

Not to be cited without permission of the author(s)

New Zealand Fisheries Assessment Research Document 88/40

Orange roughy fishery assessment, Cape Runaway to Banks Peninsula -
1988

J.H. Annala

MAFFish Fisheries Research Centre
P O Box 297
Wellington

December 1988

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.

ORANGE ROUGHY FISHERY ASSESSMENT, CAPE RUNAWAY
TO BANKS PENINSULA - 1988

I. INTRODUCTION

(a) Overview

This document contains background data and analyses for the fisheries assessment for orange roughy, Hoplostethus atlanticus, in Quota Management Areas (QMAs) 2A, 2B, and 3A, Cape Runaway to Banks Peninsula. Included in the document are:

- brief description of the fishery
- literature review
- catch and effort data for the domestic fleet
- review of resource surveys
- summary of biomass estimates
- estimates of Maximum Constant Yield (MCY) and Current Annual Yield (CAY)
- discussion of management implications of the current TAC.

The major additional source of data for this assessment were the results of a biomass survey carried out in 1987. This assessment signals a major departure from previous stock assessments along the east coast of New Zealand. For the first time orange roughy in the area between Cape Runaway and Banks Peninsula are being treated as one stock for assessment purposes instead of as three separate stocks.

(b) Description of the fishery

Ritchie (QMA 2A)

The orange roughy fishery in QMA 2A includes domestic fishing return areas 012, 013, and most of 014, and is centered on the Ritchie Bank. Commercial quantities of orange roughy were first taken in November 1984. An exploratory quota of 500 t for the old EEZ area B north of Cape Kidnappers was allocated for the 1984/85 fishing season (Table 1). This quota was filled by May 1985, and requests were made to increase the quota because fishermen believed that substantial quantities of orange roughy were present. These initiatives from the industry resulted in the 1985 multi-vessel survey (Robertson & Grimes 1987).

A biomass estimate was calculated from the results of the multi-vessel survey, and formed the basis for a TAC recommendation of 4000 t for 1985/86 (Robertson 1985). An alternative analysis of the multi-vessel survey data resulted in a recommendation to increase the TAC to 5500 t for 1986/87 (Robertson 1986). The recommended TAC for 1987/88 stands at 5500 t (Robertson et. al. 1988).

This fishery has a number of distinguishing features. First, the fish aggregate to spawn over a very small area (approximately 20 sq. km), thus far over the same hill ("Ritchie Hill"). Second, the area is fished primarily by a number of small, inshore vessels. The area is closed to vessels over 42 m, is only 5-8 hours steam from Gisborne and Napier, and the TAC is spread among 21 quota holders. Third, high wastage during fishing was observed during 1985 and 1986. Nets often burst on the surface due to extreme overfilling, and also while trying to get large catches on board small vessels in deteriorating weather conditions. High losses were also experienced by the large vessel "Otago Galliard" (length 85.5 m) during the 1986 trawl survey-- 263 t of orange roughy were caught, but an estimated 110 t lost due to net loss or damage (McMillan et. al. 1986). Fourth, orange roughy are vulnerable and are fished throughout the year. They aggregate outside the spawning period on a number of pinnacles which are now well known to local fishermen.

Wairarapa (QMA 2B)

The fishery in QMA 2B includes domestic fishing return area 015 and part of area 014. The fishery developed as a result of a joint MAF-industry survey in November--December 1981, which located large concentrations of orange roughy off Castlepoint (McMillan 1985). The fishery was largely unregulated until a 42 m maximum vessel size limit was imposed in October 1983. Total reported landings peaked at 6685 t in 1983-84 (Table 1).

Catches through the 1983-84 fishing year came off the combined quota of the old deepwater and foreign licence fisheries management areas B,C, and D. A separate quota of 3500 t for the Wairarapa was imposed for the 1984-85 fishing year. The TAC was reduced to 1053 t for the 1985-86 fishing year.

Kaikoura (QMA 3A)

The fishery in QMA 3A includes most of domestic fishing return areas 16 and 18 and small parts of areas 19 and 20. Orange roughy were first located off Kaikoura in 1981 by some joint-venture and domestic vessels. The fishery was largely unregulated until a 42 m maximum vessel size limit was imposed in October 1983. Fishing effort was low until 1984, when a TAC was introduced to the Wairarapa fishery. Many smaller vessels moved from Wairarapa to Kaikoura, and the reported annual landings for Kaikoura increased from a few hundred tonnes to nearly 3000 t in 1984-85 (Table 1). However, because of the difficulties experienced in locating and fishing on suitable aggregations of orange roughy along the Kaikoura coast, a large proportion of the quota declared as being caught in Kaikoura (estimated to be as high as 85%) has actually been caught in Wairarapa.

Before 1985-86 the quota for Kaikoura was included with that of areas B,C, and D, or some combination of one or more of these areas. A TAC of 2689 t was set for 1985-86 to prevent further expansion of fishing effort. This figure was arbitrarily based on the previous year's catch.

(c) Literature review

Ritchie (QMA 2A)

The first extensive trawl survey of the area was the multi-vessel survey carried out in June-July 1985 (Robertson & Grimes 1987). The main aim of the survey was to determine the distribution and abundance of orange roughy between East Cape and Cape Kidnappers. The survey produced the first biomass estimate for the area. However, the results were treated with caution because of a number of problems with the survey, i.e. wide variation of horsepower and gear types between vessels, varied deepwater trawling experience, and often inadequate navigational and trawl monitoring equipment. Bathymetric data were also collected, and 42 sets of length frequencies were taken totalling 4291 fish.

