Winter and summer trawl surveys of hoki south of New Zealand, 1990

R. J. Hurst
K. A. Schofield

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Inquiries to:
Publication Services, NIWA
PO Box 14901, Wellington, New Zealand.

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Abstract

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Random trawl surveys of the Southland and Sub-Antarctic areas of New Zealand were carried out in July-August (winter) and November-December (summer) 1990. The main aims were: to estimate the proportion of hoki which remain in the southern area during the winter spawning season; to determine if there are spawning grounds in the southern area (winter survey); to determine if there is significant hoki biomass deeper than 800 m by extending the usual survey depth range of 300–800 m down to 1000 m (summer survey); and to derive estimates of relative change in abundance since previous comparable surveys in October-November 1983 and 1989.

The estimated biomass is given for the 15 most abundant species and catch data are given for another 10 major species. The biomass of javelinfish, rattails (all species combined), pale ghost shark, hake, and all species combined decreased significantly between winter and summer. The adult hoki biomass doubled between winter and summer. Extension of the survey depth range in summer, from 800 to 1000 m, resulted in a small (4%) increase in the hoki biomass, and significant increases in the biomass of hake, rattails, and smooth oreo. Comparison of biomass estimates with those from earlier surveys is difficult because different vessels and gear were used. However, seasonal and annual comparisons of the biomass distribution by area and depth are made for hoki, ling, southern blue whiting, and hake.

Detailed biological data (including length, sex, weight, reproductive state, and feeding) are presented for hoki, ling, southern blue whiting, and hake. Survey comparisons of fish size distribution and other biological data are also made for these species, where appropriate data are available. No new hoki spawning grounds were found.

Introduction

The hoki (*Macruronus novaezelandiae*) fishery is currently managed as a unit stock, with a Total Allowable Commercial Catch (TACC) of 220 000 t which applies to all fishery areas of the New Zealand Exclusive Economic Zone (EEZ) except area 10 (Kermadec Islands). During the late 1980s, 80–90% of the annual catch was taken from the west coast South Island spawning fishery in winter (late June–early September). However, the occurrence of spawning areas elsewhere suggested the possibility of separate stocks. Since 1989, stock assessments have split the stock into two components, as proposed by Livingston (1990a).

1. Western and southern stock: the west coast of the North and South Islands and the area to the south of New Zealand including Puysegur, the Stewart-Snares shelf, and the Southern plateau;
2. Eastern stock: the area to the east of the North and South Islands, including Cook Strait and the Chatham Rise.

In the early 1990s, stock assessment of the western and southern stock incorporated biomass data from trawl surveys of the southern (Southland and Sub-Antarctic) area in October-November 1983 by R.V. *Shinkai Maru* (Hatanaka *et al.* 1989) and October-November 1989 by F.V. *Amaltal Explorer* (Hurst & Schofield 1990). Three important assumptions made in using these data were:

1. that all adult (over 65 cm total length (TL)) hoki found in the survey area in late spring spawn annually;
2. that all adult hoki found in the survey area in late spring contribute to the western (includes west coast South Island and Puysegur) spawning fishery in winter;
3. that changes in the relative abundance of adult hoki between 1983 (when the fishery was relatively unexploited) and 1989 (after 4 years of increased exploitation) reflect real changes in abundance (once vulnerability to different vessels and gear has been allowed for).

There were problems with all these assumptions. There was evidence from previous surveys (e.g., Chatham Rise, Livingston *et al.* (1991)) that the first assumption was unjustified. This assumption could be tested for the Sub-Antarctic area and this was the main aim of the trawl surveys reported on here. Addressing the second and third assumptions was more difficult and depended on a method of stock separation (e.g., morphometric characters, parasite markers) being found and developing a time series of trawl surveys using the same vessel and gear combination.

The main aim of the 1990 surveys was to determine what proportion of the southern summer biomass of adult hoki did not spawn, and was therefore unavailable to the spawning fisheries, by carrying out surveys in winter (July-August) and "summer" (actually late spring/early summer — November-December) using the same vessel (*Amaltal Explorer*) and gear for both. It was hoped that the biomass and biological data from the summer survey could be compared with the October-November 1983 and 1989 surveys, although the trawl gear used in 1990 was changed from that used on the same vessel in 1989 because of concerns that the 1989 gear was not operating efficiently (Hurst & Schofield 1990, Bagley 1991).

Detailed objectives of the two 1990 surveys were as follows.

1. To estimate the proportion of hoki which remain in the southern area over winter and do not spawn by comparing winter and summer non-spawning biomass estimates.
2. To estimate current hoki biomass in the western and southern stocks during the dispersed phase (November-December) and derive estimates of relative change in abundance since previous surveys in October-November 1983 and 1989.
3. To determine if hoki spawn in the southern area during winter.
4. To estimate current relative biomass and changes in seasonal biomass of associated species, in particular, hake, ling, and southern blue whiting, to refine yield estimates.
5. To collect biological data for determination of recruited biomass, growth rates, productivity, and stock relationships of hoki and associated species.
6. To define major water mass characteristics within the survey area by recording hydrographic data at each trawl station.
7. To collect bathymetric data.
8. To determine the relative abundance of hoki in deeper water, from 800 to 1000 m (summer survey only).

Hurst & Schofield (1991) gave preliminary biomass and length frequency data for selected species from these two surveys, discussed problems in determining relative catchability between *Shinkai Maru* and *Amaltal Explorer* surveys, and derived estimates of the proportion of hoki spawning during winter for a range of plausible stock sizes. This report presents more detailed data on the biomass and biology of important commercial species and makes more detailed comparisons of the distribution of hoki, ling, southern blue whiting, and hake between seasonal and annual surveys.

There have been several stratified random trawl surveys of the Southland and Sub-Antarctic areas (to 800 m depth), but no surveys during winter. Table 1 lists research surveys which are the most relevant and comparable to the surveys undertaken in 1990. Additional research surveys which only partly covered the 1990 survey area are given by Hurst *et al.* (1990).

There are important trawl fisheries in the areas and depths covered by these surveys (Hurst *et al.* 1990). The main species caught in the Southland area are arrow squid (*Nototodarus sloanii*), hoki, barracouta (*Thyrsites atun*), ling (*Genypterus blacodes*), oreos (*Allocyttus* spp.), and silver warehou (*Seriolella punctata*). Fisheries in the Sub-Antarctic area tend to be relatively large and target single species, such as arrow squid around the Auckland Islands and southern blue whiting (*Micromesistius australis*) mainly around the Campbell and Bounty Islands, but hoki, hake (*Merluccius australis*), ling, and oreos are also caught. Catches of each of the three main species (arrow squid, hoki, and southern blue whiting) in the southern area usually exceed 20 000 t per year (Annala 1994).

