New Zealand-Japan trawl survey of shelf and upper slope species off southern New Zealand, June 1986

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Contents

	Page
Abstract	5
Introduction	5
The area F (Southland) fishery	5
Previous research	5
June 1986 survey	7
Methods	13
Survey area and design	13
Vessel	13
Net features	13
Trawling procedure	13
Catch size estimation	13
Biomass estimation	13
Biological observations	14
Hydrological observations	15
Ichthyoplankton samples	15
Results	17
Survey area	17
Catch composition	17
Species distribution	17
Wingspread biomass estimates	28
Biology	28
Hydrology	37
Discussion	40
Acknowledgments	44
References	44
Appendix 1: Trawl net plans	45
Appendix 2: Individual station data and catch of the 10 major species	47
Appendix 3: Species taken during the survey	49
Appendix 4: Mean catch rates for the 10 major species	50
Appendix 5: Estimated doorspread biomass and coefficient of variation (*c.v.*) for the 20 major species	50

Abstract

Hurst, R. J., Bagley, N. W., and Uozumi, Y. 1990: New Zealand-Japan trawl survey of shelf and upper slope species off southern New Zealand, June 1986. *N.Z. Fisheries Technical Report No. 18.* 50 p.

A stratified random trawl survey of the Stewart-Snares shelf and the Puysegur Bank region in June 1986 caught 81 species of fish, squid, and crustaceans. The catch and estimated biomass of the 20 major species are given with more detailed results of relative changes in distribution and abundance between areas and depths for the 10 major species. The most abundant species, both in terms of catch and estimated biomass, were barracouta and spiny dogfish.

Biological data (including length, sex, weight, reproductive state, feeding, and parasites) are presented for 15 commercially important species. Surface and bottom temperatures measured by ship recorders and expendable bathythermographs are also summarised. Comparisons are made of biomass estimates, fish distribution and size, and temperatures from this survey with results from four previous *Shinkai Maru* surveys.

Introduction

The area F (Southland) fishery

Exclusive Economic Zone (EEZ) area F is south of the South Island of New Zealand and includes waters around Stewart Island, the Snares Islands, and Puysegur Bank (Figure 1). Catches of finfish and squid from area F constituted 15–16% of the total EEZ deepwater trawl and domestic inshore (excluding jig-caught squid and tuna) catch in the fishing years (1 October to 30 September) 1983–84 to 1985–86. It is a particularly important fishing ground for deepwater factory trawlers, which reported 20–24% of their catch from this area. In contrast, the domestic inshore vessels (all methods) caught only 2% of the national domestic total in area F.

The main trawl-caught species reported from area F from 1983–84 to 1985–86 were arrow squid (*Nototodarus sloanii*), hoki (*Macruronus novaezelandiae*), and barracouta (*Thyrsites atun*). Gemfish (*Rexea solandri*), ling (*Genypterus blacodes*), oreos (*Allocyttus* sp. and *Pseudocyttus maculatus*), silver warehou (*Seriolella punctata*), and red cod (*Pseudophycis bachus*) were also important (catches over 1000 t) in all years (Table 1).

Catches by deepwater (New Zealand chartered, New Zealand factory, and foreign licensed) trawlers in subareas F(E) and F(W) for the three fishing years are given in Table 2. All these vessels are over 42 m long, and they were prohibited from fishing inside the 12 n. mile territorial sea limit from 1 April 1978. The relative importance of areas F(E) and F(W) varied; F(E) increasing in importance. This was partly due to the closure of the Solander corridor to vessels over 43 m from 1 October 1985. New Zealand chartered vessels took most (65–72%) of the catch during these fishing years.

Previous research

There has been limited research in this important fishing area. Van den Broek *et al.* (1984) and Hatanaka *et al.* (1989) summarised research surveys by various vessels in EEZ areas F and E (Sub-Antarctic) up to the end of 1983. Four of these were joint Japan-New Zealand stratified random trawl surveys using the research vessel Shinkai Maru during 1981–83. Three were in late summer-early autumn — February 1981 (Kawahara and Tokusa 1981), March-April 1982 (van den Broek *et al.* 1984), and April 1983 (Uozumi *et al.* 1987) — and one was in spring — October-November 1983 (Hatanaka *et al.* 1989).

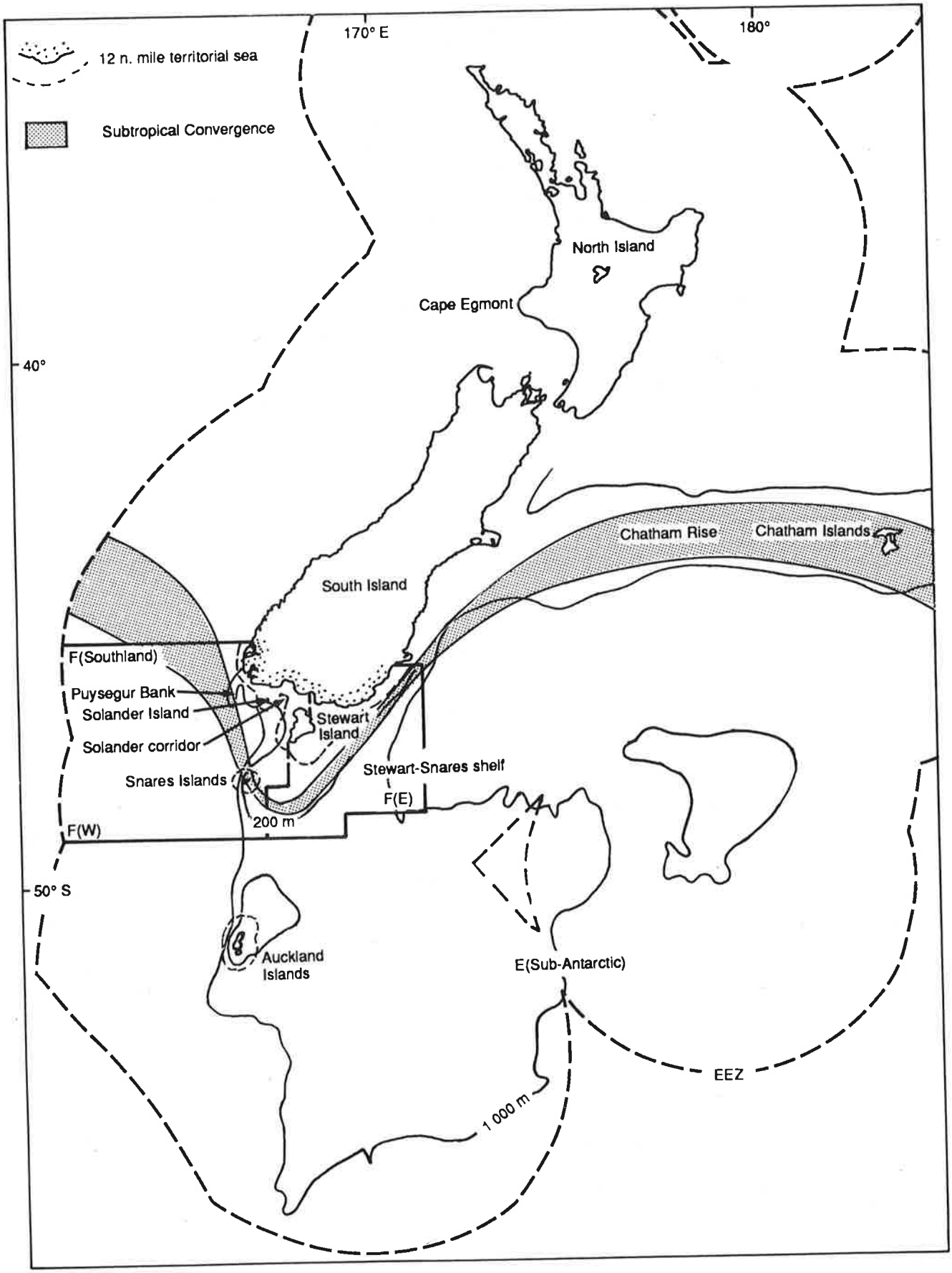

Figure 1: New Zealand Exclusive Economic Zone areas E and F and places mentioned in the text.

Table 1: Catch* (t) of the 10 major finfish and squid species reported by deepwater trawlers† (DW) and inshore domestic vessels (DOM) fishing in area F and the total EEZ catch for the fishing years 1983–84 to 1985–86

	1983–84			1984–85			1985–86		
Species	DW	DOM	Total	DW	DOM	Total	DW	DOM	Total
Arrow squid	14 750	6	14 756	19 808	4	19 812	16 540	1	16 541
Barracouta‡	6 716	151	6 967	6 672	19	6 691	6 012	14	6 026
Blue warehou	2 816	102	2 918	638	4 642	5280	550	0	1 550
Gemfish	2 816	9	2 825	1 963	1	1 964	4 527	1	4 528
Hoki	10 213	4	10 217	6 719	3	6 722	6 197	2	6 199
Ling	2 562	51	2 613	1 746	64	1 810	2 068	29	2 097
Oreos	3 158	0	3 158	1 203	1	1 204	5 159	0	5 159
Red cod	1 791	284	2 075	2 837	429	3 266	1 151	224	1 395
Silver warehou	1 408	0	1 408	2 713	0	2 713	3 298	32	3 330
Spiny dogfish	609	0	609	584	1	585	981	0	981
All species	48 616	2 251	50 867	46 423	2 230	48 653	49 866	1 750	51 616
(% of EEZ)	(24)	(2)	(16)	(23)	(2)	(16)	(20)	(2)	(15)
Total EEZ	204 841	111 995	316 836	204 127	107 861	311 988	250 079	105 463	355 542

* Excludes jig-caught squid and tunas.
† Includes New Zealand chartered, New Zealand factory, and foreign licensed trawlers.
‡ Most of the barracouta catch reported by DW trawlers from area E in 1983–84 (4 424 t) and 1984–85 (5 768 t) was probably caught in area F. This may also apply to some other species.

Table 2: Reported catch (t) by deepwater trawlers* fishing in areas F(E) and F(W) for the fishing years 1983–84 to 1985–86†

	1983–84		1984–85		1985–86	
	F(E)	F(W)	F(E)	F(W)	F(E)	F(W)
N.Z. chartered	13 352	18 130	20 136	13 185	25 557	9 174
Foreign licensed	3 604	13 472	5 947	6 742	7 364	7 719
N.Z. factory	52	5	186	227	16	36
Total	17 008	31 607	26 269	20 154	32 937	16 929
Total area F	48 615		46 423		49 866	

* These trawlers are not allowed to fish in the 12 n. mile territorial sea and, since 1 October 1985, in parts of the Solander corridor.
† Catch by inshore domestic vessels can not be broken down into these statistical areas.

The survey area, depth, number of strata, and station density varied between the four previous *Shinkai Maru* surveys, but all surveys included the Stewart-Snares shelf in area F, to a depth of at least 600 m, and all excluded the 12 n. mile territorial sea (Figure 2). None of the surveys included the Puysegur Bank, west of the Stewart-Snares shelf, and only two included the Solander corridor (March-April 1982, April 1983).

Results of these surveys, and analysis of commercial fishing patterns (for example, by Hurst (1988a and 1988b) on barracouta and gemfish) suggested there were large variations in the annual and seasonal abundance of barracouta and some of the other shelf species in EEZ area F.

June 1986 survey

This report presents results of a stratified random trawl survey, also using *Shinkai Maru*, in June 1986. This survey was restricted to area F, in waters of 50–600 m bottom depth, but it included Puysegur Bank, the Solander corridor, and the area inside the territorial sea limit, for the first time (Figure 3).

The aims of this survey were:

1. to determine the winter distribution and abundance of the major shelf and middle depth (50–600 m) species in the Stewart-Snares shelf and Puysegur Bank region;
2. to determine the biological characteristics (including size composition, age, gonad condition, diet, and parasites) of the main commercial species;
3. to collect hydrological (temperature) data;
4. to tag live school shark (*Galeorhinus galeus*) as part of a study on their movements;
5. to collect ichthyoplankton samples.

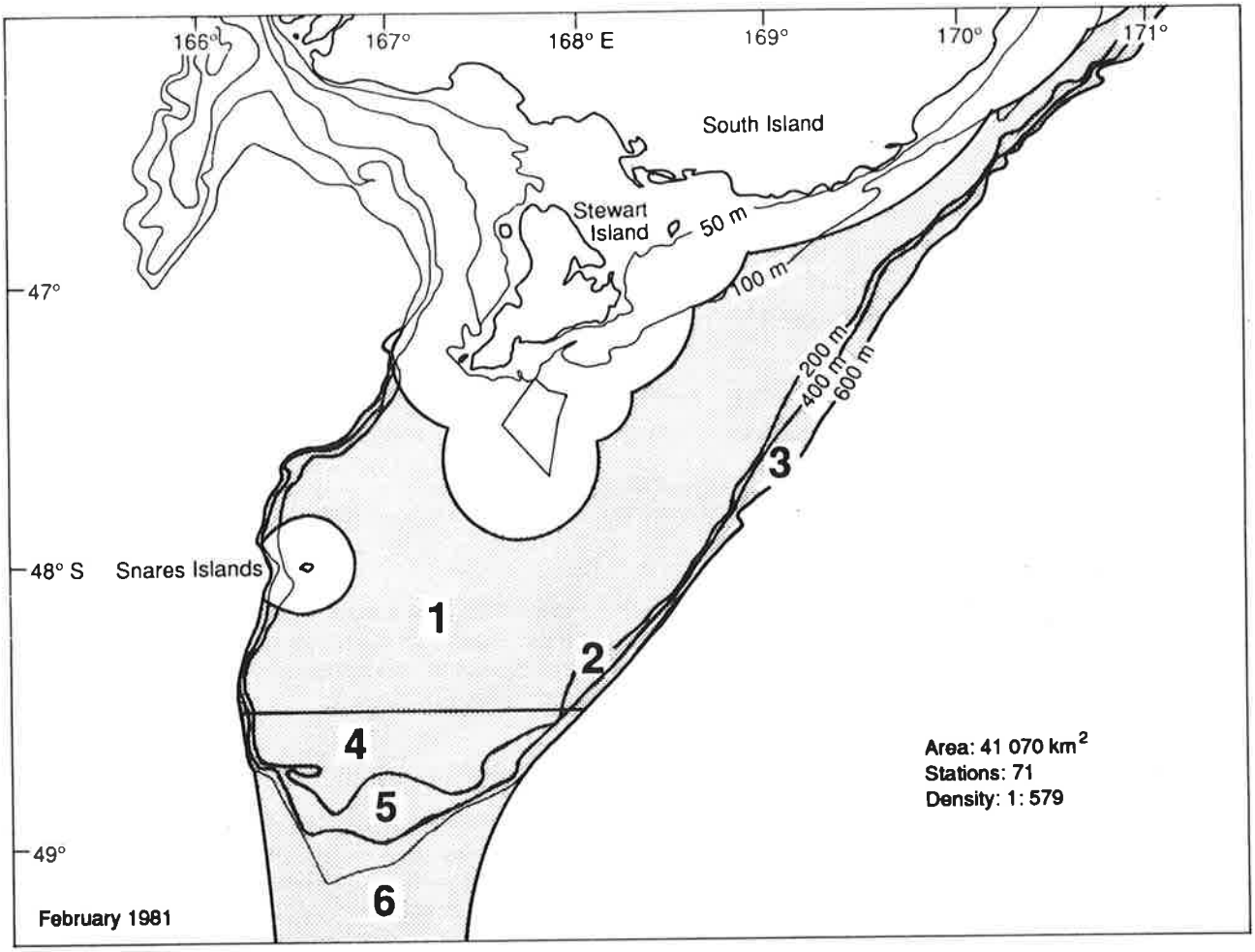

Figure 2: Survey area, strata, number of stations, and station density (number of stations per square kilometre) from the four previous *Shinkai Maru* surveys in area F.

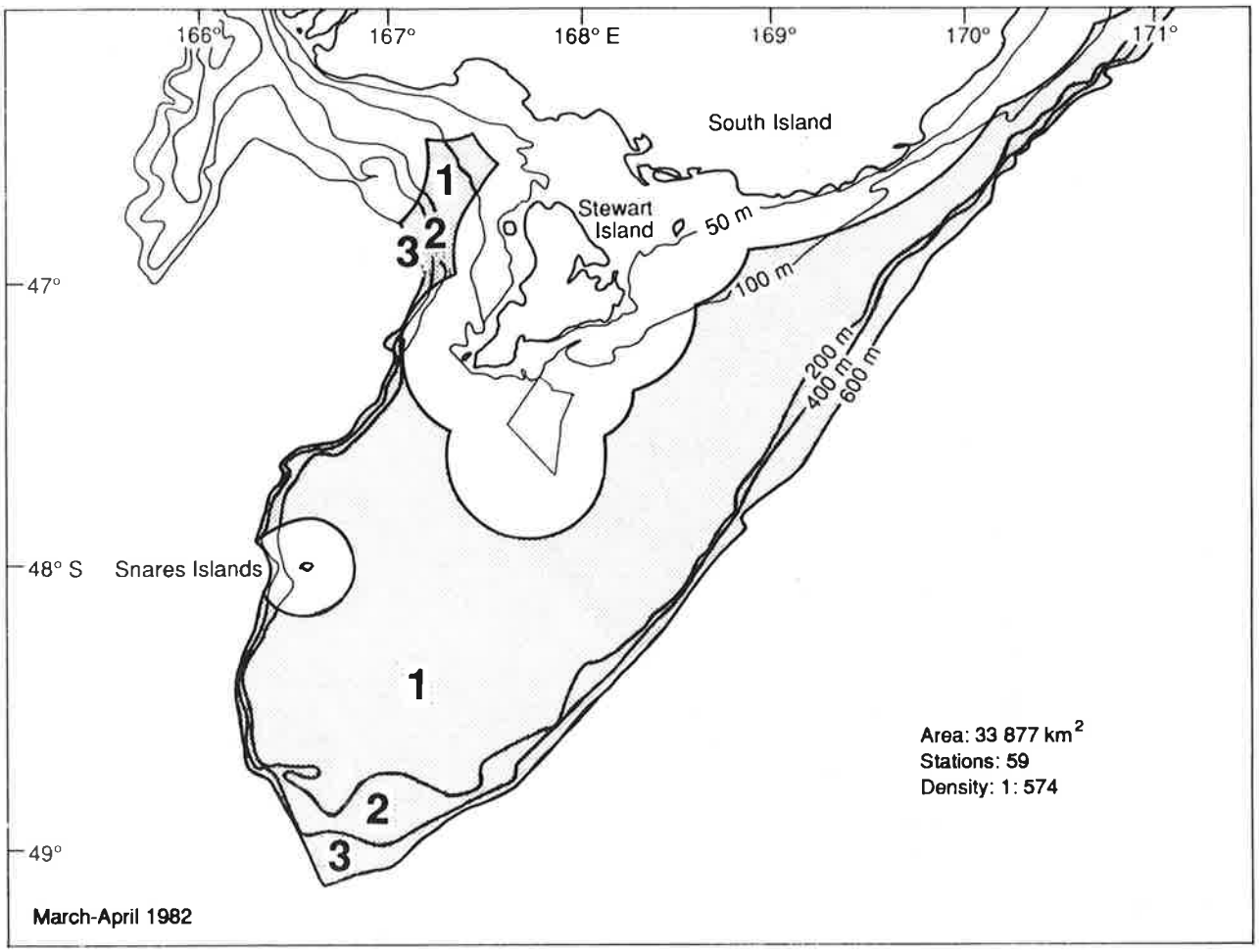

Figure 2—*continued.*

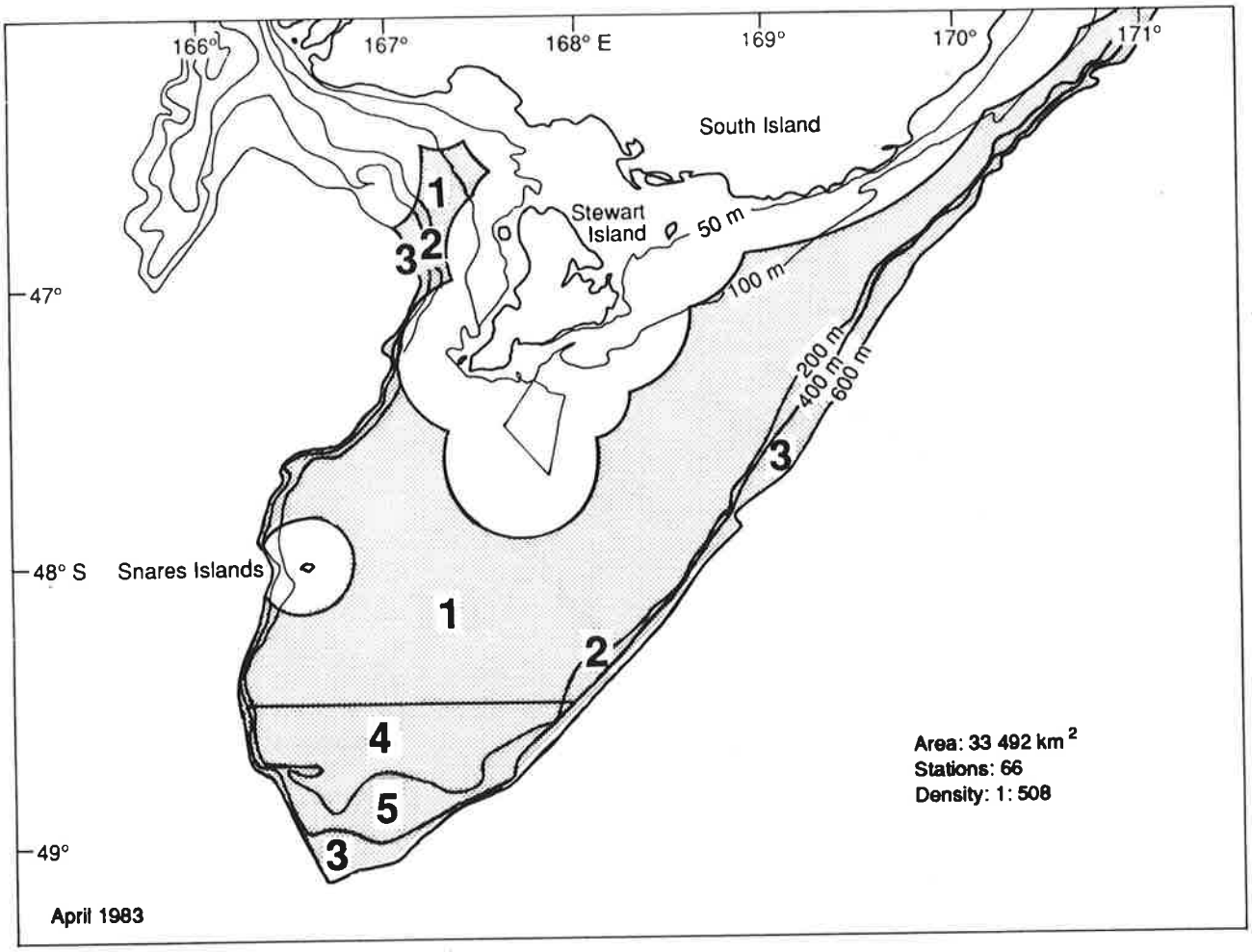

Figure 2—*continued*.

