NIWA

Taihoro Nukurangi

Hauraki Gulf trawl survey 2000

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Final Research Report for
Ministry of Fisheries Research Project INT2000/02
Objectives 1–4

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Final Research Report

Report Title:	Hauraki Gulf trawl survey 2000
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Executive Summary :

A trawl survey of the Hauraki Gulf and surrounding waters was successfully completed during October/November 2000, using the R.V. *Kaharoa.* Forty-eight stations were completed within 11 depth and area strata. The number of age 1+ snapper (the main target species) had a coefficient of variation (*c.v.*) of 15%, below the target of 20%. C.v.s for John dory and red gurnard (secondary target species) were less well estimated, at 26% and 46% respectively. Very few red gurnard were caught, with a total estimated biomass of only 24 t, suggesting very low catchability during the survey.

The snapper temperature-recruitment relationship failed to predict the strength of the 1999 year class as measured by the trawl survey. There are two possible reasons for this:

1. The trawl survey underestimated the strength of the year class. This could occur if a higher proportion than normal of the year class inhabited untrawled areas (e.g., foul bottom or shallow inshore areas). We will not be able to assess whether this is a plausible explanation until the 1999 year class recruits to the commercial fishery (in about 2004) and its strength can be determined by sampling commercial catches for age structure.
2. One or more environmental or biological factors other than SST influenced snapper YCS. There are a variety of potentially influential factors, some of which are discussed below.

We examined the monthly variation in Leigh SST, and SST deviations from the long-term monthly means, over the period from immediately before spawning to the winter following spawning. We then compared the temperature patterns experienced by the 1999 year class with those experienced by the 1989 year class (the strongest year class that has been surveyed at age 1+ during the current survey series), the 1981 year class (an extremely strong year class that was not surveyed during the survey series), and the remaining surveyed year

classes. The monthly SST pattern experienced by the 1999 year class was similar to that experienced by the strong 1981 and 1989 year classes (Figure 22) except that:

- temperatures in the months leading up to spawning (September–November 1998) were higher by around 1 °C;
- the 1999 year class experienced the highest recorded January deviation of 1.67 °C, however the absolute temperature was similar to temperatures experienced by the 1981 year class in February–March; and
- temperatures in June–August following spawning were much warmer.

One possible explanation for the weaker than expected 1999 year class is that the high spring SST may have stimulated snapper to spawn earlier than normal, and the planktonic larvae may have experienced suboptimal feeding conditions.

An alternative explanation may relate to a reduction in primary productivity observed in the Hauraki Gulf during 1999 (Zeldis et al. in press). A preponderance of easterly quarter winds generated extensive down-welling along the north-eastern shelf, which produced high salinity and low nitrate levels. This in turn led to a substantial reduction in phytoplankton production. However, the low productivity occurred in spring 1999, at a time when the 1999 year class was comprised of demersal 0+ juveniles. It is not known whether plankton productivity affects the survival of juvenile snapper.

It is not currently possible to determine whether the below-average 1999 YCS was real or an underestimate of the true abundance. This issue cannot be further addressed until 2004 onwards after the year class has recruited to the adult population. If the trawl survey did accurately measure YCS, then it is clear that the temperature-recruitment relationship derived previously does not adequately predict YCS under all possible conditions.

Updated length-weight relationships for snapper, John dory and red gurnard were derived and have been entered onto the TRAWL database. Information on reproductive stages of these three species was also collected.

Objectives : See attached draft technical report.

Methods: See attached draft technical report.

Results : See attached draft technical report.

Conclusions: See attached draft technical report.

Publications: Draft technical report.

Data Storage: All data have been stored in the TRAWL database.

Introduction

Trawl surveys have been conducted in the Hauraki Gulf using the R.V. *Kaharoa* since 1982. Target species throughout this time series have been snapper, john dory and red gurnard. However, in recent years the prime objective of the surveys has been to estimate the relative year class strength (YCS) of one year old (1+) snapper (apart from the 1997 survey, where 2+ snapper were the target, *see* Morrison & Francis 1999). One plus snapper YCS obtained from the 1984–97 spring trawl surveys of the Hauraki Gulf was strongly correlated with the mean water temperature in the summer–autumn following spawning (i.e., during the 0+ year) (Francis 1993, Francis *et al.* 1995, 1997, Morrison & Francis 1999). Nearly all (96%) of the variation in YCS is explained by mean February–June sea surface temperature (SST).

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 & Sullivan 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, but is less well defined at the lower and upper extremes.

The temperature-recruitment relationship predicted that the 1999 snapper year class would be the strongest since the time series of trawl surveys began (Francis et al. 1995, 1997, Morrison & Francis 1999). This survey (2000) provides an estimate of the number of fish of the 1999 year class at age 1+. An estimate of the 1999 YCS could 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 assessment of these two fishstocks. Information is also required on biological aspects of these stocks, including length frequencies, length-weight relationships, and reproductive condition, for use in stock assessments.

The last survey in this time series was carried out in November 1997. Previous trawl surveys of the Hauraki Gulf have been carried out in 1984–90, 1992, and 1996 (trip codes KAH8203, KAH8517, KAH8609, KAH8613, KAH9711, KAH8716, KAH8810, KAH8917, KAH9016, KAH9212, and KAH9720). Only the 1989, 1990 and 1997 surveys have been formally documented, as stand-alone reports (Drury and McKenzie 1992a,b, Morrison & Francis 1999), although subsets of the data from the surveys have been used for other purposes – eg determining snapper (Langley 1993) and other commercially targeted species distribution and abundance (Langley 1994). This survey extends this time series to November 2000.

This report presents the results of the Hauraki Gulf trawl survey conducted in October–November 2000. This research was funded by the Ministry of Fisheries through Project INT2000/02.

Project objectives

The major objectives of this research programme are

1. To determine the relative abundance and distribution of inshore finfish species in the Hauraki Gulf.

2. To estimate biological parameters for stock assessment of juvenile snapper (*Pagrus auratus*) and secondarily john dory (*Zeus faber*) and red gurnard (*Chelidonichthys kumu*) by collecting and analysing biological data (age/length frequency, length-weight, and reproductive condition).

Survey objectives

The objectives of the trawl survey for 2000 were as follows.

1. To determine the relative abundance and distribution primarily of juvenile snapper and secondarily john dory and red gurnard in the Hauraki Gulf from Whangarei Harbour to Great Mercury Island by carrying out a trawl survey. The target coefficient of variation (*c.v.*) for age 1+ snapper is 20%.

2. To collect the data and determine the length frequency, length-weight relationship and reproductive condition of snapper, john dory and red gurnard.

3. To collect otoliths from snapper, john dory and red gurnard.

4. To collect the data to determine the length frequencies of all other Quota Management System (QMS) species

Methods

Survey area and design

A trawl survey was conducted between 7 and 19 November 2000 from R.V. *Kaharoa* in 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 four most recent surveys (1992–97; Langley 1995, 1997; Morrison & Francis 1999), 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 overall survey areas was 8 216 km^2.

A simulation study of precision versus number of stations was undertaken using data from the 1997 survey (the most recent). From this, a survey design consisting of 52 trawl stations (42 phase 1, 10 phase 2) was chosen as most appropriate for achieving the target *c.v.* for 1+ snapper. Acceptable *c.v.s* (less than 20%) were also predicted for John dory and red gurnard using this station allocation. Further simulations were also done on earlier surveys, to ensure that these predicted results were consistent across different years/surveys.

The survey used a two phase stratified random design (*after* Francis 1984). Trawls were conducted at randomly selected positions (generated by the software RandStat version 1.7), with a minimum of three stations per stratum at least 2 n. miles (3.7 km) apart. Phase 2 stations were allocated on the basis of maximising reductions in the variance estimate for 1+ snapper. 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 *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 snapper age-length key from the 1997 survey (Morrison & Francis 1999) was used as the best proxy for allocating fish by size into appropriate year classes to determine 1+ abundance per trawl shot.

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 over 302 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 station substituted. Towing speed was between 3.0 and 3.5 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. miles for shallower stations, and 1.0 n. miles for deeper stations, measured using Magnavox GPS. Warp to depth ratios ranged from 22:1 at the shallowest stations to 3:1 for the deepest trawls. Trawl door spread was estimated using Scanmar gear, averaged over the tow. A summary of gear parameters is given in Appendix 2: they are similar to those of previous surveys (Francis et al. 1995, table 1, Morrison & Francis 1999, 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 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).

Lengths of fish and squid were measured to the nearest centimetre below the actual length. Snapper, red gurnard, and John dory were sexed and staged using appropriate gonad development scales (Appendices 3–5). A range of sizes of snapper, red gurnard, and John dory were also individually measured and weighed to determine length-weight relationships.

Otoliths were collected from measured snapper, with sampling spread throughout the survey area. Fish were randomly selected within 1 cm length increments; for snapper up to 25 cm, a maximum of 20 individuals (10 per sex) were sampled (incorporating the known size range for 1+ snapper); for fish greater than 25 cm, a minimum of 5 fish per sex / 1 cm size interval were collected. Otoliths were also collected from measured red gurnard and John dory (up to ten otoliths per 1 cm length class, five each per sex), and were archived at NIWA, Greta Point, Wellington.

Environmental observations

The following environmental conditions were recorded for each trawl station: sea surface temperature (from lower bucket), air temperature, bottom temperature (scanmar net monitor), 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 November 2000.

Estimation of snapper year class strength

To generate indices of relative snapper YCS, the number of individuals for the 1+ age class 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.

Results

A total of 50 stations were completed during the survey, of which stations 16 and 21 were excluded from the biomass and length frequency analysis because of poor gear performance, leaving 48 successful tows. The areal distribution of trawl stations is shown in Figure 2, and individual station information is given in Appendix 6.

Catch composition

Thirty-eight species were caught during the survey (Table 2). Snapper accounted for 88.8% of the total catch by weight, jack mackerel (*Trachurus novaezelandiae*) 5.4%, and tarakihi 1.8%. John dory and red gurnard, both secondary target species of the survey, accounted for 1.5% and 0.2% respectively of total weight. Catches of other commercial species, including barracouta, leatherjacket and arrow squid, 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 48 successfully completed stations (*see* Appendix 7). Pre-recruit snapper were most abundant at stations within the inner Hauraki Gulf proper; in particular from north-eastern Waiheke Island down into the inner Firth of Thames (Figure 3, 4). Larger snapper were more patchy in distribution, one large catch of almost 4 t was made north of Motuihe Island, while smaller catches were taken in the Firth of Thames, and in the central gulf (one shot only) (Figure 5).

John dory occurred throughout the survey area, with slightly higher catches to the south-east of Waiheke Island (Figure 6), while red gurnard were very scarce during the survey, with small catches occurring off the east of Waikehe Island (Figure 7). Jack mackerel (*Trachurus novaezealandiae*) were caught in relatively high abundance throughout the south-east of the Hauraki Gulf, and to a lesser degree in the northwest (Figure 8). Tarakihi were only caught in numbers at two stations, in the north of the survey area (Figure 9), while barracouta were widespread but in low abundance (Figure 10). Leatherjacket were only present in low abundance (Figure 11).

Biomass estimates

Biomass estimates for snapper, John dory, red gurnard, jack mackerel (*T. novaezelandiae*), tarakihi, barracouta and leatherjacket are given in Table 3. Other species were caught too infrequently to permit estimation of biomass. A large proportion of the snapper biomass (34%) was contained within the middle gulf stratum (4492), with significant amounts also in strata 1268 (22%) and 1386 (14%). Thirty nine percent of John dory biomass was also found with stratum 4492. Red gurnard biomass was almost zero (24 t). Non target species were variable in their biomass distribution; however much of their biomass was found in the outer gulf strata 4492 - 90% of tarakihi (as a result of one large catch), 53% of barracouta, and 81% of leatherjacket biomass.

The *c.v.* for 1+ snapper was 15%. John dory and red gurnard *c.v.*s around the total biomass estimates were 26% and 46% respectively (Table 3).

Biological data

Biological data collected from the catch are summarised in Table 4. The scaled length frequency of snapper (Figure 12) showed at least four modes likely to represent age classes, including one at 5–13 cm (0+) and another at 14–19 cm (1+). Other modes occurred at 19–22 cm, and 23–33 cm, with a tail of larger fish up to 60 cm FL. The age-length key derived from the otolith readings of this survey indicates that the first two modes represent the 0+ and 1+ age classes (Appendix 8). General otolith collection summaries are given in Appendix 9.

The length compositions of snapper from individual strata are presented in Figure 13. 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.

Length frequency distributions of male and female John dory were quite different, with males being mainly 30–45 cm in length, with a small mode of smaller fish at 25–26 cm. (Figure 14). A greater size range of females was found, from 18–54 cm, with no clear modes. Relatively few red gurnard were sampled; males ranged from 18–31 cm mainly, while females ranged from 15–39 cm (Figure 15). No obvious modes were present. Most of the tarakihi measured came from just two trawl shots; fish ranged from 25–42 cm in length (Figure 16). Jack mackerel (*T. novaezealandiae*) ranged from 8–32 cm (Figure 17a), with two modes apparent , while barracouta had two clear modes; one of juveniles at 10–18 cm, and one of adults at 42–49 cm (Figure 17b). Leatherjacket ranged from 15–30 cm in length (Figure 18).

Individuals of snapper, John dory, and red gurnard were measured, and standard length-weight relationships calculated for each species (Table 5).

