Results of a trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1984

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Errata:

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Table 4, page 13.
The biomass estimate for all species should be 107 934, not 197 934.

Table 20, page 35.
The biomass and c.v. figures for *Akebono Maru No. 73* are incorrect. Please replace the figures with the corrected figures on the adhesive paper below.

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Inquiries to:
The Editor,
Fisheries Research Centre,
P.O. Box 297,
Wellington,
New Zealand.

Edited by
S. J. Baird
and
G. G. Baird

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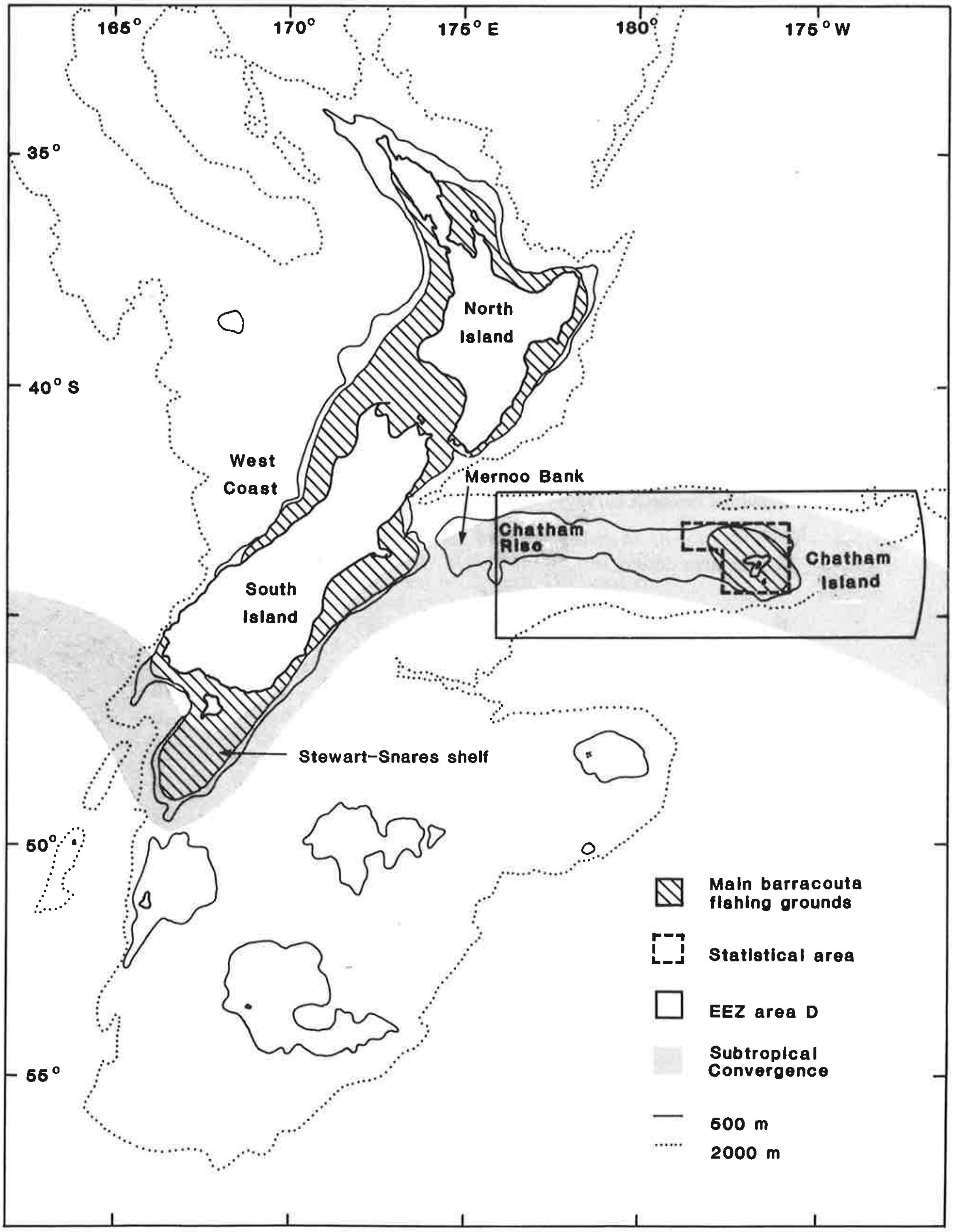

Fig. 1: Main barracouta fishing grounds around New Zealand and places and statistical areas mentioned in the text.

Abstract

Hurst, R. J., and Bagley, N. W. 1987: Results of a trawl survey of barracouta and associated finfish near the Chatham Islands, New Zealand, December 1984. *New Zealand Fisheries Technical Report No. 3.* 44 p.

A three-phase, random trawl survey of the Chatham Islands shelf in December 1984 caught 56 species of fish, squid, and crustaceans. The catch and estimated biomass of the 20 major species are given with more detailed results for the 10 major species of relative changes in distribution and abundance between area, depth, and phase of the survey. The main species caught were barracouta, silver warehou, and common roughy; though hoki replaced common roughy as the third most abundant species in terms of estimated biomass. Possible sources of bias in the estimation of biomass are discussed.

Biological data presented on barracouta include length, weight, age, gonad state, feeding, and incidence of flesh parasites. Some of these data (length frequency, age, and gonad state) suggest that barracouta around the Chatham Islands are a separate spawning "stock" from mainland fish. Length-frequency data for 10 other commercially important species are also given.

Introduction

Barracouta, *Thyrsites atun* (Euphrasen, 1791), are semipelagic fish found in temperate shelf waters around New Zealand, down to 400 m (Fig. 1). They are most abundant in southern waters of the South Island, on the Stewart-Snares shelf, and around the Chatham Islands, where they are one of the dominant shelf species. Reported annual catches from 1980 to 1984 averaged 25 000 t, which ranked barracouta in the top three finfish species landed by domestic vessels and the top four or five caught by deepwater (foreign-licensed and foreign-chartered) vessels.

In October 1983, total allowable catch (TAC) controls were applied to the barracouta fishery, under the deepwater trawl policy. This was done primarily to stop any overflow effects of the introduction of the deepwater policy on to the barracouta fishery in areas where it was felt there was no potential for increased exploitation (Hurst 1983). Biomass estimates, from research surveys, and commercial data were available for most areas as a basis for the recommended TACs. However, only commercial data from foreign-chartered and foreign-licensed vessels were available for the fishery around the Chatham Islands. The variable annual fishing effort and the short fishing history in the area precluded any analysis of trends in catch per unit of effort (CPUE), which may have indicated the health of the fishery.

The only research surveys before 1984 that provided estimates of fish abundance near the Chatham Islands were those by two foreign research vessels, *Wesermünde* and *Shinkai Maru*, in 1979 and 1983 respectively (Francis 1981, Fenaughty and Uozumi in press, Hatanaka *et al.* [1985]). Both these vessels were excluded from the 12 n. mile territorial sea and the surveys provided little information on the general distribution and abundance of barracouta or other shelf species in the region.

This report presents the results of a random trawl survey of the Chatham Islands shelf from 2 to 16 December 1984. The survey had two main aims: to estimate the abundance and map the distribution of barracouta and associated finfish species in 50–400 m and to collect biological data on the most important commercial species. *Akebono Maru No. 73* was used under a charter-for-quota arrangement with Feron Seafoods Limited, Timaru.

Domestic inshore fishery

Development of the domestic inshore fishery at the Chatham Islands has always been influenced by the distance from mainland markets and freight costs.

The blue cod (*Parapercis colias*) line fishery was the mainstay of the Chatham Islands domestic fishing industry from early this century until the rock lobster (*Jasus edwardsii*) boom during the 1960s. As the rock lobster fishery developed, blue cod landings fell sharply, from 742 t in 1965 to 13 t in 1966 (Table 1). Domestic fishery statistics show that wetfish landings were low during the rock lobster boom (1966–73). Much bait was required by rock lobster fishermen during these years, but there are no records of the quantities or species taken. Bait species probably included blue cod, groper (which included hapuku (*Polyprion oxygeneios*), bass groper (*Polyprion moeone*), and bluenose (*Hyperoglyphe antarctica*)), stargazer (*Kathetostoma giganteum*), tarakihi (*Nemadactylus macropterus*), gurnard (*Chelidonichthys kumu*), and barracouta (R. Brown pers. comm.). It was not until 1983 that the total recorded catch of wetfish again exceeded 100 t per year. Before 1983, fish caught at the Chatham Islands, but landed back into mainland New Zealand, were not itemised in the domestic statistics.

The domestic fishery is now based on rock lobster potting and handgathering of paua (*Haliotis iris*). Blue cod are the main finfish caught, mainly by potting (94%). The amount of trawling varies; catches totalled 93.2 t in 1983, but only 0.8 t in 1984. Set netting accounts for little of the fish landed. Fish that are taken for use as rock lobster bait are still not recorded on domestic fishing returns.

Deepwater fishery

Unlike domestic inshore vessels, deepwater vessels have extensively trawled the Chatham Islands shelf and slope since at least 1977. This shelf region is part of the Exclusive Economic Zone (EEZ) area D, which includes several different fisheries over a wide range of depths. A smaller statistical area was defined here to enable the estimation of deepwater vessel catches in about the same shelf region as the research survey area (*see* Fig. 1). Deepwater catches in this area and in area D are

TABLE 1: Annual catch (t) by domestic vessels at the Chatham Islands*

Year†	Blue cod	Groper‡	Stargazer	Tarakihi	Eel	Other§	Total wetfish	Rock lobster	Paua
1930	628						628		
1935	1 196‖	70					1 267		
1940	320‖	9					329		
1945	102	3					106		
1950	485	9					494		
1955	355	26					381		
1960	903	48				–¶	952		
1961	871	50				1	923		
1962	550	40				1	592		
1963	633	56				2	691		
1964	495	41				1	537		
1965	742	68				1	810	2	
1966	13	4					17	1 271	
1967								3 313	
1968						1	1	5 958	
1969	8	–					8	4 147	5
1970	40	– 2			24		64	1 751	30
1971	36	4			3		44	1 211	147
1972	4	–			2		6	1 088	80
1973	5	–					5	1 033	135
1974	1	2	7	24		27	60	518	96
1975	2	2	3	7		25	39	331	130
1976	17	13	10	17		2	59	391	245
1977	46	7		3		3	59	303	341
1978	14	8	1	6		7	36	293	85
1979	13	2			24	1	40	391	59
1980	1	1		–	11		13	342	175
1981	40	10	–	–	1	5	56	459	313
1982	13	9			2	5	28	417	219
1983	178	16	54	20		31	301	553	200
1984	241	15	–	1		28	284	491	401

* Data sources: 1930–71, N.Z. Marine Department annual report on fisheries; 1972–73, N.Z. Ministry of Agriculture and Fisheries annual report on fisheries; 1974–82, King (1985). The rock lobster data are from Sanders (1984).

† 1930–50, years ending 31 Mar; 1955–84, years ending 31 Dec.

‡ Includes hapuku, bass groper, and bluenose.

§ Predominantly rig, school shark, gurnard, and moki.

‖ Includes fish shipped direct to Wellington by the fish carrier *Southseas.*

¶ Less than 0.5 t per year.

given in Table 2. Before the introduction of the 200 n. mile EEZ in April 1978, the Chatham Islands area did not appear to have had a long history of exploitation by foreign vessels. The only available detailed information on foreign fishing for this period is for the Japanese trawl fleet, and this was analysed for the statistical area approximating the survey area for the 1977 calendar year.

Japanese catches in area D were insignificant until 1977–78, when 29 543 t were reported, 44% of which was warehou (*Seriolella* spp.). (Warehou were not listed by species until 1978–79, but analysis of recent catch composition data suggests that most were silver warehou (*S. punctata*), with a smaller quantity of white warehou (*S. caerulea*). Common warehou (*S. brama*) are rarely recorded by deepwater vessels in the region.) Comparison of the 1977–78 area D and 1977 Chatham Island catches, and similar data for 1983–84, suggests that most of the barracouta and tarakihi in area D came from around the Chatham Islands.

Deepwater fishing in this region has been extremely erratic since 1977. The amount of effort, the major targeted species, and the months of fishing have all varied because of the effect of fishing in other parts of the EEZ; for example, the major hoki (*Macruronus novaezelandiae*) fishery in area G in winter, the arrow squid (*Nototodarus sloanii*) fishery in areas E and F in summer, and, recently, the orange roughy (*Hoplostethus atlanticus*) fishery on the Chatham Rise in winter.

The major trawl fishing season around the Chatham Islands is usually November-February. However, in 1979 and 1983, fishing extended into winter, and good catches of squid and barracouta were recorded from the western side (Hurst in press).

Deepwater vessels fishing around the Chatham Islands are excluded from the 12 n. mile territorial sea. This restricts the area in which they can catch shelf species such as barracouta. Other, more inshore species, such as tarakihi and hapuku, appear to be mostly caught as by-catch of barracouta and arrow squid target fishing. However, the increase of the deepwater catch of tarakihi in 1983–84 suggests that some target fishing on this species may be possible by these vessels. Species such as hoki and hake (*Merluccius australis*), which are usually found in deeper water, are taken at the shallow edge of their range in the statistical area.

Changes in annual catches in the Chatham Islands area from 1977 to 1983–84 included a decline in warehou (mainly silver warehou), partly due to the introduction of a silver warehou limit in area D, and an increase in hoki, ling (*Genypterus blacodes*), and red cod (*Pseudophycis bachus*). Stargazer were not specified in 1977, and tarakihi catches have increased to the 1977 level. However, when area D figures are compared the 1983–84 catches are below the 1977–78 levels, except for red cod, hake, and possibly stargazer.

Previous research surveys

Finfish research surveys around the Chatham Islands have not been extensive. In 1907 the Government-chartered steam trawler *Nora Niven* carried out a trawl survey of the east coast of New Zealand that included seven trawl stations around the Chatham Islands and some line fishing (Waite 1909).

The first detailed research survey in the area was carried out by *James Cook* in November 1972. Fourteen trawls were completed in the 46–179 m depth range as part of a research programme on growth and mortality in lightly exploited tarakihi populations (Vooren 1977). Parasite infection levels of tarakihi were also recorded (Vooren and Tracey 1976).

In 1979, three stratified random bottom-trawl surveys were conducted on the main EEZ deepwater trawl grounds by *Wesermünde* (Francis

TABLE 2: Deepwater catches (t) of the main species in the Chatham Islands area (as defined in Fig. 1), 1977 to 1983–84*

	Chatham Islands								EEZ area D	
Species	1977†	1978–79	1979–80	1980–81‡	1981–82	1982–83	1983	1983–84	1983–84	1977–78†
Arrow squid	1 000	48	902	142	17	257	4 223	861	902	2 106
Barracouta	2 495	17	5 905	457	305	2 996	686	1 552	1 743	8 732
Hake	2	–§	178	53	309	10	18	29	172	51
Hapuku	–	8	109	9	8	23	5	33	38	–
Hoki	358	26	1 667	183	90	373	148	661	2 537	3 306
Ling	30	1	56	18	14	26	14	155	352	446
Red cod	46	–	49	4	–	27	15	126	506	257
Stargazer	–	10	88	20	20	60	56	146	209	–
Tarakihi	256	72	518	27	49	109	14	267	287	832
Warehou	1 142	150	356	101	150	304	57	129	647	12 913
Silver	–	150	334	74	133	292	54	117	606	–
Common	–	–	4	1	13	2	3	2	8	–
White	–	–	18	26	4	10	–	10	33	–

* 1977, 1 Jan-31 Dec; 1977–78 to 1982–83, 1 Apr-31 Mar; 1983, 1 Apr-30 Sep (6 months only); 1983–84, 1 Oct-30 Sep.

† Japanese data only.

‡ 1980–81 data unedited.

§ Species not recorded.

1981). However, there were only six trawl stations in the 200–400 m depth zone around the Chatham Islands.

The most recent research surveys in the area were two *Shinkai Maru* random trawl surveys on the Chatham Rise in March and November-December 1983 (Fenaughty and Uozumi in press, Hatanaka *et al.* [1985]). Preliminary biomass results from these and surveys of the west and east coasts of the South Island were summarised by Hurst and Fenaughty (1985). Both surveys were excluded from the 12 n. mile territorial sea and, therefore, could not sample extensively in less than 200 m. There were only nine stations in less than 400 m at the Chatham Islands on both surveys, and this resulted in the low precision of the abundance estimates of shelf species, particularly barracouta, tarakihi, and hapuku.

Methods

Survey area design

The survey area included the 50–400 m depth range around the Chatham Islands and the 12 n. mile territorial sea (Fig. 2). Initially, the survey was planned to cover 20 878 km² (Fig. 3), but this had to be reduced during the survey because of foul ground and possible gear conflicts with rock lobster potting. The resulting area surveyed was 16 367 km².

The survey was designed as a two-phase, stratified random trawl survey (after Francis 1984). The survey area was subdivided by depth (50–99, 100–199, and 200–399 m) and locality into eight strata. For phase 1, 57 random stations were chosen from a computer-generated list, and there was a minimum of 3 n. miles between them. Stations were allocated with a 2 : 1 weighting for strata in the 100–199 m depth range. This weighting was based on the results from barracouta trawl surveys elsewhere around New Zealand (Hurst and

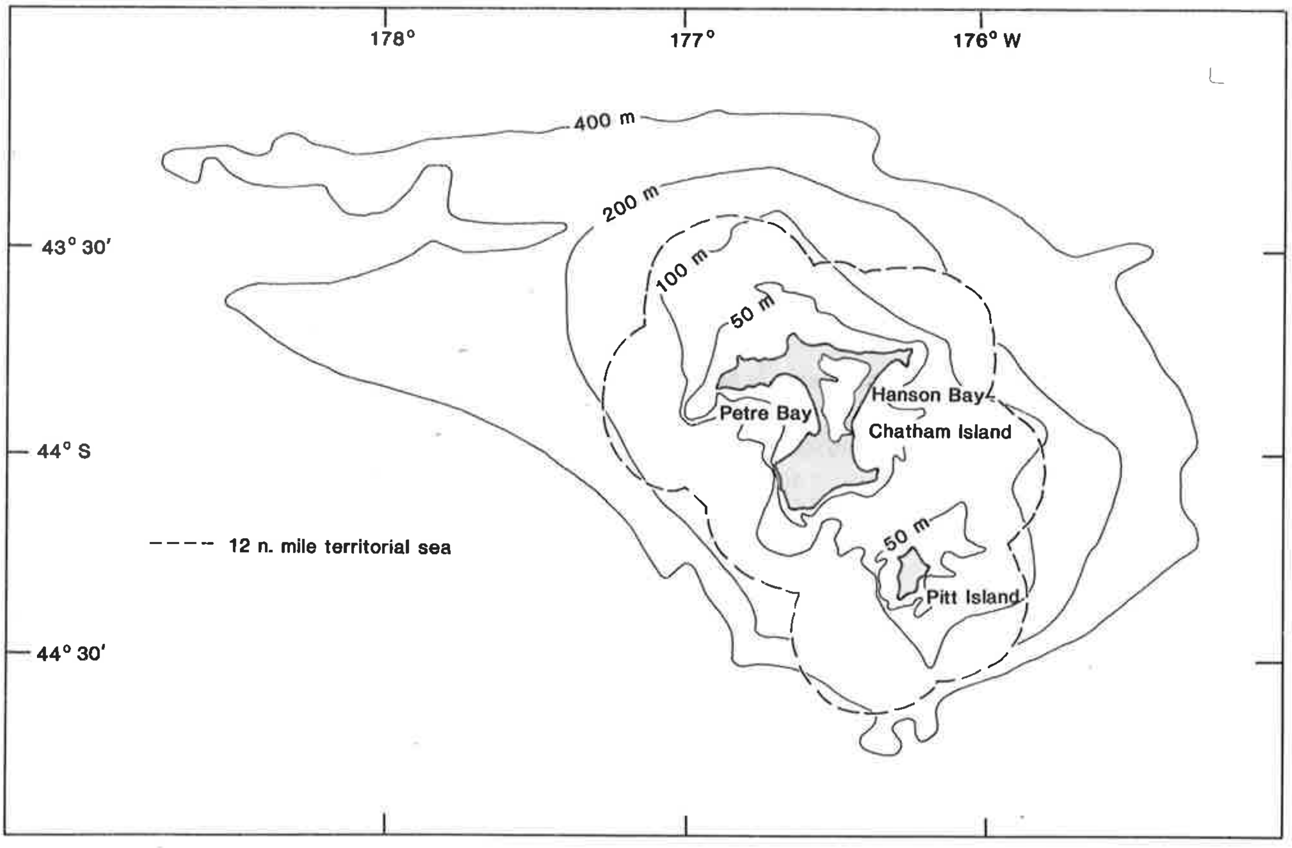

Fig. 2: The Chatham Islands survey area.

Bagley 1984b, Hurst and Fenaughty 1985). If trawlable bottom was not available within a 2 n. mile radius of the original station position, substitute stations were chosen from the next station on the list for that stratum. Stratum areas were revised during phase 1 to exclude unsuitable ground.