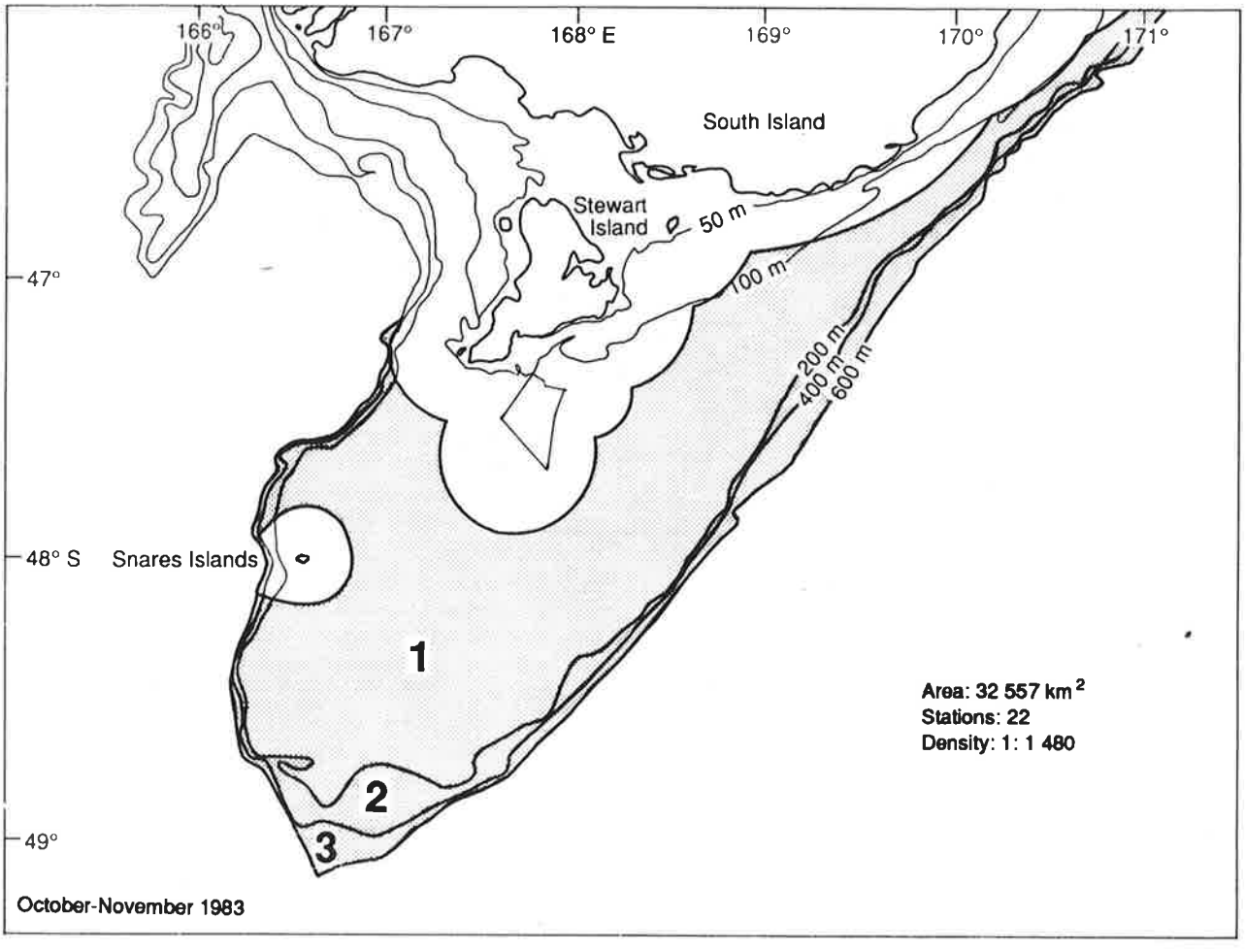

Figure 2—*continued.*

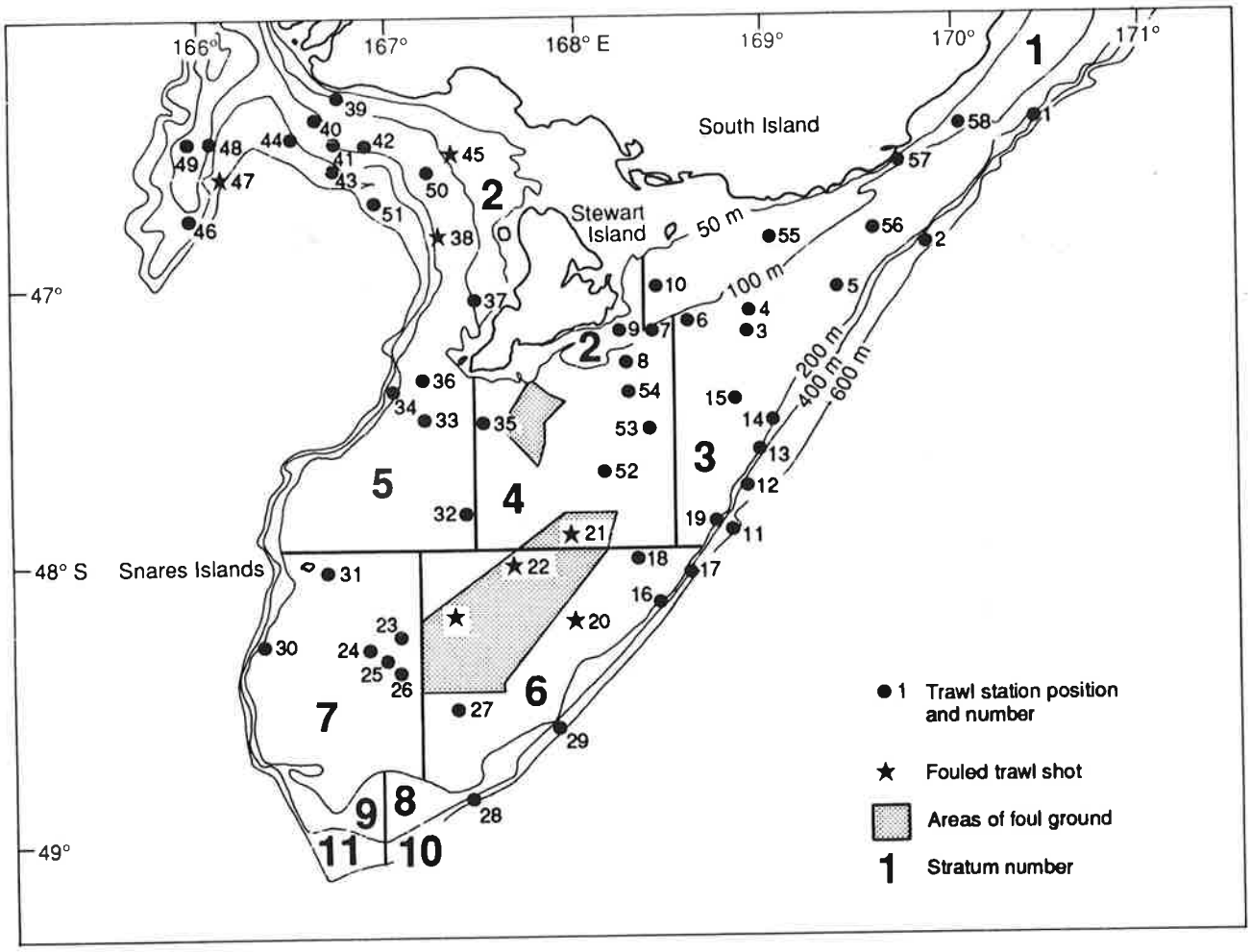

Figure 3: Survey area, strata, and trawl stations.

Methods

Survey area and design

The survey covered waters of 50–600 m, including those inside the 12 n. mile territorial sea limit, in EEZ area F. The survey area was originally calculated to be 52 866 km², but some of the stratum boundaries had to be redefined during the survey because the bathymetric data were incorrect. The resulting area surveyed was 49 524 km².

The survey was designed as a stratified random trawl survey in which all trawls were to be made during daylight (9.5–10 h per day). This limited the number of possible tows and precluded the use of a two-phase survey design (*after* Francis 1984). The survey area was divided into 11 strata, by depth and area (Figure 3, Table 3). This increased stratification compared with previous survey designs was intended to improve the precision of the biomass estimates, especially if time for a second phase became available at the end of the survey. Sixty stations were randomly generated by computer. They were at least 3 n. miles apart (i.e., the planned tow distance), and they were distributed with equal area weighting amongst strata. The planned overall station density was 1 : 881 km². Comparable data for the four previous *Shinkai Maru* surveys are shown in Figure 2.

Vessel

Shinkai Maru is a Japanese stern trawler on charter to the Japanese Marine Fishery Resource Research Center (JAMARC). It has the following specifications: length, 94.9 m; beam, 16.0 m; tonnage, 3393 GRT; horsepower, 5000 PS.

Net features

The trawl gear used on this survey was similar to that used on previous *Shinkai Maru* surveys in New Zealand waters, i.e., a six-panel high-opening bottom trawl with a nominally 80 mm knot to knot mesh codend. Two nets were used (Appendix 1) during the survey because the first net was lost in stratum 6 (at 48° 10.18′ S, 167° 27.11′ E, at a depth of 142 m). Gear parameters for the two nets are given in Table 4. Wingspread distance was calculated, when sea conditions allowed, by measuring the distance between the trawl warps at, and 4 m behind, the stern rollers (*after* Koyama 1974). The average of three measurements taken during the tow was used. When the wingspread distance was not calculated on the vessel, the average of the values for the stations in the same depth range was used. Data from the July 1986 survey of the Chatham Rise (Livingston *et al.* in press) were also used to calculate these averages.

Gear parameters for this survey are compared with those from previous *Shinkai Maru* random trawl surveys in Table 5. The basic net design, codend mesh size, and towing speed were similar for all surveys. The main differences were in headline height, wingspread and doorspread and the resulting ratios between them, and tow duration (from a standard time to a standard distance).

Trawling procedure

Station positions up to 25 n. miles offshore were determined by radar; those 25–50 n. miles offshore by radar or satellite navigator, as appropriate; and those more than 50 n. miles offshore by satellite navigator. If there was no trawlable ground found within a 2 n. mile radius of the original position, substitute stations were chosen from the next on the list for that stratum. If the depth was not correct for the stratum (as occurred on the eastern edge of the Stewart-Snares shelf), the vessel steamed perpendicularly to the depth contour until the correct depth was located.

A tow duration of 3 n. miles was aimed for, and the tow was timed from the gear reaching the bottom to the start of hauling. The actual tow length averaged 3.1 n. miles (range 2.2 to 4.0) and took 54 min (range 30 to 66), at an average speed of 3.5 kn (range 2.6 to 4.4).

Catch size estimation

The catch was sorted into species and weighed on platform scales to the nearest 0.1 kg. When the catch was large, the weight of the major species was back-calculated from product weight, and minor species were weighed. All school shark were individually weighed before being tagged.

Biomass estimation

Biomass and standard error of biomass were calculated (*after* Francis 1981) from:

$$B = \Sigma(X_i.a_i)cb_i$$
$$SB = \Sigma S_i^2.a_i^2/cb_i$$

where B is biomass (t), SB is standard error of B, X_i is mean catch rate (kg.km⁻¹) of stratum i, a_i is area of stratum i (km²), b_i is mean net mouth opening for stratum i, c is catchability coefficient (the proportion of fish in the water column which is caught), S_i is estimated standard error of X_i.

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

$$CL = B + 2SB$$

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

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

Table 3: Stratum area and number of stations

Stratum No.	Depth (m)	Planned Area (km²)	Planned No. of stations	Planned Station density (per km²)	Actual* Area (km²)	Actual* No. of stations†	Actual* Station density (per km²)
1	50–100	3 579	4	1 : 895	3 696	4	1 : 924
2	50–100	2 196	3	1 : 732	2 782	2	1 : 1 391
3	100–200	5 259	6	1 : 877	7 281	6	1 : 1 214
4	100–200	6 056	7	1 : 865	5 941	6	1 : 990
5	100–200	5 970	7	1 : 853	8 431	7	1 : 1 204
6	100–200	4 633	5	1 : 927	5 547	2	1 : 2 274
7	100–200	5 016	6	1 : 836	5 539	6	1 : 923
8	200–400	3 085	4	1 : 771	1 722	4	1 : 431
9	200–400	6 226	7	1 : 889	3 544	5	1 : 709
10	400–600	6 257	7	1 : 894	2 305	7	1 : 329
11	400–600	4 589	5	1 : 918	2 736	3	1 : 912
Total		52 866	60	1 : 881	49 524	52	1 : 952

* Excluding areas of foul ground in strata 4 and 6 resulted in areas and station densities of 5 468 km² (1 : 781) and 3 570 km² (1 : 1 785), respectively, and 47 074 km² (1 : 905) overall.

† Does not include six stations (in strata 2, 4, 6, 9, and 11) which were omitted from the biomass calculations because the trawl came fast or was flown over foul ground for at least 15 min.

Table 4: Combined gear parameters of the two nets used during this survey and that by *Shinkai Maru* in July 1986 on the Chatham Rise*

	Net 1			Net 2		
Station No. (Jun)	001–018			019–058		
(Jul)	065–074			001–064, 075–107		
Bridle length (m)	85			85		
Sweep length (m)	150			150		
Wingspread (m)						
Depth (m)	*n*	Mean	Range	*n*	Mean	Range
50–100	1	19.7		0	21.8†	
100–200	4	24.9	23.4–26.3	15	27.5	24.9–30.2
200–400	2	37.7	34.0–41.3	13	34.4	31.0–40.7
400–600	10	34.1	27.8–38.8	28	33.4	29.2–39.5
Doorspread to wingspread (mean ratio)	4.132			4.566		
Headline height (m)						
Depth (m)	*n*	Mean	Range	*n*	Mean	Range
50–100	3	9.3	9.0–9.5	5	7.3	6.5–7.5
100–200	11	8.0	6.5–10.0	32	7.1	5.6–9.0
200–400	4	8.0	6.5–11.0	29	6.3	5.0–8.0
400–600	15	7.1	5.5–10.5	50	6.2	5.0–8.0

* M. E. Livingston pers. comm.

† Estimated from the ratio of the mean width of net 1 in 100–200 : 50–100 m (1 : 1.26).

The following assumptions were made:

1. The effective sea bed area swept was the distance between the wingtips of the net multiplied by the distance towed. All previous *Shinkai Maru* survey results used this procedure to calculate biomass, and it was used here for comparability. This procedure may over- or underestimate biomass, depending on the herding effectiveness of the doors and sweeps. The ratio between doorspread and wingspread is given in Tables 4 and 5 to enable alternative assumptions to be used.
2. The catchability coefficient for wingspread estimates was assumed to be one. This is a conservative approach which assumed that:
   (1) the vulnerability of all fish in the area swept by the wings was 100% (i.e., escapement was zero — although a 60 mm mesh codend was used, some small fish would probably still have passed through the net; however, this escapement is difficult to estimate without extensive mesh selection trials);
   (2) vertical availability was 100% (i.e., there were no fish above the headline);
   (3) areal availability was 100% (i.e., there were no fish in areas of foul ground which were not able to be sampled by the trawl). Two approaches have been used to deal with the problem of if and how to include areas of foul ground:
      (a) the total survey area was used, by assuming equal catch rates over the unsurveyed foul ground. This makes the 1986 survey more comparable with previous *Shinkai Maru* surveys which all used this approach.
      (b) areas of foul ground in strata 4 and 6 which could not be sampled were excluded from the survey area (*see* Figure 3). Catches near foul ground often have different species compositions, which suggests that the first approach could give an over- or underestimate.

Biological observations

Details of the species and total numbers of individuals measured are given in Table 6. For the commercially important fish and arrow squid, up to 200 individuals per species were randomly selected from each tow and measured to the nearest centimetre below actual length (arrow squid, mantle length; barracouta, silver warehou, blue warehou (*Seriolella brama*), gemfish, tarakihi (*Nemadactylus macropterus*), jack mackerel (*Trachurus declivis* and *T. murphyii*), Ray's bream (*Brama brama*), fork length (FL); all others, total length (TL)). All species measured were sexed, except tarakihi, stargazers (*Kathetostoma* spp.), red cod, and most blue cod (*Parapercis colias*).

General observations were made on the spawning condition of most species. For teleosts the gonad stages

Table 5: Gear and tow parameters (mean values) for the June and July 1986 surveys combined, compared with previous *Shinkai Maru* surveys* in EEZ areas E and F

Survey	Headline height (m)	Codend mesh (mm)	Wingspread (m)	Doorspread to wingspread ratio	Towing speed (kn)	Target tow duration	Area swept (km^2)
Feb 1981	6.2	60–80	31	4.3	3.4	30 min	0.096
Mar-Apr 1982	9.3	60	28.6	4.2	3.5	30 min	0.093
Apr 1983							
Net A	8.8	60	27.3	4.4	3.4	30 min	0.086
Net B	8.3	60	27.6	5.1	3.5	30 min	0.089
Oct-Nov 1983	7.3	60	34.1	3.57	3.2	30 min	0.100
Jun and Jul 1986							
Net 1	7.1	60	28.4	4.13	3.5	3 n. miles (about 52 min)	0.163
Net 2	6.2	60	29.1	4.57	3.5	3 n. miles (about 52 min)	0.167

* Feb 1981, Kawahara and Tokusa (1981); Mar-Apr 1982, van den Broek *et al.* (1984); Apr 1983, Uozumi *et al.* (1987); Oct-Nov 1983, Hatanaka *et al.* (1989).

Table 6: Species and numbers of fish measured

	Length frequency		Detailed biology	
Species	No. of samples	No. of fish	No. of samples*	No. of fish
Arrow squid	51	3 788	4	68
Barracouta	41	6 694	24	465
Blue cod	14	683	1	86
Bluenose	6	12	2	6
Blue warehou	19	276	5	60
Gemfish	33	860	7	239
Hake	6	57	4	26
Hapuku	35	289	0	0
Hoki	12	1 187	9	454
Jack mackerel	29	296	0	0
Ling	28	1 363	0	0
Ray's bream	7	29	0	0
Red cod	15	603	0	0
Spiny dogfish	28	140	7	19
School shark	43	510	44	495
Silver warehou	35	1 595	5	101
Stargazers	43	1 080	0	0
Tarakihi	19	765	0	0

* Includes samples taken on stations not used for biomass estimation.

used were: 1, immature; 2, resting; 3, maturing (oocytes visible in females); 4, mature (hyaline oocytes in females, milt expressible in males); 5, running ripe (eggs and milt free flowing); 6, spent. For tagged school sharks, only the male maturity stages could be recorded from external features: 1, immature (clasper length less than or equal to pelvic fin length); 2, maturing (clasper soft and greater than pelvic fin length); 3, mature (clasper rigid and greater than pelvic fin length). More detailed data (including individual weight, gonad stage and weight, stomach contents and state of digestion, otoliths, and flesh parasites) were collected for five species: barracouta, blue and silver warehou, arrow squid, and school shark.

Hydrological observations

Water temperature data were collected daily by expendable bathythermograph (XBT) at approximately equidistant stations (Figure 4). Surface temperatures were also recorded for each station from a temperature sensor, mounted on the hull at a depth of about 7 m, and bottom temperatures were recorded from the net monitor. The XBT data were used to calibrate recordings from the other equipment.

Ichthyoplankton samples

A plankton net (60 cm in diameter, with 0.5 mm mesh) was attached to the trawl just before the codend. Samples were collected at 13 stations and were preserved in 5% formalin for later analysis. Results of these analyses are not presented here.

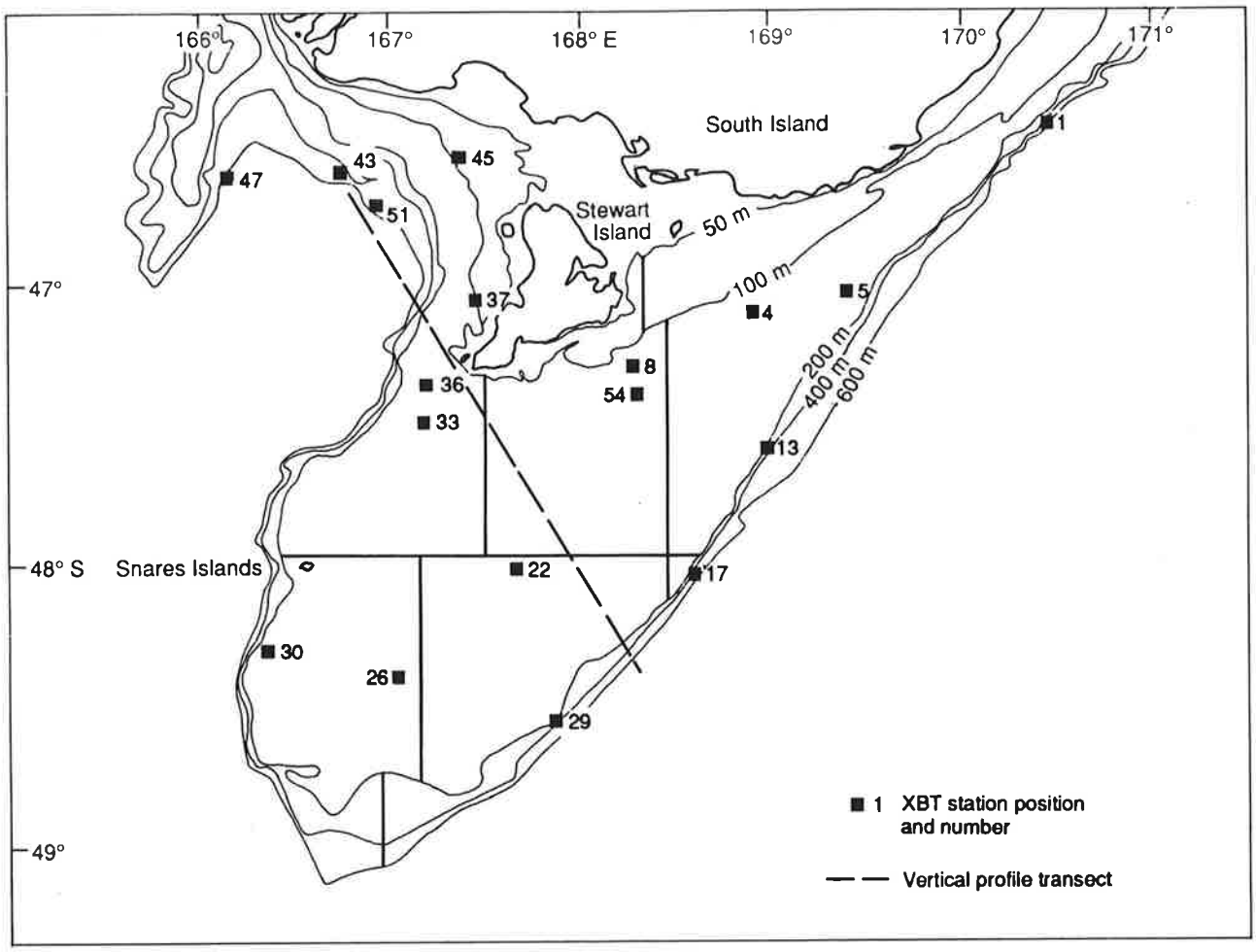

Figure 4: Expendable bathythermograph stations. (Temperatures along the vertical profile transect are shown in Figure 24.)

Results

Survey area

The redefined survey area was 49 524 km², of which 5% (2450 km²), in strata 4 and 6, was foul ground (*see* Table 3, Figure 3). Significant changes were made to stratum boundaries and areas in strata 3, 5, 8, 9, 10, and 11 because of incorrect bathymetry. Fifty-eight stations were completed, of which six have been excluded from the biomass estimation because the gear either came fast or was flown over foul ground for more than 15 min, which resulted in the possibility of over- or underestimation of catch rate. This reduced the number of stations in strata 2, 4, 6, 9, and 11. The resulting overall station density was lower than planned (1 : 952 km² for the total area or 1 : 905 km² when the areas of foul ground were omitted) and the individual station densities per stratum, though originally planned to be about equal (1 : 732 to 1 : 927 km²), ranged from 1 : 329 to 1 : 2274 km². Individual station data are given in Appendix 2.

Catch composition

Eighty-two species were recorded: 58 teleosts, 18 elasmobranchs, 4 cephalopods, 1 agnathan, and 1 crustacean (Appendix 3). The catch and estimated biomass of the 20 major species are given for successful biomass stations only in Table 7. Individual station catch data for the 10 major species are given in Appendix 2.

Of the 114 t caught on the 52 successful biomass stations, barracouta constituted 35.8%, spiny dogfish 15.0%, and hoki 8.4%. All of the top 20 species caught have some current commercial value, except rattails (including javelinfish); though spiny dogfish, school shark, smooth skate, ghost shark, and frostfish are not always processed.

Species distribution

The mean catch rate at successful biomass stations was 13.1 t.km⁻² (range 5.2–46.7), about 0.7 t per n. mile towed. The largest catch was 7.1 t, mainly barracouta. Catch rates of the 10 major species varied with area and depth (Figures 5–14, Table 8). (Means and standard deviations of the catch rates for these species, by stratum, are given in Appendix 4.)