Male snapper were predominantly in the spermatogenic (93%) or partially spermiated (5%) phases of testis development (Table 5), while females were mainly developing (39%) or ripe (49%). For John dory males, 35% were developing-resting, 41% developing, and 22% ripe-spawning, while for females 22% were maturing, 63% developing, and 10% developed. Of red gurnard males 80% were spermatogenic, and 20% spermiated, while for females 20% were previtellogenic, 42% were vitellogenic, and 60% were hydrated. (Table 6).

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Estimation of snapper year class strength

The estimated YCS of 1+ snapper (1999 year class) was 3.4 million fish (*c.v.* = 14.5%), which is well below the YCS prediction of 11.8 million fish based on mean February–June Leigh SST (Figures 19 & 20). The 1999 year class was predicted to be the strongest since 1981, but the trawl survey estimate of YCS suggests that it was below average strength. The upper 95% confidence limit of the estimate does not overlap the extrapolated lower prediction limit of the previous temperature-recruitment relationship.

The correlation between YCS and Leigh monthly SST was calculated both including and excluding the 1999 year class. Inclusion of the 1999 year class caused marked reductions in the correlation coefficients during January–October of the spawning (0+) year (Figure 21). There was no indication that a period other than February–June would produce a better predictor of YCS.

Discussion

This survey met its objectives, with an estimate of 3.4 million 1+ snapper within the survey area, with an associated c.v. of 15% (target c.v. was 20%). Biomass estimates of john dory and red gurnard were less precise, with values of 260 t (26%) and 24 t (46%) respectively. For John dory, this value was within the normal range for Hauraki Gulf surveys (average 293 t), but for red gurnard the estimated biomass was the lowest ever (average 301 t), the next lowest being 49 t, from the 1985 survey. This suggests a large drop in the catchability of the red gurnard stock during the time of survey, or that they had moved outside of the survey area. A true abundance this low seems very unlikely, given continuing stable fishery catches. Other species were caught in relatively low abundances only, a re-occurring feature of Hauraki Gulf trawl surveys.

The snapper temperature-recruitment relationship failed to predict the strength of the 1999 year class as measured by the trawl survey. There are two possible reasons for this:

3. The trawl survey underestimated the strength of the year class. This could occur if a higher proportion than normal of the year class inhabited untrawled areas (e.g., foul bottom or shallow inshore areas). We will not be able to assess whether this is a plausible explanation until the 1999 year class recruits to the commercial fishery (in about 2004) and its strength can be determined by sampling commercial catches for age structure.
4. One or more environmental or biological factors other than SST influenced snapper YCS. There are a variety of potentially influential factors, some of which are discussed below.

We examined the monthly variation in Leigh SST, and SST deviations from the long-term monthly means, over the period from immediately before spawning to the winter following spawning. We then compared the temperature patterns experienced by the 1999 year class with those experienced by the 1989 year class (the strongest year class that has been surveyed at age 1+ during the current survey series), the 1981 year class (an extremely strong year class that was not surveyed during the survey series), and the remaining surveyed year classes. The monthly SST pattern experienced by the 1999 year class was similar to that experienced by the strong 1981 and 1989 year classes (Figure 22) except that:

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An alternative explanation may relate to a reduction in primary productivity observed in the Hauraki Gulf during 1999 (Zeldis et al. in press). A preponderance of easterly quarter winds generated extensive down-welling along the north-eastern shelf, which produced high salinity and low nitrate levels. This in turn led to a substantial reduction in phytoplankton production. However, the low productivity occurred in spring 1999, at a time when the 1999 year class was comprised of demersal 0+ juveniles. It is not known whether plankton productivity affects the survival of juvenile snapper.

It is not currently possible to determine whether the below-average 1999 YCS was real or an underestimate of the true abundance. This issue cannot be further addressed until 2004 onwards after the year class has recruited to the adult population. If the trawl survey did accurately measure YCS, then it is clear that the temperature-recruitment relationship derived previously does not adequately predict YCS under all possible conditions.

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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	No. of stations Phase 2	Density (per km^2)
1149	Waiheke, Tamaki Strait	10–25	64.5	3		1 : 21.5
1219	Central Gulf	25–50	888.1	4		1 : 222.0
1268	Outer Firth of Thames	25–45	312.2	3	4	1 : 44.6
1284	Kawau, Whangaparaoa	10–25	73.2	4		1 : 18.3
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	3		1 : 1070.7
1887	Inner Firth of Thames	10–25	270.2	3	2	1 : 54.0
2229	Inner Gulf	25–45	559.9	6		1 : 93.3
4492	Outer Gulf	10–75	2 405.2	7		1 : 343.6
9292	West Coromandel	10–25	66.6	3		1 : 22.2
Total			8 216.1	42	6	

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*	13 096.3	88.8	100.0
Jack mackerel	JMN	*Trachurus novaezelandiae*	799.5	5.4	89.6
Tarakihi	TAR	*Nemadactylus macropterus*	262.2	1.8	8.3
John dory	JDO	*Zeus faber*	226.4	1.5	85.4
Barracouta	BAR	*Thyrsites atun*	87.4	0.6	43.8
Leatherjacket	LEA	*Parika scaber*	62.0	0.4	35.4
Arrow squid	SQU	*Nototodarus sloanii*	34.7	0.2	20.8
Eagle ray	EGR	*Myliobatis tenuicaudatus*	29.3	0.2	20.8
School shark	SCH	*Galeorhinus australis*	23.7	0.2	4.2
Red gurnard	GUR	*Chelidonichthys kumu*	22.7	0.2	22.9
Jack mackerel	JMD	*Trachurus declivis*	19.2	0.1	4.2
Frostfish	FRO	*Lepidopus caudatus*	12.0	0.1	6.3
Trevally	TRE	*Pseudocaranx dentex*	10.5	0.1	14.6
Hammerhead shark	HHM	*Sphyrna zygaena*	9.6	0.1	4.2
Broad squid	BSQ	*Sepioteuthis bilineata*	7.9	0.1	20.8
Blue mackerel	EMA	*Scomber australasicus*	6.7	<0.1	14.6
Kahawai	KAH	*Arripis trutta*	6.2	<0.1	8.3
Rig	SPO	*Mustelus lenticulatus*	5.6	<0.1	6.3
Pilchard	PIL	*Sardinops neopilchardus*	4.7	<0.1	16.7
Longtailed stingray	WRA	*Dasyatis thetidis*	3.4	<0.1	6.3
Spotted stargazer	SPZ	*Genyagnus monopterygius*	3.4	<0.1	4.2
Parore	PAR	*Girella tricuspidata*	3.4	<0.1	2.1
Octopus	OCT	*Octopus* sp.	3.2	<0.1	2.1
Red snapper	RSN	*Centroberyx affinis*	3.1	<0.1	2.1
Jack mackerel	JMM	*Trachurus murphyii*	2.6	<0.1	2.1
Boarfish	BOA		1.8	<0.1	2.1
Red mullet	RMU	*Upeneichthys lineatus*	1.1	<0.1	6.3
Sand flounder	SFL	*Rhombosolea plebeia*	0.4	<0.1	2.1
Spotty	STY	*Notolabrus celidotus*	0.4	<0.1	2.1
Scaly gurnard	SCG	*Lepidotrigla brachyoptera*	0.1	<0.1	2.1
Anchovy	ANC	*Engraulis australis*	0.1	<0.1	2.1
Yellow-eyed mullet	YEM	*Aldrichetta forsteri*	0.1	<0.1	2.1
Long finned boarfish	LFB	*Zanclistius elevatus*	0.1	<0.1	2.1
Mirror dory	MDO	*Zenopsis nebulosus*	0.1	<0.1	2.1
Opalfish	OPA	*Hemerocoetes spp.*	0.1	<0.1	2.1
Paddle crab	PAD	*Ovalipes cathams*	0.1	<0.1	2.1
Yellowbellied flounder	YBF	*Rhombosolea leporina*	0.1	<0.1	2.1
Porcupine fish *(not weighed, water inflation)*	POP	*Allomycterus jaculiferus*			
		Total	14 750.2		

Table 3: **Estimated biomass (t) and coefficient of variation (*c.v.*, in parentheses) by stratum of snapper (SNA), John dory (JDO), red gurnard (GUR), jack mackerel (JMN), tarakihi (TAR), barracouta (BAR), and leatherjacket (LEA)**

Stratum	SNA < 25 cm	SNA > 24 cm	SNA Total	JDO	GUR	JMN	TAR	BAR	LEA
1149	39	251	291	4	0	22	0	0	0
	(14)	(68)	(60)	(9)		(19)			
1219	125	253	378	9	6	224	0	7	6
	(36)	(23)	(22)	(30)	(91)	(37)		(71)	(39)
1268	478	1209	1 687	30	2	90	0	4	<1
	(13)	(28)	(21)	(24)	(84)	(40)		(96)	
1284	53	129	182	3	0	4	0	0	0
	(29)	(33)	(20)	(43)		(97)			
1386	49	1009	1 057	2	0	3	0	0	0
	(54)	(88)	(87)	(86)		(44)			
1449	50	206	256	1	0	28	0	3	15
	(56)	(93)	(85)	(74)		(99)		(50)	(23)
1518	6	80	86	69	0	64	75	80	0
	(55)	(40)	(40)	(57)		(97)	(91)	(62)	
1887	295	200	495	23	<1	92	0	0	0
	(19)	(38)	(21)	(7)		(44)			
2229	195	407	603	15	3	126	0	10	2
	(39)	(44)	(28)	(23)	(70)	(16)		(67)	(68)
4492	366	2299	2 665	102	12	166	680	119	95
	(38)	(76)	(70)	(53)	(76)	(49)	(97)	(77)	(45)
9292	36	33	68	2	<1	1	0	0	<1
	(55)	(68)	(60)	(57)		(60)			
Total	1 693	6 076	7 768	260	24	822	755	223	117
	(11)	(33)	(27)	(26)	(46)	(18)	(88)	(47)	(37)

Table 4: **Species and number of fish and squid measured**

Common name	No. of tows in which species occurred	No. of fish	No. of males	No. of females	No. of unsexed	No. of otoliths males	females	unsexed
Snapper	48	10 949	3 535	2 934	4 480	253	218	197
Jack mackerel (*Trachurus novaezelandiae*)	43	3 282	–	–	3 282	–	–	–
John dory	41	232	78	129	25	72	94	23
Barracouta	21	695	2	2	691	–	–	–
Leatherjacket	17	273	–	–	273	–	–	–
Red gurnard	11	106	26	74	7	19	56	7
Arrow squid	10	278	–	–	278	–	–	–
Eagle ray	10	15	4	9	2	–	–	–
Broad squid	10	32	–	–	32	–	–	–
Pilchard	8	110	–	–	110	–	–	–
Trevally	7	70	3	–	70	–	–	–
Blue mackerel	7	75	–	–	75	–	–	–
Tarakihi	4	186	90	94	2	–	–	–
Kahawai	4	14	3	3	8	–	–	–
Frostfish	3	26	–	–	26	–	–	–
Rig	3	3	3	–	3	–	–	–
Longtailed stingray	3	3	2	1	3	–	–	–
Red mullet	3	5	–	–	5	–	–	–
School shark	2	3	2	–	3	–	–	–
Jack mackerel (*Trachurus declivis*)	2	230	–	–	230	–	–	–
Hammerhead shark	2	4	2	2	–	–	–	–
Spotted stargazer	2	3	–	–	3	–	–	–
Parore	1	5	–	–	5	–	–	–
Red snapper	1	36	–	–	36	–	–	–
Jack mackerel (*Trachurus murphyii*)	1	2	–	–	2	–	–	–
Boarfish	1	1	–	1	1	–	–	–
Sand flounder	1	2	–	2	–	–	–	–
Spotty	1	5	–	–	5	–	–	–
Scaly gurnard	1	1	–	–	1	–	–	–
Anchovy	1	1	–	–	1	–	–	–
Yellow-eyed mullet	1	1	–	–	1	–	–	–
Long finned boarfish	1	2	–	–	2	–	–	–
Mirror dory	1	1	–	–	1	–	–	–
Opalfish	1	2	–	–	2	–	–	–
Yellowbellied flounder	1	1	–	–	1	–	–	–

– no data or fish not sexed

Table 5: **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	888	17 - 57	0.0429	2.8002	0.99
	Female	669	18 - 57	0.0384	2.8336	0.99
	All fish	3 634	7 - 57	0.0411	2.8130	0.99
John dory	Male	74	25 - 45	0.0084	3.1890	0.96
	Female	128	18 - 55	0.0027	3.5168	0.94
	All fish	227	13 - 55	0.0021	3.5814	0.95
Red gurnard	Male	26	18 - 39	0.0104	2.9748	0.99
	Female	74	16 - 39	0.0096	3.0027	0.98
	All fish	106	15 - 39	0.0099	2.9924	0.98

Table 6: **Numbers of male and female snapper, John dory, and red gurnard at each reproductive stage**

Species		No. of fish	Gonad stage					
			1	2	3	4	5	6
Snapper	Males	714	2%	93%	5%	0%	0%	
	Females	653	1%	10%	39%	50%	2%	
John dory	Males	63	2%	35%	41%	22%	0%	0
	Females	128						
Red gurnard	Males	15	0%	80%	20%	0%	0%	
	Females	71	8%	20%	42%	30%	0%	0

