Orange Roughy Trawl Survey Challenger Plateau and West Coast South Island, 1983

D. M. Tracey, P. J. McMillan, J. H. Armstrong, and D. A. Banks

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Tracey, D. M., McMillan, P. J., Armstrong, J. H., and Banks, D. A. 1990: Orange roughy trawl survey: Challenger Plateau and west coast South Island, 1983. *N.Z. Fisheries Technical Report No. 22.* 34 p.

A single-phase stratified random bottom trawl survey of orange roughy on the Challenger Plateau was carried out during four cruises between 23 August and 28 October 1983. Data from 177 trawl stations provided biomass estimates and biological results. Orange roughy were widely distributed on the plateau and made up 62% of the biomass of all fish species caught. Catch rates of orange roughy were low; only three stations had catch rates greater than 300 $kg.km^{-1}$. Most orange roughy sampled were in post-spawning condition. Salinity and temperature data collected on the plateau in June-July 1983 are described. Summaries of orange roughy research before August 1983, management on the Challenger Plateau, and development of the orange roughy fishery to the end of 1984 are discussed.

Introduction

Before 1982 there was little fishing on the Challenger Plateau west of New Zealand, and it was generally unrewarding. By 1982 more extensive exploratory fishing suggested that a potential orange roughy (*Hoplostethus atlanticus*) fishery existed on the Challenger Plateau. Ministry of Agriculture and Fisheries (MAF) staff, especially the late W. L. F. van den Broek, were involved in the exploratory work which led to the development of the orange roughy fishery.

When the presence of commercial concentrations of orange roughy on the Challenger Plateau became generally known, the area attracted growing interest from companies which wished to expand their fishing activities in the area. Before any such unregulated expansion could take place, it was important to carry out detailed research in the area to measure the distribution, abundance, and population parameters of orange roughy.

Therefore, in 1983 a stratified random trawl survey was carried out on the Challenger Plateau to estimate relative abundance of orange roughy.

This report discusses the research, management, and commercial fishing for orange roughy on the Challenger Plateau before 1984. Included are:

1. a summary of trawl and hydrological research carried out by New Zealand and other nations;
2. a summary of commercial fishing catches made during 1983;
3. a discussion of the management history for the fishery;
4. a detailed description of the 1983 stratified random trawl survey carried out by MAF Fisheries Greta Point (formerly Fisheries Research Centre) staff on the chartered trawler *Arrow*;
5. a description of results of a hydrological survey made during June-July 1983 on the research vessel *James Cook*.

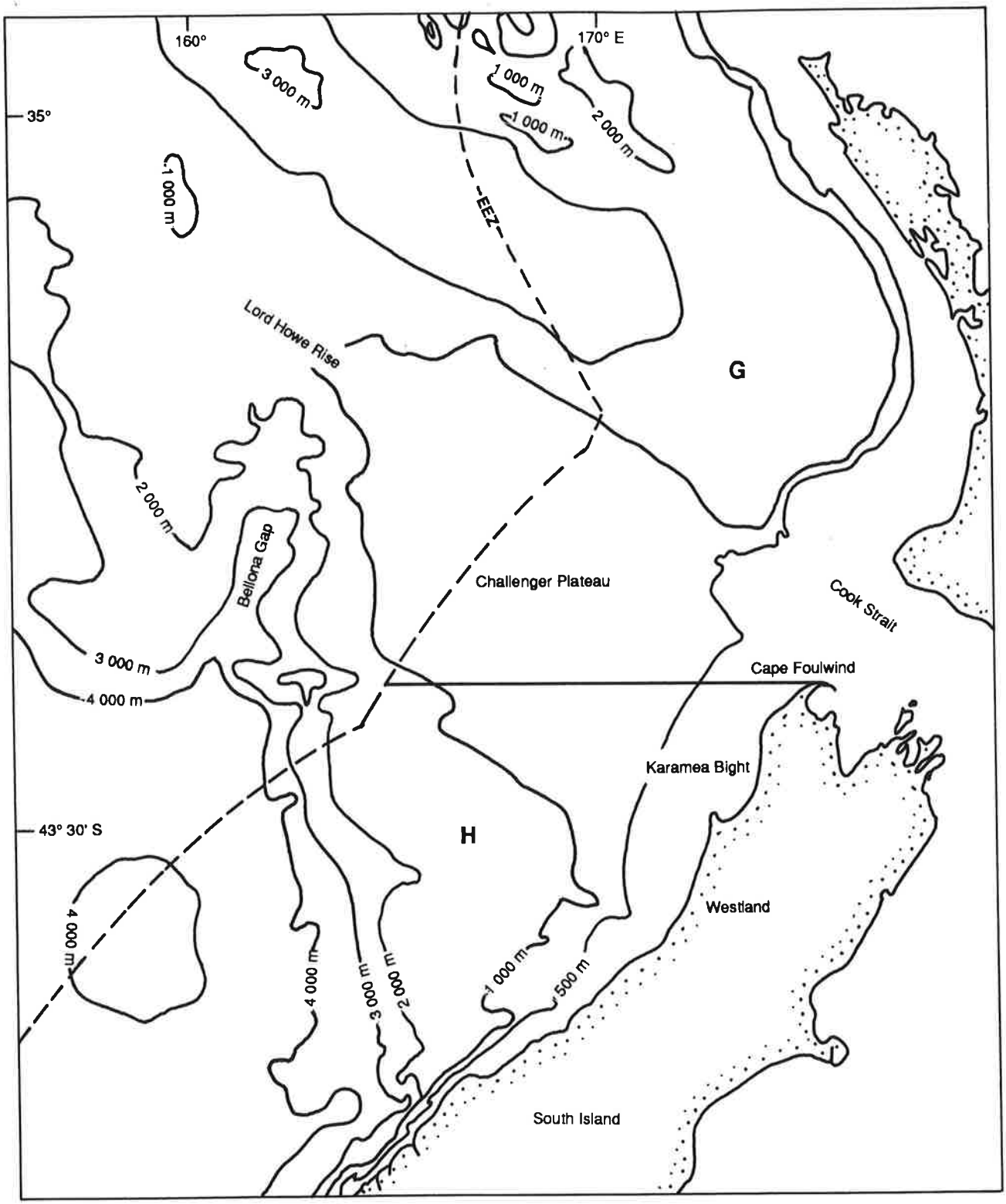


Figure 1: Challenger Plateau and west coast South Island, showing places mentioned in the text and EEZ areas G and H.

The Challenger Plateau and west coast South Island fishery

Physical features

The Challenger Plateau is a broad submarine feature defined by Wanoa and Lewis (1972) as "the shoaler, southeastern portion of the Lord Howe Rise, extending from the foot of the continental slope off western Cook Strait to the Bellona Gap". The plateau is centred on 38° 30 ′ S, 168° 30 ′ E and includes waters inside and outside the New Zealand 200 n. mile Exclusive Economic Zone (EEZ) areas G and H (Figure 1). It rises to depths of 400–500 m. West and southwest of Cape Foulwind the southern flank of the plateau merges with the steeper slope bathymetry off Westland (Probert and Swanson 1983).

The area discussed in this report is bounded to the north and west by the 1250 m depth contour of the Challenger Plateau and the west coast South Island, to the south by a line at 43° 30 ′ S, and to the east by the 750 m depth contour of the continental slope.

Research before 1983

The early survey work on the Challenger Plateau provided data on the number of trawls and catches within the orange roughy depth range of 700–1200 m. Meaningful comparisons between cruises were difficult due to different sampling strategies, vessel size and gear, time, and insufficient biological data. Early hydrological surveys have also been listed, but no detailed use and comparison have been made of the data. Most early research survey results are from either unpublished data held in the form of cruise reports at MAF Fisheries Greta Point (Wellington), *Catch* articles, or from Japanese reports. Early Soviet research (Shuntov 1979) concluded that fish resources in the New Zealand region were sufficient for the development of fishing. However, there was no reference to any early Soviet research carried out on the Challenger Plateau in the depth range occupied by orange roughy. More specific historical detail of the southern region of the Challenger Plateau, off Westland, is described in Armstrong and Tracey (1986).

Trawl surveys

A summary of the research vessel catch rates on the Challenger Plateau from August 1975 to August 1983 is given in Table 1.

The Japan Marine Fishery Resource Research Center (JAMARC) exploratory fishing stern trawler *Shinkai Maru* fished the deeper waters of the plateau in 1975 and 1976 and caught orange roughy in the depth range 695–1000 m (JAMARC 1976 and 1979) (Figure 2a). The 1975 August-November survey reported 512 kg of orange roughy at a catch rate of 10 kg.km^{-1} trawled. The 1976 *Shinkai Maru* survey in June was more successful; 3392 kg of orange roughy were landed from seven stations at a catch rate of 36 kg.km^{-1}.

New Zealand's research effort on the Challenger Plateau began in 1976 when the government research vessel *James Cook* made an exploratory cruise

Table 1: Summary of research vessel catch rates on the Challenger Plateau to August 1983

Vessel, survey, date	No. of trawls	Depth range (m)	Total distance trawled (km)	Total catch Weight (kg)	Total catch CPUE* (kg.km^{-1})	Orange roughy catch Weight (kg)	Orange roughy catch CPUE (kg.km^{-1})	Source
Shinkai Maru (Aug-Nov 1975)	10	695–970	50.8	9 521	187.4	512	10.1	JAMARC (1976 and 1979)
Shinkai Maru (Jun 1976)	7	701–935	94.3	4 988	52.9	3 392	36.0	JAMARC (1976 and 1979)
James Cook J15/76 (Sep 1976)	7	400–808	64.5	1 067	16.5	2	0.1	MAF Fisheries unpublished data
Wesermünde W04/79	7	760–1 075	18.7	380	20.3	49	2.6	MAF Fisheries unpublished data
W05/79 (Aug-Nov 1979)	1	765–775	3.7	77	20.8	3	0.8	MAF Fisheries unpublished data
James Cook J02/81 (Jan 1981)	23	483–993	69.3	4 083	58.9	680	9.8	MAF Fisheries unpublished data
Professor Bogucki (Aug-Sep 1981)	43	842–1 105	728.4	61 978	85.1	39 131	53.7	Van den Broek (1981)
Oyang No. 3 (Jun-Jul 1982)	25	840–890	159.7	-†	-	560 989	3 512.8	MAF Fisheries unpublished data
James Cook J04/83 (Feb 1983)	34	738–1 149	88.0	3 782	43.0	1 266	44.4	Van den Broek (1983)
James Cook J07/83 (Jun-Jul 1983)	6	747–945	16.5	413	25.0	84	5.1	MAF Fisheries unpublished data

* Catch per unit of effort.
† Only orange roughy were recorded.

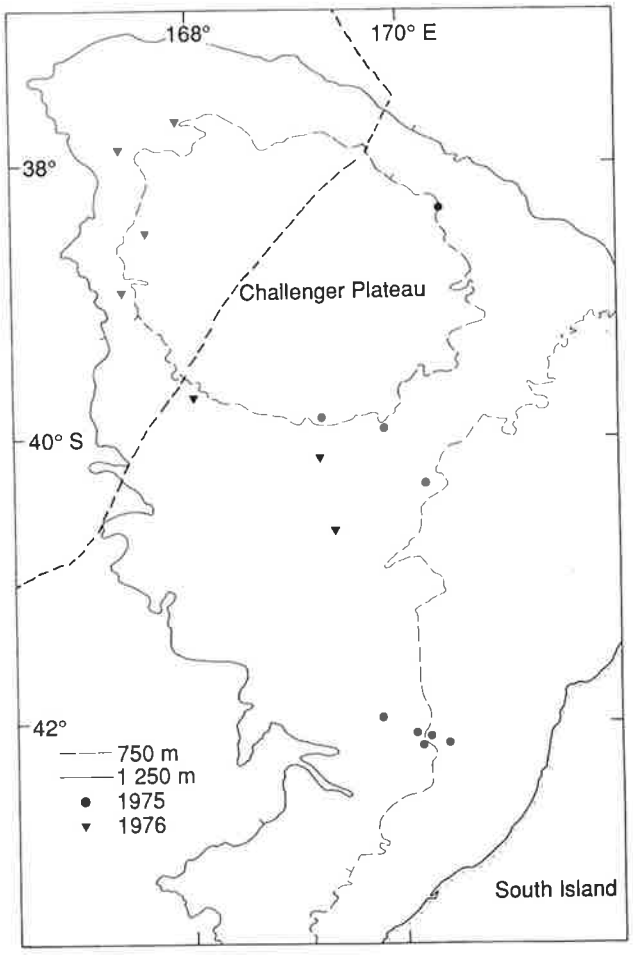


Figure 2a: Trawl stations at depths greater than 695 m occupied by *Shinkai Maru*, 1975 and 1976.

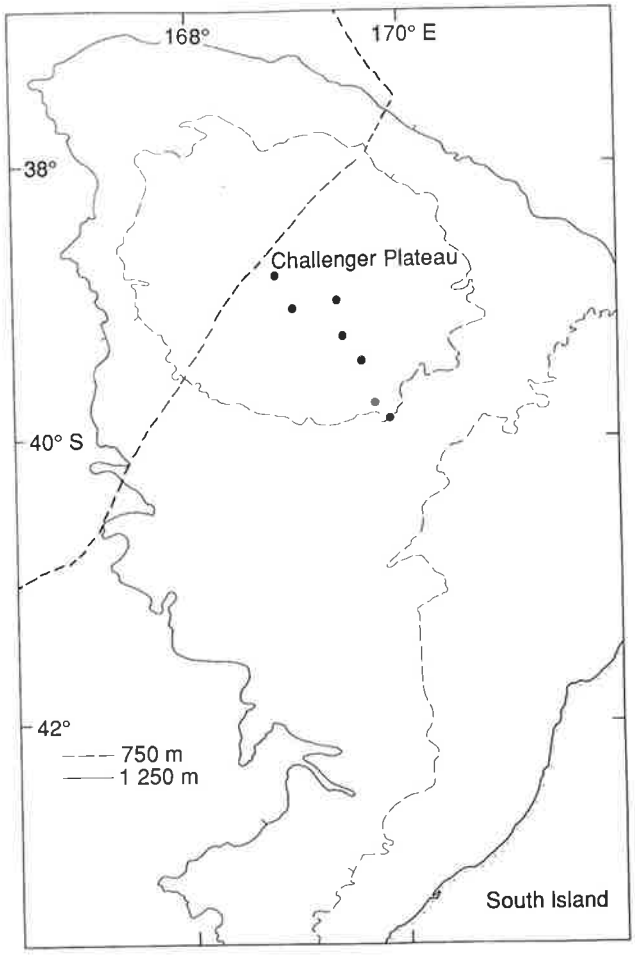


Figure 2b: Trawl stations occupied by *James Cook* (J15/76).

(J15/76) to collect information on stocks of fish at depths of 200–800 m on the plateau (Figure 2b). Only seven stations at depths greater than 400 m were fished. Catches were very poor; a total of 1067 kg of all fish species was landed. Only two individual orange roughy were caught during the cruise.

In 1979 the West German factory trawler *Wesermünde* made six trawl shots on the Challenger Plateau (Figure 2c) as part of a West German-New Zealand joint investigation of the fisheries resources around New Zealand. Catches of orange roughy on the Challenger Plateau were low, with 52 kg caught at a rate of 2 kg.km^{-1}.

James Cook cruise J02/81 in January 1981 was the first research cruise aimed specifically at investigating stocks of orange roughy on the Challenger Plateau. Twenty-three stations were sampled in 483–993 m, and 18 of these were between 800–900 m (Figure 2d). Total catch rates were low (59 kg.km^{-1}), with 680 kg of orange roughy caught at a mean rate of 10 kg.km^{-1}. Orange roughy was the dominant commercial species at depths over 800 m and comprised 22% of the total catch.

Further data on orange roughy were collected in August-November 1981 on a cruise by the joint venture vessel *Professor Bogucki* (van den Broek 1981), for the Dalmor Deepsea Fishing Enterprise in Gdynia and the Polish-New Zealand Polmark Fisheries Limited. Although the vessel was conducting commercial exploratory fishing trials, Polish scientific staff monitored catches and carried out biological investigations. MAF Fisheries scientific staff were on board for 12 fishing days from 25 August to 5 September, and trawl stations for these dates are shown in Figure 2e. The highest catches were made along the western edge of the plateau, where orange roughy consistently made up more than 50% of the catch. Of the total catch of 62 t, 63.1% were orange roughy (catch rate of 54 kg.km^{-1}). The largest catch of orange roughy (3.7 t) was at 37° 58 ′ S, 167° 18 ′ E. The largest total catch of 8 t was taken at 37° 26 ′ S, 168° 19 ′ E and was predominantly cardinal fish (*Epigonus telescopus*). This cruise was the first to suggest the presence of commercial quantities of orange roughy on the Challenger Plateau.

Two vessels belonging to the New Zealand-Korean co-operative venture company Pacific Oyang Ltd., *Oyang No. 3* and *Oyang No. 5*, found prespawning concentrations of orange roughy in June 1982 and successfully fished in the area, to the end of the calendar year. MAF Fisheries staff were present on a cruise to the area by *Oyang No. 3* in June-July. On this commercial trip, fishing was concentrated in a small area centred on 40° 00 ′ S, 168° 12 ′ E (Figure 2f).

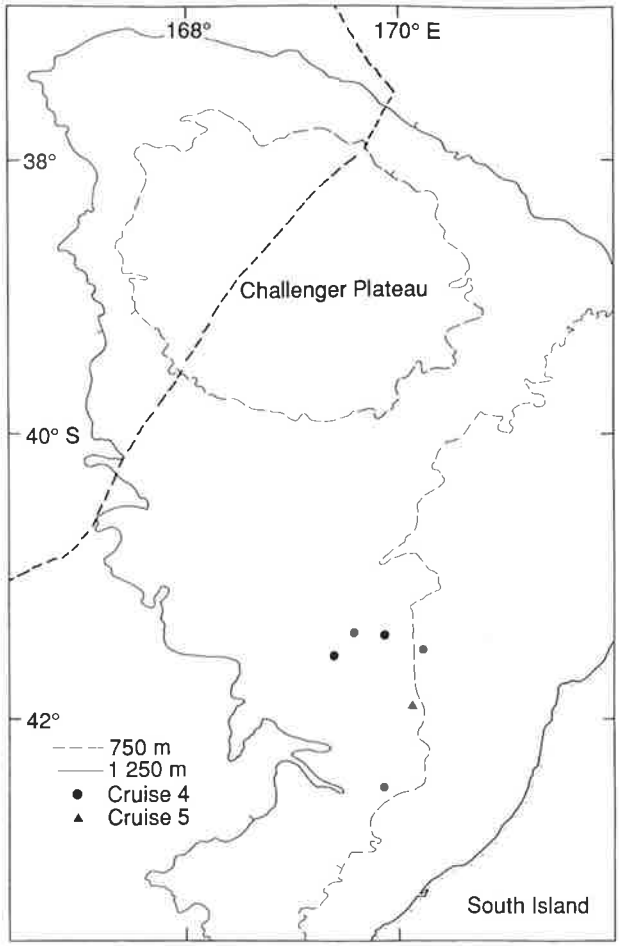


Figure 2c: Trawl stations occupied by *Wesermünde* cruises 4 and 5, 1979.

