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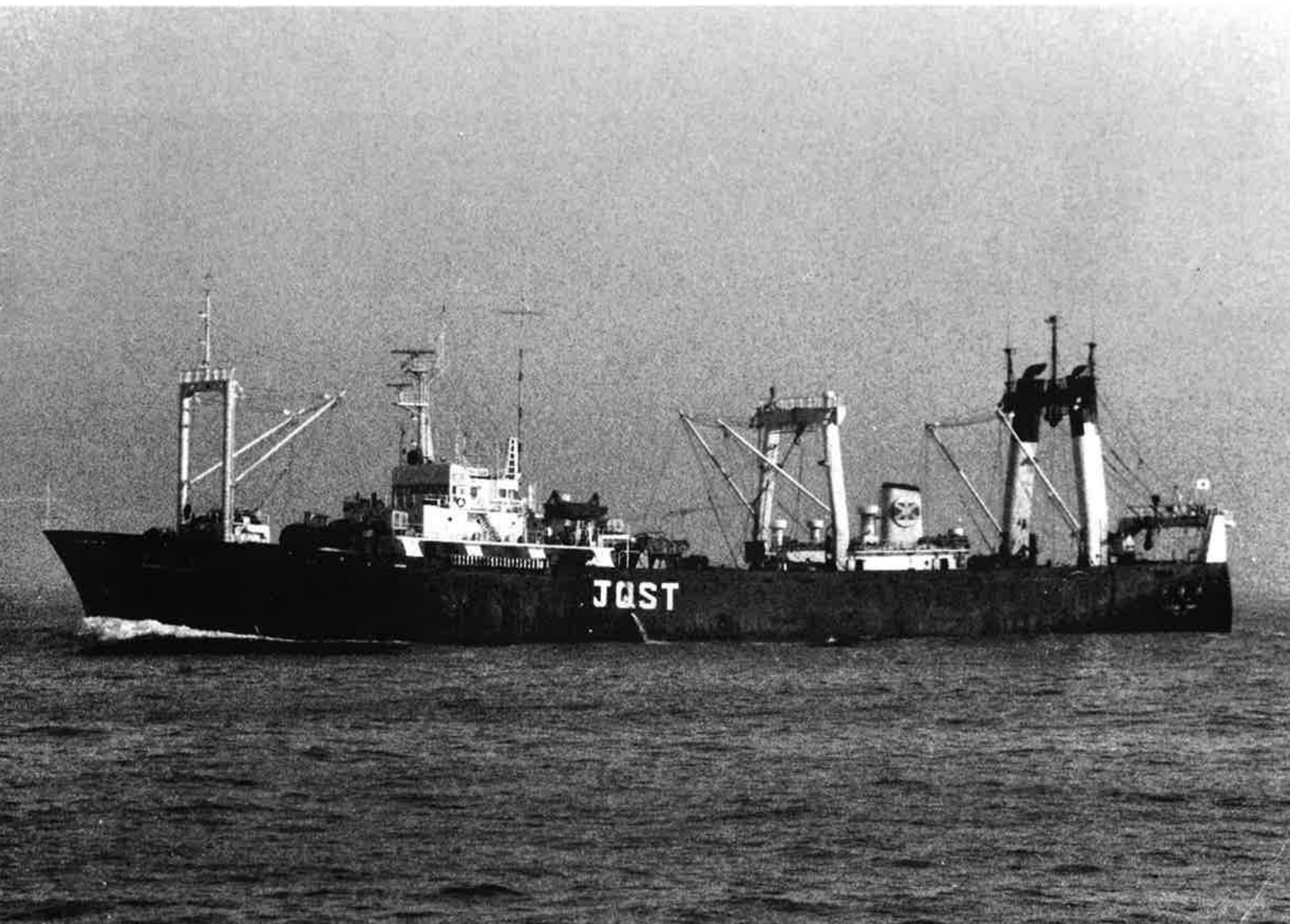
MAF Fish



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Contents

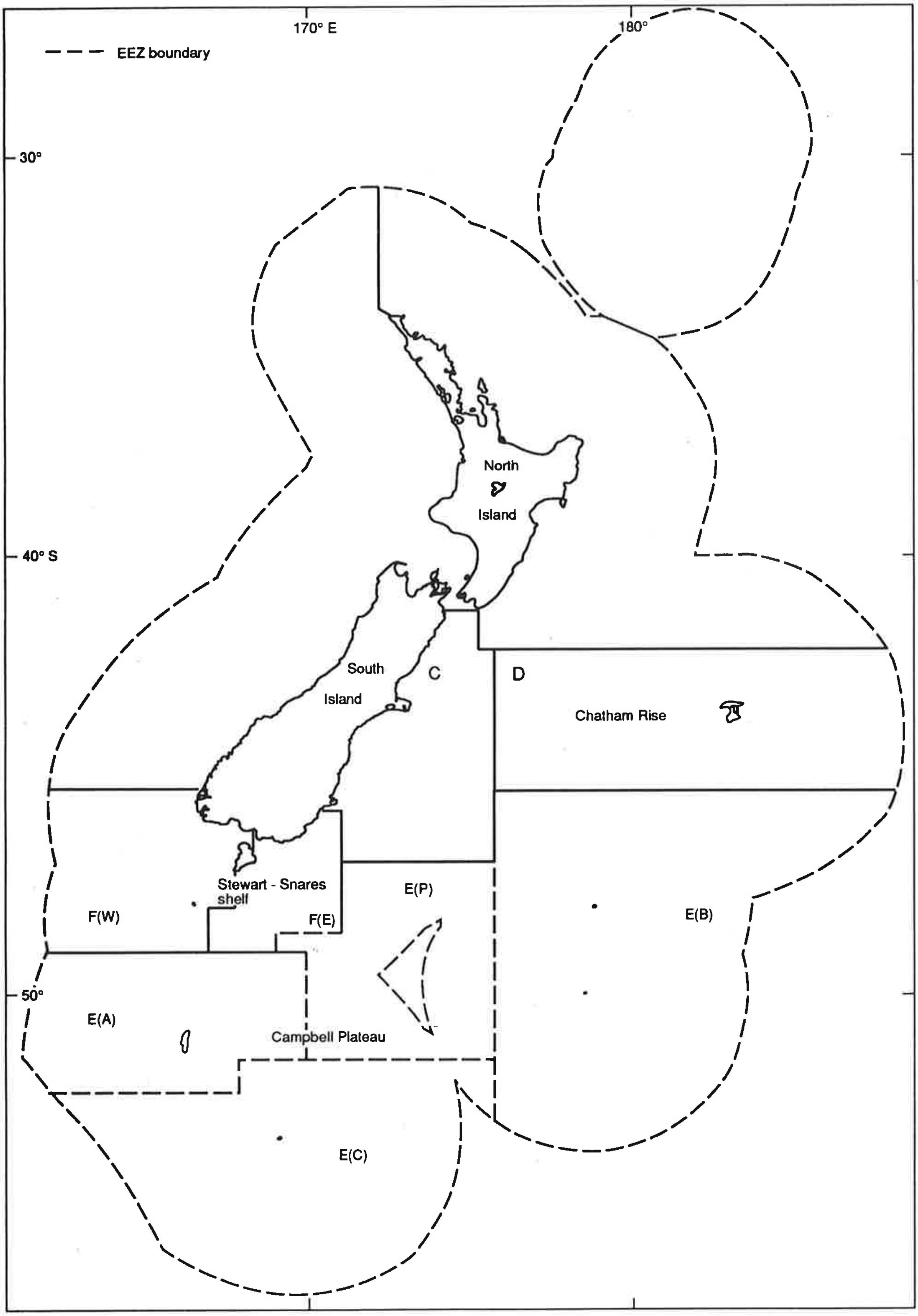

Figure 1: New Zealand Exclusive Economic Zone fisheries management areas C-F and places mentioned in the text.

Abstract

Hatanaka, H., Uozumi, Y., Fukui, J., Aizawa, M., and Livingston, M. E. 1989: Trawl survey of hoki and other slope fish on the Chatham Rise, New Zealand, November-December 1983. *N.Z. Fisheries Technical Report No. 17.* 31 p.

A joint Japan-New Zealand trawl survey was carried out in New Zealand Exclusive Economic Zone area D by *Shinkai Maru* from 22 November to 12 December 1983. The 84 stratified random trawl stations provided stock size indices and distribution and biological data for the commercially important species, with emphasis on hoki. These data and hydrological data were compared with those obtained on previous surveys. The standing stock sizes of hoki (454 300 t) and hake (29 700 t) were significantly lower than those estimated by the March 1983 survey of the same area. Possible explanations such as differences in gear operation and seasonal fish movements are discussed.

Introduction

Since the declaration of the New Zealand 200 n. mile Exclusive Economic Zone (EEZ) in 1978, most of the yearly catch quotas allocated to Japanese vessels have been from the Chatham Rise (areas C and D), the Stewart-Snares shelf (area F), and the Campbell Plateau (area E) (Figure 1).

Joint research programmes to estimate species distributions and stock abundance in these areas have been carried out between New Zealand and other nations (e.g., the Federal Republic of Germany, Japan, and the Soviet Union). Extensive Japan-New Zealand trawl surveys of areas E and F were conducted in 1981, 1982, and 1983 (van den Broek *et al.* 1984, Hurst and Fenaughty 1985, Uozumi *et al.* 1987, Hatanaka *et al.* 1989) to determine the annual and seasonal variation of relative abundance and distribution of commercial species to depths of 600 or 800 m. In March 1983, there was a similar joint trawl survey on the Chatham Rise by *Shinkai Maru* (Fenaughty and Uozumi 1989). Previous estimates of Chatham Rise fish stocks include those from exploratory deepwater surveys by *Wesermünde* (Francis 1981) and by *Shinkai Maru* (Francis and Fisher 1979).

This publication presents the results of a second Japan-New Zealand trawl survey of the Chatham Rise, in November-December 1983. The main aims were to collect catch and biological data on hoki (*Macruronus novaezelandiae*), barracouta (*Thyrsites atun*), arrow squid (*Nototodarus sloanii*), and other commercial species and to collect water temperature data.

Methods

Survey area and vessel

The survey was conducted between 22 November and 12 December 1983 in area D (east of 176° E). The survey area was 108 752 km². Trawls were carried out in waters 50–800 m deep, as were those in the March 1983 survey (Fenaughty and Uozumi 1989). *Shinkai Maru* (a stern trawler chartered by Japan Marine Fishery Resource Research Center) was used. It has the following specifications: tonnage, 3393 GRT; length, 94.9 m; main engine horsepower, 5000 PS.

Survey design and trawl operation

A stratified random sampling method (after Francis 1981) was used. The survey area was divided into 12 strata bounded by latitudinal line 42° 30′ S, longitudinal line 176° 00′ E, and the 200, 400, 600, and 800 m isobaths (Figure 2). A total of 90 stations was allocated in proportion to the area of each stratum, but in small strata at least 3 stations were allocated to strata shallower than 400 m and at least 5 stations to strata along the continental slope (Table 1). Each station within a stratum was selected randomly and separated by at least 5 min of latitude and longitude.

An average of 4.5 daytime tows per day was planned, and each tow was for 30 min. When the bottom was unsuitable for trawling, the station was shifted to the nearest 5 min block in the same stratum where a successful tow could be expected.

Comparisons of catch and stock estimates between this survey and the March 1983 survey (Fenaughty and Uozumi 1989) are made for area D only (i.e., strata 10–21 in the March 1983 survey). There are some differences in strata areas between the two surveys because of the repositioning of strata boundaries with new bathymetric data. However, overall the total areas are similar (108 752 km² this survey, 107 280 km² March 1983).

Table 1: Depth range, area, and number of stations in each stratum

Stratum	Depth range (m)	Area* (km²)	No. of stations Allocated	Completed
1	0–400	834	3	3
2	600–800	3 283	5	5
3	400–600	6 190	5	5
4	400–600	11 259	8	8
5	600–800	5 240	5	5
6	200–400	19 125	14	10
7	0–200†	810	3	3
8	600–800	9 957	7	7
9	400–600	12 536	15	9
10	400–600	20 856	15	14
11	600–800	7 685	6	6
12	0–400	11 176	10	9
Total		108 752	90	84

* For strata 11 and 12 the given areas are the values recalculated after the survey.

† This stratum was deeper than 200 m, but shallower than 250 m. It was treated as an independent stratum.

Trawl gear measurements

A bottom trawl net with a 70 mm mesh codend, similar to that used in March 1983 (Fenaughty and Uozumi 1989), was used. Details of the net are given in Appendix 1.

The distance between warps was used to estimate the distance between otter boards (doorspread) and between the wingtips of the net (wingspread) (after Koyama 1974). The formulas used in this analysis were:

$$x = c(b - a)/(4.0 + a)$$

$$y = ex/d$$

where a = distance between warps at the top rollers, b = distance between warps 4 m from the top rollers, c = length of warp between top roller and otter board, d = distance between otter board and head of codend, e = distance between net wingtip and head of codend, x = width between otter boards, y = width between net wingtips. The headline height of the net was measured by the net recorder.

Catch weight

The catch was sorted by species and weighed on platform scales to the nearest 0.1 kg. When the catch was large, the weight was estimated from the number of filled fish baskets or from the product weight (by back-calculation from frozen filleted or headed and gutted fish).

Biology

Size composition

About 100 individuals of the main commercial fish species were randomly selected from each catch, and the total weight of each sample was measured. Size composition was recorded for 12 species at each station where they were caught. The numbers of samples and specimens measured by species are given in Table 2.

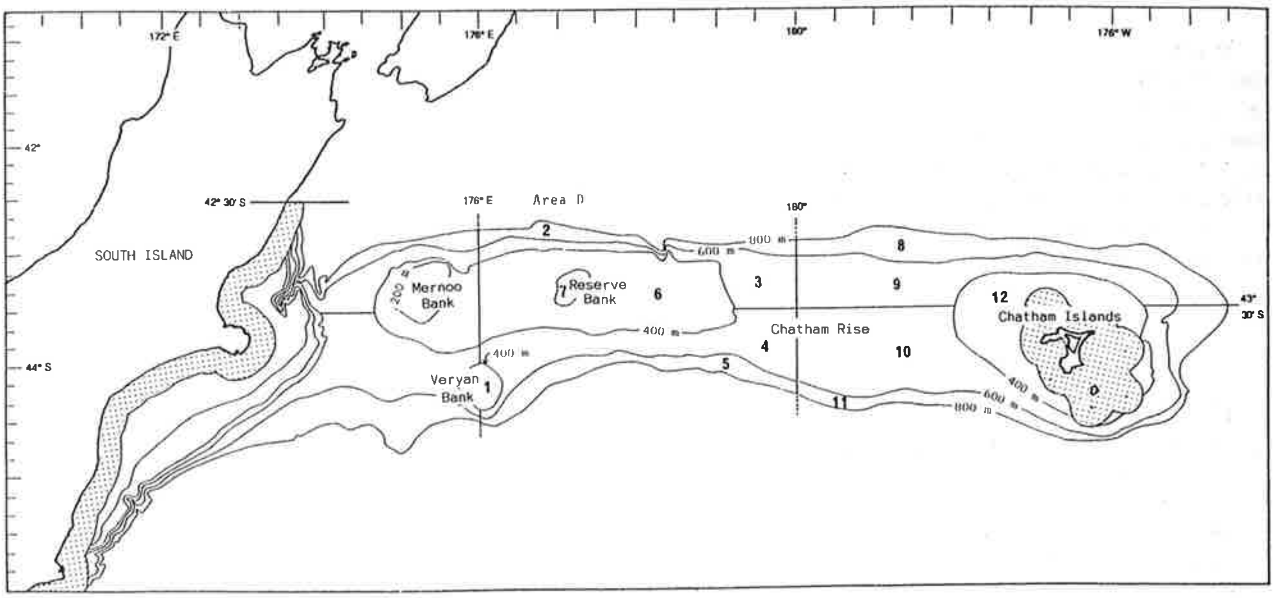

Figure 2: Survey area showing the 12 strata.

Arrow squid larger than 15 cm mantle length (ML) were separated by sex, and the structure of the hectocotylised arm in males was checked to determine the species of *Nototodarus* present (Smith *et al.* 1987). Females were separated into copulated and uncopulated categories by the presence of spermatophores around the mouth.

