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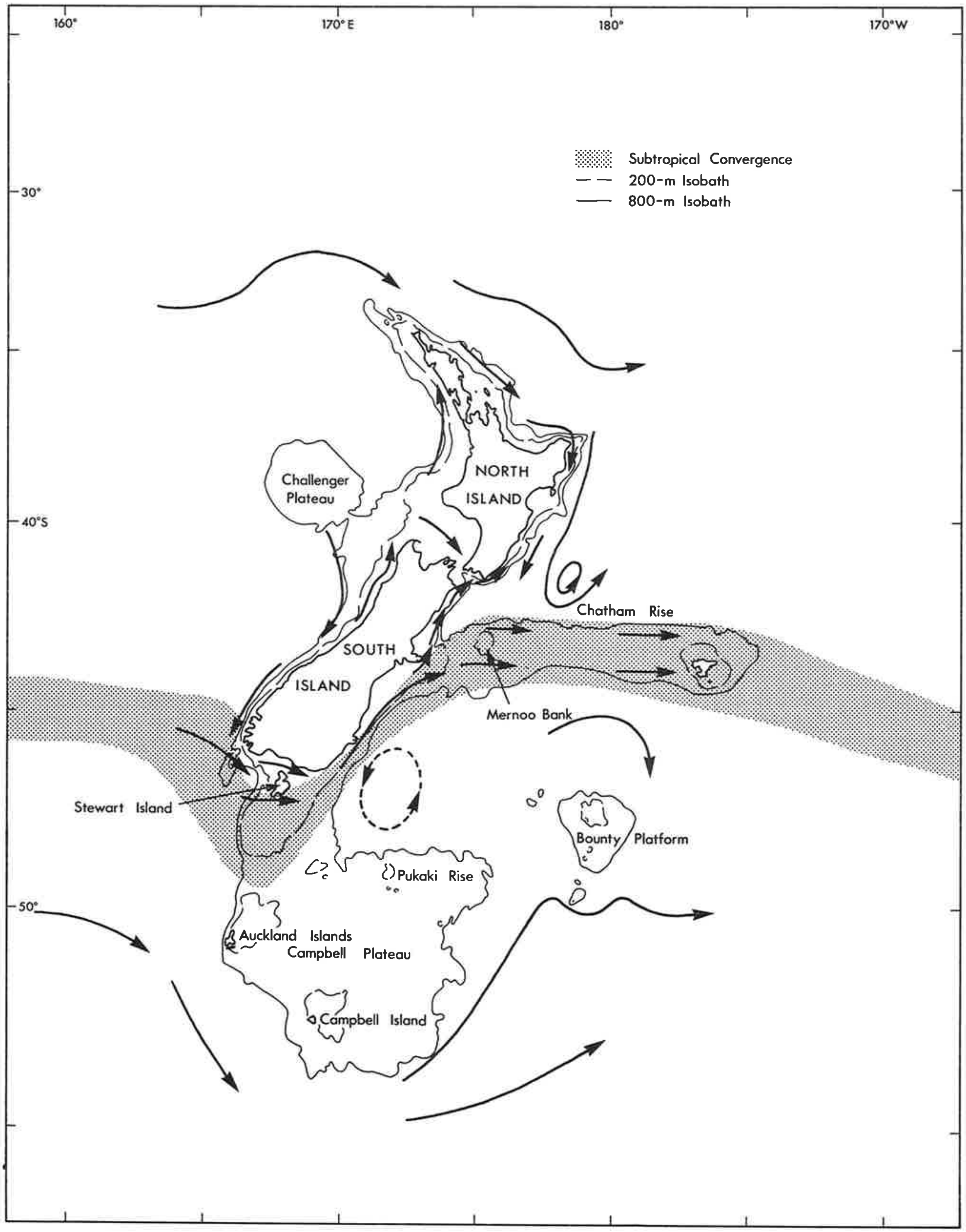

Fig. 1: Major bathymetric features, surface currents, place names, and topographic features of the New Zealand region.

Introduction

In managing the deep-water demersal stocks of its 200-mile Exclusive Economic Zone (EEZ), New Zealand has so far had to rely primarily on the results of foreign fishing activity to gauge the distribution and size of these stocks and infer safe biological yields. Most of the estimates of stock sizes and maximum sustainable yields available from foreign workers (Anon. 1978, Shpack 1978, Blagodyorov and Nosov 1978, Dudarev 1978, and Nosov 1978) are scientifically unsatisfactory in that estimation procedures have not been documented. Thus there is no basis on which to judge their reliability. Francis and Fisher (1979) used the detailed trawl-by-trawl records of the Japanese exploratory stern trawler FRV *Shinkai Maru*, with summaries of Japanese commercial trawling in the area, to make the first fully documented estimates of standing stocks and maximum sustainable yields. Kono (1979) used data from the Japanese commercial fleet in 1977 to estimate the standing stock of hoki (*Macruronus novaezelandiae*) off the west coast of the South Island by the area-swept method.

The New Zealand Government's 500-t vessel FRV *James Cook* has proved too small to cope with the depths and poor weather in many parts of the EEZ, particularly in the large area to the south. Although scientists have spent time as observers on foreign fishing vessels around New Zealand, their inability to direct fishing activities has limited the scope and usefulness of this research.

Recently New Zealand scientists had the opportunity to use a large fishing vessel over whose activities they had some control. The West German stern trawler FMV *Wesermünde* spent 1979 doing exploratory fishing in the deep waters of New Zealand's EEZ. By agreement between High Seas Fisheries (N.Z.) Ltd (the joint venture company controlling the project) and the Governments of the Federal Republic of Germany and New Zealand, the vessel's time was divided equally between commercial fishing and research. Allocation of time between these activities was made at sea jointly by the master and the chief scientist on board, with the understanding that, though commercial fishing was to take preference, exactly one-half of each of the five 2-month cruises was to be spent in research.

The research programme for the year was devised jointly by German and New Zealand scientists and at all times there were eight scientific personnel aboard, four from the Federal Republic of Germany and four from New Zealand. During the commercial phases scientists were free to take and process limited samples from the catches.

This report deals directly with the research phases of three of the five cruises; cruises II, IV, and V. These were devoted to three separate stratified random bottom-trawl surveys of the main deep-water trawling grounds of the EEZ; from them it was hoped to obtain three independent estimates of stock sizes and information on the distribution of the stocks throughout the year.

The main species considered in this survey were hoki (*Macruronus novaezelandiae*), southern blue whiting (*Micromesistius australis*), hake (*Merluccius australis*), ling (*Genypterus blacodes*), and silver warehou (*Seriolella punctata*). The fisheries for these species are described briefly in Francis and Fisher (1979) and with more detail in Patchell (1979), Paul (1979), and Cawthorn (1979). The EEZ, with its major bathymetric and hydrological features, is shown in Fig. 1.

Materials and Methods

Wesermünde has an overall length of 95 m, breadth 15.8 m moulded, tonnage 3577 GRT, and horsepower 5000. The net used throughout the surveys was a bottom trawl with 76-m (250-ft) ground rope used with polyvalent trawl doors of area 6 m^2. At 4 knots the net opening had the following dimensions: height 10.5–15 m and breadth (wingtip to wingtip) 30–35 m.

Survey design

At any time of year there are many factors which may affect the distribution of demersal fish. These include water temperature and composition, bottom depth and type, food availability, geographical location, and reproductive state of the fish. All of these may be monitored during a survey and used in the analysis and interpretation of the data. However, the choice of trawl stations can be based only on those factors for which detailed prior information is available. In this case, bottom depth and geographical location were the only two. So, to increase the precision of biomass estimates, the survey area was stratified by area and bottom depth. The ten areas (Fig. 2) were chosen partly on the basis of known fishing grounds and major bathymetric boundaries and partly to coincide with administrative areas. Area 5, west coast South Island, was made smaller than the corresponding area used by Francis and Fisher (1979) to concentrate survey effort on the rather restricted area in which most of the commercial trawling off that coast takes place. The Challenger Plateau was not included in any of the surveys because the little information to hand and the lack of commercial interest in the area indicated low fish densities. Stratification by bottom depth was in 200-m intervals with a lower limit of 1000 m; little commercial bottom trawling around New Zealand exceeds this depth. Over the Campbell Plateau (areas 3S, 3W, 3C, and 3E) and in area 5 there was a stratum from 0 to 200 m; elsewhere the uppermost stratum started at 200 m.

For optimal (in the sense of minimum variance) allocation of survey effort between strata (see, for example, Sukhatme and Sukhatme 1970, page 84), the number of stations in any stratum should be proportional to the product of the size of the stratum and the standard deviation of catches in it, divided by the square root of the cost of obtaining one sample (trawl) from it. Estimated sizes of the strata are given in Table 1 as bottom areas. The cost of a trawl may be measured in vessel time. Although deep trawls generally take more time than shallower ones, the difference is not great, because the time spent getting the net between surface and bottom is only a part of the sum of the time the net is on the bottom (nominally 30 minutes in these surveys) and the time taken to get the net aboard once the trawl doors are up. Allowances should also be made for extra steaming time for remote stations and time lost because of bad weather in more exposed parts of the study area. However, because of the difficulty of quantifying the various cost elements, the cost per trawl was taken to be equal in all strata.

Not enough information was available to estimate for each stratum the expected variance in catches, but it is common in trawl data to find that the greater the mean catch, the greater the variance (for example, Grosslein (1971) reports finding the variance approximately proportional to the square of the mean). As a general rule then, the higher the mean fish density, the more intense the survey coverage should be. Thus, in the surveys described here, the distribution of stations between strata was usually proportional to bottom area, but where fish densities were expected to be high, extra stations were added. Furthermore, because of the large area to be covered, one or two areas (considered to be of less interest at that time of year or readily accessible to other survey vessels) were omitted from each survey.

In cruise II, areas 4W and 5 were omitted, but over the other strata the allocation of stations was proportional to bottom area. Because of the low catches below 800 m in cruise II, effort in the deepest strata was reduced by half in cruises IV and V. Effort was increased on the Bounty Platform (area 3E) for cruise IV because of expected southern blue whiting spawning concentrations, and areas 4W and 4E were omitted. In cruise V all areas were covered except for the east coast of the South Island (area 1), where the Government fisheries technology vessel *W. J. Scott* was carrying out an aimed-trawling survey. Random station positions were generated by computer algorithm. A minimum distance of 5 nautical miles between stations was allowed.

