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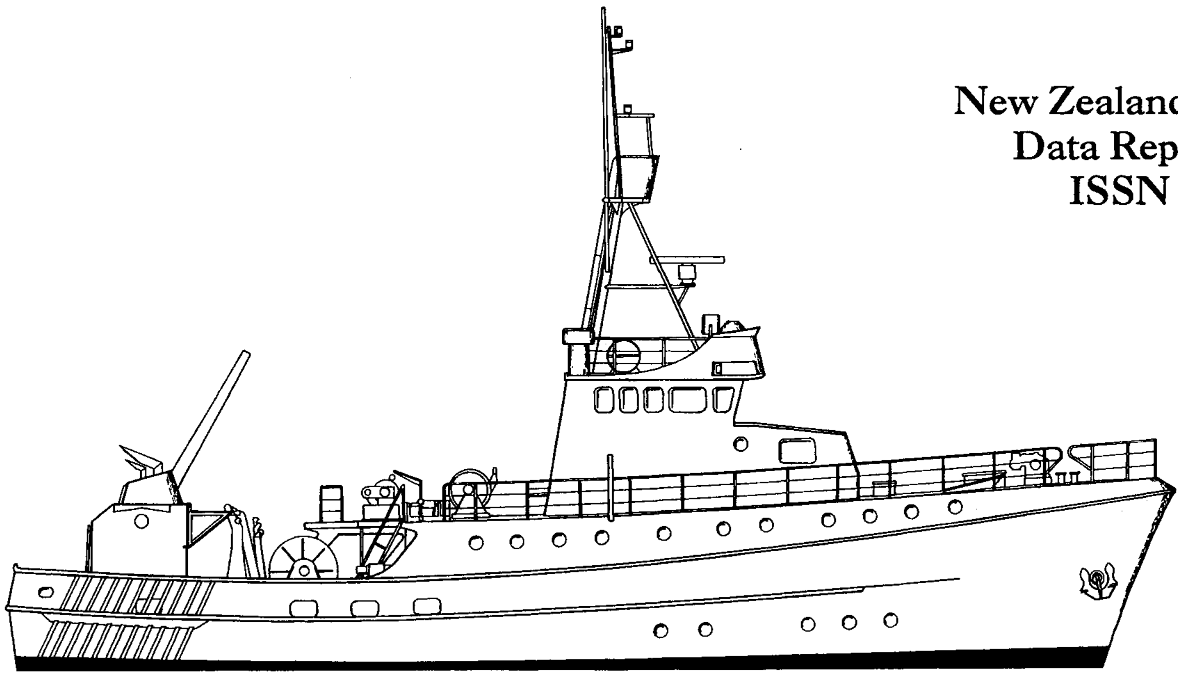
Trawl survey of juvenile snapper in Tasman and Golden Bays, July 1995 (KAH9507)

Michael L. Stevenson



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Introduction

This report presents results from the first in a planned time-series of stratified random trawl surveys at depths greater than 10 m within Tasman and Golden Bays, a nursery area for a number of important inshore fishes, including tarakihi (*Nemadactylus macropterus*) and snapper (*Pagrus auratus*). The aim of the series is to estimate the relative abundance of juvenile snapper.

The Snapper 7 fishery is highly valued by the non-commercial sector, and, up until the early 1980s, was important commercially.

The Snapper 7 fishery sustained catches in excess of 500 t over a 29 year period from 1955 to 1983. Following overfishing in the late 1970s and early 1980s (Drummond 1994), the TACC was set at a historically low level (372 t) in 1986. It was further reduced to 160 t in 1989 as a result of a biomass assessment (Drummond 1994). Recent modelling of the fishery suggests that it has been rebuilding since the mid 1980s. This view is supported by the commercial sector who advocate an increase in the TACC.

The 1986–87 tagging programme showed that the population consisted mainly of old fish (Kirk *et al.* 1988), which suggests that any increase in biomass would have come from new recruits to the fishery rather than growth within the fishery. Knowledge of cohort strength will therefore provide an important input parameter to assist with accurate modelling of the fishery.

Previous surveys have shown that juvenile snapper are dispersed throughout Tasman and Golden Bays during winter (Drummond & Kirk 1986). Winter sampling could provide better relative estimates of year class strength than summer sampling when juveniles are concentrated inshore.

Project objectives

The major objectives of the research programme are:

1. to determine the distribution of juvenile snapper in Tasman and Golden Bays and develop a time-series of relative abundance indices; and
2. to estimate the age distribution of juvenile snapper in Tasman and Golden Bays.

Survey objectives

The specific objectives of the 1995 trawl survey were:

1. to obtain relative abundance data for juvenile snapper and other commercially important species sampled by bottom trawl in Tasman and Golden Bays;
2. to collect data on length and age of juvenile snapper;
3. to collect otoliths from snapper;
4. to collect data on length and sex of Individual Transferable Quota (ITQ) and selected non-ITQ species taken during the survey; and
5. to collect data on length and weight of juvenile hake and juvenile hoki for calculation of length-weight regression coefficients.

Project and voyage personnel

The project leader was Michael Stevenson and the skipper was Roy Brown.

Methods

Survey area and design

The survey area covered depths of 10–70 m in Tasman and Golden Bays inside a line from Farewell Spit to Stephens Island (Figure 1). The total area of the survey was 4182 km^2, 90% of which was trawlable ground.

The survey was of a two-phase stratified random design (*after* Francis 1984). Six strata (*see* Figure 1) were defined based on information from previous winter surveys of juvenile snapper in Tasman and Golden Bays.

Before the survey began, sufficient trawl stations to cover both first and second phase stations within each stratum were randomly generated by the computer programme 'rand_stn v2.1'(*see* Vignaux 1994). The stations were required to be a minimum of 3 km (1.5 n. miles) apart and each tow was 15 min long. Non-trawlable ground was identified before the voyage. The distribution of non-trawlable ground is shown in Table 1 and Figure 1.

For the two-phase methodology, juvenile snapper (less than 25 cm fork length) was designated as the target species. Twenty-five stations were assigned to phase 1, with a minimum of three stations per stratum. The remaining phase 1 stations were allocated to minimise the variance of the expected catch rates of the target species, where the expected catch rates were assumed to be similar to the catch rates from previous winter surveys, and on the stratum area. Stations reserved for phase 2 were aimed at improving the precision of the biomass estimate for the target species and were to be allocated after phase 1 had been completed.

Vessel and gear

RV *Kaharoa*, a 28 m stern trawler with a beam of 8.2 m, a displacement of 302 t, and engine power of 522 kW, is capable of towing at depths of 500 m. The net used was a high opening bottom trawl (without lower wings) and was fitted with a 40 mm knotless codend. Gear specifications and net plans were given by Drury & McKenzie (1992).

Doorspread and headline height were read off Scanmar monitoring equipment with an average of three readings during each tow. Doorspread varied between 67.5 and 89.4 m. Headline height varied between 4.9 and 6.0 m.

Trawling procedure

All tows (five to seven a day) were undertaken in daylight. For each tow the vessel steamed to the station position and, if necessary, the bottom was checked with the depth sounder. Once the tow was considered safe, the gear was set away so that the midpoint of the tow would coincide as nearly as possible with the station position. The direction of the tow was influenced firstly by a combination of weather conditions and bottom contours, and secondly by the location of the next tow (to minimise steaming between stations).

All stations were on trawlable ground. Standard tows were of 15 min at a speed over the ground of 3.25 kn: the distance covered was measured by GPS. The tow was deemed to have started when the netsonde showed that the net was on the bottom, and was completed when hauling began.

A minimum of 100 m and a maximum of 250 m of warp was used during towing. Since no tows were in depths greater than 60 m, variations in the length of warp were determined by bottom conditions.

Water temperatures

The surface temperature at each station was recorded from a hull-mounted sensor. The calibration of the sensor was uncertain, so surface temperatures are only relative. Bottom temperatures were recorded from the Scanmar netsonde, on average three times during each tow.

Catch and biological sampling

The catch was sorted into species on deck and weighed on 100 kg electronic motion-compensating Seaway scales to the nearest 0.1 kg. Small (less than 15 cm fork length) jack mackerel were not separated by species because of the difficulty of identification at that size.

Lengths, to the nearest whole centimetre below actual length, and sex were recorded for all ITQ species (except arrow squid), either for the whole catch or for a randomly selected subsample of 100–200 fish per tow. Biological data were collected from all snapper and consisted of individual fish length and weight, and gonad stages for fish longer than 25 cm. The gonad stages used were: 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs or milt free flowing); 5, spent. Lengths and weights were collected from individual hoki until a total of about 500 fish had been measured. These samples were selected non-randomly to ensure a full size range of the species was represented.

Data analysis

Relative biomass was estimated by the area-swept method of Francis (1981) using the Trawlsurvey Analysis Program (Vignaux 1994) run on the computer at Greta Point, Wellington.

The catchability coefficient (an estimate of the proportion of fish in the survey area available to be caught in the net) is the product of the vulnerability (v), vertical availability (u_v), and areal availability (u_a) as defined by Francis (1989). The following assumptions were made.

1. The area swept during each tow equalled the distance between the doors multiplied by the distance towed (usually 3.5 n. miles).
2. Vulnerability was 1.0. This assumes that all fish in the volume swept were caught and there was no escapement.
3. Vertical availability was 1.0. This assumes that all fish in the water column were below the headline height and available to the net.
4. Areal availability was 1.0. This assumes that the fishstock being sampled was entirely within the area sampled at the time of the survey.
5. Within the survey area, fish were evenly distributed over both trawlable and non-trawlable ground.

Although these assumptions are unlikely to be correct, their adoption provides the basis for a time series of relative biomass estimates.

Biomass estimates were calculated using data from all stations where gear performance was satisfactory, i.e., the gear performance code was 1 or 2. A combined biomass and length frequency analysis was used for species for which biomass above a specific length was required and for deriving the weighted length frequency distributions. Length-weight coefficients used in the scaling are given in Appendix 1. All length frequencies were scaled by the percentage of catch sampled, area swept (a function of doorspread and area swept), and stratum area using the Trawlsurvey Analysis Program.

The coefficient of variation (*c.v.*) associated with estimates of biomass was calculated using the method of Vignaux (1994).

