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Assessment of the Chatham Rise (area 3B) orange roughy fishery for the 1988-89 season

Orange roughy working group
(Convenor D.A. Robertson)

MAFFish Fisheries Research Centre
P O Box 297
Wellington

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MAFFish, N.Z. Ministry of Agriculture and Fisheries

This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

3/5/89

ASSESSMENT OF THE CHATHAM RISE (AREA 3B) ORANGE ROUGHY FISHERY FOR THE 1988/89 SEASON

(Prepared by the Orange Roughy Working Group)
Convenor: D.A. Robertson

SUMMARY

This assessment of the Chatham Rise orange roughy fishery incorporates new data on age and growth, biomass and catch history. This is the first Chatham rise stock assessment analysis that treats data from the trawl surveys between 1984-88 as relative indices of biomass. (Previously biomass survey data were used as point estimates of absolute biomass). Relative biomass data were initially used to provide a regression estimate of the ratio of the most recent to the first estimate in the series. This ratio was used in a modified DeLury analysis with commercial catches adjusted for overrun and a range of productivity values to provide a set of pairs of productivity and mid-season biomass for 1987/88. Using an age structured simulation model and assuming constant recruitment during the history of the fishery, a series of simulations was run to establish an upper limit on productivity and a corresponding lower limit on the estimate of mid-season 1987/88 biomass. The derived biomass was then projected forward in the model to give biomass estimates for the 1988/89 fishing year. A yield per recruit model was applied to the age-growth data using a value of mortality consistent with these, to derive an estimate of the reference fishing mortality, $F_{0.1}$. The current annual yield (CAY) was then estimated using $F_{0.1}$ in the Baranov catch equation. CAY was estimated to be 8 000 t for 1988/89. Sensitivity analyses showed that yield was sensitive to variation in biomass ratio (r). Taking account of this gives 68% confidence limits of CAY from 2 400 - 21 000 t. The Chatham Rise population is currently estimated to be about 33% of virgin biomass and decreasing. Several options for reducing the catch to 8 000 t over 4, 3, and 2 years were simulated; these indicated the population would be reduced to 22-29% of virgin biomass.

Analysis of length frequencies from research surveys during the years 1982-87 indicates that recruitment may have been lower than was assumed in these simulations. Estimates of CAY for 1988/89 could be higher if the analyses were re-run using less optimistic assumptions about recruitment. However, unless recruitment improves the long-term outlook for the Chatham Rise orange roughy stock is poor.

1 Introduction

1.1 Overview:

This document updates the stock assessment of Chatham Rise orange roughy (Management Area 3B) and provides yield recommendations for the current (1988/89) fishing year.

Pending this assessment the total allocated catch for the Chatham Rise orange roughy fishery for the 1988/89 year is 34 000 tonnes. The status of this stock was reviewed in March 1988 and a recommendation was made to reduce the TAC to 17 430 tonnes for the 1987/88 season. Arrangements were made for fishing companies with quota in area 3B to surrender some of it for one year in exchange for quota over two seasons in area 7A, and the quota for area 3B was reduced to 22 000 tonnes for the 1987/88 fishing year. However the arrangement allowing this reduction was only for the 1987/88 season.

In 1988 two further biomass surveys were completed in the area and considerable progress made with ageing of orange roughy. The results of this recent work are considered here and a new assessment is presented for the 1988/89 season.

The most significant new factor to be taken into account in this present assessment is the interpretation of the age-growth data from the 1988 "James Cook" surveys (Mace et al. MS). This paper interprets whole otolith zones and length frequency modal shifts over time and concludes that growth is slow and that the productivity of orange roughy is exceptionally low. This is an important factor in the yield estimation that follows. Also important is the use of the trawl survey data from the last five years as indices of relative biomass, rather than using the most recent survey as an absolute estimate of biomass as was done in previous assessments. This assumes that the abundance indices are representative of the population being assessed.

1.2 Description of the fishery:

Orange roughy are trawled below about 750m along the northern, eastern and south eastern slopes of the Chatham Rise. Most fish are taken between mid-June and mid-August immediately before, during and after the spawning aggregations appear at depths of 800 - 1000m, in an area about 70 miles north of the Chatham Islands. Since 1983 about 20% of the total catch has been taken mostly outside the spawning season in similar depths on or near pinnacles and rough ground on the south Chatham Rise.

