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K. A. Schofield
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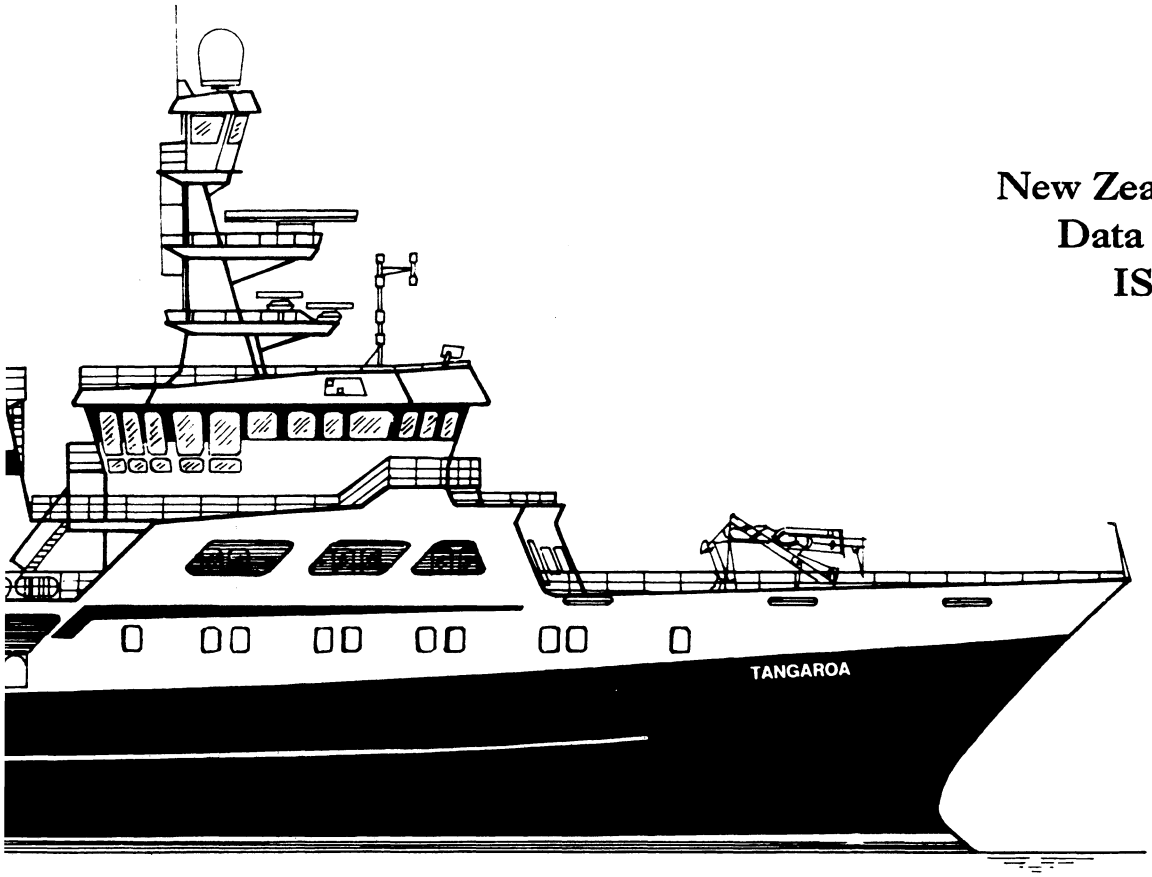

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Contents

Introduction

Hoki (*Macruronus novaezelandiae*) live predominantly around the South Island in depths of 200–800 m. During the summer months they are dispersed widely across the Sub-Antarctic area and Chatham Rise, and in winter they migrate to locations on the west coast of the South Island and near Cook Strait to form dense spawning aggregations. Currently, hoki are assessed as two stocks: a larger western stock comprising fish which spawn on the west coast of the South Island during winter and reside for the rest of the year in the Sub-Antarctic area, and a smaller eastern stock which spawns in Cook Strait in winter and otherwise resides on the Chatham Rise.

Significant quantities of juvenile hoki have been found only on the Chatham Rise. It appears that the larvae and juveniles of both stocks mix on the Chatham Rise until they approach sexual maturity (at about 4–5 years). Thereafter, up to 80% of them recruit to the Sub-Antarctic area and the remainder move to deeper waters on the Chatham Rise.

Random trawl surveys of the Southland and Sub-Antarctic areas in July-August and November-December 1990 confirmed that not all hoki of spawning size leave the area in winter. Up to 40% of adult fish present in summer remained there in winter, and most had undeveloped gonads, i.e., they were not going to spawn that winter (Hurst & Schofield 1991). The same pattern has been observed on the Chatham Rise (Livingston *et al.* 1991). Interpretation is difficult as it is not known whether hoki have a shallow maturity ogive or if they spawn, for example, biennially. The recruitment pattern of hoki to the Sub-Antarctic area is also unknown. As the annual spawning fraction and maturity ogive are critical parameters in the stock reduction model used to estimate biomass of the western hoki stock, a new project to estimate these parameters and the timing of recruitment to the area began in 1991.

A series of trawl surveys of the Southland and Sub-Antarctic areas was carried out to collect data on seasonal changes in hoki numbers at age and gonad development at a histological level. Routine abundance and distribution data were also collected in the following surveys:

Date	Voyage code	Documentation
November-December 1991	TAN9105	Chatterton & Hanchet (1994)
April-May 1992	TAN9204	This report
September-October 1992	TAN9209	Schofield & Livingston (1994a)
November-December 1992	TAN9211	Chatterton & Hanchet (unpublished results)
May-June 1993	TAN9304	Schofield & Livingston (1994b)

Chatterton & Hanchet (1994) listed publications on previous trawl surveys of the Southland and Sub-Antarctic areas, including those by *Wesermünde* in 1979 and *Shinkai Maru* in 1982–83.

This report presents results from the second trawl survey in the time series. Its main purpose is to outline the survey design, methods, and objectives, and to make available biomass, catch, and length frequency data on ITQ and commercially important non-ITQ species which are relevant to stock assessment or other management purposes. Detailed analysis of the maturity ogive, spawning fraction, and cohort numbers of hoki will be presented elsewhere.

Objectives

The main objectives of the research programme are:
1. to estimate the proportion of hoki spawning at age;
2. to estimate the total spawning fraction of hoki;
3. to measure cohort recruitment of hoki.

The specific objectives of the survey were:
1. to collect random hoki gonad samples throughout the survey area for histological analysis;
2. to estimate biomass of hoki and other middle depth species;
3. to collect biological data, including length frequencies and gonad state, and otoliths of hoki and other middle depth species;
4. to define major water mass characteristics by recording sea temperatures at each trawl station;
5. to collect bathymetric data to refine stratum boundaries.

Project and voyage personnel

The voyage was divided into two parts with the same vessel crew (skipper, A. Leachman) and a different scientific crew on each. Project leader: M. Livingston. Part 1 (17 April-3 May): voyage leader, M. Livingston. Part 2 (3–21 May): voyage leader, N. Bagley. Final database editing, K. Schofield.

Methods

Survey area and design

The survey was of a two-phase stratified random trawl design (*after* Francis 1984). Phase 1 was to cover the entire survey area and consist of 100 stations and phase 2 would target strata where hoki recruitment was evident and consist of 20 stations.

The Southland and Sub-Antarctic survey areas are bounded by latitudes 46° S and 54° S and longitudes 165° E and 176° E and divided into 15 strata by depth (300–600 m, 600–800 m) and area (Figure 1). The Bounty Platform was excluded as low catches of hoki had been recorded there in previous surveys (Schofield 1990, Hurst & Schofield 1991). Known areas of foul ground were also excluded from the survey area. The total survey area was 262 952 km^2. The phase 1 stations were allocated in proportion to the area of each stratum, with a minimum of three stations per stratum (Table 1).

Vessel specifications

GRV *Tangaroa* is a purpose-built research stern trawler. It has the following specifications: length overall, 70 m; beam, 14 m; gross tonnage, 2282 t; power, 3000 kW.

Gear specifications

The net was the same as that used for the first in this series of trawl surveys (TAN9105). It was an eight seam bottom trawl net with a 58.8 m groundrope and 45 m headrope. The codend mesh size was 60 mm. The sweeps were 100 m long, bridles 50 m, and backstrops 12 m. Chatterton & Hanchet (1994) fully described the net. The trawl doors were Super-Vee type with an area of 6.1 m^2. Doorspread and wingspread were recorded from the Scanmar system at 10 min intervals during the tow and the average for the tow was calculated. Headline heights were recorded from the Kaijo Denki net monitor, also at 10 min intervals, and the average for the tow was calculated. Gear parameters are given in Table 2.

Trawling procedure

All stations were randomly selected (except those at Puysegur Bank where tow positions from voyage TAN9105 were used) with a minimum distance of 5 km between them. All tows were conducted during daylight hours, so the previous night was spent surveying the next day's towing positions. If a station position fell on foul ground, an alternative station was chosen to replace it. If a station fell outside the depth range for that stratum, then the vessel steamed into shallower or deeper water until the appropriate depth was reached. If time was limiting at the end of the day and it was not possible to steam the full distance to the next station, the vessel headed in the direction of the next tow and shot the trawl in sufficient time to complete the tow before dark. Tows were about 3 n. miles long (mean 2.96 n. miles and made at a speed (over the ground) of 3.5 kn.

Surface temperature

The surface temperature at each station was recorded from the hull-mounted sensor. The calibration of the sensor was uncertain, so surface temperatures should be treated as relative only. Bottom temperatures were not recorded as no Scanmar temperature sensor was available.

Catch and biological sampling

The catch at each station was sorted by species and weighed on motion-compensating electronic scales to the nearest 0.3 kg. Any rare or unusual fish were kept for the Museum of New Zealand collection. Samples of up to 200 hoki and of other commercial species were randomly selected from the catch for length and sex determination. Twenty fish of the main species (hoki, hake, ling, and southern blue whiting) were then randomly selected for more detailed biological analysis. Data recorded included fish length and weight, gonad stage and weight, and stomach fullness, content, and state of digestion. In addition, at alternate stations, a section from the middle of each gonad weighed was taken and preserved in formalin for histological study. Otoliths were collected from hoki, ling, hake, and southern blue whiting for ageing studies.

Data analysis

Doorspread biomass was estimated using the area-swept method as described by Francis (1984, 1989). Vertical and areal availability and vulnerability were assumed to have a value of 1.0 for all species biomass calculations. Mean values for doorspread are shown in Table 2. The default values used in the Trawlsurvey Analysis Program were 125.8 m for doorspread and 3.5 kn for tow speed. Only the 90 tows with satisfactory gear performance (codes 1 and 2) were used for analyses.

Scaled length frequencies were calculated using the MAF Fisheries Trawlsurvey Analysis Program (version as at August 1993). This program scales length frequency data from each station by the percentage of catch sampled and the area swept, and further scales these values by the stratum area and the ratio of calculated catch biomass to calculated length frequency biomass in order to represent the total stratum population. On each length frequency figure is an estimate of the population number and its coefficient of variation and the number of tows sampled.

Results

Area sampled

Bad weather and a rescue operation at Campbell Island led to 3.5 days of survey time being lost. Short daylight hours and steaming distances resulted in only 90 successful stations being completed and phase 2 being dropped. However, the entire survey area was covered (Table 1, Figure 1). A detailed summary of station data is given in Appendix 1.

Catch

A list of all species caught during the survey, their species codes, and the number of stations at which each occurred is given in Appendix 2.

Biomass estimates

Biomass and catch of the 22 most abundant species are given in Table 3. The total catch for the survey was 45 098 kg and the biomass of all species combined was estimated to be 181 391 t. Hoki and ling were caught at every station and made up 38% and 23% of the total biomass, respectively. Hake were caught at 48 of the 90 stations and made up 3% of the total biomass, and southern blue whiting were caught at half the stations and made up 5% of the total biomass. Total biomass and *c.v.*s by stratum for the 10 most abundant species are given in Table 4.

Catch rates

Catch rates ($kg.km^{-2}$) and standard deviations by stratum of the 10 most abundant species are presented in Table 5.

Hoki catch rates were highest in the western half of the survey area, as were those of hake, particularly in the 600–800 m stratum. Ling were evenly distributed over the entire survey area. Southern blue whiting were absent from the western half of the survey area and the highest catch rate was in stratum 14.

The catch rates at each station for hoki, ling, hake, and southern blue whiting are given in Figures 2a–2d. To allow for easy comparison of catch rates between surveys, the maximum catch rate in the key of each figure is the maximum catch rate for that species in any of the following surveys: the survey described in this report (TAN9204), TAN9209 (September-October 1992), or TAN9304 (May-June 1993).

The distributions of hoki, ling, hake, and southern blue whiting were similar in all three surveys, but catch rates were higher in the two May surveys than in the September-October 1992 survey (Schofield & Livingston 1994a).

Surface temperatures

Surface temperatures decreased from 12 °C on Puysegur Bank to 7.5 °C on the southeastern Campbell Plateau (Figure 3).