Results

Trawl stations

A total of 37 stations was successfully completed (Table 1, Figure 1, Appendix 2). Almost no juvenile snapper were caught, so an additional two stations per stratum were allocated in place of second phase stations. Although no days were lost to weather, three stations in stratum 5 and all stations in stratum 6 were completed after all other stations because of strong westerly winds. At least five stations were completed in each stratum. An overall station density of one station per 113 km^2 was achieved (*see* Table 1).

Catch composition

A total of 7947 kg of fish was caught in 37 tows at an average of 215 kg per tow (range 76–1017 kg). Amongst the wetfish catch, 7 elasmobranchs and 43 teleosts were recorded, together with 3 cephalopods and 4 bivalves. Southern spiny dogfish made up 24% of the catch by weight (Table 2).

Barracouta, red cod, and red gurnard were all caught in over 90% of the tows. Catches of the six most abundant species by station and by stratum are given in Tables 3 and 4 respectively.

Catch rates and species distribution

Distributions and catch rates for all species combined and for the six most abundant species are shown in Figure 2. (N.B., catch rates are given in terms of $kg.km^{-2}$, hence a catch rate of 1000 $kg.km^{-2}$ equates to a catch of 440 kg in a standard tow as it covers 0.44 km^{-2} on average.) The catch rates for the six most abundant species by stratum are given in Table 5.

Biomass estimation

Relative biomass estimates for the 13 most abundant species and 4 other commercially important ITQ species are given in Table 6. For species subject to a regulatory or processing limit, estimates above a given size are provided. For red cod, the processing size has varied between years (38 cm in 1992, 45 cm in 1994, and 40 cm in 1995): 40 cm is used as the minimum size of recruited red cod in this report.

Water temperatures

Isotherms estimated from station data for surface and bottom water temperatures are shown in Figures 3a and 3b respectively. Surface and bottom temperatures are included in Appendix 2.

Length frequency and biological data

The numbers of length frequency and biological samples taken during the survey are given in Table 7. The scaled length frequency distributions for eight commercially important ITQ species are given in Figure 4.

The length frequency distribution for red cod was unimodal with a very strong peak around 19 cm, which corresponds to the 1 year old age class. A similar mode (though not as strong) was apparent in the data from the 1995 west coast South Island trawl survey (Drummond & Stevenson 1996).

A length-weight relationship for hoki using the geometric mean functional relationship was calculated from length and weight data collected (*see* Appendix 1). Insufficient numbers of hake were caught to calculate a length weight regression equation.

Snapper

Only 10 snapper (2 of them juveniles) were caught during the survey. The lengths and ages (estimated from otolith readings) of all snapper caught are given in Table 8.

No juvenile snapper were caught in Golden Bay and no adult snapper were taken in Tasman Bay. The low catch of adult snapper was expected because most adults move out of the bays after spawning in summer (Drummond 1994).

No biomass estimates or length frequency analyses were completed for snapper because of the few fish caught.

Discussion

The primary focus of the survey was to estimate the population of juvenile snapper in Tasman and Golden Bays. The catch of juvenile hoki, juvenile red cod, anchovy, and other small fish shows the gear was working well and would have caught juvenile snapper if they were present. The same vessel and net have been used to successfully sample juvenile snapper in the Auckland Fishery Management Area (AFMA) for several years.

The lack of juvenile snapper throughout the survey area may indicate a recruitment failure for as many as 3 years. The cause may be the Southern Oscillation (El Nino) producing lower than average sea temperatures for the years 1991–94. A similar recruitment failure in Tasman and Golden Bays occurred in the 1982–83 summer (Drummond 1994). Research in the AFMA has shown a strong relationship between the number of 1+ age snapper and sea surface temperature in the summer-autumn after spawning (Francis 1993). Additional surveys in Tasman and Golden Bays will be needed to establish whether a similar relationship exists in this area.

Data collected on other species, especially hoki, red cod, and red gurnard, may be used to compliment that gathered from other sources for input to the stock assessment process.

Acknowledgments

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Table 1: Stratum depth ranges, survey area, non-trawlable area, number of successful stations, and station density

Stratum	Depth (m)	Area (km^2)	Non-trawlable area (km^2)	Number of stations	Station density (no. per 100 km^2)
1	10–20	215	49	5	2.32
2	20–33	276	0	5	1.81
3	10–20	256	44	6	2.34
4	20–42	939	70	7	0.75
5	20–70	1 023	144	7	0.68
6	20–70	1 473	105	7	0.48
Total (average)		4 182	412	37	(0.88)

Table 2: Species caught, total weight, and number of stations out of 37 at which species occurred

Common name	Scientific name	Code	Catch (kg)	% of total catch	Occurrence
Spiny dogfish	*Squalus acanthias*	SPD	1 873.3	24	32
Jack mackerel	*Trachurus* spp.	JMA	1 153.6	15	33
Hoki	*Macruronus novaezelandiae*	HOK	1 096.2	14	19
Barracouta	*Thyrsites atun*	BAR	1 060.4	13	37
Red cod	*Pseudophycis bachus*	RCO	1 046.9	13	37
Red gurnard	*Chelidonichthys kumu*	GUR	204.6	3	34
Anchovy	*Engraulis australis*	ANC	187.2	2	18
Scaly gurnard	*Lepidotrigla brachyoptera*	SCG	164.9	2	25
Leatherjacket	*Parika scaber*	LEA	142.8	2	28
Spotty	*Notolabrus celidotus*	STY	125.9	2	26
School shark	*Galeorhinus galeus*	SCH	93.6	1	21
Blue warehou	*Seriolella brama*	WAR	92.9	1	25
Carpet shark	*Cephaloscyllium isabella*	CAR	87.9	1	28
Rattails	Macrouridae	RAT	73.1	1	9
Pilchard	*Sardinops neopilchardus*	PIL	66.6	1	16
Sprat	*Sprattus* spp.	SPR	60.4	1	20
Smooth skate	*Raja innominata*	SSK	56.7	1	4
Sand flounder	*Rhombosolea plebeia*	SFL	46.5	1	27
Tarakihi	*Nemadactylus macropterus*	TAR	39.8	1	17
Sea perch	*Helicolenus* spp.	SPE	34.4	< 1	15
Rough skate	*Raja nasuta*	RSK	31.8	< 1	11
Blue cod	*Parapercis colias*	BCO	31.5	< 1	16
Yelloweyed mullet	*Aldrichetta forsteri*	YEM	20.1	< 1	4
Rig	*Mustelus lenticulatus*	SPO	18.2	< 1	6
Snapper	*Pagrus auratus*	SNA	16.0	< 1	7
Lemon sole	*Pelotretis flavilatus*	LSO	12.2	< 1	19
Arrow squid	*Nototodarus sloanii, N. gouldi*	SQU	10.5	< 1	29
Pufferfish	*Sphoeroides pachygaster*	PUF	10.2	< 1	5
Octopus	*Octopus maorum*	OCT	9.9	< 1	3
Frostfish	*Lepidopus caudatus*	FRO	9.7	< 1	5
Giant stargazer	*Kathetostoma giganteum*	STA	9.1	< 1	6
Eagle ray	*Myliobatis tenuicaudatus*	EGR	8.4	< 1	4
Ling	*Genypterus blacodes*	LIN	7.1	< 1	7
Green-shelled mussel	*Perna canaliculus*	MSG	6.8	< 1	2
Yellowbelly flounder	*Rhombosolea leporina*	YBF	6.1	< 1	6
Silver dory	*Cyttus novaezelandiae*	SDO	4.4	< 1	3
Spotted stargazer	*Genyagnus monopterygius*	SPZ	3.9	< 1	4
N.Z. sole	*Peltorhamphus novaezelandiae*	ESO	3.6	< 1	7
Witch	*Arnoglossus scapha*	WIT	3.2	< 1	18
John dory	*Zeus faber*	JDO	2.6	< 1	8
Silver warehou	*Seriolella punctata*	SWA	2.5	< 1	9
Hake	*Merluccius australis*	HAK	2.3	< 1	6
Broad squid	*Sepioteuthis australis*	BSQ	1.9	< 1	8
Opalfish	*Hemerocoetes* spp.	OPA	1.9	< 1	15
Pigfish	*Congiopodus leucopaecilus*	PIG	1.8	< 1	8
Speckled sole	*Peltorhamphus latus*	SPS	1.2	< 1	10
Redbait	*Emmelichthys nitidus*	RBT	0.6	< 1	6
Red mullet	*Upeneichthys lineatus*	RMU	0.6	< 1	1
Nesting mussel	*Modiolarca impacta*	MIM	0.3	< 1	1
Dredge oyster	*Tiostrea chilensis*	OYS	0.3	< 1	2

Table 2—*continued*

Common name	Scientific name	Code	Catch (kg)	% of total catch	Occurrence
Sowfish	*Paristiopterus labiosus*	BOA	0.2	< 1	1
Blue mackerel	*Scomber australasicus*	EMA	0.2	< 1	2
Scallop	*Pecten novaezelandiae*	SCA	0.1	< 1	1
Seahorse	*Hippocampus abdominalis*	SHO	0.1	< 1	1
Silverside	*Argentina elongata*	SSI	0.1	< 1	1
Trevally	*Pseudocaranx dentex*	TRE	0.1	< 1	1
Porcupinefish	*Allomycterus jaculiferus*	POP *		< 1	1
			7 947.2		

