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M. A. Morrison
M. P. Francis

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Introduction

Trawl surveys have been conducted in the Hauraki Gulf using R.V. *Kaharoa* since 1982. In recent years the prime objective of the surveys has been to estimate the relative year class strength (YCS) of 1 year old (1+) snapper. Snapper YCS obtained from the 1984–94 spring trawl surveys of the Hauraki Gulf was strongly correlated with the mean water temperature in the summer–autumn after spawning (i.e., during the 0+ year) (Francis 1993, Francis *et al.* 1995, 1997). Nearly all (96%) of the variation in YCS is explained by mean February-June water temperature.

YCS predictions based on temperature for the 1981–88 year classes were strongly correlated with YCS estimates for recruited snapper derived from commercial longline age-frequency data (Maunder & Starr 1998). This indicates that the YCS indices derived from the trawl surveys are accurate and useful for predictive purposes.

A recruitment index based on the relationship between 1+ snapper abundance and water temperature has been developed and was incorporated into the SNA 1 stock assessment model until 1997 (Annala & Sullivan 1997). Thereafter, recruitment was estimated within the model from the age-frequency distributions of recruited fish (Annala *et al.* 1998). This index is an important input into the model projections of future biomass and yield for several subsequent years. The temperature-recruitment relationship is reasonably well defined in the middle of the range of observed water temperatures. The relationship is less well defined at the lower and upper extremes of observed water temperatures.

The temperature-recruitment relationship predicted that the 1995 snapper year class would be one of the strongest since the time series of trawl surveys began (Francis *et al.* 1995, 1997). No survey was carried out in 1996 to estimate the YCS of that year class at age 1+. This survey (1997) provides an estimate of the number of fish of the 1995 year class at age 2+. It also provides an estimate of YCS of the 1996 year class at age 1+. This year class was also predicted to be stronger than average. Estimates of the 1+ YCS of the 1995 and 1996 year classes can be used to improve the definition of the temperature-recruitment relationship at the upper end of the predictive range.

Estimates of relative abundance of John dory and red gurnard are required at least every 3 years for the stock assessment of these two fishstocks. The last survey in this time series was in November 1994. The relative abundance indices for these two species derived from this current survey (1997) are being incorporated into the stock assessment for JDO 1 and GUR 1 (project INS9701).

This report presents the results of the Hauraki Gulf trawl survey conducted in October-November 1997. This research was funded by the Ministry of Fisheries through contract INT9701.

Project objectives

The major objective of this research programme is to determine the relative abundance and distribution of inshore finfish species in the Hauraki Gulf".

Survey objectives

The objectives of the trawl survey for 1997 were as follows.

1. To determine the relative abundance and distribution primarily of juvenile snapper and secondarily of adult John dory and red gurnard in the Hauraki Gulf and adjacent waters by carrying out a trawl survey. The target coefficient of variation (*c.v.*) for the biomass estimate of age 2+ snapper is 15–25%.

2. To collect the data and to determine the length frequency, length-weight relationship, and reproductive condition of snapper, John dory, and red gurnard and the age-length relationship of snapper caught on the trawl survey.

Timetable and personnel

The science staff joined *Kaharoa* at Auckland on 28 October 1997 and fishing began that afternoon at inner Hauraki Gulf stations. The vessel returned to Auckland on 31 October to unload catch and take on ice. Fishing recommenced on 2 November, with the survey ending on 4 November.

Methods

Survey area and design

The survey incorporated an area extending from northeast of Bream Head (Whangarei Harbour) to Great Mercury Island in the 10–150 m depth range. The stratification was the same as that of the three most recent surveys (1992–94; Langley 1995), with the area being divided into 11 depth and area strata based on the catch rate of pre-recruit snapper (under 25 cm fork length (FL)) from previous trawl surveys (Figure 1, Table 1).

The survey was of a two-phase, stratified random design (*after* Francis 1984). Results from survey simulations indicated that a *c.v.* of 17% for 2+ snapper could be achieved with 48 sampling stations (36 phase 1, 12 phase 2), and this approach was adopted. Trawls were conducted at random positions selected using the software RandStat version 1.7. Phase 2 stations were allocated on the basis of maximising reductions in the 2+ snapper variance estimate. This was achieved by adding a station iteratively to each of the strata, and using the existing density and variance information to predict the likely improvement in the overall *c.v.*, for each possible stratum allocation. The station was then assigned to the stratum giving the greatest improvement, and the process repeated until all stations available had been allocated.The age-length key estimated from the 1994 survey (Langley 1995) was used as the best proxy for allocating fish by size into appropriate year classes to determine 2+ abundance per trawl shot.

Vessel and gear specifications

RV *Kaharoa* is a research stern trawler with an overall length of 28 m, a displacement of 300 t, and a power rating of 522 kW. All trawling used 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 during 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 with 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, measured using Magnavox GPS. Warp to depth ratios ranged from 25:1 at the shallowest stations to 2.6:1 for the deepest trawls. Trawl door spread was estimated using Scanmar gear. A summary of gear parameters is given in Appendix 2: they are similar to those of previous surveys (Francis *et al.* 1995, table 1).

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 and squid, a sample 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 (apart from jack mackerel species, for which a smaller percentage was measured).

The length of fish and squid sampled was measured to the nearest centimetre below the actual length. The first 60 mature snapper greater than 23 cm FL in each sample were sexed and the ovarian condition of female fish categorised using the six stage developmental scale of Pankhurst *et al.* (1987) (Appendix 3). Female red gurnard and John dory were also sexed and staged using the keys of Clearwater (1992) (Appendix 4) and Hore (1982) (Appendix 5). A range of sizes of snapper, John dory, and red gurnard were also individually measured and weighed to determine the length-weight relationships for each of these species.

Otoliths were collected from measured snapper, with sampling spread throughout the survey area. Fish were randomly selected within 1 cm length increments, up to a maximum of 20 individuals for snapper (both sexes combined).

Environmental observations

The following environmental conditions were recorded for each trawl station: 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 scaled 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.
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.

Age determination

Snapper otoliths were aged as described by Davies & Walsh (1995). Age classes followed Paul (1976), whereby 1 January is defined as the theoretical birthday. Ages were inferred given the collection date of October-November 1997.

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.

Estimation of snapper year class strength

To generate indices of relative snapper YCS, the number of individuals for the 1+ and 2+ age classes were estimated in the following manner. For each shot, catch rates were converted to numbers per square kilometre using the age-length key and corrections for tow length, doorspread, and percentage sampled. Total numbers per stratum were then calculated from the mean catch rate and summed over all strata.

To estimate the YCS at age 1+ for the 1995 year class (sampled as 2+ in the present survey), the relationship between YCS estimated at ages 1+ and 2+ was estimated, where data from consecutive *Kaharoa* Hauraki Gulf trawl surveys were available. A linear regression explained 79% of the variance (Figure 2), but differed markedly in slope from the expected proportional relationship (slope = 0.51, compared with expected slope of 1.0). Most year classes lay close to the 1:1 line, but the 1988 and 1991 year classes deviated substantially. It is not known whether the deviations resulted from sampling error in the estimation of the YCS or from variations in the spatial distribution of the two year classes; for example, strong year classes may inhabit untrawlable as well as trawlable ground at age 1+, thus reducing their availability to the trawl, whereas at age 2+ they may inhabit mainly trawlable ground. A log-log plot of the same data explained more of the variance (90%) and had a slope closer to 1 (slope = 0.70) (Figure 3). The 1+ YCS of the 1995 year class was estimated from both the linear and log-log regression lines.

Results

A total of 49 stations were successfully completed during the survey. Station 44 was excluded from the biomass analysis because of poor gear performance due to a tangling of one of the trawl doors. The areal distribution of trawl stations is shown in Figure 4, and individual station information is given in Appendix 6.

Catch composition

Forty-six species were caught during the survey (Table 2). Snapper accounted for 71.3% of the total catch by weight, jack mackerel (*Trachurus novaezelandiae*) 11.8%, and leatherjacket 3.9%. John dory and red gurnard, both secondary target species of the survey, accounted for 3.6% and 2.0% respectively of total weight. Catches of other commercial species, including smooth skate, barracouta, and tarakihi, were small. A summary of catch by station of the more abundant species is given in Appendix 7.

Distribution and catch rates

Snapper were caught at all 49 successfully completed stations (*see* Appendix 7). Pre-recruit snapper were most abundant at stations within the Hauraki Gulf proper, from Omaha Bay to the northern side of Waiheke Island, the Firth of Thames, and the Cape Colville area (Figure 5). However, within this area catch rates were low from the northern side of Whangaparaoa peninsula. Catch rates of pre-recruit snapper were low from stations deeper than 50 m. Adult snapper (over 24 cm FL) generally displayed similar distribution patterns to the juveniles, although a high density shot was taken at a shallow station off the eastern Coromandel Peninsula (Figure 6).

The distributions of catch rates of jack mackerel (*T. novaezelandiae*), John dory, and red gurnard are given in Figures 7–9).

Biological data

Biological data collected from the catch are summarised in Table 3. The scaled length frequencies of snapper (Figure 10) showed two well-defined modes at 6–11 cm and 12–16 cm length. The age-length key derived from the otolith readings indicates that these modes represent the 0+ and 1+ age classes (Figure 11, Appendix 8). A broader size mode from 17 to 60 cm was composed of 2+ to 20+ individuals.

The length compositions of snapper from individual strata are presented in Figure 12. Most of the snapper from the 0+ to 2+ age classes were caught in the inner Hauraki Gulf (strata 1219, 1284, 1386, 2229, 9292, 1268, 1887). The snapper catch from outer Hauraki Gulf strata was dominated by fish from the larger (over 20 cm) length classes.

Individuals of snapper, John dory, and red gurnard were measured, and standard length-weight relationships calculated for each species (Table 4).

Female snapper were predominantly in the regressed (25%) or vitellogenic (74%) phases of ovarian development (Table 5). Of John dory females, 6% were in a virgin state, 10% in the maturing virgin state, and 84% in the developed state. Of red gurnard females, 13% were immature, 25% were regressed, and 60% were vitellogenic. (Table 5).

Length frequency distributions of male and female John dory were similar (Figure 13), though adult females tended to be slightly larger. Moderate numbers of juveniles in the 15–25 cm range were encountered. Red gurnard displayed a general mode ranging from 11 to 47 cm in length (Figure 14), though most of the population was 18–30 cm long. The female component of this population had a greater proportion of individuals over 35 cm. Jack mackerel (*T. novaezelandiae* and *T. declivis*) length frequencies were composed of juvenile fish (less than 22 cm) (Figure 15).

Biomass estimates

Biomass estimates for snapper, jack mackerel (*T. novaezealandiae*), John dory, and gurnard are given in Table 6. The other species were caught too infrequently to permit estimation of biomass. A large proportion of the snapper biomass (32%) was contained within the middle gulf stratum (4492). The jack mackerel biomass (*T. novaezelandiae*) was concentrated in strata 1518 and 4492, in the middle to outer Hauraki Gulf. John dory were also concentrated in these two strata, although the Firth of Thames strata (1268 and 1887) also contained a substantial proportion of the total population biomass. Red gurnard biomass was predominantly in the middle gulf stratum (4492), which accounted for 50% of total biomass for this species.

The *c.v.* for snapper less than 25 cm FL was 17%. John dory and red gurnard *c.v.*s around the total biomass estimates were 18 and 14% respectively.

Estimation of snapper year class strength

Estimated YCS of 1+ snapper (1996 year class) was 5.18 million fish (*c.v.*, 12.7%). This estimate was very close to the YCS prediction of 5.34 million fish, using the temperature-recruitment relationship reported by Francis *et al.* (1995) (Figure 16).

The estimated YCS of the 2+ snapper (1995 year class) was 4.52 million fish (*c.v.*, 15.1%). The estimated YCS of this year class at age 1+ was 3.24 million fish when calculated from the linear regression between 1+ and 2+ YCS (*see* Figure 2), and 3.48 million fish when calculated from the log-log regression (*see* Figure 3). Neither of these estimates fell close to the temperature-recruitment relationship shown in Figure 16. The 95% prediction limits for the higher of the two YCS estimates (3.48 million) were 2–6 million fish, with the upper limit still well below the value predicted from the temperature-recruitment relationship (8.53 million).

A revised temperature-recruitment relationship incorporating the 1996 year class, but not the 1995 year class, is described by the equation:

$$\mathrm{Log_e(YCS)} = -16.991 + 0.9942\ \mathrm{SST} \qquad (N = 11,\ R^2 = 0.96) \qquad (1)$$

Predicted 1+ YCS estimates for the period 1967–98 based on Equation (1), and observed trawl survey estimates, are shown in Figure 17.

Discussion

The 1997 trawl survey of the Hauraki Gulf sampled the 1995 year class as 2+ fish and the 1996 year class as 1+ fish. The YCS estimate for the 1996 year class surveyed at age 1+ agreed extremely well with the prediction based on Leigh water temperature, thus confirming the ability to predict 1+ YCS accurately from water temperature data.