Total length (TL) and sex of hoki and ling (*Genypterus blacodes*) were recorded, and fork length (FL) was measured for other finfish, which were usually unsexed. Mantle length and sex were measured for arrow squid. All the size compositions were measured on punching cards and later transferred to data sheets. The length frequency data for individual species were analysed in two ways: mean length frequencies per stratum to show the variation in size distribution of fish caught in different parts of the survey area, and the size distribution of the estimated stock (i.e., the number of fish, scaled by the percentage of catch sampled, stratum area, and length of tow) within the entire survey area and in different depth zones.

Table 2: Numbers of samples and specimens measured by species

Species	No. of samples	No. of specimens
Southern blue whiting (*Micromesistius australis*)	1	4
Hake (*Merluccius australis*)	71	712
Hoki (*Macruronus novaezelandiae*)	78	12 886
Orange roughy (*Hoplostethus atlanticus*)	4	122
Tarakihi (*Nemadactylus macropterus*)	7	133
Ling (*Genypterus blacodes*)	81	1 218
Silver warehou (*Seriolella caerulea*)	52	1 666
White warehou (*S. punctata*)	30	713
Bluenose (*Hyperglyphe antarctica*)	10	36
Gemfish (*Rexea solandri*)	1	4
Barracouta (*Thyrsites atun*)	9	384
Arrow squid (*Nototodarus sloanii*)	58	1 541

Biological parameters

Twenty individuals of the four main commercial species (hoki, ling, silver warehou (*Seriolella punctata*), and arrow squid) were sampled daily, and other species were sampled opportunistically, for more detailed biological parameters. Observations were made on 12 parameters for arrow squid (mantle length, total body weight, sex, gonad weight, Needham's sac or nidamental gland weight, spermatophore sac or oviduct weight, nidamental gland length, copulation, gonad maturation stage, fullness of stomach, weight and composition of stomach contents) and 8 for finfish (total or fork length, body weight, sex, gonad weight, gonad maturation stage, fullness of stomach, weight and composition of stomach contents). The gonad maturation stages of arrow squid and finfish are described in Appendix 2. For finfish, fish described as immature were immature or resting. The composition of stomach contents was calculated by the occurrence method (i.e., each food item in an individual's stomach was given one point, regardless of its volume or weight). Otoliths were sampled from all finfish and were stored in paper envelopes for future aging work. Length-weight relationships were fitted by log-log regressions. The numbers of samples and specimens measured by species are given in Table 3.

Table 3: Numbers of samples and specimens for detailed biological measurements

Species	No. of samples	No. of specimens
Hoki	36	717
Hake	2	40
Ling	1	20
Silver warehou	7	140
Barracouta	1	20
Arrow squid	1	20

Hydrology

Water temperature profiles were determined by use of expendable bathythermographs (XBT) from a sampling grid of 21 stations (Figure 3). The stations were occupied in convenient order and usually at night. Bottom temperatures were taken from the net recorder during trawling. Surface temperature was recorded at each trawl station by an electric thermometer attached to the ship's hull.

Stock size

The areal expansion method was used for the estimation of stock size, and it was assumed that all the fish in the path of the net were caught and escapment once in the net was zero, that there were no fish above the headline, and that the herding effect of the otter boards and bridles was negligible (the effective area swept is defined as the distance between the wings of the net).

The first two assumptions would probably result in an underestimate of stock size because it was not likely that all fish were fully vulnerable or accessible to the net. The third assumption would probably result in an overestimate because it was likely there was some herding by the otter boards and bridles. The stock size and standard error were calculated by:

$$d_{ij} = X_{ij} / a_{ij}$$

$$B_i = A_i \,.\, \overline{d}_i$$

$$SB_i = A_i \,.\, \frac{Sd_i}{\sqrt{n_i}}$$

$$B = \Sigma B_i$$

$$SB = \sqrt{\Sigma SB_i^2}$$

$$c.v. = SB/B$$

$$CI_{95} = t_{0.05} SB$$

where d_{ij} = density at the j-th station in the i-th stratum, X_{ij} = catch at the j-th station in the i-th stratum, a_{ij} = area swept by the tow at the j-th station in the i-th stratum, B_i = stock size in the i-th stratum, A_i = area of the i-th stratum, $\overline{d}_i$ = mean density for the i-th stratum, SB_i = standard error of stock size in the i-th stratum, Sd_i = standard deviation of density in the i-th stratum, n_i = number of tows in the i-th stratum, B = overall stock size, SB = standard error of the overall stock size, $c.v.$ = coefficient of variation, CI_{95} = 95% confidence interval of the overall stock size, $t_{0.05}$ = t statistic at $p = 0.05$.

The stock size estimate expressed by weight was calculated by use of catch weights for X_{ij}. When expressed by number the estimated number of fish of a given species was used for X_{ij}, but standard error and confidence intervals were not calculated because the catch in number of fish in each tow was derived from the total catch weight and the mean body weight of individuals estimated from the number of individuals and the total weight of fish measured in length frequency samples:

$$X_{ij} = C/\overline{w}$$

$$\overline{w} = Ws/Ns$$

where X_{ij} = catch in number of fish, C = catch in weight, $\overline{w}$ = mean body weight of fish, Ws = weight of the sample, Ns = number of fish in the sample.

The area swept by the net at each trawl station was estimated as distance towed multiplied by distance between net wingtips. Doorspread stock size estimates (distance towed multiplied by distance between otter boards) can be calculated by multiplying all wingspread stock size estimates by 0.28.

Wingspread biomass estimates of hoki, ling, silver warehou, hake (*Merluccius australis*), and arrow squid from this survey were compared with results from the March 1983 survey by applying a Student's t-test:

$$t_s = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{S_1^2 + S_2^2}}$$

where t_s = t table statistic, $\overline{x}$ = mean biomass, S^2 = variance.

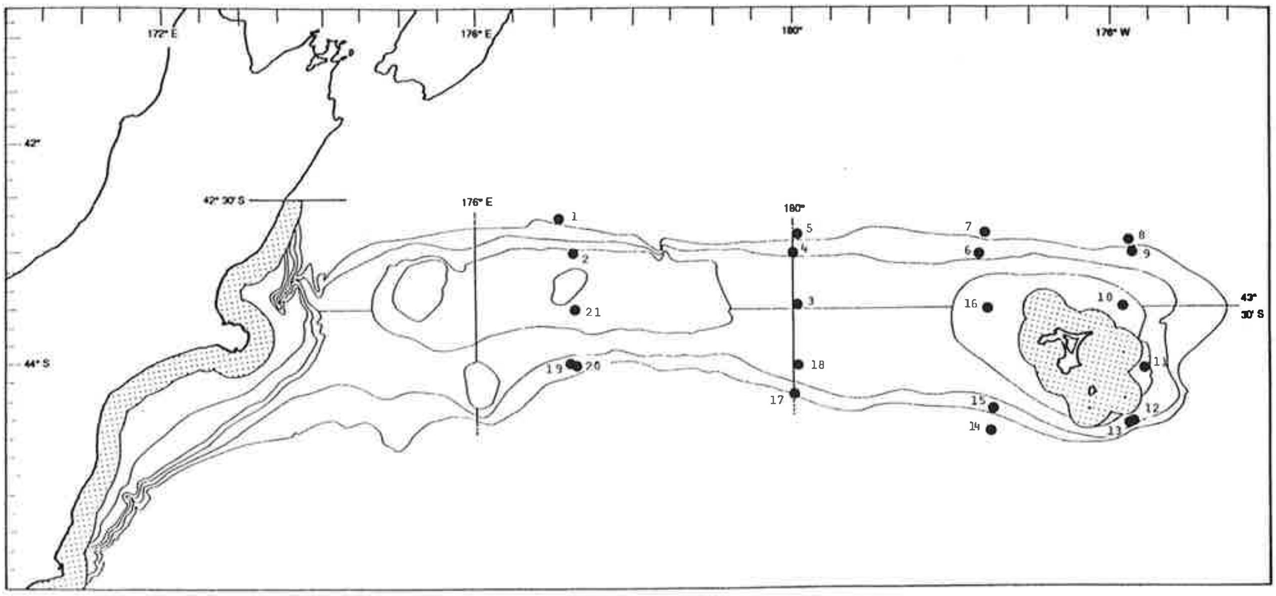

Figure 3: Hydrological station numbers and positions.

Results and discussion

Because of unsuitable sea bottom and inaccurate positioning of the 12 n. mile territorial sea boundary east of the Chatham Islands on the chart, 28 of the 90 allocated stations had to be moved to alternative positions. Tows at four stations in stratum 6 and one station in each of strata 10 and 12 were abandoned because no trawlable ground was found at the allocated positions or in the nearest 5 min block. Successful trawls were made at 84 stations (*see* Table 1 and Figure 4).

The results of trawl gear measurements taken during the survey are given in Table 4. The mean wingspread was 17% larger than in the March 1983 survey, and the mean tow speed was 3% faster, which gave a 20% increase in the mean area swept per tow. The mean headline height of the net decreased by 21%. These changes occurred mainly because the sweeps between the otter boards and the net wingtips were shortened from 370 to 215 m. The lower headline height may have led to a decrease in vulnerability (catch per unit area swept) for some semipelagic species such as hoki, barracouta, and arrow squid.

A total of 124 fish species and 3 squid species were caught during the survey (Appendix 3). Species occurrence by stratum data are available from the authors. Specimens collected during the survey are preserved at the Japanese National Museum (Tokyo) and at the National Museum (Wellington).

Hydrology

Surface (about 10 m down) isotherms are shown in Figure 5. Surface temperatures ranged from 11.4 to 14.3 °C. In general, the isotherms lay east-west and the temperature was slightly higher to the north. Surface temperatures on the Reserve Bank, the Veryan Bank, and around the Chatham Islands were slightly cooler than those in surrounding waters.

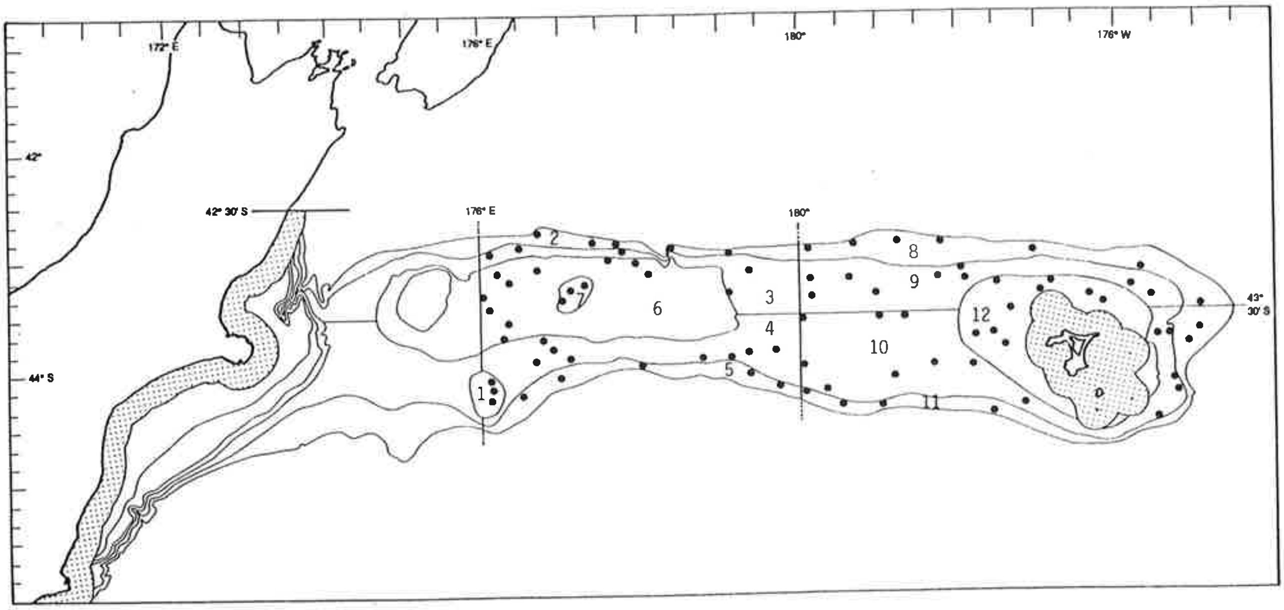

Figure 4: Trawl station positions in each stratum.

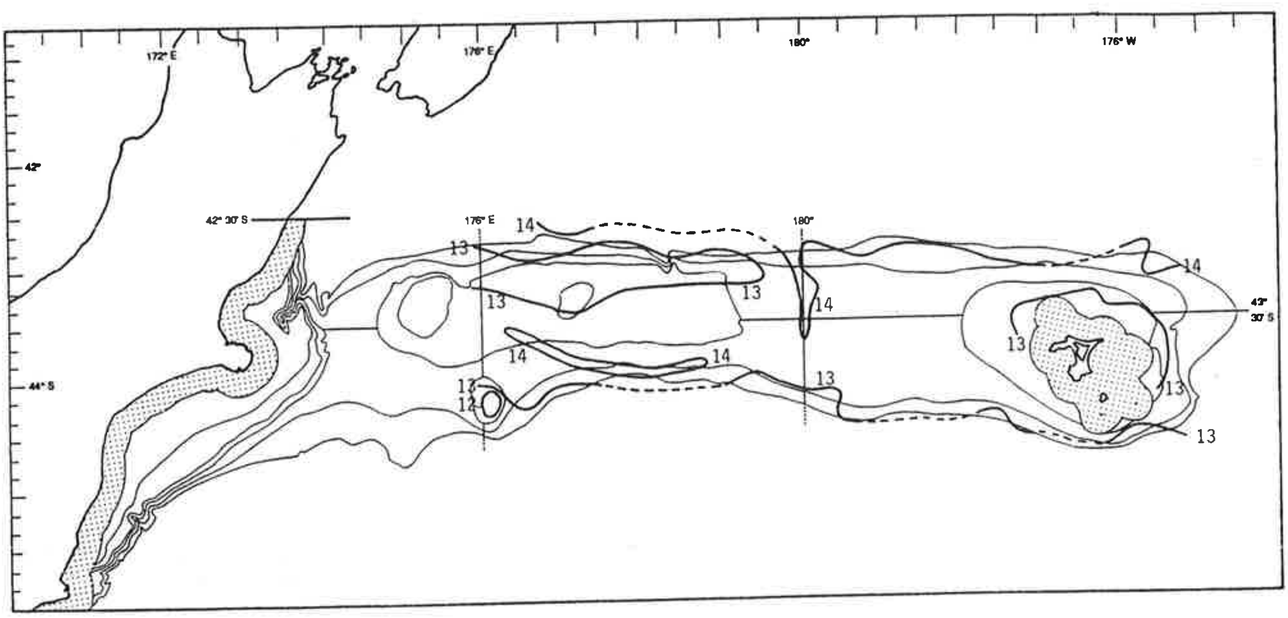

Figure 5: Sea surface (10 m) temperatures (°C).

The vertical temperature profiles along four longitudinal lines are shown in Figure 6. Bottom temperatures on the north slope of the Chatham Rise were slightly higher than on the south slope at the same depth. Bottom temperatures ranged from 6 to 9 °C in 400–800 m.

Fenaughty and O'Sullivan (1978) found that warmer water protruded south beyond the Chatham Rise between longitudes 175° E and 180°, and that there was a 14 °C isotherm at latitude 47° S in summer, south of the Chatham Rise. During winter cooler water (11 °C) moved north in the same pattern as the summer isotherm of 14 °C, to about latitude 43° S. The temperature distribution observed in this survey showed an intermediate pattern.

Distribution and stock size

Hoki

Distribution

The distribution of hoki is shown in Figure 7, and the mean catch per trawl by stratum is given in Table 5. Individuals were classified as small (under 44 cm TL) and large (at least 44 cm), and the distributions by size are shown in Figures 8 and 9.

