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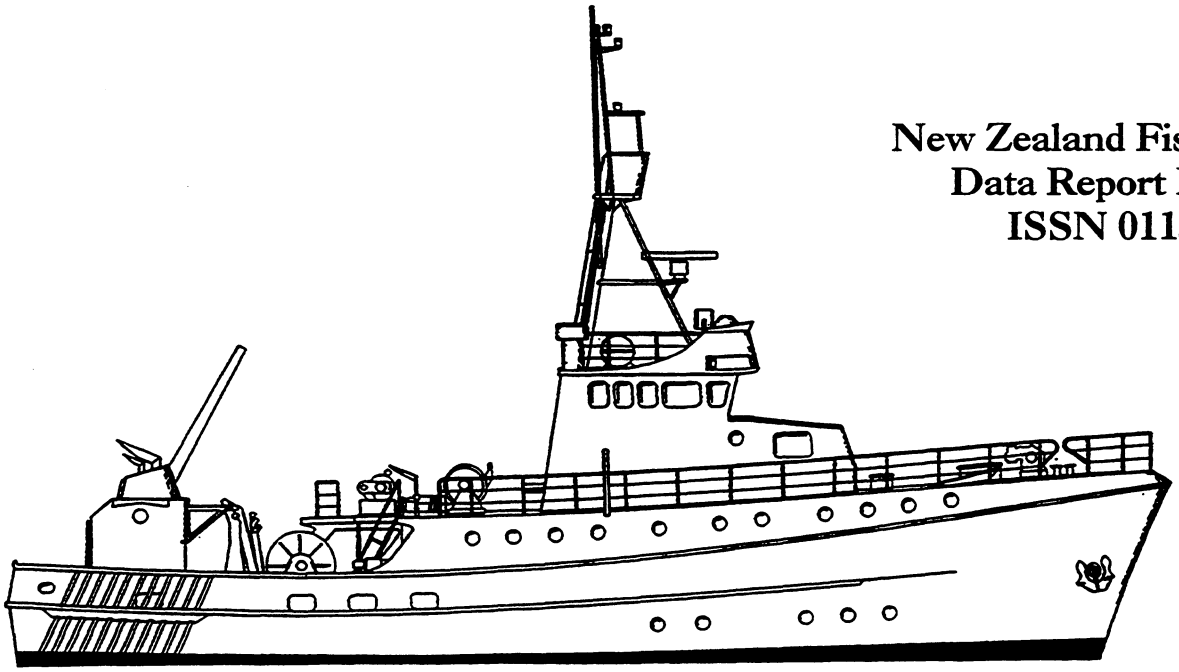
Taihoro Nukurangi

Trawl survey of snapper and associated species in the Hauraki Gulf, October-November 1994 (KAH9411)

Adam D. Langley



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Contents

Introduction

RV *Kaharoa* has conducted regular trawl surveys of the Hauraki Gulf since 1982. In recent years, the prime objective of the surveys has been to determine the relative year class strength (YCS) of juvenile snapper. Francis (1993) calculated YCS indices from the estimated number of 1+ age class snapper derived from the 1984-90 trawl surveys of the Hauraki Gulf. The relative YCS indices are strongly correlated with the mean sea surface temperature in the summer and autumn following spawning (Francis 1993). A recruitment index based on the temperature-recruitment relationship is incorporated in the assessment of SNA 1 biomass and yield (Annala 1995a).

The trawl survey programme also collects data on other commercial finfish species, particularly John dory and red gurnard. These species represent an important bycatch of the inshore trawl and Danish seine fisheries in the Auckland Fishery Management Area (AFMA). The trawl survey programme may enable trends in the relative abundance and population structure of these species to be monitored.

The results of the 1990, 1992, and 1993 Hauraki Gulf trawl surveys have been documented by Drury & McKenzie (1992) and Langley (1994a, 1994b). This report presents the results of the Hauraki Gulf trawl survey conducted in October-November 1994.

The voyage began in Auckland on 26 October 1994. During the survey two port calls were made into Auckland to unload fish and exchange scientific staff and crew. The survey was completed on 4 November 1994.

Project objectives

The major objectives of this research programme are as follows.

1. To estimate the relative year class strength of juvenile snapper in the Hauraki Gulf.
2. To estimate relative abundance, distributions, age, sex, and length frequencies of snapper and other demersal finfish species, including red gurnard, John dory, trevally, and kahawai in the Hauraki Gulf.
3. To determine the structure of fish assemblages vulnerable to bottom trawl gear in the Hauraki Gulf.
4. To determine age distributions of the Hauraki Gulf snapper population sampled by *Kaharoa* trawl surveys between 1982 and 1993.
5. To determine the catchability of juvenile snapper from *Kaharoa* trawl surveys in the Hauraki Gulf with respect to cohort age and the seasonal timing of the survey.

Survey objectives

The 1994 trawl survey was designed to contribute to the fulfilment of project objectives 1, 2, and 3. The specific objectives of the trawl survey were as follows.

1. To carry out a two-phase random stratified trawl survey of the Hauraki Gulf.
2. To collect biological data and samples from snapper and other finfish species caught the survey.

Methods

Survey area and design

The survey area extended from northeast of Bream Head (Whangarei Harbour) to Great Mercury Island in the 10–150 m depth range (Figure 1). The survey area was divided into 11 depth and area strata based on the catch rate of pre-recruit (< 25 cm fork length (FL)) snapper from previous trawl surveys (Table 1, Figure 1). Stratum boundaries remained unchanged from the 1992 and 1993 trawl surveys (Langley 1994a, 1994b).

The survey was of a two-phase stratified random design (*after* Francis 1984). Trawls were conducted at randomly selected positions with a minimum of three stations per stratum at least 1 n. mile (1.85 km) apart. A total of 60 stations was allocated to the first phase of the survey based on a simulation analysis of snapper catch rate data from the time series of Hauraki Gulf trawl surveys (Langley 1994a). A further 10 stations were retained for the second phase of the survey. These stations were allocated to strata that yielded high catch rates of pre-recruit snapper during the first phase. A summary of the station allocation to strata 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. The specifications of the trawl gear are given in Appendix 1.

Trawling procedure

All trawls were carried out during daylight hours (between 0530 and 1630 hours NZST). Trawls began at the randomly selected start position unless untrawlable ground was encountered, when a search was made for suitable ground within a 2 n. mile (3.70 km) radius of the station position. If no suitable ground was located, the station was abandoned and another random position substituted.

Towing speed was between 3.0 and 3.5 kn and tow direction was generally towards the nearest random station position. The distance trawled was constant at 0.7 n. mile (1.3 km), measured using Magnavox GPS. Warp to depth ratios decreased with increasing depth, ranging from 15 : 1 at the shallowest stations to 4 : 1 at the deepest stations.

Headline height was recorded from a net sonde and averaged over the length of the tow. Trawl doorspread was estimated using the equation given by Langley (1994b),

$$\text{Doorspread} = 88.8214\,(1 - e^{-0.0096994\,\text{warplength} + 7.3296}) \qquad \text{Eqn 1}$$

Catch and biological sampling

The catch from each trawl was sorted by species and weighed on Seaway motion-compensating scales to the nearest 0.1 kg. For all commercially important fish and squid, a sample of the catch was taken from each trawl for biological sampling. All specimens were sampled from small catches: for large catches, a random sample of about 200 fish was taken.

The length of fish and squid sampled was measured to the nearest centimetre below the actual length. The first 60 mature snapper (>23 cm FL) in each sample were also sexed and the ovarian condition of female fish was categorised using a five stage developmental scale (Appendix 2). Red gurnard, John dory, rays, and sharks were also sexed. Gonadal development data were collected from rig and school shark and vertebral sections were taken from some specimens.

Otoliths were collected from measured snapper (up to a target of 20 otoliths per 1 cm length class), John dory, red gurnard, and trevally.

Environmental observations

For each trawl station the following environmental observations were collected: sea surface temperature, bottom temperature (from net monitor), air temperature, wind direction and speed, turbidity of surface water, 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 Trawlsurvey 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. Doorspread was estimated from Equation 1.
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 the fish were within the survey area at the time of the survey.

The coefficient of variation (*c.v.*) associated with the estimates of biomass was calculated from

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

where B is the biomass estimate and S_B is the standard error of the biomass estimate.

Age determination

Snapper were aged as described by McKenzie *et al.* (1992). Age classes were defined after Paul (1976), whereby 1 January is defined as the theoretical birthday. The otoliths were aged as at the collection date (October-November 1994).

The resulting age data were applied to the scaled snapper length frequency distribution to estimate the age frequency distribution of the snapper population sampled by the survey.

Results

Sixty stations were successfully completed in phase 1 and a further 10 stations were allocated among strata 1219, 1268, and 1887 in phase 2. Stations 19 and 21 were abandoned because of gear damage or poor performance of the trawl gear and were excluded from the biomass analysis. The areal distribution of trawl stations is given in Figure 2 and individual station information in Appendix 3.

Catch composition

A total of 47 species was caught during the survey (Table 2). Snapper accounted for 59.4% of the total catch by weight, jack mackerel (*Trachurus novaezelandiae* and *T. declivis*) 24.8%, John dory 2.3%, and sand flounder 2.0%. Small catches of other commercial species, notably red gurnard, barracouta, kahawai, and rig, were also taken. One large catch of green-lipped mussels was taken from the inner Firth of Thames. A summary of the catch by station of the main commercial species is given in Appendix 4.

Distribution and catch rates

Snapper were caught at all successfully completed trawl stations (*see* Appendix 2). Pre-recruit snapper were most abundant at stations within the shallow reaches of the Hauraki Gulf, from Kawau Island to Waiheke Island, in the Firth of Thames, and off western Coromandel (Figure 3). Catch rates of pre-recruit snapper were low from trawls deeper than 50 m. The highest catch rates of legal-sized snapper (fish ≥ 25 cm FL) were taken from the inner Hauraki Gulf in depths less than 30 m (Figure 4).

The distribution of catch rates for jack mackerel (*T. novaezelandiae*), John dory, and red gurnard are given in Figures 5–7.

Biological data

Biological data collected from the catch are summarised in Table 3.

The scaled length frequency distribution of snapper is given in Figure 8. Three modes are evident in the length composition; two small modes between 6 and 11 cm and 12 and 16 cm and a broad length mode occupying the 17–40 cm length range. Snapper age data show the two small modes represent the 0+ and 1+ age classes respectively, and the broad mode includes fish of ages 2+ and greater (Appendix 5). The scaled snapper age composition is dominated by the 1+ to 5+ age classes, including a relatively strong 3+ age class (Figure 9).

The length compositions of snapper from individual strata are given in Figure 10. Most of the snapper occupying the 0+ to 2+ age classes were caught in the inner Hauraki Gulf (strata 1386, 1284, 1268, 1149, 2229, 1887, 9292, and 1219). The snapper catch from outer Hauraki Gulf strata was dominated by fish occupying the larger (> 20 cm FL) length classes.

The female snapper sampled from the catch were predominantly in the resting (34.1%) and developing (52.1%) stages of ovarian development. Female fish with ovaries in a ripe state accounted for 13.6% of fish sampled. Very few (0.2%) immature female snapper were sampled from fish of 23 cm Fl or over and no ovulated or spent fish were recorded.

Scaled length frequency distributions are also given for John dory, red gurnard, sand flounder, and the two species of jack mackerel (*T. novaezelandiae* and *T. declivis*) (Figures 11–13).

