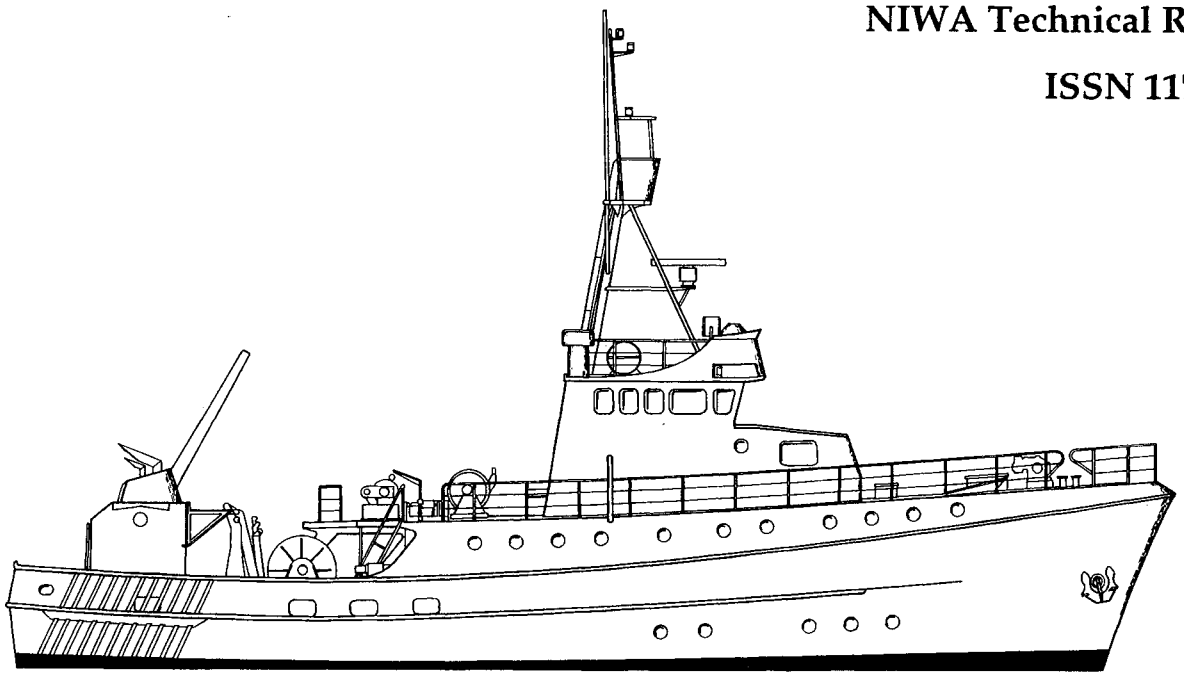
NIWA
Taihoro Nukurangi

Trawl survey of snapper and associated species in the Bay of Plenty, February 1996 (KAH9601)

M. Morrison



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Contents

Introduction

Trawl surveys have been conducted in the Bay of Plenty from R.V. *Kaharoa* in 1983, 1985, 1987, 1990, and 1992. This survey adds to this time series. Snapper (*Pagrus auratus*) is the primary focus of the surveys, with the data collected providing information on relative abundance, population size structure, and year class strength.

The trawl survey programme also collects data on other commercial finfish species, particularly red gurnard (*Cheilodonichthys kumu*) and John dory (*Zeus faber*). For this survey, additional strata in 150–200 m were added for tarakihi (*Nemadactylus macropterus*), which are generally found in deeper habitats. This project was funded by MFish, through project ISN612.

Project objectives

The major objectives of this research programme are as follows.

1. To estimate the relative abundance, distributions, age, sex, and length frequencies for snapper, John dory, red gurnard, and tarakihi in the Bay of Plenty.
2. To determine the structure of fish communities vulnerable to bottom trawl gear in the Bay of Plenty.

Survey objectives

The objectives of the trawl survey for 1996 were as follows.

1. To carry out a two phase stratified random trawl survey of the Bay of Plenty.
2. To collect biological data and samples from snapper, John dory, red gurnard, tarakihi, and other finfish species caught during the survey.

Timetable

The science staff joined *Kaharoa* at Tauranga on 1 February. Gear trials were carried out after which fishing began on 2 February. Port calls were made at Mt Maunganui on 5 and 8 February to unload fish, take on ice, and to change over some of the science staff. All stations were completed by 12 February, after which further gear trials and measurements were made. *Kaharoa* returned on 13 February to Tauranga where fish were unloaded and the science staff disembarked.

Methods

Survey area and design

The survey covered the area from the Mercury Islands to Cape Runaway between 10 and 250 m depth. The area was divided into 14 depth and area strata. Eleven strata were based on the catch rates of pre-recruit (less than 25 cm fork length (FL)) snapper from previous

Kaharoa surveys. Some of the strata from the 1992 survey were combined into larger strata to more accurately delineate the distribution of pre-recruit snapper (Table 1, Figure 1). Three additional deep strata (150–200 m) were added to provide an estimate for tarakihi.

The survey was of a two phase stratified random design (after Francis 1984), where the second phase involved the allocation of trawl shots to strata so as to maximise the anticipated reduction in the coefficients of variation. Trawls were conducted at randomly selected positions, with a minimum of three stations per stratum at least 2 n. miles (3.7 km) apart. Sixty-four stations were successfully completed in the first phase, and 14 in the second phase. Thirteen of the stations in the first phase were in the three new strata designed to estimate tarakihi population parameters. A summary of the station allocation is given in Table 1.

Vessel and gear specifications

RV *Kaharoa* is a research stern trawler with an overall length of 28 m, a displacement of 302 t, and a power rating of 522 kW. All trawling was carried out using a high opening bottom trawl (HOBT) with cut away lower wings and a 40 mm codend. Specifications of the trawl gear are given in Appendix 1.

Trawling procedure

All trawls were carried out in daylight, between 0500 and 1700 hours (NZST). Trawls were conducted from the randomly selected start position unless untrawlable ground was encountered, when a search was made for suitable ground within a 2 n. mile (3.7 km) radius of the start position. If no suitable ground was located, the station was abandoned and another random position substituted. Towing speed was between 3.0 and 3.2 knots, and tow direction was generally in a direction that maintained the same water depth throughout the tow. Distance towed was constant at 0.7 n. mile for shallower stations and 1 n. mile for deeper stations, measured using Magnavox GPS. Warp to depth ratios ranged from 18 : 1 at the shallowest stations to 2.7 : 1 for the deepest trawls. Trawl door spread was estimated using Scanmar gear. Where the Scanmar gear was not attached to the doors for a particular tow, trawl door spread was estimated using the average from other tows for which door spread was available. A summary of gear parameters is given in Appendix 2.

Catch and biological sampling

The catch from each trawl was sorted by species and weighed to the nearest 0.1 kg on Seaway motion-compensating scales. For all commercially important fish, a sample of the catch was taken from each trawl for biological sampling. All specimens were sampled from small catches, but for large catches a random sample was taken, equal to at least 25% of total fish weight.

The length of fish and squid sampled was measured to the nearest centimetre below the actual length. The first 50 mature snapper greater than 22 cm FL in each sample were also sexed and the ovarian condition of female fish categorised using a six stage developmental

scale after Pankhurst *et al.* (1987) (Appendix 3). Red gurnard, John dory, and tarakihi were also sexed.

Otoliths were collected from measured snapper (based on predetermined numbers per 1 cm size class), red gurnard, and tarakihi.

Environmental observations

For most of the trawl stations the following environmental conditions were recorded: sea surface temperature, air temperature, bottom temperature, wind direction and speed, cloud cover, bottom type and contour, barometric pressure, sea condition and colour, and swell height and direction.

Data analysis

Biomass indices and length frequency distributions of the main commercial species were calculated by the area swept method (Francis 1989) using the Trawl Survey Analysis Program (Vignaux 1994). In the calculation of biomass, the following assumptions were made.

1. The area swept was the distance between the doors multiplied by the distance towed.
2. The vertical availability was 1.0. This assumes that all fish within the area swept were below the headline height of the net.
3. The vulnerability was 1.0. This assumes that all fish in the volume swept were caught.
4. The areal availability was 1.0. This assumes that all fish were within the survey area at the time of the survey.

The coefficient of variation (*c.v.*) is a measure of the precision of the biomass estimates and is calculated from

$$c.v.\ (B) = \frac{\sqrt{Var(B)}}{B} \times 100$$

where B is the biomass estimate and $Var\ (B)$ is the variance of the biomass estimate.

Snapper age determination

Snapper otoliths were aged as described by Davies & Walsh (1995). Age classes were defined after Paul (1976), whereby 1 January is defined as the theoretical birthday. Ages were inferred given the collection date of February 1996.

Age data were then applied to the scaled snapper length frequency distribution using an age length key to estimate the age frequency distribution of the snapper population sampled by the survey.

Results

Four stations were dropped from the analysis because of foul ground (stations 13 and 35) or poor gear performance (stations 8 and 10). The areal distribution of trawl shots is shown in Figure 2 and individual station information is given in Appendix 4.

Catch composition

Seventy-one species were caught during the survey (Table 2). Snapper accounted for 40.4% of the total catch by weight, jack mackerel (*Trachurus novaezealandiae*) 10.4%, frostfish 9.6%, red gurnard 5.5%, and John dory 2.4%. Tarakihi accounted for only 1.3%, though deeper strata down to 250 m were added to the survey to cover its depth range. A summary of catch by station of the more important target species for this survey is given in Appendix 5.

Distribution and catch rates

Snapper were caught at 60 out of the 78 stations successfully completed (*see* Appendix 4). Pre-recruit and legal sized (greater than 24 cm FL) snapper were most abundant at shallow (less than 50 m) stations, especially in the stratum areas adjacent to Tairua, Tauranga, and Opotiki Harbours (Figures 3 & 4). Very few snapper were captured from stations located in the deeper water strata.

Red gurnard were caught throughout the Bay of Plenty (Figure 5), with relatively large individual catches occurring in the 10–100 m depth range. John dory were less common, with low uniform catch rates throughout the survey area (Figure 6). Relatively few tarakihi were encountered: most of the tows catching these fish were in deeper water (Figure 7). Jack mackerel showed no real trends of abundance with respect to depth or location (Figure 8).

Biological data

Biological data collected from the catch are summarised in Table 3. The scaled length frequency distribution of snapper (Figure 9) showed three apparent modes at 9–14 cm, 16–21 cm and 22–40 cm. Snapper age data indicated that the smallest size mode was almost entirely composed of 1+ fish, although otoliths were collected only from animals of 15 cm and above. The second mode represented 2+ fish, and the broader 22–40 cm mode was a mixture of fish aged from 3 to 10 years (Appendix 6). Figure 10 shows the age structure of the sampled population from the survey area.

The length compositions of snapper from the six strata with the greatest numbers of fish are shown in Figure 11. Between them these strata accounted for 97% of all snapper measured during the survey. A number of size/age peaks were apparent, with most of the 1+ fish occurring in strata 1096 and 4085.