Of the current (88/89) allocation of 34 000 tonnes, 28 586 tonnes are owned by 19 quota owners and 5 463 tonnes by MAFFish, (as at 29 November 1988). (The gazetted TAC is 38 000 tonnes, but only 34 000 tonnes of this is allocated as a recommendation late in 1986 to reduce the recommended TAC was received and agreed on too late to stop the Gazette notice).

1.3 Literature:

In addition to the published material outlined in the previous stock assessment report (Robertson and Mace 1988), a paper has been prepared on the age and growth of Chatham Rise orange roughy (Mace et al. MS). Other material available includes: Sissenwine (1988) which describes a modified DeLury method of calculating current biomass; Mace and Doonan (1988), which describes a generalised model for simulating fish population dynamics; Mace (1988), which considers the relevance of a range of biological reference points to NZ fish stock assessments and Robertson et al. (1988), which assesses the orange roughy fishery for the 1987/88 fishing year.

1.4 Total reported catch:

Annual reported catches for the Chatham Rise orange roughy fishery are as follows:

Fishing year		Reported catch (tonnes)
before	78/79	negligible
	79/80	11 800
	80/81	31 100
	81/82	28 200
	82/83*	32 605
	83/84*	32 525
	84/85	29 340
	85/86	30 075
	86/87	30 689
	87/88	24 214

(* Catch for 1982/83 and 83/84 are 15 month totals to accommodate the change over from an April - March fishing year to an October - September fishing year.)

Catches are from Robertson and Mace (1988) with the figures for the last three years updated from Fisheries Statistics Unit and Quota Monitoring System data.

For this assessment an over-run adjustment of 30% is applied to the reported catches when used in the analysis. This is because concern has been expressed that an incorrect product conversion factor, and other fishing, processing and reporting practices are leading to understatement of the true levels of fishing mortality. A value of 30% over-run was estimated and used in previous assessments (Robertson 1986; Robertson et al. 1988).

1.5 Catch and effort data:

Catch-effort data have not been of use in biomass estimation or as a measure of stock abundance because the fishery targets on dense aggregations and catch rates can be expected to remain high while stock size decreases. A preliminary analysis of monthly catch rates for 1979 - 1987 for factory trawlers showed no clear trends.

Commercial catches and trawl survey data suggest that some orange roughy move up from depths greater than 1200m to spawn between 800 - 1000m, then disperse back to deep water after spawning. Orange roughy are caught below 1200m, the normal depth limit of trawl surveys. Commercial catch -effort data from depths greater than 1200m were analysed to determine whether the fishery below these depths is important during the survey periods. While there are catches reported down to 1400m these are rare except in June and October on the north Chatham Rise. Even during these months, the numbers of tows in these depths was not very great, about 2.8% of the total number of tows in the area for the period 1979 - 1987. However, in one year, before and after the July survey period in 1987, approximately 16% of the north Chatham Rise catch was taken from depths greater than 1200m.

1.6 Other Information:

No age and very little size information exists from the commercial catches on the Chatham Rise.

1.7 Maori and Recreational Fishing:

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

2 Research

2.1 Stock Structure:

The orange roughy found on the Chatham Rise have been considered as a single separate stock since 1983. However, recent data (Fenaughty 1987) suggest that orange roughy on the south Chatham Rise may be spawning at the same time as those on the north Rise and may therefore be a separate spawning stock. This question will be addressed at Fisheries Research Centre by P. Smith in his mitochondrial DNA project currently underway.

No information exists on the relationship between the Chatham Rise populations and those treated as separate fisheries on the Ritchie Bank, Wairarapa and Kaikoura fishery management areas. Spawning occurs concurrently on both Ritchie Bank and Chatham Rise, but no spawning is known in the Wairarapa or Kaikoura areas. It is assumed that Wairarapa and Kaikoura fish do not spawn on the Chatham Rise. These stock relationship issues are also being addressed by P.Smith in his mDNA work and by B.Jones in a study of parasite infestation rates designed to test for differences between orange roughy populations. For the reasons outlined in previous assessments, the Chatham Rise is considered discrete from the other three management areas.

For the purpose of biomass estimation, the north and south Chatham Rise populations are here treated as one stock.

2.2 Research surveys:

The following surveys have been conducted on the Chatham Rise orange roughy population(s):

Table 1: Major research cruises since 1982 which have provided data on orange roughy.