–, not applicable

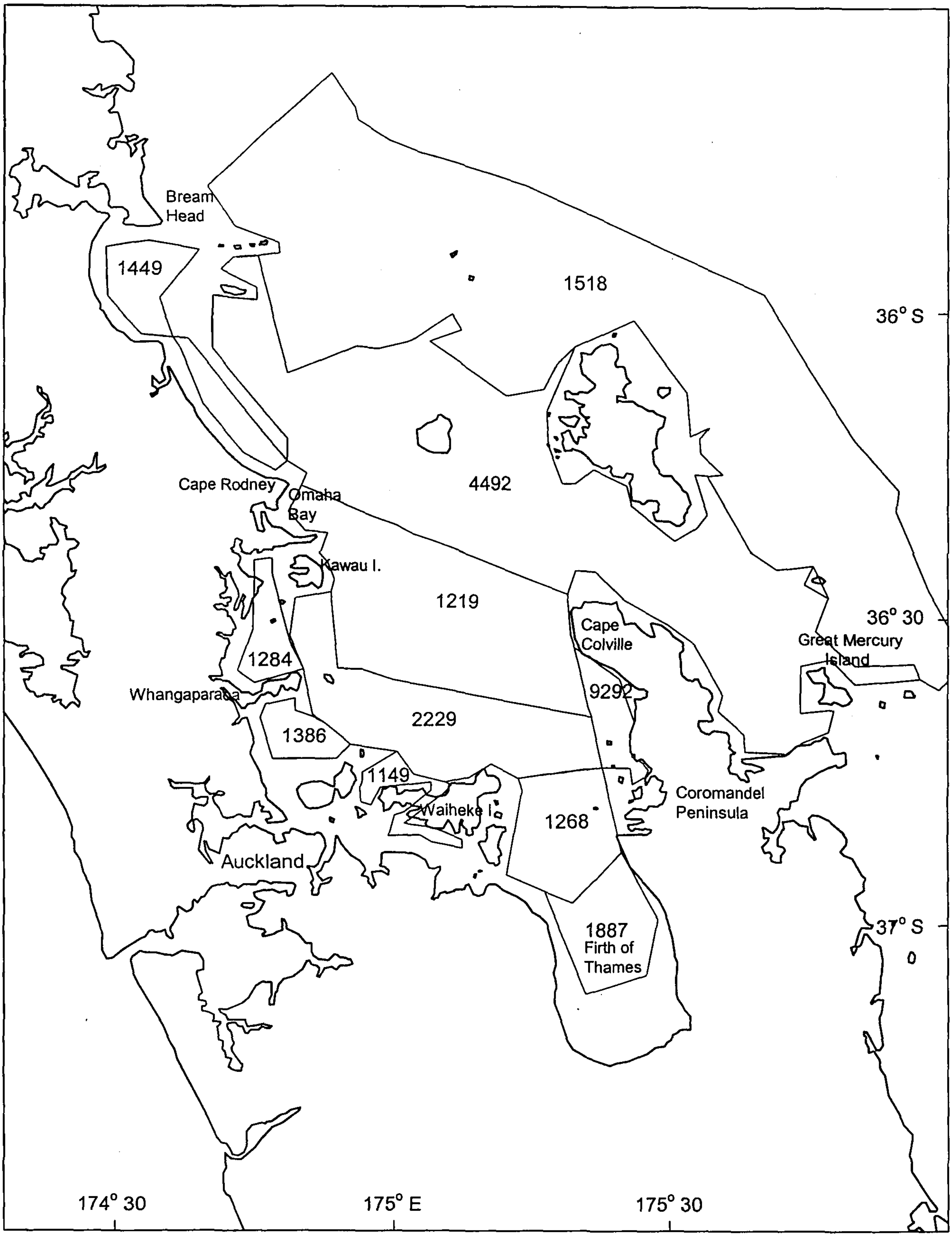


Figure 1: **Survey area and stratum boundaries.**

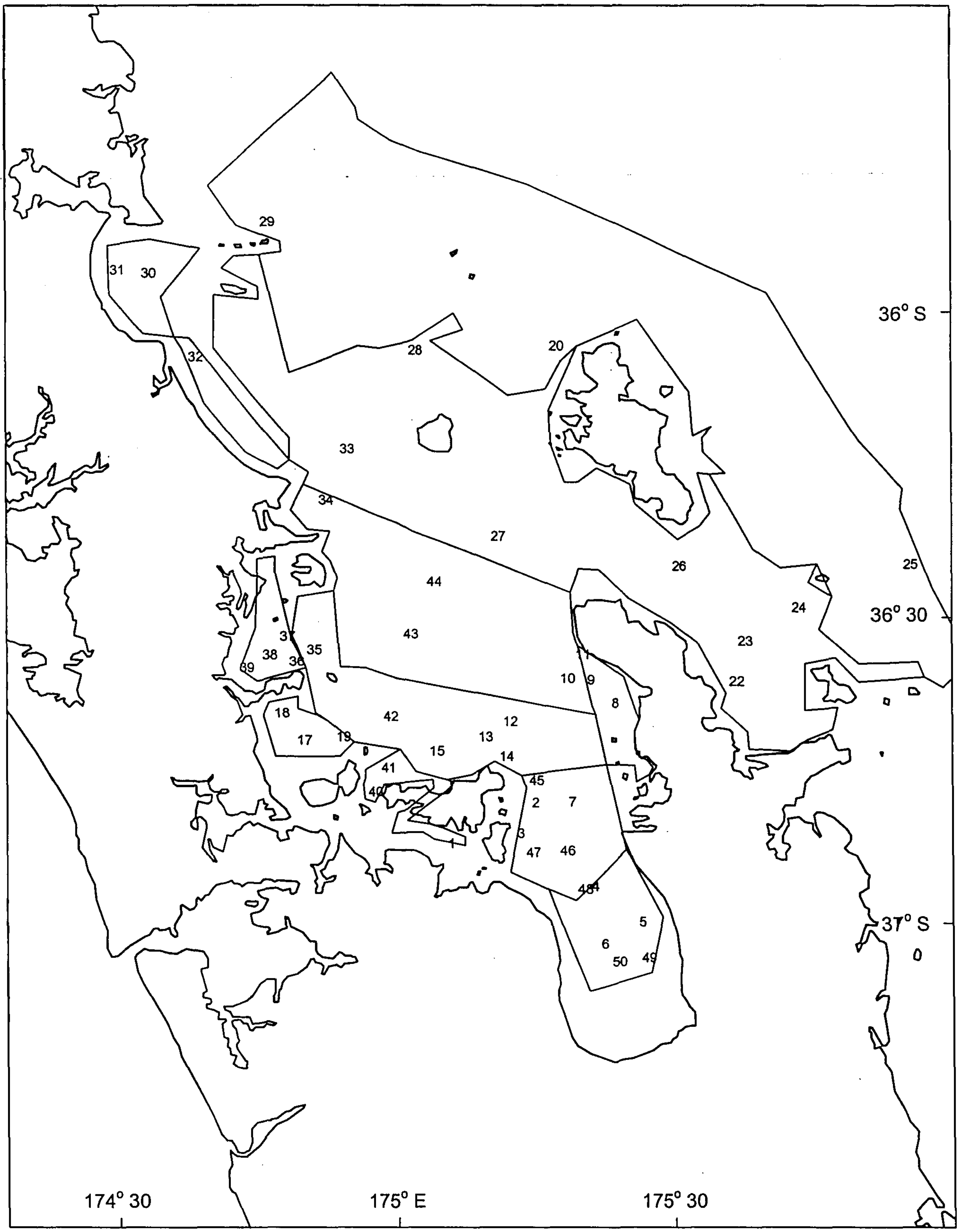


Figure 2: **Station positions and numbers.**

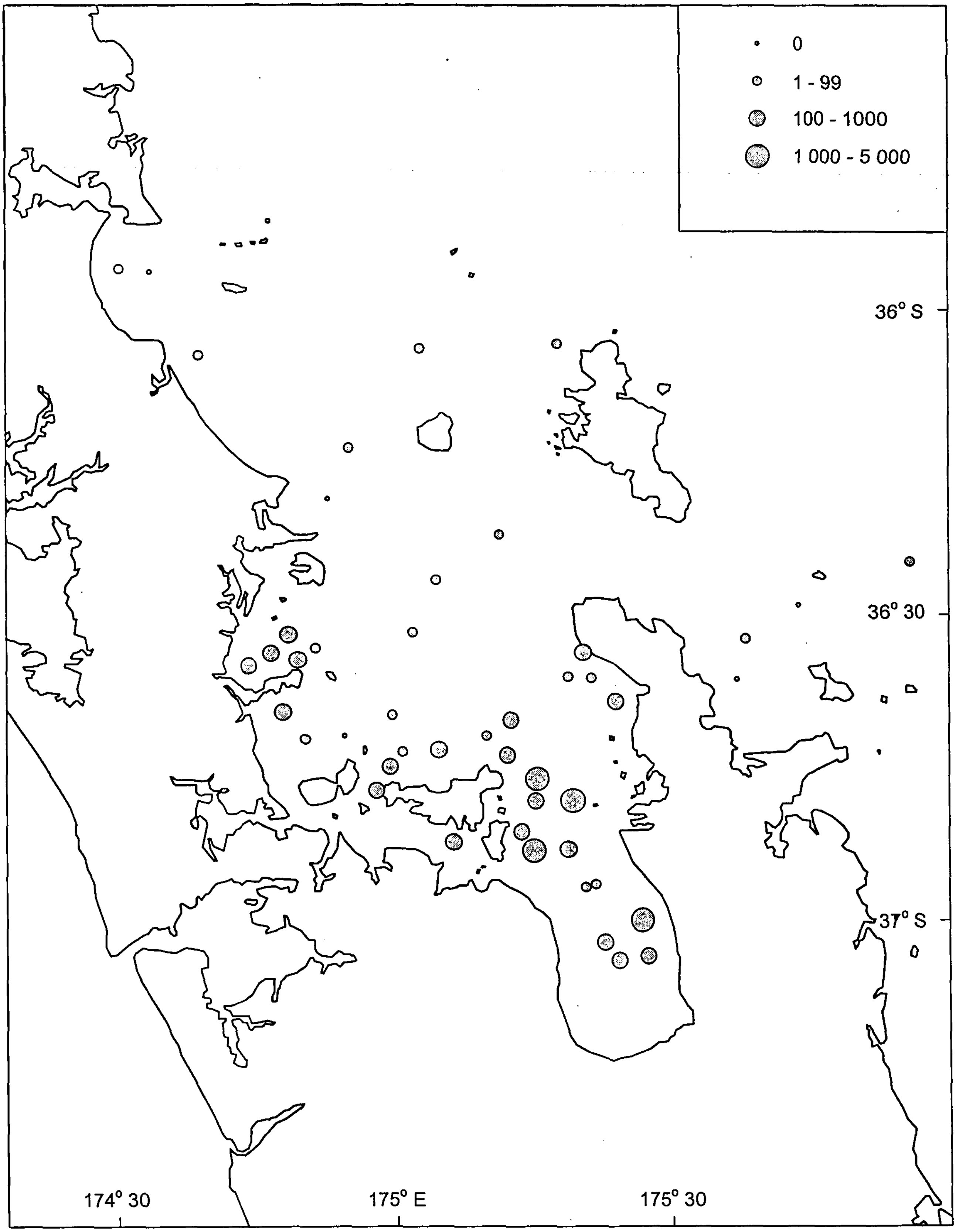


Figure 3: **Catch rates (no.km^{-2}) of 1+ snapper (*Pagrus auratus*).**

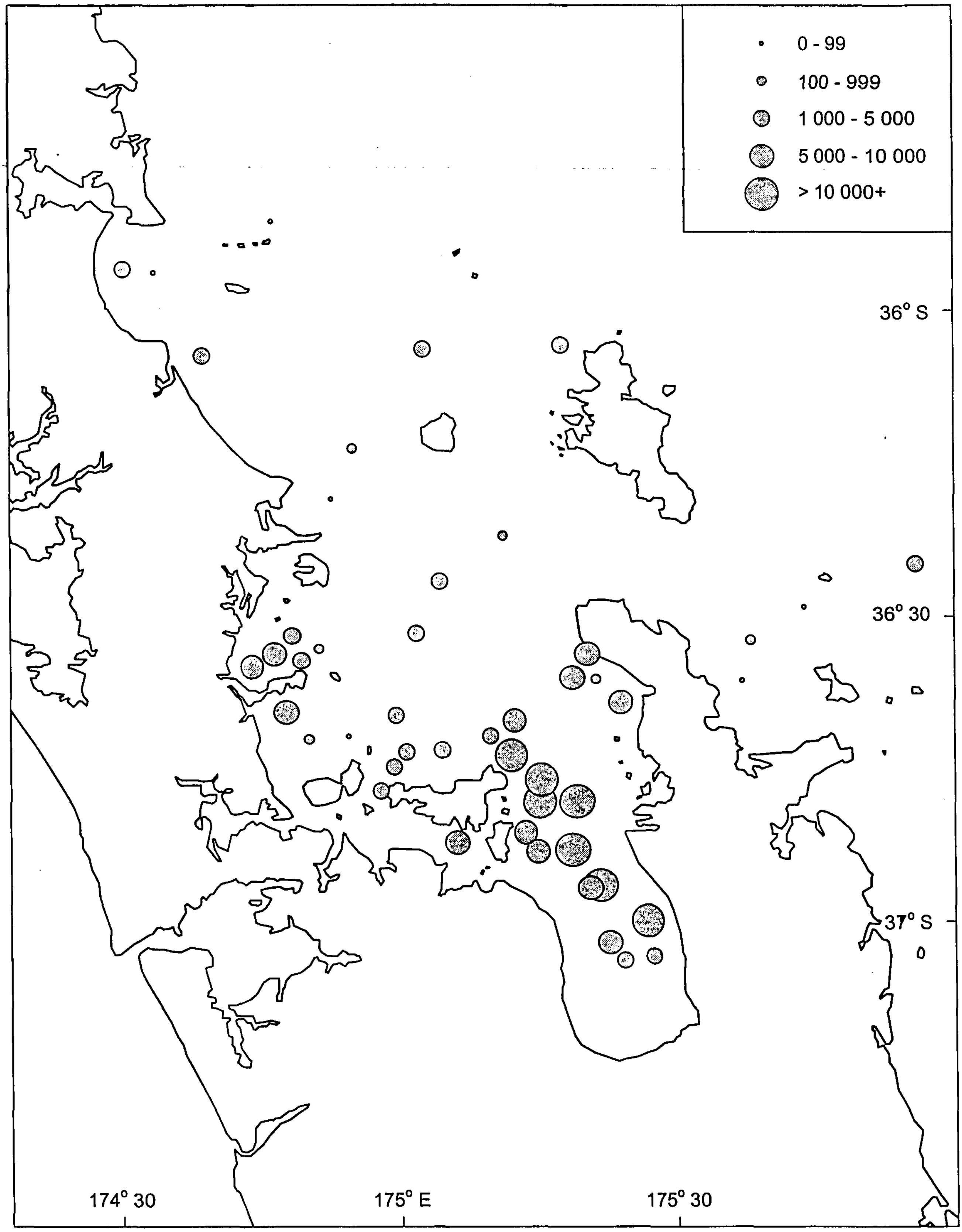


Figure 4: **Catch rates (no.km^{-2}) of juvenile (< 25 cm) snapper (*Pagrus auratus*).**

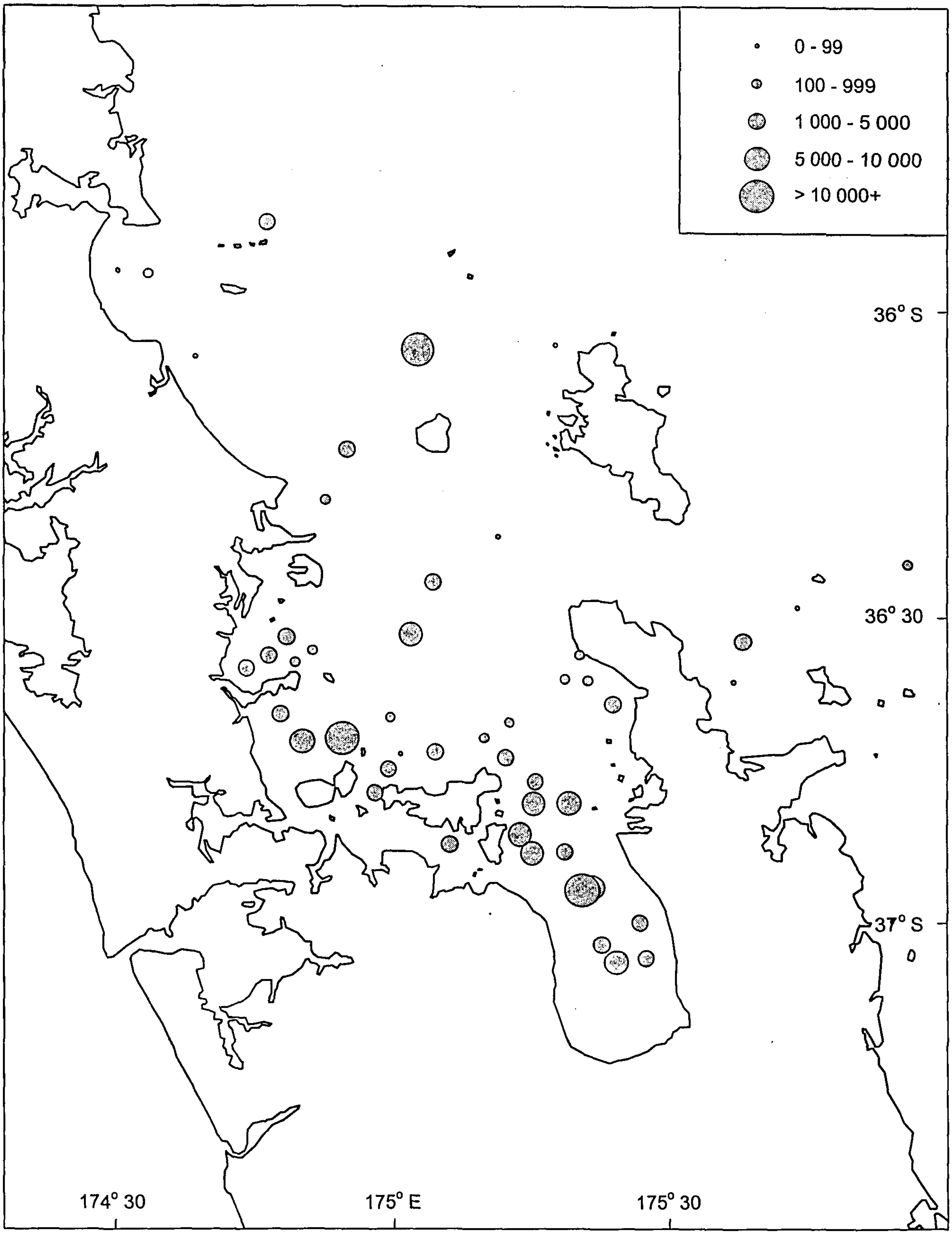


Figure 5: **Catch rates (no.km^{-2}) of adult (> 25 cm) snapper (*Pagrus auratus*).**