Hoki were widely distributed in the survey area, but generally they were not caught at stations shallower than 250 m. The catch rate per trawl was low at several deep stations (e.g., in strata 8 and 11). Small hoki were caught mainly in 200–400 m,

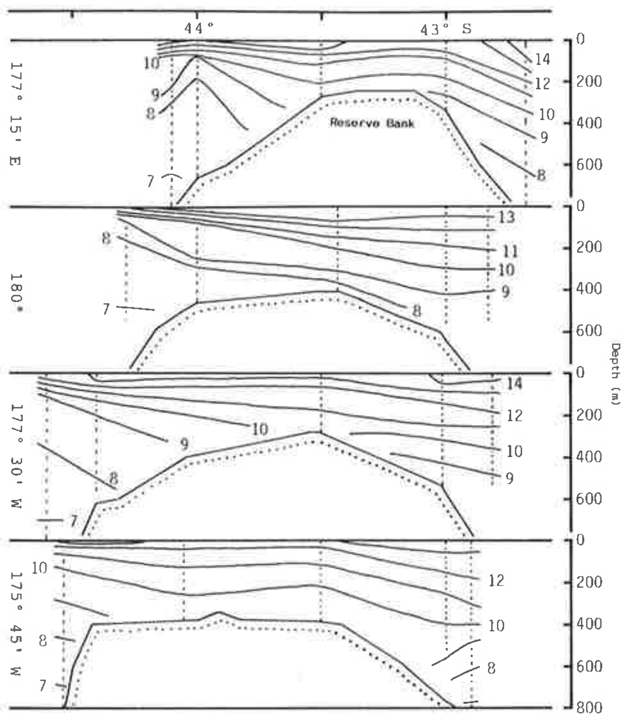

Figure 6: Sea temperature (°C) profiles by longitude showing the hydrological stations (broken line).

especially in the western part of the survey area. Although large hoki were more widely distributed, they were more abundant on the slopes north of the Reserve Bank. There was no clear relationship between hoki catch rates and bottom temperature, though catches were negligible in waters warmer than 9.8 °C.

Stock size

The total standing stock size estimates of hoki are given in Table 5. The total weight estimate was 454 300 t, with a 95% confidence interval of ± 137 100 t (*c.v.* = 15%). About 66% of the total weight estimate was caught west of 180°. The total number estimate was 892.2 × 10^6, and small and large hoki accounted for 42 and 58%. Hoki were the most abundant species by weight and by number of fish and accounted for 35% (by weight) of the total stock size estimate of all species.

The total stock size estimate for hoki was about 40% of the 1 157 000 t estimated from the same area in March 1983 (Fenaughty and Uozumi 1989), and there were substantial decreases in most strata. These decreases may be explained by factors such as seasonal changes in hoki distribution, depletion of stock size by fishing, or sampling variance including changes in gear efficiency. Kuo and Tanaka (1984a) stated that hoki were concentrated in the middle of the Chatham Rise and around the Chatham Islands (area D) in spring and summer, but that there were less fish there in autumn. However, this is inconsistent with the results from this survey and the March 1983 survey. Furthermore, the commercial catch during the 8 months between the two random trawl surveys was not as great as the decrease in estimated stock sizes. Either the sampling variances and changes in gear efficiency were altered by the shortened sweeps between the otter boards and wingtips (Table 6) or many fish had migrated out of the area. Another possible explanation could be seasonal variation in accessibility of hoki to the bottom trawl.

The lower headline height (21%) may have caused a decrease in vulnerability, especially for semipelagic species such as hoki. However, the possibility of migration from the Chatham Rise cannot be ignored. Mature size hoki (usually longer than 65 cm) migrate to the west coast spawning grounds in winter, possibly from all parts of the EEZ (Patchell 1982). These fish may leave the Chatham Rise in autumn or winter, and this could affect the biomass. However, if fish form a residential group on the Chatham Rise, they should have returned by November and December.

Table 4: Results of trawl gear measurements

	Height of net mouth (m)	Width between net wingtips (m)	Area swept (km^2)	Tow speed (kn)
Mean	7.0	33.7	0.10	3.30
s.d.*	1.0	2.5	0.10	0.23
Range	6.0–7.5	23.0–39.0	0.07–0.13	3.00–3.50

* Standard deviation.

Table 5: Mean catch per trawl and stock size estimate (wingspread) of hoki

Stratum	Depth (m)	Mean catch (kg)	Stock size (10^3 t)	Stock size (number) (10^6)* Small	Large	Total
1	0–400	573	4.6	13.6	5.0	18.6
2	600–800	760	24.2	–	20.5	20.5
3	400–600	1 026	61.6	1.8	83.2	85.0
4	400–600	748	81.6	0.1	80.8	81.0
5	600–800	370	18.8	–	13.0	13.0
6	200–400	572	105.9	354.7	121.5	476.1
7	0–200†	69	0.5	–	0.6	0.6
8	600–800	113	10.9	–	7.5	7.5
9	400–600	252	30.7	–	32.1	32.1
10	400–600	328	66.3	0.1	75.0	75.2
11	600–800	197	14.3	–	11.0	11.0
12	0–400	322	34.9	8.1	63.5	71.6
Total		431‡	454.3	378.5	513.7	892.2

* Classified into size groups: small, under 44 cm TL; and large, over 44 cm.
† *See* Table 1.
‡ Stratified mean.

Table 6: Comparison of gear measurements in the March and November-December surveys, 1983

	Mean wingspread (m)	Mean net height (m)	Tow speed (kn)
Mar	28.7	8.9	3.2
Nov-Dec	33.7	7.0	3.3

Ling

Distribution

The distribution of ling is shown in Figure 10, and the mean catch per trawl by stratum is given in Table 7. Ling occurred throughout the survey area. Small ling (under 50 cm TL) were more abundant towards the west of the survey area (stratum 1 and the west part of stratum 6, *see* Figure 24).

Stock size

The total standing stock size estimates of ling are given in Table 7. The total weight estimate was 47 200 t, with a 95% confidence interval of ± 8400 t (*c.v.* = 9%). Although this value is lower than the 63 700 t estimated in March 1983, the difference is not statistically significant.

Silver warehou and white warehou

Distribution

The distributions of silver and white warehou are given in Figures 11 and 12, and the mean catches per trawl by stratum are given in Table 8. In general, both species were caught in less than 600 m, particularly on the northern slopes of the Chatham Rise, and silver warehou had a wider distribution than white warehou. Catches of silver warehou were concentrated on and around the Reserve Bank (strata 6 and 7) and on the Chatham Islands slope (stratum 12), whereas most catches of white warehou were taken in strata 6 and 10. There was no obvious relationship between catch rate and water temperature.

Stock size

The total standing stock size estimates of silver and white warehou are given in Table 8. The total weight estimates of silver and white warehou were 66 600 t and 36 700 t respectively, with 95% confidence intervals of ± 53 300 and ± 31 400 t. In the March 1983 survey, the estimate for silver warehou was only 16 400 t (Fenaughty and Uozumi 1989), but, because the coefficients of variation were high, these estimates are not significantly different. The coefficients of variation of these species tend to be high because these fish are not evenly distributed and often form schools. Livingston and Berben (1986) reported that silver warehou spawn in spring on the Mernoo Bank, and in spring-summer at the Chatham Islands, and the increased biomass suggests a greater vulnerability to the trawl during spawning and/or an influx of migrant fish to the area for spawning.

Arrow squid

All males larger than about 15 cm ML were identified as the eastern-southern species *Nototodarus sloanii*, based on structure of the hectocotylised arm (after Smith *et al.* 1987). Therefore, it was assumed all arrow squid caught in this survey were *N. sloanii*.

Distribution

The distribution of arrow squid is shown in Figure 13, and the mean catch per trawl by stratum is given in Table 9. Although arrow squid were widely distributed in the survey area, the highest catch rates were in shallower waters (strata 1, 6, 7, and 12). At stations where more than 50 kg of arrow squid per tow were caught, bottom temperatures were higher than 9.5 °C.

Stock size

The total standing stock size estimates of arrow squid are given in Table 9. The total weight estimate was 12 000 t, with a 95% confidence interval of ± 5400 t (*c.v.* = 23%). The estimate of 13 200 t from the previous survey (Fenaughty and Uozumi 1989) was not significantly different.

Table 7: Mean catch per trawl and standing stock size estimate of ling

Stratum	Depth (m)	Mean catch (kg)	Stock size (10^3 t)	Stock size (number) (10^6)
1	0–400	45	0.4	0.2
2	600–800	33	1.1	0.3
3	400–600	37	2.2	0.5
4	400–600	55	6.0	2.7
5	600–800	21	1.1	0.4
6	200–400	64	11.9	5.1
7	0–200*	23	0.2	0.0
8	600–800	14	1.4	0.4
9	400–600	45	5.4	1.2
10	400–600	49	9.9	3.4
11	600–800	47	3.4	0.8
12	0–400	39	4.2	1.3
Total		45†	47.2	16.3

* *See* Table 1.
† Stratified mean.

Table 8: Mean catches per trawl and standing stock size estimates of silver warehou and white warehou

Stratum	Depth (m)	Mean catch (kg)		Stock size (10^3 t)	
		Silver	White	Silver	White
1	0–400	12	–	0.1	–
2	600–800	–	–	–	–
3	400–600	7	7	0.4	0.4
4	400–600	32	2	3.5	0.2
5	600–800	2	–	0.1	–
6	200–400	243	86	45.1	15.9
7	0–200*	102	–	0.8	–
8	600–800	–	–	–	–
9	400–600	15	9	1.8	1.1
10	400–600	36	80	7.3	16.3
11	600–800	13	1	0.9	0.1
12	0–400	60	26	6.5	2.8
Total		63†	35†	66.6	36.7

* *See* Table 1.
† Stratified mean.

Other main species

The distributions of the other main species are shown in Figures 14–18, and the standing stock size estimates are given in Table 10. The distribution of all species caught is shown in Figure 19, and the mean catch per trawl by stratum and the standing stock size estimates of all species combined are given in Table 11.

Hake

Hake were caught at most stations, but they were more abundant in the warmer waters of the northern slope of the Chatham Rise and only sparsely distributed in shallow waters on the Veryan and Reserve Banks (strata 1 and 7) and around the Chatham Islands (stratum 12). The total standing stock size estimate was 29 700 t, with a 95% confidence interval of 7000 t, which is significantly less than the value obtained from the previous survey (42 900 t (Fenaughty and Uozumi 1989)). The modification of fishing gear or seasonal migration might cause a decrease in the estimates of this semipelagic species.

Rattails

Fourteen species of family Macrouridae were caught, and javelin fish predominated. Although the distribution and depth ranges differed for each species, the sum of the catches was evenly distributed in the survey area, except in shallow waters on the Veryan and Reserve Banks (strata 1 and 7) and around the Chatham Islands (stratum 12). The standing stock size estimate of rattails (including javelin fish) was 201 800 t, with a 95% confidence interval of 48 300 t, second after hoki.

Lookdown dory

Lookdown dory occurred throughout the survey area, except in shallower waters on the Veryan and Reserve Banks (strata 1 and 7). The standing stock size estimate was 31 200 t, with a 95% confidence interval of 4000 t.

Table 9: Mean catch per trawl and standing stock size estimate of arrow squid

Stratum	Depth (m)	Mean catch (kg)	Stock size (10^3 t)	Stock size (number) (10^6)
1	0–400	35	0.3	0.4
2	600–800	0	0.0	0.0
3	400–600	3	0.2	0.4
4	400–600	3	0.4	0.6
5	600–800	1	0.0	0.0
6	200–400	32	5.9	6.8
7	0–200*	44	0.4	1.1
8	600–800	1	0.1	0.1
9	400–600	3	0.4	0.4
10	400–600	3	0.6	0.8
11	600–800	0	0.0	0.0
12	0–400	36	3.9	9.5
Total		11†	12.0	20.2

* *See* Table 1.
† Stratified mean.

Oreos

Smooth oreo (*Pseudocyttus maculatus*), spiky oreo (*Neocyttus rhomboidalis*), and black oreo (*Allocyttus niger*) were caught mainly in the deeper waters of the Chatham Rise, where the bottom temperature was generally below 8 °C. Spiky oreo predominated at most stations, and black oreo were limited to the southern slope of the Chatham Rise. Catches of smooth oreo were negligible. The combined standing stock size estimate was 108 800 t, with a 95% confidence interval of ± 38 400 t.

Sea perch

Sea perch (*Lepidoperca* sp.) were caught in all strata, and the highest catch rate was in stratum 6. The standing stock size estimate was 42 800 t, with a 95% confidence interval of ± 6100 t.

All species

The density of the total standing stock was fairly even throughout the survey area, and there were no obvious relationships between catch rates and depth or temperature.

Table 10: Standing stock size estimates of hake, rattails, lookdown dory, oreos, and sea perch

Stratum	Depth (m)	Stock size (10^3 t)*: Hake	Rattails	Lookdown dory	Oreos	Sea perch
1	0–400	0.0	0.3	0.1	–	0.0
2	600–800	3.1	22.8	0.7	5.2	1.2
3	400–600	3.3	10.1	1.8	0.9	3.5
4	400–600	1.6	25.2	5.8	–	3.7
5	600–800	0.3	11.3	0.8	51.6	1.0
6	200–400	6.6	44.5	4.2	–	20.1
7	0–200*	–	0.0	–	–	0.4
8	600–800	2.9	19.8	1.6	6.9	1.5
9	400–600	7.2	13.2	3.4	5.9	2.7
10	400–600	3.1	34.5	9.1	13.4	5.7
11	600–800	1.3	14.9	1.6	24.6	0.7
12	0–400	0.3	5.2	2.2	0.4	2.5
Total		29.7	201.8	31.2	108.8	42.8

* *See* Table 1.

Table 11: Mean catch per trawl and standing stock size estimate of all species combined

Stratum	Depth (m)	Mean catch (kg)	Stock size (10^3 t)
1	0–400	952	7.7
2	600–800	2 696	85.8
3	400–600	1 563	93.8
4	400–600	1 369	149.4
5	600–800	2 016	102.4
6	200–400	1 578	292.5
7	0–200*	1 466	11.5
8	600–800	789	76.2
9	400–600	723	87.9
10	400–600	1 010	204.1
11	600–800	1 115	80.9
12	0–400	857	92.8
Total		1 219†	1 284.9

* *See* Table 1.
† Stratified mean.

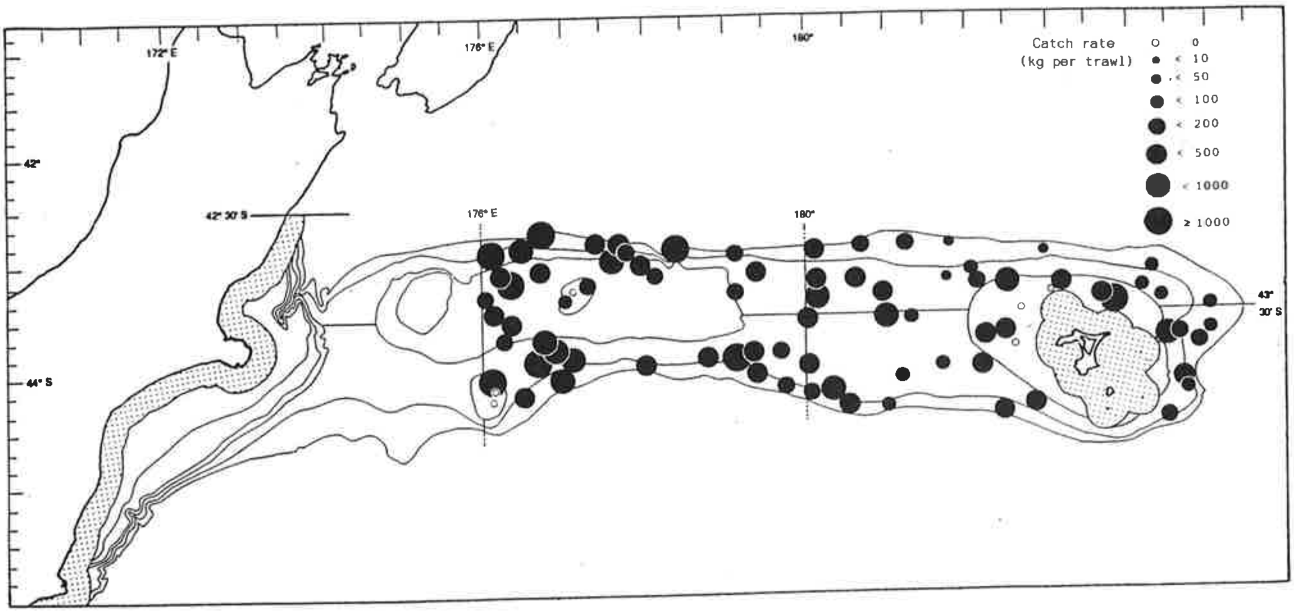

Figure 7: Distribution and catch rates of hoki.