Date month/year	Area km^2	Survey Type	Vessel	North or South Ch.Rise	Species
8-9/1982	25,000	biomass	Kaltan	N	ORH
7/1984	5,000	biomass	Otago Buccaneer	N	ORH
7/1985	5,000	biomass	Otago Buccaneer	N	ORH
7/1986	5,000	biomass	Otago Buccaneer	N	ORH
11/1986	47,100	biomass	Arrow	S	Oreos/ORH
7/1987	5,000	biomass	Otago Buccaneer	N	ORH
11/1987	47,500	biomass	Amaltal Explorer	S	Oreos/ORH
2/1988	na	juvenile	James Cook	N	ORH
5-6/1988	na	juvenile	James Cook	N	ORH
7/1988	5,000	biomass	Cordella	N	ORH
9/1988	na	juvenile	James Cook	N	ORH
9/1988	72,000	biomass	Cordella	N & S	ORH/Oreos
1/1989	na	juvenile	James Cook	N	ORH

The "James Cook" surveys are part of a continuing series designed to locate and sample small juveniles (pre-recruits) to estimate growth rates of orange roughy. Recent results from these surveys (Mace et al. MS) indicate that orange roughy grow more slowly than was previously assumed (Robertson et al. 1988).

2.3 Yield Estimation :

At the 1988 stock assessment meetings, MAFFish discussed and agreed on the use of a two tier yield assessment system which was consistent with the legal definition of maximum sustainable yield (MSY). Within this system, the first tier is a constant or static catch called the maximum constant yield (MCY) and is the maximum constant catch that is estimated to be sustainable at all future levels of stock production. The second tier is a catch that tracks fluctuations in population size. It is called the current annual yield (CAY) and is the potential yield attained by applying a reference fishing mortality to an estimate of the fishable biomass present during the next fishing year. The reference fishing mortality is an estimate of the level of fishing mortality which will achieve the long term maximum average yield (MAY) (Anon 1988).

Estimates of yield based on $0.5MB_0$ as used in earlier orange roughy assessments (see Robertson 1986) are no longer appropriate since better methods are now possible and, in any case, stocks now appear to be below the level ($0.5B_0$) at which a yield of $0.5MB_0$ is assumed to be sustainable (Gulland 1971). An alternative harvesting reference point (i.e. a fishing mortality level of $F_{0.1}$) was recommended in the previous assessment (Robertson and Mace 1988). $F_{0.1}$ is an instantaneous fishing mortality rate at which it is believed a fish population can be exploited without seriously endangering the spawning stock. It has been adopted as a biological reference point by numerous stock assessment agencies around the world; (e.g. the International Council for the Exploration of the Sea (ICES), the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC), the North Atlantic Fisheries Organisation.(NAFO), and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)).

The estimation of CAY and MCY took the following steps:

Step 1. Growth, Mortality and Age at Recruitment

Growth and mortality parameters were taken from the analyses of Mace et al. (MS). Values of the von Bertalanffy parameters L_{inf}, K, and t_0; age at recruitment, A_r; and natural mortality, M, were estimated or assumed.

Step 2. Relative Biomass Estimates

Trawl survey biomass estimates for the north Chatham Rise were standardised to ensure comparability and used as a series of abundance indices.

Step 3. Biomass Ratio

A regression on log-transformed data was used to estimate r, the biomass ratio between the first and last survey abundance indices.

Step 4. Commercial Catch

The total reported commercial catch, C, taken between the time from the first to the last surveys was calculated. This was then adjusted for over-run.

Step 5. Biomass estimation

Stock reduction analysis was used to estimate, from r and C, the mid season (July) biomass, $B_{87/88}$, for each of a series of values of P, the stock productivity (recruitment + growth -natural mortality).

Step 6. 1987/88 Biomass

A series of simulations were run to establish which was the most consistent combination of $B_{87/88}$ and P from step 5, assuming constant recruitment.

Step 7. Yield per Recruit

A yield per recruit analysis was carried out to estimate the reference fishing mortality, $F_{0.1}$.

Step 8. Yields

The $B_{87/88}$ value from step 6 was projected ahead in an age structured simulation model to estimate the current annual yield (CAY) for the 1988/89 fishing year using the estimate of $F_{0.1}$ from step 7.

Steps 1 - 8 are outlined in more detail below:

Step 1. Growth and Mortality

A number of age-growth interpretations have been made for orange roughy (Robertson et al. 1988).

In the following analysis the best available values were used for growth and mortality: natural mortality (M) = 0.05 $year^{-1}$, age of recruitment (A_r) = 20 years, K = 0.059 $year^{-1}$, t_0 = -0.346 year, and L_{inf} = 42.50cm.