In phase 2, stations were allocated according to the mean-squared algorithm of Francis (1984). On completion of this phase there was time available for further stations to be surveyed as a third phase. The same algorithm was applied to catch rates from the first two phases for the allocation of stations in phase 3. The boundary between strata 4 and 7 was redefined at about the 275 m depth contour (Fig. 4), so that there was no need for extra stations in stratum 7, which had only one large catch of barracouta (in 192–242 m). New random stations were generated by placing a 3 n. mile grid over the redefined stratum 4 (4′) and randomly selecting grid intersection numbers.

Vessel

Akebono Maru No. 73 is a Japanese stern trawler operated by Nichiro and Feron Fisheries (now Nichiro Sanford Fisheries (NZ) Limited) based at Timaru. It has the following specifications: overall length, 107 m; beam, 15.5 m; tonnage, 2985 GRT; horsepower, 7200. It had no facilities for recording detailed hydrological information, but had a Furuno NR200 net monitor, which was used to record bottom temperatures, a JRC JLE-3100 satellite navigator, and a Marayama Denki Limited surface temperature recorder (sensor mounted 4 m below the surface).

Net features

A six-panel bottom trawl with a 100 mm mesh cod-end was used throughout the survey. The high-aspect trawl doors were 13.8 m^2, with 114 m long sweeps and 60 m long bridles. The groundrope rig consisted of 0.65 m high rubber tyres in the centre of the trawl, rubber bobbins along each wing, and a steel danleno on each lower wingtip. The height of the groundrope may have allowed some escapement of species found hard down on the sea floor.

The mean headline height recorded from 84 stations, by use of a net recorder, was 6.6 m (range 5.5 to 9.5). Wingspread was calculated, when sea conditions allowed, from measurements of the distance between the trawl warps at the stern rollers and the angle of the warps (after Koyama 1974). These measurements gave an average wingtip distance of 36.2 m (range 26.2 to 48.9) (n = 84). This distance was used rather than individual station records because of the inherent inaccuracy of the measurement method.

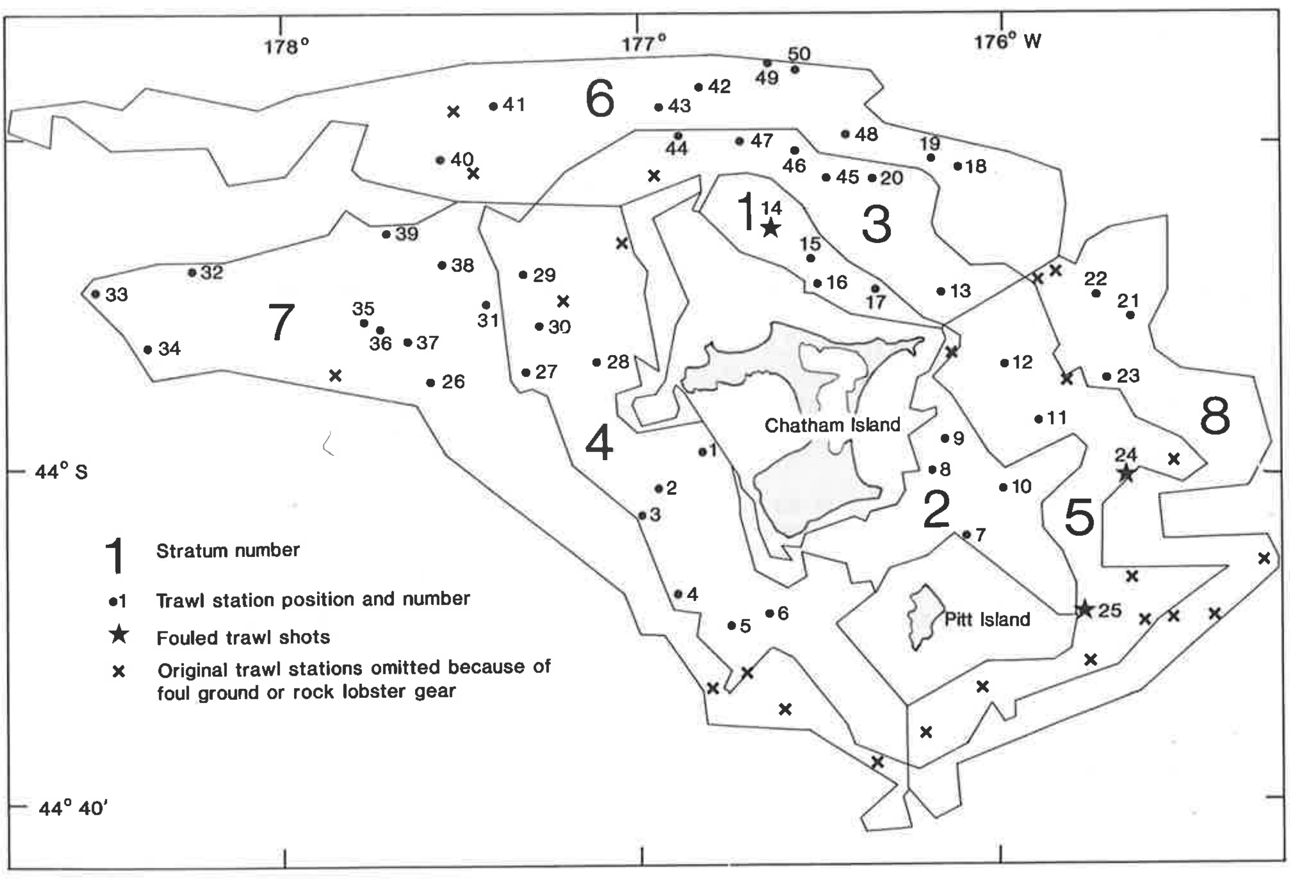

Fig. 3: Phase 1 strata and stations.

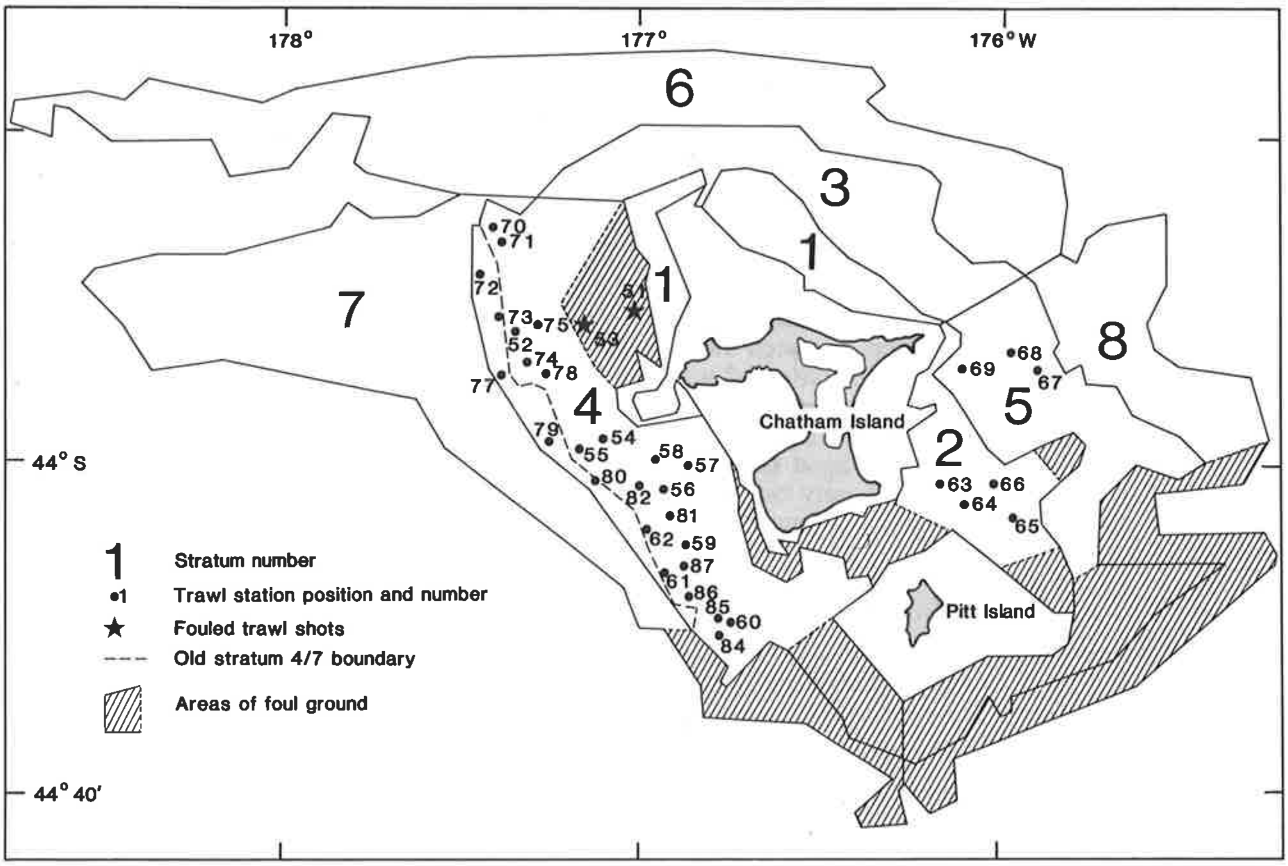

Fig. 4: Phase 2 (No. 51–69) and phase 3 (No. 70–87) stations.

Trawl procedure

All nearshore positions were determined by radar. Positions more than 30 n. miles from shore were determined from the satellite navigator. The gear was shot within 2 n. miles of the station and towed through it when possible. All shots were carried out between 0500 and 1900 h New Zealand Standard Time. A tow length of 3 n. miles was aimed for and it was timed from when the gear reached the bottom to the start of hauling. Tow length averaged 3.0 n. miles (range 2.8 to 3.2) and tows averaged 42.3 min (range 35.0 to 50.0). The towing speed averaged 3.8 kn (range 2.9 to 5.0 — some of the variability was due to differences in tidal currents).

Some data suggest that 3 n. miles is an acceptable tow length for barracouta surveys. The response of barracouta to the trawl was observed in September 1985 from FRV *Kaharoa*, and it was found that the fish tired after about 5 min of swimming between the wingtips and were overtaken by the net (G. J. Patchell pers. comm.). Experimentation with towing times on a random trawl survey conducted by *Shinkai Maru* in 1981 found no evidence of an increase in catch rate with a tow length greater than 3.5 n. miles (Robertson, Grimes, and Francis 1982).

However, at the end of the cruise, four "commercial" tows were carried out to compare research and commercial catch rates. These tows were done at stations which had the highest barracouta research catch rate of that day and were 3.0–4.3 h (12.9–18.2 n. miles) long.

Catch size estimation

All catches were examined in the hold area. Catch composition and weights were estimated "by eye". Barracouta from each tow were processed separately, and the actual catch weight was back-calculated from product weight; the conversion factor of $GW = 1.5PW$, where GW is green weight and PW is product weight, was satisfactory. Weights of by-catch species were estimated by the same method, but some species which were regularly measured (e.g., tarakihi, arrow squid, and silver warehou) were also estimated from known fish box weights. The lengths of hapuku were recorded, but the weights were back-calculated from the length-weight relationship found by Johnston (1983), because fish in good condition were tagged as soon as possible and then released.

Biomass estimation

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

$$B = \sum(X_i a_i)/cb$$

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

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 (the proportion of fish in the water column which is caught), 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:

1. The effective sea bed area swept was the distance between the wings of the net. It has been standard practice to use this measurement in the presentation of New Zealand trawl survey results (*see* Hurst and Fenaughty 1985, Robertson, Grimes, and McMillan 1984) and its use here provided some comparability; however, it makes no allowance for the possible herding effects of the doors and sweeps.
2. The catchability coefficient was assumed to be one. Therefore, the vulnerability of all fish encountered by the net was 100%, and there were no fish above the headline. The accuracy of this assumption is difficult to estimate in a mixed species fishery.
3. Escapement was assumed to be zero. Therefore, all fish were assumed to be caught once they passed between the wings. This would not hold for smaller fish, but escapement is difficult to estimate without extensive mesh selection trials.

Biomass estimates were made by use of the stratum areas defined in Table 3: phase 1, phases 1 + 2 (areas as for phase 2 after the foul ground found during phase 1 was omitted), and phases 1 + 2 + 3 (areas as for phase 2, but including the new strata 4 (4′) and 7 (7′) boundary).

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, whole weight (± 50 g), sex, gonad stage (six stages: 1, juvenile; 2, first maturation or resting; 3, maturing; 3B, maturing, but had already released at least one batch of eggs; 4, mature; 5, running ripe; 6, spent), gonad weight (± 1 g), stomach fullness and degree of digestion, and stomach contents.

Barracouta otoliths were collected from five fish of each sex to construct an age-length key. Otoliths were read whole, immersed in paraffin oil.

Flesh parasite counts were made on barracouta 75 cm or longer, on the left fillet only (right and left fillets are equally infected), to enable comparisons with samples collected elsewhere in New Zealand as part of a study on stock identification.

Length and sex data were also collected on the following commercially important species: tarakihi, silver warehou, white warehou, hapuku, alfonsino (*Beryx splendens*) (fork length); hoki and hake (total length); and arrow squid (mantle length). Additional data collected from tarakihi were individual weight and gonad state, and otoliths were taken for aging. General observations were also made on the spawning condition and stomach contents of species measured.

Results

Survey area

Extensive areas of unsurveyable ground necessitated the redefinition of strata 2, 4, 5, and 8. Fifteen of the original planned stations in phase 1 had to be substituted for and 10 were omitted. Problems with incorrect bathymetry resulted in some stations being outside the designated depth range. The original survey design was followed, even though seven stations exceeded 400 m in depth (maximum 435 m). A total of 89 trawl stations was completed, 80 were successful biomass assessment stations, 5 were fouled (Figs. 3 and 4), and 4 were targeted barracouta commercial shots (No. 76, 83, 88, and 89). The redefined survey area was 16 367 km^2 in eight strata, and the station density was one per 205 km^2 (range per stratum 1 : 78 to 1 : 461) (Table 3). Individual station data for the 10 major species are given in Appendix 1.

Catch composition

Fifty-six species were recorded: 37 teleosts, 11 elasmobranchs, 3 squid, 4 crustaceans, and 1 agnathan (Appendix 2). Barracouta dominated the catches in the 50–249 m depth range, but were rare at deeper stations, where hoki predominated. The catch and biomass compositions of the 20 major species taken at biomass assessment stations are given in Table 4. Of the total catch of 190.2 t, barracouta constituted 54.3%; silver warehou, 11.2%; and common roughy (*Paratrachichthys trailli*), 10.8%.

Species distribution

Catch rate data are expressed as kilograms per square kilometre (kg.km^{-2}), the unit of measurement used to calculate biomass indices. The mean catch rate during the biomass survey was 11.7 t.km^{-2} (range 1.3 to 214.5), and the largest catch was an estimated 20 t of common roughy from stratum 4′. Catch composition and rates varied between areas, depths, and phases of the survey. For individual stations the actual catch per tow (i.e., kilograms per 3 n. miles trawled) is given for the eight major species (excluding common roughy, which only occurred in seven trawls) in Figs. 5–12. Individual catches of the 10 major species are given in Appendix 1. Means and standard deviations of catch rates by stratum are given in Appendix 3.

The area to the west of the Chatham Islands had the greatest abundance of several species, particularly barracouta, silver warehou, and spiny dogfish (*Squalus acanthias*). Catches in the northern area were generally small, though the largest single catches of hoki and tarakihi came from this region. In the eastern area, high catch rates of barracouta, arrow squid, school shark (*Galeorhinus australis*), and hapuku were recorded during phase 1, but they dropped during phase 2.

Tarakihi, hapuku, and spiny dogfish were predominant in shallow water (50–99 m); barracouta, silver warehou, and arrow squid in middle depths (100–249 m); and hoki in deeper water (250–450 m).

Catch rates of the major species are given by phase and stratum (Table 5) and by depth (Table 6). Barracouta were the most abundant species in strata 1–5 in all three phases of the survey and generally in all 50 m depth intervals from 50 to 299 m. Catch rates of barracouta in the survey area are shown in Fig. 5. Mean catch rates were consistently high in stratum 4 (and 4′) in all phases (range 8.9 to 13.7 t.km^{-2}), but a high mean catch rate of 13.4 t.km^{-2} was also recorded from stratum 2 in phase 1, in 50–99 m. The drop to 1.3 t.km^{-2} in phase 2 in this stratum was not statistically significant. Mean catch rates in strata 6–8 and depths 300–450 m were low (less than 1.5 t.km^{-2}). The overall mean catch rate of barracouta during the biomass survey was 6.3 t.km^{-2} (range 0.0 to 35.5).

The distribution of silver warehou in part overlapped that of barracouta on the western side of the Chatham Islands (Fig. 6). However, the mean

TABLE 3: Stratum area and number of stations in each phase of the survey

		Phase 1			Phase 2		Phase 3*		Total		
Stratum No.	Depth (m)	Area (km^2)	No. of stations: Planned	No. of stations: Actual	Redefined area (km^2)	No. of stations	Redefined area (km^2)	No. of stations	Area (km^2)	No. of stations*	Station density (per km^2)
1	50–99	1 045	3	3	658		658		658	3	1 : 219
2	50–99	1 485	4	4	704	4	704		704	8	1 : 88
3	100–199	1 574	6	6	1 574		1 574		1 574	6	1 : 262
4	100–199	3 221	11	10	2 489	10	2 874	16	2 874	37	1 : 78
5	100–199	2 308	8	2	1 469	3	1 469		1 469	5	1 : 294
6	200–399	4 145	9	9	4 145		4 145		4 145	9	1 : 461
7	200–399	4 555	10	10	3 972		3 587		3 587	9	1 : 399
8	200–399	2 544	6	3	1 356		1 356		1 356	3	1 : 452
		20 878	57	47	16 367	17	16 367	16	16 367	80	1 : 205

* The stratum boundary between 4 and 7 was redefined for phase 3 at about the 275 m contour; this resulted in one station from stratum 7 being placed in the new stratum 4 (4′).

TABLE 4: **Major species* composition at the biomass assessment stations**

	Catch			Biomass				
Species	Catch (kg)	% of total (all species)	Mean catch rate (kg.km^{-2})	Lower bound (t)	Biomass estimate (t)	Upper bound (t)	Coefficient of variation (%)	% of total (all species)
BAR	103 244	54.3	6 337	35 179	46 222	57 266	12	42.8
SWA	21 233	11.2	1 276	6 103	10 834	15 565	22	10.0
RHY	20 611	10.8	1 279	0	8 846	24 371	88	8.2
ASQ	11 191	5.9	682	4 305	6 346	8 387	16	5.9
SPD	7 565	4.0	464	0	3 017	6 869	64	2.8
HOK	6 429	3.4	398	4 422	11 113	17 804	30	10.3
TAR	4 868	2.6	298	1 653	4 058	6 463	30	3.8
HAP	3 989	2.1	246	2 750	3 618	4 486	12	3.4
SCH	2 007	1.1	124	993	1 582	2 171	19	1.5
LIN	1 398	0.7	86	1 499	1 990	2 481	12	1.8
STA	1 393	0.7	86	832	1 157	1 483	14	1.1
JMA	1 342	0.7	83	388	1 238	2 089	34	1.2
RBT	732	0.4	44	0	972	2 564	82	0.9
WWA	669	0.4	41	628	1 387	2 145	27	1.3
OPE	552	0.3	33	0	896	2 209	73	0.8
FRO	359	0.2	22	0	504	1 168	66	0.5
BYX	295	0.2	19	1	658	1 315	50	0.6
LDO	275	0.1	17	449	565	681	10	0.5
SPE	236	0.1	14	277	423	570	17	0.4
BNS	200	0.1	11	173	364	555	26	0.3
All species	190 176		11 674	85 630	~~197 934~~ 107934	130 237	10	

* Species codes are given in Appendix 2.

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

	BAR	HOK	SWA	RHY	ASQ	TAR	HAP	SPD	LIN	SCH
Phase 1										
1	2 768	0	52	0	116	180	1 091	191	41	323
2	13 431	0	0	0	1 262	127	1 119	0	0	845
3	1 450	249	157	83	439	881	260	0	25	152
4	8 914	503	149	0	1 030	461	88	2 959	11	94
5	5 135	0	0	0	1 069	442	669	0	47	146
6	6	1 511	251	58	116	110	86	0	135	47
7	1 359	796	536	185	213	3	17	0	188	11
8	61	539	86	8	246	207	257	8	307	91
Phase 2										
2	1 307	0	0	0	6	110	340	0	0	320
4	9 439	0	972	0	646	436	199	674	41	69
5	685	0	174	0	47	522	583	58	8	149
Phase 3										
4′	13 704	135	5 080	6 215	1 472	249	83	6	124	14
Commercial										
4′	13 429	1 660	1 041	0	1 663	263	126	0	0	0

* Species codes are given in Appendix 2.

catch rates per stratum were low (less than 1 t.km^{-2}) until phase 3, when silver warehou were the third most abundant species (5.1 t.km^{-2}). This mean catch rate in the last phase is significantly greater than the phase 2 ($p < 0.05$) and phase 1 ($p < 0.01$) stratum 4 catch rates. It is not known whether this was due to movement of silver warehou into the area during the survey or to increased sampling at their preferred depth range (200–249 m). The overall mean catch rate was 1.3 t.km^{-2} (range 0.0 to 16.5).