However, the YCS estimate for the 1995 age class surveyed at age 2+ did not agree well with the prediction. The 1995 year class may have been much weaker than expected from water temperature. It should be possible to confirm or reject this hypothesis when the 1995 year class recruits to the commercial fishery over the period 1999–2001, at which time its YCS will be able to be assessed from samples of aged snapper taken from the commercial catch.

An alternative hypothesis is that Hauraki Gulf trawl surveys do not sample 2+ fish in proportion to their abundance, and that the empirical relationship between 1+ and 2+ YCS shown in Figures 2 and 3 is erroneous. The relationship is based on only eight data points, and is strongly influenced by two year classes (1988 and 1991) for which the 2+ YCS estimates exceeded the 1+ estimates. For year classes with 1+ YCS in the range 3–4 million fish, there was a three-fold variation in 2+ YCS (*see* Figure 2). This implies either that strong year classes are better sampled by the trawl survey at age 2+ than at age 1+, or that the proportion of the 2+ age class available to the trawl in the survey area varies markedly among years.

At present there is insufficient information to determine which of these hypotheses may be correct. The conservative approach has therefore been taken by incorporating only the YCS estimate from the 1996 year class into the revised temperature-recruitment relationship shown in Equation (1).This may require revision if the 1995 year class turns out to be weaker than predicted.

The 1997 and 1998 year classes are predicted to be slightly weaker and slightly stronger respectively than average (Figure 17). The 1995 year class is predicted from water temperature to be the strongest year class spawned since 1989. It is therefore expected to be important in sustaining the SNA 1 fishery, and in rebuilding the depleted Hauraki Gulf – Bay of Plenty substock. It is unfortunate that the 1995 year class was not surveyed at age 1+, and that there is uncertainty about whether 1+ YCS can be accurately estimated from 2+ YCS. It is strongly recommended that future Hauraki Gulf trawl surveys be planned so that they sample significant year classes (e.g. predicted very strong or very weak year classes) at age 1+ rather than age 2+, thus avoiding the need to estimate 1+ YCS from 2+ YCS.

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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 Phase 1	Phase 2	Density (per km^2)
1149	Waiheke, Tamaki Strait	10–25	64.5	3		1 : 22.5
1219	Central Gulf	25–50	888.1	4		1 : 222.0
1268	Outer Firth of Thames	25–45	312.2	3		1 : 104.1
1284	Kawau, Whangaparaoa	10–25	73.2	3		1 : 24.4
1386	Whangaparaoa, Rangitoto	10–25	67.8	3		1 : 22.6
1449	Bream Head, Cape Rodney	10–50	269.3	3		1 : 89.8
1518	Deep shelf	75–150	3 212.1	4		1 : 803.0
1887	Inner Firth of Thames	10–25	270.2	3		1 : 90.1
2229	Inner Gulf	25–45	559.9	3	2	1 : 112.0
4492	Outer Gulf	10–75	2 405.2	4	11	1 : 150.3
9292	West Coromandel	10–25	66.6	3		1 : 22.2
Total			8 216.1	36	13	

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*	7 885.2	71.3	100.00
Jack mackerel	JMN	*Trachurus novaezelandiae*	1 300.9	11.8	91.8
Leatherjacket	LEA	*Parika scaber*	429.3	3.9	49.0
John dory	JDO	*Zeus faber*	393.6	3.6	89.8
Red gurnard	GUR	*Chelidonichthys kumu*	220.7	2.0	89.8
Smooth skate	SSK	*Raja innominata*	161.2	1.5	36.7
Barracouta	BAR	*Thyrsites atun*	129.9	1.2	69.4
Eagle ray	EGR	*Myliobatis tenuicaudatus*	110.3	1.0	32.7
Tarakihi	TAR	*Nemadactylus macropterus*	56.8	0.5	16.3
Frostfish	FRO	*Lepidopus caudatus*	56.7	0.5	12.2
Longtailed stingray	WRA	*Dasyatis thetidis*	44.7	0.4	18.4
Broad squid	BSQ	*Sepioteuthis bilineata*	31.4	0.3	44.9
Rig	SPO	*Mustelus lenticulatus*	30.7	0.3	28.6
Spotted stargazer	SPZ	*Genyagnus monopterygius*	27.5	0.2	38.8
Jack mackerel	JMD	*Trachurus declivis*	27.4	0.2	14.3
Shorttailed stingray	BRA	*Dasyatis brevicaudatus*	19.8	0.2	12.2
Electric ray	ERA	*Torpedo fairchildi*	16.3	0.1	4.1
Thresher shark	THR	*Alopias vulpinus*	16.2	0.1	2.0
Carpet shark	CAR	*Cephaloscyllium isabellum*	13.9	0.1	12.2
Pilchard	PIL	*Sardinops neopilchardus*	12.3	0.1	10.2
Octopus	OCT	*Octopus* sp.	9	0.1	6.1
Red mullet	RMU	*Upeneichthys lineatus*	8.6	0.1	12.2
Trevally	TRE	*Pseudocaranx dentex*	7.2	0.1	12.2
Blue mackerel	EMA	*Scomber australasicus*	6.9	0.1	18.4
Arrow squid	SQU	*Nototodarus sloanii*	6.4	0.1	26.5
Sand flounder	SFL	*Rhombosolea plebeia*	6.1	0.1	34.7
Kahawai	KAH	*Arripis trutta*	5.3	< 0.1	6.1
Scaly gurnard	SCG	*Lepidotrigla brachyoptera*	4.5	< 0.1	12.2
Blue cod	BCO	*Parapercis colias*	4	< 0.1	4.1
Spotty	STY	*Notolabrus celidotus*	3.7	< 0.1	12.2
School shark	SCH	*Galeorhinus australis*	3	< 0.1	4.1
Parore	PAR	*Girella tricuspidata*	1.8	< 0.1	4.1
Anchovy	ANC	*Engraulis australis*	1.1	< 0.1	4.1
Yellow-eyed mullet	YEM	*Aldrichetta forsteri*	1	< 0.1	2.0
Flatfish	FLA		0.9	< 0.1	2.0
Witch	WIT	*Arnoglossus scapha*	0.9	< 0.1	2.0
New Zealand sole	ESO	*Peltorhamphus novaezeelandiae*	0.8	< 0.1	2.0
Porae	POR	*Nemadactylus douglasii*	0.7	< 0.1	2.0
Lemon sole	LSO	*Pelotretis flavilatus*	0.4	< 0.1	2.0
Cucumberfish	CUC	*Chlorophthalmus nigripinnis*	0.3	< 0.1	2.0
Spotted gurnard	JGU	*Pterygotrigla picta*	0.3	< 0.1	4.1
Sea perch	SPE	*Helicolenus* spp.	0.3	< 0.1	4.1
Boarfish	BOA		0.2	< 0.1	2.0
Scallop	SCA	*Pecten novaezelandiae*	0.2	< 0.1	2.0
Silverside	SSI	*Argentina elongata*	0.2	< 0.1	4.1
Redbait	RBT	*Emmelichthys nitidus*	0.1	< 0.1	2.0
Porcupine fish *(not weighed, water inflation)*	POP	*Allomycterus jaculiferus*			
		Total	11 058.7		

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	49	10 057	1 323	1 281
Jack mackerel *(Trachurus novaezelandiae)*	45	3 783	–	–
Red gurnard	44	915	301	466
John dory	44	381	130	171
Jack mackerel *(Trachurus declivis)*	7	284	–	–
Pilchard	5	141	–	–
Barracouta	34	140	39	30
Broad squid	22	129	–	–
Arrow squid	13	109	–	–
Blue mackerel	9	97	–	–
Smooth skate	18	83	46	36
Tarakihi	8	68	14	54
Anchovy	2	57	–	–
Trevally	6	53	–	–
Kahawai	3	42	–	–
Eagle ray	16	39	16	20
Sand flounder	17	33	–	8
Frostfish	6	30	–	–
Leatherjacket	24	29	–	–
Spotted stargazer	19	26	–	–
Rig	14	17	11	6
Blue cod	2	10	–	–
Longtailed stingray	9	10	5	5
Shorttailed stingray	6	6	3	3
Yellow-eyed mullet	1	6	–	–
Witch	3	5	–	–
School shark	2	3	2	1
Carpet shark	6	2	1	1
New Zealand sole	1	2	–	–
Lemon sole	1	2	–	–
Parore	2	2	–	–
Boarfish	1	1	–	–
Spotted gurnard	1	1	–	1
Porae	1	1	–	–
Scallop	1	1	–	–
Silverside	1	1	–	–

– no data or fish not sexed

***Table 4*: Length weight coefficients for snapper, John dory, and red gurnard, determined from $W = aL^b$ where W = weight (g) and L = length (mm)**

Species	Sex	n	Length range (cm)	a	b	r
Snapper	Male	407	15 – 76	0.0335	2.875	99.0
	Female	384	15 – 61	0.0318	2.8990	98.7
	All fish	903	7 – 76	0.0340	2.8750	98.9
John dory	Male	139	13 – 46	0.0044	3.379	95.3
	Female	198	14 – 52	0.0028	3.511	95.4
	All fish	353	13 – 52	0.0024	3.546	96.1
Red gurnard	Male	182	17 – 39	0.0060	3.17	97.8
	Female	305	16 – 47	0.0074	3.106	97.9
	All fish	518	11 – 47	0.0072	3.114	98.3

***Table 5:* Number of female snapper, John dory, and red gurnard at each reproductive stage**

Species	No. of fish	Gonad stage							
		1	2	3	4	5	6	7	8
Snapper	1 226	12	302	910	2	0	0	–	–
John dory	212	12	21	179	0	0	0	0	0
Red gurnard	422	53	106	225	8	0	0	–	–

"–", not applicable

Table 6 : **Estimated biomass (t) and coefficient of variation (*c.v.*, in parentheses) by stratum of snapper (SNA), jack mackerel (JMN), John dory (JDO), and red gurnard (GUR)**

Stratum	SNA < 25 cm	SNA > 24 cm	SNA Total	JMN	JDO	GUR
1149	72.9	66.6	139.5	54.4	3.2	0.7
	(34)	(44)	(38)	(47)	(9)	(42)
1219	259.6	338.5	608.1	26.1	29.9	22.6
	(23)	(45)	(35)	(68)	(39)	(44)
1268	384.4	364.7	749.1	32.1	66.6	4.2
	(9)	(32)	(20)	(71)	(77)	(43)
1284	55.9	172.2	228.7	61.1	16.4	2.9
	(59)	(19)	(29)	(81)	(51)	(35)
1386	85.3	127.9	213.3	18.4	7.7	0.4
	(7)	(13)	(6)	(40)	(37)	(22)
1449	23.3	130.7	154	50.2	9.9	45.7
	(71)	(92)	(89)	(70)	(47)	(48)
1518	83.5	438.1	521.6	903.6	94.8	29.5
	(78)	(48)	(52)	(91)	(37)	(29)
1887	336.5	446.7	783.2	46.4	51.9	1.8
	(11)	(26)	(19)	(40)	(17)	(23)
2229	233.1	428.9	662.1	26.1	12.5	11.2
	(40)	(32)	(33)	(36)	(37)	(79)
4492	602.3	1 441.8	2 044.1	521.1	89	122.3
	(36)	(54)	(47)	(31)	(24)	(16)
9292	87.8	110.5	198.3	5	5.4	0.1
	(45)	(55)	(50)	(69)	(92)	(100)
Total	2 234.7	4 066.75	6 301.4	1 744.6	387.4	241.6
	(12)	(21)	(17)	(48)	(18)	(14)