Barracouta were dominant during this survey and occurred in all catches on the Stewart-Snares shelf, but were not taken in 400–600 m. Catch rates were greatest on the western side of Stewart Island (maximum 37.4 t.km⁻²) and around the Snares Islands, in 100–200 m (Figure 5).

Spiny dogfish also occurred at all stations on the shelf, and few were taken in 400–600 m. Catch rates were generally low, except for two catches over 11.0 t.km⁻² off the southeast coast of the South Island, in less than 100 m (Figure 6).

The highest catches of hoki, arrow squid, silver warehou, and ling (Figures 7–10) were all off the shelf edge, in 200–600 m. Only arrow squid were caught at all successful biomass stations. The largest catches of hoki and arrow squid (up to 18.0 and 11.6 t.km⁻²

Table 7: Catch and estimated biomass for the 20 major species

	Catch			Biomass*				
				Estimate 1		Estimate 2		
Species	Catch (kg)	% of total	Mean catch rate (kg.km⁻²)	Biomass (t)	c.v.† (%)	Biomass (t)	c.v. (%)	% of total
Barracouta	0 702	35.8	4 986	292 217	18	283 632	19	44.0
Spiny dogfish	17 028	15.0	2 175	124 973	10	118 268	10	18.0
Hoki	9 520	8.4	897	29 027	50	29 022	50	4.5
Arrow squid	7 985	7.0	762	29 062	30	28 381	31	4.4
Silver warehou	6 133	5.4	566	13 715	31	13 713	31	2.1
School shark	4 512	4.0	393	30 406	17	29 427	17	4.5
Ling	3 956	3.5	534	11 645	21	11 578	22	1.8
Stargazers	3 898	3.4	489	28 098	40	27 824	41	4.3
Red cod	3 476	3.1	477	22 616	65	22 599	65	3.5
Gemfish	2 735	2.4	278	11 455	26	11 415	26	1.8
Rattails	2 183	1.9	207	6 301	17	6 290	17	1.0
Javelinfish	1 801	1.6	166	5 478	43	5 468	43	0.8
Blue warehou	1 176	1.0	143	8 506	58	8 441	58	1.3
Tarakihi	1 059	0.9	156	9 213	45	9 191	45	1.4
Hapuku	927	0.8	115	7 060	19	6 629	18	1.0
Smooth skate	794	0.7	98	5 842	15	5 314	14	0.8
Rig	705	0.6	91	5 646	31	5 183	29	0.8
Dark ghost shark	592	0.5	56	2 339	43	2 339	43	0.3
Blue cod	591	0.5	81	4 812	49	4 722	50	0.7
Sea perch	427	0.4	52	2 145	63	2 088	64	0.3
All species	113 649		13 126	669 384	10	650 184	10	

* Estimate 1, total survey area; estimate 2, survey area minus areas of foul ground in strata 4 and 6.
† Coefficient of variation.

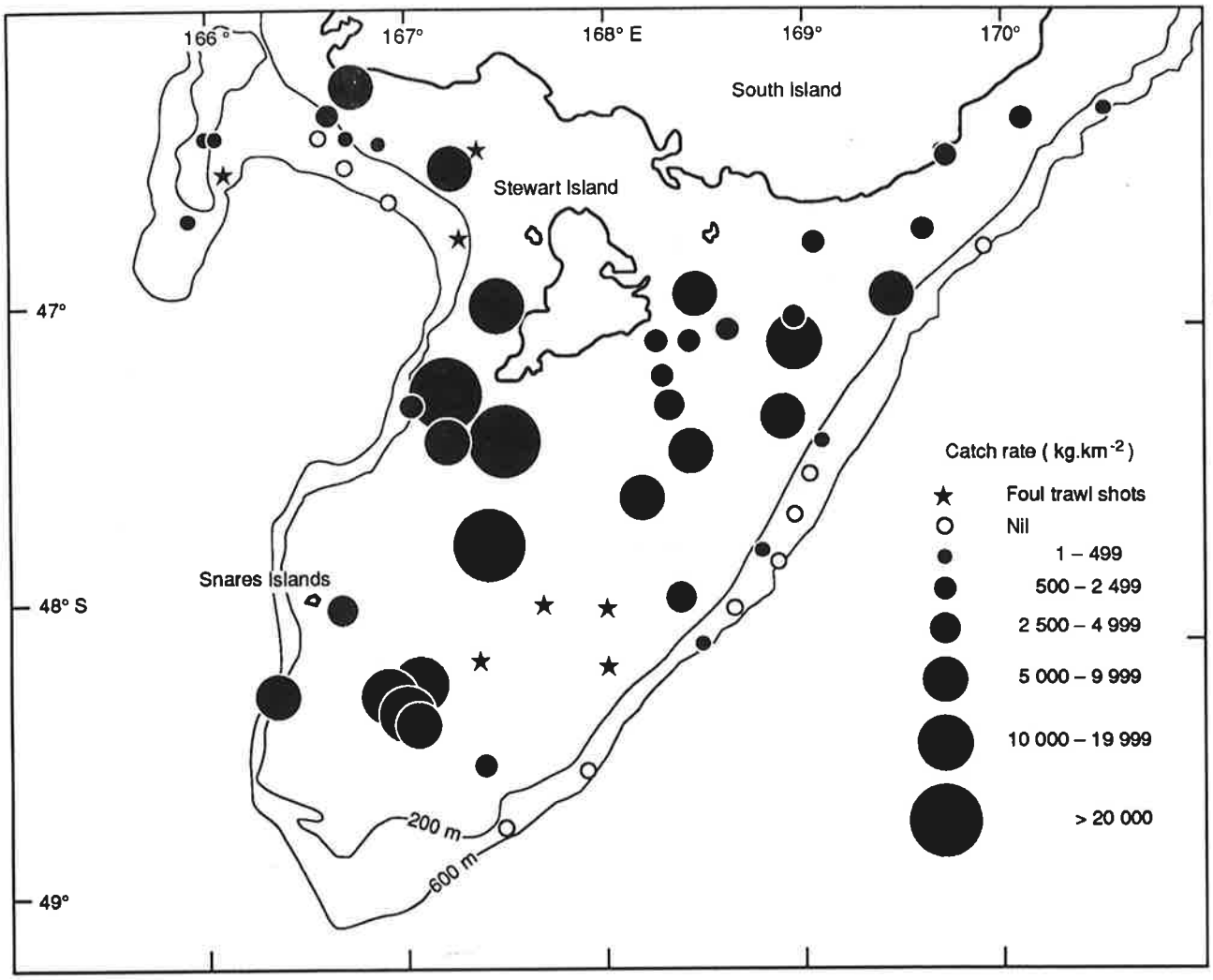

Figure 5: Distribution and catch rates of barracouta.

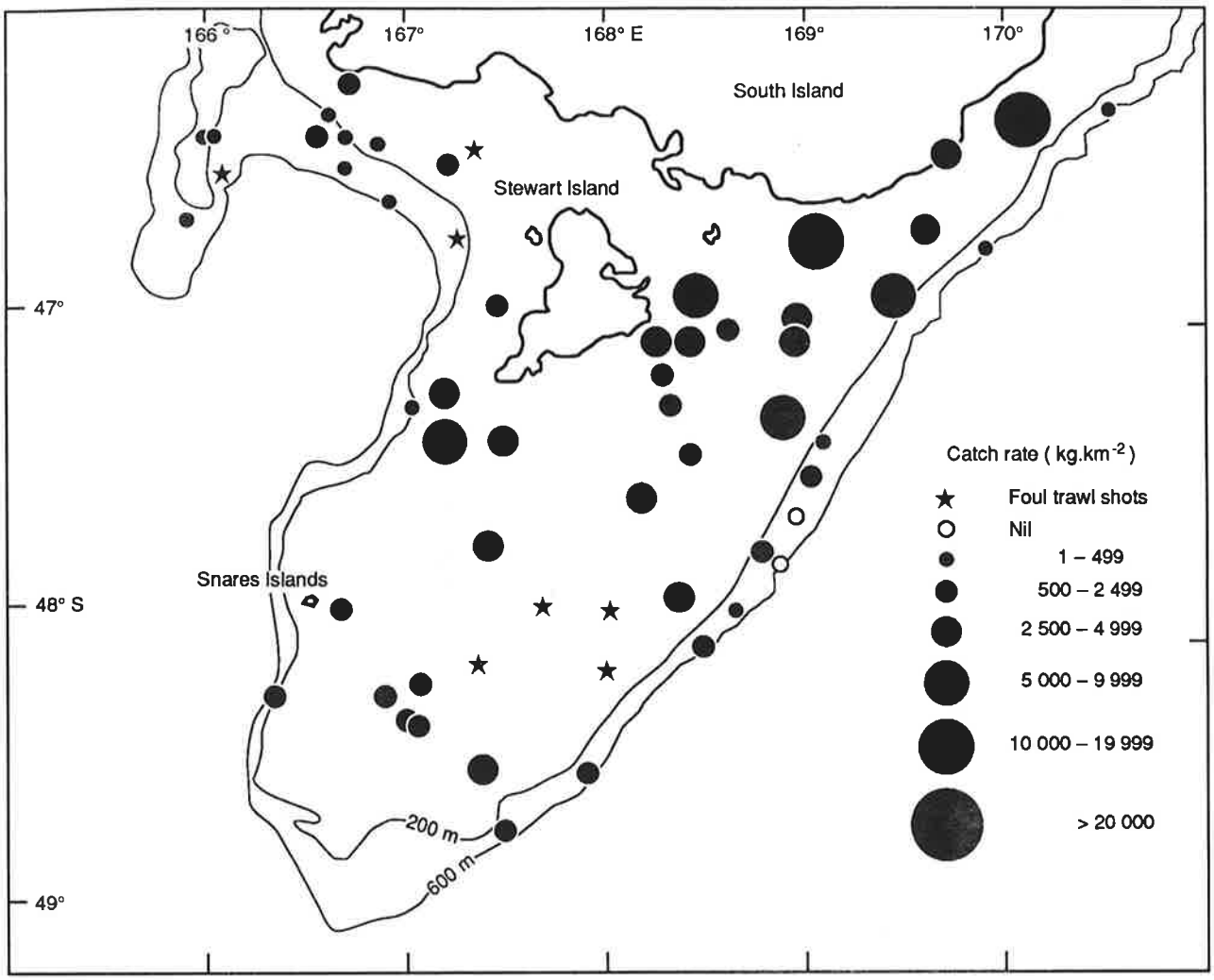

Figure 6: Distribution and catch rates of spiny dogfish.

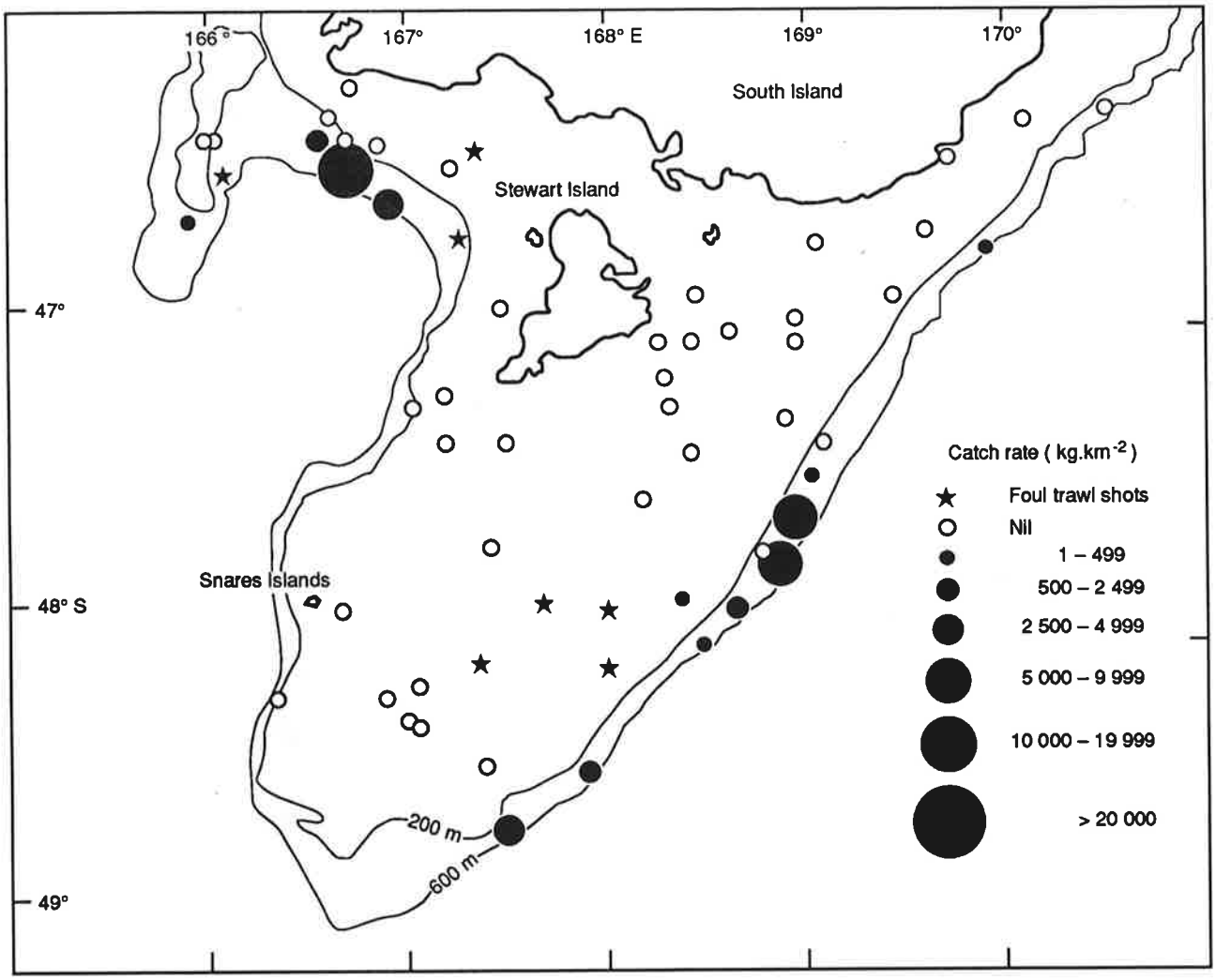

Figure 7: Distribution and catch rates of hoki.

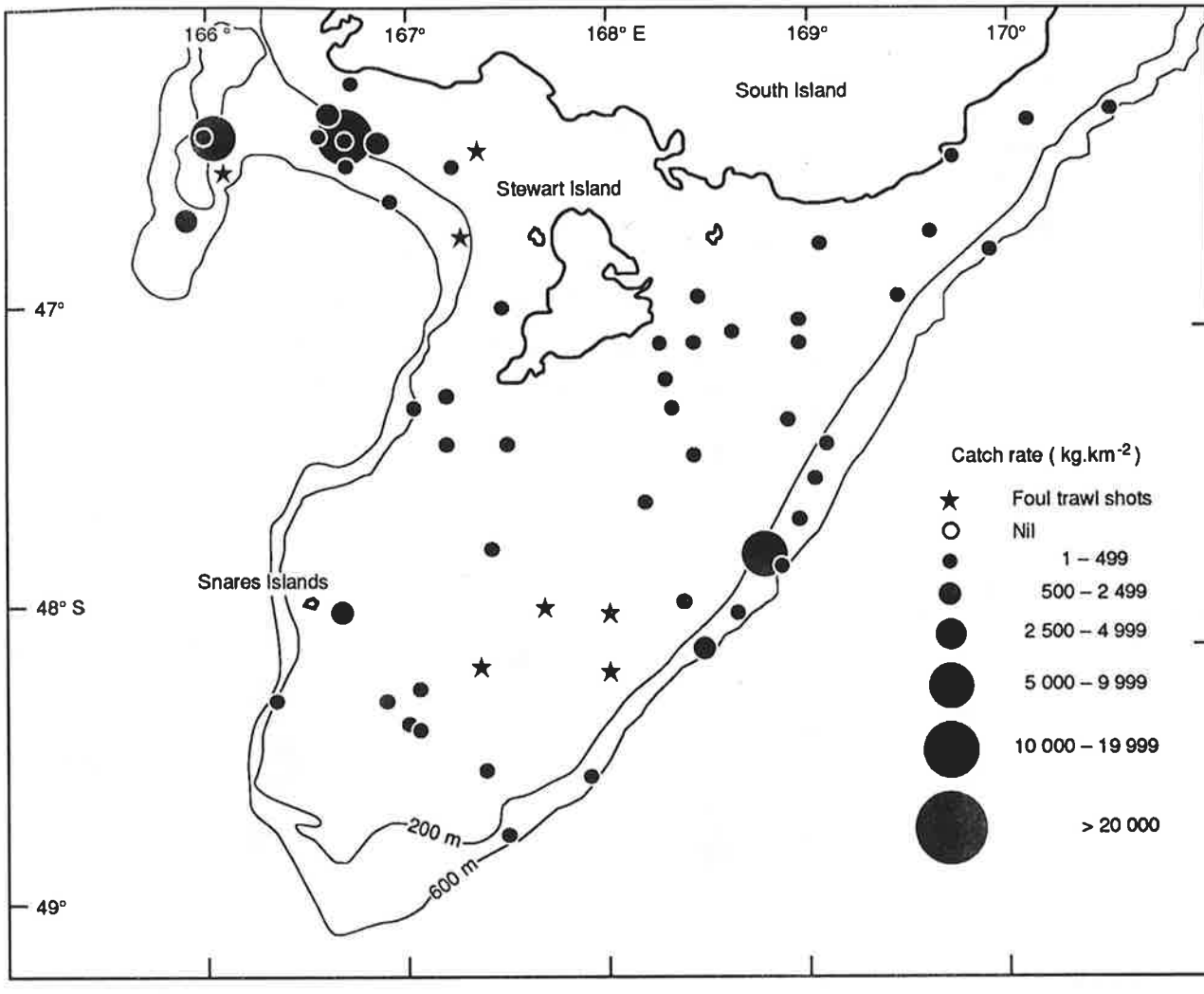

Figure 8: Distribution and catch rates of arrow squid.

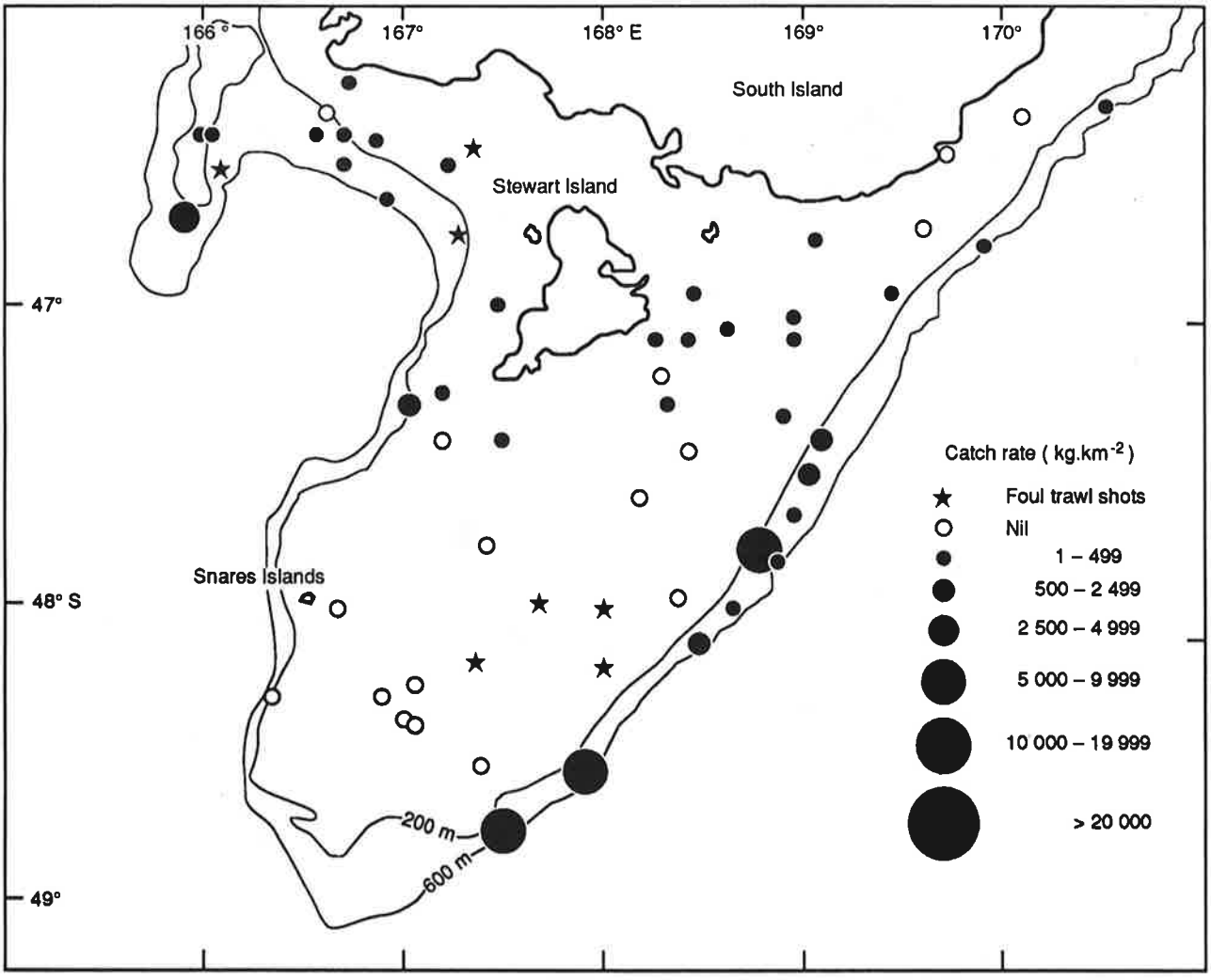

Figure 9: Distribution and catch rates of silver warehou.

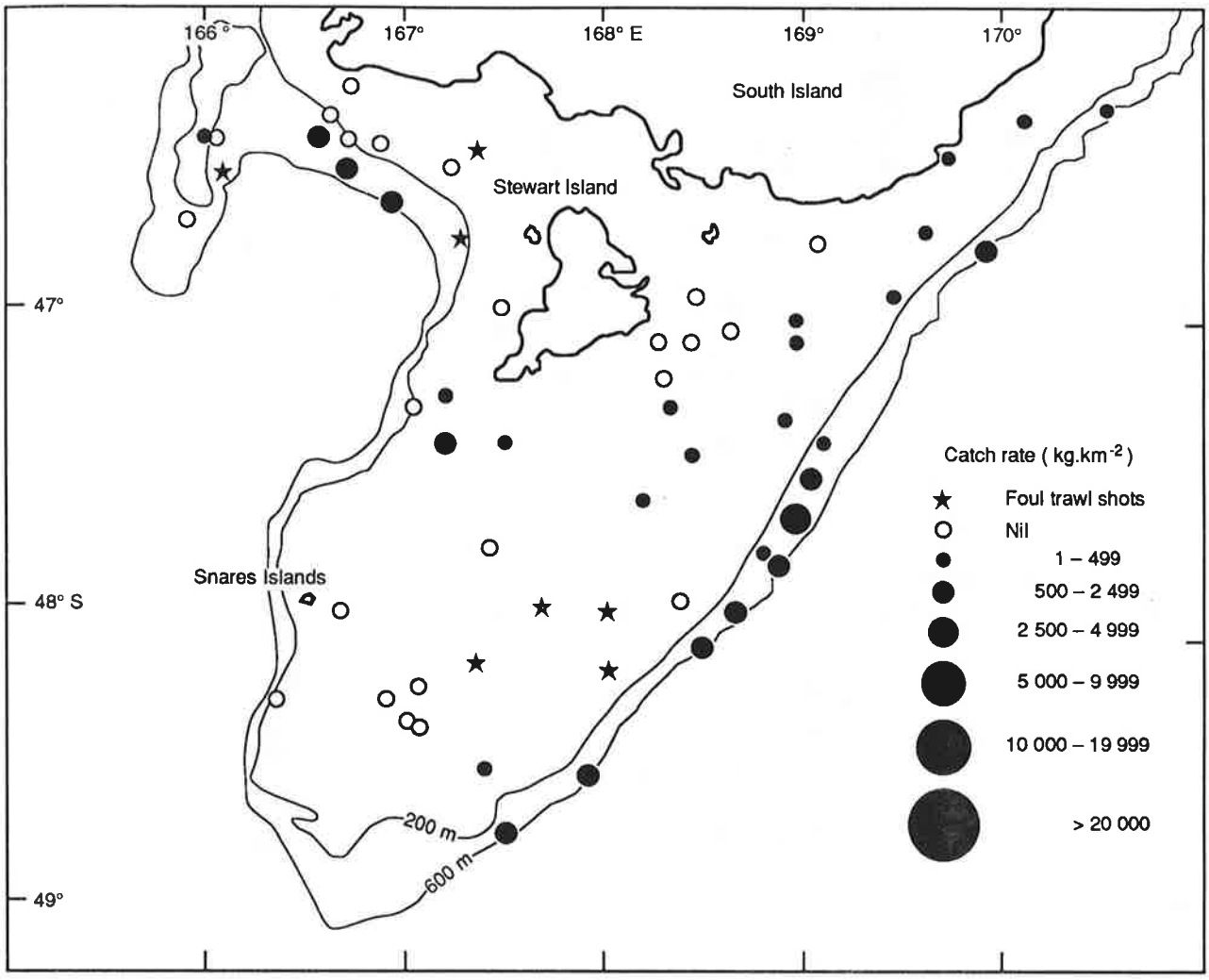

Figure 10: Distribution and catch rates of ling.