Table 1: Comparable research trawl surveys of the Southland and Sub-Antarctic areas, 1979–90

Area*	Date	Vessel	Survey area (km^2)	No. of stations	Depth range (m)	Reference
SA	Apr-May '79	*Wesermünde*	373 706	54	0–1000	Francis (1981)
SA	Sep-Oct '79	*Wesermünde*	373 706	60	0–1000	Francis (1981)
SA	Oct-Nov '79	*Wesermünde*	373 706	71	0–1000	Francis (1981)
SL, SA	Mar-Apr '82	*Shinkai Maru*	344 033	220	0–800	van den Broek *et al.* (1984) Hatanaka *et al.* (1989)
SL, SA	Oct-Nov '83	*Shinkai Maru*	342 868	184	0–800	van den Broek *et al.* (1984) Hatanaka *et al.* (1989)
SL, SA, P	Oct-Nov '89	*Amaltal Explorer*	318 398	125	200–800	Livingston & Schofield (1993)
SL, SA, P	Jul-Aug '90	*Amaltal Explorer*	291 152	119	300–800	Livingston & Schofield (1993)
SL, SA, P	Nov-Dec '90	*Amaltal Explorer*	330 831	177	300–1000	Livingston & Schofield (1993)

* SA, Sub-Antarctic; SL, Southland; P, Puysegur.

Methods

Survey area and design

The winter survey (11 July–21 August 1990, voyage AEX9001) covered an area of 291 152 km^2 including the Puysegur Bank, Southland, and the Sub-Antarctic area (Figures 1 and 2a). This is slightly less than for the October-November 1989 survey as the 200–300 m depth range and some areas of foul ground were omitted. The area was divided into 17 strata, by depth (300–600 m, 600–800 m) and area. In the summer survey slight alterations were made to some strata as a result of increased knowledge of bathymetry and areas of foul. Extra daylight hours during the summer survey (6 November–17 December, voyage AEX9002) enabled the addition of six strata in the 800–900 m depth zone and two in 900–1000 m (Figures 1 and 2b), resulting in a total area of 330 831 km^2. The extra strata were added to determine the relative biomass of hoki in over 800 m depth, as it had previously been assumed to be insignificant.

A single phase random trawl survey design was used for both surveys. If time was available at the end of the voyage, second phase clusters or stations were to be allocated according to the mean-squared algorithm of Francis (1984).

In the winter survey, random clusters of three stations (to be completed each day) were generated because of the restricted daylight hours and the large area to be covered. The first station in the cluster was randomly generated; the second station was randomly generated on the circumference of a circle, surrounding the first station, with a 24 n. mile radius (i.e., maximum possible steaming distance); and the third station was randomly generated on the

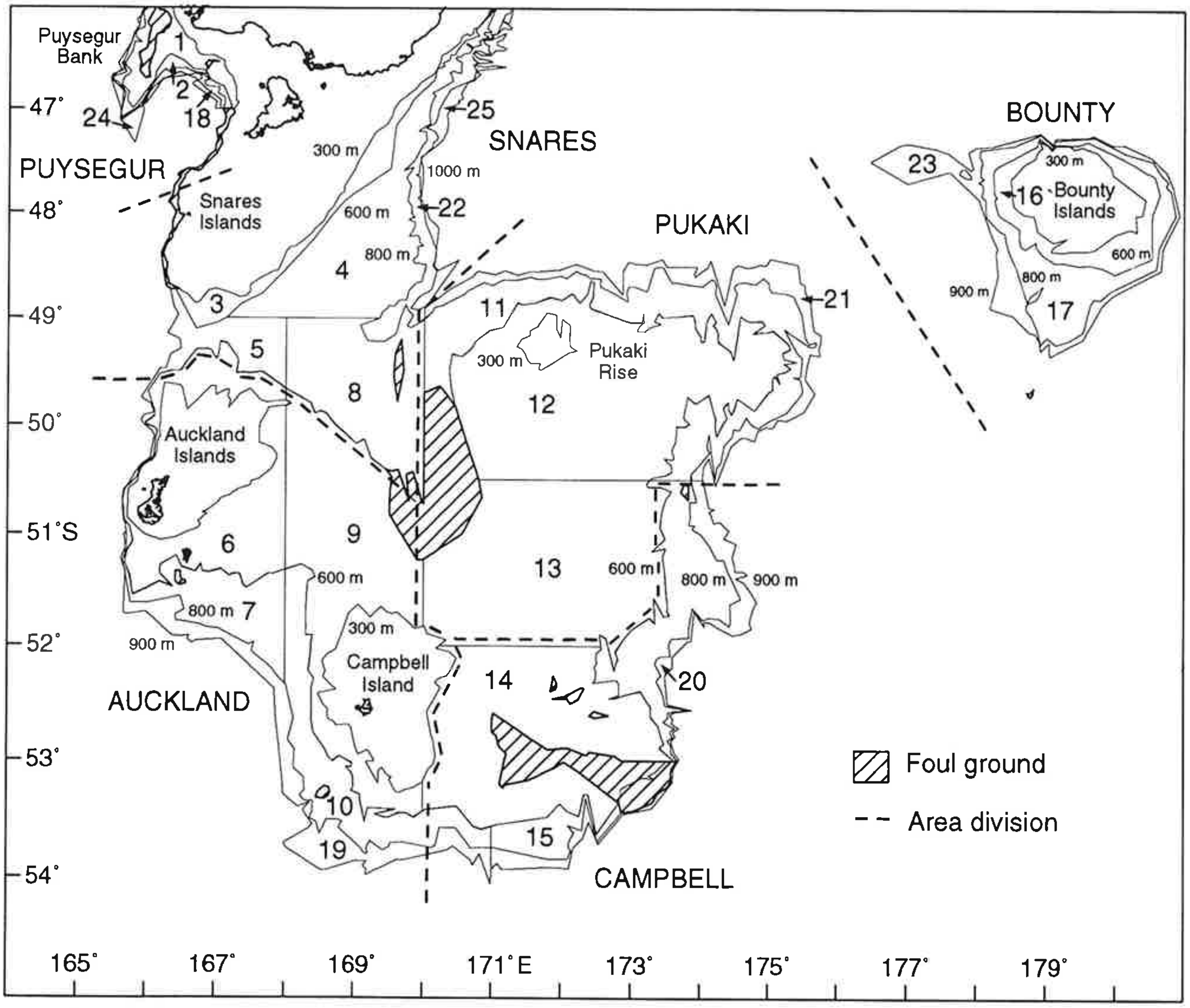

Figure 1: Survey area, strata, area divisions, and names mentioned in the text (the winter survey covered strata 1–17 only).