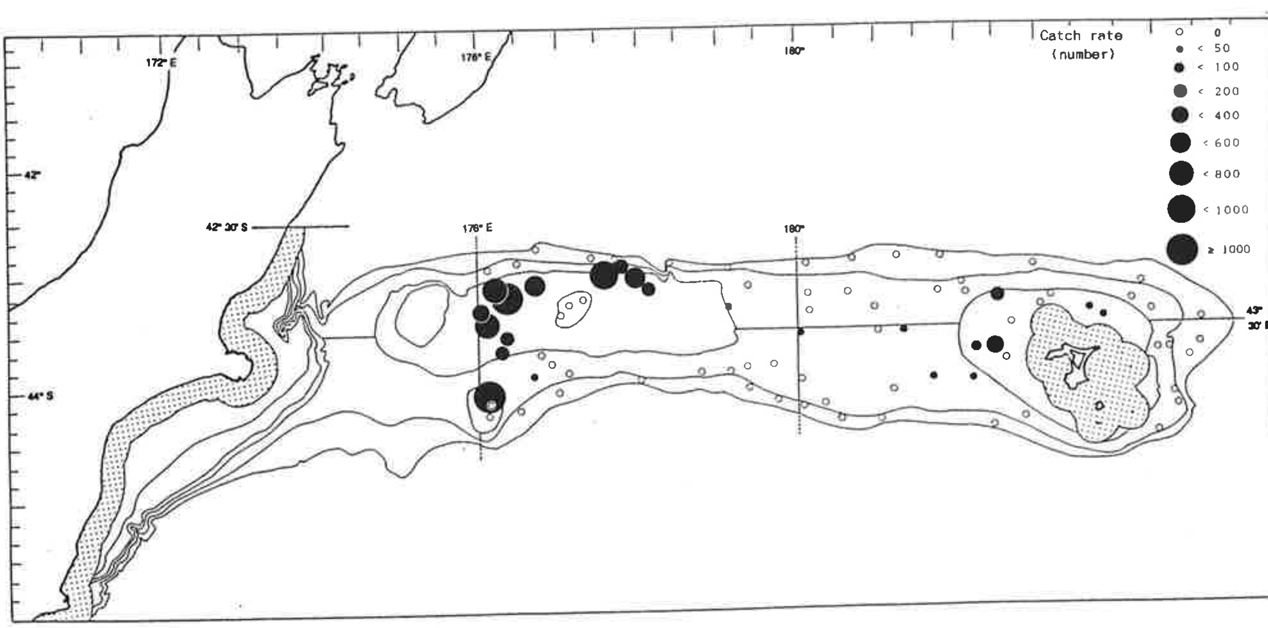

Figure 8: Distribution and catch rates of small hoki (under 44 cm TL).

The total standing stock size estimate was 1 284 900 t, with a narrow 95% confidence interval of ± 202 500 t (*c.v.* = 8%), which corresponded to small variations in the density of the total standing stock. This estimate is about 60% of that from the previous survey (Fenaughty and Uozumi 1989). This decrease was mainly because of the lower estimates of semipelagic species such as hoki and hake. Modifications of trawl gear and differences in the seasonal distribution patterns are suggested as major reasons for the decreases.

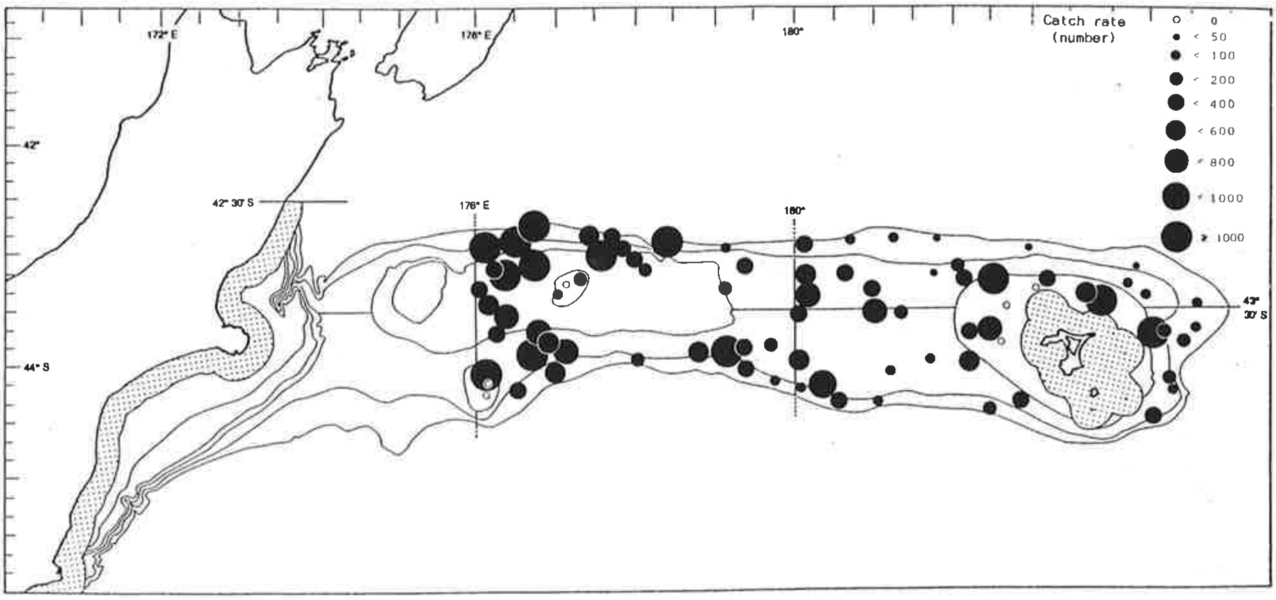

Figure 9: Distribution and catch rates of large hoki (at least 44 cm TL).

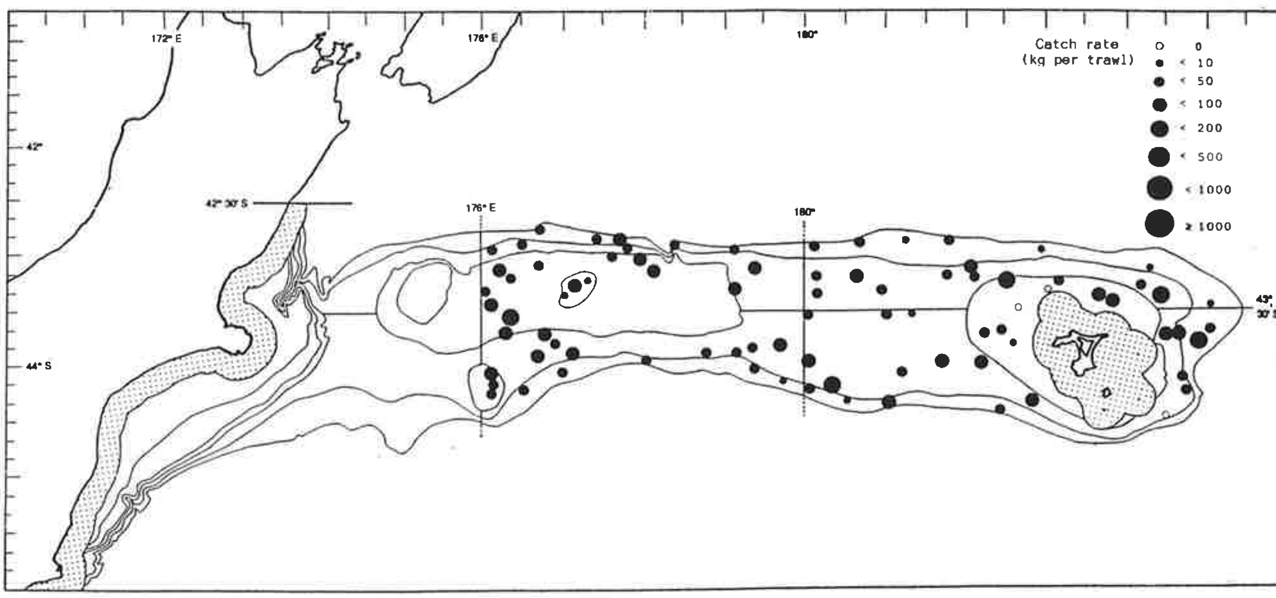

Figure 10: Distribution and catch rates of ling.

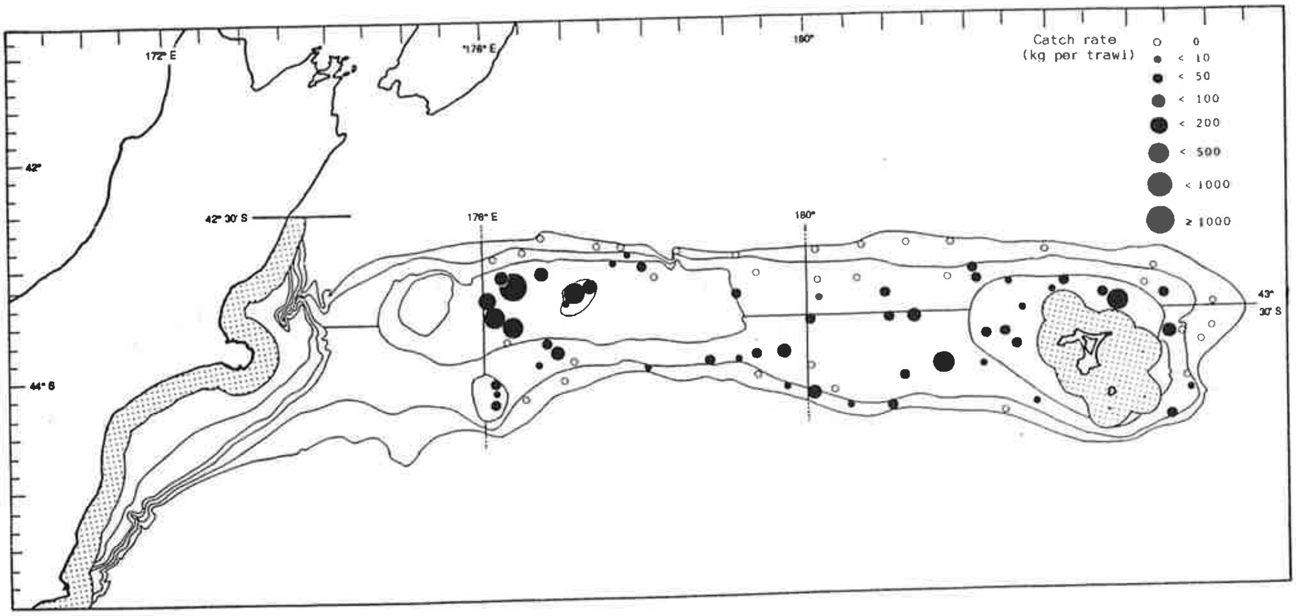

Figure 11: Distribution and catch rates of silver warehou.

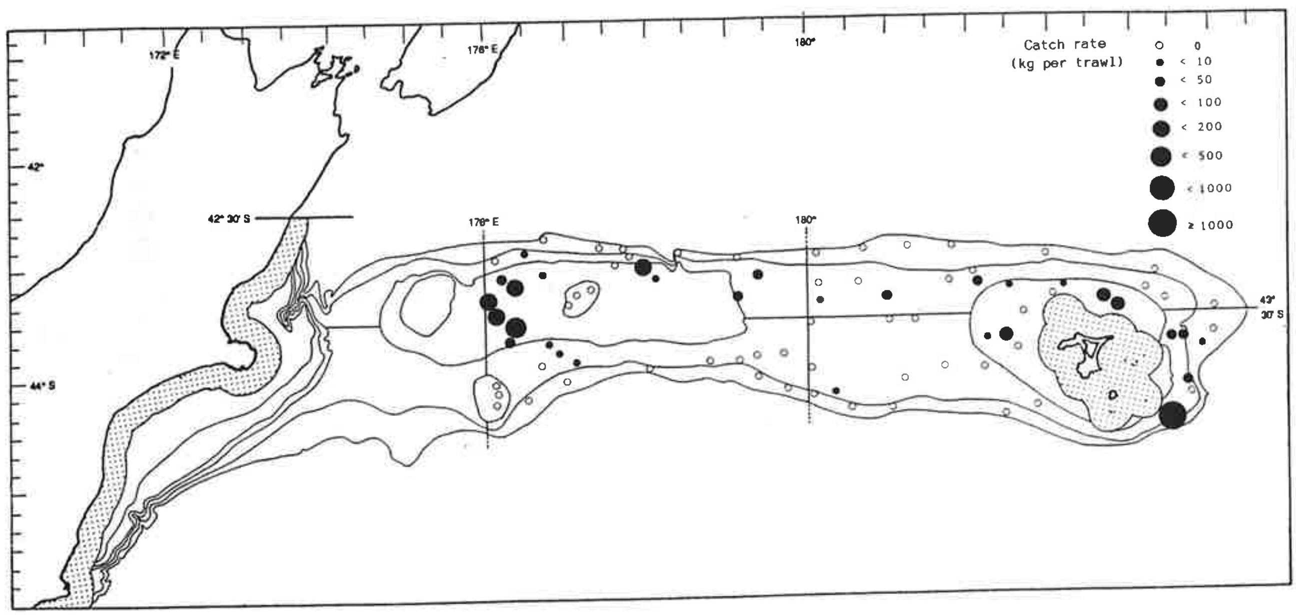

Figure 12: Distribution and catch rates of white warehou.

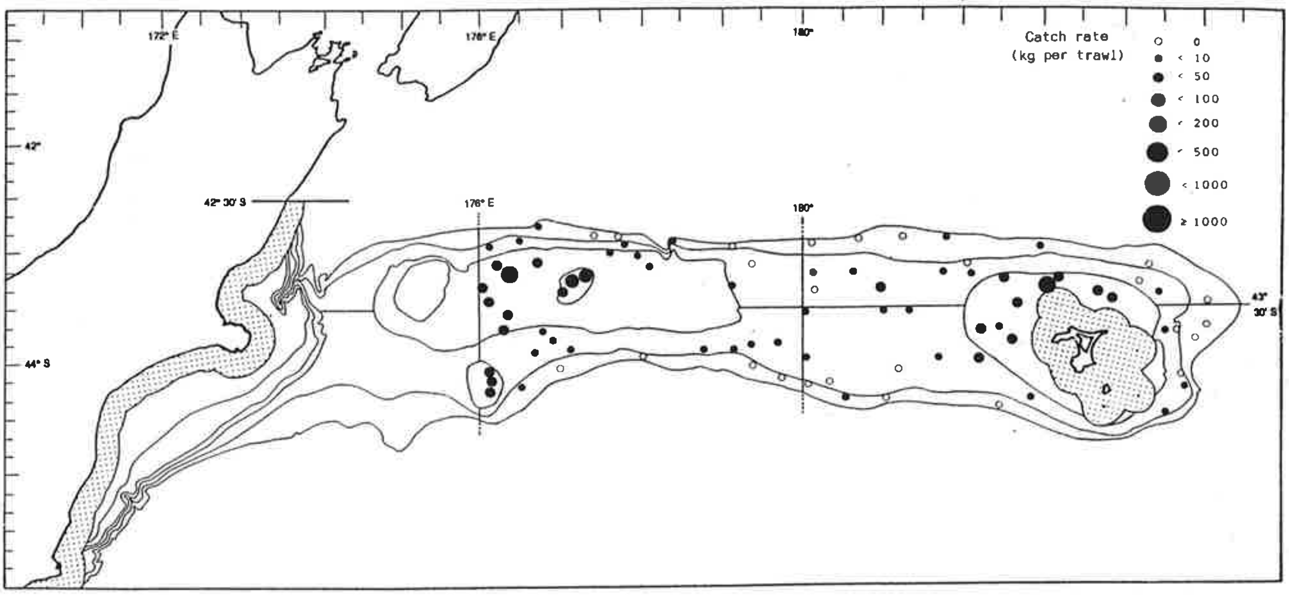

Figure 13: Distribution and catch rates of arrow squid.

