987 to 1990 trawl surveys were used in the 1992–93 stock assessment of the Challenger Fishery (Clark 1992). Biomass and yield estimates calculated from these trawl surveys were similar to, but less confident than, those from CPUE data. There have also been several voyages of GRV *James Cook* (1987, 1988) for collection of biological, plankton, and hydrographic data (*see* Clark 1991).

4.3 Catch per unit effort

4.3.1 Unstandardised catch rates

For the purposes of CPUE analyses the Challenger fishery was defined as the area between latitudes 39° and 41°S, and longitudes 166.5° and 169°E. Within the fishery, tows were assigned to five sub-areas: Westpac Bank; the Central Flat; the Pinnacles less than 2 n.miles (these tows were assumed to be on the Pinnacles); the Pinnacles greater than or equal to 2 n.miles (these tows were assumed to be tows on the flat area around the pinnacles); and, Other (included all tows not in these areas). Unstandardised seasonal catch rate (tonnes per nautical mile) for ORH 7A are shown in Figure 2. The distribution of fishing effort during the year, fishing effort, and catch rates have all changed markedly since the fishery began. In the early years of the fishery catch rates were high, especially during the June-July spawning season when there were very few zero catches. By 1987–88 the number of tows had trebled (*see* Figure 2) and were concentrated in the spawning season. However catch rates had dropped substantially. At this time tow length on all flat areas increased dramatically (Table 2). In 1988–89 catch rates dropped to very low levels. This was followed by a reduction in the TACC and fishing effort. Currently almost all fishing takes place during the spawning season.

Along with the changes in timing of fishing effort, the geographical distribution of effort also changed (Figure 3). Until 1986–87 over 80% of fishing effort had been directed at flat areas in the fishery (Table 3). Since then 30–40% of tows have been on the Pinnacles or Westpac Bank. This is due partly to the decline in catch rates on the Central Flat in the mid 1980s, and partly to increased fishing skill and new technologies (e.g., increasing GPS navigation, improved electronic net monitoring equipment) which enables fishers to fish pinnacles more successfully.

Table 2: **Mean tow length (n.miles) by sub-area (*see* Figure 2) in the Challenger fishery. -, not fished**

Year	Central Flat	Pinnacles tows < 2n.miles	Pinnacles tows > 2n.miles	Westpac Bank	Other
1982–83	5.8	1.3	5.5	-	6.1
1983–84	4.7	1.2	5.0	-	6.7
1984–85	7.8	1.0	4.6	-	7.0
1985–86	4.6	1.0	5.0	-	7.5
1986–87	4.6	1.0	4.3	4.9	7.5
1987–88	9.4	0.6	6.9	3.2	9.8
1988–89	12.0	0.5	9.4	2.2	11.1
1989–90	11.1	0.8	5.0	1.6	10.3
1990–91	13.7	0.7	6.9	2.2	11.8
1991–92	11.1	0.7	8.3	2.8	11.5
1992–93	12.0	0.6	10.5	1.4	12.3
1993–94	11.1	0.6	5.5	1.0	11.8
1994–95	9.3	0.6	7.5	1.1	11.4

Table 3: Percentage of tows by sub-area in the Challenger fishery

Year	Central Flat, Other and Pinnacles > 2n.miles	Pinnacles < 2n.miles	Westpac Bank
1982–83	98	2	0
1983–84	97	4	0
1984–85	86	14	0
1985–86	90	10	0
1986–87	81	14	5
1987–88	58	16	26
1988–89	55	21	24
1989–90	58	29	12
1990–91	80	17	4
1991–92	63	36	1
1992–93	57	18	25
1993–94	67	15	19
1994–95	76	16	8

4.3.2 Unstandardised CPUE analysis

An estimate of unstandardised CPUE was calculated as the total catch for all vessels combined for the June-September period, divided by the total number of tows. In earlier assessments this analysis had been divided by vessel size, but trends in both size groups were similar (Clark 1992). The resulting indices (Table 4) show that unstandardised CPUE in the winter months declined steadily during the mid 1980s, after which catch per tow appeared to stabilise. However, there have been changes in the timing, geographical distribution, and level (number of tows and tow length) of fishing effort between years which mean the unstandardised data may not be directly comparable. Hence, although unstandardised CPUE is thought to track general changes in abundance, it may not be a reliable index.