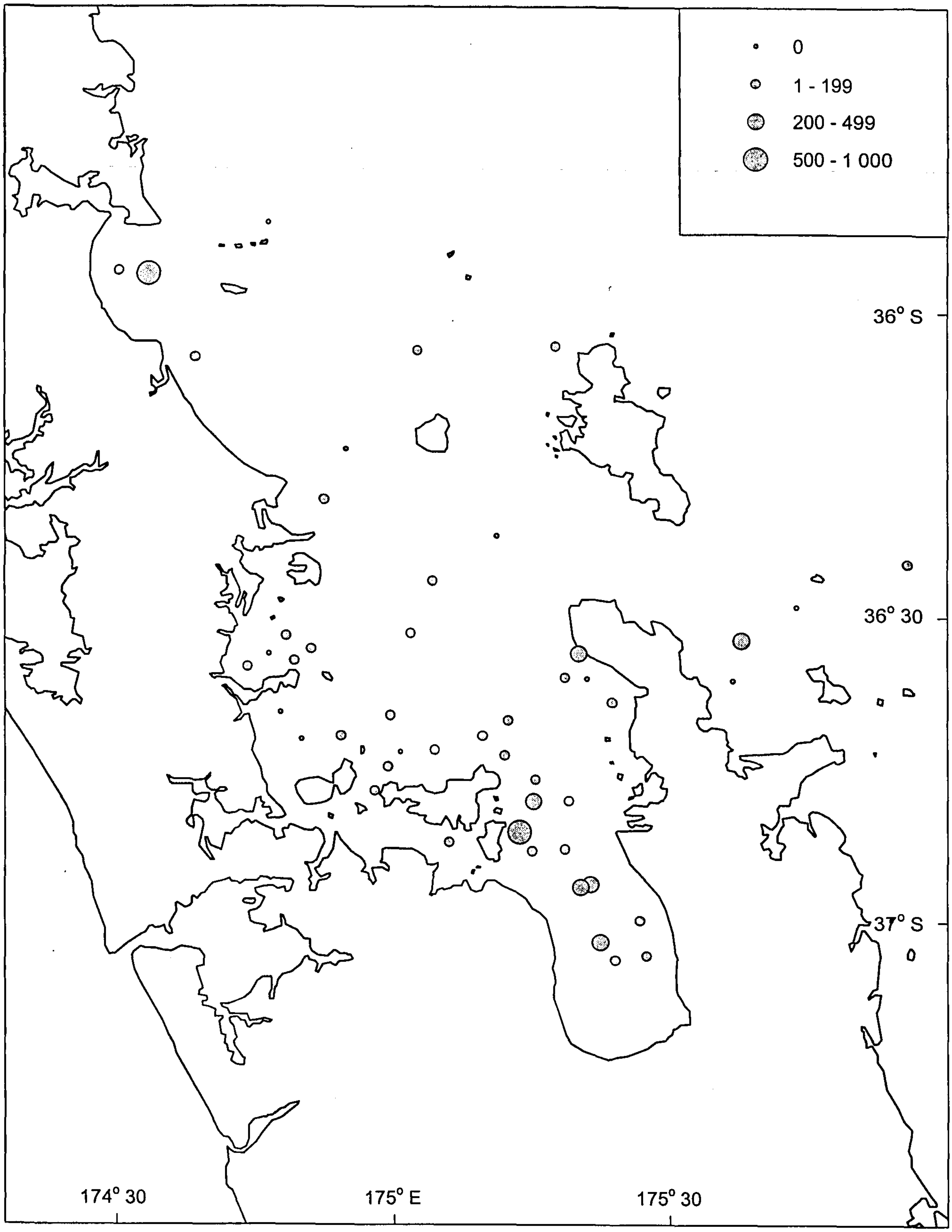


Figure 6: **Catch rates (kg.km^{-2}) of John dory (*Zeus faber*).**

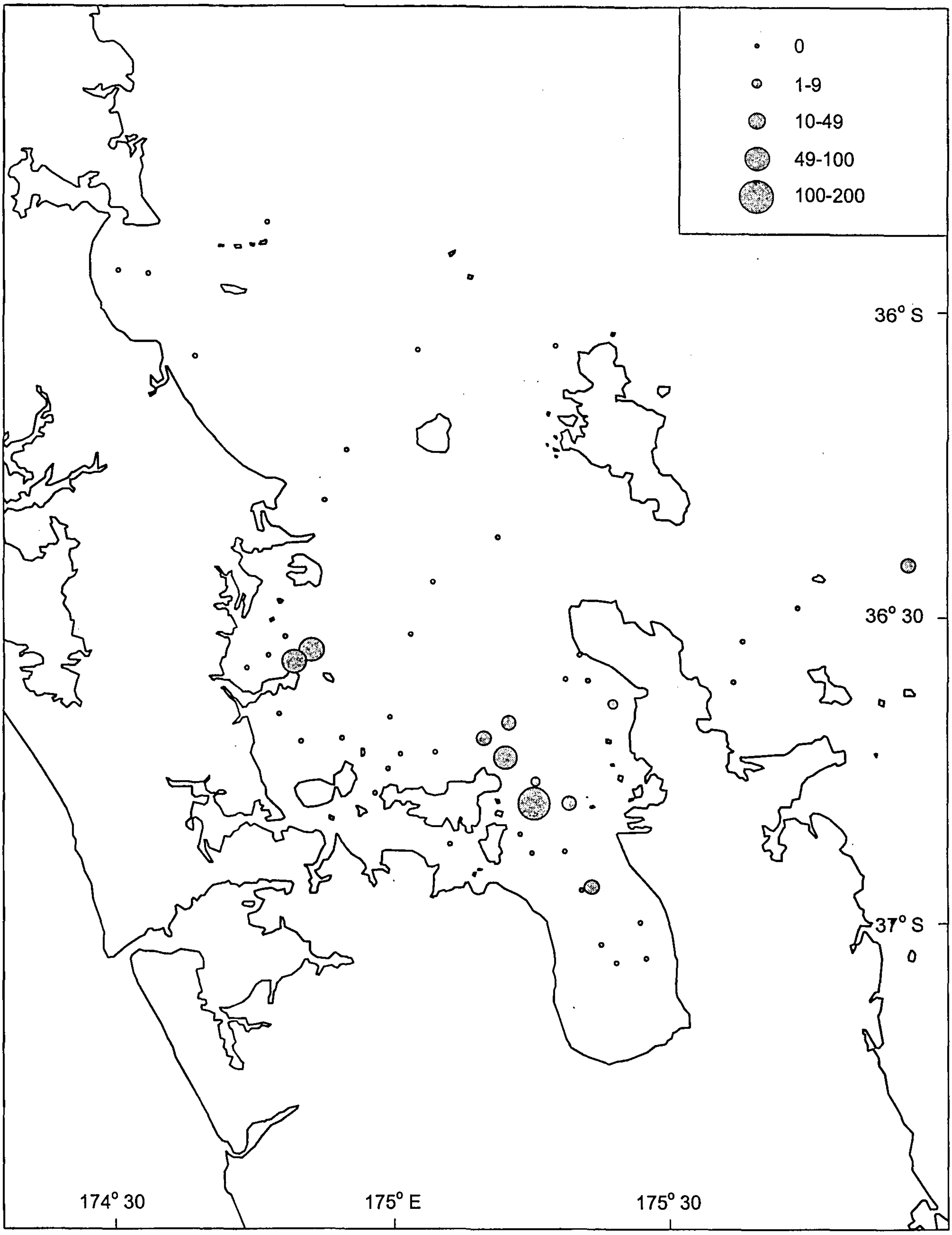


Figure 7: **Catch rates (kg.km^{-2}) of red gurnard (*Chelidonichthys kumu*).**

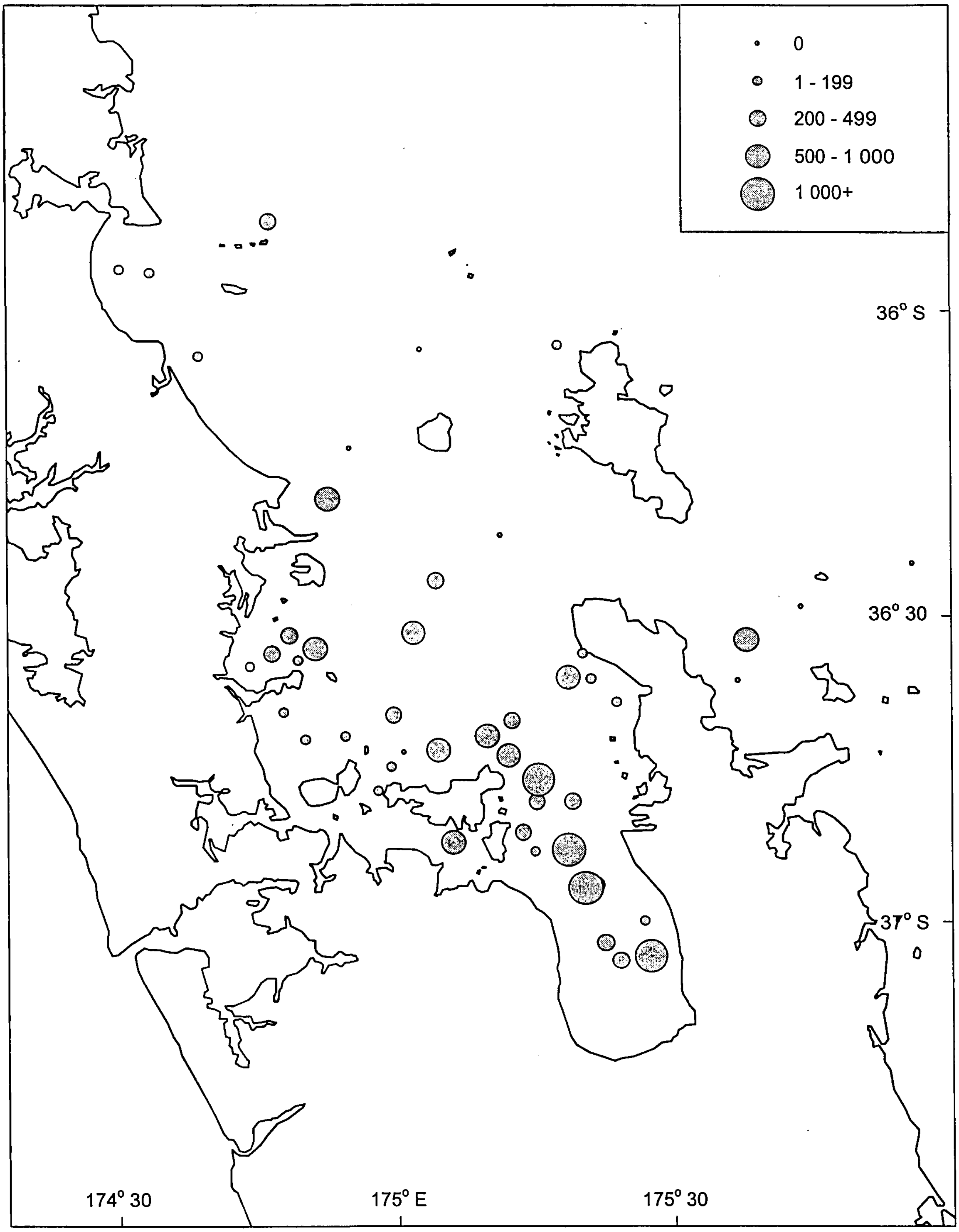


Figure 8: **Catch rates (kg.km^{-2}) of jack mackerel (*Trachurus novaezelandiaea*).**

