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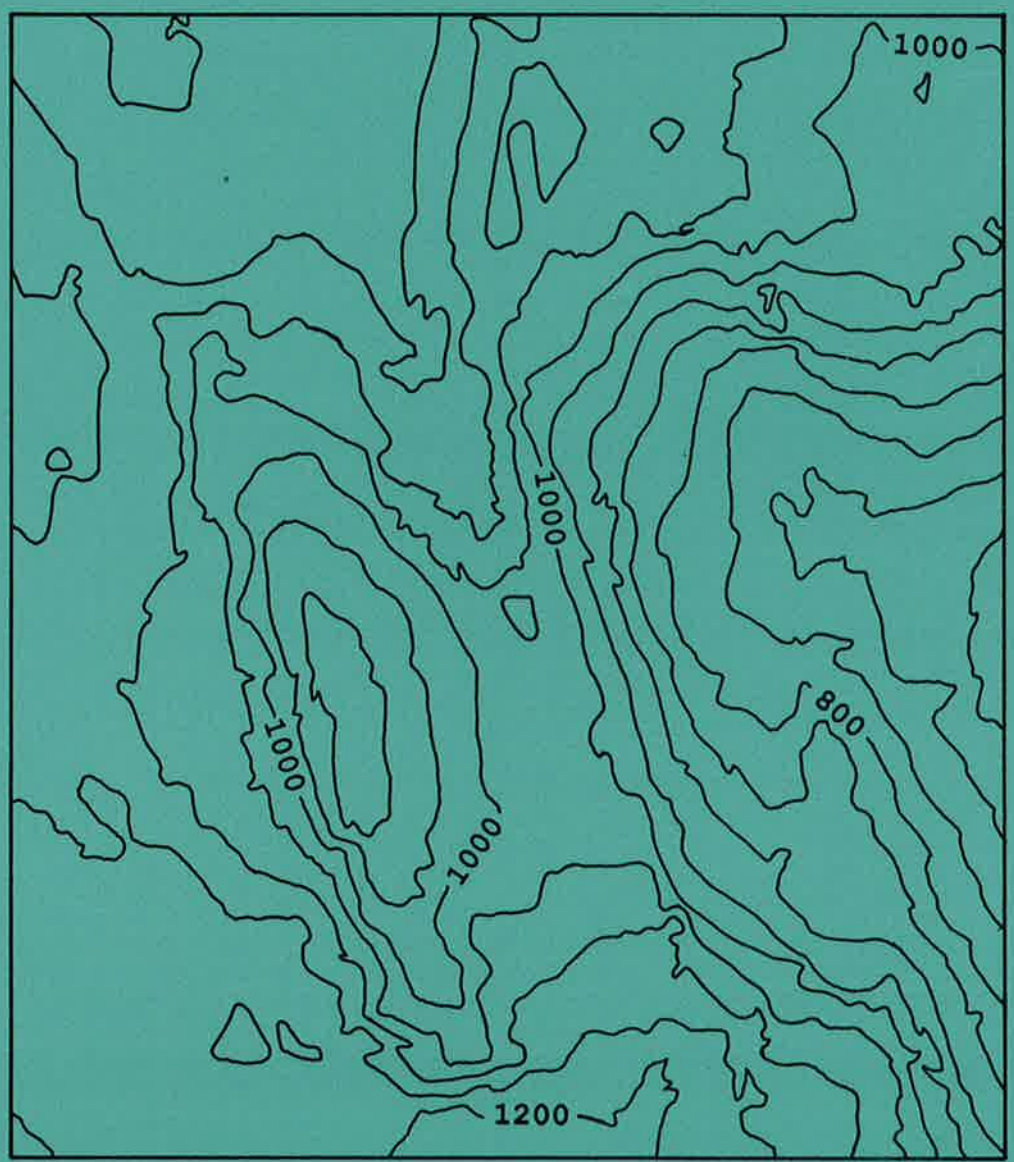

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MAF Fisheries is the fisheries group of the New Zealand Ministry of Agriculture and Fisheries. The name MAF Fisheries was formalised on 1 November 1989 and replaced MAFFish, which was established on 1 April 1987. MAFFish combined the functions of the old Fisheries Research Division and Fisheries Management Division and the fisheries functions of the old Economics Division.

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Cover: This section from a bathymetric chart of the Puysegur Bank was produced during the trip by the "HYDRO" computer plotting program installed on *Will Watch*. The ability to produce charts rapidly on board was important for identifying features and defining strata used in the research survey.

Contents

Abstract

Clark, M. R. & Tracey, D. M. 1992: Trawl survey of orange roughy in southern New Zealand waters, June-July 1991. ***N.Z. Fisheries Technical Report No. 32.*** **27 p.**

An exploratory fishing survey of orange roughy in southern New Zealand waters was carried out in June-July 1991 by FV *Will Watch*. The main objectives were to assess commercial prospects for orange roughy fishing, and to determine the distribution and estimate quantities of orange roughy.

Exploratory fishing and searching was carried out in an area extending from Puysegur Bank and Solander Trough south along the western flank of Campbell Plateau and Macquarie Ridge, to south of Campbell Island. There were indications of orange roughy aggregations on the western side of Puysegur Bank, and a research survey was subsequently undertaken.

A two-phase stratified random trawl survey was carried out around Puysegur Bank. Seventy-two research tows were completed, and they provided information on the distribution, abundance, and biology of orange roughy and on the main bycatch species, black oreo and smooth oreo.

Orange roughy were concentrated on the western side of Puysegur Bank, where high catch rates were recorded on several small hills. Biomass of orange roughy from all research survey tows was estimated at 60 000 t (95% confidence interval 5000–115 000). However, this cannot be regarded as a reliable estimate of absolute abundance, because of uncertainty about the "catchability" of orange roughy in trawl gear and the effective area of bottom swept by the trawl. The biomass value should be treated as a relative index. In addition, there was possible dispersal of orange roughy from the hills after spawning, which may have resulted in some double-counting and overestimation of biomass. The "best guess" biomass value was about 30 000 t.

Size structure and reproductive data are presented. The length frequency distribution of orange roughy is similar to that of the Chatham Rise, Cook Canyon, and Ritchie Bank spawning populations. Spawning occurred in mid to late July, which suggests that the orange roughy constitute a separate stock from the other major fisheries, where the fish spawn at a similar time. Genetic studies support this conclusion.

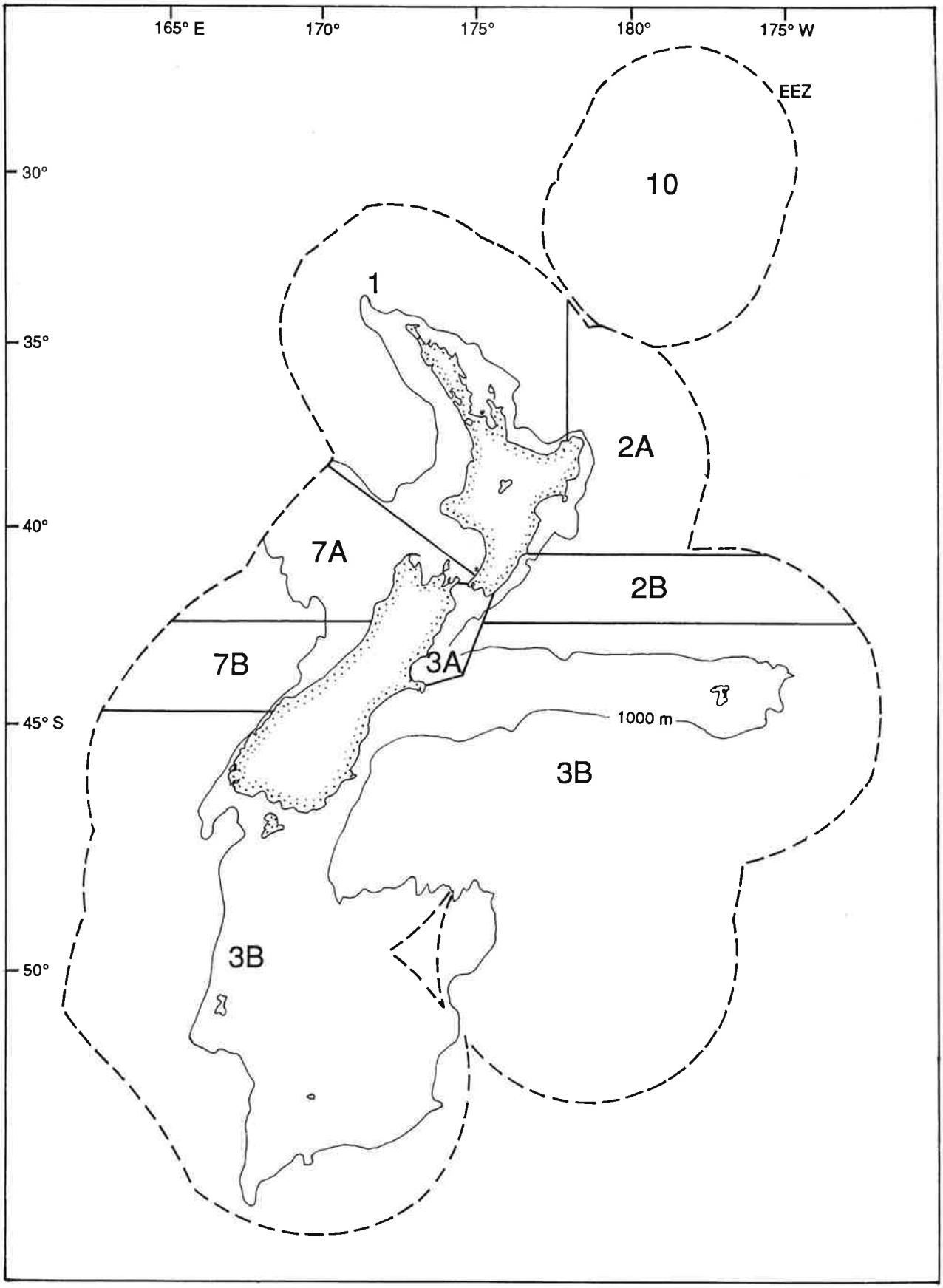

Figure 1: The New Zealand Exclusive Economic Zone (EEZ), showing quota management areas for orange roughy.

Introduction

Commercial fisheries for orange roughy (*Hoplostethus atlanticus*) have been established since the early-mid 1980s on the Chatham Rise, Challenger Plateau, Cook Canyon, Ritchie Banks, and Wairarapa and Kaikoura coasts. The largest of these fisheries is on the north Chatham Rise, part of Quota Management Area ORH 3B.

The ORH 3B area (Figure 1) extends from the northern side of the Chatham Rise southwards, covering the entire Exclusive Economic Zone (EEZ) around to about 44° S on the west coast of the South Island. The fishery for orange roughy in this area developed in 1979–80 on the northern slopes of the Chatham Rise, where the fish spawn. Throughout the 1980s catches have been controlled by a Total Allowable Catch (TAC) and have generally been around 30 000 t per year (Table 1). The fishery has focused on spawning aggregations of orange roughy on the northern Chatham Rise in winter, though in recent years an increasing proportion of the quota has been taken outside the winter season on hills of the southern rise. Recent stock assessments by MAF Fisheries have shown that the population in the main spawning area of the northern Chatham Rise has declined markedly, and consequently there have been reductions in the TAC (Francis & Robertson 1991).

Previous research

There has been little deepwater commercial or research fishing in southern New Zealand waters. In the 1970s and 1980s there were several joint research cruises on Campbell Plateau and Stewart-Snares shelf, but these generally only covered depths to 800 m and focused on species such as barracouta (*Thyrsites atun*), hoki (*Macruronus novaezelandiae*), squid (*Nototodarus sloanii*), and southern blue whiting (*Micromesistius australis*).

In 1979–80 a joint New Zealand and West German research programme using FMS *Wesermünde* trawled to depths of 1000 m. Orange roughy were recorded west and south of Campbell Island and on the northern flank of Campbell Plateau (Kerstan & Sahrhage 1980). However, no deep trawling was done on the western part of the plateau or around Stewart Island.

In July 1990, during a MAF Fisheries survey of hoki on Campbell Plateau, several orange roughy in near-spawning condition were caught southeast of Campbell Island. Later in 1990 substantial quantities of orange roughy, with black oreo (*Allocyttus niger*) and smooth oreo (*Pseudocyttus maculatus*), were caught by several commercial vessels south of Stewart Island off Puysegur Bank (Table 2).

These catches, and the reduced quotas available on the Chatham Rise, increased interest in exploring southern New Zealand waters and led to the survey described here. The trip was funded by all ORH 3B quota holders under the umbrella of a single company, "The Exploratory Fishing Company (ORH 3B) Limited". MAF Fisheries were contracted to collect scientific data and to plan and conduct a trawl survey if areas of fish concentration were located.

Objectives

There were six specific objectives in the company's cruise programme:

1. to survey the southern portion of the ORH 3B Management Zone for commercial prospects for orange roughy fishing;
2. to carry out exploratory trawl fishing to determine the distribution and to estimate quantities of orange roughy;
3. to undertake appropriate abundance assessments of located orange roughy aggregations to enable the assessment of minimum biomass estimates;
4. to collect additional relevant biological data (including length, sex, reproductive state, stomach content, and otolith) for use in age determination and in the estimation of growth rates and feeding studies;
5. to update and map the bathymetry by use of long range sonar and GPS equipment;
6. to identify and assess bycatch species.