Biomass estimates

Biomass estimates for snapper, John dory, red gurnard, sand flounder, and the two species of jack mackerel are presented in Table 4. A large proportion (50%) of the total snapper biomass was within the two Firth of Thames strata (1887 and 1268) and the outer Hauraki Gulf stratum (4492). The biomass of sand flounder was concentrated in the central Hauraki Gulf, with strata 2229 and 1219 accounting for 61% of the estimated total biomass. For the jack mackerel species, 72% of the total *T. novaezelandiae* biomass was within the Firth of Thames and central Hauraki Gulf strata (1219, 1268, 1887, and 2229) and almost the total *T. declivis* biomass was in the outer Gulf stratum 4492. The distribution of John dory and red gurnard biomass among strata was comparable, with the three large central and outer Hauraki Gulf strata (1219, 4492, and 1518) accounting for 67% and 77% of the total biomass, respectively.

For the main commercial species, except *T. declivis*, the coefficients of variation around the total biomass estimates were less than 20%, implying moderate to high precision. Catches of *T. declivis* were variable in the outer Hauraki Gulf resulting in a high *c.v.* associated with the total biomass estimate.

Discussion

The 1994 trawl survey of the Hauraki Gulf sampled the 1993 snapper year class as 1+ age fish. The survey estimated the 1993 year class to be weak compared to the time series of relative YCS indices (Annala 1995a).

The biomass estimates for John dory and red gurnard have been included in the annual assessment of these species (Annala 1995b).

The design of the trawl survey has remained unchanged for the last three surveys. Stratum boundaries and the allocation of phase 1 stations were determined from the pre-recruit snapper catch rate data collected from the nine spring-summer trawl surveys carried out between 1982 and 1990. This large database of catch rate data enabled the areal distribution and relative abundance of pre-recruit snapper in the survey area to be comprehensively described. Subsequent surveys have achieved precise estimates of 1+ snapper YCS, with a relatively low station density, and no further modifications to the survey design are proposed.

The trawling procedures, catch sampling protocols, and the configuration of the trawl gear have also remained unchanged during recent surveys. The Hauraki Gulf trawl survey programme represents the longest time-series of trawl surveys in New Zealand fisheries research. To ensure the integrity of this time series, it is crucial that the consistency in survey procedures is maintained.

Acknowledgments

I thank Jim Drury for his assistance in organising the trawl survey; Dave Allen for assuming the role of voyage leader during the first few days at short notice; Arthur Muir and the crew of *Kaharoa* for their assistance throughout the survey; and Cameron Walsh and Bruce Hartill for reading the snapper otolith collection. I also thank those NIWA and MAF staff who participated in the collection of data during the survey. Peter Horn and Malcolm Francis provided comments on a draft of the manuscript.

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

Stratum	Description	Depth range (m)	Area (km^2)	No. of stations Phase 1	No. of stations Phase 2	Density (per km^2)
1149	Waiheke, Tamaki Strait	10–25	64.5	4	0	1 : 16.1
1219	Central Gulf	25–50	888.1	8	3	1 : 80.7
1268	Outer Firth of Thames	25–45	312.2	7	3	1 : 31.2
1284	Kawau, Whangaparaoa	10–25	73.2	5	0	1 : 14.6
1386	Whangaparaoa, Rangitoto	10–25	67.8	3	0	1 : 22.6
1449	Bream Head, Cape Rodney	10–50	269.3	3	0	1 : 89.8
1518	Deep Shelf	75–150	3 212.1	4	0	1 : 803.0
1887	Inner Firth of Thames	10–25	270.2	5	4	1 : 30.0
2229	Inner Gulf	25–45	559.9	5	0	1 : 112.0
4492	Outer Gulf	10–75	2 405.2	12	0	1 : 200.4
9292	West Coromandel	10–25	66.6	4	0	1 : 16.7
Total			8 216.1	60	10	1 : 117.4

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

Common name	Species code	Scientific name	Total weight (kg)	Percentage of catch by weight	Percentage occurrence
Snapper	SNA	*Pagrus auratus*	11 138.9	59.4	98.6
Jack mackerel	JMN	*Trachurus novaezelandiae*	3 420.6	18.2	84.7
Jack mackerel	JMD	*T. declivis*	1 241.1	6.6	27.8
John dory	JDO	*Zeus faber*	426.7	2.3	93.1
Sand flounder	SFL	*Rhombosolea plebeia*	382.1	2.0	73.6
Greenlipped mussel	MSG	*Perna canaliculus*	265.6	1.4	4.2
Red gurnard	GUR	*Chelidonichthys kumu*	260.9	1.4	93.1
Smooth skate	SSK	*Raja innominata*	179.8	1.0	27.8
Leatherjacket	LEA	*Parika scaber*	166.0	0.9	44.4
Eagle ray	EGR	*Myliobatis tenuicaudatus*	149.1	0.8	29.2
Pilchard	PIL	*Sardinops neopilchardus*	145.0	0.8	8.3
Longtailed stingray	WRA	*Dasyatis thetidis*	123.5	0.7	9.7
Barracouta	BAR	*Thyrsites atun*	107.4	0.6	33.3
Kahawai	KAH	*Arripis trutta*	103.9	0.6	16.7
Arrow squid	SQU	*Nototodarus sloanii*	76.8	0.4	34.7
Rig	SPO	*Mustelus lenticulatus*	74.1	0.4	27.8
Yellowbelly flounder	YBF	*Rhombosolea leporina*	71.0	0.4	25.0
Tarakihi	TAR	*Nemadactylus macropterus*	49.9	0.3	6.9
School shark	SCH	*Galeorhinus australis*	46.2	0.2	5.6
Spotted stargazer	SPZ	*Genyagnus monopterygius*	42.0	0.2	44.4
Frostfish	FRO	*Lepidopus caudatus*	39.8	0.2	9.7
Yelloweyed mullet	YEM	*Aldrichetta forsteri*	38.0	0.2	5.6
Trevally	TRE	*Pseudocaranx dentex*	36.9	0.2	11.1
Spotty	STY	*Notolabrus celidotus*	23.7	0.1	40.3
Parore	PAR	*Girella tricuspidata*	19.1	0.1	8.3
Scaly gurnard	SCG	*Lepidotrigla brachyoptera*	18.4	0.1	15.3
Shorttailed ray	BRA	*Dasyatis brevicaudatus*	18.3	0.1	2.8
Red mullet	RMU	*Upeneichthys lineatus*	14.9	0.1	6.9
Mirror dory	MDO	*Zenopsis nebulosus*	12.5	0.1	2.8
Carpet shark	CAR	*Cephaloscyllium isabella*	10.0	0.1	2.8
Broad squid	BSQ	*Sepioteuthis bilineata*	8.7	<0.1	11.1
Lemon sole	LSO	*Pelotretis flavilatus*	7.9	<0.1	37.5
Pufferfish	PUF	*Contusus richei*	7.0	<0.1	2.8
Blue cod	BCO	*Parapercis colias*	5.5	<0.1	12.5
Blue mackerel	EMA	*Scomber australasicus*	4.9	<0.1	18.1
New Zealand sole	ESO	*Peltorhamphus novaezeelandiae*	4.5	<0.1	19.4
Conger eel	CON	*Conger verreauxi*	3.8	<0.1	2.8
Witch	WIT	*Arnoglossus scapha*	3.5	<0.1	18.1
Kingfish	KIN	*Seriola lalandi*	3.4	<0.1	1.4
Sea perch	SPE	*Helicolenus percoides*	2.7	<0.1	6.9
Brown stargazer	BRZ	*Gnathagnus innotabilis*	1.4	<0.1	1.4
Octopus	OCT	*Octopus maorum*	1.3	<0.1	1.4
Rough skate	RSK	*Raja nasuta*	1.0	<0.1	1.4
Red cod	RCO	*Pseudophycis bachus*	0.7	<0.1	4.2
Japanese gurnard	JGU	*Pterygotrigla picta*	0.5	<0.1	2.8
Giant boarfish	BOA	*Paristiopterus labiosus*	0.3	<0.1	2.8
Silverside	SSI	*Argentina elongata*	0.3	<0.1	4.2
		Total	18 759.6		

Table 3: Species and numbers of fish and squid measured

Common name	No. of tows sampled	No. of fish	No. of males	No. of females
Snapper	70	12 967	1 378	1 109
Jack mackerel *(Trachurus novaezelandiae)*	57	4 925	2	–
Red gurnard	66	1 600	1 293	435
Sand flounder	53	1 599	5	–
Jack mackerel *(T. declivis)*	19	980	–	–
John dory	64	480	152	168
Barracouta	23	222	9	28
Pilchard	4	217	–	–
Yellowbelly flounder	18	206	1	–
Kahawai	12	152	–	–
Yelloweyed mullet	4	124	–	–
Tarakihi	5	62	34	27
Trevally	7	60	10	8
Spotted stargazer	32	59	13	13
Leatherjacket	10	55	–	–
Lemon sole	27	53	–	–
Arrow squid	5	51	–	–
Spotty	10	37	–	–
Rig	17	32	20	10
Eagle ray	9	30	17	12
Blue mackerel	12	25	–	–
New Zealand sole	14	22	–	–
Parore	5	20	–	–
Blue cod	9	18	–	1
Mirror dory	2	13	1	12
School shark	3	11	6	5
Red cod	2	7	–	–
Smooth skate	4	7	5	2
Witch	3	7	–	–
Longtailed stingray	2	5	1	4
Broad squid	3	4	1	–
Giant boarfish	1	1	–	–
Brown stargazer	1	1	–	–
Frostfish	1	1	–	–
Japanese gurnard	1	1	–	–
Kingfish	1	1	–	–
Red mullet	1	1	–	–
Rough skate	1	1	1	–

– No data or fish not sexed.

Table 4: Estimated biomass (t) and coefficient of variation (%, in parentheses) by stratum for snapper (SNA), John dory (JDO), red gurnard (GUR), jack mackerel (JMN and JMD), and sand flounder (SFL)

								Species code
			SNA	JDO	GUR	JMN	JMD	SFL
Stratum	< 25 cm	≥ 25 cm	Total					
1149	68.3	129.1	197.3	2.9	0.2	79.9	0	8.2
	(22)	(24)	(20)	(40)	(62)	(55)		(37)
1219	192.5	122.2	314.7	53.4	58.4	361.8	8.6	52.5
	(30)	(28)	(25)	(19)	(23)	(43)	(56)	(46)
1268	240.7	411.4	652.1	34.4	5.4	202.8	0	25.1
	(13)	(33)	(25)	(38)	(37)	(36)		(34)
1284	65.2	198.4	263.6	7.2	3.6	9.1	0	5.4
	(19)	(45)	(36)	(28)	(33)	(61)		(48)
1386	54.0	88.5	142.6	9.2	0.5	14.1	0	9.4
	(43)	(43)	(40)	(34)	(44)	(76)		(53)
1449	46.4	148.7	195.1	9.4	32.2	136.7	24.3	1.5
	(80)	(92)	(89)	(31)	(66)	(91)	(58)	(100)
1518	26.1	215.9	242.0	56.3	37.8	51.9	35.1	0
	(82)	(46)	(43)	(72)	(40)	(91)	(60)	
1887	331.7	427.4	759.1	7.1	6.5	350.4	0	5.8
	(16)	(19)	(15)	(37)	(17)	(38)		(29)
2229	73.1	195.7	268.8	21.0	4.6	182.9	0	54.5
	(43)	(35)	(35)	(25)	(71)	(39)		(37)
4492	192.9	254.1	447.0	84.6	94.8	129.6	2 194.8	11.8
	(25)	(33)	(22)	(26)	(39)	(57)	(59)	(75)
9292	83.5	135.3	218.7	2.3	2.7	9.0	0	2.2
	(32)	(60)	(49)	(40)	(10)	(58)		(38)
Total	1 374.4	2 326.5	3 700.9	287.7	246.6	1 528.2	2 262.8	176.4
	(8)	(12)	(10)	(17)	(19)	(18)	(57)	(19)