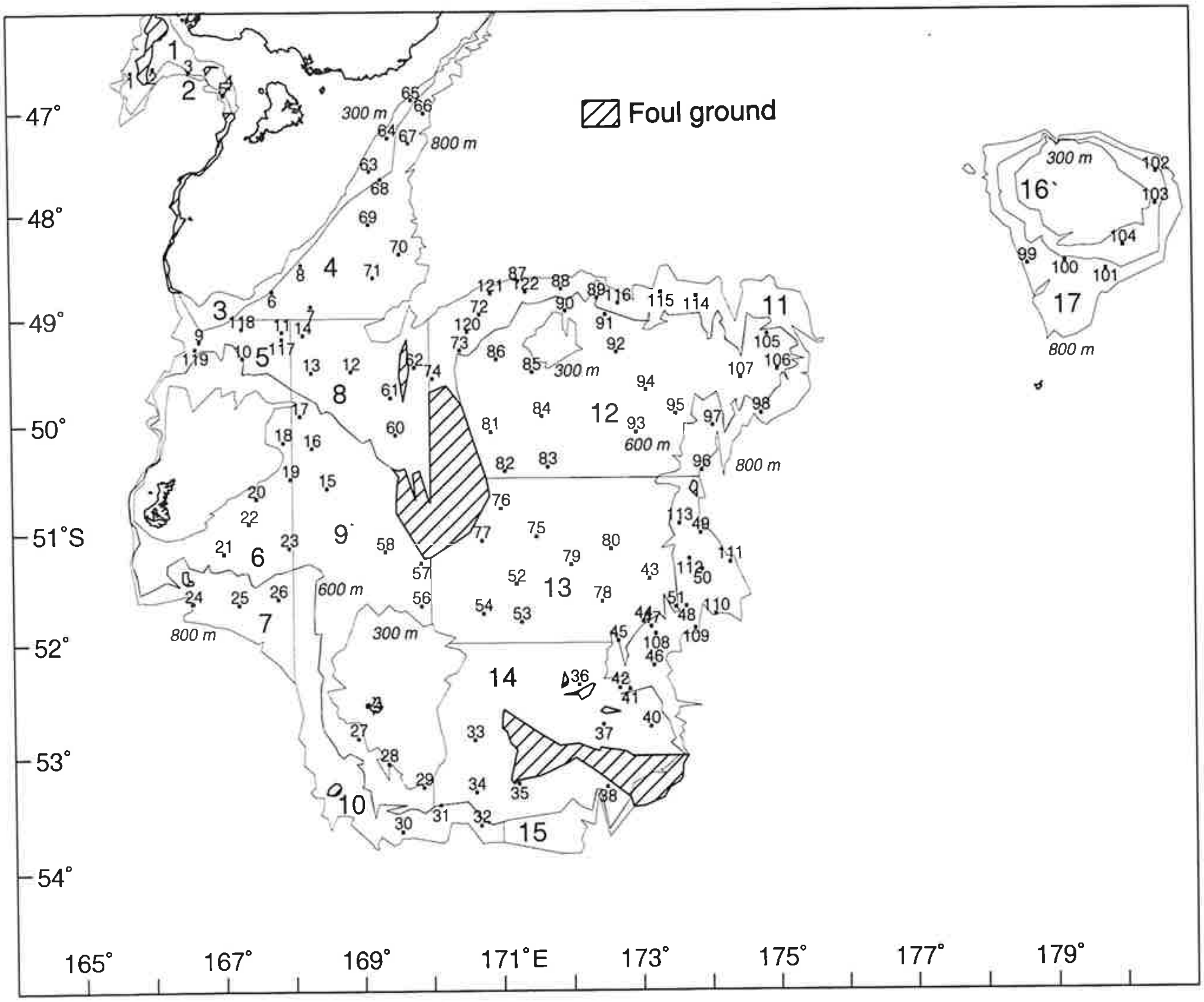

Figure 2a: Strata and station positions, winter survey.

circumference of circles surrounding either the first or second stations, but had to lie 24 n. miles from both of the other stations.

In the summer survey it was assumed that an average of 4.5 stations per day would be possible (as was achieved in the 1989 survey), and each station was randomly generated independently. This resulted in 105 and 155 stations being planned for the winter and summer surveys respectively, assuming that 5 of the 40 days would be lost through bad weather. The allocation of stations or clusters to strata was based on stratum area, except for strata which were small or in the 800–1000 m depth range when a minimum of three stations per stratum was used, regardless of stratum area (Table 2).

Vessel and gear

Amaltal Explorer is a New Zealand stern trawler owned by the Amaltal Fishing Company. It has the following specifications: overall length, 65 m; beam, 12 m; gross tonnage, 1386 t; horsepower, 2700. A Scanmar 400 system provided data on doorspread, headline height, and bottom water temperature (calibrated). Bottom temperatures (also calibrated) were taken from the net sonde in the summer survey. Surface temperatures were recorded by a hull-mounted sensor 4 m below the surface.

The trawl used for the survey was a commercial, six-panel Japanese "squid" trawl, 58.6 m long with a 53.5 m long groundrope and 60 mm mesh codend. It was rigged with 135 m (140 m in summer) long sweeps, 45 m long bridles, and 10 m long backstrops. The trawl doors were 6.5 m^2 Super WVs. Mean values and ranges for the important variable gear parameters are given in Table 3. Although not statistically significant, the mean headline height decreased by 8% from 4.9 m in winter to 4.4 m in summer. The increase in the proportion of deeper stations sampled in the summer was not a contributing factor and the cause and effect of the difference are unknown.

Doorspread values were measured by Scanmar doorspread monitors; wingspread was measured on 6 winter and 10 summer tows by attaching the

