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Assessment of the Cape Runaway to Banks Peninsula (QMAs 2A, 2B, and 3A) orange roughy fishery for the 1990–91 fishing year

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1. INTRODUCTION

1.1 Overview

This document updates the fishery assessment for orange roughy along the east coast of New Zealand between Cape Runaway and Banks Peninsula. This area includes three orange roughy Quota Management Areas (QMAs)–Ritchie (2A), Wairarapa (2B), and Kaikoura (3A).

Background data and analyses for this area were presented in the 1988 and 1989 Fishery Assessment Research Documents (FARDs) (Annala 1988, 1989) and will not be repeated here. The major additional sources of data for the present assessment are: (a) landings data for the 1988–89 fishing year; (b) the results of a trawl survey carried out in September–October 1989; and (c) the results of a stock reduction analysis carried out on a time series of biomass estimates from trawl surveys from 1986–89. Orange roughy in the area between Cape Runaway and Banks Peninsula are again treated as one stock for assessment purposes.

1.2 Description of the fishery

1.2.1 Ritchie (QMA 2A)

The orange roughy fishery in QMA 2A includes domestic fishing return areas 011, 012, 013, and part of 014. The main area of the fishery is centred on the Ritchie Bank in area 013, with some of the catch also coming from area 014. Catches were reported from this QMA during each month of the 1988–89 fishing year (Table 1). However, the fishery is concentrated on pre–spawning, spawning, and post–spawning aggregations of orange roughy on the Ritchie Hill during April–July, and about 72% of the total catch was taken during these four months.

1.2.2 Wairarapa (QMA 2B)

The fishery in QMA 2B includes domestic fishing return area 015 and part of area 014, with the main fishery off Castlepoint in area 015. Catches were reported from this QMA during each month of the 1988–89 fishing year (Table 1). No spawning grounds are known in this area, and fishing occurred mainly during December – April, when 69% of the total catch was taken. Some orange roughy caught on the Ritchie during the spawning season may have been declared as coming from the Wairarapa.

1.2.3 Kaikoura (QMA 3A)

The fishery in QMA 3A includes domestic fishing return areas 016 and 018–021, with the main area of the fishery in area 018. Catches were reported from this QMA during each month of the 1988–89 fishing year, except for August (Table 1). No spawning grounds are known in this area, and fishing occurred mainly during October–December, when 68% of the total catch was taken. It is estimated that a large proportion of the quota declared as being caught in Kaikoura in the past (as high as 85%) has actually been caught in Wairarapa (Robertson et al. 1988). In addition, some orange roughy caught on the Ritchie during the spawning season may have been declared as coming from Kaikoura.

1.3 Literature review

Previous published material was reviewed in the 1988 and 1989 FARDs (Annala 1988, 1989). Additional material that has become available since includes (a) a cruise report on the results of a trawl survey carried out by the *Will Watch* during September–October 1989 designed to estimate adult distribution and biomass (Grimes, unpubl. cruise report); (b) a cruise report on the results of a trawl survey carried out by the *James Cook* during September – October 1989 designed to estimate juvenile and pre–recruit distribution, abundance, and growth rates (Annala, unpubl. cruise report); and (c) an analysis of the length frequency distribution of the commercial catch of orange roughy from the three QMAs along the east coast of New Zealand during the 1988–89 season (Field, in prep.).

2. REVIEW OF THE FISHERY

2.1 Total Allowable Catches, landings, catch, and effort data

Total Allowable Catches (TACs) and reported landings for QMAs 2A, 2B, and 3A individually and for all three QMAs combined for the 1981–82 to 1988–89 fishing years are shown in Table 2. During the 1988–89 fishing year reported catch did not reach the TACs in any of the QMAs. Reported catch of 9520 t for all three QMAs combined was 8% less than the combined TAC of 10 266 t for all three QMAs combined. During the 1988–89 fishing year 13.919 t of orange roughy was surrendered to the Crown in QMA 2A and 58.347 t in QMA 2B.

Reported catch and effort data from domestic vessel logbooks for domestic fishing return areas 011 to 021 grouped by year for each of the 1983–84 to 1987–88 fishing years are shown in Table 3. The catch per unit effort (cpue) data have been grouped by QMA and are shown in Table 4 and Figures 1 and 2. These data have been described in detail in Annala (1989). Both catch per day and catch per tow increased during 1987–88. Cpue data for the 1988–89 fishing year are not yet available.

2.2 Other information

The weighted annual length frequency distributions (all fish lengths in this report are standard length) from the commercial catch for the three QMAs for the 1988–89 fishing year are shown in Figure 3. These data are from samples of commercial landings taken in fish processing sheds by staff of the Stock Monitoring Programme. Details of the sample collection and data analysis are found in Field (in prep.).

The length frequency distributions for all fish combined for all three QMAs had modal peaks at 35–36 cm. The distribution for Kaikoura was flatter with a less pronounced peak and contained a greater percentage of fish less than 30 cm and greater than 40 cm than the other two areas. The shape of these distributions (except for Kaikoura) and the position of the modal peak were similar to those from the 1985–87 spawning season trawl surveys.

2.3 Maori and recreational fishing patterns

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

3. RESEARCH

3.1 Stock structure

Orange roughy in the area between Cape Runaway and Banks Peninsula are treated here as one stock for assessment purposes instead of as three separate stocks. No hard data are yet available on stock structure for the east coast fisheries. However, spawning orange roughy have not been located in Wairarapa or Kaikoura. The only identified spawning location along the east coast of New Zealand is on the Ritchie Hill, and it is assumed that fish from Wairarapa and Kaikoura migrate to the Ritchie to spawn. The only other known spawning area to the east of New Zealand is on the eastern Chatham Rise, but it is unlikely that orange roughy from Kaikoura migrate to this area to spawn. Until hard data becomes available on stock structure for this area, it has been decided to treat orange roughy from the three QMAs as one "stock" for assessment purposes.

3.2 Resource surveys

Previous resource surveys of orange roughy along the east coast of New Zealand were discussed in Annala (1989). Two additional surveys were carried out in September–October 1989.