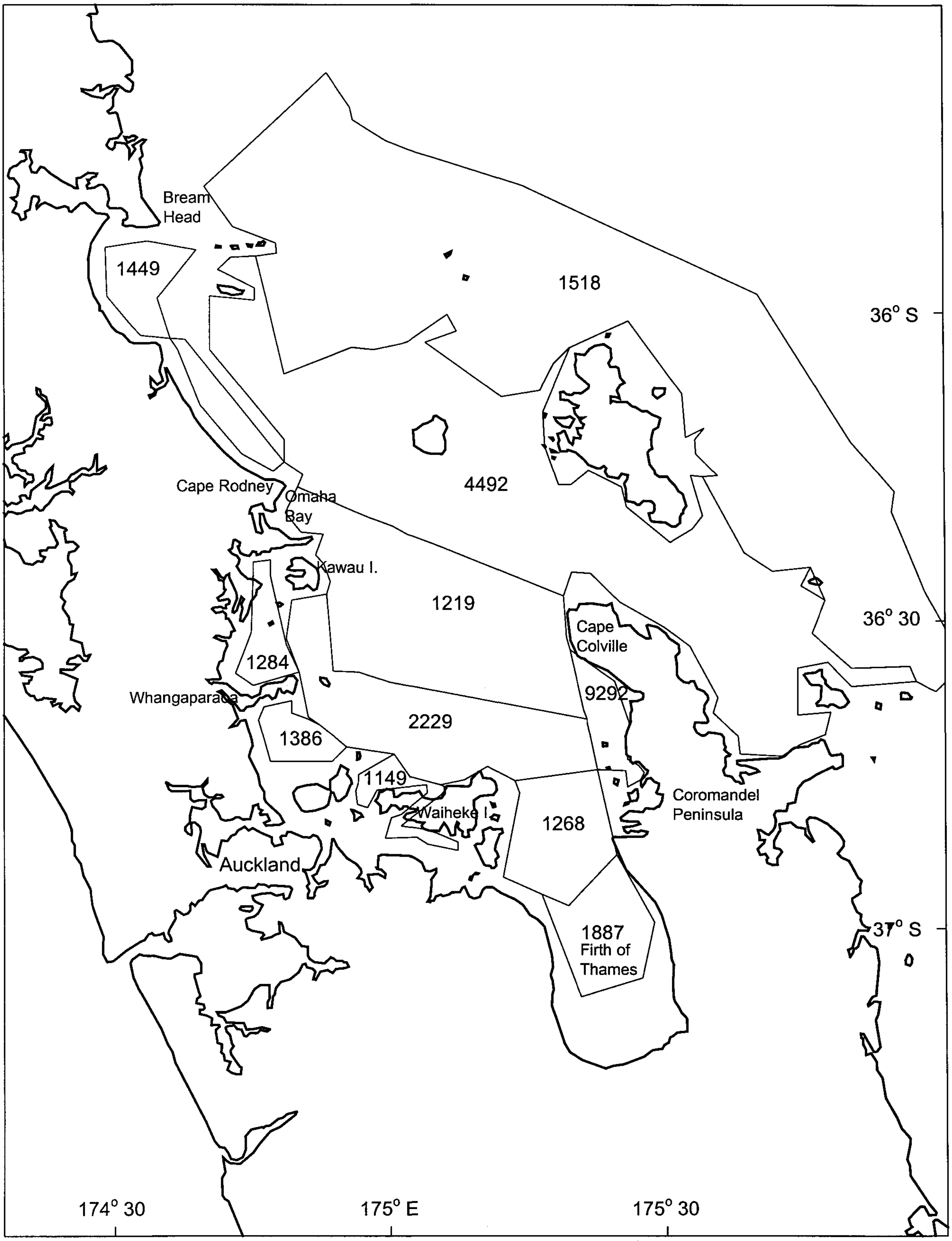


Figure 1: **Survey area and stratum boundaries.**

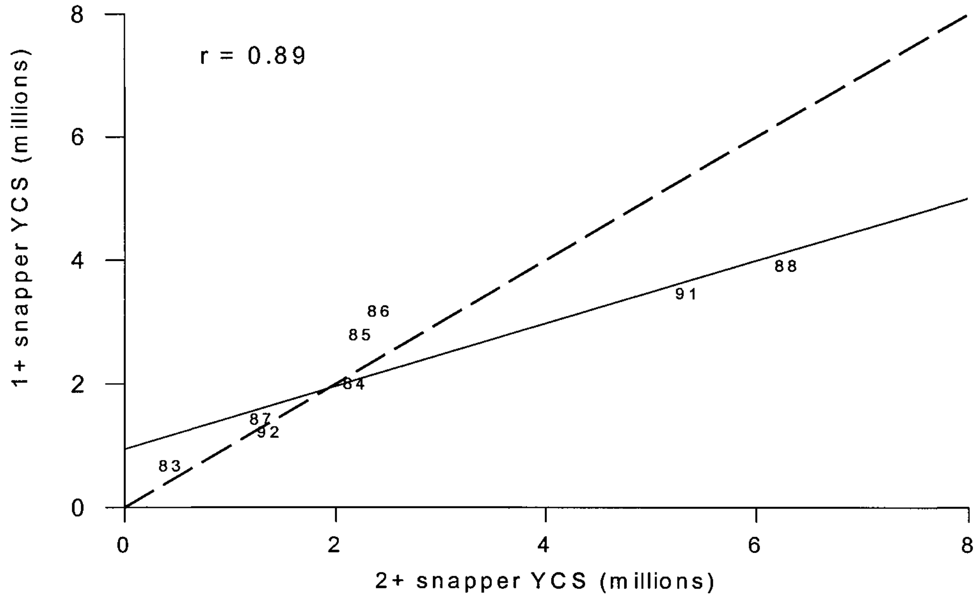


Figure 2: **Linear relationship between snapper year class strengths (YCS) estimated at ages 1+ and 2+ for year classes that were sampled during consecutive *Kaharoa* Hauraki Gulf trawl surveys. The dashed line indicates a 1:1 relationship.**

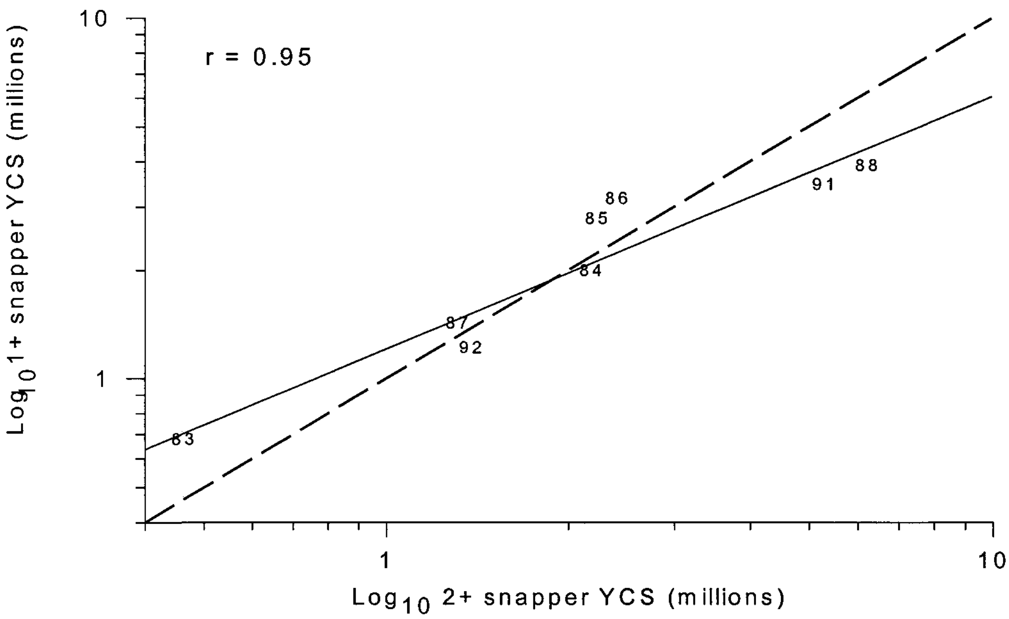


Figure 3: **Log-log relationship between snapper year class strengths (YCS) estimated at ages 1+ and 2+ for year classes that were sampled during consecutive *Kaharoa* Hauraki Gulf trawl surveys. The dashed line indicates a 1:1 relationship.**

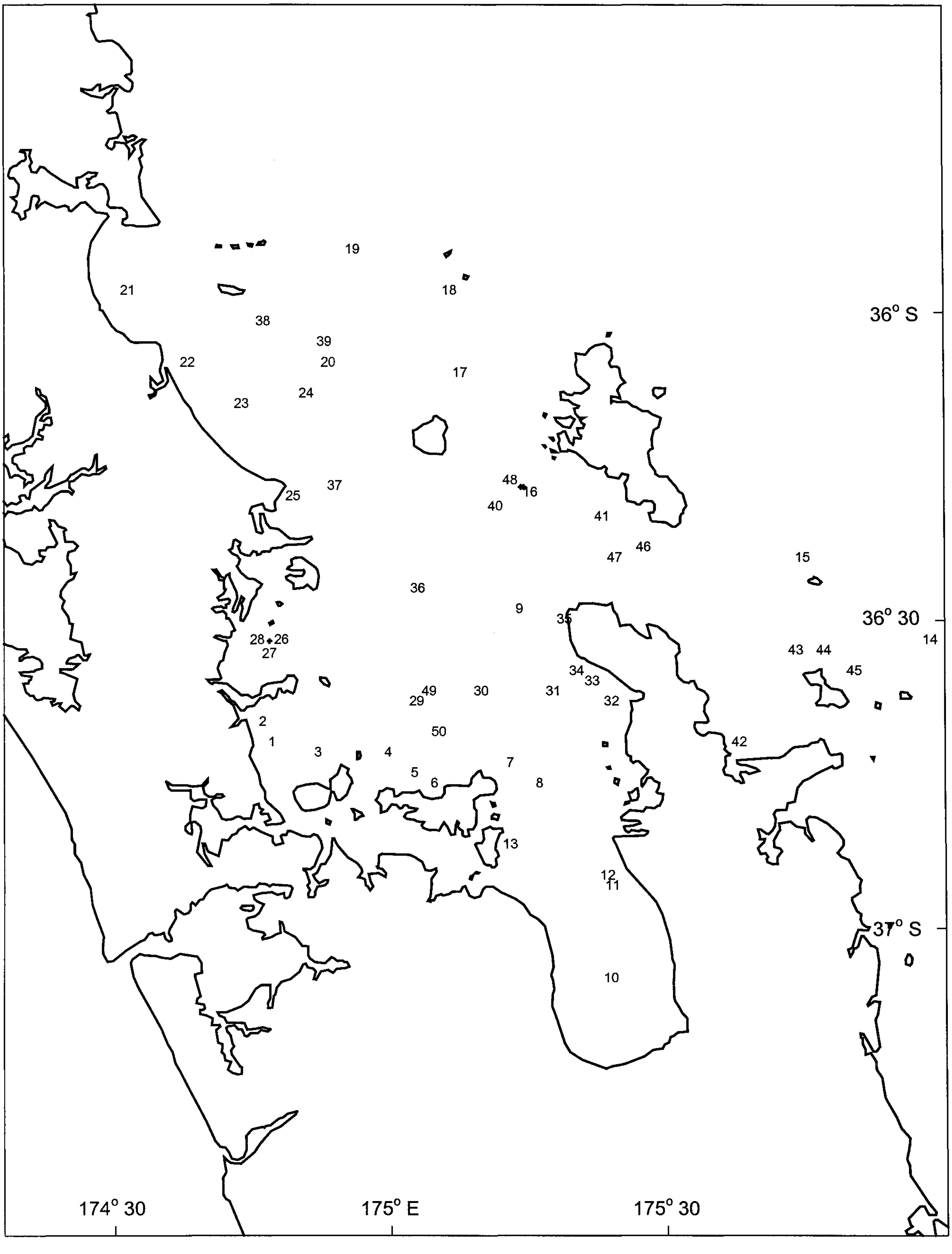


Figure 4: **Station positions and numbers.**

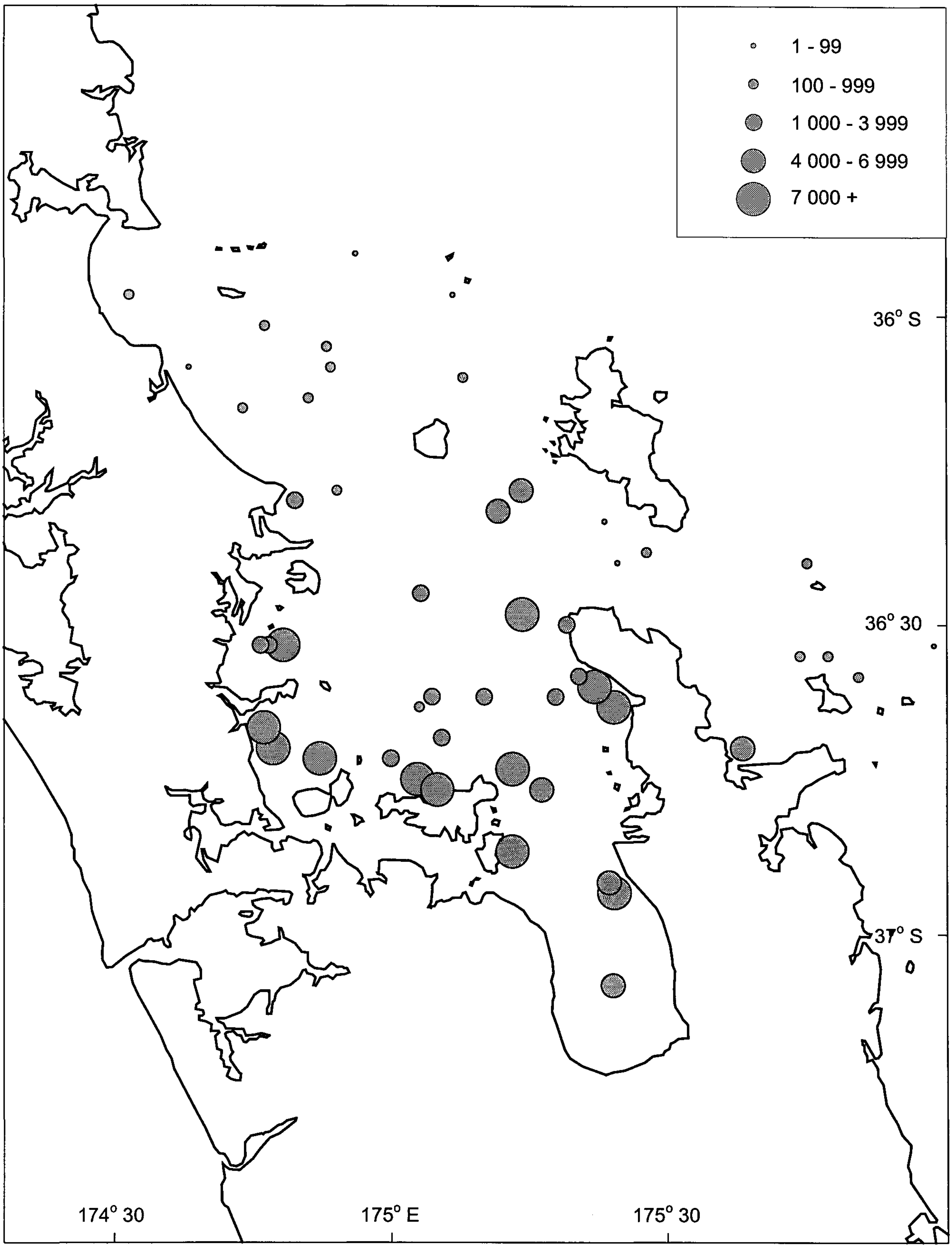


Figure 5: **Catch rates (individuals per km²) of pre-recruit (< 25 cm FL) snapper.**