The female snapper sampled from the catch were predominantly immature (78%), with the remainder in the developing phase (21%).

The male and female size frequencies of red gurnard in the sampled population were different, with females attaining a larger size (Figure 12). John dory were sampled from 20 to

53 cm in length: several modes were present in the overall distribution (Figure 13a). Jack mackerel displayed a single unimodal size structure centered around small individuals (10–20 cm) (Figure 13b). Few tarakihi were sampled: there was a distinct adult size mode around 36–40 cm (Figure 14a). Trevally had a broad range of sizes (16–53 cm) with no clear modes present in the overall size frequency distribution (Figure 14b).

Biomass estimates

Biomass estimates for snapper, red gurnard, tarakihi, John dory, and jack mackerel (*T. novaezealandiae*) are given in Table 4. Snapper biomass was concentrated in the shallower strata, with the greatest biomass in the 10–25 m depth strata accounting for 49% of the total estimate. Strata in the 25–50 m depth range contained most of the remaining biomass (34%). Red gurnard biomass had the highest biomass in the 50–100 m strata.

Snapper and red gurnard *c.v.*s were less than 15%, giving a reasonable precision level. However, for John dory, tarakihi, frostfish, and jack mackerel (*T. novaezealandiae*) *c.v.*s were over 40%, implying a high level of variability in various strata. This was to be expected given that the sampling effort was optimised for snapper for both the primary and secondary phases of sampling.

Discussion

Results from the 1996 Bay of Plenty trawl survey presented here represent part of a continuing time series of relative juvenile snapper abundance. The *c.v.*s obtained in this survey indicate that the stratification of the area and the assigning of station numbers within the various strata performed well. Both 1+ and 2+ juvenile cohorts were evident within the size frequency estimates obtained. The presence of these cohorts was verified by readings of otoliths from subsamples of these fish.

Catch rates of snapper were highest in the 10–25 m strata, which was consistent with previous *Kaharoa* surveys in the Bay of Plenty. The overall snapper biomass was estimated at 970 t, which was composed of three apparent major size modes centred at about 12, 19 and 28 cm. Eleven percent of the sampled population was under 25 cm in size. The 1992 survey recorded a total biomass of 1099 t, containing possibly three modes at 10, 22, and 26 cm. Forty-seven percent of the population was less than 25 cm in length at the time of the 1992 survey.

Commercial species other than snapper were not particularly abundant. Tarahiki, in particular, were not common, despite additional deep strata being added to the survey to include areas more likely to contain them. Coefficients of variation were high for this and other species that were not optimised for in the sampling design, but this was to be expected given their different distribution and abundance patterns relative to snapper.

Acknowledgments

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Table 1: Stratum descriptions, areas, station allocation, and station densities

Stratum	Description	Depth range (m)	Area (km^2)	No. of stations	Density (per km^2)
6085	Whale Island to Cape Runaway	50–100	740	4	1 : 185
7085	Mercury Island - Whale Island	50–100	1 696	4	1 : 424
4085	Whale Island - Cape Runaway	25–50	486	6	1 : 81
5287	Hot Water Beach - Mt Maunganui	25–50	396	9	1 : 44
5187	Mt Manganui - Whale Island	25–50	233	4	1 : 58
32NH	Te Ororoa - Opoutere	10–25	26	4	1 : 7
2096	Waihi - Town Point (formerly strata 2385+2285+31SH)	10–25	134	11	1 : 12
1096	Whale Island - Cape Runaway (formerly strata 112+1185+2185)	10–25	298	11	1 : 27
808N	Mercury Island - Major Island (formerly included in 8085)	100–150	526	4	1 : 132
808C	Major Island - Whale Island (formerly included in 8085)	100–150	324	4	1 : 81
808E	Whale Island - Cape Runaway (formerly included in 8085)	100–150	454	4	1 : 114
909N	Mercury Island - Major Island	150–250	353	5	1 : 71
909C	Major Island - White Island	150–250	240	3	1 : 80
909E	White Island - Cape Runaway	150–250	304	5	1 : 61
		Total	6 210	78	

Table 2: Species caught, total catch, and percentage of stations at which each species occurred (Occ)

Common name	Species code	Scientific name	Total weight (kg)	Percentage of catch by weight	Occ
Snapper	SNA	*Pagrus auratus*	4 481.5	40.4	76.9
Jack mackerel	JMN	*Trachurus novaezealandiae*	1 149.1	10.4	51.3
Frostfish	FRO	*Lepidopus caudatus*	1 065.3	9.6	24.4
Red gurnard	GUR	*Chelidonichthys kumu*	607.8	5.5	78.2
Barracouta	BAR	*Thyrsites atun*	598.7	5.4	24.4
Leatherjacket	LEA	*Parika scaber*	564.5	5.1	44.9
Hoki	HOK	*Macruronus novaezealandiae*	374.2	3.4	2.6
Cucumberfish	CUC	*Chlorophthalmus nigripinnis*	369.3	3.3	26.9
John dory	JDO	*Zeus faber*	262	2.4	71.8
Sea perch	SPE	*Helicolenus* spp.	178.3	1.6	29.5
Trevally	TRE	*Pseudocaranx dentex*	169.6	1.5	38.5
Eagle ray	EGR	*Myliobatus tenuicaudatus*	151.4	1.4	32.1
Tarakihi	TAR	*Nemadactylus macropterus*	141.2	1.3	19.2
Longtailed stingray	WRA	*Dasyatis thetidis*	123.7	1.1	10.3
Mirror dory	MDO	*Zenopsis nebulosus*	121.3	1.1	17.9
Arrow squid	SQU	*Nototodarus sloanii*	64.9	0.6	41.0
Shorttailed stingray	BRA	*Dasyatis brevicaudatus*	55.3	0.5	15.4
Rattail	RAT	*Macrouridae* sp.	49.8	0.4	11.5
Japanese gurnard	JGU	*Pterygotrigla picta*	46.6	0.4	26.9
Kingfish	KIN	*Seriola lalandi*	45.2	0.4	10.3
Smooth skate	SSK	*Raja innominata*	41.4	0.4	7.7
Spotted stargazer	SPZ	*Genyagnus monopterygius*	40.2	0.4	32.1
Rough skate	RSK	*Raja nasuta*	37	0.3	15.4
Gemfish	SKI	*Rexea solandri*	30.6	0.3	7.7
Kahawai	KAH	*Arripis trutta*	30	0.3	16.7
Ghost shark	GSH	*Hydrolagus novaezealandiae*	29.5	0.3	6.4
Sand flounder	SFL	*Rhombosolea plebia*	22.4	0.2	25.6
Lookdown dory	LDO	*Cyttus traversi*	22.2	0.2	14.1
School shark	SCH	*Galeorhinus australis*	17.9	0.2	5.1
Carpet shark	CAR	*Cephaloscyllium isabella*	17.2	0.2	17.9
Red cod	RCO	*Pseudophycis bachus*	16.9	0.2	15.4
Ling	LIN	*Genypterus blacodes*	15	0.1	10.3
Redbait	RBT	*Emmelichthys nitidus*	14	0.1	17.9
Rig	SPO	*Mustelus lenticulatus*	13.8	0.1	5.1
Scaly gurnard	SCG	*Lepidotrigla brachyoptera*	12.3	0.1	24.4
Silverside	SSI	*Argentina elongata*	10.5	< 0.1	14.1
Snipefish	SNI	*Macrorhamphosus scolopax*	10.4	< 0.1	16.7
Brown stargazer	BRZ	*Xenocephalus armatus*	10.4	< 0.1	6.4
Capro dory	CDO	*Capromimus abbreviatus*	10.3	< 0.1	11.5
Jack mackerel	JMA	*Trachurus* spp.	10.1	< 0.1	3.8
Jack mackerel	JMD	*Trachurus declivis*	10.1	< 0.1	1.3
Witch	WIT	*Arnoglossus scapha*	9.3	< 0.1	32.1
Hammerhead shark	HHS	*Sphyrna zygaena*	6.5	< 0.1	3.8
Electric ray	ERA	*Torpedo fairchildi*	5	< 0.1	3.8
Flatfish	FLA		3.5	< 0.1	3.8
Estuarine stargazer	ESZ	*Leptoscopus macropygus*	3.2	< 0.1	5.1

Blue cod	BCO	*Parapercis colias*	2.7	< 0.1	3.8
Rays bream	RBM	*Brama brama*	2.4	< 0.1	1.3
Turbot	TUR	*Colistium nudipinnis*	2.4	< 0.1	2.6
Lemon sole	LSO	*Pelotretis flavilatus*	2.2	< 0.1	9.0
English sole	ESO	*Peltorhamphus novaezeelandiae*	2.1	< 0.1	7.7
Porae	POR	*Nemadactylus douglasi*	1.9	< 0.1	1.3
Rock cod	ROC	*Lotella rhacinus*	1.6	< 0.1	1.3
Spotty	STY	*Notolabrus celidotus*	1.5	< 0.1	2.6
Hagfish	HAG	*Eptatretus cirrhatus*	1.4	< 0.1	1.3
Blue warehou	WAR	*Seriolella brama*	1.3	< 0.1	6.4
Octopus	OCT	*Octopus* sp.	1.3	< 0.1	5.1
Broad squid	BSQ	*Sepioteuthis bilineata*	1.3	< 0.1	2.6
Red mullet	RMU	*Upeneichthys lineatus*	1.2	< 0.1	1.3
English mackerel	EMA	*Scomber australasicus*	1.2	< 0.1	3.8
Conger eel	CON	*Conger* spp.	0.9	< 0.1	1.3
Prawn killer	PRK	*Ibacus alticrenatus*	0.8	< 0.1	9.0
Longfinned boarfish	LFB	*Zanclistius elevatus*	0.8	< 0.1	5.1
Pilchard	PIL	*Sardinops neopilchardus*	0.7	< 0.1	1.3
Opalfish	OPA	*Hemerocoetes* spp.	0.5	< 0.1	5.1
Spiny dogfish	SPD	*Squalus acanthias*	0.4	< 0.1	2.6
Sand stargazer	SAZ	*Crapatalus novaezelandiae*	0.2	< 0.1	1.3
Javelin fish	JAV	*Lepidorhynchus denticulatus*	0.1	< 0.1	1.3
Pigfish	PIG	*Congiopodus leucopaecilus*	0.1	< 0.1	1.3
Northern bastard red cod	BRC	*Pseudophycis breviuscula*	0.1	< 0.1	1.3
Porcupine fish *(not weighed because of water inflation)*	POP	*Allomycterus jaculiferus*			
		Total	4 402.6		

