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New Zealand Fisheries
Technical Report No. 30
ISSN 0113-2180
1992

MINISTRY OF AGRICULTURE AND FISHERIES
TE MANATU AHUWHENUA AHUMOANA

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Published by MAF Fisheries

Wellington

1992

ISBN 0-477-08655-1

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The *New Zealand Fisheries Technical Report* series in part continues the *Fisheries Research Division Occasional Publication* series. The *New Zealand Fisheries Occasional Publication* series contains mainly conference proceedings and bibliographies.

Edited by S. J. Baird
Set in 10 on 11 Times Roman
Typeset by Brooker & Friend Ltd
Printed by Brooker & Friend Ltd

Contents

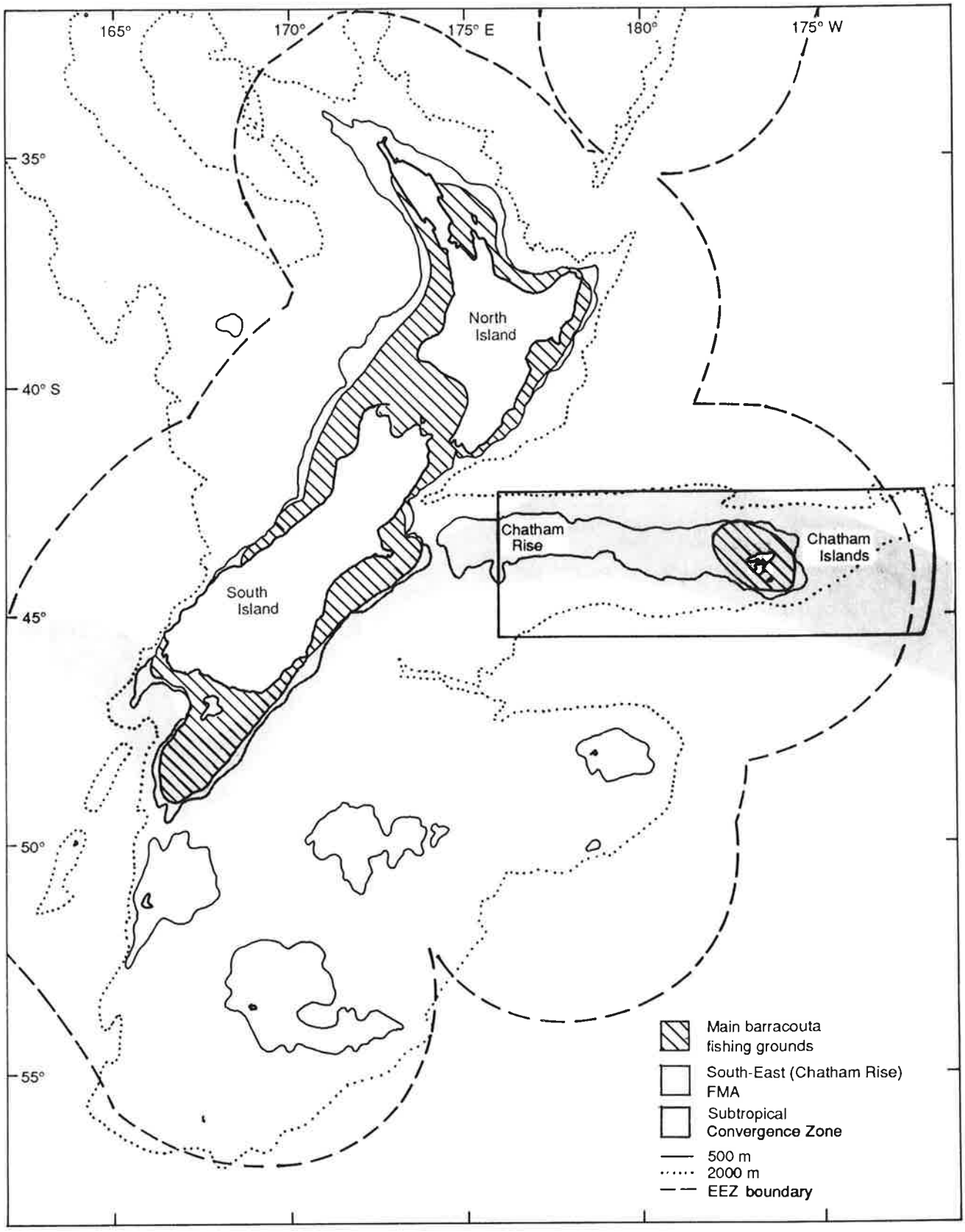

Figure 1: Main barracouta fishing grounds around New Zealand and places mentioned in the text (FMA, Fishery Management Area).

Abstract

Hurst, R. J. & Bagley, N. W. 1992: Trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1985. *N.Z. Fisheries Technical Report No. 30.* 36 p.

A three-phase random trawl survey of the Chatham Islands shelf (50-400 m) in December 1985, by *Akebono Maru No. 73* caught 64 species of fish, squid, and crustaceans. The catch and estimated biomass for the 20 major species are given, with more detailed results for the 10 major species of relative changes in distribution and abundance between survey areas and depths. The most abundant species (both as catch and estimated biomass) were barracouta, hoki, and silver warehou.

Biological data given for barracouta and silver warehou include length, weight, sex, gonad state, and feeding. Length and weight data for school shark and length frequency data for 10 other commercially important species are also given.

Results of this survey are compared with those from a similar survey in December 1984, by the same vessel, and a less intensive survey in July 1986, by *Shinkai Maru*. Barracouta and arrow squid showed significant decreases in biomass between the two December surveys, whereas ling, school shark, giant stargazer, and jack mackerels showed increases. Biomass estimates of hoki, giant stargazer, and ling from the July 1986 survey were significantly greater than one or both of the December survey estimates. Possible reasons for the changes are discussed and the value of incorporating biological data in the interpretation of biomass data is highlighted.

Introduction

Industry interest in the fisheries of the South-East (Chatham Rise) Fishery Management Area (FMA) (Figure 1) has increased during the last decade. This has included both the deepwater (New Zealand chartered and foreign licensed) sector of the industry, whose vessels are excluded from the 12 n. mile territorial sea, as well as the New Zealand domestic industry. Catches of the main middle depth and deepwater finfish species which occur in the area were restricted under the deepwater trawl policy introduced on 1 April 1983. Many of the inshore species also came under quota with the introduction of the Quota Management System on 1 October 1986. These management regimes required the establishment of Total Allowable Catches (TACs) for most of the commercial species in the South-East (Chatham Rise) FMA (an area roughly equivalent to the Exclusive Economic Zone (EEZ) Area D).

The Chatham Islands fishery

Catches reported by deepwater and domestic vessels fishing around the Chatham Islands from 1977 to the 1983-84 fishing year (1 October to 30 September) were given by Hurst & Bagley (1987, Table 2). Finfish and squid catches in the South-East (Chatham Rise) FMA for the fishing years 1983-84, 1984-85, and 1985-86 are given in Table 1.

Annual catches from 1983-84 to 1985-86 totalled between 38 600 and 42 200 t and comprised mainly orange roughy (*Hoplostethus atlanticus*) (61-67% of the total catch). Smooth oreo (*Pseudocyttus maculatus*), black oreo (*Allocyttus niger*), hoki (*Macruronus novaezelandiae*), and barracouta (*Thyrsites atun*) were also important. On the Chatham Islands shelf barracouta was the major species caught, mainly taken by New Zealand chartered vessels.

Most of the reported catch of arrow squid (*Nototodarus* spp.), jack mackerels (*Trachurus* spp.), spiny dogfish (*Squalus acanthias*), and tarakihi (*Nemadactylus macropterus*) came from the shelf area (i.e., in less than 400 m depth). Smaller quantities of red gurnard (*Chelidonicthys kumu*), hake (*Merluccius australis*), hapuku (*Polyprion oxygeneios*), hoki, ling (*Genypterus blacodes*), red cod (*Pseudophycis bachus*), silver warehou (*Seriolella punctata*), and white warehou (*S. caerulea*) were also reported from this area (MAF Fisheries unpublished data).

Table 1: Finfish and squid catches (t) in the South-East (Chatham Rise) Fishery Management Area, 1983–84 to 1985–86*

	1983-84 vessels†				1984-85 vessels				1985-86 vessels			
Species	DOM	FCD	LIC	Total	DOM	FCD	LIC	Total	DOM	FCD	LIC	Total
Alfonsino	-‡	34	82	116	-	161	105	266	0	28	516	544
Barracouta	1	1 367	376	1 744	9	1 537	372	1 918	0	1 113	397	1 510
Black oreo	821	127	0	1 209	43	1 532	0	1 575	236	723	2	961
Blue cod	260	0	0	260	287	0	0	287	349	0	-	349
Hake	6	140	32	178	3	316	79	398	4	94	35	133
Hapuku	18	17	21	56	15	15	21	51	12	30	11	53
Hoki	1	1 696	851	2 548	2	1 885	1 530	3 417	33	1 027	1 151	2 211
Jack mackerel	-	-	18	18	0	227	143	370	0	142	181	323
Ling	4	114	236	354	2	209	146	357	1	68	209	278
Moki	8	-	0	8	15	0	0	15	11	-	0	11
Orange roughy	9 729	14 097	16	23 842	11 314	14 422	57	25 793	12 030	14 980	0	27 010
Oreo unspecified	19	0	0	19	0	0	0	0	0	-	0	0
Red cod	1	370	137	508	-	47	101	148	-	21	65	86
Red gurnard	1	6	31	38	0	3	13	16	-	10	6	16
Rig§	7			7	7			7	-			-
School shark§	9			9	12			12	23	6	3	32
Sea perch	0	40	19	59	0	54	16	70	-	25	193	218
Silver warehou	1	433	173	607	-	307	280	587	1	152	208	361
Smooth oreo	1 459	3 397	7	4 863	1 825	2 831	34	4 690	2 223	2 699	0	4 922
Spiny dogfish	2	63	281	346	4	138	335	477	3	118	284	405
Squid	-	667	234	901	1	947	221	1 169	3	121	67	191
Stargazer	12	86	112	210	-	44	38	82	1	54	37	92
Tarakihi	1	160	127	288	1	119	12	132	1	149	24	174
Warehou (?)	-	8	1	9	1	1	1	2	-	4	11	15
White warehou	-	18	15	33	0	29	7	36	0	15	46	61
Others	42	249	89	380	41	193	119	353	0	137	179	316
Total	11 633	24 089	2 858	38 610	13 582	25 017	3 629	42 228	14 931	21 716	3 625	40 272

* Fishing year 1 October to 30 September.
† DOM, domestic (including small Chatham Islands and larger mainland vessels); FCD, New Zealand chartered; LIC, foreign licensed.
‡ Catch less than 0.5 t.
§ Some catches were not specified, but coded as other sharks and dogfish.

The largest Chatham Islands inshore domestic fisheries are still rock lobster (*Jasus edwardsii*) and paua (*Haliotis iris*). Trawling by Chatham Islands based vessels has always been minimal. Blue cod (*Parapercis colias*) is still the main finfish species landed locally, mainly from cod pots.

Chatham Islands trawl surveys

In December 1984 the first stratified random trawl survey of the Chatham Islands to include the 12 n. mile territorial sea was carried out by *Akebono Maru No. 73* (Hurst & Bagley 1987). This survey was aimed primarily at barracouta biomass estimation, but also provided valuable data on the distribution, abundance, and biology of this and other commercial species in the 50–400 m depth zone. Previous research surveys (by *Wesermünde* and *Shinkai Maru*) which provided estimates of fish abundance near the Chatham Islands (Francis 1981, Fenaughty & Uozumi 1989, Hatanaka *et al.* 1989a) were summarised by Hurst & Bagley (1987). Since then, results of another *Shinkai Maru* trawl survey on the Chatham Rise, in July 1986, have been published (Livingston *et al.* 1991).

This report presents the results of a second stratified random trawl survey of the Chatham Islands shelf by *Akebono Maru No. 73*, from 7 to 19 December 1985. The main aims of this survey were the same as those in December 1984: to estimate the abundance and map the distribution of barracouta and associated finfish species in the 50–400 m depth range, and to collect data on their size, spawning condition, and feeding. An additional major objective was to compare the 1985 results to those from 1984 to obtain an indication of annual variability between the two years. It was also intended to tag school shark (*Galeorhinus galeus*) and hapuku (*Polyprion oxygeneios*) to obtain data on movements and possible stock relationships.

The design of the survey was similar to that used in 1984, except that the increased knowledge of bathymetry and fish distribution gained during the 1984 research voyage enabled better stratification of the survey area, which we hoped would improve the precision of the biomass estimates for some species.

Methods

Survey area design

The planned survey area (16 144 km) included the 50–400 m depth range around the Chatham Islands and the 12 n. mile territorial sea (Figure 2). Increased knowledge of the bathymetry and depth distribution of fish from the 1984 survey enabled improvements to be made to the survey design: depth contours were revised, additional areas of untrawlable foul ground were omitted from the survey area, and strata used in the 1984 survey were further subdivided by the inclusion of east-west boundaries on the western side of the islands and the 300 m contour. These adjustments were made to increase the precision of the biomass estimate for barracouta, which was caught in depths up to 300 m in 1984. The relationship between strata from 1984 and this survey is given in Table 2.

The survey was designed as a two-phase stratified random trawl survey (*after* Francis 1984), with five phase 3 stations included in spare time on the last day. The survey area was subdivided into 13 strata by depth (50–100, 100–200, 200–300, and 300–400 m) and locality (Table 2, Figure 3). Stratum 13 (300–400 m) was abandoned during the survey due to the lack of trawlable bottom. Stations were randomly generated by computer, with a minimum of 3 n. miles (i.e., the towing distance) between them. The next substitute station on the computer list was chosen if no trawlable ground was located within 2 n. miles of the intended station position. A weighting of 2 : 1 was used to allocate stations to strata in the main areas of barracouta distribution in the 1984 survey (i.e., 100–300 m depth range, except the northern stratum 7) with a minimum of three stations per stratum.

In phases 2 and 3, computer generated stations were allocated to strata with the highest mean catch rates of barracouta, according to the mean-squared algorithm of Francis (1984). Stratum boundaries were redefined to omit additional areas of foul ground (strata 2, 3, 4, 5, and 13) and to correct bathymetry. Phases 2 and 3 are shown in Figure 4.

Vessel

Akebono Maru No. 73 is a Japanese stern trawler operated by Nichiro Sanford Fisheries (NZ) Limited based at Timaru. It has the following specifications: length overall, 107 m; beam, 15.5 m; tonnage, 2985 GRT; horsepower, 7200. Furuno NR200 net monitor thermometers were used to record bottom temperatures and were calibrated in a water bath at the beginning of the survey.

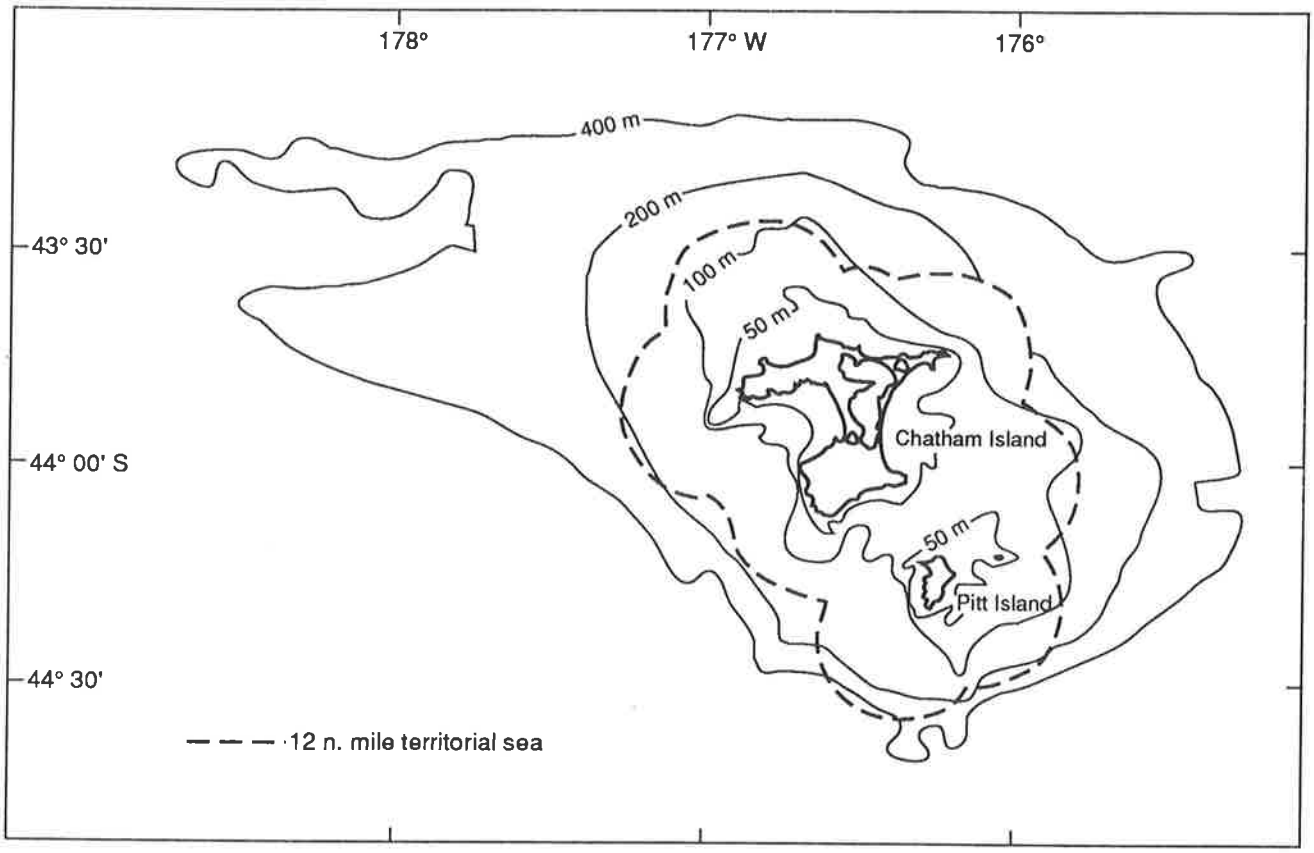

Figure 2: The Chatham Islands survey area, depth contours, and 12 n. mile territorial sea limit.

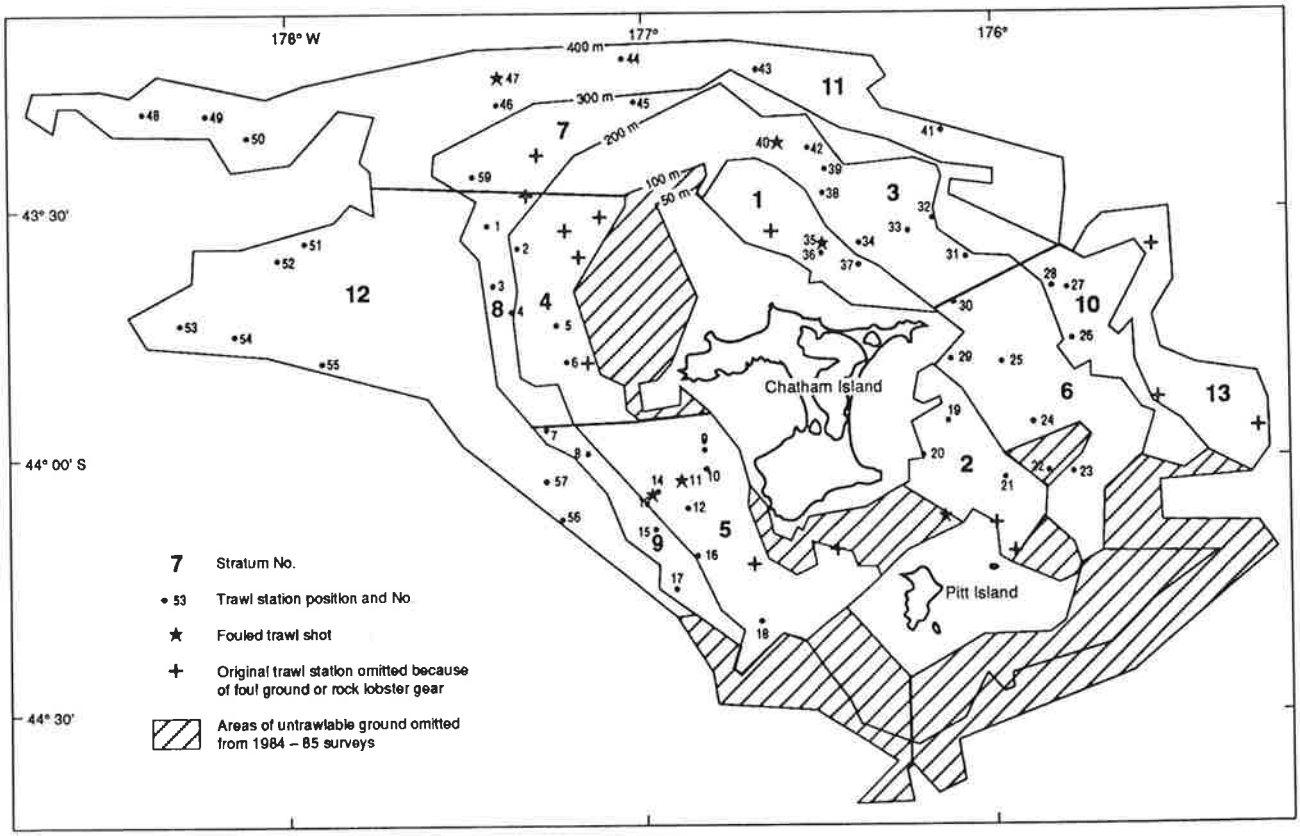

Figure 3: Phase 1 strata and survey stations.