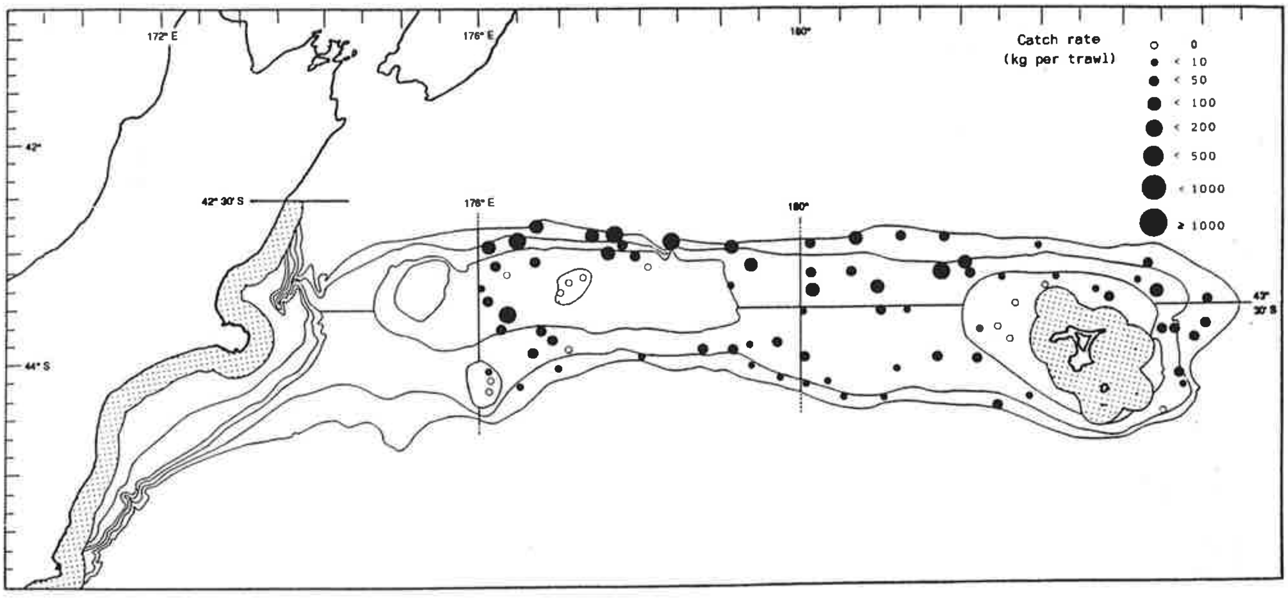

Figure 14: Distribution and catch rates of hake.

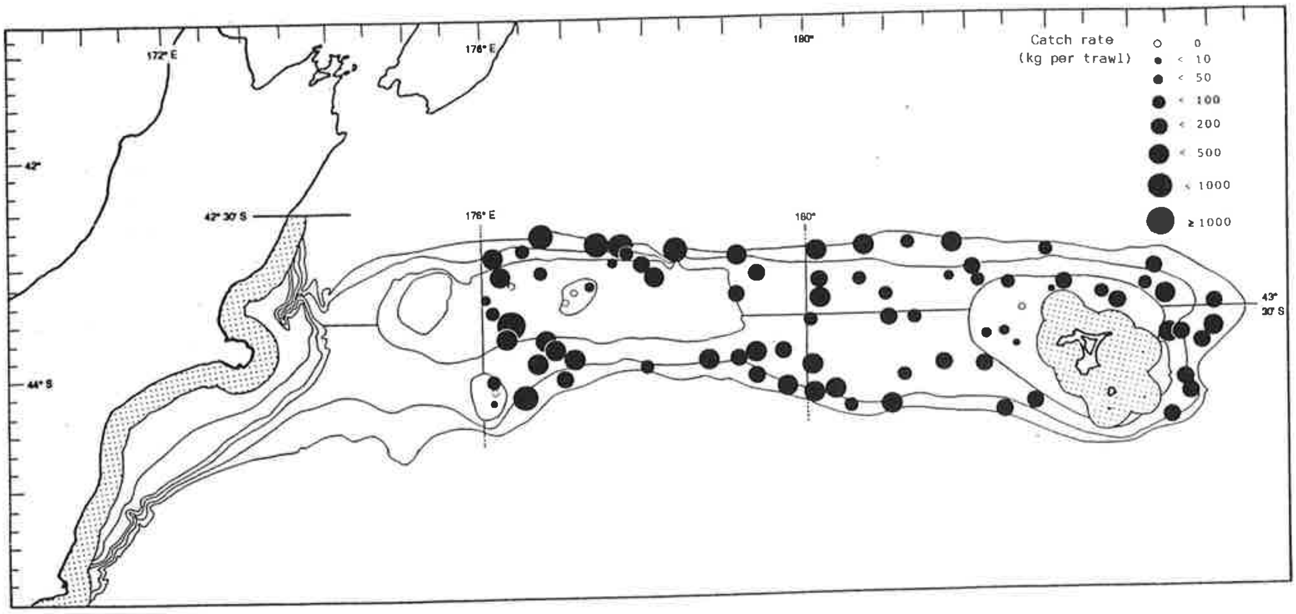

Figure 15: Distribution and catch rates of rattails (including javelin fish).

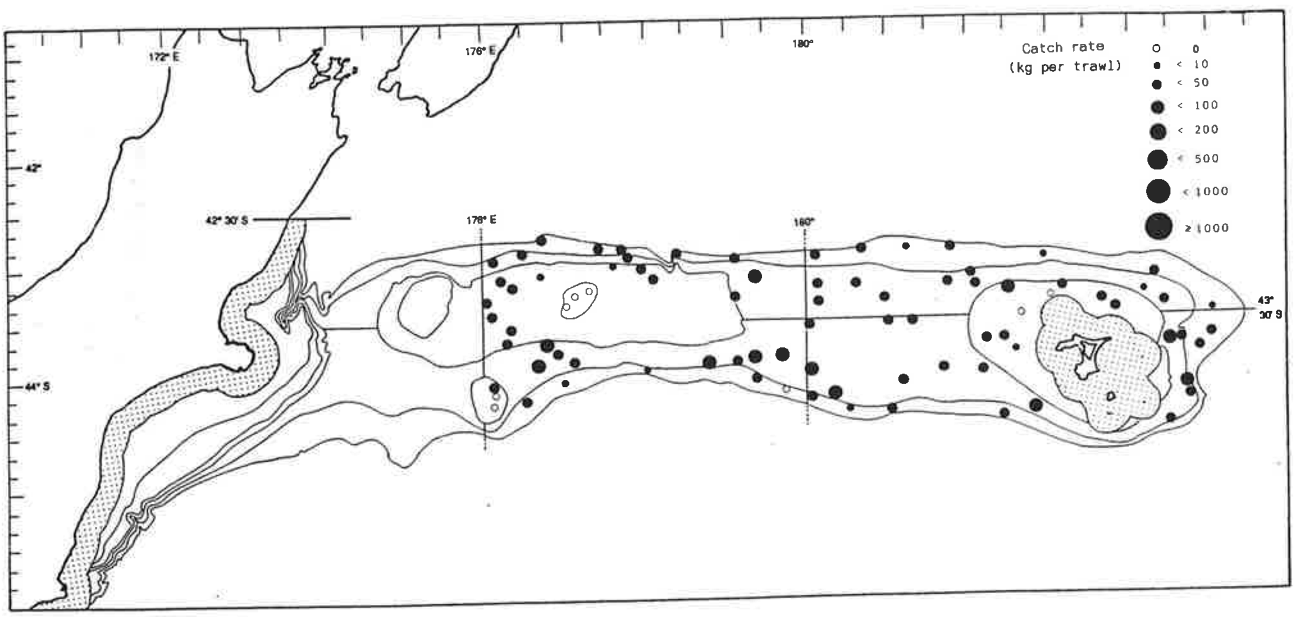

Figure 16: Distribution and catch rates of lookdown dory.

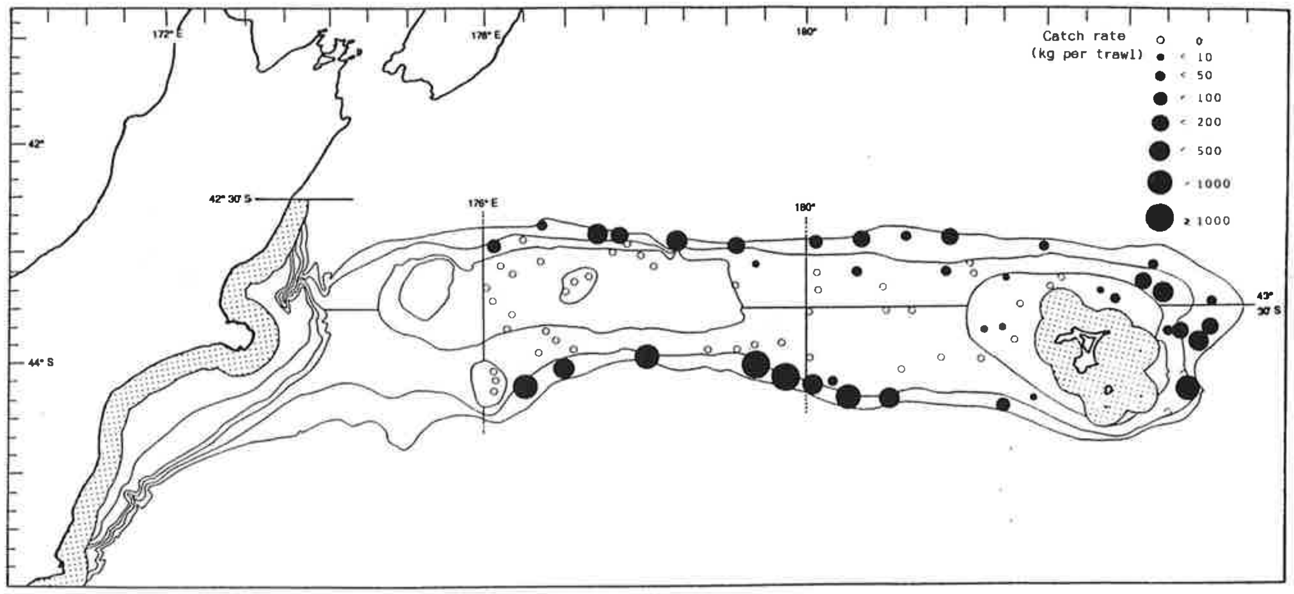

Figure 17: Distribution and catch rates of oreos.

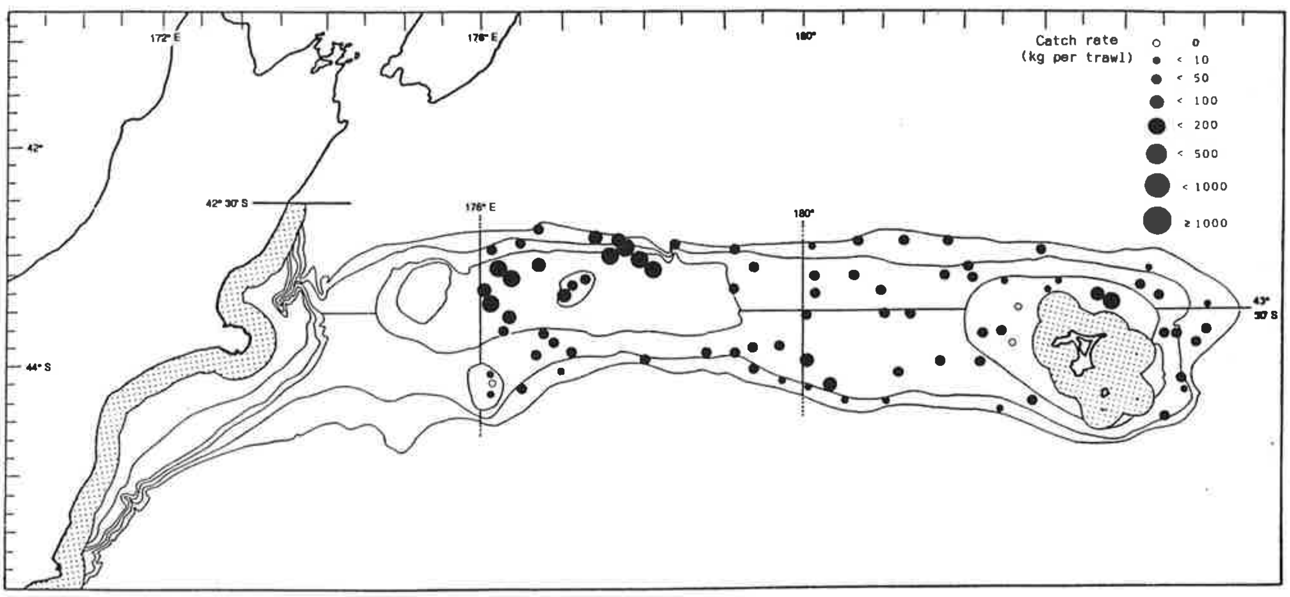

Figure 18: Distribution and catch rates of sea perch.

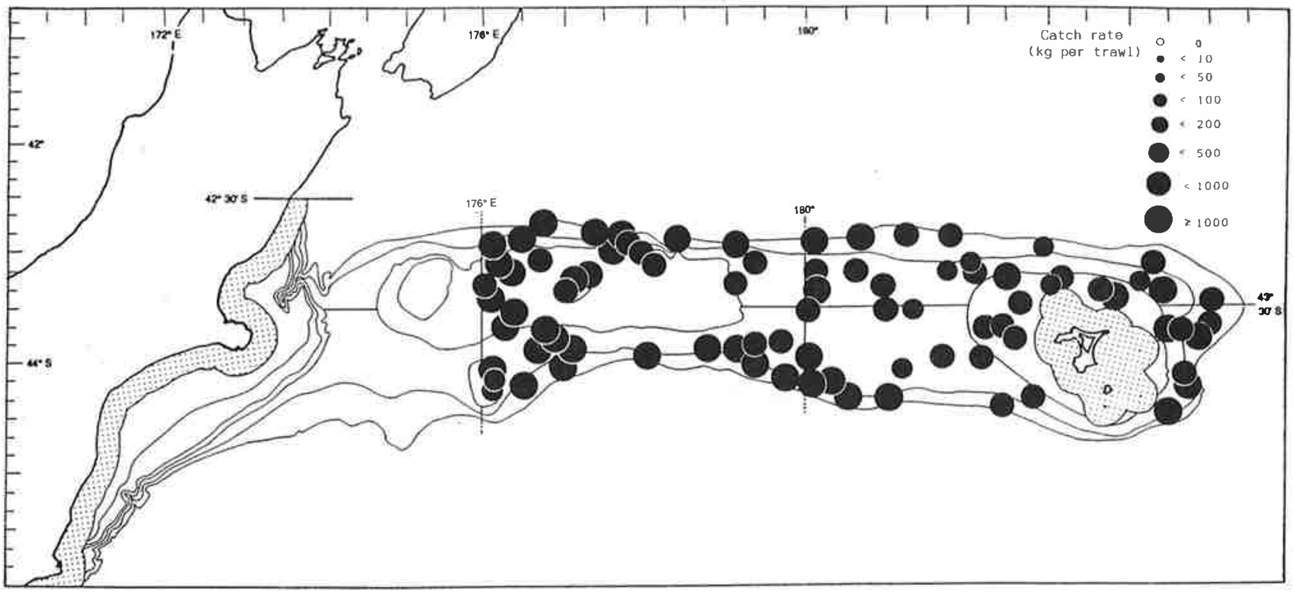

Figure 19: Distribution and catch rates of all species.

Biology

Hoki

Size composition

Size compositions of hoki by stratum and by depth zone are shown in Figures 20 and 21. The smallest size class (modal peak at 35 cm TL) dominated in strata shallower than 400 m, on the Veryan Bank and around the Reserve Bank (strata 1 and 6). Larger fish were caught in deeper water (400–800 m).

The changes in proportions of the size class modes at 35, 48, and 60 cm in the shallow strata (less than 400 m) between March 1983 and this survey suggest an increase in the numbers of fish in the smallest size class, particularly on the Reserve and Veryan Banks. In contrast, the proportions of different size fish on the central Chatham Rise and its northern and southern slopes (400–600 m), suggest an increase in the numbers of larger fish, modes 60–75 cm, in this survey. There also appears to have been an increase in stratum 2 (600–800 m).