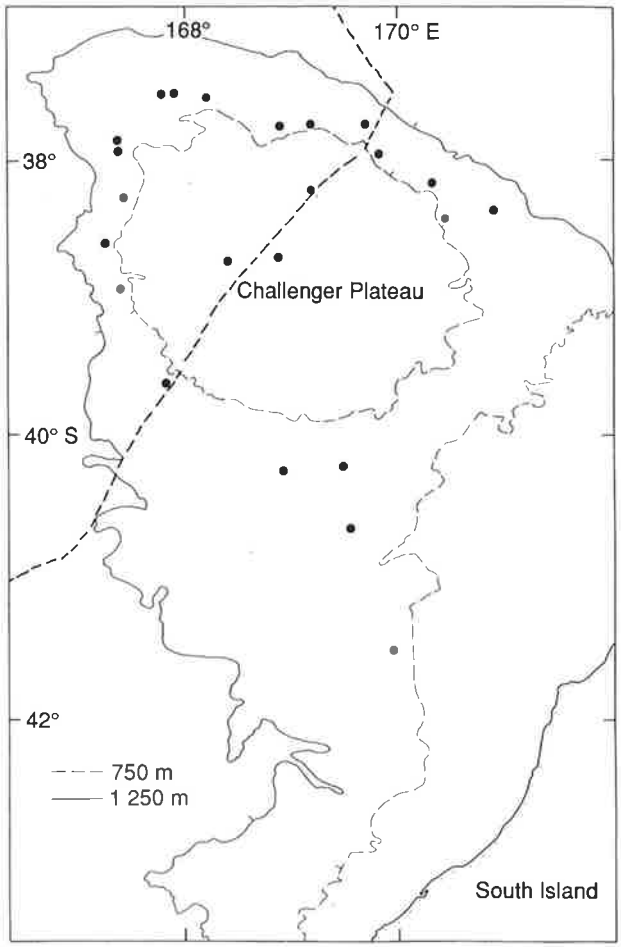


Figure 2d: Trawl and reversing bottle stations occupied by *James Cook* (J02/81).

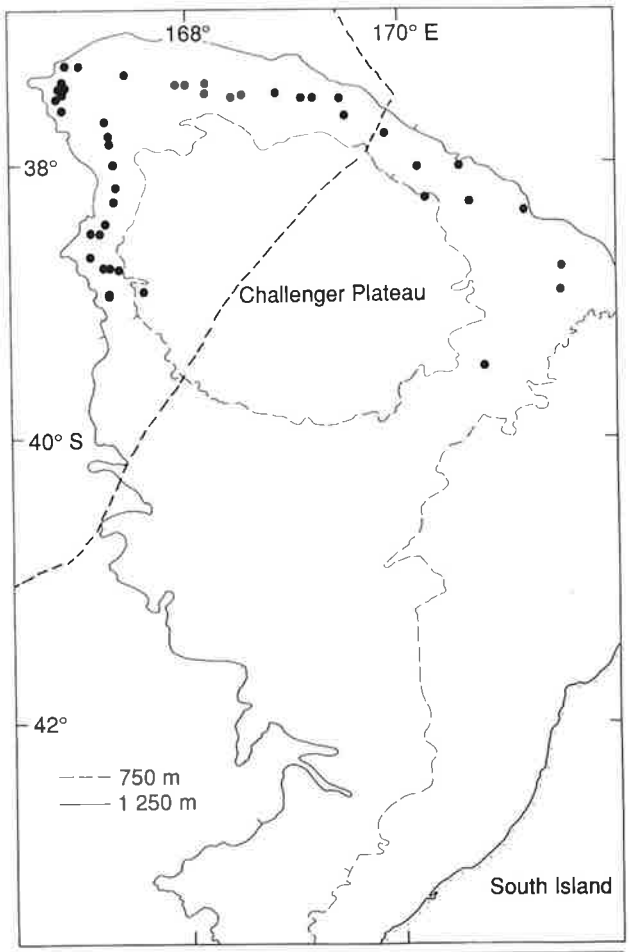
Catches of orange roughy were very large, usually about 20 000 kg per tow. The total orange roughy catch rate was 3513 kg.km^{-1}, and the largest catch (26 504 kg) was taken at 39° 56 ′ S, 168° 18 ′ E. The data obtained from this cruise and information from the fishing activity by *Oyang No. 5* were instrumental in the establishment of a commercial orange roughy fishery on the Challenger Plateau.

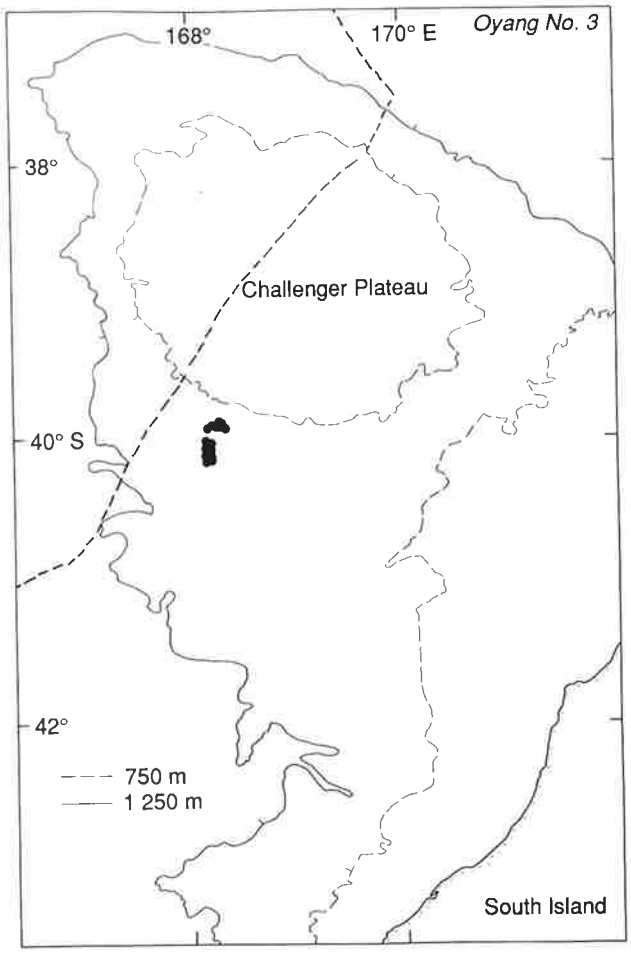
In 1983, there were two *James Cook* cruises. During the first cruise (J04/83) in February, 23 reversing bottle stations and 34 trawl shots were carried out in 750–1200 m between 37° and 42° S and 167° and 172° E, both inside and outside the EEZ (van den Broek 1983a) (Figure 2g). One aim of this cruise was to determine the geographical and depth distribution of orange roughy in late summer in this area. Catch rates for orange roughy were low (44.4 kg.km^{-1}). The largest catch rate of orange roughy (82 kg.km^{-1}) was taken at 37° 30 ′ S, 168° 32 ′ E. Catch rates were highest in 900–1000 m (increasing to this depth then decreasing subsequently). Orange roughy was the most abundant fish species by weight (33%). Hydrographic results from reversing bottles provided too few data for analysis and are not considered further.

The second *James Cook* cruise (J07/83) in June-July was designed to obtain hydrological data from the Challenger Plateau. Forty-eight conductivity temperature depth probe (CTD) and two reversing bottle stations were occupied (Figure 2h), and the data collected are discussed below. Six trawl shots were also made in 747–945 m, between 37° 41.7 ′, 40° 17.3 ′ S and 168° 17.0 ′, 170° 59.3 ′ E (Figure 2i). Of the total catch of 413 kg, 20.4% were orange roughy. Catch rates were very low (5 kg.km^{-1}). The largest catch rate of 20 kg.km^{-1} was taken at 37° 41.7 ′ S, 169° 29.7 ′ E.

Hydrological surveys

Before 1981 little data were collected on temperature, salinity, and current flows on the Challenger Plateau. In 1970 *Kaiyo Maru* was used by the Japan Fishery Agency to sample three transects over the plateau by bathythermograph (Anon. 1972) (Figure 2j). One transect was across the centre of the plateau, where limited trawling was done. This transect had 10 stations (running west to east), 8 of which were positioned over the plateau. Temperature, salinity, pH, and oxygen, phosphate, and silicate content were measured from the sea surface to the bottom at each station. There was an ascending warm current west of the plateau. Salinity was higher west of the plateau and lower to the east, and the low salinity water mass found at 950–1000 m probably represented Antarctic Intermediate Water.





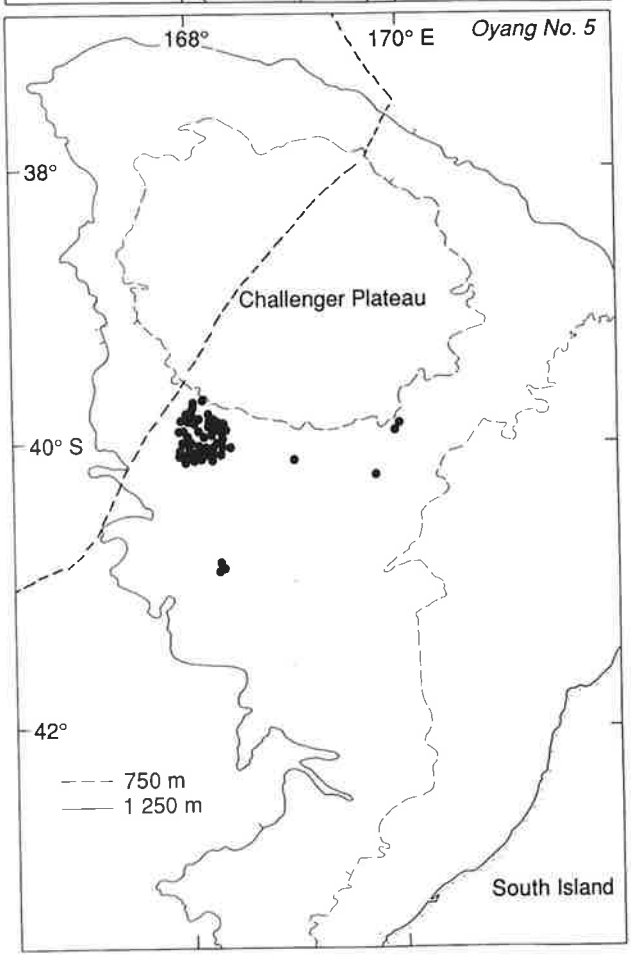


Figure 2e (*above, left*): **Trawl stations occupied by *Professor Bogucki*, 1981 (MAF Fisheries personnel on board).**

Figure 2f (*above, right and below*): **Commercial trawl stations occupied by *Oyang No. 3* and *Oyang No. 5*, 1982.**

There was no further hydrological work by MAF Fisheries staff on the Challenger Plateau until 1981. *James Cook* cruise (J02/81) in January 1981 sampled 21 hydrological stations (*see* Figure 2d) by use of bottles and reversing thermometers. Samples were taken to 800 m (MAF Fisheries unpublished data), but data are of limited use because of the small sample sizes and shallow depths sampled. *James Cook* cruise (J04/83) in February 1983 similarly sampled 22 hydrological stations, though samples were collected from depths of 0, 50, and 100 m, and every consecutive 100 m down to about 1000 m. These data have not been analysed in detail, but some preliminary results have been obtained. Bottom temperatures ranged from 8.4 °C at 686 m to 5.0 °C at 1000 m. Bottom temperature was 7.8 °C at 900 m in an area close to where the largest orange roughy catch on this cruise was made. There was a gradual decline in temperature as depth increased, and there was no pronounced thermocline (van den Broek 1983). Bottom salinity ranged from 34.47 (861 m) to 34.95 (1000 m).

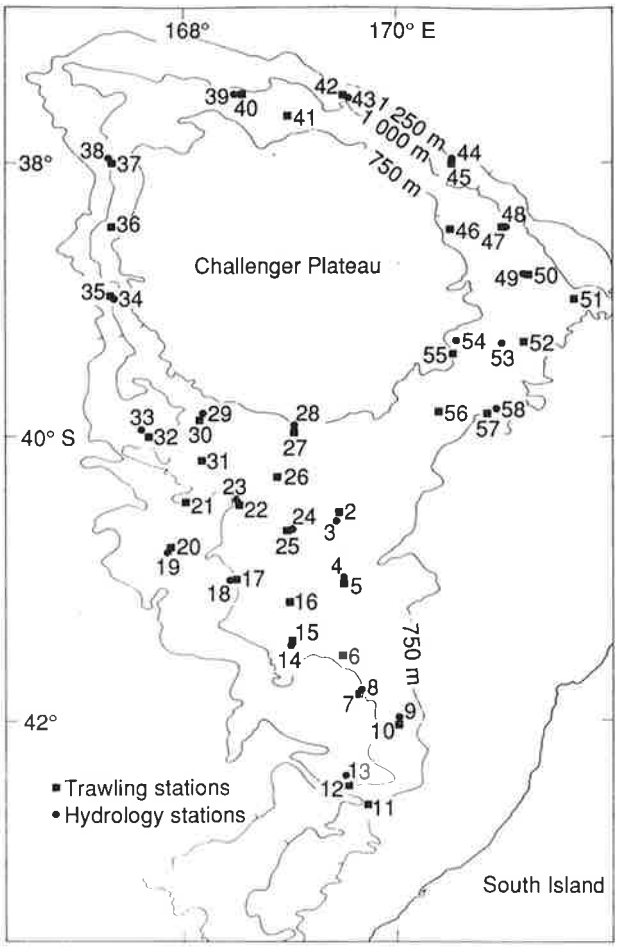


Figure 2g (*above, left*): Hydrological and trawl stations occupied by *James Cook* (J04/83).

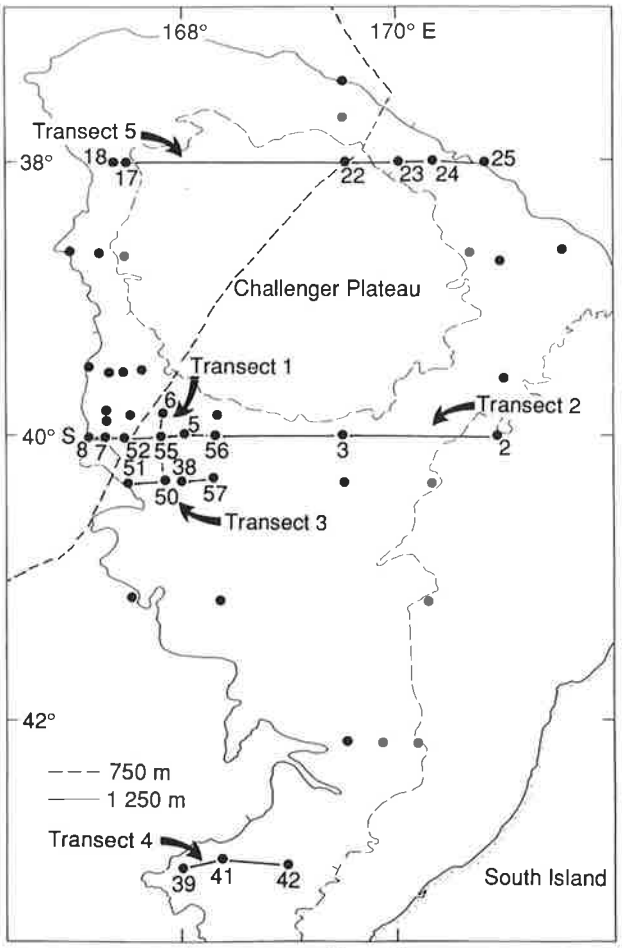


Figure 2h (*above, right*): Hydrological stations and transect locations occupied by *James Cook* (J07/83).

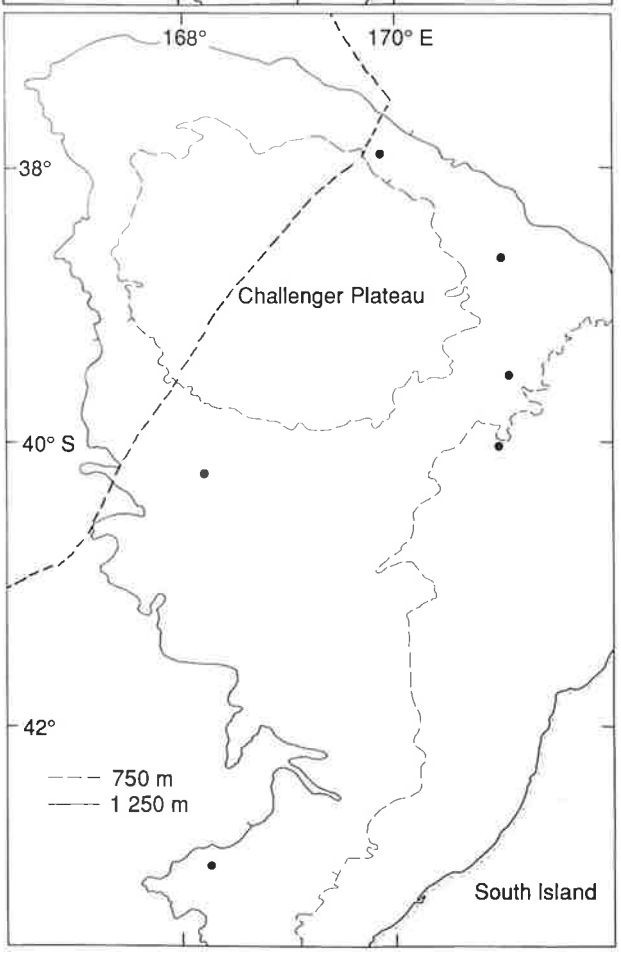


Figure 2i (*below, right*): Trawl stations occupied by *James Cook* (J07/83).