The von Bertalanffy growth parameters were estimated from data based on the analysis of length mode progression in young fish and the interpretation of otoliths based on counts of annual rings (Mace et al. MS). The average age of recruitment corresponding to these growth parameters is A_r = 20 years. This is based on a 30 cm length at recruitment. In the north Chatham Rise biomass surveys the proportion of the catch that is smaller than 30 cm is negligible.

A rate of natural mortality of M = 0.05 $year^{-1}$ was considered to be the value most consistent with the other parameters. The value of M = 0.1 $year^{-1}$ used previously (Robertson et al. 1988) would imply that less than 15% of one year old fish could survive to maturity at 30 cm.

Step 2. Relative Biomass Estimates

The conclusion from the results of trawl surveys carried out from 1984 to 1988 is that biomass has declined rapidly.

Past assessments which have treated biomass estimates as absolute values have attempted to account for fish lost through burst panels in the trawl and for fish missed by occasional tows through schools which extended above the net headline. Because the assumptions in this process are arbitrary and create uncertainty, it was decided here to use net wingtip biomass values from the five surveys in the analysis. The data were used in the most comparable way possible as indices of relative abundance over time, rather than using the most recent survey result as an estimate of absolute abundance.

North Chatham Rise

In 1988 two further biomass surveys were completed, both using the commercial trawler "Cordella". The first of these was added to the time series conducted with the "Otago Buccaneer". This series of biomass estimates (using net wingtips to define the area swept) was standardised to allow more direct comparison between the results from the "Otago Buccaneer" (1984 to 1987) and "Cordella" (1988). Standardisation involved two manipulations of the data before use in the analysis:

Restratification:

The survey area covers 4955 km^2. This was originally divided into 25 strata by depth and longitude. During the first 1988 "Cordella" (CO1) survey, stratum 6 was divided into two; a small part near the main spawning area which had high catch rates and a larger portion which had low catch rates. In the estimation of biomass, four tows made prior to the restratification were excluded. Biomass estimates from the previous four surveys were recalculated after sub-dividing stratum 6 according to the stratification used in 1988. For each of the five surveys the restratification reduced the estimated variance. This justifies the restratification and shows that a similar uneven distribution occurred in previous years in stratum 6.

Net Mouth Differences:

The headline heights of the trawl nets used in the "Otago Buccaneer" surveys were 0.705 of that used on the "Cordella" survey. The mouth width of the nets was similar (i.e. ratio about 1.0). Net monitoring traces indicated that fish school height exceeded the headline height of the "Cordella" on four tows. It was assumed that the "Otago Buccaneer" catch would have been lower (i.e. 70.5%) had it encountered the same schools. Therefore, the catches for these four "Cordella" tows were multiplied by 0.705 to make them comparable.

Table 2 shows the effects of these standardisations:

Table 2. Trawl survey estimates of recruited biomass, with upper and lower bounds (95% confidence limits) and coefficients of variation (CV's) for the north Chatham Rise spawning orange roughy population. (All values calculated from area swept by net wingtips).

BIOMASS ESTIMATIONS WITH AND WITHOUT STANDARDISATIONS ON STRATUM 6

YEAR	1984	1985	1986	1987	1988
			original estimates *		
lower bound	119 183	113 350	72 294	57 284	54 112
biomass	189 183	162 304	106 429	84 849	150 510
upper bound	259 182	211 257	140 565	112 413	246 909
CV %	18	15	16	16	32
			modified estimates **		
lower bound	112 355	104 167	70 201	56 371	48 878
biomass	164 835	149 425	102 975	80 397	97 108***
upper bound	217 314	194 684	135 750	104 423	145 338
CV%	16	15	16	15	25

* Values calculated using original stratum 6 without net mouth correction or restratification.
** values calculated after restratification and net mouth correction
*** Without the net mouth adjustment above, this figure increases to 101 453 tonnes.

South Chatham Rise

Data from only three surveys were available for the south Chatham Rise (Table 3).

Table 3. Trawl survey estimates of total biomass, with upper and lower bounds (95% confidence limits) and coefficients of variation (CV's) for the south Chatham Rise orange roughy population (Percentage recruited biomass in brackets)

Year	1986	1987	1988
Lower bound	11 026	5 553	1 553
Biomass	29 192 (93)	11 028 (73)	5 786 (74)
Upper bound	47 358	16 863	10 019
CV%	31	25	37

Data from the south Chatham Rise (Table 3), as for the north Chatham Rise, show a decline in biomass but at a much greater rate. This suggests that we are either seriously overestimating the rate of decline on the south Chatham Rise or that the south Chatham Rise contains a discrete stock subject to very high fishing mortality. Catches from the south Chatham Rise are about 20% of the total 3B QMA catch.