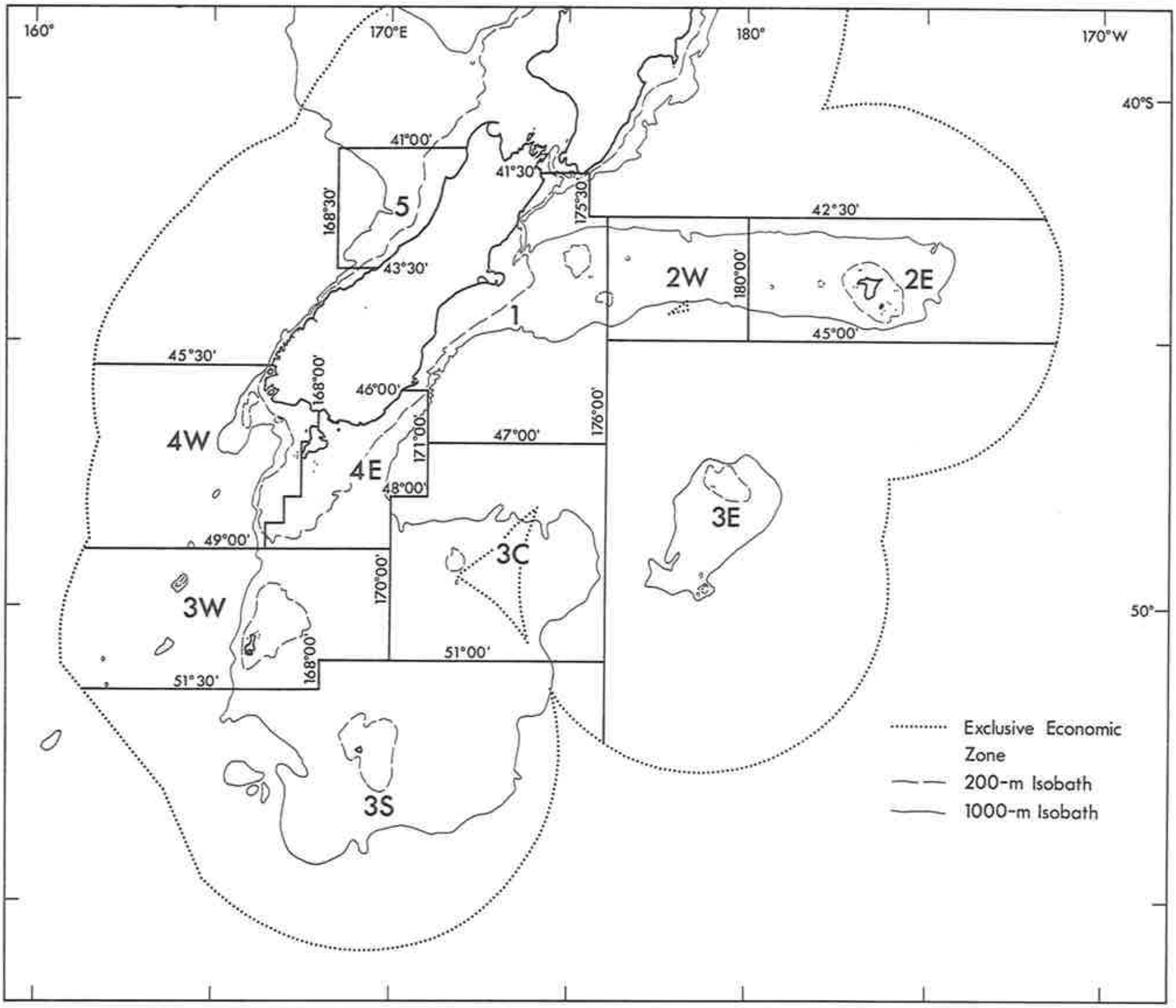

Fig. 2: Areas for stratification.

TABLE 1: Bottom area (km²) by stratum (excludes area within 12-nautical-mile territorial sea)

	Depth zone					
Area	0–200 m	200–400 m	400–600 m	600–800 m	800–1000 m	Total
1		9 129	18 224	10 525	8 817	46 695
2W		19 506	18 722	6 596	12 347	57 171
2E		15 768	26 139	13 972	11 018	66 897
3W	8 239	7 581	38 677	19 796	1 643	75 936
3S	7 318	23 266	57 762	26 725	30 668	145 739
3C	1 069	8 803	35 601	31 634	18 209	95 316
3E	2 561	6 309	8 174	14 481	25 190	56 715
4W		3 990	2 634	2 233	3 047	11 904
4E		1 974	3 781	14 810	2 308	22 873
5	3 181	5 711	3 987	6 084	20 142	39 105
	22 368	102 037	213 701	146 856	133 389	618 351

During each survey trawl (weather permitting) a 20-minute qualitative surface plankton tow was made (net dimensions: 0.5-m diameter opening, 0.333-mm mesh), and after each trawl hydrographic data and samples were collected with a bathythermograph and a series of reversing bottles. In addition, during cruise II quantitative oblique plankton tows were made with bongo nets (0.6-m diameter opening, 0.500-mm and 0.333-mm mesh). For some research trawls a sediment sampler was attached to the ground rope.

Further information on the five cruises is contained in cruise reports (Steinberg 1979, Sahrhage 1979, Kerstan 1979, 1980, and Wagner 1979), and Kerstan and Sahrhage (1980) present summaries of the sediment data and part of the biological data. Results from cruise IV on the west coast of the South Island are given by van den Broek (1980).

Survey implementation

All three surveys were limited to daylight hours, as many of the species concerned are known to move up into mid water at night and thus become unavailable to a bottom trawl. This led to a problem which became apparent during cruise II. Often several hours of daylight remained, but no stations were close enough to be occupied before dusk. It was decided at these times to move the nearest station slightly to allow its inclusion that day. The new position was chosen in the same stratum and independent of any knowledge of fish distributions. This procedure was followed through each survey. Furthermore, for cruises IV and V more stations were allocated than were expected to be occupied. This ensured that there would be enough stations for the time available and also allowed more flexibility in the choice of cruise path from station to station.

The survey in cruise II was curtailed by industrial problems causing the loss of more than a week's research, with the result that coverage in some areas was much less than planned. Because of high catch rates during the commercial part of cruise IV, this phase was extended and took up more than half of the cruise. Thus part of the planned cruise IV was actually carried out at the beginning of an extended research phase in cruise V. Nevertheless, in the results given here these stations are considered as part of the cruise IV survey.

Results

The number of stations occupied for each stratum and cruise is shown in Table 2, and the distribution of stations is shown in Figs. 3, 4, and 5. Table 3 shows the dates of occupation of each area.

The final proportional distribution of stations was not as planned, and some strata which were expected to be occupied were not. Firstly, as a result of imperfect bathymetric information, some stations were found not to lie in the expected depth zone. When time permitted, such stations were moved to the closest position in the required depth range, but this was not always possible. Secondly, decisions as to which stations would be omitted were subject to the contingencies of the day-to-day planning of the research programme rather than optimal sampling considerations and, in cruise II, were affected by the unexpected loss of more than 1 week's research.

When a trawl was cut short or the trawl gear was damaged by unfavourable bottom conditions, a judgment was made on whether the problem was sufficient to make the catch non-representative. As a result, two trawls (stations 1 and 58 in cruise V) have been omitted from this analysis. At station 79 in cruise II a thresher shark of estimated weight 200 kg was caught. This made up about 30% of the catch by weight, but was ignored in the biomass estimates.

By far the most abundant species caught was hoki, which amounted to 48% of the total catch and was present in 75% of all trawls. In its main depth range of 300–900 m (Fig. 6), and excluding the Bounty Platform, where it was rarely found, it was present in 95% of all trawls.

With the exception of two isolated fish found in separate trawls in area 2 (depths 663 and 449 m) in cruise IV, southern blue whiting was found only in area 3; most of the fish were caught in areas 3S and 3C, where they made up 45% of the total catch. In cruises II and V this species was distributed between 300 and 700 m in both areas, but in cruise IV there

TABLE 2: Distribution of stations among strata

	Depth zone						
Area	0–200 m	200–400 m	400–600 m	600–800 m	800–1000 m	Total	
1			1	1	1	3	
2W		2	3	1	1	7	
2E		3	3	2	2	10	Cruise II
3W		1	5	2		8	78 stations
3S	1	2	7	5	7	22	22½ days
3C		2	11	5	1	19	3.5 stations
3E	1	1	1	2	1	6	per day
4W							
4E			1	1	1	3	
5							
1		4	5	5	1	15	
2W		5	3	1	1	10	
2E		1	3	1	3	8	Cruise IV
3W	2	1	2	3		8	113 stations
3S	1	2	11	4	2	20	27½ days
3C	1	1	5	5	1	13	4.1 stations
3E	3	7	3	4	2	19	per day
4W							
4E							
5	3	4	6	3	4	20	
1							
2W		4	4	2	1	11	
2E		2	7	3		12	
3W		1	6	4		11	Cruise V
3S	3	1	17	2	4	27	115 stations
3C	1	1	17	3	2	24	30 days
3E	1	1	2	3	2	9	3.8 stations
4W			2			2	per day
4E			1	4		5	
5	2	2	5	5		14	

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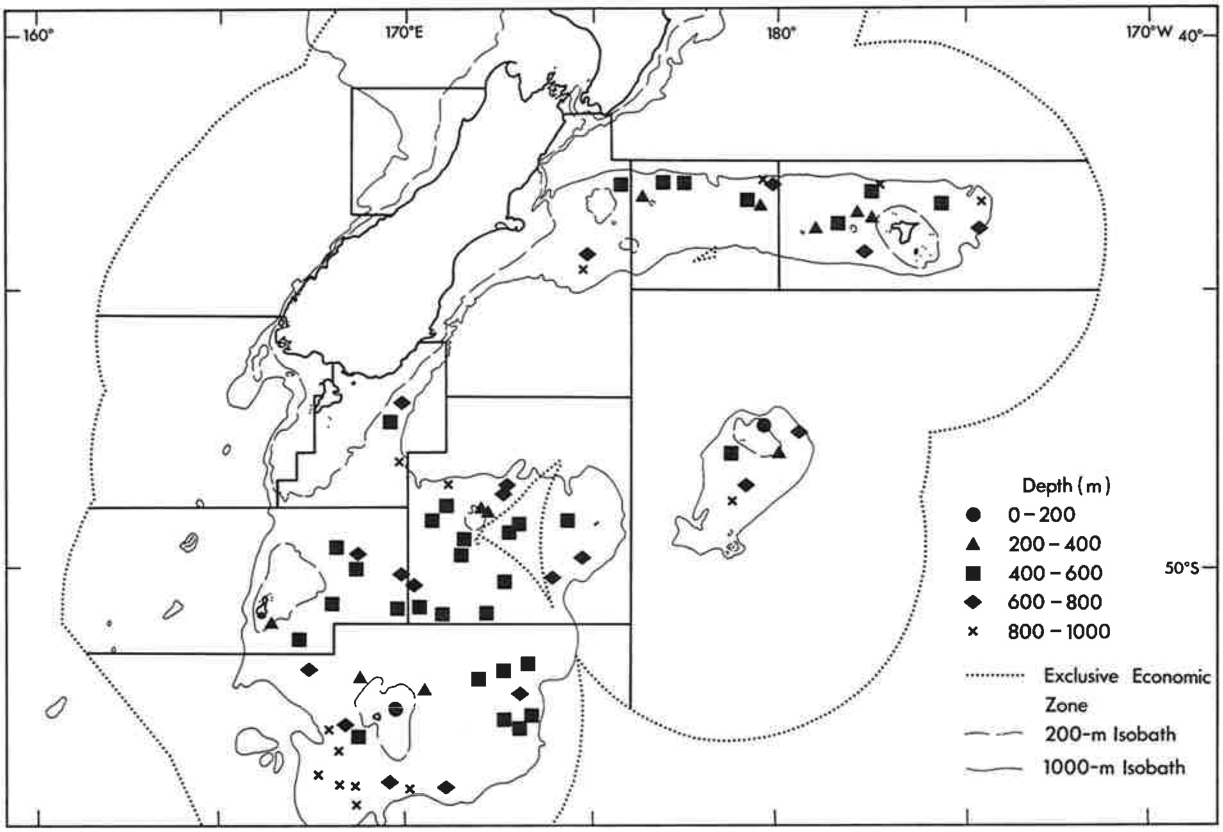

Fig. 3: Stations for Cruise II.