Development of the commercial fishery

It is unknown whether any commercial orange roughy fishing activity took place on the Challenger Plateau before 1981, though it is possible that Soviet vessels had been fishing the spawning area before this. *Professor Bogucki* found commercial concentrations of orange roughy on the plateau in August 1981 and had caught 270 t by mid November (Milosz 1986). The vessel fished outside the EEZ from August to early September 1981 and both inside and outside the EEZ from late September to mid November 1981 (*see* Figures 2e and 2k).

The establishment of a sizeable commercial fishery for orange roughy occurred in 1982, when 5485 t of orange roughy were landed by six vessels in the area, mostly reported from inside the EEZ (Table 2). Over half of this total was caught by two New Zealand-Korean co-operative venture trawlers; the remainder was caught by two New Zealand-Soviet co-operative venture trawlers and two foreign licensed vessels — one Korean and one Soviet.

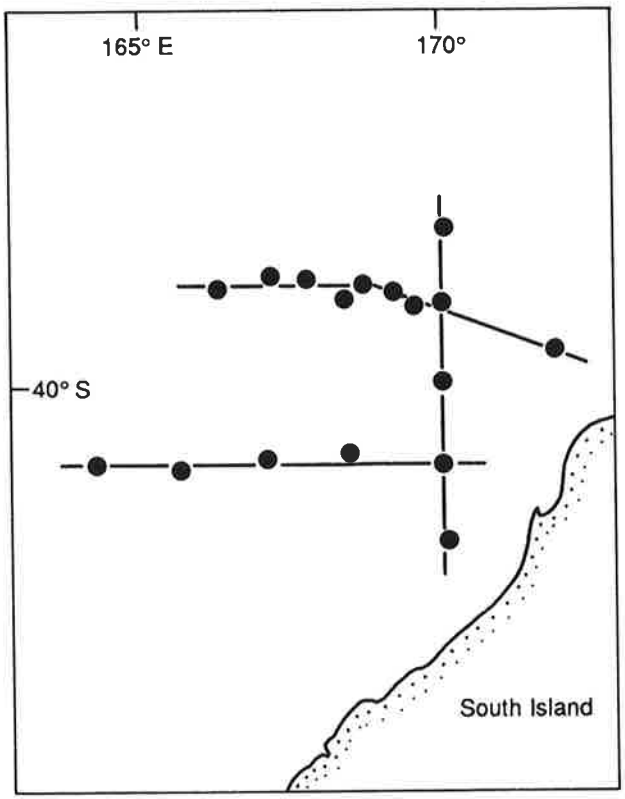


Figure 2j (*above*): Hydrological stations and transect locations occupied by *Kaiyo Maru*, 1970.

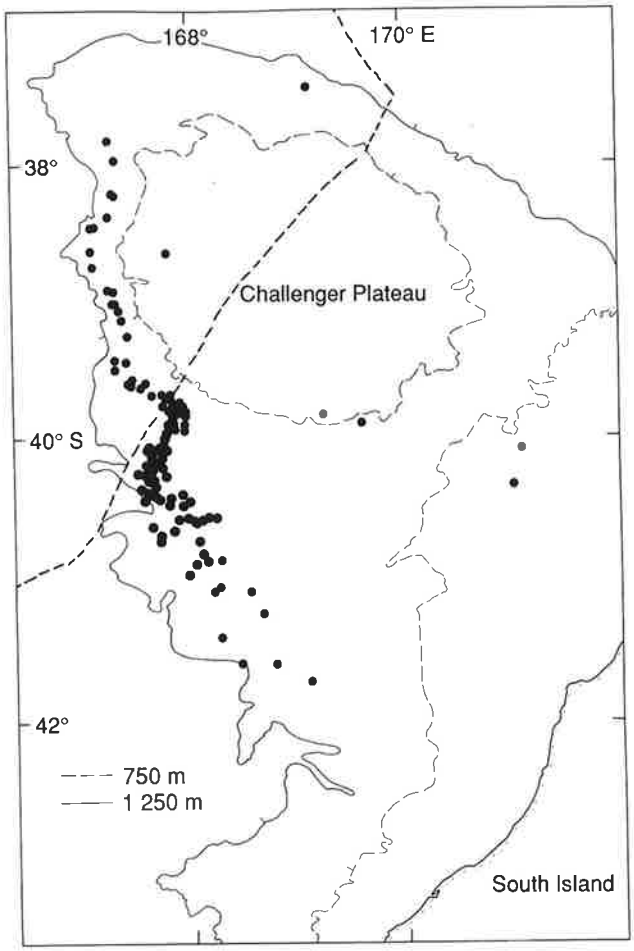


Figure 2k (*right*): Trawl stations occupied by *Professor Bogucki*, 1981 (MAF Fisheries personnel not on board).

In 1983 commercial fishing on the plateau intensified and, of the 23 vessels reported fishing in the area, 12 were co-operative venture, 2 foreign licensed, and 9 domestic. A total of 16 408 t of orange roughy was reported caught and 10 490 t of this were reported as caught outside the EEZ. It is likely that most of the orange roughy declared as being caught outside the New Zealand EEZ came from within the zone.

The commercial fishery has been centred on two small areas inside the EEZ. The first, the "hot spot", is a 20 km² area of pinnacles and valleys at about 40° S and 168° E. The other, which appears to be the major spawning ground, lies 17 km northeast and is an area of flat bottom. This area is also about 20 km² in size, though the fish density within it varies substantially.

Management of the fishery before 1983–84

Before 1983–84 there was no specific quota for the Challenger Plateau (area H, Figure 3) and the west coast South Island (area G). The first total catch quota on orange roughy in the New Zealand EEZ was set at 25 000 t for the 1 April 1981–31 March 1982 fishing year (Robertson 1982). This total was reached in July, and by July 31 the fishery was closed. For the 1982–83 fishing year a quota of 7000 t was implemented for areas of the EEZ other than the Chatham Rise (areas C and D) and Wairarapa coast (area B) and fishing for orange roughy was restricted to 1 May–31 July 1982 and 1 October 1982–28 February 1983 throughout the EEZ. For the 6 months from 1 April to 30 September 1983, a quota of 3000 t was allocated for areas other than B, C, and D because of a change of the fishing year to 1 October–30 September. For the fishing year 1 October 1983–30 September 1984, the orange roughy total quota for areas G and H was 5000 t.

Orange roughy catches from outside the EEZ were not subject to quota. This caused a problem with vessels suspected of declaring fish caught outside the EEZ when they were actually caught inside the zone. From 1 April 1982 to 31 March 1983, 618 t were declared from outside the EEZ, which gave a total catch of 5730 t inside and outside compared with the "rest of the EEZ" quota of 5000 t. For the 6 months from 1 April to 30 September 1983, 7304 t were declared caught outside and 2904 t inside the EEZ, which gave a total of 10 208 t compared with the quota of 3000 t. Quotas were recommended on the basis of the whole plateau, and therefore the inability to manage fish caught outside the EEZ resulted in considerable over-run of the recommended yield.

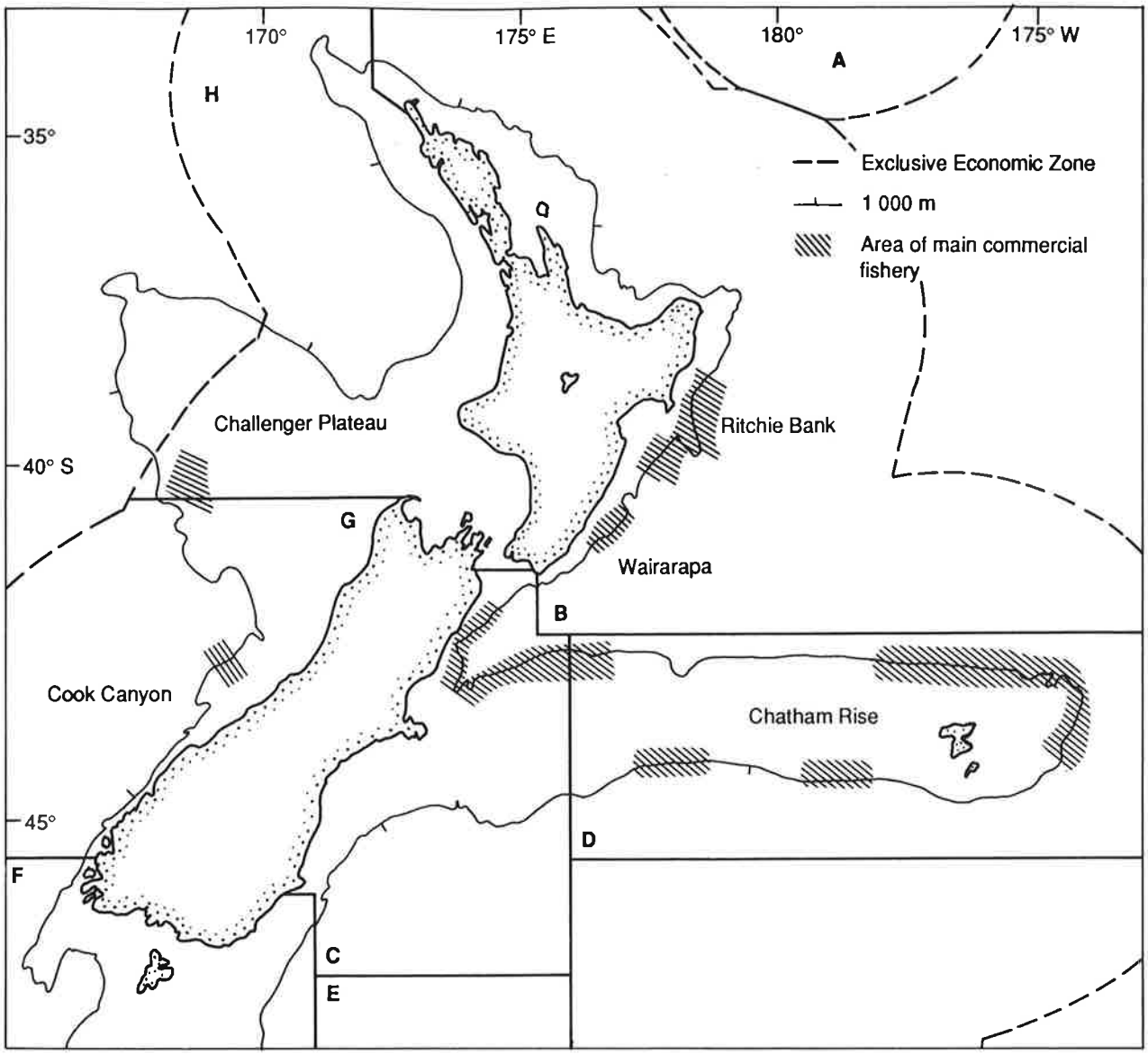


Figure 3: New Zealand 200 n. mile Exclusive Economic Zone areas B–D, G and H and the main commercial orange roughy fishery areas.

Table 2: Reported commercial orange roughy catch (t) from the Challenger Plateau (including EEZ areas G and H), 1981–83*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981													
Inside	–†	–	–	–	–	–	–	1	–	91	12	–	104
Outside	–	–	–	–	–	–	–	8	24	94	13	–	127
Total	–	–	–	–	–	–	–	9	24	185	13	–	231
1982‡													
Inside	–	–	1	12	–	998	2 422	–	–	383	975	77	4 867
Outside	–	–	–	–	–	293	323	–	–	–	–	1	618
Total	–	–	1	12	–	1 291	2 745	–	–	383	975	79	5 485
1983													
Inside	246	–	–	51	1	444	1 677	524	207	936	1 526	306	5 918
Outside	–	–	–	–	–	–	2 688	2 320	2 296	2 966	219	–	10 490
Total	246	–	–	51	1	444	4 365	2 844	2 503	3 902	1 745	306	16 408

* Data are from MAF Fisheries Greta Point, Wellington.
† No reported catch.
‡ Season was closed from 1 Aug-30 Sep.

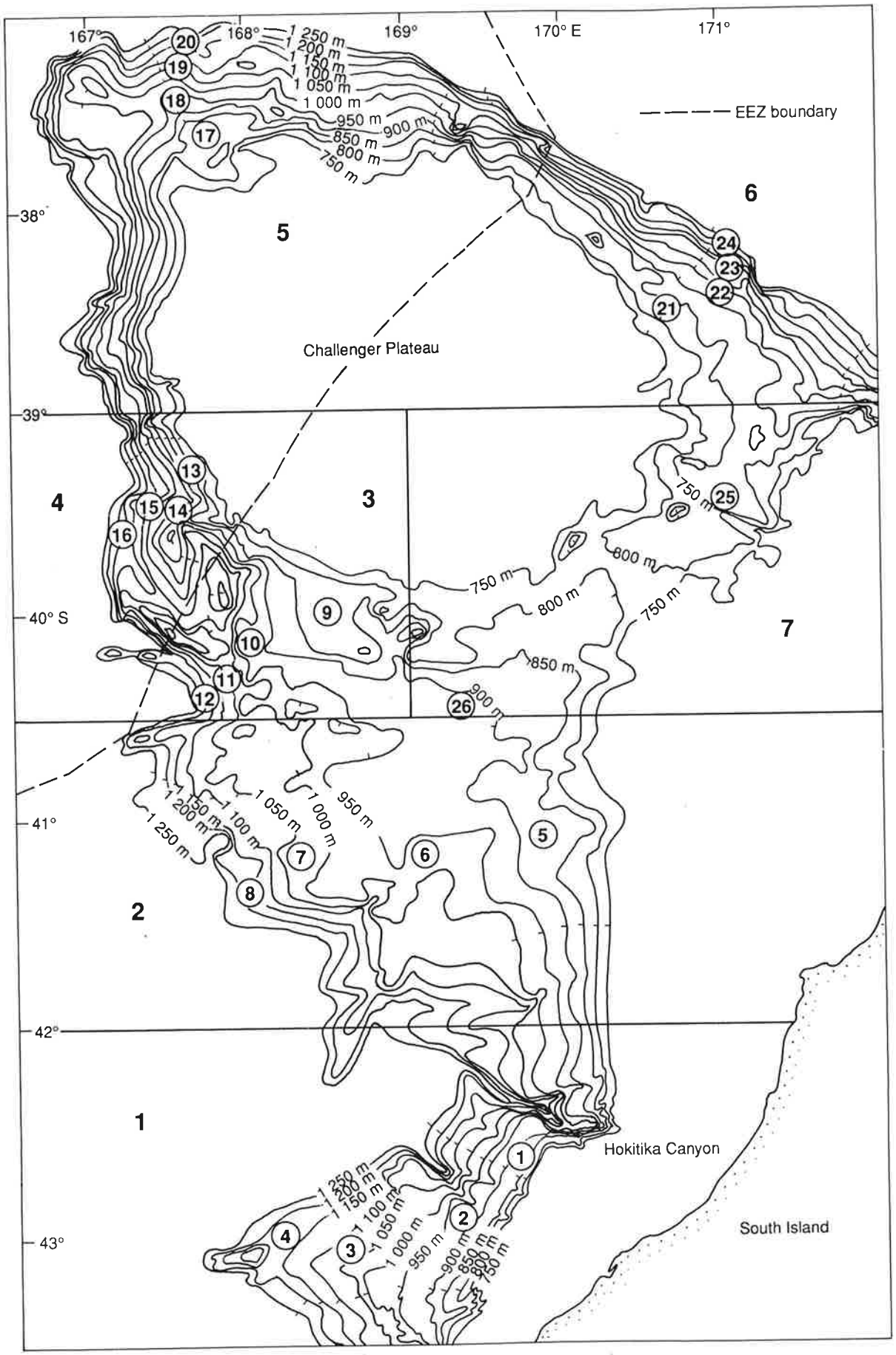


Figure 4: Subareas and strata for the Challenger Plateau *Arrow* survey, 1983.

1983 *Arrow* survey

Introduction

In July 1983, a contract was formed between the Fisheries Research Division (now MAF Fisheries) of the Ministry of Agriculture and Fisheries and the New Zealand company Sealord Products Ltd. for the research charter of the trawler *Arrow*. In exchange the company received an allocation of 1000 t of orange roughy.

The main objectives of the survey were:

1. to estimate the relative biomass and distribution of the Challenger Plateau orange roughy population and other deepwater species;
2. to describe age and growth of orange roughy;
3. to describe the feeding and reproductive status of orange roughy;
4. to collect accurate position and depth data with every satellite navigation fix so that an improved chart could be produced for later surveys.

Methods

Survey area and design

The survey was conducted on the Challenger Plateau both inside and outside the New Zealand EEZ, between 37° 00′ and 43° 30′ S and 167° 00′ and 172° 00′ E, at depths of 800–1200 m. The survey area was 100 979 km² and was defined from knowledge of the depth range of orange roughy and the distribution from previous research surveys.

The survey was divided into four cruises: 23 August–2 September, 7–16 September, 11–18 October, and 23–28 October. The first two cruises involved trawling only during the hours of daylight, and the last two cruises worked a 24 h operation.

The survey design was a single-phase stratified random bottom trawl (*after* Francis 1981). The Challenger Plateau was divided into 7 subareas chosen by convenient lines of latitude and longitude and by the EEZ line. These subareas were further subdivided by 100 m depth intervals into 26 strata (Figure 4). A total of 181 randomly generated trawl stations were then allocated proportionally to these strata based on the area of each stratum and a weighting factor. "Weighting" was applied to depth strata where catches were expected to be good, i.e., in 800–900 and 900–1000 m, where spawning aggregations might be expected, and in subareas 3 and 4 based on catches by trawlers in 1982. Strata and weighting factors are described in Table 3. Station positions were a minimum of 5 km apart.

Vessel and gear

Arrow has the following specifications: overall length 57.3 m; beam 9.7 m; gross tonnage 549.7 t; horsepower 1800 (1194 kW).

A high-opening bottom trawl with a vertical opening of 7 m and codend mesh size of 100 mm was used for all the survey stations (Appendix 1). Polyvalent doors of 5 m² surface area were used and the total distance from the doors to the wingtips of the net was 126.9 m. From recent flume tank net model measurements at 2.75 kn, the distance between the wingtips was 19.5 m and the distance between the doors was 87.4 m (J. Greening and C. M. Baker pers. comm.).