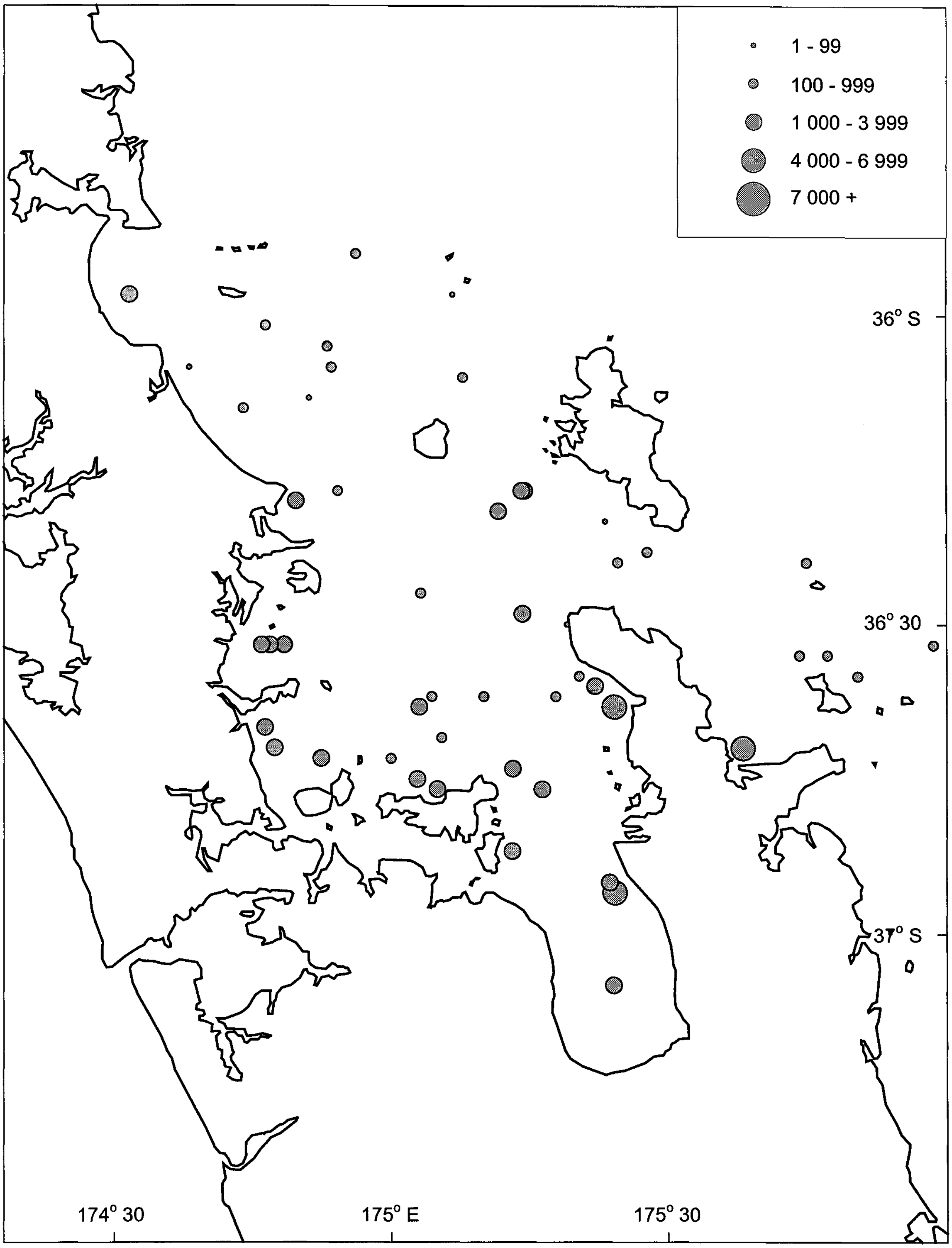


Figure 6: **Catch rates (individuals per km²) of adult (> 24 cm FL) snapper.**

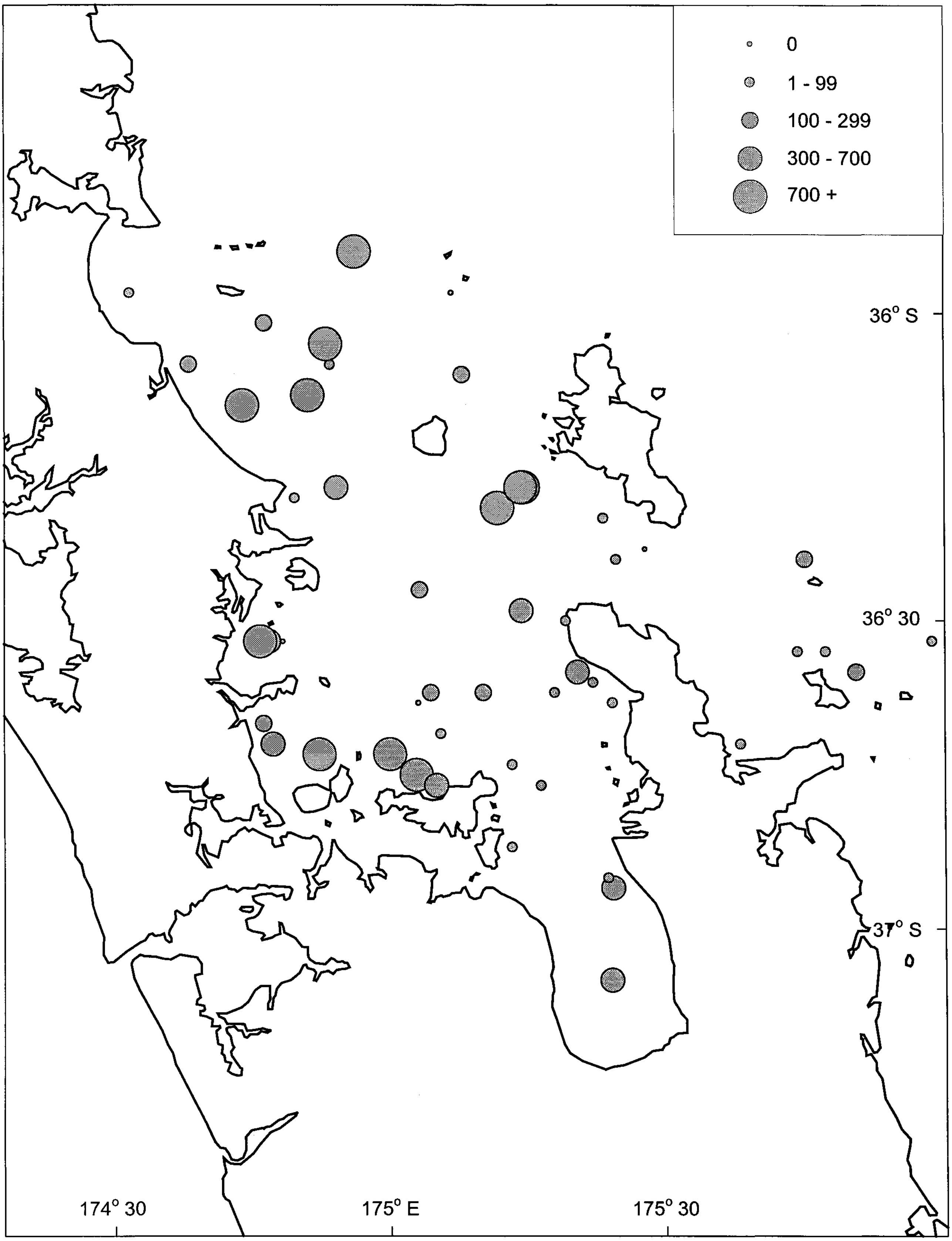


Figure 7: **Catch rates (kg.km^{-2}) of jack mackerel .**

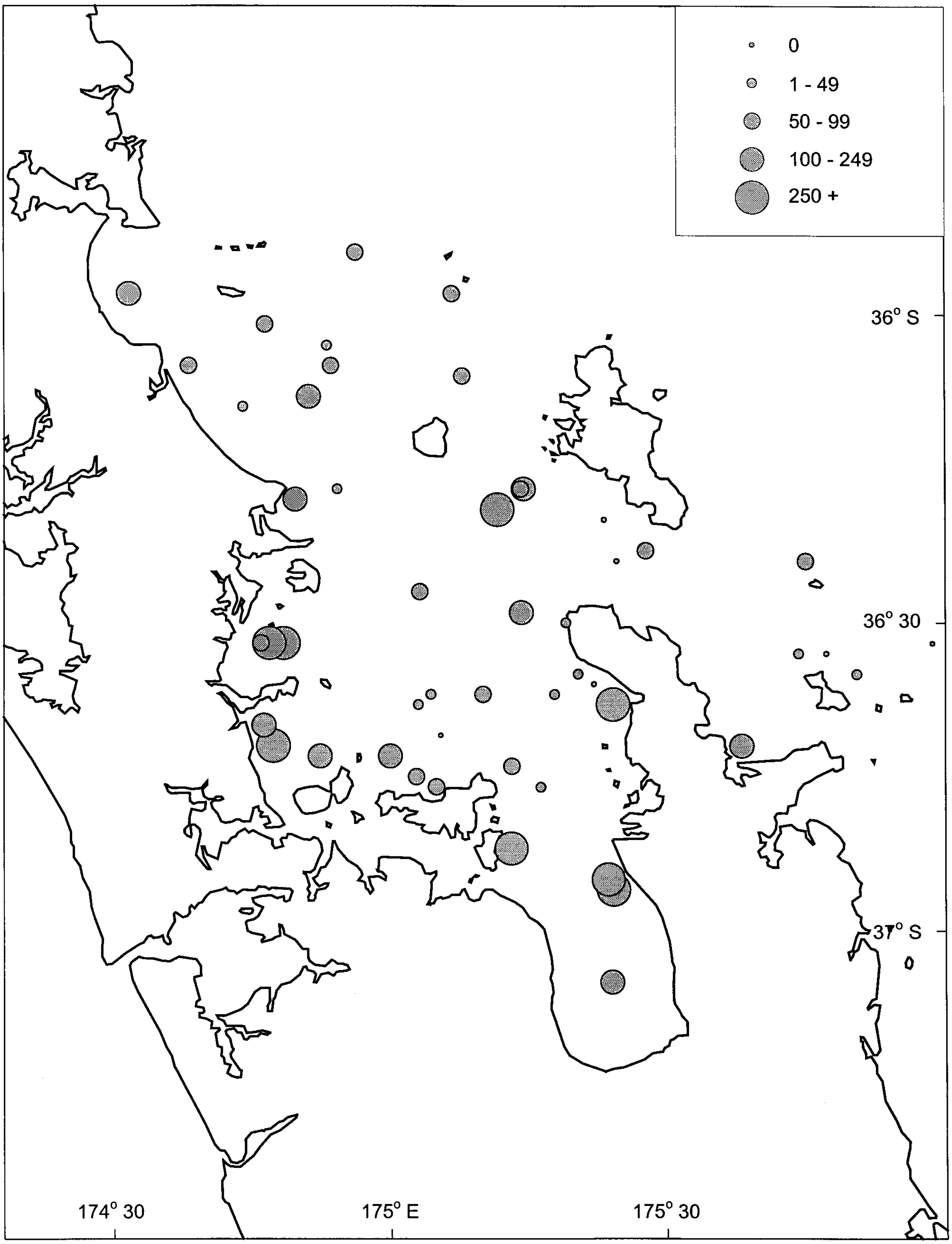


Figure 8: **Catch rates (kg.km^{-2}) of John dory.**

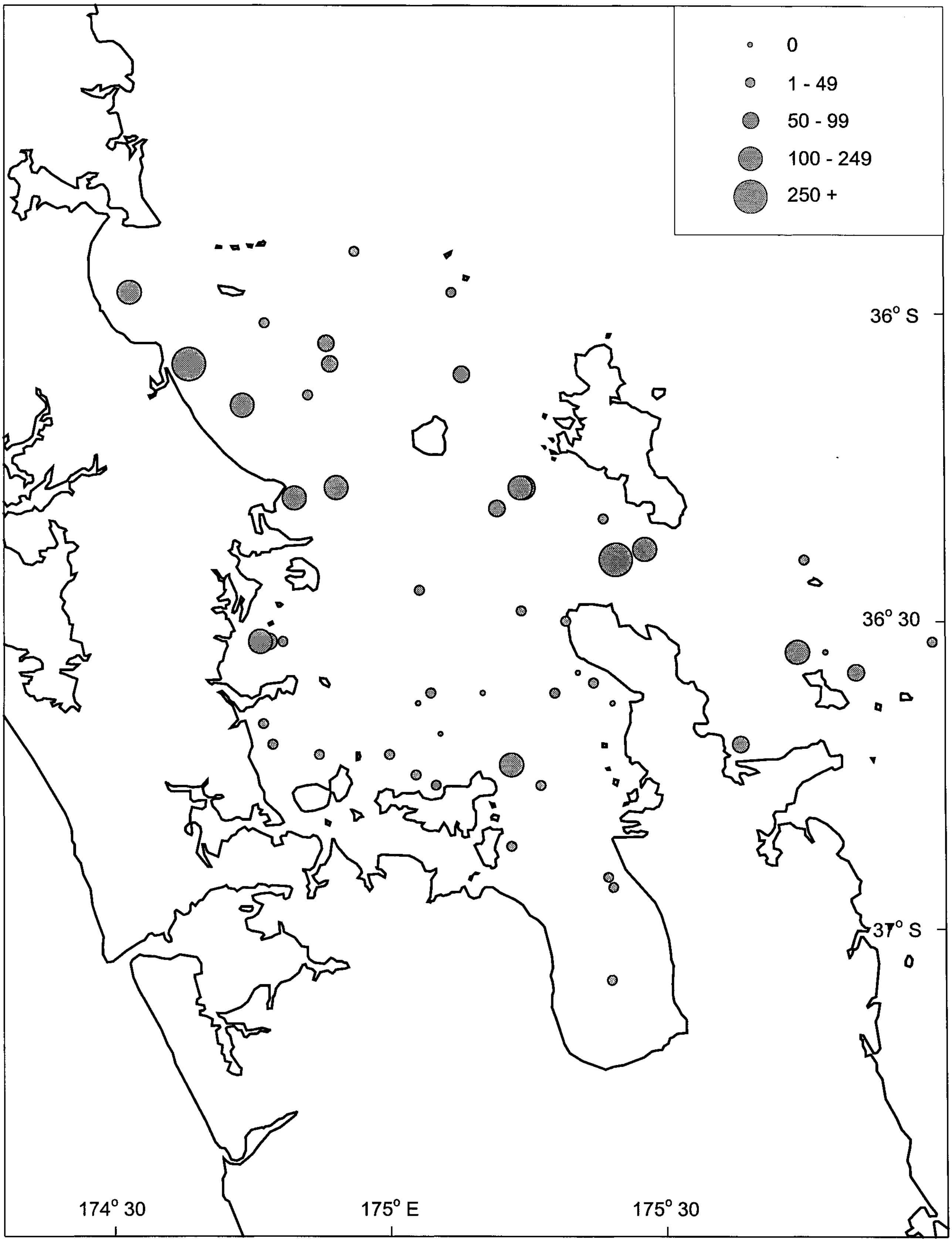


Figure 9: **Catch rates (kg.km^{-2}) of red gurnard.**

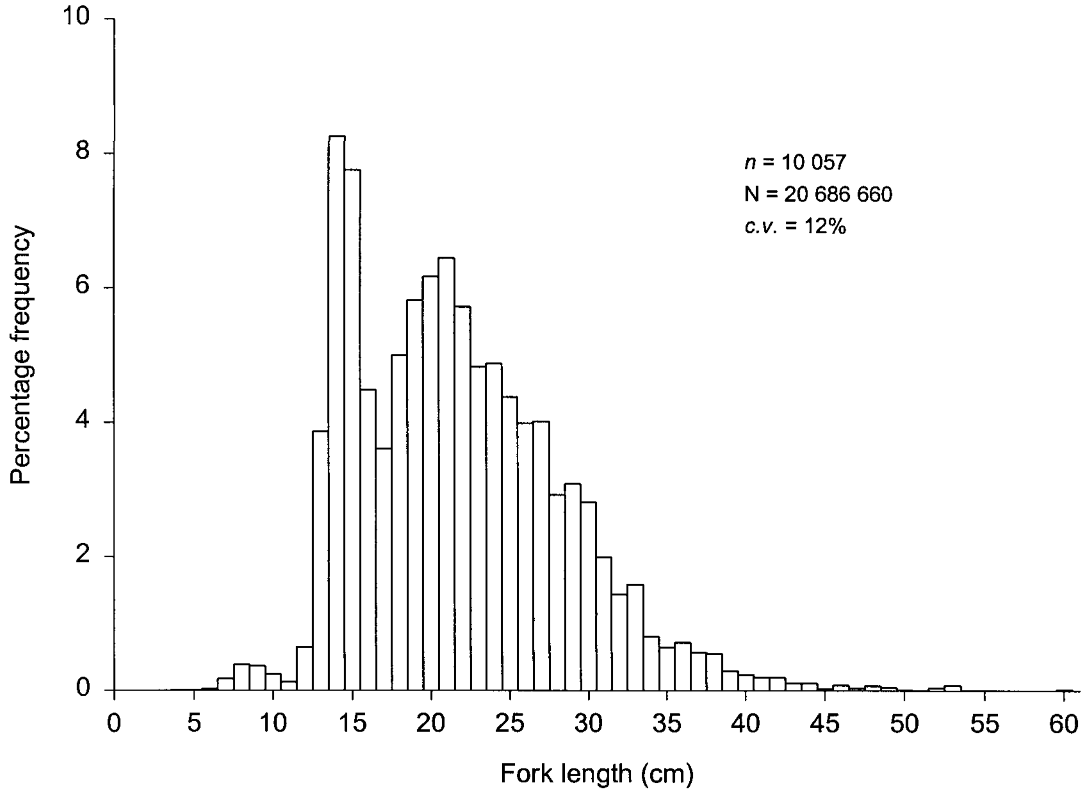