During June-July 1986 a trawl survey was carried out between Tolaga Bay and Cape Turnagain using the "Otago Galliard" (McMillan et. al. 1986; Fincham et. al. 1987). Data were collected on the distribution and abundance of orange roughy in the area. The only significant aggregation of spawning orange roughy occurred on the Ritchie Hill. This aggregation was confined to an area of about 21 sq. km and contributed 83% to the biomass estimate for the entire survey area (4077 sq. km). The following biological data were collected - sex, length, weight, gonad stage and weight, stomach state and contents, and otoliths. The distribution of the sexes on the Ritchie Hill was depth stratified, with males comprising 90-100% of the fish caught at 700-900 m, and females 80-100% of the fish at 1000-1100 m. Further data were collected on the bathymetry of the area.

Biological data were also collected from orange roughy on the Ritchie Hill during June-July 1986 during a cruise on the "James Cook" (J08/86) conducted concurrently with the "Otago Galliard" survey. During the first half of the cruise (Pankhurst, unpubl. cruise report), data were collected on orange roughy reproductive biology. The results suggested that turnover in the spawning aggregation may be rapid, and that the spawning activity of an individual occupies a relatively short period of time. Orange roughy eggs were collected in plankton samples, but no larvae. The first occurrence of eggs in the plankton coincided with the first capture of ripe fish. Only a few eggs were caught away from the spawning area. Parasites were also collected to determine if they could be used to separate orange roughy populations.

During the second half of the cruise (Zeldis, unpubl. cruise report), further plankton samples were taken, and data collected on the chlorophyll, nutrients, and hydrography (T-S-D) of the area. The data indicate that the spawning hill is located near the convergence zone between modified Southland Current water coming from the south and East Cape Current water coming from the north, with fish apparently spawning in the warmer waters of the latter current system.

During June 1987 another survey of the area was carried out using the "Arrow" (Grimes 1988). The objectives of the survey and the data collected were similar to the 1986 trawl survey; however, the 1987 survey was concentrated mostly on the Ritchie Hill. Depth stratification by sex was not obvious. The highest catch rates were in 700-900 m, with 62% of the total fish caught on the Ritchie Hill being female. This is in marked contrast to the depth stratification by sex observed in 1986.

Data are also available on the distribution and abundance of orange roughy, as well as length frequencies for some stations, from a trawl survey of the deepwater fish resources of the North Island between May 1985 and June 1986 using the "Wanaka" (Clark & King, in press).

Wairarapa (QMA 2B)

The first research cruise to the area in which orange roughy were caught was by the "James Cook" (J06/81) in April, 1981 (McMillan, unpubl. cruise report). Three trawl stations were occupied between 427-933 m depth. Orange roughy were caught in the two deepest tows and lengths measured.

In November-December 1981 the "Kalinovo" conducted an exploratory trawl survey in depths greater than 500 m principally around the North Island (McMillan 1985). A total of 66 trawl stations were occupied between Cape Turnagain and Castlepoint. Catch rates were high for some stations, and this survey established the presence of orange roughy in commercial quantities along the Wairarapa coast. The following data were collected for orange roughy - sex, length, weight, gonad stages, and stomach state and contents.

In April, 1983 the commercial f.v. "Seafire" was used on a charter-for-fish arrangement for a 10 day survey along the Wairarapa coast (Banks, unpubl. cruise report). The first phase was an echo-sounder survey to chart areas of suitable trawl bottom at orange roughy depths and to map the distribution of fish marks. In the second phase four bottom trawl and three mid-water trawl stations were occupied at promising locations observed on the first phase. The following data were collected from one sample of 50 orange roughy - sex, otoliths, length, weight, gonad stage, stomach state and contents, parasites, and heart, liver, and flesh samples for stock separation studies.

During 1984 and 1985 four bottom trawl surveys were carried out using the "James Cook" - J06/84 (Robertson, unpubl. cruise summary), J18/84 (Fenaughty, unpubl. cruise report), J03/85 (Fenaughty, unpubl. cruise summary), and J08/85 (Fenaughty, unpubl. cruise report). The main objectives of these surveys was to collect data on the distribution and abundance of orange roughy in order to estimate biomass. The following data were also collected for orange roughy - sex, otoliths, length, weight, gonad stage and weight, and stomach state and contents.

In February, 1985 the "James Cook" (J02/85) was used to carry out an acoustic survey of orange roughy off the Wairarapa coast (Surti, unpubl. cruise report). The main objective of the cruise was to carry out various tests and recordings to set up the FREDA (Fisheries Research Echo Data Acquisition) System. Two bottom trawls were also made, and the orange roughy weighed and measured.

In July-August 1985 the "James Cook" (J10/85) was used for a mid-water trawl survey of orange roughy off the Wairarapa coast (Grimes, unpubl. cruise report). The main objectives of the survey were to measure the vertical distribution of orange roughy spawning aggregations and collect adults and eggs for biological analysis and experimentation. However, an unfortunate combination of delays, bad weather, and gear problems resulted in the completion of only four tows, only one of which contained a limited number of orange roughy.

Kaikoura (QMA 3A)

In May, 1986 the "James Cook" (J06/86) was used for a bottom trawl survey of orange roughy off the Kaikoura coast (Fenaughty 1986). The major objective of the cruise was to collect data on the survey area, including bathymetry, the location of "hills" supporting orange roughy aggregations, the extent of trawlable ground, and other data relevant to designing a trawl survey programme for this area. Trawl positions were not randomly selected because another major objective was to collect orange roughy for various reproductive studies. However, the data have been used to make biomass estimates. Other biological data collected included sex, otoliths, length, weight, gonad stage and weight, and stomach state and contents.