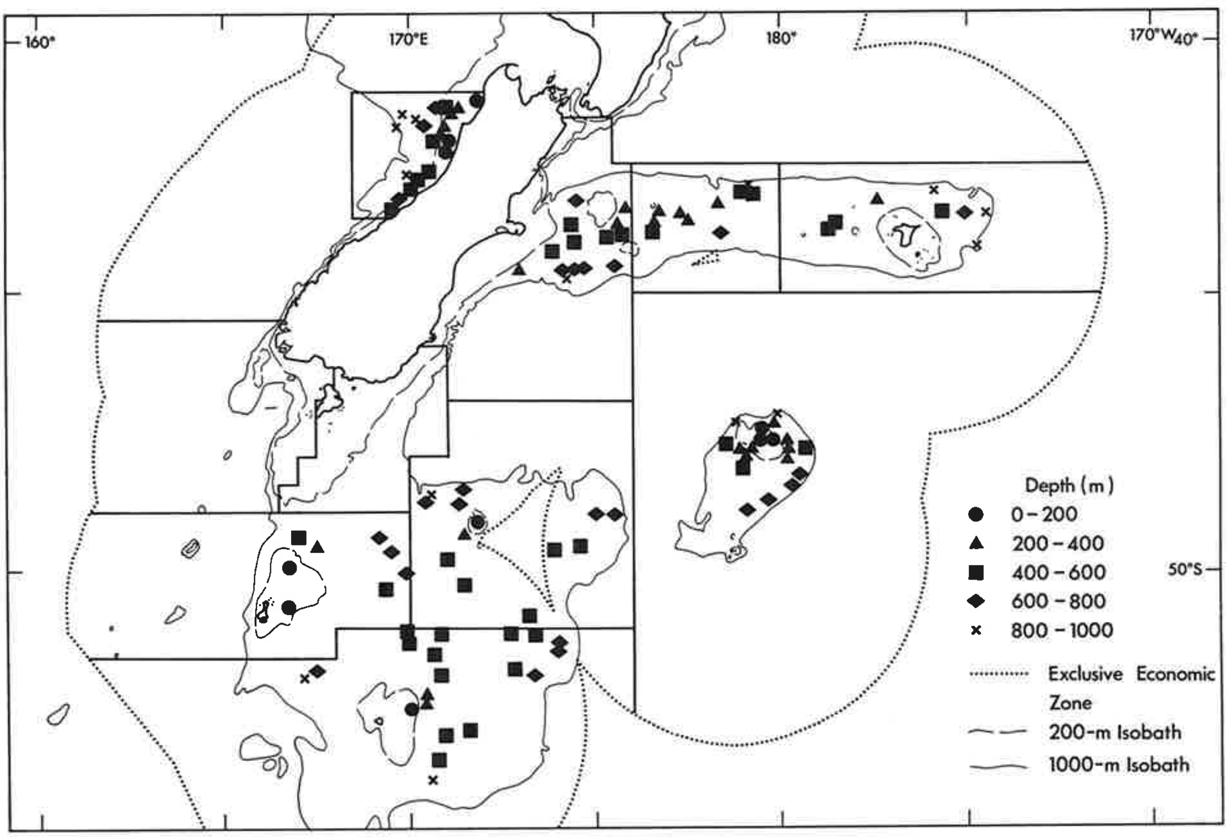

Fig. 4: Stations for Cruise IV.

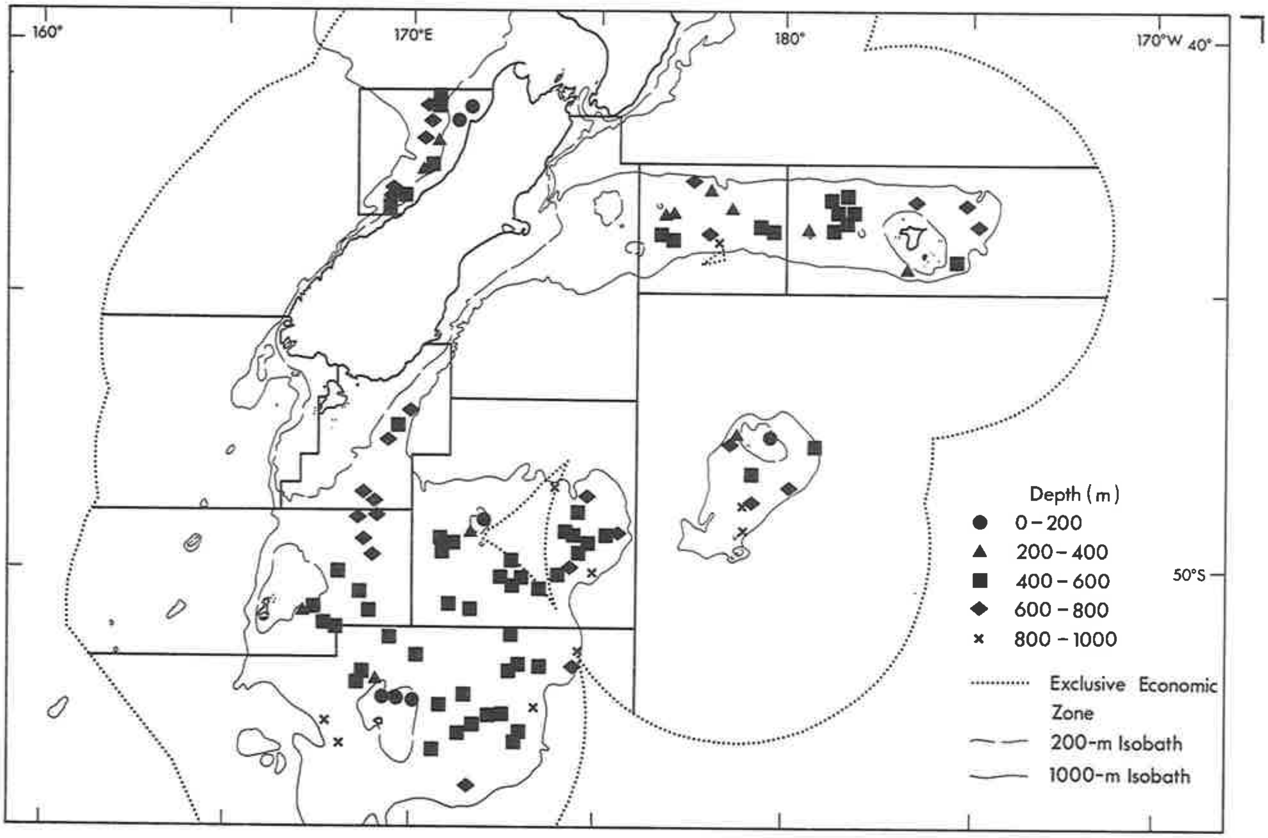

Fig. 5: Stations for Cruise V.

TABLE 3: Dates of occupation of areas

	Cruise II		Cruise IV		Cruise V	
Area	Date	Stations	Date	Stations	Date	Stations
1	20–21 Apr	3	10–14 Oct	15		
2W	19–20 Apr	7	5–6, 10 Oct	10	21–24 Nov	11
2E	16–18 Apr	10	3–4 Oct	8	24–27 Nov	12
	10 Apr	1				
3W	8–9 May	5	17–19 Sep	8	29–31 Oct	11
	17 May	2				
3S	9–15 May	22	19–24 Sep	20	20–28 Oct	27
	11–12 Apr	7	24–27 Sep	13	15–20 Oct	24
3C	16–19 May	12				
3E	13–14 Apr	6	28 Sep–10 Oct	19	28–30 Nov	9
4W					13–14 Nov	2
4E	20 May	3			31 Oct–1 Nov	5
5			25–29 Aug	20	15–17 Nov	14

was a significant change in its distribution, with much shallower catches being recorded (Fig. 7) and greatest catches being in area 3S. No spawning southern blue whiting were found and neither were the concentrations in areas 3C and 3E described by Shpack (1978).

Ling was caught in 70% of all trawls, mostly between 200 and 800 m (Fig. 8) and mostly in small quantities, averaging only 25 kg per trawl over those trawls in which it was caught. The only substantial catch was during cruise II, where 775 kg (out of a total catch of 851 kg) was caught in 210 m in area 3C.

These three species together accounted for two-thirds of the fish caught during the surveys. No other single commercial species was present in any quantity. Areas 1 and 4, which include major grounds for silver warehou, were only sparsely covered in the surveys, and the winter spawning concentration of hake in area 5 was not fished. For these reasons no attempt has been made here to estimate biomasses for these two species.

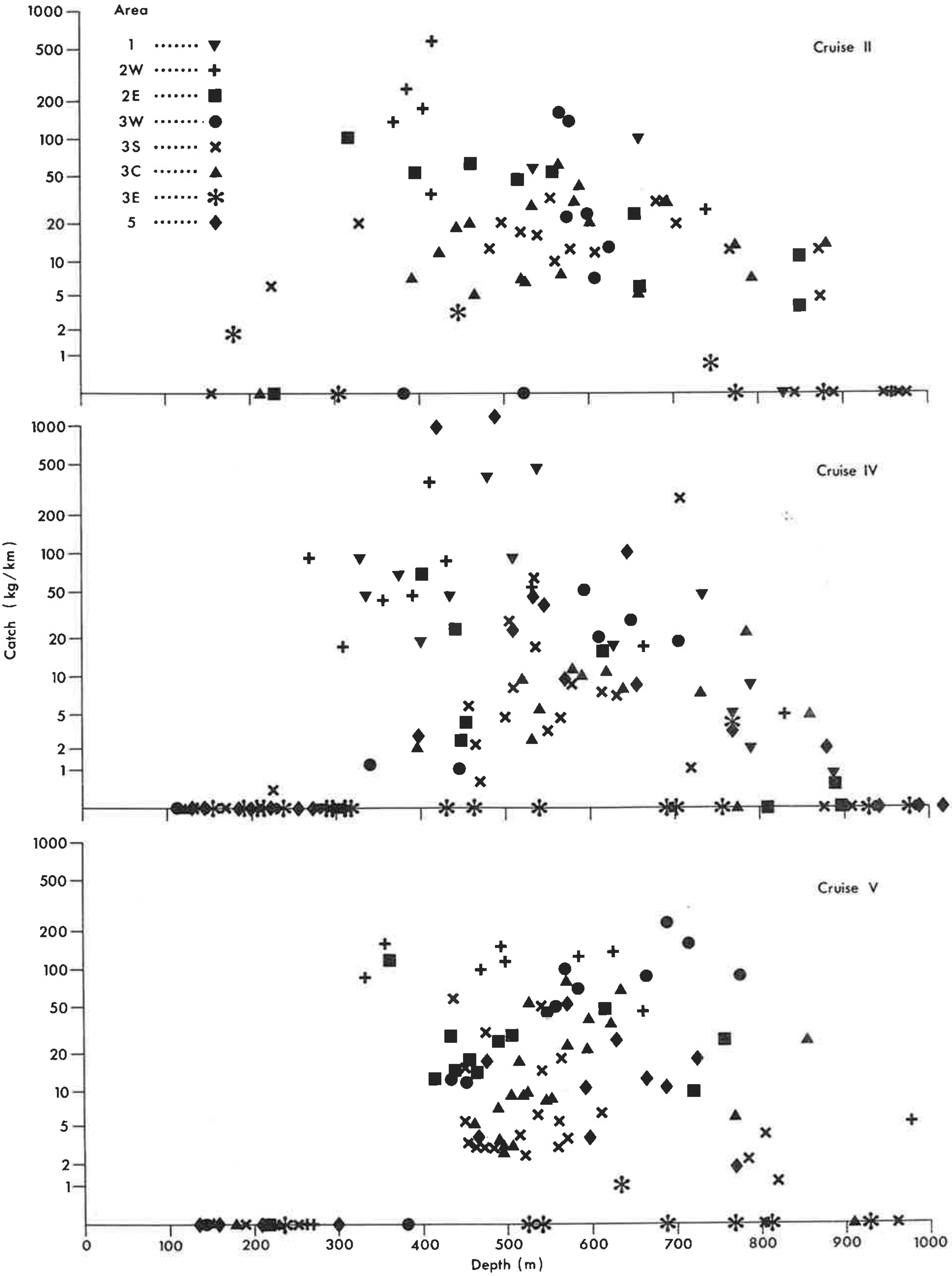

Fig. 6: Hoki catch by depth, area, and cruise.