Table 3: Species and number of fish and squid measured

Common name	No. of tows sampled	No. of fish	No. of males	No. of females
Snapper	60	5667	421	535
Red gurnard	60	2097	976	982
Jack mackerel *(Trachurus novaezelandiae)*	6	876	-	-
Arrow squid	21	433	-	-
John dory	54	284	95	188
Frostfish	15	270	-	-
Trevally	25	221	-	-
Tarakihi	15	196	104	79
Barracouta	15	192	-	-
Leatherjacket	5	152	-	-
Mirror dory	4	97	-	-
Hoki	2	79	-	-
Pilchard	1	33	-	-
Southern kingfish	6	31	-	-
Kahawai	9	30	5	0
Sand flounder	8	25	-	-
Spotted stargazer	7	18	-	-
Blue warehou	4	11	-	-
Ling	5	10	-	-
Kingfish	7	9	1	1
Red mullet	1	9	-	-
Flatfish	3	7	-	-
Eagle ray	3	6	4	2
Estuarine stargazer	2	5	-	-
Blue cod	2	4	-	-
Broad squid	2	4	-	-
Hammerhead shark	3	4	2	2
Japanese gurnard	1	4	1	3
Red cod	2	4	-	-
Brown stargazer	1	3	-	-
Lemon sole	2	3	-	-
School shark	3	3	2	1
Sea perch	1	3	-	-
Rig	3	3	1	2
English mackeral	1	2	-	-
Jack mackerel *(Trachurus* sp.*)*	1	2	-	-
Shorttailed stingray	1	1	-	-
Northern bastard cod	1	1	-	-
Conger eel	1	1	-	-
English sole	1	1	-	-
Porae	1	1	-	-
Rock cod	1	1	-	-
Turbot	1	1	-	-
Witch	1	1	-	-
Longtailed stingray	1	1	-	-

- no data or fish not sexed

Table 4: Estimated biomass (t) and coefficient of variation (cv, in parentheses) by stratum of snapper (SNA), red gurnard (GUR), tarakihi (TAR), John dory (JDO) and Jack mackerel (JMN, *Trachurus novaezealandiae*)

			SNA	GUR	JDO	TAR	JMN
Stratum	< 25 cm	≥ 25 cm	Total				
1096	18.4 (31)	179.6 (31)	197.9 (25)	28.2 (19)	5.1 (42)	0.0	26.1 (60)
2096	55.8 (66)	208.2 (67)	264.0 (27)	11.8 (48)	7.81 (33)	2.2 (100)	0.0
32NH	10 (63)	18.4 (67)	28.4 (41)	1.1 (52)	2.09 (28)	0.0	1.42 (100)
4085	20 (30)	113.7 (30)	133.8 (20)	56.4 (21)	4.58 (47)	0.0	239.4 (68)
5187	7.5 (42)	65.8 (47)	73.3 (36)	22.1 (31)	2.79 (42)	0.0	0.04 (100)
5287	17.3 (76)	101.1 (74)	118.4 (61)	29.4 (34)	9.77 (27)	0.2 (100)	1.32 (58)
6085	0.9 (71)	50.1 (71)	51.0 (74)	63.3 (34)	28.1 (44)	0.0	93.9 (51)
7085	0.8 (100)	66.9 (100)	67.7 (61)	96.4 (36)	114.4 (72)	13.8 (100)	611.2 (98)
808C	0.0	3.9 (59)	3.9 (59)	5.9 (81)	2.9 (64)	1.5 (100)	52.1 (73)
808E	0.0	1.2 (100)	1.2 (100)	2.1 (100)	3.2 (46)	0.5 (83)	97.2 (99)
808N	0.0	29.3 (20)	29.3 (20)	4.6 (63)	11.0 (62)	1.5 (58)	9.1 (58)
909C	0.0	0.0	0.0	0.9 (50)	0.8 (100)	1.2 (100)	0.0
909E	0.0	0.0	0.0	0.0	0.0	8.4 (65)	0.2 (100)
909N	0.0	1.2 (100)	1.2 (100)	0.1 (100)	0.0	6.1 (100)	1.1 (29)
Total	110.0 (30)	839.9 (13)	970.3 (14)	321.2 (14)	192.6 (44)	35.3 (46)	1133 (55)

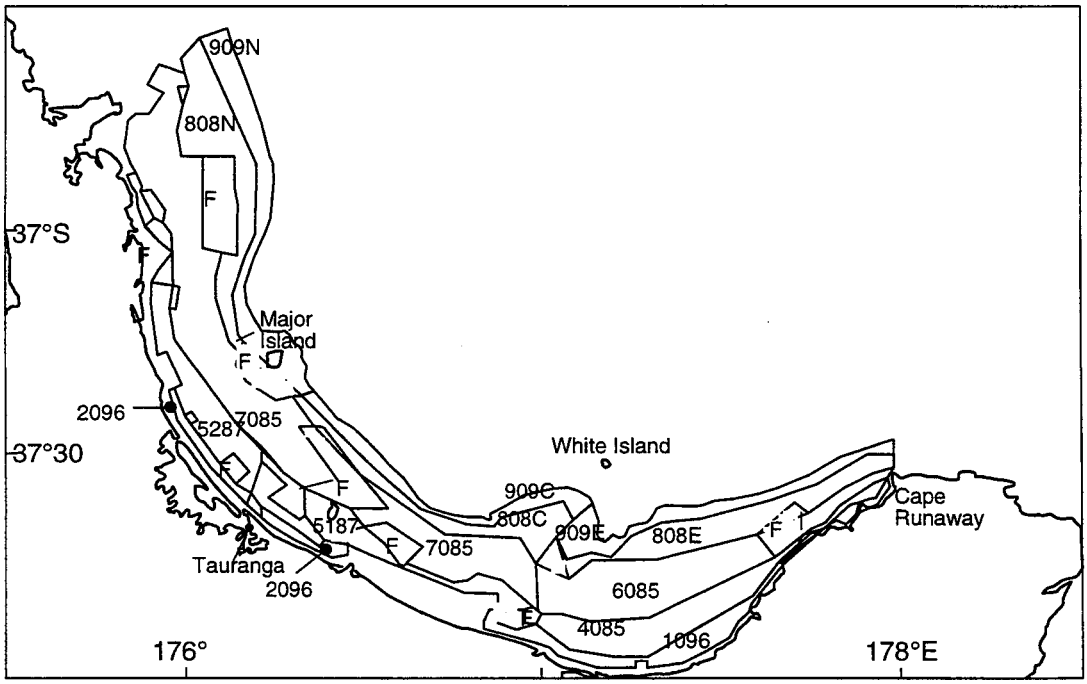

Figure 1: Survey area and stratum boundaries (F = foul ground area).

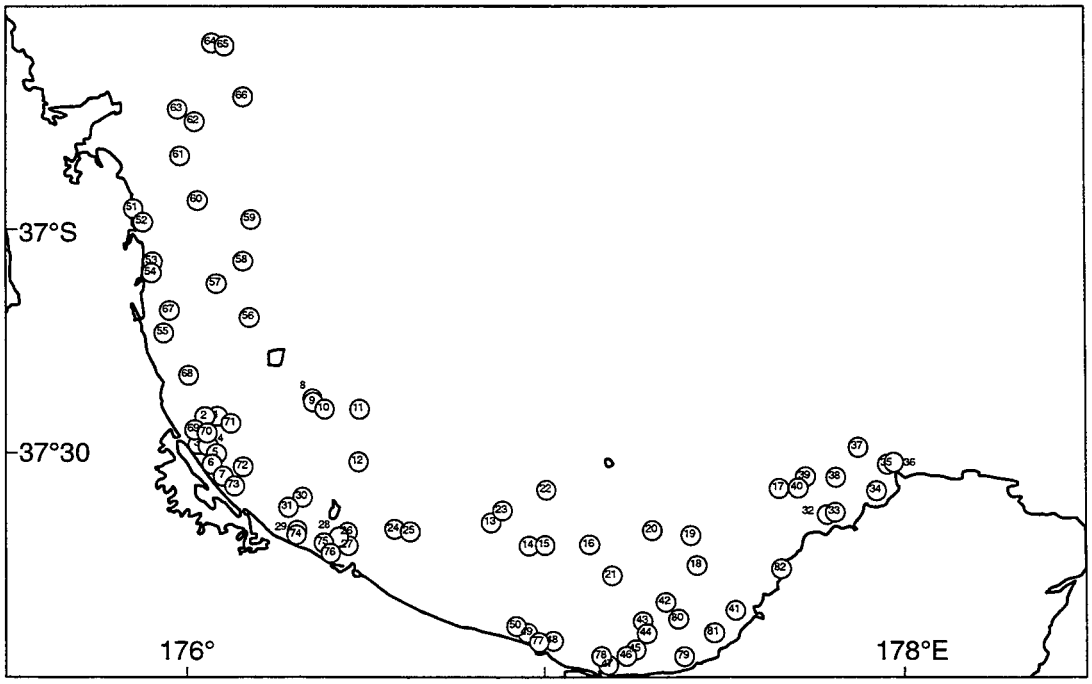

Figure 2: Station position and numbers.

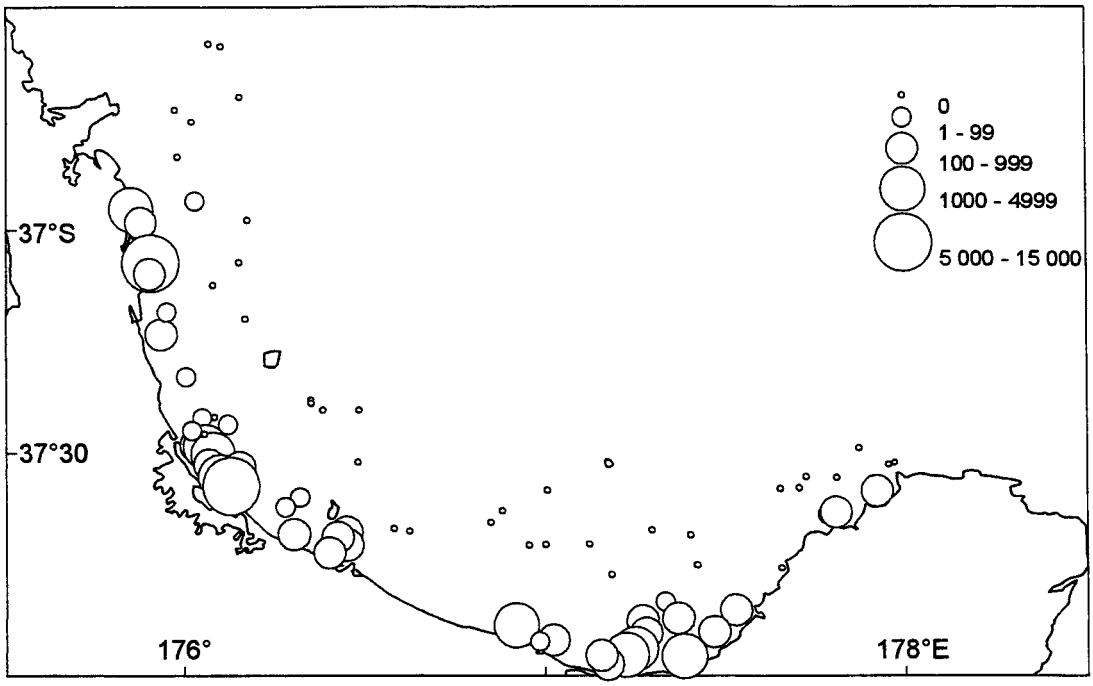

Figure 3: Catch rates (individuals per km^2) of juvenile (< 25 cm) snapper.