Trawl procedure

If the depth was incorrect at the predetermined randomly selected tow position, that trawl station was cancelled and the next reserve random station was chosen. Stations were trawled in the most convenient order with the station position fixed by satellite navigation (accuracy within 1.5 n. miles (Robertson *et al.* 1984)). Trawl duration was 30 min, from when the net was observed by net monitor to have settled on the bottom until the net left the bottom during hauling. Mean vessel speed during trawling was 3.2 kn (5.9 km.h^{-1}).

Catch weight and biological parameters

The total catch for each station was sorted by species and weighed to the nearest 0.1 kg. For large catches it was necessary to back-calculate the total catch by the number of orange roughy cases for that

Table 3: Station density weighting by stratum

Area	Stratum	Depth range (m)	Area (km²)	Weight	Area x weight (km²)	No. of stations completed	Area per station (km²)
1	1	800–900	2 823	x2	5 646	5	565
	2	900–1 000	3 629	x2	7 258	9	403
	3	1 000–1 100	3 414	x1	3 414	5	683
	4	1 100–1 200	4 474	x1	4 474	6	746
2	5	800–900	6 487	x1	6 487	6	1 081
	6	900–1 000	11 790	x1	11 790	14	842
	7	1 000–1 100	8 045	x1	8 045	10	805
	8	1 100–1 200	4 983	x1	4 983	6	831
3	9	800–900	2 926	x3	8 778	14	209
	10	900–1 000	3 353	x3	10 059	11	305
	11	1 000–1 100	1 588	x1	1 588	3*	529
	12	1 100–1 200	145	x1	145	3*	48
4	13	800–900	892	x4	3 568	4	223
	14	900–1 000	1 071	x4	4 284	7	153
	15	1 000–1 100	1 892	x1	1 892	3*	631
	16	1 100–1 200	2 757	x1	2 757	3*	919
5	17	800–900	4 181	x2	8 362	11	380
	18	900–1 000	4 952	x2	9 904	12	413
	19	1 000–1 100	5 764	x1	5 764	7	823
	20	1 100–1 200	4 145	x1	4 145	5	829
6	21	800–900	3 894	x2	7 788	10	389
	22	900–1 000	2 662	x2	5 324	6	444
	23	1 000–1 100	1 957	x1	1 957	3*	652
	24	1 100–1 200	1 657	x1	1 657	3*	552
7	25	800–900	11 048	x1	11 048	12	921
	26	900–1 000	450	x1	450	3*	150
Total			100 979			181	

* Minimum number of stations.

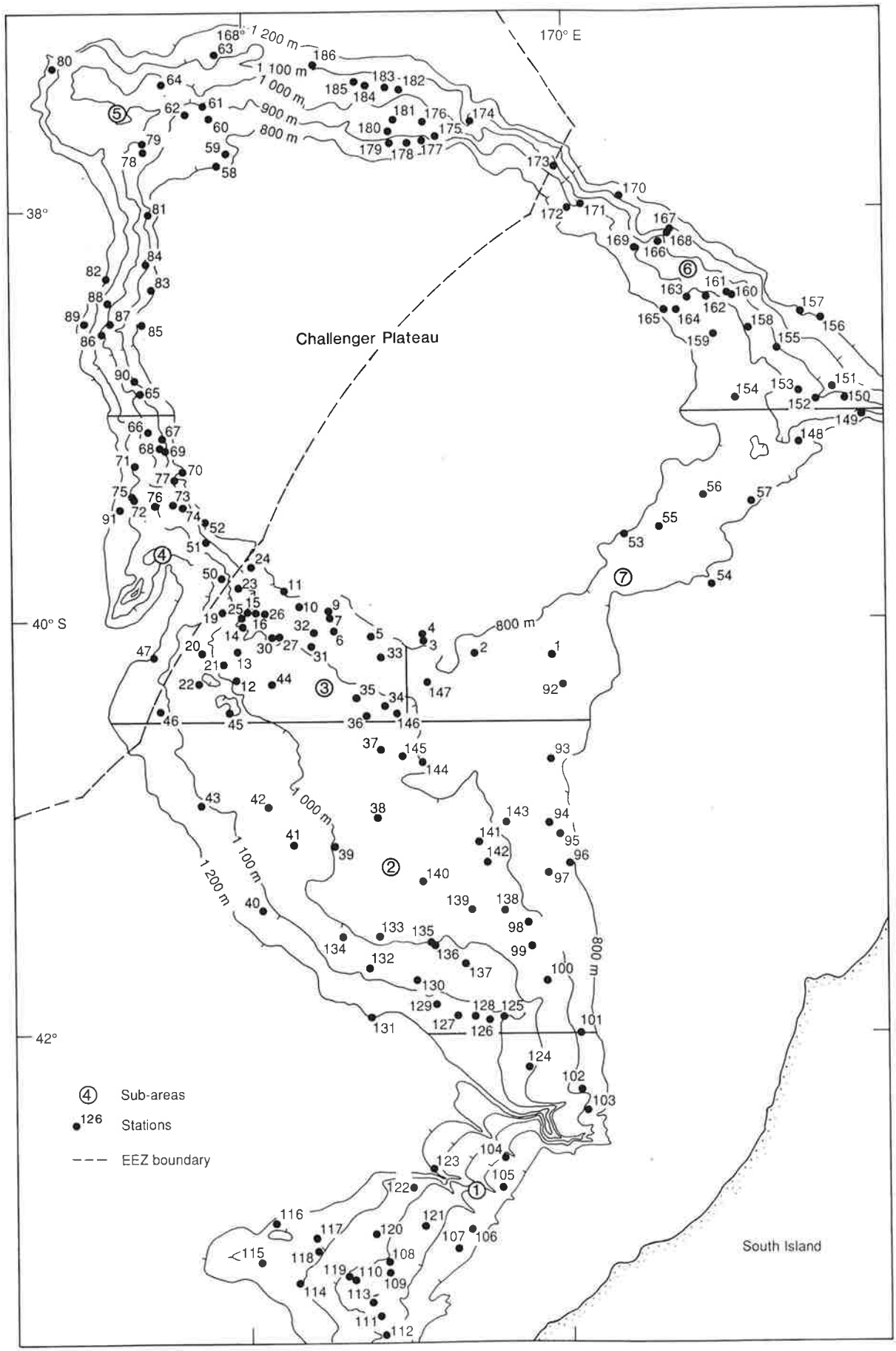


Figure 5: Trawl stations for the *Arrow* survey, 1983.

tow, multiplied by the mean weight of the fish per case. The latter was determined by randomly sampling 10 fish cases and counting the individual fish in each case, and then the mean individual fish weight (obtained from biological sampling) was used to calculate mean weight of fish per case.

A random sample of about 200 orange roughy per tow was measured and sexed. Standard length (from the front of the head to the beginning of the caudal or tail fin) was measured. From a representative subsample of 20 fish the following data were collected: standard length to the nearest millimetre, weight (nearest gram below), sex, state of gonad maturity (*after* Pankhurst *et al.* 1987), gonad weight (nearest gram below), fullness of stomach and state of digestion of contents, identification of stomach contents into major taxa, and preservation of stomachs which contained natant decapod crustaceans for later identification (Rosecchi *et al.* 1988). Otoliths were collected for aging studies and stored in 70% isopropyl alcohol and glycerine.

Biomass estimation

Biomass and standard error of biomass were calculated from the following formulas (*after* Francis 1981, Hurst and Bagley 1987, and R. I. C. C. Francis pers. comm.):

$$B_i = \Sigma_j X_{ij} a_{ij} / cb$$

$$S_B = \sqrt{\Sigma_{ij} S_{ij}^2 \; a_{ij}^2} / cb$$

$$CL_{95} = B_i \pm 2S_B$$

$$c.v. = S_B / B_i .100$$

where B_i is biomass (t) in area a_i, X_{ij} is mean catch rate (kg.km^{-1}) in stratum i, j (area i, depth zone j), a_{ij} is bottom area (km^2) of stratum i, j, c is catchability coefficient (i.e., an estimate of the proportion of fish available to the net which is caught) assumed to be equal to 1, b is width of the net (km) considered to be effectively fishing the sea floor and assumed to be constant, S_B is standard error of biomass, S_{ij} is standard deviation of X_{ij}, CL_{95} is 95% confidence limits for the biomass estimate, $c.v.$ is coefficient of variation.

Results

Catch and catch rates

Trawl station positions are shown in Figure 5. Mean station density was 1 per 558 km^2. Orange roughy catch rates (kg.km^{-1}) for all stations are shown in Figure 6, and catch rates by depth are given in Table 4. Of the total catch of 31 050 kg, orange roughy made up 67% (20 684 kg). The largest single catch of orange roughy (11 646 kg) was taken in the area of known commercial concentrations (station 15, Appendix 2). Mean catch rates of orange roughy by stratum ranged from 0.9 to 256.5 kg.km^{-1} (Table 5). Catches in subarea 1 off Westland were low, with one exception. At the southernmost trawl station 112 (*see* Appendix 2, Figure 5), 1020 kg of orange roughy were taken out of a total catch of 1117 kg.

Table 4: Summary of total and orange roughy catch rates (kg.km^{-1}) by depth zone

Depth zone (m)	No. of stations	Total catch Weight (kg)	Total catch CPUE* (kg.km^{-1})	Orange roughy catch Weight (kg)	Orange roughy catch CPUE (kg.km^{-1})
<800	4	232	15.7	24.2	1.6
800–900	61	17 962	91.5	13 700.0	69.8
900–1 000	58	7 352	40.4	4 289.0	23.6
1 000–1 100	37	4 331	38.5	2 422.8	21.6
1 100–1 200	19	1 098	19.0	236.8	4.1
>1 200	2	74	13.3	11.0	2.0
All	181	31 050	54.6	20 683.8	36.4

* Catch per unit of effort.

Table 5: Mean catch rates (kg.km^{-1}) and biomass estimates* (t) for orange roughy by stratum

Area	Stratum No.	No. of tows	Catch rate Mean	Catch rate s.d.†	Biomass estimate Wingtip	Biomass estimate Door
1	1	5	11.2	8.7	1 622	362
	2	9	49.3	103.3	9 167	2 045
	3	5	17.0	15.6	2 971	663
	4	5	1.5	1.8	355	79
2	5	6	9.2	5.7	3 063	683
	6	14	6.6	5.3	4 005	894
	8	6	0.9	0.8	226	50
3	9	14	256.5	931.7	38 492	8 588
	10	9	85.3	183.9	14 675	3 274
	11	3	7.6	3.6	617	138
	12	3	12.8	10.7	95	21
4	13	4	7.2	5.7	331	74
	14	7	17.6	5.0	968	216
	15	3	14.8	0.9	1 440	321
	16	3	1.8	0.4	254	57
5	17	11	18.6	19.8	3 980	888
	18	12	19.5	21.6	4 958	1 106
	19	7	17.1	12.0	5 057	1 128
	20	5	10.1	7.7	2 153	480
6	21	10	4.2	3.2	842	188
	22	6	5.3	1.0	727	162
	23	3	11.3	9.5	1 135	253
	24	3	5.4	3.7	463	103
7	25	11	4.2	5.8	2 354	525
	26	3	7.5	3.6	173	39
Total		177			103 657	23 127

* Estimates were calculated for wingtips (19.5 m) by use of wingspread and for doors (87.4 m) by use of doorspread as area swept.

† Standard deviation.

Only 2.5 t of orange roughy were taken at 52 stations outside the EEZ. The largest catch rate was 68 kg.km^{-1} at station 177 along the northern edge of the plateau. High catch rates were recorded inside the EEZ during the research phase at only two stations: for station 15 in stratum 9 the catch rate was 3494 kg.km^{-1}, and for station 23 in stratum 10 the catch rate was 574 kg.km^{-1}. The total catch rate for all areas combined was low, averaging 36.4 kg.km^{-1}.

Commercial trawling around the pinnacle area was carried out by the vessel during cruise 4 and several good catches were made. The average density of

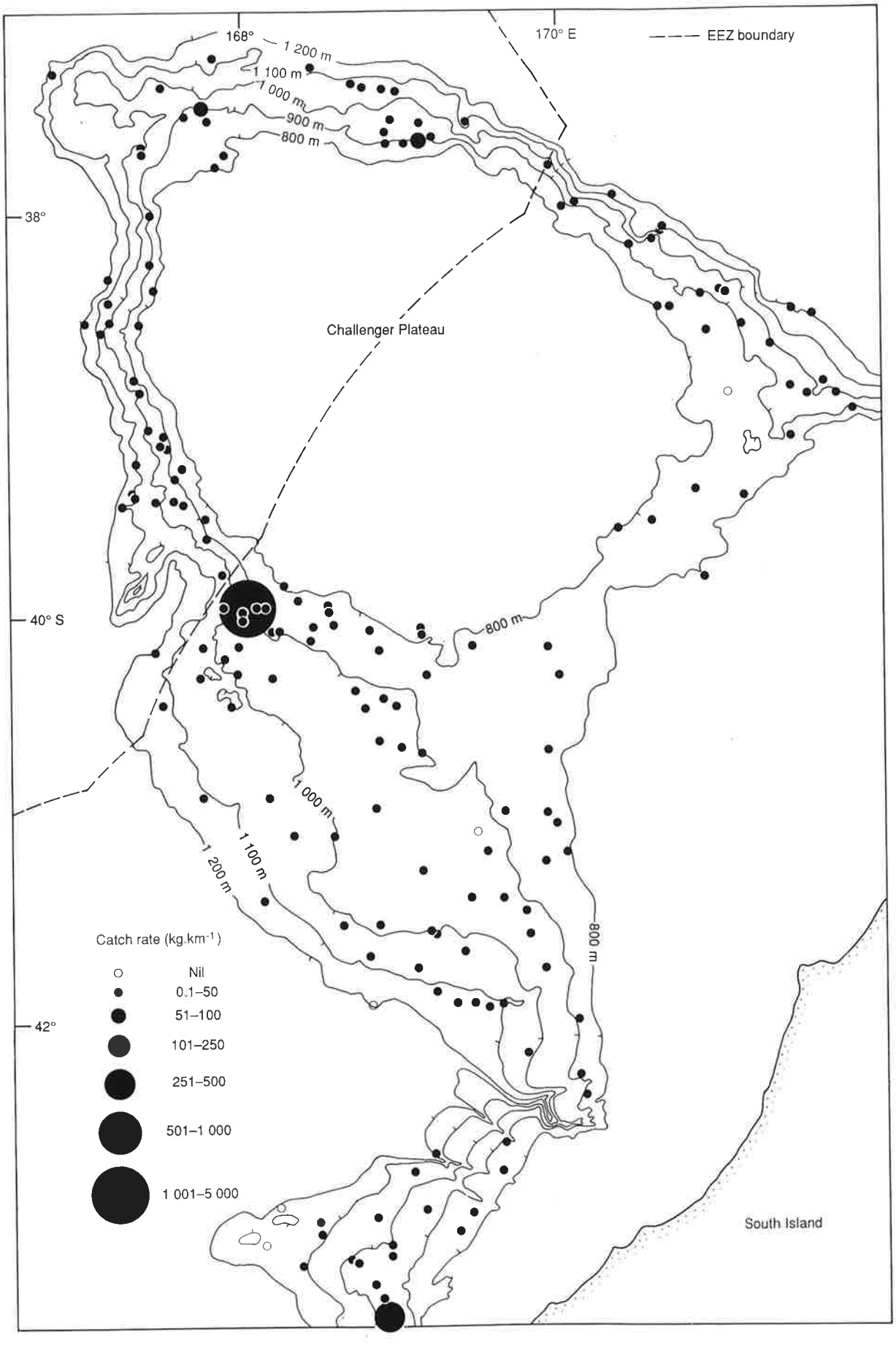


Figure 6: Orange roughy catch rates (kg.km^{-1}) for all survey stations.

Table 6: Percentage catch weight composition by depth for the 10 most abundant species

Species	Depth (m) 700–800	800–900	900–1 000	1 000–1 100	1 100–1 200	> 1 200	Total
Orange roughy (*Hoplostethus atlanticus*)	10.4	76.3	58.3	55.9	21.6	14.9	66.6
Unicorn rattail (*Trachyrincus* sp.)	8.6	3.7	9.0	7.4	4.8	2.6	5.5
Owston's dogfish (*Centroscymnus owstoni*)	10.2	4.7	7.8	3.1	4.2	–*	5.2
Smallscaled brown slickhead (*Alepocephalus australis*)	0.5	0.5	4.6	10.7	25.8	20.9	3.8
Widenosed chimaera (*Rhinochimaera pacifica*)	2.1	0.5	3.3	5.1	4.6	4.2	2.0
Shovelnosed dogfish (*Deania calceus*)	4.4	2.2	1.6	0.8	1.3	5.7	1.9
Ribaldo (*Mora moro*)	29.7	1.7	1.4	–	–	–	1.5
Hake (*Merluccius australis*)	0.9	1.6	0.5	0.4	–	–	1.1
Leafscaled gulper dogfish (*Centrophorus squamosus*)	2.5	1.5	0.6	–	1.2	–	1.1
Portuguese dogfish (*Centroscymnus coelolepis*)	–	0.6	1.5	1.6	0.3	–	0.9
Other species	30.7	6.7	11.4	15.0	36.2	51.7	10.4

* None were caught.

Table 7: Wingtip biomass estimates (t) and 95% confidence limits and coefficients of variation (%) calculated for the 10 most abundant species taken during the survey

Species	Lower bound	Biomass estimate	Upper bound	Coefficient of variation	% total biomass
Hoplostethus atlanticus	24 659	103 657	182 655	38	62.0
Trachyrincus sp.	13 656	15 851	18 046	7	9.5
Centroscymnus owstoni	10 293	12 829	15 365	10	7.7
Alepocephalus australis	10 314	12 461	14 609	9	7.5
Rhinochimaera pacifica	4 513	6 159	7 806	13	3.7
Deania calceus	3 534	4 975	6 416	14	3.0
Mora moro	1 922	2 649	3 376	14	1.6
Merluccius australis	2 638	3 634	4 631	14	2.2
Centrophorus squamosus	780	2 369	3 959	34	1.4
Centroscymnus coelolepis	1 447	2 507	3 568	21	1.5
All species	87 813	167 092	246 372	24	100.0

orange roughy in this "hotspot" area is usually very high, particularly during the winter months. A total catch of 37 274 kg was taken during three tows on October 29. These catches were similar to those of the domestic and co-operative venture vessels fishing the Challenger Plateau at the same time.