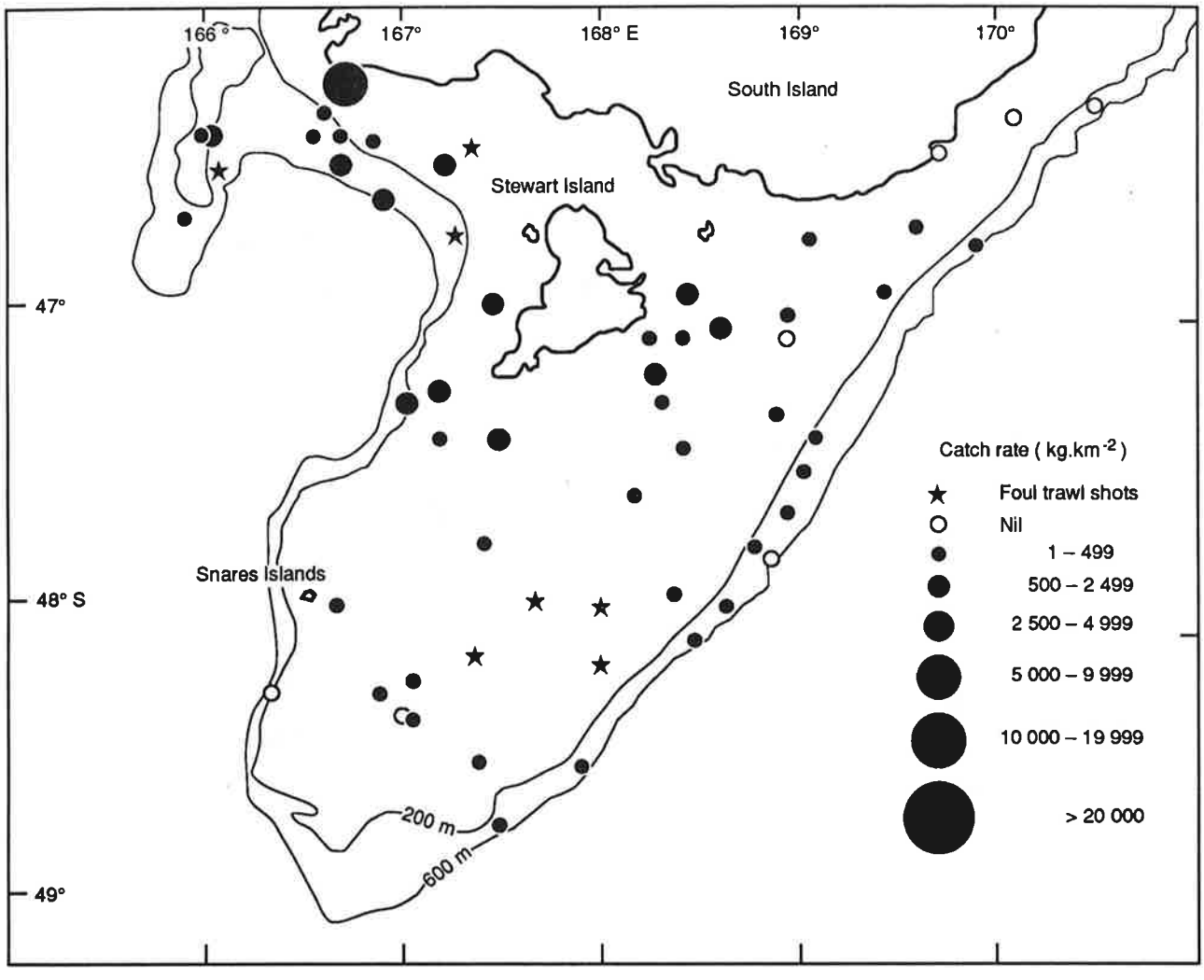

Figure 11: Distribution and catch rates of stargazers.

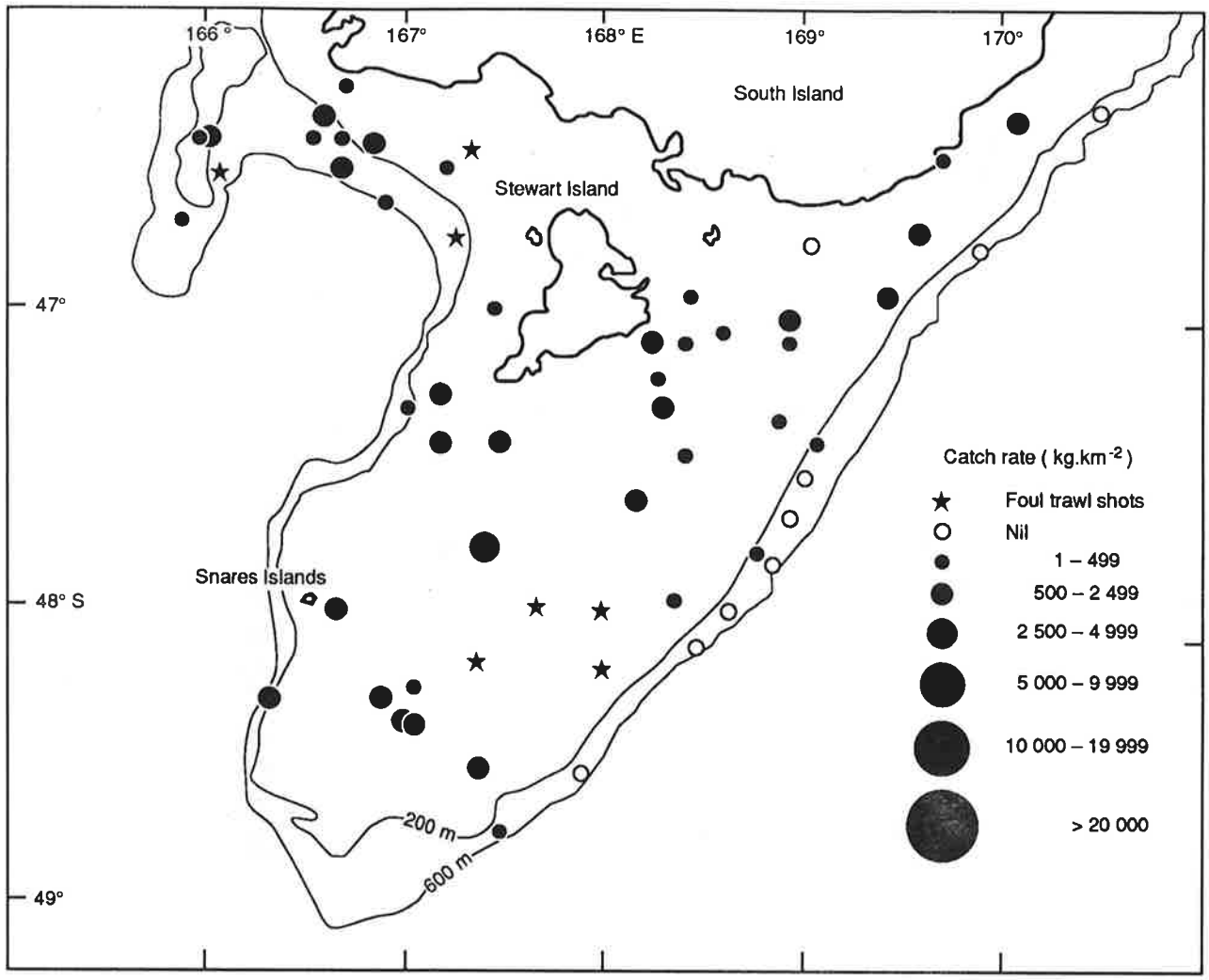

Figure 12: Distribution and catch rates of school shark.

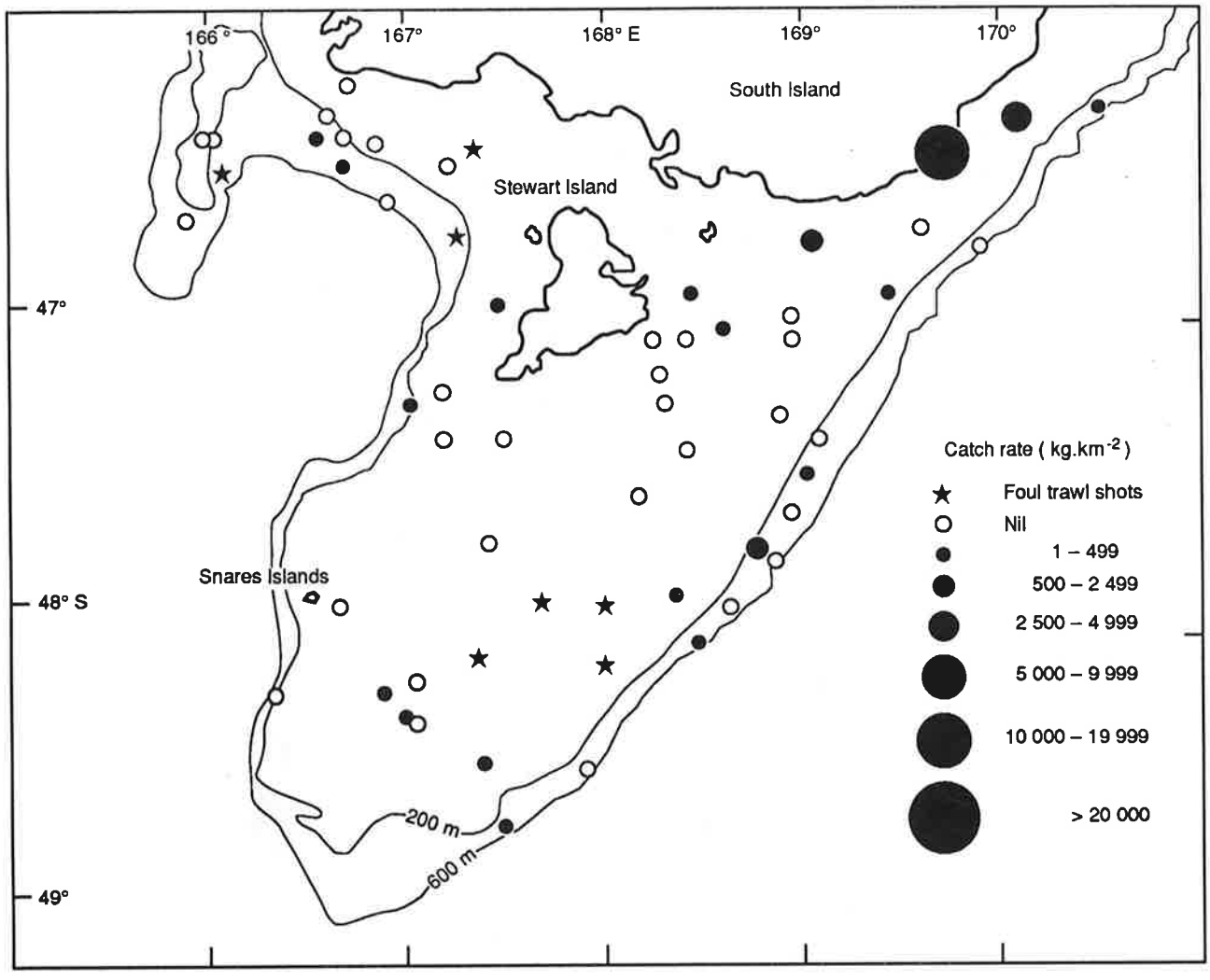

Figure 13: Distribution and catch rates of red cod.

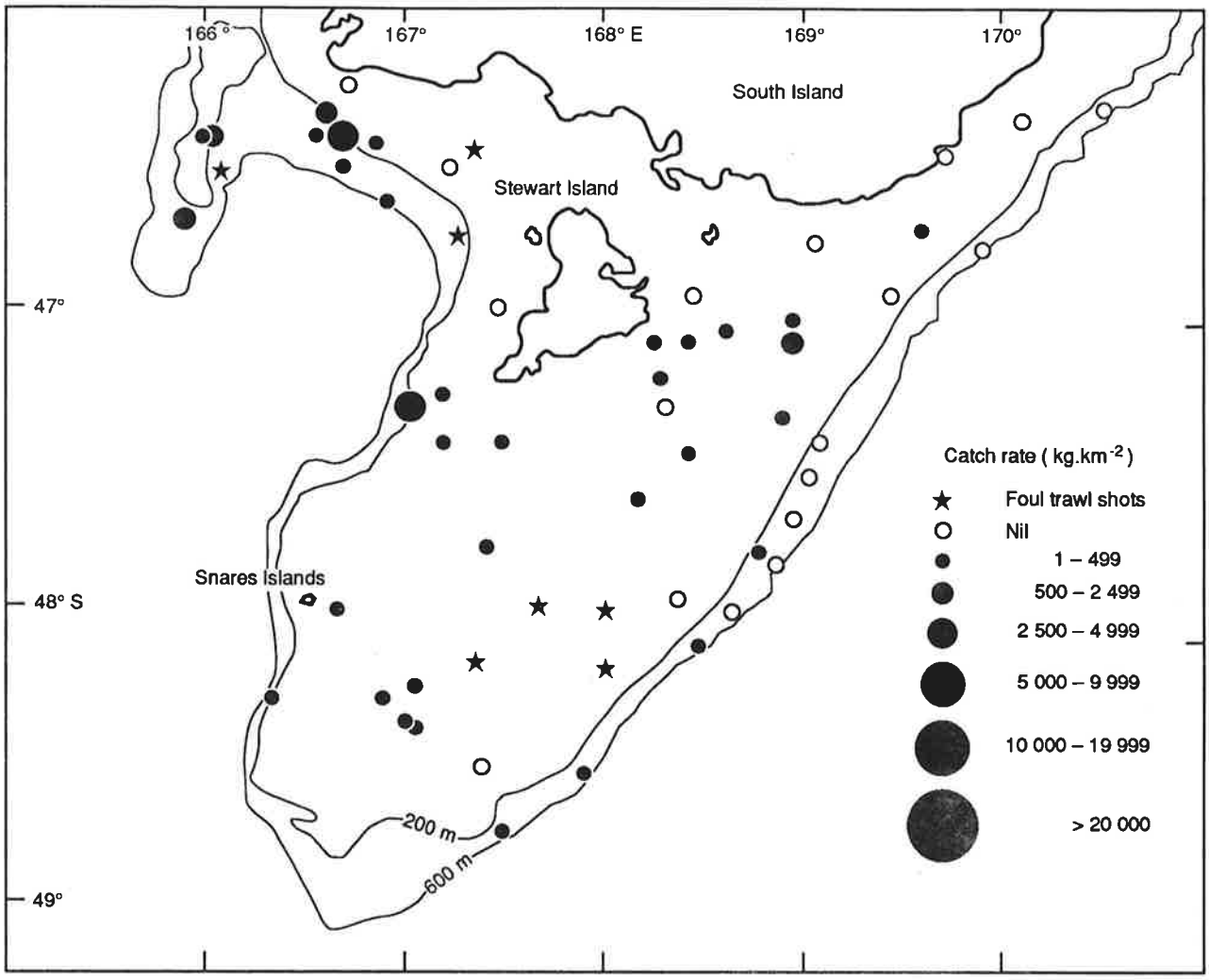

Figure 14: Distribution and catch rates of gemfish.

Table 8: Mean catch rates (kg.km^{-2}) by depth for the 10 major species

	Depth (m)			
Species	50–100 (n = 6)	100–200 (n = 27)	200–400 (n = 9)	400–600 (n = 10)
Barracouta	2 817	8 890	260	0
Spiny dogfish	6 697	2 375	410	510
Hoki	0	0	56	4 610
Arrow squid	93	202	3 585	135
Silver warehou	71	39	1 463	1 480
School shark	304	772	448	108
Ling	43	105	200	1 553
Stargazers	1 630	356	357	290
Red cod	3 872	21	102	9
Gemfish	12	103	1 179	94

respectively) were from the Solander Island to Puysegur Bank area, and there were secondary catches on the eastern edge of the shelf. The largest catches of silver warehou and ling (up to 6.0 and 3.0 t.km^{-2} respectively) were also in this eastern area.

Stargazers (Figure 11) were caught at most stations, but there may have been a different species present at some of the deeper stations, particularly in the western part of the survey area. The status of this species is being reviewed by the National Museum, Wellington. The largest catches of stargazers (up to 8.0 t.km^{-2} in less than 100 m) were taken in the Stewart-Solander Islands area.

School shark were caught at all stations in 100–400 m and occasionally at stations outside this range. Catches were generally small (up to 4.0 t.km^{-2}), but were slightly greater on the western side of the shelf and in the Solander Island to Puysegur Bank area (Figure 12).

Red cod were caught at few stations, and catches were usually small (Figure 13). The maximum catch (17.4 t.km^{-2}) was off the southeast coast of the South Island, in water less than 100 m. Gemfish were more widely distributed than red cod, but catches were also usually small (Figure 14). The maximum catch (4.2 t.km^{-2}) was southwest of Stewart Island in 200–400 m.

The largest catch rates by depth range were spiny dogfish and red cod in less than 100 m; barracouta and spiny dogfish in 100–200 m; arrow squid, silver warehou, and gemfish in 200–400 m; and hoki, ling, and silver warehou in 400–600 m (Table 8).

Wingspread biomass estimates

Biomass estimates were calculated for the 20 major species for the whole survey area and for the survey area minus areas of foul ground (*see* Table 7). Estimated biomass by depth and stratum for the 10 major species, and percent of the total biomass estimate for each species, are given in Table 9. (Doorspread biomass estimates for the 20 major species are given in Appendix 5.)

The ranking of species by estimated biomass was similar to that by catch weight, except that some of the shelf species (school shark, stargazers, red cod, blue warehou, tarakihi, hapuku, and blue cod) increased in relative importance. The most abundant species were barracouta, spiny dogfish, and school shark, and they constituted 44.0, 18.0, and 4.5% respectively of the total estimated biomass. Hoki dropped from being the third most important species in terms of catch rate to being the fourth in terms of estimated biomass (4.5% of total estimated biomass).

The precision (coefficient of variation) of the biomass estimates for the 20 major species ranged from 10 to 65%. Seventeen species had coefficients less than or equal to 50%, and six of these (barracouta, spiny dogfish, school shark, rattails, hapuku, and smooth skate) were less than 20%.

Four of the 10 major species had more than 50% of their biomass in a single stratum: arrow squid and gemfish in stratum 9, hoki in stratum 11, and red cod in stratum 1. Spiny dogfish had the most dispersed biomass, with a maximum of 28% in any stratum.

When the strata were combined by depth, species which had the highest percentage biomass in each depth range were: stargazers (46%) and red cod (95%) in 50–100 m; barracouta (94%), spiny dogfish (63%), and school shark (81%) in 100–200 m; arrow squid (72%), silver warehou (51%), and gemfish (65%) in 200–400 m; and hoki (99%) and ling (63%) in 400–600 m.

Biology

Length frequency histograms of the major commercial species measured are shown in Figures 15–22. For the more abundant species which occurred in various depth ranges, a breakdown of length frequency by depth is given; for the other species, the total length frequency only is given. Individual station data were scaled by percentage sampled and area towed and then weighted by stratum area. The resulting length frequencies represent the population structure for the survey area, as sampled by bottom trawl, and the estimated total numbers of fish are given (numbers actually measured are given in Table 6). Other biological data were not scaled.

Barracouta

Barracouta lengths ranged from 16 to 108 cm FL, with four clear modal peaks at about 23, 36–37, 61, and 72 cm and possibly one at 47 cm (Figure 15). In 50–100 m, most fish were less than 45 cm, and the smallest modal group of 17–29 cm fish was dominant. In 100–200 m, all five modal groups were apparent, but the larger fish predominated. Few fish were caught deeper than 200 m, and they were mostly over 60 cm.

The maximum length of males was smaller than that of females, and, of the fish that were sexed (40 cm and over), there were slightly fewer males overall (0.95 : 1). This ratio varied by depth and ranged from 0.42 : 1 in 50–100 m to 0.97 : 1 in 100–200 m. The modal peaks of males and females were similar: 47, 62–63, and 72 cm for males; and 46–48, 61, and 72 cm for females.

The commercial size is assumed to be 60 cm, and about 33% of the population were at least this length.

Of the remaining 67%, most (90%) were under 40 cm.

Length-weight relationships were calculated for males, females, and both sexes combined (Table 10). The overall regression equation is similar to that calculated for Chatham Islands barracouta (Hurst and Bagley 1987).

Of 460 barracouta staged, 75% had immature or resting stage gonads (stages 1–2) (Table 11). Only 2% (all males) were classified as ripe or running ripe, the rest being either in the early stage of maturity (stage 3) or recently spent (stage 6). Maximum gonadosomatic indices were less than 5 for males and 2 for females.

The left fillets of 146 of 187 barracouta examined (78%) were infected with a total of 790 trypanorhynchid cestode larvae of *Gymnorhynchus thyrsitae* (Table 12). The mean number of cestodes per fillet was 4.2 (range 0–49), and ventral muscles were more heavily infected (total 731, mean 3.9) than dorsal muscles (total 59, mean 0.3). Percentage infection and infection rate generally increased with fish length.

Eight left barracouta fillets were also infected with the anisakid nematode *Pseudoterranova decipiens*, with a range of 1–12 worms per fillet.

Stomach fullness, state of digestion of stomach contents, and identity of prey species were recorded for 458 barracouta. Most stomachs were part full (58%) or empty (39%), and the percentage of part full stomachs was greatest in the late afternoon (Table 13). Most food items were partly digested (65%) at all times of the day, but fresh items were more common in the early morning (Table 14).

Euphausiids constituted 80% of food items (Table 15). Fish and squid were the next most abundant (12 and 8%). Euphausiids were the most common prey type in all strata between 50 and 200 m, except stratum 1. Fish were the most common prey item in strata 1 and 9 (50–100 and 200–400 m). Squid were more common in barracouta caught in strata 1 and 2 (50–100 m) and in stratum 7 (100–200 m).

Hoki

Length frequency data for hoki were combined for all depths (Figure 22) because most fish were in 400–600 m. Fish ranged from 27 to 117 cm TL. Modal peaks are not clear, but they appear to be at about 30 cm for unsexed fish; 51, 61, and 75 cm for males; and 61, 68, and 80 cm for females. Most fish over 40 cm were sexed, and the overall male to female ratio was 0.74 : 1. Commercial size is assumed to be 60 cm, and 65% of the population were at least this length.

A total of 454 female hoki gonads were examined; 83% were stage 2, and 17% were stage 3.