There are a number of reasons why the south Chatham Rise surveys may not be representative:

i) The area contains rough ground which is difficult to survey but where fish may be found.

ii) The time series is short (only 3 years).

iii) Different vessels have been used (Table 1).

iv) Different survey times were used to estimate the north and south Rise biomass.

This difference in timing would result in biomass estimates being influenced by a post spawning shift of some orange roughy to depths greater than 1000m and probably greater than 1200 m, the maximum survey depth. South Rise surveys have all occurred after spawning, when orange roughy have dispersed from their known spawning depths between 750 - 1000 m to depths greater than 1000 - 1200 m. Evidence for such a movement is given in Robertson et al. (1984), and is also apparent in the differences in catch rate with depth between the two "Cordella" surveys in 1988.

We are concerned that the south Chatham Rise values are not representative and they were therefore not considered any further in the analysis. Instead, the biomass values from the north Chatham Rise were used to represent trends in abundance for the entire Chatham Rise orange roughy population.

Step 3. Relative Change in Biomass

The modified DeLury analysis used in Step 5 is based on exponential decline of biomass. Therefore to estimate r, the following regressions were done on log-transformed data.

The north Chatham Rise trawl survey estimates of recruited biomass (Table 2) were used as indices of stock abundance for the entire Chatham Rise orange roughy population for the years 1984-88 and a regression was fitted to the data as follows:

Data				Model
Year		Recruited Biomass (t)	Index	ln (index) = a - b (year)
1	(1984)	164 835	1.00	ln (index) = 0.1403 - 0.1678(year)
2	(1985)	149 425	0.91	
3	(1986)	102 975	0.63	correlation coefficient = -0.876
4	(1987)	80 397	0.49	
5	(1988)	97 109	0.59	

The biomass ratio r, when estimated by dividing the regression estimate of the biomass index for 1988 by the regression estimate of the biomass index for 1984 gives a value of 0.511. However, because of the log transformation this is a slightly biased estimate. A correction was applied and resulted in a value of r = 0.531.

Step 4. Commercial Catch

The commercial catch data were analysed to determine the catch tonnages associated with the biomass declines shown in step 3.

Commercial catch totals from the north and south Chatham Rise combined were used in the modified DeLury analysis (Step 5) and were restricted to those taken during the period between the first and last research survey (using monthly totals between 1 July 1984 and 30 June 1988). Reported catches were adjusted for over-runs as discussed earlier. This gave a total catch (C) of 140 614 tonnes.

Step 5. Biomass estimation

DeLury methods are used to estimate biomass in fish populations. They are based on the fundamental equations of population dynamics relating biomass, productivity and fishing mortality. A modified DeLury method (Sissenwine 1988) was used to calculate the biomass at the end of the time series of abundance indices (i.e. $B_{87/88}$) from r (biomass ratio) and C (catch):

$$B_{87/88} = \frac{v\ r\ C}{(v - P)(1-r)}$$

where

$B_{87/88}$ = 1987/88 mid-season (July) biomass
C = total catch (Step 4)
P = the annual instantaneous rate of productivity (R+G-M i.e. recruitment + growth - mortality).
r = biomass ratio. (Step 3)
v = (1/t) $\log_e r$ where t is the number of years between the start and end of the series.

This model assumes that productivity (P) and fishing mortality rates are constant throughout the period. Although this may not be the case, the results should be robust as long as an average value of productivity is used and total catch is not highly concentrated during a short period of the time series.

As productivity is unknown for the period 1984 - 1988, the calculation was made for a range of values from 0.037 to 0.050. Values of r = 0.531 (from Step 3) and C = 140 614 tonnes (from Step 4) were used in the equation above. Results are given in Table 4.

Table 4. $B_{87/88}$ estimates (to the nearest '000 tonnes) by Stock Reduction Analysis for a range of given productivity values.

Productivity (P)	$B_{87/88}$ (t)
0.037	129 000
0.039	128 000
0.040	127 000
0.042	126 000
0.043	125 000
0.045	124 000
0.047	123 000
0.048	122 000
0.050	121 000

Step 6. <u>1987/88 Biomass</u>

In order to select a combination of $B_{87/88}$ and P from Table 5 a series of deterministic simulations were run. Simulations were based on an age structured model incorporating a Beverton-Holt stock-recruitment relationship as described in Mace and Doonan (1988). In effect, since the simulations were initiated from a stable age distribution with A_r = 20, recruitment was constant for the time period used in this analysis. Using the growth and mortality parameters from Step 1, the following procedure was adopted.