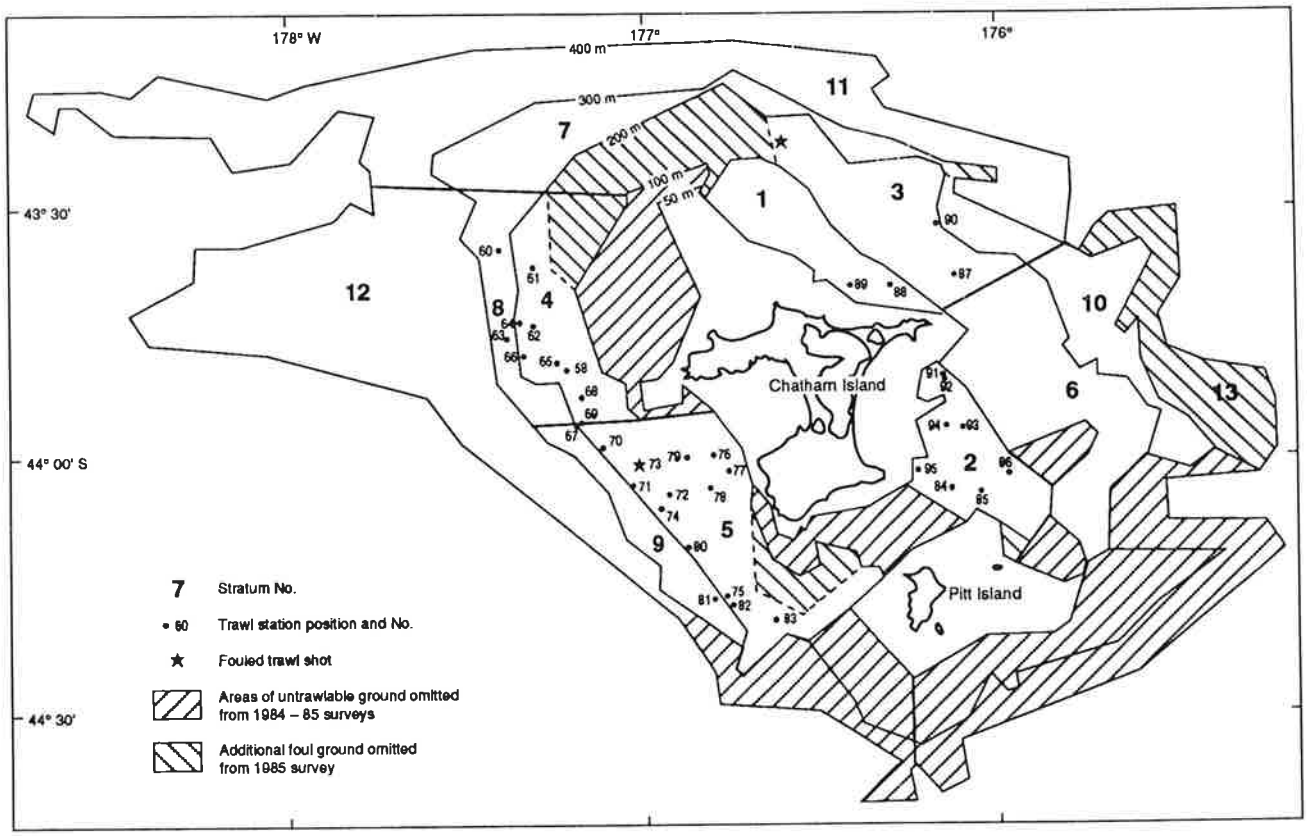

Figure 4: Phases 2 and 3 and "commercial" (No. 58, 67, 75, 90) stations.

Net features

A six-panel bottom trawl with 100 mm mesh codend was used, as during the 1984 survey. High aspect trawl doors (13.8 m) with 225 m of sweeping gear, including 60 m long bridles, were used. The heavy duty groundrope consisted of car tyres in the middle, rubber bobbins along each wing, and a steel danleno at each wingtip. The height of the groundrope was 0.65 m off the bottom, which may have allowed some species which occur hard down on the sea floor to escape towards the wingtips.

Wingspread and doorspread were calculated by measuring the distance between the trawl warps at the stern rollers and the warp angle (*after* Koyama 1974). Headline height was recorded from the net recorder. Wingspread, headline height, and warp to depth ratios are summarised by depth, and compared with 1984 mean values, in Table 3. Wingspread increased and headline height decreased with depth. Mean wingspread and headline height were similar for both years (i.e., within 5% of each other), but the mean doorspread in 1985 was 8% greater than in 1984 (i.e., 1985, 122 m; 1984, 112 m), which resulted in a mean doorspread to wingspread ratio which was 12% greater than in 1984 (i.e., 1985, 3.5 : 1; 1984, 3.09 : 1).

Trawling procedure

Trawling was carried out during daylight (0500–1900 h New Zealand Standard Time). All positions within 40 n. miles of the coastline were determined by radar and the more offshore stations were determined by satellite navigation. The trawl was shot within 2 n. miles of the station position and towed through it when possible. A tow distance of 3 n. miles was aimed for, and each tow was timed from when the gear reached the bottom to the start of hauling. Tow length averaged 2.9 n. miles (range 2.0 to 3.2) and 41 min (range 29 to 52). The towing speed averaged 4.3 kn (range 3.5 to 4.7) compared with 3.9 kn (range 2.9 to 5.0) in the 1984 survey; some of the variability was due to differences in tidal currents.

The suitability of 3 n. mile tow duration for barracouta was discussed by Hurst & Bagley (1987). As in the 1984 survey, four longer "commercial" tows targeted at barracouta were undertaken to compare catch rates with random research tows. These tows ranged from 9.9 to 13.5 n. miles (2.5–3.0 h duration) and were completed on the western side of the survey area in 124–213 m (*see* Figure 4) in late afternoon.

Catch size estimation

All catches were examined in the fish hold area. The total catch weight and composition were initially calculated by estimating the volume of the catch. Barracouta from successive tows were processed separately, and the actual catch weight was backcalculated from product weight; the conversion factor of $GW = 1.5PW$, where GW is green weight and PW is product weight, was found to be satisfactory in the 1984 survey and was used again in 1985. For some of the larger catches (especially those which included

Table 2: Stratum areas and number of biomass assessment stations

		Phase 1			Phases 2 and 3			Total	
	Depth	Area	No. of stations		Redefined	No. of stations		No. of	Station density
Stratum*	(m)	(km^2)	Planned	Actual	area (km^2) †	Phase 2	Phase 3	stations	(per km^2)
1	50–100	658	3	2	658	2	0	4	1 : 165
2	50–100	669	3	3	630	3	5	11	1 : 57
3	100–200	1 593	7	6	1 081	1	0	7	1 : 154
4	100–200	892	4	4	653	7	0	11	1 : 59
5	100–200	1 369	6	6	1 131	11	0	17	1 : 67
6	100–200	1 358	6	6	1 358	0	0	6	1 : 226
7	200–300	1 119	3	3	1 078	0	0	3	1 : 359
8	200–300	459	3	3	459	2	0	5	1 : 92
9	200–300	436	3	3	436	1	0	4	1 : 109
10	200–300	576	3	3	576	0	0	3	1 : 192
11	300–400	3 153	7	7	3 193	0	0	7	1 : 456
12	300–400	3 050	7	7	3 050	0	0	7	1 : 436
13 ‡	300–400	812	3	0	0	0	0	0	
		16 144	58	53	14 303	27	5	85	1 : 168

* 1984 equivalents: 1–3, same; 4 = 4 + 5; 5 = 6; 6 = 7 + 11; 7 = 8 + 9; 8 = 10 + 13.
† Redefined to exclude areas of foul ground and to correct bathymetry.
‡ Stratum 13 abandoned due to foul untrawlable bottom.

Table 3: Wingspread*, headline height, and warp to depth ratios by depth for 1985, and total values for 1984 and 1985

Depth range	No. of	Wingspread (m)		Doorspread	Headline height (m)		Warp : depth
(m)	stations	Mean	s.d.†	mean (m)	Mean	s.d.†	mean
50–100	15	30.9	3.08	108	7.7	0.79	3.3 : 1
100–200	41	33.6	3.25	118	6.8	0.64	2.9 : 1
200–300	14	35.6	2.21	125	6.6	0.92	2.7 : 1
300–400	15	40.5	3.18	142	6.4	0.48	2.5 : 1
1985 total	85	34.7	4.35	122	6.9	0.81	2.9 : 1
1984 total	84	36.2	4.39	112	6.6	0.74	2.8 : 1

* Wingspread values for individual tows are given in Appendix 2.
† Standard deviation.

barracouta juveniles which were not processed) a check was made by recording the number of barracouta and the number and estimated weight of bycatch species as they passed along a conveyer. Total weights of some bycatch species which were regularly measured (e.g., tarakihi, arrow squid (*Nototodarus sloanii*), and silver warehou) were also estimated from fish box weights. Individual hapuku and school shark were weighed from each tow as they were tagged.

Biomass estimation

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

$$B = \Sigma\,(X_i a_i)/cb$$

$$S_B = \Sigma\,\sqrt{S_i^2 a_i^2}/cb$$

where B is biomass (t), S_B is standard error of B, X_i is mean catch rate (kg.km^{-2}) of stratum i, a_i is area of stratum i (km^2), b is net mouth opening, c is catchability coefficient, S_i is estimated standard error of X_i.

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

$$CL = B \pm 2S_B$$

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

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

The following assumptions were made, as in the 1984 survey report:

1. The effective sea bed area swept was the distance between the wings of the net mutiplied by the distance towed. It has been standard practice to use this measurement in the presentation of New Zealand trawl survey results (e.g., Hurst & Fenaughty 1985), and its use here provides some comparability; however, it makes no allowance for the possible herding effects of the doors and sweeps. The ratio of doorspread to wingspread (3.5 : 1) allows alternative assumptions to be used.
2. The catchability coefficient for wingspread biomass estimates was assumed to be 1.0, which implies three further assumptions:
   i. that the vulnerability of all fish in the path of the wingspread was 1.0;
   ii. that the vertical availability was 1.0, i.e., there were no fish above the headline or under the groundrope (on this survey some marks were observed to pass over the headline of the net (on the net recorder), but this could not be quantified or related to a particular species);
   iii. that the areal availability was 1.0 (i.e., there were no fish in areas of untrawlable ground).

Biomass estimates were made by use of the stratum areas redefined in Table 2. All statistical comparisons of mean catch rates and biomass estimates were made with the use of t-tests.

Biological observations

A maximum of 200 barracouta was taken from each tow, measured to the nearest centimetre below actual fork length, and sexed. Twenty of these fish were randomly selected for biological measurements, which included fork length (measured as above), whole weight (± 50 g), sex, gonad stage (six stages: 1, juvenile; 2, first maturation or resting; 3, maturing; 4, mature; 5, running ripe; 6, spent), gonad weight (± 1 g), stomach fullness, and stomach contents and degree of digestion.

Barracouta otoliths were collected from five fish of each sex and each centimetre length to construct an age-length key. Flesh parasite counts were made on barracouta 75 cm or longer, on the left fillet only, to enable comparisons with samples collected elsewhere in New Zealand as part of a study on stock identification (these data are not presented in this report).

Length and sex data and general observations on the spawning condition and stomach contents were also collected on other commercially important species. Additional detailed biological data were collected from silver warehou (gonad stages as for barracouta, except: 6, partially spent; 7, spent), school shark, and hapuku. Hapuku were weighed and measured, and school shark were weighed, measured, and sexed before being tagged with yellow lock-on, dart, or tie-on spaghetti tags. Tagging of hapuku was discontinued after 104 fish were tagged because most fish floated to the surface and were prone to bird attacks.

Results

Survey area

The planned survey area was reduced from 16 144 to 14 303 km² because of unsurveyable ground and incorrect bathymetry (*see* Table 2, Figures 3 and 4). A total of 95 trawl stations was completed: 85 were successful biomass stations, 6 were fouled, and 4 were "commercial" tows targeted on barracouta (No. 58, 67, 75, and 90). The overall biomass station density was 1 : 168 km (range per stratum 1 : 57 to 1 : 456 km²).

Catch composition

Sixty-four species were recorded from 95 stations: 43 teleosts, 12 elasmobranchs, 2 squid, 6 crustaceans, and 1 agnathan (Appendix 1). The catch and biomass composition of the 20 major species taken at biomass assessment stations is given in Table 4. Of the 153.2 t caught at these stations barracouta constituted 42.7%, hoki 11.2%, silver warehou 7.5%, and spiny dogfish 7.1%.

Catch rates

General

Individual station data and catches of the 10 major species are given in Appendix 2. Species distribution and catch rate data are given by station for the 10 major species in Figures 5-12, excluding common roughy (*Paratrachichthys trailli*), which only occurred in four trawls, and silver dory (*Cyttus novaezelandiae*), most of which was caught in one tow. Mean catch rates by stratum and depth are given in Table 5. Mean catch rates by phase and time of day were not significantly different and are not given here.

Catch rates are expressed as kilograms or tonnes per square kilometre, the unit of measurement used to calculate biomass indices. The mean catch rate for all species at biomass stations during the survey was 9.5 t.km^{-2}, (range 0.5 to 37.2 t.km^{-2}, or about 0.03 to 2.80 t per n. mile towed).

In general, the western side of the Chatham Islands had mean stratum catch rates greater than 1 t.km^{-2} for barracouta (strata 4, 5, 8, and 9), hoki (9 and 12), silver warehou (9 and 12), common roughy (9), spiny dogfish (5), and hapuku (8). The highest catch rates per stratum for the survey also came from this area for 5 of the 10 species: silver warehou, common roughy, spiny dogfish, hapuku, and jack mackerels.

To the east (strata 2, 6, and 10), catch rates were generally lower, though the highest catch rates per stratum of barracouta and tarakihi for the survey (14.3 and 1.9 t.km^{-2} respectively) occurred in stratum 2. Spiny dogfish was the only other species to exceed 1 t.km^{-2} on the eastern side.

The northern strata (1, 3, 7, and 11) had mean catch rates per stratum greater than 1 t.km^{-2} of school shark (stratum 1), barracouta (1, 3), tarakihi (3), hoki and common roughy (11). For school shark, hoki, and silver dory the highest mean catch rates for the survey came from these northern strata.

The highest mean catch rates by depth range of barracouta, tarakihi, and school shark came from shallow water (50-100 m); spiny dogfish, hapuku, and jack mackerels from mid depths (100-300 m); and hoki, silver warehou, common roughy, and silver dory from water deeper than 300 m.

Table 4: Major species composition at the biomass assessment stations

	Catch			Biomass				
Species code*	Catch (kg)	% of total (all species)	Mean catch rate (kg.km^{-2})	Lower bound (t)	Biomass (t)	Upper bound (t)	Coefficient of variation (%)	% of total (all species)
BAR	65 410	42.7	4 257	22 741	28 067	33 393	9	26.4
HOK	17 089	11.2	944	0	22 766	48 493	57	21.4
SWA	11 527	7.5	648	5 278	10 370	15 462	25	14.6
SPD	10 871	7.1	737	2 900	4 925	6 950	21	6.5
TAR	10 091	6.6	651	3 529	5 237	6 945	16	6.5
HAP	7 588	5.0	460	468	4 003	7 538	44	3.8
RHY	5 481	3.6	268	0	7 188	18 604	79	6.8
JMA	5 247	3.4	312	1 468	2 509	3 551	21	2.4
SCH	3 793	2.5	253	1 794	2 899	4 003	19	2.7
STA	2 577	1.7	161	1 584	2 198	2 813	14	2.1
ASQ	1 933	1.3	120	934	1 285	1 635	14	1.2
RCO	1 722	1.1	103	0	768	1 604	54	0.7
LIN	1 686	1.1	100	1 616	2 059	2 502	11	1.9
SDO	1 284	0.8	68	0	2 411	5 583	66	2.3
HAK	1 073	0.7	52	0	1 989	5 098	78	1.9
BYX	926	0.6	47	344	1 774	3 204	40	1.7
GSH	851	0.6	46	920	1 501	2 083	19	1.4
LDO	568	0.4	30	727	1 075	1 424	16	1.0
OPE	559	0.4	30	0	463	1 028	61	0.4
BNS	535	0.3	29	0	400	802	50	0.4
All species	153 160		9 455	76 268	106 169	136 070	14	

* Species codes are given in Appendix 1.

Individual species

Barracouta was the most abundant species distributed throughout the survey area in depths which ranged from 50 to 300 m (Figure 5). Catches were highest in 100–200 m on the western side of the Chatham Islands compared with 50–100 m on the eastern side. The highest barracouta mean catch rate by stratum (14.3 t.km^{-2}) came from stratum 2, but mean catch rates were also consistently high (over 4 t.km^{-2}) in strata 1, 4, 5, and 8. The overall mean catch rate of barracouta during the biomass survey was 4.3 t.km^{-2} (range 0.0 to 32.7). Catch rates on the four longer targeted "commercial" tows were within the range observed on research tows (*see* Appendix 2).

Hoki catch rates by stratum were highest (about 5 t.km^{-2}) in depths over 200 m (strata 9 and 11) southwest and north of the Chatham Islands (Figure 6). The overall mean catch rate during the survey was 0.9 t.km^{-2} (range 0.0 to 29.3).

Silver warehou catch rates ranged from 0.0 to 15.8 t.km^{-2} and were highest on the western side of the Chatham Islands, in strata 9 and 12 (Figure 7). The highest mean catch rate by stratum was 5.1 t.km^{-2} (stratum 9) and by depth was 8.1 t.km^{-2} (300–400 m).

Tarakihi catch rates ranged from 0.0 to 15.8 t.km^{-2} and were highest on the eastern side of the islands (Figure 8), in less than 100 m. The highest mean catch rates per stratum (over 1 t.km^{-2}) were from strata 2 and 3.

Spiny dogfish were more abundant west of the Chatham Islands, in 100–200 m (Figure 9). Catch rates ranged from 0.0 to 9.8 t.km^{-2} and were highest in stratum 5 (mean 2.5 t.km^{-2}) and stratum 2 (mean 1.2 t.km^{-2}). Spiny dogfish were taken in low numbers in deeper water, but were absent from more northern stations.

Hapuku were taken on most stations in 50–300 m (Figure 10) with an unusually high catch rate (19 t.km^{-2}) recorded from 263 m of water on uneven ground northwest of the Chathams Islands. With the exception of this tow, catch rates were generally highest to the east in less than 100 m (strata 2 and 6).

School shark catch rates were also highest east of the Chatham Islands in waters less than 100 m (Figure 11), but the mean stratum catch rate only exceeded 1 t.km^{-2} in stratum 1.

Jack mackerel catches were highest west of the Chatham Islands in 100–200 m, and in stratum 5 (mean 0.9 t.km^{-2}) (Figure 12).

Table 5: Mean catch rates (kg.km^{-2}) of the 10 major species* by stratum and depth

Stratum	BAR	HOK	SWA	RHY	TAR	SPD	HAP	SCH	JMA	SDO
1	4 634	0	55	0	692	98	340	1 487	288	0
2	14 265	0	3	0	1 867	1 210	830	571	112	0
3	2 003	0	75	0	1 092	23	222	657	244	0
4	4 392	311	643	0	311	3	141	63	242	0
5	4 940	865	539	0	870	2 476	115	78	930	3
6	919	0	17	0	542	597	499	112	23	0
7	319	0	455	0	135	0	98	193	6	231
8	4 182	17	398	0	32	3	3 839	95	75	72
9	2 810	4 712	5 052	2 317	392	620	104	17	611	6
10	20	0	98	0	228	110	124	112	0	0
11	58	5 029	677	1 937	12	9	35	69	61	651
12	159	1 138	1 346	0	0	35	9	9	81	12
Depth (m)										
50–100	11 183	0	16	0	1 466	801	648	821	154	0
100–200	3 900	442	429	0	766	1 159	218	177	524	2
200–300	2 139	1 069	528	0	128	192	1 425	99	124	76
300–400	283	3 142	1 995	1 653	0	29	35	36	68	310

* Species codes are given in Appendix 1.