Similarly, the highest catch rate for common roughy occurred in phase 3 in stratum 4′. Mean catch rates in all other strata in phases 1 and 2 were very low (less than 0.2 t.km^{-2}). The high overall mean catch rate in phase 3 was entirely due to one 20 t catch.

Arrow squid were caught in all depths and at most stations sampled (Fig. 7). Their distribution resembled that of barracouta, though mean catch rates of arrow squid by stratum were usually lower (less than 1.5 t.km^{-2}). The highest catch rates occurred in strata 2–5, in depths of 100–299 m. As for barracouta, stratum 2 had the highest stratum mean catch rate during phase 1, though there was a significant drop in phase 2 ($p < 0.05$). The overall mean catch rate was 0.6 t.km^{-2} (range 0.0 to 9.4).

Spiny dogfish were more common on the western side of the Chatham Islands (Fig. 8), but catch rates were low except for one large catch (46.3 t.km^{-2}) in the shallower water close to Petre Bay. The other important species which were mainly distributed in shallow waters were tarakihi, hapuku, and school shark (Figs. 9–11). Tarakihi mean catch rates were highest in 100–149 m, in strata 3, 5 (north-east), and 4 (south-west). Hapuku and school shark were most abundant in

TABLE 6: Mean catch rates (kg.km^{-2}) by depth for the 10 major species*

Depth range (m)	No. of tows	BAR	HOK	SWA	RHY	ASQ	TAR	HAP	SPD	LIN	SCH
50–99	11	6 116	0	15	0	492	139	830	55	10	512
100–149	7	2 616	0	70	0	965	945	393	3 923	50	80
150–199	24	9 319	209	283	0	661	458	169	333	40	85
200–249	12	9 896	199	5 490	40	1 711	249	134	114	20	75
250–299	7	11 780	199	3 531	14 229	632	189	119	25	269	20
300–349	5	522	1 656	343	472	279	154	204	5	179	109
350–399	7	55	980	547	5	95	0	55	0	199	10
400–450†	7	0	1 189	293	0	85	0	5	0	159	15

* Species codes are given in Appendix 2.
† Incorrect bathymetry resulted in there being seven stations in water deeper than 400 m.

50–99 m, in strata 1 and 2, on the eastern side. The phase 2 drop in catch rate for hapuku in stratum 2 was significant ($p < 0.05$). The bottom was too rough on the western side to enable this depth range to be sampled. Therefore, the distributions of these species on the Chatham Islands shelf are possibly the most inadequately described of the main species caught during this trawl survey.

Hoki were dominant in deeper water and were most abundant in strata 6–8, in 300–450 m. However, the maximum mean catch rates by stratum and by depth were usually lower than those for barracouta and silver warehou. Catch rates of hoki are shown in Fig. 12. The overall mean catch rate was 0.4 t.km^{-2} (range 0.0 to 7.5). Ling were the second most important species in deeper water and occurred mainly in 250–450 m, but they had a low overall mean catch rate of less than 0.1 t.km^{-2}.

Catch rate data by time of day for the three most abundant and widely distributed species (barracouta, silver warehou, and arrow squid) are given for their main depth range in Table 7. There were no significant differences in catch rates by time of day for these species.

TABLE 7: Mean catch rates (kg.km^{-2}) of barracouta, silver warehou, and arrow squid, by time of day, within their main depth range

	100–300 m			150–450 m	
Time (h)	No. of tows	BAR*	ASQ	No. of tows	SWA
0500–0829	19	8 971	1 348	22	2 779
0830–1159	10	12 307	522	13	2 139
1200–1529	14	8 041	701	19	729
1530–1900	7	5 291	1 000	8	266

* Species codes are given in Appendix 2.

Biomass estimates

Biomass estimates were calculated for the 20 major species, for all three phases combined (*see* Table 4). For the 10 major species, estimates and c.v.s by stratum are given in Table 8, and percent of total biomass by stratum is given in Table 9. Table 10 gives the biomass estimates by phase.

Ranking species by catch weight and then by biomass estimate resulted in few changes in the order of importance; the main change was to hoki, which was sixth by catch weight, but third by biomass. This occurred because of the large area of strata 6–8, over which the hoki catch rates were multiplied. The c.v.s ranged from 10% for look-down dory (*Cyttus traversi*) to 88% for common roughy; 5 species had c.v.s of less than 15% (look-down dory, hapuku, ling, stargazer, and barracouta) and 13 had c.v.s of less than 30%.

Six of the 10 major species had more than 50% of their biomass in a single stratum. For five of these (barracouta, silver warehou, common roughy, arrow squid, and spiny dogfish), this was from stratum 4′ — this stratum contributed 52% of the total biomass of the 10 major species.

Most of the biomass of tarakihi came from strata 3 and 4′, hapuku from 1 and 5, ling from 6 and 7, and school shark from 2. These results do not relate exactly to the catch rates by stratum because of the station weighting factors.

When the strata were combined by depth, only school shark and hapuku had more than 30% of their biomass in less than 100 m, and only hoki and ling had their highest percentage biomass in more than 200 m. Most of the biomass of the other six top species came from 100–199 m.

Biomass estimates and c.v.s for the three phases of the survey for the 10 major species are given in Table 10. Little change is apparent for species which occurred in deeper water and which were mainly sampled during phase 1. However, the barracouta c.v. was reduced by one-third (i.e., from 18 to 12%) between phase 1 and phase 3. The main reduction occurred in phase 3 and was mostly due to the boundary change (i.e., the inclusion of the phase 1 stratum 7 station, No. 31, in the new stratum 4′). The c.v.s for three other species (arrow squid, hapuku, and spiny dogfish) were reduced by one-fifth, but for these species the major decrease resulted from phase 2. Rises in biomass and c.v. occurred for common roughy and silver warehou, mainly because of phase 3. The common roughy rises were due to a 20 t catch at one station, whereas the 177% increase in the silver warehou biomass resulted from higher catch rates in 150–249 m during phase 3.

TABLE 8: Biomass (t) and coefficients of variation (%) of the 10 major species* by stratum

Stratum	BAR	HOK	SWA	RHY	ASQ	TAR	HAP	SPD	LIN	SCH	All species
1	1 821	0	35	0	76	119	718	125	27	213	3 302
	(46)†	(0)	(100)	(0)	(37)	(95)	(43)	(60)	(54)	(84)	(25)
2	5 188	0	0	0	444	84	514	0	0	411	6 798
	(47)	(0)	(0)	(0)	(90)	(55)	(24)	(0)	(0)	(30)	(43)
3	2 285	391	247	130	690	1 386	407	0	40	239	7 457
	(73)	(100)	(52)	(99)	(40)	(80)	(24)	(0)	(45)	(38)	(42)
4′	32 135	561	7 205	7 724	3 213	1 009	331	2 829	200	143	56 148
	(13)	(71)	(32)	(100)	(23)	(17)	(15)	(68)	(46)	(32)	(17)
5	3 620	0	135	0	669	720	906	51	36	217	7 584
	(50)	(0)	(41)	(0)	(64)	(14)	(20)	(69)	(75)	(47)	(26)
6	25	6 258	1 039	238	486	458	350	0	556	189	13 569
	(83)	(51)	(48)	(67)	(14)	(74)	(37)	(0)	(27)	(49)	(25)
7′	1 066	3 174	2 039	743	435	4	43	0	715	47	10 515
	(86)	(17)	(18)	(100)	(31)	(100)	(58)	(0)	(9)	(73)	(20)
8	82	729	116	11	333	279	350	11	416	123	2 561
	(53)	(93)	(28)	(96)	(54)	(78)	(35)	(96)	(36)	(75)	(17)

* Species codes are given in Appendix 2.

† Coefficients of variation are in parentheses.

TABLE 9: Percent of total individual species biomass by stratum for the 10 major species*

Stratum	BAR	HOK	SWA	RHY	ASQ	TAR	HAP	SPD	LIN	SCH	All species
1	4	0	0	0	1	3	20	4	1	13	3
2	11	0	0	0	7	2	14	0	0	26	6
3	5	4	2	2	1	34	11	0	2	15	7
4′	70	5	67	87	51	25	9	94	10	9	52
5	8	0	1	0	11	18	25	2	2	14	7
6	0	56	10	3	8	11	10	0	28	12	13
7′	2	29	19	8	7	0	1	0	36	3	10
8	0	7	1	0	5	7	10	0	21	8	2

* Species codes are given in Appendix 2.

TABLE 10: Biomass and coefficients of variation (c.v.) by phase for the 10 major species*

	Phase 1		Phase 1 + 2		Phase 1 + 2 + 3	
Species	Biomass (10^3 t)	c.v. (%)	Biomass (10^3 t)	c.v. (%)	Biomass (10^3 t)	c.v. (%)
BAR	48.8	18	41.3	17	46.2	12
HOK	11.8	30	11.2	30	11.1	30
SWA	3.9	17	5.1	19	10.8	22
RHY	1.1	69	1.1	69	8.9	88
ASQ	7.5	20	5.6	16	6.4	16
TAR	4.1	30	4.2	29	4.1	30
HAP	3.9	15	3.7	12	3.6	12
SPD	7.5	81	4.7	65	3.0	64
LIN	1.9	13	1.9	12	2.0	12
SCH	1.9	19	1.6	18	1.6	19

* Species codes are given in Appendix 2.

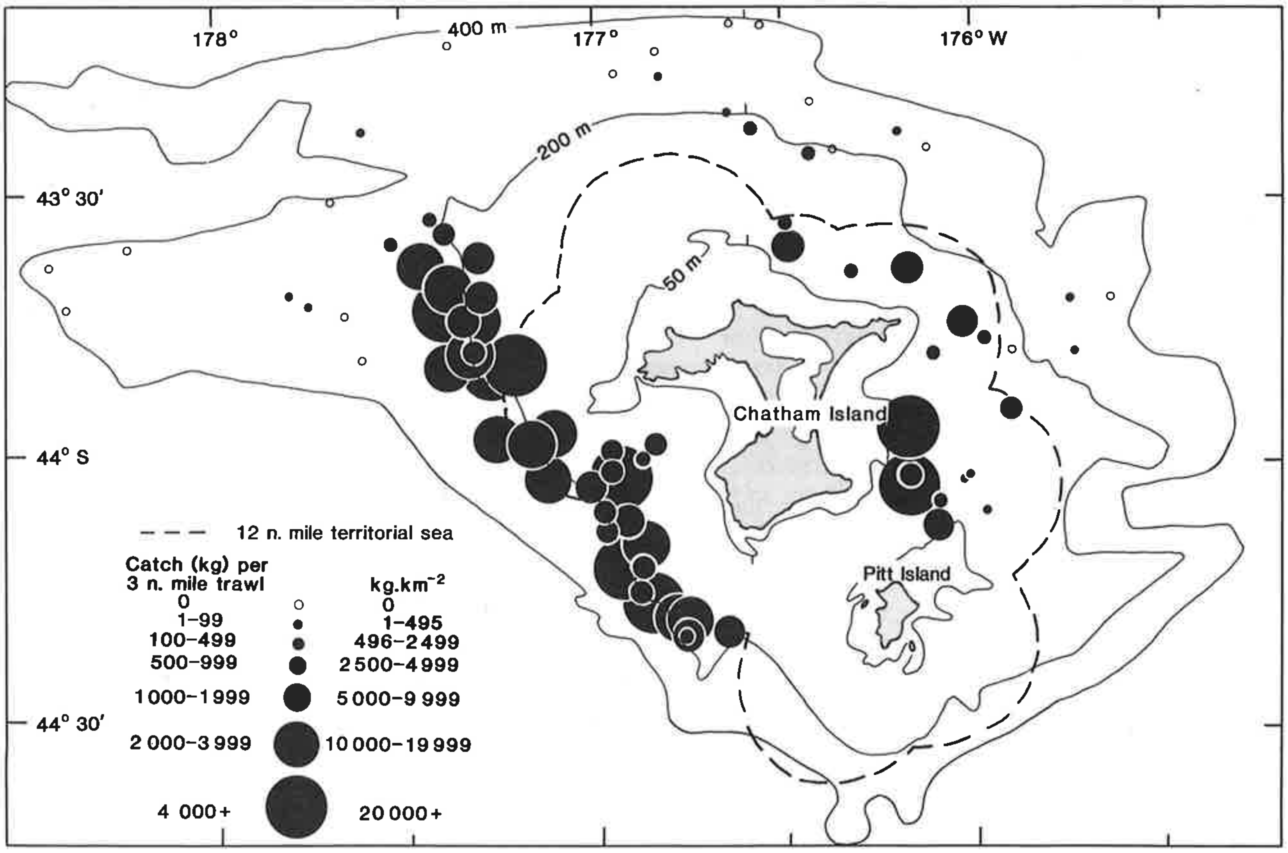

Fig. 5: Catch rates of barracouta.

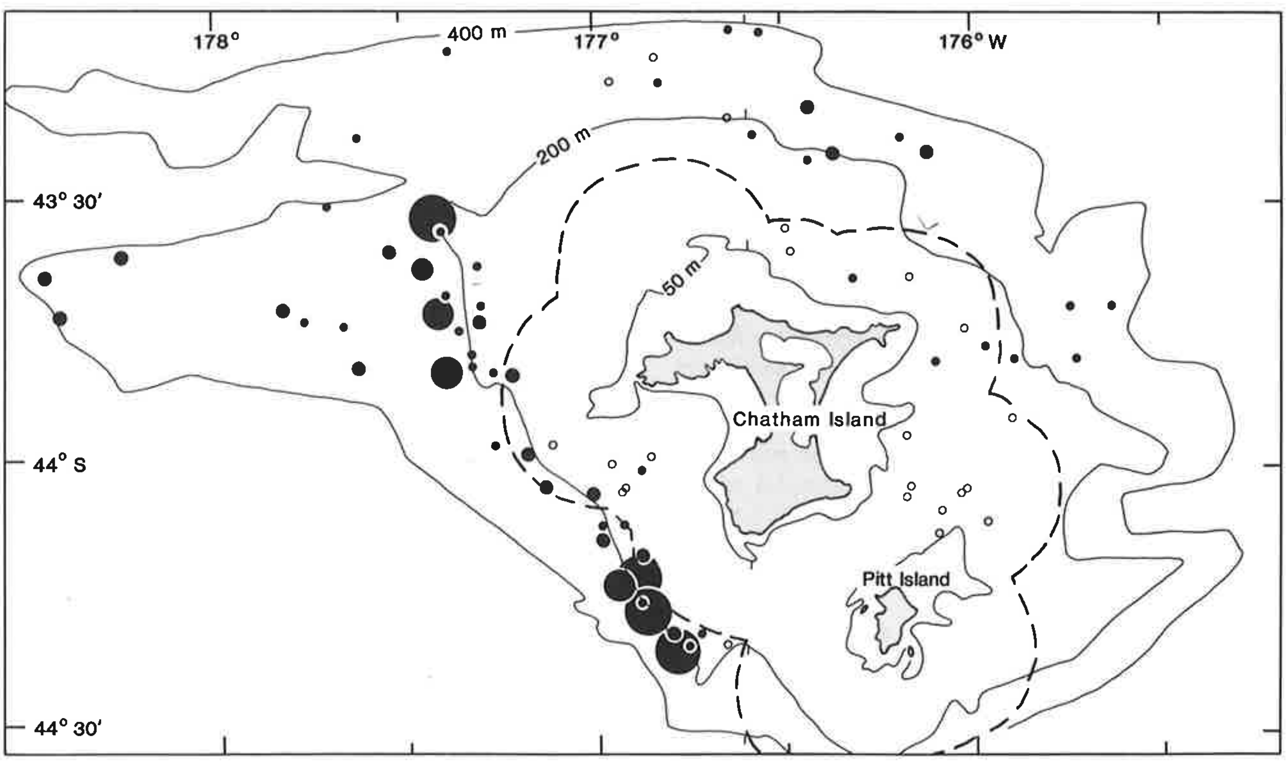

Fig. 6: Catch rates of silver warehou (see key on Fig. 5).

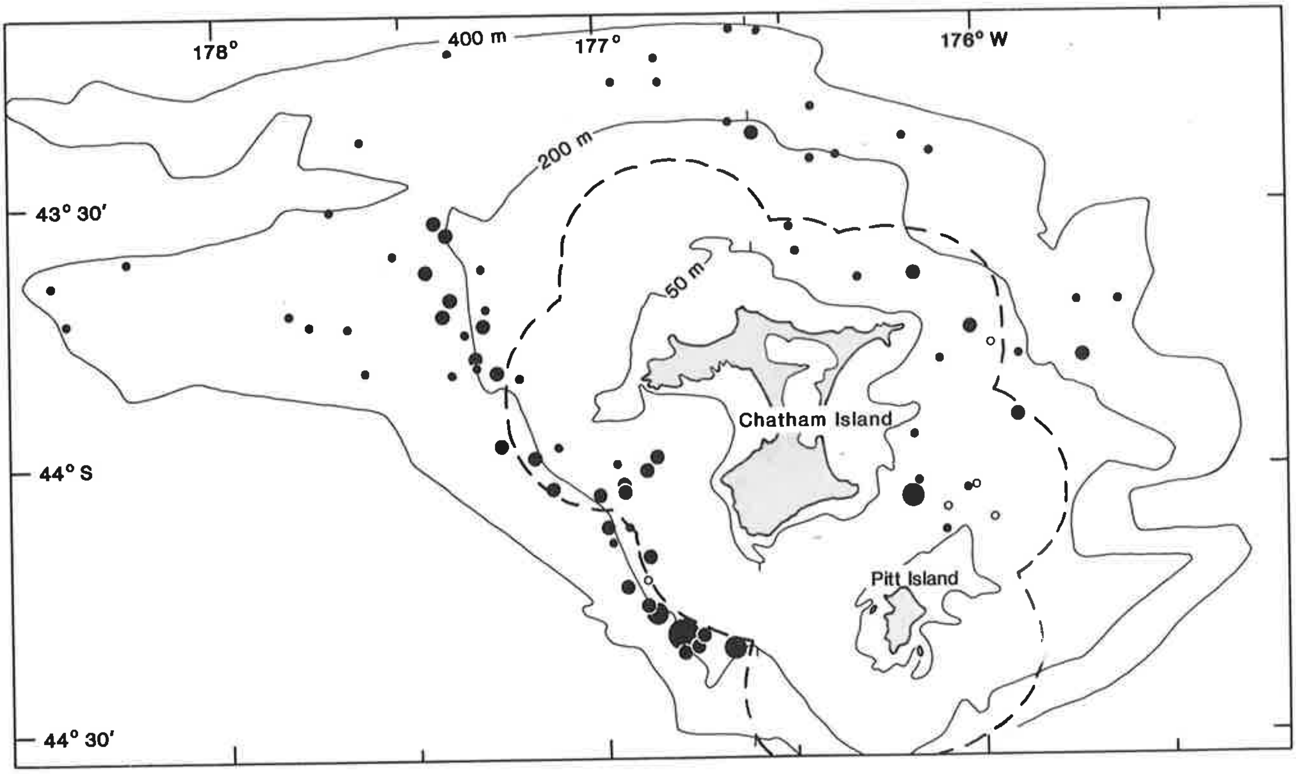

Fig. 7: Catch rates of arrow squid (see key on Fig. 5).