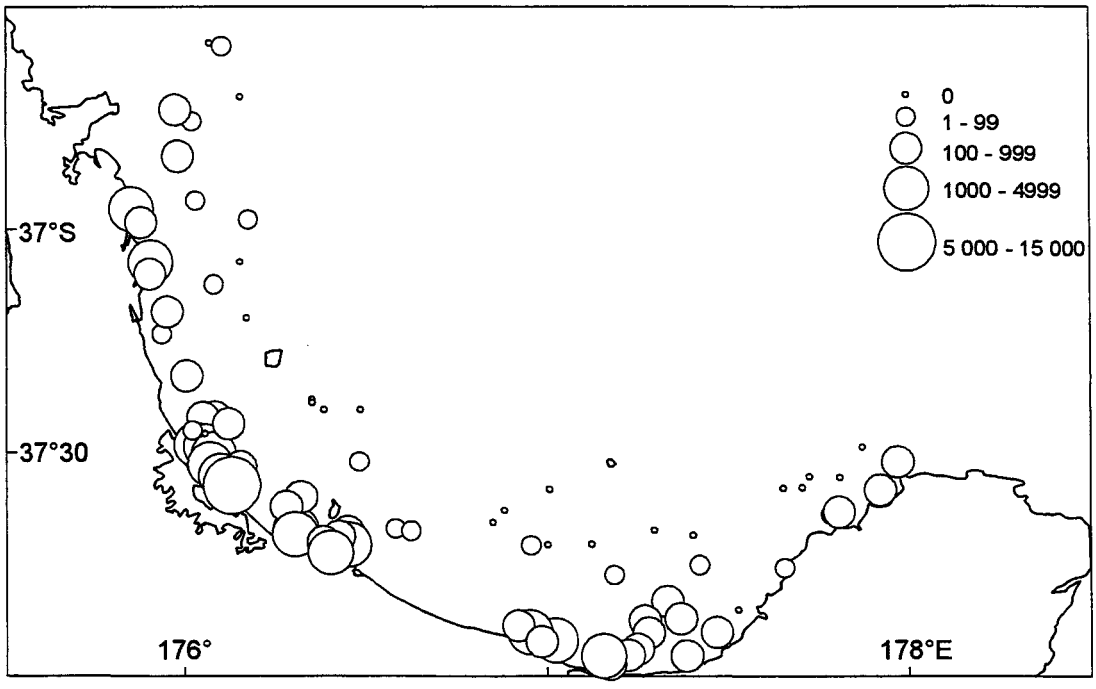

Figure 4: Catch rates (individuals per km^2) of adult (> 24 cm) snapper.

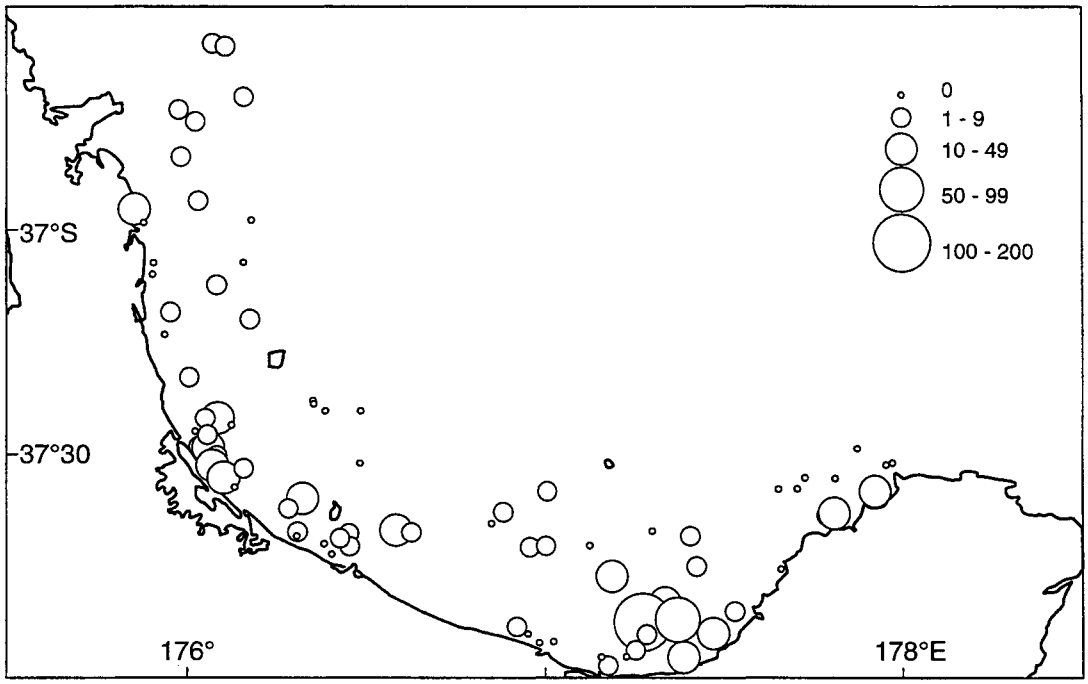

Figure 5: Catch rates (kg.km^{-2}) of red gurnard (GUR).

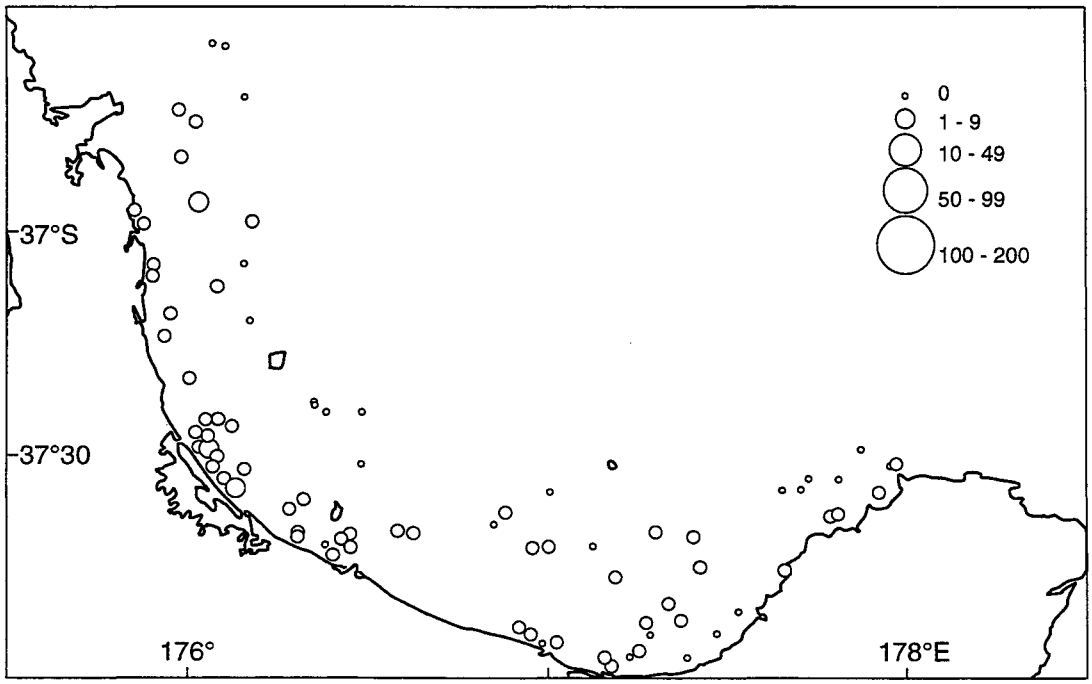

Figure 6: Catch rates (kg.km^{-2}) of John dory (JDO).

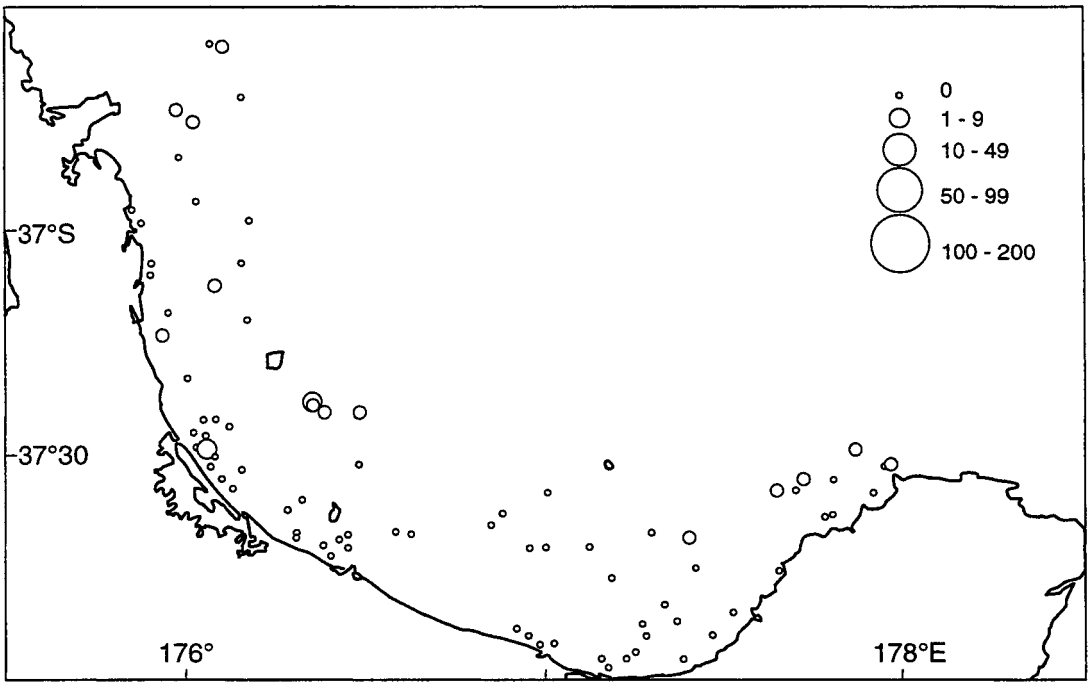

Figure 7: Catch rates (kg.km^{-2}) of tarakihi (TAR).