II. REVIEW OF THE FISHERY

(a) Landings, catch and effort data

Reported landings and TACs for QMAs 2A, 2B, and 3A are shown in Table 1. Catch and effort data from domestic fishing return areas 011-021 for the 1983/84, 1984/85, and 1985/86 fishing years from domestic vessel logbooks are shown in Table 2.

Ritchie (QMA 2A)

The main area of the fishery, centered on the Ritchie Bank, is in area 013. The exploratory quota of 500 t in QMA 2A in 1984/85 was exceeded, while the 4576 t quota in 1985/86 was not reached. In area 013 catch/day decreased by 42% between 1984/85 and 1985/86 and catch/tow decreased by 47%.

Catch and effort data from domestic vessel logbooks are not yet available for the 1986/87 fishing year. From the Quota Monitoring System orange roughy landings from QMA 2A during 1986/87 totalled 5434 t. In addition, 289 t were taken from the area on a charter-for-fish research survey, for a total orange roughy catch of 5723 t, which was greater than the 5500 t TAC.

Wairarapa (QMA 2B)

The main area of the fishery is off Castlepoint in area 015 on non-spawning aggregations during October to May. According to the reported landings, the TAC has not been reached during any of the three fishing years since 1984-85 (Table 1). In area 015 catch/day decreased by 51% between 1983-84 and 1985-86 and catch/tow decreased by 48% (Table 2).

Kaikoura (QMA 3A)

The main area of the fishery is in areas 018 and 020 on non-spawning aggregations over pinnacles from October to April. According to the reported landings, the TAC has not been reached in either fishing year since 1985-86. In area 018 catch/day increased from 3.9 t in 1983-84 to 8.1 t in 1984-85 and then decreased to 5.1 t in 1985-86. Catch/tow increased by 42% between 1983-84 and 1985-86.

Summary

The 40-50% declines in catch per unit effort (CPUE) for Ritchie and Wairarapa between 1983/84 and 1985/86 are suggestive of declines in stock size in these areas. The CPUE data for Kaikoura showed no clear trend. However, the short time series of CPUE data for all three areas, and the area mis-reporting described earlier, precludes any firm conclusions being made from these data at this stage.

(b) Other information

No data available.

(c) Maori and recreational fishing patterns

Not applicable.

III. RESEARCH

(a) Stock structure

This assessment signals a major departure from previous stock assessments along the east coast of New Zealand. For the first time orange roughy in the area between Cape Runaway and Banks Peninsula are being treated as one stock for assessment purposes instead of as three separate stocks. At present, no hard data are available on stock structure for this area. (Proposed research projects using parasite distributions and biochemical techniques may help to resolve this problem during the coming year). 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, and it is possible that some orange roughy from Kaikoura may migrate to this area to spawn. However, because the spawning location of Kaikoura fish cannot be determined at this stage, it has been decided to treat orange roughy from the three QMAs as one "stock" for assessment purposes.

(b) Resource surveys

Ritchie (QMA 2A)

The surveys carried out in the area are listed in Table 3, as well as the major sampling methods used. Limited information was available on orange roughy catch rates before 1984. On a North Island deepwater survey in January 1981, the "James Cook" made a single haul in the area. The catch rate of orange roughy (222kg/hr) was commercially promising. In November 1981 the "Kalinovo" made two hauls in the area. Both contained orange roughy, but in smaller quantities than the "James Cook" haul. In February 1985 the "James Cook" made 8 hauls in the area. All contained orange roughy, but only one tow had a catch rate > 222 kg/hr.

Three extensive research surveys have been carried out in the area (marked with an * in Table 3)-- the multi-vessel survey in 1985, the "Otago Galliard" survey in 1986, and the "Arrow" survey in 1987. One of the main objectives of these surveys was to determine the distribution and relative abundance (biomass) of orange roughy. The biomass estimates are discussed in section III(d).

Robertson & Grimes (1987) reported a modal peak of 36 cm for fish caught on the Ritchie Hill "hotspot" during the 1985 survey. Outside of the "hotspot" area, fish of a wide range of sizes were caught.

The unweighted and weighted length frequency distributions of orange roughy from the 1986 "Otago Galliard" survey (Fincham et. al. 1987) from the entire survey area are shown in Figs. 1 (Fig. 6 of Fincham et. al. 1987) and 2 (Fig. 7 of Fincham et. al. 1987), respectively. Few fish < 30 cm were caught on the Ritchie Hill, in contrast to the larger numbers of smaller fish caught in other parts of the survey area. The weighted modal peak was 36 cm, while the unweighted peak was 33 cm.

The weighted length frequency of orange roughy from the 1987 "Arrow" survey (Grimes 1988) from the Ritchie Hill is shown in Fig. 3 (Fig. 4 from Grimes 1988). It is similar to the length frequency distribution from this area in 1986, with a modal peak at 36 cm.

Inspection of Figs. 2 & 3 reveals no obvious change in the size composition of spawning fish on the Ritchie Hill between 1986 and 1987. Fig. 1 indicates that relatively large numbers of pre-recruit fish (< 30 cm) are found in areas away from the main spawning hill. Thus, there is no evidence of recruitment failure in the length frequency data.

There were obvious differences in sex ratios and depth stratification by sex on the Ritchie Hill between the 1986 and 1987 surveys. In 1986 females comprised 0-10% of the catch at 700-900 m, and 80-100% of the catch at 1000-1100 m (Fincham et. al. 1987). In contrast, 62% of the fish caught in 1987 were female, with no obvious stratification by sex (Grimes 1988).

