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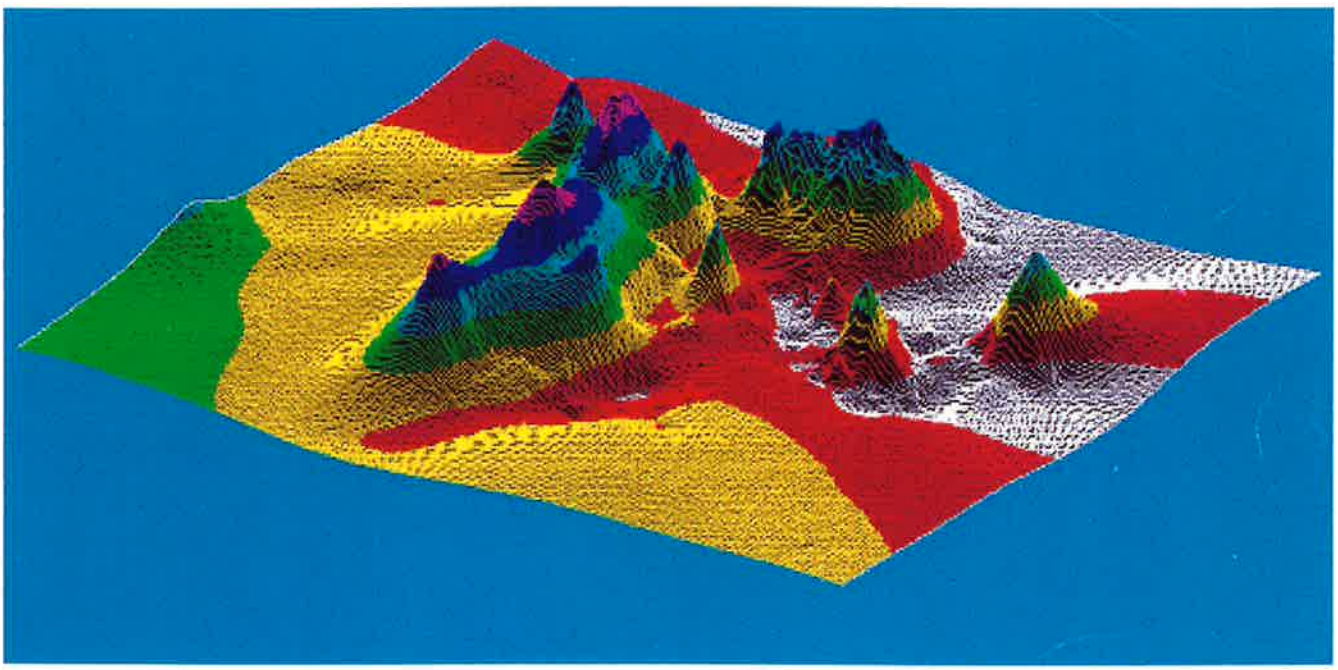
Distribution and relative abundance of orange roughy on the Chatham Rise, May-July 1994



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Cover illustration: The Andes, a complex of hills on the east Chatham Rise. Derived using Genamap from data collected by Seaplot. Vertical exaggeration 4 : 1.

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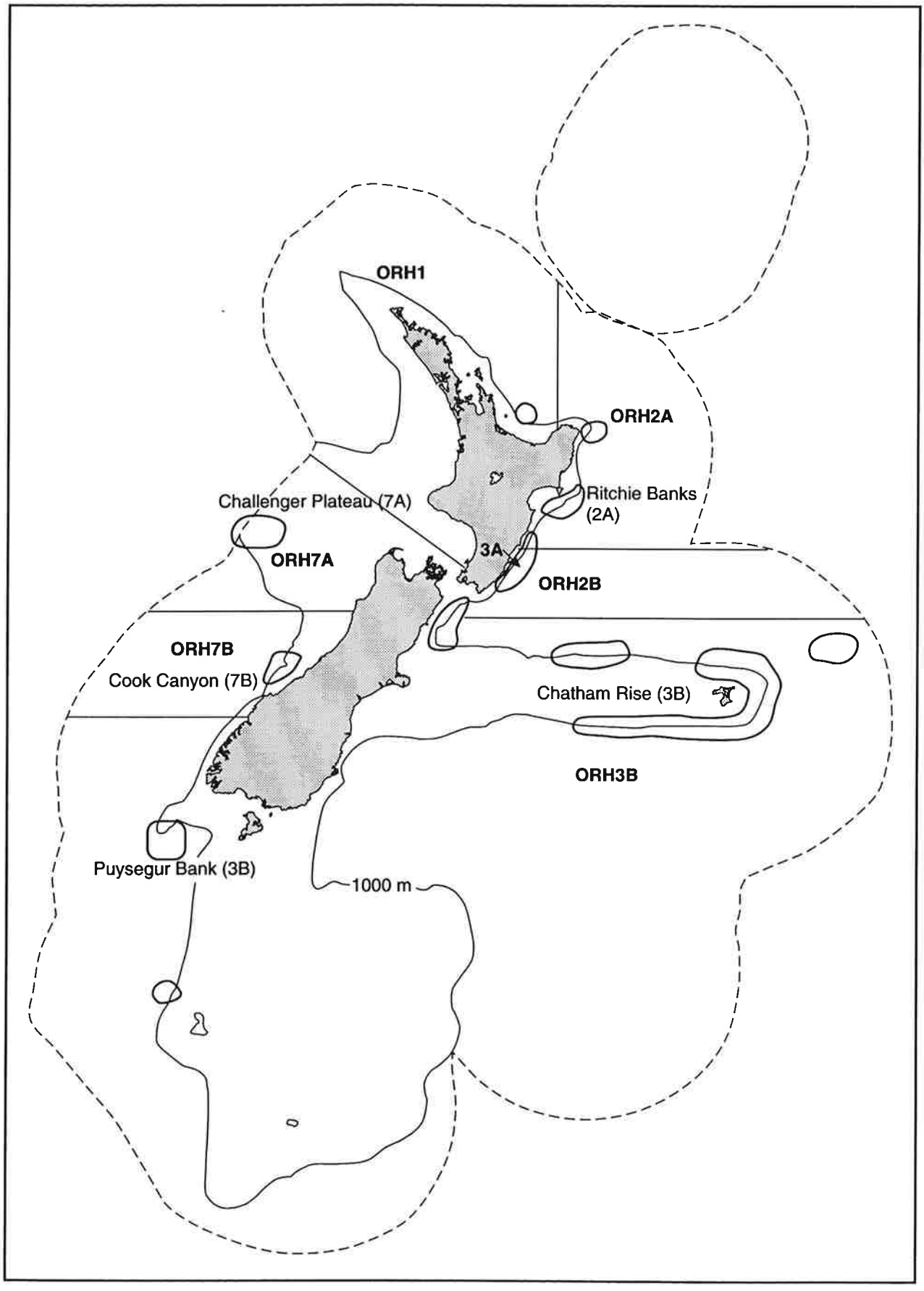


Figure 1: Major orange roughy fishing grounds in New Zealand waters and orange roughy Quota Management Areas.

Abstract

Tracey, D. M. & Fenaughty, J. M. 1997: Distribution and relative abundance of orange roughy on the Chatham Rise, May-July 1994. ***N.Z. Fisheries Technical Report No. 44.*** **43 p.**

A trawl survey on the Chatham Rise, May-July 1994, aimed to determine the location and distribution of orange roughy and associated fish species at depths between 750 and 1500 m, and to continue the time series of relative abundance indices of orange roughy within the standard spawning area (Spawning Box) surveyed since 1984. A stratified random bottom trawl survey on the Northeast Flat and Northwest Flat areas adjacent to the Spawning Box was also carried out and topographical features (pinnacles and drop-offs) that have been commercially fished on the south, east, and north Rise were sampled.

The survey in the Spawning Box followed the same design and area as the survey in July 1992. Catch rates were high in only one stratum, and the trend of a decline in biomass indices since 1984 continued, with higher coefficients of variation than observed in 1992. In the Spawning Box area, 86% of the biomass was females.

High catch rates of orange roughy were recorded on some pinnacle complexes in the northwest, northeast, and southeast survey areas. The variability of catches between and within pinnacles was assessed to see if reliable abundance indices could be obtained for stock assessment modelling. The variation in catch rates between tows was very high, resulting in imprecise estimates of abundance from the pinnacle surveys

Comparisons of the distribution and size structure of orange roughy, smooth oreo, and black oreo were made between the main survey areas. Orange roughy length frequency distributions, particularly in the areas where large aggregations were found, were characteristically unimodal in structure. This occurred both between and within the areas of high catch rates. In areas of lower catch rates, the length frequency distributions showed flatter, and in some instances bimodal, structures.

Detailed biological data (including length, weight, sex, reproductive state, and feeding) are presented for orange roughy and the oreo species. Spawning activity was evident in the Spawning Box as well as in the Graveyard area and on the Northeastern pinnacles. The onset of major spawning was evident in the Spawning Box from 20 July onwards.

Some exploratory work was carried out on features identified by a previous bathymetry survey, and included surveying and trawling on a plateau to the east of the Chatham Rise.

Introduction

Orange roughy (*Hoplostethus atlanticus*) are found in waters deeper than 750 m throughout New Zealand's Exclusive Economic Zone (EEZ). They are often aggregated over a variety of bottom types, including slope areas, edges of canyons, drop-offs, and the tops and sides of seamounts or pinnacles.

The main fishery for this species is on the Chatham Rise (ORH 3B, Figure 1). Reported annual commercial catches of orange roughy on the Chatham Rise were about 30 000 t in the 1980s and the maximum gazetted TAC (Total Allowable Catch) was 38 000 t in 1987–88. The current TAC in ORH 3B is 14 000 t.

Annala (1994) summarised the major changes in the distribution of catch and effort that have occurred in the Chatham Rise fishery since the 1978–79 fishing year. In the early years most of the catch was taken during the June to August spawning season from areas of mainly flat bottom on the northern sides. Initially catches were for an April–March fishing year. From 1984–85 onwards catches were for an October–September fishing year. From 1983 to 1989, about one-third of the catch was taken from pinnacle features from the south and east Rise. With quota changes, the TAC was reduced to about 23 000 t in 1990–91 (Grimes 1992). Effort continued to shift to new eastern and southern pinnacles from 1990 to 1992. In 1992–93 the ORH 3B area was divided into subareas (Figure 2) and overall catch limits on the Rise were reduced to 14 000 t. From 1992 to 1993, mean catch rates per tow in the south and east areas declined from 7.7 to 4.7 t.

The area of main commercial fishing (particularly during the 1980s) on the northeast Chatham Rise, known as the "Spawning Box" or "Survey Box" (and referred to as the "Spawning Box" in this report) was closed to all commercial activity in 1992 by a voluntary agreement (Francis *et al.* 1992). Most fishing now occurs on pinnacle complexes in the northwest, east, and southeast regions of the Chatham Rise.

Further descriptions of the commercial fishery and its development on the northeast Chatham Rise up to 1988 were described by Coburn & Doonan (1994). In particular,

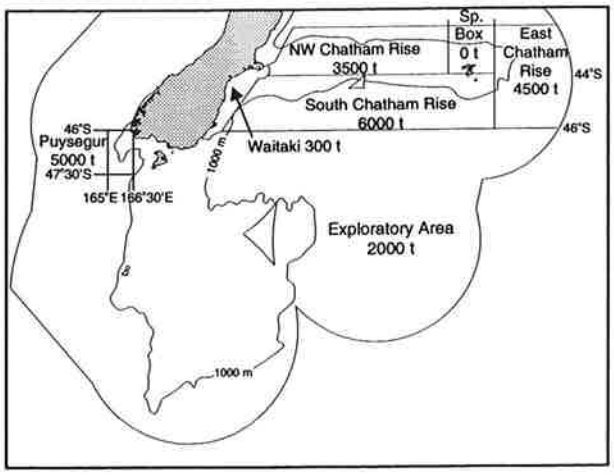


Figure 2: Seven subareas of ORH 3B and the associated 1992–93 catch limits.

they discussed fleet movements and deduced that orange roughy migrate towards the Spawning Box in July, and then disperse to the east and possibly west in August, after spawning.

Stratified random trawl surveys have been concentrated in the northeast area of the Rise, which includes the Spawning Box (Figure 3), and monitored the change in relative abundance of orange roughy. Random trawl surveys have been carried out annually on the north Chatham Rise since 1982.

The first orange roughy survey of the Chatham Rise (by FV *Kaltan* in 1982) covered most of the northern and eastern slopes of the Rise in August-September (Robertson *et al.* 1984). Since 1984, MAF Fisheries has carried out a further eight surveys of the Chatham Rise spawning population in winter, including the Spawning Box area. A two-phase random trawl survey design was used with the sequence of station occupation identical each year from 1984 to 1992. FV *Otago Buccaneer* was used for the 1984 to 1987 surveys, FV *Cordella* from 1988 (Fenaughty & Grimes 1989) to 1990, and from 1992 RV *Tangaroa* was used. There were no surveys in 1991 and 1993.

In response to the more widespread distribution of the commercial fishery during the mid to late 1980s, the Spawning Box survey area was expanded and some pinnacle and drop-off features, as well as the flat areas, were sampled on the Rise. The main aims were to determine orange roughy distribution and sample for any stock differences between the Spawning Box and other parts of the Rise.

In 1989, the winter survey area of the Spawning Box time series was extended to cover the entire north and northeast Rise and known orange roughy grounds on the south Chatham Rise. There was insufficient time to survey to the east and southeast of the Chatham Islands. In 1990, the length of survey was again increased to give wider coverage of the orange roughy grounds and the fishing depth was increased from 1250 to 1500 m.

The wide-area survey series was developed further in 1992 to cover most of the Rise from the northwest, east, and around to the south. Several new pinnacle and drop-off features were included. The sequence in which the Spawning Box stations were occupied was changed in this survey to minimise the time lapse between occupation of phase 1 and phase 2 stations and to ensure that the strata where high catch rates were expected were occupied mostly in the second half of July, when fish migration appears to be minimal (Coburn & Doonan 1994).

For the 1994 survey reported here, the area was again expanded, and included more rigorous coverage of Spawning Box and drop-off features, including those identified in April 1994 by an industry-funded ocean floor mapping sonar survey (Rognstad 1992) carried out by the Hawaiian Mapping Research Group (HMRG). The aim was to obtain abundance indices on different topographical features and use these for a time series of catch rates for stock assessment modelling of the ORH 3B fishery.

The core Spawning Box survey area time series begun in 1984 as well as the Northeast Flat and Northwest Flat area surveys begun in 1989 were continued.

Survey objectives

To provide information for the assessment of Chatham Rise stocks of orange roughy and associated fish species by:

1. determining their location and distribution at depths between 750 and 1500 m in Chatham Rise waters;

2. determining relative biomass indices, thereby continuing the time series within the Spawning Box and also over an extended area in the Northwest Flat and Northeast Flat areas surveyed since 1989;

3. comparing catch rates from a randomly selected subset of "new" and "known" (*see* Survey design, below) pinnacle and drop-off features on the Chatham Rise;

4. collecting biological data on size structure and reproduction.

The survey also aimed to collect orange roughy eggs for DNA analysis and larvae for life history and age information from plankton samples in late July, and to assess the possibility of using acoustics to estimate relative abundance of orange roughy by carrying out a pilot acoustic survey using the Simrad EK500 in the high density spawning area of the Spawning Box during the later stages of the survey.

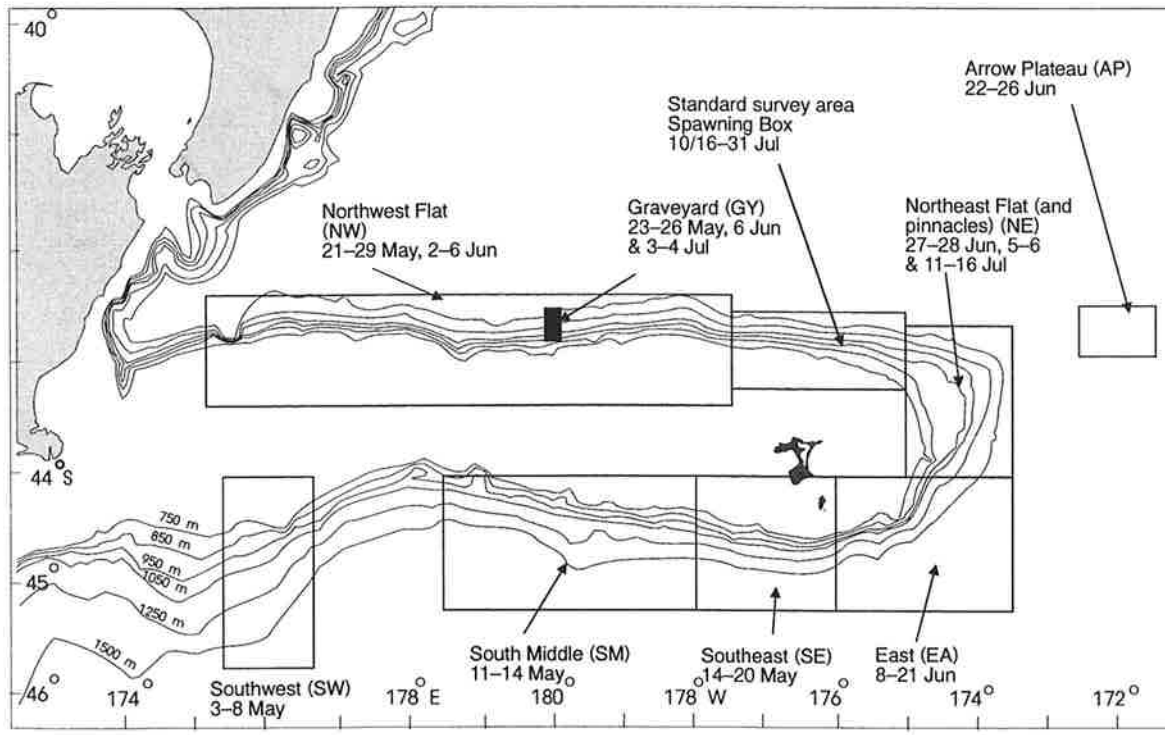


Figure 3: Research survey areas.

Methods

Survey area

The survey covered the north, east, and south Chatham Rise in depths of 750–1500 m, encompassing an area of 35 108 km^2 between latitudes 42° and 46° S. The survey area was subdivided into 10 major regions of geographically separate pinnacles and drop-off features, as well as the Spawning Box and flat areas (Figure 3). A catalogue of the topographical features was compiled before the survey began using information from industry, the HMRG charts, and MAF Fisheries databases. The catalogue included all known and new pinnacles and drop-offs on the Chatham Rise. From bathymetric charts, approximate areas were estimated for the topographical features from the surface area of the pinnacle and/or drop-off down to the base of the pinnacle where it flattens out to meet the flat slope.

The following areas and their unique codes define the various pinnacles and flat strata surveyed.

Southwest (SW): a group of 58 features between 175° 06' E and 176° 36' E longitude, south of the Mernoo and Veryan Banks, including Mt Sally and unnamed pinnacle and drop-off features in the Mernoo Gap.

South Middle (SM): an area between 178° 50' E and 178° W containing nine features including Mt Nelson and Trevs Pinni.

Southeast (SE): defined by longitude 178° W and 176° W, this area contained 45 features and included the Hagerville and Buccaneer Steps pinnacles and an unnamed pinnacle.

East (EA): an area of 70 pinnacles in the southeast corner of the Chatham Rise bounded in the north by latitude 44° S and in the west by longitudes 176° W to 173° 30' W. Cotopaxi and Big Chief are well known pinnacles. The area also includes pinnacles newly identified by the HRMG bathymetry survey .

Northeast (NE): this area of nine major pinnacles, including Not Till Sunday and Smiths City, lies east of 175° W to 173° 30' W and north of 44° S to the 1500 m contour at about 42° 40' S.

Northeast Flat (NE): the slope area with the same boundaries as NE was divided into five strata based on depth: 7A (750–849 m), 7B (850–949 m), 7C (950–1049 m), 7D (1050–1249 m), and 7E (1200–1500 m). The total area of these strata is 11 726 km^2.

Spawning Box: this slope area of 7655 km^2 contains the main survey area sampled on the Chatham Rise since 1984 and is delineated by longitudes 177° 30' W to 175° W and depths 750–1500 m. The Spawning Box strata (Figure 4) were bounded by the isobaths 750–849 m (strata 1, 6, 11, 16, 21), 850–949 m (strata 2, 7, 12, 17, 22,), 950–1049 m (strata 3, 8, 13, 18, 23), 1050–1149 m (strata 4, 9, 14, 19, 24), 1150–1249 m (strata 5, 10, 15, 20, 25), 1250–1500 m (strata 5X, 10X, 15X, 20X, 25X), and 800–849 m (stratum 26) .

Graveyard (GY): a group of pinnacles grouped about the 180° longitude on the North Rise known by fishers as the Graveyard. It contains nine pinnacles including Morgue, Graveyard, and Zombie.