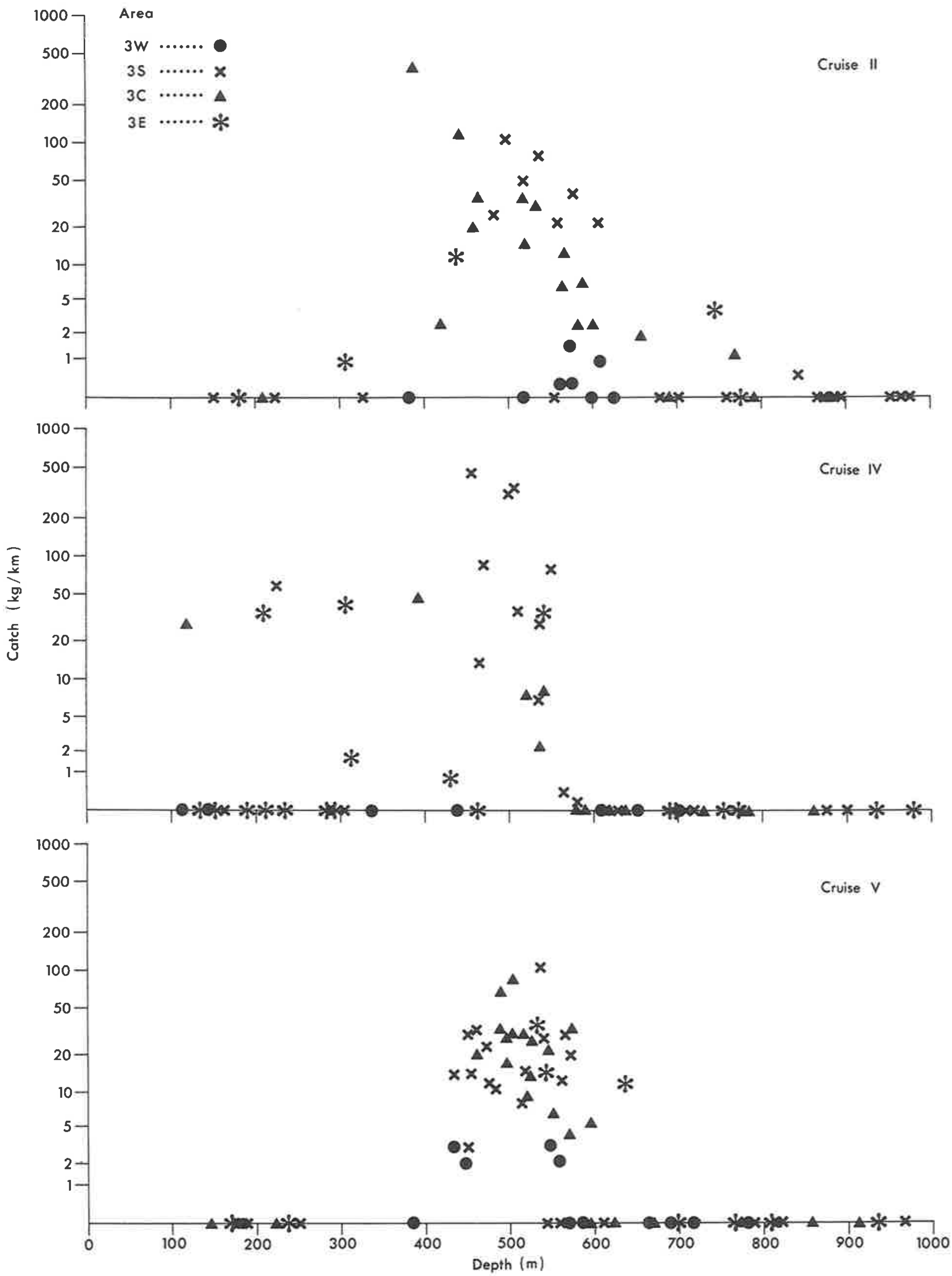

Fig. 7: Southern blue whiting catch by depth, area, and cruise.

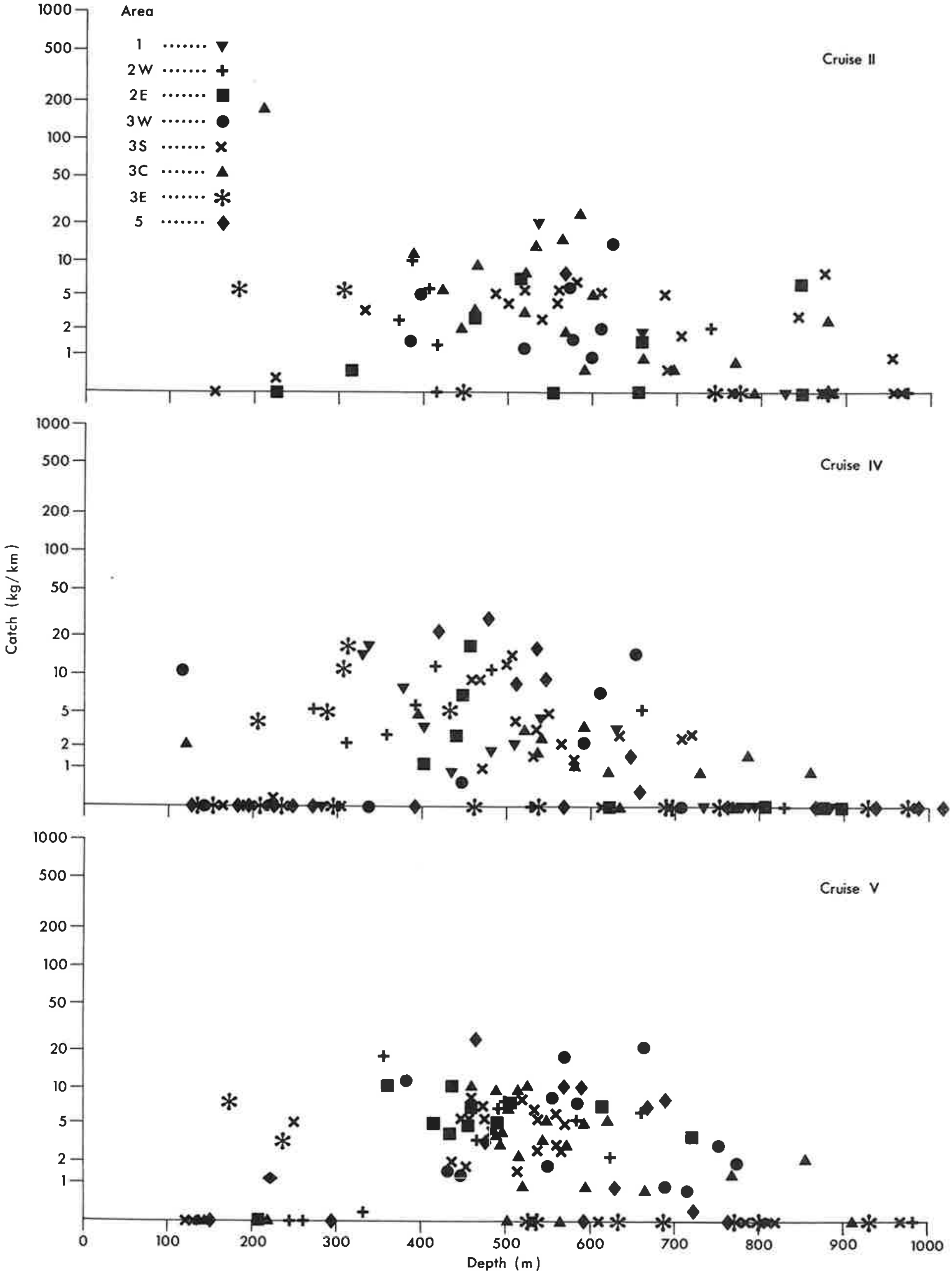

Fig. 8: Ling catch by depth, area, and cruise.

Estimation

Because of poor coverage, the following areas have not been included in the estimation procedure: areas 4W and 4E in any of the three cruises; area 1 in cruises II and V; and area 5 in cruise II. Details of the few stations which were occupied in these area-cruise combinations are summarised in Table 4.

Estimates were made independently for each cruise and separately for each of the three main species—hoki, southern blue whiting, and ling—and also for all other species combined. Strata with fewer than two stations presented a problem in estimation. To overcome this the following groupings of strata were made:

1. Strata of the same depth zone in the same cruise from areas 1 and 2;
2. Strata of the same depth zone in the same cruise from area 3;
3. Strata of depth zone 800–1000 m in areas 1 and 2 in cruise IV, and area 2 in cruise V;
4. Strata of depth zone 800–1000 m in area 5 in cruises IV and V.

Where there were no stations in a stratum, mean catch rate and biomass estimates were made from the corresponding group of strata. Similarly estimates for standard deviations were made from the grouped data when the number of stations in a stratum was less than two.

The first quantities estimated were mean catch rates and their standard deviations; the following formulae were used:

$$X_{ijk} = \frac{W_{ijk}}{d_{ijk}}$$

$$X_{ij} = \left(\sum_{k=1}^{n_{ij}} X_{ijk} \right) / n_{ij}$$

$$S_{ij} = \left(\frac{\sum_{k=1}^{n_{ij}} (X_{ijk} - X_{ij})^2}{n_{ij}(n_{ij} - 1)} \right)^{\frac{1}{2}}$$

where W_{ijk} = catch weight (kg) from trawl k in stratum i,j (area i, depth zone j) and similarly d_{ijk} = distance trawled (km) (when this was not recorded directly from the ship's log it was calculated as the product of speed and trawl duration); X = catch rate (kg/km), either for a single trawl (X_{ijk}) or as a mean over a stratum (X_{ij}), and S_{ij} is an estimate of the standard deviation of X_{ij}. Values of X_{ij} and S_{ij} are presented in Tables 5, 6, and 7.

Secondly, an index of fish abundance and its standard deviation was calculated for each area by the formulae:

$$A_i = 0.001(\sum_j X_{ij}\, a_{ij})$$

$$S_i = 0.001(\sum_j S^2_{ij}\, a^2_{ij})^{\frac{1}{2}}$$

where A_i = index of fish abundance (t.km) in area i, S_i is its standard deviation, and a_{ij} = bottom area (km^2) in stratum i,j. These indices (Tables 8–12, Fig. 9) are proportional to estimated biomass and are constructed solely from catch rates without any contribution from less easily measured quantities such as effective net width.

To convert these indices to biomass estimates the following formula should be used: $B_i = A_i/(uvb)$ where B_i = biomass (t) in area i, b = width of the trawl net (km) (wingtip to wingtip), u = availability (proportion of fish directly above the area swept by the net which are available to it, that is, above the footrope and under the headline), and v = vulnerability (proportion of available fish expected to be caught). Net measurements made during cruise I showed a net width of 30–35 m at 4 knots. Since most of the trawls in this survey were at speeds of between 4 and 5 knots, a value of b = 0.035 was used. No estimate of the variability of b is available. For hoki there are the following estimates of u and v (G. J. Patchell, pers. comm.):

area 5	$u = 0.9,\ v = 0.6$
areas 1, 2, and 3W	$u = 0.95,\ v = 0.9$
areas 3S and 3C	$u = ?,\ v = 0.6.$

No estimates of their variability are available. For other species no estimates of u and v are available. Thus, to estimate biomass one is mostly forced to use arbitrary values of u and v and confidence intervals cannot be provided for such estimates.

Since estimates without some measure of precision are of little or no scientific value, it was decided to attempt to estimate upper and lower bounds for the biomasses. After Francis and Fisher (1979) (the product uv here is equivalent to their quantity $1 - E$), upper and lower bounds on the quantity uv were set at 0.5 and 1 respectively. The following formulae were used:

Lower bound of biomass in area $i = (A_i - 2S_i)/b$

Upper bound of biomass in area $i = (A_i + 2S_i)/(0.5b)$

and the results are presented in Tables 13–17. Since the abundance indices can be expected to have distributions which are skewed to the right, these bounds will both tend to err on the low side.