Percentage catch weight composition by depth for the 10 most abundant species is given in Table 6. Mean catch rates for orange roughy and all other species combined were highest in the 800–900 m depth zone, followed by the 900–1000 and 1000–1100 m depth zones. Orange roughy catches were generally low at depths less than 800 m and greater than 1100 m. At all depths between 800 and 1200 m orange roughy was the most abundant species by weight. Ribaldo (*Mora moro*) predominated in 700–800 m, and brown slickheads (*Alepocephalus* spp.) were important components at depths greater than 1100 m. All fish, squid, and crustacean species taken during the survey are listed in Appendix 3.

Biomass estimates

Orange roughy biomass estimates were calculated for each of the 26 strata (*see* Table 5). The calculations were based on results from 177 stations. Data from 4 of the 181 stations were rejected due to poor performance of the gear or gear damage. The largest biomass was recorded from stratum 9 (800–900 m) in subarea 3 (*see* Table 5, Figure 4). This subarea contains a known spawning ground and the high biomass, which made up 37% of the total biomass, was a result of a single large catch at station 15 in 891–897 m. Stratum 10 (900–1000 m), also in subarea 3, contributed 14% of the total biomass. Estimates totalled 19 141 t (18%) outside the EEZ (subareas 4 and 5) and 84 516 t inside (subareas 1, 2, 3, 6, and 7).

Wingtip biomass estimates and coefficients of variation for the 10 most abundant species are given in Table 7.

Length and weight

Length frequency samples of orange roughy were weighted by the percentage sampled, but not by length of tow. These length frequency distributions are shown by depth (Figure 7a) and for all fish combined (Figure 7b). Lengths ranged from 8 to 43 cm, and the total modal peak was 32–34 cm. A total of 4418 females (mean length 32.3 cm) and 7561 males (mean length 31.6 cm) was measured on the four surveys. Length frequency distributions were plotted for each stratum, and there were no clear differences. The modal peak for stratum 9 (which included the high density sampling area) was 31 cm, similar to that for the whole survey area.

The standard length and body weight relationship of 2736 orange roughy is shown in Figure 8 and is expressed by the equation $W = aL^b$, where W = body weight (g), L = standard length (cm), and a, b = constants. The regression equations for females and males were the same:

females, males $W = 1.0 \times 10^{-1} L^{2.68}$
females and males combined $W = 9.7 \times 10^{-2} L^{2.69}$

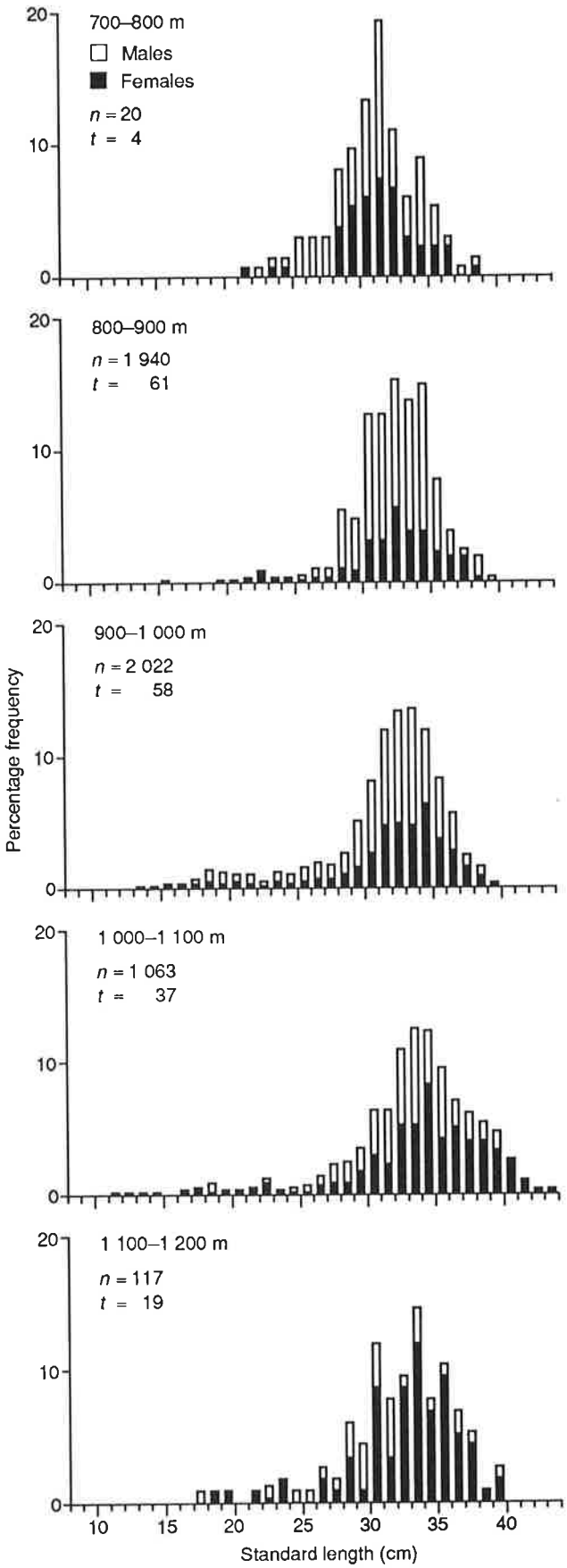


Figure 7a: Weighted (by percentage sampled) length frequency distribution of orange roughy by depth (n = number of fish measured, t = number of trawls from which samples were taken).

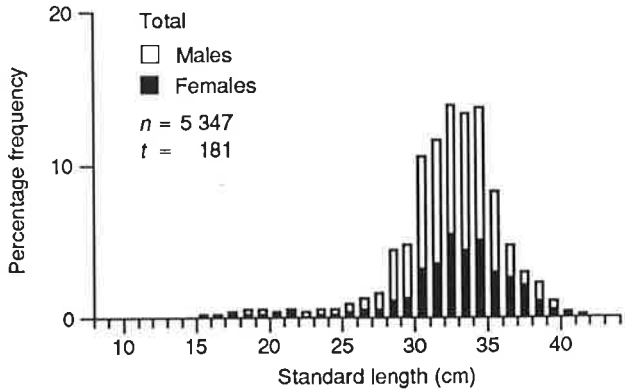


Figure 7b: Weighted (by percentage sampled) length frequency distribution of the total sample of orange roughy from the survey area (n = number of fish measured, t = number of trawls from which samples were taken).

Reproductive state

Gonad stages of females and males (*after* Pankhurst *et al.* 1987) for the five depth intervals and for all depths combined are given in Table 8. Of the 1422 female gonads examined, 31% were spent (stage 6), and 68% were in an endogenous vitellogenic or first maturation stage (stages 1 and 2). A predominance of one gonad stage at any given depth stratum was not apparent for the combined cruises. Pankhurst *et al.* (1987) investigated orange roughy reproductive cycles from the four 1983 cruises and described in detail the gonad development of females and males. In August 95% of the females were spent, and by September and October the gonads in most fish were in stage 1 or 2 (Table 9).

Sex ratio

The sex ratio for the 5347 measured orange roughy was 45 females to 55 males (Table 10). This ratio was found in the length classes up to 36 cm. Females were more abundant in classes over 36 cm.

Stomach contents

A total of 2875 orange roughy stomachs was examined and 53.5% contained food (Table 11). The ratios of empty to part full to full stomachs appear similar for each depth range, except in 700–800 m.

Of the stomach contents, 15% were fresh, 50% half digested, and 35% digested. Stomach contents comprised natant decapod crustaceans (55%), fish (36%), and squid (8%). These percentages were similar for the first three cruises. During the fourth cruise (October 23–28) the proportion of fish (44%) was almost as great as that of natant decapod crustaceans (45%). A more detailed analysis of the samples, particularly of the natant decapod group, is presented in Rosecchi *et al.* (1988).

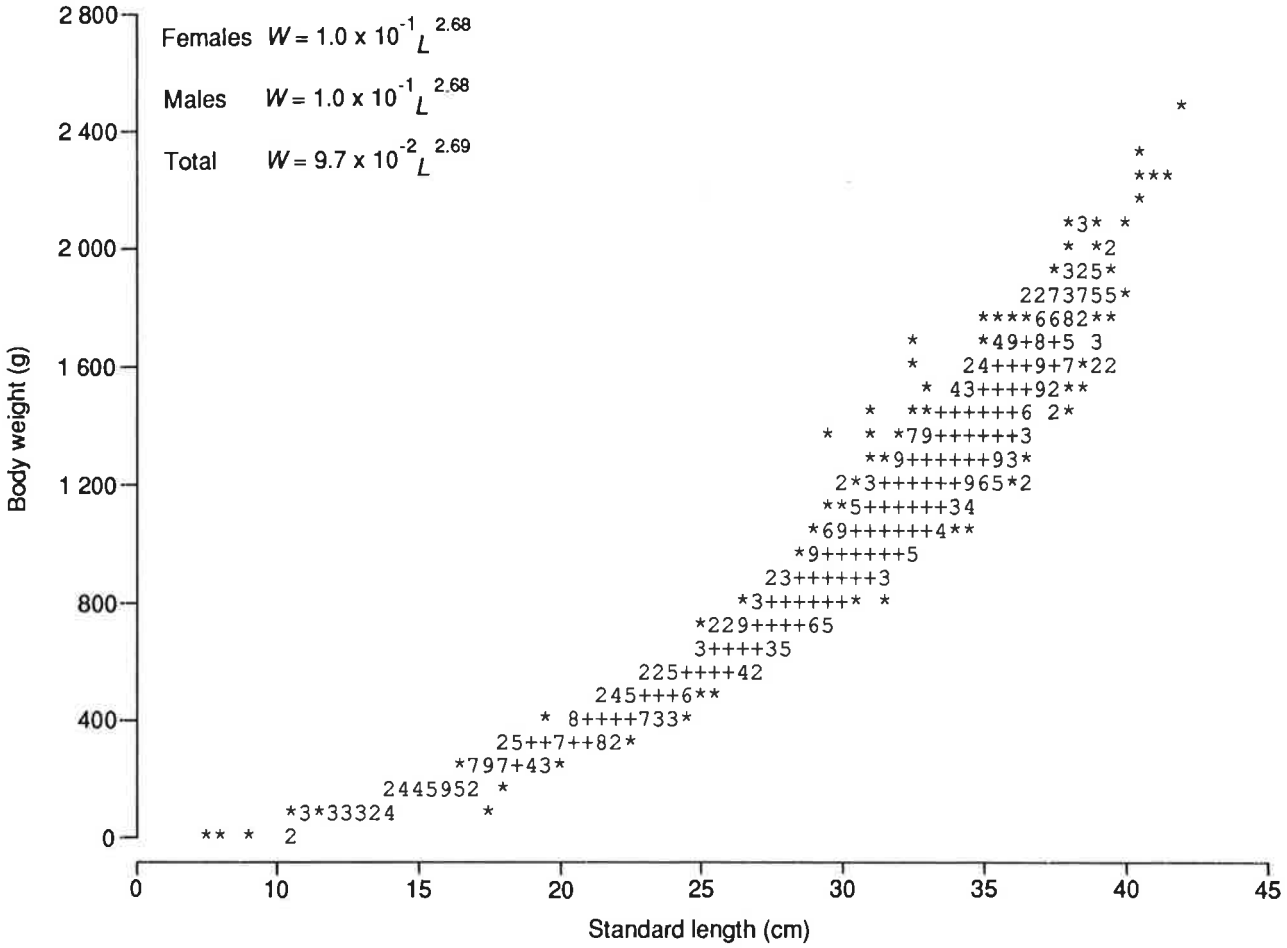


Figure 8: Length-weight relationship for orange roughy.

Table 8: Percentage of female (F) and male (M) gonad stage (1–6) by depth

Depth	Gonad stage 1		2		3		4		5		6	Total No.	
(m)	F	M	F	M	F	M	F	M	F	M	F	F	M
800–899	33.3	12.1	28.2	70.3	0.2	–*	0.4	0.4	0.2	17.3	37.3	504	556
900–999	38.2	23.8	34.3	65.7	–	–	0.2	–	1.0	10.5	26.1	495	572
1 000–1 099	42.5	14.4	32.3	70.0	–	–	–	–	–	15.6	24.9	334	257
1 100–1 200	35.4	22.8	18.3	63.2	–	–	–	–	–	14.0	46.3	82	57
Total	37.5	17.5	30.6	68.2	0.1	–	0.2	0.1	14.2	14.2	30.9	(99.7)†	(100)

* None were recorded.
† 0.3% of the female sample were not staged.

Table 9: Percentage of female (F) and male (M) gonad stage (1–6) by cruise*

Cruise	Gonad stage 1		2		3		4		5		6	
	F	M	F	M	F	M	F	M	F	M	F	M
23 Aug-2 Sep	3.2	4.1	–†	39.1	–	–	0.3	0.6	–	56.2	95.4	–
7–16 Sep	66.1	15.0	–	84.7	–	–	–	–	–	0.3	33.9	–
11–18 Oct	21.4	23.8	78.4	76.2	0.2	–	–	–	–	–	–	–
23–29 Oct	65.5	26.5	26.0	73.5	–	–	0.5	–	1.5	–	6.5	

* On the 23 Aug-2 Sep cruise 1.1% were unsexed.
† None were recorded.

Hydrology

During *James Cook* cruise (J07/83) in July 1983 CTD stations were at 633 and 1385 m (*see* Figure 2h). Two stations were sampled by use of reversing bottles to compare with CTD results. Five transects (a total of 24 stations) were selected for analysis (Table 12): three transects included part of the orange roughy "hot spot", one was situated across the north of the plateau, and another to the south. Vertical temperature, salinity (‰), and density (σ_t) sections on these transects are shown in Figures 9a–e. Values were taken from continuous vertical profiles. Density was represented by σ_t at atmospheric pressure, as determined from its salinity and in situ temperature. The variation of σ_t with depth provides a first approximation of the stability of a water column in the ocean (Harvey 1976).

Bottom temperature, salinity, and density in 600–1300 m ranged from 9.37 to 3.66 °C, 35.494 to 34.832, and 27.474 to 26.334 respectively (Table 13). On all transects, bottom water (900–1000 m) had a salinity minimum of 34.8, characteristic of Antarctic Intermediate Water. The upper 400–500 m water had temperatures and salinities of 10 °C and 34.7 or over. This high salinity and temperature water is characteristic of subtropical water (Heath 1985). Some instability of structure of the water column is apparent from the temperature, salinity, and density profiles. Transects 2 and 3 (*see* Figures 9b and 9c) in particular show instability in temperature and salinity profiles down to 700 m on the southwest flank of the plateau. Isotherms and isohalines also slope upwards along these transects. Figure 9b shows constriction of isopycnals along transect 2.

Table 10: Female : male sex ratios by standard length class

Length class (cm)	Sex ratio*
<20	86 (41) : 123 (59)
20–24	135 (43) : 177 (57)
25–29	398 (38) : 655 (62)
30–31	444 (40) : 661 (60)
32–33	538 (44) : 673 (56)
34–35	436 (48) : 468 (52)
36–37	234 (60) : 156 (40)
38–39	87 (64) : 48 (36)
>40	26 (90) : 3 (10)
Total	2 298 (45) : 2 841 (55)

* Number of fish (percentages are in parentheses).

Table 11: Percentage of stomach contents by depth

Depth (m)	Empty	Part full	Full	Everted
700–800	0.0	100.0	0.0	0.0
800–900	38.2	55.9	5.6	0.3
900–1 000	49.0	43.7	6.5	0.8
1 000–1 100	52.2	40.9	6.9	0.0
1 100–1 200	60.4	37.4	2.2	0.0
Total	46.2	47.4	6.1	0.4

Table 12: Summary of CTD transect data selected for analysis from *James Cook* cruise (J07/83) in July 1983

Transect No.	Start position		Finish position		Stations	Bottom depth range (m)
	° 'S	° 'E	° 'S	° 'E		
1	39 50.2	167 50.0	40 19.8	167 50.6	6, 55, 50	990–1 072
2	40 00.1	167 09.9	40 00.0	170 55.1	8, 7, 52, 55, 5, 56, 3, 2	755–1 385
3	40 20.0	167 30.0	40 18.7	168 18.7	51, 50, 38, 37	960–1 089
4	43 00.1	168 00.3	42 59.9	168 59.9	39, 41, 42	940–1 202
5	38 00.1	167 20.1	38 00.6	170 47.8	18, 17, 22, 23 24, 25	633–1 261

Table 13: Summary of temperature (°C), salinity (‰), and density* (σ_t) on the Challenger Plateau from *James Cook* cruise (J07/83) in July 1983

Depth (m)	Temperature		Salinity		Density		No. of observations
	Range	Mean	Range	Mean	Range	Mean	
Surface	11.63–15.07	13.61	34.917–35.494	35.258	26.334–26.638	26.482	22
600	7.91–9.37	8.54	34.832–35.025	34.924	26.894–27.180	27.087	22
700	7.02–8.52	7.74	34.855–35.406	34.928	26.946–27.129	27.003	22
800	6.14–7.30	6.86	34.846–34.984	34.917	27.018–27.152	27.093	23
900	5.56–6.44	6.06	34.876–35.013	34.933	27.113–27.288	27.180	24
1 000	4.61–5.72	5.30	34.909–35.017	34.968	26.852–27.296	27.204	9
1 100	4.41–5.12	4.70	35.005–35.091	35.039	27.084–27.357	27.310	10
1 200	4.04–4.45	4.23	35.076–35.202	35.114	27.384–27.412	27.391	5
1 300	3.66–3.86	3.76	35.170–35.210	35.190	27.437–27.474	27.456	2

* For transect stations only.