Length frequencies and biological data

The numbers of samples taken and fish measured are given in Table 6. Length-weight relationships for both sexes of hoki, ling, hake, and southern blue whiting are given in Table 7 and the length-weight relationships used for the scaling of length frequency data in Table 8.

Length frequencies of southern blue whiting are shown by the stock areas used in the 1993 stock assessment, i.e., Pukaki Rise (strata 1–8, 11, 12) and the Campbell Island area (strata 9, 10, 13–15).

Hoki had three length frequency modes: at 45–47 cm, at 70–75 cm (representing the 1987 year class), and at either 82–87 cm for females or 77–82 for males (Figure 4a). The smallest mode represents fish caught from Puysegur (strata 1 and 2) and the larger modes represent fish caught over the rest of the survey area (Figure 4b). Southern blue whiting on the Campbell Island Rise showed clear modes at 31–32, 38–40, and 43–46 cm. Only the last two modes were present, in smaller numbers, on the Pukaki Rise (Figure 4c). Ling and hake length frequency modes are difficult to interpret (Figures 4d–4e) and may need to be examined by individual strata. The dominant mode for male arrow squid was 32–34 cm and for females 33–37 cm (Figure 4f). Lookdown dory showed no clear modes (Figure 4f).

Table 9 summarises the spawning condition and gonadosomatic indices for hoki, hake, ling, and southern blue whiting. Hoki were mainly in the resting stage of gonad development, though some were beginning to mature for winter spawning. Female hake were mainly

maturing, some were already spent, and the males were most often running ripe. Ling were mainly resting, but a few females and 65% of the males were maturing. Southern blue whiting were also resting or beginning to mature for the spawning season.

Discussion

The main objectives of the survey were met. Comparison of the recruited (> 65 cm TL) hoki biomass of 66 000 t (*c.v.* = 8%) with the late spring estimate of 74 000 t (*c.v.* = 6%) (Chatterton & Hanchet 1994) suggests that most hoki were still present in the survey area and had not left to spawn on the west coast of the South Island. A comparison of length frequencies between this survey and the late spring-summer surveys of the Sub-Antarctic (TAN9105) and Chatham Rise (TAN9106) (*see* Chatterton *et al.* 1993), showed that the 1988 year class present on the Chatham Rise had not yet recruited to the Sub-Antarctic area.

Acknowledgments

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Table 1: Stratum areas, number of stations, and station densities*

Stratum		Depth (m)	Area (km^2)	No. of stations P	No. of stations A	Station density (per km^2)
1	Puysegur Bank	300–600	2 150	3	2	1:1 075
2	Puysegur Bank	600–800	798	3	3	1:266
3	Stewart-Snares Shelf	300–600	5 130	3	3	1:1 710
4	Stewart-Snares Shelf	600–800	20 727	6	5	1:4 145
5	Snares-Auckland Is	600–800	6 279	3	3	1:2 093
6	Auckland Is Shelf	300–600	16 767	6	6	1:2 795
7	Auckland Is Shelf	600–800	8 372	4	4	1:2 093
8	West Pukaki Rise	600–800	17 349	10	7	1:2 478
9	West Campbell Plateau	300–600	27 359	10	9	1:3 040
10	West Campbell Plateau	600–800	11 145	8	7	1:1 592
11	Central Pukaki Rise	600–800	23 121	8	6	1:3 854
12	Central Pukaki Rise	300–600	45 227	14	11	1:3 769
13	NE Campbell Plateau	300–600	36 090	6	7	1:5 156
14	East Campbell Plateau	300–600	27 404	10	12	1:2 284
15	East Campbell Plateau	600–800	15 034	6	5	1:3 007
	Total		262 952	100	90	1:2 922

* P = number of planned phase 1 stations.
A = number of achieved phase 1 stations with satisfactory gear performance.

Table 2: Gear parameters*

	Depth (m)		
	300–800	300–600	600–800
Mean headline height (m)	6.5	6.5	6.6
Mean doorspread (DS) (m)	125.8	124.7	127.2
Mean wingspread (WS) (m)	27.4	27.5	27.3
Ratio DS:WS	4.6:1	4.5:1	4.7:1
Sweep angle (°)	17.0	16.9	17.3
Mean tow length (n. mile)	2.96		
Mean tow speed (kn)	3.5		

* Doorspread and wingspread were measured by Scanmar measuring gear. Doorspread was measured at 80 stations and wingspread at 14.

Table 3: Total biomass estimates, *c.v.*, and catch of the major species*

	Biomass (t)	*c.v.* (%)	% of total	Catch (kg)	% of total	Occ.
ITQ species						
Hoki	67 832	8.3	37	17 421	39	90
Hoki (≥ 65 cm)	65 606	8.5	36			
Hoki (≥ 55 cm)	66 967	8.4	37			
Ling	42 334	5.8	23	7 051	16	90
Hake	5 028	14.8	3	1 534	3	48
Arrow squid	2 563	80.2	1	648	1	33
Giant stargazer	365	45.9	0.2	146	0.3	8
Smooth oreo	–	–	–	27	0.1	4
Silver warehou	–	–	–	29	0.1	6
Red cod	–	–	–	19	0	4
Black oreo	–	–	–	11	0	2
Gemfish	–	–	–	29	0.1	2
Bluenose	–	–	–	13	0	2
Orange roughy	–	–	–	3	0	2
Non-ITQ species						
Javelinfish	17 961	10.5	10	4 153	9	87
Pale ghost shark	10 531	9.5	6	2 284	5	79
Southern blue whiting	8 863	43.6	5	2 154	5	45
Other rattails	7 558	–	4	1 835	4	–
Dark ghost shark	3 741	48.6	2	872	2	9
Silverside	1 453	17.1	1	281	1	45
Lookdown dory	1 154	40.0	1	230	1	33
Spiky dogfish	926	29.9	1	262	1	29
Ribaldo	768	17.1	0.4	347	1	34
Shovelnosed dogfish	519	29.2	0.3	734	2	9
White warehou	–	–	–	48	0.1	14
Total	181 391	5.6		45 098		

* Occ. = number of stations where species occurred.
– = not calculated.

Table 4: Biomass (t) and coefficients of variation (%) (in parentheses) of the 10 most abundant species by stratum*

Stratum	Species code HOK	LIN	JAV	GSP	SBW	HAK	GSH	NOS	SSI	LDO
1	1 198	109	13	21	0	0	23	4	0	6
	(30)	(39)	(55)	(100)			(100)	(100)		(66)
2	631	55	103	1	0	32	1	2	0	1
	(41)	(38)	(21)	(100)		(16)	(100)	(31)		(100)
3	681	1 207	314	0	0	163	0	272	3	49
	(33)	(71)	(70)			(54)		(91)	(100)	(80)
4	8 513	1 352	2 152	971	0	595	0	21	4	19
	(42)	(39)	(17)	(17)		(31)		(72)	(100)	(100)
5	2 873	749	631	811	0	590	0	0	0	0
	(15)	(16)	(18)	(12)		(26)				
6	4 593	2 732	686	1 005	1	660	3 451	2 069	13	74
	(42)	(12)	(29)	(75)	(100)	(40)	(52)	(99)	(49)	(51)
7	2 082	970	437	278	0	33	0	21	0	0
	(19)	(24)	(22)	(53)		(100)		(48)		
8	7 087	1 715	1 309	559	3	1 011	0	5	0	0
	(25)	(10)	(46)	(34)	(100)	(42)		(100)		
9	7 944	5 465	1 014	1 218	46	323	0	48	388	30
	(17)	(13)	(31)	(19)	(33)	(56)		(36)	(26)	(49)
10	4 311	1 014	775	203	0	196	2	8	0	0
	(26)	(29)	(20)	(21)		(35)	(100)	(69)		
11	6 141	2 401	2 120	862	356	765	0	0	0	506
	(24)	(18)	(22)	(26)	(58)	(51)				(86)
12	4 320	7 266	2 072	1 880	2 538	189	169	0	174	399
	(19)	(12)	(22)	(16)	(68)	(53)	(100)		(32)	(35)
13	8 677	8 484	3 223	1 713	741	277	0	43	625	16
	(16)	(19)	(33)	(19)	(63)	(69)		(75)	(34)	(58)
14	5 458	6 312	1 556	723	5 133	154	95	63	243	55
	(24)	(9)	(25)	(24)	(67)	(45)	(100)	(41)	(20)	(51)
15	3 323	2 502	1 556	287	44	40	0	8	4	0
	(41)	(17)	(68)	(28)	(49)	(100)		(100)	(100)	
Total	67 832	42 334	17 961	10 531	8 863	5 028	3 741	2 563	1 454	1 154

* Species codes are given in Appendix 2.

Table 5: Catch rates (kg.km^{-2}) and standard deviations (in parentheses) of the 10 most abundant species by stratum*

	Species code									
Stratum	HOK	LIN	JAV	GSP	SBW	HAK	GSH	NOS	SSI	LDO
1	557.5	50.6	6.0	9.9	0.0	0.0	10.9	1.9	0.0	2.6
	(235.1)	(27.8)	(4.7)	(14.0)			(15.4)	(2.6)		(2.4)
2	790.6	69.5	129.3	1.0	0.0	40.7	0.9	2.8	0.0	1.3
	(563.7)	(45.7)	(46.2)	(1.7)		(11.3)	(1.5)	(1.5)		(2.2)
3	132.7	235.3	61.1	0.0	0.0	31.7	0.0	53.1	0.5	9.6
	(75.4)	(289.4)	(74.3)			(29.9)		(83.3)	(0.9)	(13.4)
4	410.7	65.2	103.8	46.9	0.0	28.7	0.0	1.0	0.2	0.9
	(389.8)	(57.4)	(38.5)	(18.0)		(19.7)		(1.7)	(0.4)	(2.1)
5	457.6	119.3	100.5	129.2	0.0	94.0	0.0	0.0	0.0	0.0
	(119.0)	(32.5)	(32.0)	(27.9)		(41.7)				
6	274.0	162.9	40.9	59.9	0.1	39.4	205.8	123.4	0.8	4.4
	(283.9)	(49.7)	(29.5)	(109.6)	(0.1)	(38.1)	(264.0)	(298.2)	(0.9)	(5.5)
7	248.7	115.9	52.2	33.2	0.0	4.0	0.0	2.5	0.0	0.0
	(95.9)	(54.7)	(23.0)	(35.1)		(7.9)		(2.4)		
8	408.5	98.8	75.5	32.2	0.2	58.3	0.0	0.3	0.0	0.0
	(265.7)	(27.4)	(92.5)	(28.7)	(0.4)	(64.9)		(0.7)		
9	290.4	199.8	37.1	44.5	1.7	11.8	0.0	1.7	14.2	1.1
	(149.5)	(78.1)	(34.8)	(25.5)	(1.7)	(19.7)		(1.9)	(11.0)	(1.6)
10	386.8	91.0	69.5	18.2	0.0	17.6	0.2	0.7	0.0	0.0
	(262.1)	(70.3)	(36.6)	(10.3)		(16.4)	(0.5)	(1.3)		
11	265.6	103.8	91.7	37.3	15.4	33.1	0.0	0.0	0.0	21.874
	(157.3)	(46.2)	(48.6)	(23.8)	(21.9)	(41.3)				(46.2)
12	95.5	160.7	45.8	41.6	56.1	4.2	3.7	0.0	3.8	8.8
	(59.1)	(64.3)	(32.7)	(22.7)	(127.2)	(7.3)	(12.4)		(4.1)	(10.1)
13	240.4	235.1	89.3	47.5	20.5	7.7	0.0	1.2	17.3	0.4
	(101.2)	(121.1)	(78.6)	(24.0)	(34.0)	(14.0)		(2.4)	(15.7)	(0.7)
14	199.2	230.3	56.8	26.4	187.3	5.6	3.5	2.3	8.9	2.0
	(167.2)	(71.1)	(49.7)	(22.0)	(432.2)	(8.7)	(12.0)	(3.3)	(6.0)	(3.5)
15	221.0	166.5	103.5	19.1	2.9	2.7	0.0	0.5	0.3	0.0
	(203.2)	(62.0)	(157.9)	(12.0)	(3.2)	(6.0)		(1.2)	(0.6)	

* Species codes are given in Appendix 2.

Table 6: Numbers of samples (*n*) and fish measured*

	Length frequency sample				Biological samples	
		No. of fish				No. of
	n	Total	Males	Females	*n*	fish
Hoki	90	9 913	4 097	5 777	90	1 756
Ling	90	3 068	1 570	1 498	48	774
Southern blue whiting	44	1 468	707	758	15	286
Hake	48	175	60	113	46	170
Orange roughy	1	1	1	0	1	1
Arrow squid	31	250	126	120		
Lookdown dory	20	104	39	62		
Giant stargazer	8	39	10	29		
Ribaldo	14	35	0	35		
Black oreo	2	30	8	22		
White warehou	13	29	15	14		
Spiky dogfish	12	20	4	16		
Smooth oreo	4	19	4	12		
Silver warehou	6	13	8	5		
Red cod	4	11	2	9		
Gemfish	2	7	2	5		
Bluenose	2	3	0	3		

* Biological samples are those where fish were examined in detail to obtain information on length-weight relationships, reproductive condition, and diet.