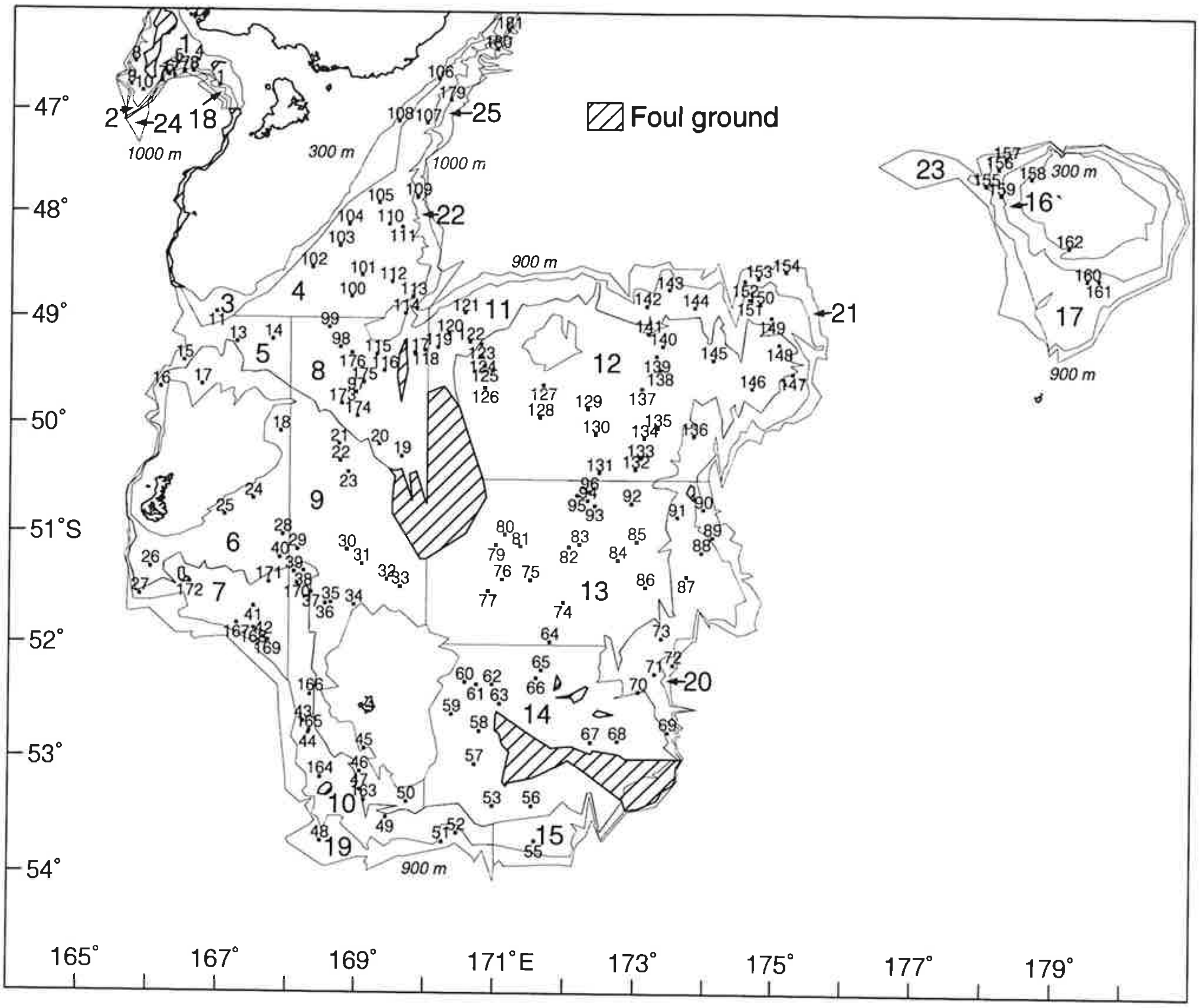

Figure 2b: Strata and station positions, summer survey.

doorspread monitors to the wingends. The mean sweep angle was estimated as about 21–22°. Comparable gear data (where available) for 1983 and 1989 surveys were given by Hurst & Schofield (1990). The *Shinkai Maru* sweep angles (estimated as 10–12°) were considerably less than those measured on the *Amaltal Explorer* surveys in 1989 (16–22°) and 1990.

Trawling procedure

All positions were determined by Global Positioning System. Trawling was restricted to daylight hours, but in the summer survey the trawl was not shot away before 0500 h NZST as results from the 1989 Sub-Antarctic survey suggested that hoki catch rates were consistently low between 0400 and 0500 h. A tow length of 3 n. miles at 3.5 kn was aimed for and was timed from the gear reaching the bottom to the start of hauling (*see* Table 3). Tow direction either followed the bottom contour or was in the direction of the next tow if time was limiting.

If foul ground was encountered, a search was made within a 5 n. mile radius for suitable ground. If the ground was still unsuitable, the station was abandoned and the next random station within steaming distance was chosen. In the winter survey, if one station in the cluster was foul, an additional station was chosen within a 24 n. mile radius of the last station in the cluster (steaming direction chosen randomly). If two stations were foul, the cluster was replaced with the nearest cluster on the randomly generated list.

Catch sampling and biological observations

The catch was sorted into species and weighed using motion-compensating electronic scales, accurate to the nearest 0.3 kg. When the catch was over 1.5 t, the weight of the main species was estimated from the number of filled fish cases.

A maximum of 300 hoki was taken randomly from each tow, measured to the nearest centimetre

Table 2: Stratum areas, number of stations completed, and station densities

Stratum		Depth (m)	Winter Area (km^2)	Winter No. of stations Total	Winter No. of stations Phase 2	Winter Station density	Summer Area (km^2)	Summer No. of stations Total	Summer No. of stations Phase 2	Summer Station density
1	Puysegur	300–600	4 498	3		1 : 1 499	4 498	3		1 : 1 499
2	Puysegur	600–800	1 314	2		1 : 657	1 314	3		1 : 438
3	Snares shelf	300–600	4 261	3		1 : 1 420	5 130	3		1 : 1 710
4	Snares shelf	600–800	21 596	9		1 : 2 400	20 727	10		1 : 2 073
5	Snares/Auckland Islands	600–800	6 279	6	3	1 : 1 047	6 279	3		1 : 2 093
6	Auckland Islands	300–600	16 767	6		1 : 2 795	16 767	8		1 : 2 096
7	Auckland Islands	600–800	8 372	3		1 : 2 791	8 372	9	5	1 : 930
8	West Pukaki	600–800	17 349	6		1 : 2 892	17 349	13	4	1 : 1 335
9	West Campbell	300–600	27 359	9		1 : 3 040	27 359	14		1 : 1 954
10	West Campbell	600–800	11 145	3		1 : 3 715	11 145	11	5	1 : 1 013
11	East Campbell	300–600	28 367	9		1 : 3 152	27 404	14		1 : 1 957
12	East Campbell	300–600	36 090	12		1 : 3 008	36 090	17		1 : 2 123
13	Central Pukaki	300–600	45 227	15		1 : 3 015	45 227	21		1 : 2 154
14	Central Pukaki	600–800	25 586	15	6	1 : 1 706	23 121	12		1 : 1 927
15	East Campbell	600–800	16 289	12	6	1 : 1 357	15 034	8		1 : 1 879
16	Bounty Platform	300–600	11 357	3		1 : 3 586	11 357	2		1 : 5 679
17	Bounty Platform	600–800	9 296	3		1 : 3 099	9 296	3		1 : 3 099
18	Puysegur	800–900	–	–		–	886	3		1 : 295
19	West Campbell	800–900	–	–		–	8 753	3		1 : 2 918
20	East Campbell	800–900	–	–		–	5 548	3		1 : 1 849
21	Pukaki	800–900	–	–		–	9 003	3		1 : 3 001
22	Snares shelf	800–900	–	–		–	5 694	3		1 : 1 898
23	Bounty Platform	800–900	–	–		–	8 213	3		1 : 2 738
24	Puysegur	900–1000	–	–		–	2 722	2		1 : 1 361
25	East Snares shelf	900–1000	–	–		–	3 543	3		1 : 1 181
Total:			291 152	119	15	1 : 2 447	330 831	177	14	1 : 1 869

– Not included in winter survey.