Table 4: CPUE indices from unstandardised data (mean catch (t/tow) in the June-September period, all NZ vessels combined)

Year	CPUE
1982–83	16.2
1983–84	15.3
1984–85	13.3
1985–86	10.5
1986–87	10.2
1987–88	5.9
1988–89	3.7
1989–90	6.6
1990–91	4.2
1991–92	4.4
1992–93	2.7
1993–94	3.5
1994–95	3.5

4.3.3 Standardised CPUE analysis

The proportion of the reported landings for ORH 7A which was also reported as estimated catch from the Challenger fishery (as defined in Section 4.3.1) is given in Table 5.

Table 5: **Percentage of total reported landings (t, inside and outside the EEZ) in ORH 7A also reported as estimated catch for individual tows on the catch-effort database. FSU, Fisheries Statistics Unit; QMS, Quota Monitoring System**

Year	Data source	Reported landings	% on database
1982–83	FSU	11 839	101
1983–84	FSU	9 527	99
1984–85	FSU	5 117	99
1985–86	FSU	7 753	99
1986–87	FSU	11 492	96
1987–88	FSU	12 181	101
1988–89	FSU & QMS	10 241	61
1989–90	QMS	4 309	72
1990–91	QMS	1 357	93
1991–92	QMS	1 911	89
1992–93	QMS	2 087	84
1993–94	QMS	1 732	78
1994–95	QMS	1 636	101

A standardised CPUE analysis of commercial data for the orange roughy fishery in ORH 7A was carried out using the multiple regression technique described by Field (1992). The analysis was run for the fishery from 1982–83 to 1994–95. Records of tows by New Zealand (DOM), USSR (SOV), Japanese (JAP), and Korean (KOR) vessels that had targeted and/or caught orange roughy were included in the analysis. This resulted in a dataset of 11 289 records for 67 vessels.

Variables used in this analysis are described in Table 6. They were regressed against a CPUE of log(tonnes/n.mile + 0.001).

Table 6: **Summary of variables in the standardised model. Variable types are: cont, continuous; cat, categorical with the given number of categories**

Variable	Type	Description
Area	cat 5	area that the tow occurred in
Year	cat 13	fishing year (1 October - 30 September) that the tow occurred in
Month	cat 12	month that the tow occurred in
Net depth	cont	depth in metres of groundrope at start of tow
Start time	cont	time in decimal hours at start of tow
End time	cont	time in decimal hours at end of tow
Speed	cont	speed of the vessel at start of tow
Nation	cat 4	country of origin of the vessel
Vessel power	cont	power of vessel engine in kilowatts
Vessel tonnage	cont	gross tonnage of the vessel

Results from this regression analysis which were used to choose the best predictor variable at each iteration are shown in Table 7. Variables were included in the model if they improved the R^2 by 1% or more. The analysis chose a model which included the variables area, year, month, nation, net depth, and gross tonnage of the vessel. Area, year, and month together explained 22% of the variability in CPUE. Inclusion of nation, net depth, and vessel tonnage explained a further 1.5% of the variability.

The relative year effects for each year included in the analysis are shown in Table 8 and Figure 4. The relative year effect showed a sharp decline between 1984–85 and 1987–88. By 1992–93 the index had dropped to 1.6% of its 1983–84 peak value. There has been little change since then.

Table 7: Choice of variables in stepwise regression against log(tonnes/n.mile). 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**	**4**	**5**	**6**	**7**
Area	8.84						
Fishing year	5.16	14.66					
Month	3.80	11.39	21.81				
Nation	2.21	11.24	15.13	22.44			
Net depth	5.05	9.49	15.72	22.32	23.03		
Vessel tonnage	1.03	9.53	14.92	22.14	22.71	23.30	
Vessel speed	0.20	8.98	15.34	22.05	22.59	23.17	23.41
Vessel power	1.23	10.06	15.39	22.24	22.71	23.28	23.35
Start time	0.11	8.91	14.74	21.85	22.49	23.07	23.34
Finish time	0.13	8.91	14.72	21.84	22.48	23.06	23.33
% improvement in R^2		65.8	48.8	2.9	2.6	1.2	0.5

Table 8: Relative year effects for regression of log(tonnes/n.miles). *n*, number of records; 2s.e., two standard errors