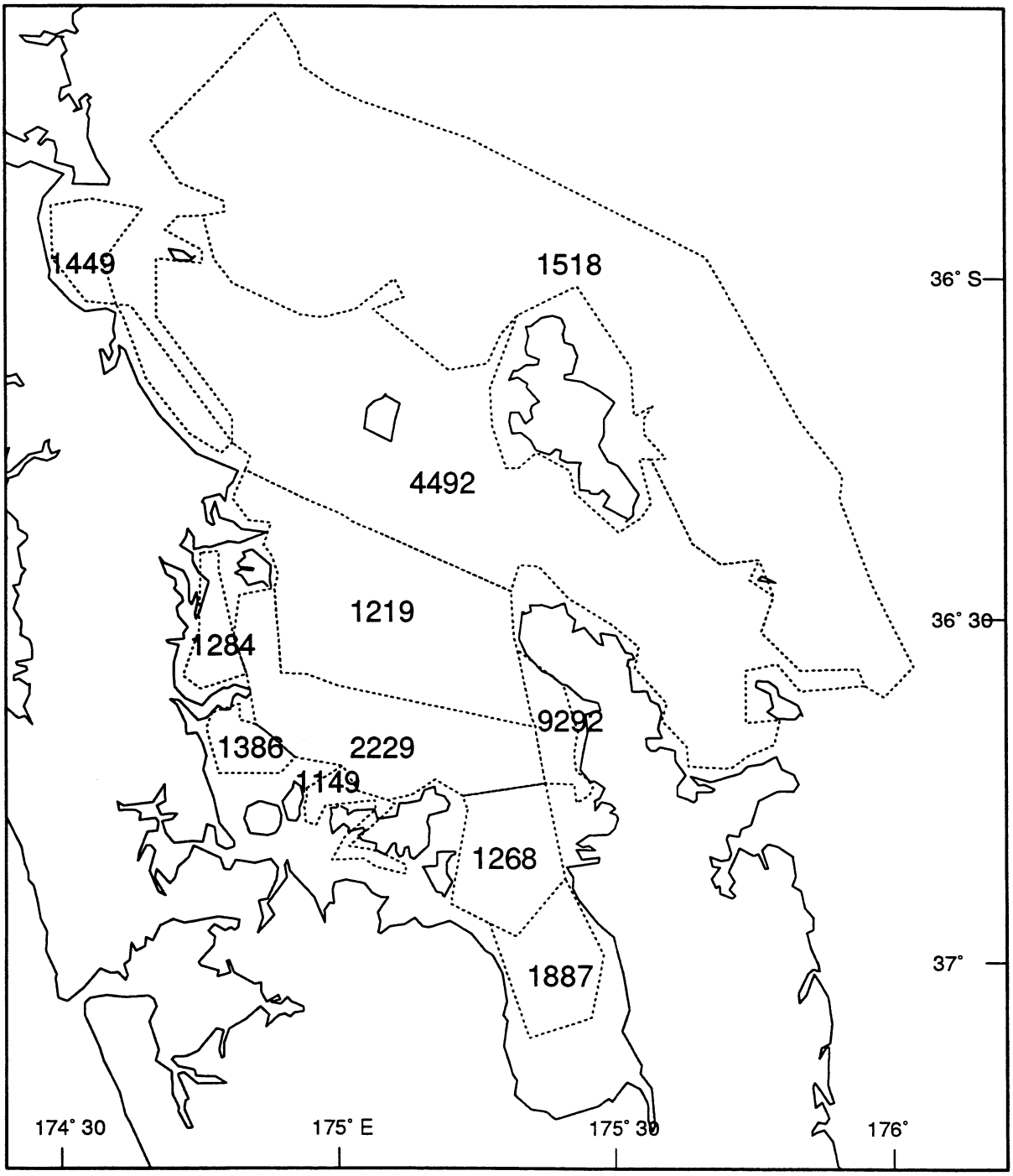

Figure 1: Survey area and stratum boundaries.

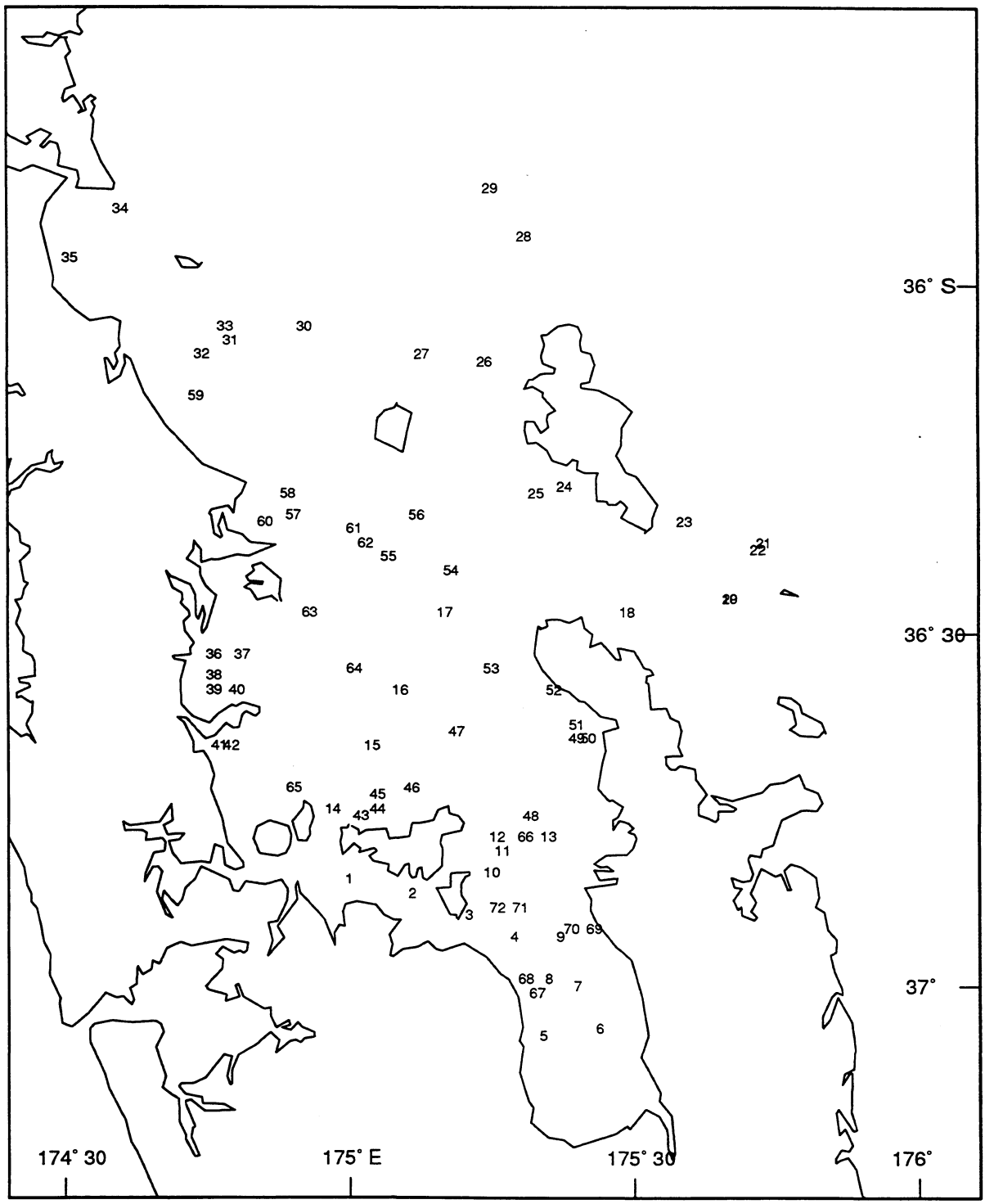

Figure 2: Station positions and numbers.

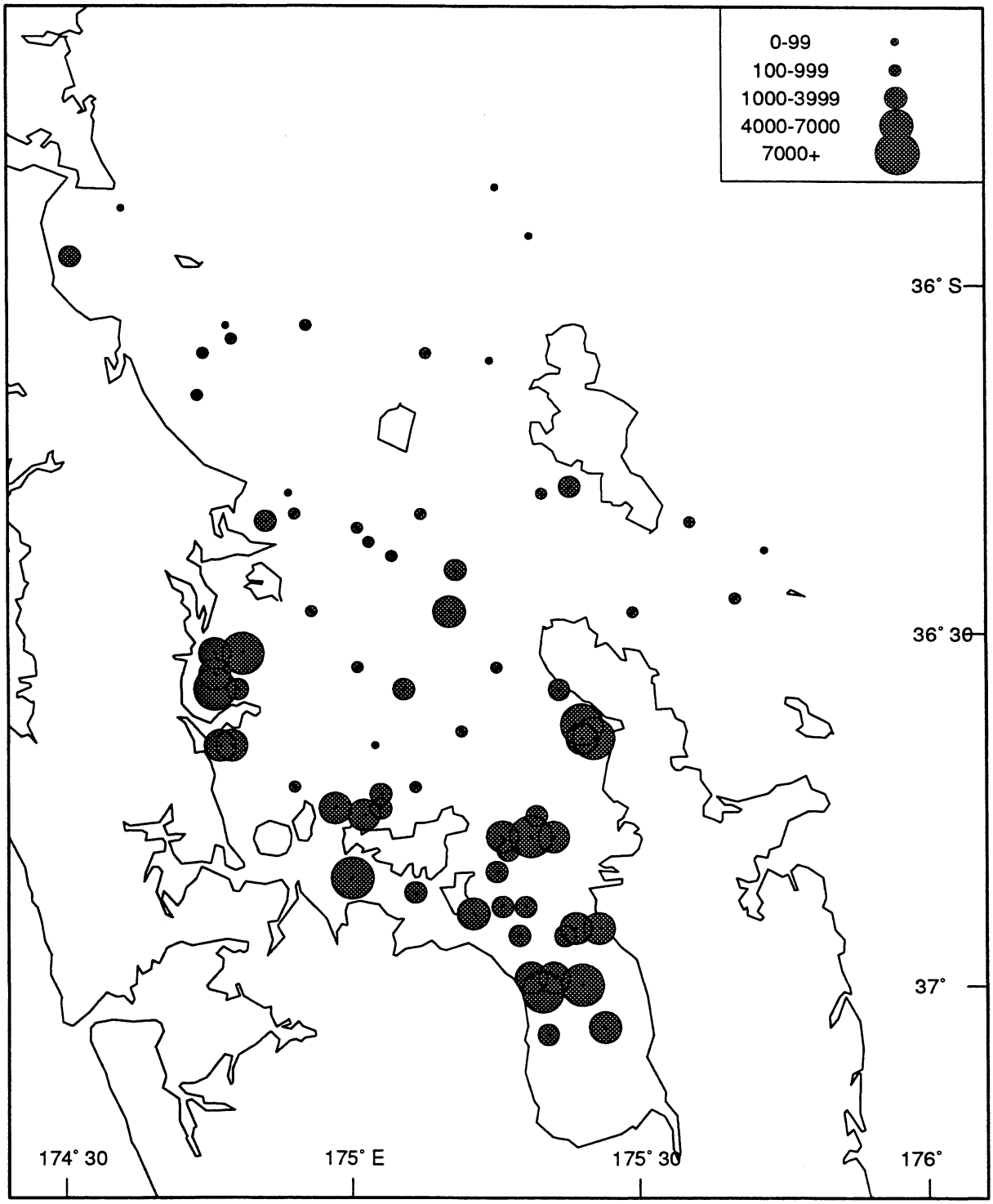

Figure 3: Catch rates (numbers.km^{-2}) of pre-recruit (< 25 cm F.L.) snapper.