This report briefly describes the exploratory fishing, but focuses on the trawl survey (objective 3) and on information on distribution, relative abundance, and biology.

Table 1: Annual reported catches and gazetted TAC (t) of orange roughy from ORH 3B (*from* Francis & Robertson 1991)

Fishing year	Reported catch	Gazetted TAC
Before 1978–79	Negligible	–
1979–80	11 800	–
1980–81	31 100	–
1981–82	28 200	23 000
1982–83*	32 605	23 000
1983–84*	32 535	30 000
1984–85	29 340	30 000
1985–86	30 075	29 865
1986–87	30 689	38 065
1987–88	24 214	38 065
1988–89	32 785	38 300
1989–90	31 669	32 787
1990–91	21 540	23 787

*Catches for 1982–83 and 1983–84 are 15 month totals to accommodate the change from an April-March fishing year to an October-September fishing year. The gazetted TAC for the interim season March-September 1983 was 16 125 t.

Table 2: Reported catches (t) of orange roughy, smooth oreo, and black oreo from the Puysegur Bank to Stewart Island region in 1990 and 1991 (MAF Fisheries data)

		Orange roughy	Smooth oreo	Black oreo
1990	Jul	< 0.1	0	0
	Sep	130	203	598
	Oct	31	225	707
1991	Mar	172	72	312
	Apr	4	76	233
	Jun	39	54	262
Total		406	630	2 112

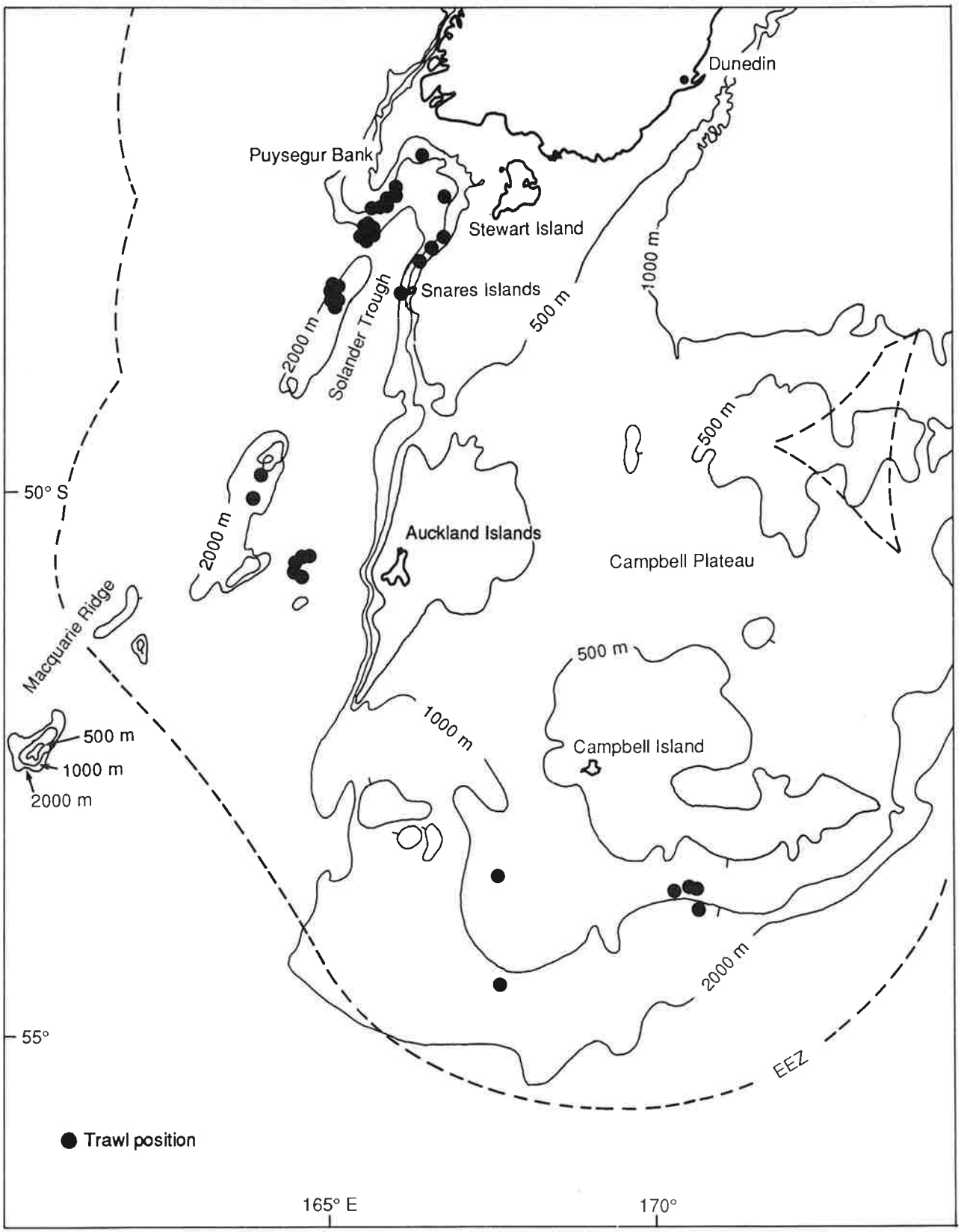

Figure 2: The southern part of the Exclusive Economic Zone (EEZ), showing the region investigated by *Will Watch* during the exploratory fishing phase.

Methods

Exploratory fishing

Exploratory fishing and searching covered the western side of Campbell Plateau from Puysegur Bank to south of Campbell Island (Figure 2). Effort focused on charted features such as hills and banks, as well as general areas of slope if they seemed promising for orange roughy. Much of the searching relied on detecting marks and features on the echosounder. The standard colour depth sounder was used, because the sonar was not operating. Trawls were carried out in likely areas of fish abundance (such as on hills), or where marks were seen. In several areas where the bathymetry was poorly defined, parallel transects about 1 n. mile apart were followed to enable detailed charting and to search for fish concentrations. Detailed charts were compiled on board by using the "HYDRO" computer plotting program. Vessel position and bottom depth were automatically recorded, and these data were then transferred to this program to derive bathymetric contour plots.

Research survey

Survey area

The survey area covered the southern Puysegur Bank, from 46° 45' S southwards, and between 165° 20' and 166° 15' E. Two hill complexes, one just to the south of Puysegur Bank, and one west of Snares Islands, were also included (Figure 3). Depths from 800 m (750 m on some hills) to 1200 m were fished. The survey area totalled about 829 km^2.

Survey design

A two-phase stratified random survey design was applied (*after* Francis 1984). The survey area was divided into 14 strata, on the basis of catches and bottom features found during exploratory fishing in the first 3 weeks, as well as using personal knowledge of distribution and abundance patterns in other orange roughy fisheries. Strata were structured on a combination of bottom depth intervals and bottom features (*see* Figure 3, Table 3).

These strata had various bottom types: gradual slope (able to be subdivided by depth), steep slope (e.g., stratum 10), undulating slope (e.g., stratum 3), and hills. These bottom types were separated into individual strata, so that within each stratum catch rates would be fairly consistent, and the area over which a mean catch rate was extrapolated would be more appropriate than if areas of expected high or low density were combined.

Within each stratum random station positions (start of tow) were generated by computer. Several methods of specifying station position were used, depending on the bottom characteristics of the strata:

1. random latitude and longitude, tow direction parallel to depth contours (strata 1, 2, 3, 7, 8, and 9);
2. random tow direction from the top of the hill (strata 4, 5, 6, 11, and 12);
3. random latitude, tow directly down slope (stratum 10, where it was too steep and rough for tows parallel to the contour);
4. random latitude or longitude, random direction, where the hill has a razorback ridge (strata 13, 14, and some of 5).

The number of stations per stratum in the first phase was based on personal experience from other orange roughy grounds, constrained by the total number thought possible in 14–18 days. More stations were allocated to strata where the type of bottom or feature suggested higher catch rates (and hence variance) were to be expected. There was a minimum of three stations per stratum.

Vessel and gear

The vessel used for the survey was FV *Will Watch*, a New Zealand factory trawler owned by Sealord Products Limited in Nelson. It has the following specifications: overall length, 74.4 m; beam, 12.7 m; gross tonnage, 1472 t; horsepower, 2850 (2100 kW).

The arrangement of the trawl gear and the net used were fairly standard for rough bottom orange roughy fishing: doors, high-aspect Super Vee, 7 m^2, 1500 kg; sweep length, 45 m; bridle length, 45 m; net type, 6 panel bottom trawl, cut away lower wings; layback, 0; headline length, 36 m; groundrope length, 20.8 m; headline floats, 18 x 360 m (about 280 kg buoyancy); bobbin rig, 3 x 6 m sections, 18 x steel 440 mm; two lengtheners, 3 codend sections, codend mesh 100 mm.

A similar net to the one used had been tested in flume tank trials at the Australian Maritime College, Tasmania. The results of the flume tank trials gave a wingend spread of about 20 m, with an estimated doorspread of 75 m (J. Greening, Sealord Products Limited, pers. comm.). At trawling speeds of 3.0–3.5 kn average headline height was 7 m.

A "window" was lightly lashed in the third codend, to limit the size of catch to less than 40 t. This is because *Will Watch* is a fillet vessel and can handle a maximum of 25–30 t greenweight of orange roughy per day.

Trawling details

The vessel operated continuously, trawling both day and night. Vessel position was determined by GPS.

A standard trawl length of 1.5 n. miles was used whenever possible, though tows on pinnacles or rough ground were often shorter. Towing speed was kept at about 3.0 kn over the ground (determined from GPS position).

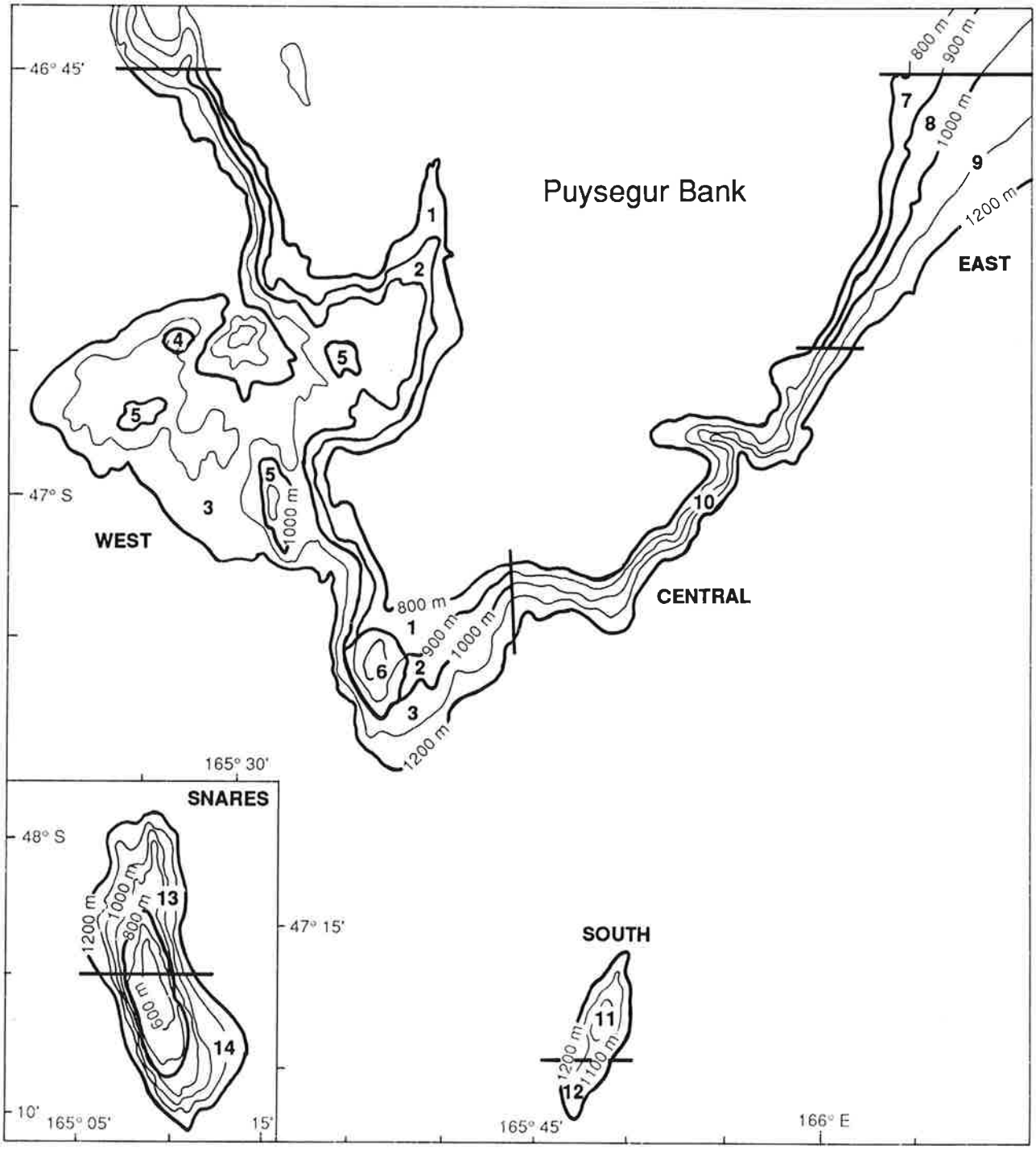

Figure 3: The research survey area, showing strata boundaries (*see* Table 3).