Figure 10 **: Scaled length frequency distribution of snapper. *n*, number of fish measured; N, estimated number of fish in the survey area; *c.v.*, coefficient of variation.**

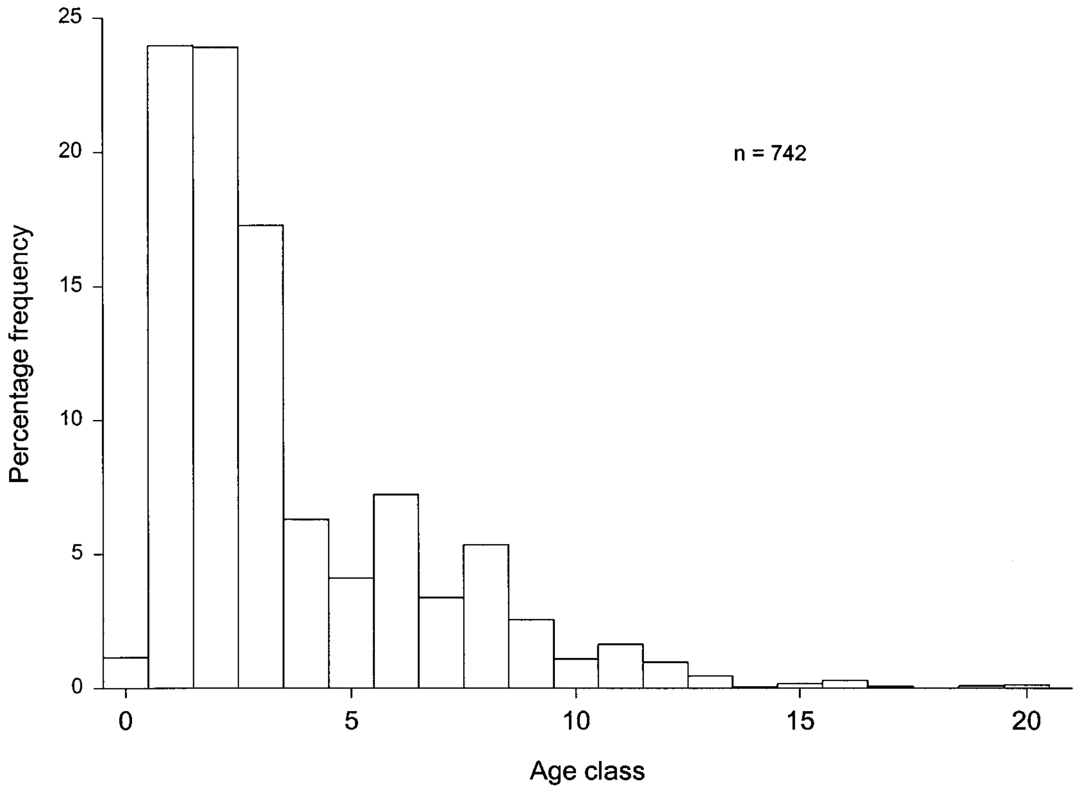


Figure 11**: Age composition of snapper. *n*, number of otolith readings used to constuct the snapper age-length key**

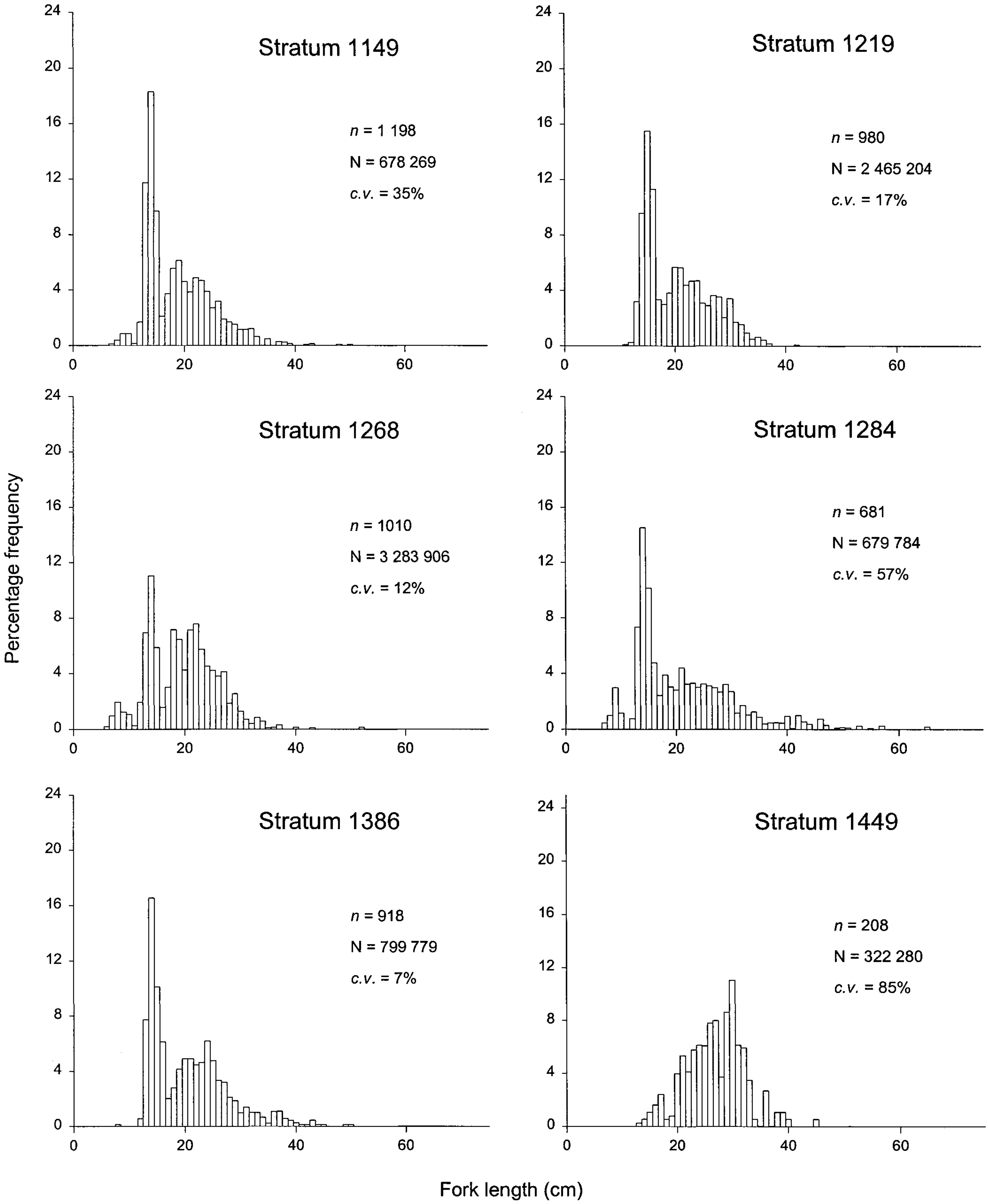


***Figure 12*: Stratum length compositions of snapper. *n*, number of fish measured; N, estimated number of snapper within the stratum; *c.v.*, coefficient of variation.**