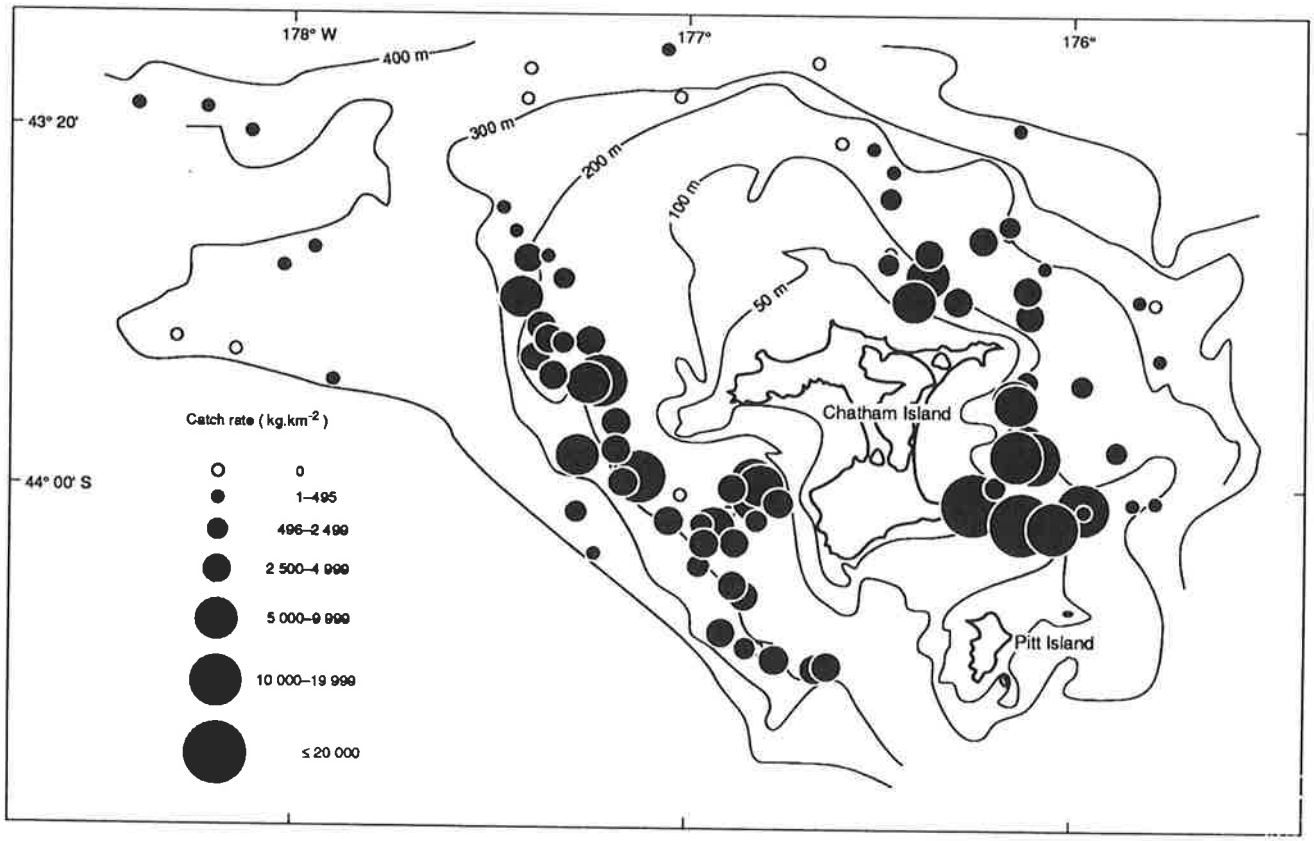

Figure 5: Catch rates of barracouta.

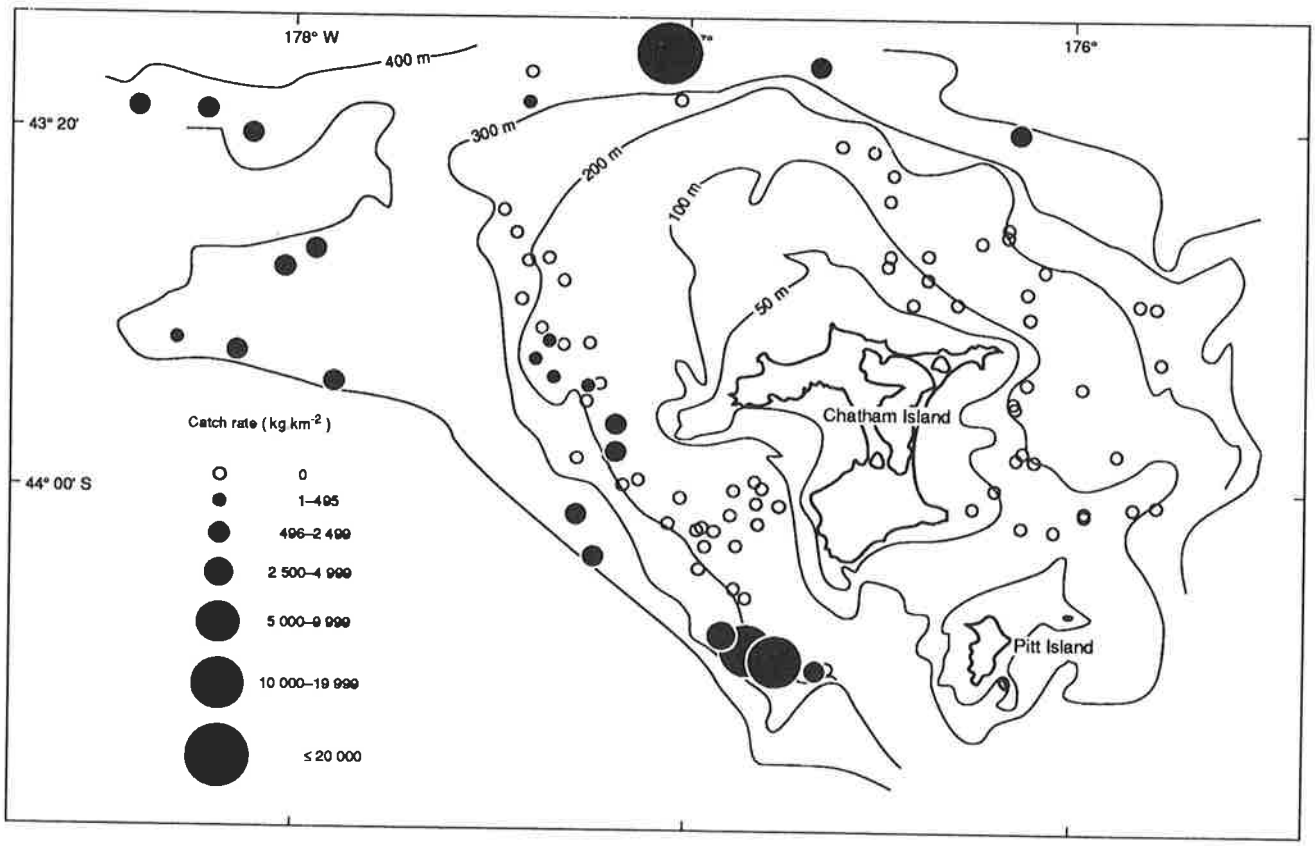

Figure 6: Catch rates of hoki.

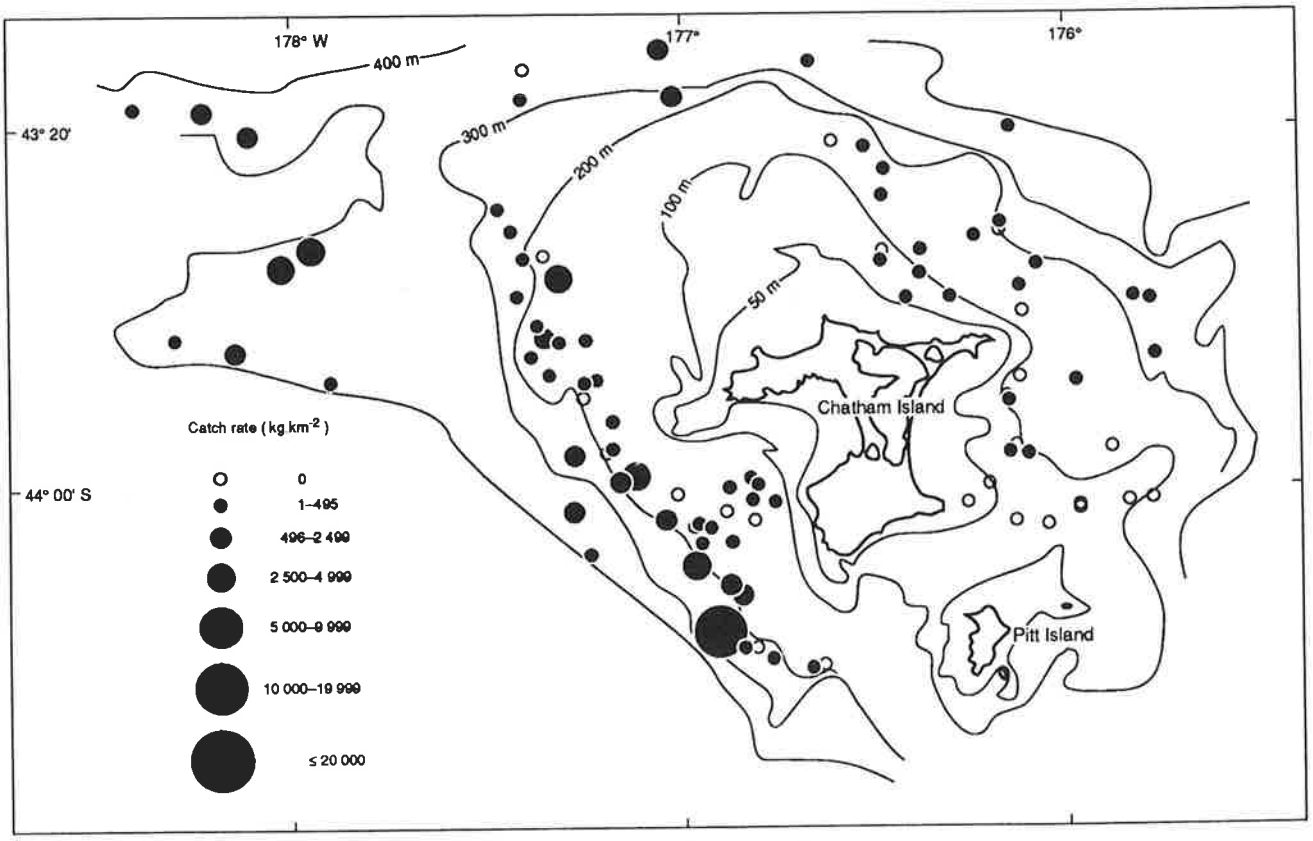

Figure 7: Catch rates of silver warehou.

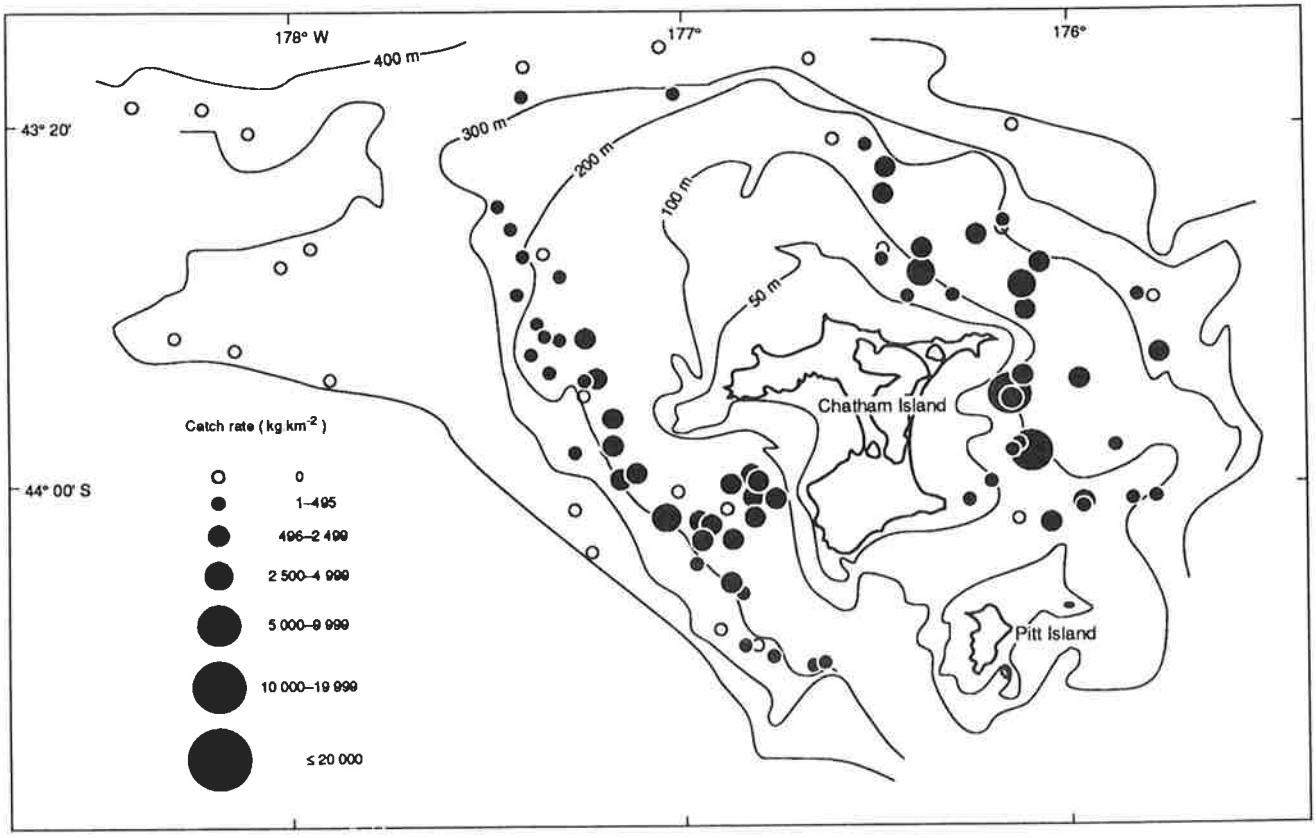

Figure 8: Catch rates of tarakihi.

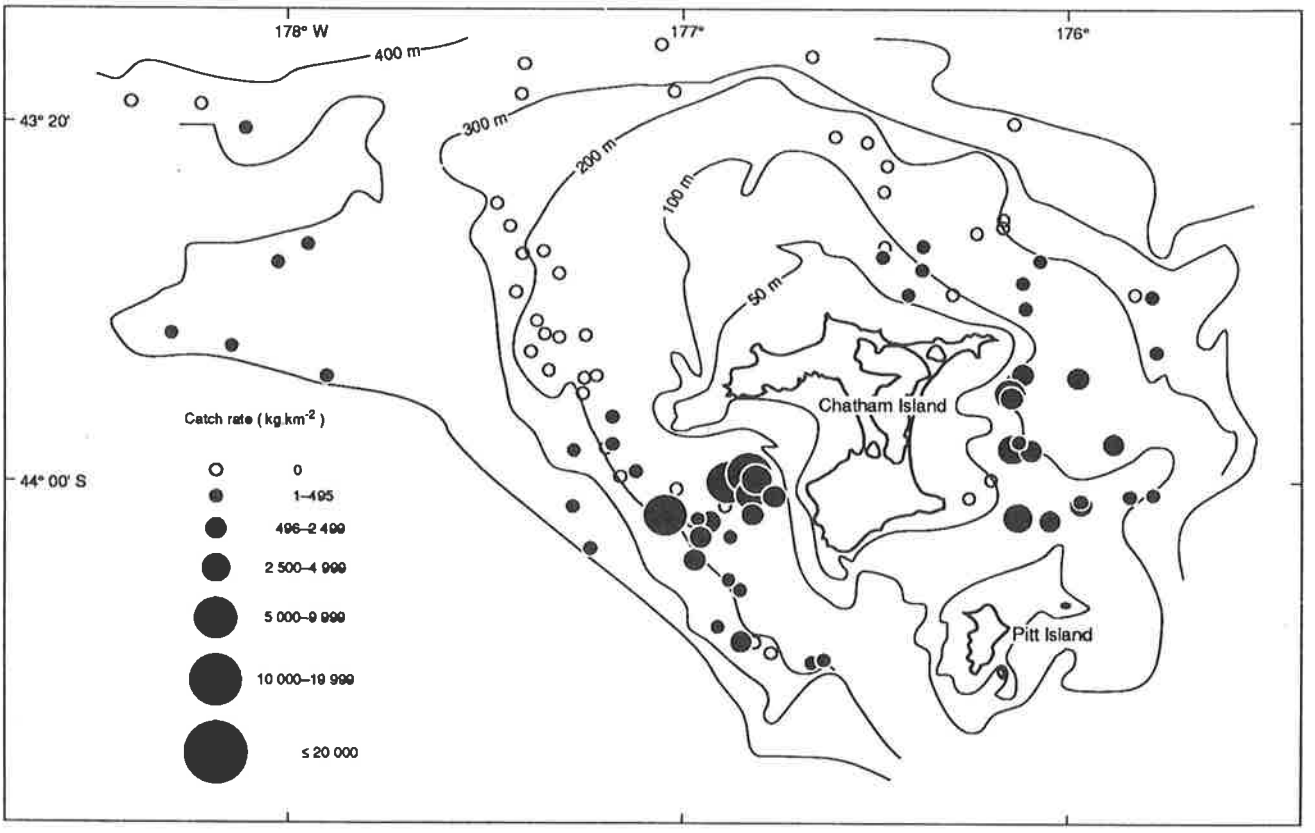

Figure 9: Catch rates of spiny dogfish.

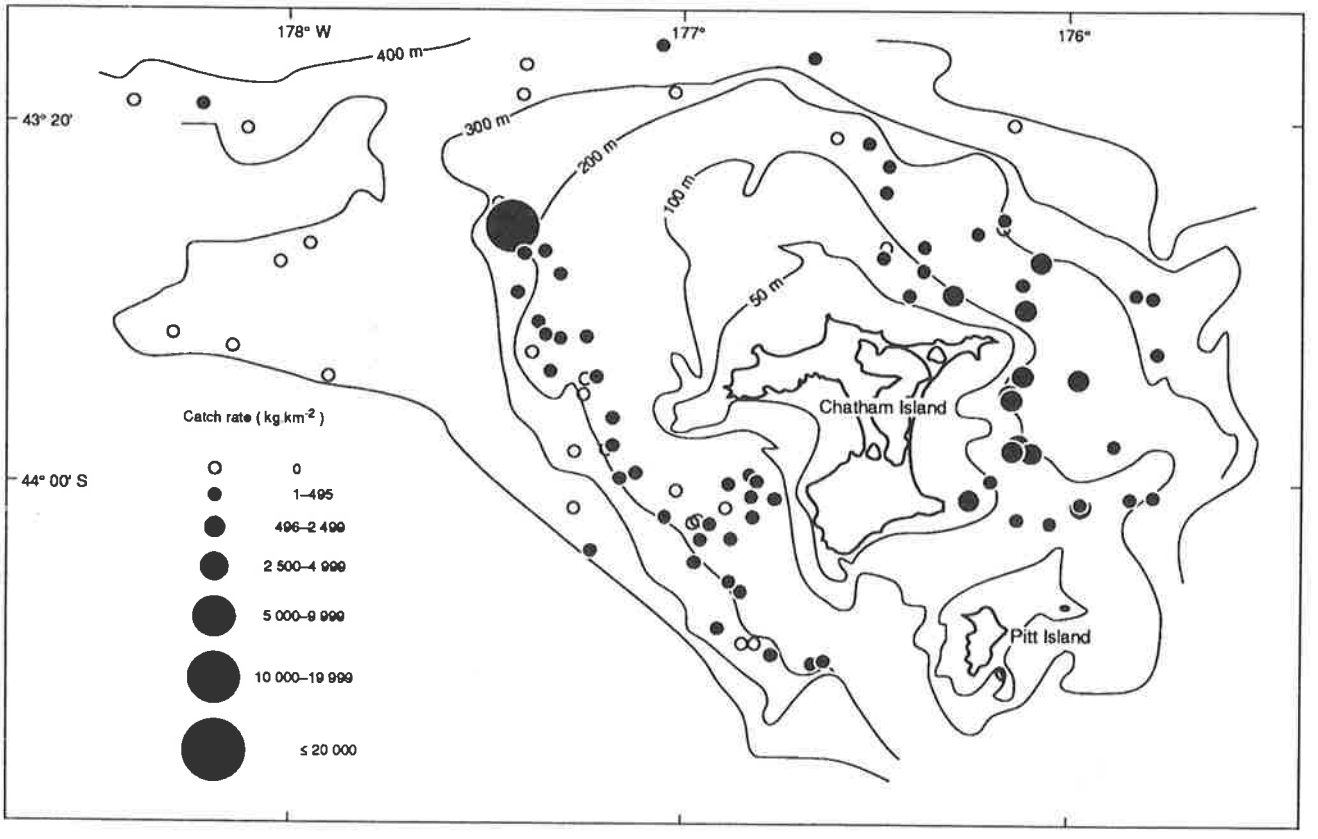

Figure 10: Catch rates of hapuku.