Table 3: Tow and gear parameters

	Winter Mean	Winter Range	Summer Mean	Summer Range
Tow length (n. miles)	3.0	3.0–3.9	3.0	1.3–3.1
Tow speed (kn)	3.4	3.0–3.9	3.4	2.5–4.2
Headline height (m)	4.9	4.2–6.1	4.4	3.8–5.8
Doorspread* (DS) by depth (m)				
300–800 m	167	142–186	170	124–194
800–1000 m	–	–	173	149–187
Wingspread* (WS) (m)				
300–800 m	30.4	30.0–30.7	29.5	28.4–31.2
800–1000 m	–		31.3	29.3–31.3
Ratio DS:WS 300–800 m	5.49	–	5.65	–
Sweep angle (°, estimated)	21	–	22	–

* Doorspread was measured on each tow by Scanmar sensors, except when wingspread was measured using the doorspread sensors (i.e., on 4 tows in winter, 10 tows in summer). This was to enable estimation of mean wingspread, doorspread:wingspread ratios, and sweep angles.

– No data or could not be calculated.

below actual total length, sexed, and staged to enable the proportion, distribution, and size of maturing and non-spawning fish to be estimated (*after* Livingston 1990b). Twenty of these hoki were randomly selected for biological measurements, which included total length, whole weight (± 50 g), sex, gonad stage, gonad weight (± 1 g) (subsampled), stomach fullness, and stomach contents and degree of digestion. Otoliths were taken for ageing and heads were frozen or measured on board for morphometric studies.

Length and sex data and general observations on the spawning condition and stomach contents were also collected on each tow from 50 to 200 fish of other commercially important species (Table 4). Additional detailed biological data were collected from ling, southern blue whiting (including morphometric measurements), and hake.

Biomass estimation

Biomass was calculated from

$$B = [1 / (u_a u_v v)] \Sigma_i a_i C_i$$

where, B is the biomass, u_a is the areal availability, u_v is the vertical availability, v is the vulnerability, a_i is area of stratum i, and C_i is mean catch rate (t per unit area) (*after* Francis 1989).

The coefficient of variation (*c.v.*) is a measure of the precision of the biomass estimate and is calculated from

$$c.v. = (s.e. / B)100$$

where *s.e.* is the standard error of the biomass.

The following assumptions were made about fish vulnerability and availability.

1. The effective seabed area swept was the distance between the trawl doors multiplied by the distance towed, and the vulnerability between the doors was assumed to be 1.0. The ratio of doorspread to wingspread (*see* Table 3) allows alternative assumptions to be used.
2. The vertical availability was 1.0 (i.e., there were no fish above the headline or under the groundrope).
3. The areal availability was 1.0 (i.e., there were no fish in areas of untrawlable ground, which made up less than 5% of the total area surveyed).

The total number of fish in the survey area was determined from the length frequency data by scaling for percentage sampled, area towed, and stratum area using the same catchability assumptions. Mean biomass estimates were compared using the t-test and differences were significant if p was less than 0.05.

There was no consistent pattern of within- and between-cluster variation for the strata in the winter survey with more than three clusters. The within-cluster variation was less than between-cluster variation in 60% of clusters examined (i.e., close to the expected 50% if there were no cluster effect) and, therefore, the data were analysed as for the individually selected random stations in the summer survey.

Table 4: Species and numbers of fish measured

	Winter						Summer					
	Length frequency data*				Biological data		Length frequency data				Biological data	
Species code†	No. of samples	No. of fish	No. of males	No. of females	No. of samples	No. of fish	No. of samples	No. of fish	No. of males	No. of females	No. of samples	No. of fish
BNS	–	–	–	–	–	–	2	57	25	32	–	–
BOE	4	293	154	138	1	9	15	976	549	423	–	–
EPT	–	–	–	–	–	–	1	1	0	1	–	–
HAK	55	312	121	191	55	228	70	921	344	576	63	323
HAP	2	2	1	1	–	–	2	5	2	3	–	–
HOK	114	10 638	3 977	6 660	107	1 925	173	18 427	6 509	11 915	163	3 063
JMA	1	2	1	1	–	–	–	–	–	–	–	–
LDO	52	281	126	145	–	–	75	280	134	145	–	–
LIN	112	3 342	1 439	1 903	103	1 600	153	3 088	1 277	1 811	145	1 818
NOS	31	222	112	110	–	–	37	406	176	230	–	–
ORH	2	14	3	5	1	8	23	623	232	221	23	338
RBM	1	2	1	1	–	–	–	–	–	–	–	–
RCO	8	69	47	22	–	–	10	117	67	24	–	–
RIB	31	273	18	254	–	–	92	1 068	71	997	–	–
RUD	1	2	0	2	–	–	–	–	–	–	–	–
SBW	56	3 065	1 357	1 623	47	653	63	3 388	1 680	1 708	62	826
SCH	1	3	3	0	–	–	4	21	15	6	–	–
SKI	2	2	0	2	–	–	5	54	30	24	3	25
SOR	–	–	–	–	–	–	3	14	8	6	–	–
SPE	–	–	–	–	–	–	1	6	4	2	–	–
SSO	2	52	33	19	2	26	20	1 724	963	752	1	3
STA	9	63	17	44	–	–	9	27	8	19	–	–
SWA	3	97	33	62	2	28	12	265	156	109	1	13
WWA	26	55	23	18	1	1	52	392	221	161	–	–

* Length frequencies for species of which less than 200 fish were measured on both surveys are not included.
† Species codes are given in Appendix 2.
– No data.

Results

Survey area and design

Stratum areas, number of stations completed, and station densities are given in Table 2 and individual station data in Appendix 1. Spare time at the end of both voyages allowed short phase 2 surveys (15 and 14 stations, respectively) to be done, resulting in totals of 119 and 177 stations. Phase 2 stations were allocated to strata with the highest catch rates of hoki. Both surveys were conducted in two parts, the first starting at Puysegur and covering the western, Auckland Islands, and Campbell Island area and the second covering the eastern Campbell Island, Pukaki Rise, and Bounty Islands area.

Catch composition

A total of 145 species was recorded from both surveys combined (98 in winter, 128 in summer): 94 teleosts, 28 elasmobranchs, 11 cephalopods, 11 crustaceans, and 1 agnathan (Appendix 2); a further 8 teleost, 1 elasmobranch, and 2 crustacean species were not identified to genus level. The greater number of species recorded in summer can be attributed to the extra depth range (800–1000 m) sampled, better identification of the more unusual species, and possibly more stations. Table 5 gives the total catch, percentage catch composition, and station occurrence data for the 25 most abundant (major) species for both surveys.

Hoki, the main species caught, made up 26 and 34% of the catch in winter and summer, respectively. Javelinfish, ling, and rattails (all species combined) were the next most important on both surveys. Species encountered most frequently (on over 85% of stations) were hoki, javelinfish, ling, pale ghost shark, and warty squid. The percentage catch composition and occurrence of the 25 major species was similar on both surveys. However, the 800–1000 m stations included on the summer survey increased the relative proportion of the catch of deeper water species such as hake, ribaldo, oreos, and deepwater dogfish (Tables 5 and 6).