The first survey was a two–phase random stratified trawl survey using the chartered f.v. *Will Watch* (WIL8901). The main objectives of the survey were to determine the distribution and estimate the biomass of adult and pre–recruit orange roughy in QMAs 2A, 2B, and 3A in depths from 600 to 1500 m. This was the first survey to cover the entire range of all three QMAs from the boundary between QMAs 3A and 3B in the south near Banks Peninsula to the boundary between QMAs 1 and 2A in the north near Cape Runaway and the first to extend to 1500 m. Data were collected on the distribution and abundance of pre–recruit (< 32 cm length) and recruited (> = 32 cm length) orange roughy, sex ratios, length frequencies, gonad stages, and stomach contents. Otoliths were collected for later analysis.

A wide size range of orange roughy was caught (between 6–42 cm length). The weighted length frequency distribution for all three areas combined (Fig. 4) displayed peaks at 22 and 32 cm. The shape of the length frequency distribution was different from the distributions observed from the commercial catch, which had modal peaks at about 35–36 cm (Figure 3). This difference could be caused by at least two factors. First, the random nature of the trawl survey design would have sampled the population in a more representative manner than the commercial catch. Fishers usually avoid fishing in areas with concentrations of small fish. Second, fish processing sheds do not usually take orange roughy much smaller than 28 cm length, and there is probably some discarding at sea of fish smaller than this size.

The second survey was a target trawl survey using the *James Cook*. The main objectives of the survey were to determine the distribution and abundance and estimate the growth rates of juvenile (<15 cm length) and pre–recruit (15 to < 32 cm length) orange roughy. Few juveniles were caught. The main areas of pre–recruit abundance were in 800–900 m depth off Kaikoura, along the Wairarapa coast, north of the Madden Canyon, and in the Hawkes Bay Sea Valley.

3.3 Biomass estimates

The biomass estimates discussed below are for fish > = 32 cm length. Biomass estimates prior to 1989 are described in Annala (1989).

Biomass estimates from the 1989 *Will Watch* survey for the three QMAs individually and for all three QMAs combined are shown in Table 5. The estimate for the three areas combined equalled 14 923 t with a cv of 18%.

Biomass estimates for all three QMAs combined are available for each of the five years from 1985 to 1989 (Table 6). The sampling and associated interpretation problems with these survey data are discussed in Annala (1988). The estimate from the 1985 multi–vessel survey has not been incorporated into previous fishery assessments because of the reasons discussed in Annala (1988). The other four surveys were all carried out by different vessels. The 1986 and 1987 surveys were carried out during the spawning season. The 1988 and 1989 surveys were carried out outside the spawning season. The biomass estimates decreased from 116 267 t in 1986 to 14 923 t in 1989. The 1988 estimate of 115 447 t had a very high cv of 75%.

Biomass estimates for fish > = 30 cm length for the three QMAs individually are shown in Table 7. No conclusions about changes in biomass in individual QMAs can be drawn because the time series for any QMA is generally short, and/or data are lacking for certain years, and the cv's are often high.

3.4 Yield estimates

3.4.1 General

As mentioned above, orange roughy in these three areas are treated here as one "stock" for assessment purposes. Furthermore, because of the short time series, missing data, and high cv's of the biomass estimates for the three individual QMAs, these estimates are considered highly uncertain. The use of biomass estimates from the three individual QMAs ignores the fact that fish probably move between areas, and that the timing of the survey can have a considerable influence on the biomass estimate for any given area. Therefore, it is considered that there is greater certainty in the estimates of biomass for all three QMAs combined, and these estimates will be used in the following assessment.

3.4.2 Stock reduction analyses

The method used here is described in Francis (1990).

Data on age and growth are not available from the east coast of New Zealand. However, the length frequency distribution of spawning fish on the Ritchie is similar to that on the Chatham Rise, so the parameter estimates for the Chatham Rise (Orange Roughy Working Group, in prep.) were used. These estimates are based on the results of Mace et. al. (in press). The following values were used in the analysis:

M = natural mortality	0.05
A_r = age at recruitment (years)	23
A_m = age at maturity (years)	23
a = length–weight parameter	9.63×10^{-5}
b = length–weight parameter	2.68
L_{inf} = growth parameter (cm)	42.5
K = growth parameter	0.059
t_0 = growth parameter (years)	–0.346
Recruitment "steepness"	0.95

These parameters are the same as those used in the 1989 assessment (Annala 1989), except for the ages at recruitment (A_r) and maturity (A_m). As was done in the 1989 assessment, age at recruitment was assumed equal to age at maturity and estimated from the length at recruitment (L_r). In the 1989 assessment, L_r was estimated subjectively as the size on the left–hand limb of the length frequency distribution where the length frequencies were increasing rapidly and equalled 30 cm. L_r is defined here as the 50% level on the left–hand limb of the length frequency distribution from the commercial catch (Fig. 3) and was estimated as 32 cm. This equals an A_r of 23 years.

An instantaneous natural mortality rate (M) of 0.05 was considered to be the value most consistent with the estimated von Bertalanffy growth parameters and age at recruitment (Orange Roughy Working Group 1989) and is the value used in this analysis. Based on analyses carried out for the Chatham Rise stock assessment in 1989, if the value of M was less than 0.05, virgin biomass would be larger, current biomass larger, productivity less, and yield would be reduced. A higher value of M would result in a smaller virgin biomass, smaller current biomass, higher productivity, and larger yield (Orange Roughy Working Group 1989).

The landings data shown in Table 2 were used as the basis for the analysis. All landings were multiplied by a factor of 1.3 to allow for the estimated past level of TAC over–run of 30%.

Because of the assumption that fish from Wairarapa and Kaikoura migrate to the Ritchie to spawn, the biomass estimates for the entire survey area between East Cape and Cape Turnagain from the 1986 and 1987 spawning season surveys (Table 6) were used as estimates of mid–year biomass for all three QMAs combined. The 1986 biomass estimate (116 447 t) was assumed equal to mid–year biomass for 1985–86 and the 1987 estimate (66 318 t) to mid–year biomass for 1986–87.