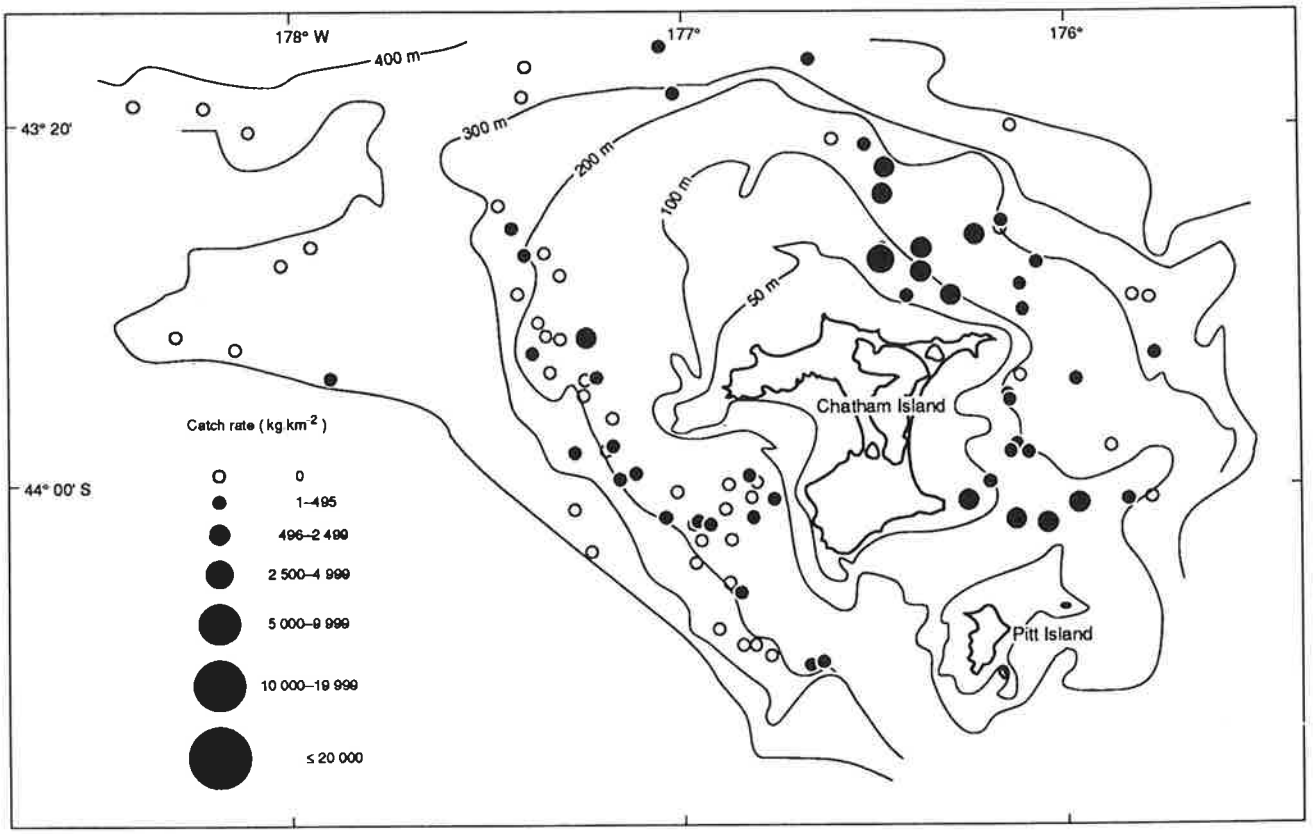

Figure 11: Catch rates of school shark.

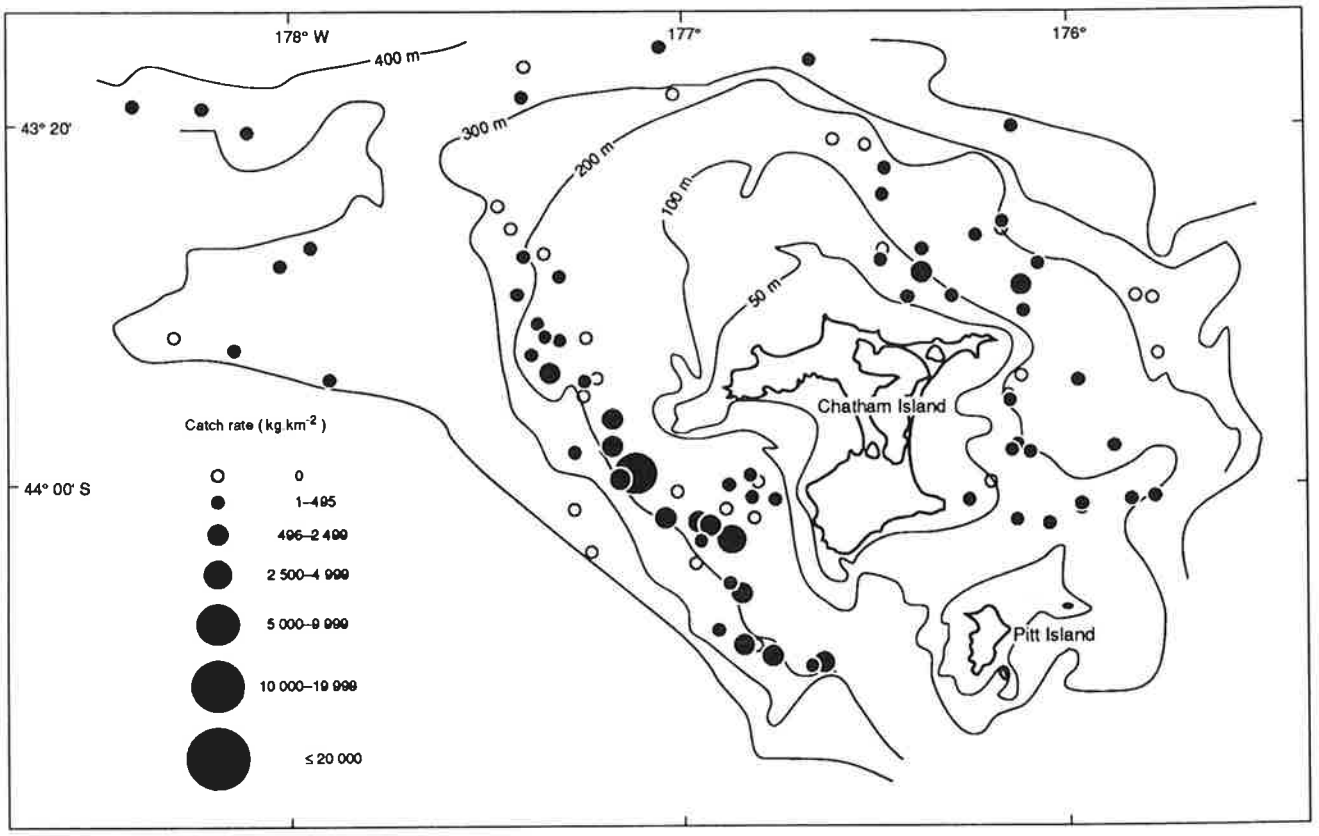

Figure 12: Catch rates of jack mackerels.

Biomass estimates

Total biomass estimates for the 20 major species for all three phases of the survey combined are given in Table 4. For the 10 major species, biomass estimates by stratum and the percent of individual species biomass by stratum are given in Tables 6 and 7. The biomass estimate and coefficient of variation (*c.v.*) by phase for each of the 10 major species are given in Table 8.

Most species remained at a similar level when ranked by catch weight and then by biomass estimate, except for common roughy and silver dory, which moved up at least three places, and arrow squid and red cod which moved down at least five places (*see* Table 4). The *c.v.*s ranged from 9% for barracouta to 79% for common roughy. Of the 20 major species, four had *c.v.*s less than 15% (barracouta, stargazer, squid, and ling) and 11 had *c.v.*s less than 30%.

Thirty-one percent of the total biomass came from the largest stratum (stratum 11, 22% of the survey area) (*see* Tables 2 and 7). Four of the ten major species had more than 50% of their biomass in a single stratum: common roughy, silver dory, and hoki in stratum 11 and spiny dogfish in stratum 5. Most other major species had more than 30% of their biomass in a single stratum (barracouta in 2, silver warehou in 12, hapuku in 8, school shark in 1, and jack mackerels in 5).

The 300–400 m depth range had the highest percentage of the total biomass (44% of the biomass and of the survey area), and the 200–300 m depth range the lowest percentage (15% of the biomass and 18% of the area) (*see* Tables 2 and 7). The 50–100 m depth range, which had the least area (9%), had 17% of the biomass. More than 40% of the biomass of school shark and barracouta came from 50–100 m; barracouta, jack mackerels, spiny dogfish, and tarakihi from 100–200 m; hapuku from 200–300 m; and hoki, common roughy, silver dory, and silver warehou from 300–400 m.

Phase 2 and 3 stations were allocated to strata with the highest mean catch rates of barracouta and resulted in a 43% decrease in *c.v.* for this species (i.e., from 16 to 9%) (Table 8). Other species which also had large decreases after phases 2 and 3 were spiny dogfish (50%) and jack

Table 6: Biomass (t) and coefficients of variation* (%) of the 10 major species† by stratum

Stratum	BAR	HOK	SWA	RHY	TAR	SPD	HAP	SCH	JMA	SDO	All species
1	3 407	0	36	0	455	64	224	978	190	0	5 576
	(20)		(32)		(78)	(34)	(32)	(36)	(46)		(13)
2	8 984	0	2	0	1 175	762	523	359	71	0	12 240
	(22)		(90)		(51)	(28)	(17)	(21)	(36)		(18)
3	2 164	0	81	0	1 181	26	239	710	263	1	5 466
	(35)		(32)		(29)	(71)	(32)	(47)	(36)	(0)	(22)
4	2 867	204	419	0	203	2	92	42	159	0	4 352
	(24)	(61)	(48)		(32)	(15)	(23)	(71)	(37)		(17)
5	5 586	977	609	0	893	2 798	132	87	1 052	4	12 875
	(16)	(96)	(45)		(17)	(33)	(13)	(24)	(42)	(49)	(14)
6	1 250	0	27	0	736	810	678	151	33	0	4 246
	(45)		(95)		(35)	(34)	(35)	(59)	(46)		(22)
7	344	0	492	0	146	0	104	207	8	250	1 897
	(58)		(73)		(52)		(98)	(68)	(115)	(100)	(3)
8	1 919	7	183	0	14	1	1 761	44	34	34	4 639
	(30)	(97)	(60)		(53)	(89)	(99)	(41)	(55)	(41)	(31)
9	1 224	2 054	2 202	1 010	171	270	45	8	266	3	7 920
	(18)	(75)	(72)	(100)	(60)	(67)	(49)	(108)	(56)	(125)	(39)
10	11	0	56	0	132	63	71	65	0	0	773
	(49)		(17)		(70)	(90)	(54)	(101)			(48)
11	187	16 056	2 162	6 178	41	24	108	225	190	2 081	32 883
	(62)	(81)	(28)	(91)	(113)	(88)	(50)	(72)	(40)	(75)	(43)
12	483	3 468	4 105	0	0	103	26	22	243	38	13 302
	(78)	(21)	(45)			(28)	(100)	(88)	(62)	(57)	(18)

* Coefficients of variation are in parentheses.
† Species codes are given in Appendix 1.

Table 7: Percent of individual species biomass by stratum for the 10 major species*

Stratum	BAR	HOK	SWA	RHY	TAR	SPD	HAP	SCH	JMA	SDO	All species
1	11	0	1	0	9	1	6	34	8	0	5
2	32	0	0	0	23	16	13	12	3	0	12
3	8	0	1	0	23	1	6	25	11	–†	5
4	10	1	4	0	4	0	2	1	6	0	4
5	20	4	6	0	19	57	3	3	42	-	12
6	5	0	1	0	14	16	17	5	1	0	4
7	1	0	5	0	3	0	3	7	1	10	2
8	7	0	2	0	1	0	44	2	1	1	4
9	4	9	21	14	3	6	1	1	11	-	8
10	0	0	1	0	3	1	2	2	0	0	1
11	1	71	21	86	1	1	3	8	8	86	31
12	2	15	40	0	0	2	1	1	10	2	13

* Species codes are given in Appendix 1.
† Less than 0.5%.

Table 8: Biomass and coefficient of variation (*c.v.*) by phase for each of the 10 major species*

	Phase 1		Phases 1 + 2		Phases 1 + 2 + 3	
	Biomass (10^3 t)	*c.v.* (%)	Biomass (10^3 t)	*c.v.* (%)	Biomass (10^3 t)	*c.v.* (%)
BAR	22.0	16	27.6	13	28.1	9
HOK	20.2	64	22.8	57	22.8	57
SWA	10.4	27	10.4	25	10.4	25
RHY	7.5	77	7.1	79	7.2	79
TAR	4.0	22	4.3	15	5.2	16
SPD	4.3	42	4.6	22	4.9	21
HAP	5.1	58	3.8	46	4.0	44
SCH	3.4	20	2.9	19	2.9	19
JMA	2.5	35	2.5	21	2.5	21
SDO	2.4	66	2.4	66	2.4	66

* Species codes are given in Appendix 1.

mackerel (40%), both mainly as a result of phase 2 of the survey. Only one species (common roughy) showed an increase (from 77 to 79%). Of the 10 major species biomass estimates, barracouta and tarakihi estimates increased most (by 28 and 30%) and hapuku decreased most (by 22%) during the three phases of the survey, but none of the changes were statistically significant.

Biology

Length frequency histograms for the major commercial species are presented in Figures 13-21. These data have been scaled by the percentage of fish sampled per tow, the area swept by the wingtips, and stratum area. A weighting factor was assigned if fish were not sampled on all stations. The resulting histograms represent an estimate of the length structure of the Chatham Islands "populations", as sampled by bottom trawl gear. Numbers of fish given represent the estimated population size; actual numbers of fish measured and sexed are given in Table 9. Length frequencies are also given by depth range for some species. All other biological data are unscaled.

Table 9: Actual numbers of fish for which length, sex, and detailed biological data were collected

	Length frequency data*				Biological data	
Species code†	No. of samples	No. of fish	No. of males	No. of females	No. of samples	No. of fish
ASQ	83	3 950	2 072	1 565	-‡	-
BAR	79	12 149	6 307	5 659	73	1 363
BCO	2	6	5	1	-	-
BNS	5	74	45	28	-	-
BYX	11	905	-	-	-	-
HAK	10	240	193	47	-	-
HAP	69	780	369	305	1	20
HOK	21	3 467	1 561	1 906	-	-
JMA§	64	1 473	995	475	-	-
RBM	1	2	1	1	-	-
RCO	4	224	33	74	-	-
RUD	1	2	1	1	-	-
SCH	50	265	248	14	45	252
SKI	2	4	3	1	-	-
SWA	68	6 730	1 474	1 078	34	572
TAR	67	3 813	1 368	2 410	-	-
TRU	2	4	1	3	-	-
WWA	16	328	155	156	-	-

* Length frequencies for BCO, RBM, RUD, SKI, and TRU are not presented in this report. BYX were not sexed.
† Species codes are given in Appendix 1.
‡ No data.
§ JMA may be either *Trachurus declivis* or *T. murphyi*.

Barracouta

Length and weight. Barracouta lengths ranged from 19 to 103 cm fork length with modal peaks for both sexes at 23, 47-48, and 64 cm, and 69 (males only) and 73 cm (females only) (Figure 13). The dominance of the various modal groups changed with depth: fish of 43-53 cm dominated in 50-100 m; fish of 60-80 cm dominated in all depths between 100-400 m. The smallest modal group (19-34 cm) were found only in the shallowest strata (50-100 m). Males were dominant in all depths, increasing from a ratio of 1.1 : 1 in 50-300 m to 2.1 : 1 in 300-400 m.

Length-weight relationships were calculated from 1363 barracouta, by sex (Table 10). (The weight for a given length in 1985 is 15-17% less than found in 1984, depending on sex, because of the higher percentage of spent and resting or recovering fish and the lower gonad weights, particularly for stage 3 females and stage 5 males, recorded in 1985; *see* Hurst & Bagley 1987, Table 11).

Feeding. Observations were made on contents, fullness, and state of digestion for 1361 barracouta stomachs (Tables 11-13). Most stomachs were partly full (58%) or empty (37%), and there were no clear differences in stomach fullness or digestion state by time of day. Stomachs with food in them contained euphausiids (81%), fish (15%, species included were small barracouta, hoki, redbait (*Emmelichthys nitidus*), scaly gurnard (*Lepidotrigla brachyoptera*), red cod, saury (*Scomberesox saurus*), silverside (*Argentina elongata*), and silver warehou), and small arrow squid (3%). Euphausiids were the most common food item in all but the two deepest strata (over 300 m depth), where fish predominated. This pattern is similar to that observed in 1984.

Reproductive state. Most (87%) of the 1349 barracouta staged had maturing, ripe, or running ripe gonads (stages 3-5) (Table 14). The maximum gonadosomatic index (GSI) reached 17.1% of the mean body weight for mature (stage 4) female barracouta. Mature and running ripe (stages 4 and 5) male GSIs both exceeded 9%. The smallest recorded stage 3 fish were a 44 cm male and a 48 cm female.

Hoki

Hoki total lengths ranged from 39 to 95 cm. The smallest modal group, 40-48 cm (with a peak of 44 cm for males and females) was found in 300-400 m, but was absent in shallower water (Figure 14). Modal peaks of larger fish become obscured, but appear to be at 58 and 65 cm for males and 54, 60, 65, and 69 cm for females. Sex ratios were the same for both depth ranges with slightly more males than females overall (1.1 : 1). Adult hoki gonads were stage 2 (resting condition).

Table 10: Length-weight relationship for barracouta

	Length (cm)				Weight (g)				
	No.	Mean	s.d.*	Range	Mean	s.d.*	Range	Equation†	Regression coefficient (r)
Males	611	67.0	8.1	44-86	1 548	469	437-2 940	$W = 0.0156L^{2.73}$	0.95
Females	752	70.7	8.9	44-103	169	569	440-5 500	$W = 0.0166L^{2.70}$	0.97
All fish	1 363	68.7	9.4	26-103	1 613	546	105-5 500	$W = 0.0153L^{2.73}$	0.97

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

Table 11: Barracouta stomach fullness by time of day

Time (h)	No. of stomachs	Empty (%)	Part full (%)	Full (%)
0500-0830	487	33	61	6
0830-1200	410	38	58	4
1200-1530	344	46	49	6
1530-1900	120	23	73	3
	1 361	37	58	5

Table 12: Digestion state of food items in barracouta stomachs by time of day

Time (h)	No. of food items	Fresh (%)	Part digested (%)	Digested (%)
0500-0830	428	24	50	26
0830-1200	320	17	52	31
1200-1530	252	21	50	29
1530-1900	127	14	57	29
	1 127	20	51	29

Table 13: Occurrence of barracouta food items by stratum

Stratum	No. of food items	Euphausiids (%)	Squid (%)	Fish (%)	Other (%)
1	65	69	11	20	0
2	166	87	7	5	1
3	97	89	1	9	1
4	107	86	1	10	3
5	229	92	1	6	1
6	101	84	3	12	1
7	31	52	3	45	0
8	31	48	6	32	13
9	30	77	3	20	0
10	11	82	0	18	0
11	32	0	0	100	0
12	1	0	0	100	0
	901	81	3	15	2

Table 14: Reproductive state of barracouta

				Gonadosomatic index*			
				Males		Females	
Stage	No.	Males	Females	No.	Mean GSI	No.	Mean GSI
1	27	12	15	-†	-	-	-
2	90	12	78	10	0.6	73	1.1
3	607	12	594	13	6.8	501	5.3
4	164	145	19	143	10.0	19	17.1
5	404	401	3	354	9.1‡	3	4.5‡
6	57	25	32	25	1.8	32	2.1
	1 349	608	741	545		628	

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

† No data.