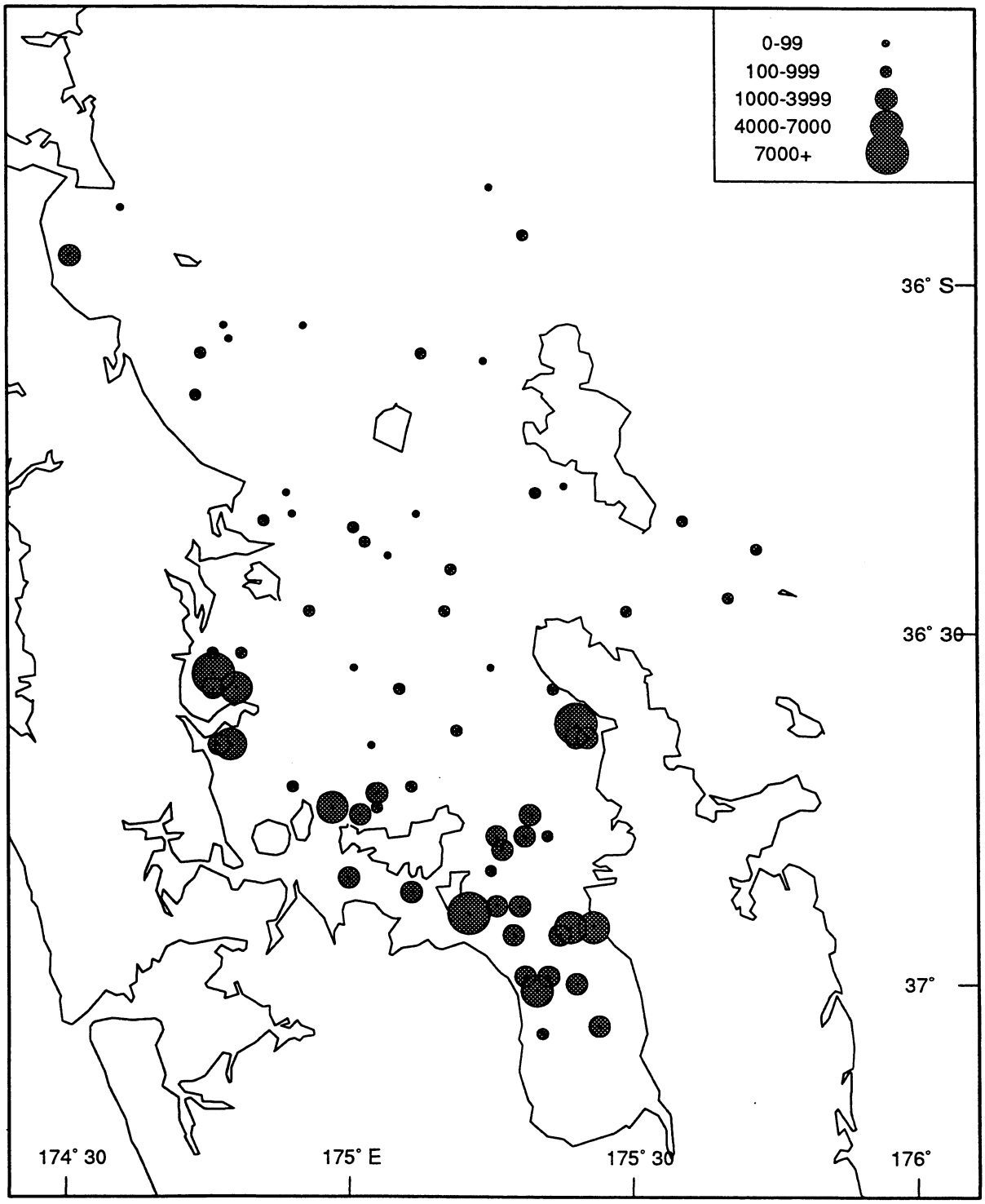

Figure 4: Catch rates (numbers.km^{-2}) of legal-size (≥ 25 cm F.L.) snapper.

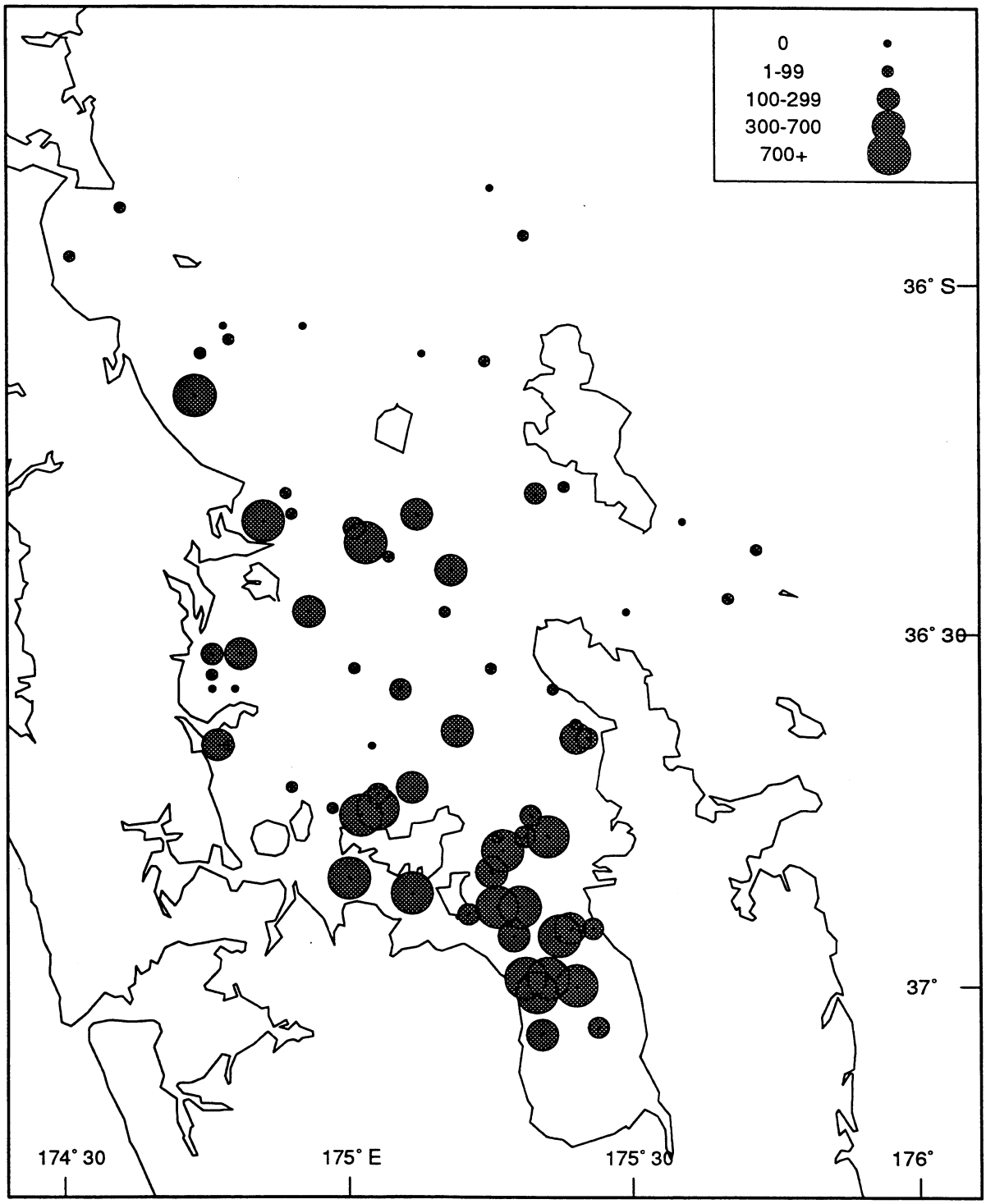

Figure 5: Catch rates (kg.km^{-2}) of jack mackerel (*Trachurus novaezelandiae*).

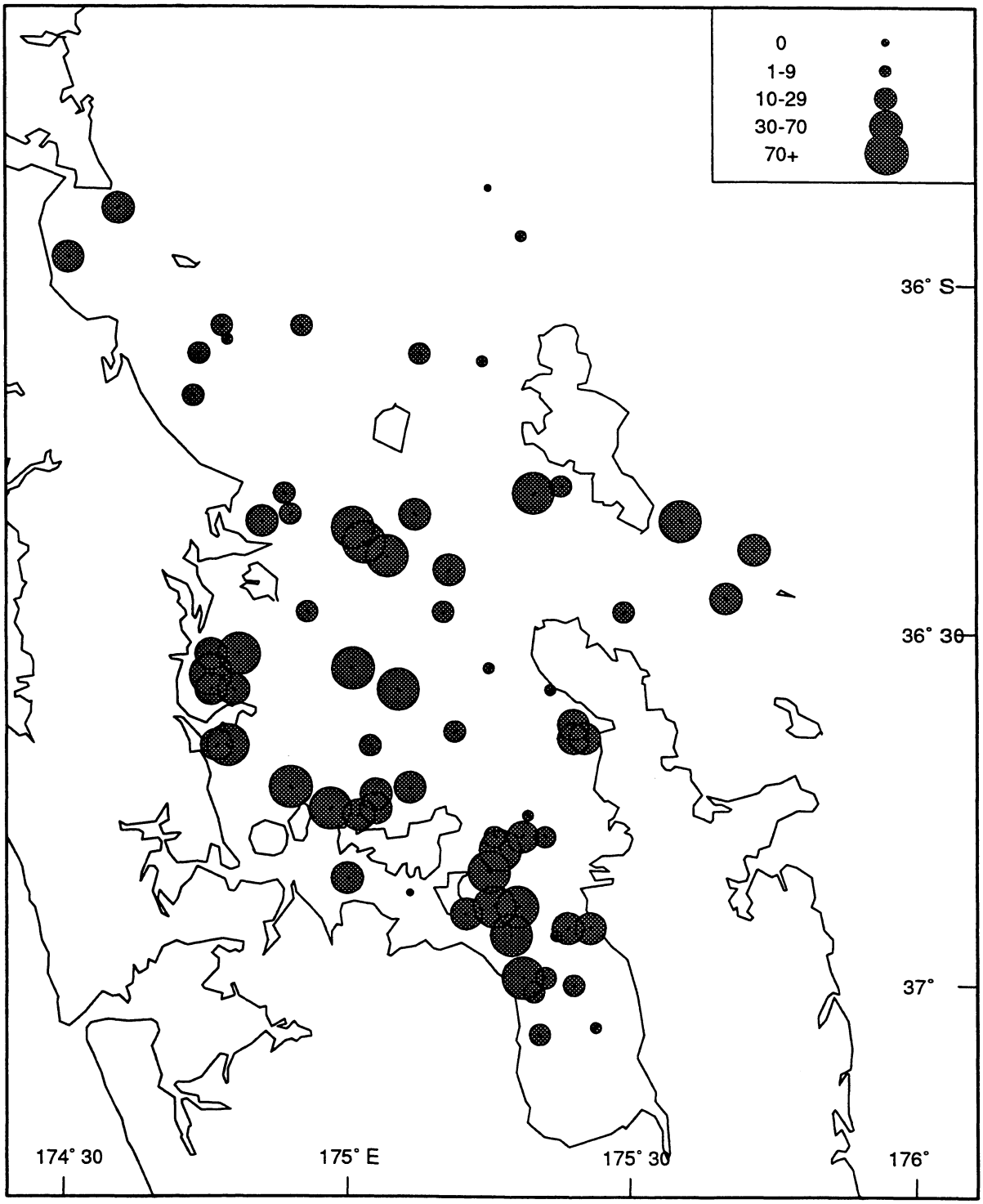

Figure 6: Catch rates (kg.km^{-2}) of John dory.