Table 3: Strata descriptions and areas (*see* **Figure 3**)

Stratum	Area (km^2)	Description
1	71.0	West Puysegur Bank slope, 800–900 m
2	62.0	West Puysegur Bank slope, 900–1000 m
3	346.0	West Puysegur Bank slope, 1000–1200 m
4	2.0	West Puysegur Bank hill (north)
5	23.0	West Puysegur Bank hills (group)
6	21.0	West Puysegur Bank hill (south)
7	20.0	East Puysegur Bank slope, 800–900 m
8	28.0	East Puysegur Bank slope, 900–1000 m
9	122.0	East Puysegur Bank slope, 1000–1200 m
10	78.0	Central Puysegur Bank, steep slope
11	26.1	South Puysegur Bank hill (north)
12	8.2	South Puysegur Bank hill (south)
13	8.0	Snares Islands hill (north)
14	14.0	Snares Islands hill (south)
Total	829.3	

Treatment of catch

The catch at each station was sorted into species and weighed on motion-compensating electronic scales to the nearest 0.1 kg. When the large size of a catch made it impractical to weigh, total weights of orange roughy, black oreo, and smooth oreo were back-calculated from processed weight by use of MAF Fisheries conversion factors: orange roughy fillet, 4.0; black oreo dressed, 2.4; smooth oreo dressed, 2.4.

Samples of 6–8 cases of orange roughy were routinely measured and sexed. If a catch was large, several samples were taken from different parts of the net and later combined. This was because sex ratios and size can vary in different parts of the catch (Clark & Tracey 1989), and taking several samples can be more representative. Black and smooth oreo were also regularly measured and sexed.

From the sample at each tow, 20–30 orange roughy were taken at random and examined in greater detail: length, weight, sex, gonad weight, gonad stage, stomach fullness, degree of digestion of stomach contents, and prey items were recorded. Otoliths were collected, as well as samples of maturing gonads for fecundity estimation, and ripe gonads, heart, liver, and muscle for genetic studies. Samples of black and smooth oreo were also frequently examined in similar detail.

Biomass index estimation

Biomass indices were calculated by use of the area swept method as described by Francis (1981). Biomass, and its standard error, were calculated from the following formulae:

$$B = \Sigma\,(X_i a_i)/cb$$

$$S_B = \sqrt{\Sigma\, s_i^2 a_i^2 / c^2 b^2}$$

where B is biomass (t), X_i is the mean catch rate ($kg.km^{-1}$) in stratum i, a_i is the area of stratum i (km^2), b is the width swept by the gear (doorspread, m), c is the catchability coefficient (an estimate of the proportion of fish available to be caught by the net), S_B is the standard error of the biomass, S_i is the standard error of X_i.

Approximate 95% confidence limits (CL) were calculated as:

$$CL = B \pm 2S_B$$

The coefficient of variation ($c.v.$) is a measure of the precision of the biomass estimate, and is calculated by:

$$c.v. = S_B / B \times 100$$

The catchability coefficient, c, is the product of vulnerability (v), vertical availability (uv), and areal availability (u_a), as defined by Francis (1989). Values used in this report are: $v = 0.27$; $u_v = 1.0$; $u_a = 1.0$.

In the absence of information on the effect of trawl gear on orange roughy schools, the effective width of the gear was taken to be the wingend spread; thus, the vulnerability was set equal to the wingend spread divided by the doorspread. Vertical availability was assigned the value of 1.0, because no fish marks were observed above the headline of the net throughout the survey. Areal availability was taken as 1.0, because the estimated biomass was intended to apply only to the area surveyed.

Biological analyses

1. Length frequency distribution

Length frequency data have been scaled by percentage sampled to represent each catch and then further scaled by stratum biomass to represent the total population.

2. Reproductive stages

Gonad stages follow Pankhurst *et al.* (1987):

Stage	Female	Male
1	Immature/resting	Immature/resting
2	Early maturation	Early maturation
3	Maturation	Maturation
4	Ripe	Ripe
5	Running ripe	Spent
6	Spent	–

3. Feeding analyses

Data on frequency of occurrence and volume of prey have been combined into a single index (IV) (Vesin *et al.* 1981) to assess relative importance of prey:

$$IV = \sqrt{(\%\ \text{frequency})\ (\%\ \text{volume})}$$

Frequency of occurrence is the number of stomachs in which a prey item was found. Volume was assessed by eye as the proportion of stomach contents, where each stomach totalled 100%.

Results

Trip schedule

The vessel left Dunedin on 14 June, for a total of 42 days on the fishing grounds. Fishing started on 15 June around Puysegur Bank and Solander Trough (Table 4). Over a week was spent searching and trawling here before the vessel headed south to examine the area around the Snares Islands, some hills in the north Macquarie Ridge, and the slope near the Auckland Islands. Exploratory fishing continued in the third week south of Campbell Island, before the vessel headed back up the Macquarie Ridge to hills off the Snares Islands and to the southern Puysegur Bank.

A research trawl survey was carried out in the Puysegur Bank region during the fourth and fifth weeks. The final week of the trip was largely spent commercially fishing hills on the western side of Puysegur Bank, and some additional research survey tows were completed.

Total catch

A total of 131 trawls (exploratory, research, and commercial) was carried out during the trip. Detailed station data with catch information are given in Appendix I. The catch of all fish, shark, squid, and crustacean species combined was 710 194 kg. The main species caught was orange roughy, which at 385 402 kg constituted 54% of the total catch. Black oreo (197 942 kg, 28%) and smooth oreo (90 837 kg, 13%) were the major bycatch species. Catch weights of the 10 most abundant species are given in Table 5. A list of species caught during the trip is given in Appendix 2.

Exploratory fishing

Exploratory fishing and searching during the first 3 weeks covered a wide area from Puysegur Bank to south of Campbell Island.

The Puysegur Bank area was searched and fished extensively, and good catches were occasionally recorded on the western side and on separate hills to the south (e.g., tows 16, 23, and 24). The dominant species in each catch varied between orange roughy, smooth oreo, and black oreo.

Areas of slope on the western side of Stewart Island and the Snares Islands produced only low catch rates, and orange roughy caught there were fairly small (*see* "Size structure" below).

Few orange roughy were caught on hills on the Macquarie Ridge (catch rates were less than 20 kg.km^{-1}), but tow 44 caught 17.6 t of smooth oreo.

There is a large expanse of 800–1200 m bottom south of Campbell Island, and, though much time was spent steaming and searching in the area, it was not covered in detail. No promising marks were seen on the echosounder, and little was caught during the six trawls in the area. Some tows were repeats of those done by *Amaltal Explorer* during a hoki survey in July 1990, when several large prespawning orange roughy were recorded (MAF Fisheries, unpublished data). However, catches during this survey were very small, and no mature fish were found.

On the basis of catch composition, catch rates, and reproductive state found during this exploratory phase, it was decided that the most promising area for spawning aggregations of orange roughy was Puysegur Bank, and consequently this area was the focus of the research trawl survey.

Table 4: Trip schedule

Date		Area	Tow
June	14	Sail from Dunedin	
		Exploratory fishing	
	15–17	West and south Puysegur Bank areas	001–007
	18	Slope west of Stewart Island	008–009
	19–20	South Puysegur Bank hills	010–016
	21	East Puysegur Bank slope	017–020
	22–24	West Puysegur Bank	021–025
	25–26	Snares Islands slope and hills	026–031
	27–29	North Macquarie Ridge, Auckland Islands slope	032–037
July	30–2	Campbell Island area	038–043
	3–4	Macquarie Ridge, Snares Islands	044–046
		Research survey	
	5–7	South Puysegur Bank hills, Snares Islands hill	047–055
	8	East Puysegur Bank slope	056–064
	9–13	West Puysegur Bank, South Puysegur Bank hills	065–081
	14–15	Snares Islands hill	082–087
	16–17	West and South Puysegur Bank hills, steam to Bluff	088–097
	18–19	West Puysegur Bank	098–106
	20	East Puysegur Bank, South Puysegur Bank hills Complete phase I	107–109
	21–22	West Puysegur Bank hills and slope Complete phase II	110–120
		Commercial fishing	
	23–27	West Puysegur Bank	121–130

Research survey

Seventy-two tows were successfully completed during the research survey. Phase I comprised 57 tows, and there were 15 phase II tows (Table 6). Most phase II stations were in stratum 3 (1000–1200 m on the western side of Puysegur Bank). Some additional random tows were assigned to hills in strata 4, 5, and 6 to monitor progress of spawning. Station positions are shown in Figure 4.

Catch composition

Sixty-seven species of fish, shark, skate, squid, and crustacean were recorded, with a total weight of 383 098 kg. Orange roughy constituted 54.7% of this (209 500 kg), the other major species being black oreo (29.9%, 114 406 kg), smooth oreo (9.7%, 37 309 kg), and Baxter's lantern dogfish (*Etmopterus baxteri*) (3.5%, 13 489 kg).

Distribution and catch rates

1. Orange roughy

Orange roughy occurred throughout the survey area, but were most abundant on the western side of Puysegur Bank (Figure 5). Catch rates over 20 000 kg.km^{-1} (up to 50 000 kg.km^{-1}) were frequently recorded on the north hill in stratum 4, and fairly high catch rates were occasionally recorded on a hill to the southwest and on the slope to the west. Single large catches were also taken on the stratum 6 hill at the southern edge of Puysegur Bank and on the hill west of the Snares Islands (stratum 13). Catch rates were consistently low on the eastern side of Puysegur Bank.

Table 5: Total catch and percentage composition by weight of the 10 most abundant species taken during the trip (*see* Appendix 2 for scientific names)

Species	Catch (kg)	% of total
Orange roughy	385 402	54.3
Black oreo	197 942	27.9
Smooth oreo	90 837	12.8
Baxter's lantern dogfish	23 608	3.3
Deepsea cardinalfish	3 777	0.5
Plunket's shark	1 690	0.2
Smallscaled brown slickhead	1 550	0.2
Longnosed velvet dogfish	815	0.1
Ridgescaled rattail	711	0.1
Owston's spiny dogfish	673	0.1
All species	710 194	

Table 6: Distribution of survey tows among strata during phase I and phase II

Stratum	Phase I	Phase II
1	3	0
2	4	0
3	5	9
4	5	1
5	5	2
6	4	3
7	3	0
8	3	0
9	3	0
10	3	0
11	6	0
12	3	0
13	7	0
14	3	0
Total	57	15

2. Smooth oreo

Smooth oreo were also widely distributed (Figure 6). Catch rates never exceeded 10 000 kg.km^{-1}, but were often over 1000 kg.km^{-1} on hills throughout the survey area.

3. Black oreo

High catch rates of black oreo, up to 52 000 kg.km^{-1}, were recorded on a hill and slope on the western side of Puysegur Bank (Figure 7). Moderate catches were also taken on hills south of Puysegur Bank and near the Snares Islands.

Biomass indices

The biomass of orange roughy at the end of phase I was estimated at about 33 000 t (*CL* = 0–68 000 t, *c.v.* = 53%). Total biomass after phase II was estimated at 60 000 t, with a 95% confidence interval of 5000–115 000 t (Table 7). Recruited fish (larger than 32 cm) constituted 86% of this (about 52 000 t).

The biomass was concentrated in stratum 3, which accounted for 77% of the total (Table 8). This stratum was the largest in area, and there were several large catches in its western end which raised the mean catch rate. Other strata had similar catch rates (e.g., strata 5, 6, 11, and 13), but covered a smaller area. Higher catch rates were recorded in stratum 4, but the contribution to biomass was minor because the stratum was very small.

Biomass index estimates are given for black and smooth oreo (*see* Table 7), though the survey area and survey design were not developed for assessing these species.