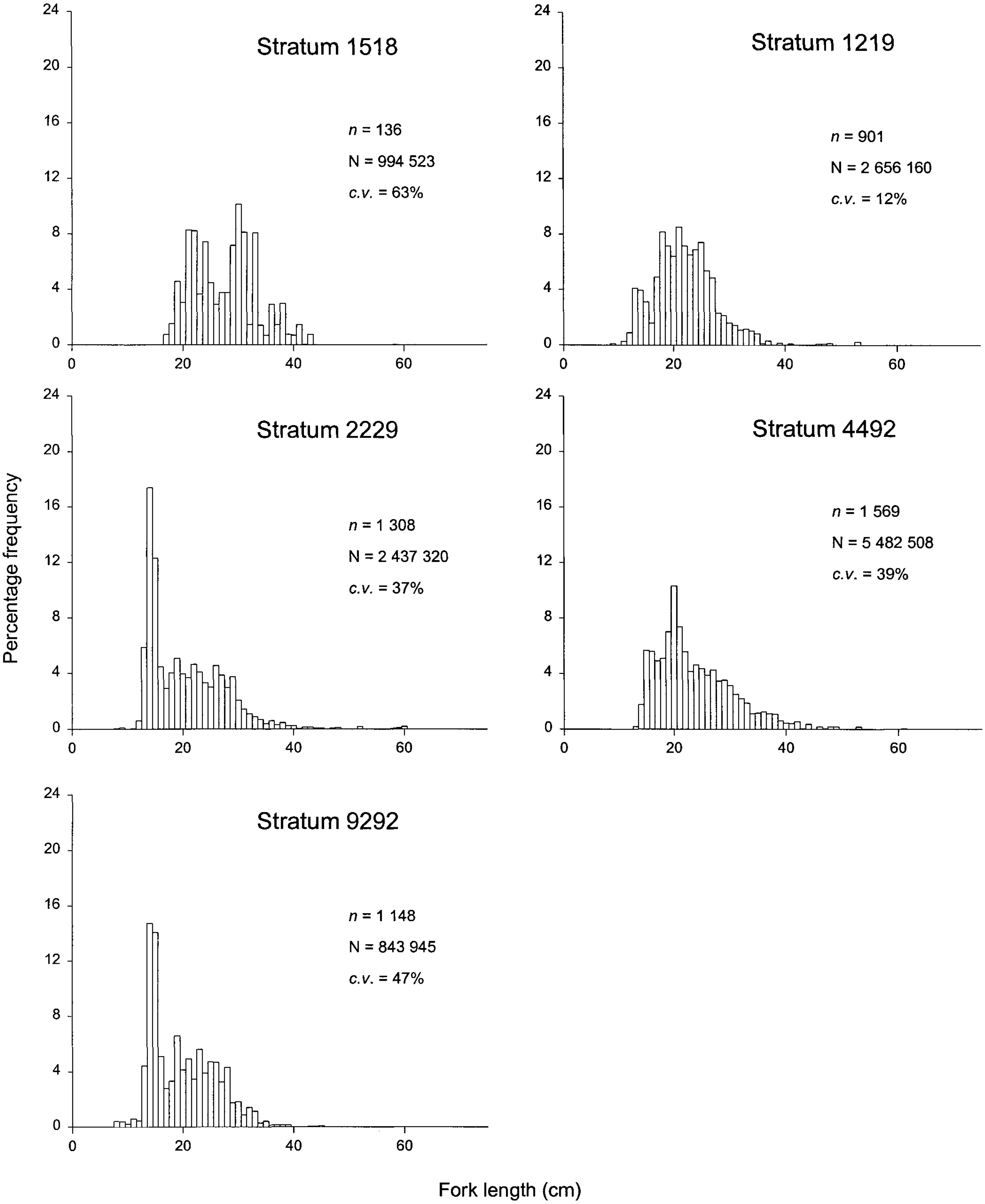


Figure 12 continued.

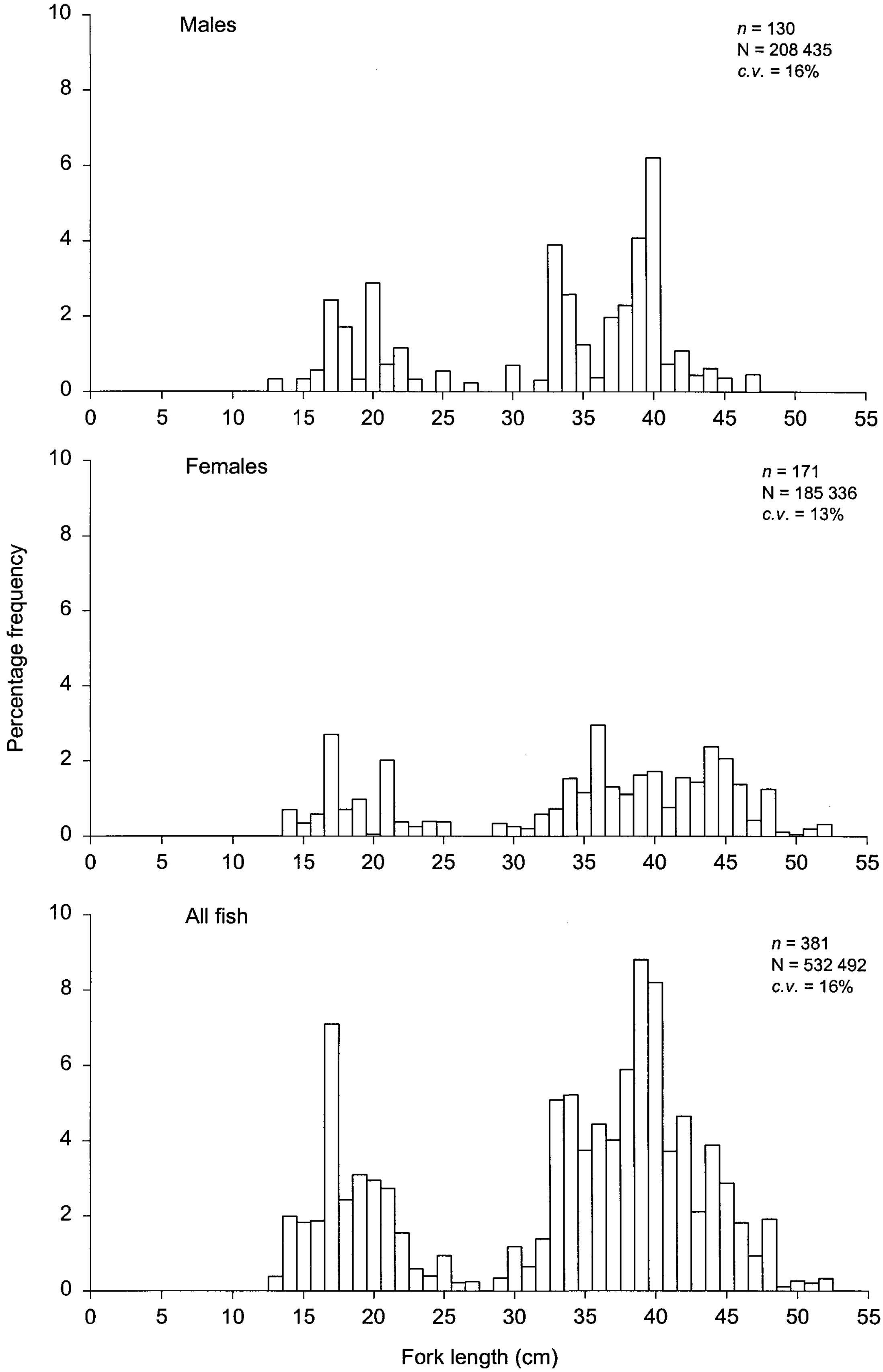


Figure 13: **Length frequency distributions of John dory. *n*, number of fish measured; N, estimated number of fish; *c.v.*, coefficient of variation.**

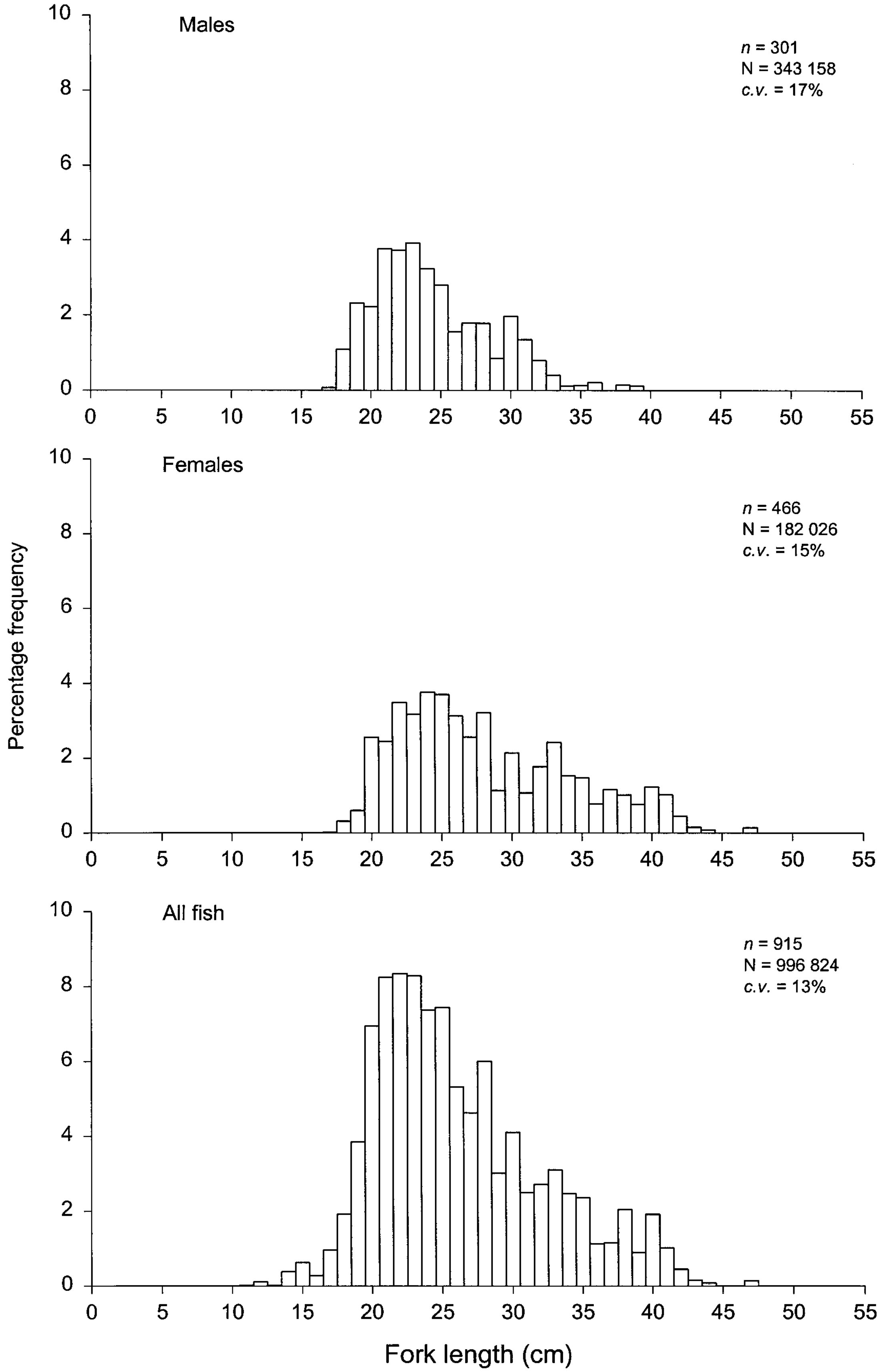
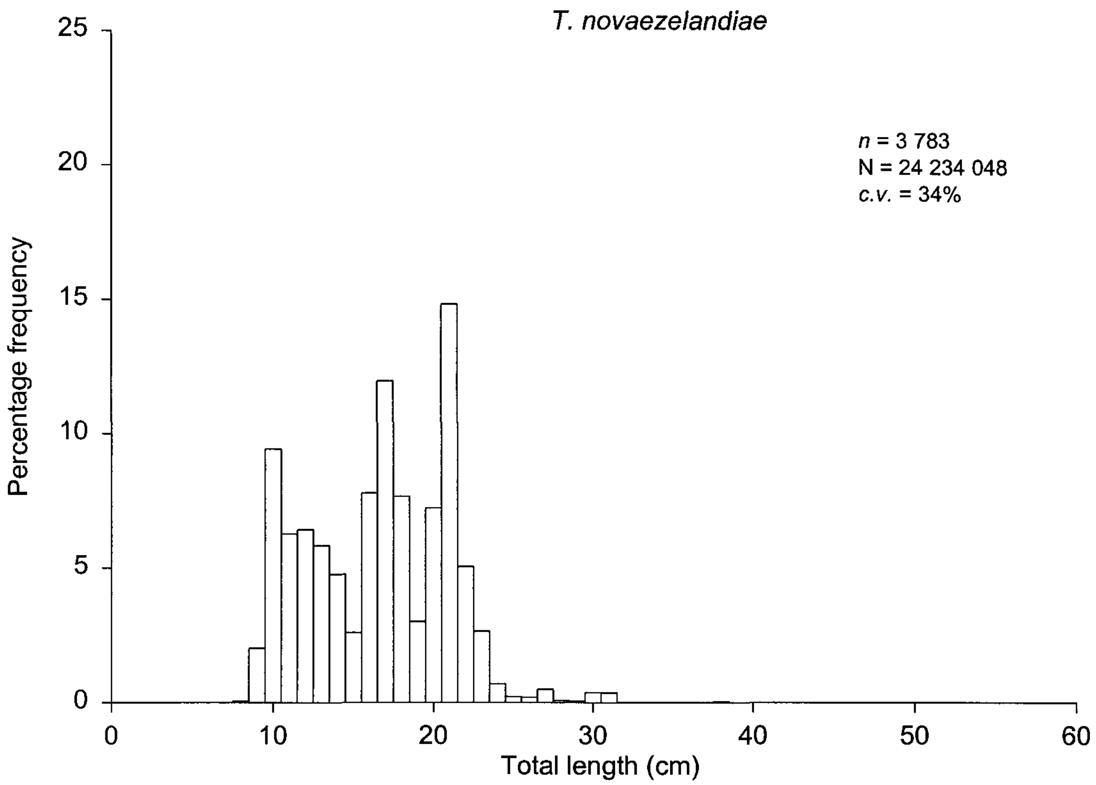