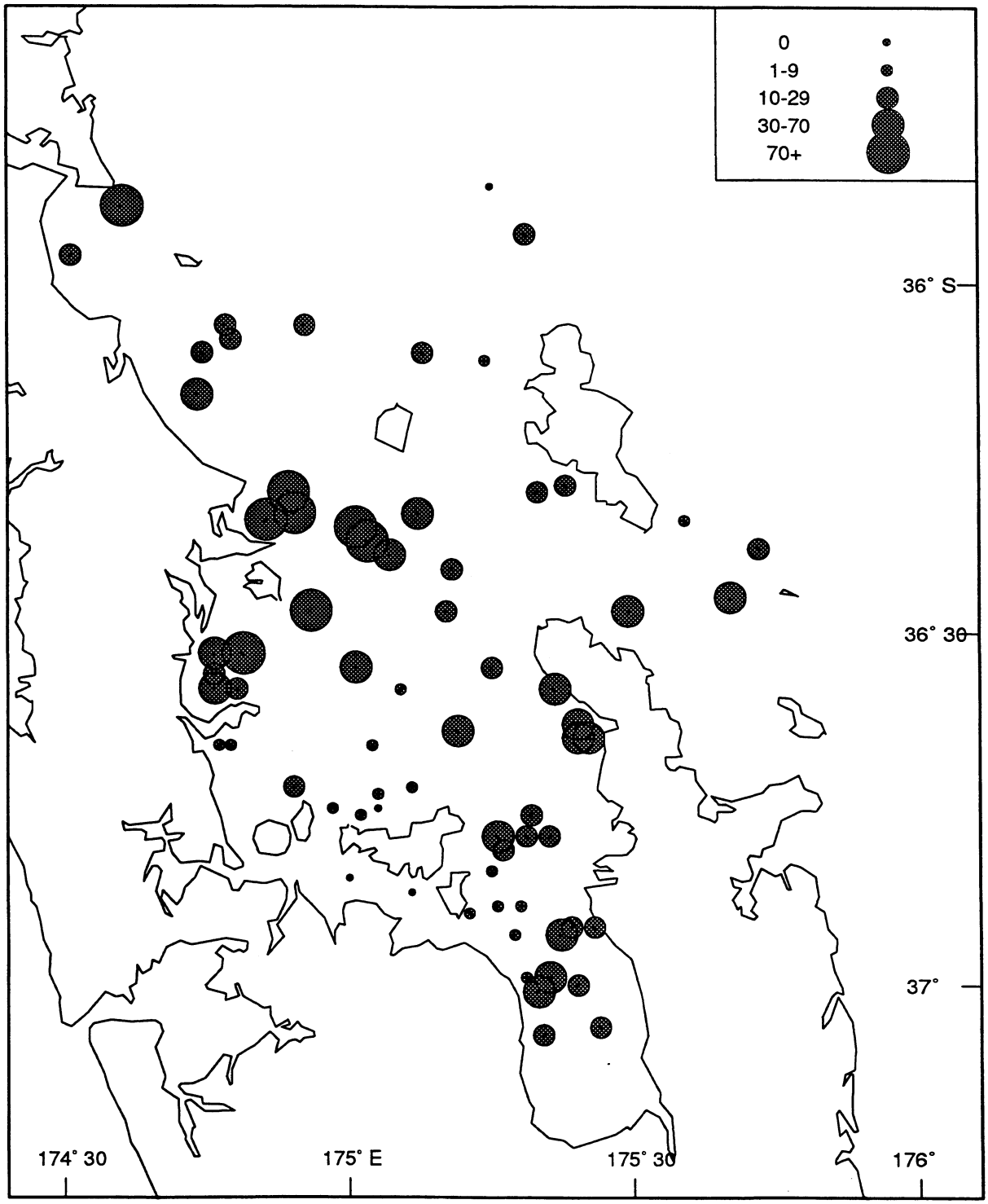

Figure 7: Catch rates (kg.km^{-2}) of red gurnard.

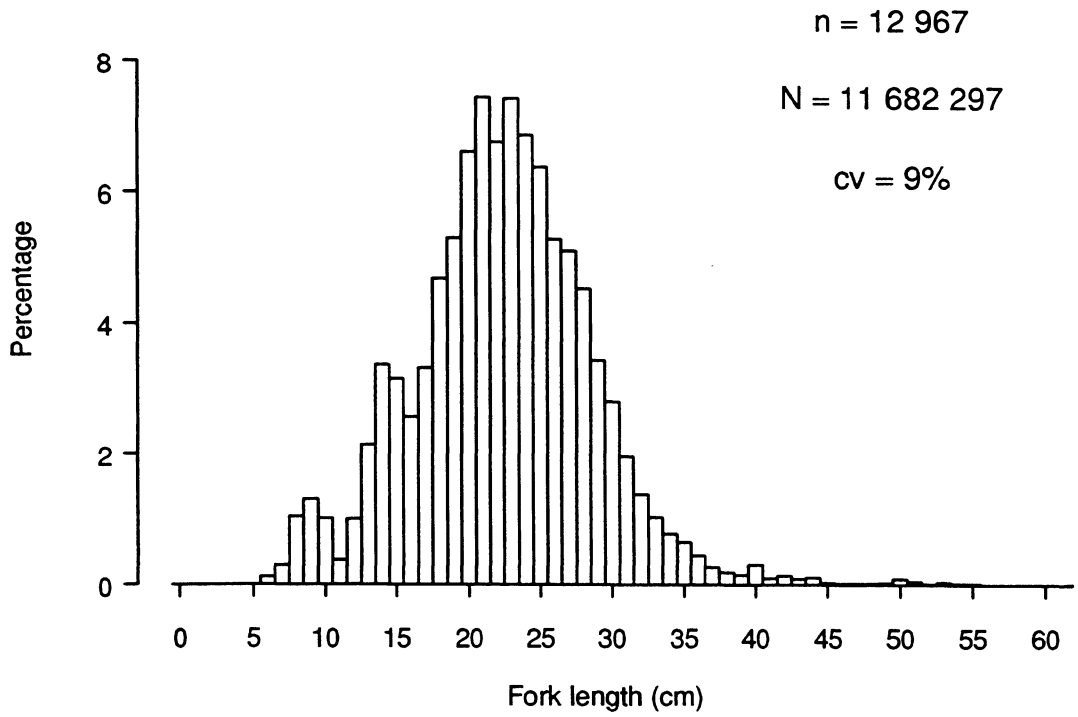

Figure 8: Length frequency distribution of snapper. n = the number of fish measured, N = the estimated number of snapper in the survey area, and cv = the coefficient of variation of the survey estimate.

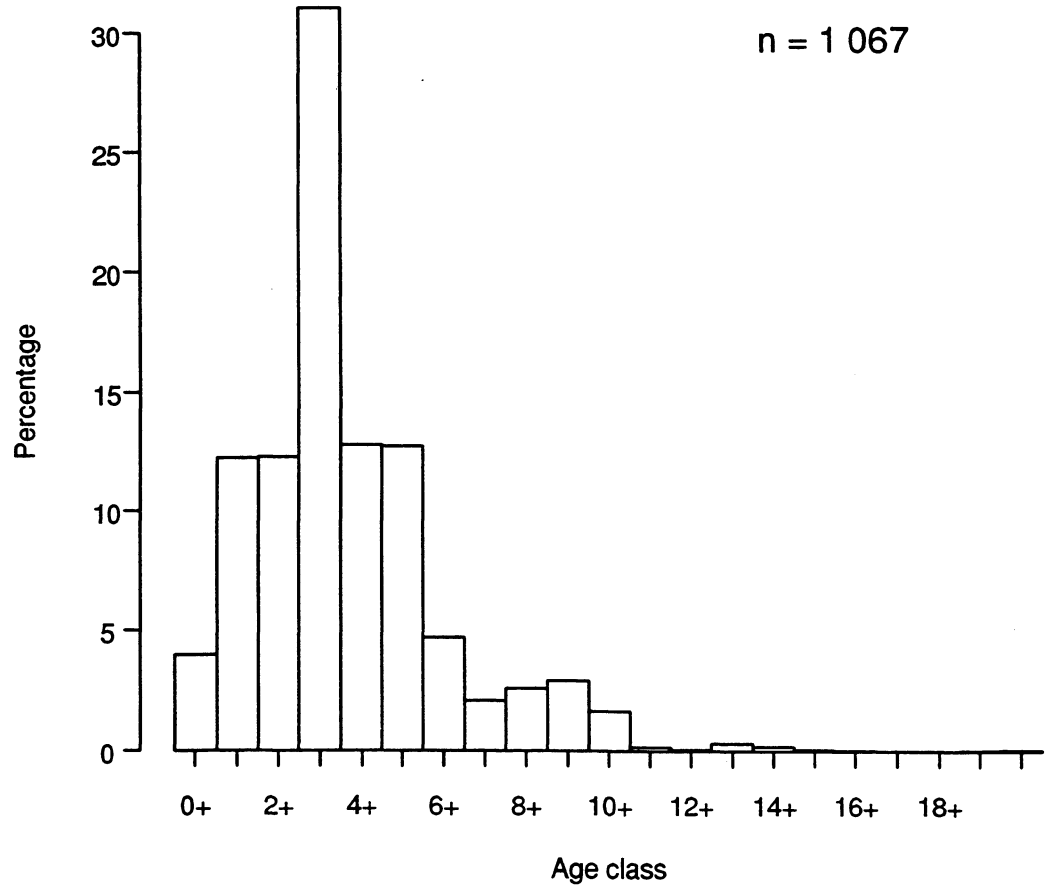

Figure 9: Age composition of snapper. n = the number of otolith readings used to construct the snapper age-length key.

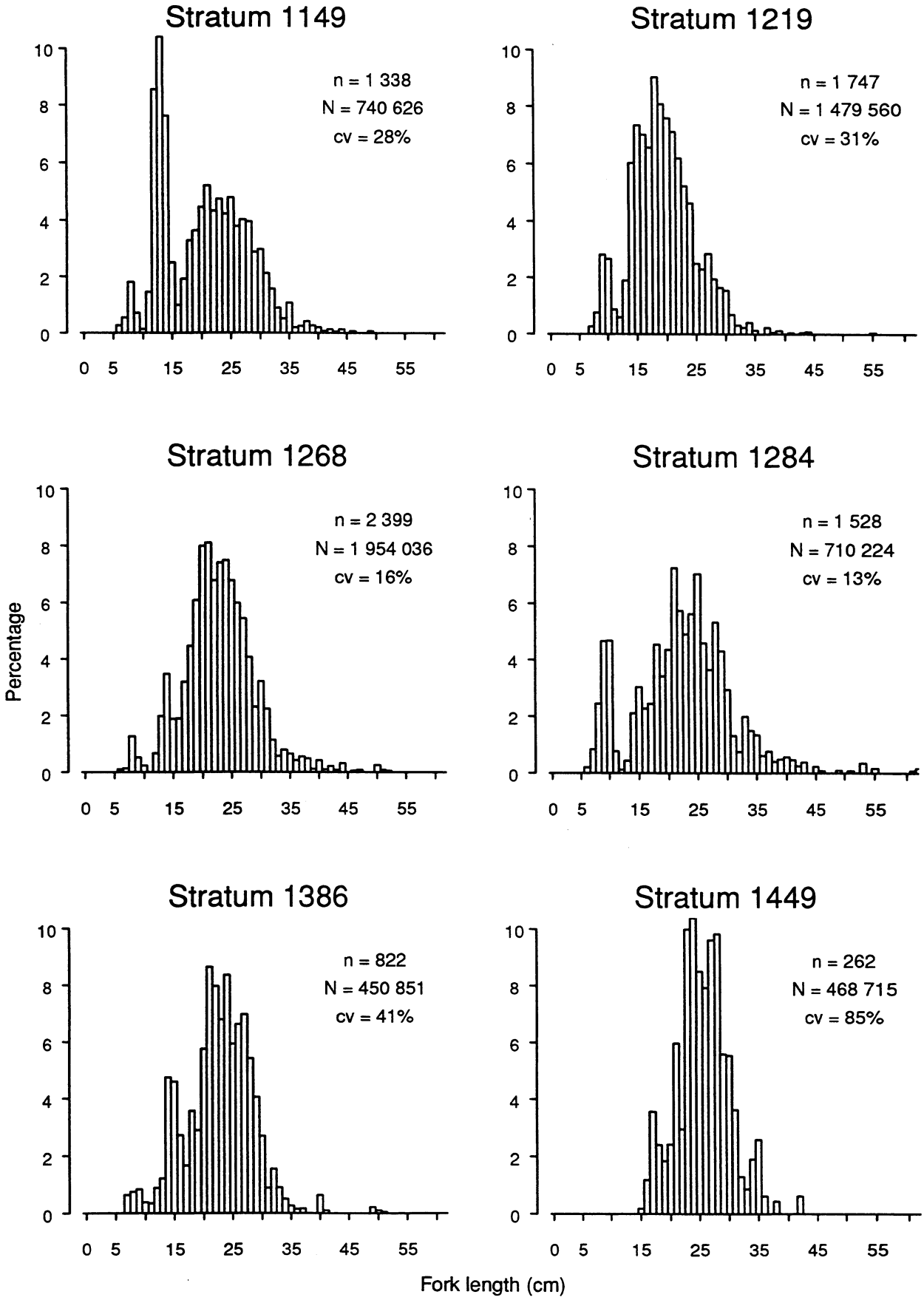

Figure 10: Stratum frequency distributions of snapper. n = the number of fish measured, N = the estimated number of snapper within the stratum, cv = the coefficient of variation associated with the stratum estimate.