Table 7: Biomass values (t) for orange roughy, smooth oreo, and black oreo

	Biomass	*CL*	*c.v.* (%)
Orange roughy			
Phase I			
All fish	32 938	0–67 844	53.0
Phase I + II			
All fish	60 027	4 847–115 207	45.9
1–32 cm	8 280	34–16 528	49.8
32–50 cm	51 746	4 562–98 930	45.6
Smooth oreo			
All fish	11 652	1 951–21 354	41.6
Black oreo			
All fish	39 887	0–100 676	76.2

Table 8: Catch rates and biomass of orange roughy (all fish) by stratum

Stratum	Area (km^2)	Mean catch rate (kg.km^{-1})	*s.d.*	Biomass (t)	Biomass (%)
1	71.0	3.7	4.7	13.2	< 0.1
2	62.0	325.0	632.6	1 007.4	1.7
3	346.0	2 668.0	5 907.4	46 156.9	76.9
4	2.0	23 372.5	18 216.2	2 337.3	3.9
5	23.0	2 456.5	3 352.5	2 825.0	4.7
6	21.0	2 517.6	5 732.9	2 643.5	4.4
7	20.0	28.3	48.6	28.3	< 0.1
8	28.0	2.9	0.7	4.1	< 0.1
9	122.0	4.7	3.5	28.6	< 0.1
10	78.0	275.5	469.6	1 074.5	1.8
11	26.1	1 703.7	3 436.6	2 223.3	3.7
12	8.2	114.8	61.8	47.3	< 0.1
13	8.0	4 085.0	9 071.2	1 634.0	2.7
14	14.0	5.0	5.7	3.6	< 0.1

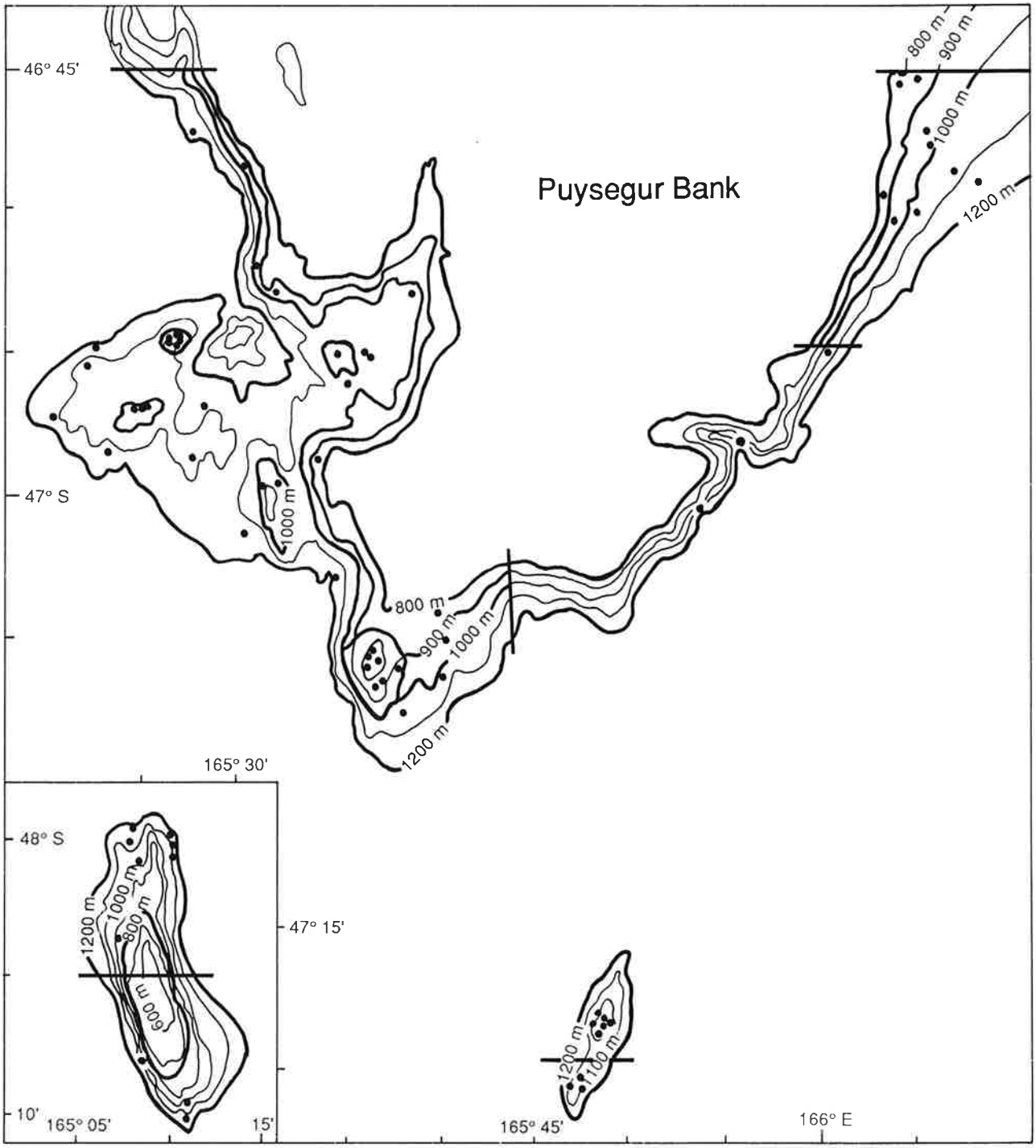

Figure 4: Station positions (vessel position, start of tow) in the research survey.

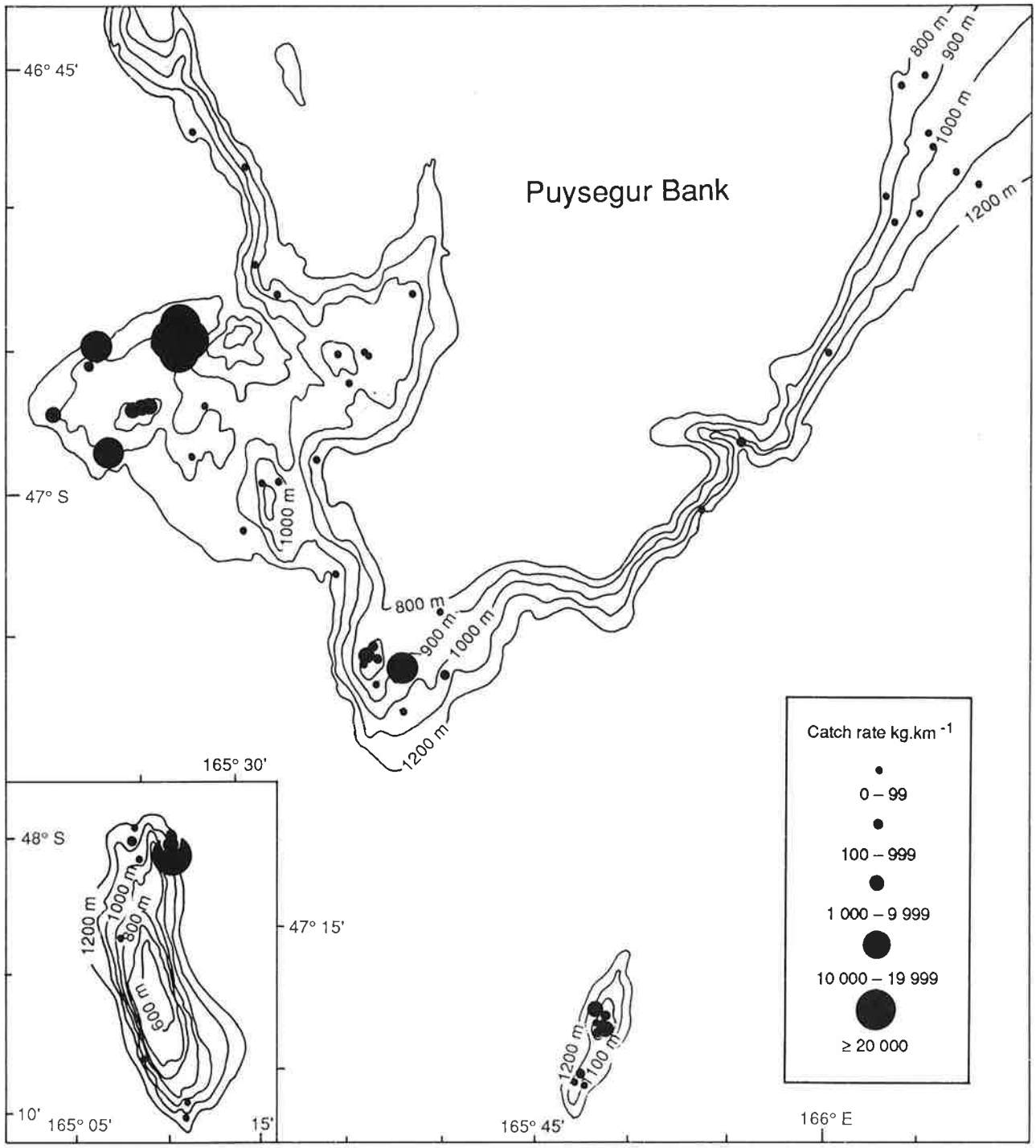

Figure 5: Catch rates (kg.km^{-1}) of orange roughy in the research survey tows.

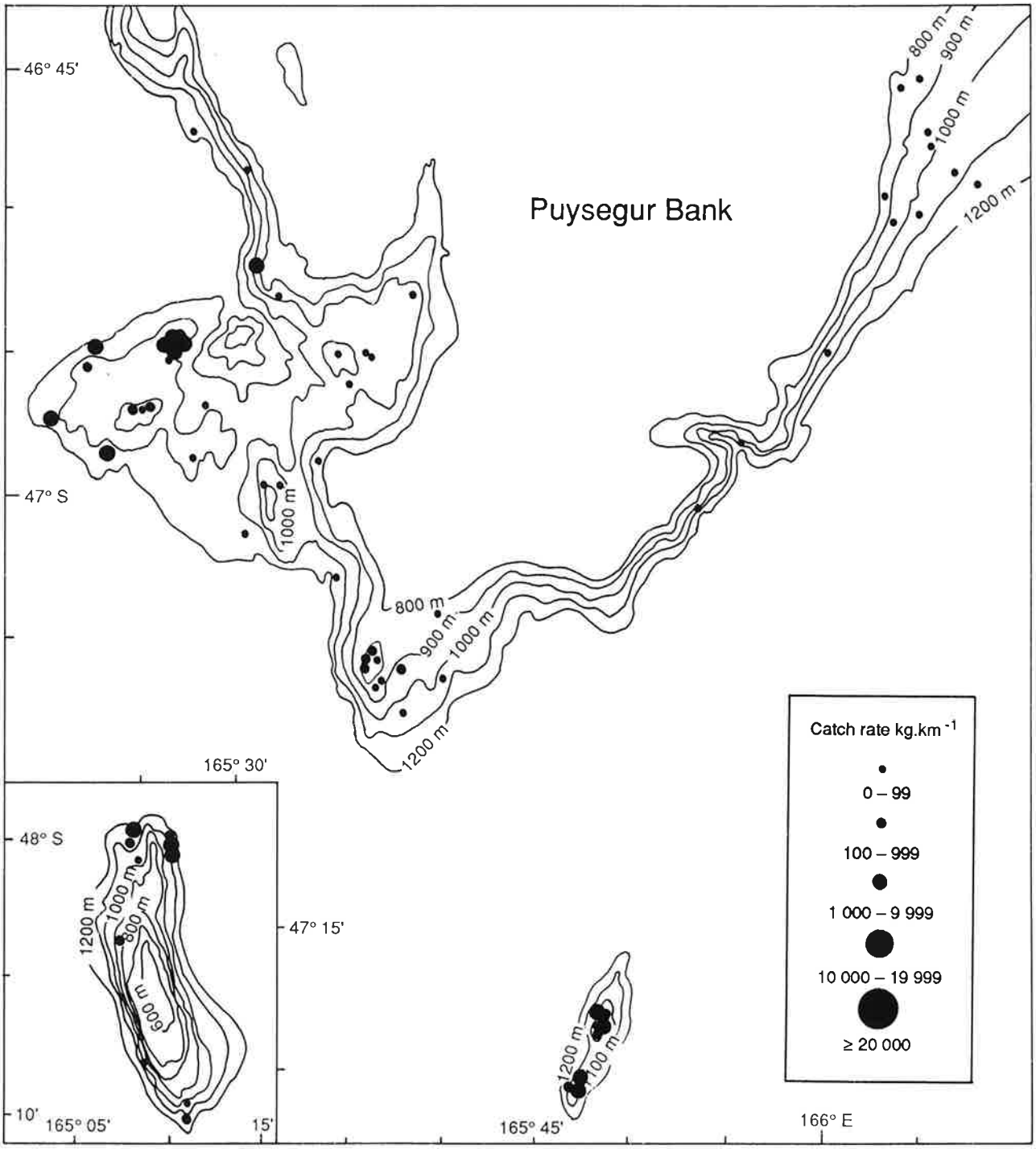

Figure 6: Catch rates (kg.km^{-1}) of smooth oreo in the research survey tows.

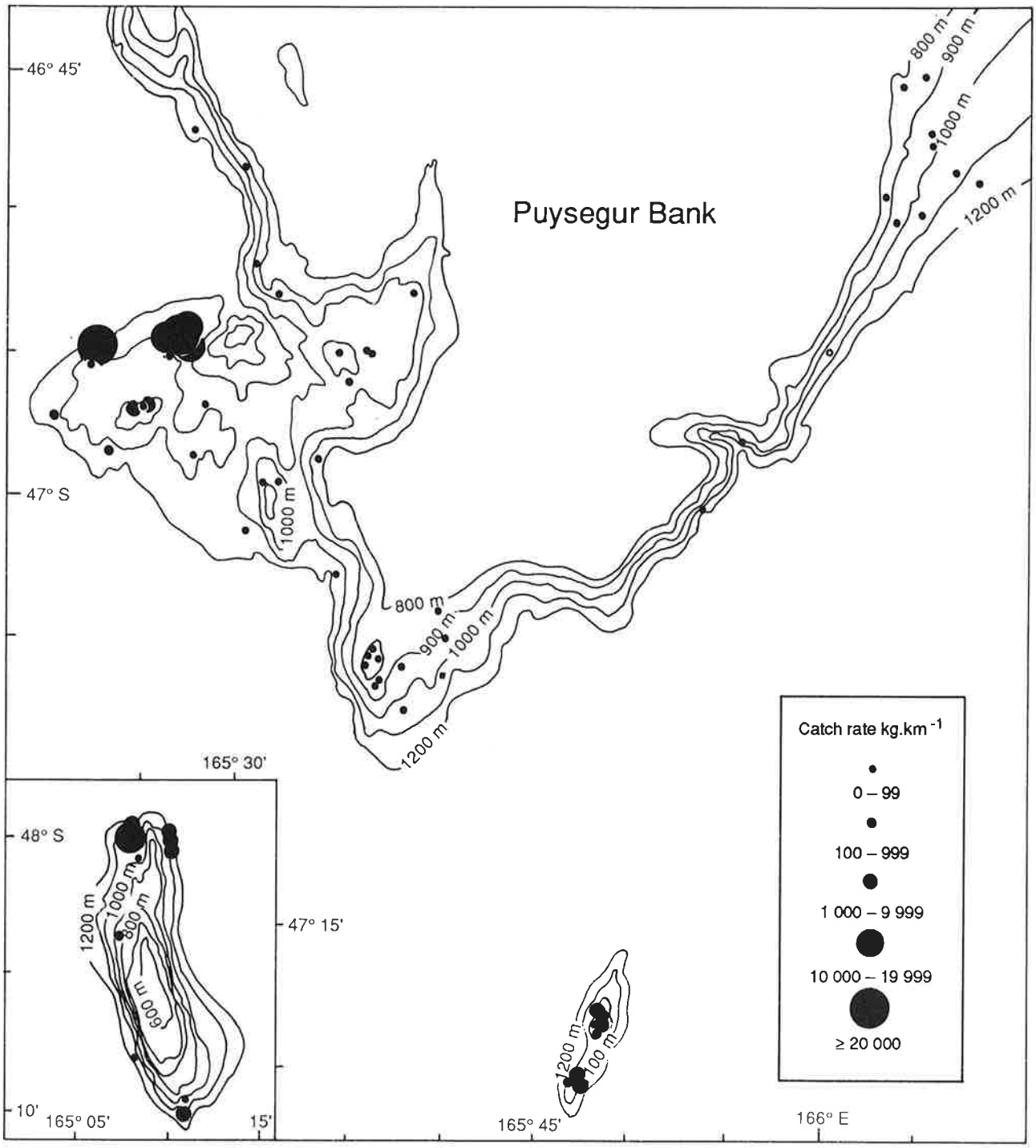

Figure 7: Catch rates (kg.km^{-1}) of black oreo in the research survey tows.