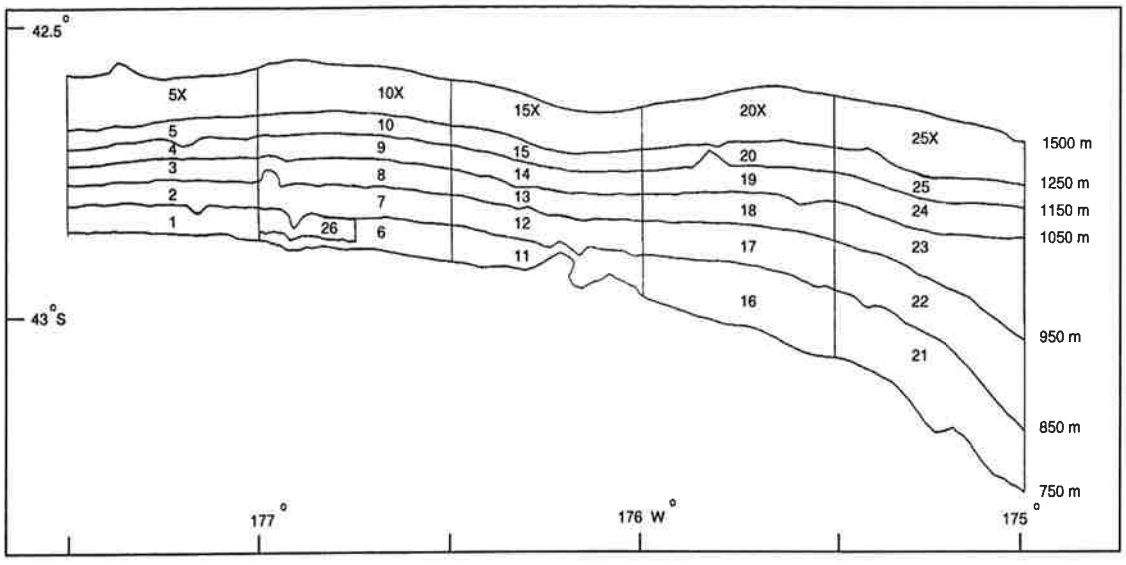


Figure 4: The Spawning Box survey area showing stratum boundaries.

Northwest Flat (NW): a slope area of 15 542.6 km^2 bounded by 175° E and 177° W and the 750–1500 m contours; 20 strata based on depth were defined as strata 1(A–E), 2(A–E), 3 (A–E), 4(A–E).

Arrow Plateau (AP): a deep plateau, also known as Far East, about 80 n. miles northeast of the 1000 m contour on the eastern Chatham Rise between about 42° 32' S and 42° 55' S and 172° 38' W and 171° 54' W. At the time of the survey seven deep pinnacles between 1212 and 1435 m had been located in this area.

Survey design

Spawning Box, Northwest Flat, and Northeast Flat areas

The survey in the Spawning Box followed the two-phase stratified random methodology of Francis (1984). Thirty-one strata were sampled using the same stations and, for comparability, following approximately the same sequence of station occupation as in the 1992 survey. In the Northeast Flat and Northwest Flat areas a single-phase random trawl method (Francis 1981) was followed, again using the same station positions and approximately the same station occupation sequence as in the 1992 wide area survey. Table 1 gives the stratum boundaries and areas used for relative abundance estimates for the Northwest Flat, Northeast Flat, and Spawning Box areas.

At least three stations were sampled in each stratum. Tows were parallel to the depth contour, distance was standardised to 3.0 n. miles, and towing speed was kept at about 3 knots.

Pinnacles and drop-offs

In the other areas surveyed, fishing was on topographical features to compare catch rates on and between pinnacles. A structured approach to the sampling of features was used (after Clark 1994).

1. The feature was described as a pinnacle or drop-off.

2. The feature was described as already "known" to ourselves and industry, or "new", i.e., recently identified by the HMRG survey.

3. A weighting factor was applied to each feature as follows:
the feature was new (weighted 1) or known (weighted 2); the dominant species caught on the known feature was historically orange roughy (weighted 1) or oreos (weighted 2).

4. Features were numbered and then randomly subsampled from the list (using the 'S' language statistical package (Becker *et al.* 1988) to generate the random numbers).

5. The tow direction on pinnacles was randomised between 0° and 360° or between trawlable directions.

6. For drop-offs, a random latitude and random direction was used intersecting the drop-off, and the tow length was bounded by the extent of the ridge.

7. The feature was sampled at least three times. Consecutive tows on any one feature were avoided to accommodate short-term changes in fish availability (e.g., fish moving into mid water from the top of the pinnacle).

8. The time of day for trawling was varied to minimise the effects of any diurnal behaviour pattern.

9. When possible, the slope of a feature was sampled from top to bottom to ensure that the catch was representative of total species composition. Tow length was shortened if gear saturation occurred during the tow or if the bottom topography was too rough.

The same methodology was used in the Graveyard area. These pinnacles were sampled over several time periods, 23–26 May, 6 June, and 3–4 July, which was possible because they were easily accessed en route to changeover ports. Such repeat sampling, designed to minimise the bias caused by short-term changes in fish availability and/or vulnerability, was logistically impossible in other areas of the Rise.

In applying the weighting factors, priority was given to new features and to those with a prominent orange roughy catch history to increase the likelihood of orange roughy

Table 1: Stratum areas, locations, and depth range

Stratum	Area (km²)	Longitude	Depth (m)
Northwest			
1A	404.20	175–176E	750–849
1B	405.90	175–176E	850–949
1C	561.20	175–176E	950–1 049
1D	1 000.00	175–176E	1 050–1 249
2A	778.30	176–178E	750–849
2B	609.10	176–178E	850–959
2C	1 177.20	176–178E	950–1 049
2D	707.60	176–178E	1 050–1 249
2E	707.60	176–178E	1 250–1 500
3A	667.80	178–180E	750–849
3B	667.20	178–180E	850–959
3C	656.80	178–180E	950–1 049
3D	1 084.90	178–180E	1 050–1 249
3E	1 084.90	178–180E	1 250–1 500
4A	885.70	180–177 30W	750–849
4B	764.20	180–177 30W	850–949
4C	692.80	180–177 30W	950–1 049
4D	1 545.70	180–177 30W	1 050–1 249
4E	1 545.70	180–177 30W	1 250–1 500
Spawning Box			
1	320.91	177 30–177W	750–849
2	173.67	177 30–177W	850–949
3	139.68	177 30–177W	950–1 049
4	137.57	177 30–177W	1 050–1 149
5	126.72	177 30–177W	1 150–1 250
6	200.15	177–176 30W	750–849
7	207.90	177–176 30W	850–949
8	181.39	177–176 30W	950–1 049
9	159.31	177–176 30W	1 050–1 149
10	153.87	177–176 30W	1 150–1 250
11	356.96	176 30–176W	750–849
12	209.91	176 30–176W	850–949
13	167.47	176 30–176W	950–1 049
14	158.66	176 30–176W	1 050–1 149
15	120.61	176 30–176W	1 150–1 250
16	527.44	176–175 30W	750–849
17	274.91	176–175 30W	850–949
18	213.20	176–175 30W	950–1 049
19	179.92	176–175 30W	1 050–1 149
20	160.48	176–175 30W	1 150–1 250
21	555.79	175 30–175W	750–849
22	406.12	175 30–175W	850–949
23	323.46	175 30–175W	950–1 049
24	229.91	175 30–175W	1 050–1 149
25	156.74	175 30–175W	1 150–1 250
26	33.01	177–176 45W	800–849
5X	368.72	177 30–177W	1 250–1 500
10X	371.09	177 176 30W	1 250–1 500
15X	316.04	176 30–176W	1 250–1 500
20X	355.95	176–175 30W	1 250–1 500
25X	367.20	175 30–175W	1 250–1 500
Northeast			
7A	1 191.50	175–173 30W	750–849
7B	3 259.00	175–173 30W	850–949
7C	1 554.40	175–173 30W	950–1 049
7D	2 436.20	175–173 30W	1 050–1 249
7E	3 285.30	175–173 30W	1 250–1 500
Total	34 924.00		

being present. When possible, all the new features were sampled, but when time was limited a subset of new features was chosen at random. Some of the new features selected were rejected because they did not exist at the position given or were too small or rugged to be fished.

The number of features sampled is given in Table 2. As only seven drop-offs from the Southwest, South Middle, and Southeast areas were identified in the catalogue, it was decided to sample all drop-offs. All remaining features on the Rise were pinnacles. Of the 200 pinnacles and drop-offs catalogued, 48 were randomly sampled at least three times during the survey: only 10 of these were new or unnamed pinnacles. Figure 5 shows all pinnacles sampled on the survey, including the new pinnacles Aloha and Diamond Head (features picked off the image produced by the HRMG and located and named on the present survey), as well as pinnacles identified on the HRMG chart before the survey (No. 2, a new pinnacle in East, Unnamed, a pinnacle in Southeast, and several unnamed pinnacles in Southwest).

Plankton survey

On 21 July a 10 n. mile plankton transect was carried out on the eastern side of stratum 2 in the Spawning Box (*see* Figure 4). Eight vertical hauls with a 2 m diameter plankton ring net were made to 850 m to collect eggs for DNA analysis and larvae for life history and age information.

Acoustic survey

A grid was drawn up to cover the areas of strong orange roughy echoes that had been observed during trawling and on 26 July an acoustic survey using the Simrad EK500 was attempted.

Vessel and gear specifications

The rough bottom orange roughy trawl gear was fully described by McMillan (1996). It incorporated two lengtheners, three codends, and a bobbin rig. The Scanmar 400 system provided data on doorspread, wingtip, headline height, and bottom water temperature.

Table 2: Number of features identified and sampled by area, feature type by area, and number of acceptable tows (gear performance = 1 or 2)

Area	No. of features	No. of features randomly selected			No. of acceptable tows
		Pinnacles	Drop-offs	Total	
Southwest	58	6	1	7	23
South Middle	9	3	3	6	18
Southeast	45	6	3	9	27
East	72	15	0	15	43
Northeast	9	5	0	5	15
Graveyard	7	6	0	6	14

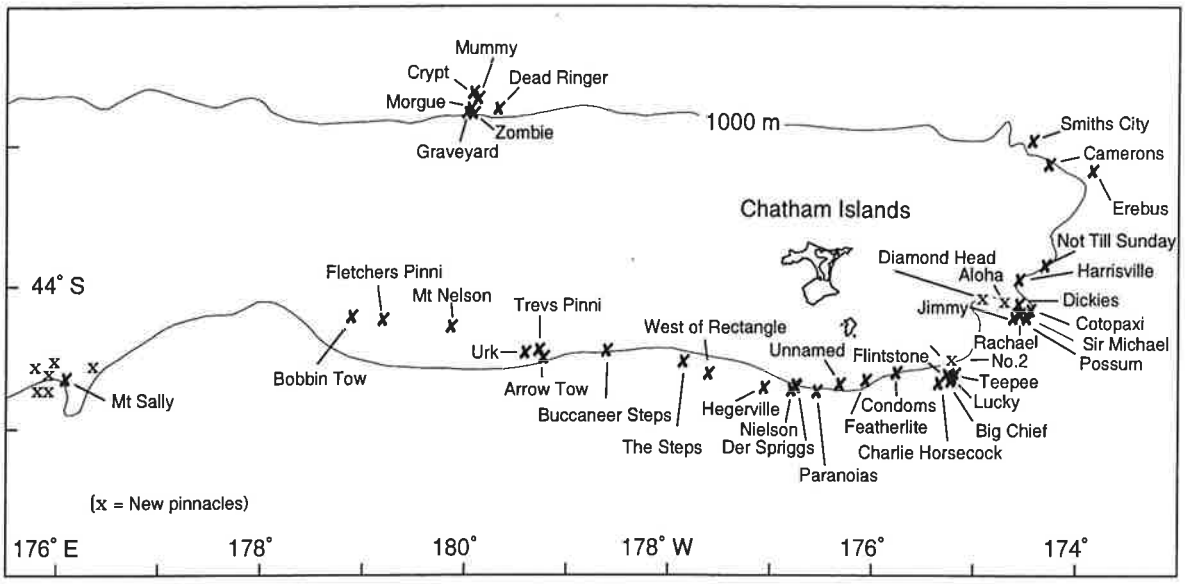


Figure 5: Named features sampled on the Chatham Rise survey.

Catch and biological sampling

The catch for each tow was sorted and weighed by species. For catches over about 2 t, the total greenweights for orange roughy, smooth oreo, or black oreo were back-calculated from a green weight-to-product conversion factor. Each station's specific conversion factor was used to estimate the catch. Mean conversion factors for the survey were 2.2 for orange roughy, 2.3 for smooth oreo, and 2.5 for black oreo.

Standard procedure during the survey was to measure the standard length (cm), and determine the sex and gonad stage of a random sample of about 200 each of orange roughy, smooth oreo, and black oreo from each tow. If a catch was large (over 10 t), several samples were taken from different parts of the net and combined to ensure sampling was representative of the catch.

Twenty fish of each of the main species (more for large catches) were randomly selected and examined in greater detail to obtain data on length (mm), weight (g), sex, gonad weight (g), gonad stage (after Pankhurst *et al.* 1987, Table 3), stomach fullness, digestion state, and stomach contents (to species where possible), and their otoliths were extracted. Heart, liver, and muscle tissue samples were collected from the Southwest, Southeast, East, Northeast, Spawning Box, Northwest, and Graveyard areas for genetic studies on stock identification and relationships.

When other quota species were caught, a random sample of up to 200 fish was measured and sexed.

Rare or unusual fish were frozen for later identification at the Museum of New Zealand Te Papa Tongarewa, Wellington and samples of rock kept for composition analysis at the Institute of Geological and Nuclear Sciences, Lower Hutt.

Biomass estimation

Biomass indices were calculated for the Spawning Box, Northeast Flat, and Northwest Flat areas using the area-swept method described by Francis (1981). All formulae were summarised by Clark & Tracey (1994a). The effective fishing width, based on Scanmar readings, was taken as 26 m with an assigned vulnerability of 0.23, which is the ratio of the distance between the wings to the distance between the doors. The vertical and areal availability were both assigned the value of 1.0.

Biomass indices were not determined for pinnacles and drop-offs. Catch rates were compared between pinnacles and between tows on each pinnacle.

Biological analyses

Orange roughy length frequency data from tows in the Spawning Box and on the Northwest Flat and Northeast Flat were scaled by percentage sampled, distance towed, and stratum area to represent the population size structure for these areas. For the remaining areas, that is for all pinnacle tows and for the oreo species, the length frequency data were scaled by percentage sampled to fully represent the catch.

Gonad development was compared for orange roughy in each area. Because size structures vary between areas, only recruited fish (over 32 cm) were used in this analysis. There was no scaling by catch rate for these analyses. The percentage occurrence of gonad stages was plotted against day for the Spawning Box. A running median was applied to smooth the data.

Stomach state and frequency occurrence of prey were estimated for orange roughy.

Table 3: Macroscopic condition of gonads of female and male orange roughy revised from Pankhurst *et al.* (1987)

Female	Male
(1) Immature or resting Ovary clear or pink, small No eggs visible	(1) Immature or resting Testes small and threadlike
(2) Maturing Ovary pink, small eggs visible as orange dots. Ovary small	(2) Maturing Testis increased in size, but still small, with no milt expressible when cut
(3) Maturing Orange, yolk filled eggs obvious (diameter 0.5–1.5 mm), filling the ovary. Ovary quite large, bright orange	(3) Partially spermiated Viscous milt present when cut. Testes can be relatively large
(4) Ripe Ovary large and mature. Hyaline eggs are present (more than just one or two). Ovary has mottled orange appearance, with mixed orange and clear eggs	(4) Spermiated, running Hydrated freely running milt. Testes shape and outline often not sharp like (3) because of milt. Milt flows freely with light pressure on abdomen
(5) Ovulated, running ripe Ovary large and thin-walled, fragile. Relatively few orange eggs remain, if any at all. Eggs flow freely when light pressure applied to abdomen	(5) Spent Testes rather flaccid, and 'bloody'. Almost no milt expressible. Often has a dull 'glazed' brownish apperance
(6) Spent Ovary flaccid and 'bloody'. Some residual eggs often present (small numbers), generally fairly empty, gonad wall thicker	(6) Partially spent Testes still quite large, with some residual milt, posterior end withered and bloody
(7) Atretic Not common, eggs often yellow or blandish, clearly degenerating	
(8) Partially spent Ovary somewhat flaccid, slightly bloody, still containing substantial numbers of clear eggs, but ovary not packed as in running ripe	

Results

Voyage schedule

The voyage was divided into three 1-month parts. *Tangaroa* sailed from Wellington on 2 May for the south Chatham Rise and Graveyard region. The second survey of Northwest Flat, Graveyard, Northeast (including the Arrow Plateau), and East Rise began from Nelson on 1 June and finished in Wellington on 30 June. The final survey from 1 to 31 July started and ended in Wellington and covered the Graveyard, Northeast Flat, and Spawning Box areas.

Trawl stations

During the survey, 416 trawl stations were completed, of which 120 (112 phase 1, 8 phase 2) were used for the biomass analyses in the Spawning Box. A further 72 and 31 phase 1 stations were used for estimating biomass in Northwest Flat and Northeast Flat, respectively. The remaining stations were on the drop-off and pinnacle features shown in Figure 5. Towing distance and speed were not as constant on the pinnacles and drop-offs as on the flat because of often rapid changes in depth and bottom condition. Trawling was at 2–3 knots on the features.

Details of all stations with an acceptable gear performance are summarised in Appendix 1.

Catch composition

All species caught during the survey are given in Appendix 2.

At least one of the three major species (orange roughy, smooth oreo, black oreo) was caught on most tows. The total catch of orange roughy, smooth oreo, black oreo, Baxter's lantern dogfish (*Etmopterus baxteri*), and all other species, by area, is given with percentage composition by weight in Table 4. Total catch of orange roughy was highest in the Spawning Box, with most fish taken in stratum 2. The more productive orange roughy areas on the Rise were the Spawning Box, Graveyard, and Northeast. Smooth oreo and black oreo were abundant on the south and east Rise and smooth oreo were also abundant in the Graveyard area.

Table 4: Total catch (kg) and percentage composition by weight (%) of species caught in the main survey areas

Area	Orange roughy	Smooth oreo	Black oreo	Baxter's lantern dogfish	Other species
Southwest	398 (1.3)	12 042 (40.3)	13 220 (44.2)	2 606 (8.7)	1 641 (5.5)
South Middle	387 (1.1)	30 78 (89.6)	1 416 (4.1)	561 (1.6)	1 190 (3.6)
Southeast	6 136 (7.4)	66 142 79.8)	5 244 (6.3)	2 645 (3.2)	2 757 (3.3)
East	48 376 (23.2)	113 337 (54.3)	32 511 (15.6)	13 004 (6.2)	1 520 (0.7)
Northeast (pinnacles)	67 534 (75.2)	12 953 (14.4)	51 (0.1)	7 437 (8.2)	1 869 (2.1)
Northeast Flat	1 798 (23.2)	187 (2.4)	1 (<0.1)	78 (1.0)	5 694 (72.4)
Spawning Box	158 500 (87.9)	3 089 (1.7)	3 (<0.1)	40 (0.4)	18 350 (10.2)
Graveyard	88 854 (85.8)	7 369 (7.1)	5 519 (5.3)	1 416 (1.3)	433 (0.5)
Northwest Flat	8 411 (33.0)	2 157 (8.5)	13 (0.1)	552 (2.2)	14 365 (56.3)

Because a higher weighting factor was given to the topographical features where orange roughy would be the dominant species, catch rates of the oreo species are not necessarily representative of oreo abundance and distribution. Catches of smooth oreo were highest in the east and south Rise areas and of black oreo in the southwest.

Other species were a minor component of the total catch, except in Northeast Flat and Northwest Flat where 72% and 56% of the catch respectively was bycatch. Shovelnosed dogfish (*Deania calceus*), longnosed velvet dogfish (*Centroscymnus crepidater*), warty squid (*Moroteuthis* spp.), and smallscaled brown slickhead (*Alepocephalus australis*) dominated in these areas. A similar bycatch species composition was present in the Spawning Box, but made up only 10% of the total catch. Baxter's lantern dogfish were abundant only in the pinnacle areas.

Distribution and catch rates

Orange roughy were distributed across the Chatham Rise and catch rates exceeded 100 000 kg.km^{-1} in some areas (Figure 6). Maximum catch rates were in stratum 2 in the Spawning Box, on pinnacles Morgue and Graveyard in the Graveyard area, on Smiths City in Northeast, and on Cotopaxi, Tomahawk, and Big Chief in East. The exploratory tows on the Arrow Plateau were in deep water over flat bottom. All catches in this area were low. Low catches were also recorded in the flat areas in Northwest and Northeast and on the south Rise.

Catch rates on the major pinnacle areas ranged from 200 to 5900 kg.km^{-1} (Table 5). The coefficients of variation (*c.v.*) were high for all major complexes and ranged from 42% for the pinnacles in East to 80% for the Graveyard area, and from 29% to 114% in South. Catch rates from the pinnacle sampling were intended to be relative and not to be used for assessment purposes until further surveys have been carried out. Comparison of catch rates between pinnacle areas is difficult because of the high *c.v.*s and limits our ability to compare *c.v.*s over time (R.I.C.C. Francis, NIWA, pers. comm.).

Table 5: Mean catch rate of orange roughy on the combined pinnacle strata

Area	Total catch (kg)	Mean catch rate (kg.km^{-1})	*c.v.*(%)	No. of tows
South Middle	387	200	29	18
Southeast	6 135	230	29	27
East	48 376	1 100	42	46
Southwest	397	200	114	23
Northeast	67 534	4 500	46	15
Graveyard	88 853	5 900	80	14

Smooth oreo were widely distributed across the Rise (Figure 7). They were abundant in East with the highest catch rates on Condom (a pinnacle to the west of Big Chief), Tomahawk, and Cotopaxi.

Black oreo were found only on the south and east Rise (Figure 8) and their catch rates were lower than those of orange roughy and smooth oreo. Catch rates of black oreo were over 20 000 kg.km^{-1} on Morgue in the Graveyard area and on a pinnacle in Southwest. The catch rates of black oreo and smooth oreo on tow 193 on Tomahawk exceeded 100 000 kg.km^{-1}, but the towing distance was only 0.04 n. mile.

Biomass

Orange roughy biomass indices for the Spawning Box, Northwest Flat, and Northeast Flat areas are compared with the 1992 indices in Table 6.

The Spawning Box biomass estimate was highly uncertain as the *c.v.* for the index was very high (67%) because 95% of the biomass was associated with one stratum (stratum 2, Table 7) and 66% of the biomass was associated with a single station (399). Catches of orange roughy were low in all other strata (*see* Table 7).