Hoki otolith annual rings have not been validated. However, otoliths were aged by the annual check ring method as described by Kuo and Tanaka (1984b), and the modes of 35, 48, and 60 cm were interpreted to represent fish of 2+, 3+, and 4+ year classes respectively.

Relationship between total length and body weight

The length-weight relationship for hoki is shown in Figure 22. There was no clear difference between males and females.

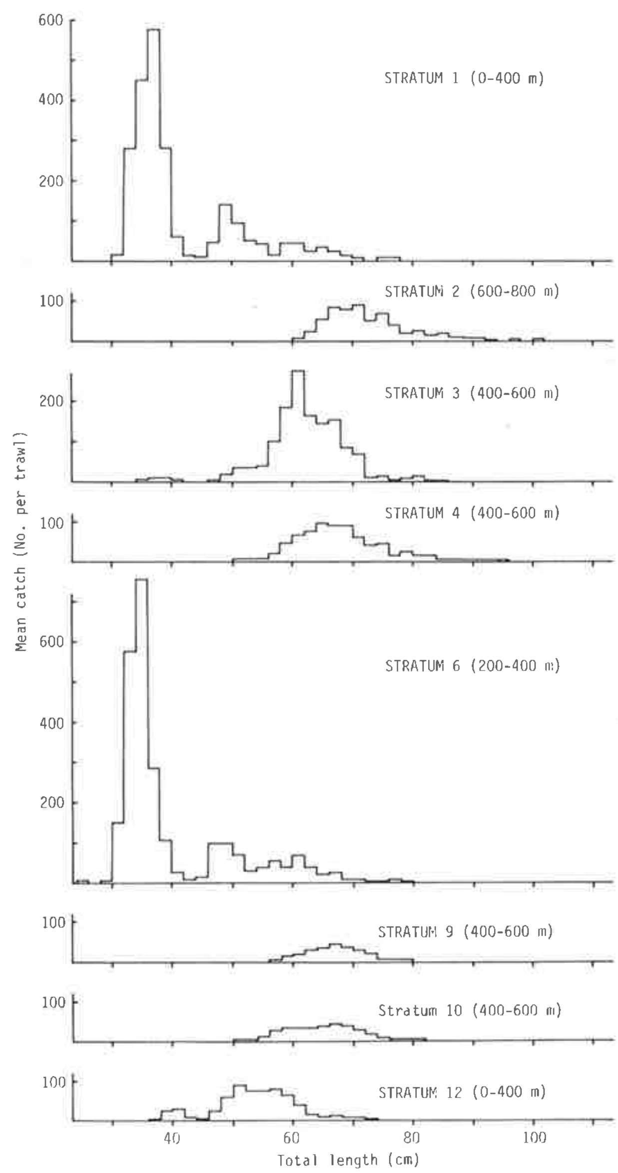

Figure 20: Size composition of hoki by stratum.

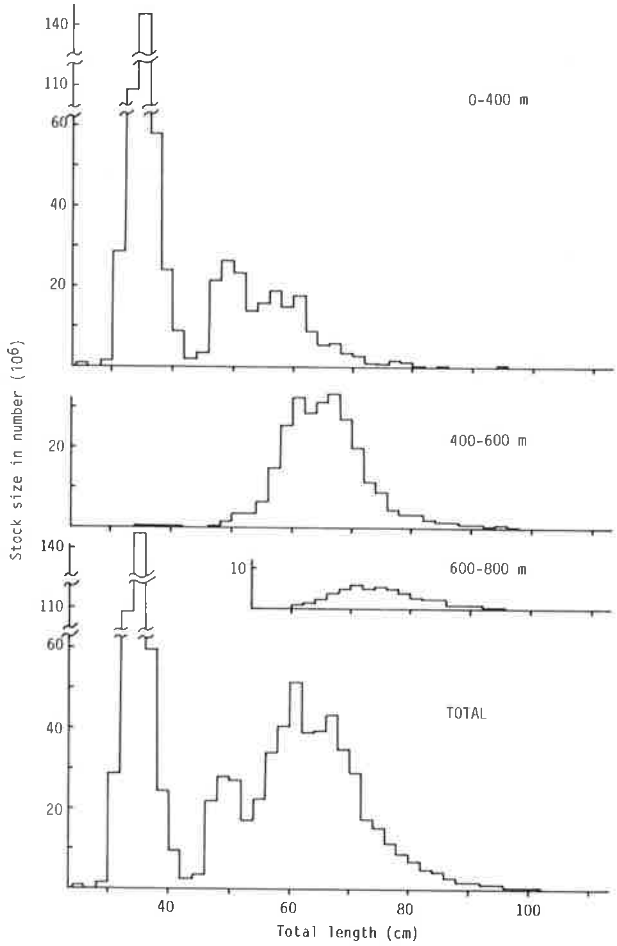

Figure 21: Estimated size composition of hoki by depth zone.

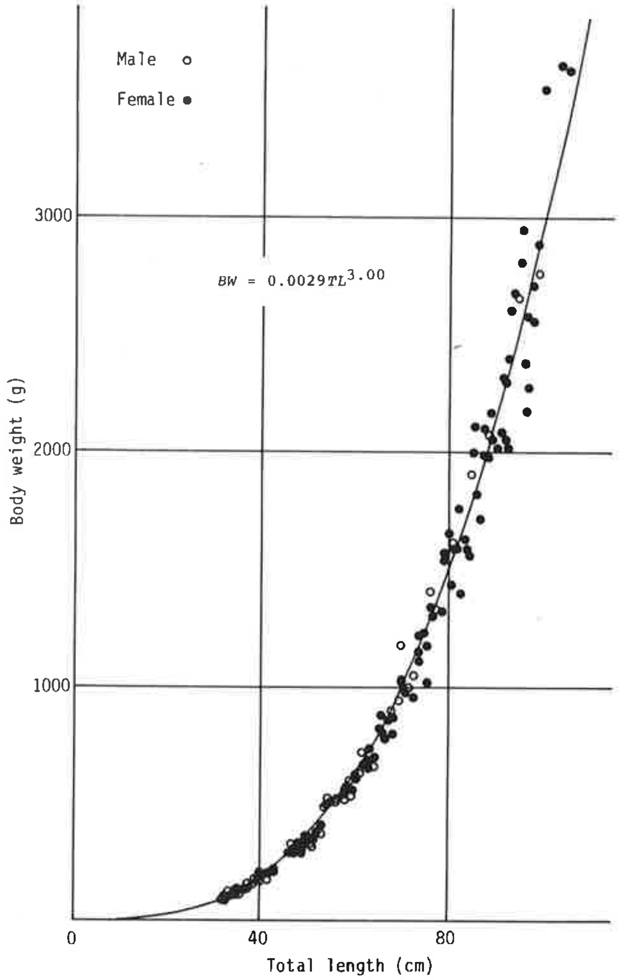

Figure 22: Relationship between total length (TL) and body weight (BW) of hoki.

Percentage of females

The percentage of females increased from about 50% in length classes less than 60 cm TL to almost 100% in length classes over 98 cm (Figure 23). Kuo and Tanaka (1984b) reported that there was almost no difference in the growth curve between males and females in area D. Therefore, the increase in the percentage of females among larger fish suggests a lower mortality and/or longer life span of female hoki. Alternatively, males may migrate out of the area as they reach maturity or become less vulnerable to the bottom trawl.

Maturity

The maturity stages were determined for 716 hoki specimens. Only two males were maturing. All other fish were immature.

Stomach contents

Hoki stomach contents comprised fish, squids, shrimps, planktonic crustaceans, and salps (Table 12). Fish predominated and were eaten by almost all size classes of hoki, whereas shrimps were eaten mainly by hoki larger than 60 cm TL. Planktonic crustaceans (euphausiids and amphipods) were present mainly in the stomachs of smaller fish.

Ling

Size composition

Size compositions of ling by stratum and by depth zone are shown in Figures 24 and 25. There was a large size range (36–140 cm TL), and there was no distinct length frequency mode, as in the March 1983 survey (*see* Fenaughty and Uozumi 1989). Size composition by depth zone showed there were less small fish at greater depths. Most fish were of medium size (50–90 cm).

Maturity and stomach contents

Twenty ling in the size range 55.8 to 88.8 cm were examined. All had immature gonads. The stomach of one specimen contained fish and shrimps, but the rest were empty.

Silver warehou

Size composition

Size compositions by stratum and by depth zone are shown in Figures 26 and 27. Length frequencies differed between strata, and there were one or more modes in each stratum. Individuals

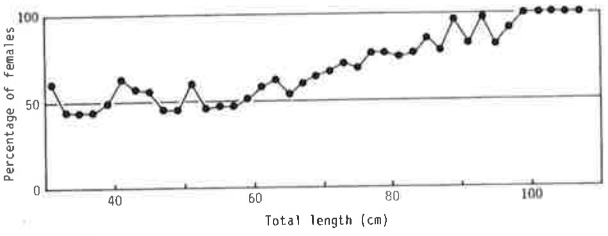

Figure 23: Percentage of females in the hoki catch.

smaller than 37 cm FL were present only in depths less than 400 m. Fish size increased with depth, and most fish were longer than 37 cm.

In March 1983, small fish (20 cm) predominated (Fenaughty and Uozumi 1989), whereas in this survey larger fish (40 cm) were dominant. These results correlate with the observation that silver warehou spawn on the Chatham Rise in spring-summer and the suggestion that fish in spawning

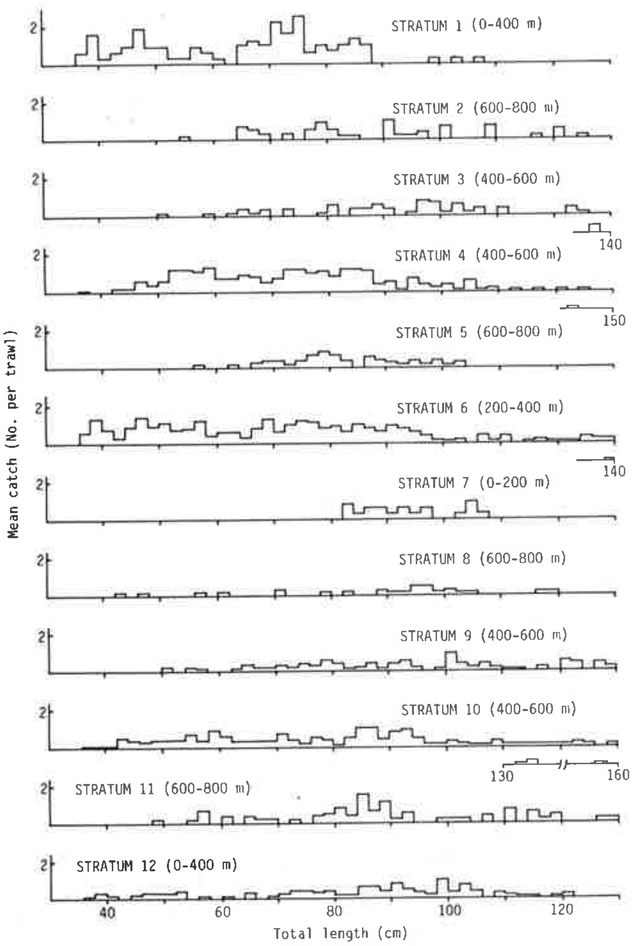

Figure 24: Size composition of ling by stratum.

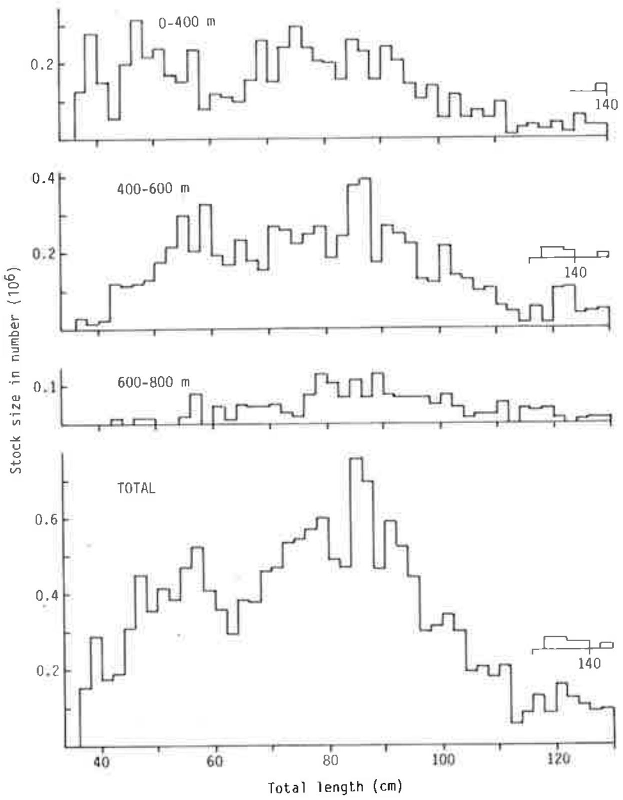

Figure 25: Estimated size composition of ling by depth zone.

Table 12: Stomach contents of hoki by occurrence

Length class (cm)	Fish	Squids	Shrimps	Crustaceans*	Salps	Empty	Everted	Total
30–35	6	–	1	1	–	15	–	23
35–40	25	–	4	7	–	35	2	73
40–45	1	–	–	1	–	4	1	7
45–50	5	–	–	2	–	9	2	18
50–55	4	–	1	5	–	12	–	22
55–60	8	–	2	8	–	22	–	40
60–65	26	1	14	6	3	51	5	106
65–70	40	8	30	7	8	77	5	175
70–75	29	3	24	1	–	54	2	113
75–80	16	3	14	–	–	35	2	70
80–85	7	2	10	2	–	18	–	39
85–90	9	1	5	1	1	14	–	31
90–95	3	–	4	–	–	5	1	13
95–100	4	–	–	–	–	6	–	10
100–105	1	–	–	–	–	1	–	2
105–110	–	–	–	–	1	–	–	1
Total	184	18	109	41	12	359	20	743

* Other planktonic crustaceans (mainly euphausiids and amphipods).

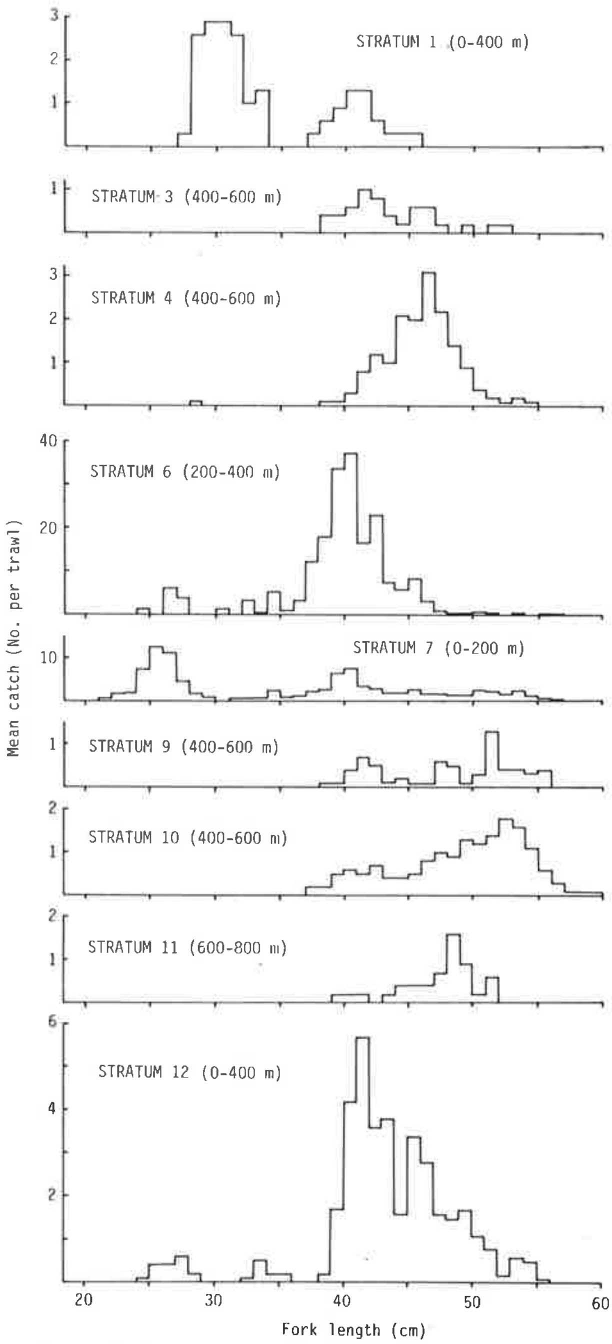

Figure 26: Size composition of silver warehou by stratum.