Size structure

1. Orange roughy

The weighted length frequency distribution of orange roughy from the survey stations is given in Figure 8. Fish size ranged from 16 to 49 cm. There was a strong unimodal distribution, with the peak at 34–35 cm.

Size structure varied within the survey area (Figure 9). Distributions were similar on the western and eastern Puysegur Bank and on the Snares Islands hill, with the modal peak at 34–35 cm; however, on the southern Puysegur hills, fish ranged in size from 21 to 49 cm, with a higher modal peak at 38–39 cm.

Outside the survey area, length frequency distributions were dominated by smaller fish (Figure 10). On the slope west of Stewart Island orange roughy ranged in size from 11 to 38 cm, with the peak at 23–24 cm. Fish from the Macquarie Ridge had a scattered distribution from 10 to 43 cm. Only two orange roughy were caught around Campbell Island; they were 22 and 30 cm long.

Sex ratios varied greatly between individual trawls. Overall, there were about equal proportions of males and females in the southern Puysegur Bank, more females on the western and eastern bank, and males dominated the Snares Islands hill region (differences have not been statistically tested).

Length-weight relationships for orange roughy (and black and smooth oreo) are given in Table 9.

Table 9: Length-weight regression equations for orange roughy, smooth oreo, and black oreo by sex for the survey area

Species	Sex	L-W regression*	n†	r^2‡
Orange roughy	Both	$W = 5.4 \times 10^{-2} L^{2.87}$	1894	0.97
	M	$W = 5.9 \times 10^{-2} L^{2.84}$	995	0.97
	F	$W = 5.3 \times 10^{-2} L^{2.88}$	899	0.97
Black oreo	Both	$W = 1.1 \times 10^{-2} L^{3.17}$	211	0.91
	M	$W = 2.4 \times 10^{-2} L^{2.96}$	94	0.88
	F	$W = 9.2 \times 10^{-3} L^{3.23}$	117	0.93
Smooth oreo	Both	$W = 1.6 \times 10^{-2} L^{3.07}$	211	0.96
	M	$W = 1.0 \times 10^{-2} L^{3.20}$	94	0.97
	F	$W = 2.5 \times 10^{-2} L^{2.95}$	117	0.94

* L = length (cm); W = weight (g).
† Sample size.
‡ Correlation coefficient.

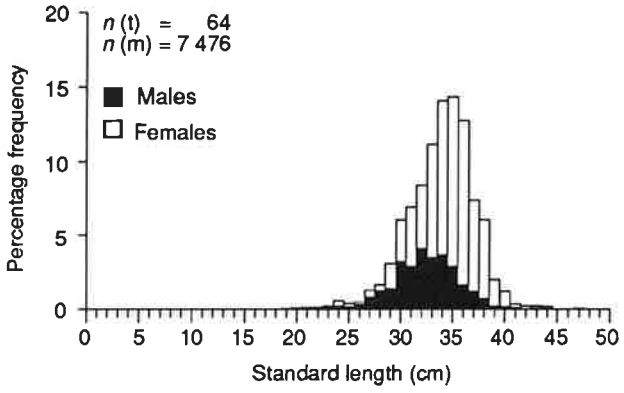

Figure 8: Length frequency distribution of orange roughy from the total Puysegur Bank survey area (scaled to represent the total population; n (t), number of trawls with samples; n (m), number of fish actually measured).

2. Smooth oreo

Smooth oreo ranged in size from 16 to 57 cm (Figure 11). They had a bimodal distribution, with peaks at 24 cm and 40–41 cm. The sex ratio overall was about even.

3. Black oreo

Black oreo had a unimodal distribution and ranged from 19 to 44 cm, with a peak at 34–36 cm (Figure 11). The sex ratio was even.

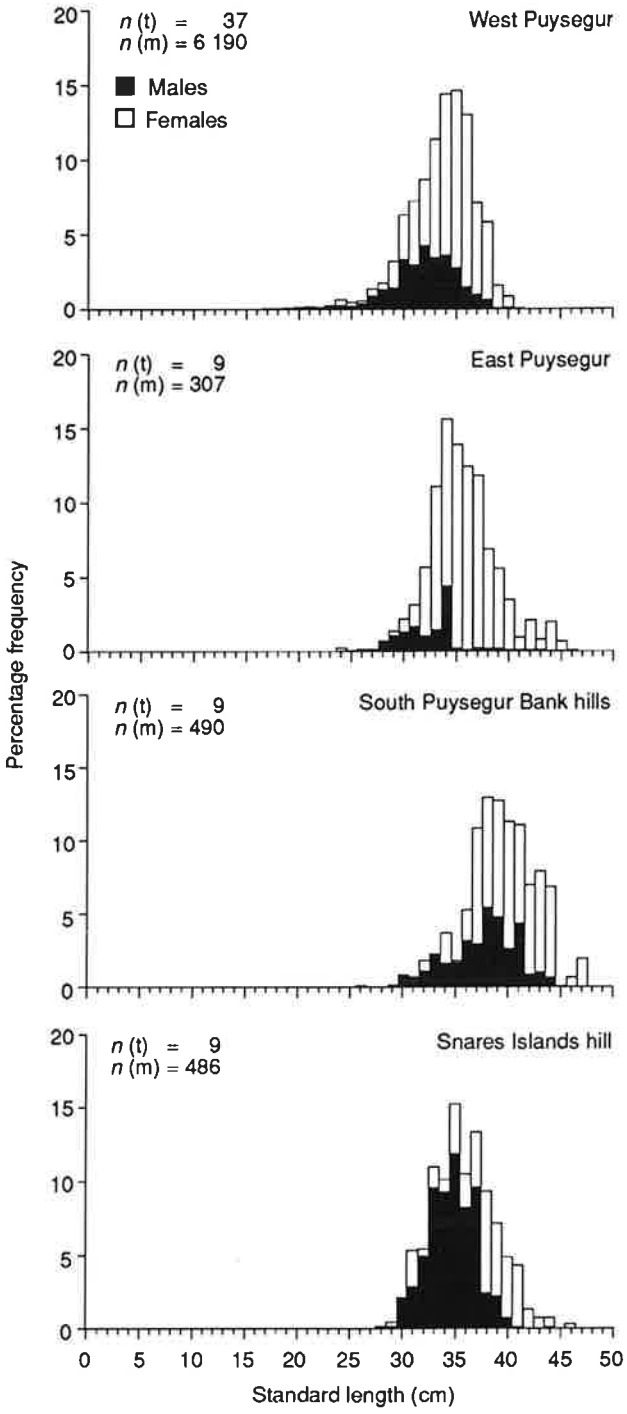

Figure 9: Length frequency distributions of orange roughy by area (scaled to represent the total population; n (t), number of trawls with samples; n (m), number of fish actually measured).

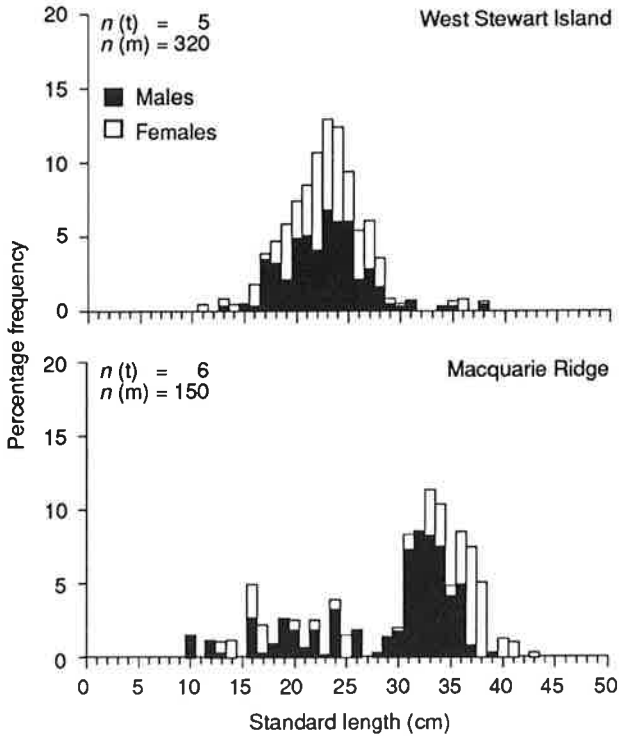

Figure 10: Length frequency distributions of orange roughy by area from west of Stewart Island and Macquarie Ridge (scaled to represent the total population; *n* (t), number of trawls with samples; *n* (m), number of fish actually measured).

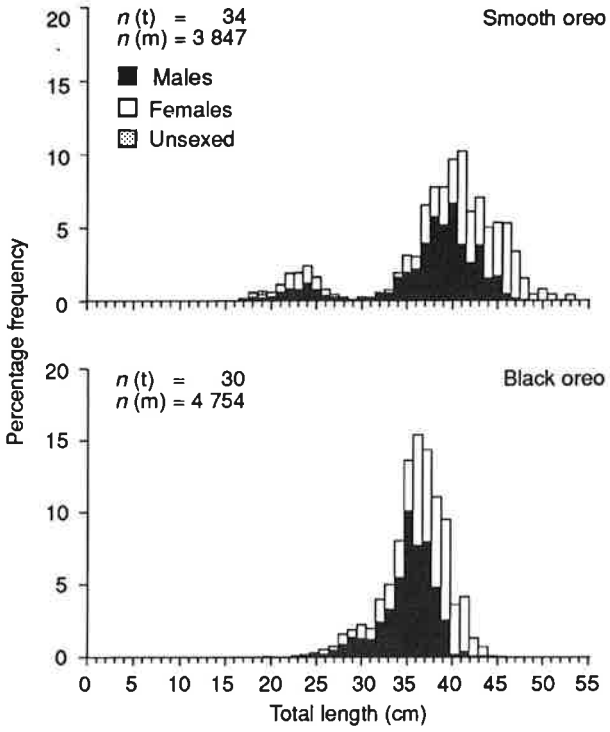

Figure 11: Length frequency distributions of smooth and black oreo from the Puysegur Bank survey area (scaled to represent the total population; *n* (t), number of trawls with samples; *n* (m), number of fish actually measured).

Reproduction

Gonadal development of orange roughy was monitored throughout the voyage. Proportions of gonad stages by sex by day in the Puysegur Bank to Snares hill region are shown in Figure 12. Data have been smoothed by applying a running median.

Reproductive stage shows a similar progression for both males and females. Maturing fish dominated samples throughout June and the first week of July. Ripe and running ripe fish began increasing in early July, peaking about the third week of July before declining. By the end of the survey at the end of July the proportion of spent fish had increased to over 60%. This suggests that the survey took place at the time of peak spawning.

For black and smooth oreos, both sexes of both species were predominantly in the early stages of maturation, and no advanced stage gonads were recorded.

Feeding

A total of 1895 orange roughy stomachs was examined, of which 44% contained food (Table 10). Many of the prey items, especially fish, were too digested for specific identification. Therefore, broad prey taxa are presented here. The most important dietary components of orange roughy were fish (*IV*% = 46), amphipods (especially *Eurythenes gryllus*) (*IV*% = 19), and natant decapod crustaceans (mainly shrimps of the genera *Sergestes* and *Acanthephyra*) (*IV*% = 16) (Table 11, Figure 13).