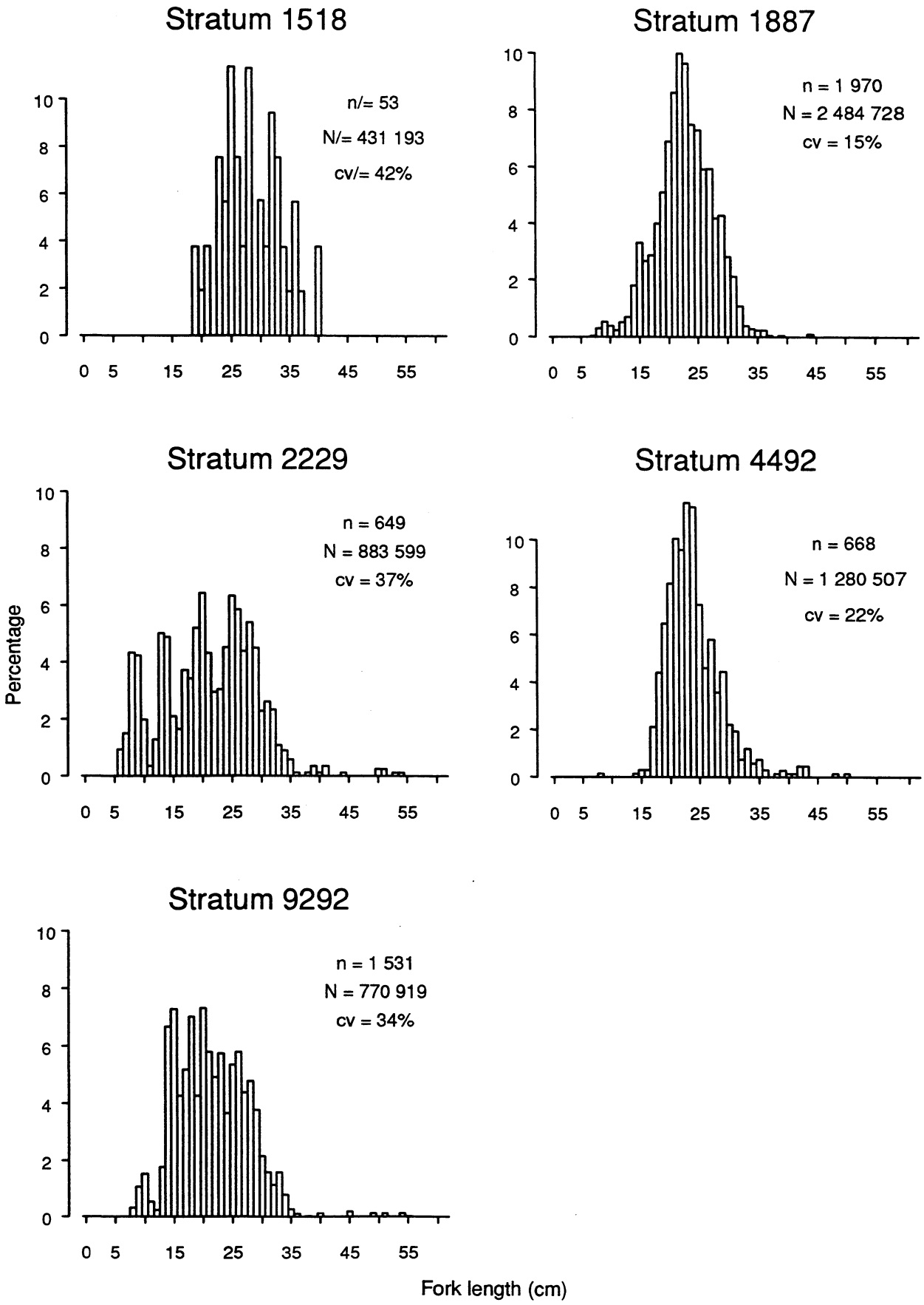

Figure 10-continued.

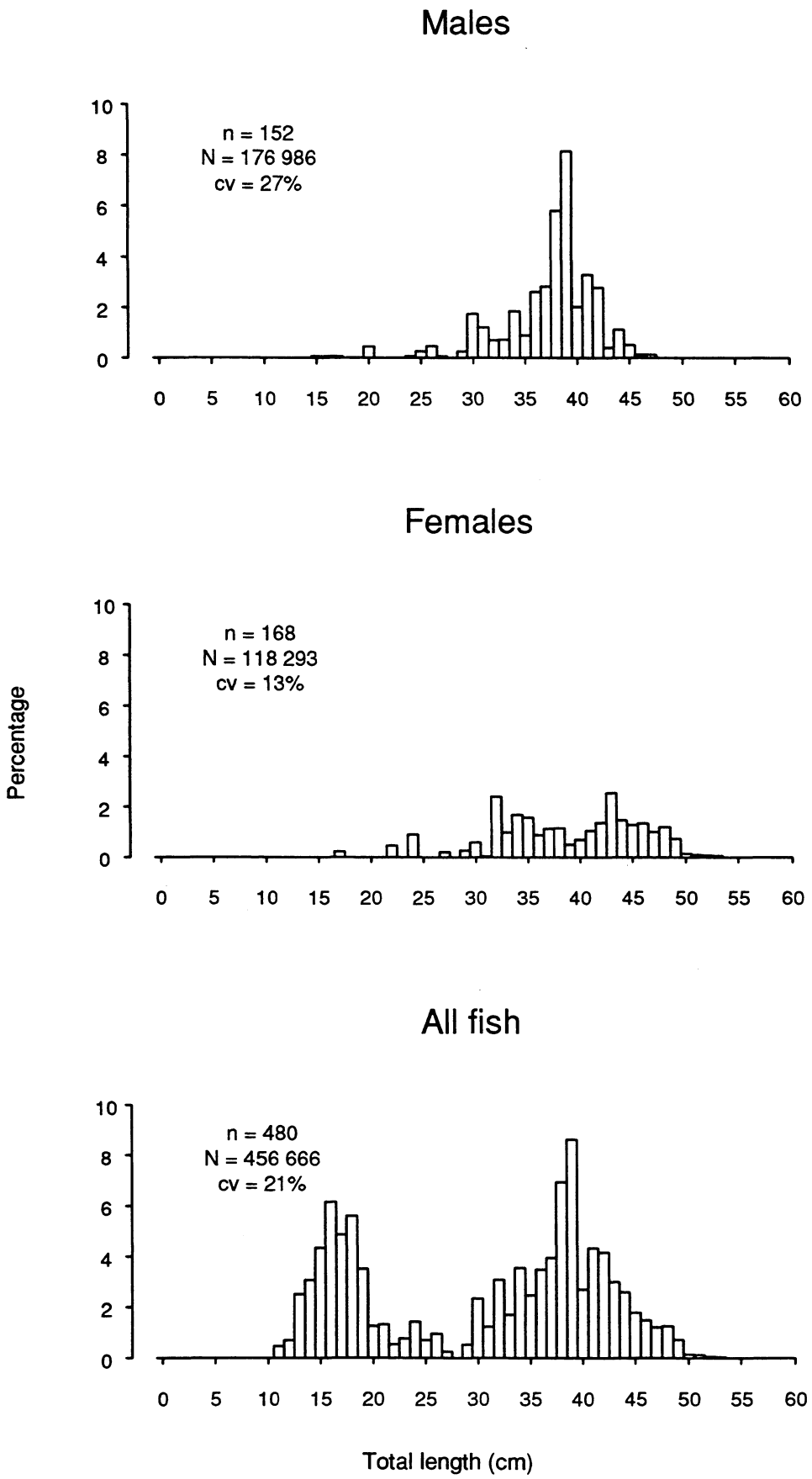

Figure 11: Length frequency distributions of male, female and all John dory. n = the number of fish measured, N = the estimated number of fish in the survey area, and cv = the coefficient of variation associated with the survey estimate.

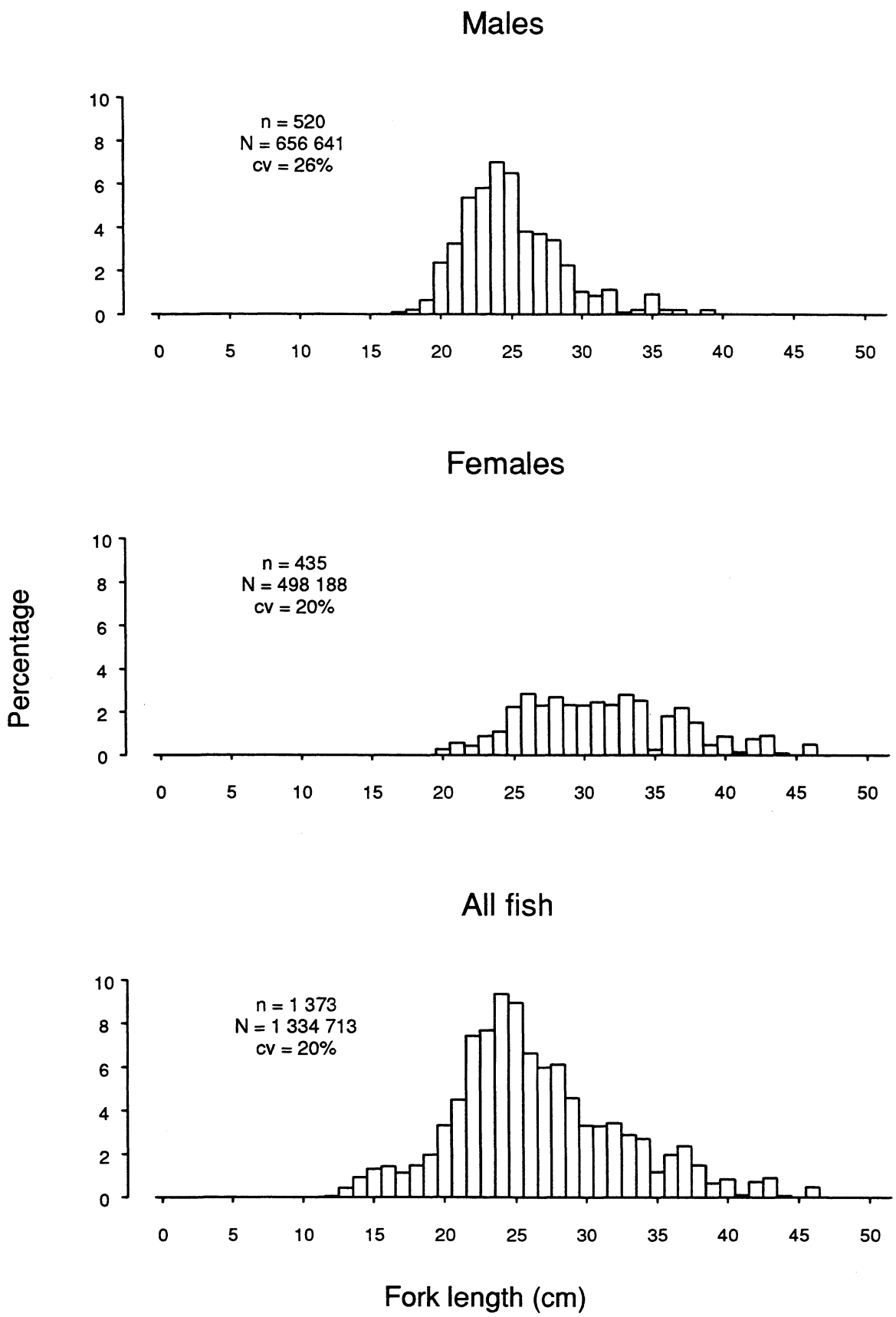

Figure 12: Length frequency distributions of male, female, and all red gurnard. n = the number of fish measured, N = the estimated number of fish in the survey area, and cv = the coefficient of variation of the survey estimate.