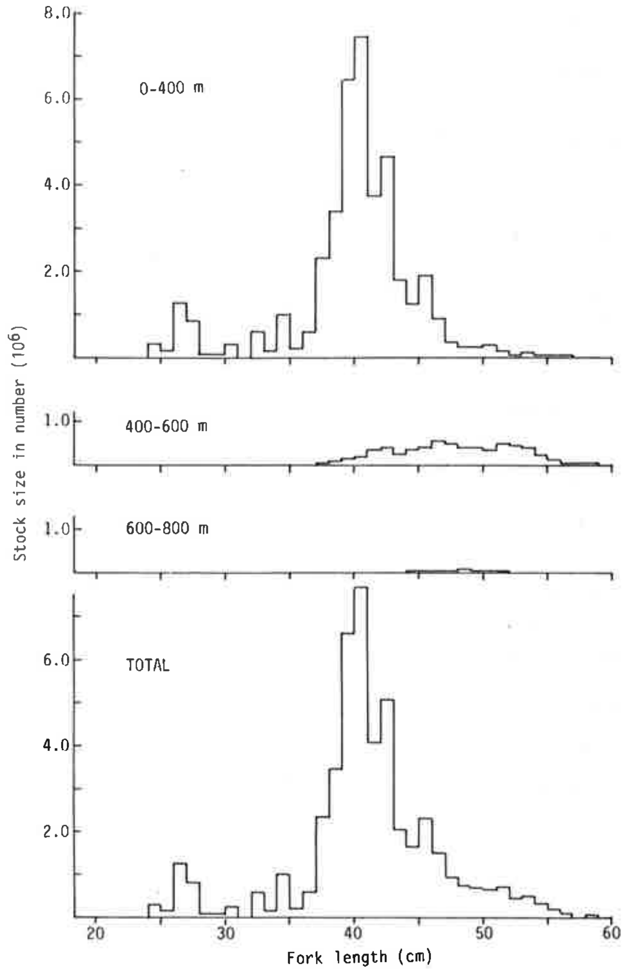

Figure 27: Estimated size composition of silver warehou by depth zone.

condition are more vulnerable to the trawl (Livingston and Berben 1986).

Relationship between fork length and body weight

The length-weight relationship is shown in Figure 28. There was no clear difference between males and females.

Maturity

The maturity stages for 140 specimens are shown in Figure 29. Most males were maturing, and some were mature. About 40% of females were maturing, but no mature females were caught.

Stomach contents

Of the 140 specimens examined, 124 had salps or jellyfish in their stomachs, and no other species were present.

White warehou

Size composition

Size compositions by stratum and depth zone are shown in Figures 30 and 31. There were five distinct size groups, with clear modal peaks at 28, 40, and 50 cm FL. The ratios of these size groups differed between strata. The two smallest size groups were present only in depths shallower than 400 m, and most fish were about 40 cm. Larger individuals were dominant in 400–600 m. White warehou were seldom caught deeper than 600 m. As with silver warehou, it appeared that larger fish were more prevalent during November-December than in March 1983 (*see* Fenaughty and Uozumi 1989).

Arrow squid

Size composition

Size compositions by stratum and by depth zone are shown in Figures 32 and 33. There were three size groups, with modal peaks at 14 (unsexed), 23 and 31 cm (males), and 22 and 35 cm ML (females). The ratios differed between strata; the third size group dominated in strata 1 and 6, the second one dominated in strata 7 and 12. In March 1983 the modal peaks were smaller, at 12, 17, and 24 cm ML (Fenaughty and Uozumi 1989).

Percentage of females

The percentage of females is shown in Figure 34. Females constituted 30–50% of arrow squid in the length classes 20–27 cm ML. This decreased to about 10% in the 29–33 cm length classes and increased to 100% in arrow squid over 37 cm. These fluctuations in size classes 28 cm and over occur because mature females are larger than mature males.

Occurrence of copulated females

The occurrence of copulated females is shown in Figures 32 and 33, and the percentage of copulated females is shown in Figure 35. Most females over 29 cm had copulated, as in March 1983 (Fenaughty and Uozumi 1989).

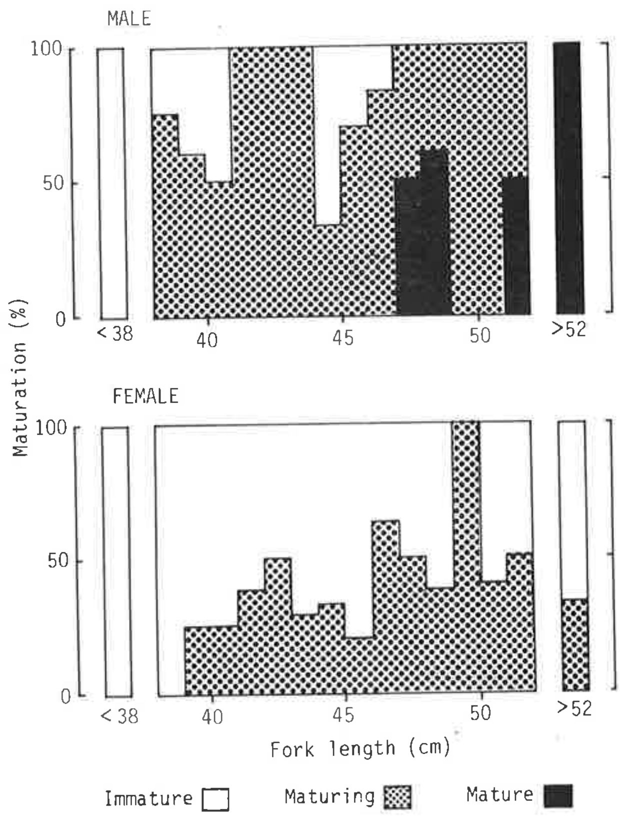

Figure 29: Maturation stages of silver warehou.

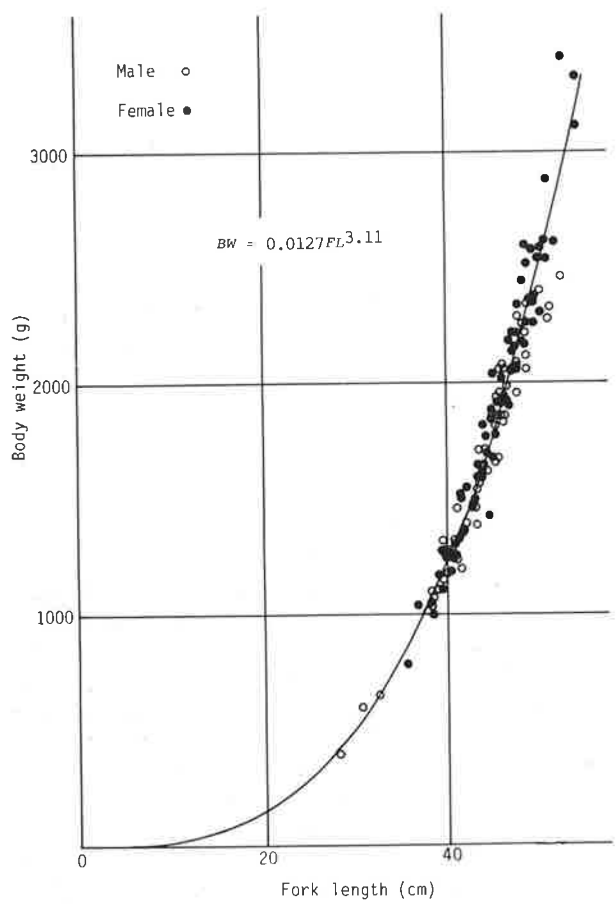

Figure 28: Relationship between fork length (FL) and body weight (BW) of silver warehou.

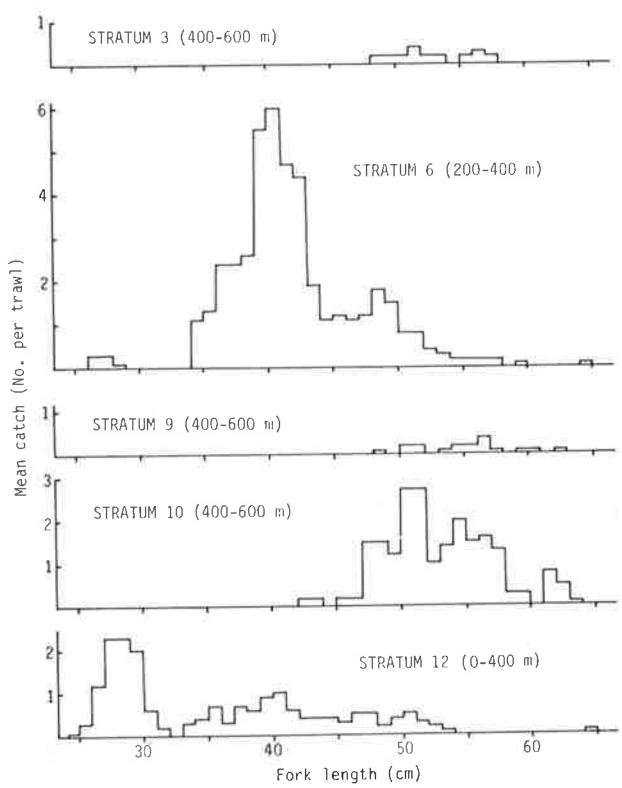

Figure 30: Size composition of white warehou by stratum.

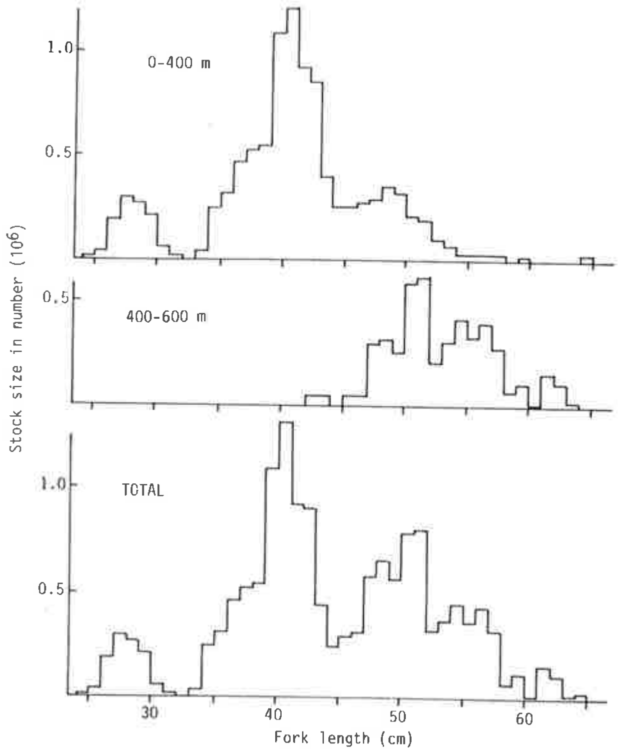

Figure 31: Estimated size composition of white warehou by depth zone.

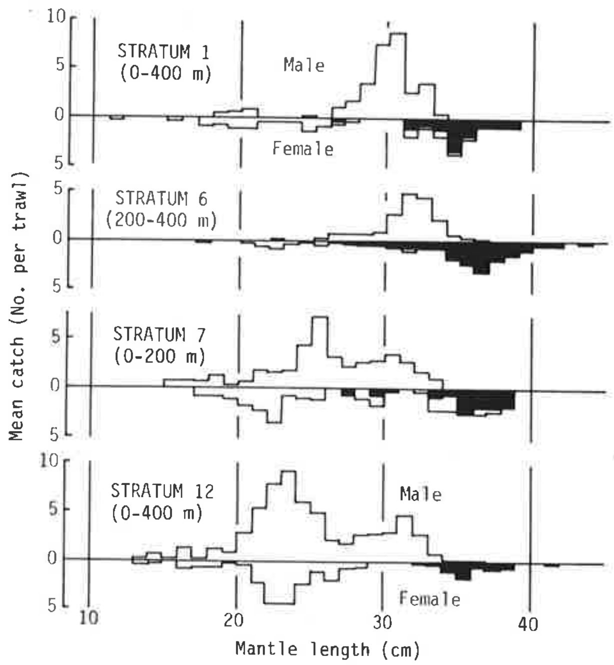

Figure 32: Size composition of arrow squid by stratum (solid areas show copulated females).

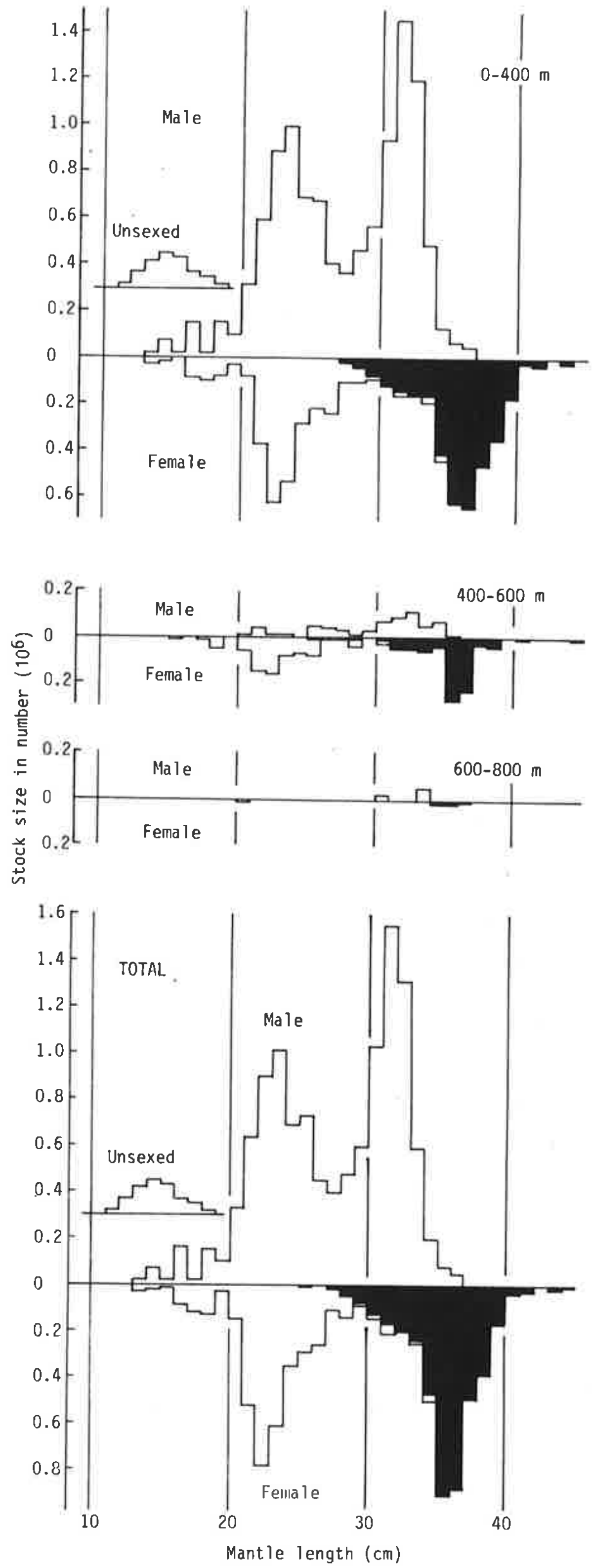

Figure 33: Estimated size composition of arrow squid by depth zone (solid areas show copulated females).

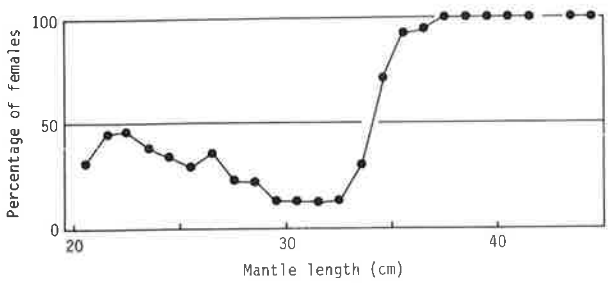

Figure 34: Percentage of females in the arrow squid catch.