The 1988 and 1989 surveys were carried out during September–October, so the survey biomass estimates were adjusted to mid-year estimates by adding the July – September reported catches for all three QMAs combined from the Quota Monitoring System (QMS) reports (multiplied by 1.3 to allow for an assumed 30% over-run) plus an estimate of losses due to natural mortality over this three month period to the survey estimate. The estimate of 1987–88 mid-year biomass = 115 447 t (survey estimate) + 1683 t (reported catches + 30% over-run) + 1400 t (natural mortality) = 118 530 t. The estimate of 1988–89 mid-year biomass = 14 923 t (survey estimate) + 1 013 t (reported catches + 30% over-run) + 182 t (natural mortality) = 16 118 t.

The biomass estimates used in the stock reduction analysis and the estimates of catchability (q), coefficient of variation (c) of q, and virgin biomass (B_0) are shown in Table 8. The best fit of the model to the biomass estimates resulted in an estimate of B_0 of 68 000 t. However, this estimate of B_0 is considered unrealistically low, because it implies a mid-year biomass estimate for 1988–89 of 3800 t (which is less than half of the 1988–89 catch) and an estimate of the annual instantaneous fishing mortality rate (F) of 1.62 (which is unrealistically high). Furthermore, this estimate of B_0 is less than the sum of the reported landings (assuming 30% over-run) since the beginning of the fishery. Anectodal information and observations of the size of the spawning schools during June–July 1989 from echo soundings on board commercial vessels suggest that the 1988–89 mid-year biomass was much higher than the 3800 t estimate. The very high value of c for the trawl surveys (61%) is probably an indication of the lack of fit to the stock reduction model. This could arise because the areal or vertical availability of the fish has varied from year to year or because the fishing power of the four vessels used in the surveys was not equal. Therefore, no reliable estimates of B_0 and current biomass are available from this assessment.

In previous assessments the biomass values from the trawl surveys were used as estimates of absolute rather than relative biomass. An attempt has been made in this assessment to improve the analysis by treating these values as relative rather than absolute estimates. However, the biomass estimates from these four trawl surveys are difficult to interpret. They were carried out at different times of the year by different vessels using different gear and covered different areas. The estimates show no apparent trend, and a very high value in 1988 was followed by a very low value in 1989. There is no information in the cpue or other data which assists in the interpretation of this large decline.

3.4.2 Yield per recruit analysis

A yield-per-recruit analysis was carried out to estimate the reference fishing mortality rate, $F_{0.1}$. The model of Mace *et. al.* (in press) was used (with a "plus group" to include all year classes over 70 years of age) with the growth parameters specified above. $F_{0.1}$ was estimated as 0.073.

3.4.3 Estimation of Maximum Constant Yield (MCY)

The estimate of MCY from the 1989 assessment (Annala 1989) was made using the biomass values from the 1986–88 trawl surveys as estimates of absolute biomass. However, the stock reduction analysis employed in the current assessment using the values from the 1986–89 trawl surveys as estimates of relative biomass gave no reliable estimates of B_0 and current biomass, and MCY cannot be calculated.

The best available estimate of MCY is from the 1989 assessment. However, the most appropriate method for estimating MCY is now considered to be the equation MCY = 2/3 MSY (Method 3) rather than the equation MCY = 0.25 $F_{0.1}$ B_0 (Method 2) which was used in the 1989 assessment. MCY has been recalculated using Method 3 with data from the 1989 assessment.

MSY was calculated using the yield per recruit analysis and the Beverton and Holt stock-recruitment relationship as follows. Given a level of fishing mortality, F, the associated stable age distribution was calculated. The stock-recruit relationship was then used to calculate the biomass (as a percentage of B_0) and recruitment that would sustain this age distribution; and from the yield per recruit analysis the catch (as a percentage of B_0) at this level of recruitment was calculated. This procedure was repeated for a range of trial values of F. The MSY was then found by searching for the value of F that maximised the catch. For the above growth, mortality and recruitment parameters it was found that

$$MSY = 2.8\%\ B_0$$

$$\begin{aligned} \text{therefore } MCY &= 2/3\ MSY \\ &= 0.67 * 0.028 * 146\ 500\ t \\ &= 2\ 750\ t \end{aligned}$$

3.4.4 Estimation of Current Annual Yield (CAY)

Because no reliable estimate of current biomass is available from this assessment, CAY cannot be estimated.

3.4.5 The effects of a constant catch policy

From the yield–per–recruit analysis the long–term yield associated with an $F_{0.1}$ strategy is 2.42% B_0. Thus, the level of B_0 required to sustain a constant catch of 10 266 t (the 1988–89 actual TAC for all three QMAs combined) was estimated using the simulation model. This level of B_0 was estimated as 424 000 t, which is approximately as large as the estimate of B_0 for the Chatham Rise orange roughy fishery. Because the spawning area on the east coast is considerably smaller than that on the Chatham Rise, it is probable that B_0 on the east coast is smaller than on the Chatham Rise. Therefore, the current TAC is probably not sustainable.

The simulation model was also used to explore the effects of various levels of B_0 on the current and future status of the stock. The last year that current biomass is greater than 33% B_0 assuming a constant catch of 10 266 t for all three QMAs combined is shown in Figure 5. The value of 33% B_0 was chosen because this is the estimate of equilibrium biomass which produces the long–term yield associated with an $F_{0.1}$ strategy. The catch history for all three QMAs combined was used assuming a 30% over–run in the past, and the model run forward assuming either a 0% or 30% over–run.

If current biomass is greater than 33% B_0, then the stock can be fished down to a size that will produce the long–term yield. If current biomass is less than 33% B_0, then the stock needs to be rebuilt to a size that will produce the long–term yield. For example, if the "true" B_0 equalled 100 000 t, then the curremt biomass is less than 33% B_0. If the "true" B_0 equalled 160 000 t, then a constant catch of 10 266 t would result in a biomass less than 33% B_0 in 1996 with a 0% over–run and in 1994 with a 30% over–run. If the "true" B_0 equalled 200 000 t or greater, then a constant catch of 10 266 t would not reduce the biomass to less than 33% B_0 until at least the late 1990's.