Wairarapa (QMA 2B) and Kaikoura (QMA 3A)

The surveys carried out in these two areas are also listed in Table 3. The results of these surveys have been summarised in the literature review section and will not be repeated here.

(c) Other studies

During June 1987 a "James Cook" cruise (J08/87) was carried out in the Ritchie Bank area. The cruise had two major objectives with regard to orange roughy: (1) to develop live recovery and transport techniques for deepwater fish species with particular reference to orange roughy, and (2) to inject live orange roughy with tetracycline and transport them to the Napier Aquarium for age validation work (Hvid, unpubl. cruise report). Some very useful information was gained concerning the capture, recovery, and transport of live orange roughy. Live orange roughy were held on board for about 36 hours before transfer to the aquarium. Six fish survived for 6 days after capture, and one for 12 days. It is hoped otoliths from these fish will yield some useful growth information.

(d) Biomass estimates

The biomass estimates discussed below are of recruited biomass, i.e. of fish => 30 cm in length.

Ritchie (QMA 2A)

Biomass estimates for the East Cape to Cape Turnagain area from the 1985, 1986, and 1987 surveys are shown in Table 4.

A number of sampling problems make the interpretation of these data difficult.

(1) The three surveys were carried out by different vessels with very different vessel and gear characteristics and with crews with very different levels of experience fishing for orange roughy.

(2) The stratification by area and depth of the Ritchie Hill was treated differently each year. Refinements were made for each survey as knowledge of the bathymetry and fish distribution improved.

(3) Problems associated with saturation fishing on densely aggregated schools, including:

- (a) Difficulties experienced in determining effective fishing time and distance trawled.
- (b) High spatial-temporal variability in catch rates resulting in high CVs of estimates.
- (c) Densely aggregated spawning schools may affect fish behaviour and their reaction to herding by warps and doors in an unknown fashion.

The 1985 estimates must be treated with caution because of the large number of different vessels involved. The biomass indices for both the Ritchie Hill and the entire survey area

declined between 1986 and 1987. However, because of the problems discussed above, no conclusions can be drawn about this decline.

Wairarapa (QMA 2B)

Biomass estimates for the Wairarapa made during 1984 and 1985 are also shown in Table 4. The biomass indices declined between these two years. However, the CVs were relatively high, and no conclusions can be drawn about the decline.

Kaikoura (QMA 3A)

A biomass estimate is available from a trawl survey carried out in May 1986 (Table 4). This was not entirely a random stratified trawl survey (some aimed trawling was carried out to collect orange roughy for reproductive studies), so the estimate must be treated with caution. The effect on the biomass estimate of incorporating catch data from non-random stations is not known.

(e) Yield estimates

(i) General

As mentioned above, orange roughy in these three areas are treated as one "stock" for assessment purposes. Combining these three areas is a more conservative approach to yield estimation. Previous yield estimates for Kaikoura and Wairarapa were based on biomass surveys conducted outside the spawning season. If these fish spawned on the Ritchie, then the use of these estimates may have resulted in the double counting of fish for the "stock" in QMAs 2A, 2B, and 3A combined. The most conservative approach for estimating biomass for these three QMAs combined is to use the biomass estimates from the trawl surveys between East Cape and Cape Turnagain conducted during the spawning season. This avoids the double counting problem.

However, the concern expressed in the orange roughy stock assessment for the 1987-88 fishing year (Robertson et. al. 1988) that populations in Wairarapa and Kaikoura are overfished still applies. Yields were estimated for these two areas combined using an instantaneous fishing mortality rate (F) ranging from 0.1 to 0.2, and ranged from 570 to 1100 t. It was recommended that about 60% of the total yield should be assigned to the Kaikoura area to allow the Wairarapa stocks to rebuild. This resulted in a yield estimate for Kaikoura of 340-660 t compared to the TAC of 2689 t and for Wairarapa of 230-440 t compared to the TAC of 1053 t.

If there are separate stocks in these areas, then the most conservative and prudent approach to take would be to estimate yields for Wairarapa and Kaikoura separately, as well as estimating an overall yield for the three areas combined.

This approach was adopted in the following analyses.

(ii) Simulation model assumptions and inputs

A simulation model (Mace and Doonan 1988) was used to back-calculate virgin biomass (B_0) from the trawl survey biomass estimates and to project ahead to estimate future biomass values. The following assumptions were made and data used as inputs into the model.

(a) Data on age and growth are not available from the east coast of New Zealand, so the parameter estimates for the Chatham Rise were used. The following values were used in the model.

M	= natural mortality	0.1
A_r	= age at recruitment (years)	6
A_m	= age at maturity (years)	6
a	= length-weight parameter	9.63×10^{-5}
b	= length-weight parameter	2.68
L_{inf}	= growth parameter (cm)	41.2
k	= growth parameter	0.26
t_0	= growth parameter (years)	0.65

(b) The catch histories shown in Table 1 were used to back-calculate B_0 .

(c) An estimated TAC over-run of 30% was used to back-calculate B_0 . An over-run of zero was assumed in the forward projections to estimate future yields.

(d) Wingtip biomass estimates from the trawl surveys were used to maintain consistency with the orange roughy assessments for other areas. The survey estimates equalled recruited biomass and were assumed to be exact estimates of mid-year biomass in the year they were carried out.