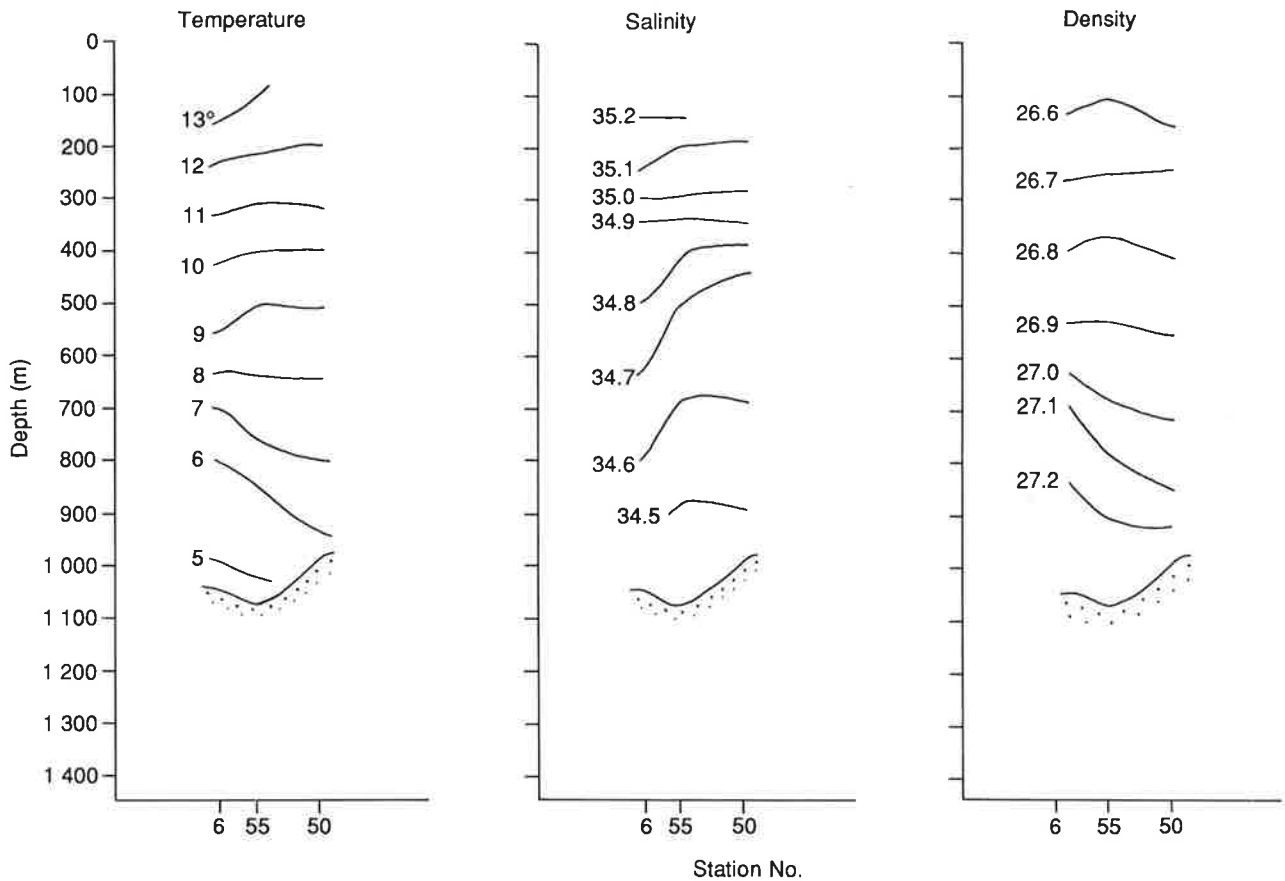


Figure 9a: Temperature (°C), salinity (‰), and density (σ_t) profiles for transect 1 on the Challenger Plateau from *James Cook* (J07/83) (*see* Figure 2h).

Discussion

Research on the Challenger Plateau between 1970 and 1980 was aimed at middle depth species rather than potential fish resources at depths greater than 700 m, particularly orange roughy. Exploratory trawling and research from 1981–83 has resulted in the development of what is now the second largest orange roughy fishery in the New Zealand EEZ.

Orange roughy are widely distributed on the Challenger Plateau from the west coast South Island to its northern margins (37° 00′–43° 30′ S), but results of the 1983 survey and records of fishing activity in the area suggest that high catch rates have been made only within small localised areas. Commercial vessels fish the "hotspot" pinnacles at about 40° 03′ S, 167° 59′ E intermittently for most of the year, and during winter-spring a flat area 17 km northeast of the pinnacles also produces very high catch rates. In late May orange roughy move into these areas, and by July dense plume-like aggregations of spawning fish are observed.

Catch rates on the *Arrow* survey were much lower than those made during the Chatham Rise survey in 1982 (Robertson *et al.* 1984), with a total mean catch rate of 36.4 kg.km^{-1} for orange roughy on the Challenger Plateau compared with a mean of 858.2 kg.km^{-1} on the Chatham Rise. The estimated mean catch rate from the *Professor Bogucki* survey on the Challenger Plateau from August to November 1981 was 69 kg.km^{-1} (Milosz 1986). However, commercial catch rates are similar in both areas, as is the depth distribution of the orange roughy.

The *Arrow* achieved catch rates of up to 324 kg.km^{-1} at the southern end of the survey area in 1983, which suggests there might be some commercial potential for orange roughy on the west coast South Island. This area was later investigated by *James Cook* (J16/83), but the total catch was only 233 kg (van den Broek 1984). However, since 1985 a commercial fishery has developed in this area (Tracey 1985,

Armstrong and Tracey 1986) centred on the Cook Canyon (*see* Figure 3), and it has an orange roughy total allowable catch of 1558 t per annum.

Orange roughy made up 62% of the total catch for the 1983 survey and 68 and 82% of the catch on the northern and southern Challenger areas, respectively, on the cruise of the *Professor Bogucki* in 1981 (Milosz 1986).

The biomass estimates from the *Arrow* survey and their calculated variability should be interpreted with caution. Some of the parameters used as inputs into the biomass estimates cannot be measured and have been assumed. The catchability coefficient (c) (the product of availability and vulnerability) was assumed equal to 1. The width of the sampling gear (b) was estimated from flume tank experiments by use of a scaled down model of the sampling trawl. The value of b was assumed to be constant throughout the survey. This is unlikely during actual trawling, e.g., because of the effects of changes in the bottom type encountered by the trawl, weather conditions which affect ship speed, currents which might slow or speed up the trawl.

Estimates of the distance trawled, and therefore the mean catch rate, are known to be imprecise. This is because distance was measured by use of the ship's electromagnetic log, i.e., ship speed through the water multiplied by time. The electromagnetic log is likely to be inaccurate, especially at low speeds, and ship speed through the water may be different to speed over the bottom because of weather and currents.

High variability of catch rates can be a problem for species such as orange roughy which form very dense localised aggregations. In the 1983 survey one large catch of 11 646 kg (station 15) was made in stratum 9; all the other catches in stratum 9 were less than 100 kg. Therefore, the mean orange roughy catch rate for that stratum has a high standard deviation and the biomass estimate has a high coefficient of variation. The variability may have been reduced by adding more stations to that stratum or by avoiding the time of year when orange roughy are either likely to be migrating to or from spawning areas or aggregated on the spawning areas. Francis (1984) developed a two-phase stratified random trawl survey which minimised this error, and this design has been used in subsequent Challenger Plateau surveys.

Future surveys could be undertaken 6 months from the spawning time, i.e., January, to try to avoid aggregated and migrating fish, but there are still problems with a survey at this time of year. These include the fact that some fish are still aggregated at all times of the year, apparently to feed. The boundaries of the survey area could be difficult to define because of the lack of information on the discreteness of orange roughy populations on the Challenger Plateau.

The 1983 survey was originally planned to take place when fish were apparently aggregated for spawning. This had been estimated in 1982 for the Challenger Plateau (W. L. F. van den Broek pers. comm.) and

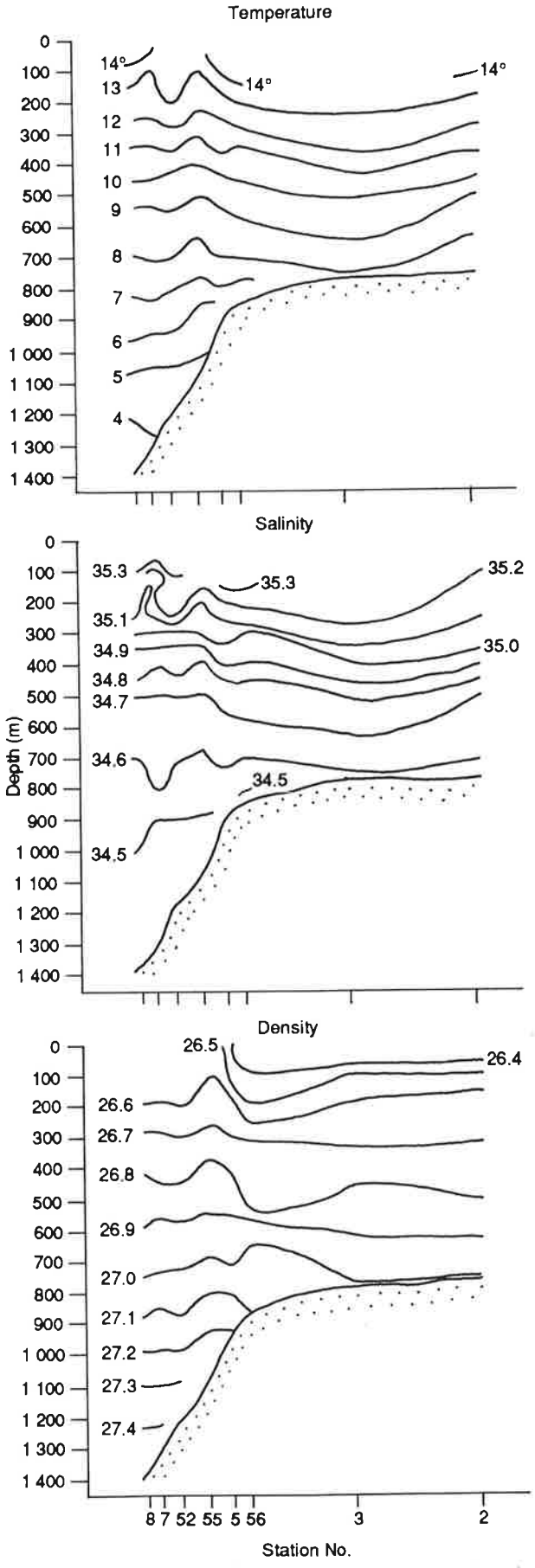


Figure 9b: Temperature, salinity, and density profiles for transect 2 on the Challenger Plateau from *James Cook* (J07/83) (*see* Figure 2h).

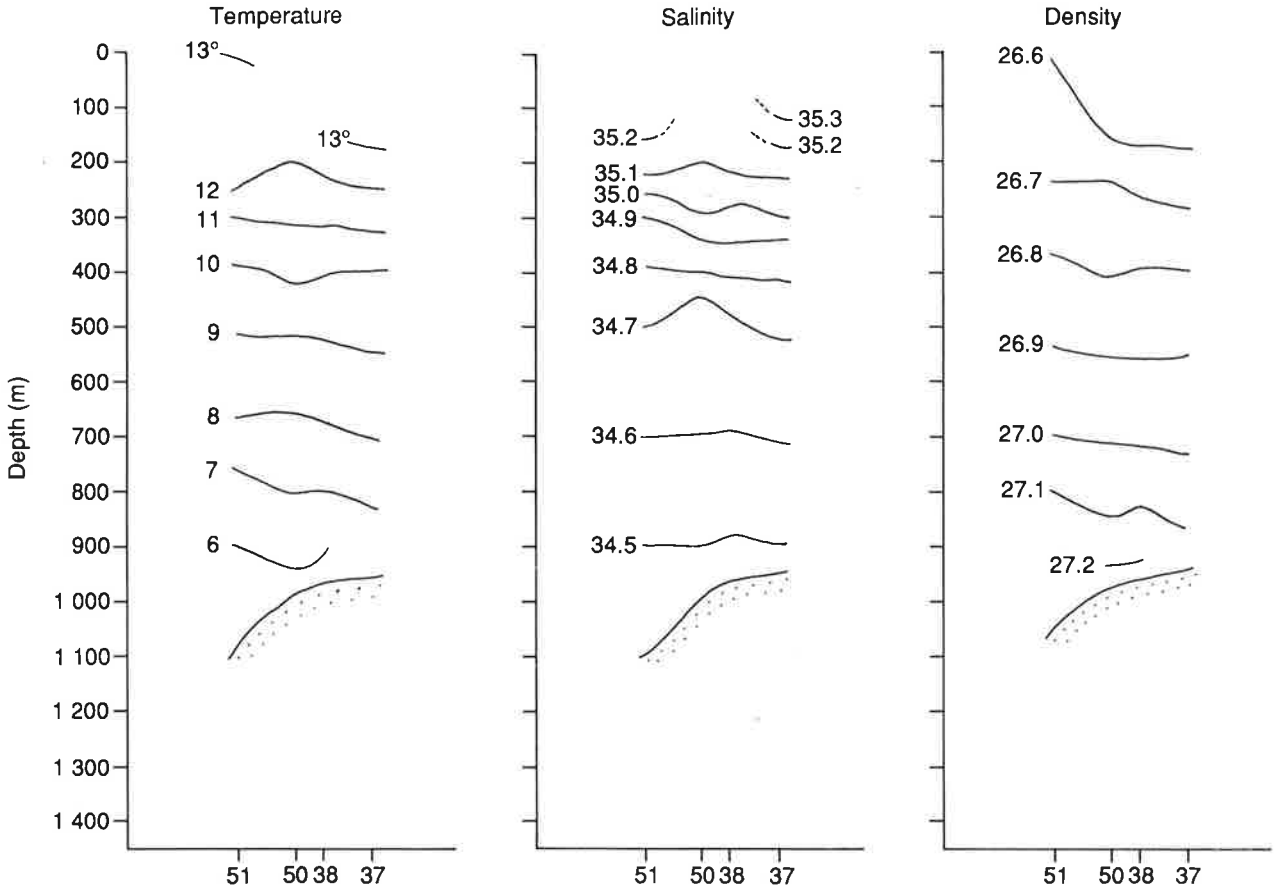


Figure 9c: Temperature, salinity, and density profiles for transect 3 on the Challenger Plateau from *James Cook* (J07/83) (*see* Figure 2h).

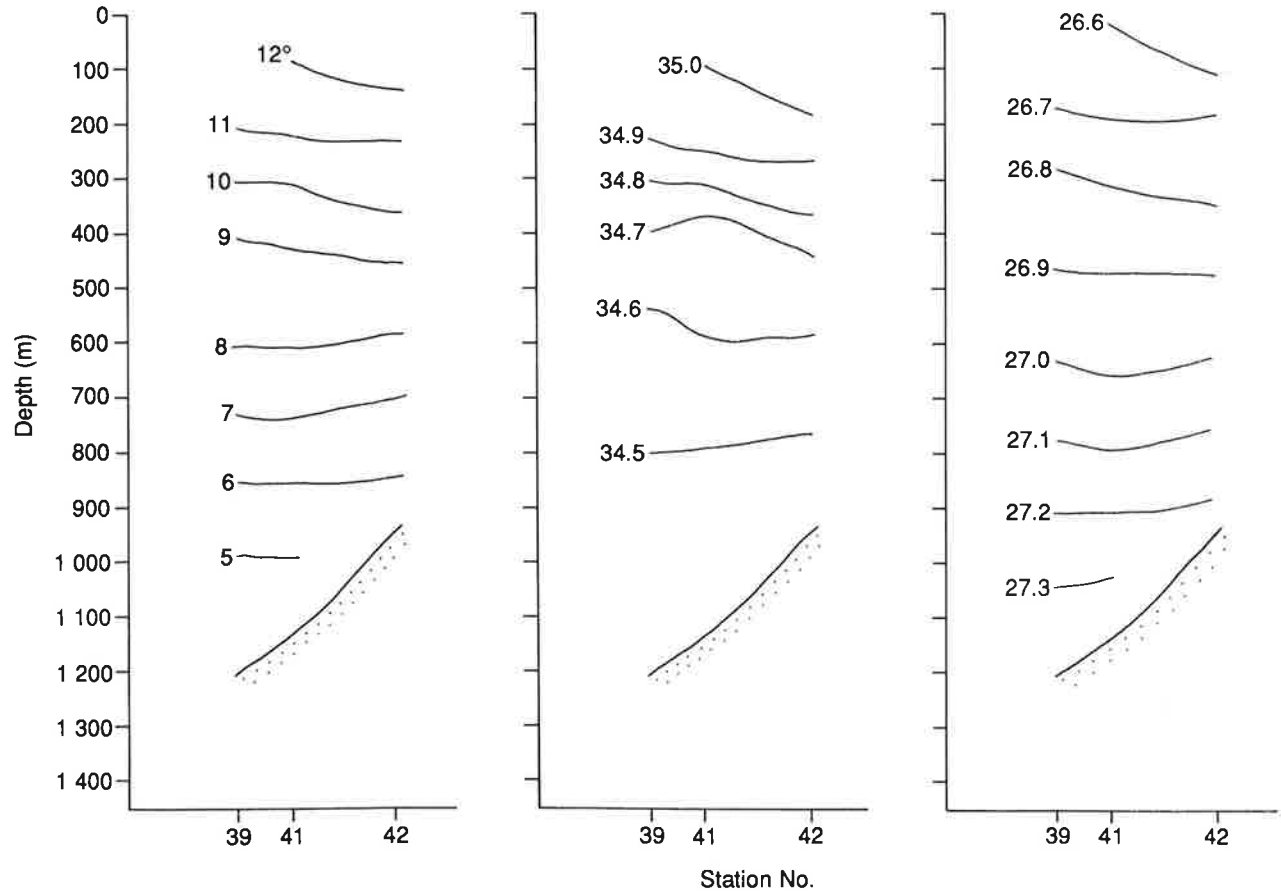


Figure 9d: Temperature, salinity, and density profiles for transect 4 on the Challenger Plateau from *James Cook* (J07/83) (*see* Figure 2h).

was also known to be the spawning time for Chatham Rise orange roughy (Robertson *et al.* 1984). A wide area survey of the Challenger Plateau offered the opportunity of discovering spawning areas other than the "known" one near 40° 00′ S, 168° 00′ E and to collect information on the reproductive biology of orange roughy. It also offered the chance to observe the commercial fishery at the time of highest catch rates.

The survey was conducted from 23 August to 28 October because of delays to the start time and therefore missed the time when orange roughy were densely aggregated to spawn. Commercial catches from the plateau were high from July to November in 1983 (*see* Table 2), which suggests that aggregations were probably present during these months. These aggregations are likely to have included fish associated with spawning and others, possibly associated with feeding, as the season progressed. Annual trawl surveys from 1984–88 have been carried out during the peak of spawning activity and are described in Tracey (1984 and 1985), Tracey *et al.* (1987), and Clark and Tracey (1988 and 1989).