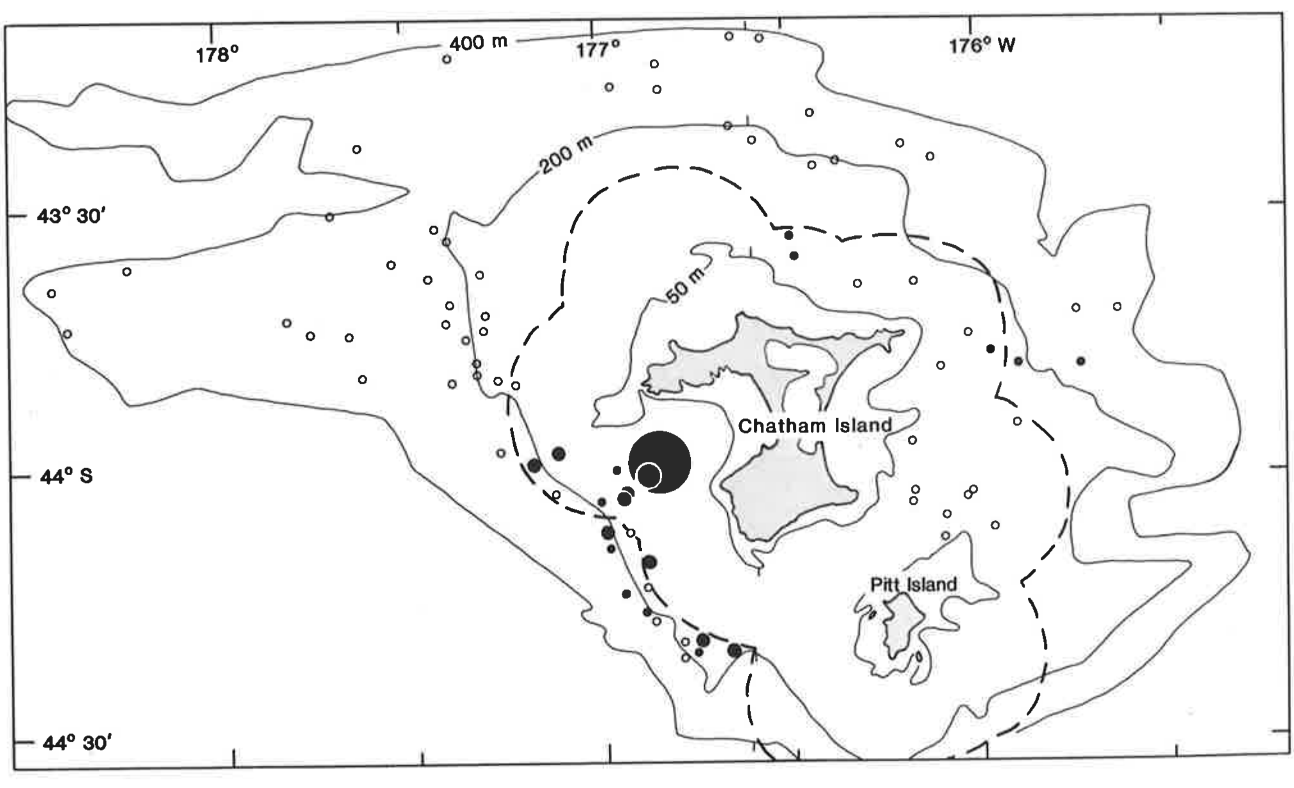

Fig. 8: Catch rates of spiny dogfish (see key on Fig. 5).

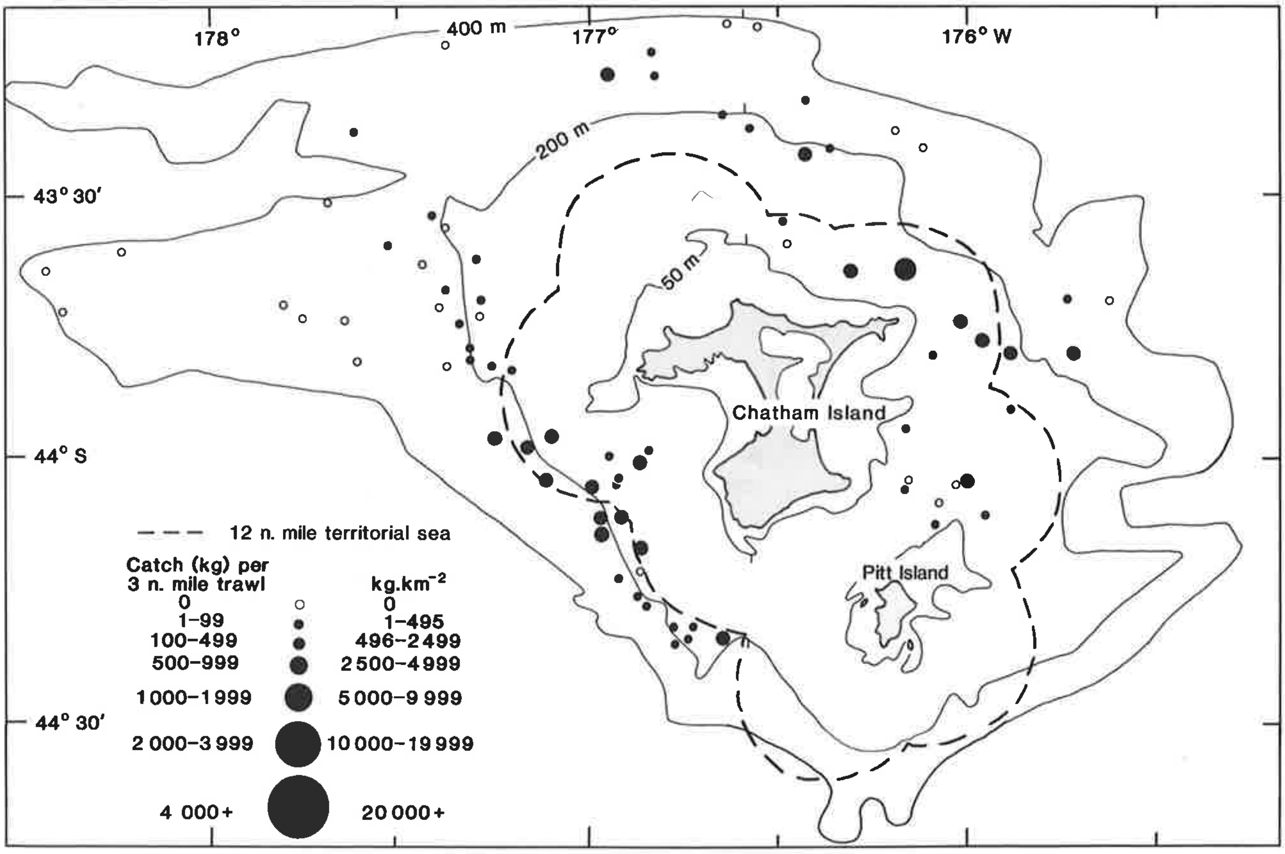

Fig. 9: Catch rates of tarakihi.

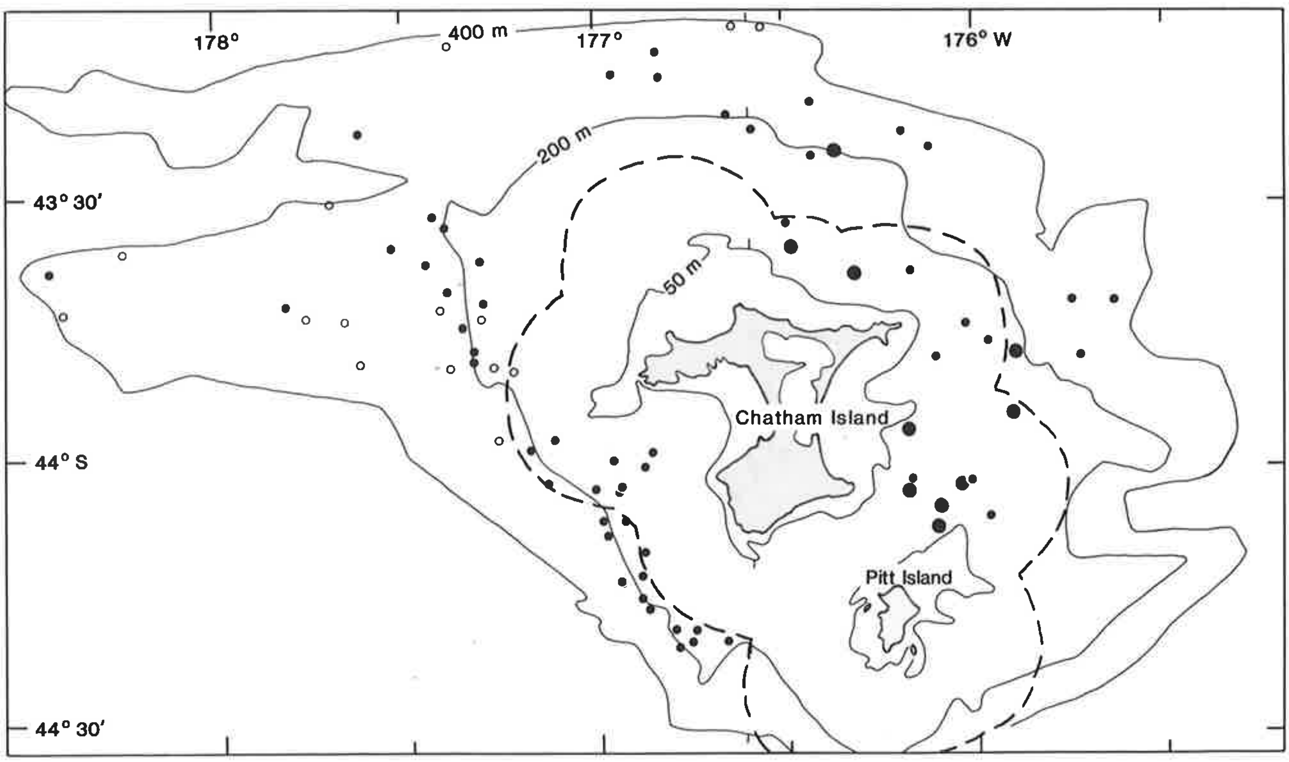

Fig. 10: Catch rates of hapuku (see key on Fig. 9).

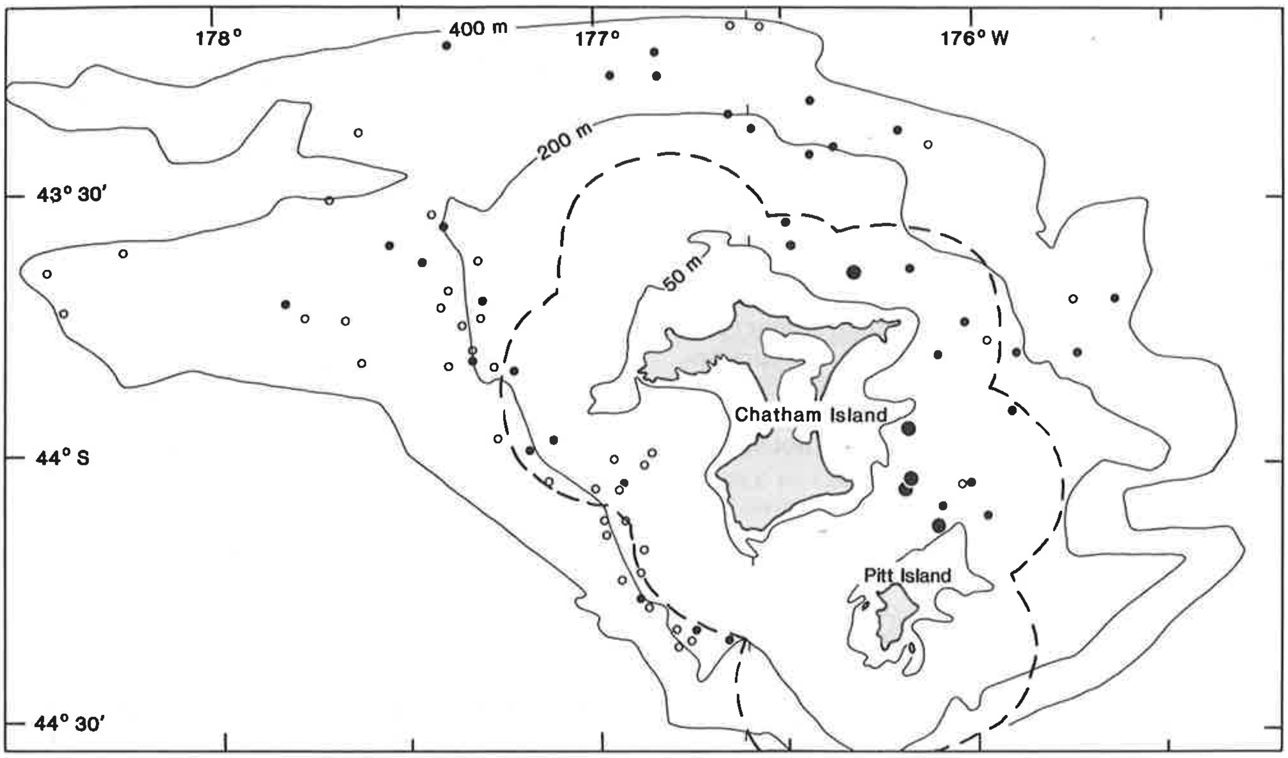

Fig. 11: Catch rates of school shark (see key on Fig. 9).

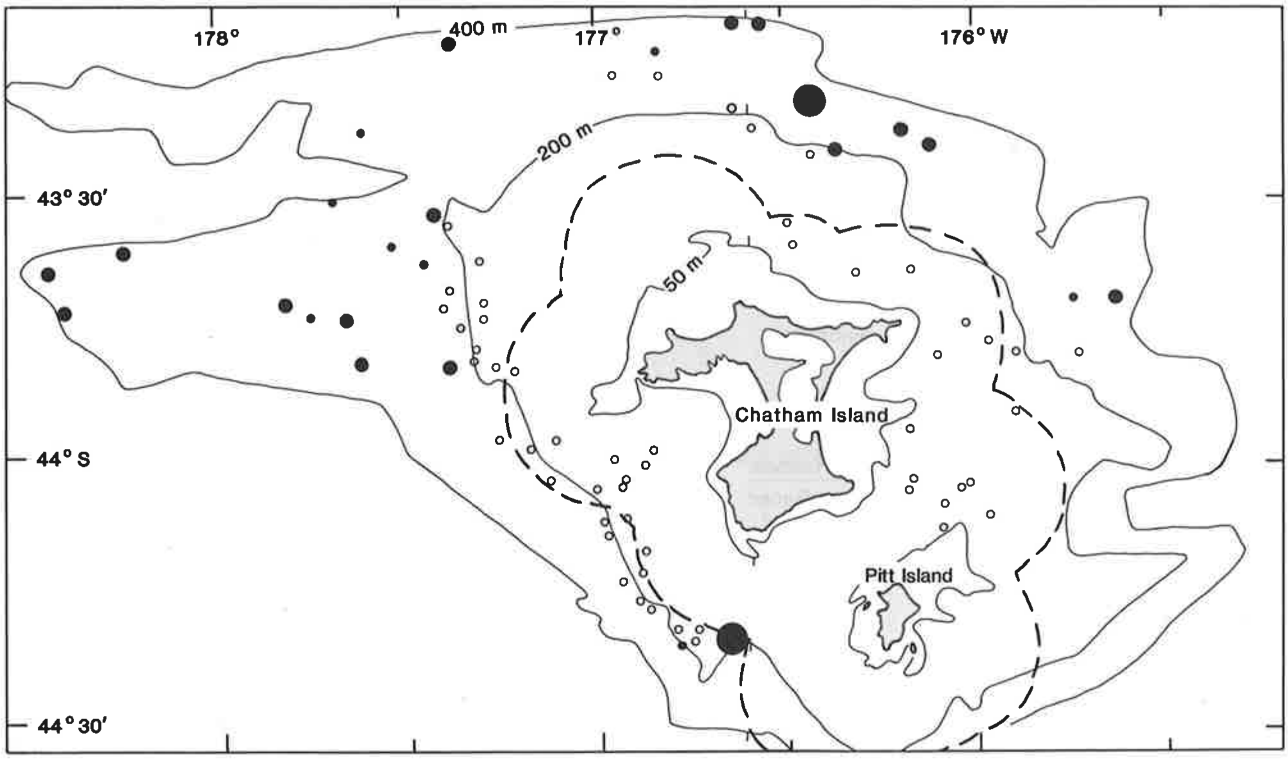

Fig. 12: Catch rates of hoki (see key on Fig. 9).

Biology

Length-frequency histograms of the main commercial species measured are shown in Figs. 13–19. These data have been scaled by the percentage of fish measured per tow and have been combined into three depth ranges: 50 to 99 m (strata 1 and 2); 100 to 199 m (strata 3, 4, and 5); and 200 to 450 m (strata 6, 7, and 8). For the five species that were regularly measured each tow (barracouta, tarakihi, hapuku, arrow squid, and silver warehou), the overall length frequencies were also scaled by stratum area to give representative length structures of the Chatham Islands "populations", as sampled by trawl gear (Fig. 20). All other biological data collected were not scaled.

Barracouta

Length and weight. Barracouta lengths ranged from 21 to 95 cm, and the modes for fish over 50 cm were similar for the three depth ranges (Fig. 13). Fish smaller than 50 cm were found only in less than 100 m. There were two modal peaks for larger fish, the peaks for males being slightly less than those for females (males, 56 and 67 cm; females, 57 and 71 cm). Overall, there were more females than males (1.9 : 1).

The overall population length frequency, when weighted by stratum area, was similar in shape to the unweighted length frequency, except that the 51–60 cm length group was slightly larger and the 65–75 cm length group was correspondingly smaller. There were few fish over 75 cm (10.2%).

Length-weight relationships were calculated for males, females, and both sexes combined (Table 11).

Age-length relationships. Of the 431 barracouta otoliths collected, 126 (31%) were rejected as unreadable. The rejection rate increased as fish length increased (Fig. 21), and it reached 59% for otoliths from fish 80 cm or over. This high level is very unusual. Previous experience of reading several thousand barracouta otoliths from other parts of New Zealand had usually resulted in a rejection rate of 5% or less (authors' unpublished data). Therefore, age data presented here are preliminary (subject to more detailed analysis of daily growth rings) and have not been used to establish an age-length key, from which the age structure of the population could have been determined.

Growth in the first 3 years is fast; fish reach a mean length of 28.9 cm after the first year and 57.8 cm after the third year (Table 12). The second year class was absent from the biological and the total length-frequency data sets. The maximum age recorded was 10 years (length 86 cm), though it is possible that some of the unaged fish were older. The mean length at age for females is usually slightly greater than that for males.

Reproductive state. Of 1041 barracouta staged, 98% had maturing to running-ripe gonads (stages 3–5). Maximum gonadosomatic indices exceeded 10 for both sexes (Table 13). Most of the stage 3 females appeared to have already spawned at least one batch of eggs and were, therefore, classified as "3B". The smallest recorded stage 3 fish were 54 cm (male) and 51 cm (female).

Flesh parasitism. The left fillets of 209 barracouta were infected with a total of 744 trypanorhynchid cestode larvae of *Gymnorhynchus thyrsitae* and 1 anisakid nematode larva of *Pseudoterranova decipiens*.

TABLE 11: Length-weight relationships for barracouta

		Length (cm)			Weight (g)				Regression
	No.	Mean	s.d.*	Range	Mean	s.d.	Range	Equation†	coefficient (*r*)
Males	246	67.6	7.4	55–95	1 822	632	580–3 920	$W = 0.0117L^{2.82}$	0.92
Females	484	70.9	9.4	25–94	2 014	723	80–4 500	$W = 0.0074L^{2.93}$	0.97
All fish	730	69.8	9.2	25–95	1 949	699	80–4 500	$W = 0.0091L^{2.88}$	0.95

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

TABLE 12: Mean length (cm) at age for barracouta

	All barracouta				Males				Females			
Age	No.	Mean	s.d.*	Range	No.	Mean	s.d.	Range	No.	Mean	s.d.	Range
0	0				0				0			
1	20	28.9	3.3	25–36	7	29.6	3.6	26–34	5	31.4	4.2	25–36
2	0				0				0			
3	41	57.8	3.5	51–68	14	58.3	3.1	54–66	27	57.5	3.7	51–68
4	21	66.5	3.5	57–72	9	65.7	2.8	62–71	12	67.2	3.9	57–72
5	52	70.2	3.5	62–77	22	68.0	2.9	62–72	30	71.8	2.9	67–77
6	78	75.2	3.3	68–83	17	72.9	3.4	68–79	61	75.8	2.9	68–83
7	48	77.8	3.0	69–84	13	75.9	3.5	69–83	35	78.5	2.5	74–82
8	13	79.5	4.6	72–88	2	75.5	5.0	72–79	11	80.3	4.4	74–88
9	6	84.3	4.7	79–91	2	90.0	1.4	89–91	4	81.5	1.9	79–83
10	3	85.0	1.7	83–86	1	83.0			2	86.0	0.0	

* Standard deviation.

The frequency distribution of the number of cestodes per fillet was characteristically skewed (Fig. 22); 82% of fillets had less than five larvae. The maximum number of cestodes per fillet was 73, and the ventral muscles (maximum 68 cestodes) were more heavily infected than the dorsal muscles (maximum 5 cestodes). Percentage and mean infection rates are given by fish length (Table 14) and age (Table 15). Problems with the aging of larger fish reduced the latter sample size from 209 to 119. The infection rates did not show a steady increase with length and age, in contrast to results of other studies in New Zealand (Mehl 1970, authors' unpublished data).

Feeding. Observations were made on the contents, fullness, and state of food digestion for 1032 barracouta stomachs. Most stomachs were partly full (62%) or empty (30%). Euphausiids constituted 87% of food items (Table 16). Squid and various fish species were other common food items (7 and 6% respectively). Fish prey species included myctophids, silverside (*Argentina elongata*), redbait (*Emmelichthys nitidus*), opalfish (*Hemerocoetes artus*), silver dory (*Cyttus novaezelandiae*), saury (*Scomberesox saurus*), and barracouta.