Table 7: Length-weight relationships (log-log regression) for hoki, ling, hake, and southern blue whiting by sex

		Length (cm)			Weight (g)				
	n	Mean	*s.d.*	Range	Mean	*s.d.*	Range	Regression	*r*
Hoki									
Males	612	75.96	8.37	46–94	1 439	432	315–2 925	$W = 0.00928 \times L^{2.75}$	93.2
Females	1 125	81.84	9.65	29–106	1 768	564	105–3 840	$W = 0.00723 \times L^{2.81}$	94.0
All fish	1 737	79.75	9.68	29–106	1 653	548	105–3 840	$W = 0.00807 \times L^{2.78}$	94.2
Ling									
Males	429	81.30	8.05	47–108	2 668	754	470– 6 410	$W = 0.00295 \times L^{3.11}$	95.0
Females	339	88.32	12.34	43–131	3 680	1 913	350–14 200	$W = 0.00109 \times L^{3.34}$	96.2
All fish	768	84.40	10.76	43–131	3 115	1 478	350–14 200	$W = 0.00165 \times L^{3.24}$	96.0
Hake									
Males	60	84.49	9.21	58–100	4 420	1 319	1 295– 7 035	$W = 0.00426 \times L^{3.11}$	93.7
Females	107	99.35	17.37	62–127	8 662	4 209	1 565–17 900	$W = 0.00132 \times L^{3.39}$	97.3
All fish	167	94.01	16.55	58–127	7 138	4 013	1 295–17 900	$W = 0.00125 \times L^{3.40}$	97.1
Southern blue whiting									
Males	111	42.52	5.61	30–52	613	252	175–1,140	$W = 0.00129 \times L^{3.47}$	98.2
Females	175	45.77	6.00	30–55	786	320	165–1,470	$W = 0.00132 \times L^{3.46}$	97.4
All fish	286	44.51	6.05	30–55	719	307	165–1,470	$W = 0.00135 \times L^{3.45}$	97.8

Table 8: Measurement methods and length-weight relationships (log-log regression) used in scaled length frequency analyses*

Species code	Method	Regression coefficients				Range (cm)	Data source
		a	*b*	*r*	*n*		
HOK	TL	0.00807	2.78	0.942	1 737	29–106	TAN9204
HAK	TL	0.00125	3.40	0.971	167	58–127	TAN9204
LDO	TL	0.03133	2.88	-	20	12–56	SHI8301
LIN	TL	0.00165	3.24	0.960	768	43–131	TAN9204
NOS	ML	0.02900	3.00	-	-	>2	Mattlin *et al.* (1985)
SBW	FL	0.00135	3.45	0.978	286	30–55	TAN9204

* Species codes are given in Appendix 2.
Measurement methods: TL, total length; ML, mantle length; FL, fork length.
- = not known.

Table 9: Spawning condition of hoki, ling, hake, and southern blue whiting*

Gonad stage		Males					Females				
		n	Length (cm)	Weight (g)	Gonad weight (g)	*GSI* (%)	*n*	Length (cm)	Weight (g)	Gonad weight (g)	*GSI* (%)
Hoki											
1	mean	40	66	953	2.35	0.25	14	50	425	1.56	0.37
	s.d.		(9)	(305)	(2.50)			(6)	(149)	(1.67)	
2	mean	280	73	1 275	4.85	0.38	743	81	1 629	12.76	0.78
	s.d.		(7)	(340)	(4.56)			(9)	(485)	(7.10)	
3	mean	263	81	1 711	10.48	0.61	323	87	2 167	26.26	1.21
	s.d.		(6)	(352)	(6.78)			(6)	(462)	(10.99)	
4	mean	6	82	1 772	25.00	1.41	0	–	–	–	–
	s.d.		(8)	(438)	(16.19)			–	–	–	
5	mean	0	–	–	–	–	1	89	2 265	–	–
	s.d.		–	–	–			–	–		
Ling											
1	mean	17	63	1 219	7.10	0.58	7	63	1 160	2.67	0.23
	s.d.		(11)	(644)	(8.08)			(11)	(543)	(2.08)	
2	mean	135	80	2 496	10.51	0.42	307	88	3 669	32.46	0.88
	s.d.		(8)	(762)	(6.18)			(12)	(1 887)	(18.70)	
3	mean	153	84	2 865	14.37	0.50	23	97	4 813	42.65	0.89
	s.d.		(6)	(632)	(6.95)			(11)	(2 256)	(23.28)	
4	mean	125	83	2 808	12.23	0.44	0	–	–	–	–
	s.d.		(7)	(638)	(6.76)			–	–	–	
Hake											
2	mean	7	66	1 981	6.29	0.32	23	77	3 587	42.1	1.17
	s.d.		(6)	(536)	(4.86)			(16)	(2 435)	(50.4)	
3	mean	1	75	2 765	23.0	0.83	65	105	9 780	216.6	2.21
	s.d.		–	–	–			(11)	(3 399)	(115.1)	
4	mean	6	92	5 397	154.5	2.86	2	114	11 950	930.0	7.78
	s.d.		(5)	(1 021)	(84.3)			(11)	(3 180)	(311.0)	
5	mean	43	87	4 778	242.8	5.08	1	117	14 400	200.0	1.39
	s.d.		(5)	(868)	(130.6)			–	–	–	
6	mean	1	94	4 660	89.0	1.91	5	108	10 863	235.8	2.17
	s.d.		–	–	–			(10)	(3 803)	(62.2)	
7	mean	0	–	–	–	–	9	112	11 244	248.2	2.21
	s.d.		–	–	–			(8)	(2 806)	(73.3)	
Southern blue whiting											
1	mean	3	32	200	–	–	7	32	207	–	–
	s.d.		(1)	(22)		(1)		(25)	–		
2	mean	29	37	393	5.0	0.15	102	46	792	9.68	1.22
	s.d.		(5)	(197)	–			(6)	(339)	(4.74)	
3	mean	77	45	712	12.27	1.72	65	47	843	11.59	1.37
	s.d.		(4)	(206)	(6.59)			(4)	(237)	(4.83)	
4	mean	1	45	685	9.0	1.31	0	–	–	–	–
	s.d.		–	–	–			–	–	–	

* *GSI* (gonadosomatic index) = (gonad weight/total weight) x 100.
Gonad stage scale: 1 = immature; 2 = resting; 3 = maturing; 4 = hyaline; 5 = ripe; 6 = semi-spent; 7 = spent.

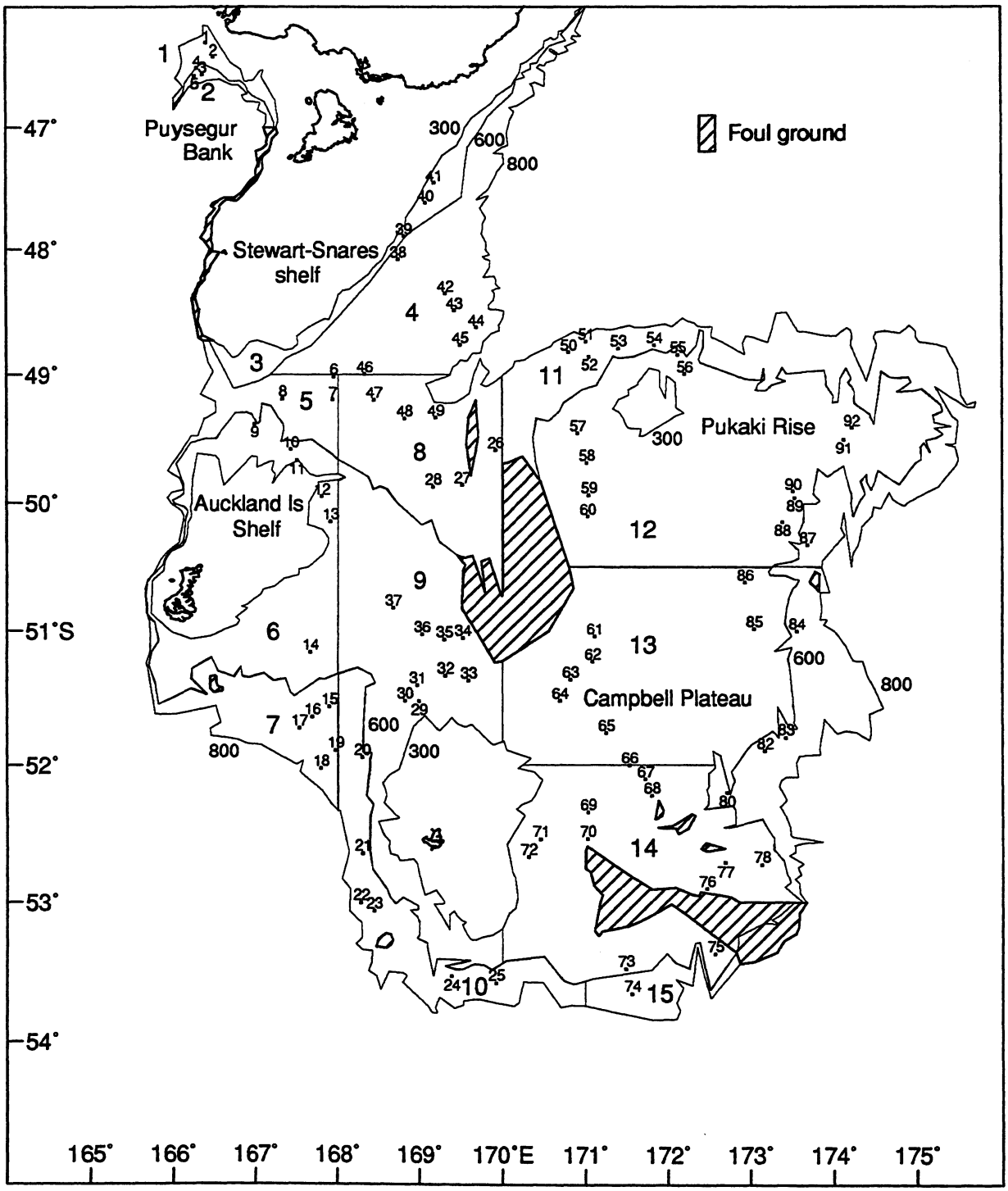

Figure 1: Survey area showing strata boundaries, station positions, and bathymetry.

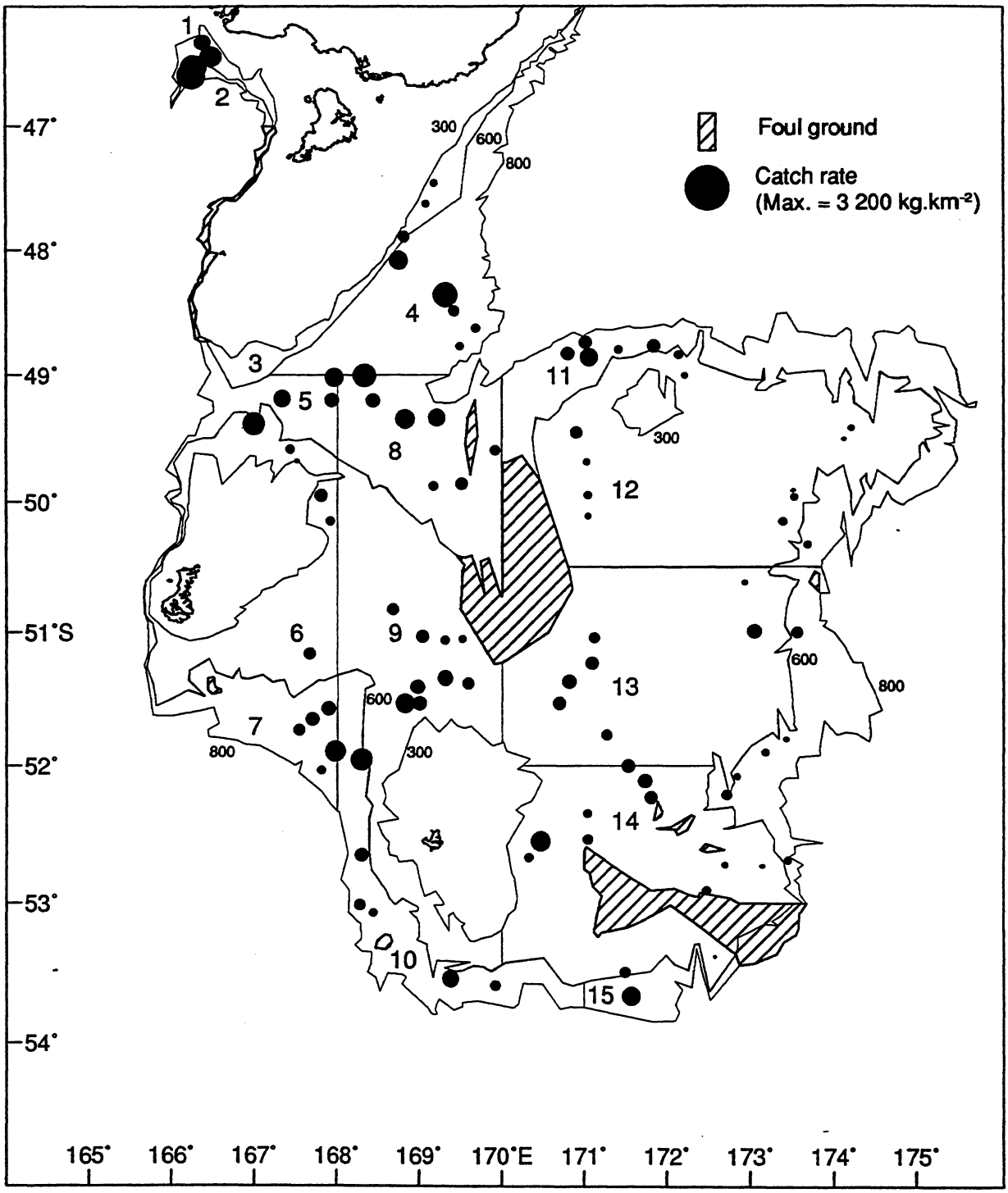

Figure 2a: Catch rates of hoki.