TABLE 4: Details of stations not included in biomass estimates

Cruise	Station No.	Area	Mean depth (m)	Distance trawled (km)	Catch (kg)	Main species (catch in kg)
II	95	1	536	4.6	892	HOK(266) SND(152) JAV(120) LIN(96)
II	96	1	659	4.6	738	HOK(448) SOR(69) JAV(54) RAT(53) GSP(43)
II	97	1	830	4.6	10	SOR(7) SSO(3)
II	165	4E	492	4.6	1 294.5	HOK(1095) LIN(95) GSH(31) HAK(26)
II	166	4E	665	4.6	265	HOK(190) HAK(25) GSH(22)
II	164	4E	814	4.6	167	HOK(65) SSO(46)
V	114	4W	406	3.9	375.7	RSK(110) SCH(105) HOK(36) LIN(27)
V	116	4W	416	3.7	71	LIN(25) HOK(12) SKI(10)
V	70	4E	494	3.3	692.8	HOK(573) GSP(41) LIN(32)
V	69	4E	632	3.5	294.6	HOK(203) HAK(185) LIN(18) JAV(16)
V	67	4E	678	4.1	114.6	HOK(28) RAT(27)
V	71	4E	678	3.9	152.3	HOK(77) GSP(29)

Species codes:

- HOK Hoki (*Macruronus novaezelandiae*)
- LIN Ling (*Genypterus blacodes*)
- HAK Hake (*Merluccius australis*)
- JAV Javelin fish (*Lepidorhynchus denticulatus*)
- RAT Rattails—Macrouridae (mainly *Coelorhynchus* spp.)
- GSP Pale ghost shark (*Hydrolagus* sp.)
- GSH Ghost shark—dark (*H. novaezelandiae*), or not specified (*H.* spp.)
- SND Shovelnose dogfish (*Deania calcea*)
- SSO Small-spined oreo (*Pseudocyttus maculatus*)
- SOR Spiky oreo (*Neocyttus rhomboidalis*)
- RSK Skates (*Raja* spp.)
- SCH School shark (*Galeorhinus australis*)
- SKI Southern kingfish (gemfish) (*Rexea solandri*)

TABLE 5: Mean catch rate, *X* (kg/km), and standard deviation of mean, *S*; Cruise II

		0–200 m		200–400 m		400–600 m		600–800 m		800–1000 m	
Area	Species	*X*	*S*	*X*	*S*	*X*	*S*	*X*	*S*	*X*	*S*
2W	HOK			19.1	55	253.5	158.3	27	20*	0	2.6*
	LIN			6.4	3.6	2.2	1.6	2.2	0.5*	0	1.3*
	Other			41.1	12.2	44.5	2.8	46.2	10.8*	28.9	5.9*
	All			238.6	70.7	300.2	160.1	75.4	30.1*	28.9	8.1*
2E	HOK			49.2	28	53.6	3.9	15.2	9.6	7.2	3.8
	LIN			1.8	1.6	3.2	1.9	0.8	0.8	2.6	2.6
	Other			50.3	6.2	59.6	11.5	17.9	4.5	23.4	1.2
	All			101.3	34.3	116.5	13.3	33.9	13.4	33.8	7.6
3W	HOK	1*	1*	0	3.2*	66	31.5	9.9	3	3.4	1.9*
	SBW	0*	0*	0	64.4*	0.4	0.3	0.4	0.4	0*	0*
	LIN	2.7*	2.7*	1.5	27.2*	3.3	1.4	8.1	5.9	1.6*	0.9*
	Other	6.5*	3.6*	18.6	4.3*	10.6	3	6.3	3.6	14.9*	5.6*
	All	10.1*	0.1*	20.1	66.9*	80.4	34.1	24.8	12.1	20*	7.9*
3S	HOK	0	1*	12.9	7	17.1	2.8	21.2	4.3	2.5	1.8
	SBW	0	0*	0	0	45.5	13.5	4.3	4.3	0.1	0.1
	LIN	0	2.7*	1.7	1.5	4.7	0.5	2.7	1.3	1.6	1.1
	Other	10	3.6*	6.4	3.3	13	3.9	13.7	2.3	16	6.8
	All	10	0.1*	21	11.9	80.2	13.2	41.9	4.9	20.1	9.4
3C	HOK	1*	1*	3.3	3.3	21.9	5.4	17	5.3	13.4	1.9*
	SBW	0*	0*	193.3	193.3	25.4	9.4	1.1	0.5	0	0*
	LIN	2.7*	2.7*	89.2	78.2	6.5	1.5	1.4	0.9	2.8	0.9*
	Other	6.5*	3.6*	19.4	3.1	15.2	3	17.2	6.8	22.7	5.6*
	All	10.1*	0.1*	305.2	121.5	69	11.2	36.7	11.3	38.9	7.9*
3E	HOK	1.9	1*	0	3.2*	3.2	7.7*	0.3	0.3	0	1.9*
	SBW	0	0*	0.9	64.4*	11.4	6.5*	1.8	1.8	0	0*
	LIN	5.4	2.7*	5.4	27.2*	0	0.8*	0	0	0	0.9*
	Other	2.9	3.6*	33.8	4.3*	17.7	1.8*	6	0.4	0	5.6*
	All	10.2	0.1*	40.1	66.9*	32.4	9.2*	8.2	1.7	0	7.9*

*Estimate made from grouped strata.

TABLE 6: Mean catch rate, X (kg/km), and standard deviation of mean, S; Cruise IV

Area	Species	0–200 m		200–400 m		400–600 m		600–800 m		800–1000 m	
		X	S	X	S	X	S	X	S	X	S
1	HOK			52.7	19.8	202.8	94.3	15.4	7.8	0.8	1.1*
	LIN			10.1	4	2.4	0.6	0.6	0.6	0	0*
	Other			62	18.1	60.9	12	77.6	17.1	12.4	20.3*
	All			124.7	33.8	266.2	103.4	93.6	21.1	13.2	21.2*
2W	HOK			38.9	14.9	152.6	107.7	17.8	5.4*	4.3	1.1*
	LIN			2.9	0.9	7.5	3.7	4.7	0.7*	0	0*
	Other			51.3	10.9	84.5	27.8	45.1	14.8*	37.3	20.3*
	All			93.1	18.2	244.5	123.8	67.6	16.9*	41.6	21.2*
2E	HOK			65.8	10.5*	9.9	6.8	16	5.4*	0.1	0.1
	LIN			1.2	1.9*	4	1.1	0	0.7*	0	0
	Other			16.7	9.4*	9.6	5.9	18.6	14.8*	28.1	6
	All			83.7	16*	23.6	12.1	34.5	16.9*	28.2	6
3W	HOK	8.3	8.3	1.1	0.2*	25.5	24.5	23	3.2	0.9*	0.9*
	SBW	0	0	0	6.9*	0	0	0	0	0*	0*
	LIN	5.2	5.2	0	1.7*	1.3	0.8	7.2	4.2	0.2*	0.2*
	Other	4.9	4.6	5.5	2.4*	16.3	8.3	28.6	7.3	5.5*	3.4*
	All	18.4	18.1	6.6	6.8*	43.7	33.6	58.8	14.4	6.5*	4.5*
3S	HOK	0	2.4*	0.2	0.2	13	5.3	70.8	66.2	0	0
	SBW	0	4.2*	27.9	27.9	123.7	49.7	0	0	0	0
	LIN	0	1.5*	0.1	0.1	5.6	1.4	1.9	0.7	0	0
	Other	3.8	3.1*	5.3	1.1	10.5	2.8	6.9	2.5	3.1	1.6
	All	3.8	6.3*	33.5	27.1	152.8	50.8	79.6	67.6	3.1	1.6
3C	HOK	0	2.4*	2	0.2*	7.3	1.5	9.5	3.7	4.6	0.9*
	SBW	29.1	4.2*	46.4	6.9*	3.4	1.7	0	0	0	0*
	LIN	2.1	1.5*	4.5	1.7*	2.3	0.4	0.6	0.3	0.8	0.2*
	Other	10.3	3.1*	15.2	2.4*	9.5	1.4	7.8	2.4	18.8	3.4*
	All	41.4	6.3*	68.1	6.8*	22.4	3.3	17.9	5.4	24.2	4.5*
3E	HOK	0	0	0	0	0	0	0.9	0.9	0	0
	SBW	0	0	11.1	7	10.9	10.5	0	0	0	0
	LIN	0	0	5.2	2.6	1.5	1.5	0	0	0	0
	Other	14.3	6	15.9	3	15.6	4	4.4	1.8	1.2	1.2
	All	14.3	6	32.1	6.3	28	13.8	5.3	2.2	1.2	1.2
5	HOK	0	0	0.7	0.7	496.2	320.4	36.1	30.5	0.5	0.5
	LIN	0	0	0	0	14.1	4.2	0.6	0.5	0	0
	Other	25.8	9.4	70.9	36.2	45.5	17	26.6	10.7	16.3	8.1
	All	25.8	9.4	71.6	36.2	555.8	337.9	63.3	40.1	16.8	8.5

*Estimate made from grouped strata.

Catch rate distribution

It is commonly assumed (Grosslein (1971), Jones and Pope (1973)) that trawl catch rates are distributed according to a lognormal distribution.

If the catch rate X_{ijk} is assumed to be distributed so that log $(1 + X_{ijk})$ is a Normal random variable with mean μ_{ij} and variance of σ^2_{ij}, the quantity

$$Z_{ijk} = \log(1+X_{ijk}) - (1/n_{ij}) \sum_{k=1}^{n_{ij}} \log(1+X_{ijk})$$

will be Normal with zero mean and variance $\sigma^2_{ij}(n_{ij} - 1)/n_{ij}$. (It is assumed that the stations are sufficiently far apart for catch rates to be independent.) Figure 10 shows histograms for the quantity Z_{ijk} over all values of i, j, and k for each cruise. The relative symmetry of these histograms indicates that the logarithmic transformation is successful in removing the strong positive skew in the data, though the sample sizes are not large enough to allow a reasonably powerful test of the Normality of the transformed data.

TABLE 7: Mean catch rate, *X* (kg/km), and standard deviation of mean, *S*; Cruise V

		0–200 m		200–400 m		400–600 m		600–800 m		800–1000 m	
Area	Species	*X*	*S*	*X*	*S*	*X*	*S*	*X*	*S*	*X*	*S*
2W	HOK			59.3	36.9	120.2	8.4	91	46.3	6.4	1.1*
	LIN			4.6	4.6	5.7	1	4.1	2	0	0*
	Other			44.6	16.2	80.8	6.6	160.4	13.2	145.8	20.3*
	All			108.6	56.9	206.6	8.9	255.6	57.3	152.2	21.2*
2E	HOK			57.2	57.2	20.2	2.6	27.1	10.2	2*	1.1*
	LIN			5.3	5.3	6.2	0.8	4.5	1.2	0*	0*
	Other			109.5	96.9	60.1	10.7	55.9	10.9	46.6*	20.3*
	All			172	159.4	86.3	10.8	87.5	20.6	48.6*	21.2*
3W	HOK	0*	0*	0	0*	47.9	13.7	140	33.7	4*	3.2*
	SBW	0*	0*	0	0*	1.7	0.5	0	0	0*	0*
	LIN	1.5*	1.5*	11.7	2.5*	6.7	2.8	6.6	5.4	0.3*	0.3*
	Other	26.8*	21.5*	5.6	10.2*	21.2	4	73.1	4.8	18.6*	3.4*
	All	28.3	23.1*	17.3	10.2*	77.5	18.3	219.7	30.3	22.8*	5.3*
3S	HOK	0	0	0	0*	13.4	4.1	4.4	2.2	1.3	1
	SBW	0	0	0	0*	21.6	6.1	0	0	0	0
	LIN	0	0	4.9	2.5*	4.6	0.5	0	0	0	0
	Other	4.8	1.9	0.4	10.2*	9	1.4	3.3	1.3	12.7	3.6
	All	4.8	1.9	5.3	10.2*	48.6	7.6	7.7	0.9	14.1	3.2
3C	HOK	0	0*	0	0*	17.8	5.1	36.5	18.1	13.2	13.2
	SBW	0	0*	0	0*	25.7	5.4	0	0	0	0
	LIN	0	1.5*	0	2.5*	4.6	0.9	2.5	1.5	1	1
	Other	6.7	21.5*	1	10.2*	16.3	3.5	13.6	4.5	21.3	2.7
	All	6.7	23.1*	1	10.2*	64.4	7.9	52.6	13.4	35.7	17.2
3E	HOK	0	0*	0	0*	0	0	0.3	0.3	0	0
	SBW	0	0*	0	0*	25.5	10.4	3.9	3.9	0	0
	LIN	7.7	1.5*	3.2	2.5*	0	0	0	0	0	0
	Other	112.7	21.5*	43.1	10.2*	12.6	2.7	5	2.9	27.3	9
	All	120.4	23.1*	46.3	10.2*	38.1	13.1	9.3	5.2	27.3	9
5	HOK	0	0	0	0	15.7	7.4	14	4	0.5*	0.5*
	LIN	0	0	0.6	0.6	10.1	4.5	3.2	1.8	0*	0*
	Other	29	3.7	293.3	285.9	38.3	13.1	32.5	4.1	16.3*	8.1*
	All	29	3.7	293.9	286.5	64	20	49.7	7.6	16.8*	8.5*

*Estimated from grouped strata.