(e) Three different recruitment assumptions were tested - recruitment constant at the virgin level, knife-edge recruitment, and a Beverton-Holt stock-recruitment function. There is no evidence of recruitment failure for these three areas, so the zero recruitment option contained in the model was not used. Model runs were conducted either by using each assumption both to back-calculate B_0 and to project ahead to estimate biomass, or by using constant recruitment from the beginning of the fishery to 1987-88 and then using one of the other assumptions from 1988-89 onwards. The results for all three recruitment assumptions were very similar because the shapes of the constant, knife-edge, and Beverton-Holt recruitment functions are all very similar at the current estimated large stock size. The shapes do not begin to differ until low stock sizes approaching 0.2-0.3 B_0 are reached. Therefore, only the results using the constant recruitment assumption are discussed here.

(f) Information suggests that area mis-reporting between Wairarapa and Kaikoura has occurred in the past, with 85% of the Kaikoura quota caught in the Wairarapa.

(iii) Estimates of B_0

(a) Cape Runaway to Banks Peninsula (QMAs 2A, 2B, 3A combined)

The biomass estimates for the entire survey area between East Cape and Cape Turnagain were used instead of the estimates for the Ritchie Hill only because the possible risk of double counting fish moving to and from the Ritchie was considered minimal. This is a departure from previous assessments which used Ritchie Hill estimates only. The biomass estimate for 1986 (126,909 t) was assumed equal to mid-year biomass for 1985-86 and the estimate for 1987 (72,165 t) to mid-year biomass for 1986-87. B_0 was back-calculated from the average of these two estimates (99,537 t) instead of using one estimate only because of the high CVs of the estimates and the fact that the large difference between the two estimates cannot be explained by any reasonable rate of population decline between the two years.

$$B_0 = 130,000 \text{ t}$$

(b) Wairarapa (QMA 2B)

B_0 was back-calculated from the average of the biomass estimates (12,800 t) from the four trawl surveys carried out during 1984 and 1985 instead of the biomass estimate from the February 1985 survey alone as was done in the 1987-88 assessment (Robertson et. al. 1988). The average was used because of the high CVs and associated variability of the estimates. The average of the two 1984 estimates (17,705 t) was assumed equal to mid-year biomass for 1983-84 and the average of the two 1985 estimates (7905 t) to the mid-year biomass for 1984-85.

$$B_0 = 25,300 \text{ t}$$

(c) Kaikoura (QMA 3A)

B_0 was back-calculated from the biomass estimate (7580 t) from the May 1986 trawl survey, which was assumed equal to the mid-year biomass for 1985-86.

$$B_0 = 13,550 \text{ t}$$

(iv) Estimates of maximum constant yield (MCY)

MCY was estimated using the equation, $MCY = 1/4MB_0$ (McKoy 1988). M was assumed equal to 0.10, and B_0 was back-calculated as described in the previous section.

(2) B_0 was back-calculated using an estimated TAC over-run of 30% instead of 0%.

(3) Catch histories were revised on the basis of updated fisheries statistics.

(4) The 1987-88 catch for each area was assumed equal to the TAC.

(5) Area mis-reporting occurs, and 85% of the 1987-88 and 1988-89 Kaikoura quota is caught in the Wairarapa.

(6) For Wairarapa, $B_0 = 25,300$ t, and for Kaikoura, $B_0 = 13,550$ t.

The model results for the constant recruitment option are shown in Table 5. Mis-reporting was assumed to equal 0 or 85% during each of the fishing years 1986-87 and 1987-88, for a total of four mis-reporting combinations. Based on information from the commercial fishing industry, it is likely that 85% of the catch was misreported during both 1986-87 and 1987-88. Therefore, the best estimates of CAY for 1988-89 are Wairarapa = 608 t and Kaikoura = 1098 t. These values reflect the estimated reduced biomass in Wairarapa resulting from the large proportion of the Kaikoura quota actually being taken from the Wairarapa. Once again, these forward projections are based on a 0% TAC over-run, so these yield estimates are of the total removals from the population (including over-runs), and allowance must be made for over-runs when recommending TACs.

IV. MANAGEMENT IMPLICATIONS

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

(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.

(2) The results of the simulation model suggest that a constant TAC of 9242 t is not sustainable, and that the TAC will need to be reduced below this level in 1990-91 (and even further in subsequent years) to prevent the stock from decreasing to less than 0.2 B_0 (defined here as stock collapse).

(3) Because the yield projections are based on a 0% TAC over-run, the yield estimates need to be reduced by the estimated

level of over-run when recommending TACs. This highlights the importance of strict enforcement of the TACs.

(4) The concern expressed in the orange roughy stock assessment for the 1987-88 fishing year that populations in Wairarapa (QMA 2B) and Kaikoura (QMA 3A) are overfished still applies. If there are separate stocks in these two areas, then the most conservative and prudent approach would be to estimate yields and recommend TACs for these two areas separately. Any TAC reductions for Wairarapa and Kaikoura could be achieved by transferring quota to the Ritchie (QMA 2A). Furthermore, any TAC increases above the current level of 9242 t for the three areas combined should be allocated as annual quota to the Ritchie only.

(5) The fishery is relatively new, and current stock size for the three areas combined appears relatively high ($>1/2 B_0$). However, biomass estimates for the area between East Cape and Cape Turnagain declined by 43% between 1986 and 1987. Separate stocks of a species may experience declines in stock size in parallel (Koslow 1984), so concern must be expressed that orange roughy on the east coast of New Zealand may be suffering a decline in biomass similar to the Chatham Rise.