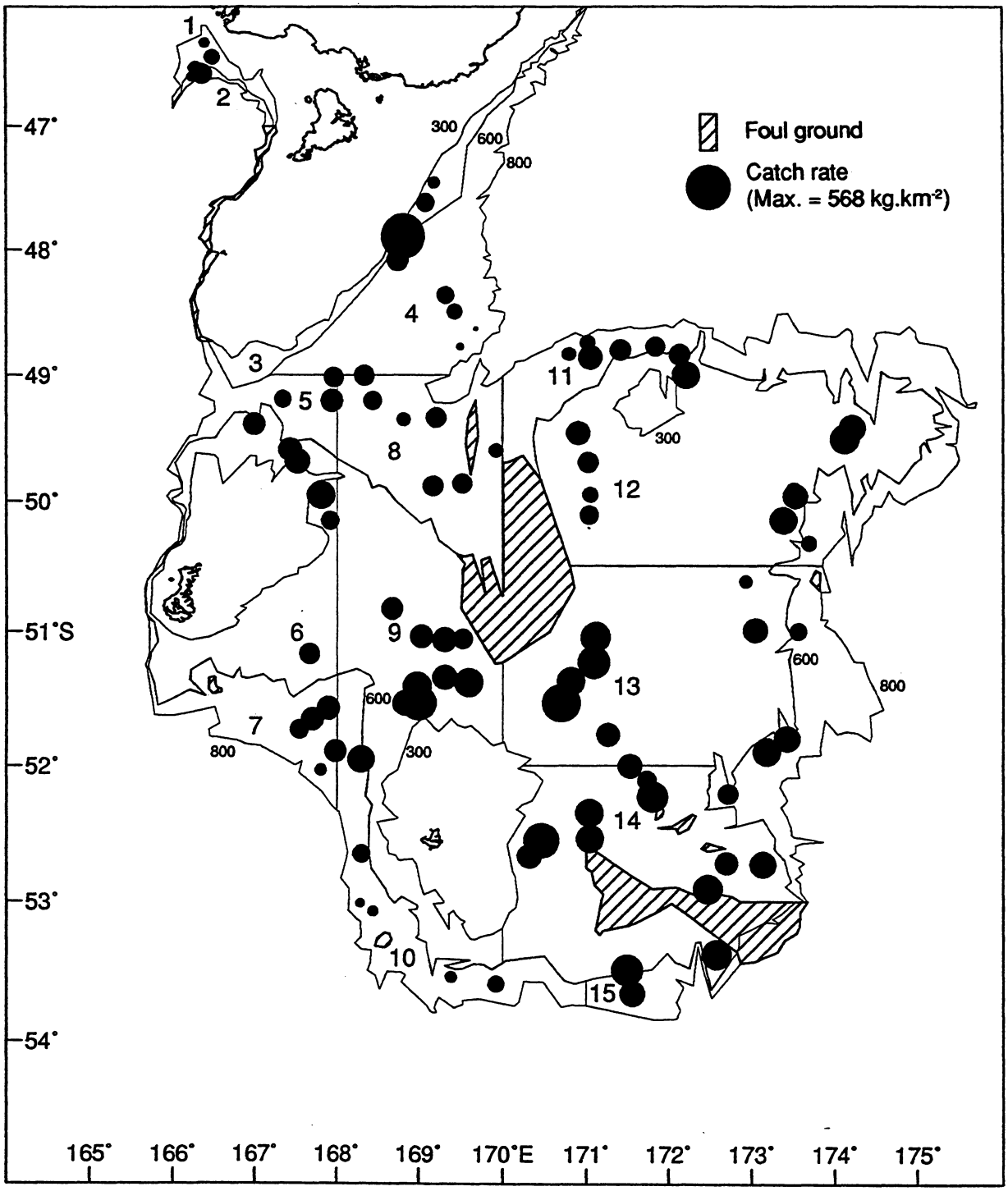

Figure 2b: Catch rates of ling.

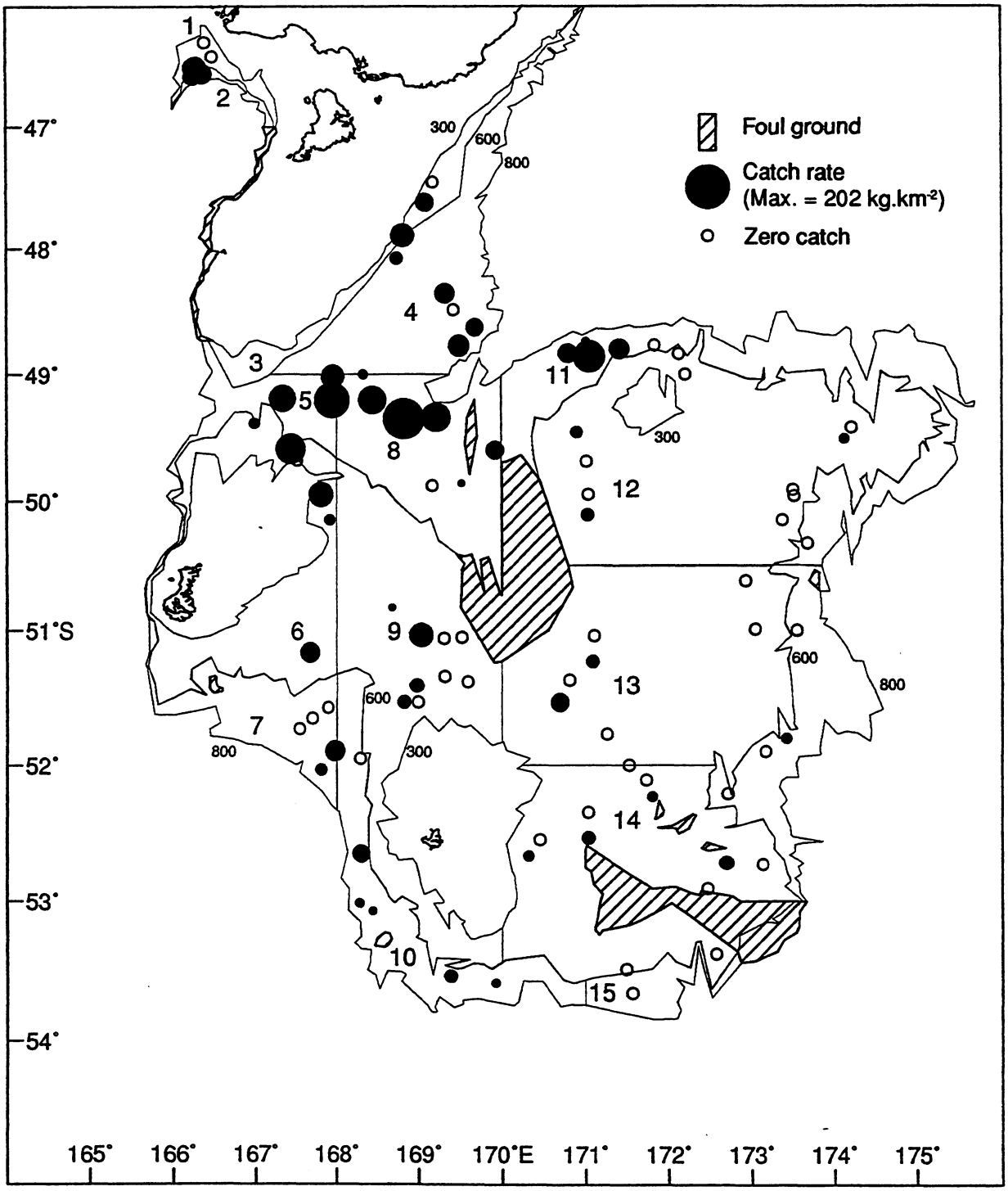

Figure 2c: Catch rates of hake.

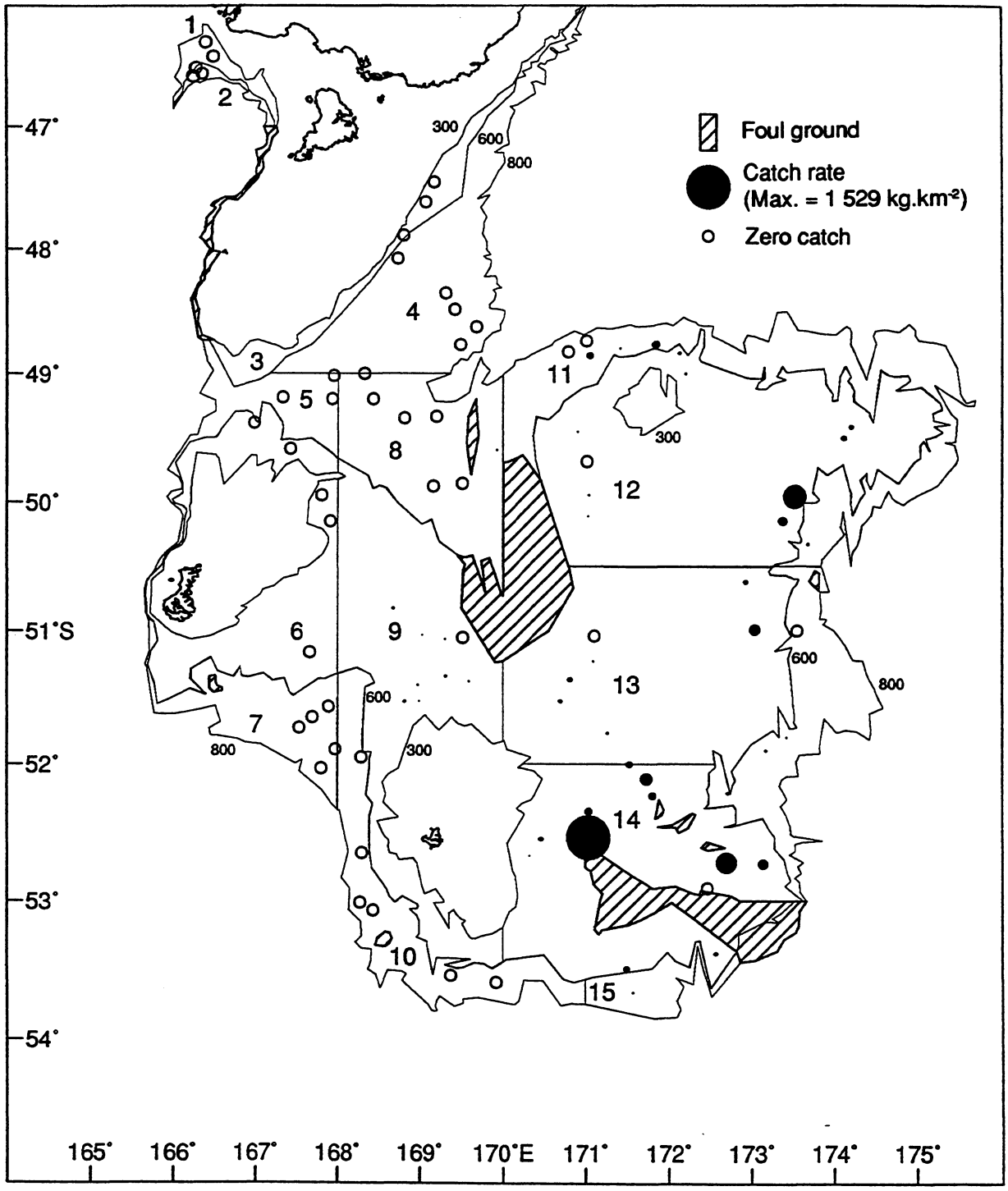

Figure 2d: Catch rates of southern blue whiting.