There was a strong imbalance in the sex ratio: 86% of the estimated biomass was female, compared with 72% in 1992. Before 1992, the sex ratios by biomass in the Spawning Box were roughly even: from 1984 to 1990 the percentage of females ranged from 43 to 51%.

Strata 1A to 1E in Northwest were excluded from the biomass analyses because they were not sampled in 1992 and so would not be directly comparable with the 1994 indices. The 1994 biomass index for all strata (including 1A–E) in Northwest is 7450 t (*c.v.* 18%). Differences between indices for recruited and all fish in the flat areas adjacent to the Spawning Box highlight the large number of smaller fish present in these areas.

Catches of smooth oreo and black oreo were low in the areas selected for orange roughy biomass estimation and no indices have been calculated.

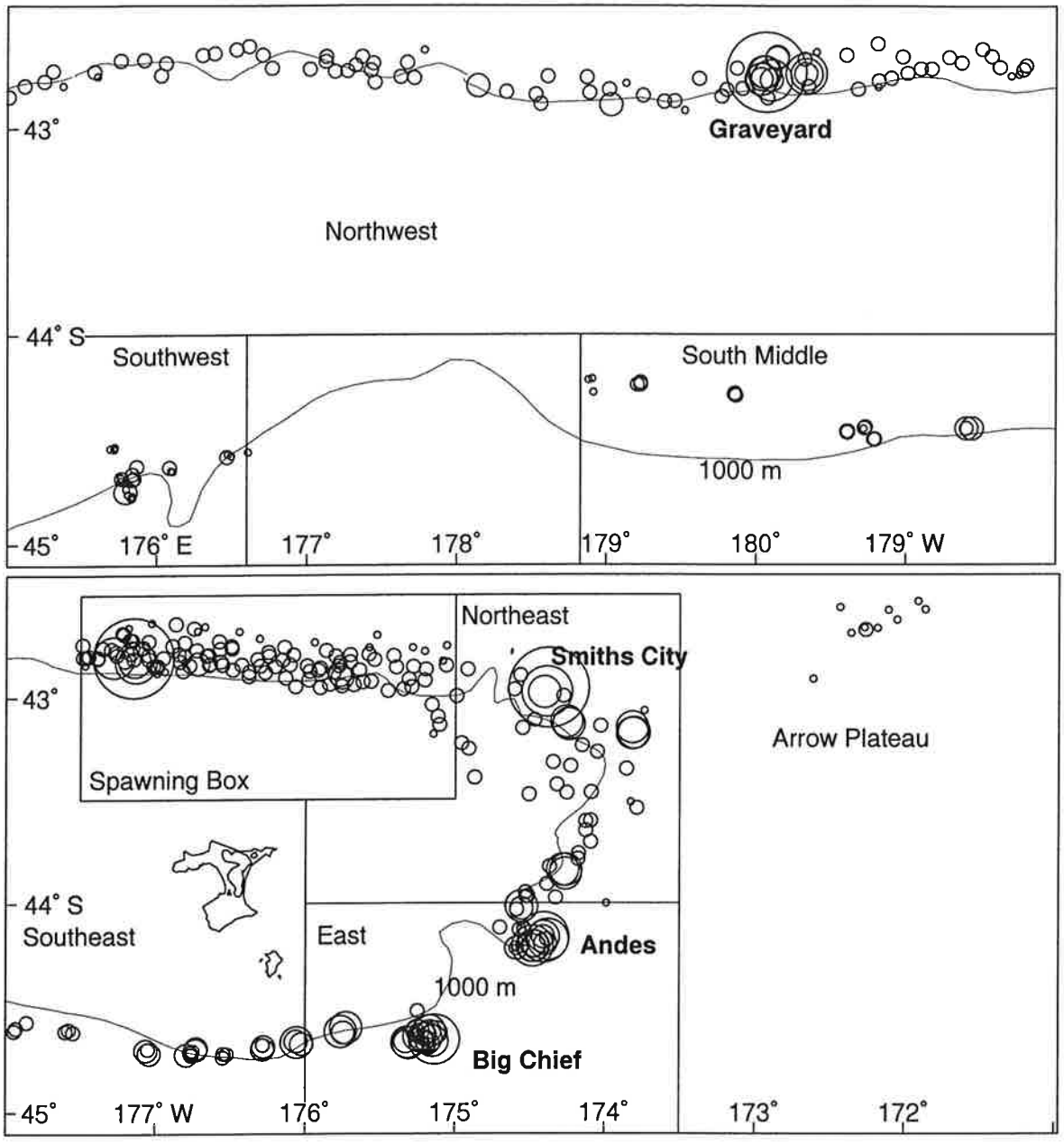
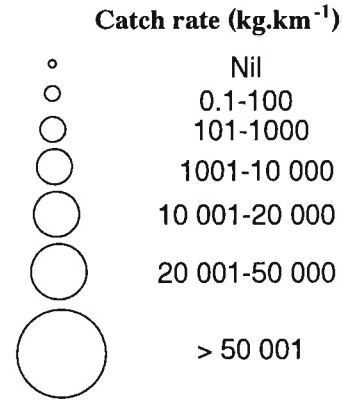


Figure 6: Catch rates of orange roughy by area.



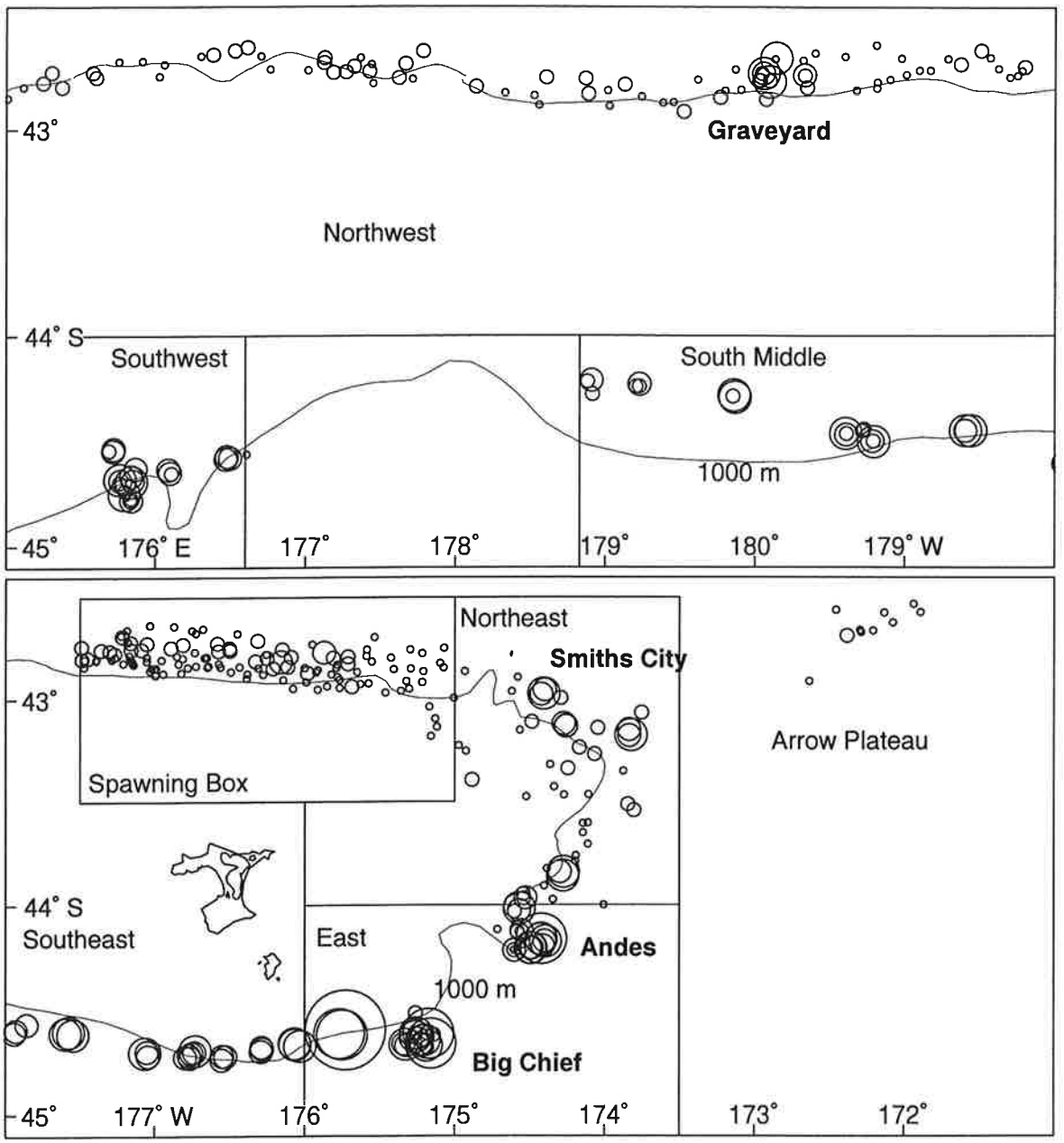
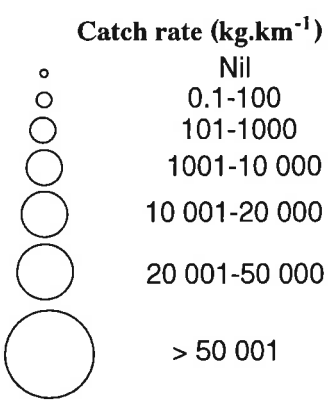


Figure 7: Catch rates of smooth oreo by area.



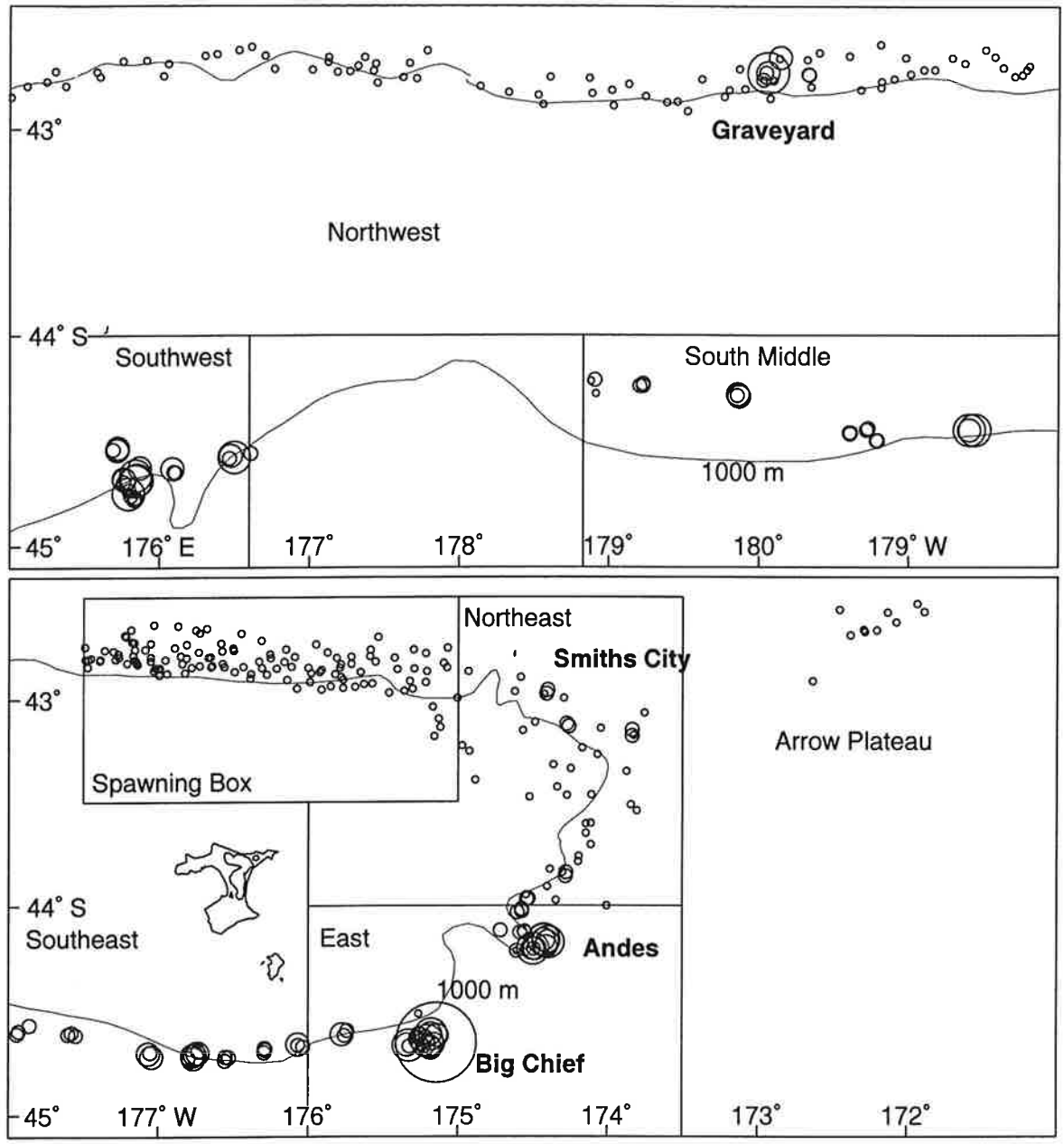


Figure 8: Catch rates of black oreo by area.

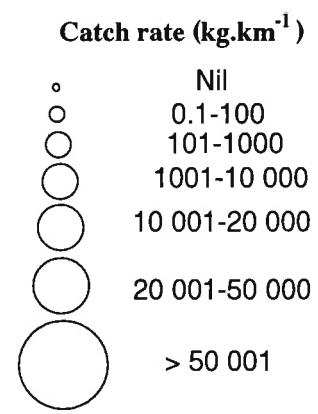


Table 6: Orange roughy biomass indices (t) for both recruited and all fish ($c.v.$) in the Spawning Box and in adjacent areas

	1992		1994	
	All fish	Recruited fish (≥ 32 cm)	All fish	Recruited fish (≥ 32 cm)
Spawning Box	21 419 (33)	19 810 (35)	60 834 (67)	55 531 (68)
Northwest Flat	12 804 (19)	6 378 (26)	9581 (15)*	4 917 (17)*
Northeast Flat	9 851 (26)	8 058 (29)	3 225 (22)	2 360 (27)

* Analysis excluded strata 1A–1E so that results were comparable with the 1992 data.

Table 7: Mean catch rates and biomass of recruited (≥ 32 cm) orange roughy by stratum (s.d., standard deviation)

Stratum	Mean catch rate (kg.km^{-1})	s.d.	Biomass (t)
Spawning Box			
1	0.17	0.07	1.34
2	8 607.68	22 126.45	53 058.99
3	29.00	17.96	125.02
4	9.72	4.03	39.30
5	9.78	3.29	32.98
6	nil	nil	nil
7	53.13	87.72	353.33
8	12.48	5.95	47.70
9	31.01	15.91	89.63
10	9.83	3.59	28.76
11	4.78	3.68	9.50
12	44.97	23.54	227.63
13	16.91	7.32	70.98
14	19.69	10.19	57.78
15	7.41	0.86	15.48
16	4.06	2.35	54.75
17	74.94	87.08	744.80
18	11.95	9.54	82.88
19	7.02	1.14	34.20
20	4.16	1.43	12.81
21	4.39	3.58	50.24
22	15.36	8.93	205.30
23	10.79	5.16	112.24
24	2.39	0.83	13.38
25	1.02	0.47	5.00
26	27.76	14.02	27.01
5X	1.93	2.58	17.50
10X	0.67	0.69	4.63
15X	0.54	0.44	2.84
20X	0.25	0.43	2.05
25X	0.32	0.36	3.29
Northwest			
1B	0.65	0.13	1.91
1C	2.10	1.99	18.99
1D	3.78	1.31	116.59
2A	13.74	9.76	4.24
2B	28.10	25.83	84.31
2C	14.02	4.04	454.98
2D	9.48	11.15	154.87
2E	1.68	1.03	28.10
3A	35.52	59.26	61.96
3B	79.51	54.12	1 122.34
3C	65.75	45.35	1 431.61
3D	13.54	20.23	419.91
3E	1.49	0.02	40.35
4A	2.20	3.43	7.24
4B	40.34	34.02	387.26
4C	7.93	4.26	143.85
4D	10.24	5.30	466.91
4E	4.25	2.94	108.65
Northeast			
7A	12.67	11.33	363.16
7B	4.06	2.16	245.29
7C	19.92	28.08	1 010.98
7D	9.79	8.46	713.07
7E	0.22	0.38	27.77

Size structure

The scaled length frequency distributions of orange roughy by sex and area are shown in Figure 9. The length distributions for the individual pinnacles appear to be similar to the combined area frequencies.

Most distributions were unimodal, except for males and females in South Middle and females in Southwest where a bimodal distribution was apparent although the sample size was small as the catch rates were low. In Northwest Flat and Northeast Flat, away from the Spawning Box, the length frequencies covered similar size ranges to the other areas, but there was a higher proportion of pre-recruits (less than 32 cm SL) and there were flatter distributions. Length frequency data for the orange roughy sampled on the Arrow Plateau are not presented because of the small sample sizes.

There were dominant modes at about 36 cm for females and 34 cm for males. Mean male lengths from the various areas ranged from 26.6 to 33.4 cm, and medians from 27 to 35 cm. The mean lengths for the females ranged from 28.2 to 35.1 cm, and medians from 29 to 35 cm (Table 8). Females were larger overall by 1–2 cm and dominated in the Spawning Box where they made up 86% of the biomass. The median length was higher for the Graveyard, East, and Northeast areas.

There were two length modes for both sexes of smooth oreo in all areas except East (Figure 10) where there was a unimodal distribution and the fish were larger. Smaller fish dominated in Southwest and South Middle. Larger fish were found in East, Northeast, and Graveyard. Overall, smooth oreo ranged from 15 to 56 cm T L and the large fish were females. The unscaled sex ratios were fairly even.

Black oreo also showed a strong bimodal distribution in most areas, with peaks ranging from 25–27 and 32–40 cm (Figure 11). As with smooth oreo, larger fish were found on the Graveyard and eastern pinnacles complexes: smaller fish dominated on the south Rise.

For use in this year's biomass analyses, and for the continuation of the Chatham Rise time series of length-weight relationships, length-weight regression equations were calculated for orange roughy, smooth oreo, and black oreo for each area (Table 9).

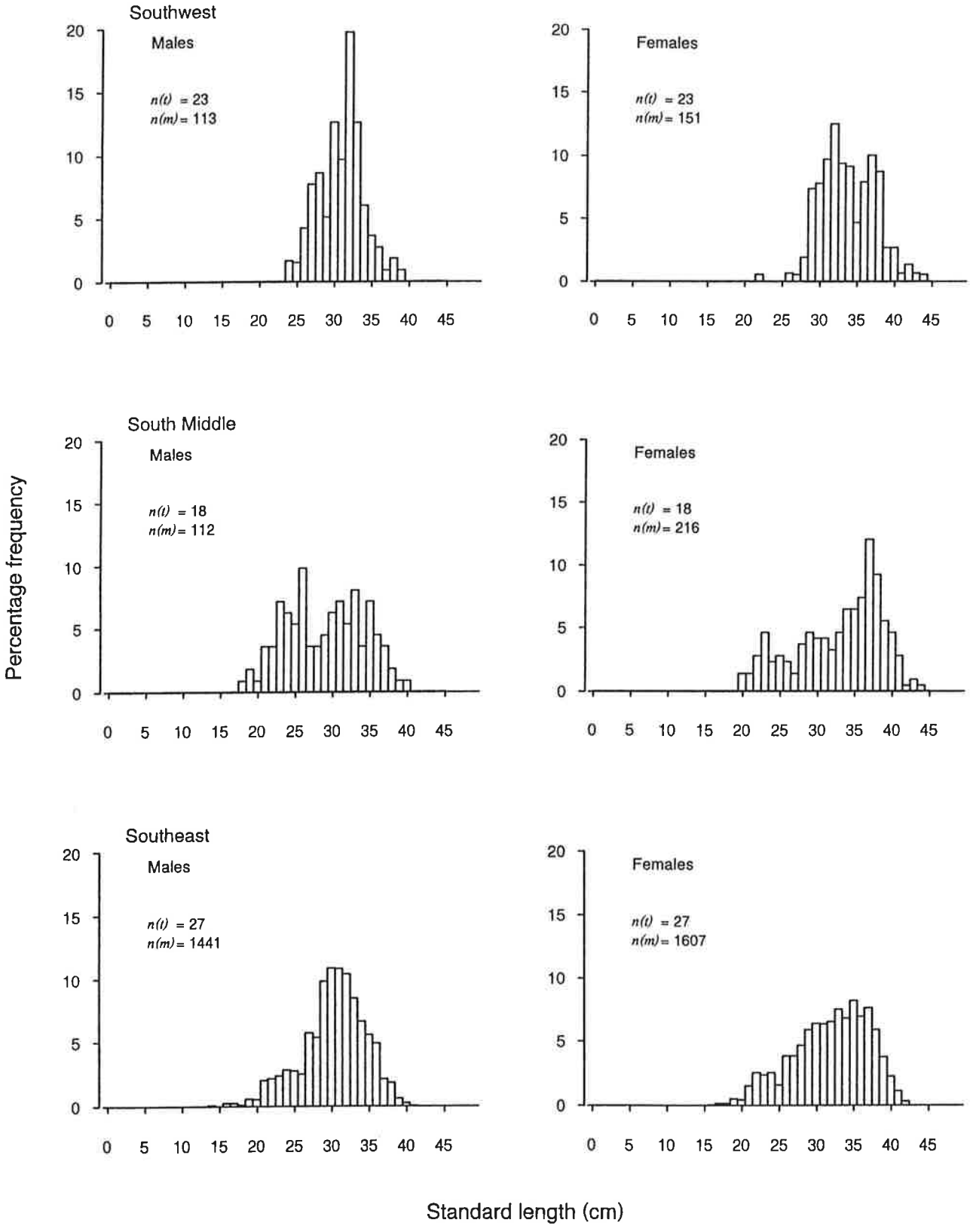


Figure 9: Length frequency distributions of orange roughy in the main survey areas and specific strata with high catches of orange roughy (scaled to represent the total catch, except for the Spawning Box, Northwest Flat, and Northeast Flat areas which are scaled to represent the total population; *n(t)*, number of trawls with samples; *n(m)*, number of fish measured).