Year	***n***	**Relative year effect**	**2s.e.**
1982–83	747	1.00	–
1983–84	786	1.29	0.199
1984–85	678	0.35	0.057
1985–86	876	0.55	0.082
1986–87	1 379	0.26	0.034
1987–88	2 265	0.078	0.010
1988–89	1 872	0.056	0.008
1989–90	507	0.074	0.013
1990–91	302	0.033	0.006
1991–92	369	0.033	0.006
1992–93	649	0.024	0.004
1993–94	428	0.023	0.004
1994–95	431	0.024	0.004

4.4 Estimation of biomass

A deterministic stock reduction analysis technique (*after* Francis 1990) was used to estimate virgin (B_o) and current (B_{1996}, mid-season 1995–96) biomass. Biological parameters were the same as used for Chatham Rise (ORH 3B) orange roughy (*see* Doonan 1994, Francis *et al.* 1995) (Table 9). The catches used in the model were the "Total estimated catch" given in Table 1 (i.e., total catches including estimated overrun). Catches in 1995–96 were assumed to be equal to the TACC plus 5% overrun. In keeping with previous orange roughy assessments, the maximum exploitation rate (E_{max}) is assumed to be 0.67 (Francis *et al.* 1995).

Table 9: Biological parameters used in this assessment

Parameter	Symbol	Male	Female	Both sexes
Natural mortality	M	–	–	0.045 yr^{-1}
Age of 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 10. All estimates were used as indices of relative abundance. They were assumed to have a *c.v.* of 30%, and this was constant across all years. Model structure considers both sexes separately, and involves natural mortality occurring before fishing mortality. The latter is because most of the catch occurs in June-July, which is towards the end of the fishing year. Confidence intervals for B_o were derived from bootstrap analysis. Population trajectories for both cases and scaled index values are given in Figure 5.

Table 10: Summary of stock reduction results: indices used, and biomass estimates

	Unstandardised CPUE	Standardised CPUE
Indices:		
1982–83	16.2	1.00
1983–84	15.3	1.29
1984–85	13.3	0.35
1985–86	10.5	0.55
1986–87	10.2	0.26
1987–88	5.9	0.078
1988–89	3.7	0.056
1989–90	6.6	0.074
1990–91	4.2	0.033
1991–92	4.4	0.033
1992–93	2.7	0.024
1993–94	3.5	0.023
1994–95	3.5	0.024
Estimates:		
B_0 (t)	110 000	90 700
B_0 (95% confidence interval)	90 700 – 132 000	90 700 – 94 000
$B_{mid1995-96}$	32 000 – 54 000	12 200 – 15 600
$B_{1995-96}/B_0$ (%)	35 – 41	13 – 17
Exploitation rates:		
1992–3	0.08	0.23
1996–4	0.06	0.17
1994–5	0.06	0.15

The estimates of B_0 from the stock reduction analyses were 110 000 t for the unstandardised indices and 90 700 t for the standardised indices. In Table 10, a range is given for B_0 of B_{min}, the minimum biomass consistent with the catch history and an assumed maximum instantaneous fishing mortality of 1 yr^{-1} (this corresponds to a maximum exploitation rate of about 0.67), and an upper 95% confidence limit for B_0 (calculated using the bootstrap procedure of Cordue & Francis 1994). The current (mid-season 1995–96) biomass is estimated as 35–41% and 13–17% B_0 for the unstandardised and standardised indices, respectively.

4.5 Yield estimates

Yield estimates were calculated for the biomass range, B_{min}, to the upper 95% confidence limit for B_0 (Table 11). Maximum Constant Yield (MCY) and Current Annual Yield (CAY) were estimated using the simulation model of Francis (1992) with the biological parameters of Table 9. By this method the long-term MCY is 1.54% of B_0, and under continued fishing at this level the mean biomass is 53% B_0. Where the mid-season $B_{1995-96}$ was estimated to be less than 20% of B_0 the MCY was adjusted by MCY = $MCY*B_{1995-96}/(0.2B_0)$ (*after* Francis 1992).

The exploitation rate associated with CAY, E_{CAY}, is 0.069. This was applied to beginning of season biomass (less natural mortality) for 1996–97. The mean catch when fishing at E = 0.069 is 2.10% B_0, and the mean biomass is 29% B_0. All these estimates are sensitive to assumed values of natural mortality and steepness (*see* Tables 7 and 9 of Annala 1995, pp 179–180).