(i) a biomass ($B_{87/88}$) was selected from Table 4.

(ii) trial and error was used to determine the level of virgin biomass (B_0 or $B_{78/79}$) that corresponded to the selected value of $B_{87/88}$ from step (i).

(iii) the population was simulated for the years 1978/79 - 1987/88.

(iv) mean productivity was then calculated for the years 1984/85 - 1986/87.

(v) The above steps were repeated until $B_{87/88}$, (the input from step (i)) and P (the output from step(iv)) matched one of the pairs in Table 4.

This method resulted in the following biomass and productivity estimates for the values of growth and mortality from step 1:

Mortality M	Age at Recruitment A_r (years)	$B_{87/88}$ (t)	Productivity P
0.05	20	128 000	0.039

Step 7. <u>Yield per Recruit</u>

Yield per recruit (YPR) analysis was carried out using the growth and mortality values from Step 1. The number of age classes used in the analysis was increased until the estimated value of $F_{0.1}$ converged. The estimated value of $F_{0.1}$ was 0.067.

Step 8. <u>Yields</u>

<u>Current Annual Yield (CAY)</u>

The virgin biomass (B_0 or $B_{78/79}$) estimated from step 6(ii) was used to determine the level of constant recruitment for the simulations. The model was initialised with stable age distribution and projected forward from the virgin conditions in 1978/79. Current Annual Yields (CAY) for 1988/89 and 1989/90 (Table 6) were estimated using $F_{0.1}$ in the Baranov catch equation.

Table 5. Projected yields for Chatham Rise orange roughy. (Biomass rounded to the nearest '000 tonnes, CAY's to the nearest '00 tonnes).

M	A_r	$F_{0.1}$	$B_{87/88}$	B_0	$CAY_{88/89}$	$CAY_{89/90}$
0.05	20	0.067	128 000	389 000	8 000	8 100

Maximum Constant Yield (MCY)

The Maximum Constant Yield (MCY) is defined in Anon (1988). It is estimated as:

$$MCY = 0.25 * F_{0.1} * B_0$$

$$= 6\ 500 \text{ t.}$$

2.4 Sensitivity Analysis:

A sensitivity analysis was conducted to determine the effects on CAY of uncertainty in growth and mortality parameters (M and A_r), the biomass ratio (r) and catch (C) overrun. The implications of violations in the assumption of constant recruitment (Step 6) are discussed under Management Implications (Section 3).

a) Growth and Mortality parameters:

It is important that the age of recruitment (A_r) used in the sensitivity analysis is consistent with the value of M used. Ages of recruitment from 15 - 20 years are consistent with values of M below 0.1, while the value of 0.1 for M is consistent with an age of recruitment no greater than 10. When lower ages of recruitment and/or different rates of natural mortality were used in the YPR model, the von Bertalanffy growth parameters were adjusted so that length at A_r was fixed at 30 cm. This was done by holding L_{inf} constant at 42.5cm and setting

$$K = 0.059 * 20 / A_r$$

$$t_0 = -0.346 * A_r / 20$$

Growth and mortality parameters were selected to represent a possible range of values (Table 7).
Using Step 6, estimates were made of biomass and productivity for these growth parameters.

Table 6. Growth and mortality parameters used in sensitivity analysis with biomass and productivity values.

Natural mortality M	Age of recruitment A_r	K	t_0	$B_{87/88}$ (t)	Productivity P
0.025	20	0.059	-0.346	134 000	0.030
0.05	15	0.079	-0.260	130 000	0.036
0.10	10	0.118	-0.173	110 000	0.071

Following Step 8 above, values were used to estimate yields. The percentage effects on biomass values and CAYs are shown in Table 7.

Table 7. Sensitivity analysis on effects of changes in growth and mortality parameters for Chatham Rise orange roughy on current and virgin biomass, and CAYs. All values expressed as a percentage of values in Table 5. (Percentages based on biomass rounded to the nearest '000 tonnes, and CAYs to the nearest '00 tonnes).

M	A_r	$F_{0.1}$	P	$B_{87/88}$	B_0	$CAY_{88/89}$	$CAY_{89/90}$
0.025	20	-49.2	-22.2	+4.7	+1.0	-48	-47
0.05	15	-16.4	-6.7	+1.6	+1.6	-15	-15
* 0.10	10	+94.0	-83.9	-14	-9.0	+70	+72

* Most unlikely to be a valid option: this combination of growth and mortality parameters is not compatible with data in Mace et al. (MS).