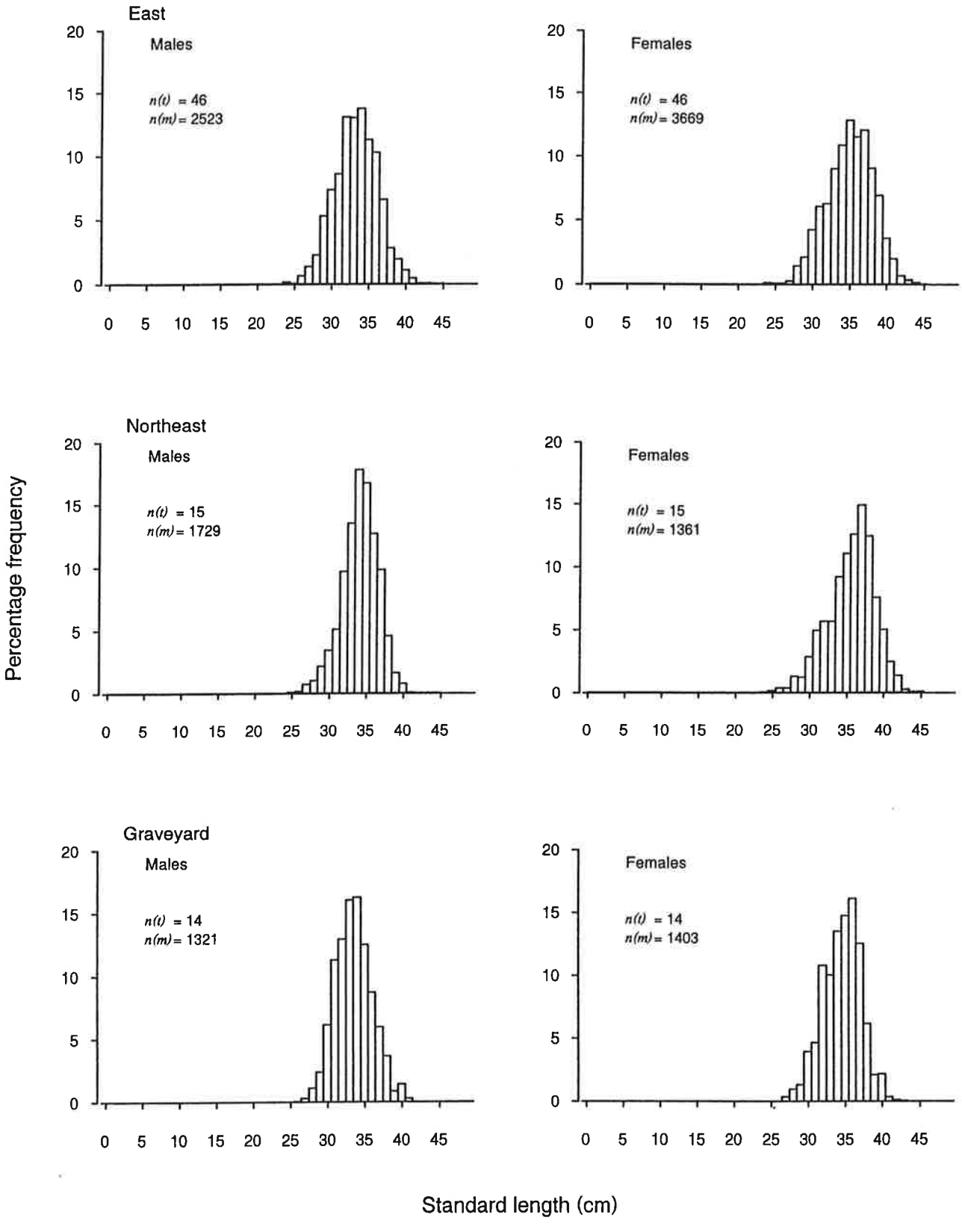
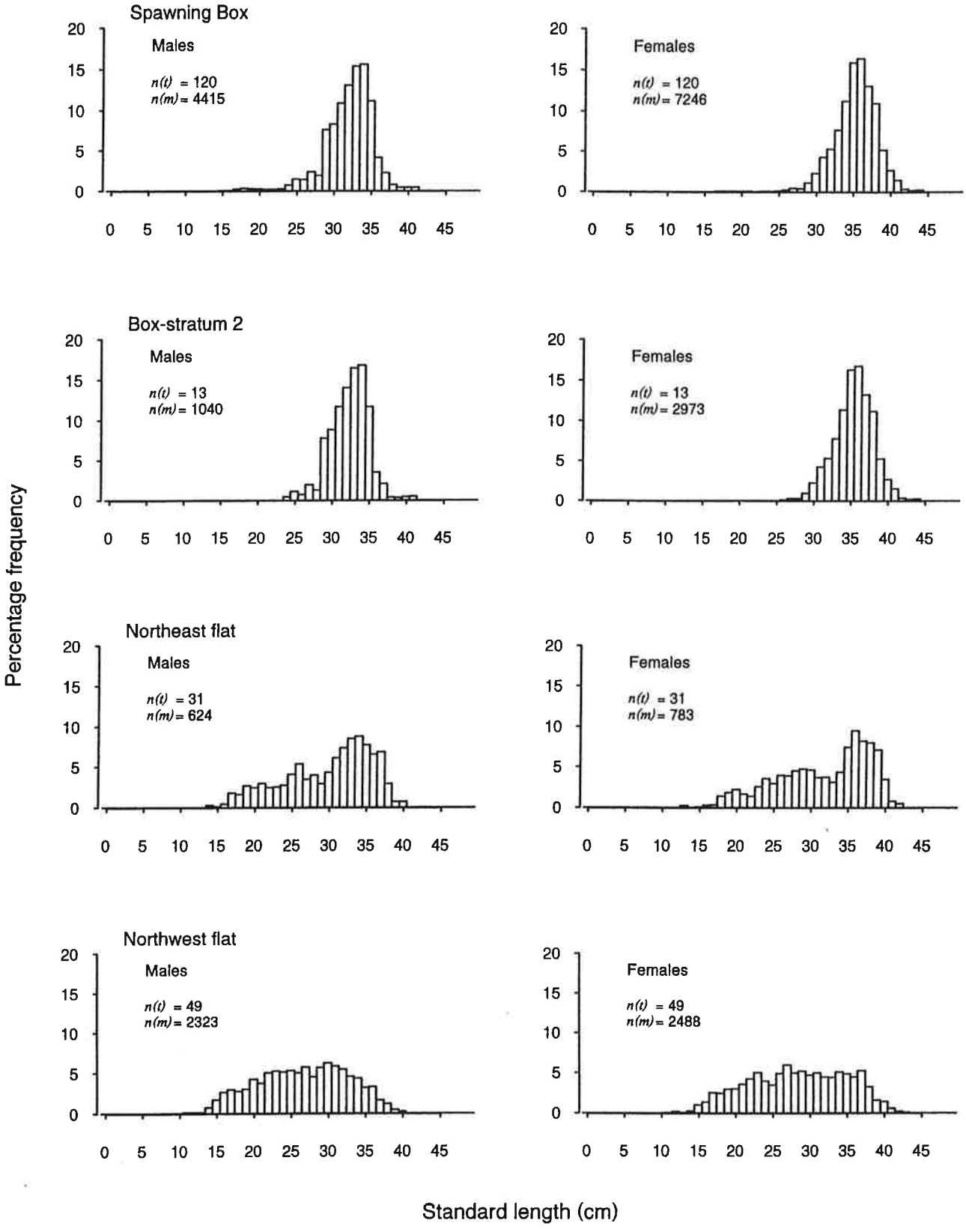


Figure 9—*continued*



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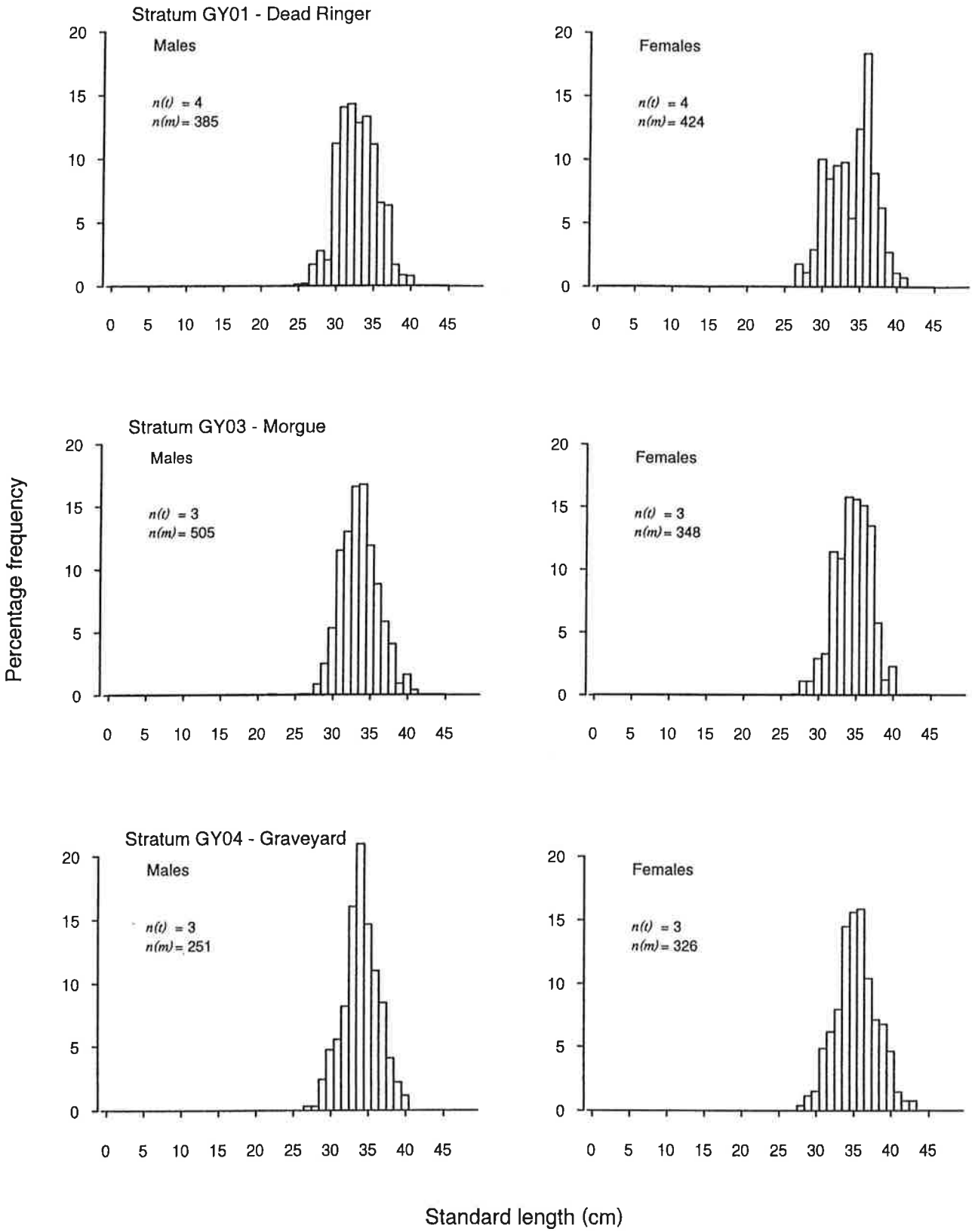

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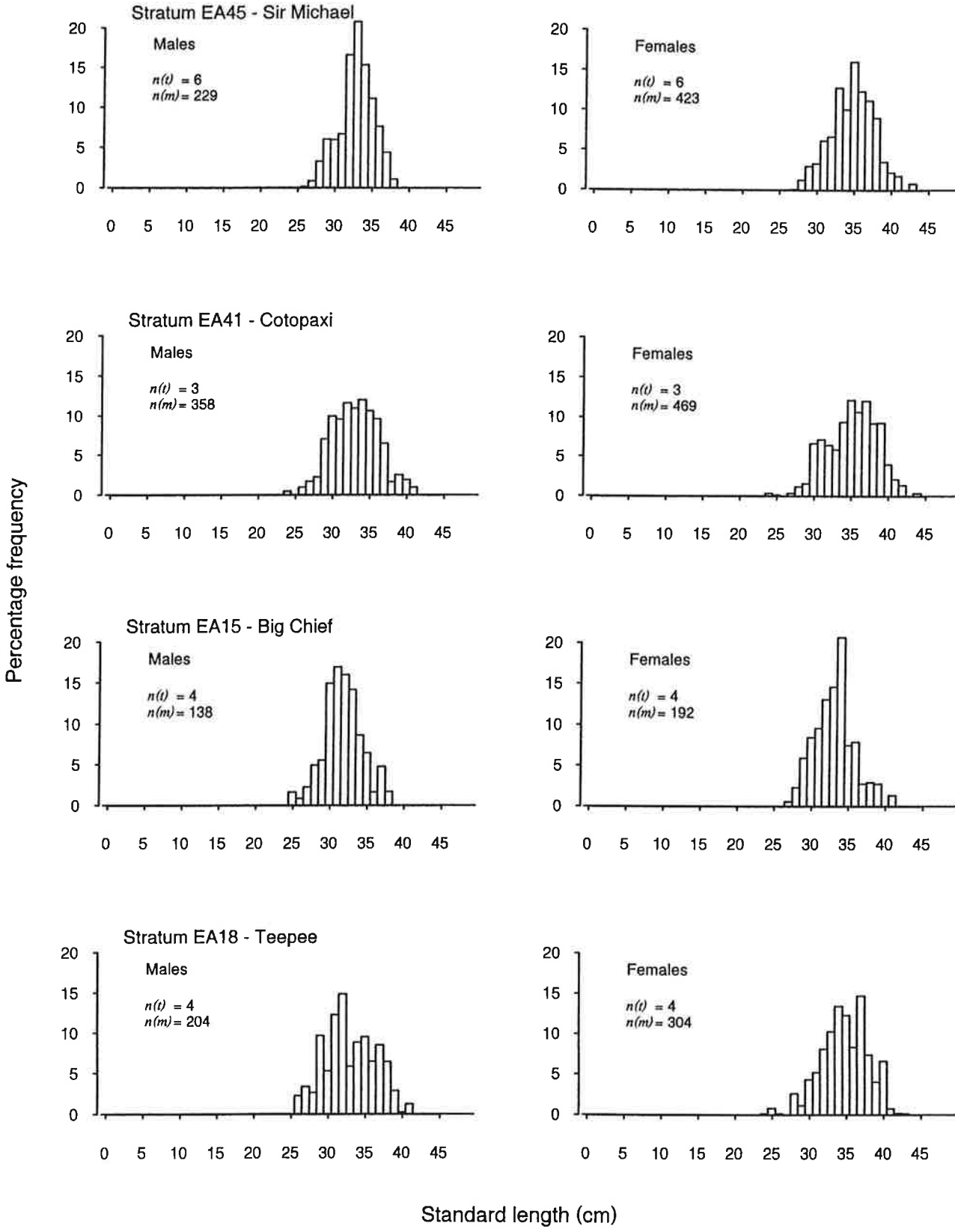

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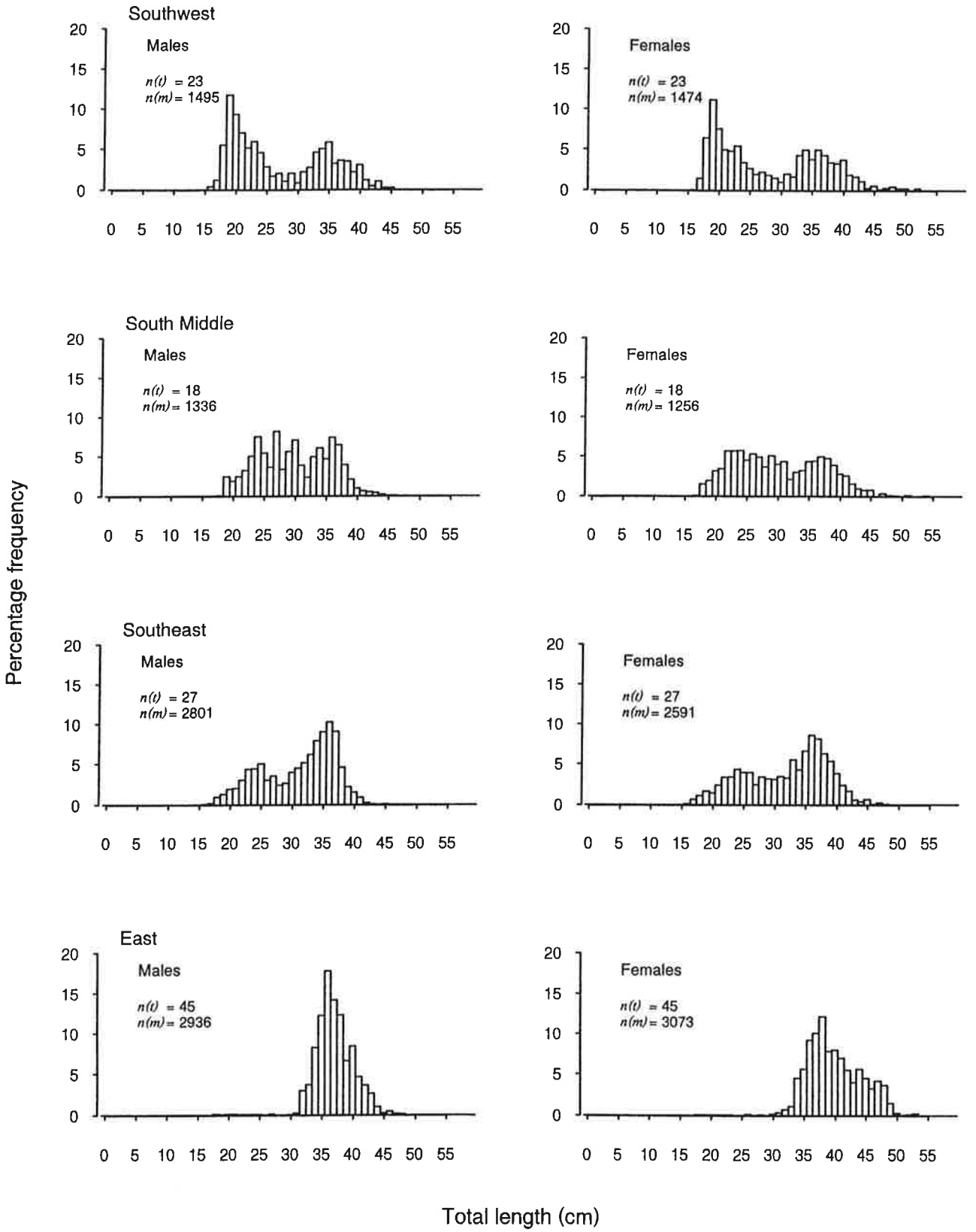

Figure 10: Length frequency distributions of smooth oreo in the main survey areas (scaled to represent the total catch for all areas; *n(t)*, number of trawls with samples; *n(m)*, number of fish measured).