‡ GSIs of running ripe fish are probably low because of loss of gonad contents during catching and handling.

Silver warehou

Length and weight. Small silver warehou (25-30 cm) formed the dominant modal peak (26-27 cm) in all depths except 300-400 m (Figure 15). Larger fish occurred in all depths over 100 m with modes at 36, 40, 45 (both sexes), 48-49 (for males), and 50 cm (for females). The overall sex ratio was 0.8 : 1 (males to females), but varied by depth with males dominant in 100-200 m (2.1 : 1) and females dominant in over 200 m (0.6-0.7 : 1). Length-weight relationships were calculated by sex (Table 15).

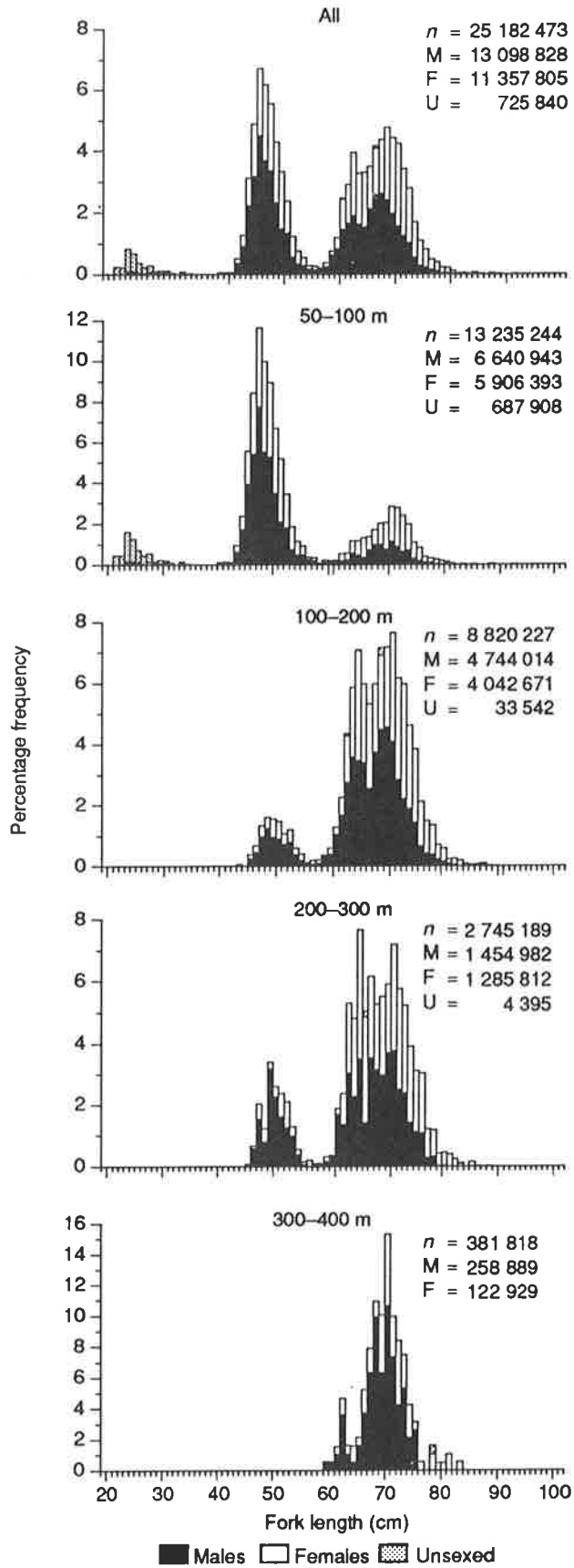

Figure 13: Length frequency of barracouta by depth (weighted by percentage sampled, area swept (by the wingtips), and stratum area; *n* is estimated population size).

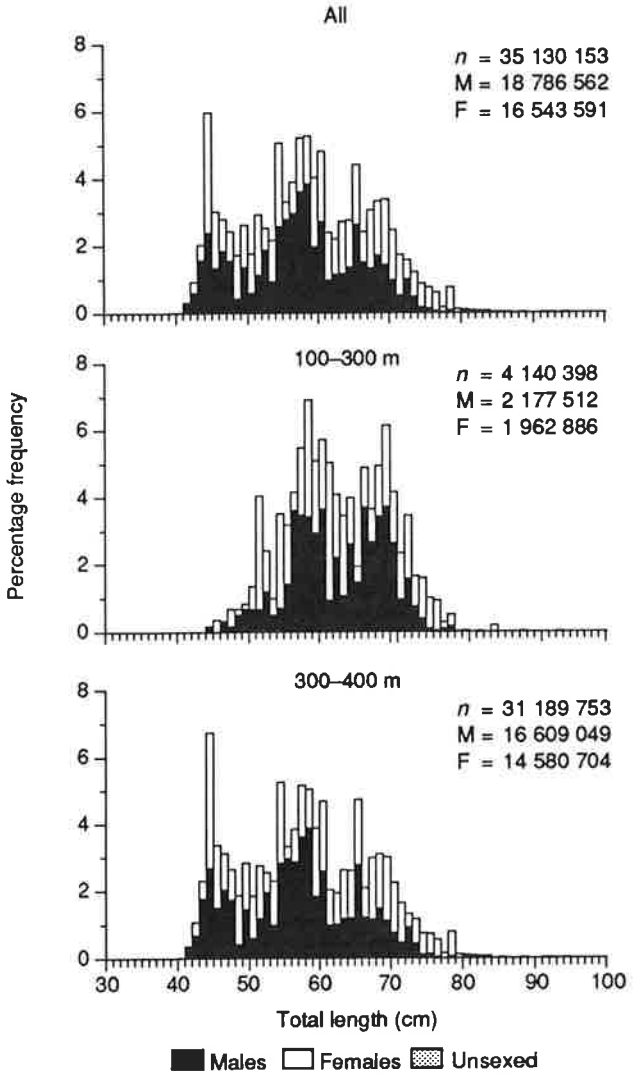

Figure 14: Length frequency of hoki by depth (weighted as for Figure 13; *n* is estimated population size).

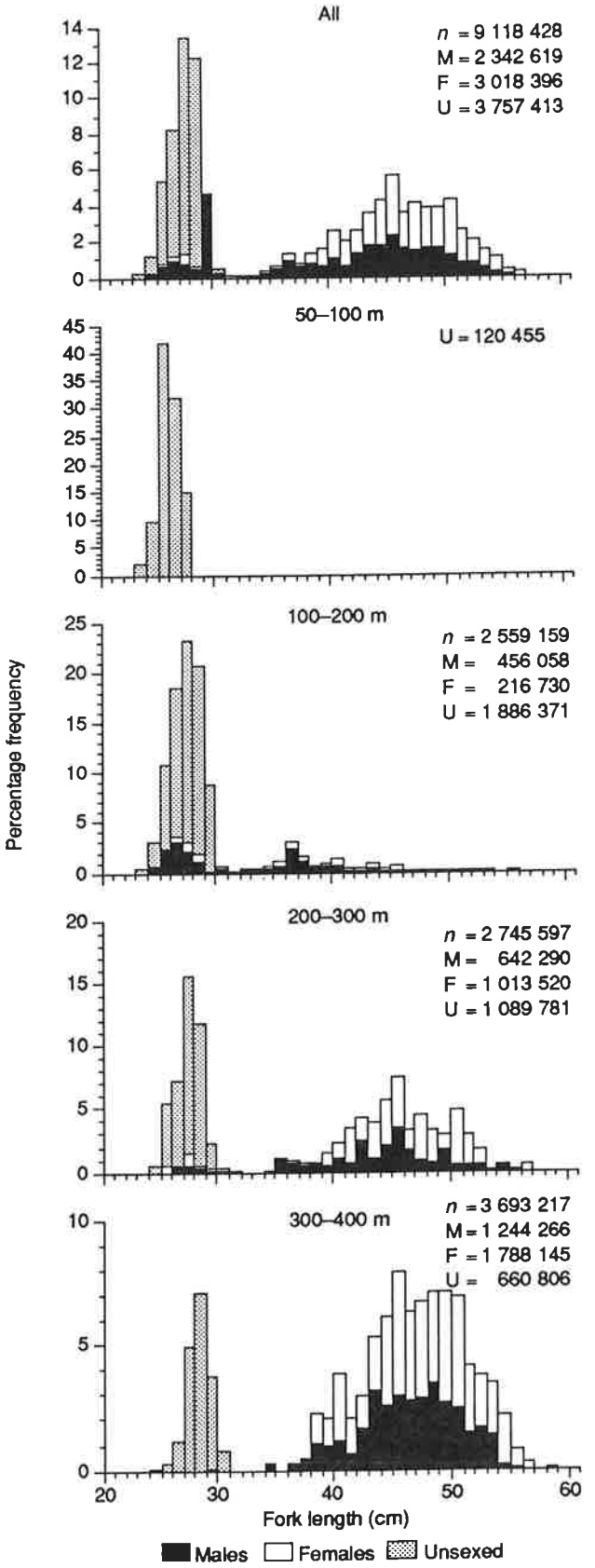

Figure 15: Length frequency of silver warehou by depth (weighted as for Figure 13; *n* is estimated population size).

Reproductive state. The main gonad stages were spent (33.6%) and resting (46.7%) (Table 16), which indicated that spawning had recently taken place. The female GSIs for mature (stage 4) fish were low (2.25%), compared with other species such as barracouta. The smallest mature fish recorded were a 36 cm female and a 35 cm male.

Feeding. The stomach contents recorded from 463 silver warehou contained salps (91%), pelagic polychaetes (5%), isopods, amphipods, shrimps, larval fish, and jellyfish. Most stomachs (72%) were partly full, with no obvious difference in stomach fullness with time of day.

Tarakihi

Tarakihi ranged from 12 to 57 cm, and most were between 39 and 46 cm (Figure 16). Fish smaller than 30 cm were only taken in waters less than 200 m, whereas larger fish occurred in all depths. Overall, the main modal peak for females (44 cm) was 4 cm greater than that for males. Other modal peaks were not clear. Females outnumbered males overall (0.7 : 1) and in strata less than 200 m (0.6–0.7 : 1), but not in deeper strata (1.7 : 1). Gonads were maturing (stage 3).

Table 15: Length-weight relationship for silver warehou

	Length (cm)				Weight (g)				
	No.	Mean	s.d.*	Range	Mean	s.d.*	Range	Equation†	Regression coefficient (r)
Males	246	41.0	7.1	24-55	1 440.3	630.9	271-2 950	$W = 0.0388L^{2.81}$	0.99
Females	326	43.8	3.3	25-56	1 769.1	735.3	288-3 400	$W = 0.0273L^{2.91}$	0.99
All fish	572	42.6	7.4	24-56	1 627.4	710.6	271-3 400	$W = 0.0314L^{2.87}$	0.99

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

Table 16: Reproductive state of silver warehou

				Gonadosomatic index*			
				Males		Females	
Stage†	No.	Males	Females	No.	Mean GSI	No.	Mean GSI
1	77	48	29	-‡	-	6	0.27
2	266	142	124	126	0.41	119	0.87
3	9	4	5	-	-	2	1.32
4	17	2	15	-	-	14	1.32
5	2	1	1	-	-	-	-
6	7	7	0	7	1.34	-	-
7	191	41	150	38	0.67	147	1.14
	569	245	324	171		288	

* Gonadosomatic index (GSI) = $\frac{\text{gonad weight}}{\text{body weight}} \times 100$.
† Stage 6, partially spent; stage 7, spent.
‡ No data.

Hapuku

Lengths ranged from 48 to 126 cm, and smaller fish were more abundant in 50-200 m (Figure 17). Not all fish were sexed because some were tagged and released. The overall sex ratio from fish not tagged was 1.2 : 1 (males to females).

School shark

School shark ranged from 114 to 168 cm, and males were dominant overall (18.4 : 1) in all depth ranges (Figure 18). Modal groups are difficult to interpret. Length-weight data are given by sex in Table 17.

Jack mackerels

The data shown in Figure 19 are probably mostly for *Trachurus murphyi*, but could include some *T. declivis*. Fish sampled ranged from 43 to 67 cm fork length, with an overall modal peak at 56 cm (males 56-57, females 55 cm). The presence of several modal peaks, particularly in deeper water could show different age classes or species (or both). Males outnumbered females by 2.4 : 1, and this was consistent in all depth ranges. Opportunistic observations indicated that some jack mackerel had been feeding on very small white warehou and euphausiids; male jack mackerel gonads were usually running ripe and females maturing to ripe.

Arrow squid

Arrow squid ranged from 10 to 38 cm with two modal groups present, peaking at 15 and 26 cm mantle length (Figure 20). The smaller size group was dominant in the 50-100 m depth range with the same modal peak for males and females. In larger arrow squid female modal peaks were 1-4 cm greater than for males. Males outnumbered females overall by 1.4 : 1 and in all depth ranges except 50-100 m.

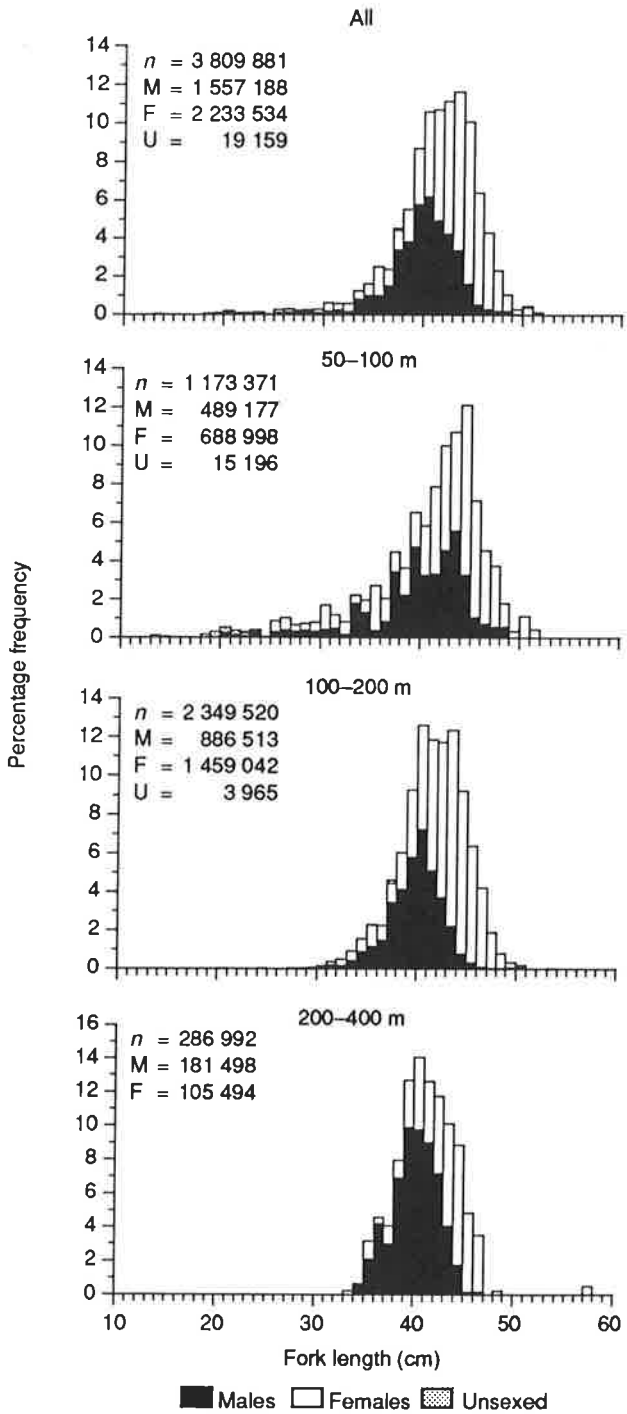

Figure 16: Length frequency of tarakihi by depth (weighted as for Figure 13; n is estimated population size).

Table 17: Length-weight relationship for school shark

	Length (cm)				Weight (g)				Regression
	No.	Mean	s.d.*	Range	Mean	s.d.*	Range	Equation†	coefficient (r)
Males	242	141.2	10.4	114-168	14.9	3.3	7.2-28.0	$W = 0.0250L^{2.68}$	0.91
Females	10	129.8	8.5	121-150	12.0	2.4	9.0-17.6	$W = 0.0100L^{2.87}$	0.95
All	252	140.7	10.5	114-168	14.8	3.3	7.2-28.0	$W = 0.0250L^{2.68}$	0.91

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

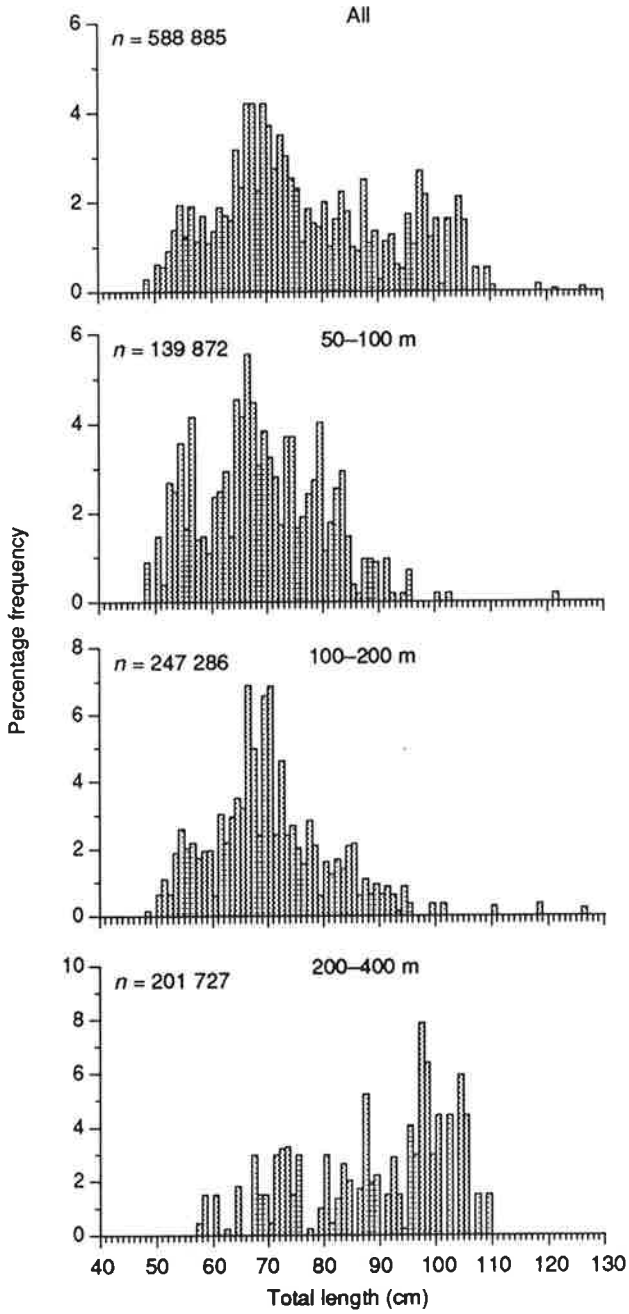

Figure 17: Length frequency of hapuku (unsexed) by depth (weighted as for Figure 13; n is estimated population size).