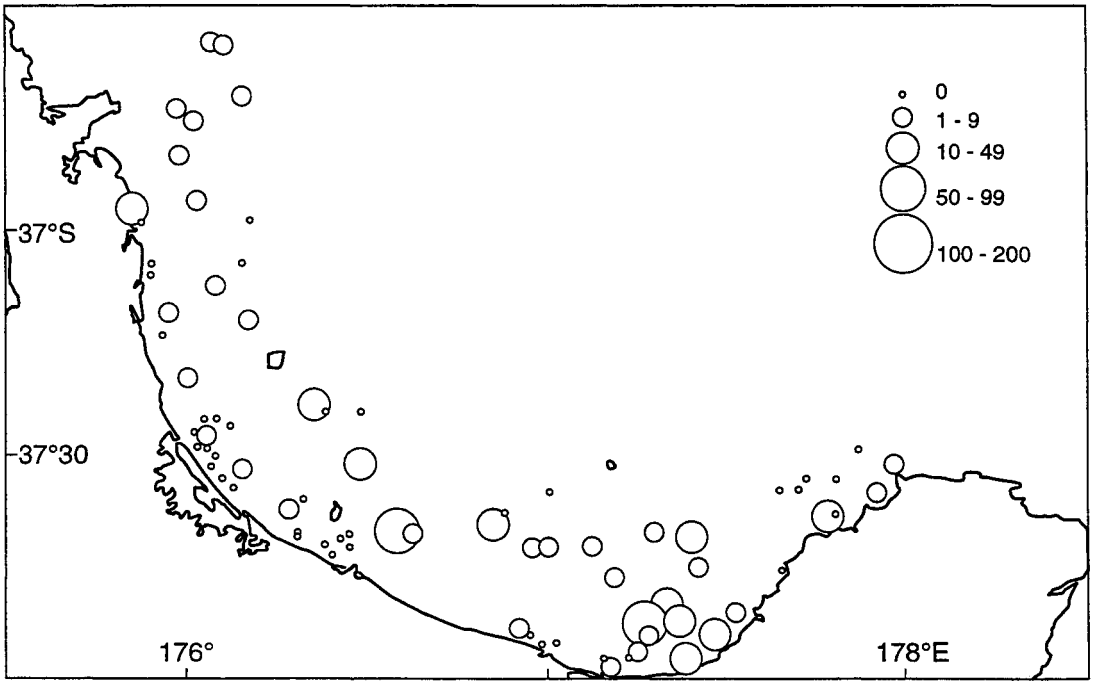

Figure 8 : Catch rates (kg.km^{-2}) of jack mackerel (JMN).

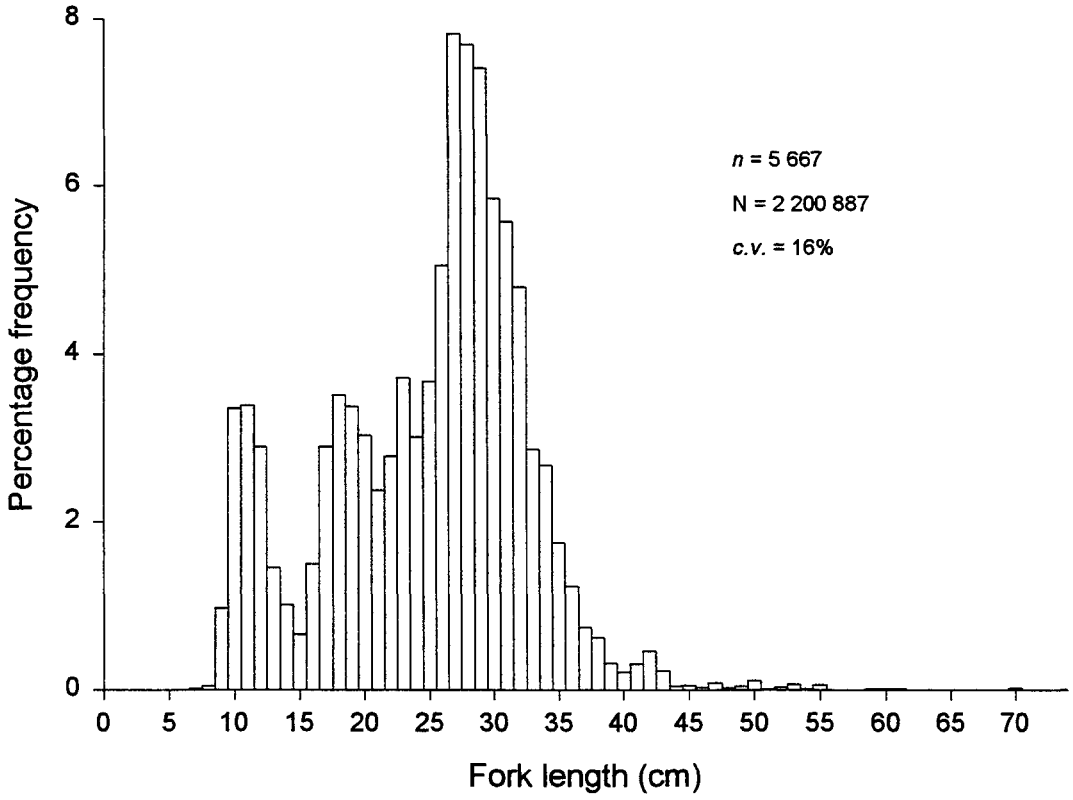

Figure 9: Length frequency distribution of snapper. *n* = number of fish measured, N = estimated number of fish in the survey area, *c.v.* = coefficient of variation.

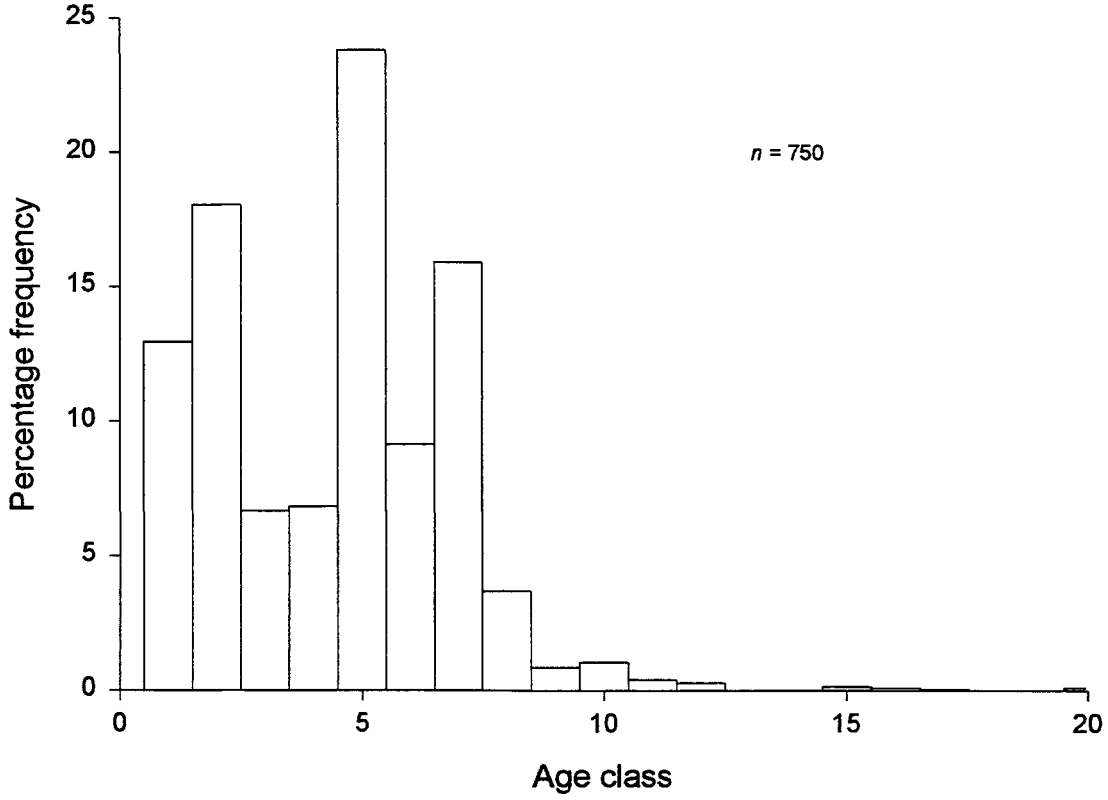

Figure 10: Age composition of snapper. *n* = number of otolith readings used to constuct the snapper age-length key

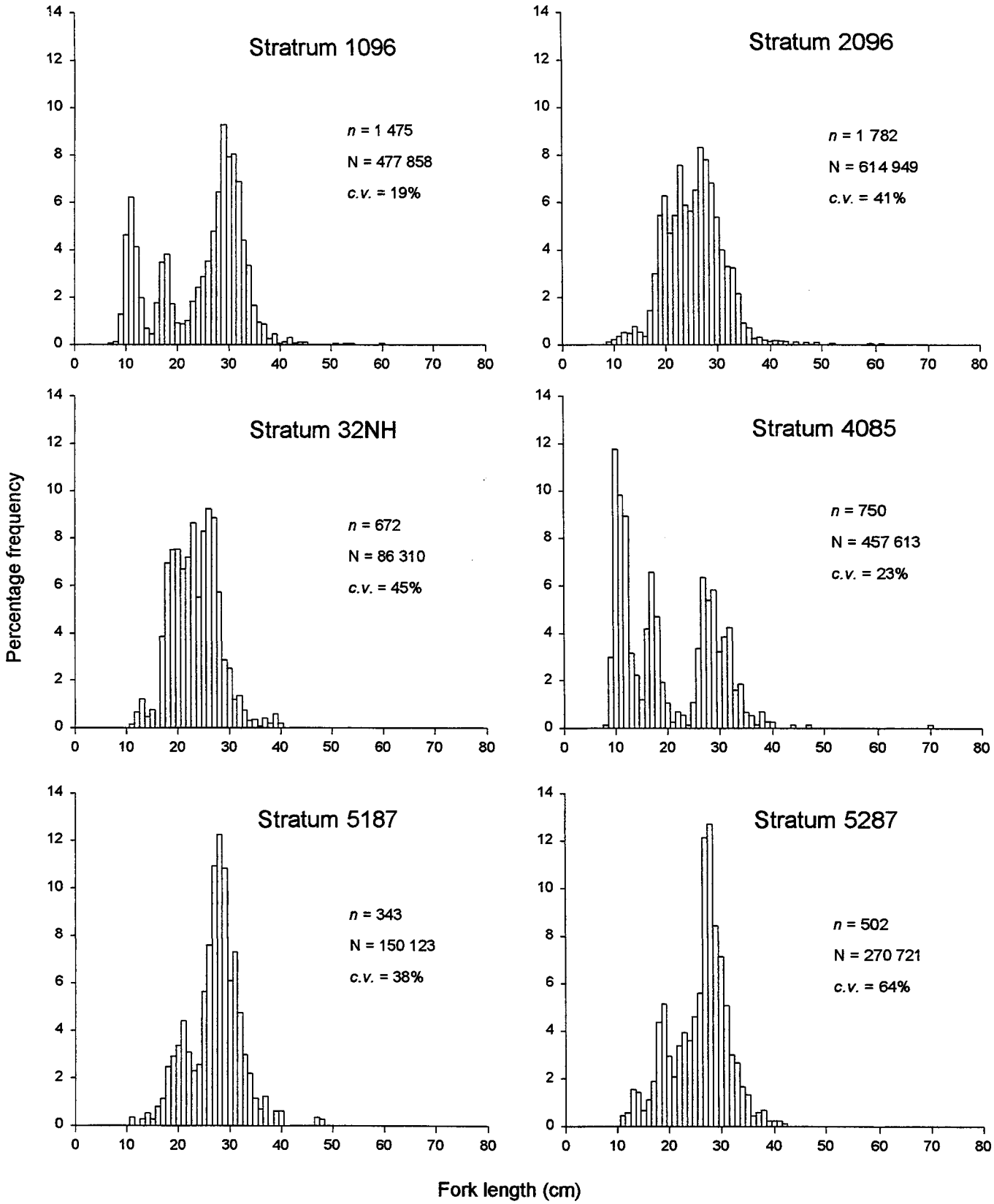

Figure 11: Stratum length compositions of snapper (for strata where more than 100 fish were measured). *n* = number of fish measured, N = estimated number of snapper within the stratum, *c.v.* = coefficient of variation.