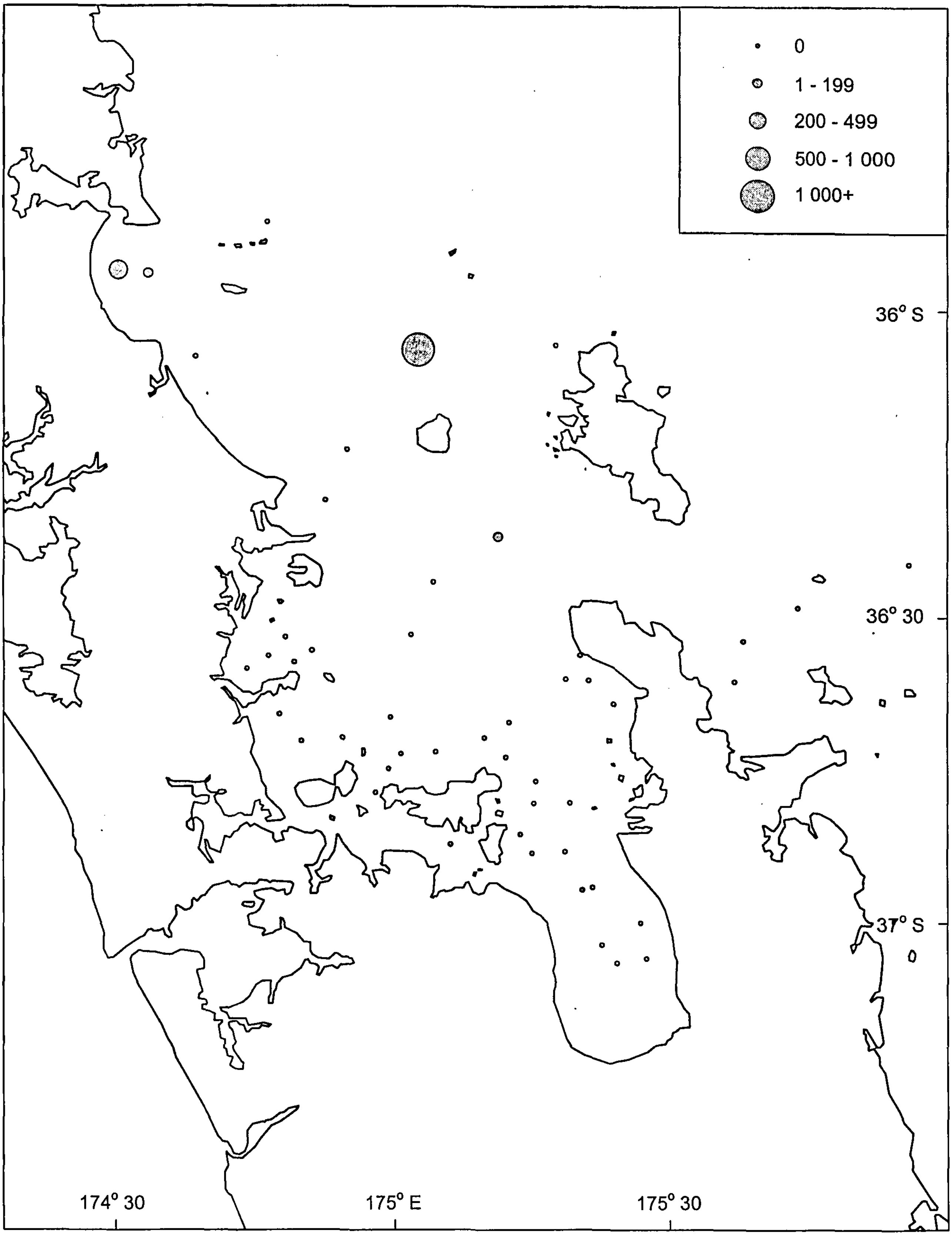


Figure 9: **Catch rates (kg.km^{-2}) of tarakihi (*Nemadactylus macropterus*).**

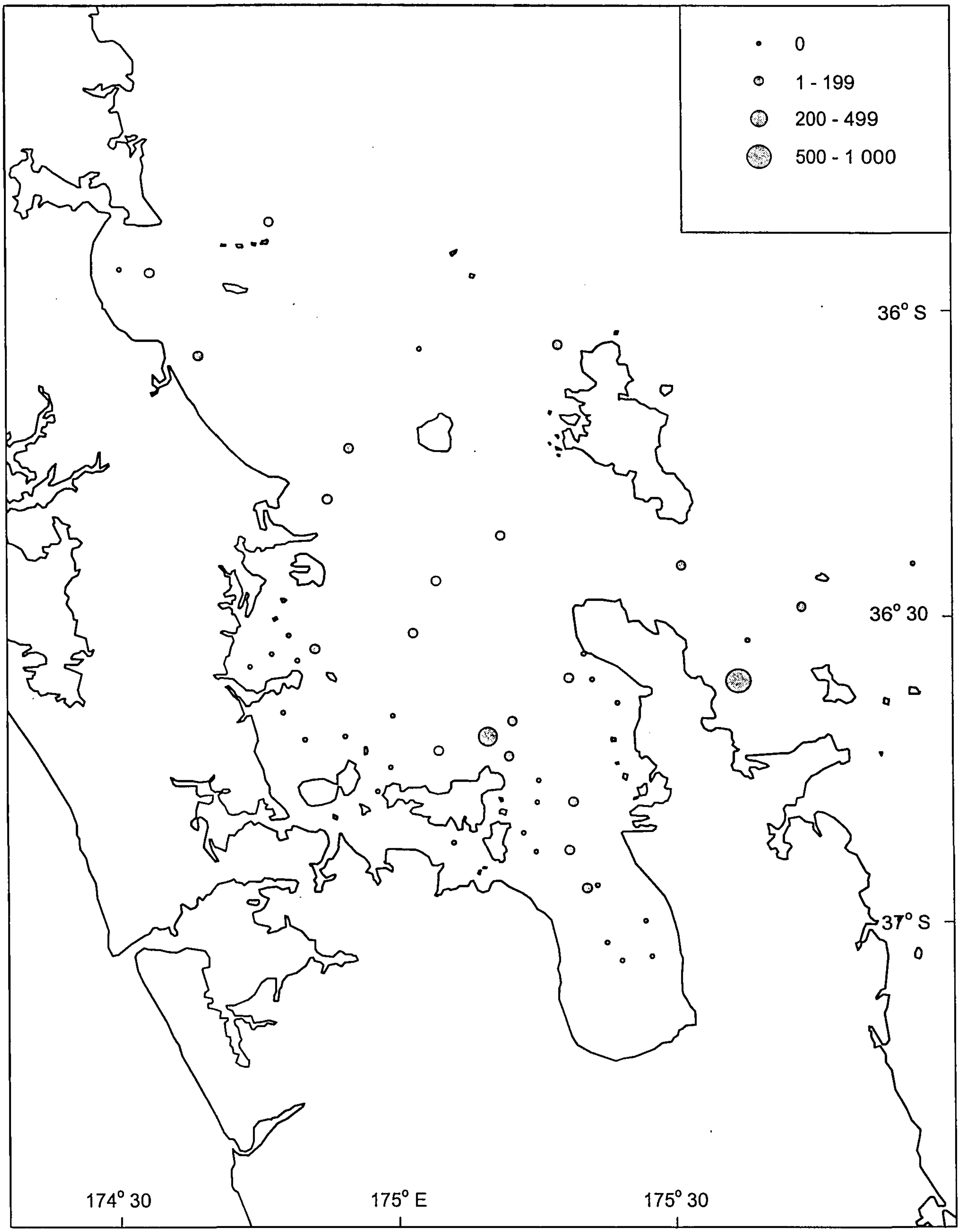


Figure 10: **Catch rates (kg.km^2) of barracouta (*Thyrsites atun*).**

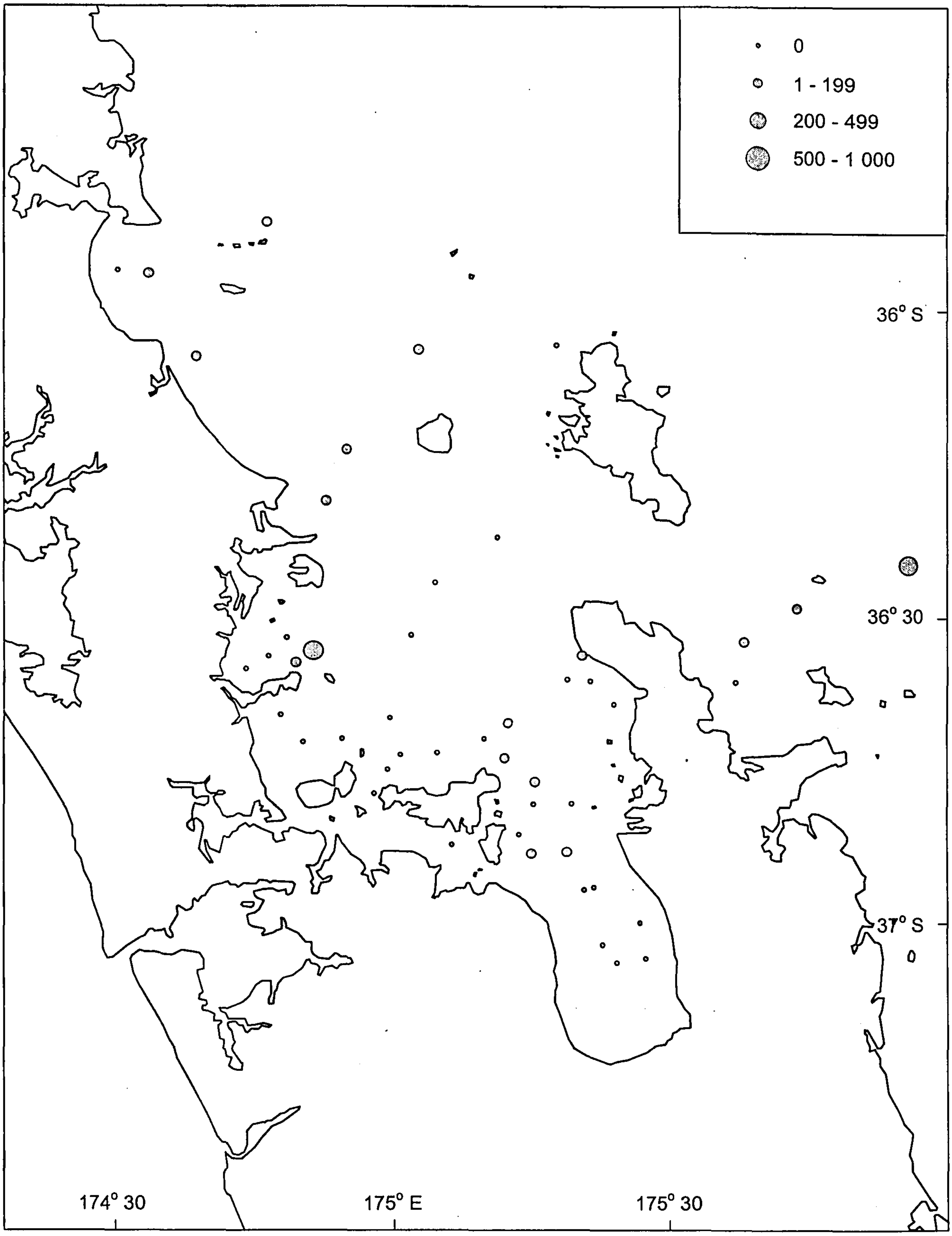


Figure 11: **Catch rates (kg.km^{-2}) of leatherjacket (*Parika scaber*).**

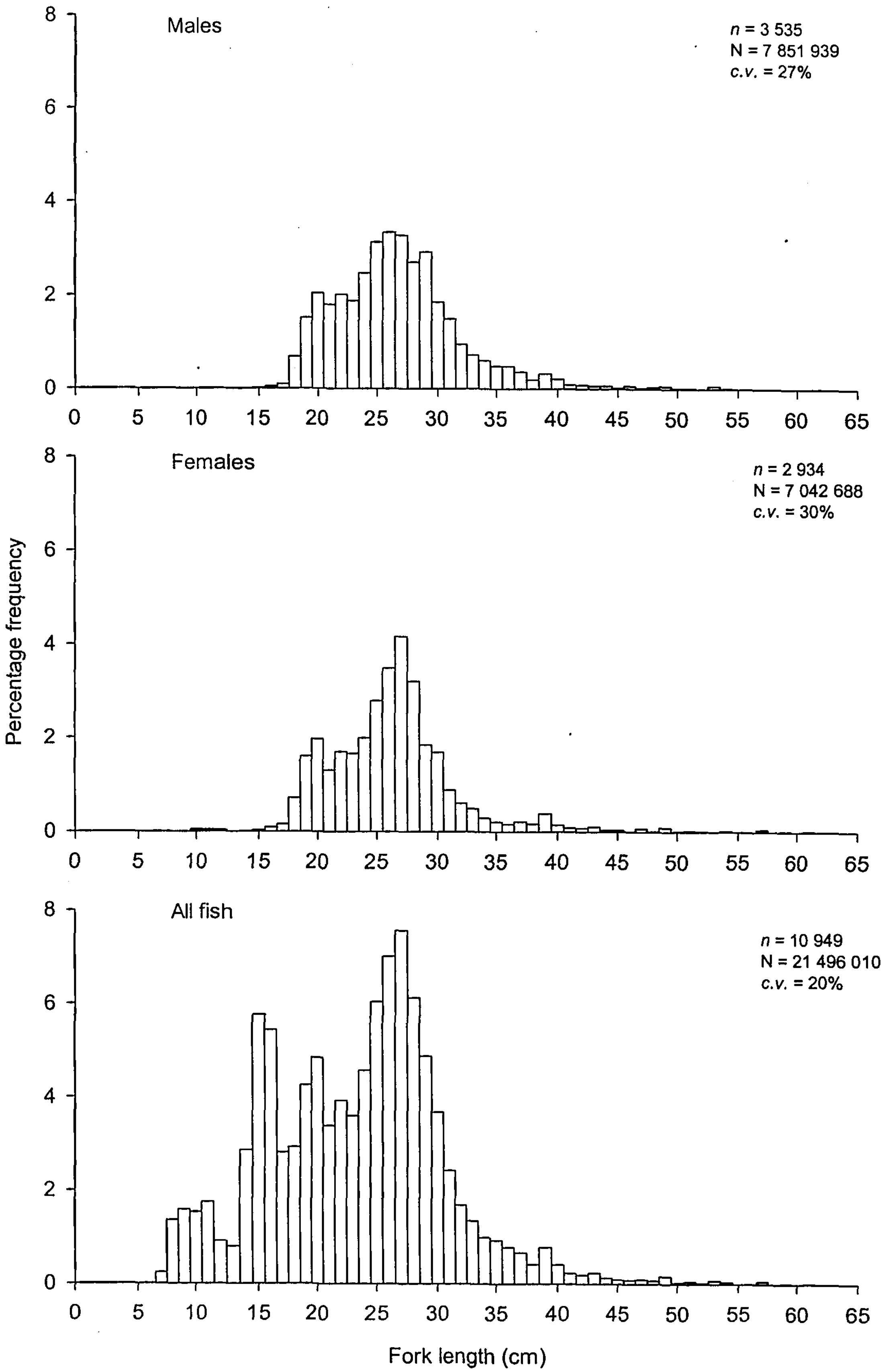