* Counted but not weighed

Table 3: Catch (kg) of the six most abundant species by station*

Station	SPD	JMA	HOK	BAR	RCO	GUR	Total	All species
1	0.0	0.5	419.1	8.9	14.4	7.5	450.4	472.0
2	1.0	0.1	0.1	14.9	14.5	5.7	36.3	68.2
3	0.0	0.1	7.2	1.3	13.7	3.0	25.3	38.7
4	0.0	0.2	58.5	21.9	16.7	9.9	107.2	165.8
5	3.5	0.3	0.1	27.7	14.6	0.5	46.7	76.4
6	186.1	733.1	0.0	24.2	11.5	4.6	959.5	1 016.7
7	48.2	5.9	0.0	19.8	10.4	15.6	99.9	133.6
8	20.2	1.6	0.0	48.8	18.6	2.3	91.5	119.5
9	16.9	58.7	0.0	13.6	20.1	3.3	112.6	198.4
10	11.5	67.7	0.0	8.3	29.3	8.5	125.3	176.9
11	56.2	40.5	0.1	3.1	18.4	3.9	122.2	160.4
12	176.4	4.6	0.2	150.2	39.5	28.9	399.8	451.2
13	8.6	6.4	0.0	0.3	5.7	6.4	27.4	141.7
14	8.4	1.0	0.0	29.3	5.3	1.2	45.2	75.5
15	0.0	0.0	206.2	4.4	4.3	0.7	215.6	218.7
16	16.7	0.5	3.8	7.0	28.3	1.4	57.7	121.5
17	647.1	2.4	10.4	12.2	39.6	7.1	718.8	751.8
18	45.9	0.1	194.6	7.5	9.0	6.6	263.7	294.0
19	147.5	3.6	0.1	100.9	19.3	9.1	280.5	358.1
20	59.5	4.9	0.0	62.0	19.4	11.4	157.2	193.8
21	10.3	29.2	0.0	3.6	24.4	8.5	76.0	112.8
22	44.1	1.0	9.2	49.5	4.2	7.4	115.4	144.2
23	35.8	0.1	82.8	12.9	7.7	4.1	143.4	152.6
24	0.0	0.1	5.3	67.8	9.2	4.3	86.7	117.4
25	4.5	0.1	0.0	28.4	0.7	0.0	33.7	83.9
26	76.0	1.1	0.0	41.7	10.9	6.7	136.4	188.2
27	4.5	3.5	0.0	13.8	19.4	1.1	42.3	97.6
28	11.3	0.4	7.6	69.8	18.2	7.6	114.9	136.7
29	1.5	0.8	90.5	1.4	17.7	8.2	120.1	132.9
30	72.6	3.4	0.2	89.5	13.8	9.3	188.8	211.9
31	28.3	11.0	0.0	40.2	44.4	5.6	129.5	167.1
32	9.1	28.0	0.0	10.7	35.2	1.0	84.0	121.0
33	28.4	14.0	0.0	5.4	485.1	0.2	533.1	548.4
34	35.2	8.7	0.0	8.2	1.2	0.6	53.9	84.7
35	9.2	6.7	0.0	31.2	0.2	0.0	47.3	118.6
36	18.7	21.1	0.0	19.7	0.7	0.0	60.2	126.7
37	30.1	92.2	0.2	0.3	1.3	2.4	126.5	169.6
Total	1 873.3	1 153.6	1 096.2	1 060.4	1 046.9	204.6	6 435.0	7 947.2

* Species codes are given in Table 2

Table 4: Catch (kg) of the six most abundant species by stratum*

Stratum	Depth (m)	SPD	JMA	HOK	BAR	RCO	GUR	Total	All species
1	10–20	21.5	7.6	211.5	130.2	25.2	12.6	408.6	637.2
2	20–33	789.6	4.1	300.8	89.1	88.8	26.6	1 299.0	1 464.1
3	10–20	85.0	5.6	426.5	108.3	87.5	24.5	737.4	941.1
4	20–42	284.2	800.7	156.6	199.5	113.2	51.5	1 605.7	1 903.6
5	20–70	496.6	159.2	0.4	336.3	151.5	70.9	1 214.9	1 537.9
6	20–70	196.4	176.4	0.4	197.0	580.7	18.5	1 169.4	1 463.3

* Species codes are given in Table 2

Table 5: Mean catch rates (kg.km^{-2}) of the six most abundant species by stratum*

		Species code					
Stratum	Depth (m)	SPD	JMA	HOK	BAR	RCO	GUR
1	10–20	37.6	13.5	401.1	213.2	43.7	21.7
2	20–33	1 224.5	6.4	532.3	146.0	140.5	44.1
3	10–20	124.9	7.2	527.2	149.4	118.6	33.0
4	20–42	298.0	821.4	187.8	218.0	126.1	57.1
5	20–70	544.0	173.8	0.4	373.1	169.1	79.4
6	20–70	207.4	191.9	0.4	209.8	617.9	19.3

* Species codes are given in Table 2

Table 6: Relative doorspread biomass estimates (t) of the 13 most abundant species and selected other ITQ species*

Common name	Lower 95% confidence interval	Biomass	Upper 95% confidence interval	*c.v.* (%)
Southern spiny dogfish	782.5	1 520.4	2 258.2	24.3
Jack mackerel	0.0	1 238.5	2 660.6	57.4
Hoki	115.4	545.9	976.5	39.4
Barracouta	577.9	1 020.3	1 462.6	21.7
Red cod (all)	0.0	1 280.5	2 762.3	57.9
Red cod (40 + cm)	0.0	967.8	2 482.0	78.2
Red gurnard (all)	123.2	188.7	254.1	17.3
Red gurnard (30 + cm)	58.7	106.6	154.5	22.5
Anchovy	11.7	105.9	200.0	44.5
Scaly gurnard	117.2	204.0	290.7	21.3
Leatherjacket	68.1	199.9	331.7	33.0
Spotty	39.6	58.2	76.9	16.0
School shark	61.1	111.1	161.2	22.5
Blue warehou	0.0	74.1	158.4	56.8
Carpet shark	57.3	94.7	132.0	19.7
Sand flounder (all)	16.7	42.4	68.0	30.3
Sand flounder (25 + cm)	10.2	25.0	39.8	29.5
Blue cod (all)	14.6	40.5	66.4	32.0
Blue cod (33 + cm)	7.8	19.4	30.9	29.9
Tarakihi (all)	10.0	45.8	81.7	39.1
Tarakihi (25 + cm)	0.0	6.4	14.8	65.6
Lemon sole (all)	6.7	14.2	21.7	26.3
Lemon sole (25 + cm)	4.0	9.4	14.9	28.9
Arrow squid	2.0	12.1	22.2	41.7

* Species codes are given in Table 2

Table 7: Numbers of length frequency and biological samples collected

Species	Length frequency		Biological data	
	No. of samples	No. of fish	No. of samples	No. of fish
Barracouta	38	1 731		
Blue cod	17	65		
Blue mackerel	1	1		
Blue warehou	26	755		
Hake	4	7		
Hoki	19	2 107	6	533
Jophn dory	8	9		
Jack mackerel (*Trachurus* spp.)	2	18		
T. novaezelandiae	4	8		
Ling	8	8		
Lemon sole	19	63		
N.Z. sole	7	9		
Red cod	38	3 125		
Red gurnard	34	777		
School shark	22	121		
Sand flounder	27	224		
Snapper	8	12	7	12
Rig	7	7		
Speckled sole	6	11		
Spotted stargazer	3	3		
Giant stargazer	7	7		
Silver warehou	10	27		
Tarakihi	18	635		
Trevally	1	1		
Yellowbelly flounder	6	14		

Table 8: Ages of snapper caught during the survey

Station	Length (cm)	Sex	Age
15	39	M	8
18	26	M	6
22	29	F	6
22	32	F	6
22	33	F	6
23	29	F	6
23	30	M	6
24	78	M	55
26	10	I*	1+
26	11	I*	1+

* Immature

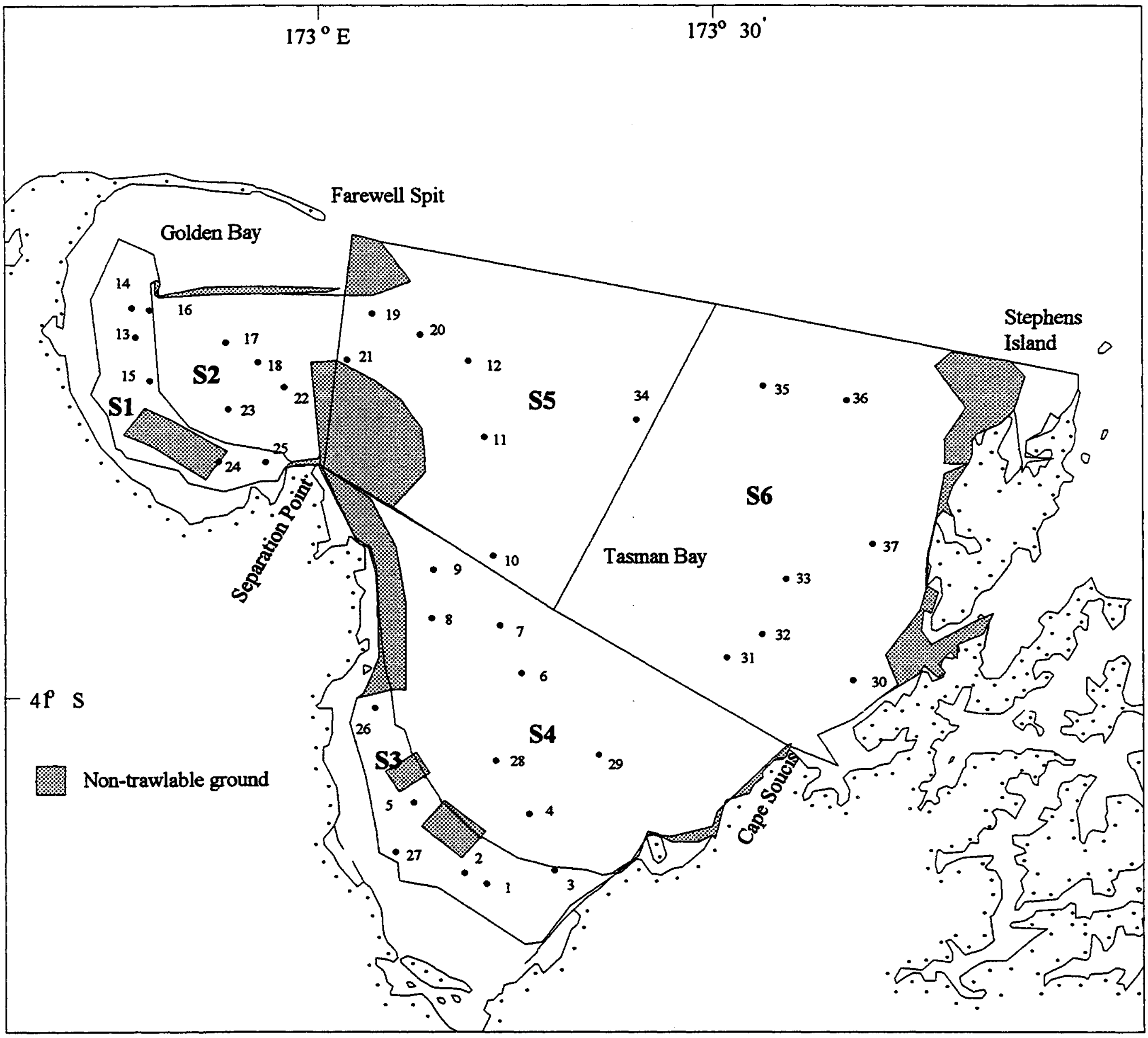

Figure 1: Stratum boundaries with station positions and numbers.