Table 5: Catch composition and station occurrence of the 25 major species*

	Winter			Summer		
	Total catch (kg)	% of all spp.	% station occurrence	Total catch (kg)	% of all spp.	% station occurrence
Hoki	20 240	25.9	94	34 863	33.8	97
Javelinfish	15 584	19.9	97	14 596	14.2	94
Ling	9 844	12.6	92	8 312	8.1	86
Rattail spp.	9 683	12.4	–	7 197	7.0	–
Pale ghost shark	5 731	7.3	91	3 447	3.3	87
Southern blue whiting	3 245	4.1	46	3 873	3.8	36
Hake	2 457	3.1	46	5 407	5.2	40
Baxter's dogfish	1 375	1.8	40	729	0.7	33
Warty squid	1 104	1.4	86	1 333	1.3	93
Ribaldo	1 083	1.4	54	3 632	3.5	54
Dark ghost shark	1 060	1.4	7	420	0.4	12
Silverside	916	1.2	74	1 662	1.6	54
Longnosed chimaera	519	0.7	61	295	0.3	49
Shovelnosed dogfish	463	0.6	12	810	0.8	8
Lookdown dory	424	0.5	49	381	0.4	45
Deepwater dogfish 1‡	410	0.5	3	1 505	1.5	14
Spineback eel	337	0.4	49	440	0.4	47
Finless flounder	331	0.4	67	197	0.2	53
Swollenheaded conger eel	308	0.4	54	392	0.4	46
Spotted spiny dogfish	297	0.4	28	602	0.6	31
Black oreo	192	0.2	3	1 521	1.5	8
Silver warehou	121	0.2	3	428	0.4	7
Deepwater dogfish 2‡	114	0.1	4	748	0.7	11
White warehou	61	< 0.1	23	2 762	2.7	30
Smooth oreo	43	< 0.1	3	3 288	3.2	11
Total	78 241			103 096		

* Defined as ≥ 0.4% of the total catch on either survey.
– Not calculated because species combined.
‡ Deepwater dogfish: 1, *Centroscymnus crepidater*; 2, *Centrophorus squamosus*.

Table 6: Mean catch rates (kg.km^{-2}) for the 15 major* and all combined species by stratum and depth range

	Species code†															All
Stratum	HOK	JAV	LIN	GSP	SBW	HAK	GSH	SSI	ETB	WSQ	RIB	LDO	SPD	BOE	WWA	spp.
Winter																
300–600 m																
1	1 430	34	162	0	0	0	25	+	0	0	0	4	6	0	+	1 873
3	63	86	102	128	0	4	0	6	3	6	2	7	21	0	+	762
6	99	77	86	19	+	23	124	+	0	3	1	15	7	0	2	577
9	132	75	73	37	4	3	40	24	0	4	2	2	1	0	+	457
11	83	74	98	21	236	4	0	13	0	10	1	2	0	0	+	648
12	48	131	97	37	11	5	0	14	+	9	1	4	0	0	+	419
13	90	143	88	69	53	2	0	17	0	6	1	4	11	0	1	535
16	1	1	5	57	153	0	0	0	17	6	0	13	0	0	0	309
Mean 300–600 m	149	98	89	45	59	5	20	13	1	6	1	5	5	+	+	588
600–800 m																
2	156	148	20	27	0	25	5	+	0	8	34	2	1	0	0	881
4	151	85	32	89	0	41	0	1	13	5	13	2	1	16	1	519
5	408	185	43	132	0	228	0	2	23	7	13	16	+	0	1	1 188
7	90	279	121	39	0	6	0	1	0	9	16	2	0	0	2	794
8	225	118	77	51	+	24	0	17	5	9	21	1	2	0	1	751
10	152	241	76	80	0	10	0	+	16	10	24	0	0	0	0	853
14	234	272	176	62	1	19	0	2	15	20	21	1	+	2	0	1 008
15	232	187	79	19	3	4	0	+	65	22	22	1	0	0	+	811
17	5	10	0	4	+	0	0	0	31	13	3	0	0	7	0	217
Mean 600–800 m	212	183	89	59	1	39	+	3	24	14	19	3	+	3	+	822
Overall mean	180	140	89	52	30	22	10	8	13	10	10	4	3	2	+	704
Summer																
300–600 m																
1	188	69	132	0	0	0	13	+	0	0	0	12	31	0	1 046	1 941
3	150	14	73	26	0	5	42	1	0	2	0	12	114	8	1	781
6	160	71	19	5	+	5	30	3	0	5	+	2	1	0	+	345
9	218	54	103	33	4	5	+	27	0	6	5	5	2	0	2	521
11	139	7	62	20	71	2	0	17	0	7	+	1	+	0	+	342
12	101	55	64	20	9	2	0	57	0	7	0	2	4	0	3	340
13	173	59	61	30	35	1	0	8	0	4	+	4	2	0	3	397
16	4	2	34	8	1 067	0	0	0	10	5	0	3	0	0	2	1 221
Mean 300–600 m	154	50	67	23	50	3	5	22	+	5	1	4	7	0	40	483
600–800 m																
2	303	136	71	0	0	26	13	0	0	0	74	1	0	0	7	1 029
4	200	56	58	48	0	11	0	+	3	5	21	3	1	88	+	559
5	143	116	80	86	0	82	0	0	20	6	19	12	20	0	7	659
7	338	203	37	9	0	24	0	+	3	19	23	1	0	0	1	771
8	319	98	36	22	+	52	2	2	11	9	29	+	2	0	1	657
10	552	82	63	21	0	9	0	1	1	10	17	2	0	0	3	852
14	257	115	41	15	+	4	0	3	3	7	10	2	+	0	4	516
15	261	74	40	2	0	0	0	1	4	7	40	1	+	0	+	484
17	2	2	3	2	25	0	0	0	8	3	0	0	0	+	0	55
Mean 600–800 m	302	101	47	21	1	20	1	1	5	9	24	2	1	12	2	635
Mean 300–800 m	223	74	58	22	27	11	3	12	2	7	11	3	4	6	22	554
800–1000 m																
18	492	864	11	0	0	627	3	0	0	13	297	0	0	0	3	2 743
19	18	26	0	7	0	4	0	0	46	25	7	0	0	0	0	685
20	49	108	0	7	0	0	0	0	13	18	12	0	0	0	0	364
21	51	88	3	13	0	0	0	0	19	7	7	0	0	30	0	358
22	114	41	3	35	0	20	0	0	3	17	+	1	+	147	0	859
23	2	0	0	1	0	0	0	0	7	12	0	0	0	2	0	540
24	41	426	0	4	0	1 004	0	0	3	5	21	0	0	0	0	1 884
25	16	0	0	17	0	11	0	0	33	15	0	0	0	35	0	1 244
Mean 800–1000 m	100	184	2	11	0	174	+	0	16	14	44	+	+	28	+	1 050
Overall mean	208	87	50	21	23	32	3	11	4	8	16	2	4	9	19	618

* Defined as the most abundant species on both surveys in 300–800 m depth.
† Species codes are given in Appendix 2.
\+ = < 0.5.