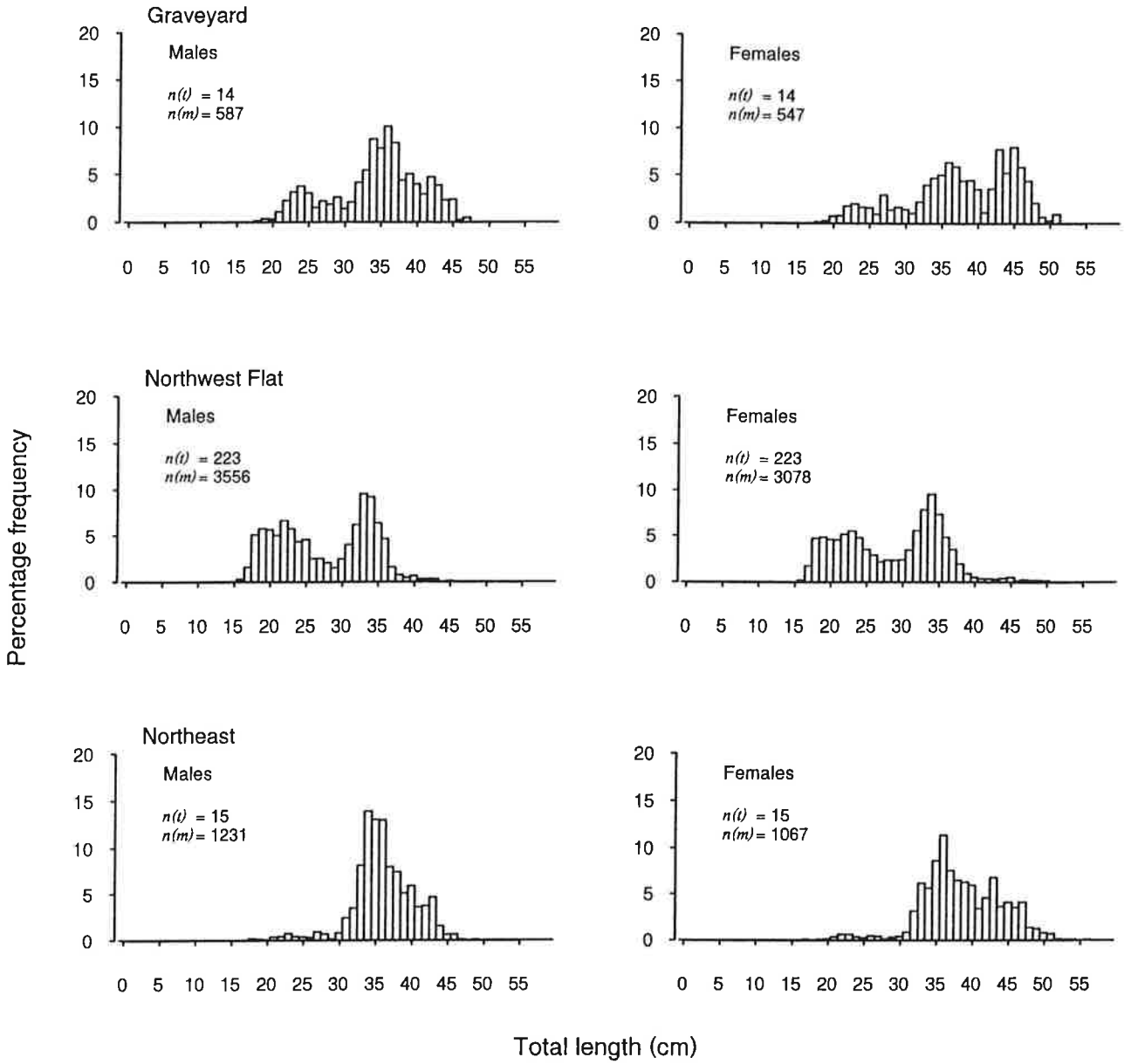

Figure 10—*continued*

Table 8: Summary of orange roughy length data (cm) by area (*n*, number of fish; *x*, mean; s.d., standard deviation)

	Males					Females				
Area	*n*	*x*	s.d.	Median	Range	*n*	*x*	s.d.	Median	Range
Southwest	113	30.9	3.1	31	24–39	151	33.8	3.7	33	22–44
South Middle	112	29.0	5.2	29	18–40	216	33.0	5.7	34	20–44
Southeast	1 441	30.2	4.3	31	14–41	1 607	31.8	5.0	32	16–42
East	2 523	33.4	3.0	35	23–43	3 669	35.1	3.3	35	23–45
Northeast (pinnacles)	1 729	33.6	2.8	34	22–43	1 361	34.8	3.4	35	24–45
Northeast Flat	624	30.2	5.7	32	14–40	783	32.0	6.1	34	13–42
Spawning Box	4 415	30.7	4.7	31	2–43	7 246	33.3	4.8	34	15–44
Graveyard	1 321	33.4	2.6	33	22–41	1 403	34.6	2.8	35	25–43
Northwest Flat	2 323	26.6	6.0	27	10–40	2 488	28.2	6.5	29	11–43

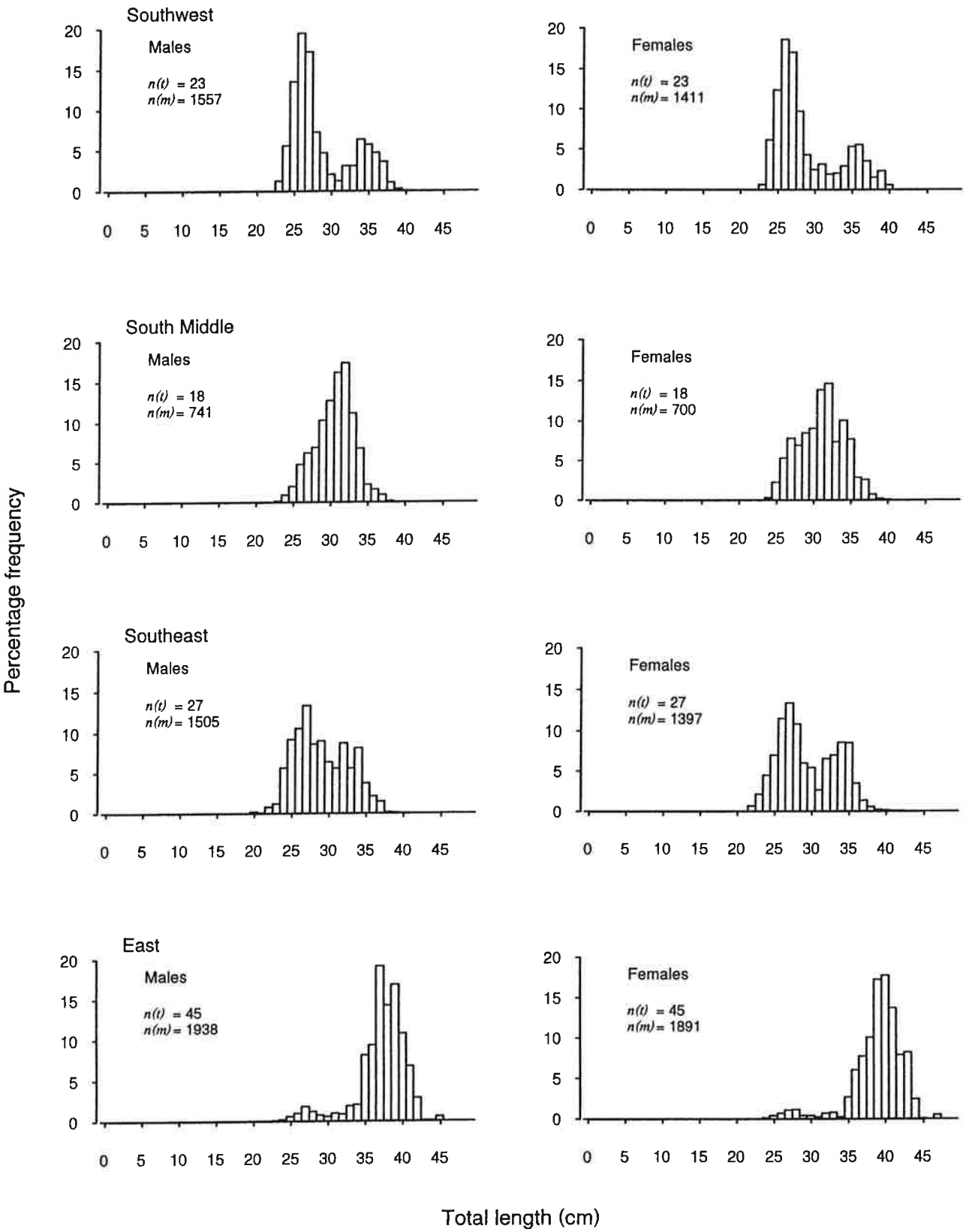

Figure 11: Length frequency distributions of black oreo in the main survey areas (scaled to represent the total catch for all areas; *n(t)*, number of trawls with samples; *n(m)*, number of fish measured).

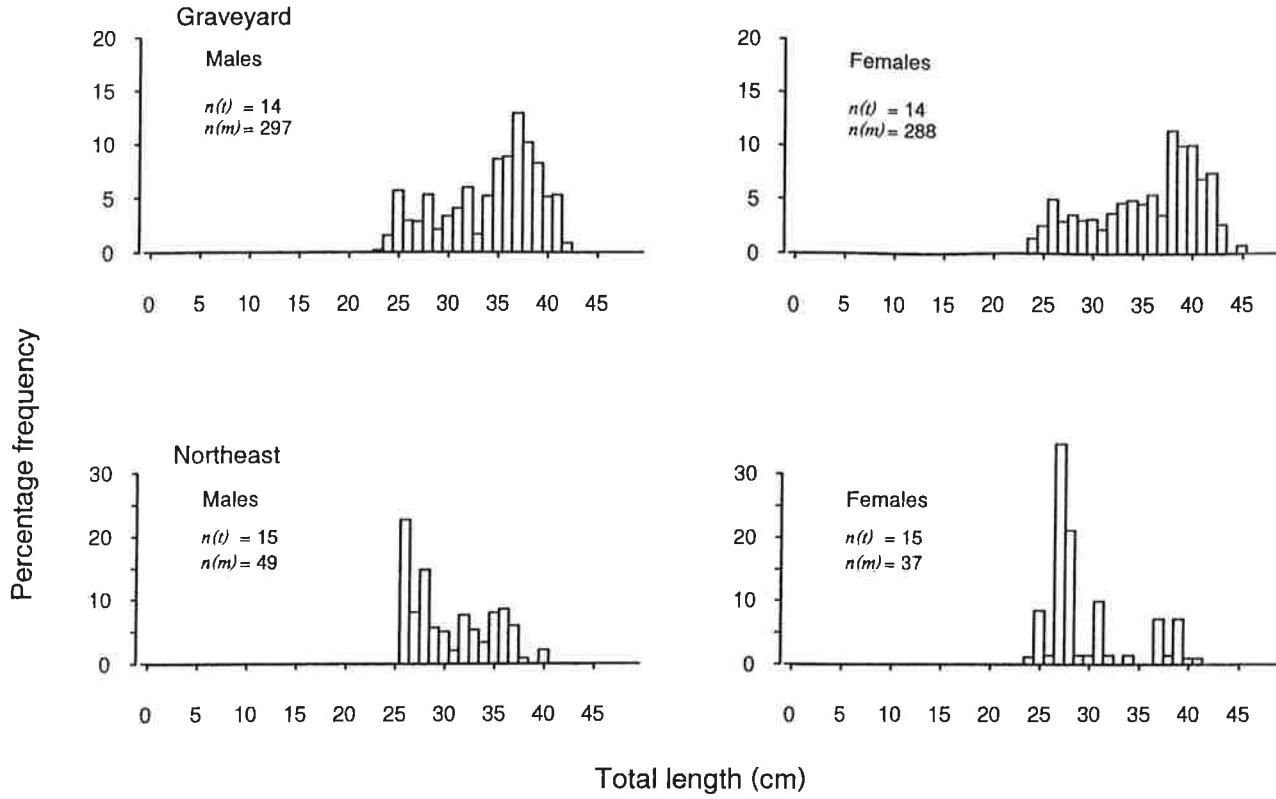

Figure 11—*continued*

Table 9: Length–weight regression coefficients for orange roughy by sex for the main Chatham Rise survey areas where $W = aL^b$ (weight in g; length in cm)

		Coefficients			
	Sex	*a*	*b*	*n*	r^2
Southwest	Both	0.0484	2.891	115	0.94
	M	0.0698	2.781	52	0.90
	F	0.0480	2.896	63	0.94
South Middle	Both	0.0872	2.721	191	0.96
	M	0.0920	2.697	50	0.97
	F	0.1010	2.684	141	0.95
Southeast	Both	0.0443	2.940	804	0.95
	M	0.0628	2.809	334	0.95
	F	0.0400	2.945	470	0.95
East	Both	0.0630	2.806	908	0.91
	M	0.0910	2.694	381	0.90
	F	0.0630	2.805	527	0.91
Northeast (pinnacles & Flat)	Both	0.0859	2.717	961	0.97
	M	0.1254	2.599	482	0.97
	F	0.0671	2.796	479	0.97
Spawning Box	Both	0.0886	2.710	2 194	0.97
	M	0.1120	2.638	867	0.97
	F	0.0830	2.732	1 327	0.96
Graveyard	Both	0.0808	2.733	559	0.84
	M	0.1340	2.583	318	0.84
	F	0.0747	2.763	241	0.83
Northwest Flat	Both	0.0625	2.812	1 236	0.97
	M	0.0677	2.785	563	0.97
	F	0.0625	2.816	672	0.97

Table 10: Percentage gonad stage of recruited orange roughy (≥ 32 cm S.L) sampled during the voyage for each major area and on selected pinnacle features in the northeast (*see* description of gonad stages in Table 3)

				Gonad stage									
		n		Male				Females					
Area	Sampling period	M	F	1/2	3	4	5	1/2	3	4	5/8	6	7
Southwest/ South Middle	3–14 May	89	228	98.9	1.1	0	0	62.7	36.4	0	0	0.9	0
Southeast	14–20 May	563	862	82.6	17.4	0	0	41.4	58.6	0	0	0	0
East	8–21 June, 5–6 July	1 869	3 138	63.9	35.3	0.8	<0.1	56.1	41.0	1.6	0.1	0.8	0.4
Northeast Flat	27–28 June, 7–17 July	321	452	22.4	65.4	9.7	2.5	11.1	69.2	15.7	3.1	0.7	0.2
Northeast	6 June, 5–16 July	1 461	1 168	17.4	55.2	16.9	10.5	34.2	26.7	30.8	7.0	1.2	0
Spawning Box	8–30 July	2 187	5 245	13.8	35.2	22.6	28.4	16.4	12.5	25.4	17.6	28.0	<0.1
Graveyard	23–26 May, 6 June, 3 4 July	1 948	1 620	51.6	30.1	7.6	10.6	27.6	57.7	8.0	4.8	1.7	0.3
Northwest Flat	21–29 May, 2–6 June	723	1 121	66.4	32.6	1.0	0	32.9	62.2	4.3	0.3	0.4	0.2
Smiths City	8–13 July	831	340	5.1	63.3	20.8	10.8	4.1	30.6	52.1	12.9	0.3	0
Camerons	12–16 July	287	262	7.0	48.8	23.3	20.9	5.7	29.3	48.1	12.6	4.2	0
Not till Sunday	5–6 July	209	280	31.6	65.0	2.9	0.5	36.4	45.0	17.1	1.4	0	0

Reproduction

The percentage occurrence of gonad stages of orange roughy sampled from May to July are given for each major area on the Chatham Rise and for selected pinnacle strata in Northeast in the July spawning period in Table 10.

In May there was a high proportion of reproductively inactive fish. Immature, resting, and early maturation (stages 1 and 2) males and females were sampled in the southern and Northwest Flat areas. Orange roughy size structures were smaller in these areas. Maturing fish (stage 3) were recorded in all areas sampled in June.

Ripe and spent fish (stages 4–6) were found on the Northeast pinnacles in the first 2 weeks of July, mainly on Smiths City (stratum NE03) and Camerons (stratum NEO4). Spent fish were also evident in early July in the Graveyard area.

Fish sampled in the Spawning Box in July showed fairly even proportions of immature to ripe and spent fish. There was an obvious daily decline in the proportion of maturing fish up to 20 July for females, and a subsequent increase in the proportion of spent fish (Figure 12), indicating that the onset of major spawning was from 20 July. Numbers of resting males and females in the Spawning Box remained fairly constant throughout the sampling period.

Macroscopic gonad stages of smooth oreo and black oreo were also recorded. These fish were either immature or developing throughout the sampling period.

Feeding

A summary of stomach condition for orange roughy, smooth oreo, and black oreo is given in Table 11. A total of 6268 orange roughy stomachs was examined during the survey, of which 30% contained food. Prey were identified to major taxa, and, where possible, to family groups (Table 12). Fish were the most frequent prey item, followed by natant decapod crustaceans. The diet of smooth oreo comprised salps and squid. Fish were the most frequent prey for black oreo.

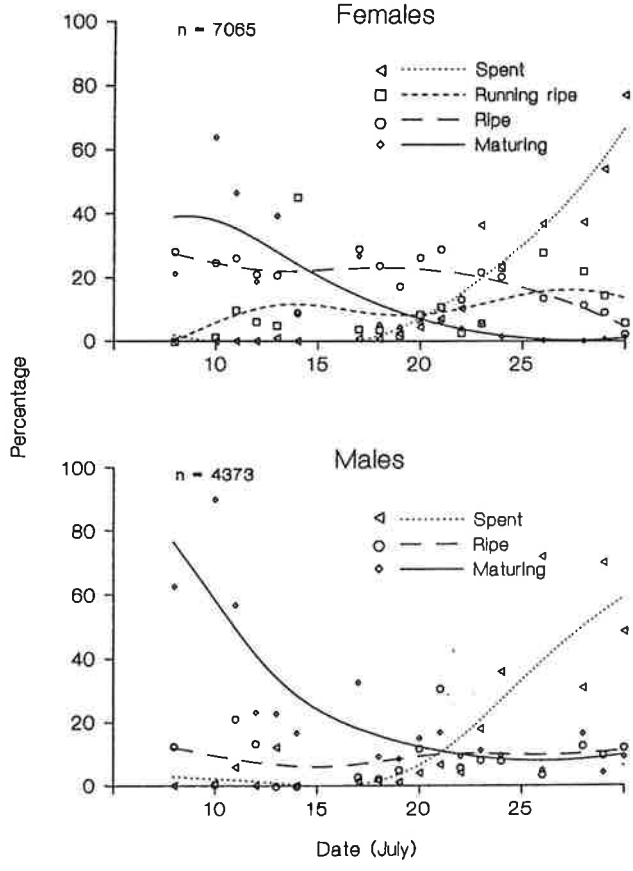

Figure 12: Daily changes in the proportion of gonad stages of orange roughy in the Spawning Box (maturing, stage 3; ripe, stage 4; running ripe, females stage 5; spent, males stage 5, females stage 6).

Table 11: Percentage stomach states of orange roughy, smooth oreo, and black oreo examined during the survey (*n*, no. of stomachs examined)

State	Orange roughy %	Orange roughy *n*	Smooth oreo %	Smooth oreo *n*	Black oreo %	Black oreo *n*
Empty	70	4 400	53	316	46	90
Trace	5	312	3	18	3	6
Part-full	18	1 237	11	66	8	16
Full	5	309	2	9	1	2
Everted	< 1	10	32	192	42	82
n		6 268		601		196

Table 12: Percentage occurrence of the major prey groups (*n* = 2050) of orange roughy from the survey area

	%
Crustacea	
Amphipoda	2.7
Isopoda	0.2
Decapoda Natantia	27.3
Euphausiacea	4.1
Mysidacea	1.1
Crustacean remains	12.9
Cephalopoda	
Octopoda	0.2
Decapoda	8.3
Pisces	
Macrouridae	0.7
Mesopelagic group *	2.3
Other groups †	0.4
Fish remains	37.3
Thaliacea	
Salpidae	0.9
Unidentified	1.2

* Includes families Myctophidae, Chauliodontidae, Melamphaidae, Idiacanthidae, Melanocoetidae, Paralepididae.
† Includes families Bathylagidae, Platytroctidae, Apogonidae, Melanonidae, Carapidae, Nototheniidae.

Plankton survey

About 3000 orange roughy eggs and 138 larvae were caught in eight plankton tows in stratum 2 on 21 July. These larvae, as well as specimens hatched on board from "strip fertilised" eggs, were kept alive until the end of the survey and then transferred to tanks at the laboratory. The longest survival period for the artificially reared orange roughy was 40 days. Additional descriptions, photographs, and drawings of the embryology and early larval development were obtained (Grimes *et al.* in press.)

Acoustics survey

High density orange roughy marks were observed during trawling over a small area to the east of stratum 2 in the Spawning Box. These fish were very mobile and were not visible as plumes when the vessel returned to carry out a planned acoustic grid. Consequently, the echosounder survey failed to produce any usable results.

Discussion

This 3 month programme surveyed an extensive area of the Chatham Rise. Data from the random trawl survey in the Spawning Box were combined with commercial catch and productivity data and used in the annual stock reduction analyses of the ORH 3B fishery (Francis *et al.* 1995). This added to the time series of abundance indices in ORH 3B. Comparable research trawl surveys in the Spawning Box were summarised by Francis *et al.* (1995).

Several other orange roughy trawl surveys have been carried out on the Chatham Rise (*see* Francis *et al.* 1995, section 4.2), but none have contributed to estimates of current stock status. In September 1988, a 26 day out-of-spawning biomass survey of depths between 750 and 1200 m on the entire Chatham Rise was carried out from FV *Cordella*. In 1988 and 1989, eight seasonal RV *James Cook* surveys in Northeast Flat aimed to locate and sample juveniles for a growth and productivity study (Mace *et al.* 1990). Finally, surveys of the two oreo species by MAF Fisheries on the south Rise in October and November from 1990 to 1993 and in 1995 and 1996 obtained catch rates and abundance estimates for orange roughy (McMillan & Hart 1994a, 1994b, 1994c, 1995).

The comprehensive coverage on this survey of the Spawning Box, Northeast Flat, Northwest Flat, and topographical features added to our understanding of distribution, abundance, and biology of orange roughy on the entire Chatham Rise during the winter. Previous spawning season surveys were less extensive and primarily surveyed the Spawning Box. Full coverage of the flat areas was not made annually, and previous sampling of topographical features was minimal.

The important pinnacles fished commercially for orange roughy were sampled and the low orange roughy catch rates in the south were anticipated from previous surveys in the area (McMillan & Hart 1994a, 1994b, 1994c, 1995).

During the survey the bathymetric features on the HMRG chart were located (where possible) and surveyed. Some were not new but had been identified and named on previous research surveys or by commercial fishers. Others did not exist at the given positions and were probably side lobes or false echoes, or were too small, shallow, or rugged to be fished. No orange roughy were caught on some of the newly identified pinnacles. New pinnacles located in East, Aloha, Diamond Head, and No. 2, gave very low catch rates of orange roughy.

Distribution and catch rate

Catches of orange roughy were high only in stratum 2 in the Spawning Box, in the Graveyard area, and on the eastern pinnacles complexes. The remaining areas yielded little, and catches were low on the flat areas and on the south Rise pinnacles.

These results are consistent with the historical pattern of commercial catch and effort data on the Chatham Rise described by Francis *et al.* (1993, 1995). There has been an eastward trend in the south Rise fishery as the catch rates on the southern pinnacles have declined substantially and more effort has resulted on the eastern pinnacle complexes and in the Graveyard area. Before the Spawning Box was closed to commercial fishing in the 1992–93 fishing year, its contribution to ORH 3B catches had declined and effort was shifted to other parts of the northeast Rise.

Coburn & Doonan (1994) described a movement of orange roughy from the Spawning Box to the east after spawning. However, because we were sampling around stratum 2 on the western side of the Spawning Box during the peak spawning time we did not see this migration.