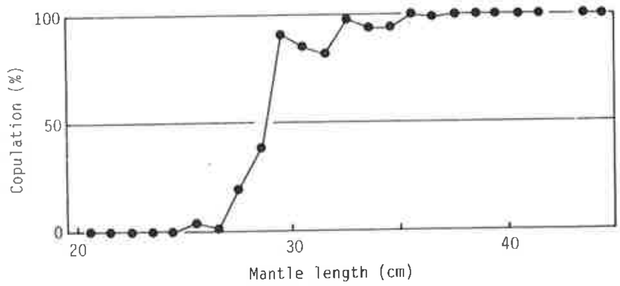

Figure 35: Percentage of copulated females in the arrow squid catch.

Summary

During this survey, as in March 1983, the catch was dominated by hoki and rattails (including javelin fish). Other important commercial species were hake, silver warehou, and ling. There was a large decrease in biomass for most species compared with the same area in March 1983, though only the decreases in the hoki and hake estimates were statistically significant (Table 13). Seasonal movements in and out of the survey area may have caused these differences. However, such effects are masked partly by the differences in gear efficiency, and it is difficult to determine how significant the observed changes in estimated fish biomass really are.

A summary of wingspread biomass estimates of principal species calculated from both surveys is given in Table 13. The November-December estimates have also been adjusted to account for the 21% loss of headline height in this survey compared with the March survey. If it is assumed that fish were distributed evenly in the water column to the top of the net in March 1983, the results are more comparable by this adjustment. However, irrespective of adjustment, the stock sizes of hoki and hake in particular differ greatly between the two surveys and were much lower in the second survey. The specific effects of altering gear efficiency on catch rate cannot be estimated, but it is possible that these estimates represent real differences in relative biomass.

Other hoki biomass estimates obtained in spring and autumn surveys by *Wesermünde* showed a similar pattern to the *Shinkai Maru* surveys for area D (April 1979, 143 000–1 000 000 t; November 1979, 100 000–480 000 t (Francis 1981)). However, the number of stations (20 in April and 23 in November) was much lower in the *Wesermünde* surveys. Large changes in hoki biomass on a seasonal basis may also be expected because this species is a gadoid, renowned for highly migratory behaviour before and after spawning. Silver warehou biomass estimates from

Table 13: Comparison of wingtip biomass estimates (t) of the five main commercial species on the Chatham Rise (area D), March 1983 (Fenaughty and Uozumi 1989) and November-December 1983 (this survey)

	Hoki	Ling	Silver warehou	Hake	Arrow squid
Mar					
Biomass estimate	1 157 741	63 700	16 400	42 900	13 200
c.v. (%)	11	27	33	12	26
Nov-Dec					
Biomass estimate	454 300	47 200	66 600	29 700	12 000
c.v. (%)	15	9	40	12	23
t statistic	4.9*	0.9	1.8	2.1†	0.3
Biomass estimate‡	549 703	57 112	80 586	35 937	14 520

* Significant at $p \leq 0.001$.
† Significant at $p \leq 0.05$.
‡ This estimate has been adjusted for the net headline height.

Wesermünde have not been published, but it is known that spring spawning occurs on the Chatham Rise, and, therefore, fish may have migrated into the area before the survey in November 1983.

The main hoki spawning ground is the west coast of the South Island (Patchell 1982), though some spawning also occurs in Cook Strait and on the western Chatham Rise (Livingston and Berben 1987b, Uozumi 1988, Murdoch and Chapman 1989). It is possible that adult Chatham Rise hoki (over 65 cm TL) migrate as far as the west coast for winter spawning. The biomass estimate of mature fish (over 65 cm TL) in March 1983 was 814 000 t (Fenaughty and Uozumi 1989). If many large fish migrated from the Chatham Rise (e.g., to spawning grounds), the biomass of hoki on the Chatham Rise could be significantly affected. More small hoki (under 40 cm) were caught in the present survey than in the March 1983 survey. However, the mean weight of a 35 cm fish is about 10% that of a 70 cm fish, thus their contribution to biomass would be substantially less. Therefore, most of the difference in hoki biomass between the March and November surveys could have been due to a decrease in the numbers of larger hoki (greater than 40 cm).

Acknowledgments

We thank the officers and crew of *Shinkai Maru* for their efficient work during this survey. We also thank W. Ichikawa (Japan Marine Fishery Resource Research Center), J. Colman (Fisheries Research Centre, N.Z. Ministry of Agriculture and Fisheries), and J. Rudolph (Fisheries Management Division, N.Z. Ministry of Agriculture and Fisheries) for their assistance during the cruise.

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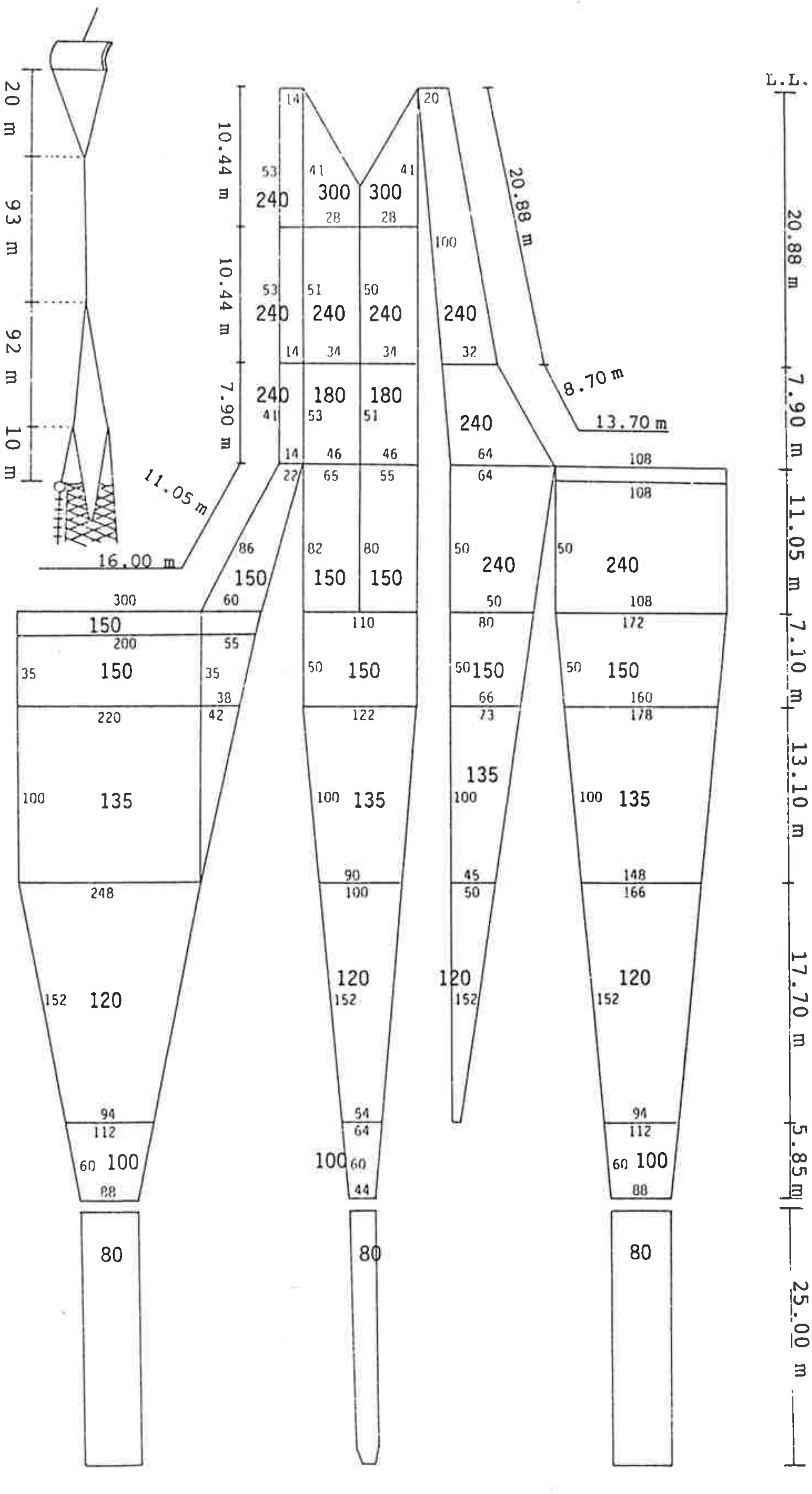
Appendix 1

Details of trawl net

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



Appendix 2

The criteria used for the determination of maturity stages in arrow squid and finfish

	Male	Female
Arrow squid		
Stage 1 (immature)	Testis thin or small; spermatophoric sac empty	Ovary thin or granular; nidamental gland thin or small
Stage 2 (maturing)	Testis large; spermatophoric sac contains few spermatophores and/or whitish particles	Eggs forming; nidamental gland opaque
Stage 3 (mature)	Testis large; spermatophoric sac contains many spermatophores	Eggs in oviduct; nidamental gland white
Stage 4 (spent)	Spermatophores released and spermatophoric sac empty	Spent
Finfish		
Stage 1 (immature)	Testis threadlike	No granular eggs distinguishable by eye
Stage 2 (maturing)	Testis enlarged and whitish, but no fluid semen	Eggs distinguishable by eye, but no transparent eggs visible
Stage 3 (mature)	Testis white with fluid semen	Some eggs transparent
Stage 4 (spent)	Testis shrunken and without fluid semen	Ovaries shrunken or empty, some remaining eggs

Appendix 3

Species caught during the survey

Scientific name	Common name
Agnatha	
Eptatretidae	
Eptatretus cirrhatus	hagfish
Chondrichthyes	
Hexanchidae	
Hexanchus griseus	sixgilled shark
Squalidae	
Centrophorus squamosus	leafscale gulper shark
Centroscymnus crepidater	longnosed velvet dogfish
C. owstoni	Owston's dogfish
C. plunketi	Plunket's shark
Deania calceus	shovelnosed dogfish
Etmopterus baxteri	Baxter's dogfish
E. lucifer	Lucifer dogfish
Oxynotus bruniensis	prickly dogfish
Scymnorhinus licha	seal shark
Squalus acanthias	spiny dogfish
S. mitsukurii	northern spiny dogfish
Carcharhinidae	
Galeorhinus galeus	school shark
Scyliorhinidae	
Apristurus sp. A	deepwater catshark
Cephaloscyllium isabellum	carpet shark
Halaelurus dawsoni	Dawson's catshark
Lamnidae	
Lamna nasus	porbeagle shark
Torpedinidae	
Torpedo fairchildi	electric ray
Narkidae	
Typhlonarke aysoni	blind electric ray
Rajidae	
Pavoraja asperula	deepsea skate
Pavoraja sp.	
P. spinifera	prickly deepsea skate
R. innominata	smooth skate
R. nasuta	rough skate
Chimaeridae	
Chimaera sp.	
Hydrolagus novaezelandiae	dark ghost shark
Hydrolagus sp.	pale ghost shark
Rhinochimaeridae	
Harriotta raleighana	longnosed chimaera
Rhinochimaera pacifica	widenosed chimaera
Osteichthyes	
Congridae	
Bassanago bulbiceps	swollenheaded conger
Synaphobranchidae	
Diastobranchus capensis	basketwork eel
Notacanthidae	
Notacanthus sexspinis	spineback

Appendix 3—*continued*

Halosauridae	
Halosaurus pectoralis	halosaur
Gonorynchidae	
Gonorynchus gonorynchus	sandfish
Argentinidae	
Argentina elongata	silverside
Alepocephalidae	
Rouleina squamilatera	slickhead
Photichthyidae	
Photichthys argenteus	lighthouse fish
Sternoptychidae	
Argyropelecus gigas	giant hatchetfish
Chauliodontidae	
Chauliodus sloani	viperfish
Stomiidae	
Stomias boa boa	scaly dragonfish
Malacosteidae	
Malacosteus niger	bluntheaded dragonfish
Notosudidae	
Scopelosaurus ahlstromi	slender silverside
Paralepididae	
Magnisudis prionosa	barracudina
Myctophidae	lanternfish
Diaphus spp.	
Gymnoscopelus spp.	
Lampanyctodes hectoris	
Lampanyctus sp. A	
Neoscopelidae	
Neoscopelus macrolepidotus	
Gadidae	
Micromesistius australis	southern blue whiting
Merlucciidae	
Macruronus novaezelandiae	hoki
Merluccius australis	hake
Moridae	
Austrophycis marginata	dwarf cod
Halargyreus johnsoni	slender cod
Lepidion microcephalus	smallheaded cod
Mora moro	ribaldo
Pseudophycis bachus	red cod
P. barbata	southern bastard cod
Tripterophycis gilchristi	grenadier cod
Macrouridae	
Coelorinchus aspercephalus	oblique banded rattail
C. biclinozonalis	two saddled rattail
C. bollonsi	Bollons's rattail
C. cookianus	Cook's rattail
C. fasciatus	banded rattail
C. innotabilis	notable rattail
C. matamua	Mahia rattail
C. oliverianus	Oliver's rattail
Coryphaenoides armatus	cosmopolitan rattail
C. serrulatus	serrulated rattail
C. subserrulatus	four rayed rattail
Lepidorhynchus denticulatus	javelin fish
Trachyrincus longirostris	white rattail
Ventrifossa nigromaculata	blackspotted rattail
Ophidiidae	
Genypterus blacodes	ling
Ceratiidae	
Cryptopsaras couesii	sea devil
Trachichthyidae	
Hoplostethus atlanticus	orange roughy
H. mediterraneus	silver roughy
Paratrachichthys trailli	common roughy
Berycidae	
Beryx splendens	alfonsino
Zeidae	
Capromimus abbreviatus	capro dory
Cyttus novaezealandiae	silver dory
C. traversi	lookdown dory

Oreosomatidae	
Allocyttus niger	black oreo
Neocyttus rhomboidalis	spiky oreo
Pseudocyttus maculatus	smooth oreo
Macrorhamphosidae	
Centriscops humerosus	bluebanded bellowsfish
C. obliquus	redbanded bellowsfish
Notopogon fernandezianus	orange bellowsfish
N. lilliei	crested bellowsfish
Scorpaenidae	
Helicolenus sp.	sea perch
Triglidae	
Chelidonichthys kumu	red gurnard
Lepidotrigla brachyoptera	scaly gurnard
Congiopodidae	
Alertichthys blacki	alert pigfish
Congiopodus coriaceus	deepsea pigfish
C. leucopaecilis	southern pigfish
Hoplichthyidae	
Hoplichthys haswelli	deepsea flathead
Psychrolutidae	
Neophrynichthys angustus	pale toadfish
Percichthyidae	
Polyprion oxygeneios	hapuku
Serranidae	
Lepidoperca sp. A	orange perch
Apogonidae	
Epigonus denticulatus	
E. lenimen	bigeyed cardinalfish
Epigonus sp.	
E. telescopus	deepsea cardinalfish
Bramidae	
Brama brama	Ray's bream
Emmelichthyidae	
Emmelichthys nitidus	redbait
Plagiogeneion rubiginosus	rubyfish
Pentacerotidae	
Pentaceros decacanthus	yellow boarfish
Cheilodactylidae	
Nemadactylus macropterus	tarakihi
Uranoscopidae	
Kathetostoma giganteum	giant stargazer
Gnathagnus innotabilis	brown stargazer
Percophidae	
Hemerocoetes monopterygius	opalfish
Pinguipedidae	
Parapercis colias	blue cod
P. gilliesi	yellow weever
Gempylidae	
Rexea solandri	gemfish
Thyrsites atun	barracouta
Trichiuridae	
Lepidopus caudatus	frostfish
Centrolophidae	
Centrolophus niger	rudderfish
Hyperoglyphe antarctica	bluenose
Seriolella caerulea	white warehou
S. punctata	silver warehou
Nomeidae	
Cubiceps caeruleus	cubehead
Bothidae	
Arnoglossus scapha	witch
Neoachiropsetta milfordi	finless flounder
Pleuronectidae	
Pelotretis flavilatus	lemon sole

Cephalopoda

Onychoteuthidae	
Moroteuthis sp.	warty squid
Ommastrephidae	
Todarodes filippovae	
Nototodarus sloanii	arrow squid

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