The overall modal standard length from the 1983 survey was smaller than that observed for the July-August Chatham Rise fishery (34 cm SL, Robertson *et al.* 1984). Liwoch and Linkowski (1986) also found that mean (31.5–33.4 cm) and modal (32.6–34.3 cm) standard lengths were smaller in the northern Challenger area during August-October than on the Chatham Rise (mean 35.9 cm, modal 36.2 cm) in July. The length frequency distributions of spawning orange roughy from the Cook Canyon area (Armstrong and Tracey 1987) were significantly larger than those caught during the spawning season on the Challenger Plateau "hotspots" ($p < 0.01$, $n_1 = 741$, $n_2 = 4317$, Kolmogorov-Smirnov test). In addition, the spawning periods in the two areas are similar, which suggests that the populations could be separate.

Changes in the proportions of gonad stages of orange roughy indicated that the survey took place well after most spawning had occurred. Peak spawning takes place on the Challenger Plateau in early to mid July compared with the late June to early July spawning on the Ritchie Bank off the east coast North Island and the mid to late July spawning on the northern Chatham Rise (Pankhurst 1988). It has been suggested that the synchrony of annual midwinter spawning of orange roughy is cued by photoperiod (Pankhurst *et al.* 1987). However, the Cook Canyon fishery on the west coast South Island, at a similar latitude to the northern Chatham Rise fishery, has a spawning time in late June to early July (Armstrong and Tracey 1987). This suggests some inconsistency with the photoperiodicity hypothesis. Further monitoring of the Cook Canyon fishery will establish the time range in this area within which orange roughy spawn.

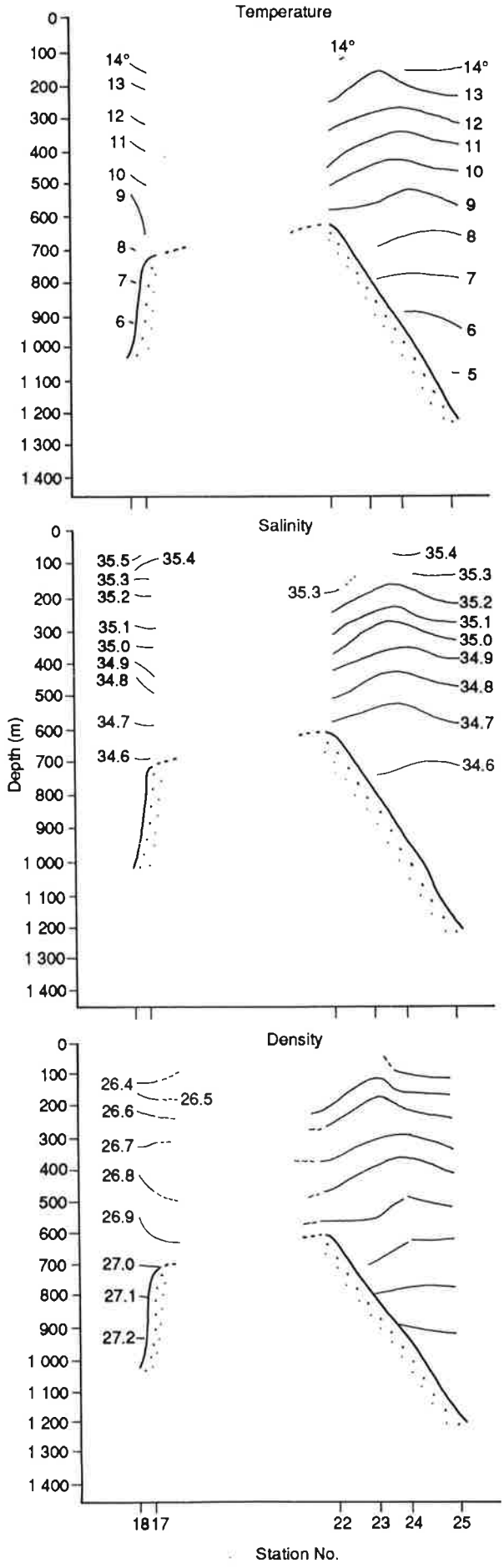


Figure 9e: Temperature, salinity, and density profiles for transect 5 on the Challenger Plateau from *James Cook* (J07/83) (*see* Figure 2h).

Feeding activity was high during the survey, and more stomachs were part full and full than empty. Rosecchi *et al.* (1988) recorded a peak in the proportion of empty stomachs during the spawning season and an increase in feeding activity for the months after July. Robertson *et al.* (1984) also found a high level of feeding after spawning. Prey items were similar to those recorded on other surveys (Liwoch and Linkowski 1986, Robertson *et al.* 1984, Rosecchi *et al.* 1988). The main prey groups of the predominant length class in this study (32–34 cm) were natant decapod crustaceans, fish, and squid. These results are consistent with those found by Rosecchi *et al.* (1988).

There is some evidence from the temperature and salinity profiles that the Challenger Plateau influences the direction and rate of water circulation and the temperature and salinity in the region. These factors may influence spatial distribution and relative abundance of adult orange roughy and be important in defining egg and larval drift and potential areas of juvenile habitat. Water masses on the plateau show similar characteristics to those on the Chatham Rise (Heath 1981, Robertson *et al.* 1984).

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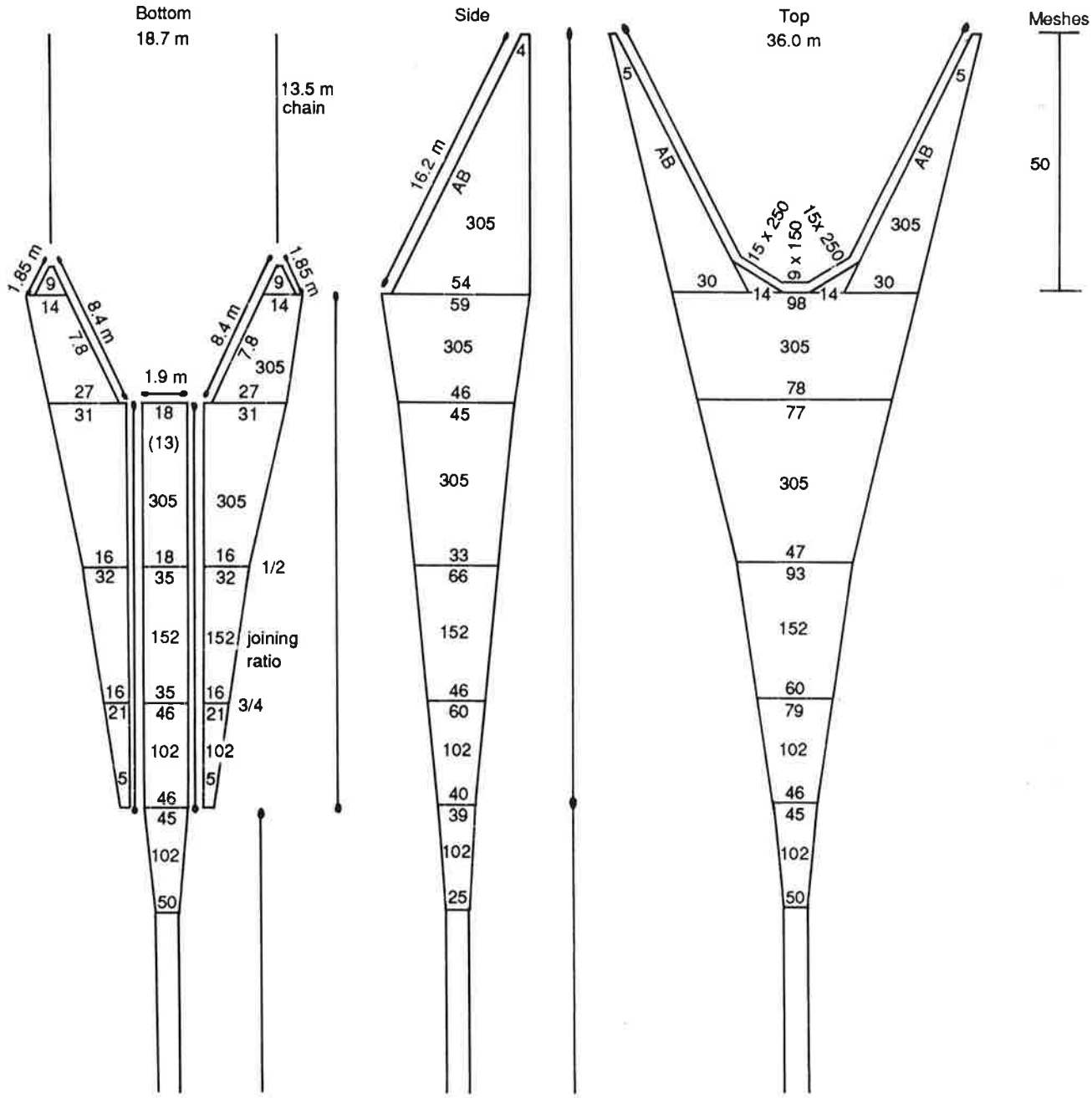
Appendix 1

Trawl net plan



Appendix 2

Individual station data, 1983 *Arrow* survey

Station No.	Stratum No.	Date	Start position ° 'S	° 'E	Finish position ° 'S	° 'E	Minimum-maximum depth range (m)	Orange roughy weight (kg)
A01001	25	23 AUG	40 09.9	169 55.7	40 08.8	169 54.6	858–862	10.7
A01002		23 AUG	40 09.6	169 27.6	40 09.5	169 25.7	819–824	11.5
A01003		23 AUG	40 07.7	169 08.3	40 05.5	169 08.2	793–805	6.0
A01004		23 AUG	40 03.6	169 07.2	40 01.9	169 06.3	767–777	2.9
A01005	9	23 AUG	40 05.4	168 48.4	40 05.8	168 46.0	810–816	6.3
A01006		24 AUG	40 03.9	168 34.6	40 05.6	168 33.7	842–852	63.0
A01007		24 AUG	39 59.6	168 33.9	40 00.6	168 32.2	828–836	41.7
A01008		24 AUG	40 01.5	168 26.7	40 03.1	168 25.4	847–856	0.0
A01009		24 AUG	39 57.9	168 32.5	39 59.7	168 31.8	836–844	12.6
A01010		24 AUG	39 56.4	168 21.0	39 58.3	168 20.9	823–836	9.5
A01011		24 AUG	39 52.0	168 16.5	39 49.7	168 16.3	789–803	14.4
A01012		25 AUG	40 18.2	167 57.0	40 16.4	167 57.7	965–971	37.3
A01013	10	25 AUG	40 09.6	167 57.3	40 09.1	167 57.3	944–954	41.7
A01014		25 AUG	40 03.3	167 58.5	40 04.0	167 59.9	911–920	179.3
A01015	9	25 AUG	39 58.1	168 00.5	39 59.7	168 01.0	891–897	11 646.0
A01016	10	25 AUG	39 58.8	168 03.9	40 00.6	168 03.6	878–884	88.3
A01019	12	26 AUG	39 58.4	167 50.5	40 00.3	167 50.7	987–1 012	83.8
A01020	10	26 AUG	40 09.7	167 42.8	40 10.7	167 40.1	1 028–1 035	136.7
A01021	11	26 AUG	40 12.9	167 50.7	40 14.6	167 51.1	976–985	41.0
A01022		26 AUG	40 18.6	167 41.7	40 17.9	167 40.9	1 024–1 026	20.5
A01023	10	27 AUG	39 50.9	167 57.4	39 52.8	167 57.1	969–978	2 124.2
A01024	9	27 AUG	39 44.3	168 03.3	39 43.1	168 01.3	813–828	25.2
A01025	10	27 AUG	39 58.7	167 59.0	40 00.3	167 57.1	901–945	150.1
A01026	9	27 AUG	39 59.1	168 08.1	39 58.6	168 09.5	866–872	28.5
A01027		27 AUG	40 06.2	168 12.8	40 07.8	168 11.7	897–905	9.7
A01030		28 AUG	40 05.6	168 10.1	40 04.0	168 11.6	889–897	20.5
A01031		28 AUG	40 08.0	168 25.0	40 08.2	168 26.2	891–895	19.0
A01032		28 AUG	40 04.1	168 25.8	40 04.3	168 27.5	872–872	82.0
A01033		28 AUG	40 11.1	168 51.0	40 11.8	168 49.4	855–857	18.6
A01034	10	28 AUG	40 25.0	168 51.6	40 26.3	168 51.7	914–919	16.2
A01035		29 AUG	40 22.6	168 40.5	40 24.5	168 40.7	926–932	13.9
A01036	6	29 AUG	40 29.1	168 43.8	40 30.8	168 42.9	939–941	16.5
A01037		29 AUG	40 38.3	168 48.3	40 39.9	168 48.6	932–932	16.0
A01038		29 AUG	40 57.5	168 47.8	40 59.5	168 47.4	941–943	17.9
A01039		29 AUG	41 06.5	168 32.6	41 07.8	168 31.0	999–1 005	25.2
A01040	8	29 AUG	41 25.3	168 05.2	41 24.1	168 04.4	1 138–1 141	0.8
A01041	7	30 AUG	41 04.7	168 18.6	41 02.9	168 19.0	1 050–1 052	18.1
A01042		30 AUG	40 55.2	168 07.0	40 54.8	168 05.7	1 045–1 046	67.8
A01043	8	30 AUG	40 54.2	167 42.7	40 52.8	167 40.9	1 114–1 116	5.9
A01044	10	30 AUG	40 19.0	168 10.0	40 17.0	168 09.6	959–965	51.8
A01045	11	31 AUG	40 28.4	167 51.8	40 30.1	167 51.6	1 029–1 038	15.5
A01046	12	31 AUG	40 27.6	167 27.6	40 26.2	167 26.0	1 109–1 114	24.5
A01047		31 AUG	40 11.7	167 23.5	40 10.5	167 24.2	1 148–1 159	19.9
A01050	15	01 SEP	39 48.8	167 50.3	39 48.1	167 51.3	1 036–1 051	48.7
A01051	14	01 SEP	39 37.6	167 45.1	39 37.8	167 46.0	928–951	58.0
A01052	13	01 SEP	39 31.8	167 47.0	39 31.8	167 45.0	804–817	1.2
A01053	25	02 SEP	39 36.9	170 22.6	39 35.9	170 24.4	815–815	4.4
A02054		07 SEP	39 49.9	170 55.6	39 48.0	170 54.8	813–819	1.5
A02055		07 SEP	39 32.6	170 34.3	39 30.9	170 34.3	849–852	4.3
A02056		07 SEP	39 23.3	170 52.0	39 22.3	170 52.7	853–855	4.0
A02057		07 SEP	39 25.3	171 08.5	39 26.6	171 08.4	840–844	1.4
A02058	17	08 SEP	37 46.8	167 51.2	37 46.2	167 49.3	802–808	37.0
A02059		08 SEP	37 42.4	167 54.3	37 41.1	167 56.2	806–812	17.5
A02060		09 SEP	37 32.5	167 48.0	37 30.9	167 48.1	847–861	41.0
A02061	18	09 SEP	37 29.3	167 46.8	37 28.5	167 45.1	878–887	207.0
A02062	17	09 SEP	37 31.8	167 38.7	37 32.8	167 36.8	835–840	80.0
A02063	20	09 SEP	37 13.7	167 49.9	37 13.7	167 51.9	1 109–1 123	45.1
A02064	18	09 SEP	37 22.5	167 30.2	37 23.8	167 31.9	962–980	66.2
A02065		11 SEP	38 54.6	167 21.3	38 54.1	167 23.7	891–935	30.4
A02066	14	11 SEP	39 05.7	167 23.2	39 07.0	167 24.6	972–988	55.7
A02067	13	11 SEP	39 06.7	167 30.0	39 06.4	167 32.0	859–892	18.7
A02068	14	11 SEP	39 09.4	167 27.6	39 11.4	167 28.1	954–956	18.7
A02069	13	11 SEP	39 10.6	167 30.8	39 09.9	167 32.7	853–896	42.1
A02070		11 SEP	39 17.1	167 36.8	39 18.8	167 36.8	839–848	26.7
A02071	16	12 SEP	39 15.3	167 17.9	39 16.8	167 18.0	905–1 099	5.6
A02072	15	12 SEP	39 24.9	167 17.5	39 26.7	167 17.4	1 067–1 077	50.0
A02073	14	12 SEP	39 26.4	167 31.6	39 27.5	167 32.9	945–964	54.8
A02074		12 SEP	39 27.3	167 36.7	39 27.7	167 38.6	871–904	46.7
A02075	16	13 SEP	39 23.9	167 16.7	39 24.0	167 18.8	1 111–1 138	4.7