The percentage occurrence of food items was similar between strata, though there were more squid in barracouta stomachs in stratum 2. (The high percentage of fish in stratum 8 was a result of the small sample size.) There were no clear differences in stomach fullness (Table 17) or digestion state (Table 18) by time of day, except that there were more fresh items in the stomachs in early morning and late afternoon.

Silver warehou

Silver warehou caught during the survey ranged in length from 15 to 59 cm (Fig. 14). Both juvenile and adult fish were taken in depths of 100–450 m, and there were more juveniles (21–29 cm) in 100–199 m. Modal peaks occurred at 26, 36, and 43 cm. The female to male ratio was 1.7 : 1.

The stratum-weighted length structure (Fig. 20) was similar to the unweighted one. Most fish were large; 89% were 40 cm or longer. The gonads were maturing or ripe, and the stomachs examined contained salps.

Arrow squid

Arrow squid ranged from 9 to 43 cm mantle length, and the narrowest length range occurred in shallow water (Fig. 15). Sex determination was usually possible in squid over 15 cm mantle length. Females attained a greater size than males (up to 43 cm). However, the modal peaks of the two sexes appeared to be similar and slightly larger in deeper water (24–26 cm in over 100 m, 21 cm in less than 100 m).

TABLE 13: Reproductive state of barracouta

				Gonadosomatic index*			
				Males		Females	
Gonad stage	No.	Males	Females	No.	GSI	No.	GSI
1	3		3				
2	6	4	2				
3	641	11	630	2	6.1	430	6.4
4	79	60	19	52	10.3	14	16.9
5	303	290	13	158	10.4†	4	9.8†
6	9	4	5	4	2.5	5	2.5
	1 041	369	672	216		453	

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

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

TABLE 14: Cestode (*Gymnorhynchus thyrsitae*) larval infection of barracouta left fillets by fish length (n = 209)

Length (cm)	No. of fish	Infected (%)	Mean No. of larvae	s.d.*	Range
70–74	7	86	3.14	2.34	0–7
75–79	139	76	2.27	2.48	0–15
80–84	53	85	4.51	5.62	0–29
85–89	4	100	3.50	2.08	1–6
90–94	6	83	19.00	27.72	0–73

* Standard deviation.

TABLE 15: Cestode (*Gymnorhynchus thyrsitae*) larval infection of barracouta left fillets by fish age (n = 119)

Age	No. of fish	Infected (%)	Mean No. of larvae	s.d.*	Range
5	10	90	3.10	2.47	0–7
6	51	77	2.20	2.30	0–9
7	42	76	2.17	1.87	0–7
8	10	70	2.50	2.76	0–8
9	4	100	19.25	35.84	1–73
10	2	100	5.99	5.66	1–9

* Standard deviation.

TABLE 16: Occurrence of barracouta food items by stratum

Stratum	No. of food items	Euphausiids (%)	Squid (%)	Fish (%)	Other (%)
1	46	91	7	0	2
2	131	81	18	1	0
3	52	85	2	13	0
4	462	88	6	6	1
5	58	83	7	10	0
7	14	100	0	0	0
8	7	57	0	43	0
	770	87	7	6	0

TABLE 17: Barracouta stomach fullness by time of day

Time (h)	No. of stomachs	Empty (%)	Part full (%)	Full (%)
0500–0829	493	28	65	7
0830–1159	229	36	58	6
1200–1529	254	28	61	11
1530–1900	56	27	57	16

The stratum-weighted length structure was similar to the unweighted one (Fig. 20). Fifty-two percent were 25 cm or longer.

TABLE 18: Digestion state of food items in barracouta stomachs by time of day*

Time (h)	No. of food items	Fresh (%)	Partly digested (%)	Digested (%)
0500–0829	480	34	52	14
0830–1159	183	18	57	25
1200–1529	263	18	61	21
1530–1900	54	27	57	16

* The number of food items does not equal the total in Table 16 because one prey type was often present in more than one state of digestion.

Tarakihi

There was a wide range of lengths of tarakihi (13 to 51 cm) in shallow waters (50–99 m), whereas most fish in over 100 m were 37–48 cm long (Fig. 16). Modal peaks occurred at 20, 25, and 31 cm, but peaks for larger fish were obscured. The sex ratio was about equal, though females reached a greater length than males.

The stratum-weighted population length structure (Fig. 20) was similar to the unweighted one, though there were slightly more fish in the 38–40 cm length group. About half (57%) of the population sampled was 40 cm or longer.

Length-weight relationships were calculated on 173 tarakihi and similar results were found for males and females (Table 19).

Most of the tarakihi gonads examined were resting stage (stage 2), though a few were starting to mature (stage 3). Stomach contents included various benthic organisms (crabs and shrimps) and small fish.

Hapuku

There was an increase in hapuku size as depth increased (Fig. 17). A total of 163 fish was tagged and released during the survey. The male to female ratio of untagged fish was 1.1 : 1. The stratum-weighted length structure showed an increase in the proportion of fish over 62 cm; 58% were 70 cm or over. The gonads were usually in resting condition, and one fish had fresh barracouta heads in its stomach.

Hoki

Hoki were not caught in water less than 100 m and were only infrequently taken in 100–199 m. They ranged from 38 to 90 cm in total length (Fig. 18). In waters of 100–199 m, most fish measured 64–76 cm. Fish this size were also found in deeper water, with smaller fish (46–54 cm). The male to female ratio was about 1 : 1. Hoki length frequencies were not scaled by stratum area because too few stations were sampled. Gonads were in resting condition.

Other species

Length frequencies were completed on several other by-catch species (white warehou, jack mackerels (possibly *Trachurus declivis* or a species similar to *T. murphyii*), bluenose, alfonsino, and hake) on an opportunistic basis (Fig. 19). The largest jack mackerel taken during the survey was 64 cm, which may have been from a recently recorded, but unconfirmed, third species.

General observations on the gonad stage of measured fish were: resting — hoki, trumpeter (*Latris lineata*), alfonsino; mostly resting, with a few maturing or ripe — tarakihi, bluenose, hapuku, jack mackerels; ripe or running ripe — barracouta, silver warehou, white warehou, common roughy, hake (males only), and some jack mackerels.

Hydrology

Temperature recordings were treated with caution because of the way they were taken. However, surface and bottom temperatures (Figs. 23 and 24) were similar to those seen by Hatanaka *et al.* [1985] in November-December 1983.

On the western side of the Chatham Islands, surface temperatures were slightly lower in shallower waters than in deeper waters, and bottom temperatures were slightly higher. This suggests some localised upwelling or mixing. Generally, surface and bottom temperatures were similar between phase 1 and phases 2 and 3, except for a 2.0–2.5 °C increase in bottom temperatures in the south-eastern area (stratum 2).

TABLE 19: Length-weight relationships for tarakihi

		Length (cm)			Weight (g)				Regression
	No.	Mean	s.d.*	Range	Mean	s.d.	Range	Equation†	coefficient (*r*)
Males	74	35.4	6.9	19–48	1 014	406	137–1 834	$W = 0.017L^{3.02}$	0.99
Females	93	39.7	7.9	18–51	1 402	552	129–2 361	$W = 0.023L^{2.94}$	0.99
All fish‡	173	37.1	8.4	13–51	1 189	560	35–2 361	$W = 0.018L^{3.00}$	0.99

* Standard deviation.
† *W* is weight in grams and *L* is length in centimetres.
‡ Includes six fish that were unsexed.

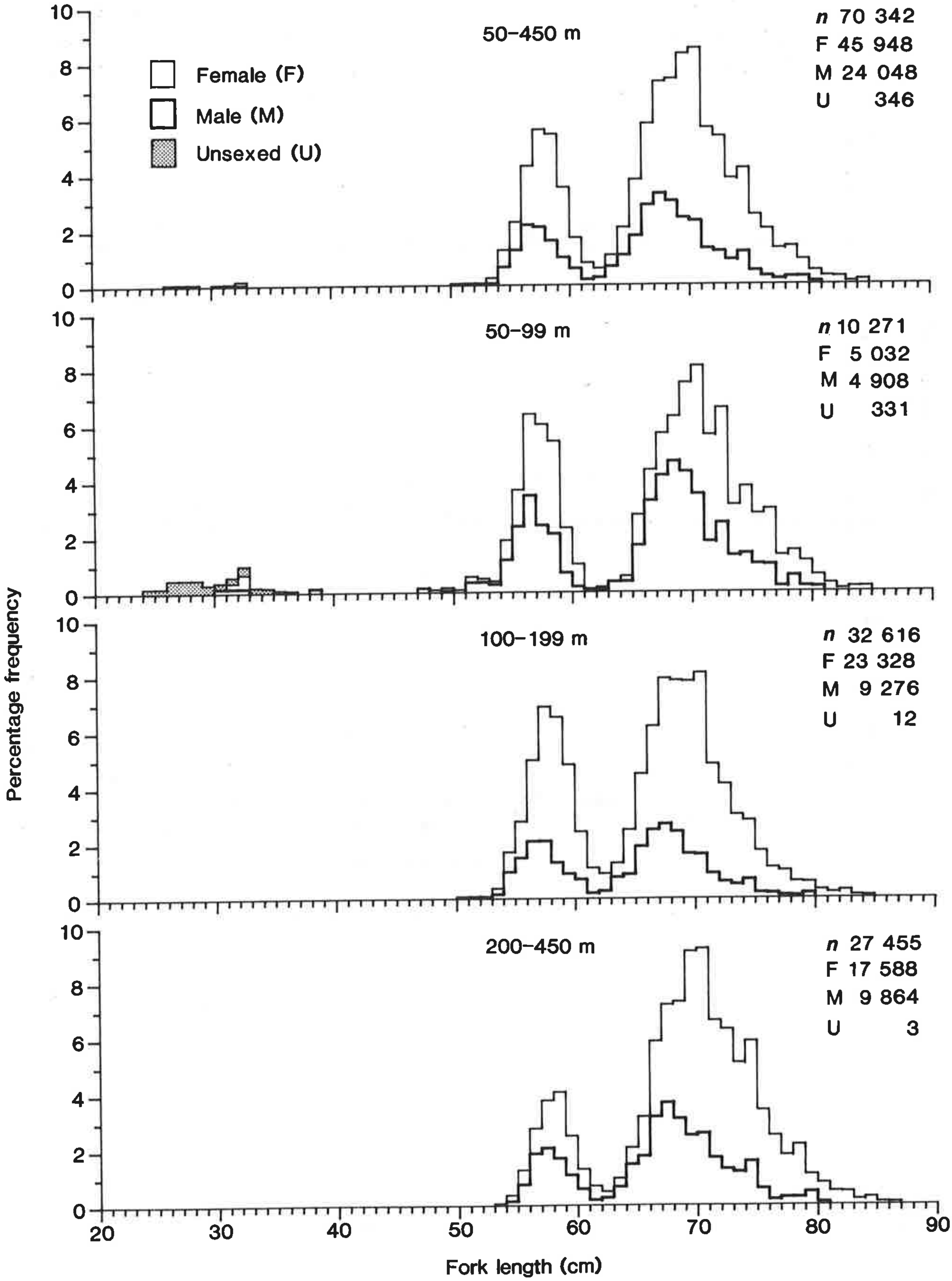

Fig. 13: Length frequencies of barracouta by depth.

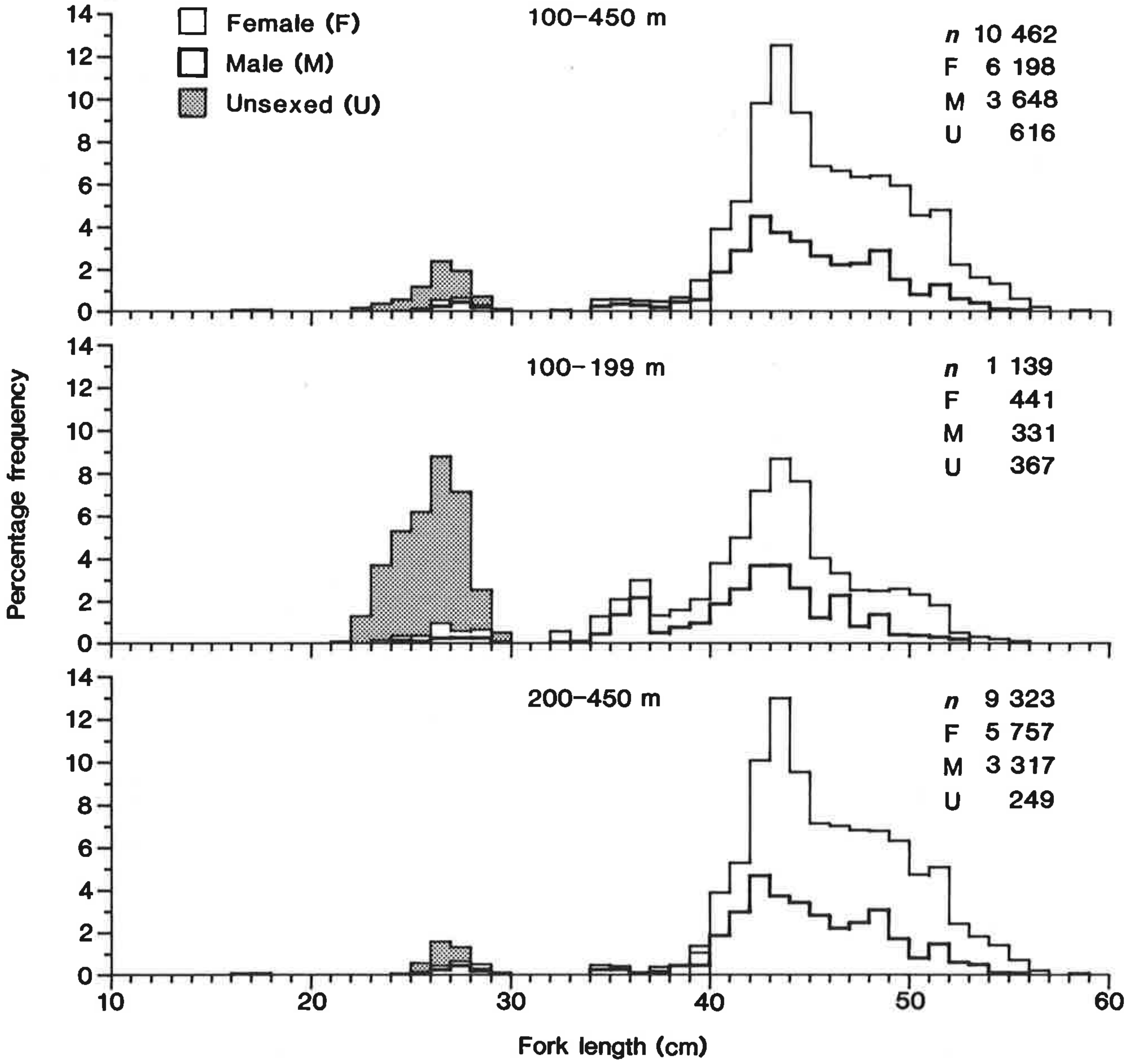

Fig. 14: Length frequencies of silver warehou by depth.

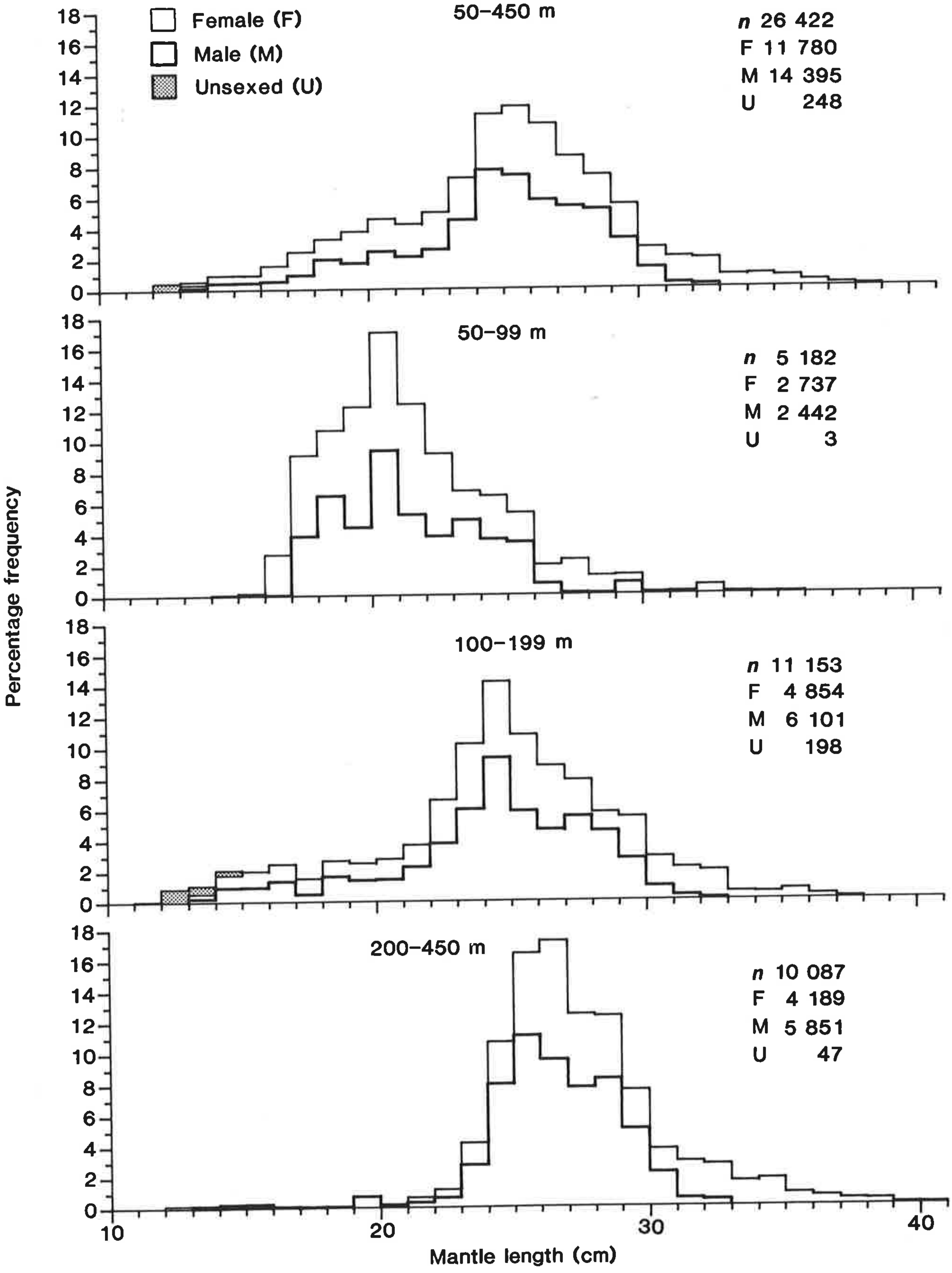

Fig. 15: Length frequencies of arrow squid by depth.