Thus the effect of decreasing M by 50% has the effect of reducing CAY values by a similar amount. Doubling M to 0.1 and making appropriate adjustments to the other growth parameters increases the CAY values by about 70%, while keeping M at 0.05 and altering age of recruitment to 15 reduces CAY's by 15%.

<u>b) Biomass ratio (r) and catch over-run:</u>

The effects of variation in values of the biomass ratio (r) and catch over-run are shown in Table 8.

Table 8. Sensitivity analysis on effects of variation in biomass ratio (r) and catch over-run on biomass and yields. (All values expressed as percentages).

Biomass Ratio r^*	B_0	$B_{87/88}$	$CAY_{88/89}$	$CAY_{89/90}$
+42%	+48	+155	+161	+149
-51%	-21	-68	-70	-64
Over-run**				
+10%	+2.3	+2.3	+2.5	+2.5
-10%	-2.3	-2.3	-2.5	-2.5

* Changes in r are equivalent to ± 1 standard deviation.
** Changes in over-runs represent ± 10% of the 30% over-run previously assumed.

Thus, a change of ±1SD in r results in a large increase or a smaller decrease in CAYs. CAYs are far more sensitive to changes in r than changes in catch over-run.

3 Implications of various catch levels:

The present allocated catch of 34,000 tonnes is not sustainable. The population is about 33% of B_0 and declining. The new interpretation of growth (and productivity) of orange roughy implies that the CAY for the Chatham Rise fishery for 1988/89 is about 8 000 tonnes. Lowering the annual catch to 8 000 t should allow a gradual recovery of the population to about 40% of B_0 within 15 - 20 years under a constant catch strategy. CAY would then be about 10 000 t. The yield should be divided by 1.3 to allow for TAC over-runs, assuming they continue.

The south Chatham Rise orange roughy fishery may be vulnerable in the short term if it is a separate stock and continues to be combined with the north Chatham Rise population for assessment and managed purposes.

3.1 Effects of no change in Catch

If the present allocated catch of 34 000 tonnes (plus a 30% over-run) is continued, the fishery is likely to collapse within 5 years. (i.e. recruited biomass will be less than the catch).

3.2 Effects of reducing the catch in steps

Four options of delayed catch reductions were simulated (deterministically) in which the catch is reduced to 8 000 t over 4 years (option 1; 27 500t, 21 000t, 14 500t, 8 000t), and 3 years, (option 2; 25 000t, 17 000t, 8 000t), over 2 years, (option 3; 17 000t, 8 000t), and a fourth option with status quo for 1988/89, 21 000 t, 8 000 t, with $F_{0.1}$ applied thereafter (Fig. 1). The population does not collapse under these scenarios and mid-year biomass is reduced to 22 - 29% of virgin biomass (Table 9).

Table 9: Effects of reducing Chatham Rise catch in steps linearly over 4 years (option 1), over 3 years (options 2 & 4) and over 2 years (option 3).

	option 1	option 2	option 3	option 4
year CAY returns to 8 000 t	2000	1997	1993	1999
year and value of lowest	1992	1991	1990	1991
$B_{midyear}/B_0$ ratio	23%	25%	29%	22%

3.3 Implications of recruitment assumptions

All of the analyses in this document assume a Beverton-Holt stock recruitment relationship with parameters set such that recruitment is 80% of the virgin level when recruited biomass is 20% of virgin biomass. Since the simulations were initiated with virgin biomass and stable age distribution (in 1978/79), and since $A_r = 10\text{-}20$, recruitment was effectively constant over the time period used to estimate CAY levels.

If recruitment was constant while biomass declined at the rate indicated by the surveys, mean length of the recruited population should have exhibited a decrease. In fact, mean length has increased by about 1 cm over the years 1982-87 (Mace et al. MS). This implies that annual recruitment has declined even more than rapidly than the annual rate of decrease in the population.

If the present analyses were re-run using less optimistic assumptions about recruitment, the estimates of B_0, $B_{87/88}$, $CAY_{88/89}$ and MCY would all be higher. The critical issue is whether the estimated virgin biomass was the norm and recruitment has been abnormally low since then, or virgin biomass was unusually high and subsequent recruitment has been normal. If the former applies then steps should be taken to conserve the stock until recruitment improves to normal levels. If the latter applies then the long-term outlook for the fishery is even worse than indicated by the analyses in this document.