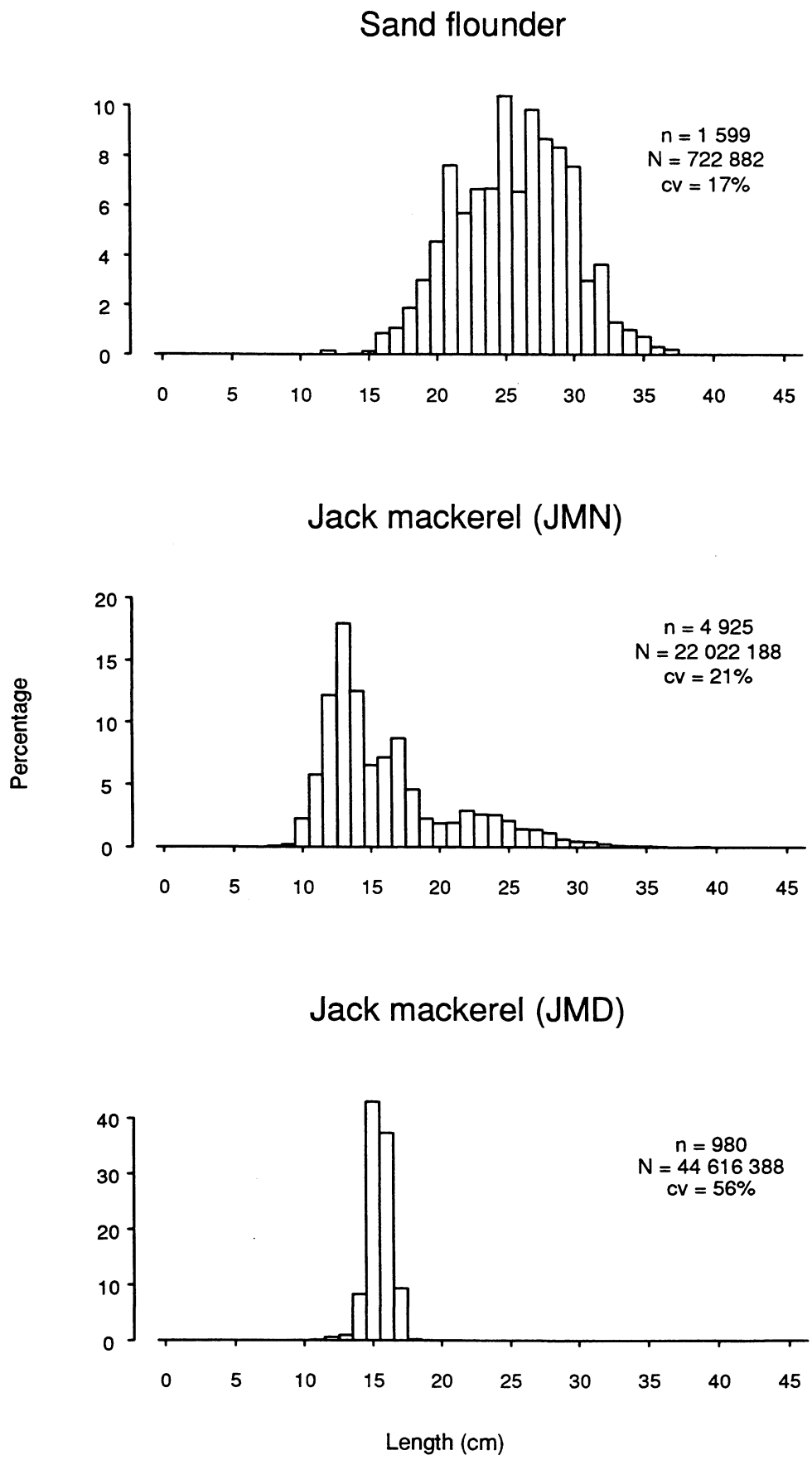

Figure 13: Length frequency distributions of sand flounder and the two species of jack mackerel, *Trachurus novaezelandiae* (JMN) and *T. declivis* (JMD).

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 added
Floats:	62 x 20 cm
Total flotation:	217 kgf
Vertical opening of trawl:	5.5–6.0 m
Codend mesh:	40 mm

Appendix 2: 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 3: Individual station data

Station	Stratum	Date	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)	Sea surface temp. (°C)
1	1149	26 Oct 94	1240	36 50.76	174 59.89	11	0.70	150	5.5	16.0
2	1149	26 Oct 94	1348	36 52.14	175 06.71	9	0.70	150	6.0	15.8
3	1268	26 Oct 94	1513	36 53.70	175 12.82	17	0.70	200	6.0	15.4
4	1268	26 Oct 94	1615	36 55.62	175 17.39	20	0.70	200	6.0	15.0
5	1887	27 Oct 94	0522	37 04.48	175 20.68	10	0.70	200	6.2	15.4
6	1887	27 Oct 94	0636	37 03.63	175 26.37	9	0.70	200	6.0	15.0
7	1887	27 Oct 94	0739	37 00.11	175 23.71	17	0.70	200	6.0	15.0
8	1887	27 Oct 94	0912	36 59.40	175 20.95	25	0.70	250	6.0	14.9
9	1887	27 Oct 94	1027	36 55.70	175 22.31	26	0.70	250	6.6	14.5
10	1268	27 Oct 94	1157	36 50.66	175 15.28	30	0.70	250	6.1	15.0
11	1268	27 Oct 94	1248	36 48.79	175 16.33	34	0.70	250	6.0	15.0
12	1268	27 Oct 94	1402	36 47.35	175 15.42	32	0.70	250	6.0	15.1
13	1268	27 Oct 94	1509	36 47.23	175 21.20	35	0.70	250	6.0	15.3
14	1149	28 Oct 94	1234	36 45.12	174 58.48	16	0.70	250	5.5	15.2
15	2229	28 Oct 94	1400	36 39.44	175 02.53	40	0.70	250	5.8	15.2
16	1219	28 Oct 94	1456	36 34.96	175 05.26	48	0.70	250	5.8	15.1
17	1219	28 Oct 94	1606	36 28.07	175 10.05	50	0.70	250	5.0	14.9
18	4492	29 Oct 94	0527	36 28.44	175 29.29	57	0.70	250	5.0	14.7
F 19	4492	29 Oct 94	0706	36 26.99	175 40.17	66	0.25	300	–	14.8
20	4492	29 Oct 94	0745	36 27.20	175 40.09	65	0.70	300	5.7	14.9
F 21	1518	29 Oct 94	0849	36 22.27	175 43.84	97	–	400	4.0	14.7
22	1518	29 Oct 94	0923	36 22.90	175 43.46	95	0.70	400	5.3	14.7
23	4492	29 Oct 94	1100	36 20.46	175 35.26	73	0.70	300	5.8	14.7
24	4492	29 Oct 94	1241	36 17.46	175 23.05	43	0.70	250	6.1	15.0
25	4492	29 Oct 94	1324	36 17.87	175 19.98	48	0.70	250	5.9	15.2
26	1518	29 Oct 94	1508	36 06.68	175 14.40	79	0.70	350	5.9	15.0
27	4492	29 Oct 94	1611	36 06.24	175 07.67	76	0.70	350	5.9	15.2
28	1518	30 Oct 94	0552	35 55.60	175 18.70	123	0.70	400	6.3	15.0
29	1518	30 Oct 94	0704	35 51.41	175 14.79	138	0.70	450	5.6	15.1
30	4492	30 Oct 94	0931	36 03.87	174 54.94	73	0.70	350	6.0	15.2
31	4492	30 Oct 94	1033	36 04.90	174 47.56	58	0.70	250	6.0	16.0
32	4492	30 Oct 94	1141	36 05.71	174 44.14	54	0.70	250	5.5	16.2
33	4492	30 Oct 94	1227	36 03.82	174 46.54	63	0.70	300	5.8	16.1
34	1449	30 Oct 94	1447	35 53.32	174 36.10	49	0.66	250	6.0	15.9
35	1449	30 Oct 94	1548	35 57.58	174 30.89	23	0.70	250	6.2	16.0
36	1284	31 Oct 94	0529	36 31.74	174 45.33	19	0.70	250	6.2	15.9
37	1284	31 Oct 94	0638	36 31.63	174 48.46	25	0.70	250	6.2	16.1
38	1284	31 Oct 94	0732	36 33.61	174 45.84	19	0.71	250	6.0	15.8
39	1284	31 Oct 94	0908	36 34.92	174 45.32	16	0.70	250	6.2	16.1
40	1284	31 Oct 94	1008	36 34.73	174 47.88	20	0.70	250	6.2	16.3
41	1386	31 Oct 94	1149	36 39.63	174 45.99	15	0.70	250	6.1	15.6
42	1386	31 Oct 94	1241	36 39.79	174 47.65	19	0.70	250	6.0	16.0
43	1149	01 Nov 94	1236	36 45.31	175 01.14	22	0.70	250	5.5	15.3
44	2229	01 Nov 94	1325	36 44.96	175 03.27	27	0.70	250	5.5	15.6
45	2229	01 Nov 94	1417	36 43.80	175 02.89	32	0.70	250	–	15.6
46	2229	01 Nov 94	1504	36 42.93	175 06.86	37	0.70	250	5.5	15.5
47	2229	01 Nov 94	1604	36 38.55	175 11.38	45	0.70	250	5.5	15.4
48	1268	02 Nov 94	0534	36 45.53	175 19.21	37	0.70	250	6.0	15.2
49	9292	02 Nov 94	0647	36 39.02	175 24.20	19	0.70	250	5.9	15.7