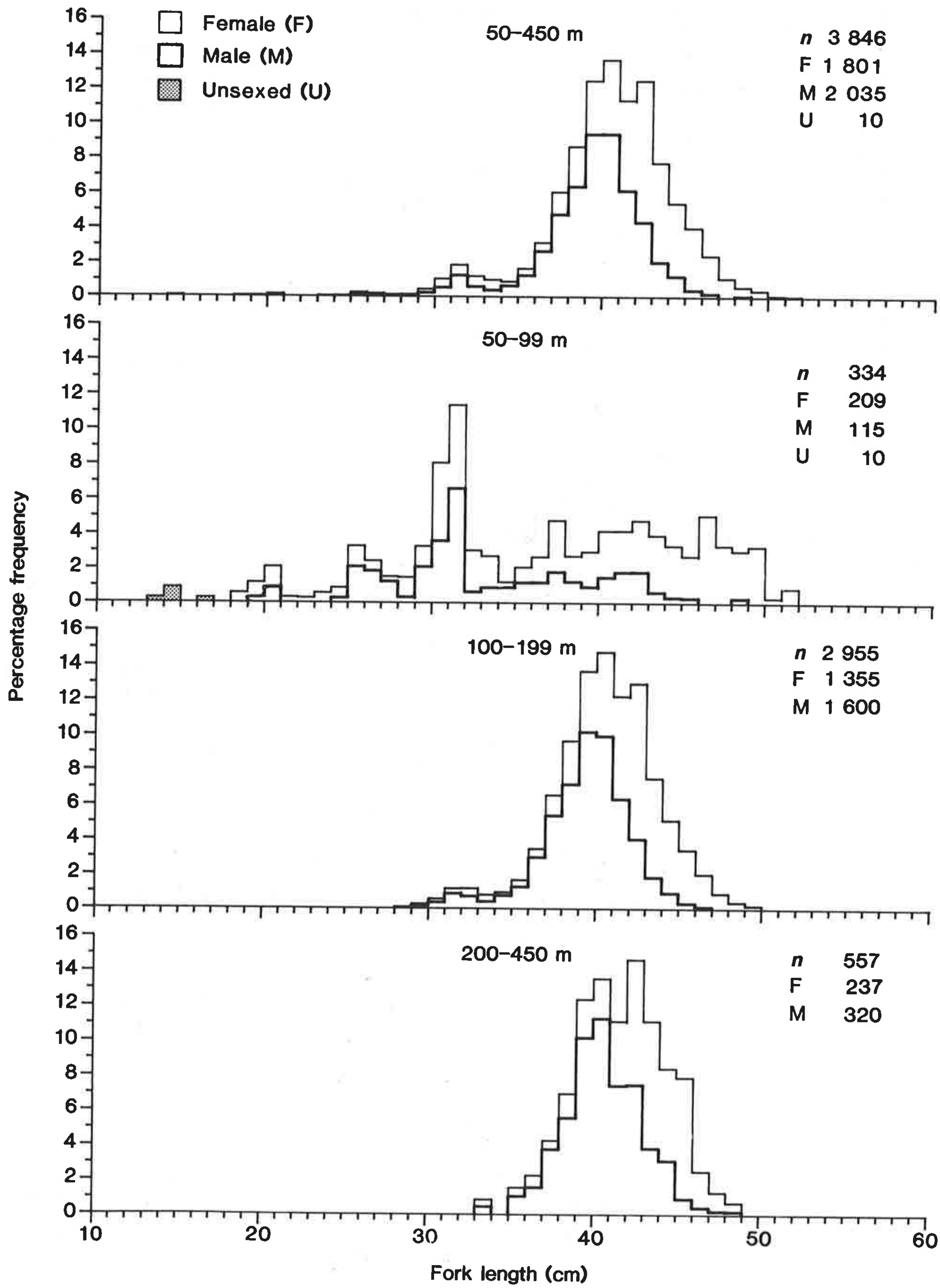

Fig. 16: Length frequencies of tarakihi by depth.

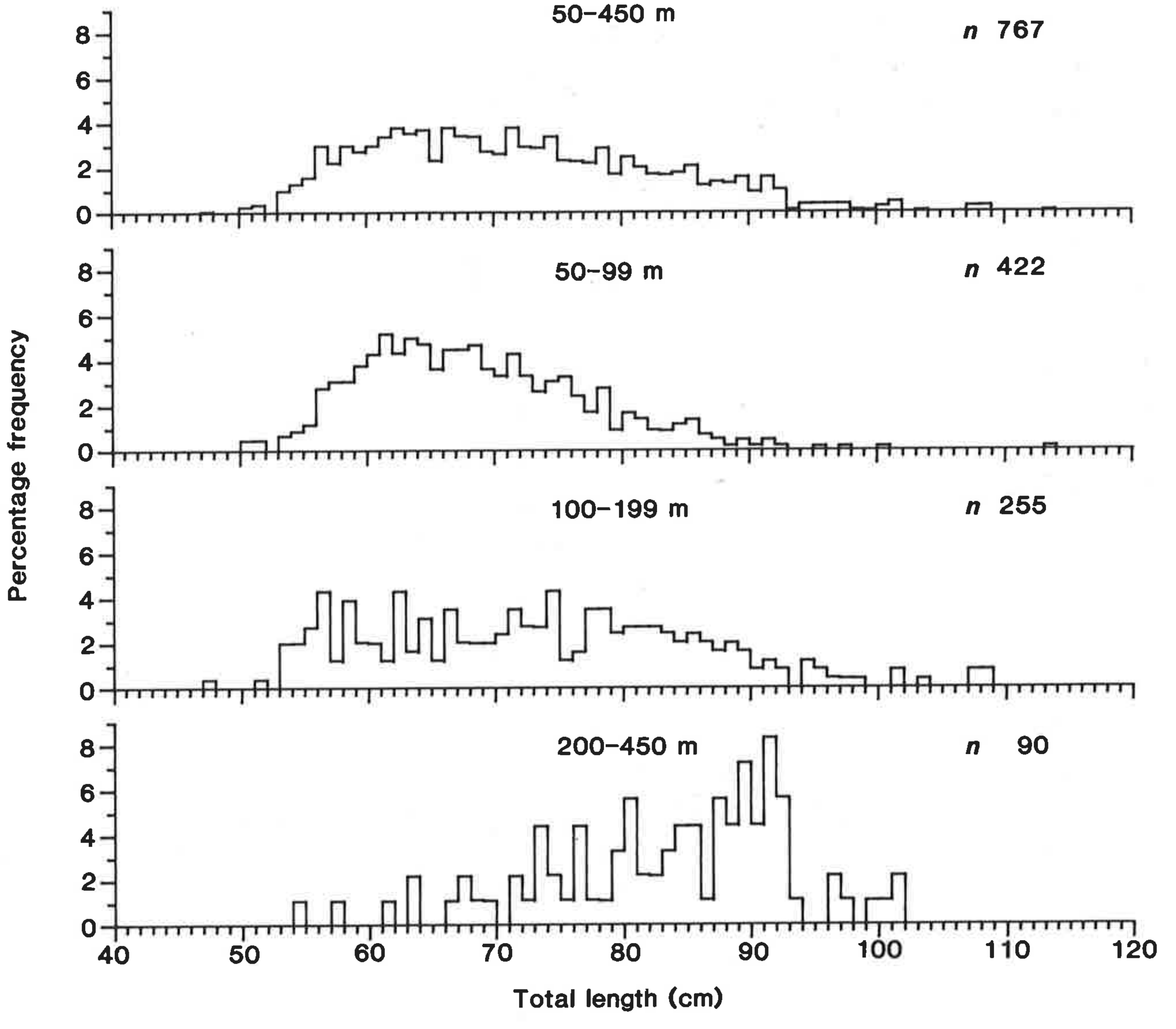

Fig. 17: Length frequencies of hapuku by depth.

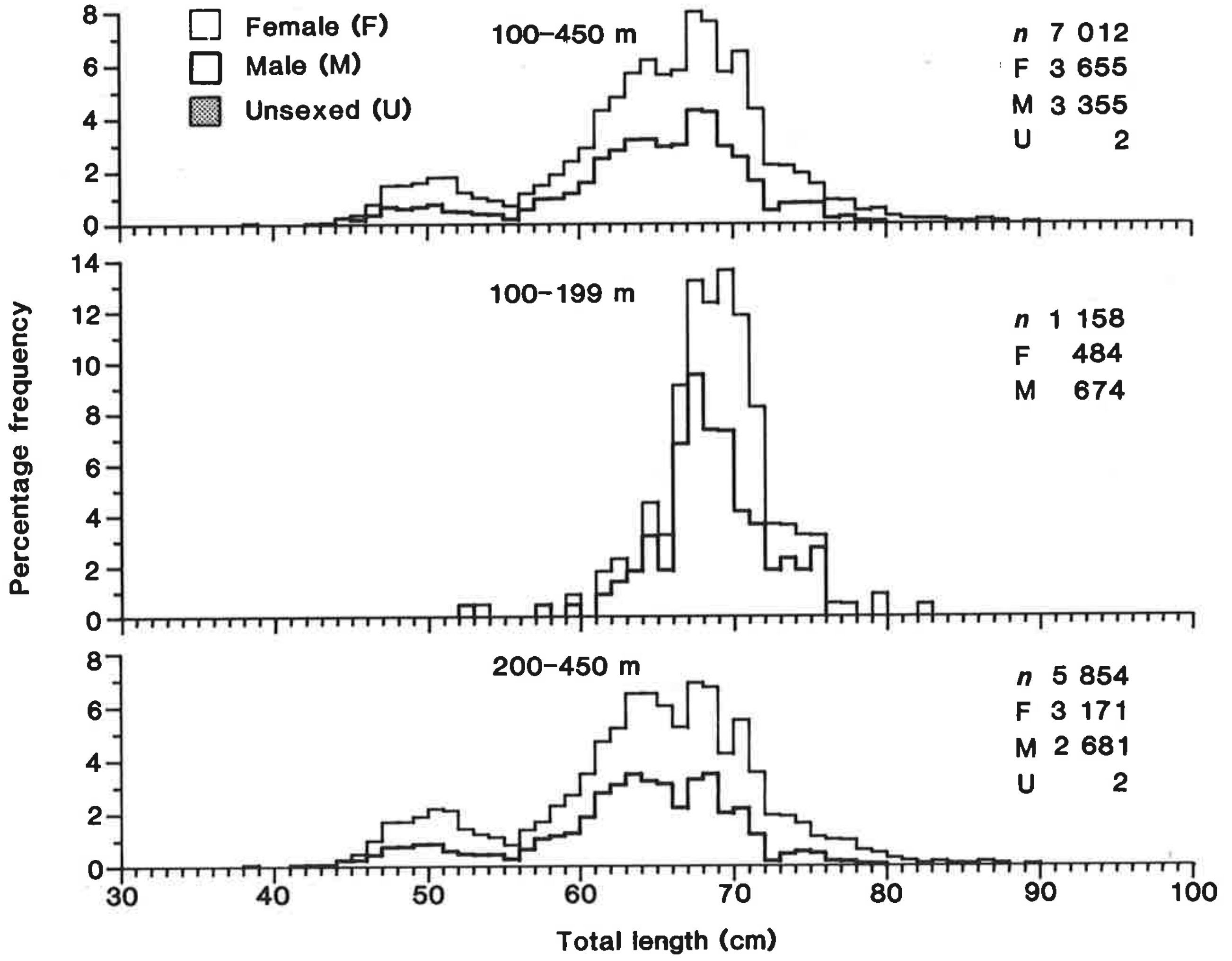

Fig. 18: Length frequencies of hoki by depth.

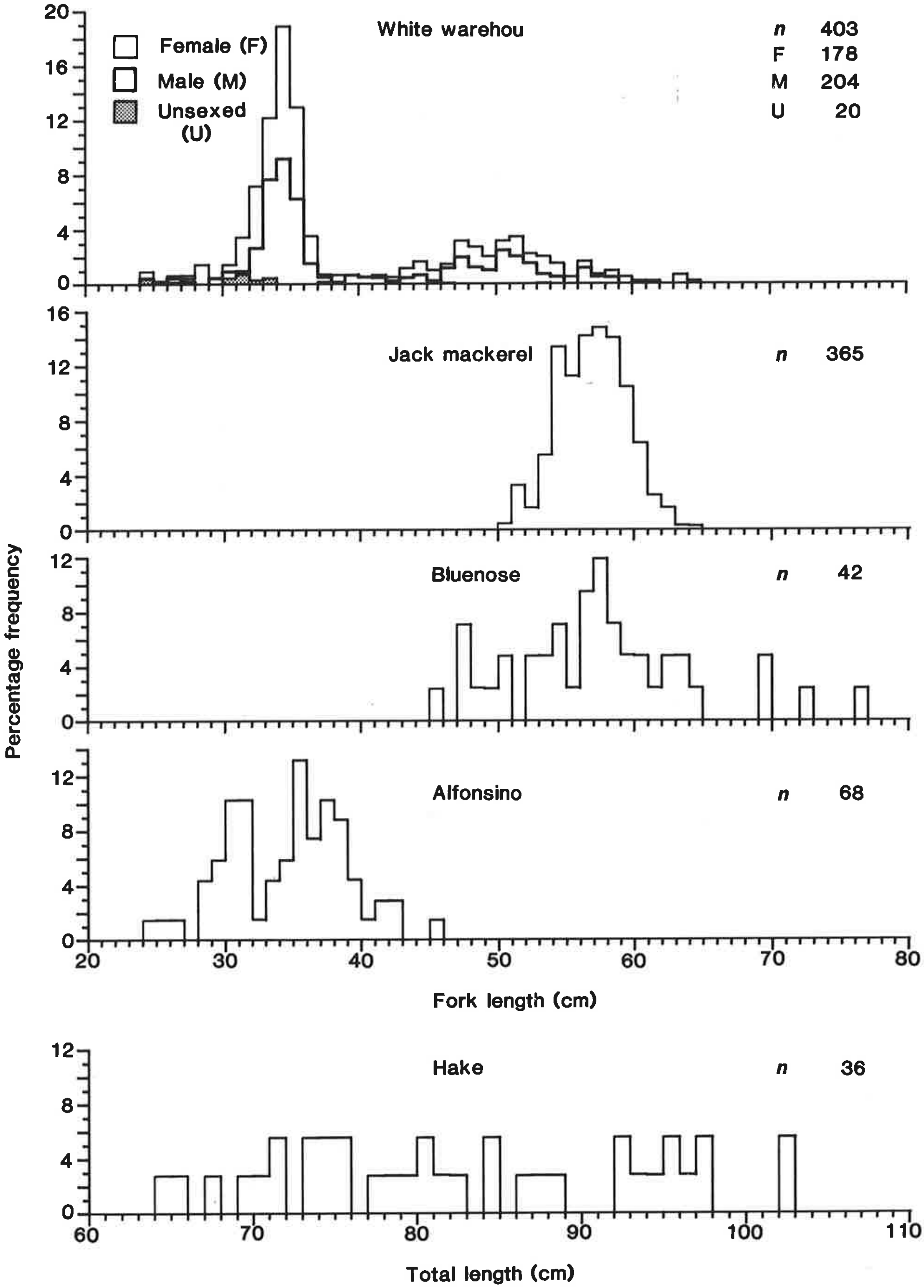

Fig. 19: Length frequencies of other species sampled.

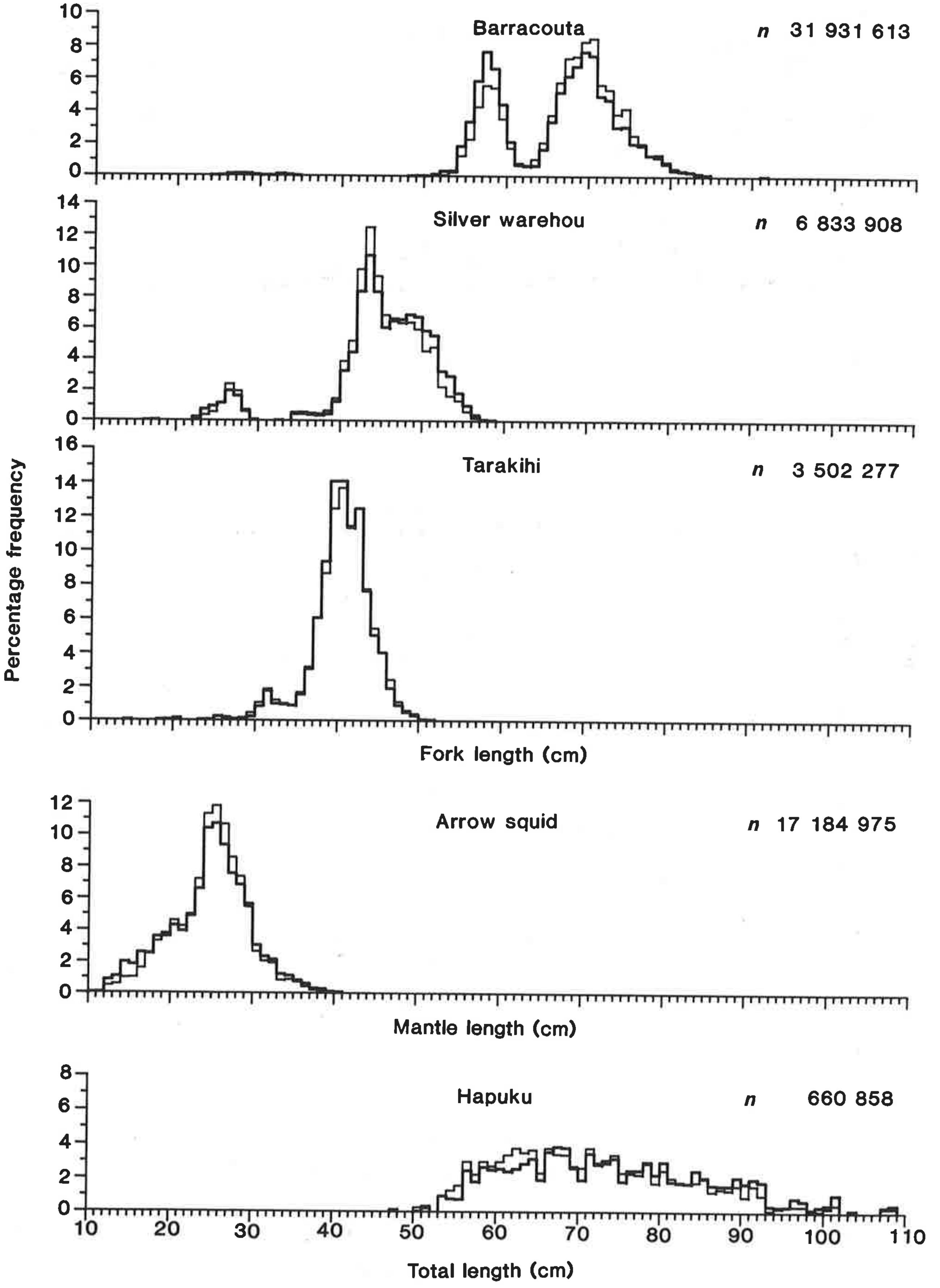

Fig. 20: Length frequencies scaled by stratum area. (*n* is the estimated total number of fish in the survey area after scaling by percentage sampled, area swept, and stratum area. Weighted strata are shown by thicker lines.)

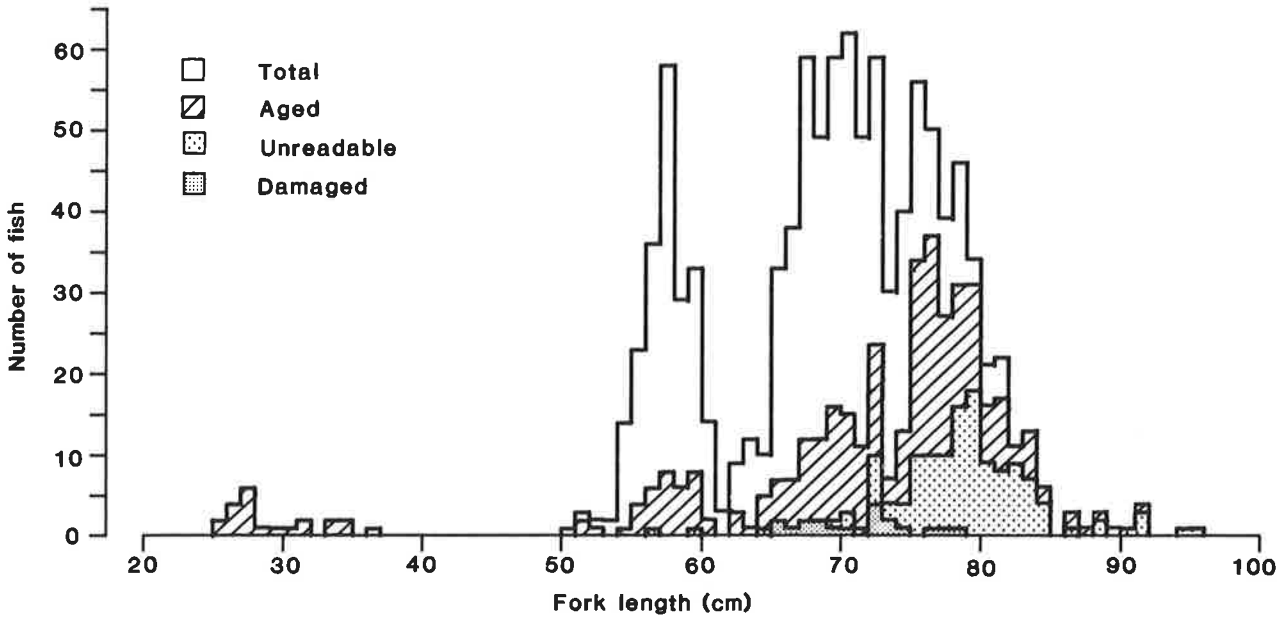

Fig. 21: Length frequencies of barracouta with unreadable otoliths.