Figure 14 **: Length frequency distributions of red gurnard. *n,* number of fish measured; N, estimated number of snapper in the survey area; *c.v.*, coefficient of variation of the survey estimate.**

(a)



(b)

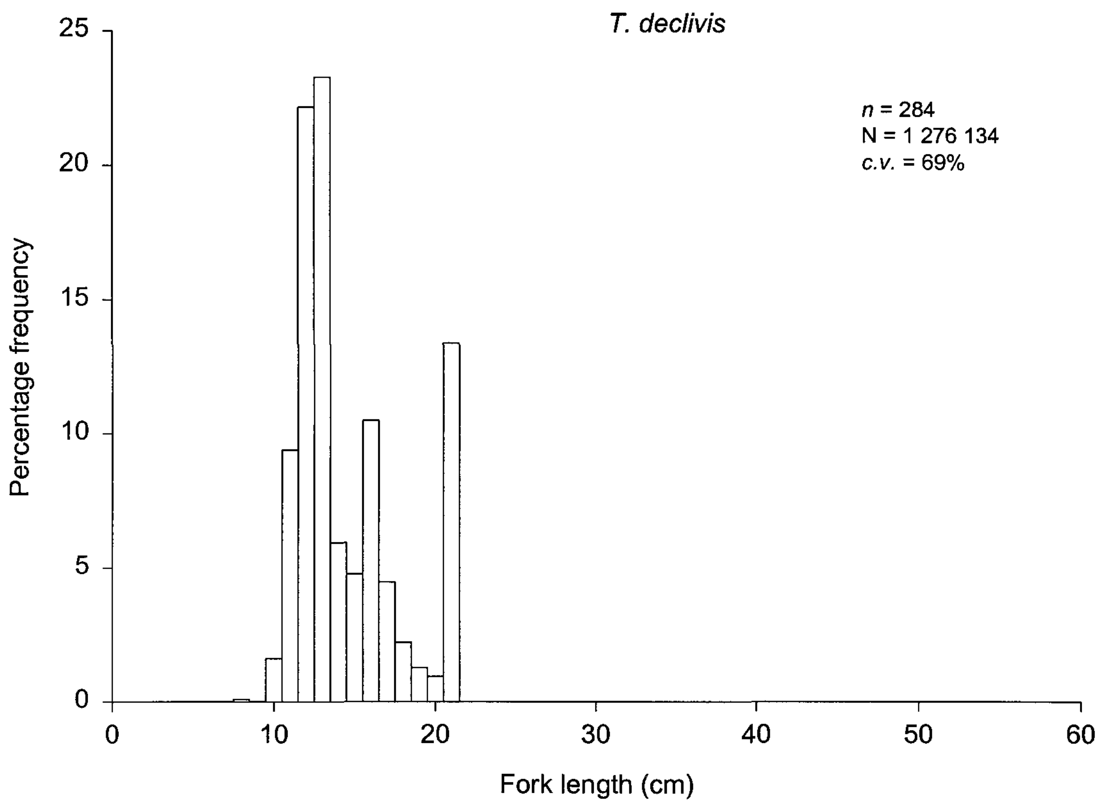


***Figure 15*: Length compositions of jack mackerel *T. novaezealandiae* and *T. declivis*.**

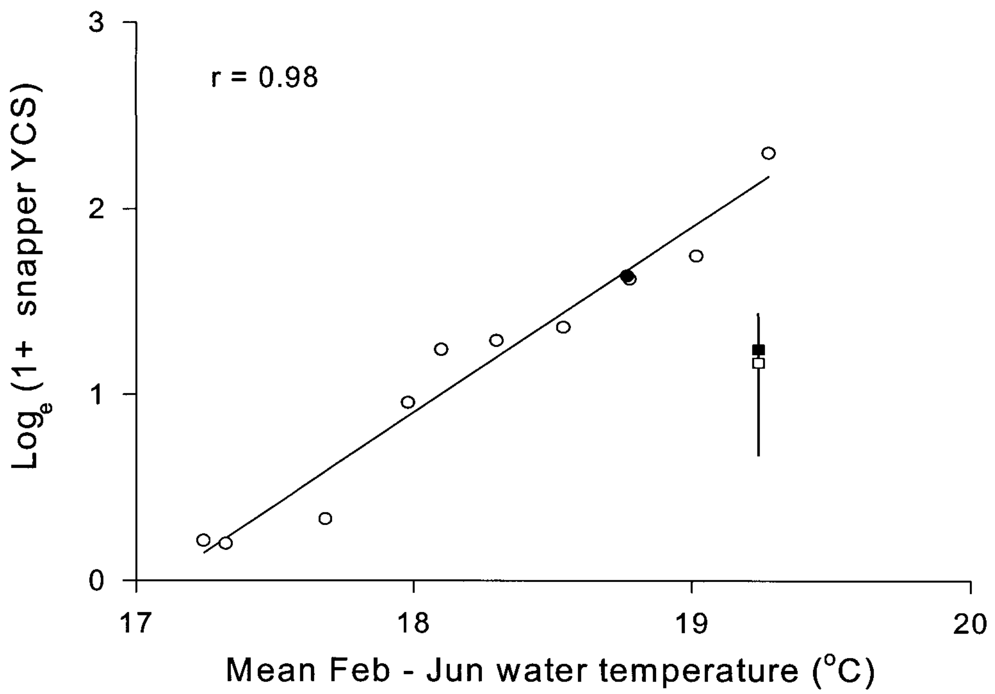


Figure 16: **Relationship between 1+ snapper year class strength (YCS) and Leigh February–Junesea surface temperature based on data up to and including the 1993 year class (open circles) and regression line; (from Francis *et al.* 1995, fig. 11). Superimposed is the 1+ YCS for the 1996 year class estimated by the 1997 trawl survey (solid circle). Also shown are two estimates of the 1+ YCS of the 1995 year class from the 1997 trawl survey using a linear regression of 1+ YCS against 2+ YCS (open square), and a log-log regression (solid square), plus the 95% prediction limits for the log-log regression.**

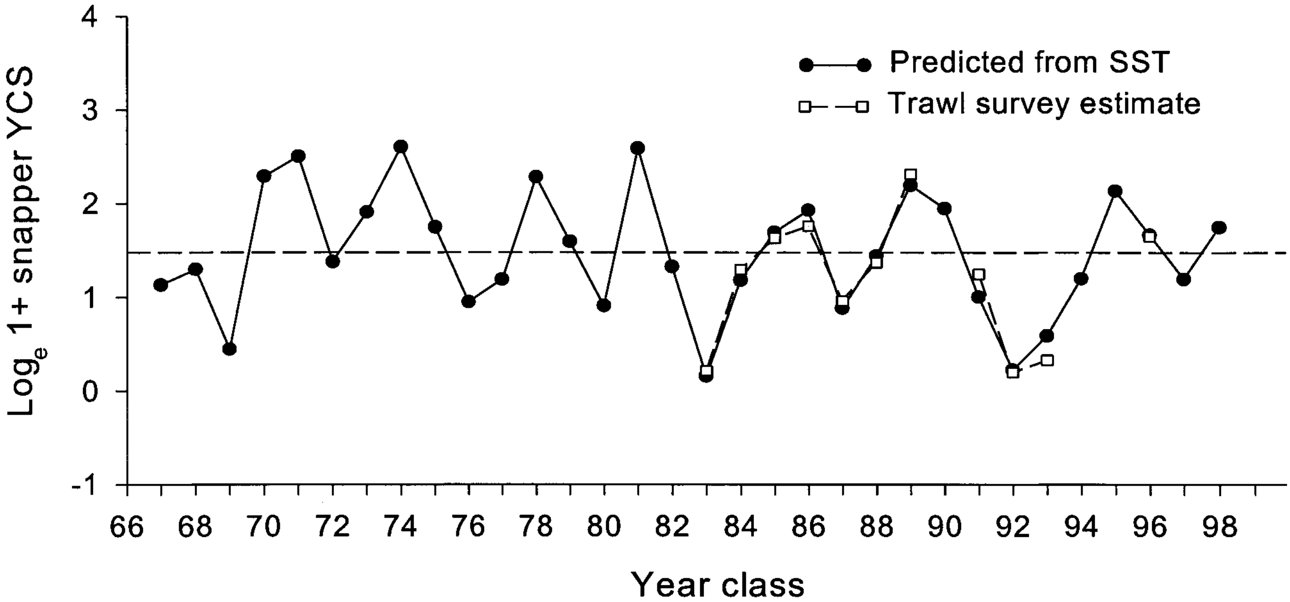


Figure 17: **Variation in predicted 1+ snapper year class strength (YCS) about the mean (horizontal dashed line) calculated from Leigh sea surface temperature (SST) using Equation (1). Also shown are the Hauraki Gulf trawl survey estimates of 1+ YCS, scaled to the mean of the predicted YCS in the same years.**

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 :	5.2–7.3 m
Codend mesh :	40 mm
Doorspread	72.1–90.3 m

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

	Depth range (m)									
	0–50			50–100			100–150			Total
	n	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*
Headline height (m)	32	6.1	0.3	15	5.7	0.4	2	6.0	0.1	49
Tow speed (knots)	32	3.1	0.2	15	3.1	0.4	2	3.0	0.0	49
Doorspread (DS) (m)	32	80.3	4.0	15	83.2	4.1	2	84.8	0.2	49

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: **Macroscopic condition stages of gonads of female John dory (*after* Hore 1982)**

Stage	Macroscopic condition
1	Virgin; ovaries thin, lie along posterior edge of ventral cavity, orange colouration
2	Maturing virgin; ovaries enlarged, no eggs visible to the eye, orange colouration
3	Developing; eggs visible to eye, orange in colour with reddish tinge, network of blood vessels developed
4	Developed; eggs clearly discerbable, some hyaline eggs present. Ovary fills ¼ of ventral cavity, yellow
5	Gravid: ovary fills 1/3 of ventral cavity, some transparent eggs, opaque and small yellow eggs predominate
6	Running ripe; transparent eggs expressed from ovary under slight pressure. Opaque and yellow eggs still present
7	Partly spent; not fully empty, some transparent eggs still present, hyaline and small yellow eggs predominate
8	Fully spent; ovaries flaccid and bloodshot. Some opaque and small yellow eggs visible, ovary walls purple

Appendix 5: **Macroscopic condition stages of gonads of female red gurnard (*after* Clearwater 1992)**

Stage	Macroscopic condition
1	Immature; ovaries small, translucent pink, no eggs visible
2	Previtellogenic/regressed; ovaries small, pink-orange granular oocytes may be visible
3	Vitellogenic; ovaries plump, pink-orange or yellow vitellogenic oocytes (~0.6 mm diameter), visible in large numbers
4	Hydrated; ovaries plump, orange red. Clear, hydrated oocytes (~1.2 mm diameter), dispersed evenly amongst vitellogenic oocytes characterising the previous stage
5	Mature; ovulated oocytes expressed from the oviduct when slight pressure applied to the abdomen
6	Spent; ovaries flaccid, often dark red or 'bloody' in colouration. Oocytes if present are unevenly dispersed. Dark brown specks of material sometimes visible