The highest catches of smooth oreo were on the eastern pinnacles and of black oreo in Southwest and Graveyard. This is also consistent with commercial fishery catches where oreo bycatch has risen in the south Rise and eastern pinnacle fisheries.

Spawning Box survey

There has been a general downward trend in the abundance indices for the Spawning Box since 1984 (Francis *et al.* 1995). The Spawning Box biomass indices from this survey were described in detail by Annala (1994) and Francis *et al.* (1995). A revised vulnerability and the inclusion of the deep strata (5X to 25X, Figure 4b) means that the Spawning Box biomass result in this report is not directly comparable with that presented by Francis *et al.* (1995).

The 1992 and 1994 surveys had the same sequence of station occupation and show, along with a decline in abundance, high *c.v.*s and an imbalance in the sex ratios (86% of the biomass was female). Similar results were obtained in 1992: the *c.v.* was 34% and 72% of the biomass was females. The sex ratio imbalance could have been caused by factors such as the males being fished out, the change in the sequence of station occupation in the Spawning Box from 1992 onward, or the vertical availability by sex. Future sampling in the Spawning Box is planned to resolve how sex ratio and biomass vary in the main strata through the spawning season and if the vertical distribution of orange roughy by sex can be explained by the anomalous sex ratios.

The precision of the biomass indices has been problematic because of high *c.v.*s consistent with the continued contraction of the high catch rate area. This will also be addressed in the design of future Spawning Box surveys. Acoustic techniques could be used to give more reliable biomass estimates with lower *c.v.*s than the current trawl survey design.

Northwest Flat and Northeast Flat

Biomass results for the flat areas adjacent to the Spawning Box were down on estimates from the 1992 survey. Single phase stratified random trawl surveys have been carried out in the Northwest Flat and Northeast Flat areas since 1989: there has been an overall decline in biomass (NIWA unpublished data held on NIWA database).

Survey of topographical features

This survey was designed primarily as a pilot study to investigate orange roughy catch rates and their variability between pinnacles and between tows on each pinnacle, and to see if the sampling method can provide indices of relative fish abundance and so enable stock assessment modelling of the entire Chatham Rise fishery. Sampling design was based on results from orange roughy surveys on topographical features in other parts of the EEZ, aspects of which were summarised by Clark (1994). Each feature has to be considered as a separate stratum as the topography of a feature can range from a large and distinct seamount to small, steep pinnacles and drop-offs. All features can host orange roughy as well as smooth oreo and black oreo aggregations.

To obtain precise orange roughy abundance indices we needed to ascertain if there had been sufficient tows per pinnacle, and if there were acceptable *c.v.* levels between and within the pinnacles. The *c.v.*s ranged from 29% to 114% (Table 5), which is unacceptable for a precise index measurement on any one pinnacle. Simulations using the survey data suggest that to improve our estimates, future surveys may need to limit the numbers of pinnacles surveyed, have more tows per pinnacle, and survey the same pinnacles each year (R.I.C.C. Francis, NIWA, pers. comm.).

Biology

The orange roughy size distributions for each area were similar in size range and in having a unimodal structure, except in the areas east and west of the Spawning Box, where length frequency distributions were very flat. The distribution was bimodal in South Middle and for females in Southwest, probably due to the small sample size and low catches in these areas. In the Spawning Box, Graveyard, Northeast, and East most fish were 25–45 cm long. In these areas there were high catch rates and spawning orange roughy. East, Northeast, and Graveyard fish were larger overall (median length 35 cm for females).

In general, the length frequency distributions in the Spawning Box have remained consistent over time with similar modal lengths between years (Fenaughty & Grimes 1989, Anderson & Fenaughty 1996). However, analyses of the 1992 length data show that the mean length of males in the Spawning Box has declined compared to the earlier surveys (Francis *et al.* 1993).

Unimodal distributions for orange roughy occur in other areas of New Zealand's EEZ. Clark & Tracey (1994b) described winter size distributions from 1984 to 1990 on the Challenger Plateau, where a strong unimodal modal peak was present each year at 32–33 cm. On the Ritchie Banks, the unimodal peak for the March-April 1994 survey was at 34 cm for females and 33 cm for males (Grimes 1994). Unimodal size distributions for orange roughy were also shown by Clark & Tracey (1994a) from surveys of the southern area of ORH 3B on the Puysegur Bank.

Orange roughy are slow growing and long lived (Mace *et al.* 1990, Doonan 1994), and there is a poor correspondence between fish size and age. The length frequencies from this survey that showed some bimodality (the South Middle fish and Southwest females) do not relate to age frequencies.

Gonad development in orange roughy followed a pattern similar to that found previously. In May and early June fish were developing, and by mid June to July the incidence of ripe fish had increased. Spawning and spent fish were recorded in July in the Graveyard area, the Spawning Box, and on the northeastern pinnacles, including Not Till Sunday, Smiths City, and Camerons. Previous surveys have identified these features as spawning pinnacles (NIWA, unpublished data) Some localised spawning activity was apparent on the eastern pinnacles, but the timing of the survey was too early to measure its extent.

The prey of orange roughy, smooth oreo, and black oreo has been similar between areas and years (Anderson & Fenaughty 1996).

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Appendix 1: Summary of station data
(RP, random pinnacle; RD, random drop-off; RF, flat biomass tows; *, new pinnacle; EXPL, exploratory tows; Hdg, heading; ORH, orange roughy; SSO, smooth oreo; BOE, black oreo)

Date 1994	Stn. no.	Type	Stratum	Feature names	Start Latitude ° '	Start Longitude ° '	Depth (m) Min.	Depth (m) Max.	Hdg (°)	Distance (n. mile)	Catch (kg) ORH	Catch (kg) SSO	Catch (kg) BOE
3 May	1	RD	SW11	*	44 46.89 S	175 50.22 E	1055	1155	356	2.04	–	1381.5	180.1
3 May	2	RP	SW13	*	44 37.79 S	175 51.85 E	672	1012	78	0.90	8.3	301.9	358.6
3 May	3	RP	SW01	Mt Sally	44 38.99 S	176 05.54 E	814	851	212	0.23	–	68.3	42.0
4 May	4	RD	SW11		44 46.21 S	175 50.08 E	1066	1148	332	2.01	–	40.3	53.4
4 May	7	RP	SW01		44 38.19 S	176 04.97 E	882	1048	278	0.76	3.1	582.8	364.5
4 May	8	RD	SW11		44 46.81 S	175 49.78 E	1055	1120	345	2.07	–	21.1	12.8
5 May	10	RP	SW01		44 39.27 S	176 06.24 E	900	1090	171	0.94	–	3.1	9.5
5 May	11	RP	SW12	*	44 41.54 S	175 50.07 E	743	996	163	0.54	13.9	2514.4	4718.9
5 May	12	RP	SW07	*	44 41.21 S	175 45.71 E	770	960	77	0.70	1.6	148.9	172.7
5 May	13	RP	SW09	*	44 45.74 S	175 48.31 E	869	1052	183	0.39	–	–	7.0
5 May	14	RP	SW12		44 40.01 S	175 50.23 E	673	804	11	0.51	2.1	452.8	970.1
6 May	15	RP	SW07		44 40.85 S	175 45.48 E	767	995	56	0.70	1.1	1532.7	637.7
6 May	16	RP	SW09		44 44.17 S	175 47.62 E	960	1050	323	0.43	–	24.5	14.8
6 May	17	RP	SW12		44 41.30 S	175 50.78 E	673	1069	181	0.61	2.7	806.8	1478.8
6 May	18	RP	SW07		44 41.90 S	175 45.51 E	840	981	138	0.59	–	38.3	81.9
6 May	20	RP	SW09		44 45.14 S	175 47.19 E	922	1033	241	0.25	363.5	3077.3	2754.3
7 May	21	RP	SW59	*	44 34.83 S	176 29.73 E	655	977	78	0.51	–	690.6	951.3
7 May	23	RP	SW59		44 34.40 S	176 28.37 E	785	1044	328	0.48	–	178.5	182.2
8 May	24	RP	SW59		44 35.12 S	176 27.91 E	700	825	270	0.16	1.3	36.7	10.9
8 May	25	RP	SW06	*	44 32.13 S	175 43.17 E	714	850	75	0.27	–	79.0	82.2
8 May	26	RP	SW06		44 32.82 S	175 42.96 E	714	870	125	0.17	–	56.9	82.3
8 May	27	RP	SW06		44 32.68 S	175 41.49 E	690	866	245	0.36	–	4.6	35.2
10 May	28	RP	SW61	*	44 33.71 S	176 36.40 E	823	1043	254	0.32	–	0.5	18.8
11 May	30	RD	SM01	Bobbin	44 13.23 S	178 52.81 E	1007	1021	71	3.23	3.2	586.9	5.8
11 May	31	RD	SM01		44 16.81 S	178 54.75 E	1105	1139	109	2.55	–	107.9	–
11 May	32	RD	SM01	Fletcher	44 12.88 S	178 54.31 E	980	1150	116	3.96	–	3571.7	161.7
11 May	33	RP	SM02		44 13.94 S	179 13.53 E	903	975	91	1.02	31.3	750.2	134.6
11 May	35	RP	SM02		44 14.61 S	179 12.12 E	937	972	198	1.08	2.8	3.7	8.6
11 May	36	RP	SM02		44 14.52 S	179 13.51 E	935	963	130	1.06	10.8	9.5	99.0
12 May	37	RD	SM06	Urk	44 27.98 S	179 23.91 W	995	1052	123	1.95	30.2	6688.2	57.6
12 May	38	RP	SM07	Trevs Pinni	44 27.05 S	179 16.81 W	946	1005	84	1.96	51.5	39.5	49.6
12 May	39	RD	SM08	Arrow	44 30.21 S	179 13.16 W	1056	1098	106	3.00	62.8	4331.0	30.6
12 May	40	RD	SM06		44 28.04 S	179 23.49 W	999	1026	71	2.04	11.7	41.7	5.9
12 May	41	RP	SM07		44 26.73 S	179 16.52 W	950	952	153	2.01	6.2	58.2	107.6
12 May	42	RD	SM08		44 30.36 S	179 12.69 W	1017	1080	117	2.10	17.6	8058.4	12.6
12 May	43	RD	SM06		44 28.30 S	179 23.71 W	1001	1108	142	3.02	15.6	1505.2	8.5
12 May	44	RP	SM07		44 27.23 S	179 17.03 W	963	983	70	3.01	3.5	91.2	213.2
13 May	45	RD	SM08		44 30.12 S	179 12.64 W	1020	1083	100	3.00	17.3	194.7	5.9
13 May	46	RP	SM05	Mt Nelson	44 17.34 S	179 51.16 E	866	946	248	1.01	5.6	176.5	100.2
14 May	47	RP	SM05		44 17.70 S	179 51.71 E	860	955	208	0.40	66.2	2158.1	185.2
14 May	48	RP	SM05		44 17.08 S	179 51.23 E	861	922	259	0.56	50.9	2406.9	228.9
14 May	49	RD	SE07	Buccaneer Steps	44 27.27 S	178 36.08 W	823	849	285	0.27	17.0	739.0	426.6

Date 1994	Stn. no.	Type	Stratum	Feature names	Start Latitude ° '	Start Longitude ° '	Depth (m) Min.	Depth (m) Max.	Hdg (°)	Distance (n. mile)	Catch (kg) ORH	Catch (kg) SSO	Catch (kg) BOE
14 May	50	RD	SE07		44 27.29 S	178 36.02 W	750	812	268	0.31	166.2	427.6	1027.5
14 May	51	RD	SE07		44 27.26 S	178 33.85 W	775	836	82	0.38	352.9	981.9	1094.7
15 May	53	RD	SE11	The Steps	44 35.82 S	177 56.04 W	1000	1154	136	3.01	32.2	784.4	25.4
15 May	54	RD	SE11		44 34.00 S	177 51.64 W	940	1037	128	3.00	71.9	647.2	19.5
15 May	55	RD	SE11		44 36.52 S	177 56.64 W	1038	1106	93	2.97	47.0	2050.4	19.9
15 May	57	RD	SE13	West of Rectangle	44 36.28 S	177 34.70 W	960	956	125	0.99	16.2	14882.6	58.2
15 May	58	RD	SE13		44 36.97 S	177 33.13 W	940	956	122	1.56	113.9	10107.4	121.2
17 May	59	RD	SE13		44 36.72 S	177 36.11 W	966	996	101	3.00	28.4	6998.7	53.0
17 May	61	RP	SE17	Hagerville	44 43.26 S	177 02.93 W	720	890	134	0.30	107.1	203.4	285.3
17 May	62	RP	SE17		44 41.93 S	177 03.36 W	660	1031	7	1.55	47.3	845.3	57.5
18 May	63	RP	SE17		44 42.24 S	177 04.30 W	644	1036	312	1.02	840.6	15185.1	319.3
18 May	64	RP	SE19	Nielson	44 43.66 S	176 46.02 W	685	900	93	0.82	121.1	389.0	486.7
18 May	65	RP	SE19		44 43.51 S	176 48.09 W	671	960	274	1.00	325.1	1532.7	179.0
19 May	66	RP	SE19		44 42.91 S	176 46.55 W	682	891	38	0.79	24.5	461.7	401.8
19 May	67	RP	SE20	Der Spriggs	44 42.14 S	176 44.25 W	658	1064	111	0.83	192.6	888.4	170.7
19 May	68	RP	SE20		44 42.38 S	176 45.50 W	685	1021	198	0.65	91.7	637.0	137.5
19 May	69	RP	SE20		44 41.71 S	176 44.10 W	650	1051	79	0.93	395.2	1922.2	51.2
19 May	70	RP	SE24	Paranoias	44 43.38 S	176 31.77 W	787	1065	45	0.54	62.9	162.8	3.5
19 May	71	RP	SE24		44 44.24 S	176 33.47 W	779	1200	249	0.78	23.5	183.2	13.1
19 May	72	RP	SE24		44 43.27 S	176 33.08 W	882	1091	329	0.35	7.7	65.9	5.4
20 May	74	RP	SE28	Unnamed	44 41.93 S	176 17.72 W	848	1046	167	0.78	147.8	1076.1	23.2
20 May	75	RP	SE28		44 40.68 S	176 17.40 W	722	1014	133	1.38	151.7	365.4	24.1
20 May	76	RP	SE28		44 41.18 S	176 17.30 W	832	1050	148	1.13	656.8	271.6	35.4
20 May	77	RP	SE31	Featherlite	44 40.35 S	176 02.11 W	972	1088	130	0.35	245.6	2135.1	10.2
20 May	78	RP	SE31		44 39.58 S	176 04.25 W	960	1055	275	0.31	468.9	998.4	118.2
20 May	79	RP	SE31		44 39.99 S	176 04.20 W	949	1066	249	0.48	1379.7	1199.2	76.2
21 May	80	RF	5		42 43.12 S	177 10.79 W	1175	1186	272	3.01	31.3	5.4	0.4
21 May	81	RF	5X		42 41.09 S	177 13.54 W	1298	1319	98	3.00	22.3	2.8	–
21 May	82	RF	4C		42 41.63 S	178 12.27 W	1021	1026	268	3.02	50.5	9.6	–
21 May	83	RF	4B		42 42.76 S	178 13.39 W	937	939	88	2.99	34.1	0.7	–
21 May	84	RF	4B		42 44.24 S	178 15.13 W	854	857	271	3.05	2.2	–	–
21 May	85	RF	4A		42 44.63 S	178 18.20 W	838	842	91	2.96	–	0.3	–
21 May	86	RF	4C		42 42.16 S	178 22.60 W	959	1010	269	3.01	15.2	1.9	–
22 May	87	RF	4D		42 38.97 S	178 26.00 W	1110	1117	99	3.01	8.9	0.8	–
22 May	88	RF	4D		42 36.78 S	178 29.65 W	1196	1196	267	2.99	66.3	12.3	0.3
22 May	89	RF	4C		42 40.79 S	178 38.01 W	1001	1001	260	3.00	31.5	9.0	–
22 May	90	RF	4D		42 39.25 S	178 42.97 W	1120	1121	76	3.00	84.3	5.4	–
22 May	91	RF	4C		42 42.56 S	178 50.04 W	1003	1010	258	3.04	79.9	2.7	–
22 May	92	RF	4C		42 42.60 S	178 54.28 W	1032	1033	81	3.00	44.5	0.3	–
22 May	94	RF	4D		42 39.04 S	179 01.57 W	1158	1173	106	2.99	73.3	1.8	–
23 May	95	RF	4B		42 45.28 S	179 06.08 W	870	877	269	3.00	369.1	2.3	–
23 May	96	RF	4B		42 46.15 S	179 11.14 W	859	859	80	2.98	156.4	2.1	0.8
23 May	97	RF	4A		42 47.95 S	179 11.33 W	789	789	252	3.01	2.5	0.2	–
23 May	98	RF	4E		42 35.20 S	179 11.66 W	1415	1420	263	3.01	17.2	0.6	–
23 May	99	RF	4D		42 38.63 S	179 24.00 W	1235	1242	270	3.01	51.5	1.5	–
23 May	100	RP	GY01	Dead Ringer	42 44.16 S	179 40.32 W	908	1164	94	0.52	1009.8	6.4	2.0
23 May	101	RP	GY04	Graveyard	42 45.68 S	179 58.36 W	798	1104	95	0.73	695.7	8.0	–

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24 May	103	RP	GY03	Morgue	42 43.61	S	179 57.59	W	932	1140	102	0.77	2892.2	5.2	66.8
24 May	104	RP	GY01		42 44.12	S	179 40.47	W	830	1163	94	0.54	12701.7	763.3	44.6
24 May	105	RF	4A		42 48.60	S	179 19.46	W	811	812	80	3.02	34.4	–	–
24 May	106	RF	4B		42 47.77	S	179 39.32	W	921	922	98	2.93	305.6	32.8	–
24 May	107	RF	4E		42 37.60	S	179 36.10	W	1329	1374	235	2.04	3.5	0.3	–
24 May	108	RF	4E		42 39.72	S	179 40.98	W	1342	1367	265	2.04	29.5	1.7	–
24 May	109	RP	GY01		42 44.15	S	179 40.24	W	884	1076	96	0.31	1106.4	53.3	1.2
25 May	110	RP	GY06	Mummy	42 39.39	S	179 52.05	W	1106	1224	146	0.25	117.5	–	–
25 May	111	RP	GY03		42 43.50	S	179 56.80	W	893	1076	124	0.27	1388.7	2098.4	5035.5
25 May	112	RF	3C		42 50.43	S	179 14.42	E	1018	1023	85	1.68	44.3	–	–
25 May	113	RF	3B		42 52.17	S	179 22.84	E	880	884	87	3.02	430.4	4.0	–
25 May	114	RF	3B		42 52.00	S	179 27.06	E	880	880	89	3.01	255.1	4.1	–
25 May	115	RF	3A		42 54.73	S	179 31.26	E	764	765	271	3.04	2.2	7.7	–
25 May	116	RF	3B		42 50.70	S	179 45.78	E	934	934	84	3.03	385.1	19.4	1.0
26 May	119	RP	GY04		42 45.70	S	179 58.52	W	755	1026	93	0.50	2559.4	8.9	6.2
26 May	120	RP	GY01		42 44.11	S	179 40.42	W	820	1160	94	0.52	350.80	122.3	1.1
26 May	122	RP	GY03		42 43.52	S	179 56.84	W	895	1156	132	0.42	58419.5	287.0	291.8
27 May	123	RF	3D		42 47.02	S	179 07.74	E	1207	1238	268	3.02	3.3	10.4	0.6
27 May	124	RF	3D		42 48.67	S	179 00.89	E	1118	1123	271	3.01	37.6	0.6	–
27 May	125	RF	3B		42 53.23	S	179 01.58	E	859	867	90	3.00	1038.5	4.3	1.0
28 May	126	RF	3D		42 49.67	S	178 53.03	E	1051	1055	272	3.02	244.1	8.1	–
28 May	127	RF	3E		42 45.26	S	178 51.94	E	1357	1365	87	2.99	8.2	172.4	–
28 May	128	RF	4E		42 44.93	S	178 36.27	E	1258	1260	279	3.01	28.9	299.8	–
28 May	129	RF	2E		42 37.17	S	177 46.83	E	1357	1375	265	3.02	3.5	5.8	–
28 May	130	RF	2D		42 40.77	S	177 39.89	E	1129	1133	265	3.00	33.1	22.2	0.4
29 May	131	RF	2D		42 41.07	S	177 26.16	E	1112	1120	275	3.15	6.7	2.7	–
29 May	132	RF	2E		42 39.08	S	177 21.95	E	1302	1305	280	3.00	14.9	4.3	–
2 Jun	133	RF	1C		42 47.61	S	175 06.77	E	998	1021	62	3.00	5.7	4.7	–
2 Jun	134	RF	1C		42 50.86	S	175 00.63	E	858	886	67	1.73	3.4	1.2	0.3
2 Jun	135	RF	1C		42 46.38	S	175 14.83	E	470	988	84	2.97	6.9	81.4	0.6
2 Jun	136	RF	1D		42 43.31	S	175 18.29	E	1103	1133	63	3.03	12.8	84.1	–
2 Jun	137	RF	1B		42 47.62	S	175 22.32	E	873	873	77	3.04	4.2	67.3	–
2 Jun	138	RF	1C		42 43.39	S	175 34.77	E	993	980	94	2.95	27.8	536.4	0.7
3 Jun	139	RF	1B		42 44.81	S	175 36.05	E	921	928	83	3.01	3.1	157.4	0.4
3 Jun	140	RF	1D		42 40.23	S	175 45.34	E	1110	1120	84	3.06	25.0	3.8	0.5
3 Jun	141	RF	1D		42 40.07	S	175 54.78	E	1063	1065	82	1.24	10.7	0.2	–
3 Jun	142	RF	2A		42 44.56	S	176 01.56	E	814	815	75	2.96	13.6	3.8	–
3 Jun	143	RF	2B		42 40.98	S	176 03.52	E	942	944	77	3.00	17.8	1.4	–
3 Jun	144	RF	2C		42 38.54	S	176 18.10	E	990	1014	88	3.02	60.7	2.3	0.9
3 Jun	145	RF	2C		42 38.14	S	176 22.95	E	1030	1030	92	3.02	103.2	6.2	–
3 Jun	146	RF	2D		42 37.02	S	176 31.71	E	1142	1170	94	3.03	21.5	11.0	–
3 Jun	147	RF	2E		42 36.00	S	176 36.73	E	1263	1284	89	2.98	9.5	6.6	–
4 Jun	148	RF	2D		42 38.58	S	176 42.22	E	1100	1107	96	3.05	163.6	5.5	–
4 Jun	149	RF	2B		42 42.44	S	176 45.92	E	864	865	94	3.01	106.5	0.7	–
4 Jun	150	RF	2B		42 42.84	S	177 00.85	E	860	864	93	3.03	40.4	3.9	–
4 Jun	151	RF	2C		42 40.45	S	177 07.28	E	1018	1018	97	3.00	69.9	212.5	–