TABLE 8: Fish abundance indices (t.km) (standard deviations in brackets) for hoki

Area	Cruise II		Cruise IV		Cruise V	
1			4 350	(1 730)		
2W	8 650	(3 150)	3 790	(2 040)	4 090	(798)
2E	2 470	(475)	1 520	(255)	1 830	(916)
3W	2 760	(1 220)	1 520	(951)	4 630	(852)
3S	1 930	(264)	2 650	(1 800)	930	(243)
3C	1 590	(258)	662	(130)	2 030	(646)
3E	36.2	(81.0)	12.7	(12.7)	4.89	(4.89)
5			2 210	(1 290)	157	(39.7)
2W, 2E	11 100	(3 190)	5 310	(2 050)	5 920	(1 210)
3W, 3S, 3C	6 280	(1 270)	4 830	(2 040)	7 590	(1 100)

TABLE 9: Fish abundance indices (t.km) (standard deviations in brackets) for southern blue whiting

Area	Cruise II		Cruise IV		Cruise V	
1			0			
2W	0		0		0	
2E	0		0.6	(0.6)	0	
3W	23.7	(488)	0	(52.3)	64.4	(21.3)
3S	2 740	(787)	7 790	(2 940)	1 250	(354)
3C	2 640	(1 730)	560	(85.2)	914	(194)
3E	126	(411)	159	(96.7)	266	(102)
5			0		0	
2W, 2E	0		0.6	(0.6)	0	
3W, 3S, 3C	5 410	(1 970)	8 350	(2 950)	2 230	(404)

TABLE 10: Fish abundance indices (t.km) (standard deviations in brackets) for ling

Area	Cruise II		Cruise IV		Cruise V	
1			143	(38.3)		
2W	179	(77.1)	228	(72.4)	223	(91.9)
2E	152	(64.1)	125	(43.9)	307	(87.5)
3W	325	(244)	237	(99.2)	491	(155)
3S	432	(68.0)	378	(86.0)	380	(64.6)
3C	1 120	(691)	160	(23.3)	263	(63.4)
3E	47.9	(173)	44.5	(20.1)	40.1	(16.0)
5			59.5	(17.1)	63.3	(21.2)
2W, 2E	331	(100)	352	(84.7)	530	(127)
3W, 3S, 3C	1 870	(736)	774	(133)	1 130	(180)

TABLE 11: Fish abundance indices (t.km) (standard deviations in brackets) for all species except hoki, southern blue whiting, and ling

Area	Cruise II		Cruise IV		Cruise V	
1			2 600	(373)		
2W	2 300	(264)	3 340	(623)	5 240	(430)
2E	2 860	(323)	1 080	(305)	4 590	(1 580)
3W	756	(143)	1 310	(355)	2 560	(266)
3S	1 830	(322)	1 030	(186)	1 040	(277)
3C	1 680	(262)	1 070	(113)	1 420	(216)
3E	453	(144)	358	(57.0)	1 420	(247)
5			1 160	(281)	2 450	(1 640)
2W, 2E	5 160	(417)	4 420	(694)	9 830	(1 630)
3W, 3S, 3C	4 260	(439)	3 410	(416)	5 020	(441)

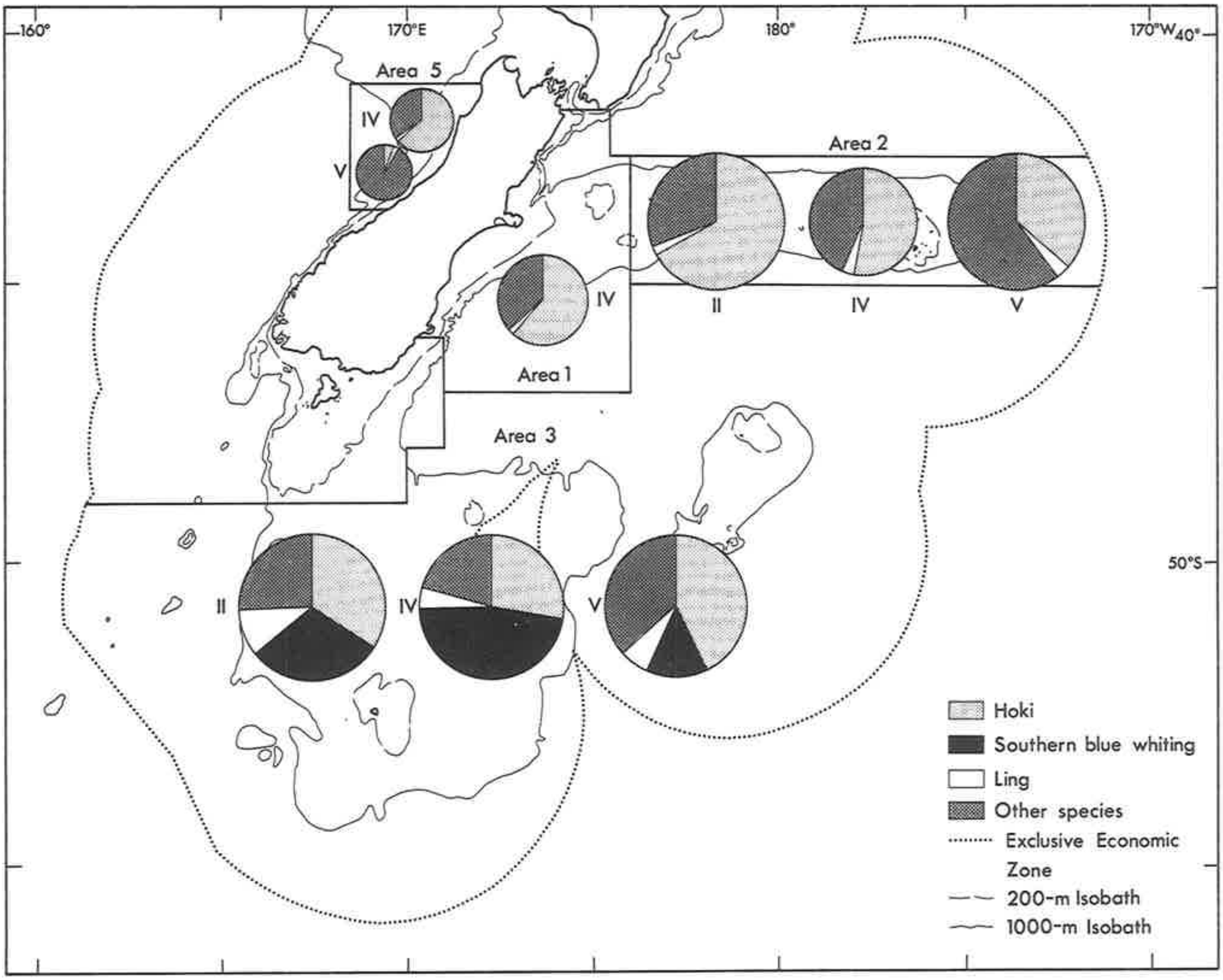

Fig. 9: Abundance indices by species, area, and cruise.

TABLE 12: Fish abundance indices (t.km) (standard deviations in brackets) for all species combined

Area	Cruise II		Cruise IV		Cruise V	
1			7 090	(1 930)		
2W	11 100	(3 310)	7 350	(2 360)	9 550	(1 210)
2E	5 480	(675)	2 730	(473)	6 730	(2 560)
3W	3 870	(1 430)	3 070	(1 340)	7 750	(951)
3S	6 930	(873)	11 900	(3 510)	3 600	(507)
3C	7 020	(1 210)	2 450	(230)	4 620	(604)
3E	663	(474)	575	(128)	1 740	(276)
5			3 430	(1 400)	2 670	(1 650)
2W, 2E	16 600	(3 370)	10 100	(2 410)	16 300	(2 830)
3W, 3S, 3C	17 800	(2 070)	17 400	(3 760)	16 000	(1 240)

TABLE 13: Lower and upper bounds for biomass (t × 10^3) for hoki

Area	Cruise II	Cruise IV	Cruise V
1		25–450	
2	140–1000	34–540	100–480
3	110–510	22–510	150–560
5		0–270	2.2–14

TABLE 14: Lower and upper bounds for biomass (t × 10^3) for southern blue whiting

Area	Cruise II	Cruise IV	Cruise V
1		0	
2	0	0–0.1	0
3	43–550	75–820	47–190
5		0	0

TABLE 15: Lower and upper bounds for biomass (t × 10^3) for ling

Area	Cruise II	Cruise IV	Cruise V
1		1.9–13	
2	3.7–30	5.2–30	7.9–45
3	12	16–62	23–88
5		0.72–5.4	0.60–6.0

TABLE 16: Lower and upper bounds for biomass (t × 10^3) for all species except hoki, southern blue whiting, and ling

Area	Cruise II	Cruise IV	Cruise V
1		53–190	
2	120–340	87–330	190–750
3	110–320	84–260	160–430
5		17–98	0–330

TABLE 17: Lower and upper bounds for biomass (t × 10^3) for all species combined

Area	Cruise II	Cruise IV	Cruise V
1		92–630	
2	280–1300	150–850	300–1300
3	410–1300	100–1460	430–1160
5		18–360	0–340

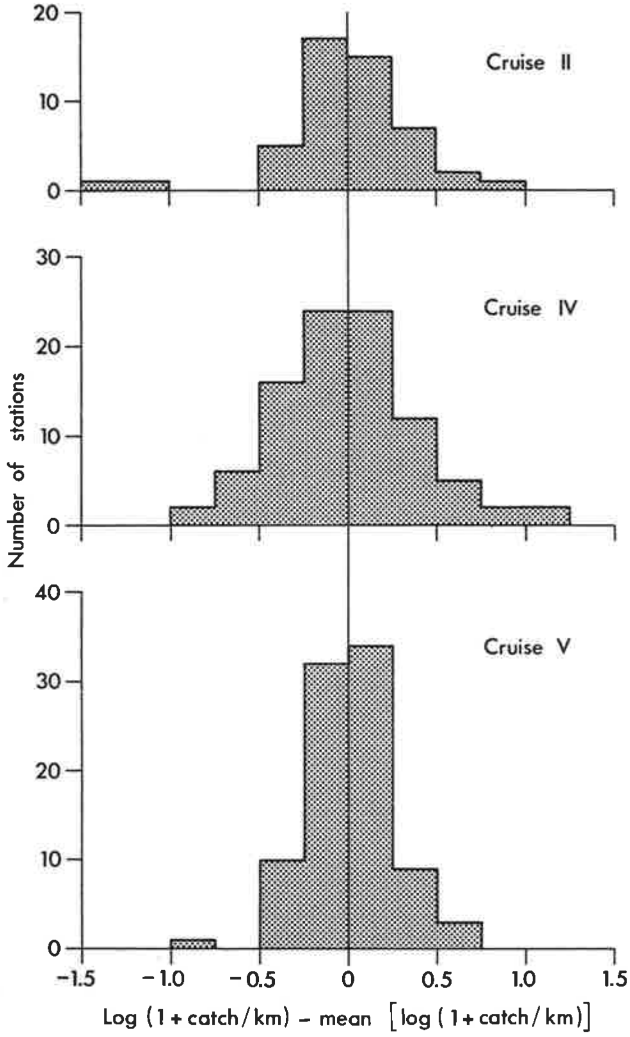

Fig. 10: Distribution of log-transformed and zero-meaned catch rates.