Figure 12**: Length frequency distributions of snapper. *n*, number of fish measured; N, estimated number of fish; *c.v.*, coefficient of variation.**

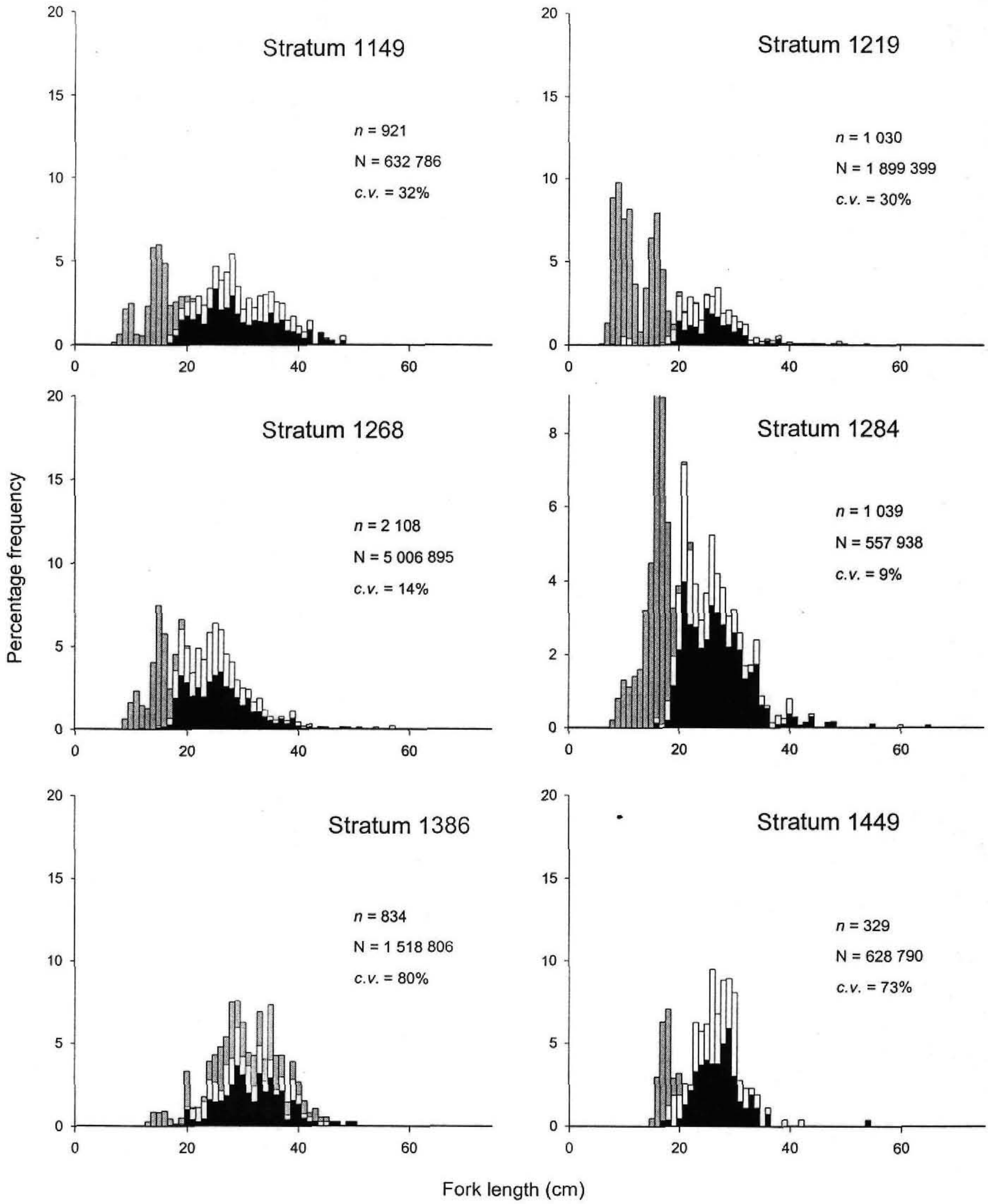


***Figure 13*: Stratum length compositions of snapper. *n*, number of fish measured; N, estimated number of snapper within the stratum; *c.v.*, coefficient of variation.**

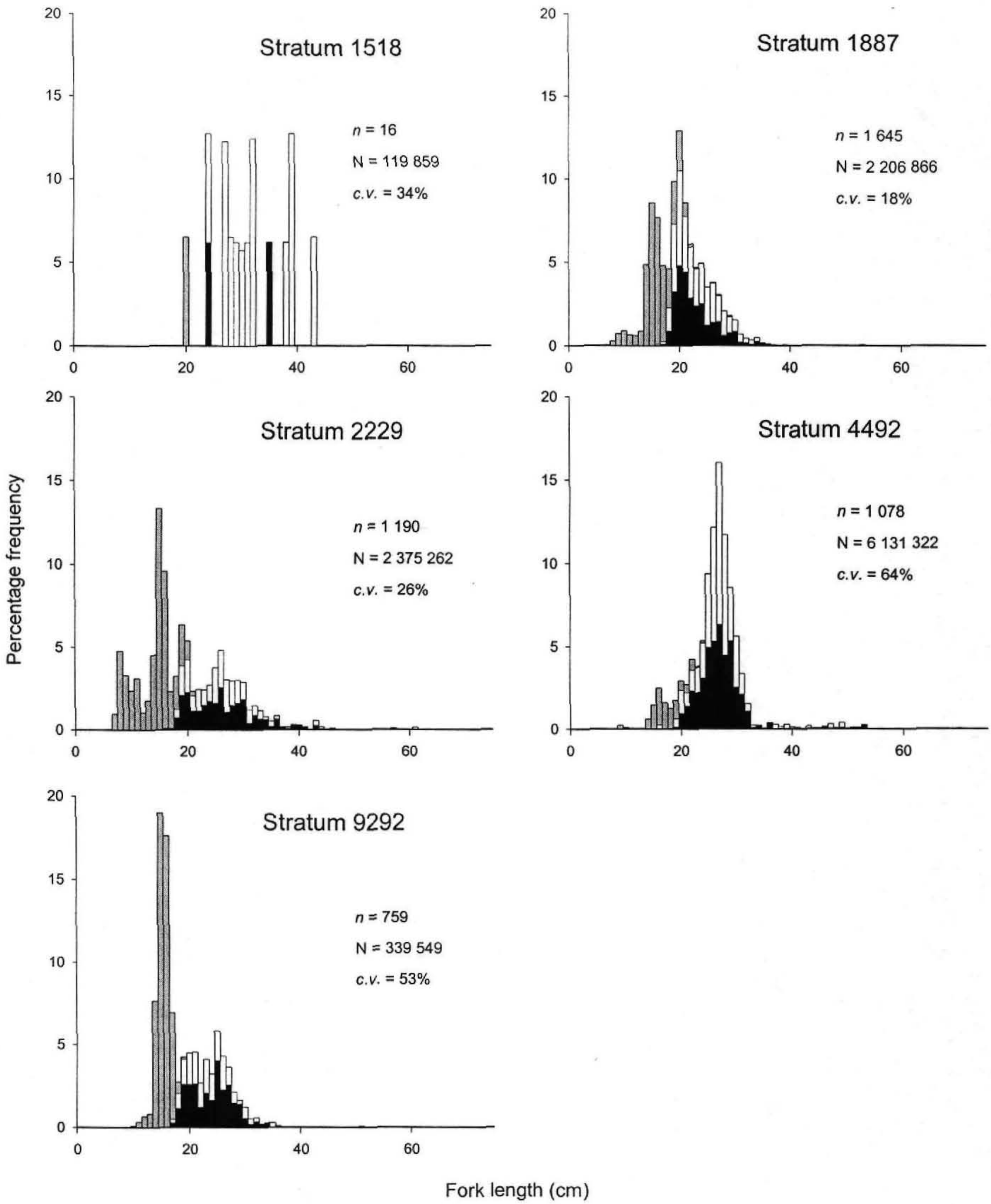


Figure 13 continued.