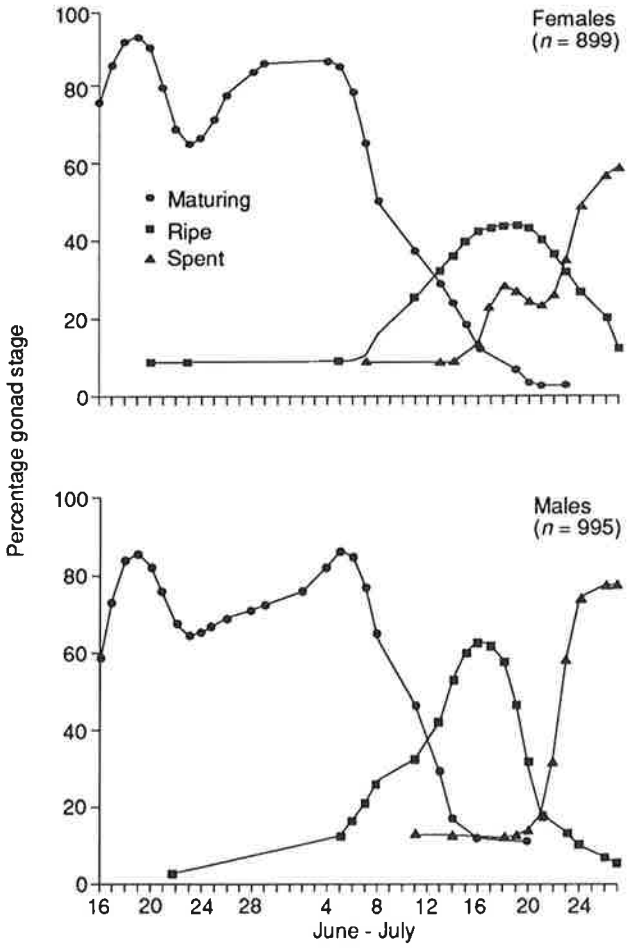

Figure 12: Daily changes in the proportion of gonad stages of orange roughy in the Puysegur Bank area (includes all tows).

Fewer (211 of each species) black and smooth oreo were examined. Only 33% of smooth oreo and 20% of black oreo stomachs contained prey (*see* Table 10). The diet of both species comprised salps, fish, natant decapod crustaceans, and small squid.

Table 10: Percentage stomach state of orange roughy, smooth oreo, and black oreo sampled during the survey

State	Orange roughy (n = 1 895)	Smooth oreo (n = 211)	Black oreo (n = 211)
Empty	55.3	49.8	20.4
Trace	1.2	1.9	–
Part-full	33.5	24.6	15.2
Full	9.6	6.2	5.2
Everted	0.4	17.5	59.2

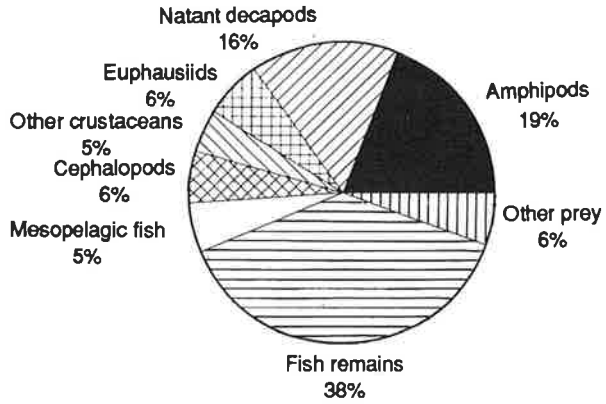

Figure 13: *IV*% index of major prey groups of orange roughy (835 stomachs contained food).

Genetics

Samples of heart, liver, and muscle were taken from orange roughy for electrophoretic analysis. Preliminary examination of these tissue samples showed a high level of genetic variation in the Puysegur Bank fish. Levels of genetic variation in these fish were higher than in fish collected from other orange roughy fisheries in 1988. There are significant differences in gene frequencies between the Puysegur Bank samples and similar samples from the Chatham Rise (Smith & Conroy, MAF Fisheries, unpublished data).

Samples of eggs were taken from running ripe females for DNA analyses. Preliminary analyses showed that most Puysegur Bank samples contained a DNA marker not found in orange roughy samples from the Chatham Rise and west coast South Island. This result provides strong evidence that the Puysegur Bank orange roughy are genetically isolated from other stocks (Smith & McVeagh, MAF Fisheries, unpublished data).

Ageing

Otoliths from orange roughy, smooth oreo, and black oreo were retained for ageing studies. These have not yet been examined.

Table 11: Major prey groups of orange roughy, frequency of occurrence, volume, and *IV* index* (n = number of fish, v = volume; number of stomachs with food = 835)

Prey group	Frequency n	Frequency %	Volume v	Volume %	*IV* index *IV*	*IV* index %
Crustacea						
Amphipoda	223	26.7	14 728	17.6	21.7	19.3
Decapoda Natantia	170	20.4	12 620	15.1	17.6	15.6
Isopoda	2	0.2	80	0.1	0.1	0.1
Euphausiacea	74	8.9	4 714	5.6	7.1	6.3
Mysidacea	22	2.6	1 690	2.0	2.3	2.0
Crustacean remains	51	6.1	3 780	4.5	5.2	4.6
Mollusca						
Cephalopoda Decapoda	56	6.7	4 505	5.4	6.0	5.3
Thaliacea						
Salpidae	2	0.2	80	0.1	0.1	0.1
Pisces						
Macrouridae	21	2.5	1 930	2.3	2.4	2.1
Mesopelagic group†	51	6.1	4 640	5.6	5.8	5.2
Other groups‡	9	1.1	850	1.0	1.1	1.0
Fish remains	384	46.0	33 723	40.4	43.1	38.2
Scales	1	0.1	60	0.1	0.1	0.1
Unidentified	1	0.1	100	0.1	0.1	0.1

* 835 stomachs contained food.
† Includes families Myctophidae, Malacosteidae, Stomiatidae, Chauliodontidae, Idiacanthidae, and Astronesthidae.
‡ Includes families Bathylagidae, Platytrocidae, Alepocephalidae, and Synaphobranchidae.

Discussion

The objectives of the trip were ambitious, because of the large area being investigated, with more detailed research survey work in the most promising regions. The trip combined these objectives well, considering the limited prior knowledge of bathymetry, fish distribution, and abundance and the limited time available.

Orange roughy were caught throughout the area from Puysegur Bank to south of Campbell Island. This extended information on their location and confirmed their widespread distribution throughout the New Zealand EEZ. Orange roughy were abundant only in the Puysegur Bank to Snares Islands region, though the more southern waters were not searched or fished in as much detail.

Biomass estimation

The estimation of biomass from the trawl survey is based on a mean catch rate for a given area of bottom swept by the trawl gear and extrapolated to represent a larger stratum area. There are several areas of uncertainty over the use of this technique to estimate the absolute abundance of fish.

The first relates to defining the effective area swept by the trawl gear. In this report wingend distance has been used (*see* "Methods" above). This assumes there is no herding of fish into the net by the trawl doors, sweeps, and bridles. If there is herding, the width of bottom swept by the gear will be greater than the wingend distance, each catch will come from a larger area of bottom, and the total biomass estimate will be too high.

Another aspect of the effective area swept is the "true" wingend spread. If the assumed net parameters are incorrect, then the biomass estimate will be incorrect. If the actual wingend spread is greater than assumed, the biomass estimate will be too high, and if wingend spread is less than assumed, the estimate will be too low. There is uncertainty in the wingend distance of the gear used in this survey: a value of 20 m has been used on the basis of flume tank trials, but very recent measurements of a similar net and gear set up on GRV *Tangaroa* using Scanmar distance-measuring equipment gave a wingend spread of 25–30 m (with a doorspread of 110–130 m) (MAF Fisheries, unpublished data). If 25 m is used, the biomass is 80% of that calculated by assuming a wingend spread of 20 m.

Vertical distribution of the fish is another factor related to the effective area swept. The area swept relates to the volume of water under the headline of the net. If fish occur above the height sampled by the net, then the biomass estimate will be too low. We observed no fish marks above the headline of the net, though orange roughy have been caught during other research surveys in midwater trawls over 50 m above the bottom. It is also possible that orange roughy are herded down towards the bottom by the warps and doors.

These uncertainties about behaviour and herding emphasise the need to treat data from individual trawl surveys in a relative, not absolute, sense, and to use changes in biomass indices over several years to estimate absolute abundance. This has been done, for example, with orange roughy on the Chatham Rise where stratified random trawl surveys have been carried out annually since 1984, and stock reduction analyses have related the change in survey biomass indices to the level of commercial catch, to obtain an estimate of absolute abundance.

In the present survey, strata were defined primarily on the basis of bathymetry, because few trawls had been carried out in the area before the survey. Hill features were each assigned their own stratum, or were combined into a multiple-hill stratum, and areas of slope were divided into depth zones. This was done using experience from other orange roughy fishing grounds and research surveys. In general, stratification appears appropriate, with the possible exception of stratum 3. This was a large area of 1000–1200 m bottom depth surrounding several hills. Catch rates were low throughout much of the stratum, but several large catches were taken on the western and southern side of the stratum towards the end of the survey. However, it is likely that this was due to fish moving off the hills after spawning (*see* below). Ten of the 14 trawls in the stratum had catch rates of less than 100 $kg.km^{-1}$, whereas 3 had rates over 1000 $kg.km^{-1}$. This stratum provided over 75% of the biomass estimate. If the three large catches were excluded (assuming the fish were dispersing off the hills, and they would have already been counted in the hill strata), there would be a substantial reduction in the overall biomass estimate: from 60 027 t (*c.v.* = 46%) to 21 865 t (*c.v.* = 38%).

There was also a major change between the first and second phases of the survey in the total biomass estimate and its distribution among strata. At the end of phase I, biomass of all orange roughy totalled 32 900 t, to which stratum 3 contributed 16 700 t (50%). Biomass almost doubled in phase II, and all of this 27 000 t increase came from stratum 3. The three large catches in stratum 3 were all during phase II.

This apparent movement of fish between strata during the survey means care is needed in using the overall biomass estimate as a relative index. If double counting has occurred, the total biomass estimate of 60 000 t is too high. A more realistic index is probably that of about 33 000 t from phase I, which was completed before there were signs of fish movement.

This value of 33 000 t would overall be our "best guess" mean estimate. It has a wide confidence interval (*CL* = 0–68 000 t) and is not necessarily a minimum biomass. The uncertainty in factors

discussed above means it cannot be considered a reliable estimate of absolute biomass. Additionally, we cannot be confident of applying results from the Chatham Rise stock reduction analyses to the present survey. Chatham Rise survey biomass indices have generally been about 69% of the estimated true biomass (Francis & Robertson 1991). However, there are differences between the Chatham Rise and Puysegur Bank surveys in the vessels used, the trawl gear set up, and the nature of the bottom (the relatively flat bottom on the north Chatham Rise compared with the predominance of hills and steep slope around Puysegur Bank), which may affect fish distribution, reaction to the trawl, and the performance of the trawl itself. In addition, the 69% figure includes a component to account for fish that were outside the Chatham Rise survey area at the time of the survey.

Size distribution

The length frequency distribution of orange roughy from the Puysegur Bank area (with a modal peak at 34–35 cm) is similar to that of fish from the north Chatham Rise and the Cook Canyon (Clark & Tracey 1988, Fenaughty & Grimes 1989, Field 1991). Orange roughy from the hill complex south of Puysegur Bank were larger than those in most other New Zealand areas.

There were larger black and smooth oreo taken during this survey than in surveys of the south Chatham Rise. Modal peaks of fish from Puysegur Bank compared with those from the Chatham Rise were 35 cm versus 28 cm for black oreo, and 41 cm versus 37 cm for smooth oreo (e.g., Fincham *et al.* 1987, Fenaughty *et al.* 1988).

Reproduction

The research survey clearly identified aggregations of spawning orange roughy. Gonad stages progressed from initial dominance of maturing fish, to ripe fish by the middle of July, to spent fish by the end of July. Spawning, defined by 20% of fish being spent, occurred about 20 July. This is similar to the north Chatham Rise, where spawning is typically mid to late July, and later than the other orange roughy spawning grounds (Ritchie Banks, Cook Canyon, and Challenger Plateau) (Clark 1990).

The research trawl survey intentionally covered the period of peak spawning. However, as discussed above, biomass estimates were markedly affected by several tows in stratum 3 late in the survey period, when most orange roughy were spent (Table 12). On the slope tows the proportion of ripe fish was very low and that of spent fish was high, in contrast with the proportions on the two hills. This suggests that it was unlikely that major spawning was taking place on the slope, and these data are consistent with fish moving off the hills into deeper water after spawning.

Table 12: Percentage of ripe and spent gonad stages for male and female orange roughy combined on hills (strata 4 and 5) and slope (western part of stratum 3) in the west Puysegur Bank area, 5–27 July

		July												
		5	8	11	16	18	19	20	21	22	23	24	26	27
Hills	Ripe	18	25	35	50	70	70	80	28	40	23		8	12
	Spent	0	0	3	5	25	10	20	26	30	50		77	88
Slope	Ripe					0			0			0	20	
	Spent					80			70			78	70	

The presence of aggregations of spawning orange roughy in mid to late July suggests that they are a separate stock from other orange roughy fisheries where the fish spawn at about the same time. The region is 280–300 n. miles south of Cook Canyon (on the west coast of the South Island) and about 800 n. miles southwest of the north Chatham Rise. These distances make movement between the areas within a spawning season unlikely.

General comments

Spawning in the Puysegur Bank region is associated with several small hills on a tongue of the bank surrounded on three sides by deep water. Bathymetry is complex and different from other known orange roughy spawning grounds in New Zealand waters. There are no large hills, such as on Ritchie Banks or Challenger Plateau, nor areas of flat or sloping bottom equivalent to the north Chatham Rise or Challenger Plateau, nor a large trench like Cook Canyon. The research survey covered most of the hills, small trenches, and "drop-off" areas identified during a systematic search and mapping of the region in the first 2 weeks of the trip. However, it does not preclude there being other areas of orange roughy spawning in the vicinity, though there were no indications from catch rate or gonad stage data of major activity away from the bank in the area surveyed.