Discussion

The density of stations used in these surveys (average one station per 5288 km^2) was extremely low. In trawl surveys off the north-east coast of the United States from the Woods Hole laboratory (Grosslein 1969) a density of one station per 714 km^2 was used, and Jones and Pope (1973) used a density of one station per 65 km^2 in an unusually well-designed trawl survey of Faroe Bank. Thus it was inevitable that the precision of the surveys reported here would be low. Apart from the high degree of variability inherent in a strongly positively skewed quantity like fish density, there are other sources of variance. Wathne (1977) found that, even under controlled conditions, the performance of a trawl net (and thus the vulnerability and availability of fish) varied widely.

Another problem associated with the low density of the survey coverage was the high proportion of time spent steaming between stations. The practice of allocating more stations than were expected to be occupied and then moving stations to enable more to be covered in a day helped to reduce this problem. It resulted in an estimated 30%–40% more stations occupied than would have been if the sampling procedure had been followed rigidly. It is felt that the effect of the non-randomness (manifested as a slight degree of "clumping" in the station distribution) introduced thereby was minimal and certainly small compared with the gain from the increased number of stations occupied.

The arrangement concerning the division of vessel time between research and commercial activities was unsatisfactory. Firstly, because preference was given to commercial fishing, it was unlikely that fish would be surveyed when they were highly aggregated for feeding or spawning. Secondly, uncertainty as to the precise timing of each survey made it difficult to allocate stations optimally among strata because it was not known whether expected concentrations would be surveyed. Thirdly, the period for each survey was not continuous, so that the total time from beginning to end of each survey was always greater than necessary and the chance of serious error due to fish movements during the surveys was increased. Finally, the order in which the various areas were covered was subject to the pattern of commercial fishing and thus not under the control of the survey designers.

Estimation procedures

There are many difficulties in estimating parameters of a highly skewed distribution. One approach is to transform the data to remove the skew, and this has been done by Grosslein (1971). He calculates the mean of a log-transformed catch rate and uses this as an index of fish abundance. Unfortunately, this mean, when transformed back to a natural scale (that is, via an antilog), will not necessarily be a good estimate of the mean catch rate. If the catch rate is lognormally distributed (where the transformed variable has mean μ and variance σ^2, say), the true mean catch rate will be $\exp(\mu + \frac{1}{2}\sigma^2)$, whereas the antilog of Grosslein's fish abundance index is $\exp(\mu + \frac{1}{2}\sigma^2/n)$, where n is the sample size. (For simplicity I consider here the transformation log (x) rather than the log $(1+x)$ used by Grosslein. My comments apply equally to both transformations, but the exposition is simpler for the former.) The bias in this estimate of the mean catch rate is thus a factor of $\exp(\frac{1}{2}\sigma^2(1-n)/n)$. The seriousness of this bias clearly depends on the magnitude of σ^2.

For the largest samples available in the surveys reported here (that is, cruise V, areas 3S, 3C, depth zone 400–600 m), $n = 17$ and estimate $\sigma^2 = 0.92$ and 0.90 respectively (for hoki catches), which would give a bias of approximately -35%. Furthermore, this bias increases with sample size. Grosslein goes on to calculate sample size necessary to detect various size changes in his abundance index. In doing so he seems to overlook the fact that, in a situation where μ remains constant but σ^2 varies over time, fish abundance will fluctuate from year to year, but this will never be detected by his index, no matter how large a sample is taken. Thus it is clear that this is not an index of fish abundance.

If the lognormal model for catch rate distribution may be assumed, Finney (1941) provides minimum variance unbiased estimators for the mean and variance. These require the evaluation of several power series of the variance of the log-transformed catch rates. It should be stressed that Finney's calculation of the efficiencies of the sample mean and variance as estimates of the population mean and variance are valid only for large samples and the sample sizes here are very small. A simple calculation shows that, for sample size 2 (which occurs in about a quarter of the calculations in these surveys), Finney's estimators are identical with the sample mean and variance. For this reason, and because of uncertainties about the robustness of the assumption of normality, the sample mean and variance have been used in preference to the more complex estimators. We are left with the difficulty that our variances are imprecise and positively correlated with the means.

Availability and vulnerability

One of the most difficult aspects of the area-swept method of biomass estimation is that of evaluating the quantities b, u, and v (net width and fish availability and vulnerability). For some species it is known that the trawl doors and bridles exert a shepherding effect, so that the effective net width is much greater than the wingtip-to-wingtip distance. Diver observation and underwater cameras may be used to investigate this as well as the problem of vulnerability. Some information may be obtained on fish availability from echo-sounder observations, both from hull- and net-mounted transducers. With the present state of quantitative fisheries acoustics it may be feasible to obtain reliable estimates in this way. To complicate matters, these quantities cannot be taken as constant, even for a given species in a given area. Large short-term fluctuations in availability have been observed (G. J. Patchell pers. comm.) in the hoki fishery off the west coast of the South Island (area 5) during the winter spawning season. The usually high catch rates sometimes drop dramatically for several days as the fish come up off the bottom and are thus unavailable to trawls. Recent photographic evidence suggests that ling spend some time in burrows on the sea floor. This has obvious implications in terms of their availability to trawls and probably explains why they seem to be more easily caught by long-liners.

In these surveys no attempt was made to standardise towing speed. In view of the sometimes strong dependence of fish vulnerability on towing speed, this was a mistake.

Interpretation of estimates

Some care is needed in the interpretation of the results of these surveys. There is a tendency for one or two large catches to dominate the total biomass estimate of a species for one cruise (Table 18). At first sight this may seem to be due to the high degree of stratification and resulting low number of stations per stratum, but, as Table 18 shows, these catches represent a high proportion of the total catch for the respective species and so would contribute about the same amount to the biomass estimates even were there no stratification. The fault seems to lie rather in the small number of stations occupied relative to the large range in catch rates.

Comparison with previous biomass estimates

The estimates most directly comparable with those in this publication are from Francis and Fisher (1979). The authors assumed the width swept by the *Shinkai Maru* net lay between 33 and 39 m, and the proportion of demersal fish caught by it lay between 0.5 and 1.0. By taking respectively the lower and upper values of these two parameters they derived two estimates of biomass for each area and species (Table 19). It should be noted that no attempt was made to calculate the imprecision in their estimates due to sampling error in catch rates.

Shpack (1978) made a series of estimates of the southern blue whiting stocks on the spawning grounds of the Bounty Platform between 1972 and 1976 (Table 20). What he called the "regional" method of estimation presumably uses the area-swept approach, but no details of number or distribution of stations or catch rate variability are given. The "acoustic" method is referenced to Prokopets and Ovsyannikov (1975), but again no information is given on which to judge the precision of the estimates. The low figure in 1974 is attributed to anomalous water temperatures in that year, which caused a change in spawning activity.

Blagodyorov and Nosov (1978) used trawl surveys to estimate the biomass of hoki in the Mernoo Bank area each winter from 1968 to 1977 (Table 21). There is surprisingly little variation in the estimates from year to year, but there are no details of the surveys with which to judge the plausibility of the apparently very high degree of precision in these results. Kono (1979) took catch records from 20 Japanese trawlers fishing off the west coast of the South Island in July-August 1977 and, stratifying the area (essentially the same as area 5) into two depth zones (200–500 m and 500–750 m) within each ½-degree rectangle, obtained three estimates of hoki biomass (Table 22). The estimate of 810 000 t for the middle time period was considered most accurate, since the fleet was most widely dispersed then. Furthermore, since few small fish (less than 65 cm) were caught, this figure was thought to underestimate the total stock size.

The estimates described above do not allow statistical comparison, but they have been juxtaposed in Fig. 11 for visual comparison. Major disparities which are immediately apparent are those between the estimates of Francis and Fisher and others in area 3 and between Kono and others in area 5. These disparities could well be explained by the lack of randomness in station distribution in the data of these authors, since the vessels concerned were target fishing and this would tend to give a positive bias to the estimates. In addition, Kono assumes that one-third of hoki escape from the net.

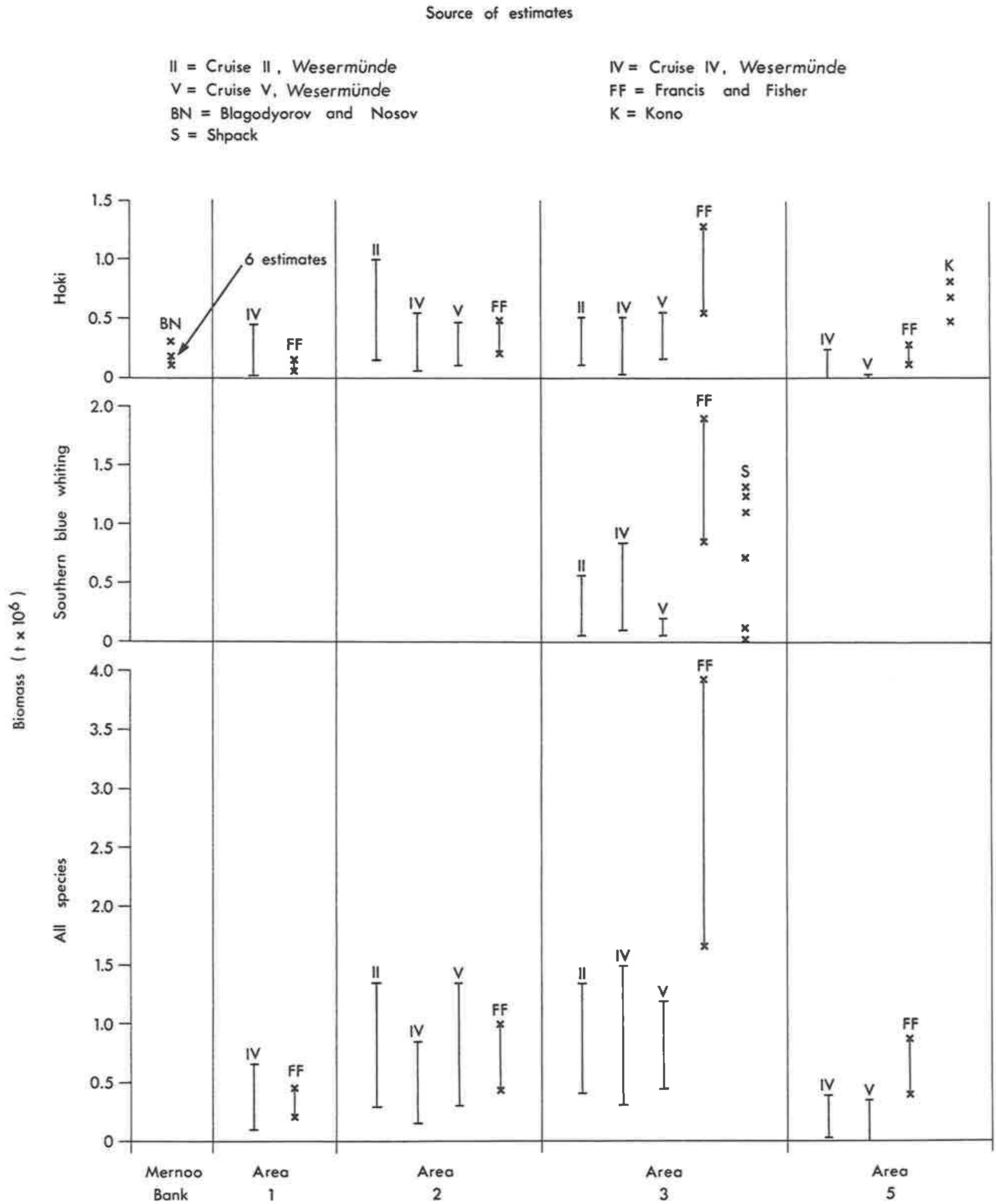

Fig. 11: Biomass estimates from this and other sources (see text and Tables 13, 14, 17, and 19–22 for details).