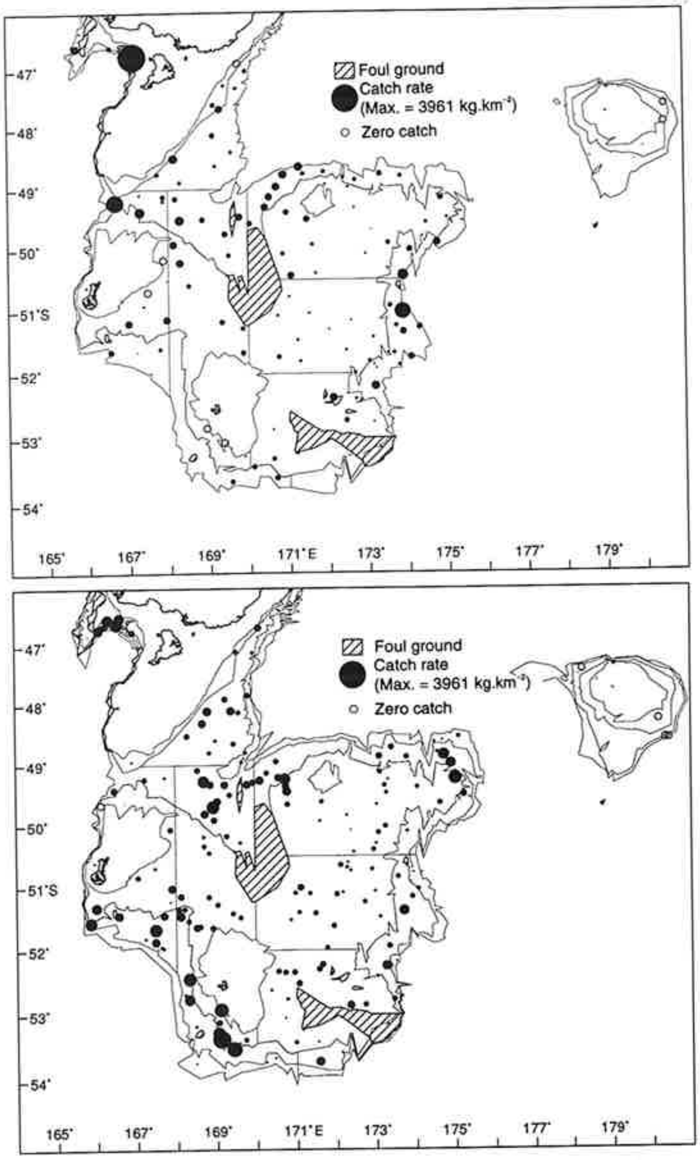

Figure 3: Distribution and catch rates of hoki in winter (*above*) and summer (*below*).

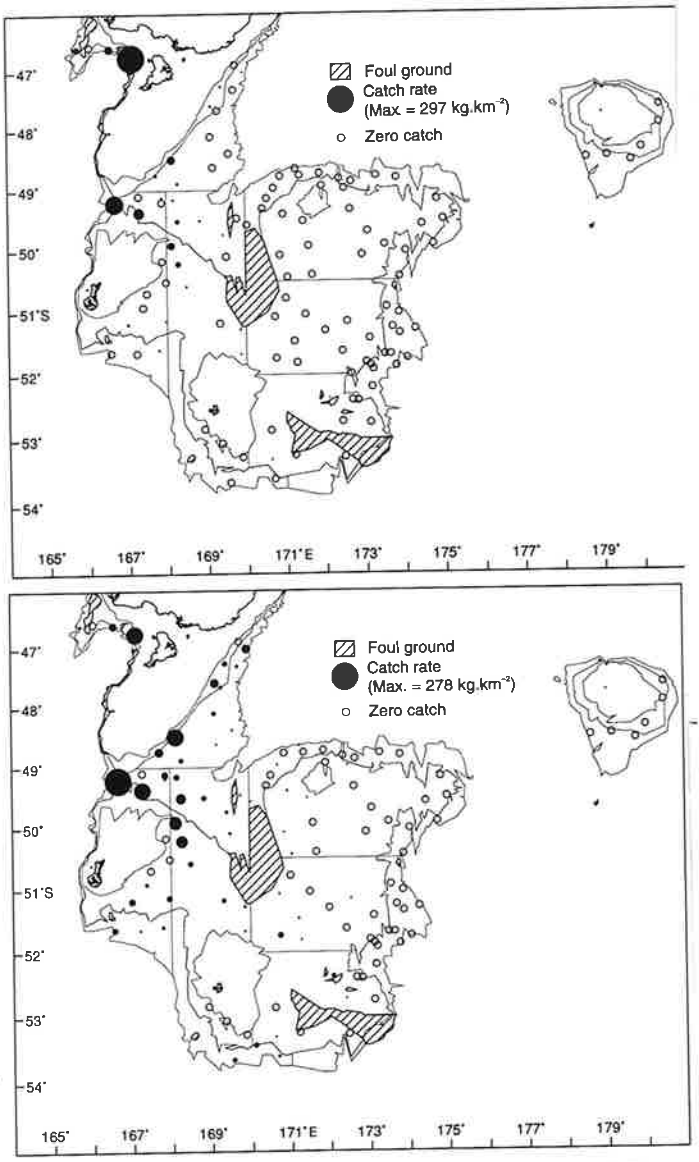

Figure 4: Distribution and catch rates of maturing (stages 3–5) male (*above*) and female (*below*) hoki.

Catch rates

General

Catch rates of the 15 major species and all species combined, by stratum and depth, are given in Table 6. The catch rates by station of hoki, ling, southern blue whiting, and hake are given in Figures 3–7. The mean catch rates for all species combined in the 300–800 m depth range were similar for both surveys — 0.7 $t.km^{-2}$. The combined species catch rate in the 800–1000 m depth range in summer (about 1.1 $t.km^{-2}$) was almost twice that recorded in the 300–800 m range.

Hoki

Winter catch rates (Figure 3) were highest (> 1.0 $t.km^{-2}$) on stations at Puysegur, south of the Snares Islands, and in the far east of the survey area. The highest stratum mean catch rates occurred in strata 1 and 5. In summer, comparable station catch rates were recorded only to the west of Campbell Island, and high mean stratum catch rates occurred in strata 10 and 18. The overall mean catch rates for both surveys (300–800 m depth only) were similar at about 0.2 $t.km^{-2}$. Hoki were relatively scarce around the Bounty Islands.

Mean catch rates of hoki in winter were slightly lower in shallower strata (300–600 m) than in deeper strata (600–800 m). The same trend occurred in summer. Mean catch rates in the 800–1000 m strata in summer were relatively low, except for stratum 18.