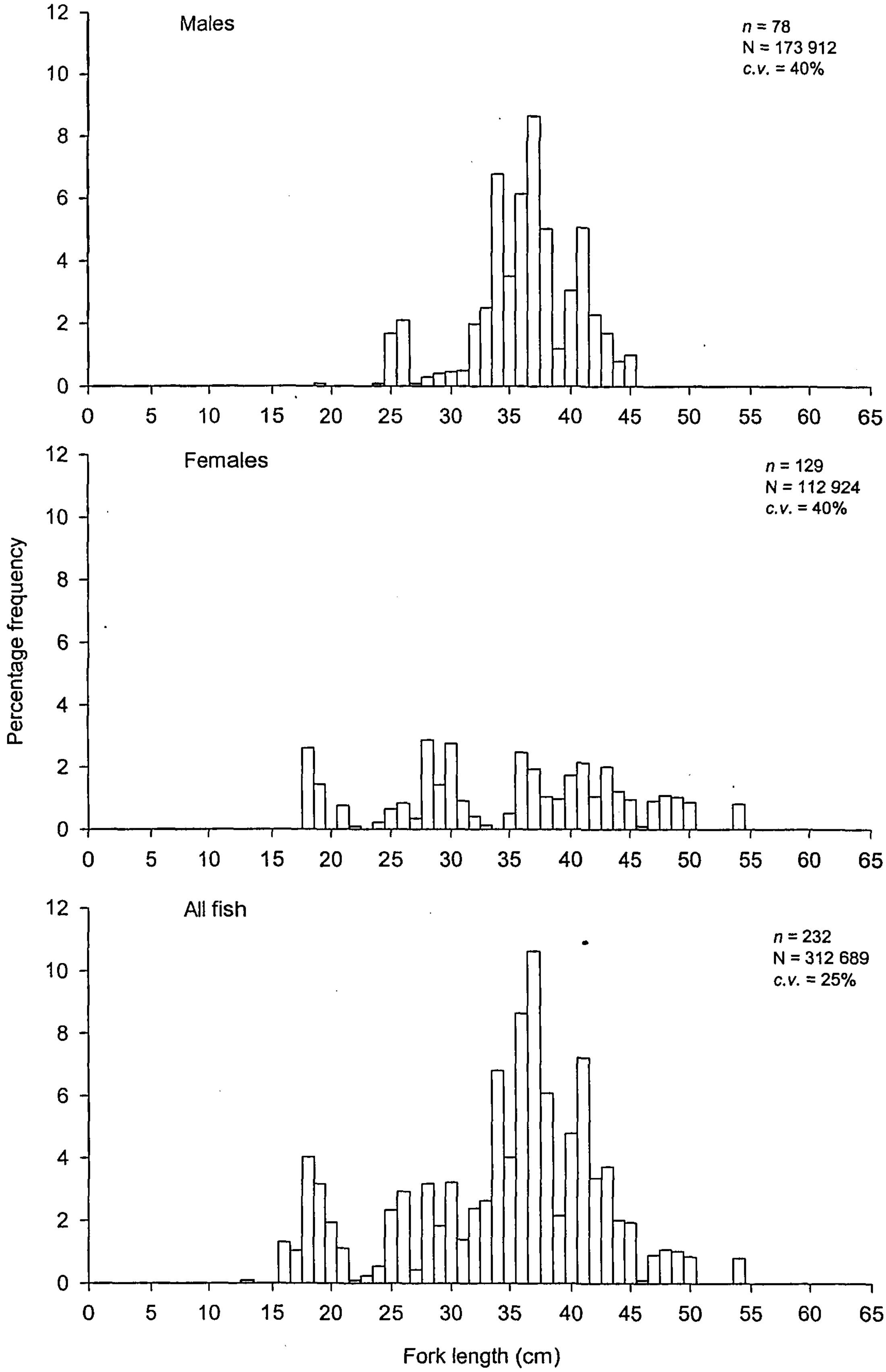


***Figure 14*: Length frequency distributions of john dory. *n*, number of fish measured; N, estimated number of fish; *c.v.*, coefficient of variation.**

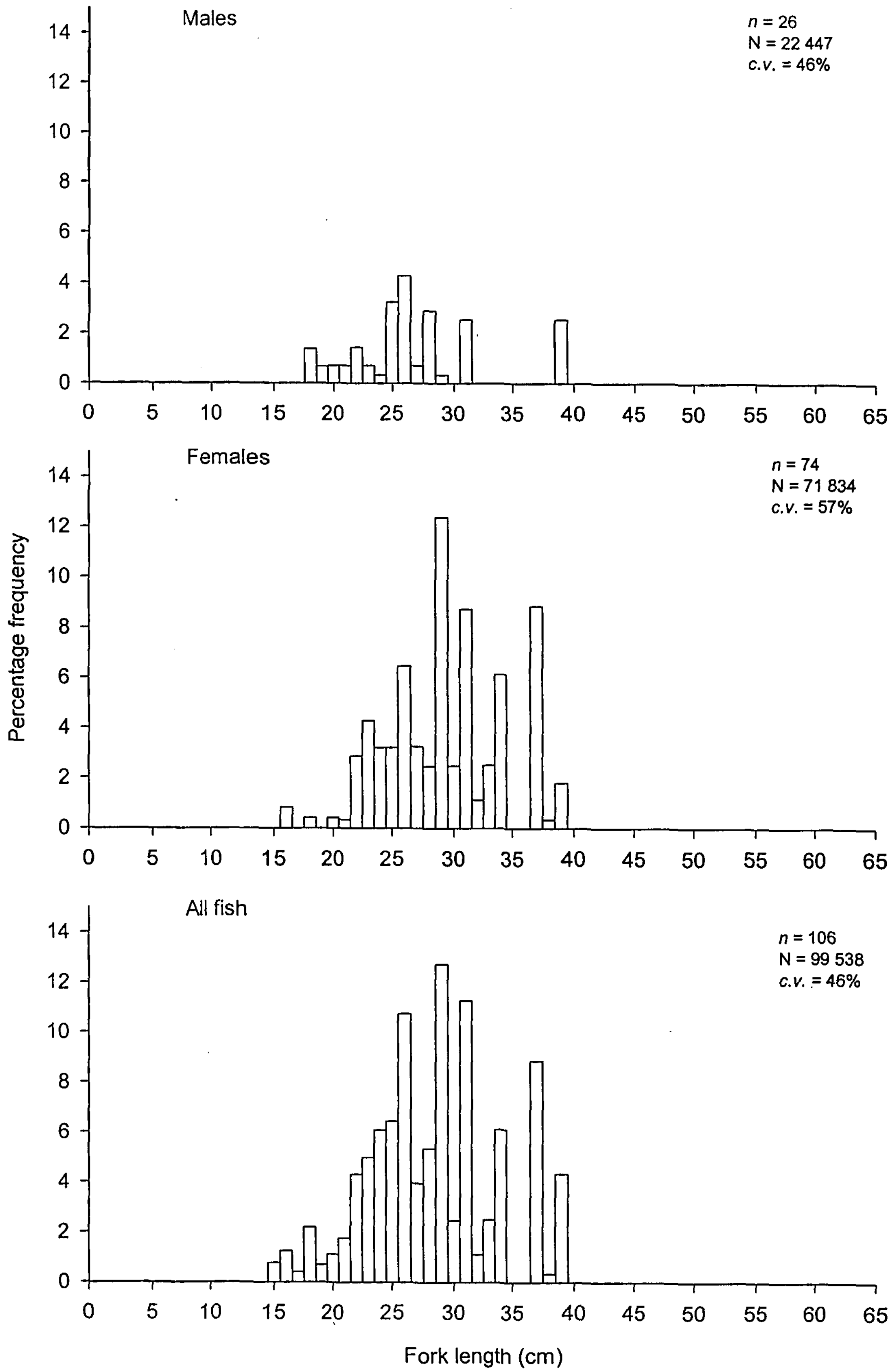


***Figure 15*: Length frequency distributions of red gurnard. *n*, number of fish measured; N, estimated number of fish; *c.v.*, coefficient of variation.**

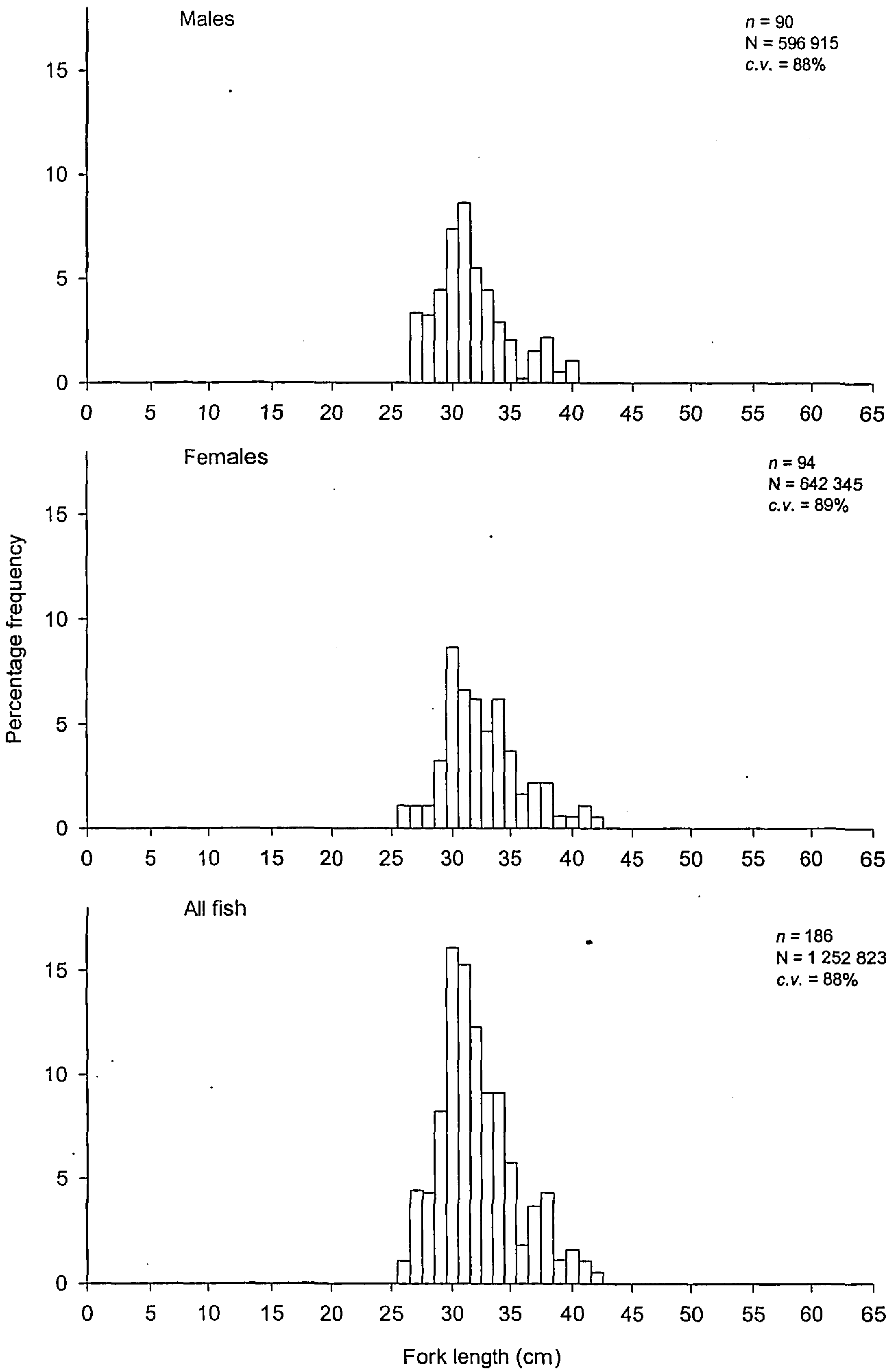
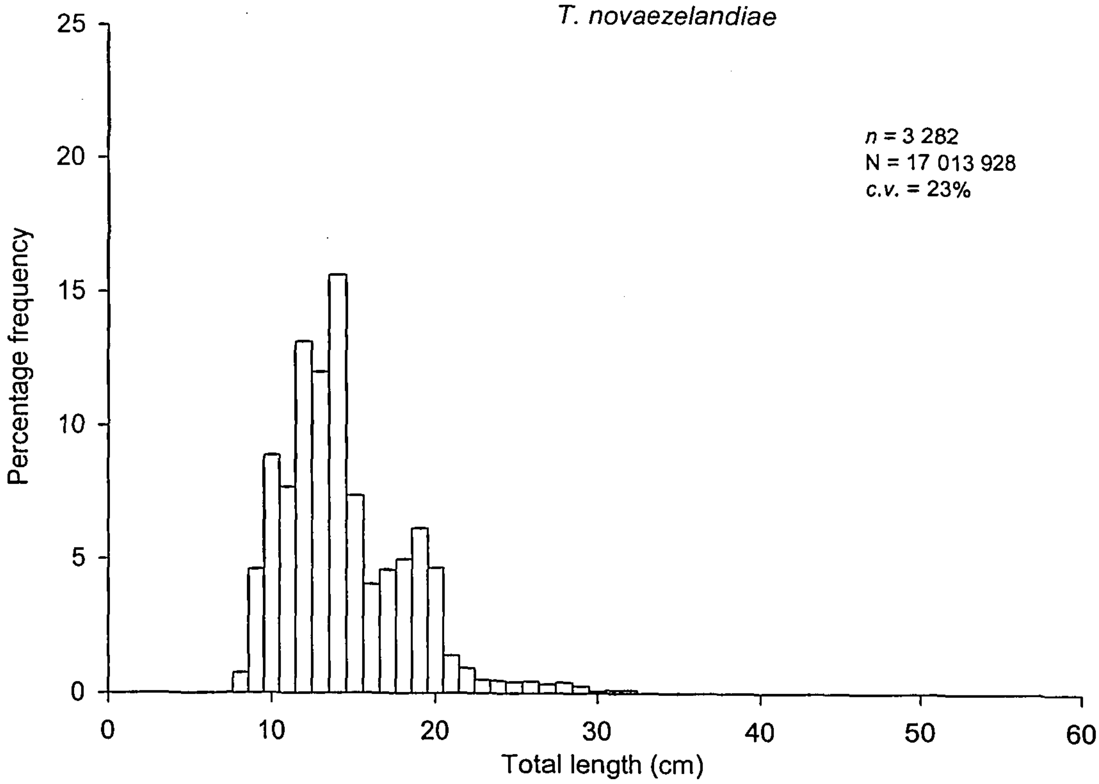