TABLE 18: Effect of large catches on biomass estimates

Species	Cruise	No. of trawls	Catch (kg)	% of total catch	% contribution to biomass estimate
HOK	II	2	3 739	27	34
SBW	II	1	1 790	38	31
LIN	II	1	775	37	33
SBW	IV	3	3 720	63	68

TABLE 19: Biomass estimates (t × 10^3) from Francis and Fisher (1979)

Area	Southern blue whiting	Hoki	All species
1		65–154	192–454
2		212–501	410–969
3	808–1910	548–1295	1608–3801
5		125–295	355–839

TABLE 20: Estimates of southern blue whiting biomass on the spawning grounds by Shpack (1978)

Year	Area covered (km^2)	Mean catch rate (t/hr)	Estimated biomass (t × 10^3)	Method of estimation
1972	6 253	92.6	1 240	Regional
1973	6 013	83.5	1 120	Regional
1973	2 307	83.5	1 280	Acoustic
1974	1 203	6.5	17.4	Regional
1975	2 165	22.8	110	Regional
1976	3 608	90.0	720	Regional

TABLE 21: Estimates by Blagodyorov and Nosov (1978) of the commercial stock size of hoki in the Mernoo Bank area during winter

Year	Stock size (t × 10^3)
1968	180
1969	160
1970	170
1971	300
1972	150
1973	160
1974	175
1975	170
1976	140
1977	130

TABLE 22: Estimated biomass of hoki off the west coast of the South Island (essentially the same as area 5) in 1977 by Kono (1979) from Japanese commercial trawl data

Period	Estimated biomass (t × 10^3)
1–15 Jul	480
16–31 Jul	810
1–15 Aug	690

If the values quoted in this publication for availability and vulnerability of hoki in area 5 are used instead, Kono's estimates will be reduced by about one-third.

A further source of biomass estimates for the New Zealand EEZ is Anon. (1978), in which data from Japanese research and exploratory vessels were used to make estimates for nine major species over seven areas (shown in Fig. 12). Boundaries between Anon.'s areas West Coast South Island and West Coast North Island, and between areas East Coast South Island and South Coast South Island, are not given. To facilitate comparison with estimates in this publication, three aggregate areas are defined:

Eastern—East Coast South Island plus Chatham Rise, which is approximately the same as areas 1 and 2 together;

Southern—Campbell Rise plus Pukaki Rise, which is approximately the same as areas 3S and 3C together;

Western—West Coast South Island, which is presumably approximately the same as area 5.

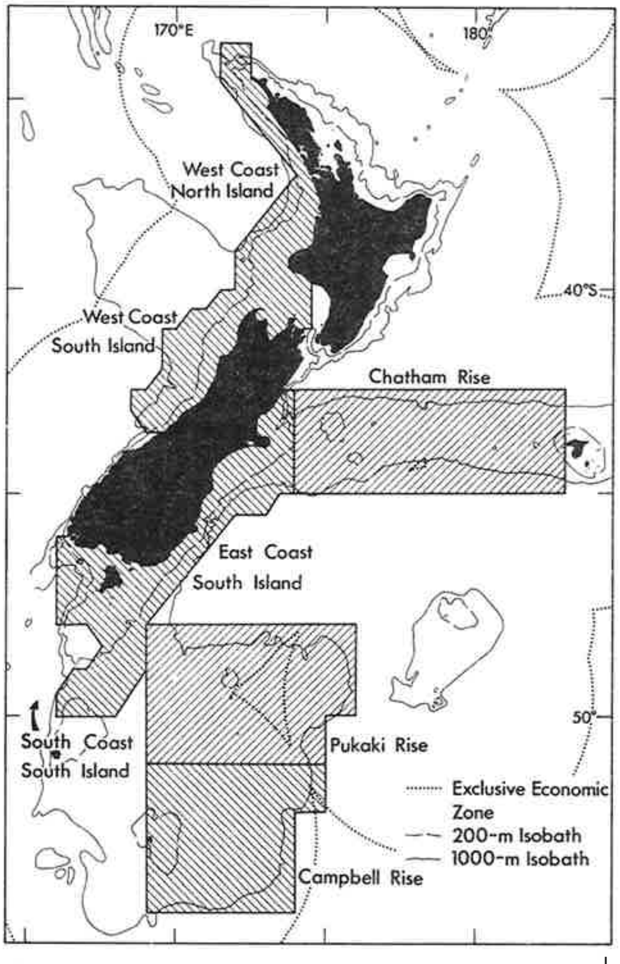

Fig. 12: Areas used for biomass estimates in Anon. (1978).

Estimates for these areas are given in Table 23 and Fig. 13. The great discrepancy in estimates in the Western area may indicate that this area as used by Anon. extended further north than our area 5. Some large differences in species composition are also apparent. Barracouta (*Thyrsites atun*) and jack mackerels (*Trachurus declivis* and *T. novaezelandiae*) contributed 63% of the total biomass estimated by Anon. in West Coast South Island, whereas these species together made up 4.7% and 0.5% respectively of the total catches in area 5 in cruises IV and V. In the Eastern area barracouta made up 43% of the total biomass in the estimates of Anon., but were less than 0.2% of the catch in areas 1 and 2 combined in cruise IV.

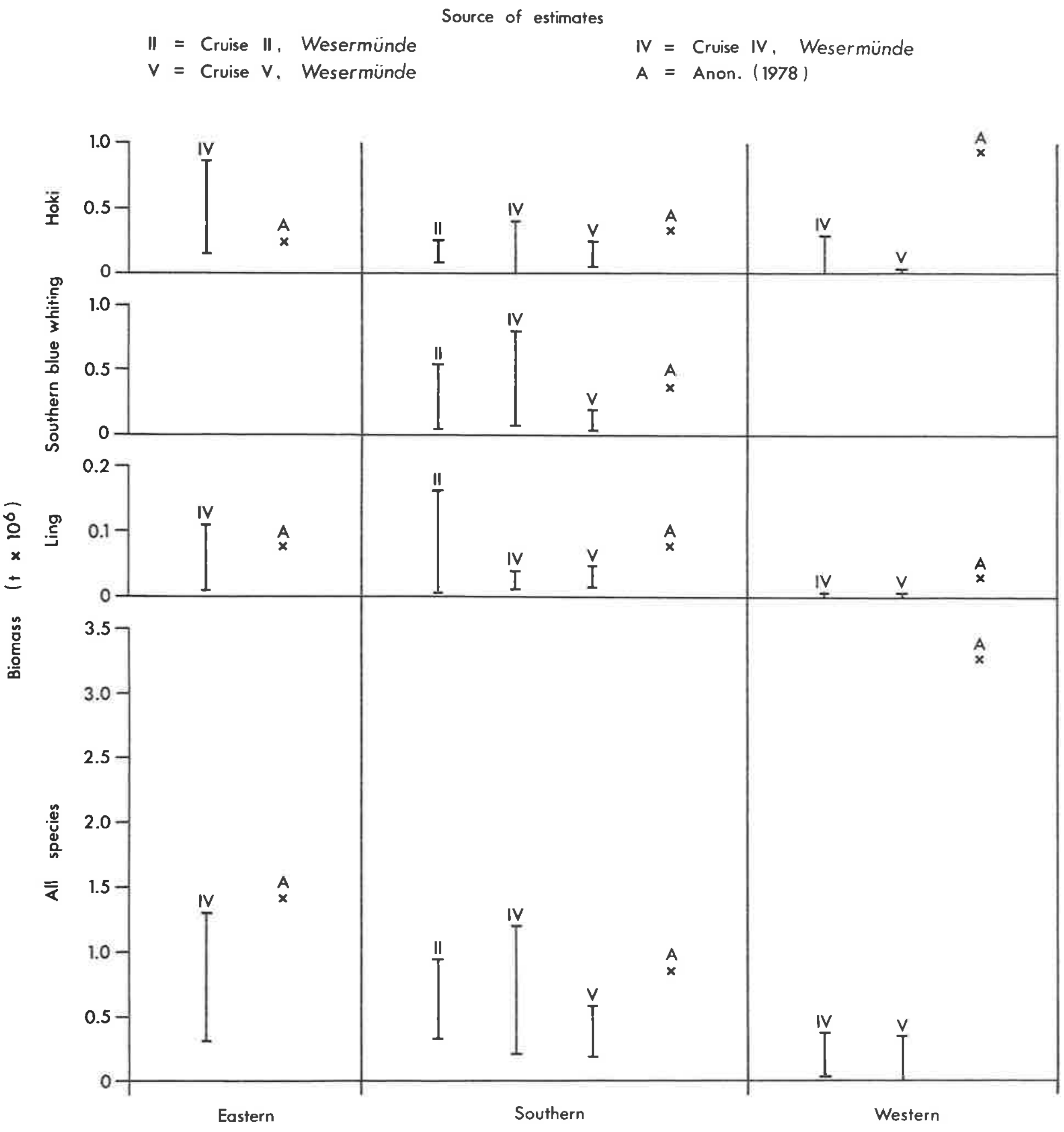

Fig. 13: Comparison between biomass estimates from *Wesermünde* cruises II, IV, and V and from Anon. (1978).

TABLE 23: Comparison of biomass estimates between *Wesermünde* cruises II, IV, and V and Anon. (1978)

Species	Area	Anon. (1978)	Cruise II	Cruise IV	Cruise V
		Estimated biomass (t × 10^3)			
Hoki	Eastern	225		120–860	
	Southern	326	79–240	0–400	45–250
	Western	962		0–270	2.2–14
Southern blue whiting	Southern	383	45–520	71–810	39–170
Ling	Eastern	79		8.9–39	
	Southern	76	4.7–170	11–39	13–47
	Western	33		0.72–5.4	0.60–6.0
All bottom fish	Eastern	1 397		310–1 300	
	Southern	872	310–970	210–1 200	190–560
	Western	3 287		18–360	0–340

Conclusions

In evaluating the success of the surveys, two aims must be considered:

1. To produce information on the distribution (in time and space) of New Zealand deep-water fish species;
2. To produce biomass estimates for these species.

The first aim, which was accorded higher priority, has been achieved as well as it could have been within the resources available, though had it been possible to choose the exact time of each survey, certain hypotheses relating to fish distribution may have been testable. However, the data obtained have given a clearer picture of the behaviour of some species and this may be used in planning further research.

For the second aim, the surveys cannot be said to have been successful. The upper and lower bounds which have been calculated for biomass are very wide and require careful interpretation; both because of the disproportionate effect of a few large catches on them and also in the light of other knowledge of species distribution. It must be recognised that the two aims were fundamentally incompatible and, with the resources available, success in one inevitably implied a poor design for the other. Had the second aim been of primary importance, it would have been better to concentrate the survey effort in more restricted areas, and attempts should have been made to obtain a better understanding of the availability and vulnerability of important species to the trawl. The data have been presented here in such a way that, should better estimates of these last quantities become available, the biomass estimates herein may be refined considerably by a simple application of the appropriate formula to the abundance indices in Tables 8–12.

In considering further surveys the following points may be made:

1. There is little point in repeating as a whole any of the surveys described here. Certain parts of them may be worth repeating and, if so, the present surveys will provide a useful comparison;
2. The information here will provide for better design in future surveys, but the attempt to cover all species with one survey will result in the design being less than optimal for each of them;
3. Any arrangement which precludes prior knowledge of the duration and exact timing of a survey is unsatisfactory;
4. Much further study remains to be done on the question of the vulnerability and availability of New Zealand fish to trawl nets, and without this work the area-swept method of estimating biomass (as used here) is of limited use;
5. Towing speed should be standardised in future;
6. Density of station coverage will need to be much higher in subsequent surveys to obtain usefully precise biomass or abundance index estimates.

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