Working Group Assessment Data : Data, models and simulation parameters are filed in the FRC computer in: /grp3/orh/workingGroup/Chat8889. For access contact D.A. Robertson, Convenor, Orange Roughy Working Group.

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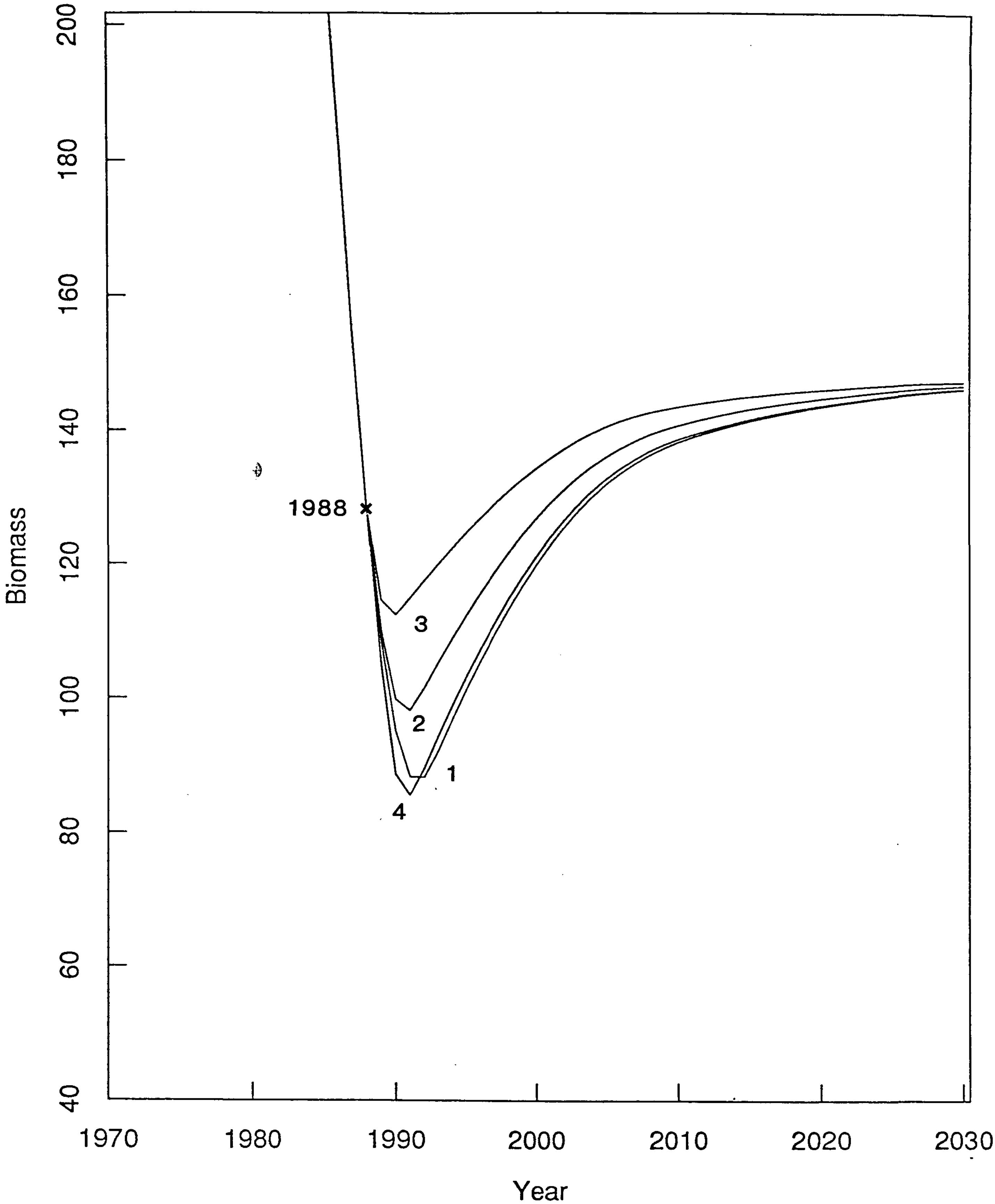

Figure 1. Projected Chatham Rise orange roughy biomass ('000 tonnes) using 4 options to step the catch down to 8,000 tonnes. Thereafter, the catch is set by applying an $F_{0.1}$ strategy, (Virgin Biomass 389,000t).