All species combined

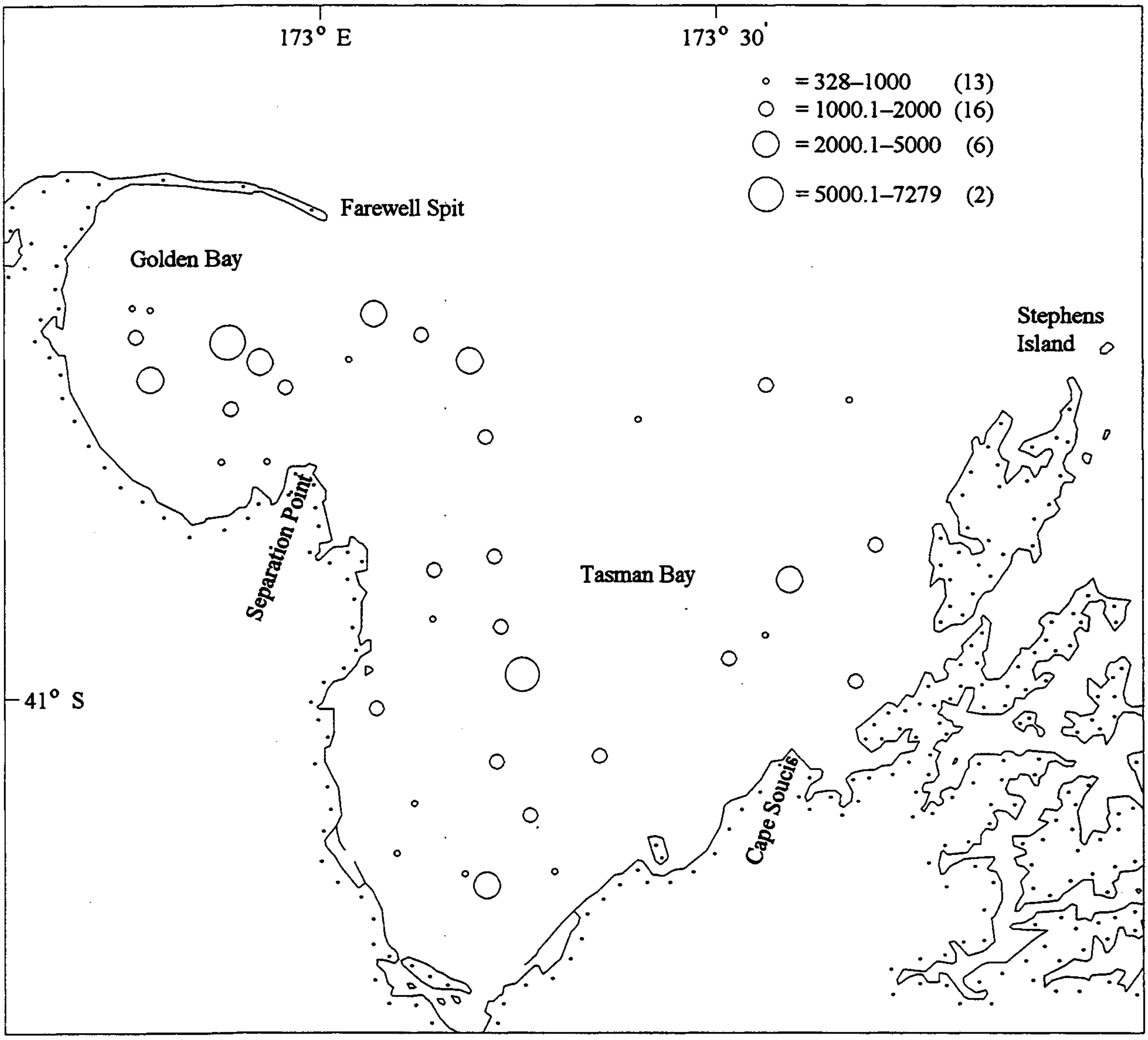

Figure 2: Catch rates (kg.km^{-2}) for all species combined and of the six most abundant species (numbers in parentheses are the number of stations at the given catch rate).