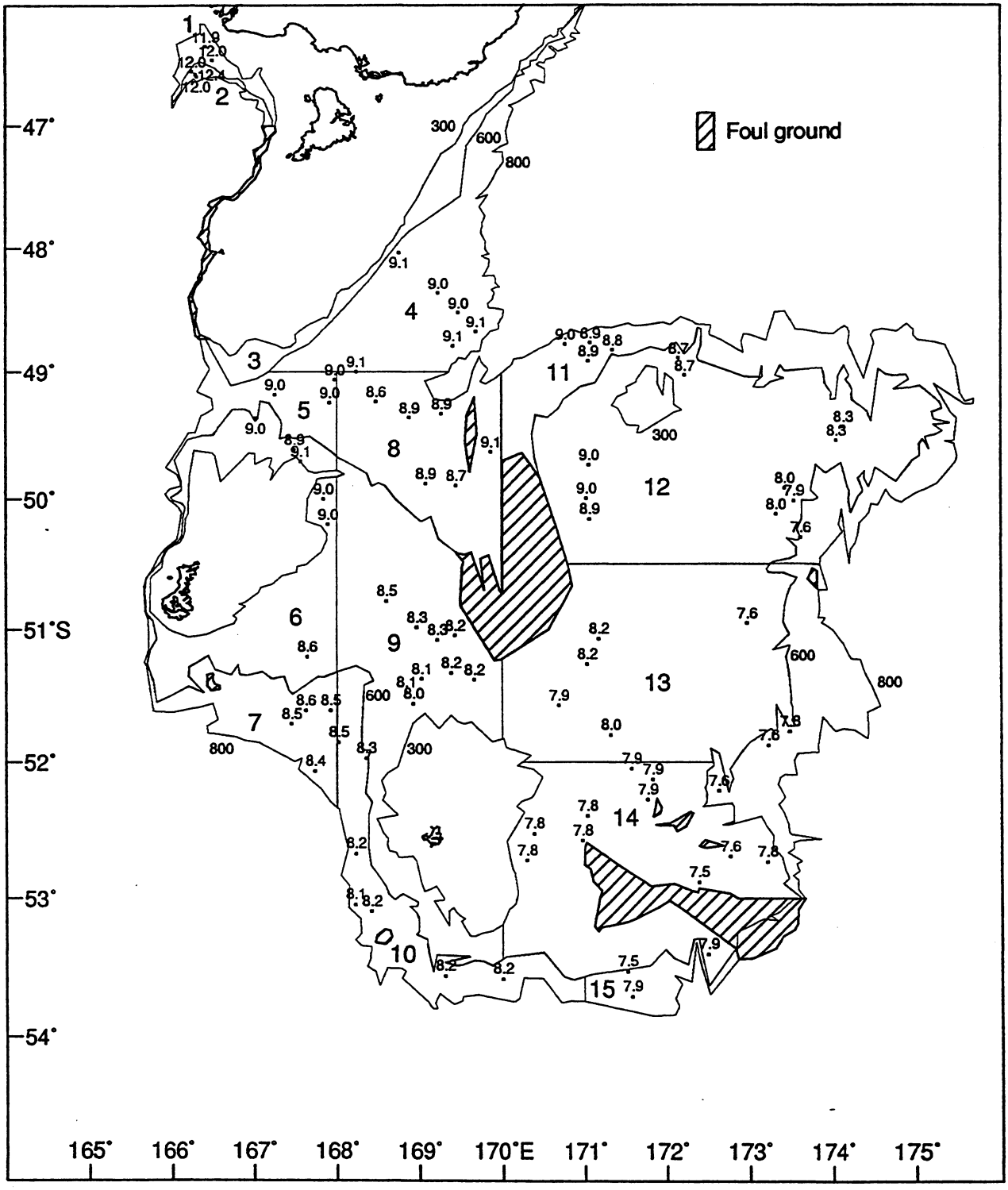

Figure 3: Surface temperatures (°C).

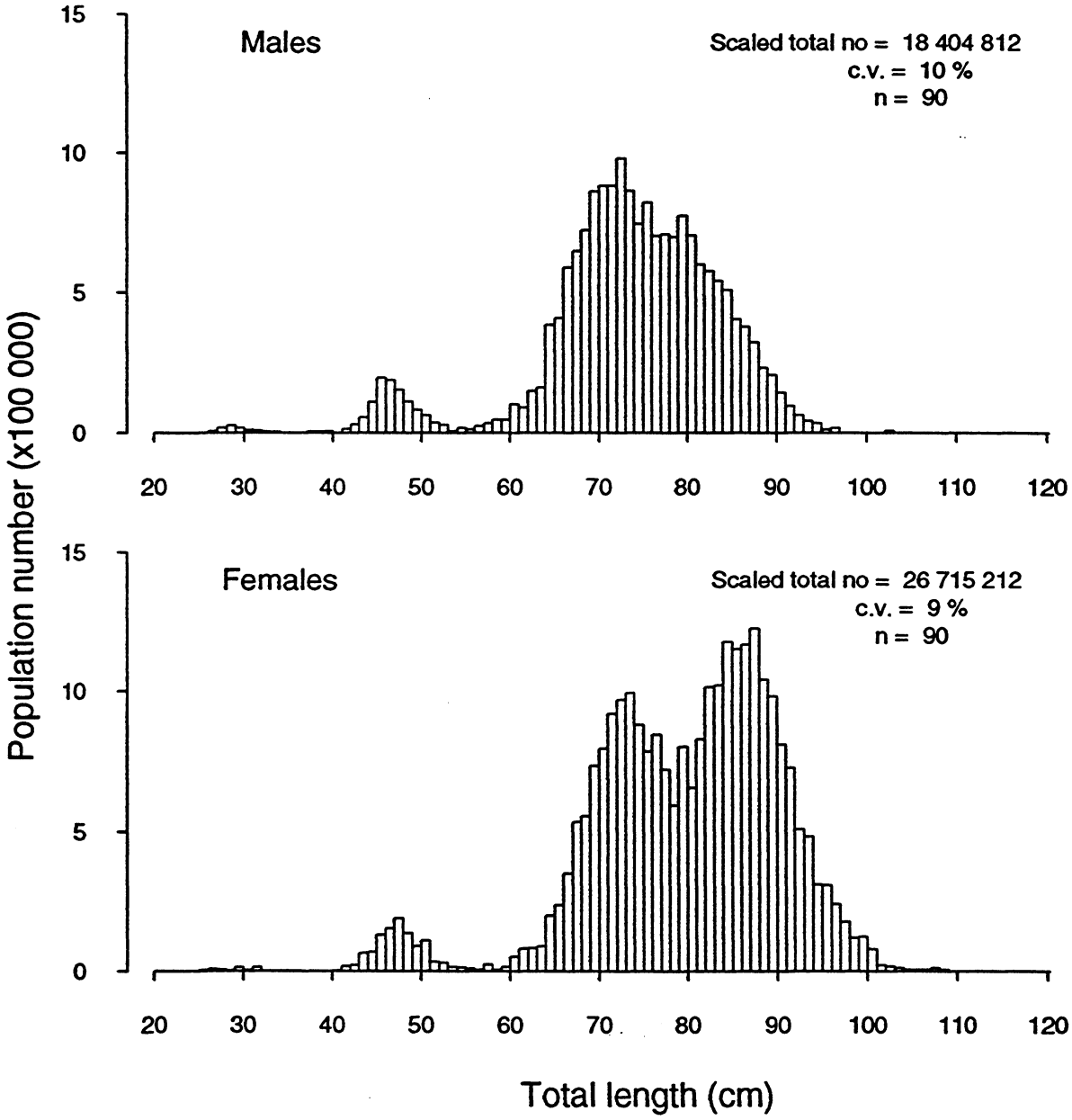

Figure 4a: Scaled length frequencies of male and female hoki for the total survey area.

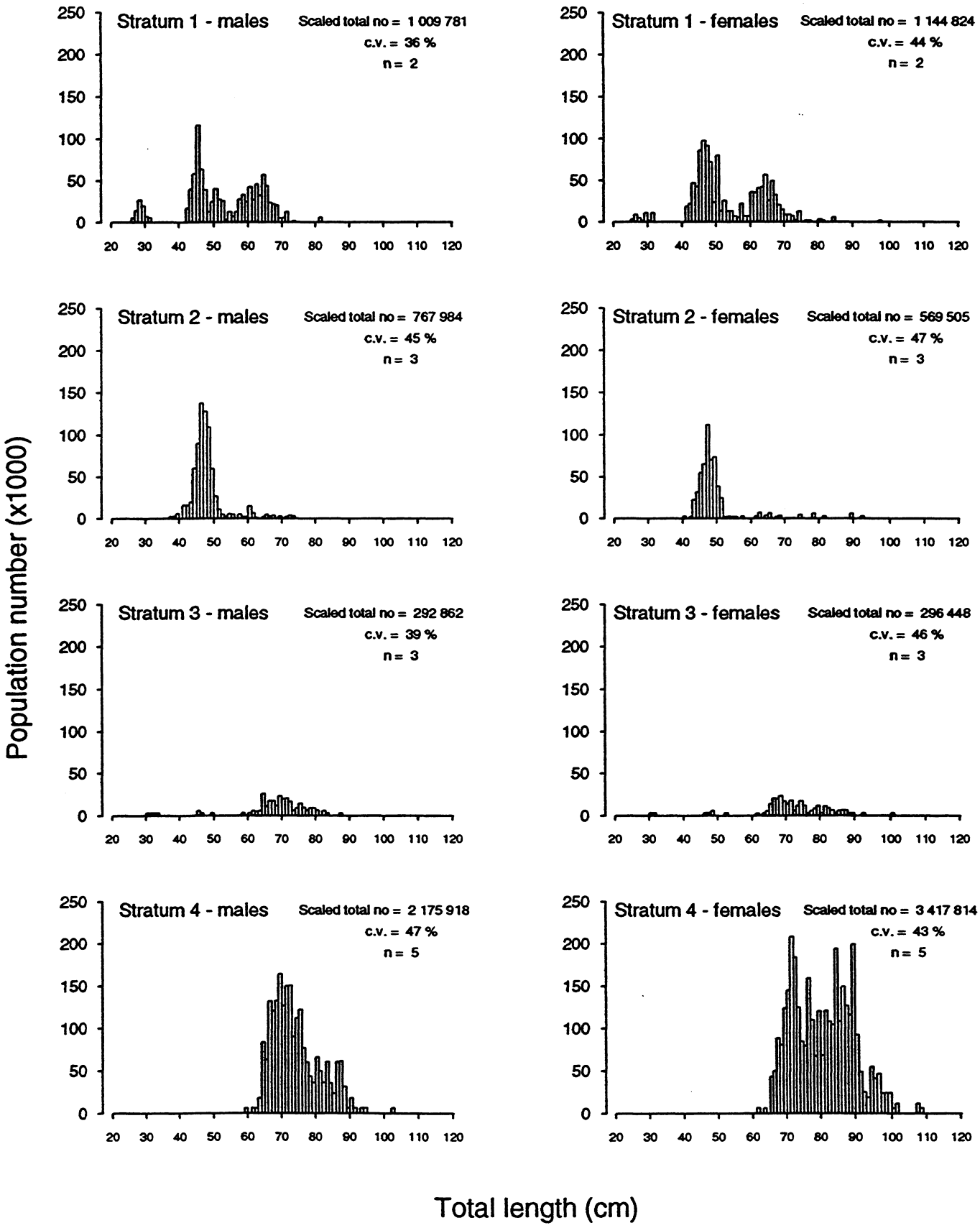

Figure 4b: Scaled length frequencies of male and female hoki by stratum.