4. MANAGEMENT IMPLICATIONS

The following is a summary of the management implications of the stock assessment.

(1) Spawning orange roughy have not been located in Wairarapa or Kaikoura, and the only identified spawning location along the east coast of New Zealand is on the Ritchie Hill. Therefore, orange roughy in QMAs 2A, 2B, and 3A have been treated as one "stock" for assessment purposes. However, the boundaries between these three QMAs should be retained for TAC setting purposes pending the results of current investigations into stock structure. If there are separate stocks in these three areas, then the most conservative and prudent approach would be to estimate yields and recommend TACs for these three areas separately.

(2) The sustainability of the current TAC of 10 266 t for all three OMAs combined cannot be determined explicitly. However, the level of B_0 required to sustain the current TAC is approximately as large as the estimate of B_0 for the Chatham Rise. Because the spawning area on the east coast is considerably smaller than that on the Chatham Rise, it is probable that B_0

on the east coast is smaller than on the Chatham Rise. The estimate of long–term yield under an $F_{0.1}$ strategy for the Chatham Rise is about 10 000 t (Orange Roughy Working Group 1989), and therefore the current TAC for the east coast is probably not sustainable.

5. ACKNOWLEDGEMENTS

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Table 1. Reported orange roughy landings (t) x QMA x month for the 1988–89 fishing year.

Month	Ritchie	Wairarapa	Kaikoura	Combined
Oct	43	2	388	433
Nov	340	106	753	1198
Dec	344	160	509	1013
Jan	347	120	18	486
Feb	153	121	94	367
Mar	360	299	172	831
Apr	785	148	92	1026
May	1022	83	202	1308
Jun	1942	71	64	2078
Jul	488	74	76	638
Aug	4	1	0	5
Sep	26	49	62	137
Total	5853	1236	2431	9520

Table 2. Reported orange roughy landings (t) and TACs (t) for QMAs 2A, 2B, and 3A. Fishing year = 1 Oct–30 Sep. Source–unpublished MAFFish statistics (1981–82 and 1982–83); Fisheries Statistics Unit statistics (1983–84 to 1985–86); Quota Monitoring System (1986–87 to 1988–89).

	QMA 2A (Ritchie)		QMA 2B (Wairarapa)		QMA 3A (Kaikoura)		Total	
Fishing Year	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1981–82	–	–	554	–	–	–	554	–
1982–83	–	–	3510	–	253	–	3763	–
1983–84	162	–	6685	–	554	–	7401	–
1984–85	1862	–	3310	3500	3266	*	8438	–
1985–86	2819	4576	867	1053	4326	2689	8013	8318
1986–87	5187	5500	963	1053	2555	2689	8705	9242
1987–88	6239	5500	982	1053	2510	2689	9731	9242
1988–89	5853	6060	1236	1367	2431	2839	9520	10266

* = included in QMA 3B TAC

Table 3. Reported catch and effort data for orange roughy caught in domestic fishing return areas 011–021 from domestic vessel logbooks using the Fisheries Statistics Unit extract programme. Does not include amounts caught during charters or some of multi-vessel survey data. Fishing year = 1 Oct–30 Sep. 1987–88 data provisional only. – = no data.

	Fishing year				
Area	1983–84	1984–85	1985–86	1986–87	1987–88
			Catch(t)		
011	–	2	–	152	3
012	–	3	41	2	15
013	–	1204	2022	2285	2975
014	162	653	757	788	943
015	6685	3310	867	750	796
016	1	1	28	48	60
018	352	2986	2246	1326	1862
019	38	115	243	384	261
020	8	118	1807	290	426
021	157	46	1	105	–
			Catch per day (t)		
011	–	0.2	–	10.1	0.7
012	–	0.3	13.6	1.7	3.8
013	–	10.9	6.3	5.6	11.6
014	6.5	3.2	7.0	5.7	6.6
015	13.0	5.1	6.4	5.8	7.4
016	0.2	0.1	1.9	2.3	10.0
018	3.9	8.1	5.1	4.4	7.5
019	3.8	4.0	10.6	6.7	14.5
020	2.6	2.1	13.2	5.8	7.5
021	3.7	4.6	0.9	17.6	–
			Catch per tow (t)		
011	–	–	–	8.4	0.2
012	–	0.1	–	0.9	2.2
013	–	5.5	2.9	2.7	5.3
014	3.9	3.2	3.0	2.6	3.3
015	4.4	1.9	2.3	1.7	3.0
016	0.05	0.04	0.5	0.6	5.5
018	1.2	1.6	1.7	1.5	2.4
019	1.7	1.6	4.8	2.6	5.4
020	1.0	1.0	4.4	2.2	2.3
021	1.4	1.5	0.5	3.8	–

Table 4. Reported catch per unit effort data for orange roughy from domestic fishing return areas 011–021 grouped by Quota Management Area (QMA). Data taken from Table 2a.

	Fishing year				
QMA	1983–84	1984–85	1985–86	1986–87	1987–88
			Catch per day (t)		
Ritchie*	6.5	5.5	6.6	5.7	9.9
Wairarapa§	13.0	5.1	6.4	5.8	7.3
Kaikoura#	3.7	6.9	7.0	5.0	7.9
			Catch per tow (t)		
Ritchie	3.9	2.8	2.9	2.7	4.6
Wairarapa	4.4	1.9	2.9	1.9	3.0
Kaikoura	1.2	2.7	2.4	1.7	2.6

* Includes data from areas 011–013 for all years. For 1983–84 to 1985–86 includes all data for area 014. For 1986–87 and 1987–88 data for area 014 apportioned according to Quota Management System reported landings.

§ Includes data from area 015 for all years. Includes no data for area 014 for 1983–84 to 1985–86. For 1986–87 and 1987–88 data for area 014 apportioned according to Quota Management System apportioned landings.