Table 11: **Biomass (t) and yield estimates (t, corrected for an assumed overrun of 5%). The ranges given correspond to B_{min} to the upper 95% confidence limit for B_0. The long-term MCY is the MCY when the biomass is greater then 20% B_0; the MAY is the long-term average CAY**

Series	B_0	$B_{mid1995-96}$	$MCY_{1996-97}$	$MCY_{long-term}$	$CAY_{1996-97}$	MAY
Unstandardised	90 700–132 000	32 000–54 000	1330–1930	1330–1930	930–3680	1820–2630
Standardised	90 700–94 000	12 200–15 600	860–1170	1330–1380	930–1150	1820–1880

5. MANAGEMENT IMPLICATIONS

Commercial catch per unit effort and research trawl survey data clearly indicate that the orange roughy stock in the southwestern region of the Challenger Plateau (both inside and outside the EEZ) declined markedly during the 1980s.

The estimates of B_0 calculated from the unstandardised and standardised CPUE indices are 90 700–132 000 t and 90 700–94 000 t, respectively, with current biomass for these results estimated to be between 13% and 41% of B_0. However, neither CPUE data set gives a very good fit to the population model, and consequently current biomass and the ratio of current to virgin biomass are not thought to be well estimated. The population model estimates that stock size is currently increasing slowly (*see* Figure 4), though this is not reflected in the CPUE data. It should be noted that these results are based on a deterministic model using constant recruitment, and that there is inadequate information on the levels of current recruitment. The uncertainty in estimates of biomass and yield means the fishery needs to be carefully monitored.

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Figure 1: Location of the Challenger Plateau orange roughy fishery.