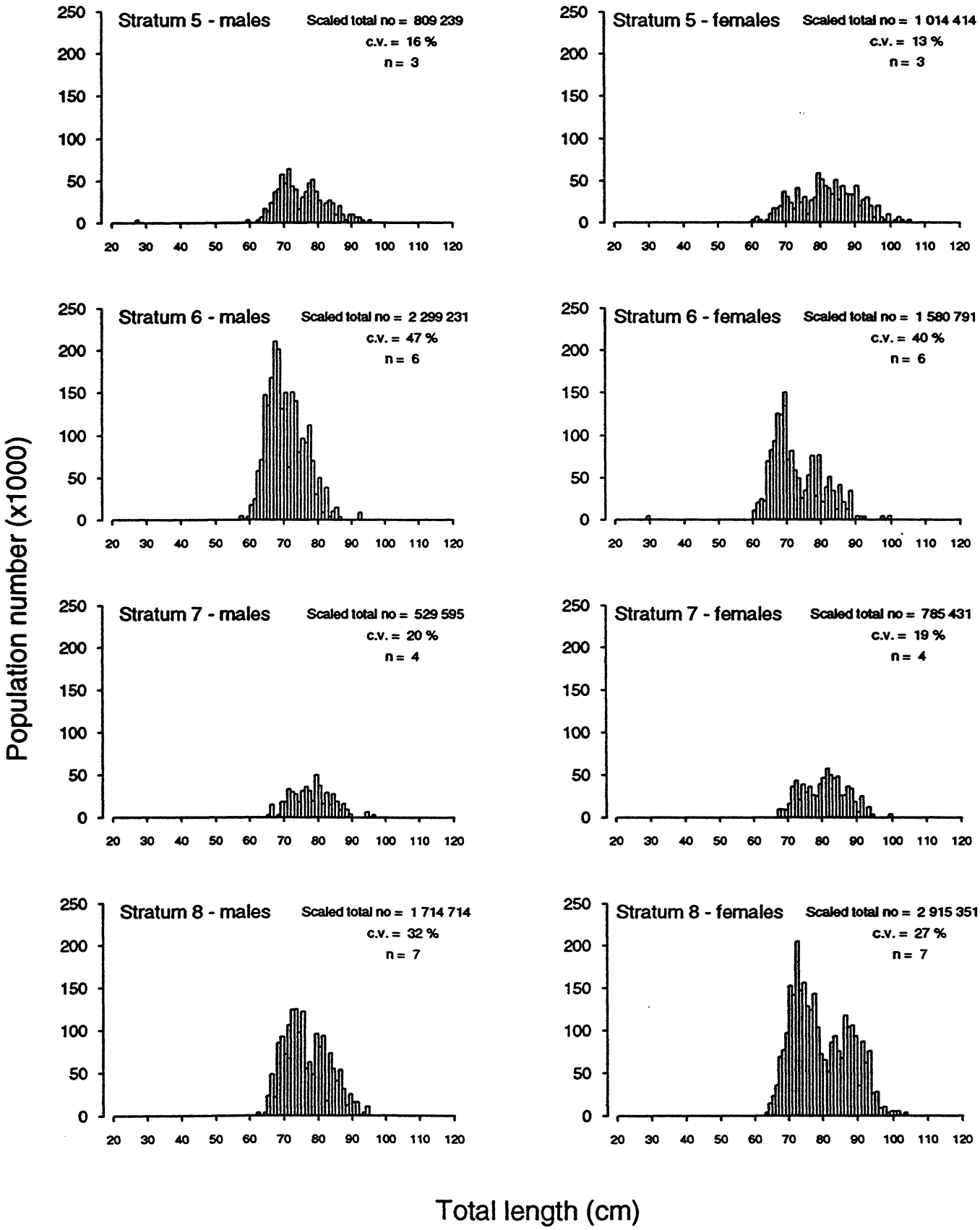

Figure 4b—*continued*

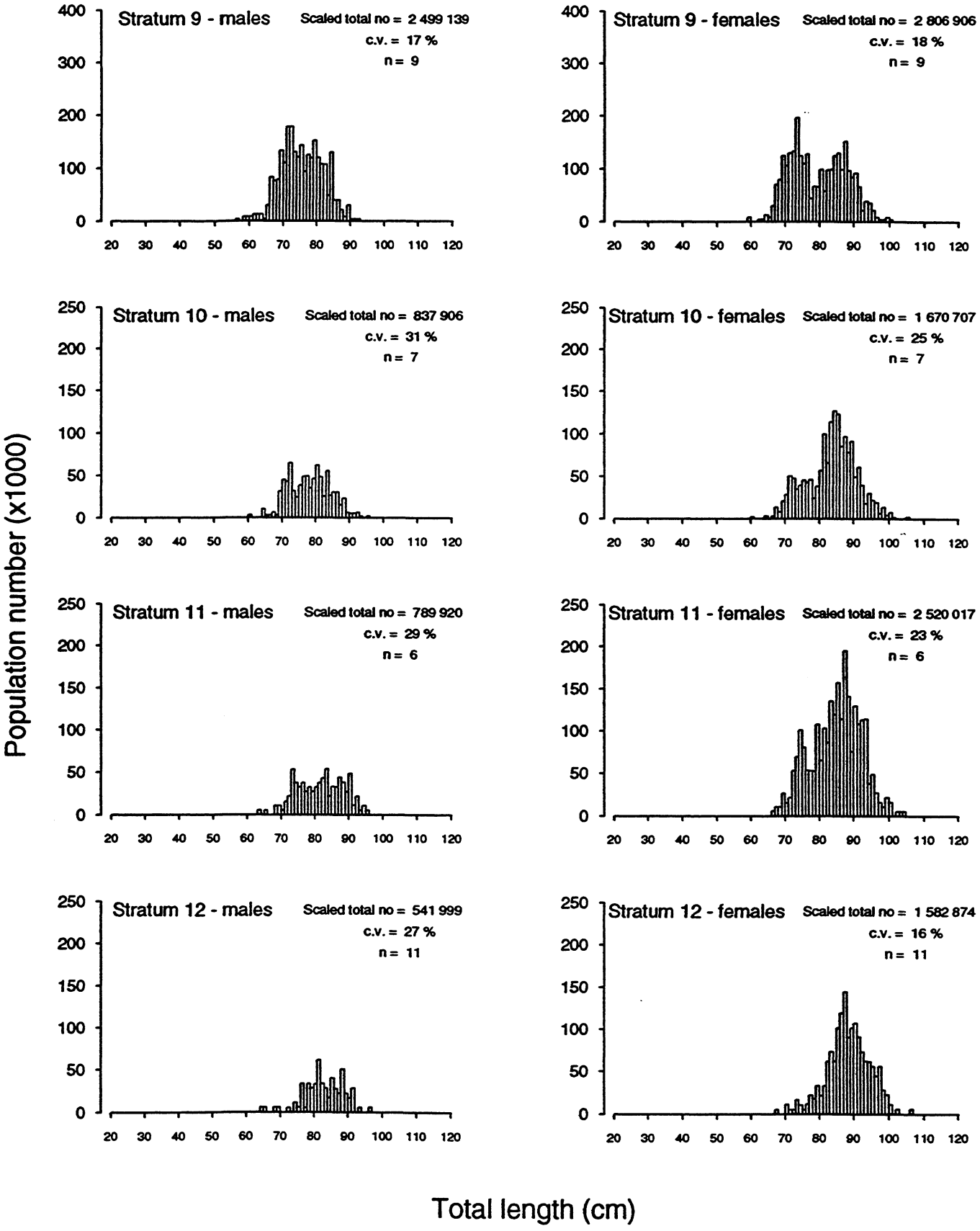

Figure 4b—*continued*

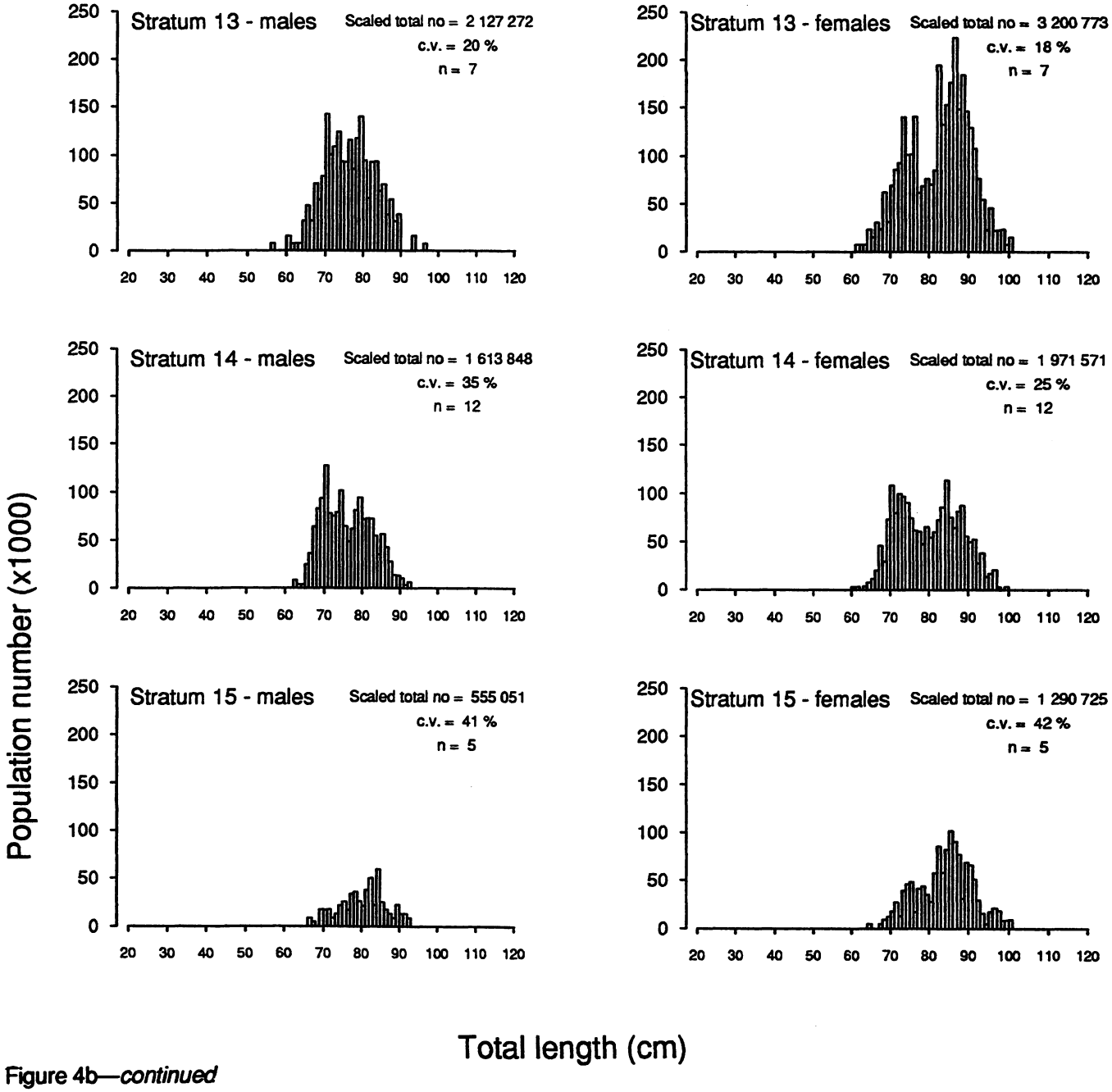

Figure 4b—*continued*

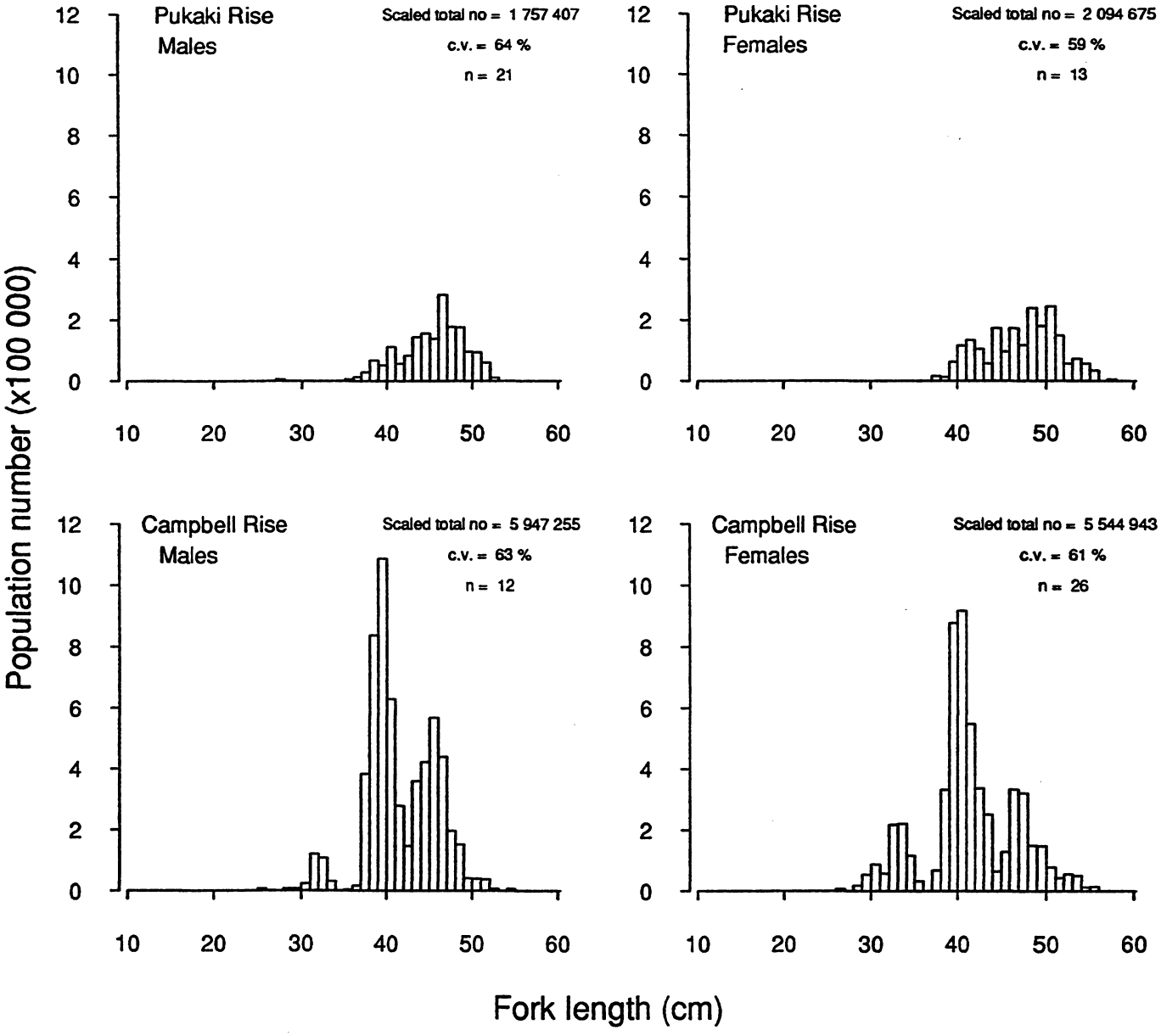

Figure 4c: Scaled length frequencies of southern blue whiting from the Pukaki Rise and Campbell Island Rise.