Includes data from areas 016–021 for all years.

Table 5. Estimates of biomass (t) of fish > = 32 cm length for Ritchie (QMA2A), Wairarapa (QMA2B), and Kaikoura (QMA3A), and all areas combined from the 1989 *Will Watch* survey (WIL8901). Areal and vertical availability = 1.0, vulnerability factor = 0.27. CV = coefficient of variation.

Area	No. of strata	No. of stations	Area (sq km)	Biomass	CV(%)
Ritchie	20	97	12,395	6021	25
Wairarapa	4	38	4152	5748	35
Kaikoura	8	44	5369	3128	36
Combined	32	179	21,916	14,923	18

Table 6. Estimates of biomass (t) of fish > = 32 cm length for QMAs 2A, 2B, and 3A combined. Areal and vertical availability = 1.0. CV, coefficient of variation; –, no data.

Year	Vessel	Area (sq km)	No. of stations	Vulnerability factor	Biomass	CV(%)	Timing*
1986	O. Galliard	4 077	83	0.19	116 267	28	S
1987	Arrow	2 229	71	0.22	66 318	36	S
1988	James Cook	11 850	56	0.20	1151 447	75	NS
1989	Will Watch	21 916	179	0.27	14 923	18	NS

* S = spawning season survey

NS = survey outside of spawning season

Table 7. Estimates of biomass (t) of fish > = 30 cm length for Ritchie (QMA2A), Wairarapa (QMA2B), and Kaikoura (QMA3A). Areal and vertical availability = 1.0. CV = coefficient of variation.

Date	Cruise	No. of stations	Vulnerability factor	Biomass(t)	CV(%)
		Ritchie			
1988–Sep/Oct	J12/88	24	0.20	27 979	54
1989–Sep/Oct	WIL8901	97	0.27	6 757	23
		Wairarapa			
1984–Apr	J06/84	23	0.20	14 865	27
1984–Oct	J18/84	9	0.20	20 540	51
1985–Feb	J03/85	29	0.20	9 688	38
1985–May/Jun	J08/85	20	0.20	6 118	14
1988–Sep/Oct	J12/88	8	0.20	1 044	42
1989–Sep/Oct	WIL8901	38	0.27	7 477	38
		Kaikoura			
1986–May	J06/86	17	0.20	7 580	45
1988–Sep/Oct	J12/88	24	0.20	102 430	90
1989–Sep/Oct	WIL8901	44	0.27	4 076	31

Table 8. Biomass estimates used in the stock reduction analysis and estimates of catchability (q), coefficient of variation (c) of q, and virgin biomass (B_0) from the analysis.

Year	Biomass estimate(t)
1986	116 267
1987	66 318
1988	118 530
1989	16 118
Parameter estimates	
q	4.20
c	61%
B_0 (t)	68 000

Figure captions

Figure 1. Catch per day (t) for the 1983–84 to 1987–88 fishing years. The year shown on the x–axis is the last year of the fishing year.

Figure 2. Catch per tow (t) for the 1983–84 to 1987–88 fishing years. The year shown on the x–axis is the last year of the fishing year.

Figure 3. Estimated yearly length frequency distributions from the commercial catch from QMAs 2A, 3A, and 3B during the 1988–89 fishing year. This is a catch weighted length frequency from shed samples.

Figure 4. Estimated length frequency distribution for the entire survey area from the 1989 *Will Watch* survey. Station length frequencies were weighted by percentage sampled, catch rate, and stratum area.

Figure 5. Last year that biomass is greater than 33% B_0 with a future constant catch of 10 266 t.