Barracouta

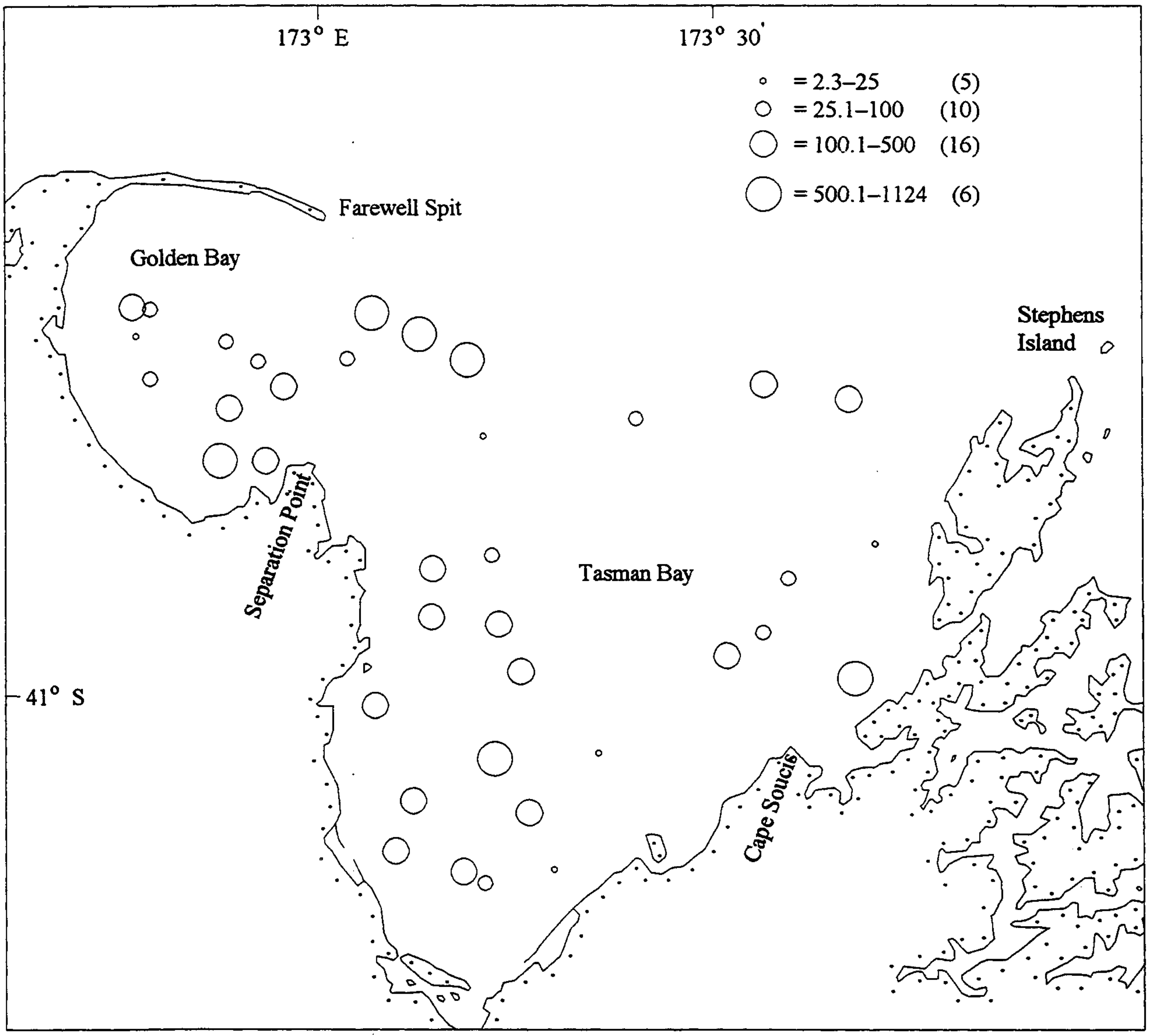

Figure 2 —*continued*

Hoki

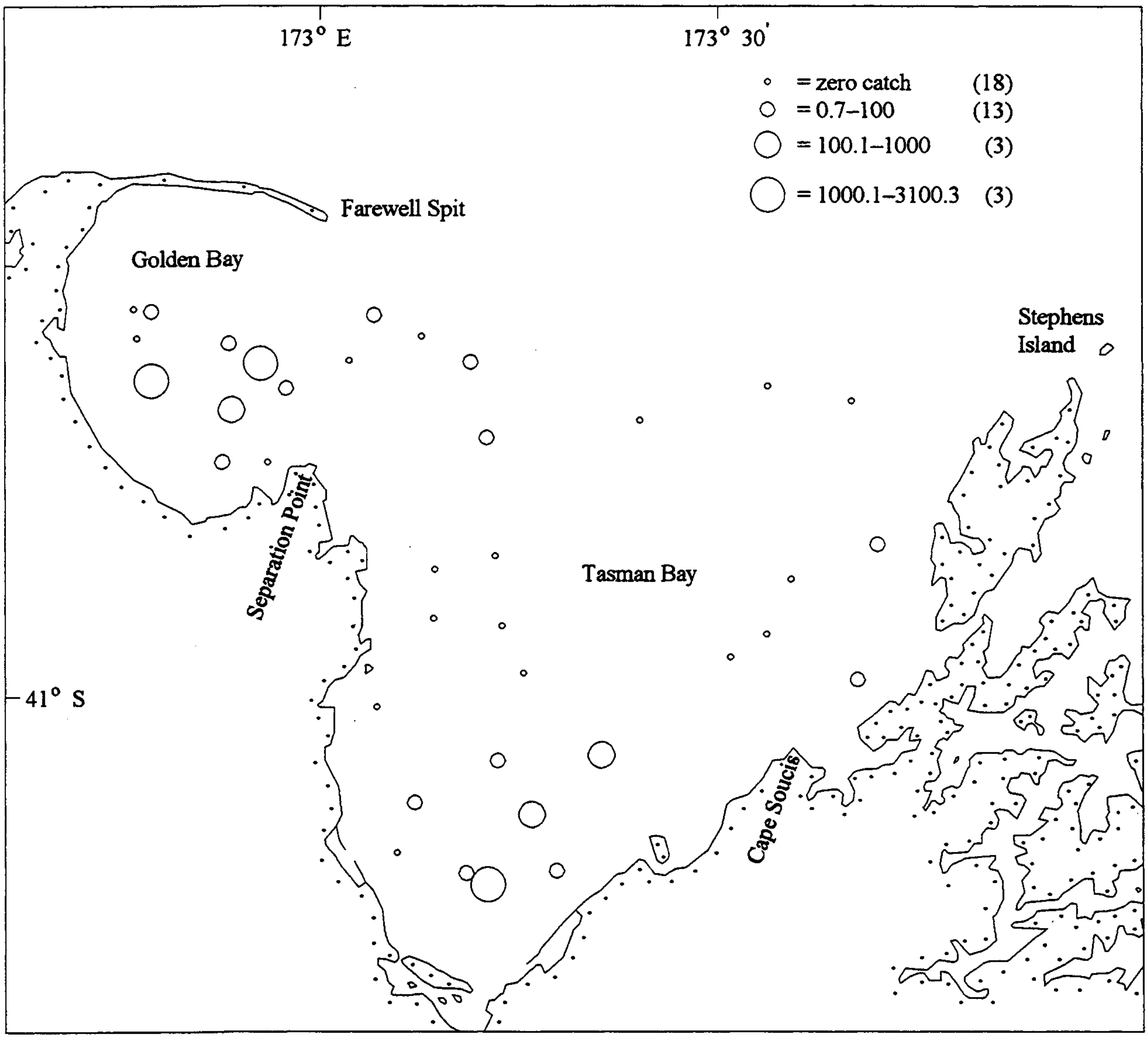

Figure 2 —*continued*

Jack mackerel

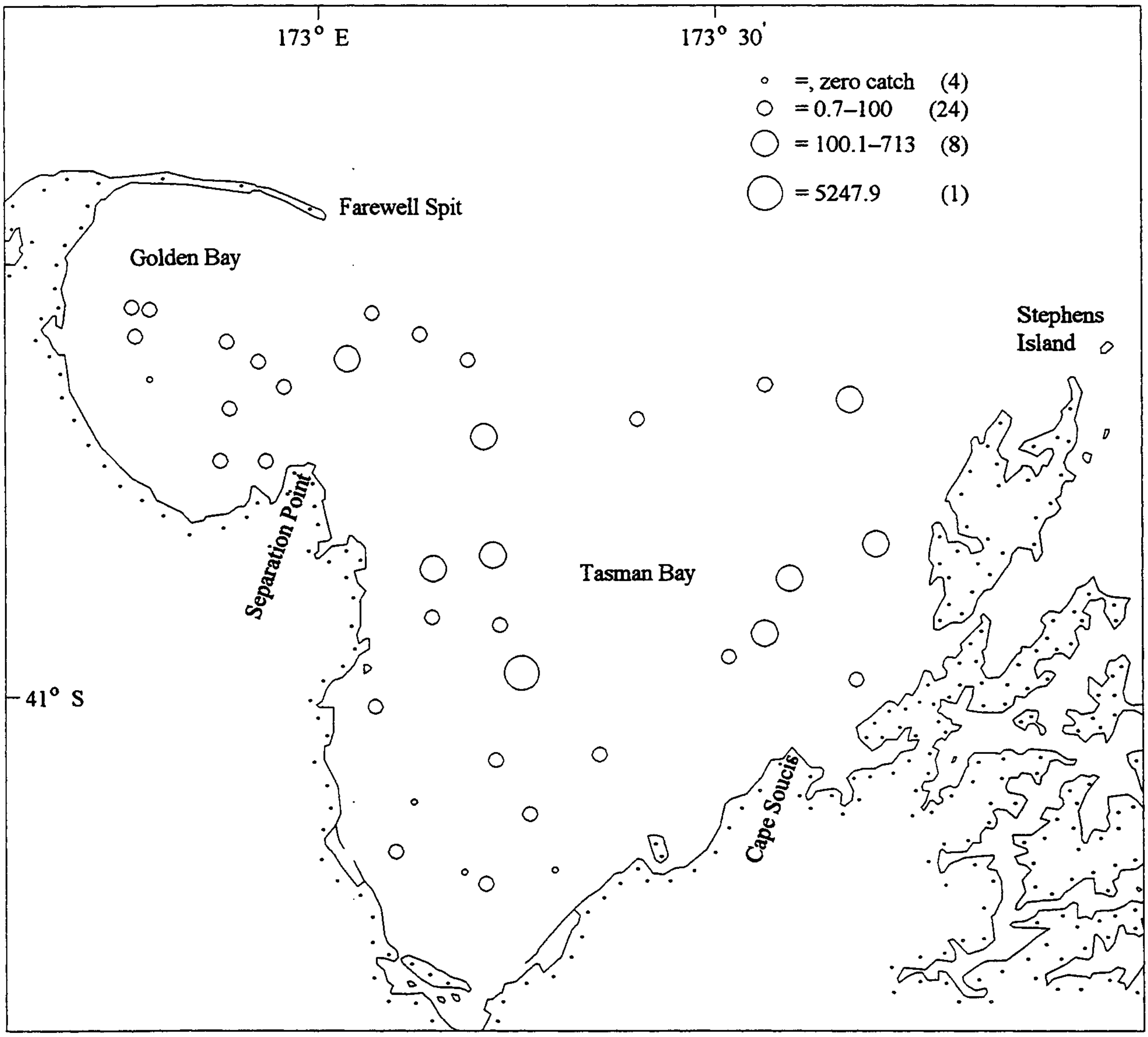

Figure 2 —*continued*

Red cod

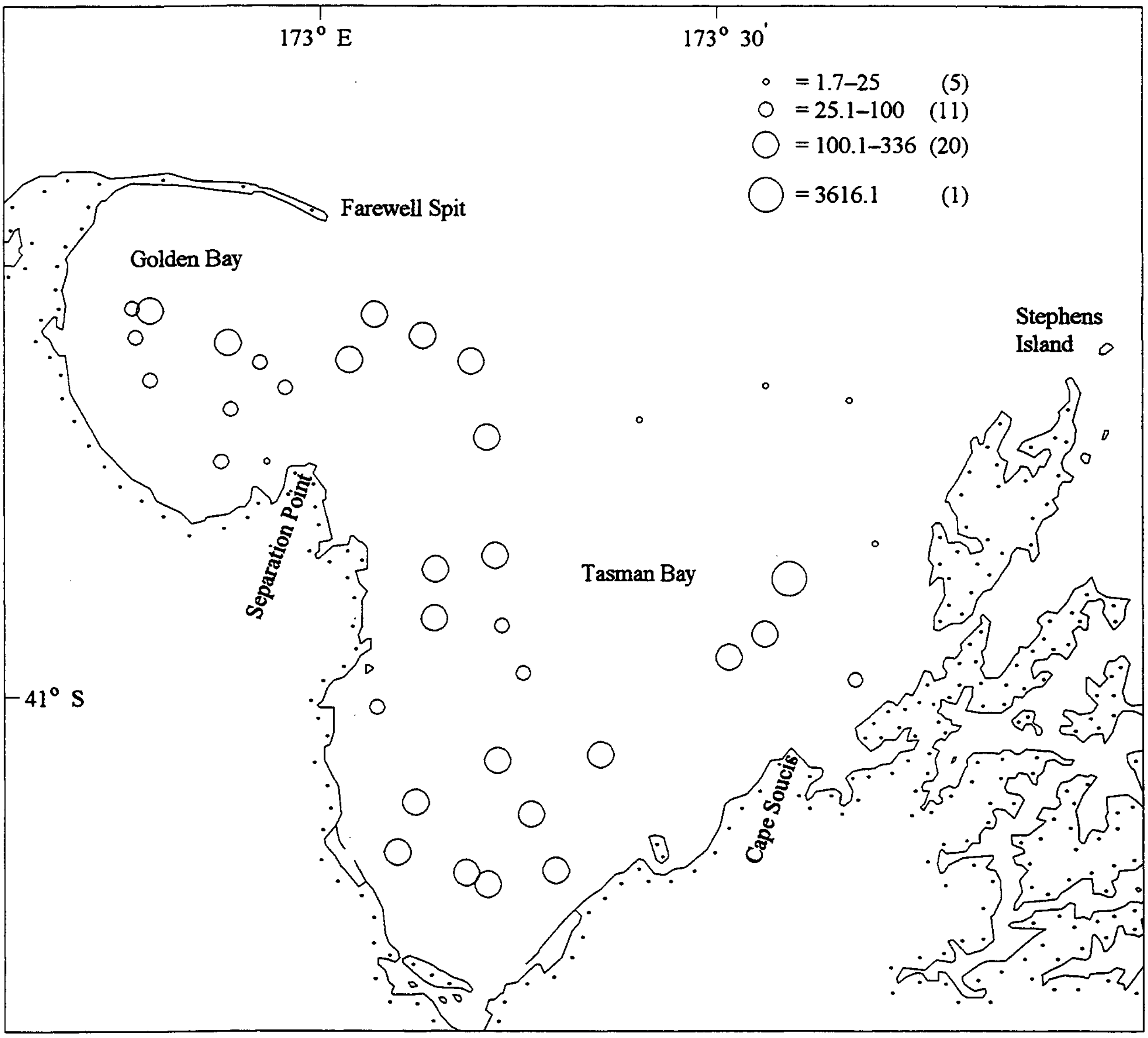