Arrow squid

Arrow squid ranged from 6 to 43 cm mantle length. Over all depths combined there appeared to be one mode, which peaked at 26–30 cm for males and 25–28 cm for females (Figure 16). When the data were analysed by depth it appeared that the overall stratum weighted structure had been determined mainly by the large number of squid from 200–400 m, which had a modal peak at 26 cm for both sexes. Squid in shallower

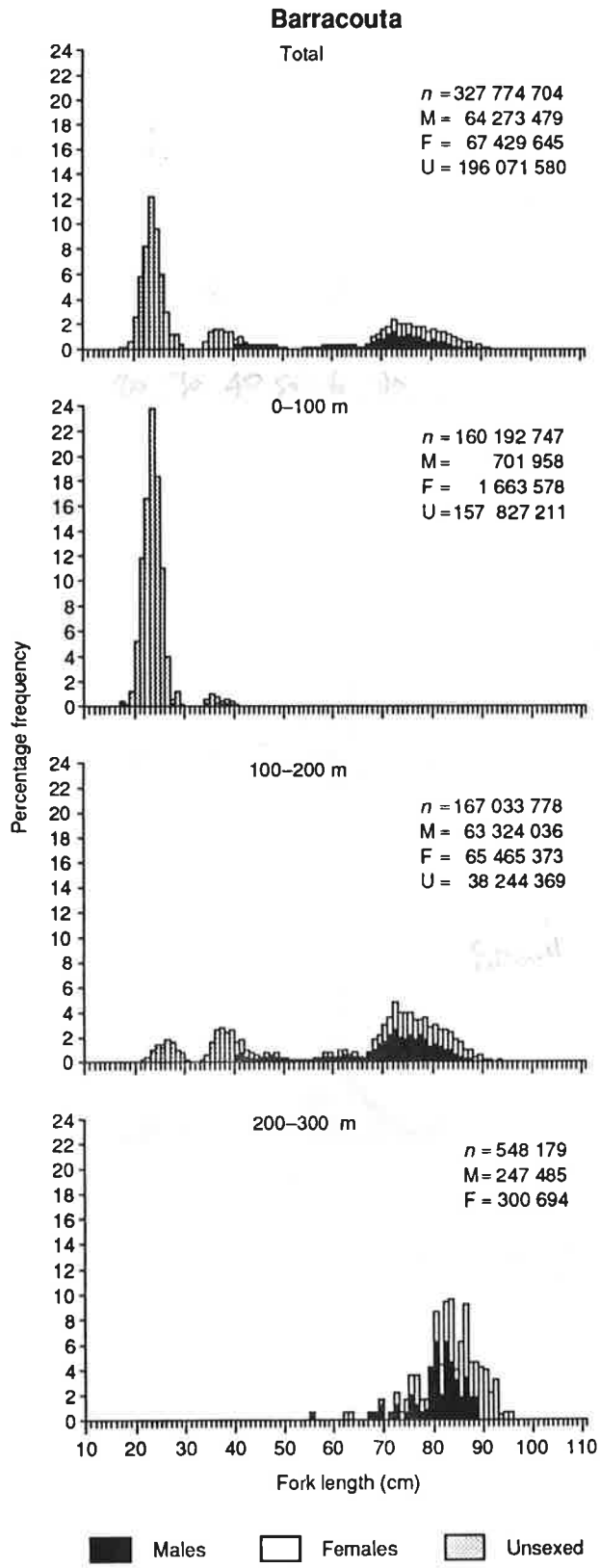

Figure 15: Scaled length frequency distribution for barracouta by depth, with the estimated total number of fish (*n*, total; M, male; F, female; U, unsexed).

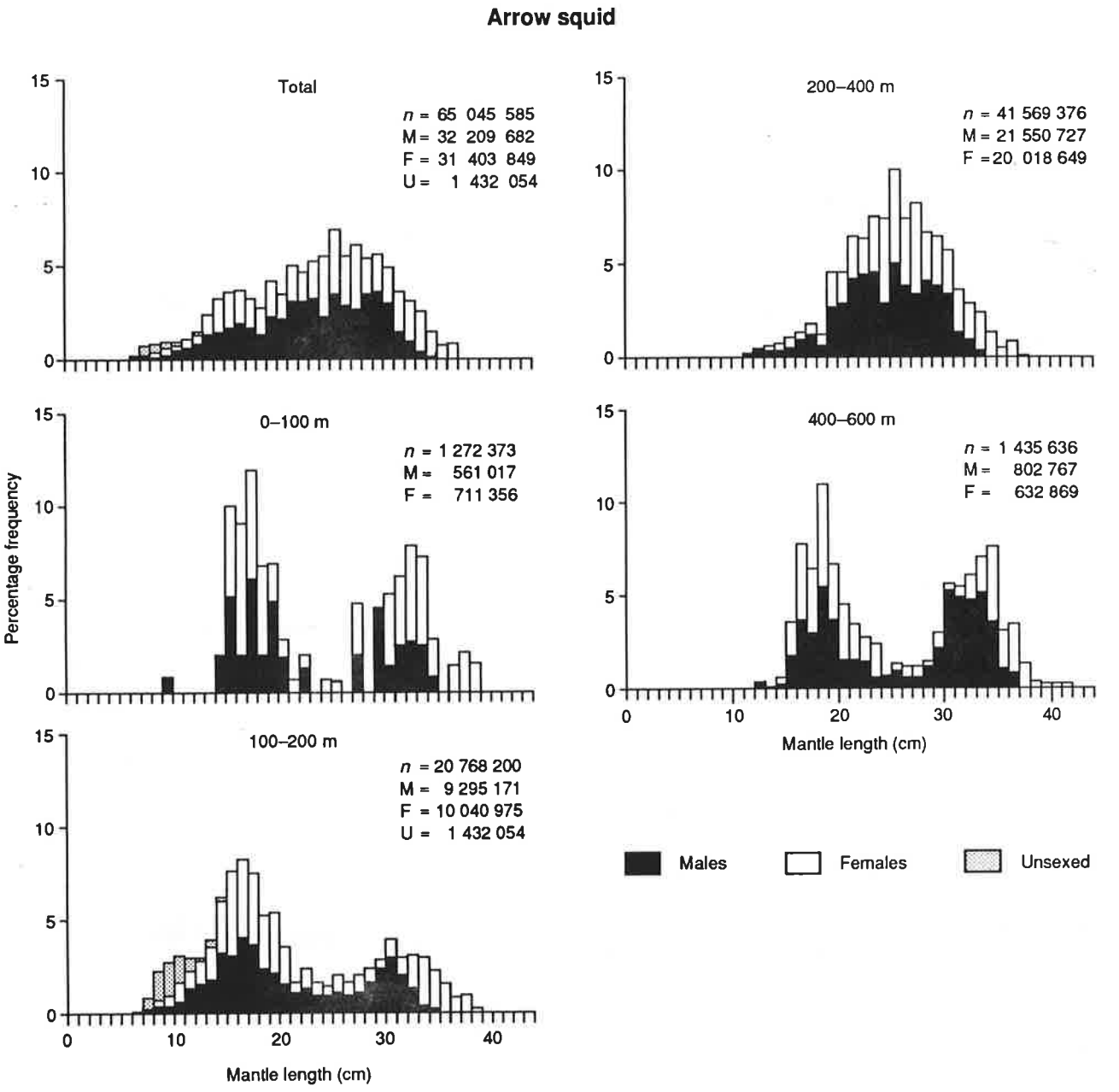

Figure 16: Scaled length frequency distribution for arrow squid by depth, with the estimated total number of fish (*n*, total; M, male; F, female; U, unsexed).

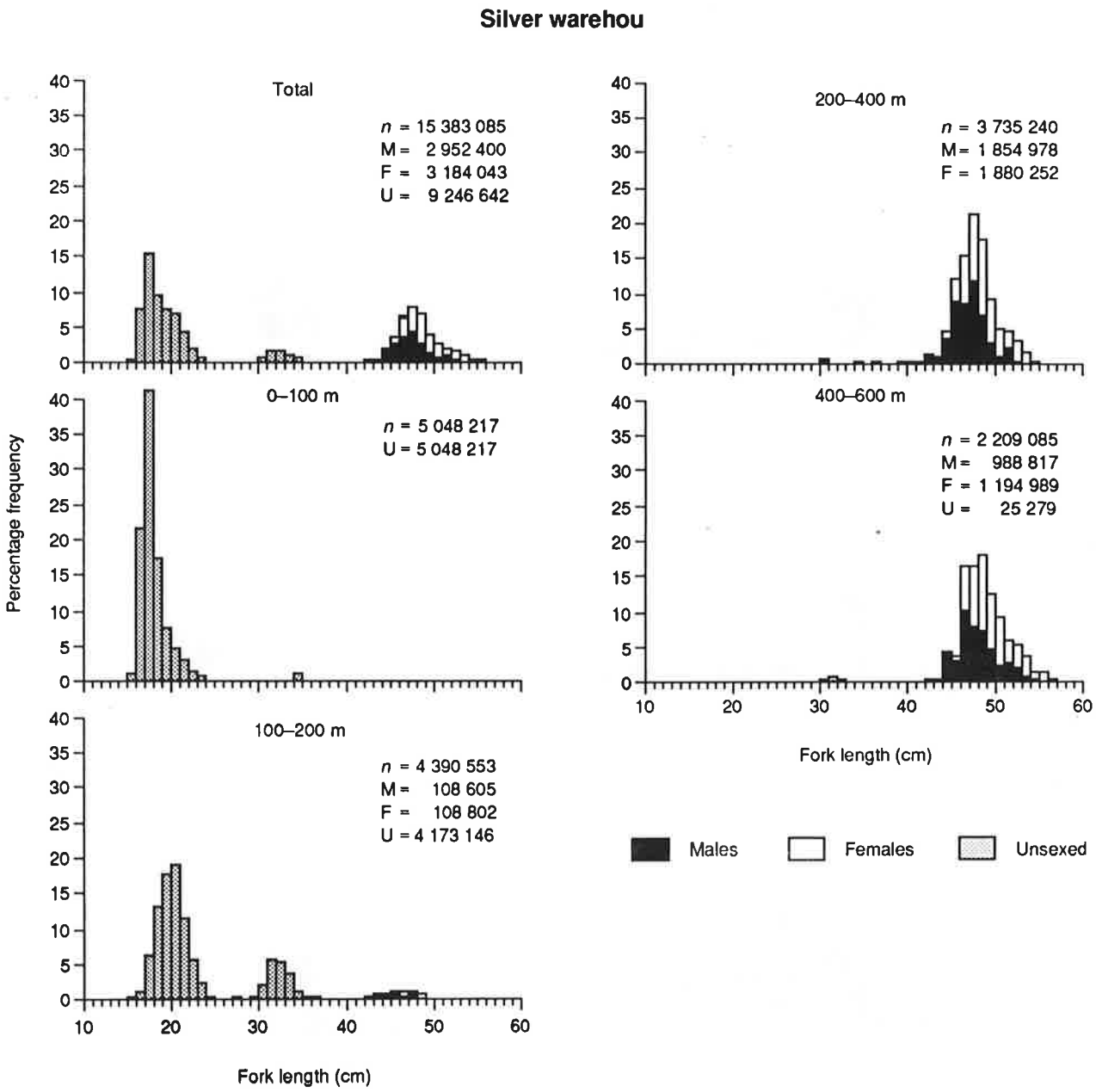

Figure 17: Scaled length frequency distribution for silver warehou by depth, with the estimated total number of fish (*n*, total; M, male; F, female; U, unsexed).

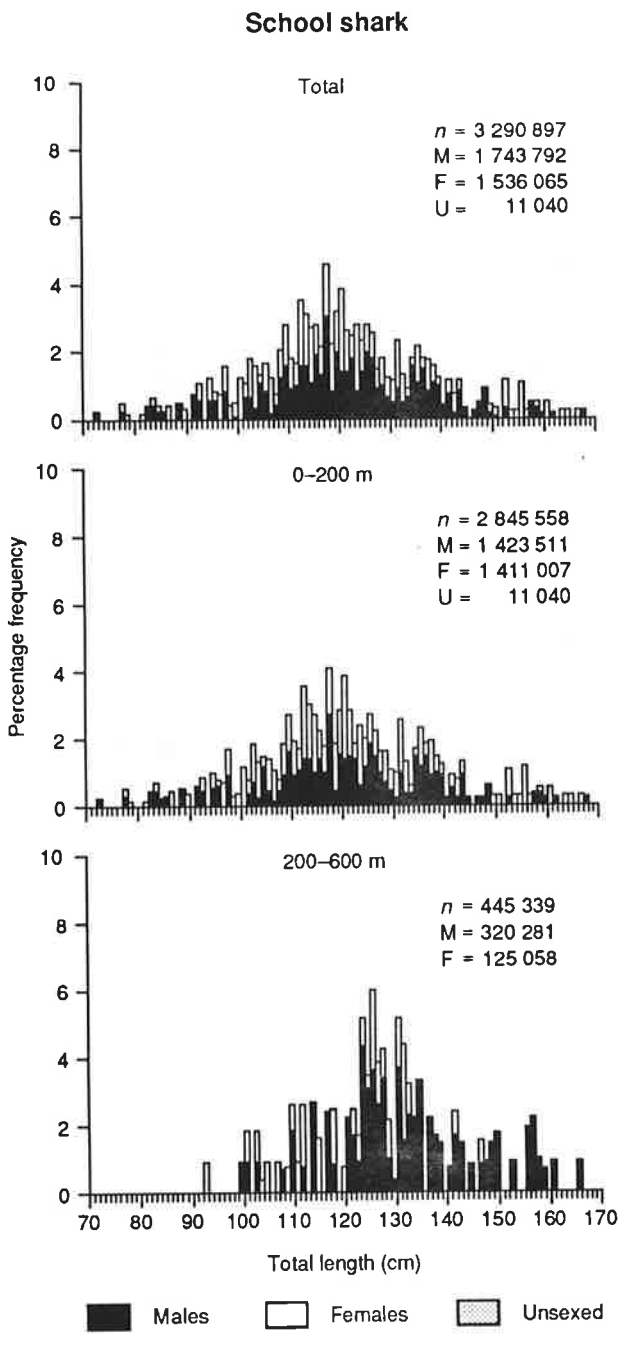

Figure 18: Scaled length frequency distribution for school shark by depth, with the estimated total number of fish (*n*, total; M, male; F, female; U, unsexed).

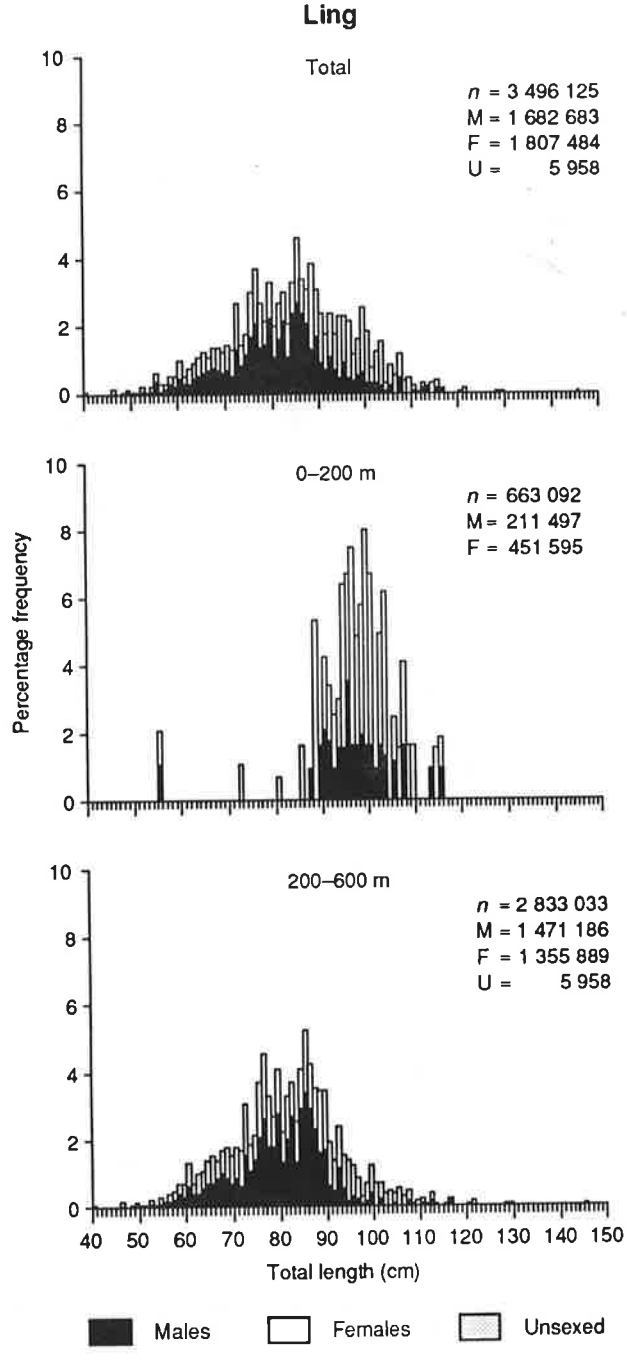

Figure 19: Scaled length frequency distribution for ling by depth, with the estimated total number of fish (*n*, total; M, male; F, female; U, unsexed).

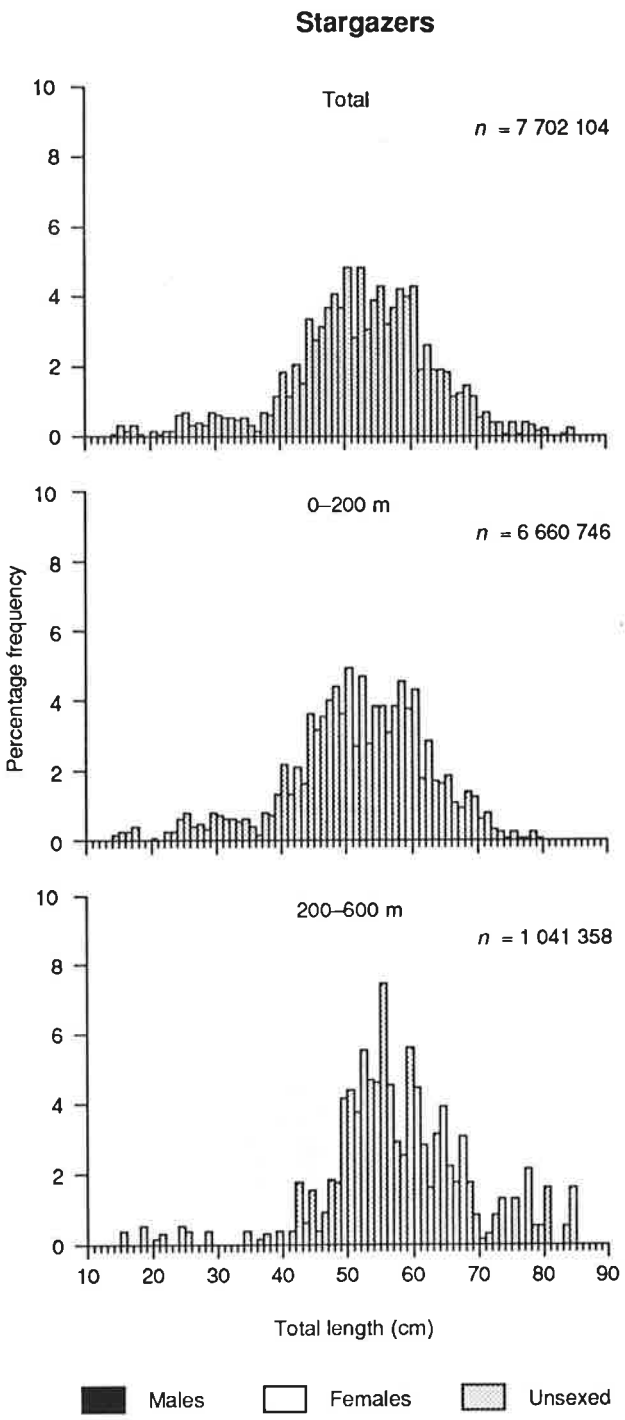

Figure 20: Scaled length frequency distribution for stargazers by depth, with the estimated total number of fish.

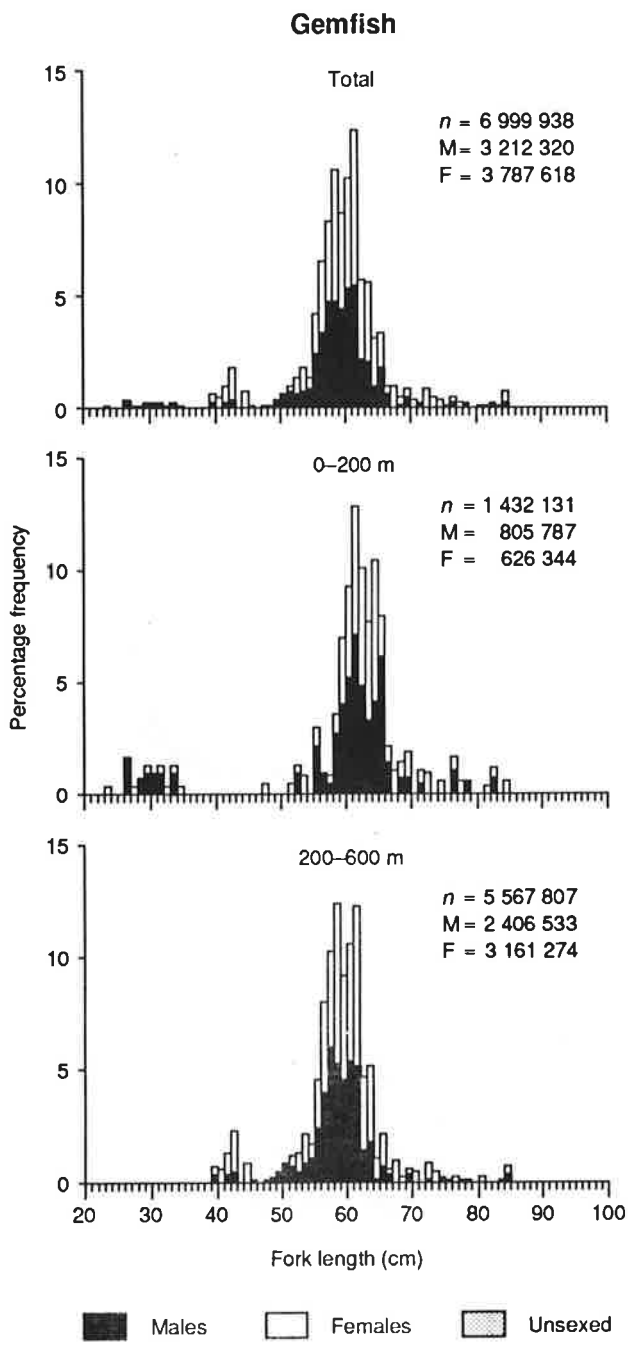

Figure 21: Scaled length frequency distribution for gemfish by depth, with the estimated total number of fish (*n*, total; M, male; F, female).