Puysegur Bank and several hill complexes to the south appear to be productive multispecies areas. In addition to orange roughy, black and smooth oreo were regularly caught. Oreos dominated catches on several hills, especially south on the Macquarie Ridge. On Puysegur Bank, large catches were generally a mix of orange roughy, smooth oreo, and black oreo, with other major bycatch at times being black cardinalfish (*Epigonus telescopus*) and Baxter's lantern dogfish. It was not possible to distinguish species by marks on the echosounder, net monitor traces were often confusing, and the catch generally could not be predicted. This is a potential problem for fishing and managing this multispecies fishery.

Few heavy marks were seen on the echosounder during the trip, and there were no characteristic orange roughy marks or plumes, often typical of other spawning grounds. On only two occasions were heavy marks, which turned out to be orange roughy, seen on the net monitor when the gear landed on the bottom. Generally, marks on the monitor were

scattered, and orange roughy appeared hard down on the bottom and were difficult to distinguish from the more spiked oreo marks higher up towards the headline. Several large catches were taken with no marks on the monitor. These observations contrast with the common occurrence on some other spawning grounds of large, clean catches of orange roughy being regularly taken in tows of only a few minutes duration.

The trip achieved most of its objectives. Much information was obtained on bathymetry, distribution, abundance, and biology of several fish species. It was essentially the first exploratory orange roughy trip with research objectives into this area, and it raised as many, if not more, questions than it answered. Aggregations of spawning orange roughy were located. However, there were no indications of a population as large as those on the north Chatham Rise and Challenger Plateau. Nevertheless, there is the basis for an important commercial fishery. Reproductive stage and genetic results suggest that the population in the Puysegur Bank area is separate from other orange roughy fisheries, and it should be treated as a discrete unit for management purposes.

Future research

The research trawl survey was designed "on the spot", with very limited information apart from bathymetry. It provided much useful data, and provided a basis for future research to further evaluate and monitor the population. The main problem with the survey was the possible movement of fish between strata towards the end of the trip. A repeat of the survey would need to account for this: firstly, by sampling the slope areas more intensively earlier, to check whether there was a stable distribution on the hills; secondly, to finish earlier, before any postspawning movement occurred. On the basis of the timing of spawning observed during this survey, future surveys should intensively sample the area in the second to third weeks of July.

Our current knowledge of orange roughy behaviour in relation to trawl gear is inadequate to estimate absolute abundance from a one-off survey. Time series of comparable survey data, and accurate catch-effort information, are needed for stock assessment. In 1991 an agreement was made by industry to catch at least 5000 t of ORH 3B quota for the 1991–92 fishing year south of 46° S (essentially the Puysegur Bank area fishery), so there is a clear need for future research on this fishery.

Acknowledgments

We wish to thank skipper Mike Baker, first mate Dick Harris, and the crew of *Will Watch* for their excellent cooperation during the survey; other scientific staff (Andrew Hill, Alistair Lash, and Chris Carey from fishing companies and Allan Frazer from the University of Otago); and George Clement for organisation and liaison onshore. Thanks also to John Annala, Chris Francis, Don Robertson, John McKoy, and Geoff Baird (MAF Fisheries) for constructive comments on the manuscript. We also acknowledge The Exploratory Fishing Company (ORH 3B) Limited for permission to publish data and results in this report.

References

Clark, M. R. 1990: A review of stock structure of orange roughy (*Hoplostethus atlanticus*) in the New Zealand EEZ and Tasman Sea. MAF Fisheries Greta Point Internal Report No. 144. 16 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Clark, M. R. & Tracey, D. M. 1988: Report of a commercial fishing trip for orange roughy off the west coast of the South Island, June 1988. Fisheries Research Centre Internal Report No. 102. 21 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Clark, M. R. & Tracey, D. M. 1989: Report of an orange roughy trawl survey on the Challenger Plateau, July 1988. Fisheries Research Centre Internal Report No. 112. 42 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Fenaughty, J. M. & Grimes, P. J. 1989: Cruise report: northern Chatham Rise, July-August 1988. Fisheries Research Centre Internal Report No. 116. 43 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Fenaughty, J. M., Banks, D. A., Hart, A. C., & McMillan, P. J. 1988: Cruise report: the second stratified random bottom trawl survey of the south Chatham Rise, November 1987. Fisheries Research Centre Internal Report No. 99. 73 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Field, K. 1991: Catch sampling of orange roughy from New Zealand fisheries during 1988/89. MAF Fisheries Greta Point Internal Report No. 160. 35 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Fincham, D. J., Banks, D. A., & McMillan, P. J. 1987: Cruise report: stratified random bottom trawl survey of the southern Chatham Rise, 600–1200 m, 31 October-7 December 1986. Fisheries Research Centre Internal Report No. 74. 63 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Francis, R. I. C. C. 1981: Stratified random trawl surveys of deepwater demersal fish stocks around New Zealand. *Fisheries Research Division Occasional Publication No. 21.* 30 p.

Francis, R. I. C. C. 1984: An adaptive strategy for stratified random trawl surveys. *N.Z. Journal of Marine and Freshwater Research 18*: 59–71.

Francis, R. I. C. C. 1989: A standard approach to biomass estimation from bottom trawl surveys. N.Z. Fisheries Assessment Research Document 89/3. 4 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Francis, R. I. C. C. & Robertson, D. A. 1991: Assessment of the Chatham Rise (ORH 3B) orange roughy fishery for the 1991/92 season. N.Z. Fisheries Assessment Research Document 91/3. 36 p. (Draft report held in MAF Fisheries Greta Point library, Wellington.)

Kerstan, M. & Sahrhage, D. 1980: Biological investigations on fish stocks in the waters off New Zealand. *Mitteilungen aus dem Institut für Seefischerei der Bundesforschungsanstalt für Fischerei No. 29.* 168 p.

Pankhurst, N. W., McMillan, P. J., & Tracey, D. M. 1987: Seasonal reproductive cycles in three commercially exploited fishes from the slope waters off New Zealand. *Journal of Fish Biology 30*: 193–211.

Vesin, J.-P., Leggett, W. C., & Able, K. E. 1981: Feeding ecology of capelin (*Mallotus villosus*) in the estuary and western Gulf of St. Lawrence and its multispecies implications. *Canadian Journal of Fisheries and Aquatic Sciences 38*: 257–267.

Appendix 1: Individual station data and catch rates for orange roughy (ORH), smooth oreo (SSO), and black oreo (BOE)

Date	Station*	Time	Start of tow ° 'S	° 'E	Trawling time (min)	Depth (m) Min.	Max.	Direction of tow °T	Distance towed (n. mile)	Total catch (kg)	ORH catch (kg)	SSO catch (kg)	BOE catch (kg)
15/6/91	001 E	1715	46 49.04	166 05.97	32	800	1 025	084	1.75	9	0	0	0
16/6/91	002 E	0230	46 37.43	166 26.06	57	930	943	098	2.97	148	81	0	0
16/6/91	003 E	1427	46 55.88	166 01.34	12	855	1 080	093	0.56	87	13	0	0
16/6/91	004 E	1756	46 58 86	165 57.18	9	920	1 181	226	0.35	148	111	22	0
16/6/91	005 E	2207	47 18.38	165 47.51	3	930	1 020	277	0.16	2 990	419	806	1 742
17/6/91	006 E	0004	47 20.99	165 46.39	5	926	1 052	265	0.24	1 406	10	749	634
17/6/91	007 E	0346	47 20.70	165 48.61	6	924	1 080	064	0.25	4 482	59	1 843	2 534
17/6/91	008 E	1314	47 24.80	166 49.64	18	868	1 023	081	0.88	151	23	2	25
18/6/91	009 E	0902	47 07.44	166 56.99	30	1 020	1 026	018	1.38	108	39	0	0
19/6/91	010 E	0524	47 18.44	165 50.00	14	878	951	076	0.70	1 336	32	184	450
19/6/91	011 E	0857	47 18.47	165 49.83	15	874	1 009	078	0.67	690	204	70	326
19/6/91	012 E	1641	47 03.37	165 45.19	21	812	1 072	164	1.22	57	24	0	1
19/6/91	013 E	2040	47 18.11	165 47.99	7	865	1 026	307	0.33	4 642	9	486	341
20/6/91	014 E	0034	47 21.25	165 46.45	10	925	1 050	245	0.37	536	2	151	307
20/6/91	015 E	0402	47 18.68	165 47.81	5	876	972	254	0.30	2 091	199	267	1 489
20/6/91	016 E	0615	47 18.44	165 49.87	11	883	995	086	0.56	16 244	13 546	173	1 954
21/6/91	017 E	0639	46 49.18	166 06.17	31	801	1 023	092	1.55	79	35	1	0
21/6/91	018 E	1025	46 53.30	166 03.36	21	700	1 070	108	1.14	168	9	2	4
21/6/91	019 E	1352	46 58.81	165 57.24	8	888	1 100	212	0.34	965	822	52	0
21/6/91	020 E	1733	46 58.18	165 56.34	6	847	1 030	176	0.32	265	214	2	0
22/6/91	021 E	0208	46 47.32	165 29.57	29	701	1 153	257	1.14	59	11	0	0
22/6/91	022 E	0531	46 51.87	165 31.57	9	806	862	267	0.40	190	26	122	0
22/6/91	023 E	0832	46 55.03	165 28.16	4	975	1 028	082	0.14	41 314	39 005	1 728	581
23/6/91	024 E	1828	46 55.19	165 21.68	20	1 015	1 157	325	0.62	15 597	1 714	346	13 517
24/6/91	025 E	1756	46 54.95	165 26.05	9	958	1 025	272	0.34	10 675	979	1 037	8 606
25/6/91	026 E	0823	47 30.33	166 43.00	25	777	1 064	299	1.28	116	9	1	19
25/6/91	027 E	1535	47 38.04	166 25.21	21	710	1 149	294	1.01	122	12	0	0
25/6/91	028 E	2216	47 59.88	166 06.86	6	1 095	1 140	304	0.22	1 951	0	173	1 531
26/6/91	029 E	0449	48 00.22	165 10.77	3	910	983	98	0.22	2 317	916	88	961
26/6/91	030 E	0642	48 00.04	165 08.74	9	860	983	211	0.65	5 015	1 714	182	1 003
26/6/91	031 E	1449	48 09.14	165 11.39	21	994	1 150	198	0.99	35 584	13	20 477	14 645
27/6/91	032 E	1432	49 46.94	164 07.80	16	938	1 115	088	0.72	9	1	0	0
28/6/91	033 E	1246	50 58.59	164 34.62	61	950	1 070	046	2.47	378	84	193	4
28/6/91	034 E	1902	51 00.85	164 32.93	76	940	968	192	3.65	235	28	51	37
28/6/91	035 E	2301	50 57.29	164 36.34	14	990	1 038	041	0.57	79	37	23	4
29/6/91	036 E	0327	50 59.76	164 31.28	28	940	1 062	281	1.26	101	51	13	2
29/6/91	037 E	0803	51 03.58	164 30.78	23	971	1 074	286	1.16	7	2	4	0
30/6/91	038 †	1634	54 34.25	167 14.66	31	752	869	237	1.42	0	0	0	0
01/7/91	039 E	0619	53 42.85	170 16.12	53	881	911	100	3.00	90	0	1	0
01/7/91	040 E	0913	53 37.89	170 30.08	56	865	880	075	2.99	314	3	1	0
01/7/91	041 E	1138	53 35.93	170 41.49	51	775	778	120	3.02	284	0	0	0
01/7/91	042 E	1457	53 49.48	170 39.95	66	998	1 015	265	3.00	139	0	0	0
02/7/91	043 E	0459	53 36.85	167 54.81	59	912	928	298	2.97	208	2	4	0
03/7/91	044 E	1922	50 05.98	163 28.25	5	1 070	1 100	235	0.25	17 827	0	17 626	0
04/7/91	045 R	1330	48 09.28	165 11.42	18	1 026	1 107	189	0.82	5 862	4	1 267	4 330
04/7/91	046 R	1655	48 00.26	165 10.75	6	861	980	108	0.26	16 940	11 750	1 055	2 398
05/7/91	047 R	0156	47 18.41	165 49.98	7	908	987	075	0.30	452	77	174	90
05/7/91	048 R	0450	47 19.56	165 49.30	9	902	968	181	0.44	3 496	96	752	770
05/7/91	049 E	0711	47 21.59	165 48.22	4	937	962	141	0.21	1 106	19	374	652
05/7/91	050 R	1157	46 54.91	165 25.98	9	959	1 037	273	0.39	24 624	16 565	2 650	5 407
06/7/91	051 R	0554	47 59.67	165 08.73	5	861	940	270	0.22	7 137	55	407	4 840
06/7/91	052 R	0859	48 00.03	165 10.62	6	861	960	088	0.25	7 419	1 795	720	3 313
06/7/91	053 R	1733	47 18.96	165 47.86	14	871	1 120	243	0.70	118	6	23	26
06/7/91	054 †	2115	47 21.51	165 48.43	10	962	1 120	119	0.43	253	2	59	169
07/7/91	055 R	0248	47 18.48	165 49.95	16	864	1 050	082	0.83	7 440	1 958	1 555	2 323
07/7/91	056 R	1623	46 49.55	166 05.10	30	829	861	182	1.46	526	228	25	28
07/7/91	057 R	1938	46 47.55	166 07.40	34	945	980	194	1.50	64	6	0	2
07/7/91	058 R	2320	46 44.50	166 08.07	37	842	887	191	1.55	105	1	1	8
08/7/91	059 R	0430	46 50.22	166 07.00	32	1 014	1 079	194	1.48	83	11	16	0
08/7/91	060 R	0735	46 50.66	166 05.28	30	906	952	203	1.54	69	10	0	0
08/7/91	061 R	1021	46 47.83	166 07.44	35	944	970	200	1.49	32	9	2	0
08/7/91	062 R	1249	46 49.51	166 07.79	36	1 000	1 127	110	1.48	95	23	0	0
08/7/91	063 R	1515	46 48.59	166 09.22	35	1 065	1 130	174	1.55	53	4	0	0
08/7/91	064 R	1750	46 44.56	166 07.47	31	823	855	205	1.52	91	1	0	0
08/7/91	065 R	2157	46 54.77	165 26.16	13	970	1 047	285	0.46	40 068	34 010	2 650	3 326