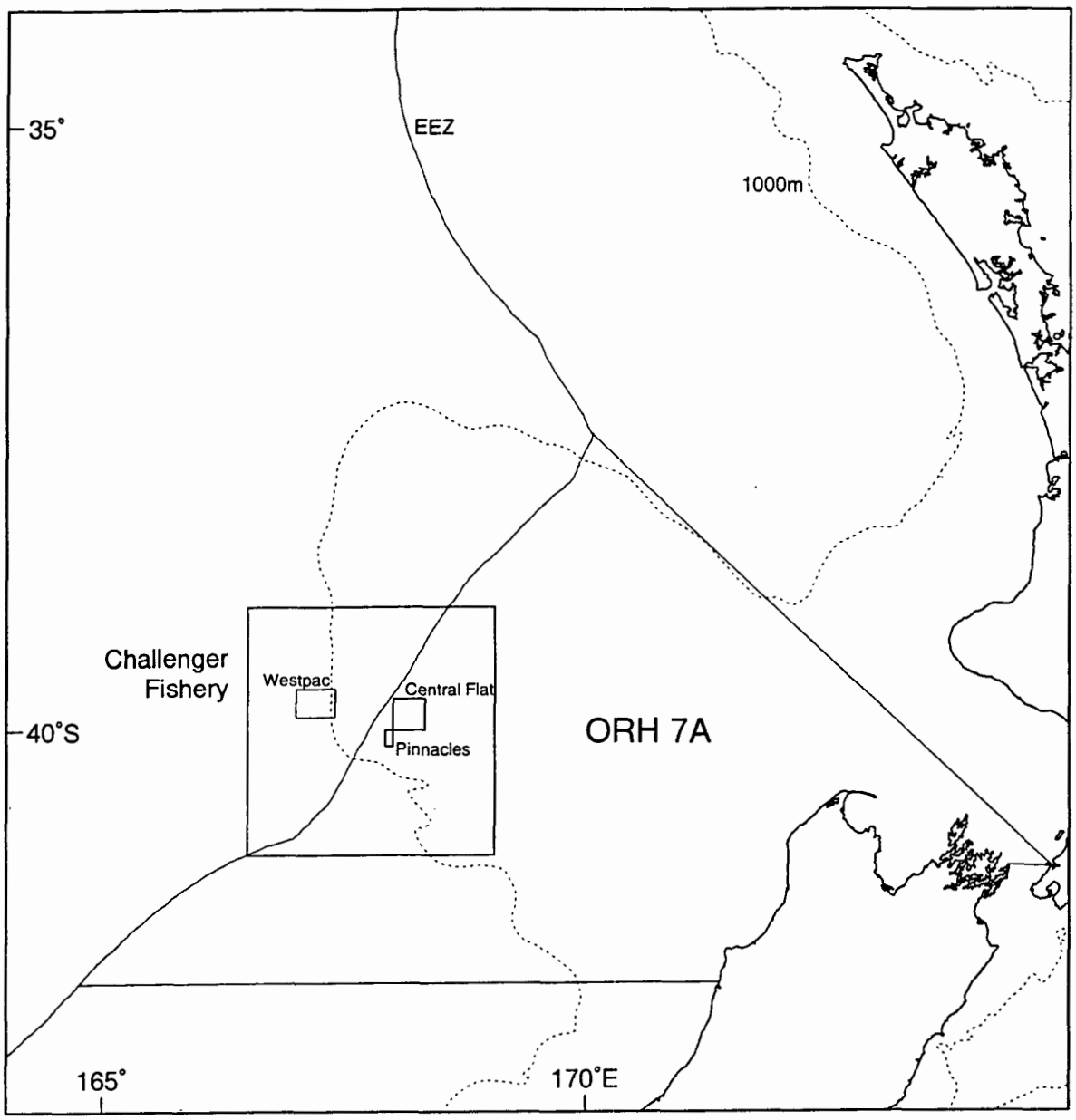


Figure 2: Unstandardised catch rates (t/nm) by fishing year for orange roughy caught in the Challenger fishery. June-July is the spawning period.