Fig. 1 - Catch per day 1984-1988

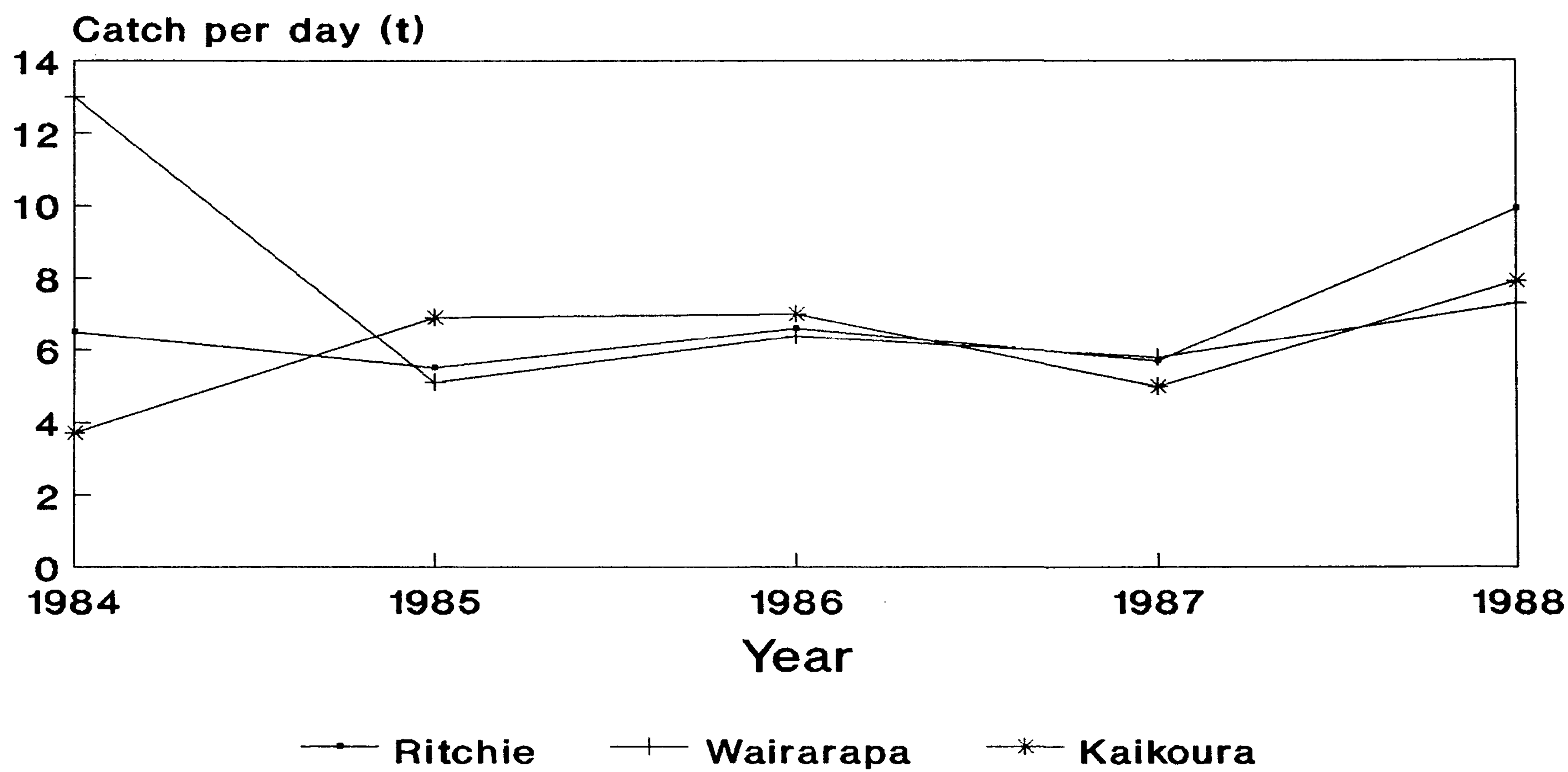


Fig. 2 - Catch per tow
1984-1988

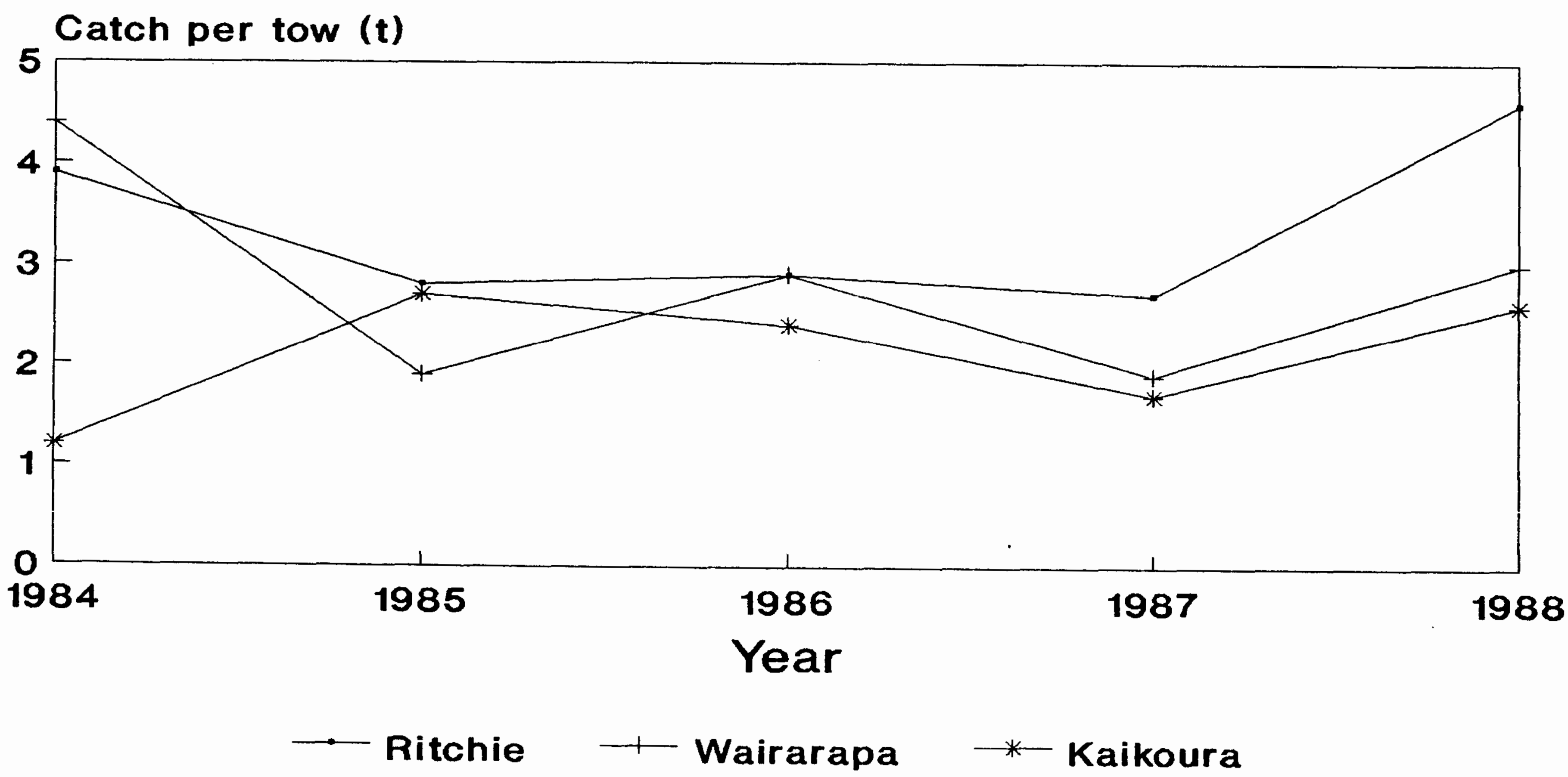