Figure 2 *—continued*

Red gurnard

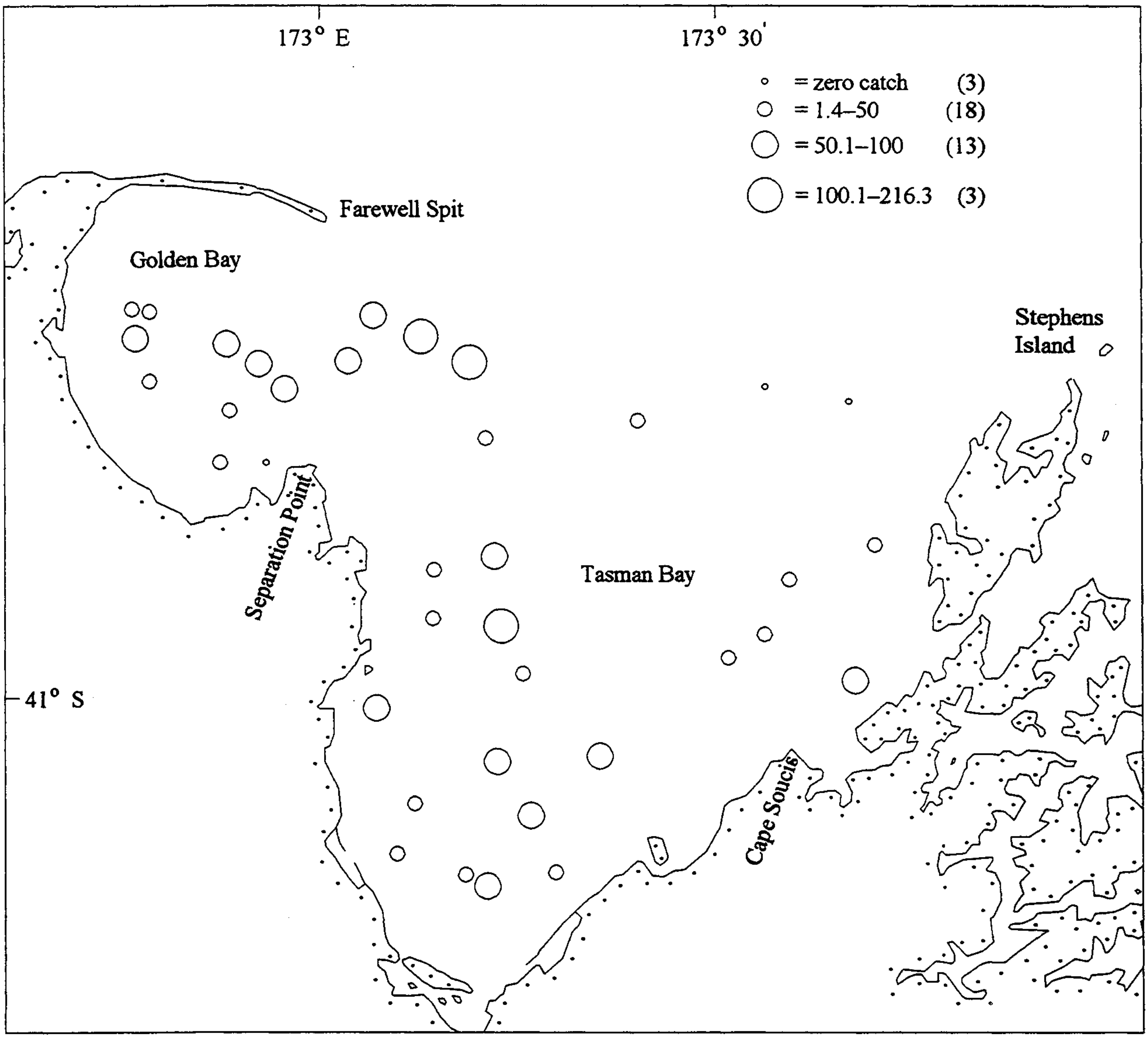

Figure 2 —*continued*

Southern spiny dogfish

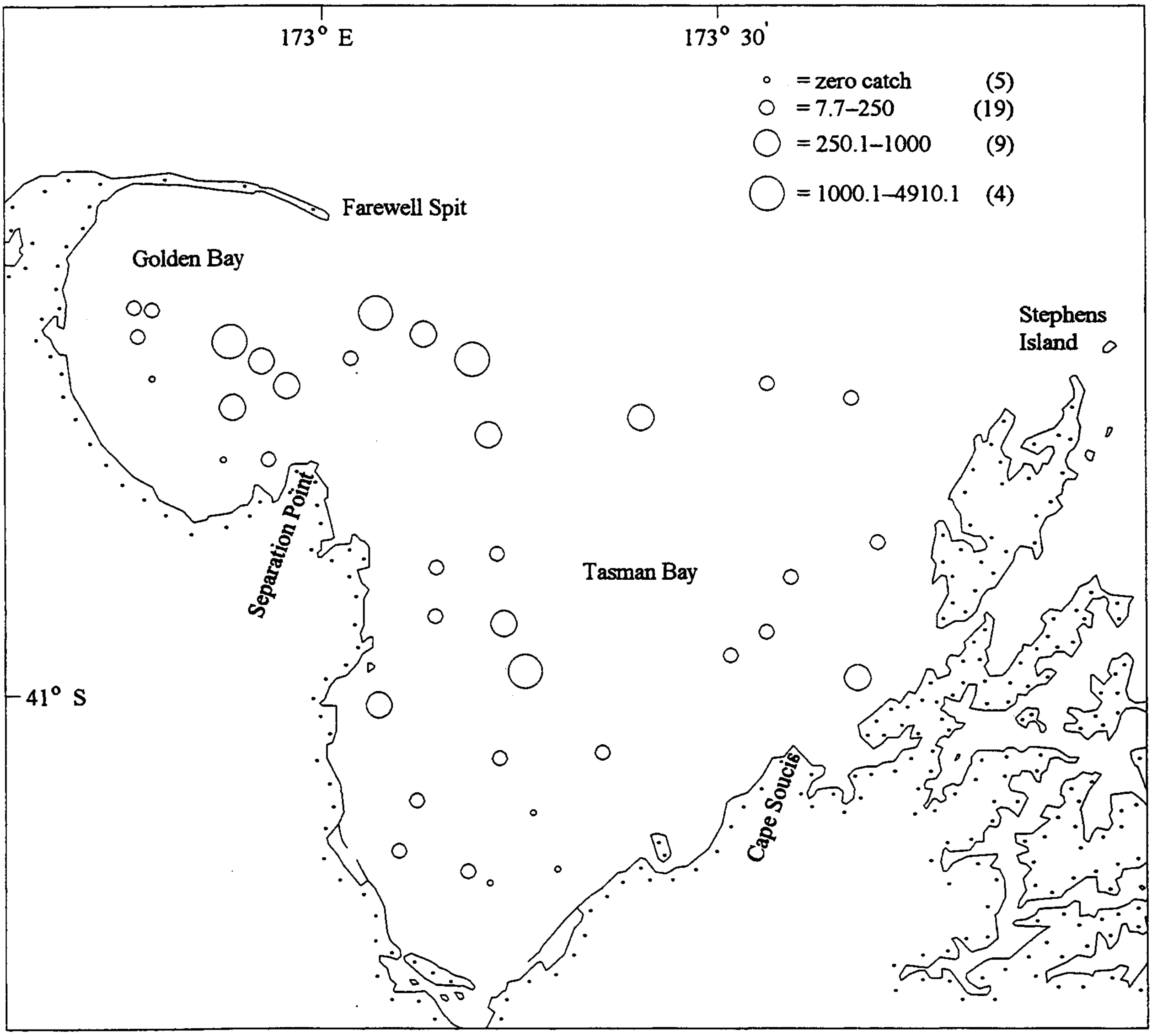

Figure 2 —*continued*

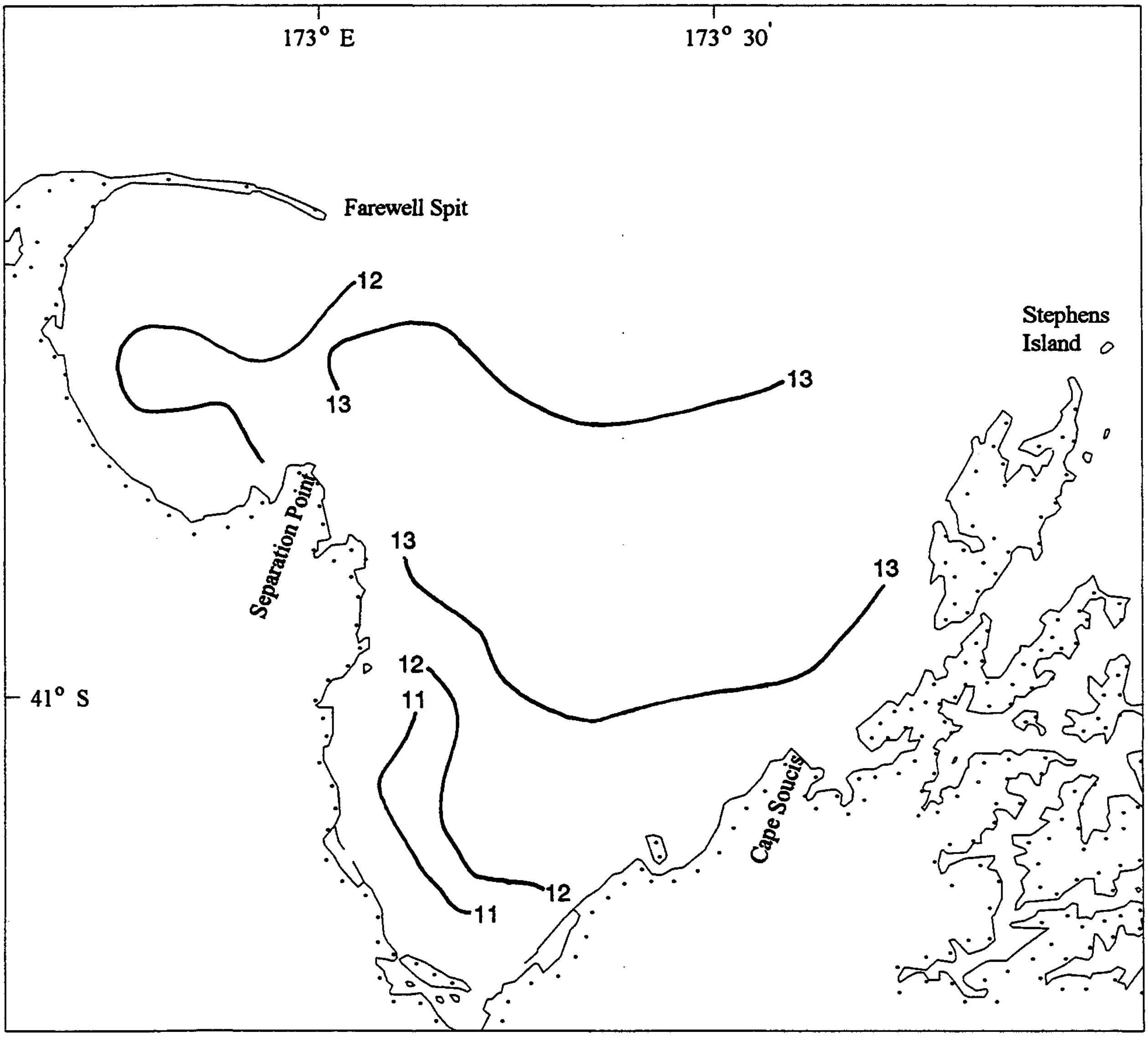

Figure 3a: Sea surface isotherms estimated from station data.