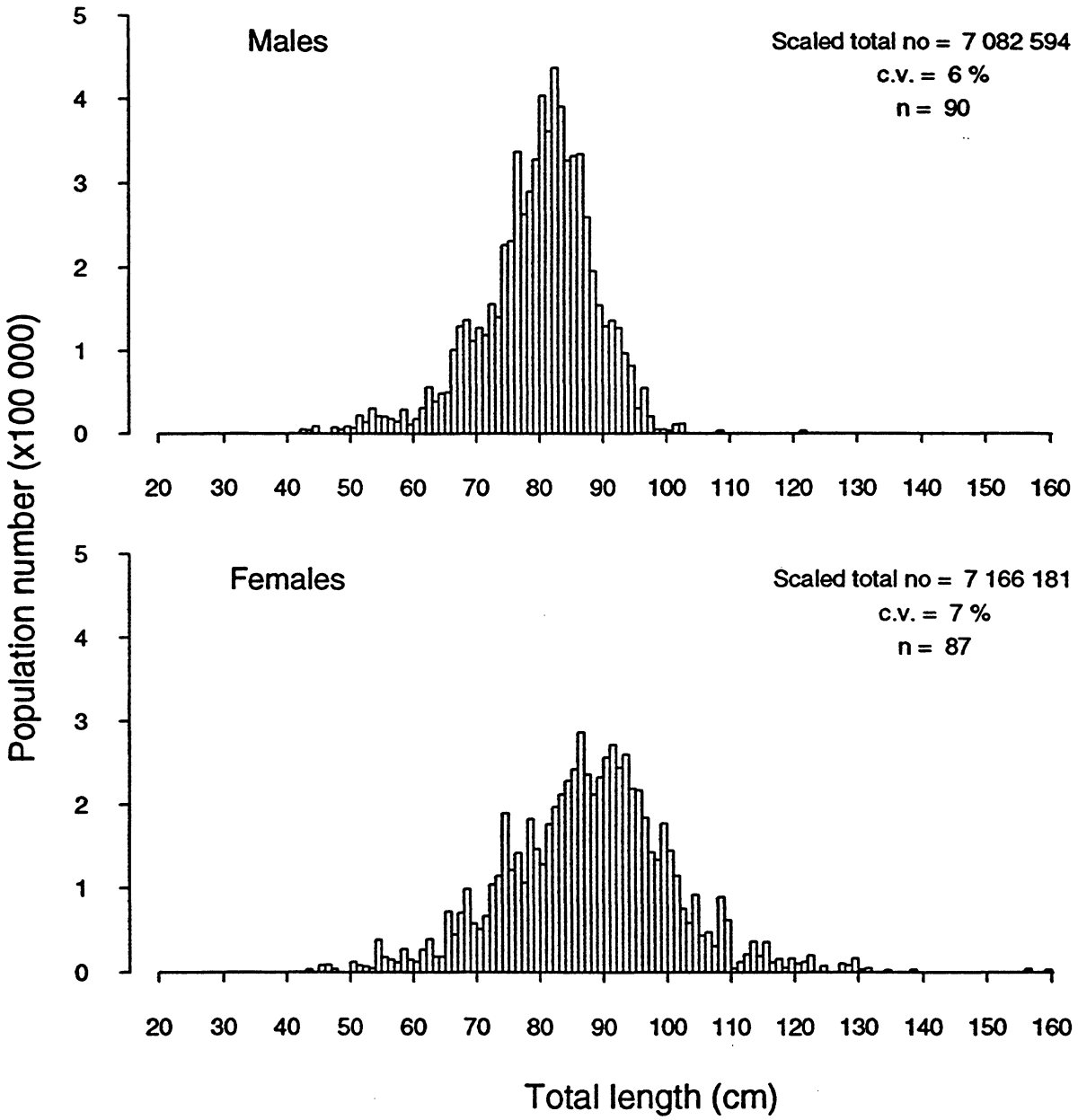

Figure 4d: Scaled length frequencies of male and female ling for the total survey area.

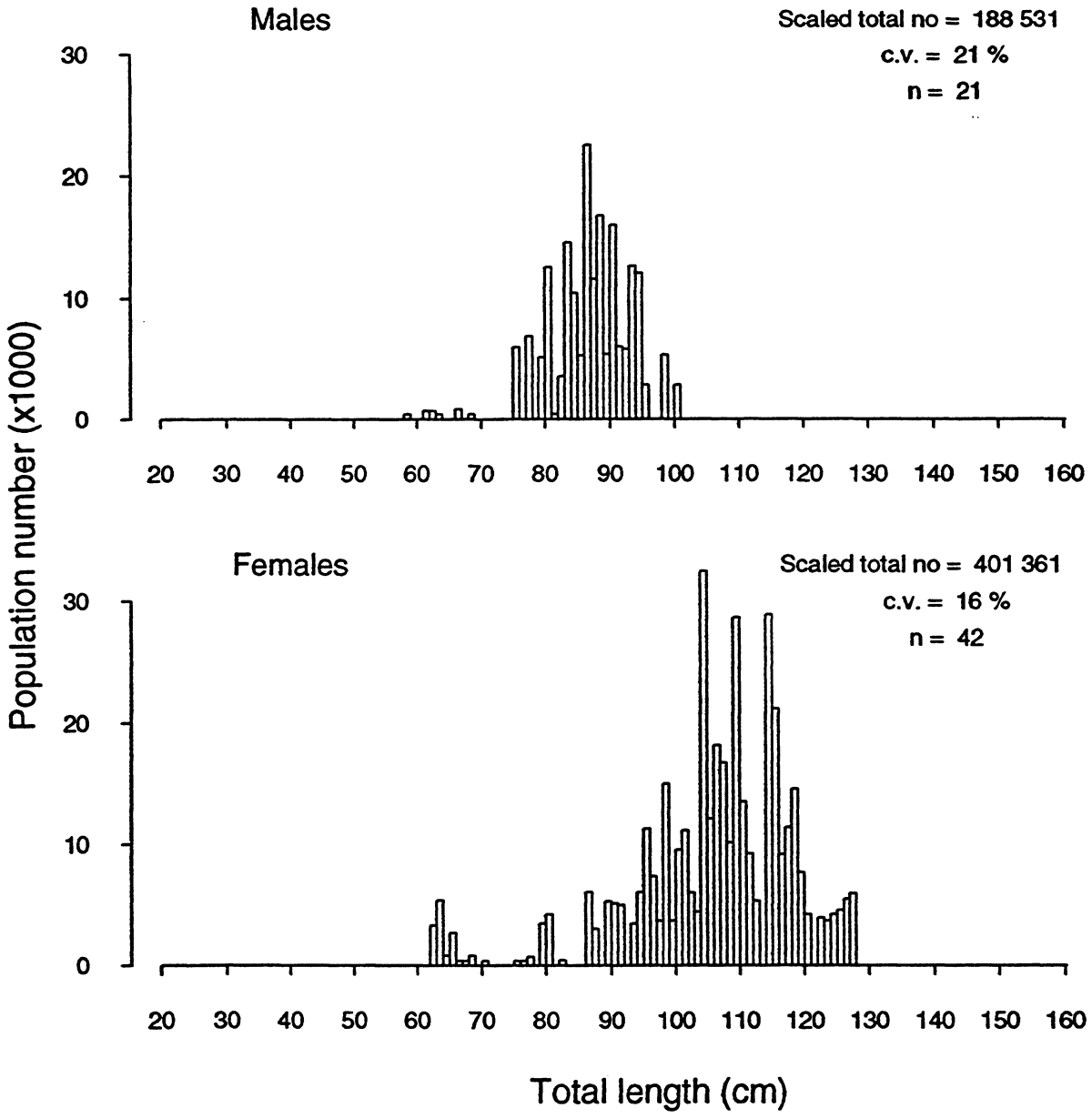

Figure 4e: Scaled length frequencies of male and female hake for the total survey area..

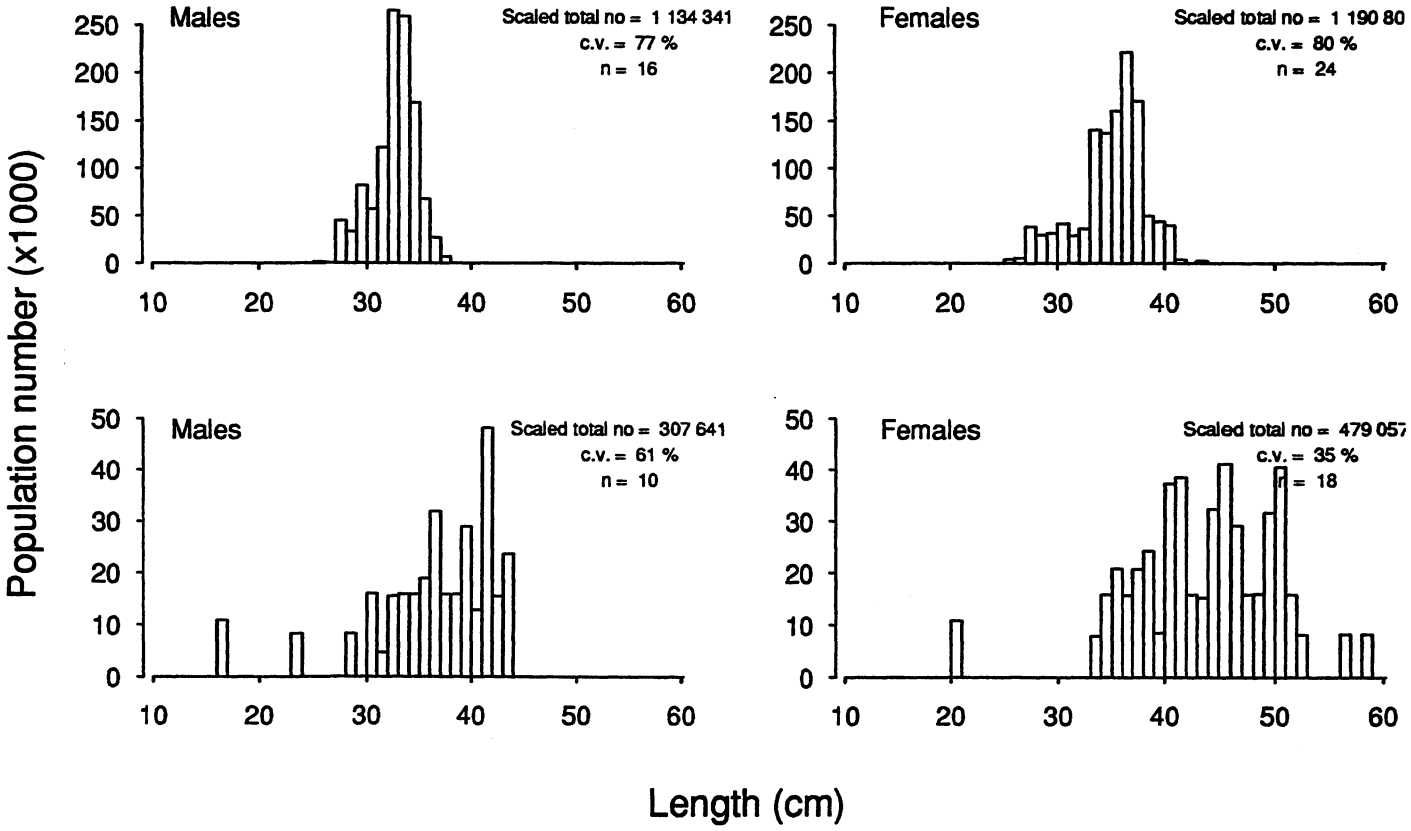

Figure 4f: Scaled length frequencies of arrow squid (above) and lookdown dory (below) for the total survey area.