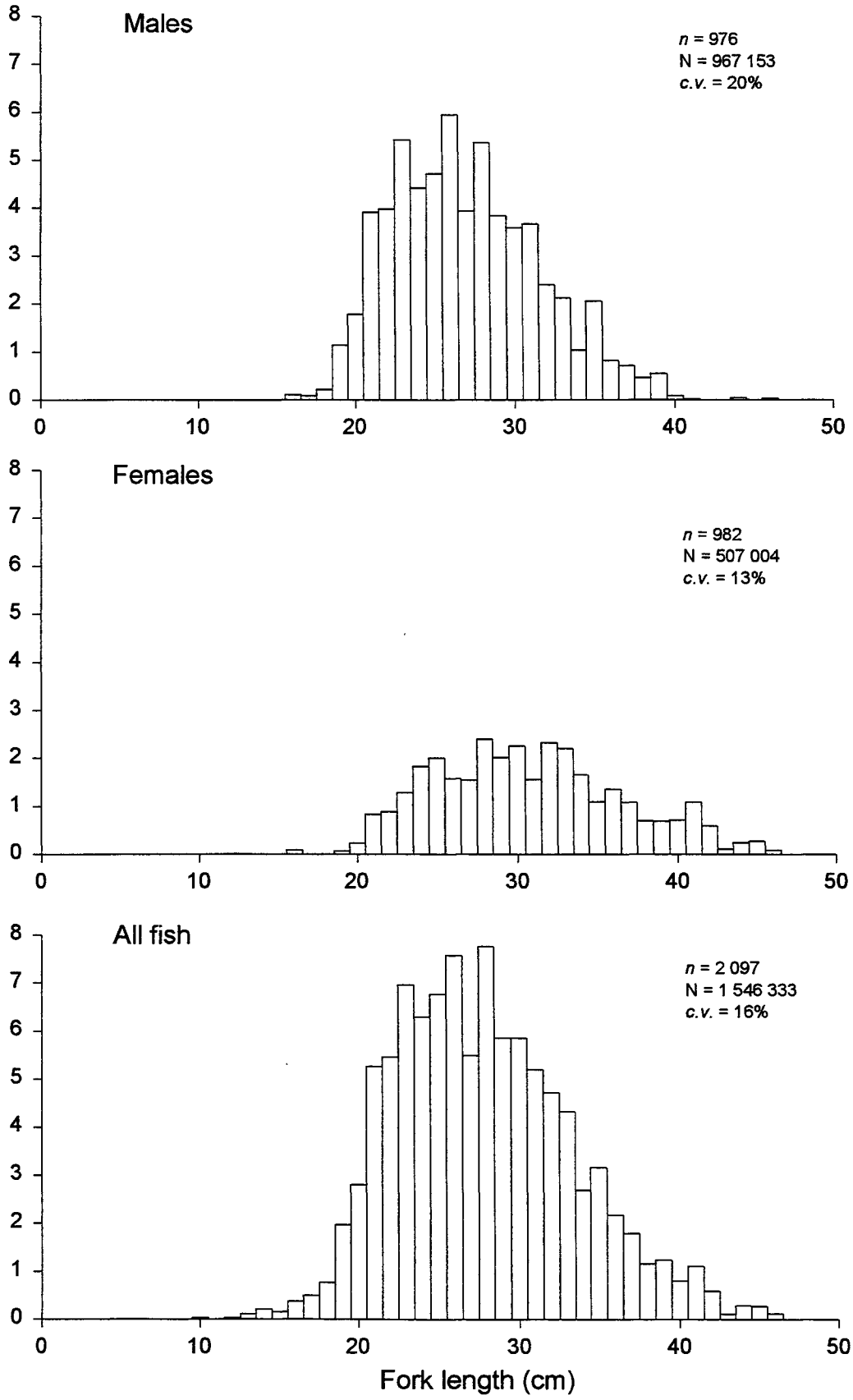

Figure 12 : Length frequency distributions of male, female and all red gurnard. *n* = number of fish measured, N = estimated number of fish in the survey area, and *c.v.* = coefficient of variation of the survey estimate.

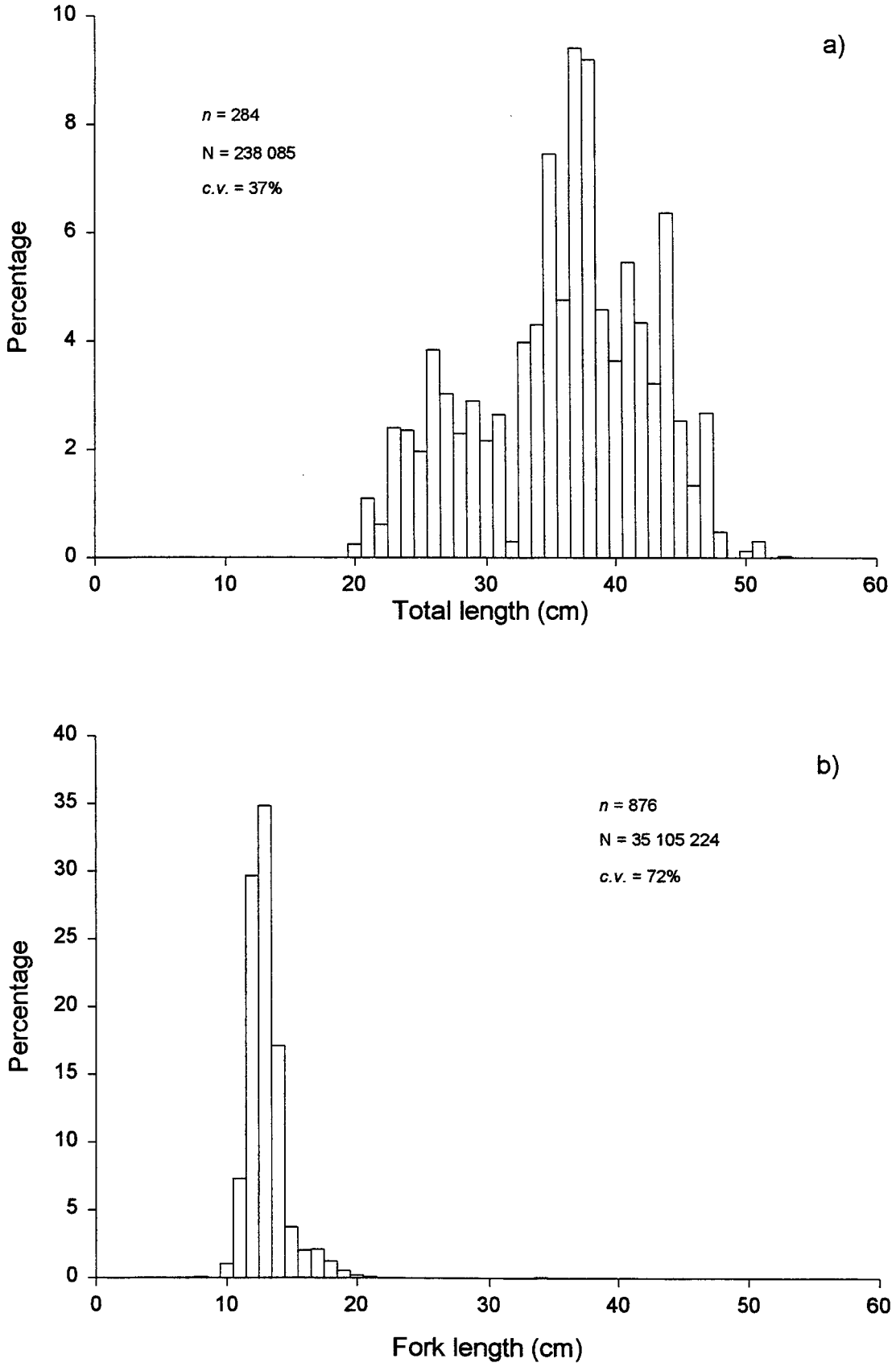

Figure 13: Length compositions of (a) John dory and (b) jack mackerel *(T. novaezelandiae).*