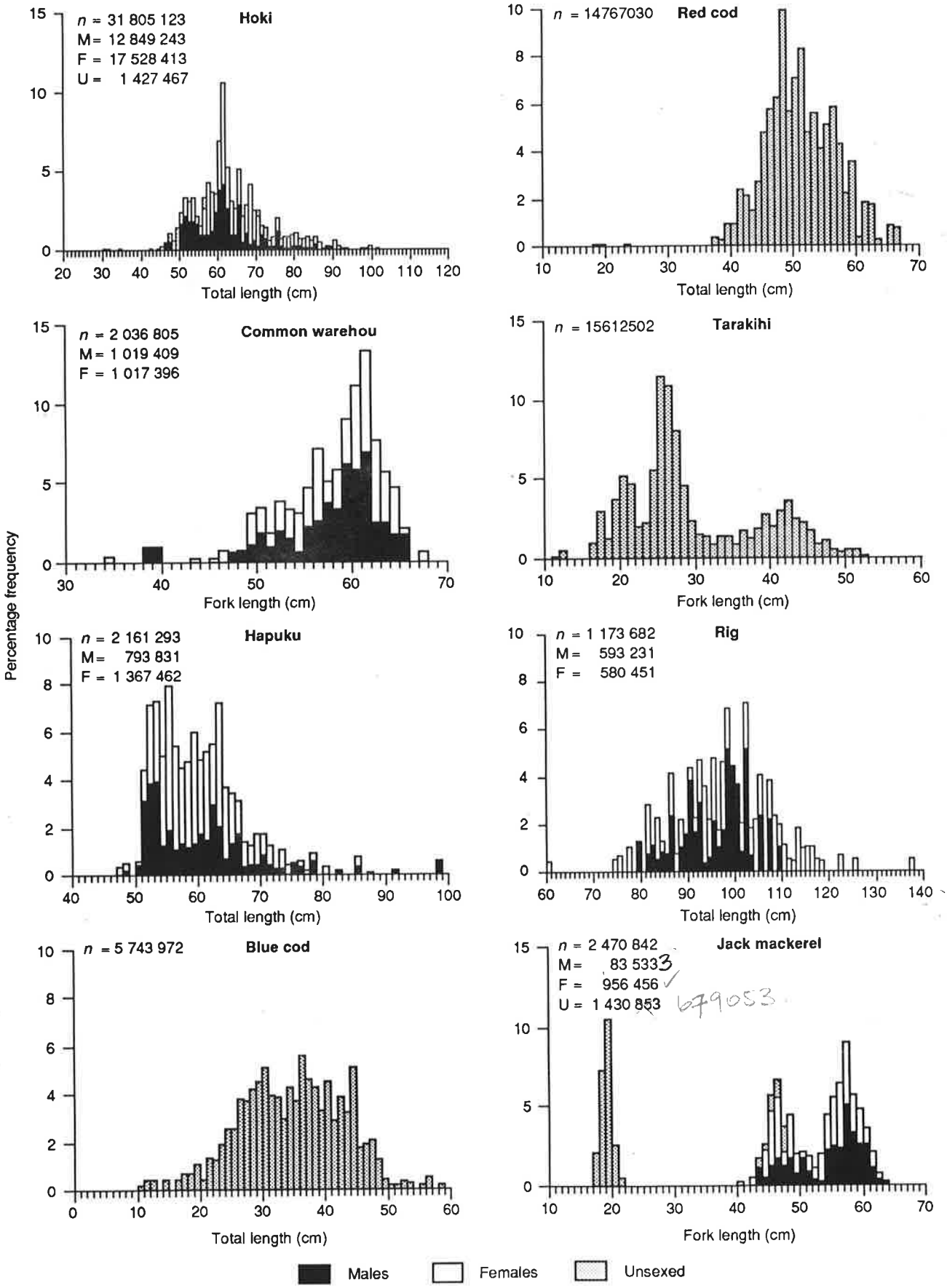

Figure 22: Scaled length frequency distribution for other species, with the estimated total number of fish (*n*, total; M, male; F, female; U, unsexed).

Table 9: Estimated biomass (t) by depth and stratum for the 10 major species (and percent of the total biomass estimate for each species)

	50–100 m		100–200 m					200–400 m		400–600 m	
Species	1	2	3	4	5	6	7	8	9	10	11
Barracouta	9.3	9.5	35.4	35.3	123.2	10.0	59.3	–*	1.6	0.0	0.0
	(3)	(3)	(13)	(13)	(43)	(4)	(21)	(0)	(1)	(0)	(0)
Spiny dogfish	32.6	6.8	27.5	13.0	16.8	10.1	7.0	1.5	0.2	1.1	1.7
	(28)	(6)	(23)	(11)	(14)	(9)	(6)	(1)	(0)	(1)	(1)
Hoki	0.0	0.0	0.0	0.0	0.0	–	0.0	–	0.3	7.6	21.1
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1)	(26)	(73)
Arrow squid	0.2	0.5	0.4	0.2	2.5	1.2	1.9	3.5	17.1	0.3	0.6
	(1)	(2)	(1)	(1)	(9)	(4)	(7)	(12)	(60)	(1)	(2)
Silver warehou	–	0.5	0.4	–	0.8	0.0	0.0	3.7	3.3	4.8	0.1
	(0)	(4)	(3)	(0)	(6)	(0)	(0)	(27)	(24)	(35)	(1)
School shark	1.0	1.1	3.7	2.0	12.3	1.5	4.2	0.2	2.6	–	1.0
	(3)	(4)	(13)	(7)	(42)	(5)	(14)	(1)	(9)	(0)	(3)
Ling	0.2	0.0	1.0	0.4	1.9	0.1	0.0	0.8	0.0	3.9	3.3
	(2)	(0)	(9)	(3)	(16)	(1)	(0)	(7)	(0)	(34)	(29)
Stargazers	1.5	11.3	1.7	2.5	6.2	0.1	0.2	0.1	2.1	0.3	1.8
	(5)	(41)	(6)	(9)	(22)	(0)	(1)	(0)	(8)	(1)	(7)
Red cod	21.5	0.0	0.4	0.0	0.2	–	–	0.4	0.0	–	0.1
	(95)	(0)	(2)	(0)	(1)	(0)	(0)	(2)	(0)	(0)	(0)
Gemfish	0.0	0.1	1.6	0.5	0.6	0.0	0.4	0.1	7.3	0.1	0.7
	(0)	(1)	(14)	(4)	(5)	(0)	(4)	(1)	(64)	(1)	(6)

* Less than 50 kg.

Table 10: Length-weight relationship for barracouta

		Length (cm)			Weight (g)				
	No.	Mean	s.d.*	Range	Mean	s.d.	Range	Equation†	Regression coefficient (r)
Males	194	70.9	12.9	24–88	1 917	758.4	63–3 500	$W = 0.0070L^{2.92}$	0.98
Females	268	73.9	14.7	24–99	2 131	897.5	86–4 300	$W = 0.0105L^{2.82}$	0.99
All fish‡	465	72.4	14.2	22–99	2 033	852.9	61–4 300	$W = 0.0090L^{2.86}$	0.99

* Standard deviation.
† W is weight in grams and L is length in centimetres.
‡ Includes unsexed juveniles.

Table 11: Reproductive state of barracouta

				Gonadosomatic index*			
				Males		Females	
Gonad stage	No.	Males	Females	No.	GSI	No.	GSI
1	32	14	18	0		0	
2	314	108	206	90	1.2	189	1.3
3	50	29	21	26	3.1	20	1.9
4	8	8	0	8	4.6	0	
5	2	2	0	2	4.1	0	
6	54	32	22	22	1.7	21	1.4
Total	460	193	267	148		230	

* Gonadosomatic index (GSI) = $\frac{\text{gonad weight}}{\text{body weight}} \times 100$.

and deeper strata had bimodal length frequency distributions, with peaks at 16–18 (both sexes), 30 (males), and 33–34 cm (females). This suggests there were at least two, possibly three, separate cohorts in the survey area.

Most squid 15 cm or longer could be sexed, and the ratio of males to females overall was about equal (1.03 : 1). However, females dominated in the shallowest (50–100 m) strata (male : female, 0.79 : 1), whereas males dominated in the deepest (400–600 m) strata (1.27 : 1). In intermediate depths the male to female ratio was about equal (0.92 : 1) in 100–200 m and 1.08 : 1 in 200–400 m). Squid over 20 cm are assumed to be of most value to the fishery, and 75% of the population were in this category. Length-weight relationships were calculated for males, females, and both sexes combined (Table 16).

Most of the 33 female arrow squid examined were either immature (30%) or maturing (42%), and only 21% were copulated. The smallest copulated female was 32.5 cm, and the largest noncopulated female was 36.5 cm. Most of the 34 males were mature (71%), 24% were maturing, and 6% were immature. Mature males were over 28.6 cm.

Of 68 stomachs examined, 34% contained prey items. Of those stomachs containing food, 48% contained crustaceans (mainly euphausiids), 39% squid, and 13% fish.

Silver warehou

Silver warehou ranged from 11 to 56 cm FL, and there were modal peaks at 17–20, 30–31, and 46–47 cm for males and 48 cm for females (Figure 17). The two smaller modes predominated in shallower waters, 50–200 m, the largest in depths of 200–600 m.

All fish over 35 cm were sexed. The ratio of males to females was almost equal overall (0.93 : 1) and ranged from 0.83 : 1 in the deepest strata to 1 : 1 in 100–200 m. Although the small fish are sometimes frozen whole, the fish of most commercial value are probably at least 30 cm, and fish of this size constituted 46% of the total number estimated.

Length-weight relationships were calculated for males, females, and both sexes combined (Table 17).

Table 12: Cestode (*Gymnorhynchus thyrsitae*) larval infection of barracouta left fillets by fish length

Length (cm)	No. of fish	Infected (%)	Mean No. of larvae	s.d.*	Range
60–74	2	50	0.50	0.71	0–1
75–79	62	60	2.08	3.61	0–19
80–84	65	81	3.88	4.66	0–29
85–89	42	95	6.26	6.64	0–24
90–94	11	100	6.18	8.80	1–30
95–99	5	80	15.40	19.78	1–49
All	187	78	4.23	6.35	0–49

* Standard deviation.

Table 13: Barracouta stomach fullness by time of day

Time (h)	No. of stomachs	Empty (%)	Part full (%)	Full (%)
0700–0930	119	38	59	3
0931–1200	113	49	50	2
1201–1430	158	39	58	3
1431–1700	68	24	72	4
All	458*	39	58	3

* The number of food items does not equal the total in Table 14 because one prey type was often present in more than one digestion state.

Table 14: Digestion state of food items in barracouta stomachs by time of day

Time (h)	No. of food items	Fresh (%)	Partly digested (%)	Digested (%)
0700–0930	79	30	57	13
0931–1200	59	19	68	14
1201–1430	106	14	70	16
1431–1700	57	25	63	12
All	301	21	65	14

Table 15: Occurrence of barracouta food items by stratum

Stratum	No. of food items	Euphausiids (%)	Fish (%)	Squid (%)	Shrimp (%)
1	19	26	58	16	0
2	12	67	17	17	0
3	47	89	9	2	0
4	69	91	4	4	0
5	58	88	5	7	0
6	37	89	3	8	0
7	35	86	0	14	0
9	14	0	86	7	7
All	291	80	12	8	0

Three gonad stages (2–4) were found in the 100 fish examined (Table 18). Males were either maturing or mature, whereas most females were still maturing. Gonadosomatic indices were low: 6.3 for males and 3.6 or less for females.

Observations on the stomach fullness and state of food digestion of 100 silver warehou suggested no clear relationship with time of capture. Salps and euphausiids were found in 65 and 1% of stomachs, and 34% were empty.

School shark

School shark ranged from 72 to 167 cm TL, and they peaked overall at 117 cm (117 cm for males and 120 cm for females) (Figure 18). Other modal peaks were not clear. The length frequency distributions of fish in 50–200 m and 200–600 m were similar, except that there were less smaller fish in deeper water.

The ratio of males to females overall was 1.14 : 1. This changed from 1.01 : 1 in shallower water to 2.56 : 1 in deeper water. Males and females reached a similar maximum size. A total of 453 school shark were tagged (251 males and 202 females). Individual weights were recorded for 495 fish, and the length-weight relationships for males, females, and both sexes combined are given in Table 19.

The male maturity stages related to fish length were: stage 1, 83–121 cm; stage 2, 103–144 cm; and stage 3, 116–161 cm.

Ling

Ling ranged from 40 to 145 cm TL, and they peaked overall at 85 cm (85 cm for males and 88 cm for females) (Figure 19). Other modal peaks were not clear. There were fewer fish in shallower water (0–200 m), but they were larger on average than those in deeper water (200–600 m). The ratio of males to females overall was about equal (0.93 : 1); males were less common in shallow water (0.47 : 1 in 0–200 m), but predominated in deeper water (1.09 : 1 in 200–600 m). The maximum size of males (116 cm) was much less than that of females. Most (86%) of the fish caught were probably of commercial size (over 60 cm). General observations on gonad stages showed that the fish were mainly resting.

Stargazers

Stargazers ranged from 14 to 84 cm TL (Figure 20). The determination of modal peaks is probably meaningless because there may have been more than one species present. Most of the fish were between 40 and 70 cm, and the larger fish occurred in deeper water (which may have also been because of differences between species). The stargazers measured were not sexed. Stargazers examined on station 48 were feeding on octopus and large arrow squid, and the gonads of females were maturing.

Gemfish

Gemfish ranged from 23 to 94 cm FL, and there were modal peaks at 27–33, 42, and 58–61 cm (Figure 21). The smallest modal group was absent from deeper water (over 200 m), and the medium group was absent from shallow water (under 200 m). All fish were sexed, and the overall ratio of males to females was 0.85 : 1. Males predominated in shallow water (1.28 : 1), and females predominated in deeper water (0.76 : 1). Commercial size is assumed to be 50 cm, and 93% of the fish were this size or larger.

Red cod

Red cod ranged from 18 to 69 cm TL, 98% being at least 40 cm (Figure 22). Modal peaks were difficult to interpret, but the main peak was at 48 cm. None of the fish were sexed, and an analysis by depth was not done because most fish were caught in less than 100 m.

Table 16: Length-weight relationship for arrow squid

	No.	Length (cm) Mean	s.d.*	Range	Weight (g) Mean	s.d.	Range	Equation†	Regression coefficient (r)
Males	33	29.5	2.45	20.5–32.5	664	165.0	260–1 000	$W = 0.0169L^{3.12}$	0.93
Females	33	32.7	3.30	23.0–37.0	762	214.8	260–1 200	$W = 0.0130L^{3.14}$	0.96
All fish	66	31.1	3.31	20.5–37.0	714	196.9	260–1 200	$W = 0.0550L^{2.74}$	0.92

* Standard deviation.
† W is weight in grams and L is length in centimetres.

Table 17: Length-weight relationship for silver warehou

	No.	Length (cm) Mean	s.d.*	Range	Weight (g) Mean	s.d.	Range	Equation†	Regression coefficient (r)
Males	53	47	2.1	41–52	2 024	278	1 500–2 920	$W = 0.0880L^{2.6}$	0.89
Females	47	48	2.8	42–55	2 217	431	1 300–3 380	$W = 0.0063L^{3.3}$	0.96
All fish	100	47	2.5	41–55	2 115	369	1 300–3 380	$W = 0.0194L^{3.0}$	0.93

* Standard deviation.
† W is weight in grams and L is length in centimetres.

Table 18: Reproductive state of silver warehou

Gonad stage	Gonadosomatic index* Males No.	GSI	Females No.	GSI
2	0		2	1.9
3	24	6.3	44	3.6
4	29	6.3	1	3.4
Total	53		47	

* Gonadosomatic index (GSI) = $\frac{\text{gonad weight}}{\text{body weight}} \times 100$.

Blue warehou

Blue warehou ranged from 34 to 67 cm FL, with a small modal peak at 38–39 cm and a large modal peak at 61 cm (both sexes) (Figure 22). There may be additional peaks at 49–52 cm and 56–57 cm. These fish are probably all of commercial size. Length frequencies were not analysed by depth because of the small sample size. All fish were sexed, and the ratio of males to females was 1 : 1.

Tarakihi

Tarakihi ranged from 11 to 52 cm FL, with clear modal peaks at 20, 25, and 42 cm (Figure 22). Most fish were small, only 27% being at least 35 cm (i.e., the approximate commercial size). They were not sexed, and length frequencies were not analysed by depth range because most tarakihi were taken in shallow water.

Hapuku

Hapuku ranged from 47 to 98 cm TL, most being less than 65 cm (Figure 22). Males appeared to have modal peaks at 53, 62, 66, and 70 cm, whereas females peaked at 55, 58, 63, and 69 cm. The male to female ratio was 0.56 : 1.

Rig

Rig ranged from 60 to 137 cm TL, most being between 80 and 110 cm (Figure 22). Modal peaks were difficult to distinguish. The male to female ratio was 0.88 : 1.

Blue cod

Blue cod ranged from 10 to 58 cm TL, most being between 25 and 45 cm (Figure 22). Only about 12% were sexed, so a ratio is not given. Gonad stages 3 and 4 were recorded for both sexes.

Jack mackerel

Jack mackerel ranged from 17 to 63 cm FL, with modal peaks at 19, 46, and 57 cm (Figure 22). They were mostly *Trachurus declivis*, but *T. murphyii* (*see* Kawahara *et al.* (1988) for the first published record of this species from New Zealand waters) were also present in the larger modal group.

Other species

Hake ranged from 68 to 118 cm TL (n = 57), and the numbers of males and females were about equal. The two male gonads examined were stages 4 and 5; females were stage 2 (n = 10) and stage 3 (n = 14). Bluenose ranged from 50 to 77 cm TL (n = 12). Gonads of one male and five females were in the resting stage. Ray's bream ranged from 31 to 44 cm FL (n = 29). Other observations on gonad stages were: white warehou, stage 3 (n = 10); lookdown dory, stage 2 (n = 13).

Hydrology

Surface and bottom temperatures (from combined ship recorder and XBT data) are shown in Figure 23. Surface temperatures showed little variability over the survey area. They decreased gradually from over 12 °C in the northwest (Puysegur Bank, Solander Island, Stewart Island area) to over 11 °C in the southeast (Snares Islands to the southeast South Island). Temperatures down to 9.9 °C were recorded over the edge of the eastern slope.

Bottom temperatures over the shelf areas were similar to surface temperatures, usually being within 1 °C less. They followed the same general trend of being warmer (over 12 °C) in the northwest and east of Stewart Island and slightly cooler (over 11 °C) on

the southern and eastern shelf. In deeper areas of the slope, bottom temperatures decreased sharply, though they were still warmer in the northeast than in the southwest (XBT minima at about 500 m were 10.3 and 7.7 °C respectively). This trend is illustrated in a vertical profile of XBT stations drawn diagonally from the northeast (near Solander Island) to the southeast slope (*see* Figures 4 and 24).

Table 19: Length-weight relationship for school shark

		Length (cm)			Weight (g)				
	No.	Mean	s.d.*	Range	Mean	s.d.	Range	Equation†	Regression coefficient (r)
Males	270	121.5	16.3	72–167	9 660	3 919	2 400–2 540	$W = 0.0112L^{2.84}$	0.96
Females	220	118.1	17.2	77–166	9 550	5 230	2 200–3 150	$W = 0.0038L^{3.09}$	0.96
All fish	490	120.0	16.7	72–167	9 610	4 550	2 200–3 150	$W = 0.0068L^{2.94}$	0.96

* Standard deviation.
† W is weight in grams and L is length in centimetres.

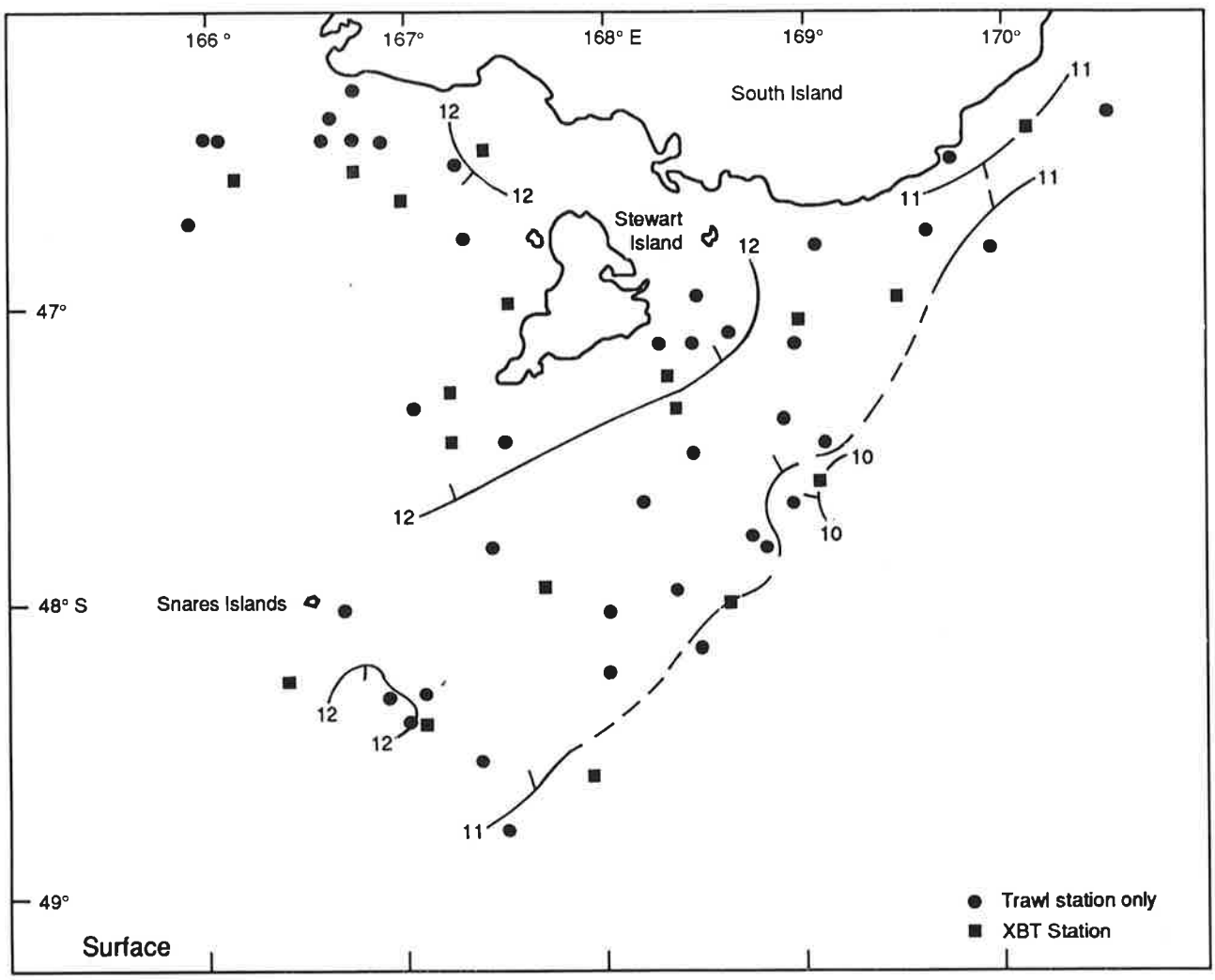

Figure 23: Surface and bottom temperatures.

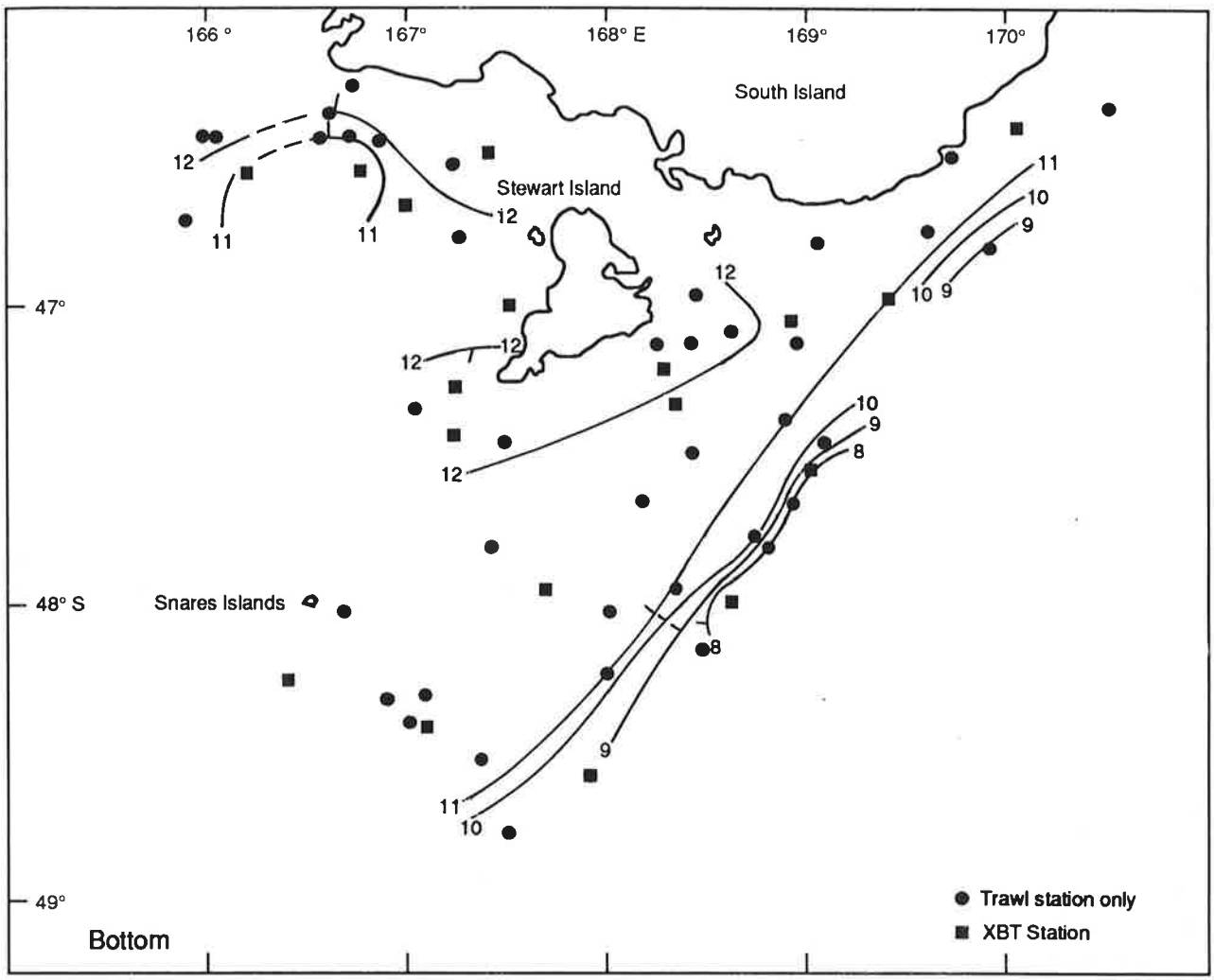

Figure 23—*continued*.