Fig. 3

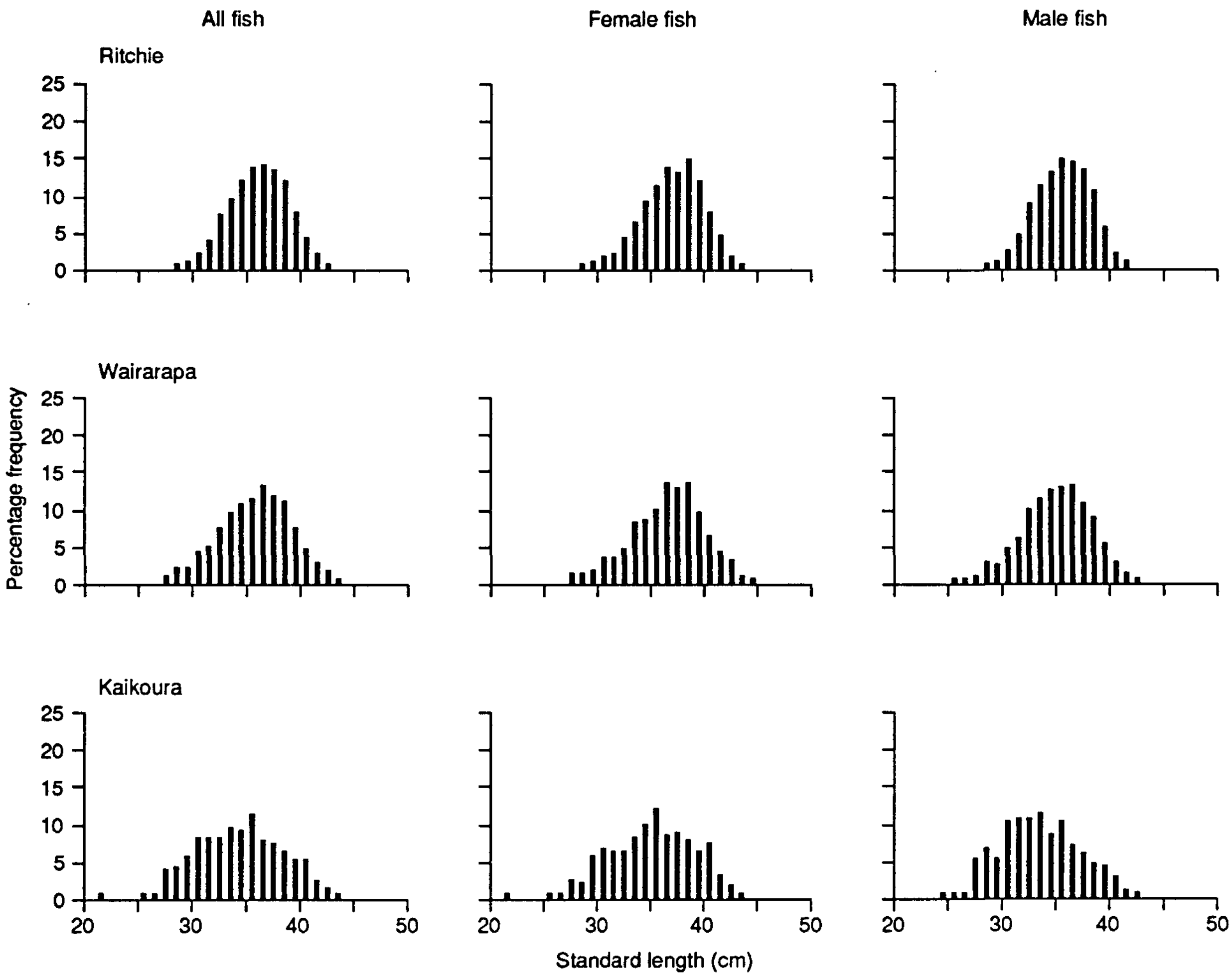
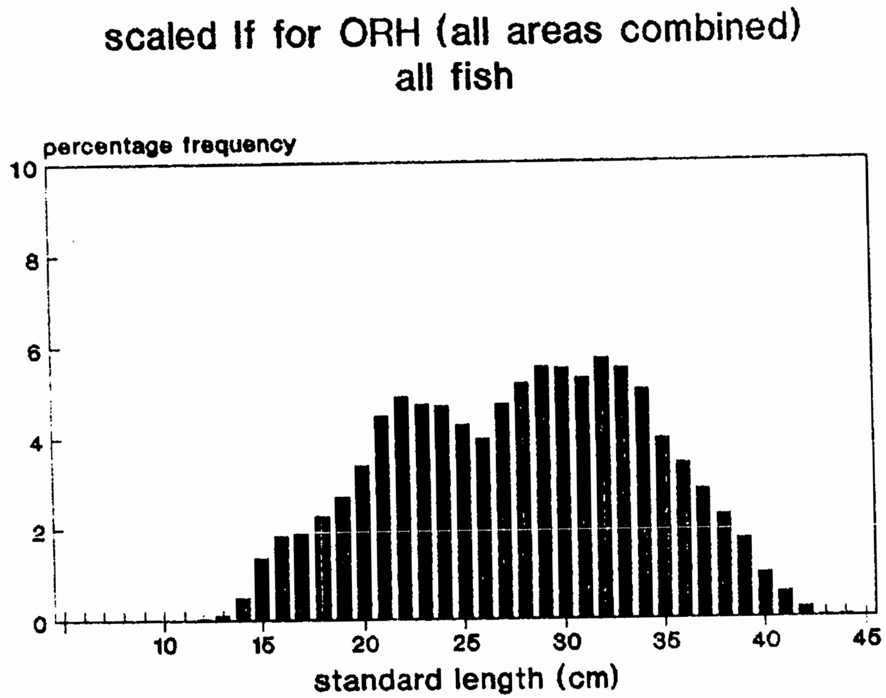
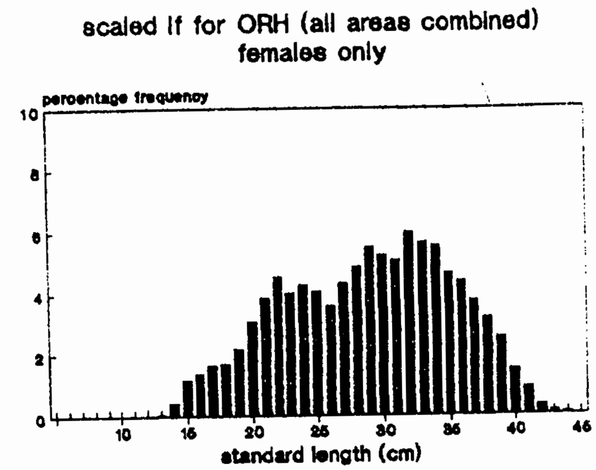