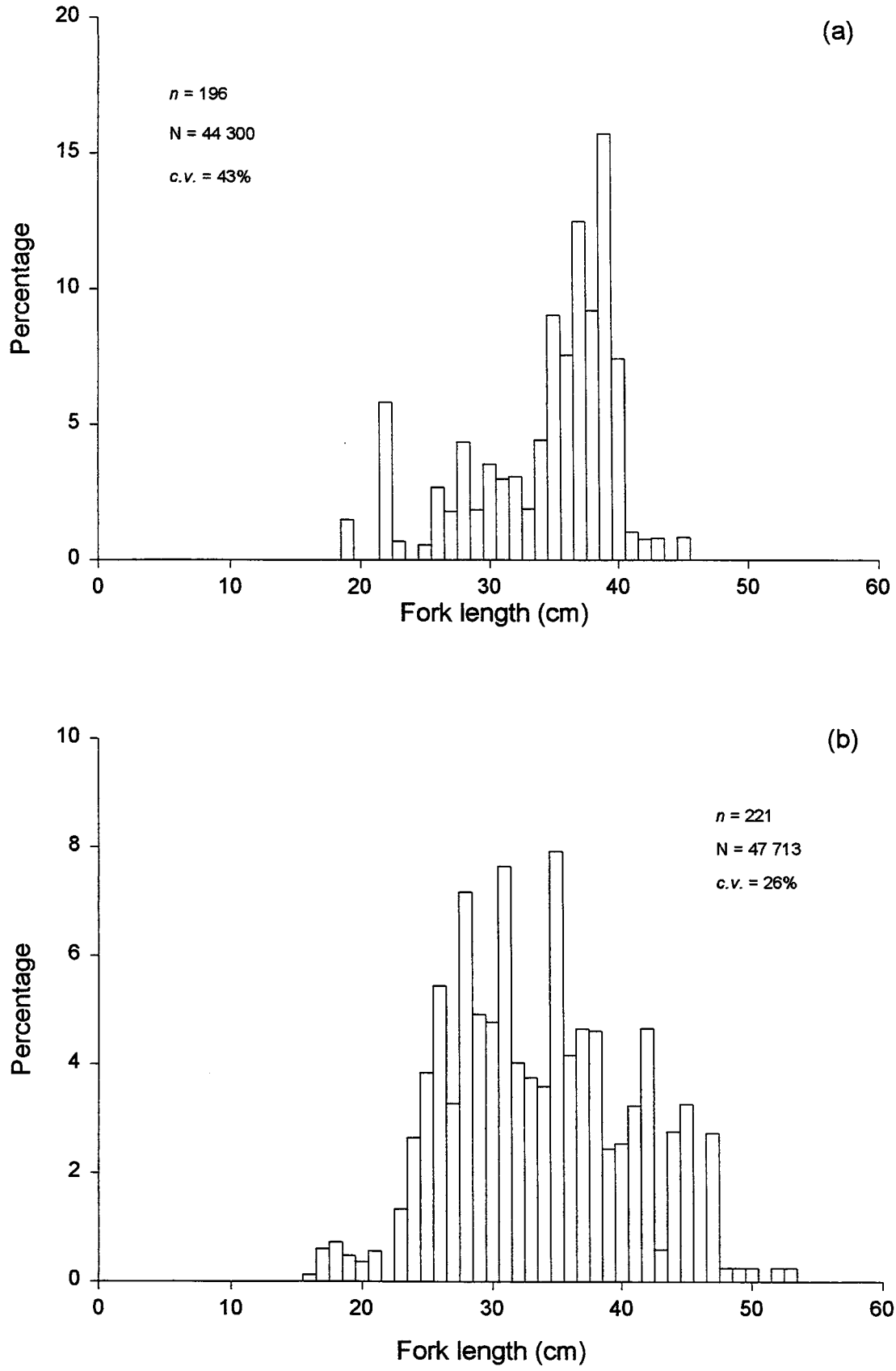

Figure 14: Length compositions of (a) tarahiki and (b) trevally.

Appendix 1: Trawl gear specifications

Type :	High opening bottom trawl (HOBT) without lower wings
Doors :	
Type	Rectangular vee
Area	3.4 m^2
Weight	480 kg
Backstrop :	6.6 m
Sweeps :	55 m x 16 mm diam.
Bridles :	
Top	55 m x 12 mm diam.
Bottom	55 m x 16 mm diam.
Headline :	34.5 m
Ground rope :	18.66 m
Ground chains :	2 x 14.5 m x 13 mm diam.
Ground rope weight :	120 kg plus 40 kg
Floats :	60 x 20 cm
Total floatation :	217 kgf
Vertical opening of trawl :	3.3–6.5 m
Codend mesh :	40 mm
Doorspread	74.5–114 m

Appendix 2 : Gear and tow parameters (recorded values only) by depth range (*n* = number of tows)

	Depth range (m)														Total
	0–50			50–100			100–150			150–200			200–250		
	n	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*
Headline Height (m)	57	5.6	0.4	20	5.3	0.7	12	5.6	0.6	9	5.1	0.8	5	5.7	0.6	103
Tow speed (knots)	58	3.0	0.1	20	3.1	0.2	12	3.0	0.0	9	3	0.0	5	3.0	0.0	104
Doorspread (DS) (m)	44	81.7	4.3	14	88.3	0.6	8	92.0	8.7	9	104.8	4.6	4	98.4	3.5	79
Wingspread (WS) m	13	18.4	1.0	6	19.3	0.6	2	20.7	1.7	-	-	-	1	21.4	-	22

Appendix 3: Macroscopic condition stages of gonads of female snapper (after Pankhurst *et al.* 1987).

Stage	Macroscopic condition
1	Immature or regressed; ovary clear, no oocytes visible.
2	Resting; ovary pink or clear. Small clear oocytes visible against the light.
3	Developing; opaque orange ovary; oocytes present.
4	Ripe; hyaline oocytes present.
5	Ovulated; eggs flow freely when light pressure applied to abdomen
6	Spent; ovary flaccid and 'bloody'; residual eggs sometimes present in oviduct.

Appendix 4 : Individual station data

Station no.	Stratum	Date	Start time	Start of tow Latitude ° 'S	Start of tow Longitude ° 'E	Start of tow Depth (m)	Tow distance (n. mile)	Warp length (m)	Headline height (m)	Door width (m)
1	5287	2 Feb 96	1002	37 25 07	176 05 42	42	1.0	200	6.0	80.2
2	5287	2 Feb 96	1056	37 25 15	176 03 71	34	1.0	200	6.0	82.7
3	2096	2 Feb 96	1159	37 29 32	176 02 21	11	0.7	200	6.0	79.3
4	2096	2 Feb 96	1248	37 29 65	176 03 94	25	0.7	200	5.8	80
5	5287	2 Feb 96	1336	37 30 39	176 05 18	26	1.0	200	5.5	84
6	2096	2 Feb 96	1431	37 31 70	176 04 02	15	0.7	200	5.6	80
7	2096	2 Feb 96	1521	37 33 36	176 06 13	20	0.7	200	5.6	83.3
* 8	909C	3 Feb 96	0537	37 23 19	176 21 10	173	1.0	500	4.7	102
9	808C	3 Feb 96	0648	37 23 93	176 21 28	150	1.0	400	4.8	102
* 10	909C	3 Feb 96	0806	37 24 49	176 23 54	204	1.0	550	3.3	114
11	909C	3 Feb 96	0929	37 28 07	176 29 43	213	1.0	550	5.0	98.7
12	808C	3 Feb 96	1043	37 31 10	176 29 19	121	1.0	300	5.8	80
* 13	909C	3 Feb 96	1325	37 39 63	176 51 01	156		400	5.0	
14	808C	3 Feb 96	1423	37 42 81	176 57 77	105	1.0	300	5.9	80
15	808C	3 Feb 96	1513	37 42 62	177 00 30	123	1.0	400	6.5	89
16	909E	3 Feb 96	1623	37 42 55	177 07 69	179	1.0	500	6.0	98.3
17	909E	4 Feb 96	0523	37 34 98	177 39 34	231	1.0	600	6.3	103
18	6085	4 Feb 96	0737	37 45 17	177 25 45	85	1.0	275	6.2	82.1
19	808E	4 Feb 96	0849	37 41 47	177 24 74	115	1.0	300	6.1	74.5
20	808E	4 Feb 96	1002	37 40 32	177 18 13	140	1.0	450	5.6	100
21	6085	4 Feb 96	1135	37 46 42	177 11 90	88	1.0	300	5.8	91.4
22	909C	4 Feb 96	1348	37 35 39	177 00 82	181	1.0	500	5.2	102
23	909C	4 Feb 96	1512	37 37 99	176 53 27	153	1.0	500	5.6	101
24	7085	5 Feb 96	0538	37 40 06	176 35 20	70	1.0	250	5.1	91.2
25	7085	5 Feb 96	0630	37 40 58	176 37 50	78	1.0	250	5.5	90.2
26	5187	5 Feb 96	0753	37 40 75	176 27 09	34	0.7	200	6.0	83.9
27	2096	5 Feb 96	0841	37 42 71	176 27 18	22	0.7	200	6.4	77
28	5187	5 Feb 96	0924	37 41 87	176 25 54	27	1.0	200	6.0	79.3
29	2096	5 Feb 96	1037	37 40 32	176 18 68	23	0.7	200	6.0	83.3
30	5187	5 Feb 96	1138	37 36 01	176 19 23	46	1.0	200	5.7	80.1
31	5187	5 Feb 96	1228	37 37 20	176 17 21	37	1.0	200	5.8	80.3
32	6085	6 Feb 96	0517	37 38 86	177 47 61	55	1.0	200	5.3	87.6
33	4085	6 Feb 96	0605	37 38 35	177 48 81	41	1.0	200	5.3	87.2
34	4085	6 Feb 96	0713	37 35 48	177 55 34	31	1.0	200	5.9	86
* 35	808E	6 Feb 96	0811	37 31 61	177 57 47	123	0.2	400		
36	808E	6 Feb 96	0849	37 31 17	177 58 23	123	1.0	350	4.5	98.3
37	909E	6 Feb 96	1013	37 29 87	177 52 29	228	1.0	600	6.3	97.4
38	808E	6 Feb 96	1145	37 33 56	177 48 99	136	1.0	450	6.0	90.4
39	909E	6 Feb 96	1300	37 33 42	177 43 66	243	1.0	650	6.0	94.6
40	909E	6 Feb 96	1401	37 34 91	177 42 59	174	1.0	500	5.9	105
41	1096	7 Feb 96	0530	37 51 22	177 32 02	24	0.7	200	5.8	88.1
42	6085	7 Feb 96	0718	37 50 40	177 20 71	57	1.0	200	5.8	80
43	4085	7 Feb 96	0817	37 52 69	177 16 46	48	1.0	200	5.5	80
44	4085	7 Feb 96	0916	37 54 39	177 17 44	39	1.0	200	5.5	80
45	4085	7 Feb 96	1018	37 56 98	177 15 45	28	1.0	200	5.5	80
46	1096	7 Feb 96	1127	37 57 39	177 13 84	24	0.7	200	5.5	80
47	1096	7 Feb 96	1221	37 58 44	177 10 72	13	0.7	200	5.5	80