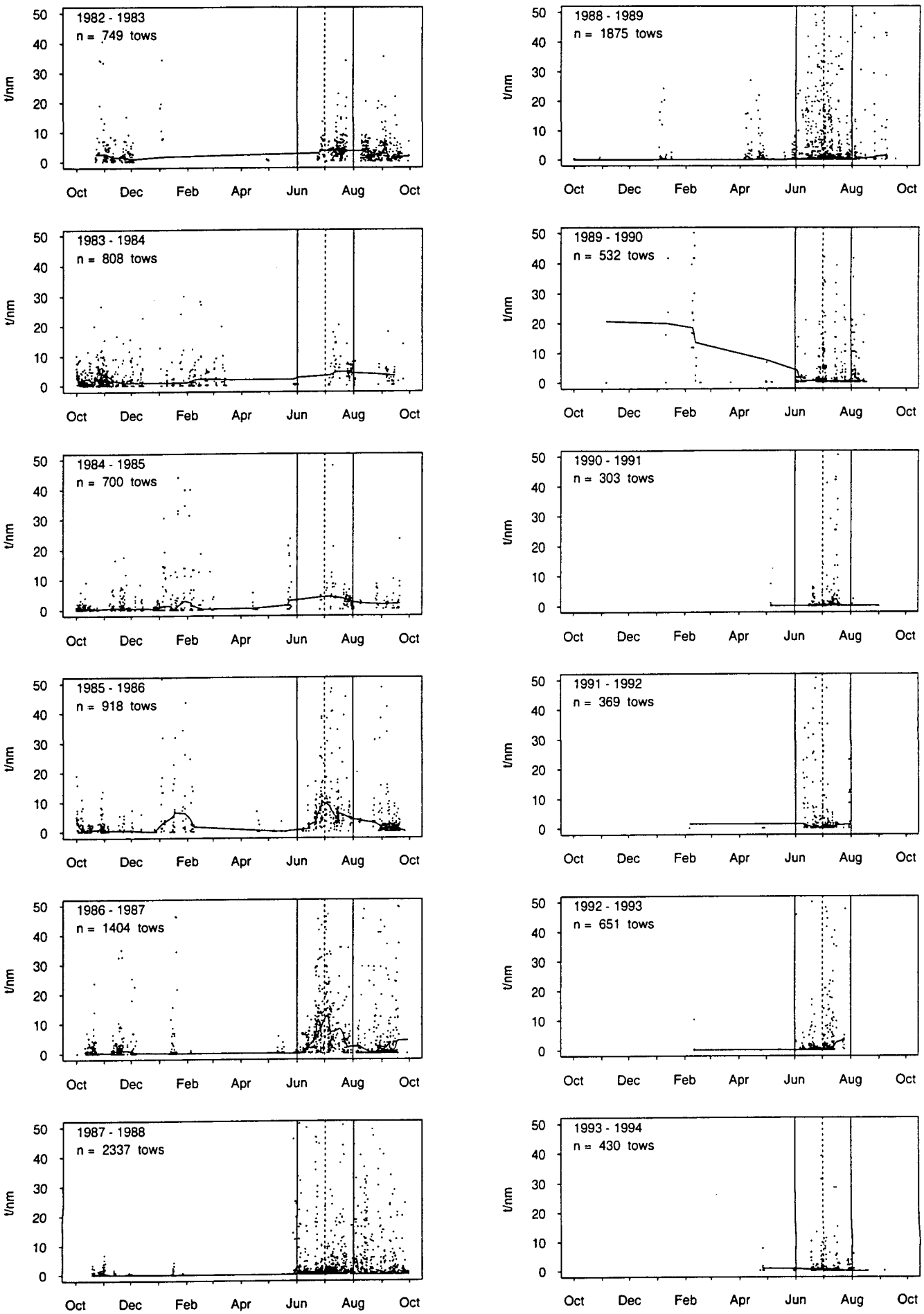
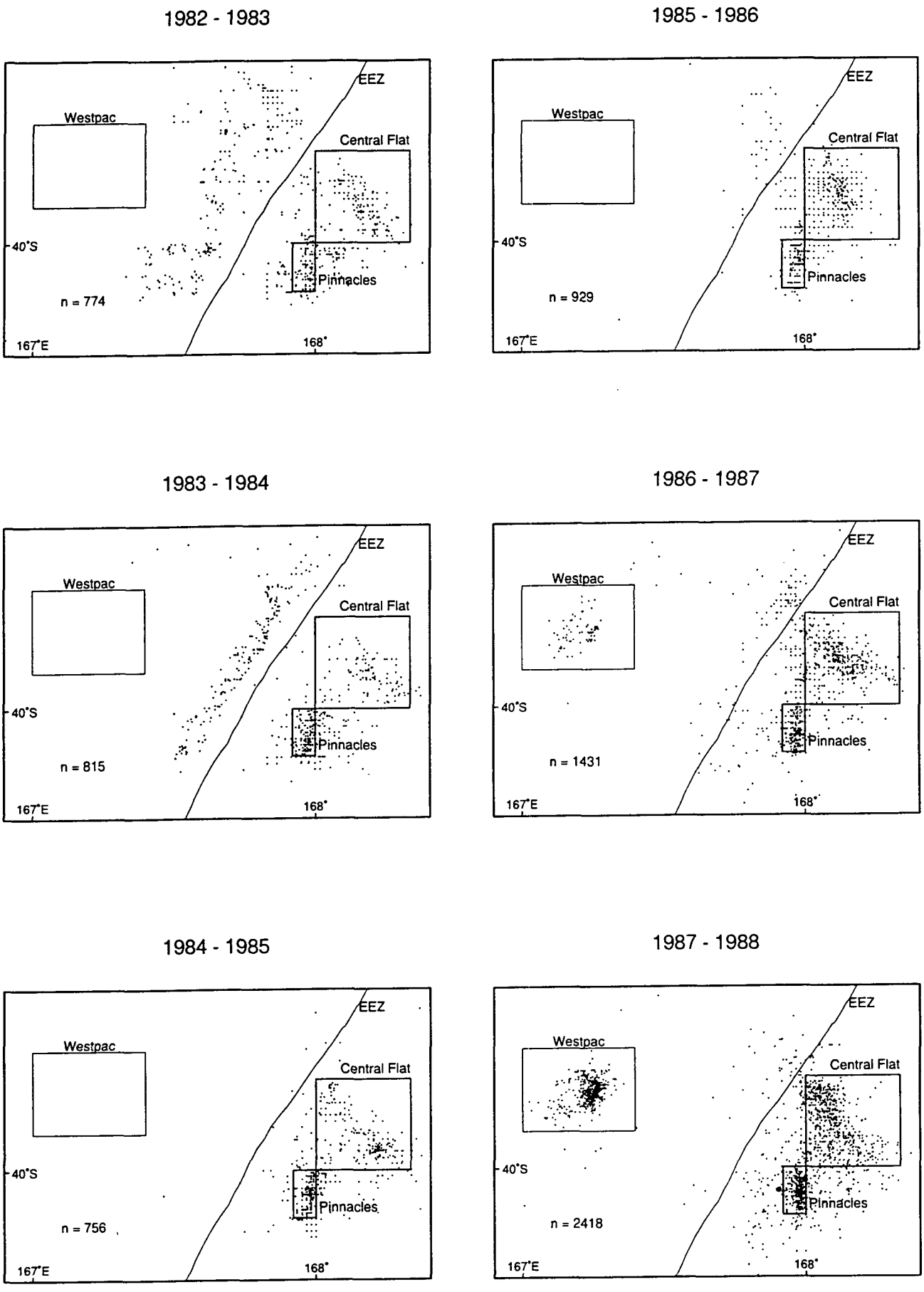
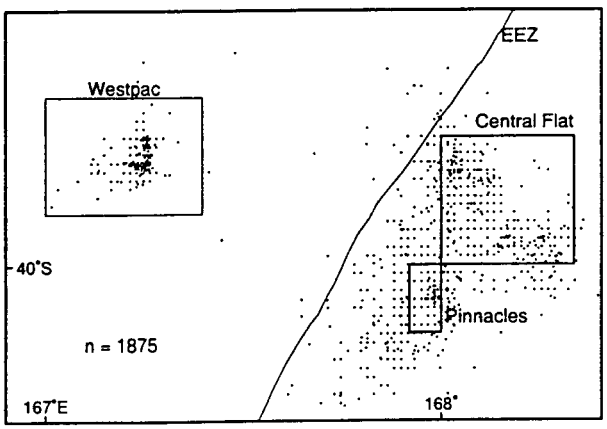