Catch rates of males and females with gonads in maturation stages 3 to 5 during the winter survey are shown in Figure 4. Most of these fish were at stage 3 and were concentrated at the western edge of the survey area, particularly in the Puysegur area and on the shelf edge between the Snares Islands and the Auckland Islands.

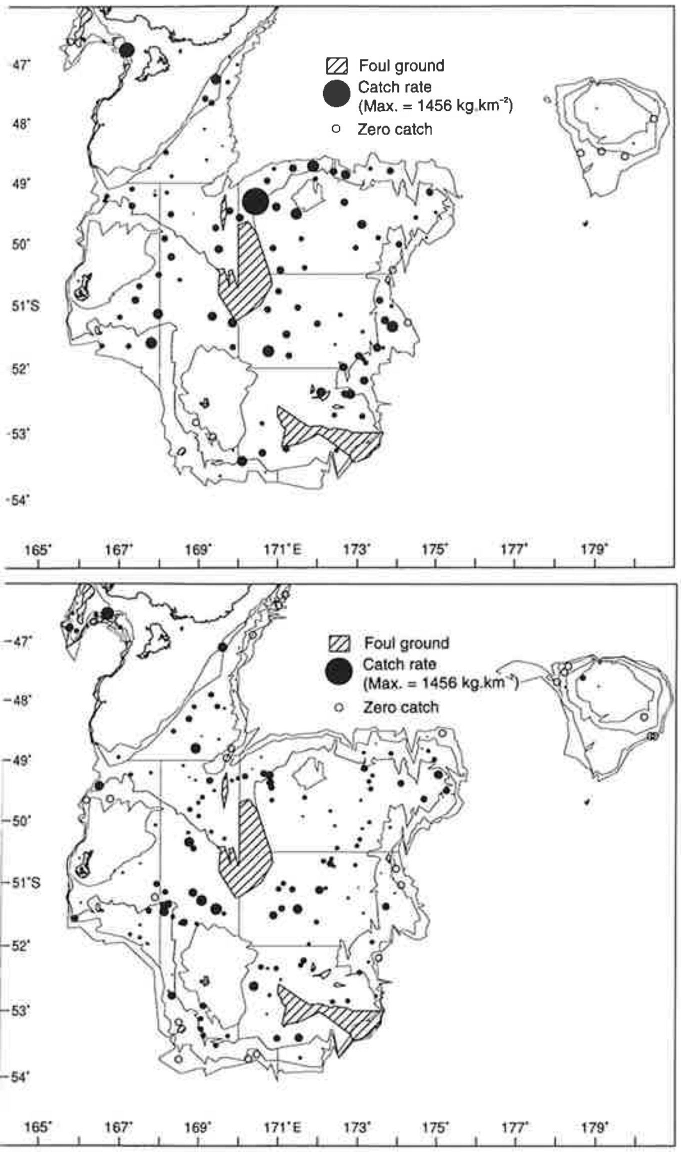

Figure 5: Distribution and catch rates of ling in winter (*above*) and summer (*below*)

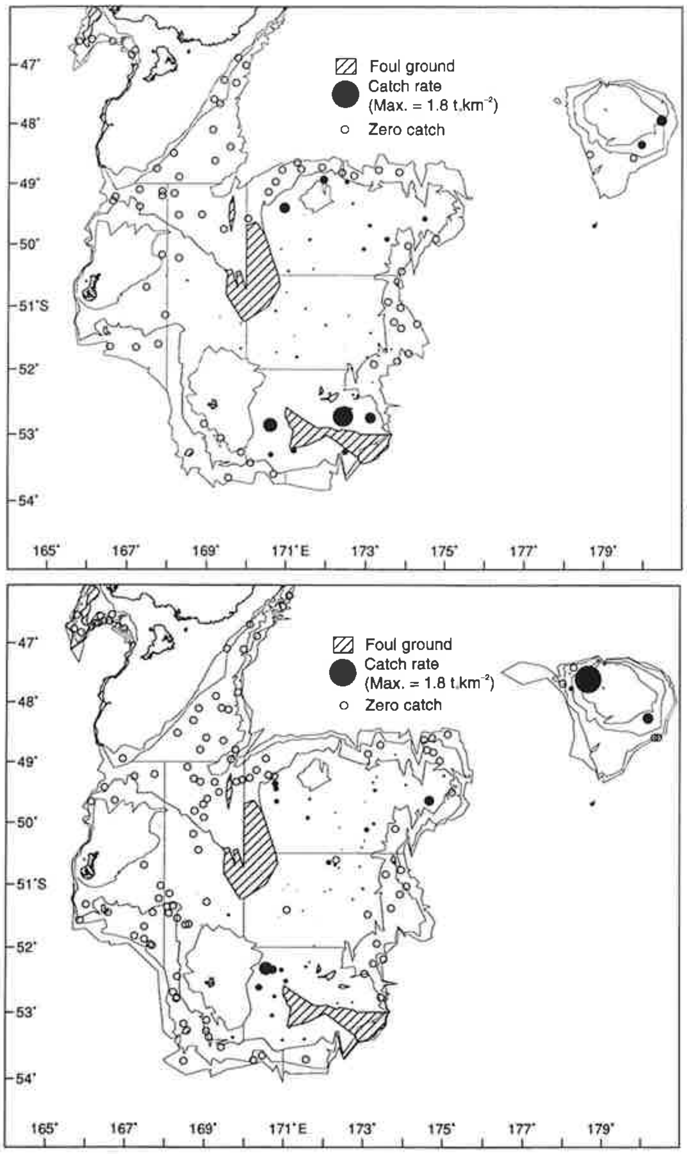

Figure 6: Distribution and catch rates of southern blue whiting in winter (*above*) and summer (*below*).

Ling

Ling were present in all areas, but relatively scarce around the Bounty Islands.

In winter, individual station catch rates (Figure 5) exceeded 1.0 $t.km^{-2}$ only once, on the western side of Pukaki Rise (stratum 14). Catch rates of over 0.3 $t.km^{-2}$ occurred at Puysegur (stratum 1) on both surveys. The overall mean catch rate for winter and summer surveys (300–800 m depth only) were similar — 0.09 and 0.06 $t.km^{-2}$.

In both surveys catch rates in 300–600 m were the same as, or similar to, those in 600–800 m depth. Mean catch rates in the 800–1000 m strata in summer were low: the overall mean was only 2 $kg.km^{-2}$.

Southern blue whiting

Maximum individual station catch rates of southern blue whiting in winter (Figure 6) were 1.0 $t.km^{-2}$ to the east of Campbell Island (stratum 11), and in summer 1.8 $t.km^{-2}$ at the Bounty Islands (stratum 16). These strata also had the highest stratum mean catch rates in both surveys. Southern blue whiting were rare west of Pukaki Rise and Campbell Island and absent from the Puysegur and Snares areas. The overall mean catch rates in both surveys were about 0.03 $t.km^{-2}$.

Mean catch rates were 50 to 60 times higher in 300–600 m than in 600–800 m, and were zero in 800–1000 m.