Appendix 1: Trawl stations completed*

Station	Stratum	Date	Start of tow Latitude ° 'S	Start of tow Longitude ° 'E	Depth (m) Min.	Depth (m) Max.	Headline height (m)	Doorspread (m)
1	1	20 Apr 92	46 18.09	166 22.18	418	438	7.0	122.0
2	1	20 Apr 92	46 25.02	166 27.41	452	499	6.5	121.6
3	2	20 Apr 92	46 33.72	166 19.89	682	774	6.9	122.0
4	2	20 Apr 92	46 30.58	166 15.60	601	643	7.1	121.3
5	2	20 Apr 92	46 34.61	166 14.02	607	714	6.3	123.3
6	5	21 Apr 92	49 01.03	167 56.76	665	672	7.0	123.0
7	5	21 Apr 92	49 11.87	167 55.94	677	699	6.8	117.3
8	5	21 Apr 92	49 11.54	167 19.09	748	750	7.2	126.4
9	6	21 Apr 92	49 23.50	166 58.45	460	469	6.6	118.5
10	6	22 Apr 92	49 35.31	167 25.01	522	532	6.5	114.3
11	6	22 Apr 92	49 40.53	167 29.87	398	415	6.5	112.7
12	6	22 Apr 92	49 57.24	167 48.21	301	389	6.4	121.3
13	6	22 Apr 92	50 08.97	167 54.69	415	427	6.6	116.2
14	6	23 Apr 92	51 09.68	167 39.79	563	570	6.2	130.0
15	7	23 Apr 92	51 34.21	167 53.60	632	634	6.4	112.7
16	7	23 Apr 92	51 38.77	167 41.25	637	659	6.5	NR
17	7	23 Apr 92	51 43.75	167 31.62	661	665	6.5	NR
18	7	24 Apr 92	52 01.76	167 47.72	783	788	6.3	127.6
19	10	24 Apr 92	51 53.57	167 58.42	643	664	6.4	122.0
20	10	24 Apr 92	51 56.84	168 17.68	619	634	6.6	NR
21	10	25 Apr 92	52 38.92	168 18.22	692	755	6.5	130.0
22	10	25 Apr 92	53 00.45	168 16.94	753	785	6.6	138.0
23	10	25 Apr 92	53 03.99	168 26.66	731	752	6.6	NR
24	10	26 Apr 92	53 32.24	169 23.04	650	683	6.3	132.0
25	10	26 Apr 92	53 35.21	169 55.44	731	754	6.5	NR
26	8	29 Apr 92	49 35.70	169 55.05	633	635	6.5	NR
27	8	29 Apr 92	49 51.87	169 30.77	642	648	6.5	NR
28	8	29 Apr 92	49 52.73	169 09.69	636	647	6.5	137.0
29	9	30 Apr 92	51 31.81	168 59.49	469	480	6.5	131.3
30	9	30 Apr 92	51 31.70	168 49.04	546	563	6.4	124.4
31	9	30 Apr 92	51 24.69	168 58.14	510	510	6.6	120.5
32	9	30 Apr 92	51 20.41	169 18.62	524	529	6.7	122.4
33	9	30 Apr 92	51 22.62	169 35.51	503	513	6.6	125.2
34	9	01 May 92	51 03.29	169 31.34	563	566	6.6	120.2
35	9	01 May 92	51 03.86	169 17.70	551	552	6.5	126.5
36	9	01 May 92	51 01.65	169 01.69	568	587	6.6	125.5
37	9	01 May 92	50 49.25	168 40.31	575	582	6.5	130.0
38	4	02 May 92	48 04.96	168 43.99	634	657	6.5	118.7
39	3	02 May 92	47 53.61	168 48.21	549	557	6.7	110.2
40	3	02 May 92	47 37.35	169 04.43	512	539	6.6	115.5
41	3	02 May 92	47 27.57	169 10.39	428	433	6.7	116.0
42	4	04 May 92	48 21.51	169 18.38	648	649	6.5	NR
43	4	04 May 92	48 29.56	169 25.22	693	712	6.5	124.2
44	4	04 May 92	48 37.74	169 40.98	787	788	6.6	125.7
45	4	04 May 92	48 46.09	169 29.21	770	783	6.6	127.2
46	8	05 May 92	48 59.95	168 19.26	671	673	6.4	129.8
47	8	05 May 92	49 11.99	168 26.09	659	682	6.5	123.5
48	8	05 May 92	49 20.79	168 48.83	752	760	6.7	122.8
49	8	05 May 92	49 20.36	169 11.82	719	732	6.5	128.6

Station	Stratum	Date	Start of tow Latitude ° 'S	Start of tow Longitude ° 'E	Depth (m) Min.	Depth (m) Max.	Headline height (m)	Doorspread (m)
50	11	06 May 92	48 49.60	170 48.26	731	767	6.4	137.2
51	11	06 May 92	48 44.39	171 01.25	739	780	6.5	131.7
52	11	06 May 92	48 51.72	171 03.65	657	690	6.6	127.0
53	11	07 May 92	48 47.73	171 24.97	650	684	6.6	132.3
54	11	07 May 92	48 46.17	171 50.85	645	646	6.7	125.0
55	12	07 May 92	48 50.69	172 08.32	564	592	6.5	130.0
56	12	07 May 92	48 59.94	172 12.99	497	528	6.6	130.0
57	12	08 May 92	49 27.71	170 54.81	486	488	6.3	133.2
58	12	08 May 92	49 41.64	171 01.77	487	488	6.3	134.5
59	12	08 May 92	49 56.70	171 03.13	503	516	6.3	134.5
60	12	08 May 92	50 06.61	171 02.36	536	543	6.5	136.8
61	13	09 May 92	51 02.50	171 07.50	534	541	6.4	129.8
62	13	09 May 92	51 14.06	171 05.93	533	534	6.5	123.3
63	13	09 May 92	51 22.05	170 49.31	533	533	6.6	121.8
64	13	09 May 92	51 31.78	170 42.01	504	513	6.6	123.1
65	13	10 May 92	51 45.97	171 15.94	513	514	6.5	120.9
66	14	10 May 92	52 00.25	171 32.56	519	529	6.4	125.5
67	14	10 May 92	52 06.46	171 44.26	536	541	6.5	118.8
68	14	10 May 92	52 13.74	171 48.55	551	571	6.5	120.2
69	14	11 May 92	52 20.88	171 02.50	496	504	6.6	120.2
70	14	11 May 92	52 32.63	171 02.25	486	496	6.5	121.0
71	14	11 May 92	52 32.73	170 27.75	445	458	6.6	121.0
72	14	11 May 92	52 40.45	170 19.07	442	444	6.6	122.0
73	14	12 May 92	53 29.11	171 30.01	497	525	6.6	123.5
74	15	12 May 92	53 39.64	171 34.41	600	648	6.6	119.5
75	14	12 May 92	53 22.57	172 34.77	539	547	6.2	129.1
76	14	13 May 92	52 54.38	172 28.65	414	419	6.5	130.4
77	14	13 May 92	52 42.97	172 42.11	491	504	6.6	124.3
78	14	13 May 92	52 43.77	173 08.65	530	531	6.7	124.6
79 *	15	13 May 92	52 41.11	173 26.84	623	642	6.2	125.2
80	15	15 May 92	52 12.38	172 43.37	608	610	6.6	136.7
81 *	15	15 May 92	52 04.72	172 50.13	608	612	5.5	117.5
82	15	15 May 92	51 53.94	173 10.93	665	671	6.6	125.0
83	15	15 May 92	51 47.92	173 25.70	642	643	6.6	128.4
84	15	16 May 92	51 00.05	173 33.70	633	642	6.4	141.0
85	13	16 May 92	50 59.13	173 03.30	563	576	6.6	NR
86	13	16 May 92	50 37.46	172 56.53	549	557	6.4	NR
87	11	17 May 92	50 19.84	173 41.53	644	666	6.5	135.4
88	12	17 May 92	50 09.18	173 23.51	544	568	6.4	134.2
89	12	17 May 92	49 57.81	173 31.99	533	568	6.5	124.8
90	12	17 May 92	49 54.77	173 31.14	535	544	6.3	132.4
91	12	18 May 92	49 30.86	174 07.68	490	494	6.5	136.0
92	12	18 May 92	49 25.04	174 13.34	477	481	6.5	136.3
93 *	12	18 May 92	49 17.42	174 45.74	509	514	6.5	135.2

* Gear performance was unsatisfactory at stations 79, 81, and 93 and hence they were not used in any analysis.
NR = not recorded.

Appendix 2: Species caught. Taxonomic names follow Paulin *et al.* (1989). Occ. = number of tows in which each species occurred (n = 90).

Scientific name	Common name	Code	Occ.
Elasmobranchii			
Scyliorhinidae: cat sharks			
Halaelurus dawsoni	Dawson's catshark	DCS	1
Apristurus macrorhynchus	deepwater catshark	APR	1
Squalidae: dogfishes			
Centrophorus squamosus	deepwater spiny dogfish	CSQ	2
Centroscymnus crepidater	deepwater dogfish	CYP	16
Deania calcea	shovelnosed spiny dogfish	SND	9
Etmopterus baxteri	Baxter's lantern dogfish	ETB	20
E. lucifer	Lucifer spiny dogfish	ETL	8
E. molleri	blackbelly lantern shark	EMO	7
Oxynotus bruniensis	prickly dogfish	PDG	1
Scymnodon plunketi	Plunket's shark	PLS	2
Squalus acanthias	spiny dogfish	SPD	29
Rajidae: skates			
Pavoraja asperula	deepsea skate	BTA	6
P. spinifera	prickly deepsea skate	BTS	7
Raja innominata	smooth skate	SSK	3
R. nasuta	rough skate	RSK	1
Raja sp.	pale longnosed skate	PSK	10
Chimaeridae: ghost sharks			
Chimaera phantasma	giant ghost shark	CHG	1
Chimaera sp. C	purple chimaera	CHP	1
Hydrolagus novaezelandiae	dark ghost shark	GSH	9
Hydrolagus sp.	pale ghost shark	GSP	79
Rhinochimaeridae: longnosed ghost sharks			
Harriotta raleighana	longnosed chimaera	LCH	40
Rhinochimaera pacifica	widenosed chimaera	RCH	2
Teleostei			
Notacanthidae: spiny eels			
Notacanthus sexspinis	spineback	SBK	24
Synaphobranchidae: cutthroat eels			
Diastobranchus capensis	basketwork eel	BEE	2
Congridae: conger eels			
Bassanago bulbiceps	swollenheaded conger	SCO	18
B. hirsutus	hairy conger	HCO	15
Argentinidae: silversides			
Argentina elongata	silverside	SSI	45
Gonostomatidae: lightfishes			
Gonostoma elongatum	elongate lightfish	GEL	3
Photichthyidae: lighthouse fishes			
Species not identified	lighthouse fish	PHO	1
Paralepididae: barracudinas			
Magnisudis prionosa	barracudina	BCA	4
Moridae: morid cods			
Austrophycis marginata	dwarf cod	DCO	2
Halargyreus johnsoni	Johnson's cod	HJO	1
Mora moro	ribaldo	RIB	34
Pseudophycis bachus	red cod	RCO	4
Gadidae: true cods			
Micromesistius australis	southern blue whiting	SBW	45

Merlucciidae: hakes			
Macruronus novaezelandiae	hoki	HOK	90
Merluccius australis	hake	HAK	48
Macrouridae: rattails, grenadiers			
Caelorinchus aspercephalus	obliquebanded rattail	CAS	31
C. bollonsi	bigeyed rattail	CBO	41
C. fasciatus	banded rattail	CFA	54
C. matamua	Mahia rattail	CMA	1
C. oliverianus	Oliver's rattail	COL	20
Coryphaenoides murrayi	abyssal rattail	CMU	2
C. sp. B	longbarbelled rattail	CBA	4
C. subserrulatus	fourrayed rattail	CSU	4
Lepidorhynchus denticulatus	javelinfish	JAV	87
Macrourus carinatus	ridgescaled rattail	MCA	11
Ventrifossa nigromaculata	blackspotted rattail	VNI	24
Ophidiidae: cusk eels			
Genypterus blacodes	ling	LIN	90
Trachichthyidae: roughies			
Hoplostethus atlanticus	orange roughy	ORH	2
H. mediterraneus	silver roughy	SRH	2
Zeidae: dories			
C. traversi	lookdown dory	LDO	33
Oreosomatidae: oreos			
Allocyttus niger	black oreo	BOE	2
Neocyttus rhomboidalis	spiky oreo	SOR	2
Pseudocyttus maculatus	smooth oreo	SSO	4
Macrorhamphosidae: snipefishes			
Centriscops obliquus	redbanded bellowsfish	BBE	1
Congiopodidae: pigfishes			
Alertichthys blacki	alert pigfish	API	1
Hoplichthyidae: ghostflatheads			
Hoplichthys haswelli	deepsea flathead	FHD	1
Psychrolutidae: toadfishes			
Cottunculus nudus	bonyskull toadfish	COT	1
Neophrynichthys angustus	pale toadfish	TOP	24
N. latus	dark toadfish	TOD	1
Apogonidae: cardinalfishes			
Epigonus lenimen	bigeyed cardinalfish	EPL	2
Bramidae: pomfrets			
Brama brama	Ray's bream	RBM	1
Uranoscopidae: armourhead stargazers			
Kathetostoma giganteum	giant stargazer	STA	8
Gempylidae: snake mackerels			
Rexea solandri	gemfish	SKI	2
Trichiuridae: cutlassfishes			
Lepidopus caudatus	frostfish	FRO	1
Centrolophidae: raftfishes, medusafishes			
Centrolophus niger	rudderfish	RUD	2
Hyperoglyphe antarctica	bluenose	BNS	2
Seriolella caerulea	white warehou	WWA	14
S. punctata	silver warehou	SWA	6
Bothidae: lefteyed flounders			
Arnoglossus scapha	witch flounder	WIT	1
Neoachiropsetta milfordi	finless flounder	MAN	42
Cephalopoda			
Ommastrephidae			
Nototodarus sloanii	arrow squid	NOS	33
Onychoteuthidae			
Moroteuthis ingens/M. robsoni	warty squids	WSQ	69

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