REFERENCES

- Clark, M.R., King, K.J. (in press). Deepwater fish resources of North Island: results of a trawl survey May 1985-June 1986. New Zealand Fisheries Technical Report.
- Fenaughty, J. M. 1986: Cruise report of the James Cook survey of the Kaikoura orange roughy grounds, J06/86. Fisheries Research Division Internal Report No. 56.
- Fincham, D.J., Grimes, P.J., McMillan, P.J. 1987: Orange roughy trawl survey, Tolaga Bay to Cape Turnagain, 14 June-11 July 1986: Cruise report. Fisheries Research Division Internal Report No. 60. 38p.
- Grimes, P. 1988: Ritchie Banks fishery. *Catch*. 15(1):5-7.
- Koslow, J.A. 1984: Recruitment patterns in northwest Atlantic fish stocks. *Canadian Journal of Fisheries and Aquatic Sciences*. 41: 1722-1729.
- McKoy, J.L. (Comp.) 1988: Report from the Fishery Assessment Meeting April-May 1988. 135 p. (Unpublished report held in Fisheries Research Centre library, Wellington.)
- McMillan, P.J. 1985: Cruise report - deepwater exploratory trawling by "Kalinovo", 1981. Fisheries Research Division Internal Report No. 23.

- McMillan, P., Fincham, D., Grimes, P., and Zeldis, J. 1986: Ritchie Bank area. *Catch*. 13(10):22-24.
- Mace, P.M., and Doonan, I.J. 1988: A generalised bioeconomic model for fish population dynamics. *New Zealand Fisheries Assessment Research Document* 88/4.
- Robertson, D.A. 1985: Orange roughy. In Colman, J.A., McKoy, J.L., and Baird, G.G. (Comps. and Eds.), *Background papers for the 1985 Total Allowable Catch recommendations*, pp. 136-141. Fisheries Research Division, N.Z. Ministry of Agriculture and Fisheries.
- Robertson, D.A. 1986: Orange roughy. In Baird, G.G., and McKoy, J.L. (Comps. and Eds.), *Background papers for the Total Allowable Catch recommendations for the 1986-87 New Zealand fishing year*, pp. 88-108.
- Robertson, D.A., Grimes, P.J. 1987: Orange roughy multi-vessel survey: East Cape to Cape Kidnappers, June-July 1985. Fisheries Research Center Internal Report No. 72. 20 p.
- Robertson, D.A., Mace, P.M., Doonan, I.J. 1988: Orange roughy. In Baird, G.G., and McKoy, J.L. (Comps. and Eds.), *Papers from the workshop to review fish stock assessments for the 1987-88 New Zealand fishing year*, pp 172-198.

Table 1. Orange roughy landings(t) and TACs(t) for QMAs 2A, 2B, and 3A. Fishing year = 1 Oct--30 Sep. (Source - unpublished MAFFish statistics, except for 1986-87.)

Fishing year	QMA 2A (Ritchie)		QMA 2B (Wairarapa)		QMA 3A (Kaikoura)		Total	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1981-82	-	-	554	-	-	-	554	-
1982-83	-	-	3510	-	-	-	3510	-
1983-84	162	-	6685	-	353	-	7200	-
1984-85	1854	-	3310	3500	2987	*	8151	-
1985-86	2787	4576	867	1053	2285	2689	5939	8318
1986-87 [#]	5723	5500	787	1053	2532	2689	9042	9242

* = included in QMA 3B TAC

[#] = provisional totals from the Quota Monitoring System

Table 2. Catch and effort data for orange roughy caught in domestic fishing return areas 012-021 from domestic vessel logbooks using the FSU extract program. Does not include amounts caught during charters or some of multi-vessel survey data. Fishing year = 1 Oct-30 Sep.

Area	Fishing year		
	1983-84	1984-85	1985-86
	Catch(t)		
012	-	3	41
013	-	1198	2022
014	162	653	724
015	6685	3310	867
016	0.6	0.7	28
018	352	2986	2220
019	38	115	243
020	8	118	1810
021	157	46	1

Catch per day(t)			
012	-	0.3	13.6
013	-	10.9	6.3
014	6.5	3.2	7.0
015	13.0	5.1	6.4
016	0.2	0.1	1.9
018	3.9	8.1	5.1
019	3.8	4.0	10.6
020	2.6	2.1	13.2
021	3.7	4.6	0.9

Catch per tow(t)			
012	-	0.1	-
013	-	5.5	2.9
014	1.9	3.2	3.0
015	4.4	1.9	2.3
016	0.05	0.04	0.5
018	1.2	1.6	1.7
019	1.7	1.6	4.8
020	1.0	1.0	4.4
021	1.4	1.5	0.5

Table 3. Orange roughy resource surveys in the area between East Cape and Banks Peninsula

Date	Vessel	Sampling Method(s)
Ritchie (QMA 2A)		
1981		
Jan	James Cook (J06/81)	Bottom trawl
Nov	Kalinovo	" "
1985		
Feb	James Cook (J03/85)	" "
Jun-Jul *	Multi-vessel	" "
May-Jul	Wanaka (WK1)	" "
Aug-Oct	Wanaka (WK2)	" "
Nov-Feb	Wanaka (WK3)	" "
1986		
Mar-Apr	Wanaka (WK4)	" "
May-Jun	Wanaka (WK5)	" "
Jun-Jul *	Otago Galliard (G03/86)	" "
Jun-Jul	James Cook (J08/86)	Plankton, nutrients hydrography
Aug-Sep	James Cook (J10/86)	Bottom trawl, FMMWT plankton
1987		
Jun-Jul *	Arrow	Bottom trawl
Jun	James Cook (J08/87)	Bottom trawl, fish traps
Wairarapa (QMA 2B)		
1981		
Apr	James Cook (J06/81)	Bottom trawl
Nov-Dec	Kalinovo	Bottom trawl
1983		
Apr	Seafire	Echo-sounder survey Bottom trawl
1984		
Apr *	James Cook (J06/84)	Bottom trawl
Oct *	James Cook (J18/84)	Bottom trawl

1985		
Feb	James Cook (Jo2/85)	Acoustic survey, Bottom trawl
Feb *	James Cook (J03/85)	Bottom trawl
May-Jun *	James Cook (J08/85)	Bottom trawl
Jul-Aug	James Cook (J10/85)	Mid-water trawl

Kaikoura (QMA 3A)

1986		
May *	James Cook (J06/86)	Bottom trawl

* = biomass estimates available

Table 4a. Estimates of recruited biomass (fish => 30 cm in length) for the East Cape-Cape Turnagain area from the 1985 multi-vessel survey, 1986 "Otago Galliard" survey, and 1987 "Arrow" survey.