Station	Stratum	Date	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)	Sea surface temp. (°C)
50	9292	02 Nov 94	0734	36 39.27	175 25.32	14	0.70	250	5.7	15.6
51	9292	02 Nov 94	0821	36 37.63	175 24.01	17	0.70	250	6.4	15.7
52	9292	02 Nov 94	0939	36 35.09	175 21.33	24	0.70	250	5.5	15.9
53	1219	02 Nov 94	1037	36 32.88	175 14.71	47	0.70	250	5.5	15.5
54	1219	02 Nov 94	1154	36 24.85	175 10.56	50	0.70	250	5.8	15.3
55	1219	02 Nov 94	1303	36 23.48	175 03.97	50	0.70	250	5.3	15.3
56	4492	02 Nov 94	1355	36 19.88	175 07.47	53	0.70	250	5.4	15.4
57	1219	02 Nov 94	1541	36 19.76	174 53.86	53	0.70	250	5.6	15.4
58	4492	02 Nov 94	1616	36 18.03	174 53.13	53	0.70	250	5.3	15.4
59	1449	03 Nov 94	0557	36 09.87	174 43.54	49	0.70	250	5.5	15.2
60	1219	03 Nov 94	0802	36 20.28	174 50.88	41	0.70	250	5.5	15.4
61	1219	03 Nov 94	0915	36 21.07	175 00.53	57	0.70	300	5.5	15.6
62	1219	03 Nov 94	1001	36 22.02	175 01.77	53	0.70	250	5.5	15.8
63	1219	03 Nov 94	1120	36 28.29	174 55.78	41	0.70	250	5.5	17.6
64	1219	03 Nov 94	1222	36 33.27	175 00.34	45	0.70	250	5.5	17.8
65	1386	03 Nov 94	1459	36 43.29	174 54.04	21	0.70	200	5.5	17.2
66	1268	03 Nov 94	1627	36 47.47	175 18.37	36	0.70	250	6.0	16.8
67	1887	04 Nov 94	0513	37 00.73	175 19.82	16	0.70	250	5.5	16.5
68	1887	04 Nov 94	0603	36 59.23	175 18.76	19	0.70	250	5.5	16.5
69	1887	04 Nov 94	0720	36 55.42	175 25.65	21	0.70	250	5.5	16.1
70	1887	04 Nov 94	0806	36 55.16	175 23.66	28	0.70	250	5.5	16.7
71	1268	04 Nov 94	0858	36 53.43	175 17.78	30	0.70	250	5.5	16.3
72	1268	04 Nov 94	0937	36 53.22	175 15.59	22	0.70	250	5.5	16.5

F Fouled trawl shots
– No data

Appendix 4: Catch (kg) at each station for the six most abundant commercial teleost species: snapper (SNA), jack mackerel (JMN, Trachurus novaezelandiae; JMD, T. declivis), John dory (JDO), sand flounder (SFL), and red gurnard (GUR).

Station	SNA	JMN	JMD	JDO	SFL	GUR
1	294.8	288.0	0.0	3.8	1.5	0.0
2	136.9	75.2	0.0	0.0	7.2	0.0
3	633.5	11.5	0.0	3.8	2.0	0.5
4	200.4	46.7	0.0	9.8	0.2	0.2
5	74.7	40.8	0.0	0.0	0.1	1.9
6	286.4	22.8	0.0	0.1	0.0	2.3
7	408.3	479.9	0.0	2.2	0.6	2.5
8	182.6	246.3	0.0	2.1	4.8	3.5
9	139.4	84.8	0.0	0.4	4.0	3.2
10	78.0	35.2	0.0	48.1	8.0	0.4
11	130.0	251.2	0.0	20.3	5.4	2.4
12	267.8	2.3	0.0	3.0	0.2	7.4
13	126.8	80.1	0.0	2.6	25.3	1.4
14	472.2	2.6	0.0	9.1	21.2	0.4
15	1.6	0.0	0.0	1.7	1.7	0.4
16	77.7	20.3	3.4	12.3	7.1	0.9
17	78.8	5.9	0.3	2.9	1.0	3.1
18	21.0	0.0	0.0	1.3	0.0	4.4
19	5.0	0.0	0.0	5.0	0.0	0.5
20	37.8	0.1	0.2	5.7	0.0	5.0
21	0.0	0.0	0.0	0.0	0.0	0.0
22	12.5	0.4	1.5	6.2	0.0	2.4
23	53.1	0.0	481.0	11.8	0.0	1.0
24	32.8	0.6	0.6	2.2	0.0	1.9
25	32.2	16.0	0.3	8.6	0.0	2.2
26	2.9	0.1	3.2	0.8	0.0	1.0
27	10.1	0.0	0.6	2.8	0.0	1.4
28	16.7	6.8	0.2	0.9	0.0	1.9
29	1.9	0.0	0.0	0.0	0.0	0.0
30	12.3	0.0	1.2	0.0	0.0	1.9
31	9.6	7.8	49.3	0.5	0.0	2.7
32	8.0	4.6	61.4	2.1	0.0	1.3
33	2.7	0.0	585.0	3.0	0.0	1.4
34	3.2	9.0	9.0	5.1	0.0	27.4
35	213.5	0.5	0.0	4.1	1.8	2.4
36	119.7	29.8	0.0	5.0	14.7	5.8
37	107.8	35.3	0.0	15.6	18.9	10.8
38	867.1	0.5	0.0	19.5	1.9	1.4
39	442.4	0.0	0.0	5.2	1.8	6.2
40	377.3	0.0	0.0	7.0	1.6	1.7
41	207.8	55.0	0.0	5.9	0.6	0.4
42	382.0	6.9	0.0	22.5	15.9	0.5
43	313.8	94.6	0.0	5.3	22.2	0.7
44	40.0	81.0	0.0	6.7	11.5	0.0
45	107.6	17.8	0.0	5.7	23.8	0.4
46	70.4	32.7	0.0	3.5	4.9	0.2
47	34.0	41.1	0.0	2.2	9.5	3.3
48	111.6	12.8	0.0	0.1	18.6	2.0

Station	SNA	JMN	JMD	JDO	SFL	GUR
49	264.1	35.8	0.0	7.3	4.2	3.4
50	211.7	19.1	0.0	3.5	3.2	4.6
51	839.6	1.9	0.0	3.8	6.7	4.0
52	71.9	0.4	0.0	0.1	0.1	5.4
53	11.9	3.8	0.0	0.1	0.6	1.5
54	89.3	37.8	0.0	7.0	1.4	1.7
55	11.8	7.3	0.0	11.0	3.0	5.7
56	14.2	37.9	12.9	4.3	1.7	6.1
57	7.4	3.1	0.0	1.7	2.3	10.6
58	6.1	1.3	0.0	3.1	4.5	21.1
59	12.8	150.9	19.0	1.5	0.0	6.4
60	49.8	189.9	0.0	5.8	1.9	16.8
61	27.9	24.8	1.8	8.5	34.7	11.1
62	30.6	127.8	5.7	10.3	9.3	8.0
63	14.8	52.4	0.0	3.1	5.8	13.3
64	12.7	1.2	0.1	7.5	2.8	4.1
65	72.1	3.6	0.0	13.6	25.9	1.4
66	227.8	13.9	0.0	5.0	19.0	2.1
67	432.3	104.1	0.0	1.9	0.3	5.2
68	306.7	143.3	0.0	9.8	3.2	0.8
69	412.6	19.7	0.0	5.3	3.0	1.9
70	382.7	59.0	0.0	3.2	4.3	1.3
71	121.1	97.6	0.0	13.1	5.5	0.8
72	260.3	131.6	0.0	9.7	0.7	0.9
Total	11 138.9	3 415.2	1 236.7	426.7	382.1	260.9

F Fouled trawl shots

Appendix 5. 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	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
8	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
9	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
10	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
11	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
12	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
13	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
14	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12
15	–	0.94	0.06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17
16	–	0.71	0.29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14
17	–	0.28	0.72	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18
18	–	–	0.75	0.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16
19	–	–	0.73	0.27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	22
20	–	–	0.16	0.74	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	19
21	–	–	0.05	0.85	0.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
22	–	–	–	0.85	0.15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
23	–	–	–	0.75	0.15	0.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
24	–	–	–	0.40	0.40	0.15	0.05	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
25	–	–	0.03	0.32	0.26	0.29	0.06	–	0.03	–	–	–	–	–	–	–	–	–	–	–	–	31
26	–	–	–	0.18	0.33	0.30	0.09	0.06	0.00	0.03	–	–	–	–	–	–	–	–	–	–	–	33
27	–	–	–	–	0.24	0.51	0.07	0.04	0.07	0.04	0.02	–	–	–	–	–	–	–	–	–	–	45
28	–	–	–	0.03	0.23	0.37	0.10	0.06	0.08	0.10	0.04	–	–	–	–	–	–	–	–	–	–	71
29	–	–	–	0.03	0.09	0.43	0.19	0.09	0.07	0.10	0.00	–	–	–	–	–	–	–	–	–	–	69
30	–	–	–	–	0.14	0.27	0.18	0.09	0.12	0.09	0.11	–	–	–	–	–	–	–	–	–	–	74
31	–	–	–	0.02	0.05	0.25	0.31	0.08	0.06	0.13	0.08	0.03	–	–	–	–	–	–	–	–	–	64
32	–	–	–	–	0.04	0.20	0.20	0.11	0.07	0.23	0.16	–	–	–	–	–	–	–	–	–	–	56
33	–	–	–	–	–	0.17	0.25	0.08	0.29	0.08	0.08	–	–	0.02	0.04	–	–	–	–	–	–	52
34	–	–	–	–	–	0.04	0.17	0.13	0.28	0.17	0.17	0.02	–	0.02	–	–	–	–	–	–	–	47
35	–	–	–	–	–	0.02	0.27	0.18	0.09	0.20	0.18	–	0.02	0.02	0.02	–	–	–	–	–	–	45
36	–	–	–	–	–	0.03	0.15	0.18	0.27	0.21	0.09	–	–	0.03	0.03	–	–	–	–	–	–	33
37	–	–	–	–	–	0.04	0.12	0.04	0.20	0.28	0.20	0.04	–	0.04	–	–	0.04	–	–	–	–	25
38	–	–	–	–	–	–	0.05	–	0.19	0.52	0.10	–	–	0.10	0.05	–	–	–	–	–	–	21
39	–	–	–	–	–	0.05	–	0.05	0.11	0.32	0.21	0.05	–	0.11	0.11	–	–	–	–	–	–	19
40	–	–	–	–	–	–	–	0.09	0.04	0.35	0.26	–	–	0.17	0.09	–	–	–	–	–	–	23
41	–	–	–	–	–	–	–	0.05	0.10	0.30	0.30	–	–	0.15	–	0.05	–	–	–	0.05	–	20
42	–	–	–	–	–	–	–	–	0.15	0.31	0.08	0.15	0.15	0.08	0.08	–	–	–	–	–	–	13
43	–	–	–	–	–	–	–	–	0.09	0.09	0.36	0.18	0.09	0.09	0.09	–	–	–	–	–	–	11
44	–	–	–	–	–	–	–	–	–	0.40	0.10	0.10	–	–	0.20	0.20	–	–	–	–	–	10
45	–	–	–	–	–	–	–	–	0.13	0.13	0.38	–	0.13	0.13	–	–	–	0.13	–	–	–	8
46	–	–	–	–	–	–	–	–	–	0.57	–	–	–	0.14	–	0.14	0.14	–	–	–	–	7
47	–	–	–	–	–	–	–	–	–	0.20	–	0.20	0.20	0.40	–	–	–	–	–	–	–	5
48	–	–	–	–	–	–	–	–	–	–	0.33	–	–	–	0.17	0.33	–	–	–	–	0.17	6
49	–	–	–	–	–	–	–	–	–	–	0.33	–	0.17	–	0.17	0.17	–	–	–	–	0.17	6
50	–	–	–	–	–	–	–	–	–	–	–	–	–	0.83	0.17	–	–	–	–	–	–	6
51	–	–	–	–	–	–	–	–	–	–	0.25	–	–	0.50	–	0.25	–	–	–	–	–	4
52	–	–	–	–	–	–	–	–	–	–	–	–	–	0.25	–	–	–	–	0.25	–	0.50	4
53	–	–	–	–	–	–	–	–	–	0.25	–	–	–	0.25	0.25	0.25	–	–	–	–	–	4
54	–	–	–	–	–	–	–	–	–	–	–	–	–	0.50	–	–	–	–	–	–	0.50	2
55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.33	–	–	–	–	0.67	3
56	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.50	–	0.50	–	0.00	2
57	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
58	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
59	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.33	0.67	3
61	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
62	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	3
63	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	–	–	–	–	1
64	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	2
65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
66	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
68	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
69	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
70	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
71	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
72	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
73	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
74	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
75	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
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