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4 Jun	152	RF	2D		42 39.06	S	177 07.53	E	1103	1106	100	3.25	45.0	74.2	0.2
4 Jun	153	RF	2B		42 43.38	S	177 10.90	E	859	866	95	3.01	387.7	41.4	0.6
4 Jun	154	RF	2B		42 43.20	S	177 16.05	E	911	915	96	3.03	273.6	68.2	0.8
4 Jun	155	RF	2C		42 41.70	S	177 19.16	E	1015	1022	99	3.01	55.8	9.9	0.2
4 Jun	156	RF	2C		42 43.04	S	177 25.32	E	956	960	96	2.96	99.7	67.8	–
4 Jun	157	RF	2A		42 46.67	S	177 26.95	E	762	767	84	3.01	105.2	4.3	–
5 Jun	158	RF	2B		42 45.01	S	177 37.28	E	851	854	87	3.00	115.5	7.3	0.4
5 Jun	159	RF	2A		42 45.29	S	177 42.58	E	818	819	85	3.06	112.5	4.3	–
5 Jun	160	RF	3A		42 47.53	S	178 08.05	E	796	800	109	3.02	581.3	9.4	–
5 Jun	161	RF	3B		42 49.34	S	178 19.56	E	850	853	104	3.02	253.9	2.7	0.8
5 Jun	162	RF	3B		42 50.13	S	178 31.44	E	918	920	99	3.04	300.7	2.1	1.1
5 Jun	163	RF	3A		42 52.87	S	178 33.32	E	766	770	101	3.01	12.4	0.6	–
5 Jun	164	RF	3D		42 45.44	S	179 36.80	E	1207	1213	84	3.00	17.6	3.6	–
5 Jun	165	RF	3C		42 48.64	S	179 47.89	E	1010	1013	82	3.01	464.7	0.8	–
6 Jun	166	RF	3E		42 42.42	S	179 51.93	E	1311	1313	77	3.01	8.4	4.8	–
6 Jun	167	RF	3C		42 48.31	S	179 54.15	E	999	1011	81	3.02	557.4	2.1	0.6
6 Jun	168	RF	4B		42 51.19	S	179 55.77	W	857	858	85	2.03	317.3	11.2	0.4
6 Jun	172	RP	GY04		42 45.70	S	179 58.26	W	816	1000	80	0.18	1583.9	10.2	–
8 Jun	173	RP	EA04	Condom	44 36.83	S	175 46.54	W	888	888	260	0.06	180.10	2875.6	60.1
8 Jun	174	RP	EA04		44 37.20	S	175 45.46	W	863	1010	174	0.27	185.8	17079.0	5.1
8 Jun	175	RP	EA04		44 35.78	S	175 44.44	W	850	966	49	0.07	598.5	14917.5	2.5
8 Jun	176	RP	EA09	Charlie Horsecock	44 39.77	S	175 20.73	W	950	990	138	0.75	297.9	237.7	153.2
9 Jun	178	RP	EA12	Flintstones	44 37.97	S	175 16.86	W	865	1185	167	0.25	10.4	1.9	–
9 Jun	179	RP	EA16	Lucky	44 37.55	S	175 12.93	W	990	1100	27	0.16	210.4	76.4	15.5
9 Jun	181	RP	EA15	Big Chief	44 40.30	S	175 13.66	W	740	800	278	0.14	1.3	107.2	3.0
9 Jun	182	RP	EA12		44 37.73	S	175 16.06	W	809	1232	140	0.35	38.8	4048.4	15.5
10 Jun	183	RP	EA09		44 39.88	S	175 19.91	W	944	1150	33	0.14	676.8	692.4	592.3
10 Jun	184	RP	EA15		44 40.75	S	175 11.15	W	796	850	275	0.22	2.2	11.9	40.8
11 Jun	185	RP	EA12		44 36.61	S	175 15.87	W	960	970	139	0.17	2.7	2.2	1.0
11 Jun	186	RP	EA12		44 36.76	S	175 15.86	W	910	1200	73	0.35	189.5	1662.0	32.6
11 Jun	187	RP	EA15		44 40.24	S	175 11.73	W	810	1074	77	0.58	373.4	1432.8	210.1
11 Jun	188	RP	EA16		44 38.18	S	175 15.15	W	980	1138	52	0.15	278.6	104.6	108.4
11 Jun	189	RP	EA09		44 40.30	S	175 19.46	W	950	1057	72	0.23	486.0	289.7	18.9
11 Jun	190	RP	EA16		44 38.71	S	175 12.47	W	995	1247	106	0.33	1188.3	2422.0	1853.1
11 Jun	191	RP	EA17	Tomahawk	44 38.49	S	175 12.11	W	1050	1248	68	0.16	12.5	3.0	8.2
11 Jun	192	RP	EA15		44 39.86	S	175 13.84	W	790	1094	263	0.42	132.0	269.1	115.4
11 Jun	193	RP	EA17		44 39.16	S	175 09.48	W	1030	1100	144	0.04	2451.3	34305.1	22101.0
13 Jun	194	RP	EXPL	No. 2	44 30.86	S	175 15.81	W	680	927	184	0.53	6.0	5.5	–
16 Jun	195	RP	EA17		44 39.57	S	175 10.16	W	1077	1101	193	0.06	200.3	5510.2	96.6
16 Jun	196	RP	EA18	Teepee	44 36.70	S	175 11.20	W	1070	1227	287	0.21	2452.8	33.8	369.0
16 Jun	197	RP	EA18		44 37.10	S	175 08.64	W	1060	1267	99	0.26	223.1	1–	67.3
16 Jun	198	RP	EA18		44 36.70	S	175 11.13	W	1030	1249	287	184.20	2.0	64.3	–
16 Jun	199	RP	EA18		44 36.85	S	175 11.02	W	1000	1090	277	0.09	70.8	4949.2	402.6
16 Jun	200	RP	EA26	Jimmy	44 12.99	S	174 36.61	W	779	999	297	0.09	101.7	91.5	3.1
17 Jun	201	RP	EA30	Rachael	44 11.44	S	174 32.89	W	785	959	326	0.27	–	–	–
17 Jun	202	RP	EA39	Possum Saddle	44 12.41	S	174 30.09	W	830	996	0	0.44	1489.6	215.9	113.6

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18 Jun	205	RP	EA38	Possum East	44 12.31	S	174 29.71	W	900	1219	319	0.74	516.1	235.7	17.4
18 Jun	206	RP	EA41	Cotopaxi	44 09.77	S	174 25.73	W	950	1100	86	0.27	13963.3	872.1	704.0
18 Jun	207	RP	EA29	Dickies	44 07.58	S	174 33.33	W	660	1033	86	0.68	9.1	65.4	21.6
18 Jun	208	RP	EA26		44 13.00	S	174 36.49	W	863	1050	203	0.05	–	–	–
18 Jun	209	RP	EA39		44 12.33	S	174 30.11	W	890	977	0	0.24	5338.4	1285.2	694.1
18 Jun	210	RP	EA38		44 12.30	S	174 29.69	W	898	962	321	0.22	1593.1	595.1	22.4
18 Jun	211	RP	EA41		44 09.62	S	174 25.70	W	954	1123	69	0.28	491.6	4498.2	592.9
19 Jun	212	RP	EA29		44 07.31	S	174 33.49	W	648	1069	59	0.74	11.40	222.8	58.4
19 Jun	213	RP	EA45	Sir Michael	44 10.40	S	174 24.15	W	901	1194	350	0.35	10467.7	4868.5	1831.5
20 Jun	214	RP	EA39		44 12.39	S	174 30.10	W	870	1136	357	0.55	1118.1	454.7	1332.8
20 Jun	215	RP	EA38		44 12.34	S	174 29.23	W	878	988	341	0.39	322.1	515.1	78.4
20 Jun	216	RP	EA41		44 09.75	S	174 25.71	W	942	1023	90	0.14	2038.5	7712.4	247.0
21 Jun	218	RP	EA45		44 11.69	S	174 25.00	W	971	1181	219	0.22	193.5	129.7	101.0
21 Jun	219	RP	EA29		44 07.64	S	174 35.09	W	706	1057	266	0.71	5.5	28.1	37.0
21 Jun	220	RP	EA45		44 10.35	S	174 24.21	W	892	1198	357	0.47	72.9	344.3	261.0
21 Jun	221	RP	EA26		44 13.04	S	174 36.52	W	902	1181	281	0.43	63.5	23.9	31.1
21 Jun	223	RP	EXPL	Diamond Head	44 06.97	S	174 42.98	W	877	967	270	0.39	10.5	0.1	5.8
21 Jun	224	RP	EXPL	Aloha	44 00.85	S	174 34.62	W	882	949	211	0.07	260.9	213.5	0.7
22 Jun	225	RE	*NECR		43 32.52	S	173 48.38	W	1450	1481	165	3.00	3.0	8.1	13.1
22 Jun	226	RE	NECR		42 54.83	S	172 38.03	W	1694	1707	225	2.09	–	–	–
23 Jun	227	RE	NECR		42 39.79	S	172 12.51	W	1458	1477	70	3.00	1.4	–	–
24 Jun	228	RE	NECR		42 41.36	S	172 23.04	W	1435	1449	68	0.93	–	2.4	–
24 Jun	229	RE	NECR		42 39.65	S	172 17.66	W	1505	1524	64	1.47	–	–	–
25 Jun	230	RE	NECR		42 40.36	S	172 17.40	W	1442	1452	68	2.00	7.7	3.3	–
25 Jun	231	RE	NECR		42 37.36	S	172 04.60	W	1500	1509	76	1.73	–	–	–
25 Jun	232	RE	NECR		42 34.40	S	171 53.51	W	1583	1638	87	2.00	–	–	–
26 Jun	233	RE	NECR		42 33.67	S	172 27.38	W	1598	1626	124	0.90	–	–	–
26 Jun	234	RE	NECR		42 34.62	S	172 08.19	W	1531	1592	129	2.00	–	–	–
26 Jun	235	RE	NECR		42 31.93	S	171 56.33	W	1581	1591	133	3.00	3.6	–	–
* = Arrow Plateau tows 225–235															
27 Jun	236	RF	7C		43 36.19	S	174 06.85	W	1041	1047	23	2.97	101.6	0.3	–
27 Jun	237	RF	7C		43 36.34	S	174 08.67	W	1002	1014	214	3.00	71.3	2.6	–
27 Jun	238	RF	7C		43 38.97	S	174 08.71	W	1030	1031	19	2.75	446.1	0.6	–
27 Jun	239	RF	7C		43 27.90	S	174 06.57	W	1026	1026	357	2.69	98.5	0.2	–
28 Jun	240	RF	7B		43 27.98	S	174 16.45	W	898	901	188	3.00	44.6	0.6	–
28 Jun	241	RF	7A		43 28.45	S	174 31.43	W	796	800	324	3.01	40.1	0.8	–
28 Jun	242	RF	7B		43 25.74	S	174 20.27	W	876	889	344	2.98	18.5	3.8	–
28 Jun	243	RF	7B		43 19.21	S	174 21.89	W	889	889	355	3.00	21.0	4.3	–
28 Jun	244	RF	7B		43 20.20	S	174 14.88	W	938	948	349	3.01	16.2	12.1	–
28 Jun	245	RF	7C		43 14.20	S	174 10.21	W	999	1009	340	3.01	33.3	7.2	–
3 Jul	246	RP	GY05	Zombie	42 45.87	S	179 54.30	W	975	1067	77	0.17	117.7	7.3	–
4 Jul	250	RP	GY05		42 45.94	S	179 54.38	W	899	1060	91	0.19	5801.8	1119.1	–
4 Jul	253	RP	GY06		42 39.01	S	179 51.83	W	1047	1156	111	0.17	108.5	2879.1	69.3

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5 Jul	255	RP	EXPL		44 01.54 S	174 34.51 W	775	940	78	0.43	97.1	80.6	24.6
5 Jul	256	RP	NE01	Not till Sunday	43 50.41 S	174 16.80 W	842	942	313	0.19	1301.1	443.5	0.9
6 Jul	257	RP	NE02	Harrisville	43 57.96 S	174 31.98 W	689	885	142	0.45	40.9	507.0	9.3
6 Jul	258	RP	EXPL		44 01.87 S	174 36.39 W	789	1024	253	0.36	28.9	48.5	2.7
6 Jul	260	PR	NE01		43 51.47 S	174 17.08 W	754	1000	110	0.46	1341.7	1230.2	9.3
6 Jun	261	RP	NE02		43 56.80 S	174 32.89 W	662	836	6	0.46	9.6	41.0	–
6 Jul	262	RP	NE02		43 58.03 S	174 32.64 W	665	855	151	0.40	7.6	13.9	1.8
6 Jul	263	RP	NE01		43 50.34 S	174 18.14 W	885	1127	358	0.80	2433.0	433.3	–
7 Jul	264	RF	7E		44 00.00 S	174 00.39 W	1436	1438	51	3.03	–	–	–
7 Jul	265	RF	7D		43 58.37 S	174 20.69 W	1155	1155	219	3.02	36.8	0.9	–
7 Jul	266	RF	7C		43 54.51 S	174 24.23 W	1034	1040	40	3.02	44.4	2.3	0.5
7 Jul	267	RF	7C		43 49.42 S	174 23.23 W	926	1001	42	3.01	24.1	0.7	0.4
7 Jul	268	RF	7D		43 45.62 S	174 11.49 W	1136	1146	206	3.03	92.1	1.8	–
7 Jul	269	RF	7D		43 47.16 S	174 11.71 W	1200	1206	35	3.01	154.6	2.3	–
7 Jul	270	RF	7D		43 42.33 S	174 06.76 W	1207	1235	48	2.96	55.6	0.3	–
7 Jul	271	RF	7E		43 30.77 S	173 50.88 W	1389	1418	42	2.98	–	8.1	–
8 Jul	272	RF	7D		43 21.14 S	173 52.62 W	1215	1241	25	3.00	9.2	1.5	–
8 Jul	273	RF	7D		43 16.09 S	174 04.24 W	1058	1050	324	3.04	42.1	25.6	–
8 Jul	274	RF	7D		43 08.56 S	174 02.89 W	1128	1139	323	3.02	22.9	6.8	–
8 Jul	275	RF	7B		43 09.19 S	174 34.09 W	892	889	315	3.00	25.2	0.6	–
8 Jul	276	RP	NE03	Smiths City	42 57.25 S	174 24.29 W	893	977	58	0.11	15560.6	146.3	12.4
8 Jul	277	RF	21		43 05.82 S	175 07.91 W	847	898	119	3.00	35.8	0.8	–
9 Jul	278	RF	7A		43 13.58 S	174 58.56 W	827	828	140	3.02	51.1	1.1	–
9 Jul	279	RF	7A		43 23.65 S	174 53.34 W	787	790	131	3.01	27.2	6.3	0.4
9 Jul	280	RF	7D		42 51.86 S	174 56.10 W	1163	1173	106	3.02	26.7	1.6	–
9 Jul	281	RF	7D		42 53.71 S	174 34.92 W	1160	1190	96	3.00	99.1	3.5	–
10 Jul	282	RF	17		42 56.29 S	175 41.39 W	856	860	96	3.01	125.7	6.9	–
10 Jul	283	RF	16		42 56.66 S	175 46.24 W	833	836	276	2.96	34.2	5.4	–
10 Jul	284	RF	16		42 57.22 S	175 54.83 W	802	804	276	3.05	8.9	1.8	–
10 Jul	285	RF	17		42 52.39 S	175 59.12 W	937	949	91	2.99	182.8	5.8	–
10 Jul	286	RF	17		42 52.67 S	175 49.52 W	940	940	95	3.02	210.3	0.4	–
10 Jul	287	RF	17		42 53.53 S	175 47.02 W	918	920	276	3.01	564.3	–	–
10 Jul	288	RF	16		42 56.22 S	175 51.12 W	835	837	96	3.00	24.2	1.1	–
11 Jul	289	RF	17		42 54.30 S	175 46.10 W	895	900	93	3.00	1460.4	0.4	–
11 Jul	290	RF	18		42 52.06 S	175 39.21 W	980	982	99	3.02	125.7	1.9	–
11 Jul	291	RF	17		42 55.34 S	175 34.69 W	906	915	288	3.00	132.5	–	0.3
11 Jul	292	RF	17		42 55.58 S	175 37.98 W	885	887	105	3.00	241.6	0.6	–
11 Jul	293	RF	22		42 58.16 S	175 27.91 W	862	865	109	3.04	76.6	4.8	–
11 Jul	294	RF	22		42 57.68 S	175 21.64 W	903	910	–	3.00	75.6	0.4	–
11 Jul	295	RF	22		42 56.99 S	175 18.37 W	941	942	110	3.05	156.9	0.6	–
11 Jul	297	RP	NE03		42 58.52 S	174 25.49 W	904	1068	195	0.47	1704.9	646.9	–
12 Jul	298	RP	NE04	Camerons	43 07.96 S	174 15.80 W	784	901	103	0.22	3574.2	57.8	0.9
12 Jul	299	RP	NE04		43 07.88 S	174 15.78 W	799	952	88	0.35	3457.8	143.2	3.5
12 Jul	300	RF	7A		43 15.14 S	174 55.64 W	827	844	311	3.01	164.2	4.2	–
12 Jul	301	RF	21		43 10.90 S	175 09.64 W	752	758	324	3.04	1.4	0.1	–
12 Jul	302	RF	21		43 08.19 S	175 07.32 W	811	818	134	2.98	35.7	3.1	–

Date 1994	Stn. no.	Type	Stratum	Feature names	Start Latitude ° '	Start Longitude ° '	Depth (m) Min.	Depth (m) Max.	Hdg (°)	Distance (n. mile)	Catch (kg) ORH	Catch (kg) SSO	Catch (kg) BOE
12 Jul	303	RF	22		43 02.22 S	175 10.36 W	895	899	302	2.99	35.8	1.8	–
12 Jul	304	RF	23		42 59.68 S	175 00.62 W	968	983	287	3.02	68.2	0.2	–
13 Jul	305	RF	23		42 55.12 S	175 13.25 W	1019	1020	289	3.02	28.4	1.9	–
13 Jul	306	RF	23		42 54.71 S	175 19.55 W	990	995	292	2.98	83.4	0.2	–
13 Jul	307	RF	24		42 51.06 S	175 17.71 W	1118	1127	94	3.02	9.4	0.5	–
13 Jul	308	RF	24		42 51.95 S	175 12.80 W	1108	1109	281	3.04	12.3	1.0	–
13 Jul	309	RF	24		42 51.24 S	175 24.66 W	1062	1064	286	3.02	18.5	0.4	–
13 Jul	310	RF	19		42 49.05 S	175 33.36 W	1106	1097	266	3.04	42.3	0.9	–
13 Jul	311	RF	25		42 47.82 S	175 25.63 W	1195	1197	103	3.02	7.6	0.8	–
13 Jul	312	RP	NE03		42 58.38 S	174 24.64 W	888	1180	146	0.58	30677.8	1766.2	8.3
14 Jul	313	RF	25X		42 45.46 S	175 18.08 W	1387	1398	101	3.02	1.4	0.9	–
14 Jul	314	RF	25X		42 46.57 S	175 13.31 W	1363	1365	94	3.03	4.0	0.3	–
14 Jul	315	RF	25X		42 44.95 S	175 04.45 W	1482	1524	99	2.96	–	–	–
14 Jul	316	RF	25		42 49.49 S	175 06.06 W	1221	1224	273	3.04	2.7	1.1	–
14 Jul	317	RF	25		42 50.79 S	175 04.59 W	1157	1164	103	3.00	6.8	3.6	–
14 Jul	318	RF	20X		42 41.80 S	175 32.29 W	1482	1498	284	2.00	–	–	–
16 Jul	319	RP	NE05	Erebus	43 10.73 S	173 50.43 W	1016	1215	174	0.14	1622.3	199.9	0.7
16 Jul	320	RP	NE05		43 08.97 S	173 50.44 W	991	1261	357	0.39	1027.6	273.0	0.8
16 Jul	321	RP	NE05		43 10.49 S	173 49.71 W	996	1207	138	0.37	2062.9	6804.8	–
16 Jul	322	RF	7E		43 04.06 S	173 45.34 W	1348	1352	343	3.03	3.7	69.6	–
16 Jul	323	RF	7D		42 59.66 S	174 17.81 W	1195	1196	295	2.94	6.7	11.1	–
16 Jul	324	RP	NE04		43 07.24 S	174 16.59 W	779	1034	359	0.69	2711.9	246.4	2.8
16 Jul	325	RF	7B		43 06.67 S	174 29.25 W	948	949	318	2.28	7.3	5.9	–
17 Jul	326	RF	7C		42 57.86 S	174 37.43 W	1026	1031	288	3.02	13.8	0.1	–
17 Jul	327	RF	20X		42 45.40 S	175 35.22 W	1283	1285	278	3.00	4.1	1.8	–
17 Jul	328	RF	20		42 47.39 S	175 35.39 W	1169	1185	99	3.00	18.2	5.2	–
17 Jul	329	RF	19		42 49.69 S	175 42.91 W	1060	1067	274	3.08	41.6	13.1	–
17 Jul	330	RF	18		42 50.81 S	175 47.43 W	1010	1020	93	3.03	98.4	0.4	–
17 Jul	331	RF	19		42 49.72 S	175 47.05 W	1056	1056	269	2.99	43.8	4.5	–
17 Jul	332	RF	19		42 47.83 S	175 48.77 W	1140	1154	92	2.99	29.6	29.0	–
18 Jul	333	RF	20		42 47.49 S	175 42.98 W	1159	1177	280	3.02	18.9	22.7	–
18 Jul	334	RF	20		42 46.32 S	175 52.46 W	1220	1223	265	3.03	32.6	789.8	–
18 Jul	335	RF	20X		42 43.88 S	175 57.15 W	1381	1398	74	3.07	–	1.4	–
18 Jul	336	RF	18		42 51.39 S	175 54.96 W	988	991	270	3.02	17.1	2.2	–
18 Jul	337	RF	18		42 52.03 S	175 55.70 W	957	967	95	3.04	26.6	1.5	–
18 Jul	338	RF	12		42 54.89 S	175 59.51 W	857	861	275	3.05	77.3	0.3	–
18 Jul	339	RF	11		42 56.86 S	176 04.70 W	785	785	280	3.00	12.1	0.2	–
18 Jul	340	RF	12		42 54.24 S	176 08.60 W	842	858	104	3.00	126.3	1.1	–
19 Jul	341	RF	13		42 50.82 S	176 00.20 W	1011	1021	271	3.01	39.2	0.2	–
19 Jul	342	RF	13		42 50.38 S	176 06.86 W	1026	1027	274	3.02	136.8	10.6	–
19 Jul	343	RF	15		42 47.53 S	176 05.55 W	1178	1185	86	2.93	43.5	18.1	–
19 Jul	344	RF	14		42 48.92 S	176 09.76 W	1102	1087	271	3.05	79.8	737.5	0.5
19 Jul	345	RF	14		42 47.81 S	176 15.26 W	1128	1141	277	3.02	75.4	33.2	–
19 Jul	346	RF	15		42 46.73 S	176 15.55 W	1202	1225	91	3.01	37.9	3.9	–
19 Jul	347	RF	15X		42 45.35 S	176 09.22 W	1309	1313	271	3.01	5.7	331.6	–
19 Jul	348	RF	15X		42 40.60 S	176 26.95 W	1441	1474	85	2.47	0.8	3.5	–