Biomass estimates (t)						
Year	Area (sq km)	No. of tows	Door-spread	Average of doorspread + wingtip estimates	Wingtips	CV(%)
Ritchie Hill only						
1985	3	22	2400	10,665	18,930	35
1986						
phase 1	21	10	20,022	62,701	105,380	19
phase 2	21	5	8,180	25,610	43,040	
1987						
phase 1	27	18	14,940	41,424	67,908	39
phase 2	27	26	13,462	37,327	61,192	
combined	27	44	14,493	40,185	65,877	35
Entire survey area						
1985	9089	191	17,910	75,515	133,120	
1986 *	4077	83	23,990	75,450	126,909	16
1987 #	2229	71	15,876	44,021	72,165	

* includes data from phase 1 of Ritchie Hill survey only

includes data from phase 1 and 2 combined

Table 4b. Wingtip estimates of recruited biomass (fish => 30 cm in length) for the Wairarapa area from four "James Cook" trawl surveys during 1984 and 1985.

Date	Cruise	No. of stations	Biomass estimate(t)	CV(%)
1984				
Apr	J06/84	23	14,865	27%
Oct	J18/84	9	20,540	51%
1985				
Feb	J03/85	29	9,688	38%
May-Jun	J08/85	20	6,118	14%

Table 4c. Wingtip biomass estimate for the Kaikoura area from a "James Cook" trawl survey in May 1986.

Date	Cruise	No. of stations	Biomass estimate(t)	CV(%)
1986				
May	J06/86	17	7,580	45%

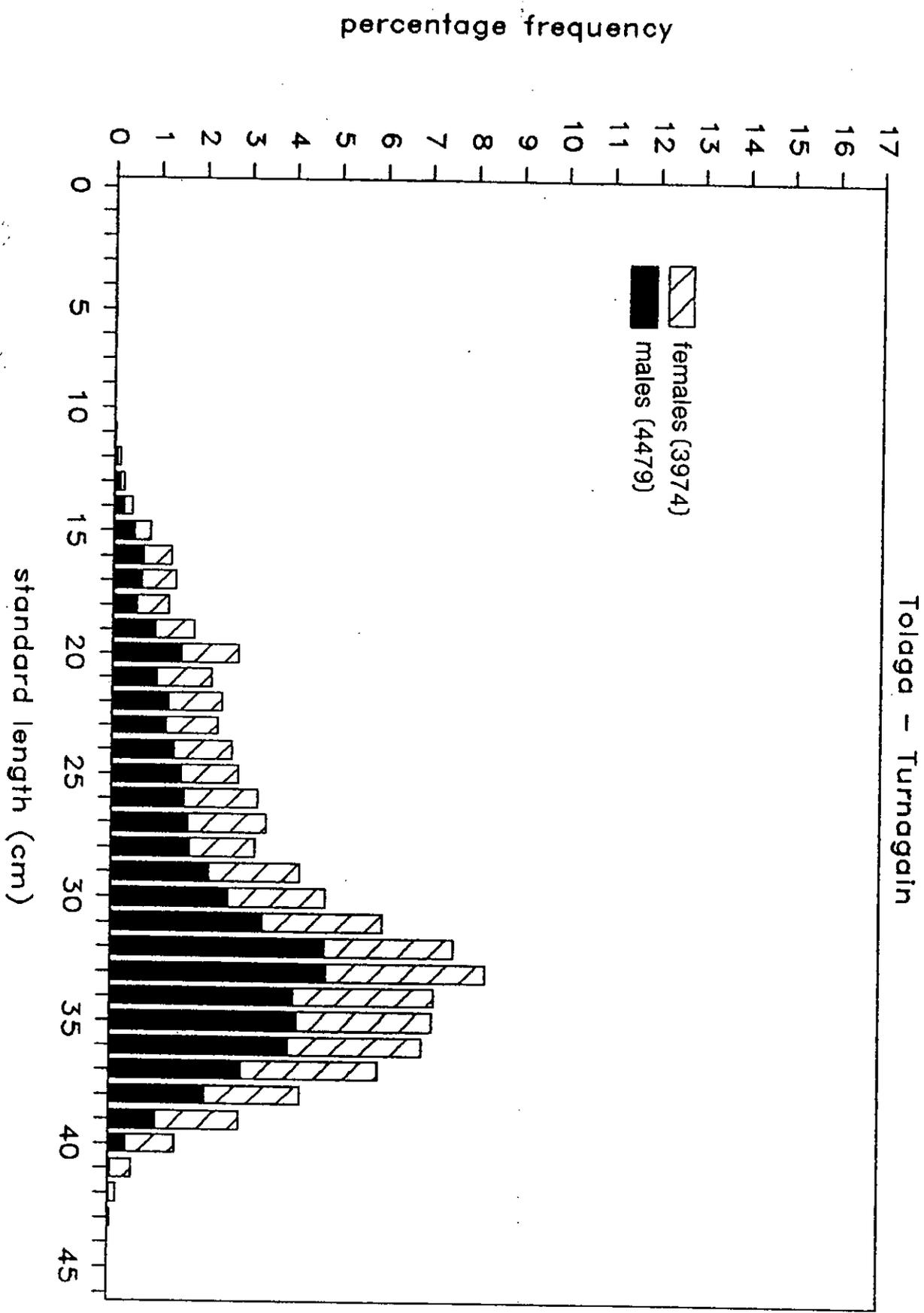
Table 5. Estimates of CAY (t) for Wairarapa (QMA 2B) and Kaikoura (QMA 3A) using the equation, $Yield = F_{0.1} * B_{current}$, with constant recruitment and two mis-reporting options. $F_{0.1} = 0.18$, $B_{current}$ estimated from simulation model.