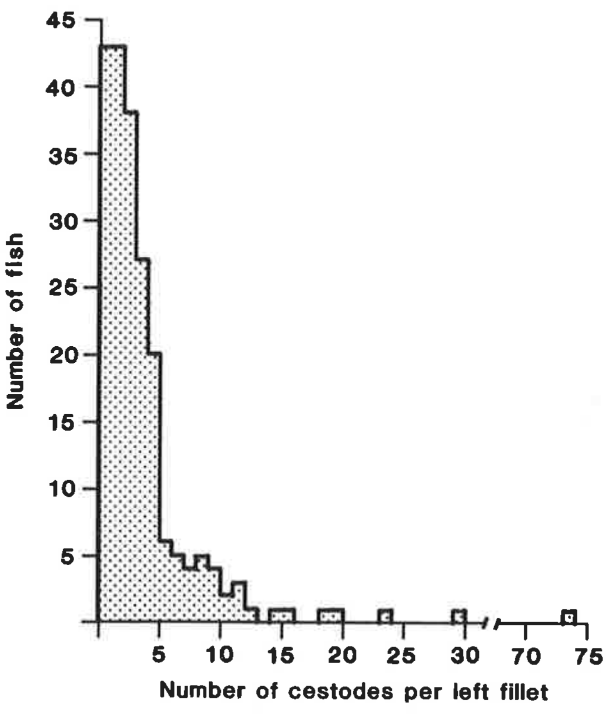

Fig. 22: Infection of barracouta left fillets with *Gymnorhynchus thyrsitae.*

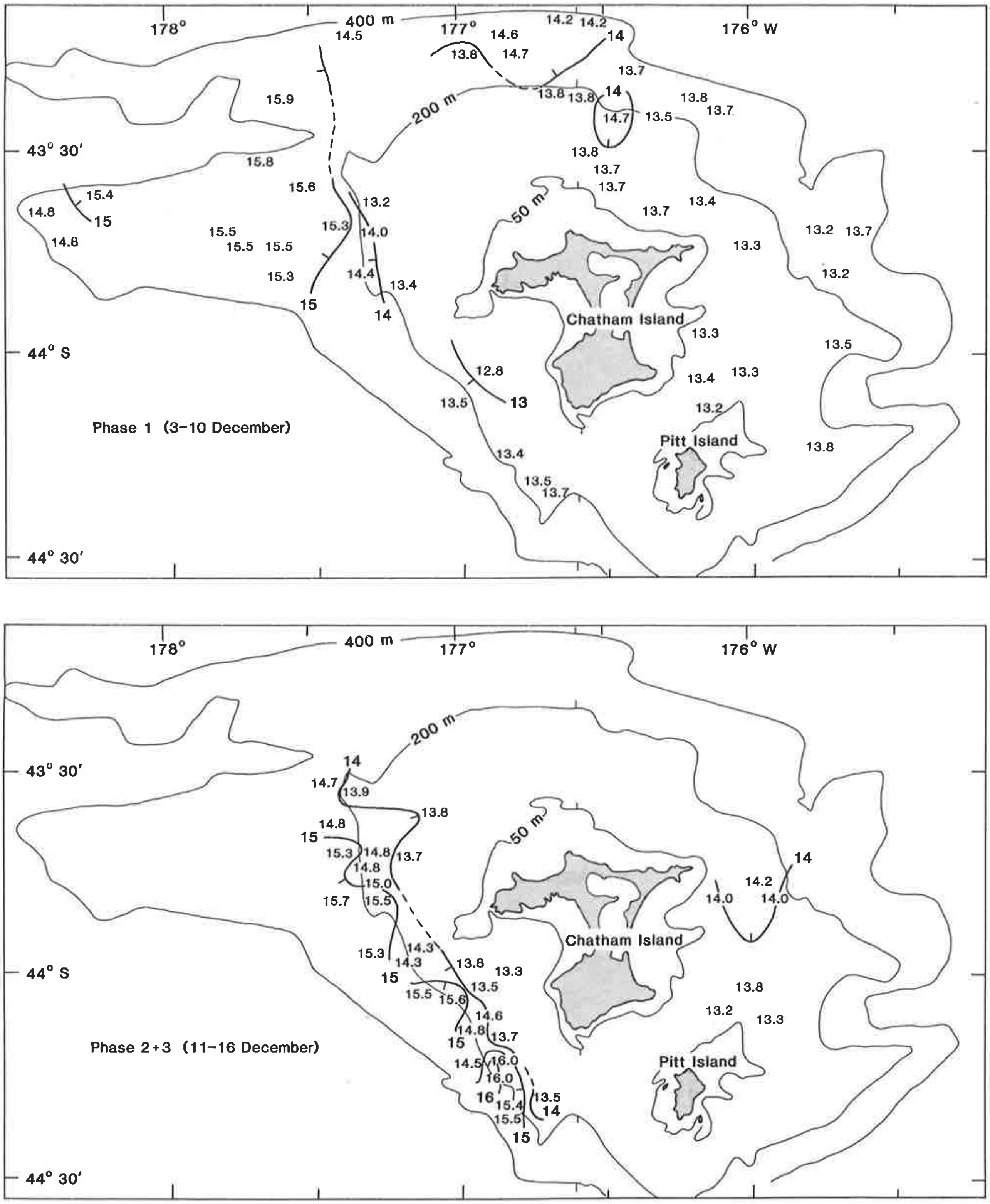

Fig. 23: Surface temperatures.

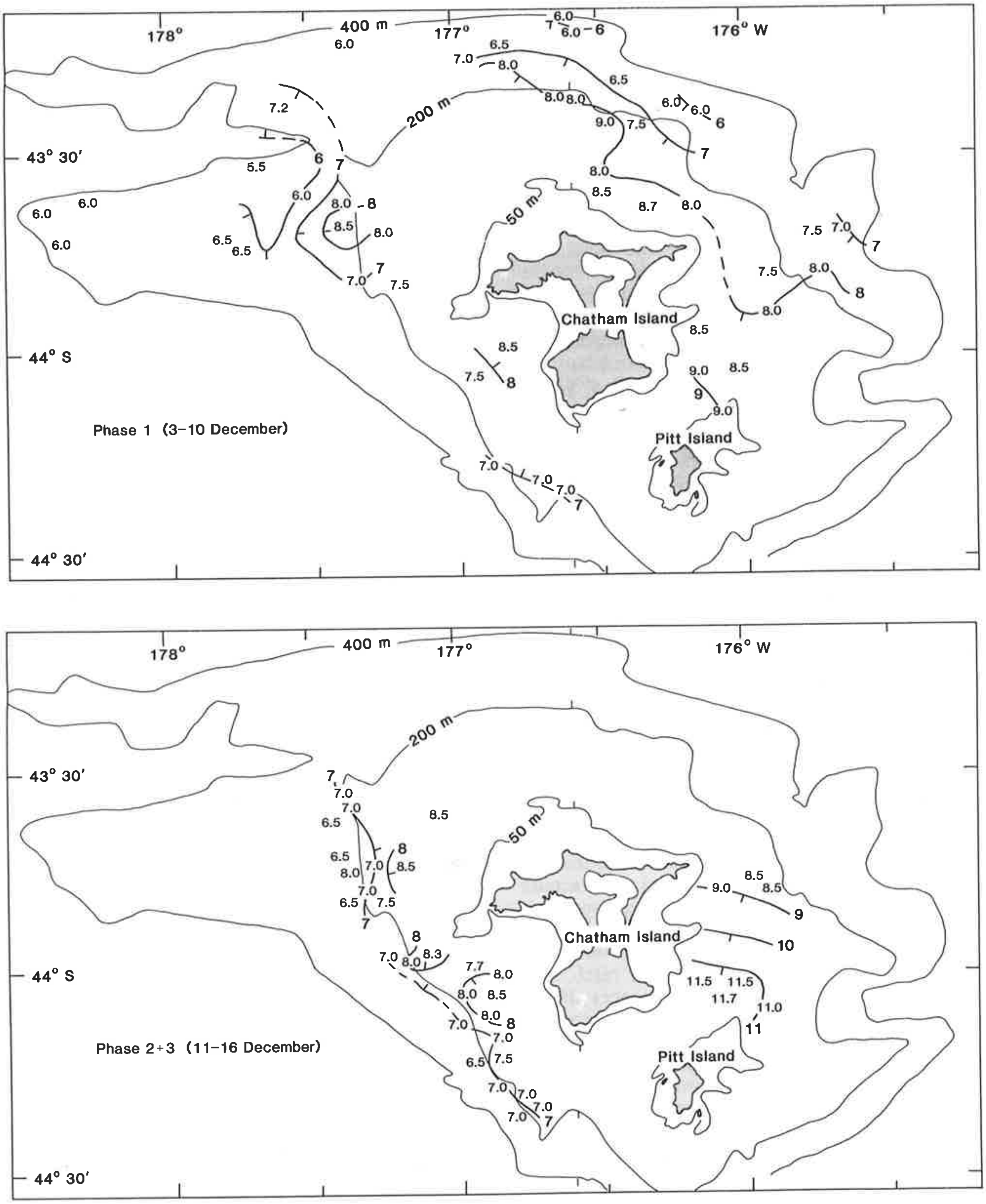

Fig. 24: Bottom temperatures.

Discussion

The hydrology of the Chatham Islands is influenced by the Subtropical Convergence, which passes south of New Zealand and extends northeast along the east coast of the South Island out on to the Chatham Rise (Garner 1959). The catch composition during this trawl survey was typical of shelf faunas influenced by this convergence and sampled by trawling (*see* Hurst and Fenaughty 1985). Common warehou and rig (*Mustelus lenticulatus*) occur around the Chatham Islands in small numbers, but were not caught during this survey, nor in either of the *Shinkai Maru* surveys in 1983.

The catch composition of the research survey was similar to that reported by deepwater vessels working in the area, though the proportions differed, partly because the research survey was random, whereas the commercial trawls were targeted and seasonal. However, the absence of school shark in reported deepwater commercial catches is probably due to problems with, or the undesirability of, processing this species. Although deepwater vessels are excluded from the 12 n. mile territorial sea, they can fish in survey strata 6, 7′, and 8, most of stratum 3, and part of stratum 4′; therefore, they would have access to about 40% of the school shark biomass estimated by this survey.

Blue cod and gurnard have been caught in commercial quantities by domestic vessels at the Chatham Islands, but were rarely taken during this survey. This was because the type of trawl gear and bottom area were not suitable for catching these species.

The site of the major barracouta concentrations during the survey included the main barracouta target area of deepwater vessels during summer. This area was based almost entirely in one half-degree square, between 43° 30′ and 44° 00′ S and 177° 30′ and 177° 00′ W. The higher catch rates in 150–299 m, with no clear differences during daylight, were also consistent with data recorded in deepwater vessel logbooks (Hurst in press). The identification of barracouta and silver warehou spawning aggregations in December in the area explains the high catches and catch rates reported in the 1977–78 summer. (The warehou catch was not recorded by species, but it was assumed that most were silver warehou.)

The use of biomass estimates from this survey for comparison with other surveys, and for the derivation of potential yields, first requires consideration of the discreteness of the Chatham Islands shelf fish fauna. Studies by Vooren (1977) and Vooren and Tracey (1976) on growth, mortality, and parasite (*Anisakis*) infection of tarakihi suggested that the Chatham Islands population was separate from the more heavily exploited east coast populations. Data from tagging observations elsewhere in New Zealand and in Australia (Hurst and Bagley 1984a, Johnston 1983, Olsen 1984) suggested that other shelf species (e.g., barracouta, hapuku, and school shark) were capable of migrating long distances. It is also possible that larvae and juveniles are recruited from east coast New Zealand and Mernoo Bank spawning grounds.

The barracouta population examined in this survey appeared to have a different length structure from barracouta from other parts of New Zealand, which suggested it may be a separate population or stock. Only 10% of the population was 75 cm or longer, compared with, for example, 66% of barracouta from the Snares shelf in March 1982 (van den Broek, Tokusa, and Kono 1984) and 80 and 64% of barracouta from the west coast of the South Island during spring 1983 and spring 1984 respectively (Hurst and Bagley 1984b). Some of the differences in these length-frequency structures could be related to the presence of strong year classes, but this is usually more apparent in smaller fish (e.g., the absence of 2 year olds may be because they are a weak year class). There is also some evidence that spawning barracouta may school by size (authors' unpublished data). However, only 11% of 194 barracouta taken during the *Shinkai Maru* survey around the Chatham Islands in March 1983 were longer than 75 cm (Fenaughty and Uozumi in press). The age structure of the Chatham Islands population has yet to be determined, but the interpretation of as yet unreadable otoliths, or the collection of further samples, should help to improve the age-length key. Growth rates of younger fish are similar to those found in other parts of New Zealand (authors' unpublished data) and in Australia (Grant, Cowper, and Reid 1978).

Several other observations suggest that the Chatham Islands barracouta may form a separate population. The large proportion of unreadable otoliths (31%) was much higher than the 5% or less found elsewhere. The spawning season is 2–3 months later than the major east coast New Zealand season (August-September), and qualitative examinations of peritoneal cavities showed a higher level of infection of Chatham Islands barracouta with nematode larvae of *Anisakis simplex*. Arrow squid also appeared to have high levels of infection with this parasite compared with observations of arrow squid elsewhere around New Zealand (Smith, Roberts, and Hurst 1981). These qualitative observations are consistent with the pattern found in tarakihi (Vooren and Tracey 1976).

Comparison of biological observations between this and other surveys at the Chatham Islands is limited because of the lack of previous research. The tarakihi length range and length-weight relationships found in this survey were similar to those recorded during November 1972 (Vooren 1977). Length frequencies of silver and white warehou recorded on the November-December *Shinkai Maru* survey (Hatanaka *et al.* [1985]) were similar to those described here, even though a smaller cod-end mesh size (60 mm) was used. The squid length frequency was different because it was bimodal, but there was a similar range in sizes.

The relationship between mainland and Chatham Islands populations of hapuku and school shark is probably best studied by tagging. No returns have yet been received from the hapuku tagged during this survey.

A winter survey of the study area would also provide some indication of possible seasonal movements into or out of the Chatham Islands shelf. The high commercial catch rates of barracouta and arrow squid recorded on the western side of the Chatham Islands during the winters of 1980 and 1983 suggested there may be substantial resident populations. The two *Shinkai Maru* surveys in 1983, though in different seasons, had such high coefficients of variation associated with the abundance estimates of shelf species (because shelf sampling was limited) that any seasonal variability effects were lost (Table 20).

Biomass estimates from this survey should be used with reference to the assumptions on page 11 and in relation to two possible sources of bias: fish movement and stratum boundary changes.

The movement of fish during a trawl survey can cause problems with biomass estimation, but is more likely to be detected by use of a survey design of more than one phase. There was some suggestion of movement of silver warehou into the survey area during phase 3, but this could not be established because of the change made to the stratum boundary. There may also have been some movement of barracouta, arrow squid, school shark, and hapuku out of stratum 2 between phases 1 and 2, though the decrease in catch rates was only significant for arrow squid and hapuku. The movement of fish may have been associated with the apparent increase in bottom temperature of about 2°C during this time. The hydrological data collected were inadequate to allow this hypothesis to be tested.

Phases 2 and 3 of the survey were aimed at improving the precision of the biomass estimate for barracouta. Although the phase 2 stations were allocated strictly according to the method of Francis (1984), the movement of the boundary between strata 4 and 7, and the generation of random stations for phase 3, may have introduced bias. Hence, the overall biomass estimate for barracouta may be artificially high and the coefficient of variation artificially low. The estimates of other commercial shelf species, except perhaps arrow squid, (i.e., tarakihi, hapuku, and school shark) were not similarly affected.

Biomass estimates for barracouta are unlikely to be low because of the short tow time. Comparison of catch rates during the research survey with the four commercial target stations and with target barracouta fishing carried out by *Akebono Maru No. 73* in the area after the survey suggests that the randomly chosen, 3 n. mile research stations were capable of providing the same maximum catch rate as targeted commercial operations: research, 10.1 t.h^{-1}; commercial during this survey, 7.8 t.h^{-1}; commercial *Akebono Maru No. 73* December 1984-January 1985, 8.3 t.h^{-1}; commercial all vessels November 1983-January 1984,

TABLE 20: Comparison of wingtip spread biomass estimates and coefficients of variation (c.v.) for the main species* at the Chatham Islands

	Akebono Maru No. 73		*Shinkai Maru*							
	Dec 1984, strata 1–8 (n = 80)		Mar 1983†, stratum 21 (n = 9)		Nov-Dec 1983‡, stratum 12 (n = 9)		Mar 1983†, areas C–D§ (n = 124)		Nov-Dec 1983 area D‡, (n = 84)	
Species	Biomass (10^3 t)	c.v. (%)	Biomass (10^3 t)	c.v. (%)	Biomass (10^3 t)	c.v. (%)	Biomass (10^3 t)	c.v. (%)	Biomass (10^3 t)	c.v. (%)
BAR	46.2	12	11.4	75	8.9	66	28.5	33	9.4	63
SWA	10.8	22	0.3	56	6.5	–‖	38.6	33	66.6	40
ASQ	6.4	16	4.0	63	3.9	–	27.1	26	12.0	23
HOK	11.1	30	19.1	50	34.9	41	1 771.7	11	454.3	15
SPD	3.0	64	0.0	0	–	–	30.1	15	13.0	15
TAR	4.1	30	3.3	42	0.9	72	5.2	33	1.1	61
HAP	3.6	12	2.9	53	0.6	78	4.3	37	1.6	40
LIN	2.0	12	19.5	92	4.2	–	67.6	27	47.2	14
SCH	1.6	19	0.5	72	0.5	52	2.2	34	0.8	38
STA	1.2	14	6.4	33	5.9	54	36.9	18	16.9	24

* Species codes are given in Appendix 2.

† From Fenaughty and Uozumi (in press), except HAP and SCH from raw data files on Fisheries Research Centre research data base.

‡ Calculated from raw data files on Fisheries Research Centre research data base, except SWA, ASQ, HOK, and LIN from Hatanaka *et al.* [1985].

§ EEZ areas.

‖ Not recorded.

11.2 t.h^{-1}. The same conclusions cannot be applied to any of the other species caught during the survey without making similar comparisons with target fishing operations.

The wingtip spread abundance estimates from this survey are compared with the results of the two *Shinkai Maru* 1983 surveys in Table 20. The biomass estimates from this survey were usually larger and always more precise for the predominantly shelf species (in particular, barracouta, tarakihi, hapuku, and arrow squid) in waters of 50–450 m around the Chatham Islands. This is directly attributable to the survey design, with the increased number of stations, stratification, and number of phases and the extension of the survey area inside the 12 n. mile territorial sea. The survey only touched on the shallow edge of the range for species which occur in deeper water (e.g., hoki, hake) and, therefore, only sampled a small part of the Chatham Rise population. Thus, the biomass estimates for these species from this survey are much lower and less precise than those from the *Shinkai Maru* surveys.

The use of biomass estimates of shelf species to estimate yields for the Chatham Islands is complicated by: the lack of knowledge of stock migrations across the Chatham Rise; difficulties in extrapolating catch rates over unsurveyed areas (Petre Bay, Hanson Bay, and areas of foul ground or gear conflict; i.e., 22% of the original planned survey area); and problems in determining the effective area swept.

However, from these data, annual yield estimates were made for several shelf species for the recommended 1985–86 TACs (Colman, McKoy, and Baird 1985). The average of the wing and door spread biomass estimates was used to allow for possible herding effects of the doors and sweeps. The resulting biomass was then multiplied by an estimated productivity value to obtain the yield (Table 21). For barracouta, yield estimates are given for phases 1 + 2 and phases 1 + 2 + 3 because the survey design may have introduced bias in phase 3. Tarakihi, hapuku, and school shark catch rates were also expanded over the unsurveyed foul ground by assuming equal density.

TABLE 21: Possible annual yields of the main Chatham Islands shelf species (excluding arrow squid)

	Biomass (t)*	Coefficient of variation (%)	Assigned productivity (%)	Yield (t)†	Expanded area‡ Biomass (t)	Expanded area‡ Yield (t)
BAR§						
Phases 1 + 2	27 304	17	15	4 096		
Phases 1 + 2 + 3	30 590	12	15	4 589		
TAR	2 686	30	10	269	3 223	322
HAP	2 394	12	10	239	3 352	335
SCH	1 047	19	5	52	1 522	76

* Calculated from $(WT + D)/2$, the average of wingtip spread and door spread biomass estimates ($D = WT/3.09$).
† Yield is biomass multiplied by productivity.
‡ Expanded area includes unsurveyed areas of foul ground between 50 and 400 m.
Stratum expansion factors were (from Table 3): 1, 1.00; 2, 2.11; 3, 1.00; 4, 1.12; 5, 1.57; 6, 1.00; 7, 1.27; 8, 1.88.
§ Species codes are given in Appendix 2.