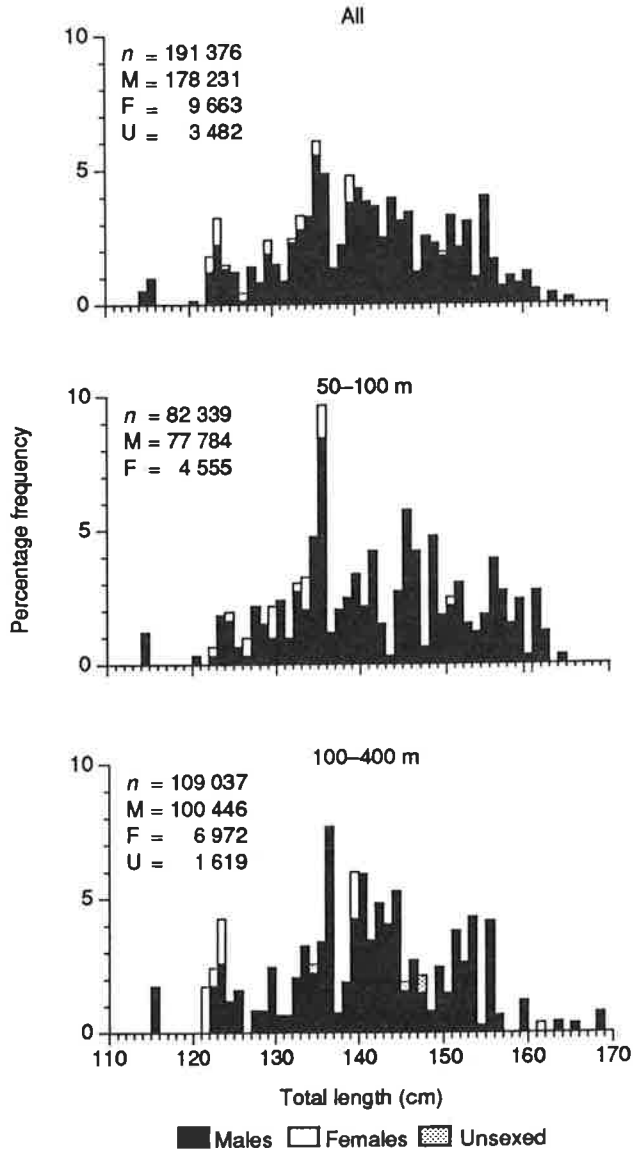

Figure 18: Length frequency of school shark by depth (weighted as for Figure 13; n is estimated population size).

Other species

Overall length frequencies of red cod, bluenose (*Hyperoglyphe antarctica*), hake, white warehou, and alfonsino (*Beryx splendens*) are given in Figure 21. Opportunistic observations on gonad stage and stomach contents were made on several other species: common roughy were mature, stargazer and red gurnard were maturing, red cod were resting, spiny dogfish females were observed with fully developed young in the uterus; rudderfish had been feeding on salps and small red cod, red cod on arrow squid and fish, and Ray's bream on amphipods.

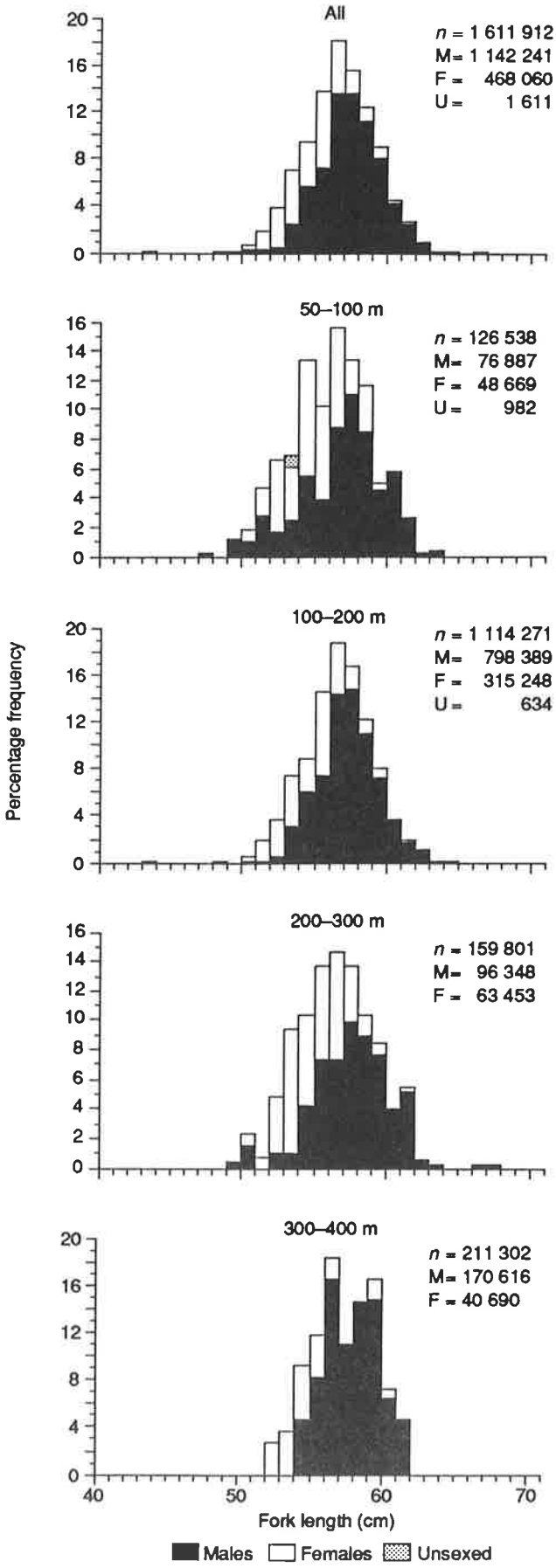

Figure 19: Length frequency of jack mackerels by depth (weighted as for Figure 13; *n* is estimated population size).

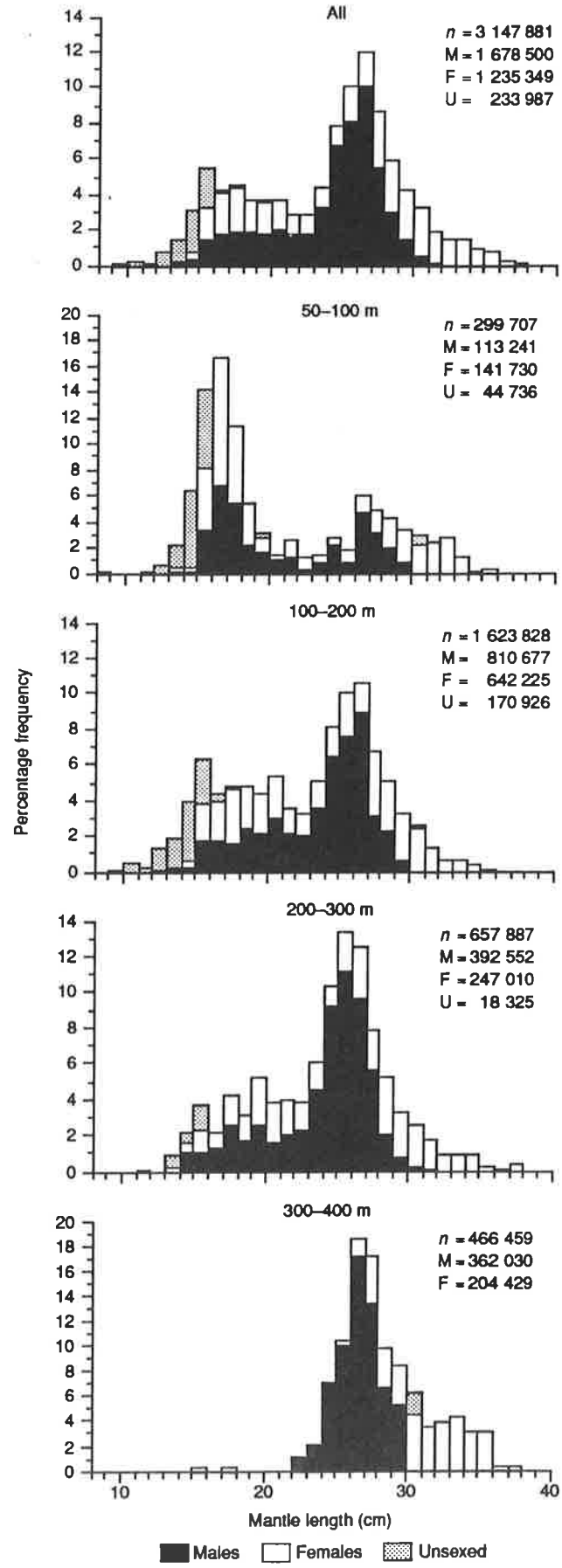

Figure 20: Length frequency of arrow squid by depth (weighted as for Figure 13; *n* is estimated population size).

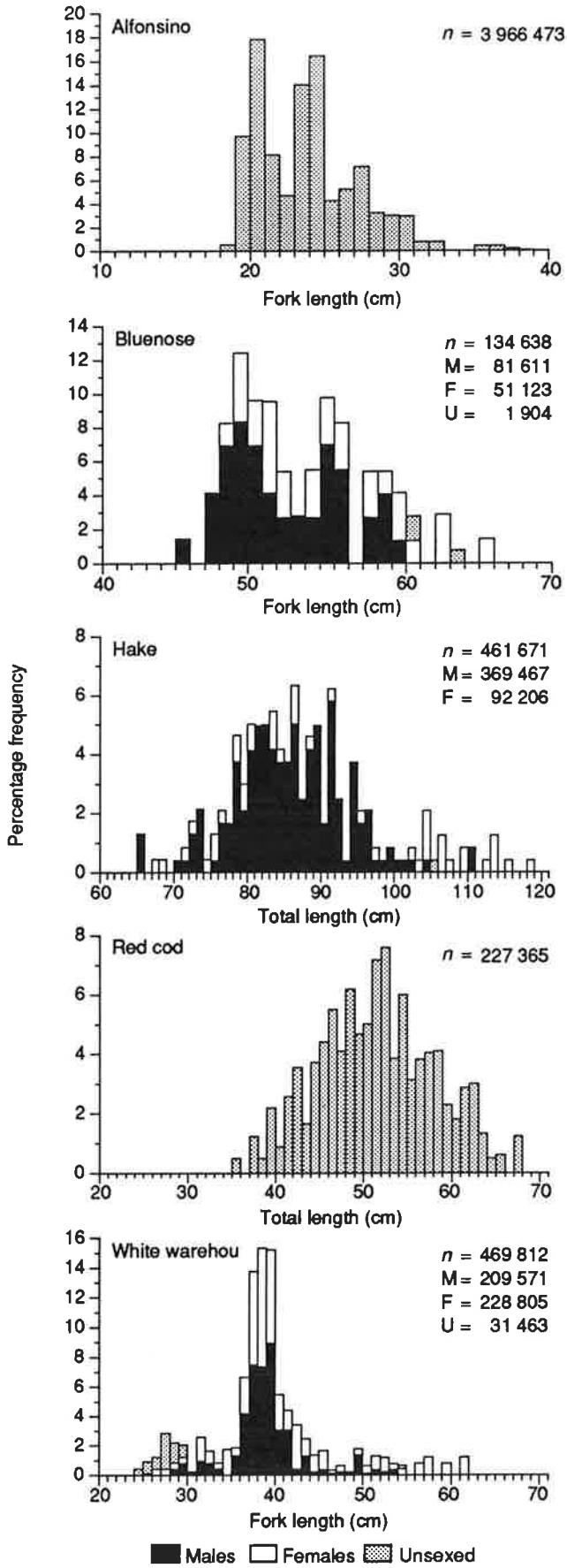

Figure 21: Length frequencies of other species sampled (weighted as for Figure 13; *n* is estimated population size).

Tagging

Totals of 248 school shark and 105 hapuku were tagged and released. Towards the end of the voyage, tagging of hapuku was discontinued because fish often floated and were prone to bird attacks. As at March 1992, one school shark tag had been returned, after 627 days at liberty; it was recaptured at the Chatham Islands (minimum distance travelled 55 n. miles).

Hydrology

Surface and bottom temperatures are shown in Figures 22 and 23, respectively. Data for the different phases of the survey were similar and have been combined. The main difference was to the east of Chatham Island, where bottom temperatures were 1 °C warmer in phases 2 and 3.

Temperatures over the shelf were predominantly 13-14 °C at the surface and 10-12 °C at the bottom. Surface temperatures were similar west and east of Chatham Island, whereas bottom temperatures were 1 °C warmer to the east. Over the upper slope, surface temperatures were slightly higher than in shelf waters and bottom temperatures were slightly lower. The same pattern was observed in December 1984, which suggested some localised upwelling or mixing, particularly on the western side of the island. Surface temperatures were similar to those observed in 1984, but bottom temperatures were 2-3 °C higher, probably because of the lack of calibration of the bottom temperature sensors in 1984.

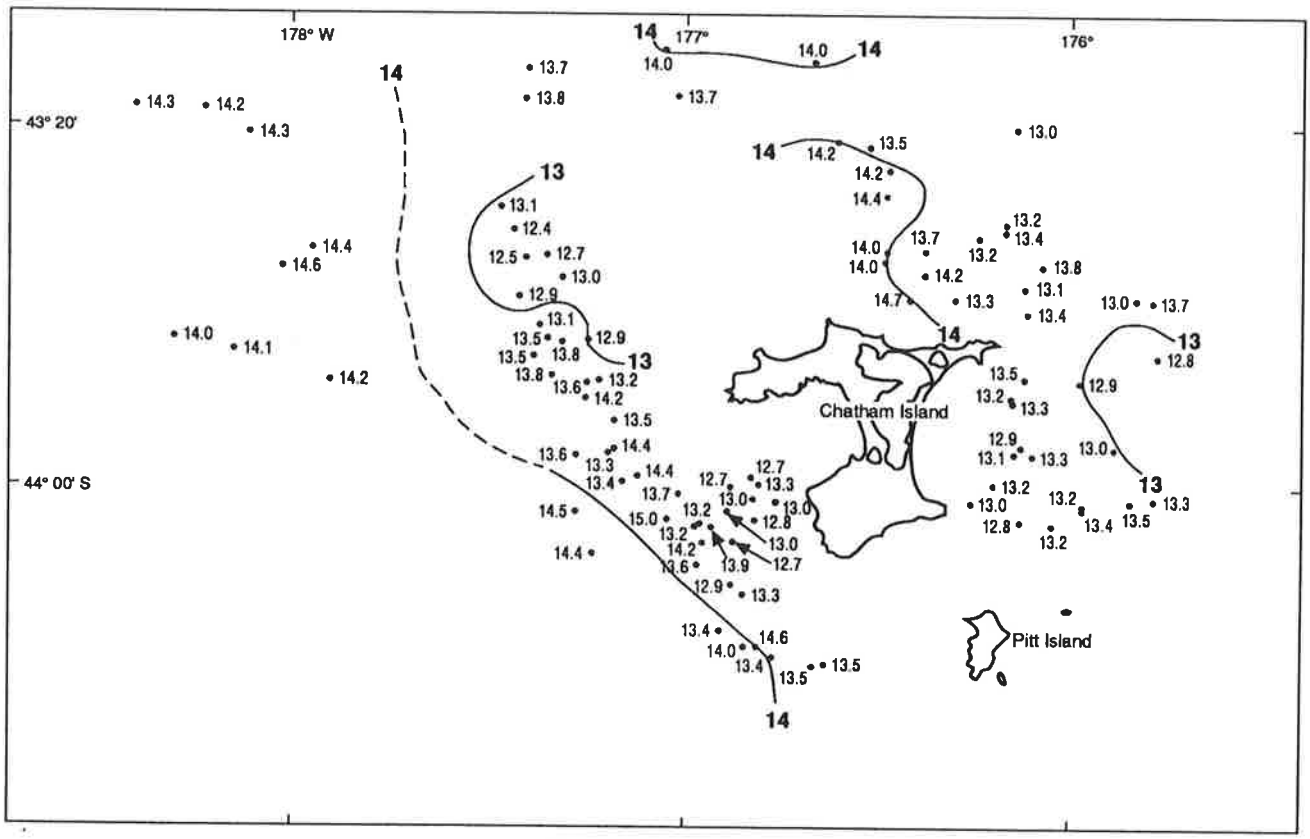

Figure 22: Surface temperatures (°C).

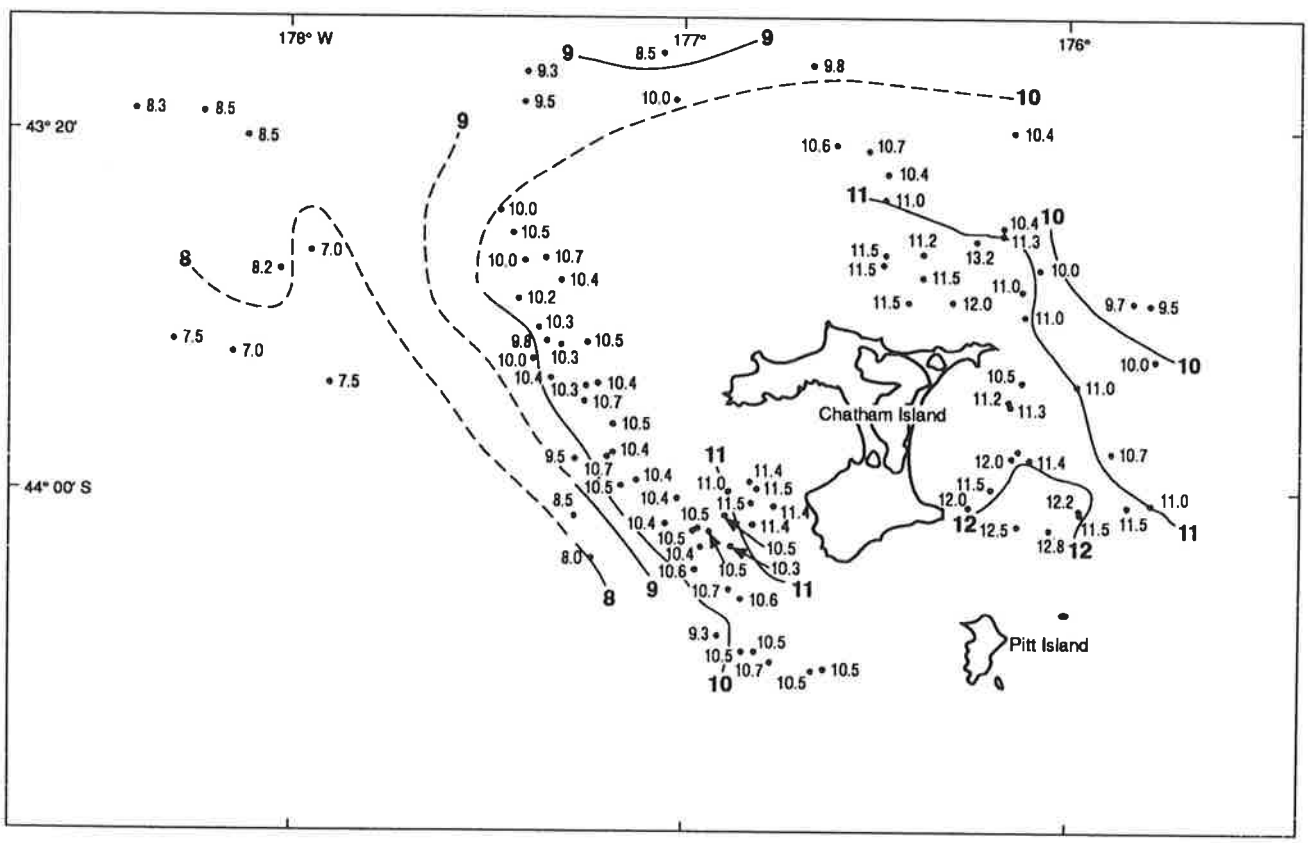

Figure 23: Bottom temperatures (°C).

Discussion

The main aim of the survey was to assess the annual variability in the abundance, distribution, and biology of barracouta and associated species, by comparing results given here with those from December 1984 (Hurst & Bagley 1987). There were considerable similarities in many of the findings from the two surveys; hence the 1985 results are not discussed here in detail, but differences between surveys are highlighted. Some limited comparisons can also be made with the Chatham Islands part of the July 1986 *Shinkai Maru* survey. Results of earlier *Shinkai Maru* surveys (discussed by Hurst & Bagley (1987)) are not repeated here as they included only nine stations in less than 400 m around the Chatham Islands.

Survey design and comparability

Increased stratification of the survey area in 1985 may have slightly improved the precision of the biomass estimates for barracouta and some of the other shelf species, compared with 1984, but it is more likely that the total number of stations (80 and 85), the station density (about 1 : 200 km^2), and the multi-phase survey design were the main contributing factors leading to relatively low *c.v.*s of many species in both surveys. For the 12 species given for each of the 1984 and 1985 surveys in Table 18, *c.v.*s were less than 30% for 9 species and less than 15% for 4 species.

In contrast, the July 1986 *Shinkai Maru* survey of the same area had less stations (14), a lower station density (about 1 : 1200 km^2), and only one phase, which resulted in only three species with *c.v.*s less than 30% and none less than 15%. The low number of stations not only limits the value of making biomass estimate comparisons with the December surveys, but probably affects the comparability of area weighted length frequency data as well. This is apart from any problems caused by different vessel or gear catchability factors. Therefore, July 1986 data have been treated with caution in survey comparisons.