Mis-reporting option		Yield(t)
1986-87	1987-88	
Wairarapa (QMA 2B)		
None	None	1520
85%	None	1088
None	85%	1042
85%	85%	608
Kaikoura (QMA 3A)		
None	None	211
85%	None	629
None	85%	524
85%	85%	1098

Figure Captions

- Fig. 1. Unweighted orange roughy size frequency distribution from 1986 "Otago Galliard" survey. Entire survey area. n = 8453. (Fig. 6 of Fincham et. al. 1987).
- Fig. 2. Orange roughy size frequency distribution from 1986 "Otago Galliard" survey weighted up to the total catch weight. Entire survey area. (Fig. 7 of Fincham et. al. 1987).
- Fig. 3. Orange roughy size frequency distribution from 1987 "Arrow" survey weighted up to the total catch weight. Ritchie Hill only. n = 8413. (Fig. 4 of Grimes 1988).

Fig. 1



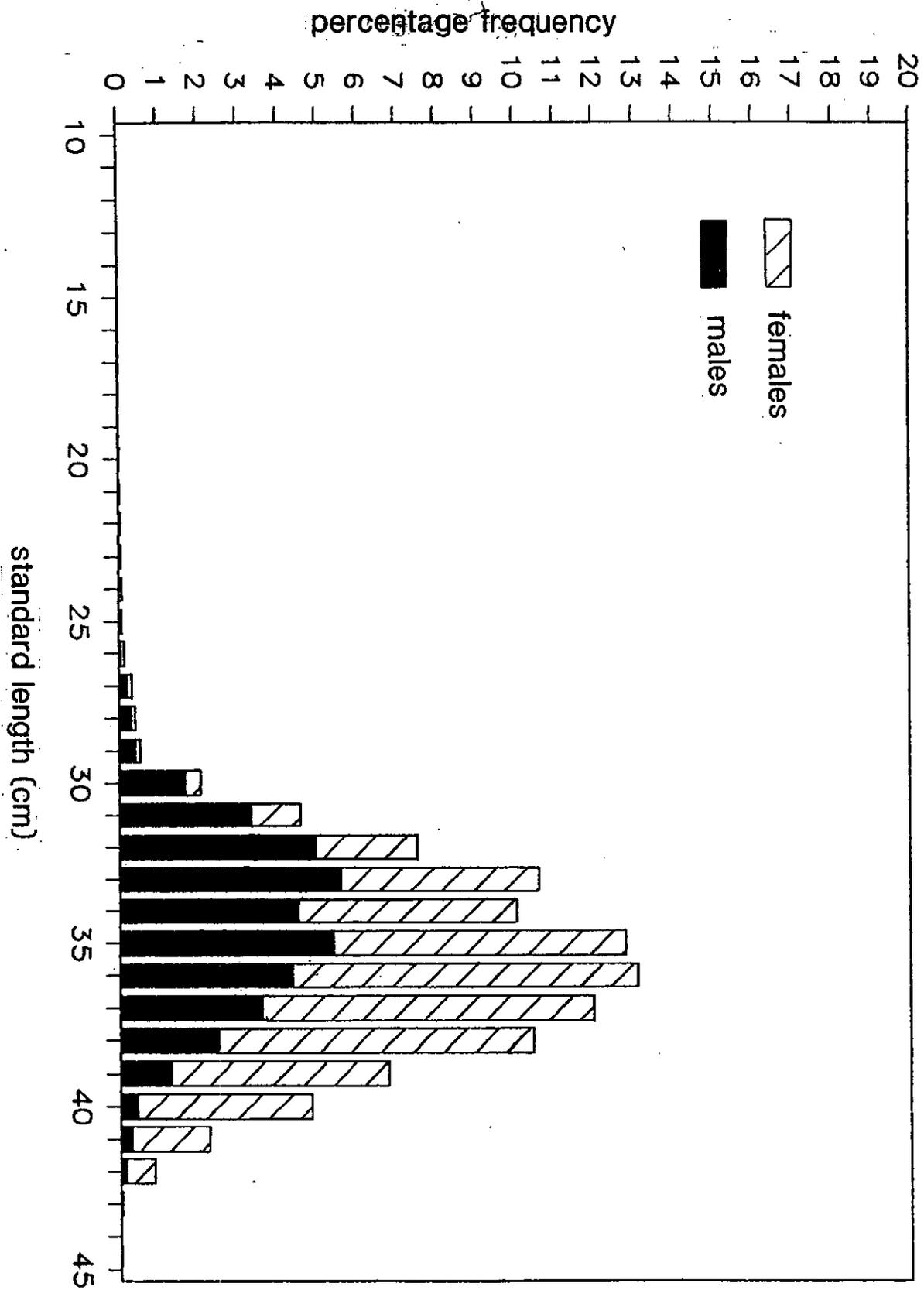


Fig. 3