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Appendix 1

Individual station data

Station No.	Date	Start position ° 'S	Start position ° 'W	Start time (h)	Start depth (m)	Stratum No.	Tow length (n. mile)	Net width (m)
1	3/12/84	43 57.2	176 52.8	708	130	4	3.0	35.0
2	3/12/84	44 01.3	176 58.2	905	166	4	3.1	35.5
3	3/12/84	44 04.9	177 01.0	1050	191	4	3.2	41.0
4	3/12/84	44 13.5	176 54.5	1215	207	4	3.0	43.0
5	3/12/84	44 17.4	176 46.2	1435	183	4	3.1	36.0
6	3/12/84	44 18.5	176 41.0	1728	172	4	3.0	36.0
7	4/12/84	44 07.9	176 04.4	500	54	2	3.0	28.0
8	4/12/84	44 03.0	176 08.8	620	58	2	3.0	28.0
9	4/12/84	43 57.2	176 09.1	800	84	2	3.0	36.7
10	4/12/84	44 03.3	175 59.1	1015	83	2	3.0	36.7
11	4/12/84	43 55.5	175 53.2	1230	120	5	3.1	38.0
12	4/12/84	43 45.4	176 00.8	1455	150	5	3.0	43.0
13	4/12/84	43 39.7	176 08.8	1710	134	3	3.0	41.3
14	5/12/84	43 26.0	176 40.7	500	97	1†	0.0	–‡
15	5/12/84	43 32.0	176 31.3	622	92	1	3.0	37.0
16	5/12/84	43 34.4	176 30.6	745	82	1	3.0	37.0
17	5/12/84	43 37.6	176 20.8	950	92	1	3.0	37.0
18	5/12/84	43 23.7	176 08.8	1350	368	6	3.0	35.0
19	5/12/84	43 21.5	176 13.3	1555	361	6	3.0	35.0
20	5/12/84	43 23.6	176 23.9	1805	239	3	3.0	38.0
21	6/12/84	43 40.8	175 39.8	502	351	8	3.1	38.7
22	6/12/84	43 40.4	175 46.3	657	291	8	3.1	36.7
23	6/12/84	43 46.2	175 45.4	825	301	8	3.0	39.0
24	6/12/84	43 58.2	175 42.9	1140	135	5†	0.6	–
25	6/12/84	44 12.4	175 47.0	1700	126	5†	0.5	–
26	7/12/84	43 49.6	177 35.9	502	396	7	3.0	31.5
27	7/12/84	43 49.1	177 18.4	742	192	4	3.0	27.0
28	7/12/84	43 47.8	177 14.4	1028	177	4	3.0	35.0
29	7/12/84	43 35.2	177 18.5	1507	158	4	3.1	43.0
30	7/12/84	43 39.8	177 18.2	1620	157	4	3.1	40.0
31	7/12/84	43 41.7	177 22.5	1740	192	4	3.2	34.5
32	8/12/84	43 34.0	178 14.7	506	423	7	3.0	37.0
33	8/12/84	43 36.1	178 26.8	700	410	7	3.0	37.0
34	8/12/84	43 42.1	178 25.8	850	400	7	3.0	39.0
35	8/12/84	43 39.6	177 48.8	1210	375	7	3.0	41.0
36	8/12/84	43 41.7	177 35.7	1352	385	7	2.9	41.0
37	8/12/84	43 43.5	177 41.7	1525	400	7	3.0	42.0
38	8/12/84	43 37.1	177 32.5	1720	343	7	3.2	44.3
39	9/12/84	43 31.6	177 41.9	458	385	7	3.1	36.6
40	9/12/84	43 21.2	177 35.8	705	338	6	3.1	38.0
41	9/12/84	43 13.6	177 25.2	935	410	6	3.0	35.4
42	9/12/84	43 13.8	176 48.0	1250	325	6	3.0	40.6
43	9/12/84	43 16.2	176 54.7	1445	282	6	2.9	40.6
44	9/12/84	43 16.6	176 52.0	1706	170	3	3.0	36.7
45	10/12/84	43 25.8	176 24.2	505	172	3	3.1	35.7
46	10/12/84	43 23.1	176 32.9	625	145	3	3.0	35.0
47	10/12/84	43 20.7	176 36.8	747	136	3	2.8	35.0
48	10/12/84	43 20.1	176 24.0	956	316	6	3.0	44.0
49	10/12/84	43 10.3	176 40.0	1230	429	6	3.0	30.6
50	10/12/84	43 11.0	176 31.1	1410	434	6	3.0	30.7
51	11/12/84	43 37.2	177 03.7	513	141	4†	2.0	–
52	11/12/84	43 42.7	177 22.5	735	183	4	3.1	34.4
53	11/12/84	43 44.5	177 12.4	951	168	4†	2.4	–
54	11/12/84	43 58.2	177 05.8	1315	172	4	3.0	34.0
55	11/12/84	43 56.8	177 11.7	1450	201	4	3.0	34.4
56	11/12/84	44 01.2	176 58.2	1635	167	4	3.0	34.4
57	12/12/84	43 58.3	176 54.6	501	140	4	3.2	32.7
58	12/12/84	43 57.8	176 58.8	637	160	4	3.2	36.4
59	12/12/84	44 07.8	176 54.0	810	172	4	3.2	36.5
60	12/12/84	44 20.8	176 44.0	1045	200	4	3.0	33.7
61	12/12/84	44 13.9	176 55.4	1235	288	4	3.0	33.7
62	12/12/84	44 08.9	176 57.5	1410	220	4	2.9	33.7
63	13/12/84	44 01.1	176 13.4	505	56	2	3.0	28.0
64	13/12/84	44 03.1	176 07.0	612	60	2	3.0	31.4
65	13/12/84	44 04.5	176 00.0	727	74	2	3.1	35.0
66	13/12/84	44 03.1	176 00.1	842	78	2	3.0	36.7
67	13/12/84	43 46.7	175 55.9	1140	160	5	3.0	35.5
68	13/12/84	43 47.2	175 56.7	1215	151	5	3.0	36.2
69	13/12/84	43 46.2	176 06.5	1447	122	5	3.0	37.1

Appendix 1—*continued*

											Catch (kg)
Station No.	BAR	SWA	RHY	ASQ	SPD	HOK	TAR	HAP	SCH	LIN	All species
1	712	0	0	400	5 000	0	94	32	0	0	6 244
2	4 444	0	0	120	240	0	140	3	0	0	4 953
3	1 013	63	0	160	350	0	280	20	0	0	1 956
4	525	35	0	140	60	0	60	20	50	5	941
5	2 213	10	0	280	240	0	70	50	50	0	2 958
6	1 744	0	0	800	100	1 013	157	15	50	10	3 949
7	1 613	0	0	45	0	0	80	290	200	0	2 286
8	4 350	0	0	920	0	0	20	234	200	0	5 774
9	4 800	0	0	40	0	0	3	245	280	0	5 368
10	43	0	0	10	0	0	0	131	0	0	234
11	700	0	0	320	0	0	60	200	50	20	1 498
12	1 388	0	0	120	0	0	120	75	10	0	1 909
13	1 350	0	0	200	0	0	880	75	10	15	2 780
14	0	0	0	0	0	0	0	0	0	0	0
15	420	0	0	40	80	0	4	30	10	0	635
16	1 050	0	0	20	35	0	0	300	10	10	1 485
17	200	32	0	10	0	0	105	328	175	15	907
18	0	210	0	20	0	300	0	25	0	40	770
19	9	85	0	20	0	105	0	12	2	40	380
20	0	100	100	45	0	300	35	100	15	5	735
21	0	25	5	10	0	320	0	35	10	40	467
22	15	20	0	40	0	15	20	35	0	110	263
23	22	8	0	100	5	0	105	88	45	40	432
24	0	0	0	10	0	0	90	30	0	0	142
25	0	0	0	2	0	0	6	0	0	3	18
26	0	100	0	10	0	160	0	0	0	25	345
27	700	45	0	70	0	0	50	6	10	0	898
28	4 390	150	0	60	0	0	50	0	20	0	4 805
29	1 160	2	0	40	0	0	50	20	0	0	1 291
30	1 390	2	0	30	0	0	3	15	10	5	1 470
31	2 340	50	0	220	0	0	3	10	0	20	2 718
32	0	150	0	10	0	160	0	0	0	40	447
33	0	100	0	5	0	250	0	10	0	45	659
34	0	100	0	10	0	320	0	0	0	20	608
35	65	230	0	30	0	300	0	4	5	45	865
36	4	70	0	10	0	96	0	0	0	40	340
37	0	50	0	40	0	150	0	0	0	40	352
38	500	190	400	80	0	70	2	8	20	60	1 492
39	0	50	0	30	0	100	0	0	0	50	286
40	2	35	70	40	0	60	5	50	0	70	897
41	0	6	0	20	0	175	0	0	20	30	464
42	0	0	0	20	0	35	35	12	5	0	220
43	0	0	30	20	0	0	145	10	15	5	293
44	25	1	0	12	0	0	10	23	30	0	139
45	105	60	0	30	0	0	125	55	90	0	626
46	200	30	0	200	0	0	10	20	20	5	1 217
47	70	0	0	40	0	0	6	38	20	5	224
48	0	110	5	40	0	1 500	10	45	40	10	1 841
49	0	4	0	13	0	315	0	0	0	40	572
50	0	5	0	20	0	245	0	0	0	10	505
51	140	0	0	40	0	0	140	75	20	5	435
52	1 690	80	0	40	0	0	35	60	0	15	1 932
53	710	14	0	10	0	0	35	6	5	0	821
54	3 600	0	0	80	210	0	140	20	40	20	4 165
55	2 625	220	0	260	175	0	140	24	80	20	3 619
56	600	0	0	100	175	0	85	10	20	0	1 041
57	385	30	0	180	525	0	210	95	0	20	1 475
58	863	0	0	50	70	0	12	70	0	10	1 090
59	2 436	160	0	110	175	0	175	50	0	0	3 151
60	1 163	50	0	240	20	0	20	30	0	0	1 527
61	5 250	1 140	0	200	35	0	5	50	0	0	6 855
62	635	280	0	60	20	0	80	6	0	0	1 103
63	525	0	0	0	0	0	0	75	100	0	717
64	450	0	0	0	0	0	0	120	80	0	722
65	70	0	0	0	0	0	90	40	45	0	282
66	9	0	0	0	0	0	1	40	35	0	163
67	0	35	0	8	25	0	120	175	75	0	668
68	150	35	0	0	10	0	125	87	0	0	622
69	263	35	0	20	0	0	70	90	15	5	543

Appendix 1—*continued*

Station No.	Date	Start position ° 'S	° 'W	Start time (h)	Start depth (m)	Stratum No.	Tow length (n. mile)	Net width (m)
70	14/12/84	43 33.4	177 25.9	500	259	4'	3.0	38.0
71	14/12/84	43 32.2	177 24.0	625	239	4'	3.2	44.5
72	14/12/84	43 35.5	177 27.5	750	295	4'	3.0	49.5
73	14/12/84	43 40.8	177 24.8	925	271	4'	3.0	46.5
74	14/12/84	43 45.0	177 20.7	1130	181	4'	3.0	36.9
75	14/12/84	43 45.0	177 18.4	1250	177	4'	2.9	43.0
76	14/12/84	43 32.0	177 25.8	1515	267	4§	14.8	44.5
77	15/12/84	43 47.3	177 24.5	500	247	4'	3.0	36.7
78	15/12/84	43 47.8	177 17.6	635	180	4'	2.9	30.5
79	15/12/84	43 55.6	177 17.2	803	251	4'	3.2	30.5
80	15/12/84	44 01.2	177 09.0	940	230	4'	3.2	30.5
81	15/12/84	44 07.2	176 54.8	1137	179	4'	3.0	36.7
82	15/12/84	44 03.9	176 59.0	1340	180	4'	3.0	42.3
83	15/12/84	44 01.0	177 09.6	1515	244	4§	12.9	35.5
84	16/12/84	44 21.4	176 45.5	500	234	4'	3.2	39.1
85	16/12/84	44 19.2	176 46.5	625	204	4'	3.1	33.0
86	16/12/84	44 16.6	176 50.4	750	217	4'	3.2	33.0
87	16/12/84	44 13.3	176 51.6	915	206	4'	3.2	33.0
88	16/12/84	44 09.0	176 56.5	1040	205	4§	13.2	–
89	16/12/84	44 04.0	177 05.8	1410	263	4§	18.2	–

* Species codes are given in Appendix 2.
† Fouled trawl shot.
‡ No recording.
§ Commercial tow.

Appendix 1—*continued*

Station No.	BAR	SWA	RHY	ASQ	SPD	HOK	TAR	HAP	SCH	LIN	Catch (kg) All species
70	385	2 079	1	120	0	225	2	25	0	40	2 913
71	1 050	105	0	160	0	0	0	12	30	5	1 400
72	2 100	630	20 000	120	0	40	0	45	15	225	23 290
73	4 687	1 040	0	105	0	0	0	0	0	0	5 832
74	3 225	70	0	100	0	0	30	15	0	0	3 440
75	3 075	126	0	270	0	0	0	0	0	75	3 581
76	23 400	441	0	1 782	0	150	63	85	0	0	26 244
77	2 963	1 418	0	95	0	160	0	0	0	10	4 648
78	6 020	35	0	297	0	0	35	0	0	38	6 931
79	4 144	63	0	284	0	0	95	0	0	0	4 652
80	3 731	126	0	216	0	0	158	40	0	0	4 371
81	1 350	63	0	40	0	0	189	25	0	0	1 677
82	1 050	370	0	160	15	0	210	23	0	0	1 874
83	11 881	337	0	242	0	187	251	170	0	0	13 298
84	350	3 134	0	405	0	15	32	8	0	0	4 002
85	2 475	221	0	1 944	0	0	32	50	0	0	4 737
86	7 613	3 780	0	567	0	0	40	15	0	0	12 036
87	750	3 780	0	0	0	0	0	20	0	0	4 610
88	3 788	1 402	0	1 080	0	0	504	43	0	0	6 952
89	14 738	2 127	0	4 090	0	7 650	158	213	0	0	29 722

Appendix 2

Species taken during the survey

Scientific name	Common name	Species code
Agnatha		
Eptatretidae	Blind eels	
Eptatretus cirrhatus	hagfish, blind eel	HAG
Elasmobranchii		
Hexanchidae	Sixgill sharks	
Notorhynchus cepedianus	broadsnouted sevengill shark	SEV
Scyliorhinidae	Catsharks	
Cephaloscyllium isabella	carpet shark	CAR
Carcharhinidae	Requiem sharks	
Galeorhinus australis	school shark	SCH
Squalidae	Spiny dogfish	
Oxynotus bruniensis	prickly dogfish	PDG
Squalus acanthias	spotted spiny dogfish	SPD
Squalus blainvillei	grey spiny dogfish	NSD
Narkidae	Blind electric rays	
Typhlonarke aysoni	blind electric ray	BER
Rajidae	True skates	
Raja nasuta	rough skate	RSK
Raja innominata	smooth skate	SSK
Bathyraja spp.	deepsea skate	BTH
Chimaeridae	Ghost sharks	
Hydrolagus novaezelandiae	dark ghost shark	GSH
Teleostei		
Congridae	Conger eels	
Bassanago hirsutus	hairy conger	HCO
Argentinidae	Argentines	
Argentina elongata	silverside	SSI
Moridae	Morid cods	
Pseudophycis bachus	red cod	RCO
Merlucciidae	Hakes	
Macruronus novaezelandiae	hoki	HOK
Merluccius australis	hake	HAK
Macrouridae	Rattails	
Coelorinchus biclinozonalis	twobanded rattail	CBI
Coelorinchus bollonsi	big-eye rattail	CBO
Lepidorhynchus denticulatus	javelin fish	JAV
Ophidiidae	Lings	
Genypterus blacodes	ling	LIN
Trachichthyidae	Roughies	
Paratrachichthys traillі	common roughy	RHY
Berycidae	Alfonsinos	
Beryx splendens	alfonsino	BYX
Zeidae	Dories	
Cyttus novaezelandiae	silver dory	SDO
Cyttus traversi	lookdown dory	LDO
Macrorhamphosidae	Snipefish	
Centriscops obliquus	redbanded bellowsfish	BBE
Scorpaenidae	Scorpion fish	
Scorpaena papillosus	sea perch	SPE
Triglidae	Gurnards	
Chelidonicthys kumu	red gurnard	GUR
Lepidotrigla brachyoptera	scaly gurnard	SCG
Hoplichthyidae	Ghost flatheads	
Hoplichthys haswelli	deepsea flathead	FHD
Percichthyidae	Temperate basses	
Polyprion oxygeneios	hapuku	HAP
Serranidae	Sea perches	
Lepidoperca pulchellus	orange perch	OPE
Carangidae	Jacks	
Trachurus spp.	jack mackerels	JMA
Bramidae	Pomfrets	
Brama brama	Ray's bream	RBM
Emmelichthyidae	Bonnetmouths	
Emmelichthys nitidus	redbait	RBT
Pentacerotidae	Boarfish	
Pseudopentaceros richardsoni	southern boarfish	SBO

Appendix 2—*continued*

Scientific name	Common name	Species code
Cheilodactylidae	Morwongs	
Nemadactylus macropterus	tarakihi	TAR
Latridae	Trumpeters	
Latris lineata	trumpeter	TRU
Mugiloididae	Weevers	
Parapercis colias	blue cod	BCO
Uranoscopidae	Armour-head stargazers	
Kathetostoma giganteum	giant stargazer	STA
Gempylidae	Snake mackerels	
Rexea solandri	southern kingfish	SKI
Thyrsites atun	barracouta	BAR
Trichiuridae	Cutlassfish	
Lepidopus caudatus	frostfish	FRO
Centrolophidae	Warehou and butterfish	
Centrolophus niger	rudderfish	RUD
Hyperoglyphe antarctica	bluenose	BNS
Seriolella caerulea	white warehou	WWA
Seriolella punctata	silver warehou	SWA
Nomeidae	Eyebrow fish, scissortails	
Cubiceps caeruleus	cubehead	CUB
Pleuronectidae	Righteyed flounders	
Pelotretis flavilatus	lemon sole	LSO
Cephalopoda		
Ommastrephidae		
Nototodarus sloanii	arrow squid	ASQ
Todarodes filippovae	southern arrow squid	SQU
Onychoteuthidae		
Moroteuthis ingens	warty squid	WSQ
Crustacea		
Nephropsidae		
Metanephrops challengeri	scampi	SCI
Palinuridae		
Jasus edwardsii	rock lobster	CRA
Majidae		
Leptomithrax sp.	masking crab	CRB
Portunidae		
Ovalipes catharus	common swimming crab, paddle crab	PAD

Appendix 3

Mean catch rates (kg.km^{-2}) and standard deviations of the 20 major species* by stratum

	1	2	3	4′	5	6	7′	8
BAR	2 768	7 370	1 450	11 182	2 464	6	298	61
	(2 193)†	(9 851)	(2 600)	(8 677)	(2 779)	(14)	(771)	(55)
HOK	0	0	249	196	0	1 511	884	539
	(0)	(0)	(608)	(848)	(0)	(2 301)	(456)	(870)
SWA	53	0	158	2 508	105	251	569	86
	(91)	(0)	(202)	(4 823)	(97)	(359)	(301)	(41)
RHY	0	0	83	2 688	0	58	207	8
	(0)	(0)	(202)	(16 348)	(0)	(116)	(622)	(14)
ASQ	116	630	439	1 119	456	116	122	246
	(75)	(1 597)	(434)	(1 594)	(652)	(47)	(113)	(229)
TAR	180	119	881	351	489	111	0	207
	(296)	(185)	(1 727)	(359)	(158)	(246)	(3)	(279)
HAP	1 091	729	260	116	616	86	11	257
	(818)	(486)	(155)	(105)	(276)	(94)	(19)	(155)
SPD	191	0	0	983	36	0	0	8
	(199)	(0)	(0)	(4 072)	(55)	(0)	(0)	(14)
LIN	41	0	25	69	25	135	199	307
	(39)	(0)	(28)	(193)	(41)	(111)	(55)	(193)
SCH	323	583	152	50	146	47	14	91
	(472)	(489)	(141)	(97)	(155)	(69)	(30)	(119)
WWA	0	0	0	0	0	124	243	0
	(0)	(0)	(0)	(0)	(0)	(141)	(274)	(0)
JMA	17	0	111	100	359	58	0	0
	(28)	(0)	(202)	(398)	(492)	(113)	(3)	(0)
STA	182	53	105	102	124	25	61	28
	(14)	(69)	(127)	(91)	(72)	(50)	(86)	(25)
RBT	0	0	497	0	116	0	6	0
	(0)	(0)	(1 218)	(0)	(221)	(0)	(17)	(0)
OPE	0	0	0	25	0	199	0	0
	(0)	(0)	(0)	(91)	(0)	(475)	(0)	(3)
BYX	0	0	0	0	0	152	8	3
	(0)	(0)	(0)	(0)	(0)	(238)	(17)	(6)
LDO	0	0	3	0	0	64	83	3
	(0)	(0)	(6)	(3)	(0)	(30)	(33)	(6)
FRO	0	0	149	0	169	3	0	6
	(0)	(0)	(343)	(0)	(379)	(11)	(0)	(8)
SPE	0	0	6	6	0	47	58	0
	(0)	(0)	(11)	(28)	(0)	(41)	(39)	(0)
BNS	0	0	3	6	0	64	8	33
	(0)	(0)	(8)	(28)	(0)	(64)	(11)	(36)
All species	5 017	9 658	4 738	19 536	5 163	3 274	2 931	1 890
	(2 158)	(11 644)	(4 845)	(19 583)	(3 028)	(2 434)	(1 782)	(539)
No. of stations	3	8	6	37	5	9	9	3

* Species codes are given in Appendix 2.
† Standard deviations are in parentheses.

V. R. WARD, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND—1987

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