All fish
Female fish
Male fish
Ritchie
Wairarapa
Kaikoura
Percentage frequency
25
20
15
10
5
0
20
30
40
50
Standard length (cm)

Fig. 4


scaled lf for ORH (all areas combined)
all fish
percentage frequency
10
8
6
4
2
0
10
15
20
25
30
35
40
45
standard length (cm)


scaled lf for ORH (all areas combined)
females only
percentage frequency
10
8
6
4
2
0
10
15
20
25
30
35
40
45
standard length (cm)

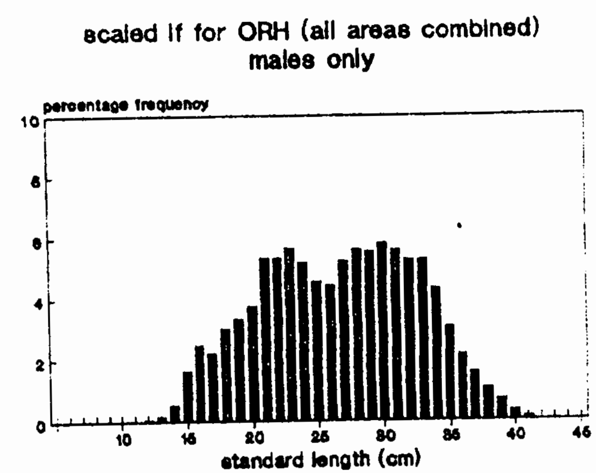
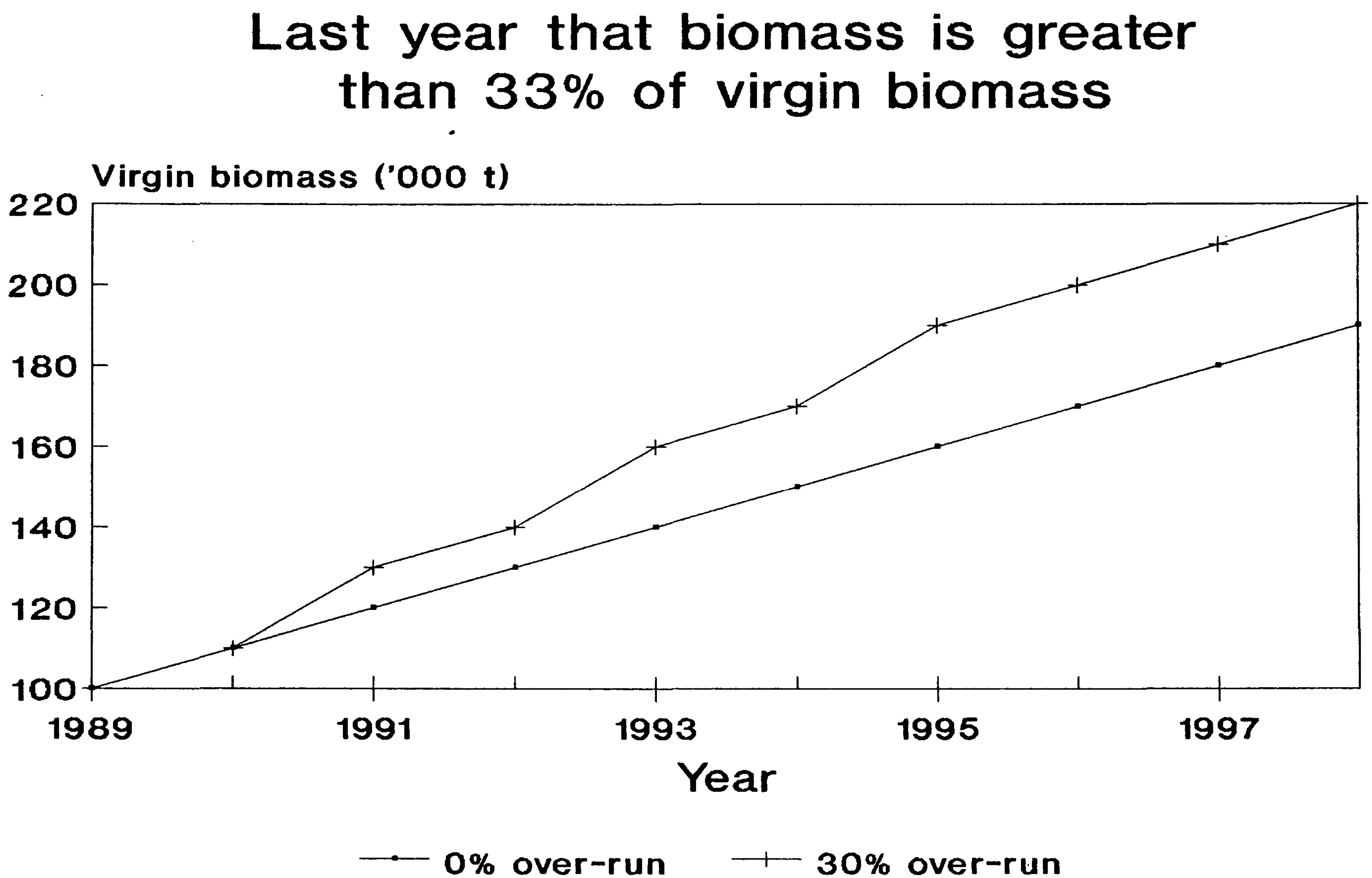

scaled lf for ORH (all areas combined)
males only
percentage frequency
10
8
6
4
2
0
10
15
20
25
30
35
40
45
standard length (cm)

Fig. 5


Last year that biomass is greater
than 33% of virgin biomass
Virgin biomass ('000 t)
220
200
180
160
140
120
100
1989
1991
1993
1995
1997
Year
0% over-run
30% over-run