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20 Jul	349	RF	15X		42 42.66 S	176 19.01 W	1377	1403	114	3.02	2.3	316.6	–
20 Jul	350	RF	14		42 48.85 S	176 19.89 W	1050	1073	291	3.02	175.9	9.8	–
20 Jul	351	RF	12		42 50.37 S	176 26.21 W	942	947	102	3.00	225.6	–	–
20 Jul	352	RF	13		42 50.71 S	176 18.77 W	963	967	99	2.98	92.6	1.6	–
20 Jul	353	RF	13		42 50.95 S	176 12.84 W	983	988	277	3.03	108.6	43.1	–
20 Jul	354	RF	12		42 52.72 S	176 16.78 W	886	897	103	3.02	394.7	0.6	–
20 Jul	355	RF	12		42 52.53 S	176 23.18 W	873	877	282	3.00	379.0	1.1	–
20 Jul	356	RF	12		42 51.91 S	176 29.76 W	866	867	100	2.97	297.2	0.3	0.3
20 Jul	357	RF	11		42 53.73 S	176 23.31 W	817	835	270	3.00	41.0	0.1	–
21 Jul	358	RF	26		42 52.15 S	176 49.54 W	820	847	282	4.11	358.0	1.0	–
21 Jul	359	RF	26		42 50.80 S	176 59.61 W	832	870	89	3.73	189.5	0.3	–
21 Jul	360	RF	7		42 50.56 S	176 46.95 W	875	877	94	3.02	238.6	0.5	0.3
21 Jul	361	RF	7		42 50.11 S	176 43.63 W	898	902	94	3.01	1498.6	0.4	–
21 Jul	362	RF	7		42 50.47 S	176 39.07 W	892	905	271	2.98	137.6	0.8	–
21 Jul	363	RF	8		42 47.69 S	176 40.23 W	1003	1005	98	3.00	57.1	0.7	0.5
21 Jul	364	RF	8		42 47.51 S	176 39.37 W	1018	1019	279	3.02	92.2	0.9	–
21 Jul	365	RF	8		42 46.15 S	176 44.18 W	1058	1072	86	3.02	114.4	2.8	–
21 Jul	366	RF	7		42 50.10 S	176 38.74 W	904	913	99	3.02	79.5	1.4	–
22 Jul	367	RF	7		42 50.44 S	176 33.89 W	910	914	278	3.04	121.9	–	–
22 Jul	368	RF	7		42 49.55 S	176 34.49 W	939	948	103	3.00	66.1	0.3	–
22 Jul	369	RF	9		42 45.67 S	176 30.04 W	1126	1138	275	3.01	169.2	16.5	–
22 Jul	370	RF	9		42 45.74 S	176 34.67 W	1109	1121	107	3.10	271.2	17.6	–
22 Jul	371	RF	10		42 44.91 S	176 30.34 W	1188	1188	279	2.99	51.9	61.9	–
22 Jul	372	RF	10		42 43.50 S	176 35.18 W	1230	1235	280	3.03	36.4	27.6	–
22 Jul	373	RF	10		42 43.81 S	176 48.95 W	1167	1171	275	3.03	76.4	12.2	–
22 Jul	374	RF	9		42 44.81 S	176 53.81 W	1112	1114	272	3.02	86.3	15.3	–
22 Jul	375	RF	8		42 47.18 S	176 51.26 W	1008	1011	89	3.05	30.7	2.3	–
22 Jul	376	RF	8		42 47.81 S	176 48.93 W	986	988	275	3.03	54.8	2.7	–
23 Jul	377	RF	7		42 49.55 S	176 50.76 W	902	910	269	3.01	150.3	1.4	–
23 Jul	378	RF	7		42 48.36 S	176 57.36 W	947	948	273	3.01	77.3	1.8	–
23 Jul	379	RF	3		42 47.49 S	177 03.29 W	972	979	279	3.04	55.1	1.5	–
23 Jul	380	RF	4		42 45.31 S	177 05.45 W	1076	1081	92	3.12	29.4	27.9	–
23 Jul	381	RF	5		42 43.47 S	177 03.22 W	1174	1186	–	3.02	72.2	39.6	–
23 Jul	382	RF	5		42 43.18 S	177 09.84 W	1190	1190	274	3.03	56.5	46.3	–
23 Jul	383	RF	4		42 45.37 S	177 09.74 W	1064	1067	95	3.15	72.5	9.3	–
23 Jul	384	RF	3		42 47.09 S	177 10.36 W	980	985	276	3.01	127.0	0.7	–
23 Jul	385	RF	3		42 45.86 S	177 18.08 W	1029	1033	267	2.88	280.5	29.9	–
24 Jul	387	RF	3		42 46.55 S	177 16.12 W	994	1003	274	3.03	173.1	120.9	–
24 Jul	388	RF	4		42 45.54 S	177 21.76 W	1034	1079	255	2.99	64.4	110.8	–
24 Jul	389	RF	5		42 44.53 S	177 29.47 W	1141	1163	82	2.96	34.8	34.8	–
24 Jul	390	RF	2		42 47.91 S	177 27.22 W	928	929	270	3.02	272.6	30.4	–
24 Jul	391	RF	2		42 48.12 S	177 29.29 W	929	889	103	3.00	131.5	7.3	–
24 Jul	392	RF	1		42 50.48 S	177 28.39 W	795	798	89	2.99	1.2	–	–
24 Jul	393	RF	2		42 48.17 S	177 17.20 W	910	912	92	2.91	57764.3	1.8	0.6
26 Jul	394	RF	10X		42 38.41 S	176 52.39 W	1444	1455	96	3.01	5.7	2.1	–
26 Jul	395	RF	10X		42 39.73 S	176 45.20 W	1387	1424	95	2.99	8.1	3.4	–

Date 1994	Stn. no.	Type	Stratum	Feature names	Start Latitude ° '	Start Longitude ° '	Depth (m) Min.	Depth (m) Max.	Hdg (°)	Distance (n. mile)	Catch (kg) ORH	Catch (kg) SSO	Catch (kg) BOE
26 Jul	396	RF	10X		42 39.15 S	176 40.82 W	1437	1456	280	3.02	–	–	–
26 Jul	397	RF	10X		42 40.52 S	176 43.77 W	1347	1350	96	3.01	1.1	2.7	–
26 Jul	398	RF	5X		42 38.11 S	177 02.06 W	1494	1497	263	3.04	–	–	–
26 Jul	399	RF	2		42 48.36 S	177 09.84 W	915	924	282	0.48	71730.1	–	–
28 Jul	400	RF	5X		42 39.54 S	177 11.21 W	1423	1432	270	3.01	5.1	–	–
28 Jul	401	RF	5X		42 41.42 S	177 13.05 W	1267	1328	103	3.00	27.0	7.7	–
28 Jul	402	RF	1		42 51.50 S	177 02.12 W	799	803	275	3.02	0.7	0.1	–
28 Jul	403	RF	6		42 52.79 S	176 59.76 W	754	764	103	3.02	–	–	–
28 Jul	404	RF	6		42 52.36 S	176 56.85 W	786	787	280	3.02	–	–	–
28 Jul	405	RF	26		42 50.81 S	177 01.39 W	823	828	102	1.46	61.4	0.2	–
28 Jul	406	RF	26		42 50.84 S	177 00.33 W	832	835	98	3.99	102.5	–	–
29 Jul	407	RF	2		42 49.38 S	177 09.10 W	872	876	267	0.94	14087.2	0.2	0.3
29 Jul	408	RF	2		42 48.20 S	177 28.20 W	911	933	258	3.04	82.3	0.9	–
29 Jul	409	RF	2		42 49.28 S	177 12.74 W	872	875	89	1.56	127.8	0.2	–
29 Jul	410	RF	2		42 48.68 S	177 09.18 W	942	905	288	3.00	236.3	0.4	–
29 Jul	411	RF	2		42 49.67 S	177 08.61 W	861	862	263	0.08	1795.8	–	–
29 Jul	413	RF	2		42 47.59 S	177 16.01 W	915	949	259	3.01	291.0	0.2	–
29 Jul	414	RF	2		42 48.57 S	177 23.70 W	894	894	270	3.04	83.3	0.2	–
29 Jul	415	RF	2		42 48.14 S	177 23.35 W	910	918	269	3.04	59.5	–	–
30 Jul	416	RF	2		42 48.70 S	177 03.42 W	916	923	90	2.99	152.1	0.3	–

Appendix 2: Species caught

Species code	Scientific name	Common name
ABR	*Alepisaurus brevirostris*	shortsnouted lancetfish
AGI	*Argyropelecus gigas*	giant hatchetfish
AGR	*Agrostichthys parkeri*	ribbonfish
ALA	*Aldrovandia affinis*	
AMP	*Amphitretus* sp.	deepwater octopod
ANP	*Anotopterus pharao*	daggertooth
ANT	Anthozoa	sea anemones
APE	*Acanthephyra pelagica*	
APR	*Apristurus* spp.	catshark
ASR	Asteroidea	starfish
AST	Astronesthidae	snaggletooths
AVO	*Avocettina* spp.	black snipe eel
BAC	*Bathygadus cottoides*	codheaded rattail
BAF	Lynophyrynidae	black anglerfish
BAT	*Rouleina* sp.	large headed slickhead
BBE	*Centriscops humerosus*	redbanded bellowsfish
BCA	*Magnisudis prionosa*	barracudina
BCR	*Brotulotaenia crassa*	blue cusk eel
BEE	*Diastobranchus capensis*	basketwork eel
BFE	*Bathysaurus ferox*	deepsea lizardfish
BJA	*Mesobius antipodum*	black javelinfish
BLB	*Centriscops obliquus*	bluebanded bellowsfish
BNS	*Hyperoglyphe antarctica*	bluenose
BNT	*Benthodesmus tenuis*	scabbard fish
BOE	*Allocyttus niger*	black oreo
BSH	*Scymnorhinus licha*	seal shark
BSL	*Xenodermichthys* spp.	black slickhead
BTA	*Pavoraja asperula*	
BTH	*Bathyraja* sp.	bluntnose skate
BTS	*Pavoraja spinifera*	
BYS	*Beryx splendens*	alfonsino
CBA	*Coryphaenoides* sp. B	long barbelrattail
CBO	*Caelorinchus bollonsi*	Bollons's rattail
CCA	*Cubiceps caeruleus*	cubehead
CCR	*Cetonurus crassiceps*	globosehead rattail
CDO	*Capromimus abbreviatus*	capro dory
CER	*Ceratias* spp.	
CEX	*Caelorinchus celaenostoma*	rattail
CFA	*C. fasciatus*	banded rattail
CHA	*Chauliodus sloani*	viper fish
CHG	*Chimaera phantasma*	giant chimaera
CHP	*Chimaera* sp.	purple chimaera
CHQ	Cranchiidae	cranchiid squid
CHX	*Chaunax pictus*	pink frogmouth
CIN	*Caelorinchus innotabilis*	notable rattail
CJX	*C. mycterismus*	upturned snout rattail
CKA	*C. kaiyomaru*	Kaiyomaru rattail
CKX	*C. acanthiger*	spottyfaced rattail
CMA	*C. matamua*	Mahia rattail
CMU	*Coryphaenoides murrayi*	abyssal rattail
CMX	*C. mcmillani*	
COB	Antipatharia (order)	black coral
COL	*Caelorinchus oliverianus*	Oliver's rattail
COR	Stylasterina (order)	red coral
COT	*Cottunculus nudus*	bonyskulled toadfish
COU		coral (unspecified)
CRB	Crustacea	crab

Species code	Scientific name	Common name
CSE	*Coryphaenoides serrulatus*	serrulate rattail
CSQ	*Centrophorus squamosus*	leafscaled gulper shark
CSU	*Coryphaenoides subserrulatus*	four-rayed rattail
CTR	*C. striatura*	abyssal rattail
CUB	*Cubiceps* spp.	cubehead
CYL	*Centroscymnus coelolepis*	Portuguese spiny dogfish
CYO	*C. owstoni*	smooth skin dogfish
CYP	*C. crepidater*	longnosed velvet dogfish
DEA	*Trachipterus trachypterus*	dealfish
DIS	*Diretmus argenteus*	discfish
DPO	*Desmodema polystictum*	dealfish
DSK	*Raja* (*Amblyraja*) sp.	deepwater spiny skate
DSS	*Bathylagus* spp.	deepsea smelt
DWE	Synaphobranchidae	deepwater eel
DWO	*Graneledone* spp.	deepwater octopus
ECH	Echinodermata	sea urchin
ECR	*Echiodon cryomargarites*	messmate fish
EPL	*Epigonus lenimen*	bigeyed cardinalfish
EPR	*E. robustus*	robust cardinalfish
EPT	*E. telescopus*	deepsea cardinalfish
ERA	*Torpedo fairchildi*	electric ray
ETB	*Etmopterus baxteri*	Baxter's lantern dogfish
ETL	*E. lucifer*	lucifer's dogfish
GAO	*Gadomus aoteanus*	filamentous rattail
GIG	*Gigantactis* sp.	
GSP	*Hydrolagus* sp.	pale ghost shark
GST	Gonostomatidae	
GUL	*Eurypharynx pelecanoides*	gulper
HAK	*Merluccius australis*	hake
HAL	*Halosauropsis macrochir*	abyssal halosaur
HAT	*Sternoptychidae*	hatchetfish
HCO	*Bassanago hirsutus*	hairy conger
HJO	*Halargyreus johnsonii*	Johnson's cod
HOK	*Macruronus novaezelandiae*	hoki
HPE	*Halosaurus pectoralis*	common halosaur
HYB	*Hydrolagus* sp.	black hydrolagus
HYP	*Hydrolagus* sp.	purple finned hydrolagus
IDI	*Idiacanthus* spp.	starry dragonfish
JAV	*Lepidorhynchus denticulatus*	javelinfish
JFI		jellyfish
LAE	*Laemonema* spp.	
LAN	Myctophidae	lanternfish
LCH	*Harriotta raleighana*	longnosed chimaera
LDO	*Cyttus traversi*	lookdown dory
LEG	*Lepidion schmidti* & *L. inosimae*	giant lepidion
LHO	*Lipkius holthuisi*	omega prawn
LIN	*Genypterus blacodes*	ling
LMU	*Lithodes murrayi*	southern stone crab
LPI	*Lepidion inosimae*	giant lepidion
LPR	*Lampichthys procerus*	
LPS	*Lepidion schmidti*	giant lepidion
LYC	*Lyconus* sp.	
MAL	Malacosteidae	loosejaw
MAN	*Neoachiropsetta milfordi*	finless flounder
MCA	*Macrourus carinatus*	ridgescaled rattail
MEJ	*Melanocetus johnsonii*	humpbacked anglerfish
MIQ	*Moroteuthis ingens*	warty squid
MPH	Melamphaidae	bigscaled fish
MRQ	*Moroteuthis robsoni*	warty squid

Species code	Scientific name	Common name
MSQ	*Mastigoteuthis* sp.	
MST	Melanostomiidae	scaleless black dragonfish
NAT	Natantia	natant decapod prawn
NEB	*Neolithodes brodiei*	
NEC	*Nematocarcinus*	natant decapod prawn
NNA	*Nezumia namatahi*	squashfaced rattail
NPU	*N. leonis*	
OAR	*Regalecus glesne*	oarfish
OMI	*Opostomias micrpnus*	giant black dragonfish
ONG	Porifera	sponges
OPH	Ophiuroidea	brittle star
OPI	*Opisthoteuthis*	umbrella octopus
ORH	*Hoplostethus atlanticus*	orange roughy
OSQ	Octopoteuthiidae	deepwater octopus
PAL	*Paralepididae*	barracudinas
PBA	*Pasiphaea barnardi*	natant decapod prawn
PDG	*Oxynotus bruniensis*	prickly dogfish
PED	*Plesiopenaeus edwardsianus*	scarlet prawn
PER	*Persparsia kopua*	
PHO	*Photichthys argenteus*	lighthouse fish
PIN	*Idiolophorhynchus andriashevi*	pineapple rattail
PLA	*Platyberyx* sp.	
PLS	*Scymnodon plunketi*	Plunket's shark
PRK	*Polychaeles*	prawn killer
PSK	*Bathyraja shuntovi*	longnosed deepsea skate
PSY	*Psychrolutes* sp.	blobfish
RAG	*Icichthys australis*	ragfish
RBM	*Brama brama*	Ray's bream
RCH	*Rhinochimaera pacifica*	widenosed chimaera
RIB	*Mora moro*	ribaldo
ROS	*Rosenblattia robusta*	
RUD	*Centrolophus niger*	rudderfish
SAL	Urochordata	salps
SAW	*Serrivomer* sp.	sawtooth eel
SBI	*Alepocephalus* sp.	bigscaled brown slickhead
SBK	*Notacanthus sexspinis*	spineback
SCC	*Stichopus mollis*	sea cucumber
SCO	*Bassanago bulbiceps*	swollenhead conger
SCY	Scyphozoa	jellyfish
SDE	*Cryptopsaras couesi*	seadevil
SEP	*Sergia potens*	natant decapod prawn
SER	*Sergestidae* spp.	natant decapod prawn
SFI	Asteroidea	starfish
SKA	Rajidae, Arhynchobatidae (families)	skate
SLK	Alepocephalidae	slickhead
SMC	*Lepidion microcephalus*	small-headed cod
SME	*Retropinna retropinna*	smelt
SND	*Deania calcea*	shovelnosed spiny dogfish
SOR	*Neocyttus rhomboidalis*	spiky oreo
SPD	*Squalus acanthias*	spiny dogfish
SPE	*Helicolenus* sp.	sea perch
SPL	*Scopelosaurus* sp.	
SQB	*Brachioteuthis* sp.	squid
SQX	Cephalopoda	squid
SRH	*Hoplostethus mediterraneus*	silver roughy
SSM	*Alepocephalus australis*	slickhead, smallscaled brown
SSO	*Pseudocyttus maculatus*	smooth oreo
STA	*Kathetostoma giganteum*	giant stargazer
STO	*Stomias* spp.	

Species code	Scientific name	Common name
SUH	*Schedophilus huttoni*	
SUS	*Schedophilus* sp.	
TAL	*Talismania longifilis*	
TAM	*Araeosoma* spp.	Tam-o-shanter urchin
TET	*Tetragonurus* sp.	squaretail
TOP	*Neophrynichthys angustus*	pale toadfish
TRS	*Trachyscorpia capensis*	Cape scorpionfish
TSQ	*Todarodes filippovae*	
TUB	*Tubbia tasmanica*	
TRX	*Trachonurus* sp.	
VCO	*Antimora rostrata*	violet cod
VNI	*Ventrifossa nigromaculata*	blackspotted rattail
VSQ	*Histioteuthis* spp.	violet squid
WHR	*Trachyrincus longirostris*	white rattail
WHX	*Trachyrincus* sp.	unicorn rattail
WOE	*Allocyttus verrucosus*	warty oreo
WSQ	*Moroteuthis* spp.	warty squid
WWA	*Seriolella caerulea*	white warehou
ZAS	*Zameus squamulosus*	
ZEL	*Zu elongatus*	scalloped dealfish

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