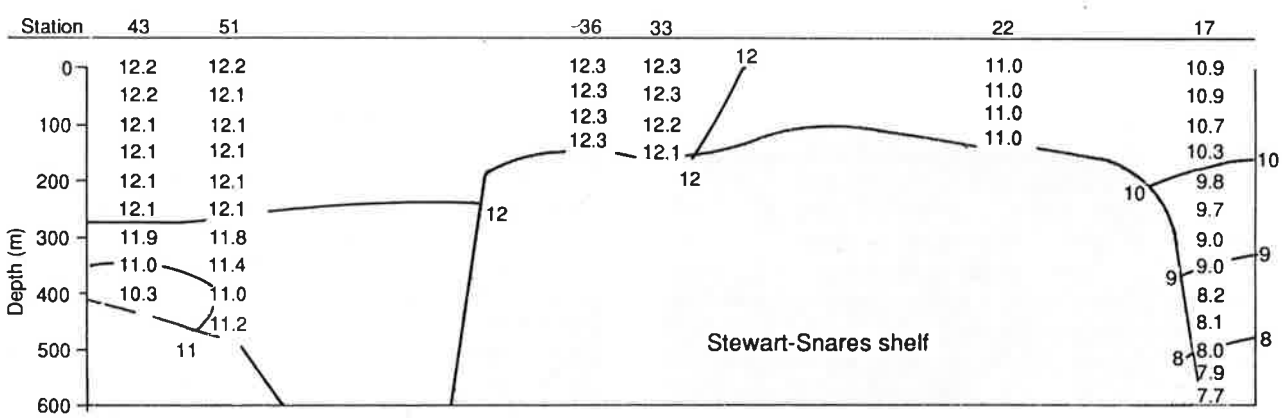

Figure 24: Vertical profile of XBT stations on a northwest-southwest diagonal from near Solander Island to the southeast slope (*see* Figure 4).

Discussion

The study area is just north of the Subtropical Convergence, a front between water masses of subtropical (northern) and subantarctic (southern) origin. This front passes from west to east around southern New Zealand, usually just south of the Stewart-Snares shelf, and extends northeast along the continental shelf of the South Island (Garner 1959). This convergence is defined roughly by surface isotherms of 15 °C in February and 10 °C in August.

The convergence is not easy to locate from data collected from trawl surveys over several weeks and without salinity data. However, it appears that the steeper temperature gradients are often on the eastern edge of the Stewart-Snares shelf, which suggests that water over the shelf is subtropical or a mixture of subtropical and subantarctic in origin.

Comparison of temperature patterns from June 1986 and the four previous *Shinkai Maru* surveys off Southland (*see* Table 5 for dates and references) suggests that there is little difference in surface and bottom temperatures within (about 1 °C) or between (about 2–3 °C) surveys over the main shelf (< 200 m). The late summer surveys in 1981 and 1982 recorded relatively warm temperatures compared with early autumn and spring 1983, the latter possibly caused by the El Nino that year. The winter 1986 temperatures are intermediate between the 1983 lows and the late summer highs.

Other features common to all surveys were a gradual decrease in temperature from the northwest to the southeast of the survey area and a sharper decrease with depth over the upper slope, down to about 7–8 °C at 600 m.

Fish caught during the survey were typical of shelf and upper slope faunas influenced by the Subtropical Convergence, with a few exceptions which are discussed below. In all five surveys, barracouta, spiny dogfish, arrow squid, and hoki were among the five most abundant species. Gemfish, ling, and blue warehou were among the seven major species in at least three of the five surveys. Wingspread biomass estimates for the 10 major species from the June 1986 survey and comparable data from previous *Shinkai Maru* surveys are given in Table 20. All previous surveys included areas south of the Subtropical Convergence, and these areas showed distinct changes in species composition, with hoki, southern blue whiting, ling, arrow squid, ghost shark, and rattails being the most abundant species in depths less than 600 m.

Comparison of the catch composition of Stewart-Snares shelf and upper slope surveys with that of surveys just north of the Subtropical Convergence (i.e., the west and east coasts of the South Island and the Chatham Rise — *see* Fenaughty and Bagley 1981, Hurst and Fenaughty 1985, Hurst and Bagley 1987, Livingston *et al.* in press) suggests that the most abundant species in each area tend to be similar, particularly barracouta, spiny dogfish, hoki, and arrow squid. Exceptions are gemfish and blue warehou, which appear to be less common on the Chatham Rise, and tarakihi, which are abundant in all areas except the Stewart-Snares shelf. This pattern is unlikely to be explained by inadequate sampling of seasonal abundance or depth distribution.

Comparison of catch compositions of the five southern trawl surveys with commercial catch data for area F (*see* Tables 1 and 20) suggests that most of the abundant species are caught and processed by commercial vessels. Notable exceptions are stargazers and school shark, which are not major species in the total commercial catch. This may be mainly because the larger trawlers are excluded from the 12 n. mile territorial sea, where these species were most abundant in this survey (*see* Figures 11 and 12). However, school shark have been an undesirable catch for deepwater trawlers, and these vessels have often not processed or reported them. Oreos are a big part of commercial catches in area F (*see* Table 1), but were not caught during the trawl survey because they occur in water deeper than 600 m.

None of the wingspread biomass estimates from the June 1986 survey were significantly lower than estimates from the same area and depth range from previous surveys (*see* Table 20). However, estimates for five species (barracouta, spiny dogfish, school shark, stargazers, and silver warehou) were significantly greater than those from some or all of the previous surveys. These differences are not necessarily related to changes in the abundance or availability of the fish, but may be caused by the differences in sampling areas (*see* Figure 2). The June 1986 survey area was greater than in all previous surveys of the Stewart-Snares Islands area to 600 m, by a factor of about 1.5. Thus, if it were assumed that there would have been equal catch rates in unsurveyed areas, for the June 1986 biomass estimates to represent significant changes in availability or abundance, their lower bounds would need to be greater than the upper bounds of the other survey estimates by about 1.5 (N.B., this is only approximate because the area differences should ideally be related to the depth range applicable to each species). However, for all five species there are still significant differences in biomass estimates even when this factor is accounted for.

The upper bound of the barracouta biomass estimate from October-November 1983 is significantly less than the June 1986 lower bound, by at least 6.5 times (the mean biomass differs by 16 times). It is also lower than that on all other surveys, except March-April 1982, which had a high coefficient of variation (50%). This suggests either movement of barracouta out of the survey area or much reduced availability to bottom trawls during late winter-spring (i.e., the

Table 20: Wingspread biomass estimates and coefficients of variation (*c.v.*) of the 10 major species from the June 1986 survey, and comparable data* from previous *Shinkai Maru* surveys off Southland in 0–600 m, 1981–86

	Feb 1981†		Mar-Apr 1982		Apr 1983		Oct-Nov 1983		Jun 1986	
Species	Biomass (10^3 t)	*c.v.* (%)	Biomass (10^3 t)	*c.v.* (%)	Biomass (10^3 t)	*c.v.* (%)	Biomass (10^3 t)	*c.v.* (%)	Biomass (10^3 t)	*c.v.* (%)
Arrow squid	21.3	20	17.6	30	10.9	22	17.1	29	29.1	30
Barracouta	99.5	25	102.8	50	200.4	25	18.5	27	292.2	18
Hoki	108.6	37	77.6	69	52.8	45	9.8	46	29.0	50
Ling	22.1	16	~~58.5~~ 5.8	40	5.6	21	12.4	48	11.6	21
Red cod	0.1	30	0.2	56	0.3	54	1.8	54	22.6	65
School shark	10.7	22	3.1	19	13.6	15	2.6	38	30.4	17
Gemfish	18.4	17	14.5	31	26.8	33	4.3	42	11.5	26
Spiny dogfish	71.0	25	32.9	19	50.9	16	51.6	31	125.0	10
Stargazers	5.0	16	3.6	18	10.0	36	3.9	21	28.1	40
Silver warehou	10.6	25	0.4	47	0.7	29	1.0	50	13.7	31

* Strata: Feb 1981, 1–6; Mar-Apr 1982, 1–3; Apr 1983, 1–5; Oct-Nov 1983, 1–3 (*see* Figure 2 for details on strata, number of stations, station density, and area and Table 5 for references to previous surveys). Not all species biomass estimates were published and missing values were calculated from data files held at MAF Fisheries Greta Point, Wellington. The Jun 1986 survey included Puysegur Bank and the Solander corridor, which were only partly sampled in Mar-Apr 1982 and Apr 1983 and were not sampled at all in the other surveys.
† Four stations in stratum 6 were off the Auckland Islands.

spawning season). From commercial data it is known that large catches and high catch rates of barracouta have been taken from the Solander corridor area during spring (Hurst 1988). This area was not included in the October-November 1983 survey, and, therefore, movement away from the Stewart-Snares shelf seems the most likely explanation for the low biomass estimate (which invalidates the assumption of equal catch rates in unsurveyed areas). None of the summer, autumn, or winter biomass estimates appear to be significantly different when the survey area factor is taken into account.

The June 1986 spiny dogfish biomass estimate is significantly greater than the estimates from all other surveys except February 1981. If allowance were made for the different survey areas, only the estimate from the March-April 1982 survey is less than that from the June 1986 survey. However, the assumption of equal catch rates in areas not surveyed before 1986 may not be valid because the highest catch rates in June 1986 were recorded inside the 12 n. mile territorial sea limit. There are likely to be seasonal changes in abundance because they have been found in other surveys. For example, spring and summer trawl surveys off Southland by *W.J. Scott* during 1974–77 caught more spiny dogfish from January to April than from October to December (Fenaughty and O'Sullivan 1978). Such seasonal (or any annual) changes are not detectable from the series of biomass estimates given here.

The June 1986 school shark biomass estimate is significantly greater than estimates from all previous surveys. Allowance for the area factor results in the estimate being significantly greater than those from the March-April 1982 and October-November 1983 surveys, the lower bound of the June survey being 4.6 times the upper bound of the other surveys. As with spiny dogfish, the June 1986 survey recorded the higher catch rates in areas not sampled in previous surveys, and, therefore, the assumption of equal catch rates in these areas is probably not valid. Thus, any seasonal or annual changes in abundance suggested by the data are obscured by the survey area differences. However, some seasonal change in abundance may occur, because tagging results from the June 1986 survey and a later survey off Southland have shown that school shark can move at least 700 n. miles. Most of the larger movements from this area were up the east coast of the South Island (McGregor 1988), but one fish was recaptured as far north as Cape Egmont, on the west coast of the North Island.

The stargazer biomass estimate from June 1986 is significantly greater than those from March-April 1982 and October-November 1983. However, the differences are less than the differences in the survey areas. As with the two previous species, much of the June 1986 biomass came from areas not included in the previous surveys, and so seasonal and annual changes in abundance cannot be detected. The *W.J. Scott* surveys found little seasonal variation in the catch rate of stargazer through spring and summer (Fenaughty and O'Sullivan 1978).

The silver warehou biomass estimate from June 1986 is significantly greater than all previous estimates except that from February 1981. Comparison of the respective lower and upper bounds suggests differences of at least 8.5 times in March-April 1982, 4.7 in April 1983, and 3.4 in October-November 1983. This could represent significant changes in annual abundance because silver warehou are fast growing (Gavrilov 1979), and year class strengths could vary greatly from year to year. However, variability in vertical distribution may also be an important factor, affecting the availability to bottom trawl gear. Differences in areas surveyed are not likely to be important because the highest catch rates were recorded off the eastern edge of the Stewart-Snares shelf.

Trends in silver warehou commercial catch data (Livingston 1988) also suggest that large changes in annual abundance could be a feature of the Southland fishery. Annual catches vary about three-fold from the 1981–82 fishing year (April to March) to the 1985–86 fishing year (October to September), the most recent year recording the highest catch. Thus, catches show a similar trend to that in biomass. A summary of

seasonal catch data from 1978 to 1984 suggests little seasonal variation over the Stewart-Snares shelf, except for a slight increase in spring.

From the biomass estimates given in Table 20, and from the catch rate diagrams given here (*see* Figures 5–14) and published previously (*see* Table 5 for references), seasonal changes in distribution and the relative importance of the Solander corridor to Puysegur Bank area have been summarised for five of the main species (Table 21). Other species either had relatively low catch rates or distribution maps were not provided in all of the survey reports.

In four of the five surveys, barracouta catch rates over 1 t per 0.5 h were recorded around the Snares Islands. These surveys were all in late summer to early winter. No high catch rates were recorded in the spring survey, and, because there was also a significantly lower biomass estimate during this survey, this suggests that fish had moved away from the Stewart-Snares shelf, possibly to the Solander corridor area, where high catch rates for barracouta are recorded during spring.

Hoki are taken mainly in deeper water (400–800 m), and surveys down to 600 m in area F may be sampling only the shallow limit of their distribution in the Southland and Sub-Antarctic areas. Four of the five surveys recorded catch rates over 1 t per 0.5 h on the slope south, east, and/or northeast of the Stewart-Snares shelf. Only in the June 1986 survey were high catch rates recorded in the Solander Island to Puysegur Bank area, which could reflect a seasonal change in distribution. Patchell (1983) described seasonal hoki commercial fishing activity off Puysegur Bank in 1982. It began in early June and peaked in late September. Patchell suggested that this pattern was consistent with the hypothesis that hoki migrate to and from the west coast South Island spawning grounds via the Snares slope and Puysegur Bank.

Spiny dogfish are fairly common on the Stewart-Snares shelf, and catch rates of over 1 t per 0.5 h were recorded in the south in three of the five surveys. The low catch rates in the south and higher catch rates in the northeast in June 1986 suggest a more northern distribution of the species in the survey area during winter. (N.B., the biomass estimate from the June survey was not significantly lower than that from the other surveys.) The *W.J. Scott* survey off Southland found low catch rates during spring and high catch rates during summer. This seasonal pattern is not apparent in the *Shinkai Maru* data, perhaps because the shallower depth range of spiny dogfish was inadequately sampled in spring and summer.

Table 21: General distribution of five of the main species* from five *Shinkai Maru* surveys off Southland in 0–600 m†

	BAR	HOK	SPD	ASQ	LIN
Feb 1981	SNA	S, NE	S, E, NE	S	E?
Mar-Apr 1982	SNA	NE	SNA	S, SE	E?
Apr 1983	SNA	S	–	S, SOL	E
Oct-Nov 1983	–	–	S	SE	SE
Jul 1986	SNA	E, PUY	NE	PUY, E	E, PUY

* Species codes: BAR, barracouta; HOK, hoki; SPD, spiny dogfish; ASQ, arrow squid; LIN, ling.

† *See* Table 5 for references to previous surveys. Catch rates of at least 1.0 t per 0.5 h for BAR, HOK, and SPD; 0.5 t per 0.5 h for ASQ; and 0.2 t per 0.5 h for LIN. Catch rates from the Jun 1986 survey have been converted to tonnes per 0.5 h by assuming equal catch rate over time towed.

Area codes: E, east; S, south; NE, northeast; SE, southeast; PUY, Puysegur; SNA, Snares Islands; SOL, Solander.

Arrow squid were usually caught at most stations on the Stewart-Snares shelf and upper slope. The highest catch rates were more common on the south and southeastern edges of the shelf and were quite localised (except in March-April 1982). Two of the three surveys which included the Solander Island to Puysegur Bank area also found high catch rates. There were no apparent changes in seasonal distribution.

Catch rates of ling were low in most surveys, the higher rates of over 0.2 t per 0.5 h being most common on the southern and eastern Stewart-Snares slope. The only survey to include Puysegur Bank (June 1986) also found evidence of higher catch rates there. These findings are consistent with the main ling fishing areas reported by commercial vessels (Patchell 1987). Previous surveys which extended south to the Sub-Antarctic area (March-April 1982 and October-November 1983) found better and more consistent catch rates in this area.

The length frequency modes of arrow squid, barracouta, and hoki from the five *Shinkai Maru* surveys of the Stewart-Snares shelf are summarised in Figure 25 (N.B., the February 1981 report gave data for arrow squid only). Comparisons are limited because the presentation of results varied (e.g., by scaling by time or distance towed or stratum area). Other species were not measured often enough for meaningful comparison.

Arrow squid characteristically have two or three distinct modal peaks, with a peak of about 20 cm present in all seasons, which suggests that spawning occurs throughout the year. The larger modal peak, at about 30 cm, was absent or insignificant in all three late summer to early autumn surveys on the Stewart-Snares shelf, but was predominant in the same surveys around the Auckland Islands. This could indicate a seasonal movement of larger squid away from the Stewart-Snares shelf, perhaps south to the Auckland Islands, or it could just be a reflection of different cohorts in different areas. In June 1986 the larger modal peak (34 cm) was also present off Southland, but was less important than the 16–18 and 26 cm peaks (*see* Figure 16). Measurements taken by scientific observers on commercial vessels during summer-autumn 1987 and 1988 also found few larger squid on the Stewart-Snares shelf, but mainly larger squid around the southern Auckland Islands (R. H. Mattlin pers. comm.).

In October-November 1983 both the smaller (about 20 cm) and larger (about 30 cm) modal peaks were present in both areas. Spawning appears to occur in both areas in winter, because juvenile squid (2–3 cm mean mantle length) were found on the Stewart-Snares shelf and the Aucklands Shelf in August-September

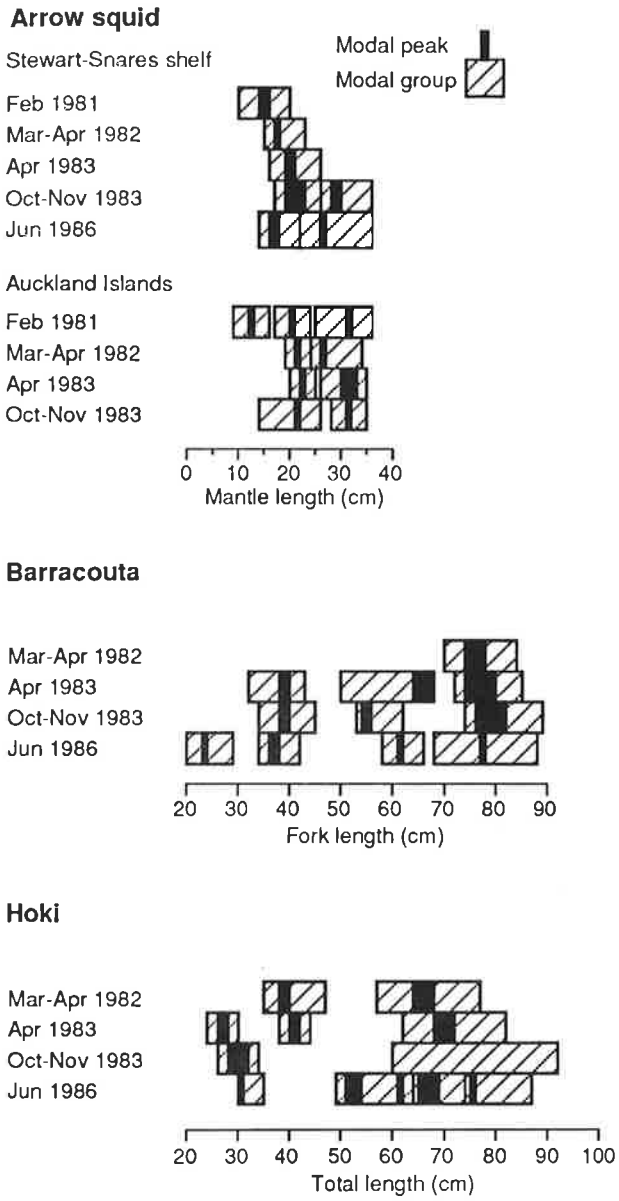

Figure 25: Main length frequency modes for arrow squid, barracouta, and hoki from the five *Shinkai Maru* surveys off Southland in 0–600 m (*see* Table 5 for references to previous surveys).

1985 by a *Kaiyo Maru* survey (Uozumi 1987). It is not known whether the presence of larger squid only off the Auckland Islands in summer-autumn reflects area or temperature preferences for spawning at this time of year.

Barracouta show between three and five clear modal groups, with modes of the larger fish (over about 70 cm) becoming obscured. An exception to this was in March-April 1982, when only the larger mode was present, perhaps because of the lack of sampling in shallow water, the sampling strategy for fish measurement, or the weak year class strengths of smaller fish. The combined mode of larger fish was always dominant, except in the October-November 1983 survey, when the smallest mode (38–39 cm) dominated. This, with the significantly lower biomass estimate, supports the earlier suggestion that adult sized fish undergo a spawning migration, in late winter to early spring, away from the area sampled in the spring survey.

The appearance of a modal peak at 23 cm (0+ y) in the June 1986 survey is probably due to the increased sampling of more inshore waters compared with the other surveys. This year class is often found only in shallow water less than 100 m in bottom trawl surveys (e.g., *see* Hurst and Bagley 1987).

The 200–600 m depth range on the Stewart-Snares slope only samples the shallow edge of the hoki population, and so modal peaks may not be representative of the population as a whole. In general, this depth range had smaller modal peaks around 30 and 40 cm, which were not present (or greatly reduced) in areas to the south and east. Adult sized fish (over about 50 cm) are usually less prominent in the Stewart-Snares Islands area than in areas to the south and east, but the maximum fish size is similar.

Comparison of biomass estimates, species distributions, and length frequencies from the June 1986 survey with the four previous *Shinkai Maru* surveys illustrates the value of conducting several surveys with the same vessel in one area over several years and seasons. It also highlights the importance of the area surveyed in the interpretation of results and trends. For example, the seasonal importance of the Solander Island to Puysegur Bank area in the Southland fishery would have been better understood if the earlier surveys had included this area. For some species, the importance of sampling in the 12 n. mile territorial sea to obtain more accurate estimates of biomass and fish size was also apparent from the June 1986 survey.

To some extent these problems when comparing surveys result from different survey objectives. Earlier surveys concentrated either on arrow squid, and thus included the Auckland Islands (February 1981 and April 1983), or included investigating the much wider distribution of hoki and southern blue whiting as major objectives (March-April 1982 and October-November 1983). The June 1986 survey was shorter and had less daylight hours in which to sample; therefore, it concentrated on the shelf and upper slope species of the Southland area, and it included waters in the 12 n. mile territorial sea and in the Solander Island to Puysegur Bank area.

The Southland area (EEZ area F) fisheries are important for New Zealand, and the surveys carried out by *Shinkai Maru* have provided valuable data on the species potential there. Future research should include additional seasonal surveys of the complete area, to overcome the problem outlined above and provide a continuing time series of surveys to enable trends in species biomass to be better estimated and understood.