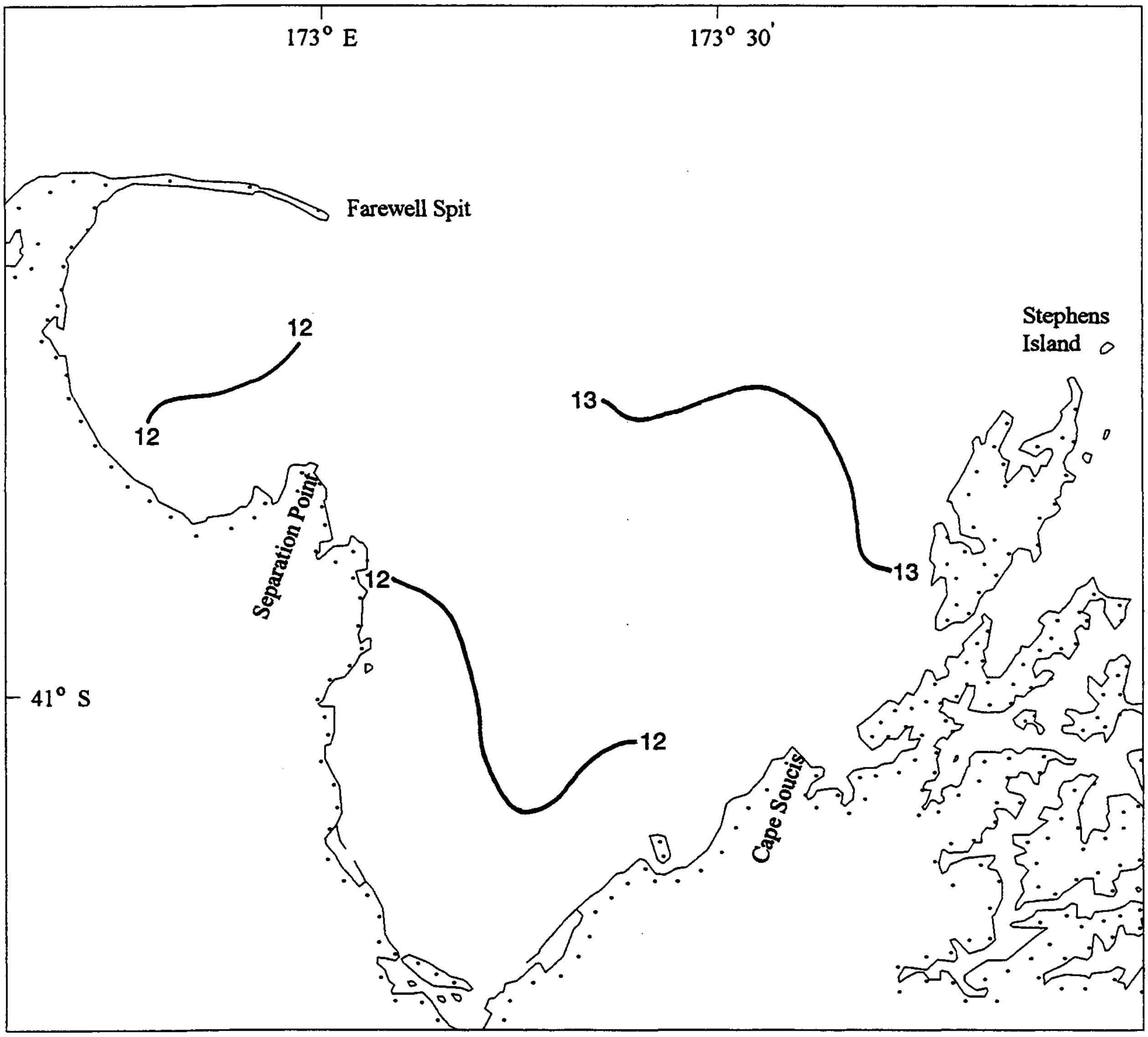

Figure 3b: Bottom isotherms estimated from station data.

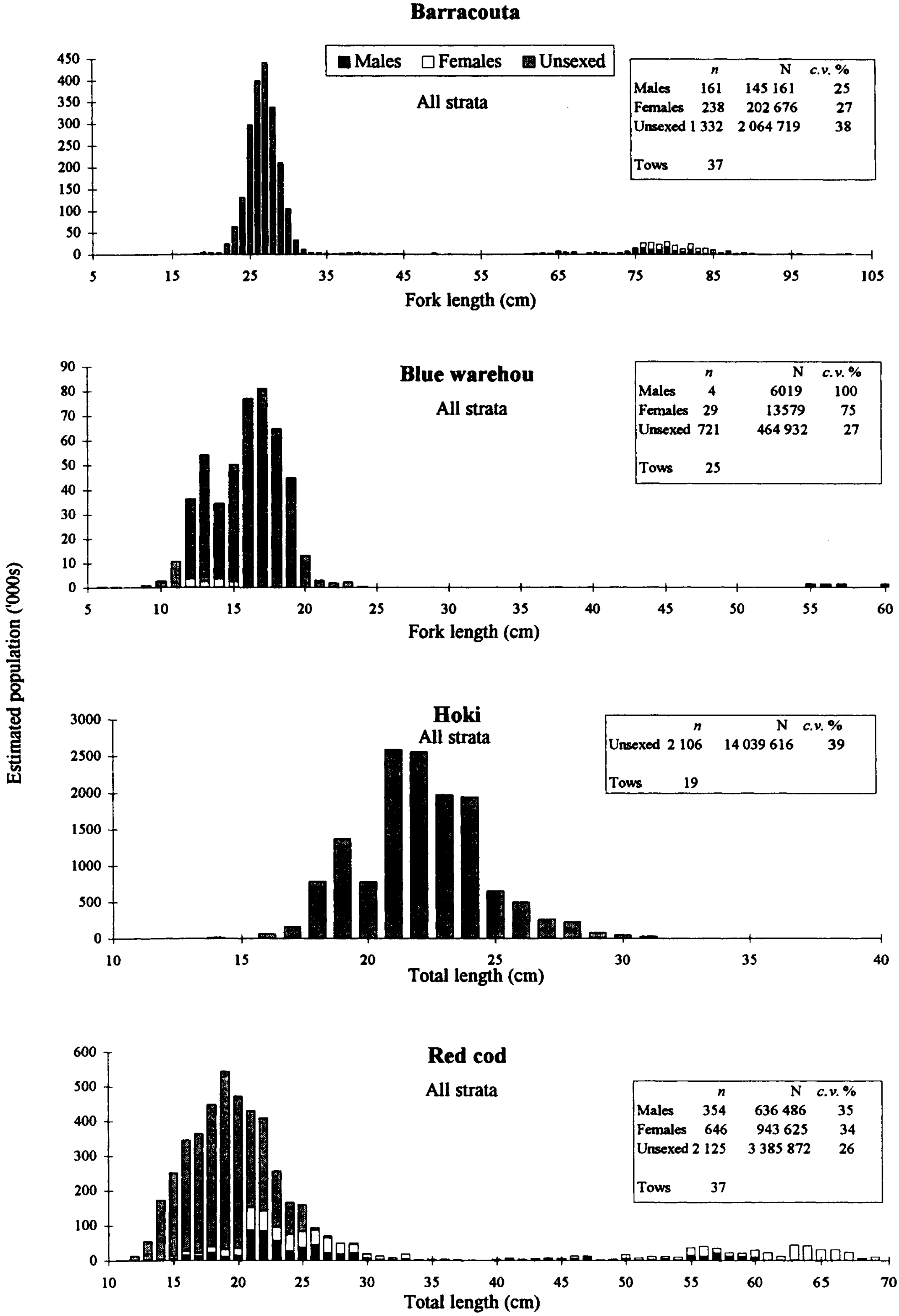

Figure 4: Scaled length frequency distributions of eight commercially important ITQ species (*n*, number of fish measured; N, estimated population; Tows, number of stations where species was caught).