Appendix 6: **Individual station data**

Station no.	Stratum	Date	Start of tow: Start Time	Latitude ° 'S	Longitude ° 'E	Depth (m)	Tow distance (n. mile)	Warp length (m)	Headline height (m)	Door width (m)
1	1386	28 Oct 97	1038	36 42 16	174 46 99	12	0.70	200	6.0	79.0
2	1386	28 Oct 97	1420	36 40 16	174 46 14	12	0.70	200	6.0	88.8
3	1386	28 Oct 97	1437	36 43 71	174 52 20	24	0.70	200	6.2	77.8
4	1149	29 Oct 97	0520	36 43 67	174 59 77	27	0.70	200	5.6	80.4
5	1149	29 Oct 97	0613	36 45 78	175 02 66	24	0.70	200	5.6	76.5
6	1149	29 Oct 97	0712	36 46 23	175 04 81	24	0.70	200	6.0	85.8
7	2229	29 Oct 97	0820	36 44 19	175 12 99	42	0.70	200	5.7	81.6
8	1268	29 Oct 97	0933	36 46 34	175 16 31	38	0.70	200	5.7	71.0
9	1268	29 Oct 97	1022	36 29 14	175 14 20	25	0.70	200	6.7	83.4
10	1887	29 Oct 97	–	37 05 68	175 23 93	8	0.70	200	5.6	77.2
11	1887	29 Oct 97	1358	36 56 42	175 24 22	22	0.70	200	6.2	75.4
12	1887	29 Oct 97	1442	36 55 56	175 23 59	26	0.74	200	6.2	76.4
13	1268	29 Oct 97	1619	36 52 35	175 12 95	21	0.70	200	6.2	81.8
14	1518	30 Oct 97	0512	36 32 83	175 58 51	132	0.71	400	5.9	84.9
15	1518	30 Oct 97	0711	36 24 24	175 44 84	91	0.71	270	5.1	76.8
16	4492	30 Oct 97	1004	36 17 97	175 14 38	52	0.70	200	5.1	84.3
17	4492	30 Oct 97	1138	36 06 57	175 07 63	75	0.70	250	4.9	88.6
18	1518	30 Oct 97	1302	35 58 90	175 06 54	84	0.70	250	5.5	81.8
19	1518	30 Oct 97	1430	35 54 53	174 55 90	114	0.70	300	6.1	84.6
20	4492	30 Oct 97	1602	36 05 21	174 53 32	64	0.70	200	5.8	83.1
21	1449	31 Oct 97	0514	35 58 40	174 31 47	21	0.70	200	6.0	83.0
22	1449	31 Oct 97	0646	36 05 31	174 37 83	34	0.70	200	6.0	84.1
23	1449	31 Oct 97	0750	36 09 96	174 43 71	49	0.71	–	6.0	84.3
24	4492	31 Oct 97	0850	36 08 71	174 50 81	60	0.71	200	5.8	80.3
25	1219	31 Oct 97	1022	36 18 26	174 49 43	35	0.71	–	5.8	80.4
26	1284	31 Oct 97	1240	36 32 51	174 48 21	23	0.70	200	5.8	79.0
27	1284	31 Oct 97	1329	36 32 34	174 46 60	20	0.70	200	5.8	84.9
28	1284	31 Oct 97	1414	36 32 52	174 45 67	18	0.70	206	6.0	84.4
29	2229	2 Nov 97	0542	36 38 18	175 02 85	45	0.70	206	6.2	86.6
30	2229	2 Nov 97	0641	36 37 74	175 09 87	45	0.70	200	6.7	78.8
31	1219	2 Nov 97	0738	36 37 72	175 17 72	40	0.70	200	6.0	79.0
32	9292	2 Nov 97	0838	36 38 92	175 24 17	18	0.81	200	7.0	75.8
33	9292	2 Nov 97	0948	36 36 30	175 22 10	22	0.70	200	6.5	78.1
34	9292	2 Nov 97	1030	36 35 82	175 20 33	31	0.70	200	6.5	80.3
35	1219	2 Nov 97	1133	36 30 36	175 18 90	40	0.70	200	6.2	83.9
36	1219	2 Nov 97	1316	36 27 17	175 02 98	48	0.70	200	6.2	82.1
37	4492	2 Nov 97	1450	36 17 13	174 53 90	59	0.70	200	6.2	79.2
38	4492	3 Nov 97	0537	36 01 33	174 46 19	66	0.70	200	5.8	77.2
39	4492	3 Nov 97	0645	36 03 37	174 52 78	70	0.70	225	5.8	81.1
40	4492	3 Nov 97	0920	36 19 20	175 11 51	53	0.70	200	5.7	81.6
41	4492	3 Nov 97	1038	36 20 61	175 23 19	44	0.70	200	6.2	79.4
42	4492	3 Nov 97	1320	36 42 25	175 37 93	22	0.70	200	6.0	81.9
43	4492	3 Nov 97	1449	36 33 18	175 44 20	66	0.70	200	6.4	83.7
44 *	4492	3 Nov 97	1537	36 33 52	175 47 23	–	0.60	–	6.3	85.5
45	4492	4 Nov 97	0518	36 35 49	175 50 46	70	0.70	250	5.7	90.2
46	4492	4 Nov 97	0805	36 23 24	175 27 62	51	0.70	200	5.9	85.3
47	4492	4 Nov 97	0848	36 24 87	175 24 50	54	0.70	–	5.1	88.5
48	4492	4 Nov 97	1020	36 17 68	175 13 96	53	0.70	200	5.6	86.8
49	2229	4 Nov 97	1304	36 37 54	175 04 31	44	0.70	–	6.2	77.1
50	2229	4 Nov 97	1354	36 41 88	175 05 36	36	0.71	200	5.7	72.9

* = fouled or poor performance shot

- = no data

Appendix 7: **Catch (kg) at each station for the most abundant commercial teleost species; snapper (SNA), jack mackerel (JMN), John dory (JDO), and red gurnard (GUR)**

Station	SNA	JMN	JDO	GUR
1	313.8	31.8	20.2	0.4
2	331.7	7.6	7.8	1.0
3	351.8	44.3	7.5	0.6
4	75.9	169.1	6.0	0.3
5	214.8	59.4	4.7	1.2
6	399.7	34.3	4.7	2.2
7	284.1	2.4	3.8	8.7
8	150.8	3.2	2.2	1.7
9	354.5	26.8	8.4	2.2
10	212.7	22.8	13.1	0.5
11	390.4	24.5	23.5	0.5
12	269.9	3.8	21.5	1.0
13	242.0	2.7	57.1	0.2
14	18.3	0.5	0.0	0.9
15	40.0	7.2	5.2	1.6
16	130.7	71.9	6.7	10.1
17	33.1	9.1	3.9	3.1
18	0.7	0.0	3.0	0.3
19	9.1	115.1	4.2	1.1
20	17.2	3.0	3.3	3.1
21	171.1	0.9	6.2	10.3
22	2.0	12.1	5.5	36.1
23	11.9	48.8	0.3	9.1
24	10.0	42.2	6.0	2.0
25	140.7	1.5	6.6	6.2
26	502.2	0.0	44.7	2.0
27	244.9	35.8	20.9	3.7
28	242.6	238.6	5.1	7.4
29	131.9	0.0	2.0	0.0
30	91.2	5.8	4.7	0.0
31	41.1	0.9	0.6	1.2
32	632.1	1.6	26.1	0.0
33	303.2	3.4	0.0	0.7
34	39.2	18.6	1.4	0.0
35	27.0	0.6	2.0	2.0
36	80.7	9.5	5.1	1.4
37	17.4	23.4	0.1	6.1
38	37.2	5.6	3.9	2.6
39	28.5	56.4	1.2	3.9
40	157.7	47.0	14.0	2.8
41	5.3	0.7	0.0	1.2
42	655.4	3.6	7.8	4.7
43	48.6	0.5	2.1	9.2
44 *	–	–	–	–
45	44.2	7.8	2.3	3.8
46	17.0	0.0	4.5	8.0
47	16.5	1.2	0.0	13.9
48	152.9	78.6	4.0	9.0
49	65.1	9.9	1.2	1.8
50	48.7	5.2	0.0	0.0
Total	7 885.2	1 300.7	393.5	220.7

*, fouled or poor performance shot

Appendix 8: Snapper age-length key

Length																	Age class	No.
(cm)	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	>15+	aged
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
6	1.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
7	1.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
8	1.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17
9	1.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	21
10	1.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9
11	0.33	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
12	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
13	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	21
14	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
15	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16
16	–	0.74	0.26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	19
17	–	0.28	0.72	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18
18	–	0.05	0.95	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20
19	–	–	0.89	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	19
20	–	–	0.89	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	18
21	–	–	0.26	0.63	0.05	0.05	–	–	–	–	–	–	–	–	–	–	–	19
22	–	–	0.05	0.74	0.16	0.05	–	–	–	–	–	–	–	–	–	–	–	19
23	–	–	0.15	0.35	0.30	0.15	0.05	–	–	–	–	–	–	–	–	–	–	20
24	–	–	–	0.24	0.29	0.18	0.24	0.06	–	–	–	–	–	–	–	–	–	17
25	–	–	–	0.53	0.11	0.05	0.16	0.05	0.05	–	0.05	–	–	–	–	–	–	19
26	–	–	–	0.65	–	0.06	0.18	0.06	0.06	–	–	–	–	–	–	–	–	17
27	–	–	–	0.05	0.11	0.11	0.11	0.16	0.37	0.11	–	–	–	–	–	–	–	19
28	–	–	–	0.15	0.20	0.05	0.20	0.05	0.15	0.10	–	0.10	–	–	–	–	–	20
29	–	–	–	–	0.05	0.10	0.33	–	0.10	0.19	0.05	0.14	0.05	–	–	–	–	21
30	–	–	–	0.05	0.10	0.05	0.45	0.10	0.10	–	–	0.05	0.05	–	–	0.05	–	20
31	–	–	–	–	0.05	0.05	0.26	0.32	0.26	–	–	0.05	–	–	–	–	–	19
32	–	–	–	–	0.10	0.05	0.30	0.15	0.15	0.10	0.05	0.05	–	0.05	–	–	–	20
33	–	–	–	–	–	0.05	0.05	0.09	0.36	0.14	0.14	–	0.09	–	–	–	0.09	22
34	–	–	–	–	–	0.05	0.10	0.10	0.38	0.14	0.05	0.10	0.05	0.05	–	–	–	21
35	–	–	–	–	–	–	0.20	0.15	0.40	0.20	–	–	0.05	–	–	–	–	20
36	–	–	–	–	–	–	0.05	0.15	0.10	0.35	0.10	0.10	0.10	–	–	–	0.05	20
37	–	–	–	–	–	–	–	0.10	0.24	0.14	0.29	0.10	0.10	0.05	–	–	–	21
38	–	–	–	–	–	–	–	0.15	0.20	0.25	0.10	0.10	0.10	0.05	–	–	0.05	20
39	–	–	–	–	–	–	–	–	0.18	0.12	0.12	0.12	0.18	0.18	–	–	0.12	17
40	–	–	–	–	–	–	–	0.15	0.15	0.08	–	0.15	0.38	0.08	–	–	–	13
41	–	–	–	–	–	–	–	–	0.11	–	–	0.44	–	0.11	–	–	0.33	9
42	–	–	–	–	–	–	–	–	0.08	0.08	0.15	0.23	0.15	0.08	0.08	0.08	0.08	13
43	–	–	–	–	–	–	–	–	0.09	0.09	0.18	0.09	0.36	0.09	–	–	0.09	11
44	–	–	–	–	–	–	–	–	–	0.13	–	0.25	0.13	0.50	–	–	–	8
45	–	–	–	–	–	–	–	0.13	0.13	–	–	0.13	0.38	0.25	–	–	–	8
46	–	–	–	–	–	–	–	–	–	–	–	0.11	0.22	0.33	–	–	0.33	9
47	–	–	–	–	–	–	–	–	–	–	–	–	0.25	0.13	–	–	0.63	8
48	–	–	–	–	–	–	–	–	–	0.14	–	0.14	0.14	0.29	–	–	0.29	7
49	–	–	–	–	–	–	–	–	–	0.14	–	–	0.14	0.43	0.14	–	0.14	7
50	–	–	–	–	–	–	–	–	–	–	0.20	–	–	0.20	–	–	0.60	5
51	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.33	0.67	3
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	6
53	–	–	–	–	–	–	–	–	–	–	–	–	0.40	0.20	0.20	–	0.20	5
54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.33	–	0.67	3
55	–	–	–	–	–	–	–	–	–	–	–	–	–	0.50	–	–	0.50	2
56	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	2
57	–	–	–	–	–	–	–	–	–	–	–	–	–	0.25	–	–	0.75	4
58	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.25	0.75	4
59	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
61	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	3
62	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1
63	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
64	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	2
66	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
68	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
69	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
70	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Total																		735