Appendix 2—*continued*

Station No.	Stratum No.	Date	Start position ° 'S	° 'E	Finish position ° 'S	° 'E	Minimum-maximum depth range (m)	Orange roughy weight (kg)
A02076	15	13 SEP	39 25.5	167 25.5	39 25.3	167 27.3	996–1 013	43.6
A02077	14	13 SEP	39 19.5	167 32.4	39 19.3	167 34.3	902–931	31.8
A02078	18	14 SEP	37 42.3	167 22.6	37 42.8	167 24.3	946–954	20.8
A02079		14 SEP	37 40.7	167 22.8	37 40.0	167 24.7	994–998	7.3
A02080	20	14 SEP	37 18.4	166 49.3	37 19.9	166 48.8	1 104–1 113	16.9
A02081	18	15 SEP	38 01.5	167 24.4	38 02.8	167 25.1	943–946	22.3
A02082	20	15 SEP	38 19.6	167 08.1	38 17.9	167 08.3	1 204–1 230	11.0
A02083	17	15 SEP	38 22.8	167 24.6	38 21.1	167 24.6	836–837	76.9
A02084		15 SEP	38 15.9	167 23.4	38 14.9	167 23.6	866–872	26.9
A02085		15 SEP	38 33.5	167 22.5	38 35.3	167 22.2	792–796	0.9
A02086	19	15 SEP	38 37.1	167 06.9	38 36.0	167 07.8	1 008–1 022	136.0
A02087	18	16 SEP	38 32.6	167 10.4	38 31.0	167 10.7	966–1 083	28.5
A02088	19	16 SEP	38 27.3	167 08.4	38 26.0	167 09.1	1 035–1 050	83.9
A02089	20	16 SEP	38 33.6	167 00.2	38 35.0	166 59.6	1 168–1 179	13.1
A02090	17	16 SEP	38 49.5	167 18.9	38 50.3	167 20.7	842–880	34.1
A02091	16	16 SEP	39 27.9	167 13.6	39 26.4	167 14.0	1 153–1 155	5.4
A03092	25	11 OCT	40 19.4	169 57.9	40 20.5	169 58.0	857–859	26.6
A03093	5	11 OCT	40 41.1	169 54.2	40 42.8	169 54.3	828–830	28.7
A03094		11 OCT	40 59.4	169 52.0	41 00.3	169 53.5	826–834	17.4
A03095		11 OCT	41 03.1	169 56.9	41 04.4	169 58.2	814–814	6.3
A03096		11 OCT	41 11.5	170 00.1	41 13.0	169 59.9	816–818	16.7
A03097		12 OCT	41 14.4	169 52.4	41 16.4	169 52.2	850–853	48.0
A03098	6	12 OCT	41 28.7	169 42.7	41 30.2	169 43.3	925–931	4.3
A03099		12 OCT	41 36.1	169 44.8	41 37.5	169 45.5	952–955	17.7
A03100		12 OCT	41 44.8	169 51.9	41 46.4	169 52.0	945–954	27.5
A03101	1	12 OCT	41 59.7	170 03.2	42 01.2	170 03.2	853–856	14.0
A03102		12 OCT	42 16.9	170 03.7	42 18.4	170 05.3	850–857	61.5
A03103		12 OCT	42 22.2	170 06.2	42 23.4	170 06.3	808–886	44.3
A03104	2	12 OCT	42 36.7	169 34.1	42 38.3	169 35.0	928–934	43.4
A03105		12 OCT	42 44.3	169 34.0	42 42.2	169 30.4	923–923	77.5
A03106	1	13 OCT	42 57.5	169 22.2	42 59.3	169 21.4	810–813	15.8
A03107		13 OCT	43 02.3	169 16.5	43 03.4	169 15.0	843–849	16.0
A03108	2	13 OCT	43 06.6	168 50.0	43 07.0	168 47.3	971–976	22.8
A03109		13 OCT	43 09.9	168 50.2	43 11.8	168 51.3	930–944	28.2
A03110		13 OCT	43 11.5	168 38.0	43 11.2	168 36.0	982–993	41.1
A03111		13 OCT	43 22.5	168 46.0	43 23.8	168 44.7	917–931	68.4
A03112		13 OCT	43 27.3	168 49.6	43 28.8	168 49.7	928–1 267	1 020.4
A03113		13 OCT	43 17.7	168 45.3	43 16.8	168 43.6	930–940	21.2
A03114	4	14 OCT	43 13.0	168 17.6	43 11.8	168 16.3	1 097–1 102	11.0
A03115		14 OCT	43 06.4	168 02.5	43 05.1	167 59.6	1 166–1 176	0.0
A03116		14 OCT	42 55.9	168 10.3	42 54.8	168 11.5	1 170–1 181	0.0
A03117		14 OCT	42 59.3	168 25.2	42 59.3	168 26.4	1 113–1 126	2.8
A03118		14 OCT	43 03.1	168 24.2	43 04.4	168 23.3	1 092–1 092	8.2
A03119	3	14 OCT	43 09.5	168 36.3	43 08.4	168 37.4	1 022–1 025	17.0
A03120		14 OCT	42 58.9	168 46.2	42 57.8	168 47.6	1 035–1 035	16.6
A03121	2	14 OCT	42 56.2	169 05.3	42 55.5	169 07.5	941–950	38.9
A03122	3	15 OCT	42 44.6	169 00.2	42 42.8	169 00.4	1 026–1 041	121.8
A03123		15 OCT	42 40.0	169 07.3	42 38.2	169 08.0	1 029–1 125	104.0
A03124	3	15 OCT	42 09.6	169 43.5	42 08.8	169 43.1	1 041–1 055	12.1
A03125	7	15 OCT	41 55.0	169 34.7	41 53.9	169 33.7	1 090–1 105	0.2
A03126	8	15 OCT	41 57.4	169 28.4	41 58.5	169 28.1	1 113–1 204	0.3
A03127		15 OCT	41 56.4	169 17.3	41 55.8	169 14.9	1 135–1 136	0.9
A03128		15 OCT	41 54.9	169 23.0	41 54.8	169 25.2	1 110–1 115	5.3
A03129		15 OCT	41 52.1	169 10.0	41 51.9	169 09.0	1 117–1 118	3.4
A03130	7	16 OCT	41 45.7	169 02.7	41 44.3	169 03.6	1 063–1 077	3.2
A03131	4	16 OCT	41 59.2	168 41.2	41 58.0	168 42.1	1 213–1 222	0.0
A03132	7	16 OCT	41 41.2	168 44.2	41 39.5	168 44.8	1 043–1 056	25.0
A03133		16 OCT	41 31.8	168 47.2	41 30.9	168 45.4	987–990	7.8
A03134		16 OCT	41 32.9	168 33.4	41 34.2	168 33.4	1 017–1 026	52.1
A03135		16 OCT	41 33.6	169 07.6	41 33.5	169 09.9	1 002–1 002	38.5
A03136		16 OCT	41 35.8	169 09.4	41 37.5	169 09.3	1 011–1 018	44.8
A03137		17 OCT	41 39.6	169 20.9	41 39.5	169 22.0	1 025–1 025	14.0
A03138	6	17 OCT	41 23.5	169 35.4	41 22.1	169 36.0	922–929	18.7
A03139		17 OCT	41 23.1	169 23.5	41 23.2	169 21.4	956–961	11.6
A03140		17 OCT	41 16.1	169 05.2	41 14.5	169 04.3	938–941	69.9
A03141		17 OCT	41 04.3	169 27.2	41 03.5	169 28.9	909–914	0.0
A03142		17 OCT	41 10.5	169 29.0	41 12.3	169 28.8	918–921	31.5
A03143	5	17 OCT	40 59.0	169 35.8	40 58.1	169 36.9	887–890	46.4
A03144	6	17 OCT	40 42.7	169 05.1	40 42.0	169 03.0	903–905	11.5
A03145		18 OCT	40 39.3	168 57.7	40 38.2	168 56.1	911–913	28.8
A03146	26	18 OCT	40 28.2	168 55.2	40 26.8	168 55.2	906–907	21.0
A03147	25	18 OCT	40 18.3	169 07.6	40 17.7	169 08.8	862–864	55.7
A04148		23 OCT	39 08.9	171 28.2	39 08.3	171 27.2	830–840	3.7

Appendix 2—*continued*

Station No.	Stratum No.	Date	Start position ° 'S	° 'E	Finish position ° 'S	° 'E	Minimum-maximum depth range (m)	Orange roughy weight (kg)
A04149	26	23 OCT	39 00.7	171 51.1	39 00.2	171 52.5	956–998	23.8
A04150	22	23 OCT	38 56.9	171 45.6	38 56.5	171 44.2	980–985	21.0
A04151	23	23 OCT	38 52.4	171 40.5	38 50.8	171 39.3	1 004–1 011	19.5
A04152	22	23 OCT	38 55.7	171 34.9	38 56.6	171 33.9	935–1 025	19.3
A04153	26	23 OCT	38 53.8	171 27.7	38 52.7	171 26.1	907–918	10.8
A04154	21	23 OCT	38 54.9	171 04.0	38 55.1	171 02.2	841–845	0.0
A04155	22	23 OCT	38 40.5	171 20.6	38 42.1	171 17.6	913–930	11.2
A04156	24	24 OCT	38 32.8	171 36.7	38 33.3	171 35.1	1 147–1 170	3.7
A04157		24 OCT	38 29.9	171 29.2	38 30.9	171 27.3	1 091–1 124	19.8
A04158	21	24 OCT	38 35.1	171 09.6	38 36.2	171 08.1	882–895	1.1
A04159		24 OCT	38 37.1	170 55.8	38 37.7	170 53.8	840–845	5.8
A04160	22	24 OCT	38 25.2	171 03.9	38 27.3	171 02.9	909–928	14.1
A04161		24 OCT	38 24.5	171 02.2	38 26.0	171 01.9	915–934	18.4
A04162	21	25 OCT	38 26.9	170 53.3	38 28.5	170 53.3	869–875	18.6
A04163		25 OCT	38 26.8	170 45.8	38 28.5	170 45.2	852–854	7.3
A04164		25 OCT	38 30.3	170 41.9	38 30.8	170 40.8	827–836	21.1
A04165		25 OCT	38 29.6	170 37.5	38 28.7	170 35.6	818–821	33.4
A04166	22	25 OCT	38 10.0	170 34.9	38 08.4	170 34.7	944–977	14.9
A04167	23	25 OCT	38 06.7	170 39.5	38 05.3	170 41.0	1 068–1 100	16.1
A04168	24	25 OCT	38 07.6	170 39.4	38 07.5	170 38.2	1 022–1 045	28.0
A04169	21	25 OCT	38 11.1	170 26.9	38 12.3	170 26.3	856–871	18.9
A04170	23	25 OCT	37 56.6	170 21.1	37 56.2	170 21.9	1 061–1 094	33.0
A04171	21	26 OCT	37 59.1	170 06.8	37 59.8	170 04.7	848–861	12.1
A04172		26 OCT	37 59.6	170 01.6	37 58.5	169 53.2	834–836	20.5
A04173	18	26 OCT	37 47.8	169 55.8	37 46.3	169 55.4	937–945	9.9
A04174	19	26 OCT	37 32.9	169 25.9	37 32.9	169 24.4	1 075–1 106	20.1
A04175	18	26 OCT	37 37.8	169 12.3	37 38.3	169 10.2	900–904	143.7
A04176		26 OCT	37 33.8	169 08.0	37 32.4	169 07.5	949–961	55.1
A04177	17	26 OCT	37 39.8	169 07.1	37 41.8	169 07.6	846–875	265.3
A04178		26 OCT	37 40.3	169 01.9	37 39.7	169 00.3	878–891	121.6
A04179		26 OCT	37 40.5	168 55.0	37 40.9	168 53.3	874–883	18.4
A04180	18	26 OCT	37 38.0	168 54.2	37 37.0	168 56.9	915–928	18.8
A04181		27 OCT	37 33.7	168 55.5	37 33.7	168 53.4	952–957	58.9
A04182	19	27 OCT	37 24.3	168 59.0	37 24.1	168 56.9	1 020–1 022	33.0
A04183		27 OCT	37 23.2	168 53.1	37 23.0	168 51.2	1 033–1 036	47.7
A04184	19	27 OCT	37 23.2	168 46.8	37 22.4	168 46.3	1 041–1 043	40.6
A04185		27 OCT	37 22.4	168 41.6	37 21.1	168 39.1	1 051–1 051	15.8
A04186	20	27 OCT	37 16.1	168 27.4	37 15.8	168 25.5	1 109–1 110	64.3
A04187	14	28 OCT	39 29.5	167 29.2	39 31.4	167 30.6	984–985	111.9

* Commercial tows are not included. Data from 4 of the 181 stations were rejected due to poor performance of the gear or gear damage.

Appendix 3

Species taken during the survey

Scientific name	Common name
Chondrichthyes	
Chlamydoselachidae	
Chlamydoselachus anguineus	frill shark
Squalidae	
Centrophorus squamosus	leafscaled gulper shark
Centroscymnus coelolepis	Portuguese dogfish
C. crepidater	longnosed velvet dogfish
C. owstoni	Owston's dogfish
Deania calceus	shovelnosed dogfish
Etmopterus baxteri	Baxter's dogfish
E. lucifer	Lucifer dogfish
Scymnodon plunketi	Plunket's shark
Scymnorhinus licha	seal shark
Scyliorhinidae	
Apristurus spp.	deepwater catshark
Rajidae	
Bathyraja shuntovi	pale longnosed skate
Pavoraja spp.	deepsea skate
Raja innominata	smooth skate
Chimaeridae	
Chimaera sp. C	purplefinned chimaera
Hydrolagus sp. A	black ghost shark
Hydrolagus sp. B	pale ghost shark
Rhinochimaeridae	
Harriotta raleighana	longnosed chimaera
Rhinochimaera pacifica	widenosed chimaera
Osteichthyes	
Halosauridae	
Halosauropsis macrochir	abyssal halosaur
Halosaurus pectoralis	common halosaur
Notacanthidae	
Notacanthus sexspinis	spineback
Nemichthyidae	
Avocettina infans	black snipe eel
Nemichthys scolopaceus	slender snipe eel
Synaphobranchidae	
Diastobranchus capensis	basketwork eel
Simenchelys parasiticus	snubnosed eel
Congridae	
Bassanago bulbiceps	swollenheaded conger
Serrivomeridae	
Serrivomer samoensis	sawtooth eel
Bathylagidae	
Bathylagus antarcticus	deepsea smelt
Bathylagus sp.	deepsea smelt
Alepocephalidae	
Alepocephalus australis	smallscaled brown slickhead
Alepocephalus sp.	bigscaled brown slickhead
Xenodermichthys sp.	bluntsnouted slickhead
Platytroctidae	
Holtbyrnia sp.	
Persparsia kopua	
Gonostomatidae	
Diplophos rebainsi	elongate lightfish
Gonostoma elongatum	lightfish
Sternoptychidae	
Argyropelecus hemigymnus	common hatchetfish
Photichthyidae	
Ichthyococcus sp.	
Photichthys argenteus	lighthouse fish
Chauliodontidae	
Chauliodus sloani	viperfish
Stomiidae	
Stomias boa	dragonfish
Astronesthidae	
Borostomias sp.	deepsea snaggletooth
Melanostomiidae	
Melanostomias sp.	
Opostomias micripnus	
Malacosteidae	
Malacosteus sp.	loosejaw
Idiacanthidae	
Idiacanthus sp.	dragonfish
Synodontidae	
Bathysaurus ferox	deepsea lizardfish
Paralepididae	
Magnisudis prionosa	barracudina
Evermannellidae	
Evermannella sp.	sabretoothed fish
Omosudidae	
Omosudis lowei	
Alepisauridae	
Alepisaurus brevirostris	shortsnouted lancetfish
Myctophidae	lanternfish
Diaphus hudsoni	
D. ostenfeldi	
Electrona risso	
Hygophum hanseni	
Lampadena sp.	
Lampanyctus achirus	
L. australis	
L. lepidolychnus	
L. macdonaldi	
Lampanyctus sp.	
Lampichthys procerus	
Notolychnus valdiviae	
Moridae	
Antimora rostrata	violet cod
Halargyreus johnsoni	Johnson's cod
Lepidion schmidti	giant lepidion
Mora moro	ribaldo
Melanonidae	
Melanonus zugmayeri	
Merlucciidae	
Lyconus sp.	blackmouthed hake
Macruronus novaezelandiae	hoki
Merluccius australis	hake
Macrouridae	
Coelorinchus bollonsi	Bollons' rattail
C. fasciatus	banded rattail
C. innotabilis	notable rattail
C. matamua	Mahia rattail
C. oliverianus	Oliver's rattail
Coelorinchus sp. J	upturned snout rattail
Coryphaenoides murrayi	abyssal rattail
C. serrulatus	serrulate rattail
C. subserrulatus	four!rayed rattail
Coryphaenoidaes sp. B	longbarbel rattail
Gadomus aoteanus	filamentous rattail
Lepidorhynchus denticulatus	javelinfish
Macrourus carinatus	ridgescaled rattail
Mesobius antipodum	bathypelagic rattail
Nezumia bubonis	bulbous rattail
N. namatahi	squashedfaced rattail
Nezumia sp. P	false bulbous rattail
Odontomacrurus murrayi	largefanged rattail
Trachonurus sp.	
Trachyrincus sp.	unicorn rattail
Ventrifossa nigromaculata	blackspotted rattail

Appendix 3—*continued*

Scientific name	Common name
Bythitidae	
Cataetyx sp.	white brotula
Chaunacidae	
Chaunax pictus	pink frogmouth
Ceratiidae	
Ceratias holboelli	filamentous anglerfish
Cryptopsaras couesi	sea devil
Gigantactinidae	
Gigantactis sp.	
Linophrynidae	
Linophryne arborifera	black anglerfish
Oneirodidae	
Oneirodes notius	smooth anglerfish
Trachipteridae	
Trachipterus trachypterus	dealfish
Trachichthyidae	
Hoplostethus atlanticus	orange roughy
H. mediterraneus	silver roughy
Diretmidae	
Diretmoides parini	spinyfin
Diretmus argenteus	discfish
Anoplogastridae	
Anoplogaster cornuta	fangtooth
Melamphaidae	
Melamphaes sp.	bigscaled fish
Zeidae	
Cyttus traversi	lookdown dory
Oreosomatidae	
Allocyttus verrucosus	warty oreo
Neocyttus rhomboidalis	spiky oreo
Pseudocyttus maculatus	smooth oreo
Scorpaenidae	
Helicolenus sp.	sea perch
Trachyscorpia capensis	cape scorpionfish
Psychrolutidae	
Neophrynichthys angustus	pale toadfish
Psychrolutes sp.	blobfish
Apogonidae	
Epigonus robustus	
E. telescopus	deepsea cardinal fish
Rosenblattia robusta	
Bramidae	
Brama brama	Ray's bream
Emmelichthyidae	
Plagiogeneion rubiginosus	rubyfish
Chiasmodontidae	
Chiasmodon niger	black swallower
Uranoscopidae	
Kathetostoma giganteum	giant stargazer
Trichiuridae	
Benthodesmus sp.	slender frostfish
Lepidopus caudatus	frostfish
Centrolophidae	
Centrolophus niger	rudderfish
Seriolella punctata	silver warehou
Tubbia tasmanica	

Cephalopods

Octopoteuthidae	
Octopoteuthis rugosa	
O. sicula	
Octopoteuthis sp.	
Onychoteuthidae	
Moroteuthis ingens	warty squid
M. robsoni	warty squid
Gonatidae	
Gonatus sp.	
Histioteuthidae	
Histioteuthis macrohista	
H. miranda	
Histioteuthis sp.	violet squid
Brachioteuthidae	
Brachioteuthis sp.	
Ommastrephidae	
Ommastrephes bartrami	red squid
Todarodes filippovae	Antarctic flying squid
Chiroteuthidae	
Chiroteuthis sp.	
Cranchiidae	
Cranchia? sp.	
Liocranchia sp.	
Teuthowenia pellucida	
Teuthowenia sp.	
Opisthoteuthidae	
Opisthoteuthis sp.	umbrella octopus

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