Although the 1984 and 1985 surveys were designed to be comparable, some changes were made to 1985 strata to increase the number and include new data on bathymetry and areas of foul ground. Therefore, 1984 biomass data given in Tables 18 and 19 and Figure 24 have been recalculated by the use of 1985 stratum boundaries (*see* Appendix 3). The July 1986 survey used the same survey area from 50–400 m as in the December 1985 survey (*see* Livingston *et al.* 1991). July 1986 biomass and length frequency data discussed here were extracted from the trawl survey database at MAF Fisheries Greta Point, Wellington.

Catch composition

The catch composition in 1985 was similar to the 1984 survey and typical of shelf faunas influenced by the Subtropical Convergence Zone. There were 12 additional species caught in minor quantities in 1985, but, of these, only blue moki and rubyfish have any commercial value. Of the top 20 species caught in 1984, four (redbait, white warehou, frostfish, and sea perch) did not feature in the top 20 in 1985 and were replaced by red cod, silver dory, hake, and ghost shark.

The total catch on biomass stations in 1985 (153.2 t on 85 stations) was less than that recorded for the 1984 survey (190.2 t on 80 stations). Barracouta dominated catches in both surveys, but made up less of the total catch in 1985 (42.7%) than in 1984 (54.3%) (Table 18). The relative

Table 18: Comparison of catch composition, wingspread biomass estimates, and percentage coefficients of variation (*c.v.*) for the main species* at the Chatham Islands, 1984–86 (*n* is number of stations)

			Akebono Maru No. 73				*Shinkai Maru*	
			Biomass				Biomass	
	Catch (% of total)		Dec 1984 *n* = 80		Dec 1985 *n* = 85		Jul 1986 *n* = 14	
Species	Dec 1984	Dec 1985	(10^3 t)	*c.v.*	(10^3 t)	*c.v.*	(10^3 t)	*c.v.*
BAR	54.3	42.7	42.4	12	28.1 †,‡	9	49.7	32
HOK	3.4	11.2	9.5 ‡	26	22.8	57	77.4	75
SWA	11.2	7.5	8.7	18	10.4	25	1.6	53
SPD	4.0	7.1	3.7	65	4.9	21	6.1	23
TAR	2.6	6.6	3.6	25	5.2	16	7.6	28
HAP	2.1	5.0	3.4	14	4.0	44	2.5	82
RHY	10.8	3.6	5.2	82	7.2	79	< 0.05	69
JMA	0.7	3.4	1.1 §	35	2.5	21	0.9	61
SCH	1.1	2.5	1.5 §	19	2.9	19	2.5	65
STA	0.7	1.7	1.0 ‡,§	13	2.2 ‡	14	4.9	18
ASQ	5.9	1.3	5.7	16	1.3 †	14	2.9	32
LIN	0.7	1.1	1.5 ‡,§	11	2.1 ‡	11	7.5	38

* Species codes are given in Appendix 1.
† Significantly lower than 1984 estimate, $p < 0.05$.
‡ Significantly lower than 1986 estimate, $p < 0.05$.
§ Significantly lower than 1985 estimate, $p < 0.05$.

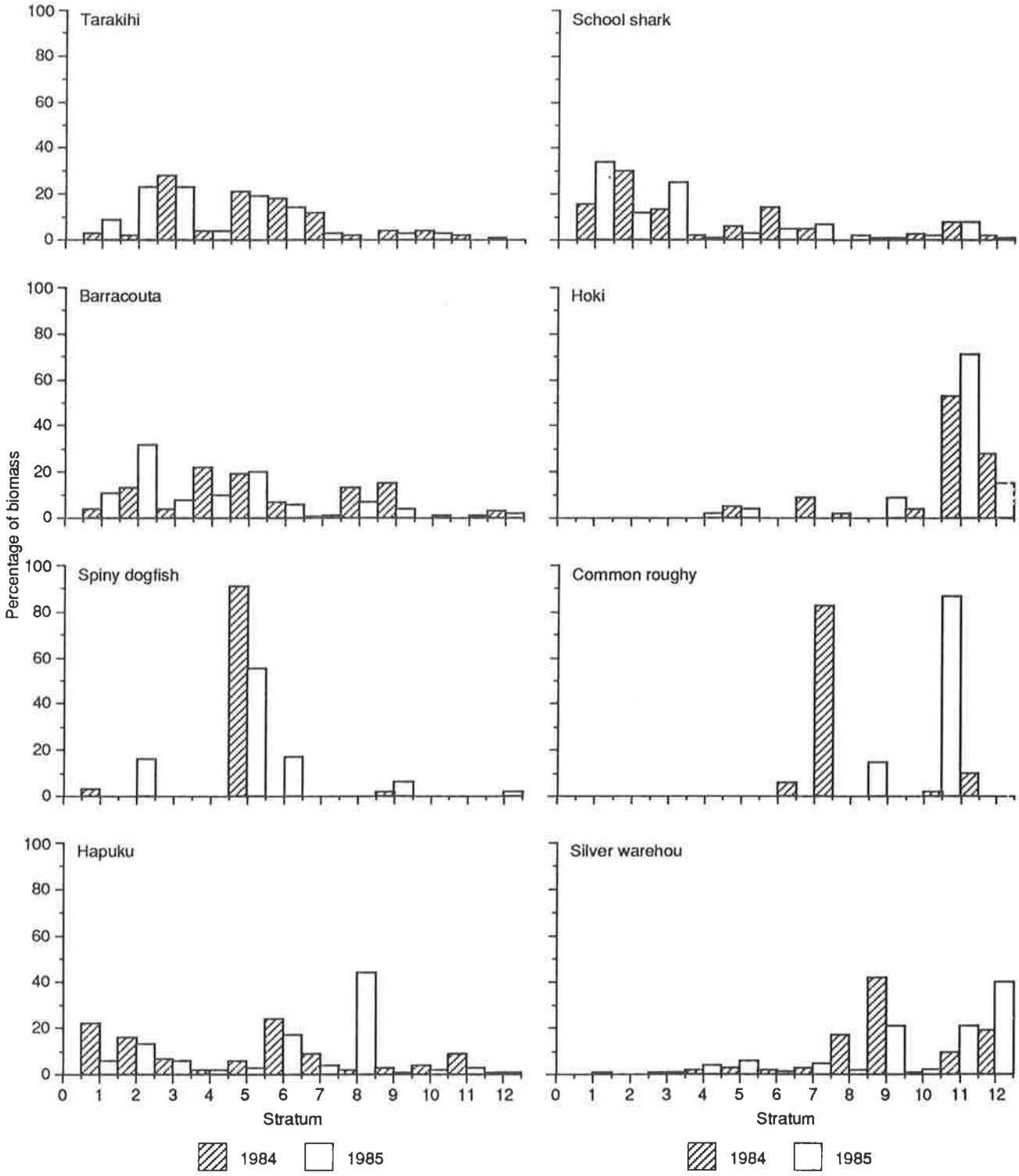

Figure 24: Comparisons of species percentage of biomass by stratum, 1984 and 1985, for eight major species.

dominance of other species changed; most notable were silver warehou, which was important in the catch in both years, but less so in 1985 (i.e., 11.2 and 7.5% of the total, respectively), and hoki, which ranked only sixth in 1984 (3.4%), but was second in 1985 (11.2%). When the biomass estimates are compared between years, barracouta decreased from 42.8 to 26.4% of the total, silver warehou increased from 10.0 to 14.6%, and hoki increased from 10.3 to 21.4%.

Species distribution

Stratum biomass data were used in the comparison of the area and depth distribution of 8 of the 10 major species in 1984 and 1985 (*see* Figure 24). Hoki was the only species which had a similar distribution in both years. Main differences in the 1985 distribution of other species were: common roughy and school shark occurred in

similar depth ranges to 1984, but more to the north of the survey area; silver warehou were more to the north and deeper in 1985; hapuku were more to the west and deeper; and barracouta, tarakihi, and spiny dogfish were more to the east and shallower. The change in barracouta biomass distribution is partly related to the higher proportion of smaller fish, which are usually more abundant in shallower water.

Biomass estimates

There are two main problems in comparing biomass estimates between surveys. Firstly, there are few data on the discreteness of stocks in the survey area. Middle depth species such as hoki, silver warehou, and hake are all at the shallow edge of their depth distribution and probably migrate in and out of the survey area. Hurst & Bagley (1987) noted that some of the shelf species (barracouta, hapuku, and school shark) are also known to be capable of long distance migrations, but discussed evidence which suggested that at least barracouta and tarakihi at the Chatham Islands may be separate stocks. (Note: the relatively small size attained by most adult barracouta recorded in 1984 was also found in the 1985 and 1986 surveys; only 10% of the population was over 75 cm in 1984, 4% in 1985, and 3% in July 1986.)

Secondly, the relative fishing power of the two different vessel and gear combinations is unknown. The two December surveys both used *Akebono Maru No. 73*, but the July 1986 survey used *Shinkai Maru*. The vessels are of similar size (about 3000 t), but *Akebono Maru No. 73* has greater horsepower (i.e., 7200 compared with 5000), and the trawl nets were different.

Summer survey comparisons

Comparison of biomass estimates between December 1984 and 1985 (*see* Table 18) showed significant decreases in 1985 for two species (barracouta decreased by 34% and arrow squid by 77%) and significant increases for four species (ling, school shark, giant stargazer, and jack mackerels, by 40 to 127%).

The significant decrease in barracouta biomass was unexpected, given the low catches during 1983-85 (*see* Table 1). However, the estimated total number of fish was similar (26 million in 1984 (recalculated), 25 million in 1985) because there were more smaller fish in 1985. When the biomass data were analysed by sex and size class (Table 19), there was a significant difference in the barracouta sex ratio between 1984 and 1985, in fish over 40 cm (i.e., 0.5 : 1 males to females compared with 1 : 1). When this was related to the biomass of size groups 40-60 cm and over 60 cm, the biomass of males was similar in both years, but the biomass of females over 60 cm had declined significantly in 1985, by 52%. If the assumption that the Chatham Islands barracouta stock remains mostly within the survey area is correct, then this suggests that there were more adult females vulnerable or available to the survey gear in 1984.

There are various possible explanations for the significant changes in biomass of the other species. Annual estimates of squid biomass are known to fluctuate widely

Table 19: Comparison of wingspread biomass estimates (t) and percentage coefficients of variation (*c.v.*) of barracouta by sex and size group at the Chatham Islands, 1984-86

	Akebono Maru No. 73				*Shinkai Maru*	
Size group	Dec 1984		Dec 1985		Jul 1986	
(cm)	Biomass	*c.v.*	Biomass	*c.v.*	Biomass	*c.v.*
All fish	42 431	12	28 133 *,†	9	49 570	32
40-60‡	8 244	16	6 764 †	29	24 558	64
>60‡	34 107	13	21 282 *	9	19 757	25
All females	28 459	13	14 066 *,†	9	25 346	36
40-60	4 880	17	2 827 †	32	12 876	68
>60	23 557	14	11 228 *	9	9 689	25
All males	14 147	15	13 938 †	10	23 934	27
40-60	3 318	19	3 947	28	11 393	59
>60	10 805	17	9 986	10	10 069	27

* Significantly lower than 1984 estimate, $p < 0.05$.
† Significantly lower than 1986 estimate, $p < 0.05$.
‡ Size groups incorporated modal groups as follows: 1984, 50-62, ≥ 63
1985, 40-58, ≥ 59
1986, 45-62, ≥ 63

(e.g., *see* Hatanaka *et al.* 1989b), partly because the species is thought to live only 12-18 months, and also because its vulnerability and availability to bottom trawl gear probably varies considerably. Ling, jack mackerel, and school shark stocks probably extend outside the survey area, and hence the proportion inside the survey area could fluctuate between surveys.

The apparent increase in biomass of stargazer in 1985 could be due to more accurate estimation of catch weight in 1985, because the conversion factor used in 1984 was found to be too low (i.e., the conversion factor in the regulations was 1.7, compared with our estimate of 2.8 in 1985). Correction of 1984 catch weights would make the two survey biomass estimates similar. It is also possible that the accurate recording of school shark weights in 1985, compared with estimates made "by eye" in 1984, may have contributed to the significant change in biomass estimates.

This highlights the need to accurately weigh all species and not rely on conversion factors used in fisheries regulations. Although many of these conversion factors have since been revised, there can be considerable differences between vessels, particularly for species such as giant stargazer. Accurate estimation of conversion factors on board each vessel is not always possible as many of the bycatch species occur too infrequently in each tow to enable a sample of sufficient size to be processed.

Summer-winter comparisons

The July 1986 biomass estimate of barracouta was significantly greater than in December 1985, but not different to 1984. However, the estimated total number of fish (53 million) was about twice that of the two December surveys, due to a much higher proportion of smaller fish. The biomass of male and female fish over 60 cm in July 1986 was similar to that in December 1985 (*see* Table 19). This suggests that perhaps the 1 : 1 sex ratio found in 1985 is more common and that the 1984 ratio was unusual. Other surveys on the Chatham Rise (Fenaughty & Uozumi 1989) and south of New Zealand, both during and outside the spawning season (authors' unpublished data, Hurst *et al.* 1990), have also recorded about 1 : 1 ratios.

The biomass of hoki was greater in July 1986 than in December 1984, perhaps indicative of seasonal movements or differences in the year class strength. Biomass estimates of giant stargazer and ling in July 1986 were greater than for both of the December surveys, probably because the *Shinkai Maru* trawl gear fishes harder down, and therefore such species are more vulnerable. Similar results have been found from comparisons of biomass estimates of hard down species (i.e., giant stargazer, smooth skate) from *Shinkai Maru* and *Akebono Maru No. 3* surveys off southern New Zealand (authors' unpublished data).

Biological data

Other biological data of interest from the Chatham Islands trawl surveys include unusual sex ratios and strong or weak modal groups.

Most of the main species sampled in 1985 had about 1 : 1 male to female ratios, the most notable exceptions being school shark (18 : 1) and hake (4 : 1). These results illustrate the importance of collecting routine biological data on at least all commercially important species, particularly if biomass data are to be used for stock assessment. For example, the biomass of school shark which might be estimated from this survey could not realistically be expected to be the total Chatham Islands population, with the females presumably either more inshore, in areas more inaccessible to the gear, or outside the survey area. Large schools of adult females of this species are known to move into shallow bays and harbours during the spring and early summer to give birth to their young (Ayling & Cox 1982).

Species for which there appeared to be missing or weak modal groups were barracouta, hoki, and silver warehou. The youngest barracouta mode (about 20–35 cm, age 1) was found only in the shallowest strata in both 1984 and 1985 surveys and would be underestimated by the survey gear and possibly the lack of sampling in water shallower than 50 m, but either had a slower growth rate in 1985 (Table 20), or spawned at a later date. The lack of an age 2 modal group in 1984 (i.e., peaks usually at about 47 cm), also showed up as a missing age 3 modal group in 1985. In July 1986, however, the age 3+ modal group was strong, but there could have been some sampling bias because there were only seven stations in barracouta depths in this survey.

Hoki and silver warehou data also appeared to have strong or weak modal groups, though these results must be treated with caution because the survey sampled only part of their population distribution. For hoki, the range of lengths was similar in 1984 and 1985, but the relative dominance of modal peaks was different. Whereas the largest mode (peak about 67–70 cm) was dominant in 1984, the smallest mode (peak 44 cm) was important in 1985. In the July 1986, 50–800 m survey of the Chatham Rise, the smaller mode (48 cm) was also dominant in 200–400 m and 400–600 m depth ranges and overall. Silver warehou length frequency modes were similar for the two December surveys, but the main mode peaked at 43 cm in 1984, compared with 37 cm in 1985. This December 1985 mode was also dominant on the Chatham Rise in July 1986 (peaked at 39 cm), in 200–400 m, but not in deeper water and not overall.

Table 20: Barracouta modal groups and peaks from three trawl surveys at the Chatham Islands, 1984–86

	December 1984*		December 1985		July 1986†	
Approximate age	Group‡ (cm)	Peak(s) (cm)	Group (cm)	Peak(s) (cm)	Group (cm)	Peak(s) (cm)
1–1+	24–34	32	19–34	23	32–45	39
2–2+	–§	–	43–53	47	–	–
3–3+	53–62	57	–	–	53–62	57
≥4	62–79	70,74	58–78	64,70	62–86	67,70

* *See* Figure 20, Hurst & Bagley (1987).
† *See* Appendix 4.
‡ Upper and lower bounds of modal groups are approximate only; peaks are for all fish, though slight sex differences occur.
§ Weak or absent modal group.

Conclusions

1. The survey design used in the December 1984 and 1985 surveys enabled detection of significant changes in the biomass estimates of some of the more abundant species (i.e., barracouta, arrow squid, ling, stargazer, jack mackerels, school shark). These species had *c.v.*s of between 9 and 35% and changes in biomass of -77 to +127%. The much lower number of stations used in the Chatham Islands part of the July 1986 survey made apparently large changes in biomass of some species (e.g., silver warehou, hoki) statistically undetectable, with *c.v.*s rarely below 30%.
2. Detailed recording of length and sex are vital in the interpretation of biomass data, as seen from the unusual sex ratios found for barracouta and school shark. Collection of these data can be very time consuming on multi-species shelf surveys, and careful consideration should be given to balancing an adequate number of stations against biological data requirements.
3. Changes in the biomass and sex ratio of adult barracouta between 1984 and 1985 cannot be explained, but it appears (from other Chatham Rise and Southland survey data) that the 1984 ratio of males to females (0.5 : 1) may have been unusual. This emphasises the value of carrrying out repeat surveys and the need to carry out further annual or seasonal surveys if patterns in the fishery are to be more accurately described and understood.

Acknowledgments

We are grateful to E. Barratt, the late R. Morris, and T. Kozuma of Sanford South Island Limited for their assistance with the survey; Captain N. Toyota, Chief Officer Takahara, and the crew of *Akebono Maru No. 73* for their co-operation and hospitality; J. Fenaughty, M. Livingston, and D. Tracey for their assistance with data collection; and M. Clark and L. Paul for constructive comments on the manuscript.