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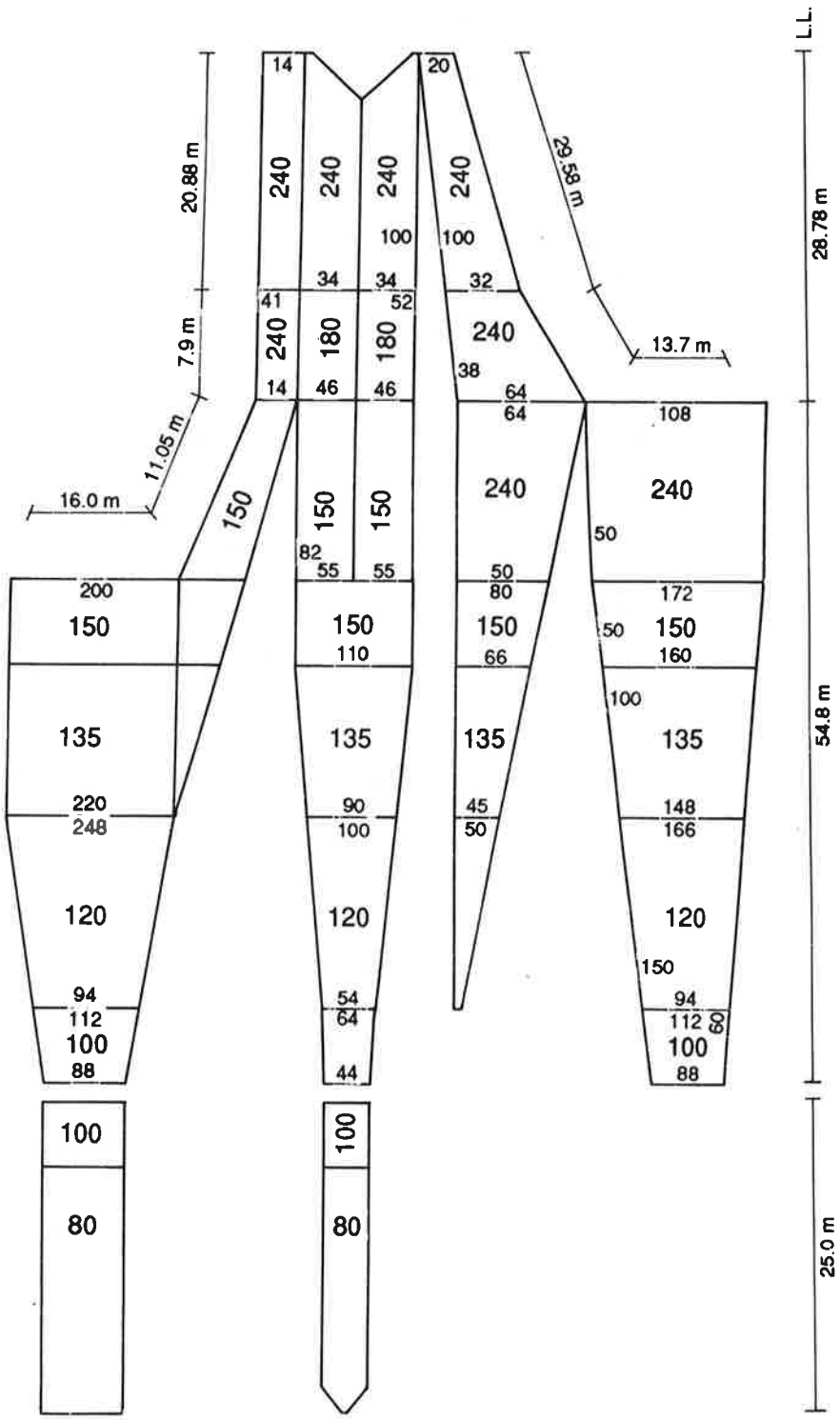
Appendix 1

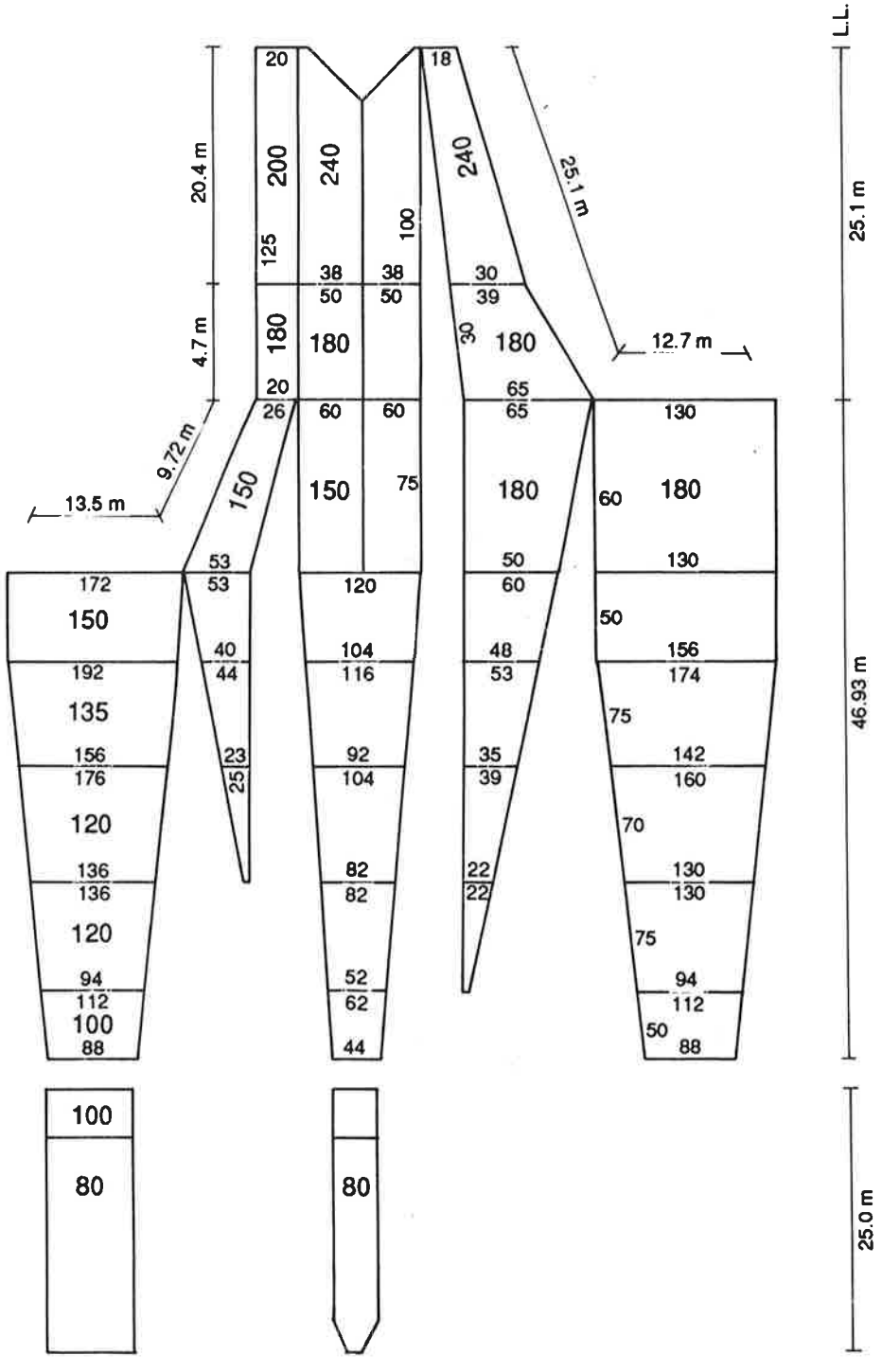
Trawl net plans

(Large figures denote mesh size in terms of "knot to knot" and small figures denote the number of meshes.)

(1) Larger net



(2) Smaller net



Appendix 2

Individual station data*

Station No.	Date	Start time	Start position ° 'S	Start position ° 'E	Start depth (m)	Stratum No.	Tow length (n. mile)	Net width (m)
1	5/6/86	0910	46 22	170 28	225	8	2.2	37.7
2	5/6/86	1630	46 47	169 57	512	10	3.2	34.1
3	6/6/86	0815	47 09	168 53	117	3	2.7	24.9
4	6/6/86	1045	47 05	168 52	110	3	3.2	24.9
5	6/6/86	1330	47 00	169 20	123	3	3.6	24.9
6	7/6/86	0755	47 07	168 33	100	3	2.6	24.9
7	7/6/86	1000	47 07	168 28	100	4	2.8	24.9
8	7/6/86	1200	47 14	168 21	103	4	2.8	24.9
9	7/6/86	1400	47 11	168 12	97	2	3.4	19.7
10	7/6/86	1605	47 02	168 24	81	1	3.3	19.7
11	8/6/86	0800	47 55	168 47	570	10	3.0	34.1
12	8/6/86	1020	47 48	168 56	558	10	3.6	34.1
13	8/6/86	1235	47 39	168 59	472	10	3.0	34.1
14	8/6/86	1426	47 31	169 04	270	8	2.9	37.7
15	8/6/86	1625	47 25	168 58	127	3	3.1	24.9
16	9/6/86	0745	48 11	168 26	335	8	3.4	37.7
17	9/6/86	1000	48 06	168 36	600	10	3.1	34.1
18	9/6/86	1320	48 02	168 20	137	6	3.8	24.9
19	9/6/86	1610	47 53	168 43	317	8	4.0	37.7
20	12/6/86	0840	48 12	168 04	136	6†	2.9	-‡
21	12/6/86	1220	48 00	168 02	137	4†	2.0	-
22	12/6/86	1605	47 59	167 43	140	6†	2.1	-
23	13/6/86	0842	48 14	167 06	148	7	3.1	27.5
24	13/6/86	1115	48 17	166 55	150	7	3.0	27.5
25	13/6/86	1340	48 21	167 00	146	7	3.0	27.5
26	13/6/86	1545	48 22	167 03	144	7	3.2	27.5
27	14/6/86	0900	48 31	167 24	138	6	3.1	27.5
28	14/6/86	1300	48 49	167 25	546	10	3.0	33.4
29	14/6/86	1610	48 38	167 49	494	10	3.0	33.4
30	15/6/86	1020	48 19	166 26	158	7	3.8	27.5
31	15/6/86	1405	48 04	166 37	142	7	2.6	27.5
32	16/6/86	0830	47 47	167 22	145	5	3.0	27.5
33	16/6/86	1230	47 29	167 12	155	5	2.2	27.5
34	16/6/86	1525	47 24	167 00	281	9	3.6	34.4
35	17/6/86	0815	47 28	167 33	142	4	3.0	27.5
36	17/6/86	1055	47 21	167 16	155	5	3.5	27.5
37	17/6/86	1355	47 04	167 25	115	5	3.7	27.5
38	17/6/86	1630	46 51	167 17	201	9†	2.4	-
39	18/6/86	0810	46 16	166 49	96	2	2.8	21.8
40	18/6/86	1005	46 19	166 35	250	9	2.7	34.4
41	18/6/86	1140	46 25	166 39	243	9	2.7	34.4
42	18/6/86	1325	46 28	166 47	163	5	3.1	27.5
43	18/6/86	1547	46 34	166 46	433	11	3.5	33.4
44	19/6/86	1140	46 25	166 30	441	11	3.4	33.4
45	19/6/86	1643	46 26	167 20	80	2†	2.4	-
46	20/6/86	0800	46 47	165 56	276	9	3.0	34.4
47	20/6/86	1055	46 37	166 00	484	11†	3.6	-
48	20/6/86	1308	46 30	166 00	248	9	3.4	34.4
49	20/6/86	1525	46 23	166 00	145	5	3.7	27.5
50	21/6/86	0820	46 31	167 11	132	5	3.2	27.5
51	21/6/86	1120	46 41	166 59	498	11	2.6	33.4
52	22/6/86	1010	47 41	168 00	138	4	3.2	27.5
53	22/6/86	1250	47 34	168 29	128	4	3.7	27.5
54	22/6/86	1530	47 24	168 15	117	4	3.8	27.5
55	23/6/86	0810	46 49	168 59	88	1	3.4	21.8
56	23/6/86	1145	46 48	169 32	116	3	3.0	27.5
57	23/6/86	1400	46 36	169 39	82	1	3.2	21.8
58	23/6/86	1615	46 25	178 00	82	1	3.7	21.8

* Species codes: BAR, barracouta; SPD, spiny dogfish; HOK, hoki; ASQ, arrow squid; SWA, silver warehou; SCH, school shark; LIN, ling; STA, stargazers; RCO, red cod; SKI, gemfish.

† Fouled trawl shot.

‡ No value calculated for wingspread.

Appendix 2—*continued*

Station No.	BAR	SPD	HOK	ASQ	SWA	SCH	LIN	STA	RCO	SKI	Catch (kg) All species
1	7	17	0	4	6	0	13	0	2	0	397
2	0	7	9	18	1	0	107	4	0	0	348
3	1 497	524	0	3	0	52	60	0	0	83	2 336
4	320	458	0	7	5	101	4	25	0	33	1 225
5	1 023	914	0	5	3	91	22	13	48	0	2 898
6	181	229	0	7	2	28	0	109	1	46	788
7	199	439	0	4	1	8	0	41	0	8	847
8	194	200	0	6	0	2	0	95	0	10	673
9	100	426	0	8	1	67	0	19	0	9	942
10	706	671	0	15	10	14	0	169	0	0	1 815
11	0	0	1 754	9	7	0	283	0	0	0	2 640
12	0	0	1 802	18	15	0	683	22	0	0	3 608
13	0	242	27	32	279	0	266	62	3	0	1 039
14	3	69	0	47	214	64	36	31	0	0	480
15	853	785	0	26	42	65	23	27	0	4	1 848
16	3	507	11	181	343	0	266	14	8	41	1 514
17	0	43	102	4	17	0	416	20	0	0	1 157
18	666	552	1	55	0	5	0	4	0	0	1 373
19	11	232	0	1 989	1 683	28	116	21	243	27	4 460
20	708	401	0	40	0	23	0	30	8	15	1 279
21	759	93	0	7	0	14	0	6	12	0	759
22	302	98	0	6	0	5	0	15	0	0	450
23	2 157	227	0	13	0	48	0	11	0	11	2 521
24	3 003	169	0	16	0	84	0	2	12	13	3 338
25	2 161	248	0	18	0	113	0	0	2	2	2 720
26	1 122	301	0	39	0	96	0	2	0	6	1 652
27	284	395	0	57	0	124	6	6	2	0	1 009
28	0	142	770	34	1 320	8	367	49	3	8	2 316
29	0	171	171	30	1 089	0	255	28	0	24	1 910
30	1 327	173	0	34	0	223	0	0	0	41	1 835
31	398	94	0	182	0	167	0	12	0	8	919
32	5 709	576	0	11	0	605	0	24	0	26	7 139
33	1 105	601	0	11	0	243	171	40	0	11	2 404
34	220	12	0	75	239	86	0	373	0	957	2 006
35	3 119	400	0	12	3	83	32	174	0	17	3 975
36	5 340	452	0	25	0	400	5	191	0	29	6 624
37	3 489	105	0	12	6	42	0	205	32	0	4 021
38	5	9	0	73	14	154	0	243	0	51	693
39	683	167	0	32	35	25	0	904	0	0	2 295
40	100	17	0	388	0	158	0	38	0	149	1 224
41	82	13	0	2 002	14	65	0	8	0	677	3 011
42	12	36	0	166	63	197	0	54	0	3	732
43	0	105	3 894	38	12	117	197	227	4	92	5 723
44	0	284	261	61	4	92	461	62	9	54	2 691
45	216	612	0	37	32	47	0	71	0	9	1 466
46	7	3	89	172	650	91	0	47	0	128	1 212
47	0	0	25	28	87	34	60	0	0	23	321
48	37	6	0	1 950	16	318	0	169	0	151	2 672
49	11	19	0	79	0	64	5	80	0	8	419
50	1 050	226	0	41	39	11	0	283	0	0	2 092
51	0	8	629	22	12	9	85	96	0	13	1 287
52	1 073	536	0	6	0	122	9	33	0	39	1 974
53	1 155	290	0	1	0	46	13	15	0	2	1 689
54	494	350	0	8	0	112	14	48	0	0	1 229
55	97	1 565	0	6	2	0	0	33	131	0	2 548
56	211	380	0	2	0	103	4	9	0	4	762
57	183	577	0	3	0	31	3	0	2 244	0	3 316
58	309	2 066	0	4	0	105	35	0	734	0	3 498

Appendix 3

Species taken during the survey

Scientific name	Common name
Agnatha	
Eptatretidae	
Eptatretus cirrhatus	hagfish, blind eel
Chondrichthyes	
Scyliorhinidae	
Cephaloscyllium isabellum	carpet shark
Halaelurus dawsoni	Dawson's catshark
Triakidae	
Mustelus lenticulatus	rig
Gollum attenuatus	slender smoothhound
Squalidae	
Centrophorus squamosus	leafscale gulper dogfish
Deania calceus	shovelnosed dogfish
Etmopterus lucifer	Lucifer spiny dogfish
Scymnorhinus licha	seal shark
Squalus acanthias	spiny dogfish
Carcharhinidae	
Galeorhinus galeus	school shark
Torpedinidae	
Torpedo fairchildi	electric ray
Rajidae	
Pavoraja asperula	smooth deepsea skate
P. spinifera	prickly deepsea skate
Pavoraja sp.	deepsea skate
Raja innominata	smooth skate
R. nasuta	rough skate
Callorhinchidae	
Callorhinchus milii	elephantfish
Chimaeridae	
Hydrolagus novaezelandiae	dark ghost shark
Osteichthyes	
Congridae	
Bassanago hirsutus	hairy conger
Gnathophis habenatus	silver conger
Notacanthidae	
Notacanthus sexspinis	spineback
Argentinidae	
Argentina elongata	silverside
Gadidae	
Micromesistius australis	southern blue whiting
Merlucciidae	
Macruronus novaezelandiae	hoki
Merluccius australis	hake
Moridae	
Mora moro	ribaldo
Pseudophycis bachus	red cod
P. barbata	southern bastard cod
Macrouridae	
Coelorinchus spp.	rattails
Lepidorhynchus denticulatus	javelinfish
Ophidiidae	
Genypterus blacodes	ling
Trachipteridae	
Trachipterus trachypterus	dealfish
Berycidae	
Beryx splendens	alfonsino
Trachichthyidae	
Hoplostethus mediterraneus	silver roughy
Paratrachichthys trailli	common roughy
Zeidae	
Cyttus novaezelandiae	silver dory
C. traversi	lookdown dory
Zeus faber	John dory
Macrorhamphosidae	
Centriscops obliquus	redbanded bellowsfish
Notopogon fernandezianus	bluebanded bellowsfish
N. lilliei	crested bellowsfish
Scorpaenidae	
Helicolenus sp.	sea perch
Congiopodidae	
Congiopodus leucopaecilus	southern pigfish
Hoplichthyidae	
Hoplichthys haswelli	deepsea flathead
Triglidae	
Chelidonichthys kumu	red gurnard
Lepidotrigla brachyoptera	scaly gurnard
Psychrolutidae	
Neophrynichthys angustus	pale toadfish
N. latus	dark toadfish
Percichthyidae	
Polyprion oxygeneios	hapuku
Serranidae	
Caesioperca lepidoptera	butterfly perch
Lepidoperca sp. A	orange perch
Lepidoperca sp. B	wavyline perch
Bramidae	
Brama brama	Ray's bream
Emmelichthyidae	
Emmelichthys nitidus	redbait
Carangidae	
Trachurus declivis	jack mackerel
T. murphyii	jack mackerel
Cheilodactylidae	
Nemadactylus macropterus	tarakihi
Latridae	
Latridopsis ciliaris	blue moki
Latris lineata	trumpeter
Labridae	
Notolabrus miles	scarlet wrasse
N. cinctus	girdled wrasse
Uranoscopidae	
Kathetostoma giganteum	giant stargazer
Kathetostoma sp.	mottled stargazer
Pinguipedidae	
Parapercis colias	blue cod
P. gilliesi	yellow cod
Gempylidae	
Rexea solandri	gemfish, southern kingfish
Thyrsites atun	barracouta
Trichiuridae	
Lepidopus caudatus	frostfish
Centrolophidae	
Centrolophus niger	rudderfish
Hyperoglyphe antarctica	bluenose
Seriolella brama	blue (common) warehou
S. caerulea	white warehou
S. punctata	silver warehou
Bothidae	
Arnoglossus scapha	witch
Pleuronectidae	
Azygopus pinnifasciatus	spotted flounder
Pelotretis flavilatus	lemon sole
Cephalopoda	
Ommastrephidae	
Nototodarus sloanii	arrow squid
Todarodes filippovae	southern arrow squid
Onychoteuthidae	
Moroteuthis ingens	warty squid
Octopodidae	
Octopus maorum	octopus
Crustacea	
Nephropsidae	
Metanephrops challengeri	scampi

Appendix 4

Mean catch rates (kg.km^{-2}) (and standard deviations) of the 10 major species by stratum

Species	Stratum 1	2	3	4	5	6	7	8	9	10	11
Barracouta	2 514	3 428	4 869	6 455	14 617	2 800	10 707	28	445	0	0
	(2 303)	(3 700)	(4 117)	(7 197)	(14 613)	(1 417)	(6 155)	(17)	(362)	(0)	(0)
Spiny dogfish	8 821	2 455	3 783	2 369	1 993	2 828	1 272	855	55	459	631
	(4 521)	(1 383)	(1 531)	(855)	(2 000)	(462)	(438)	(903)	(35)	(521)	(662)
Hoki	0	0	0	0	0	3	0	10	93	3 283	7 717
	(0)	(0)	(0)	(0)	(0)	(3)	(0)	(21)	(207)	(3 907)	(9 000)
Arrow squid	52	176	59	41	300	335	348	2 035	4 826	107	200
	(45)	(155)	(62)	(24)	(355)	(35)	(503)	(3 407)	(5 152)	(66)	(80)
Silver warehou	24	162	59	4	97	0	0	2 141	921	2 093	48
	(41)	(214)	(114)	(7)	(159)	(0)	(0)	(2 659)	(1 452)	(3 072)	(28)
School shark	266	383	504	366	1 646	407	766	104	724	7	345
	(310)	(228)	(172)	(300)	(1 424)	(538)	(372)	(148)	(476)	(14)	(255)
Ling	66	0	138	69	224	17	0	452	0	1 700	1 210
	(114)	(0)	(179)	(079)	(572)	(24)	(0)	(469)	(0)	(772)	(872)
Stargazers	410	4 072	235	455	741	31	31	72	586	138	648
	(669)	(548)	(338)	(403)	(572)	(10)	(40)	(62)	(645)	(121)	(379)
Red cod	5 810	0	48	0	24	7	14	228	0	4	21
	(8 000)	(0)	(117)	(0)	(66)	(10)	(31)	(428)	(0)	(7)	(21)
Gemfish	0	35	224	83	72	0	79	69	2 069	24	255
	(0)	(48)	(266)	(86)	(76)	(0)	(69)	(83)	(1 817)	(48)	(172)

Appendix 5

Estimated doorspread biomass and coefficient of variation (*c.v.*) for the 20 major species

Species	Estimate 1*		Estimate 2*	
	Biomass (t)	*c.v.* (%)	Biomass (t)	*c.v.* (%)
Barracouta	65 236	18	59 893	19
Spiny dogfish	28 530	10	26 580	10
Hoki	6 494	50	6 492	50
Arrow squid	6 483	30	6 217	31
Silver warehou	3 113	31	3 113	31
School shark	6 751	17	6 295	17
Ling	2 656	21	2 641	21
Stargazers	6 259	40	6 187	40
Red cod	4 973	65	4 964	65
Gemfish	2 553	26	2 520	26
Rattails	1 428	17	1 425	17
Javelinfish	1 231	42	1 229	42
Blue warehou	2 002	60	1 977	60
Tarakihi	2 037	44	2 032	44
Hapuku	1 581	18	1 461	18
Smooth skate	1 345	16	1 204	14
Rig	1 246	31	1 056	29
Dark ghost shark	517	43	517	43
Blue cod	1 112	50	1 092	51
Sea perch	488	62	472	64
All species	150 325	10	141 607	10

* Estimate 1, total survey area; estimate 2, survey area minus areas of foul ground in strata 4 and 6.

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