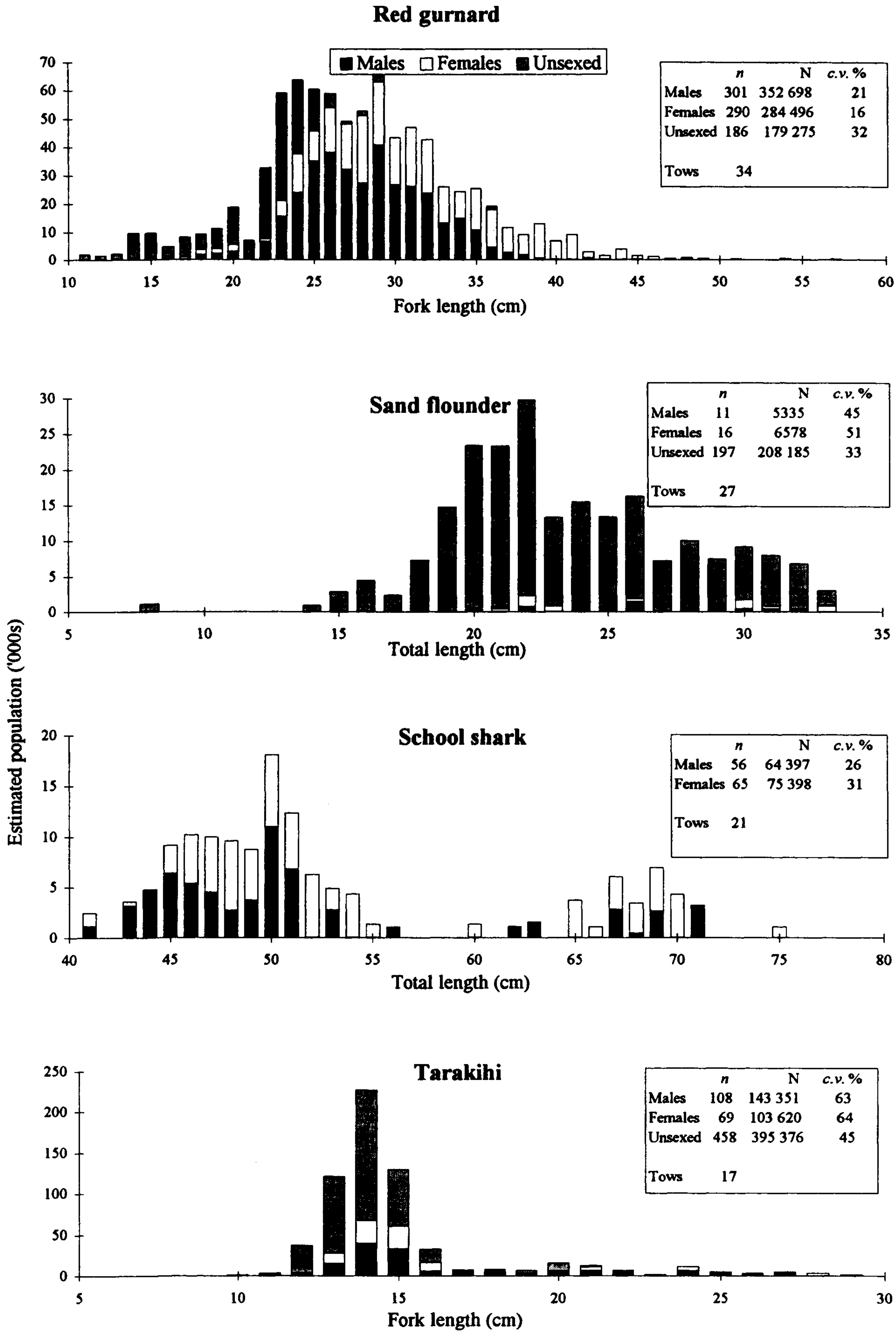

Figure 4—*continued*

Appendix 1a: Length-weight coefficients *a* and *b* calculated using the geometric mean functional relationship from data collected during this survey, and used to scale length frequencies and calculate biomass above a minimum size*

	a	*b*	*N*	Range (cm)
Hoki	0.0028	3.0695	533	18–34

Appendix 1b: Additional length-weight coefficients *a* and *b* used to scale length frequencies and calculate biomass above a minimum size*

	a	*b*	Source	*N*	Range (cm)
Barracouta	0.0091	2.88	TAN9301	919	15–96
Blue warehou	0.0191	3.03	TAN9301	281	29–67
Red cod	0.0055	3.14	KAH9008 KAH9105 KAH9205	1187	13–72
Red gurnard	0.0017	3.48	KAH9008 KAH9105 KAH9205	227	19–54
Sand flounder	0.0125	3.02	IKA8003	–	–
School shark	0.0070	2.91	Seabrook-Davidson (unpub.)	804	30–166
Tarakihi	0.0159	3.05	KAH9504	1 369	11–54

* Determined from $W = aL^b$, W, weight (g); L, length (cm)
N, sample size.

Appendix 2: Summary of station data

Station	Stratum	Date	Time	Start of tow ° ' S	Start of tow ° ' E	End of tow ° ' S	End of tow ° ' E	Gear depth (m) Min.	Gear depth (m) Max.	Doorspread (m)	Distance trawled (n. miles)	Surface temp (°C)	Bottom temp (°C)
1	3	7-Jul-95	0851	41 10.99	173 12.47	41 10.25	173 11.87	15	16	83.9	0.87	11.5	–
2	3	7-Jul-95	0957	41 10.37	173 10.85	41 09.74	173 11.57	15	17	81.5	0.85	12.0	11.6
3	3	7-Jul-95	1103	41 10.22	173 17.62	41 10.40	173 18.64	21	21	80.3	0.79	12.2	11.5
4	4	7-Jul-95	1215	41 06.97	173 15.74	41 06.65	173 14.64	28	28	85.9	0.87	12.6	12.0
5	3	7-Jul-95	1324	41 06.31	173 07.00	41 05.78	173 06.23	19	20	80.1	0.87	11.8	11.6
6	4	7-Jul-95	1457	40 58.84	173 15.17	40 58.17	173 14.72	38	39	86.7	0.87	13.1	12.6
7	4	7-Jul-95	1641	40 56.10	173 13.50	40 55.44	173 12.88	40	40	86.7	0.82	13.1	12.6
8	4	8-Jul-95	0731	40 55.68	173 08.36	40 56.41	173 08.87	33	34	82.2	0.82	12.8	11.8
9	4	8-Jul-95	0825	40 52.88	173 08.48	40 52.12	173 07.84	37	37	82.4	0.89	13.1	12.6
10	5	8-Jul-95	0925	40 52.08	173 13.00	40 51.24	173 13.02	42	44	87.4	0.84	13.3	12.8
11	5	8-Jul-95	1044	40 45.29	173 12.33	40 44.62	173 13.04	45	46	88.3	0.86	13.3	12.5
12	5	8-Jul-95	1152	40 40.91	173 11.12	40 40.92	173 10.03	45	47	88.0	0.82	13.1	12.6
13	1	8-Jul-95	1514	40 39.54	172 46.00	40 38.64	172 46.21	21	22	67.5	0.9	12.0	11.8
14	1	8-Jul-95	1606	40 37.89	172 45.73	40 37.50	172 46.23	21	23	67.8	0.86	11.9	11.4
15	1	9-Jul-95	0736	40 42.00	172 47.09	40 42.79	172 47.32	20	21	70.0	0.81	12.2	11.8
16	2	9-Jul-95	0841	40 38.01	172 47.08	40 37.99	172 48.24	20	26	78.6	0.88	11.7	11.8
17	2	9-Jul-95	0934	40 39.87	172 52.78	40 39.86	172 53.96	29	30	78.2	0.91	12.0	11.6
18	2	9-Jul-95	1121	40 41.01	172 55.18	40 40.97	172 56.24	29	30	73.5	0.8	12.0	11.8
19	5	9-Jul-95	1308	40 38.24	173 03.83	40 38.26	173 04.99	38	42	81.3	0.89	12.1	12.5
20	5	9-Jul-95	1407	40 39.44	173 07.48	40 39.40	173 08.50	41	43	78.3	0.77	13.2	12.7
21	5	9-Jul-95	1521	40 40.86	173 01.93	40 40.84	173 02.98	37	37	76.9	0.8	13.2	12.7
22	2	9-Jul-95	1635	40 42.44	172 57.16	40 42.40	172 58.28	22	33	77.4	0.85	12.4	12.5
23	2	10-Jul-95	0814	40 43.68	172 53.01	40 43.63	172 54.17	26	28	73.6	0.88	12.0	12.2
24	1	10-Jul-95	0921	40 46.69	172 52.29	40 46.66	172 53.46	16	16	77.7	0.88	11.8	12.4
25	1	10-Jul-95	1005	40 46.71	172 55.77	40 46.80	172 57.09	16	19	77.7	0.92	12.0	12.6
26	3	10-Jul-95	1227	41 00.83	173 04.09	41 01.63	173 04.02	14	15	75.9	0.8	10.5	–
27	3	10-Jul-95	1402	41 09.17	173 05.64	41 09.31	173 06.82	10	11	70.3	0.9	10.8	–
28	4	10-Jul-95	1522	41 03.89	173 13.20	41 04.44	173 14.11	30	30	80.2	0.87	12.6	12.0
29	4	10-Jul-95	1640	41 03.55	173 20.97	41 03.41	173 21.97	36	37	77.2	0.76	12.5	12.0
30	6	11-Jul-95	0806	40 59.25	173 40.26	40 59.17	173 39.13	41	42	89.4	0.86	13.1	12.6

Appendix 2—*continued*

Station	Stratum	Date	Start of tow Time	Start of tow ° ' S	Start of tow ° ' E	End of tow ° ' S	End of tow ° ' E	Gear depth (m) Min.	Gear depth (m) Max.	Doorspread (m)	Distance trawled (n. miles)	Surface temp (°C)	Bottom temp (°C)
31	6	11-Jul-95	0928	40 57.95	173 30.71	40 57.87	173 29.56	47	48	82.1	0.87	13.2	12.6
32	6	11-Jul-95	1041	40 56.61	173 33.43	40 56.62	173 34.53	49	51	81.2	0.9	13.2	12.6
33	6	11-Jul-95	1146	40 53.44	173 35.26	40 53.88	173 36.31	53	53	79.6	0.91	13.2	12.6
34	5	11-Jul-95	1352	40 44.27	173 23.86	40 44.71	173 24.80	50	50	80.9	0.84	13.0	12.3
35	6	11-Jul-95	1616	40 42.33	173 33.53	40 42.61	173 34.57	55	56	74.8	0.83	13.0	12.6
36	6	12-Jul-95	0748	40 43.17	173 39.83	40 44.16	173 39.64	56	57	75.7	0.98	13.2	12.6
37	6	12-Jul-95	0900	40 51.42	173 41.75	40 52.06	173 40.91	53	55	77.6	0.9	13.2	12.7

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