Figure 3: Position of tows which caught or targetted orange roughy in the Challenger Plateau fishery 1982–83 to 1993–94.



1988 - 1989



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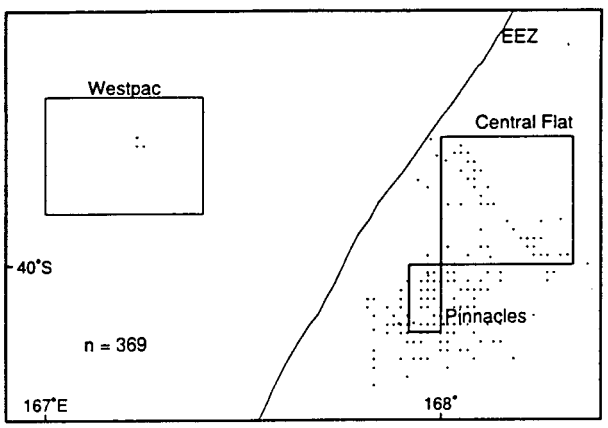
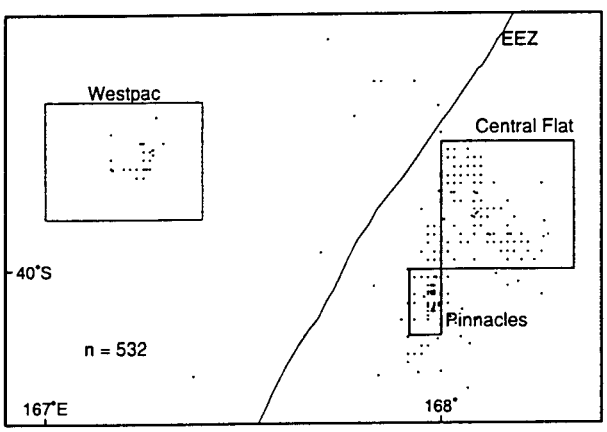
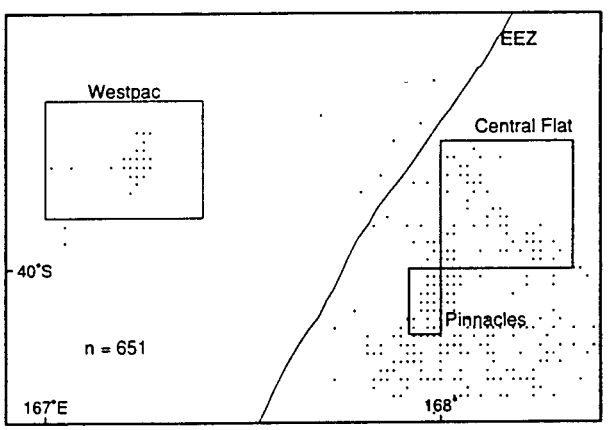