Appendix 1—*continued*

Date	Station*	Time	Start of tow ° 'S	° 'E	Trawling time (min)	Depth (m) Min.	Max.	Direction of tow °T	Distance towed (n. mile)	Total catch (kg)	ORH catch (kg)	SSO catch (kg)	BOE catch (kg)
10/7/91	066 R	1404	46 47.33	165 28.71	24	1 161	1 168	158	1.01	35	1	0	0
10/7/91	067 R	1600	46 48.76	165 31.45	17	818	892	163	0.70	260	1	0	0
10/7/91	068 R	1754	46 53.35	165 32.89	27	904	1 004	127	1.19	89	24	0	1
10/7/91	069 R	2108	46 52.11	165 31.49	9	786	858	258	0.45	2 813	22	1 152	0
10/7/91	070 R	2313	46 55.77	165 37.66	33	994	1 048	024	1.52	54	15	16	1
11/7/91	071 R	0152	46 55.12	165 27.94	4	970	1 080	094	0.20	38 855	18 605	677	19 464
12/7/91	072 †	1305	46 53.58	165 41.55	12	791	835	201	0.62	12	1	0	5
13/7/91	073 R	0639	46 52.34	165 39.56	20	897	983	197	0.96	69	11	0	0
13/7/91	074 R	0835	46 54.44	165 38.80	31	1 051	1 062	194	1.56	92	31	0	1
13/7/91	075 R	1103	47 03.29	165 35.58	33	1 016	1 192	308	1.37	54	8	0	0
13/7/91	076 E	1317	47 06.45	165 38.81	32	902	963	211	1.51	8 293	8 160	61	0
13/7/91	077 E	1605	47 07.30	165 38.39	43	872	1 106	149	2.12	168	118	3	0
13/7/91	078 E	1931	47 06.08	165 38.38	11	769	850	132	0.41	6 624	6 202	110	1
14/7/91	079 R	0036	47 20.76	165 46.44	8	928	1 141	302	0.40	372	46	204	104
14/7/91	080 R	0223	47 20.40	165 47.98	9	920	950	028	0.34	2 329	115	1 094	1 040
14/7/91	081 R	0507	47 18.25	165 47.90	5	876	965	297	0.27	10 588	4 325	643	4 504
14/7/91	082 R	1228	47 59.61	165 10.82	5	900	990	086	0.26	1 149	81	63	881
14/7/91	083 R	1515	48 03.24	165 07.67	29	701	1 002	316	1.54	1 068	18	329	598
15/7/91	084 R	1100	48 08.63	165 11.40	19	904	1 000	182	0.71	153	2	28	95
15/7/91	085 R	1311	48 07.94	165 08.72	15	791	1 166	233	0.63	100	13	8	68
15/7/91	086 R	1519	48 00.14	165 08.67	29	868	1 132	353	1.25	77	2	5	31
15/7/91	087 R	1738	47 59.19	165 08.95	14	864	1 154	305	0.83	11 504	8	2 762	8 670
16/7/91	088 R	0140	47 01.66	165 54.33	11	880	1 109	141	0.51	231	8	9	88
16/7/91	089 R	0408	47 06.17	165 36.68	10	740	754	261	0.44	575	8	108	0
16/7/91	090 R	0532	47 05.70	165 37.62	31	742	848	022	1.55	2 180	1 061	218	0
16/7/91	091 E	0754	47 06.48	165 36.74	22	734	880	223	1.02	572	45	259	1
16/7/91	092 R	0950	47 05.33	165 41.36	35	908	970	048	1.52	3 867	3 586	67	1
16/7/91	093 R	1414	46 57.66	165 37.03	36	889	986	001	1.56	71	25	3	0
16/7/91	094 R	1846	46 54.45	165 35.55	22	896	1 093	004	0.98	63	27	4	0
16/7/91	095 R	2114	46 54.06	165 27.14	3	992	1 031	000	0.19	10 073	2 442	2 194	5 386
17/7/91	096 R	0329	47 20.64	165 48.35	9	917	1 097	055	0.48	8 025	88	1 843	5 980
17/7/91	097 R	0829	47 06.53	165 37.71	26	738	957	137	1.51	533	162	84	57
18/7/91	098 E	0336	46 48.58	166 04.97	28	755	925	100	1.45	171	11	1	0
18/7/91	099 R	0606	46 55.81	166 01.09	8	788	895	081	0.27	63	0	0	0
18/7/91	100 R	1149	47 00.75	165 31.05	21	898	1 070	221	0.98	190	112	5	6
18/7/91	101 R	1405	46 54.82	165 28.08	7	970	1 043	063	0.35	11 780	9 510	1 958	211
18/7/91	102 R	1815	46 57.66	165 20.71	27	1 069	1 135	257	1.20	14 707	10 690	3 629	317
19/7/91	103 R	0403	46 56.69	165 25.33	34	962	1 044	354	1.58	19 905	19 013	288	211
19/7/91	104 R	1509	46 59.05	165 34.49	30	801	900	019	1.44	77	24	27	13
19/7/91	105 R	1823	47 04.28	165 40.83	32	799	875	222	1.58	226	6	10	3
19/7/91	106 R	2037	47 06.15	165 38.72	13	820	905	128	0.60	17 675	17 218	119	0
20/7/91	107 R	0215	46 58.36	165 57.75	21	809	1 217	218	0.97	1 518	1 469	23	0
20/7/91	108 R	0807	47 18.43	165 49.81	21	867	1 028	076	0.69	1 445	48	310	368
20/7/91	109 R	1208	46 56.79	165 24.87	19	957	1 008	001	0.73	16 246	10 390	579	4 814
20/7/91	110 R	2230	47 00.40	165 28.58	34	1 082	1 157	159	1.52	28	10	0	9
21/7/91	111 R	0040	46 56.80	165 25.50	28	952	1 038	356	1.29	13 182	6 921	457	4 494
21/7/91	112 R	0833	46 58.67	165 28.12	34	1 063	1 074	260	1.54	88	15	0	18
21/7/91	113 R	1210	46 54.60	165 27.61	9	977	987	075	0.35	9 706	3 590	1 094	4 928
21/7/91	114 R	1843	46 56.34	165 22.22	44	1 037	1 121	292	1.55	1 405	490	461	200
21/7/91	115 R	2121	46 59.98	165 33.13	14	882	1 008	066	0.70	63	18	15	7
21/7/91	116 R	2313	47 06.74	165 37.96	34	772	1 000	139	1.57	561	400	44	1
22/7/91	117 R	0128	47 05.44	165 36.52	5	741	764	320	0.22	1 551	411	95	0
22/7/91	118 R	0430	47 07.65	165 39.11	34	1 023	1 059	218	1.53	220	141	4	0
22/7/91	119 R	0714	47 06.06	165 42.53	33	1 028	1 124	211	1.52	522	407	18	1
22/7/91	120 R	1017	47 05.20	165 36.25	17	789	938	305	0.75	1 132	757	253	0
22/7/91	121 C	1437	46 56.57	165 25.39	20	959	1 037	011	1.04	24 943	20 890	864	2 429
23/7/91	122 C	1034	46 54.79	165 25.92	6	964	1 045	277	0.23	4 873	2 938	691	1 214
23/7/91	123 C	1738	46 56.57	165 25.35	23	957	1 032	008	1.02	36 241	31 797	979	2 904
24/7/91	124 R	1529	46 57.15	165 28.74	32	1 094	1 123	023	1.52	314	126	62	73
24/7/91	125 R	1737	46 55.13	165 21.72	11	1 028	1 100	309	0.54	46 825	18 789	3 380	24 564
26/7/91	126 C	0238	46 56.73	165 26.00	19	959	1 010	021	0.97	132	7	33	0
26/7/91	127 C	0621	46 55.05	165 28.09	4	954	998	101	0.21	16 602	8 459	634	7 445
26/7/91	128 R	1957	46 58.78	165 23.64	11	1 020	1 091	216	0.47	13 629	11 586	1 670	317
27/7/91	129 R	0522	46 56.11	165.27.55	25	1 002	1 173	051	1.34	92	13	2	22
27/7/91	130 C	0751	46 58.78	165 23.58	14	1 013	1 114	215	0.73	3 548	1 795	1 282	1
27/7/91	131 C‡	0957	46 56.50	165 25.33	4	972	977	002	0.17	54 350	35 000	1 300	18 000

* E, exploratory fishing; R, research survey tow; C, commercial fishing; †, fast, gear damage; ‡, some fish loss, total catch estimated.

Appendix 2: Species caught during the trip

Crustacea

Lithodes murrayi (southern stone cab)
Sergestes sp.

Cephalopoda

Moroteuthis spp. (warty squid)
Histioteuthis spp. (violet squid)
Ommastrephes bartrami (red squid)
Cranchiidae (cranch squid)
Mastiogoteuthis sp.

Octopoda

Octopoteuthis sp.

Chondrichthyes

Selachiformes

Centrophorus squamosus (leafscaled gulper shark)
Centroscymnus coelolepis (Portuguese spiny dogfish)
C. crepidater (longnosed velvet dogfish)
C. owstoni (Owston's spiny dogfish)
C. plunketi (Plunket's shark)
Centroscymnus sp. A (roughskinned *Centroscymnus*)
Dalatias licha (seal shark)
Deania calcea (shovelnosed spiny dogfish)
Etmopterus baxteri (Baxter's lantern dogfish)
E. lucifer (Lucifer spiny dogfish)
Apristurus sp. A (catshark)
Apristurus sp. B (catshark)
Apristurus sp. C (catshark)
Apristurus sp. D (catshark)

Rajiformes

Bathyraja shuntovi (pale longnosed skate)
Pavoraja spp.

Chimaeriformes

Hydrolagus sp. B (pale ghost shark)
Hydrolagus sp. C (purplefinned *Hydrolagus*)
Chimaera phantasma (giant chimaera)
Harriotta raleighana (longnosed chimaera)
Rhinochimaera pacifica (widenosed chimaera)

Osteichthyes

Anguilliformes

Diastobranchus capensis (basketwork eel)
Serrivomer sp. (sawtooth eel)
Notacanthus sexspinis (spineback eel)

Salmoniformes

Bathylagus spp. (deepsea smelt)
Alepocephalus australis (smallscaled brown slickhead)
Alepocephalus sp. (bigscaled brown slickhead)

Stomiiformes

Chauliodus sloani (viperfish)
Opostomias micripinis (giant black dragonfish)
Stomias boa (scaly dragonfish)

Aulopiformes

Alepisaurus brevirostris (shortsnouted lancetfish)

Gadiformes

Mora moro (ribaldo)
Antimora rostrata (violet cod)
Halargyreus johnsoni (Johnson's cod)
Lepidion microcephalus (smallheaded cod)
L. schmidti (giant lepidion)
Merluccius australis (hake)
Macruronus novaezelandiae (hoki)
Trachyrincus spp. (white rattail)
Caelorinchus bollonsi (Bollons's rattail)
C. fasciatus (banded rattail)
C. innotabilis (notable rattail)
C. kaiyomaru
C. matamua (Mahia rattail)
C. oliverianus (Oliver's rattail)
Coryphaenoides serrulatus (serrulated rattail)
C. subserrulatus (fourrayed rattail)
Lepidorhynchus denticulatus (javelinfish)
Macrourus carinatus (ridgescaled rattail)
Nezumia namatahi (squashedfaced rattail)
N. bubonis (bulbous rattail)
Mesobius antipodum (black javelinfish)

Ophidiiformes

Genypterus blacodes (ling)

Beryciformes

Hoplostethus atlanticus (orange roughy)

Zeiformes

Capromimus abbreviatus (capro dory)
Pseudocyttus maculatus (smooth oreo)
Neocyttus rhomboidalis (spiky oreo)
Allocyttus niger (black oreo)

Lampridiformes

Trachipterus (dealfish)

Scorpaeniformes

Helicolenus spp. (sea perch)

Perciformes

Rosenblattia robusta
Epigonus telescopus (black cardinalfish)
Benthodesmus sp. (slender frostfish)
Trachurus declivis (jack mackerel)
Centrolophus niger (rudderfish)
Schedophilus huttoni
Tubbia tasmanica
Seriolella brama (common warehou)
S. caerulea (white warehou)

Pleuronectiformes

Mancopsetta sp. (finless flounder)

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