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Appendix 1

Species taken during the survey

Scientific name	Common name	Species codes used in text
Agnatha		
Myxinidae		
Eptatretus cirrhatus	hagfish, blind eel	
Chondrichthyes		
Hexanchidae		
Notorynchus cepedianus	broadsnouted sevengill shark	
Scyliorhinidae		
Cephaloscyllium isabellum	carpet shark	
Squalidae		
Etmopterus lucifer	Lucifer spiny dogfish	
Squalus acanthias	spiny dogfish	SPD
S. mitsukuri	grey spiny dogfish	
Carcharhinidae		
Prionace glauca	blue shark	
Triakidae		
Galeorhinus galeus	school shark	SCH
Narkidae		
Typhlonarke aysoni	blind electric ray	
Torpedinidae		
Torpedo fairchildi	electric ray	
Rajidae		
Raja innominata	smooth skate	
R. nasuta	rough skate	
Chimaeridae		
Hydrolagus novaezelandiae	dark ghost shark	GSH
Osteichthyes		
Congridae		
Bassanago bulbiceps	swollenheaded conger	
Argentinidae		
Argentina elongata	silverside	
Merlucciidae		
Macruronus novaezelandiae	hoki	HOK
Merluccius australis	hake	HAK
Moridae		
Pseudophycis bachus	red cod	RCO
Macrouridae		
Caelorinchus spp.	rattails	
C. biclinozonalis		
C. bollonsi		
Lepidorhynchus denticulatus	javelinfish	
Ophidiidae		
Genypterus blacodes	ling	LIN
Berycidae		
Beryx splendens	alfonsino	BYX
Trachichthyidae		
Hoplostethus mediterraneus	silver roughy	
Paratrachichthys trailli	common roughy	RHY
Zeidae		
Capromimus abbreviatus	capro dory	
Cyttus novaezelandiae	silver dory	SDO
C. traversi	lookdown dory	LDO
Macrorhamphosidae		
Centriscops obliquus	redbanded bellowsfish	
Scorpaenidae		
Helicolenus sp.	sea perch	
Congiopodidae		
Alertichthys blacki	alert pigfish	
Hoplichthyidae		
Hoplichthys haswelli	deepsea flathead	
Psychrolutidae		
Neophrynichthys latus	dark toadfish	
Percichthyidae		
Polyprion oxygeneios	hapuku	HAP
Serranidae		
Lepidoperca sp.	orange perch	OPE
Apogonidae		
Epigonus lenimen	bigeyed cardinal fish	
Bramidae		
Brama brama	Ray's bream	RBM
Emmelichthyidae		
Emmelichthys nitidus	redbait	
Plagiogeneion rubiginosus	rubyfish	
Carangidae		
Trachurus spp.	jack mackerels	JMA
Cheilodactylidae		
Nemadactylus macropterus	tarakihi	TAR
Latrididae		
Latridopsis ciliaris	blue moki	
Latris lineata	trumpeter	TRU
Uranoscopidae		
Kathetostoma giganteum	giant stargazer	STA
Pinguipedidae		
Parapercis colias	blue cod	BCO
Gempylidae		
Rexea solandri	gemfish, southern kingfish	SKI
Thyrsites atun	barracouta	BAR
Trichiuridae		
Lepidopus caudatus	frostfish	
Centrolophidae		
Centrolophus niger	rudderfish	RUD
Hyperoglyphe antarctica	bluenose	BNS
Seriolella caerulea	white warehou	WWA
S. punctata	silver warehou	SWA
Bothidae		
Arnoglossus scapha	witch	
Pleuronectidae		
Pelotretis flavilatus	lemon sole	
Cephalopoda		
Ommastrephidae		
Nototodarus sloanii	arrow squid	ASQ
Todarodes filippovae	southern arrow squid	
Onychoteuthidae		
Moroteuthis ingens	warty squid	
Crustacea		
Nephropsidae		
Metanephrops challengeri	scampi	
Palinuridae		
Jasus edwardsii	rock lobster	
Majidae		
Leptomithrax sp.	masking crab	
Jacquinotia edwardsii	southern spider crab	
Portunidae		
Ovalipes catharus	common swimming crab	
Ovalipes molleri	paddle crab	

Appendix 2

Individual station data

Station No.	Date	Start Position ° 'S	° 'W	Start time (h)	Start depth (m)	Stratum No.	Tow length (n. mile)	Wingspread (m)
1	7/12/85	43 28.3	177 26.5	0507	263	8	3.0	37.1
2	7/12/85	43 31.3	177 20.9	0653	198	4	3.0	35.7
3	7/12/85	43 35.9	177 25.5	0823	266	8	3.0	34.2
4	7/12/85	43 38.9	177 22.5	0949	214	4	3.0	35.7
5	7/12/85	43 45.4	177 11.8	1155	168	4	3.0	29.7
6	7/12/85	43 46.0	177 16.4	1315	166	4	3.0	29.9
7	7/12/85	43 54.3	177 19.7	1510	255	8	3.0	34.2
8	7/12/85	43 56.7	177 11.5	1634	187	9	3.0	31.7
9	8/12/85	43 56.7	176 52.2	0505	130	5	3.0	29.4
10	8/12/85	44 02.9	176 47.5	0633	126	5	2.0	29.4
11†	8/12/85	44 02.3	176 53.6	0748	152	5	0.4	36.2
12	8/12/85	44 08.5	176 49.9	0904	154	5	3.0	39.4
13†	8/12/85	44 04.8	176 57.7	1025	174	5	0.7	NR‡
14	8/12/85	44 02.4	177 00.7	1121	170	5	3.0	39.4
15	8/12/85	44 06.2	176 57.3	1250	208	9	3.0	33.1
16	8/12/85	44 09.2	176 53.2	1412	176	5	3.0	33.9
17	8/12/85	44 13.4	176 56.8	1550	308	9	3.0	40.8
18	8/12/85	44 17.9	176 43.2	1737	176	5	3.0	35.1
19	9/12/85	43 52.9	176 09.1	0458	99	2	3.0	31.1
20	9/12/85	44 02.6	176 09.7	0802	56	2	3.0	22.5
21	9/12/85	44 00.4	176 01.0	1014	94	2	3.0	31.1
22	9/12/85	44 04.5	175 53.0	1155	92	6	3.0	31.1
23	9/12/85	44 04.4	175 48.7	1324	123	6	3.0	33.1
24	9/12/85	43 56.6	175 57.1	1533	113	6	3.0	30.5
25	9/12/85	43 51.4	175 56.4	1700	136	6	3.0	44.2
26	10/12/85	43 48.4	175 44.0	0603	250	10	3.0	37.6
27	10/12/85	43 42.4	175 44.7	0739	306	10	3.0	38.5
28	10/12/85	43 37.3	175 52.4	0924	253	10	3.0	39.4
29	10/12/85	43 50.8	176 04.9	1139	119	6	3.0	31.4
30	10/12/85	43 41.4	176 02.7	1337	154	6	3.0	35.1
31	10/12/85	43 37.4	176 00.8	1525	203	3	3.0	33.7
32	10/12/85	43 32.7	176 06.9	1652	219	7	3.0	33.7
33	11/12/85	43 32.5	176 18.6	0505	140	3	3.0	35.1
34	11/12/85	43 35.8	176 19.3	0645	112	3	3.0	30.5
35†	11/12/85	43 35.3	176 27.3	0818	94	1	1.7	29.7
36	11/12/85	43 33.0	176 32.2	0933	84	1	3.0	26.2
37	11/12/85	43 38.3	176 19.5	1115	93	1	3.0	29.4
38	11/12/85	43 29.4	176 25.3	1252	138	3	3.0	38.5
39	11/12/85	43 23.3	176 31.7	1431	153	3	3.0	33.4
40†	11/12/85	43 21.6	176 37.2	1651	136	3	0.7	NR
41	12/12/85	43 22.5	176 05.4	0531	400	11	3.0	47.3
42	12/12/85	43 20.5	176 35.2	0816	175	3	3.0	32.8
43	12/12/85	43 13.9	176 36.0	1002	372	11	3.0	45.1
44	12/12/85	43 10.9	176 59.0	1210	403	11	3.0	42.8
45	12/12/85	43 16.6	176 57.1	1414	283	7	3.0	33.9
46	12/12/85	43 16.8	177 20.4	1631	323	11	3.0	36.2
47†	12/12/85	43 13.8	177 25.0	1800	396	11	0.7	36.2
48	13/12/85	43 18.0	178 28.6	0513	396	11	3.0	45.1
49	13/12/85	43 20.3	178 10.7	0742	384	11	3.0	40.8
50	13/12/85	43 23.4	178 05.0	0955	383	11	3.0	40.8
51	13/12/85	43 34.9	178 01.2	1248	386	12	3.2	35.9
52	13/12/85	43 37.3	178 05.0	1514	394	12	3.0	39.1
53	14/12/85	43 43.2	178 22.3	0516	394	12	3.0	40.8
54	14/12/85	43 44.5	178 13.0	0650	394	12	3.0	40.8
55	14/12/85	43 46.5	177 58.1	0841	396	12	3.0	40.8
56	14/12/85	44 08.5	177 10.4	1248	386	12	3.0	35.9
57	14/12/85	44 04.4	177 13.4	1424	381	12	3.0	35.9
58§	14/12/85	43 59.2	177 10.0	1610	215	4	9.9	31.4
59	15/12/85	43 25.9	177 28.3	0502	281	7	3.0	36.5
60	15/12/85	43 31.6	177 25.0	0630	257	8	3.0	36.8
61	15/12/85	43 33.7	177 19.1	0754	160	4	3.0	34.2
62	15/12/85	43 40.9	177 19.0	0910	167	4	3.0	34.2
63	15/12/85	43 42.5	177 23.2	1028	209	8	3.0	35.7
64	15/12/85	43 46.4	177 20.3	1148	183	4	3.0	32.5
65	15/12/85	43 46.0	177 17.5	1308	173	4	3.0	36.5
66	15/12/85	43 50.3	177 18.7	1431	197	4	3.0	35.1
67§	15/12/85	43 45.3	177 18.7	1600	170	9	12.0	35.1
68	16/12/85	43 50.0	177 13.1	0507	184	4	3.0	35.7
69	16/12/85	43 53.1	177 12.9	0622	194	4	3.0	37.1
70	16/12/85	43 56.1	177 09.3	0741	183	5	3.0	37.1
71	16/12/85	44 01.2	177 05.3	0904	184	5	3.0	37.1

Appendix 2—*continued*

Station No.	BAR*	HOK	SWA	RHY	TAR	SPD	HAP	SCH	JMA	SDO	Catch (kg) All species
1	55	0	6	0	19	0	3 918	48	0	15	4 409
2	50	0	0	1	0	0	52	0	0	1	163
3	1 110	0	23	0	3	0	8	0	2	32	2 019
4	750	0	8	0	1	0	10	0	1	0	827
5	825	0	62	0	90	0	33	83	0	0	1 139
6	2 288	0	75	0	105	0	16	19	0	0	2 612
7	1 388	0	245	0	1	3	0	18	30	5	1 792
8	750	0	130	0	181	0	22	13	187	5	1 388
9	825	0	10	0	150	1 600	19	36	6	0	2 699
10	1 012	0	1	0	144	450	26	0	4	0	1 701
11	150	0	0	0	12	60	0	16	0	0	252
12	1 763	0	18	0	138	45	38	0	1 029	1	3 157
13	225	0	8	0	15	4	30	0	15	1	333
14	375	0	40	0	206	96	0	19	121	0	916
15	413	0	595	0	87	96	10	0	0	0	1 223
16	525	0	150	0	70	64	18	15	147	5	1 046
17	619	900	3 574	2 100	0	32	53	0	10	0	8 429
18	675	113	55	0	40	68	28	18	78	0	1 159
19	1 763	0	0	0	12	50	181	49	25	0	2 175
20	188	0	0	0	8	0	59	61	0	0	355
21	50	0	0	0	4	135	128	30	4	0	442
22	13	0	0	0	8	15	26	71	2	0	222
23	44	0	0	0	41	50	22	0	2	0	237
24	125	0	0	0	36	192	32	0	6	0	457
25	140	0	24	0	145	300	157	28	4	0	933
26	7	0	20	0	112	64	10	71	0	0	540
27	0	0	15	0	0	5	55	0	0	0	209
28	5	0	28	0	33	0	14	0	0	0	102
29	184	0	0	0	206	120	211	0	0	0	771
30	555	0	0	0	195	35	134	28	14	0	1 028
31	50	0	17	0	156	3	106	46	12	0	530
32	120	0	6	0	48	0	55	25	4	1	315
33	561	0	12	0	252	0	38	126	30	0	1 081
34	19	0	10	0	914	7	99	111	35	0	1 253
35	650	0	10	0	159	5	22	417	84	0	1 423
36	312	0	11	0	2	20	69	431	64	0	959
37	975	0	10	0	375	18	6	230	95	0	1 866
38	524	0	0	0	130	0	19	127	60	0	1 030
39	27	0	5	0	160	0	20	57	18	1	535
40	6	0	0	0	0	0	0	0	4	0	29
41	2	280	25	0	0	0	0	0	12	0	524
42	11	0	15	0	45	0	14	50	0	0	260
43	0	480	74	3 120	0	0	28	87	14	8	4 233
44	3	6 970	296	260	0	0	20	35	4	0	8 008
45	0	0	209	0	3	0	0	84	0	1	346
46	0	2	72	0	18	0	0	0	2	30	163
47	0	15	10	3	2	0	0	0	0	15	162
48	2	200	118	0	0	0	0	0	8	20	1 498
49	35	140	321	0	0	0	10	0	44	800	1 794
50	52	336	195	0	0	12	0	0	14	175	1 094
51	7	272	882	0	0	14	0	0	68	10	1 596
52	5	112	661	0	0	8	0	0	48	5	1 361
53	0	80	27	0	0	3	0	0	0	1	278
54	0	232	194	0	0	5	0	0	2	1	883
55	2	240	110	0	0	2	0	12	2	0	660
56	32	448	32	0	0	15	12	0	0	1	815
57	176	296	122	0	0	3	0	0	0	1	927
58	8 438	3 638	0	0	214	0	74	0	5 792	0	18 264
59	64	0	46	0	27	0	0	0	0	140	359
60	512	0	15	0	7	0	27	13	2	20	639
61	386	0	678	0	5	0	66	0	2	0	1 162
62	376	0	38	0	24	0	17	0	24	1	542
63	990	16	95	0	1	0	0	17	38	0	1 184
64	729	4	228	0	28	0	19	0	74	1	1 123
65	1 152	32	76	0	30	0	0	0	34	0	1 339
66	895	27	53	0	37	0	6	0	108	0	1 764
67	5 552	3 725	124	0	221	0	43	0	1 764	0	12 492
68	732	253	13	0	114	3	30	0	128	0	1 321
69	717	380	93	0	210	3	44	17	156	0	1 690
70	2 786	0	813	0	175	3	15	15	1 147	0	5 047
71	787	0	390	0	599	1 600	16	17	147	2	3 793

Appendix 2—*continued*

Station No.	Date	Start Position ° 'S	Start Position ° 'W	Start time (h)	Start depth (m)	Tow Stratum No.	Tow length (n. mile)	Wingspread (m)
72	16/12/85	44 06.8	176 53.2	1142	164	5	3.0	34.2
73†	16/12/85	44 03.0	176 57.3	1258	167	5	2.8	34.2
74	16/12/85	44 04.2	177 00.1	1432	179	5	3.0	33.1
75§	16/12/85	44 06.5	176 59.0	1555	196	9	13.5	34.5
76	17/12/85	43 57.1	176 50.0	0522	124	5	3.0	27.1
77	17/12/85	44 04.7	176 45.2	0717	125	5	3.0	28.8
78	17/12/85	44 06.7	176 48.5	0900	141	5	3.0	31.7
79	17/12/85	43 57.3	176 54.8	1112	138	5	3.0	30.5
80	17/12/85	44 08.1	176 54.7	1251	178	5	3.0	32.5
81	17/12/85	44 15.3	176 53.3	1422	262	9	3.0	31.7
82	17/12/85	44 16.7	176 49.2	1541	194	5	3.0	33.9
83	17/12/85	44 17.8	176 41.7	1656	224	5	3.0	33.9
84	18/12/85	44 02.0	176 10.8	0500	55	2	3.0	30.5
85	18/12/85	44 02.3	176 05.9	0657	72	2	3.0	32.5
86	18/12/85	44 05.0	175 55.7	0832	81	2	3.0	32.2
87	18/12/85	43 35.8	176 09.8	1128	143	3	3.0	31.1
88	18/12/85	43 41.2	176 14.9	1308	84	1	3.0	34.8
89	18/12/85	43 40.8	176 21.2	1426	64	1	3.0	30.2
90§	18/12/85	43 30.7	176 27.8	1704	124	3	11.8	32.8
91	19/12/85	43 50.2	176 13.6	0508	87	2	3.0	33.4
92	19/12/85	43 53.5	176 07.2	0640	100	2	3.0	32.5
93	19/12/85	43 54.2	176 08.2	0803	99	2	3.0	32.5
94	19/12/85	43 54.7	176 12.0	0940	84	2	3.0	33.4
95	19/12/85	44 04.0	176 12.6	1134	60	2	3.0	32.5

* Species codes are given in Appendix 1.
† Foul shot.
‡ Not recorded.
§ "Commercial" tow.

Appendix 2—*continued*

											Catch (KG)
Station No.	BAR*	HOK	SWA	RHY	TAR	SPD	HAP	SCH	JMA	SDO	All species
72	1 650	0	50	0	136	160	37	35	146	1	2 312
73	200	0	88	0	96	96	25	0	42	0	588
74	589	0	91	0	196	96	11	0	38	0	1 124
75	5 350	6 788	298	0	221	0	255	0	2 881	0	16 179
76	825	0	1	0	210	640	33	0	0	0	1 832
77	712	0	24	0	131	320	18	25	2	0	1 259
78	262	0	0	0	140	256	24	28	0	0	756
79	464	0	7	0	94	1 600	18	0	4	0	2 259
80	842	0	110	0	123	70	17	0	60	1	1 291
81	352	2 620	82	0	12	320	0	0	235	0	3 689
82	562	2 656	63	0	49	0	10	0	156	1	3 917
83	487	0	0	0	66	24	14	34	161	2	851
84	5 545	0	0	0	0	480	82	156	14	0	6 407
85	3 600	0	0	0	240	96	64	107	16	0	4 215
86	2 860	0	0	0	225	27	75	251	2	0	3 504
87	756	0	35	0	495	21	68	13	106	1	1 641
88	838	0	15	0	28	0	100	235	24	0	1 421
89	1 020	0	1	0	52	24	56	61	2	0	1 433
90	3 200	0	32	0	471	0	0	0	1 058	0	4 828
91	1 259	0	0	0	1 536	480	93	70	0	0	3 540
92	1 395	0	4	0	244	320	167	57	20	0	2 367
93	2 790	0	1	0	1 444	320	332	35	26	0	5 098
94	2 903	0	3	0	11	480	272	78	88	0	3 972
95	5 530	0	0	0	20	0	161	189	30	0	5 990

Appendix 3

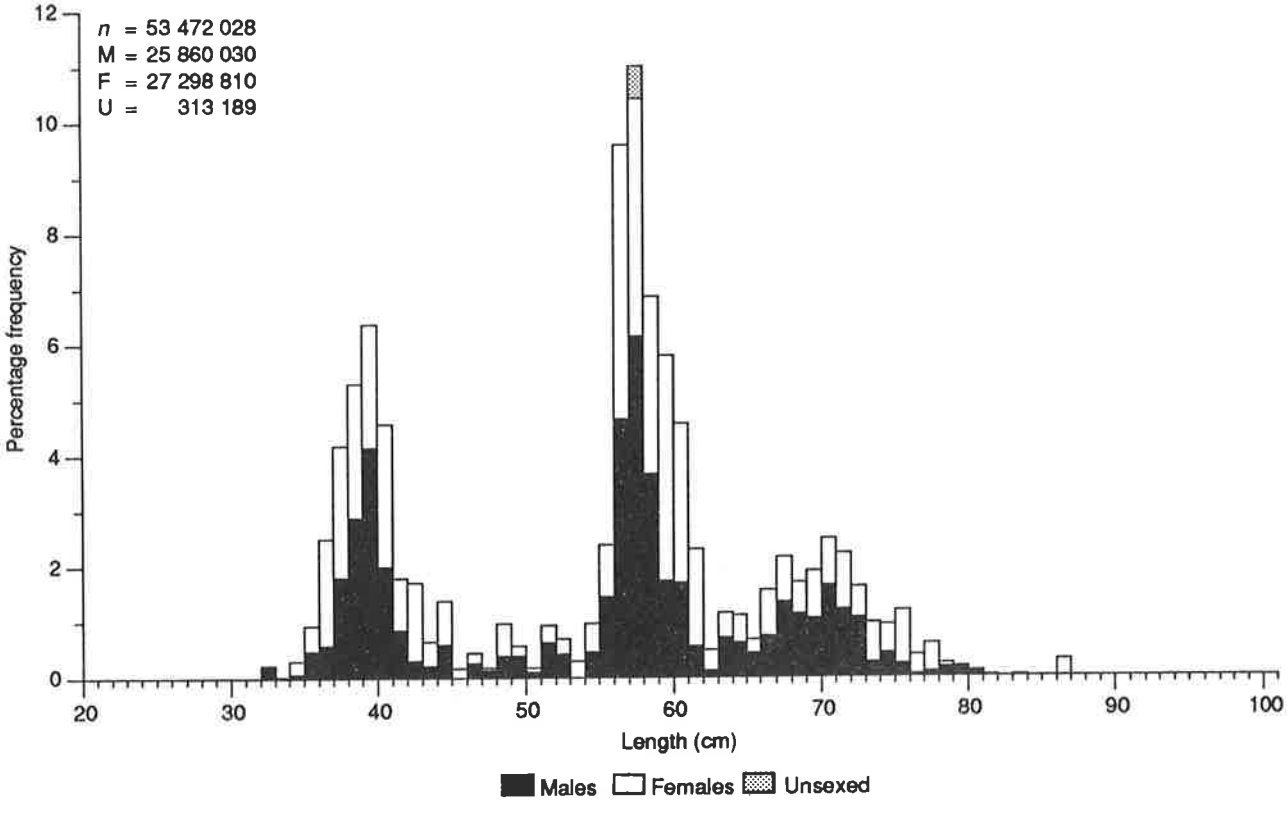
Recalculated December 1984 wingspread biomass estimates (t), by use of 1985 stratum areas, for eight species given in Figure 24

Stratum	BAR*	HOK	SWA	RHY	TAR	HAP	SPD	SCH
1	1 833	0	35	0	120	722	126	214
2	5 527	0	0	0	90	547	0	440
3	1 748	0	100	0	1 009	225	0	186
4	9 508	0	200	0	151	49	80	31
5	7 992	505	306	0	762	191	3372	80
6	2 988	0	141	0	635	808	48	196
7	0	781	260	334	448	285	0	76
8	5 666	116	1 435	4 222	75	33	0	10
9	6 353	4	3 616	0	107	62	78	25
10	34	296	48	4	114	143	5	49
11	22	5 149	881	139	87	264	0	121
12	760	2 599	1 633	527	3	33	0	34

* Species codes are given in Appendix 1.

Appendix 4

Length frequency of barracouta from around the Chatham Islands, July 1986 (scaled by percentage sampled, wingspread area swept, and stratum area; *n* = estimated population size)



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