48	1096	7 Feb 96	1339	37 55 04	177 01 54	23	0.8	200	5.5	80
49	1096	7 Feb 96	1430	37 54 26	176 57 29	18	0.7	200	5.5	80
50	1096	7 Feb 96	1512	37 53 72	176 55 02	24	0.7	200	5.6	80
51	32NH	8 Feb 96	0528	36 57 45	175 51 26	17	0.7	200	5.7	79.5
52	32NH	8 Feb 96	0609	36 59 48	175 52 91	21	0.7	200	5.7	81.9
53	32NH	8 Feb 96	0702	37 45 01	175 54 66	23	0.7	200	5.7	82.3
54	32NH	8 Feb 96	0744	37 60 02	175 54 35	24	0.7	200	5.5	77.4
55	5287	8 Feb 96	0857	37 14 45	175 56 72	42	1.0	200	5.5	82.3
56	909N	9 Feb 96	0953	37 12 01	176 10 22	215	1.0	600	5.1	80
57	808N	9 Feb 96	1111	37 73 09	176 05 18	108	1.0	300	5.1	80
58	909N	9 Feb 96	1218	37 43 08	176 09 56	156	1.0	450	5.1	80
59	808N	9 Feb 96	1327	36 58 93	176 10 79	141	1.0	450	5.4	80
60	7085	9 Feb 96	1459	36 56 06	176 02 07	75	1.0	250	5.6	80
61	808N	10 Feb 96	0553	36 50 65	175 59 23	103	1.0	300	5.5	93
62	808N	10 Feb 96	0701	36 45 86	176 01 27	117	1.0	350	5.8	89
63	7085	10 Feb 96	0756	36 44 19	175 58 63	97	1.0	300	5.5	93.2
64	909N	10 Feb 96	0939	36 35 34	176 04 02	162	1.0	500	5.6	107
65	909N	10 Feb 96	1045	36 35 99	176 06 54	194	1.0	600	5.0	107
66	909N	10 Feb 96	1205	36 42 33	176 09 66	190	1.0	550	4.6	107
67	5287	10 Feb 96	1537	37 11 46	175 57 26	48	1.0	200	5.6	80.9
68	5287	11 Feb 96	0530	37 19 92	176 00 61	39	1.0	200	5.5	83.5
69	2096	11 Feb 96	0643	37 27 03	176 01 26	18	0.7	200	5.5	83.9
70	5287	11 Feb 96	0719	37 27 77	176 03 72	25	1.0	200	5.5	82.1
71	5287	11 Feb 96	0813	37 26 68	176 07 29	44	1.0	200	5.5	81.1
72	5287	11 Feb 96	0915	37 32 27	176 09 64	34	1.0	200	5.7	82.9
73	2096	11 Feb 96	1003	37 34 46	176 08 18	23	0.7	200	5.8	79.8
74	2096	11 Feb 96	1137	37 41 39	176 18 57	23	0.7	200	5.7	80.6
75	2096	11 Feb 96	1227	37 42 16	176 23 21	22	0.7	200	5.5	81.4
76	2096	11 Feb 96	1318	37 43 48	176 24 16	16	0.7	200	5.5	77.5
77	1096	12 Feb 96	0546	37 55 36	176 59 49	17	0.7	200	5.6	85
78	1096	12 Feb 96	0656	37 57 49	177 09 88	21	0.7	200	5.5	85.1
79	1096	12 Feb 96	0826	37 57 59	177 23 89	17	0.7	200	5.8	82.4
80	4085	12 Feb 96	0928	37 52 17	177 22 24	42	1.0	200	5.5	85.4
81	1096	12 Feb 96	1030	37 54 25	177 28 11	24	0.7	200	5.5	82.3
82	1096	12 Feb 96	1215	37 45 87	177 39 86	20	0.7	200	5.6	81.9

* = fouled or poor performance shot

Appendix 5. Catch (kg) at each station for 5 of the more important commercial species : snapper (SNA), gurnard (GUR), jack mackerel (JMN, *Trachurus novaezealandiae*), John dory (JDO), and tarakihi (TAR).

Station	SNA	GUR	JDO	TAR	JMN
1	15.3	18.7	4.5	0.0	0.0
2	13.1	7.6	1.2	0.0	0.0
3	329.4	0.2	2.0	0.0	0.0
4	205.3	15.6	19.6	18.5	0.0
5	267.0	1.3	5.3	0.0	0.0
6	169.9	48.0	11.1	0.0	0.0
7	283.9	20.8	4.0	0.0	0.0
8	0.0	0.0	0.0	53.5	14.9
9	0.0	0.0	0.0	3.5	25.5
10	0.0	0.0	0.0	12.1	0.0
11	0.0	0.0	0.0	2.7	0.0
12	4.2	0.0	0.0	0.0	73.9
13	n/a	n/a	n/a	n/a	n/a
14	3.1	9.1	3.6	0.0	1.3
15	0.0	1.8	2.0	0.0	0.1
16	0.0	0.0	0.0	0.0	0.6
17	0.0	0.0	0.0	4.9	0.0
18	3.4	7.6	12.7	0.0	4.6
19	0.0	2.6	2.2	0.5	116.9
20	0.0	0.0	1.1	0.0	0.1
21	1.4	28.7	7.1	0.0	0.1
22	0.0	1.0	0.0	0.0	0.0
23	0.0	1.1	1.8	0.0	0.0
24	4.2	18.5	4.7	0.0	238.9
25	1.8	7.3	4.6	0.0	1.2
26	53.6	4.0	1.2	0.0	0.0
27	75.1	2.5	3.7	0.0	0.0
28	78.8	17.4	0.5	0.0	0.0
29	167.5	0.4	0.7	0.0	0.0
30	13.1	24.6	1.1	0.0	0.0
31	22.0	8.7	3.9	0.0	0.1
32	3.8	13.4	3.0	0.0	39.6
33	20.7	29.5	3.6	0.0	0.0
34	44.3	29.0	0.4	0.0	0.8
35	n/a	n/a	n/a	n/a	n/a
36	2.0	0.0	1.2	0.1	1.6
37	0.0	0.0	0.0	17.5	0.0
38	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	2.7	0.0
41	64.1	10.1	0.0	0.0	2.1
42	32.8	5.9	1.2	0.0	34.5
43	32.1	18.3	1.1	0.0	292.7
44	76.1	14.9	0.0	0.0	0.6
45	47.1	4.9	3.5	0.0	1.4
46	69.2	12.6	0.0	0.0	0.0
47	31.3	10.7	7.3	0.0	0.1
48	144.4	15.1	4.4	0.0	0.0

49	192.0	6.6	5.0	0.0	0.0
50	68.5	25.6	1.3	0.0	7.7
51	222.2	10.3	12.1	0.0	22.5
52	35.6	1.2	11.6	0.0	0.0
53	167.3	5.5	9.2	0.0	0.0
54	40.3	0.6	1.7	0.0	0.0
55	10.9	18.7	10.9	0.7	0.0
56	0.0	0.3	0.0	0.0	0.3
57	5.0	1.8	2.0	0.9	3.8
58	0.0	0.0	0.0	0.0	0.0
59	7.6	0.0	1.4	0.0	0.0
60	1.8	1.7	31.5	0.0	0.1
61	14.9	4.0	10.1	0.0	7.2
62	8.5	0.0	0.3	0.9	0.3
63	19.3	10.8	0.3	5.6	3.3
64	0.0	0.0	0.0	0.0	0.8
65	3.4	0.0	0.0	17.1	0.9
66	0.0	0.0	0.0	0.0	0.9
67	7.6	12.4	2.7	0.0	0.2
68	13.5	33.9	2.0	0.0	1.5
69	2.4	0.2	4.1	0.0	0.0
70	0.0	0.6	1.4	0.0	0.4
71	15.0	0.5	2.8	0.0	0.0
72	73.2	4.5	3.0	0.0	2.5
73	682.6	8.3	16.5	0.0	0.0
74	103.7	2.8	1.4	0.0	0.0
75	31.5	1.9	0.0	0.0	0.0
76	220.1	0.4	3.9	0.0	0.0
77	28.9	10.5	0.0	0.0	0.0
78	126.2	7.1	2.2	0.0	0.0
79	44.8	7.9	0.0	0.0	52.9
80	31.2	11.7	0.1	0.0	152.1
81	17.7	4.0	0.0	0.0	40.1
82	5.8	2.1	0.2	0.0	0.0
Total	4 481.5	607.8	262.0	141.2	1 149.1

Appendix 6. Snapper age-length key

Length (cm)	Age Class 0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	>19+	No. aged
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
7	-	*1.00*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8	-	*1.00*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9	-	*1.00*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
10	-	*1.00*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
11	-	*1.00*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
12	-	*1.00*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
13	-	*1.00*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
14	-	*0.91*	*0.09*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
15	-	0.50	0.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
16	-	0.09	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
17	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
18	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
19	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
20	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
21	-	-	0.77	0.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
22	-	-	0.33	0.60	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
23	-	-	0.07	0.60	0.20	0.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
24	-	-	-	0.33	0.33	0.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
25	-	-	-	-	0.38	0.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
26	-	-	-	0.15	0.35	0.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
27	-	-	-	-	0.10	0.83	0.03	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	29
28	-	-	-	-	0.04	0.64	0.18	0.11	0.02	-	-	-	-	-	-	-	-	-	-	-	-	45
29	-	-	-	-	-	0.55	0.27	0.15	0.03	-	-	-	-	-	-	-	-	-	-	-	-	62
30	-	-	-	-	0.02	0.20	0.34	0.41	0.02	0.02	-	-	-	-	-	-	-	-	-	-	-	61
31	-	-	-	-	-	0.09	0.30	0.55	0.04	0.02	-	-	-	-	-	-	-	-	-	-	-	53
32	-	-	-	-	-	-	0.14	0.68	0.14	-	0.02	-	0.02	-	-	-	-	-	-	-	-	50
33	-	-	-	-	-	-	0.19	0.71	0.07	0.02	-	-	-	-	-	-	-	-	-	-	-	42
34	-	-	-	-	-	-	0.10	0.66	0.22	-	0.02	-	-	-	-	-	-	-	-	-	-	41
35	-	-	-	-	-	-	0.10	0.41	0.21	0.15	0.08	0.05	-	-	-	-	-	-	-	-	-	39
36	-	-	-	-	-	-	0.09	0.13	0.48	0.04	0.22	0.04	-	-	-	-	-	-	-	-	-	23
37	-	-	-	-	-	-	-	0.24	0.43	0.10	0.14	0.10	-	-	-	-	-	-	-	-	-	21
38	-	-	-	-	-	-	-	0.17	0.30	0.17	0.30	0.04	-	-	-	-	-	-	-	-	-	23
39	-	-	-	-	-	-	-	0.08	0.50	0.08	0.17	0.08	0.08	-	-	-	-	-	-	-	-	12
40	-	-	-	-	-	-	-	0.12	0.24	0.18	0.29	0.12	-	0.06	-	-	-	-	-	-	-	17
41	-	-	-	-	-	-	-	0.08	0.17	0.17	0.17	0.25	0.17	-	-	-	-	-	-	-	-	12
42	-	-	-	-	-	-	-	0.08	0.15	0.08	0.31	0.08	0.23	-	-	0.08	-	-	-	-	-	13
43	-	-	-	-	-	-	-	-	0.20	0.20	0.40	0.20	-	-	-	-	-	-	-	-	-	5
44	-	-	-	-	-	-	-	-	0.20	-	0.40	0.40	-	-	-	-	-	-	-	-	-	5
45	-	-	-	-	-	-	-	-	-	0.20	-	0.40	0.40	-	-	-	-	-	-	-	-	5
46	-	-	-	-	-	-	-	-	-	-	-	-	0.50	-	-	-	-	0.50	-	-	-	2
47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	1
48	-	-	-	-	-	-	-	-	-	-	0.25	-	0.25	-	-	-	0.25	0.25	-	-	-	4
49	-	-	-	-	-	-	-	-	-	-	-	-	0.33	-	-	0.33	-	-	-	-	0.33	3
50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	1
51	-	-	-	-	-	-	-	-	-	-	0.50	0.50	-	-	-	-	-	-	-	-	-	2
52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33	0.33	-	0.33	-	-	-	3
53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	2
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	1
55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1
56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	1
58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	1
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	1
61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1
62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1
71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1
75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Total																						750

NB : Proportions in italics estimated (given previous trawl survey results), since otoliths were not taken from snapper in this size range.