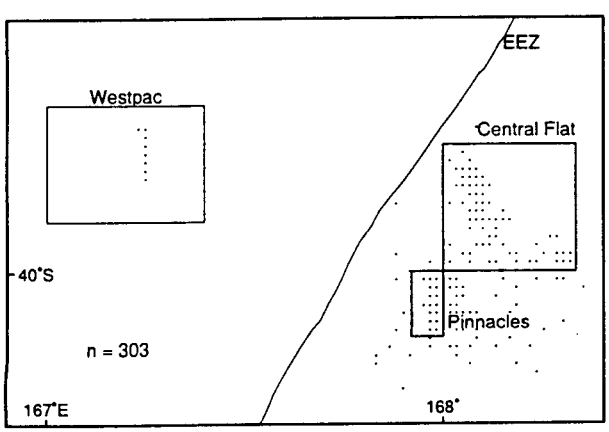
1989 - 1990



1992 - 1993



1990 - 1991



1993 - 1994

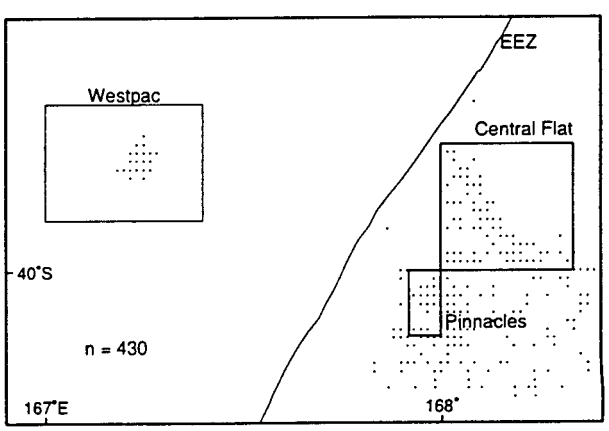


Figure 4: Relative year effects for the standardised regression of CPUE in the Challenger fishery with error bars representing two standard errors.

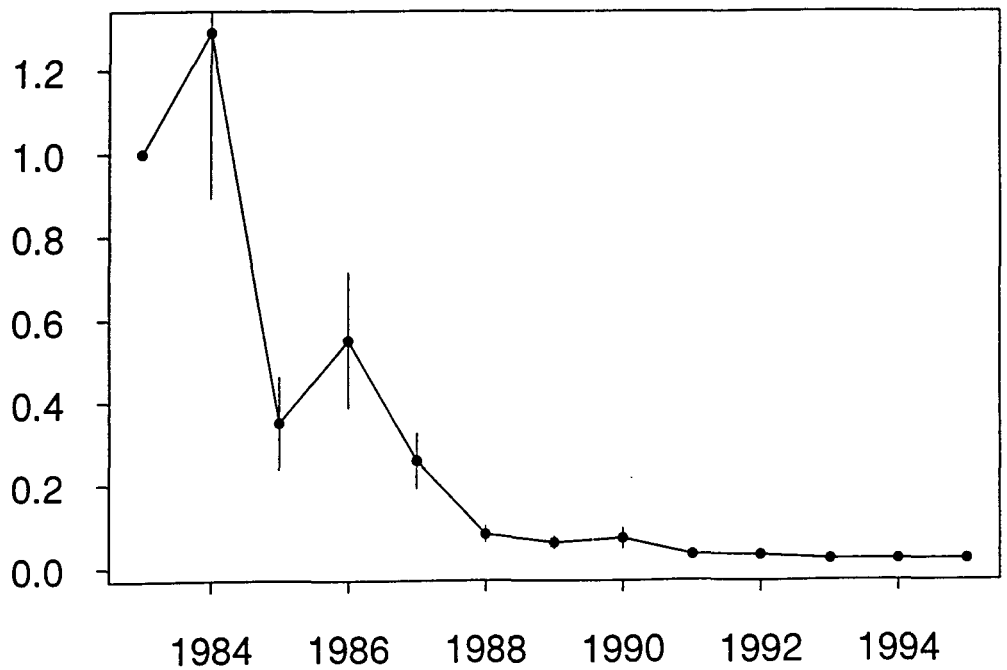


Figure 5: Biomass trajectory estimated from the deterministic stock reductions analysis using a) unstandardised CPUE indices, and b) standardised CPUE indices.