Figure 16: **Length frequency distributions of tarakihi. *n*, number of fish measured; N, estimated number of fish; *c.v.*, coefficient of variation.**

(a)



(b)

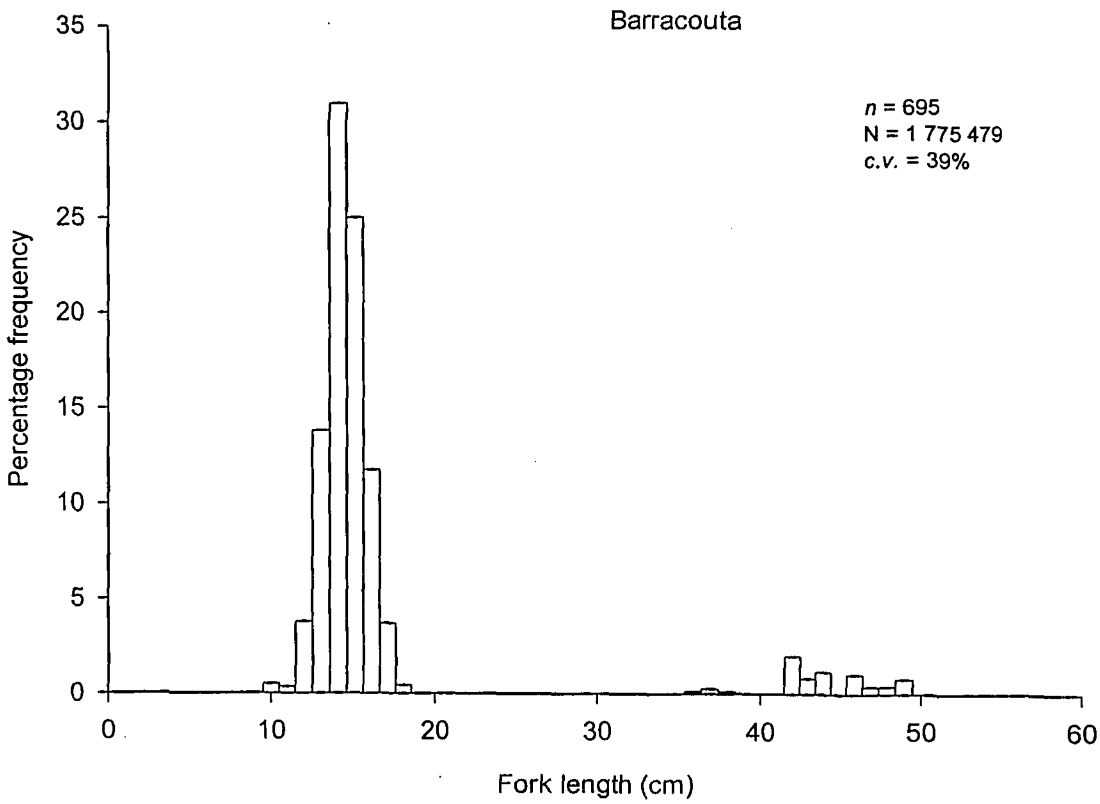


***Figure 17*: Length compositions of jack mackerel (*T. novaezealandiae*) and barracouta.**

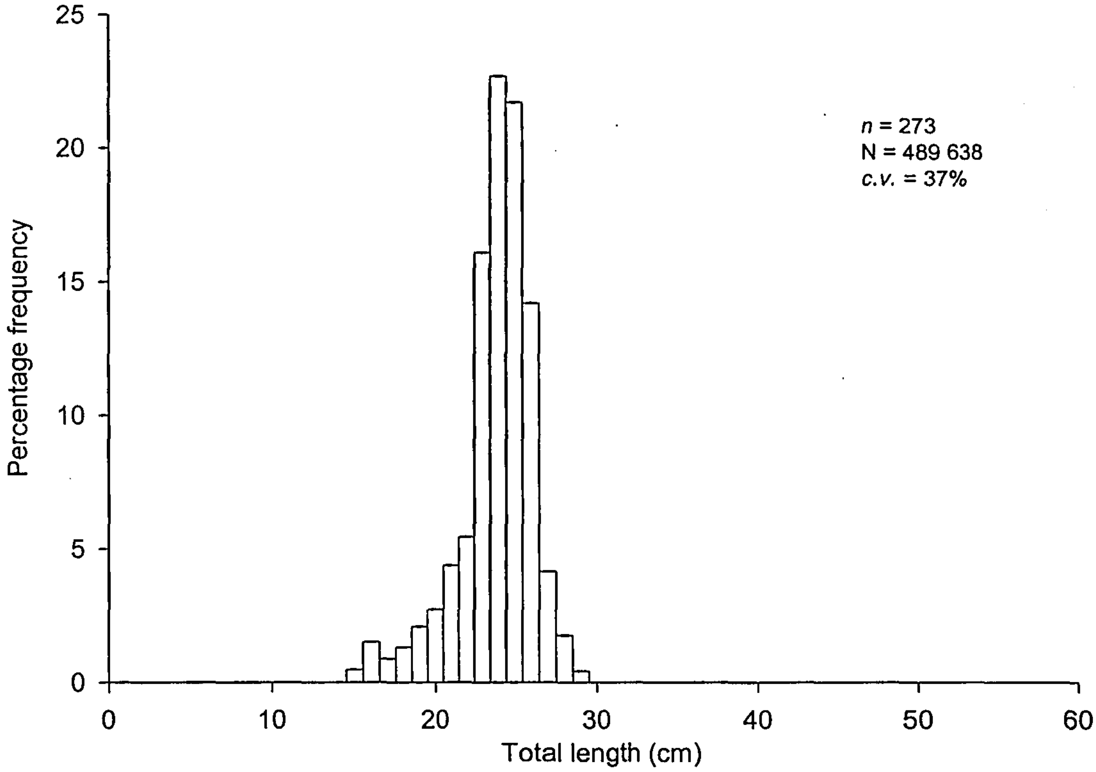


***Figure 18*: Length composition of leatherjacket.**

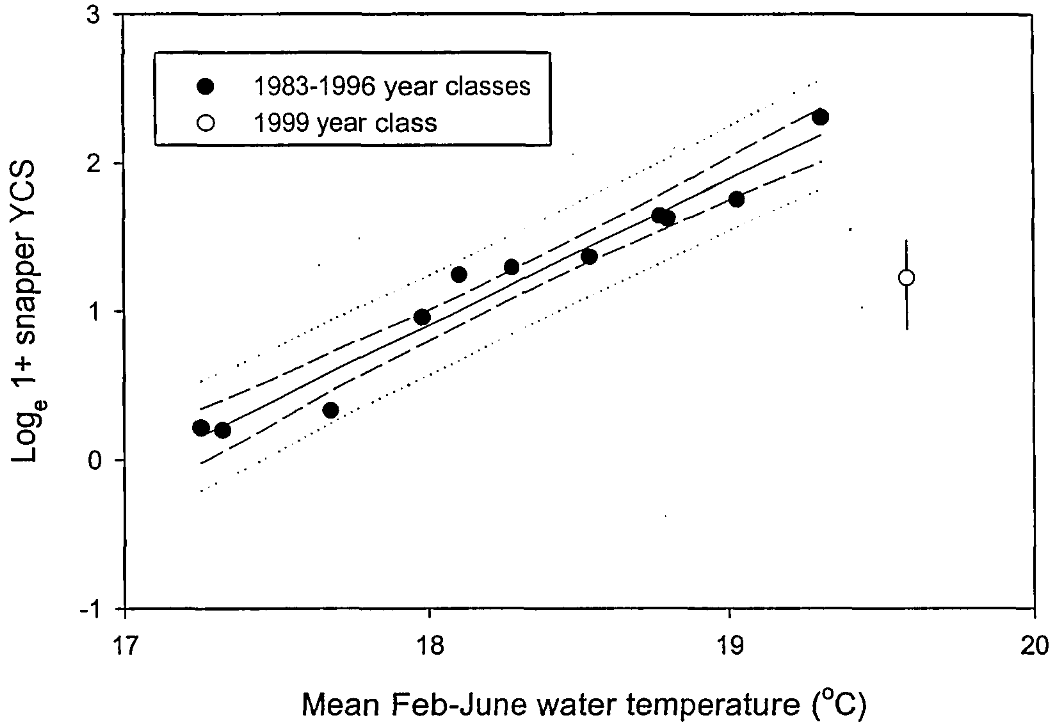


Figure 19: Relationship between snapper year class strengths (YCS) estimated at age 1+ during *Kaharoa* Hauraki Gulf trawl surveys and mean February–June Leigh sea surface temperature. A regression line is fitted to all year classes except 1999, and 95% confidence limits (dashed lines) and prediction limits (dotted lines) for the regression are shown. The 95% confidence limits for the 1999 YCS estimate are also shown.

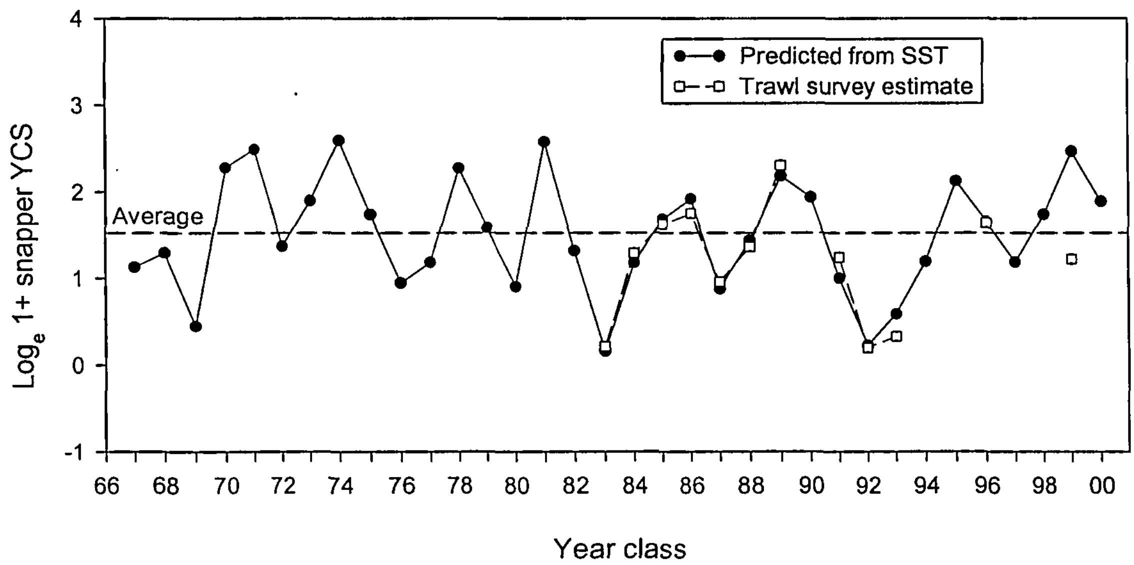


Figure 20: Variation in predicted 1+ snapper year class strength (YCS) calculated from Leigh sea surface temperature (SST). Also shown are the Hauraki Gulf trawl survey estimates of 1+ YCS, scaled to the mean of the predicted YCS for the 1983–1996 year classes.

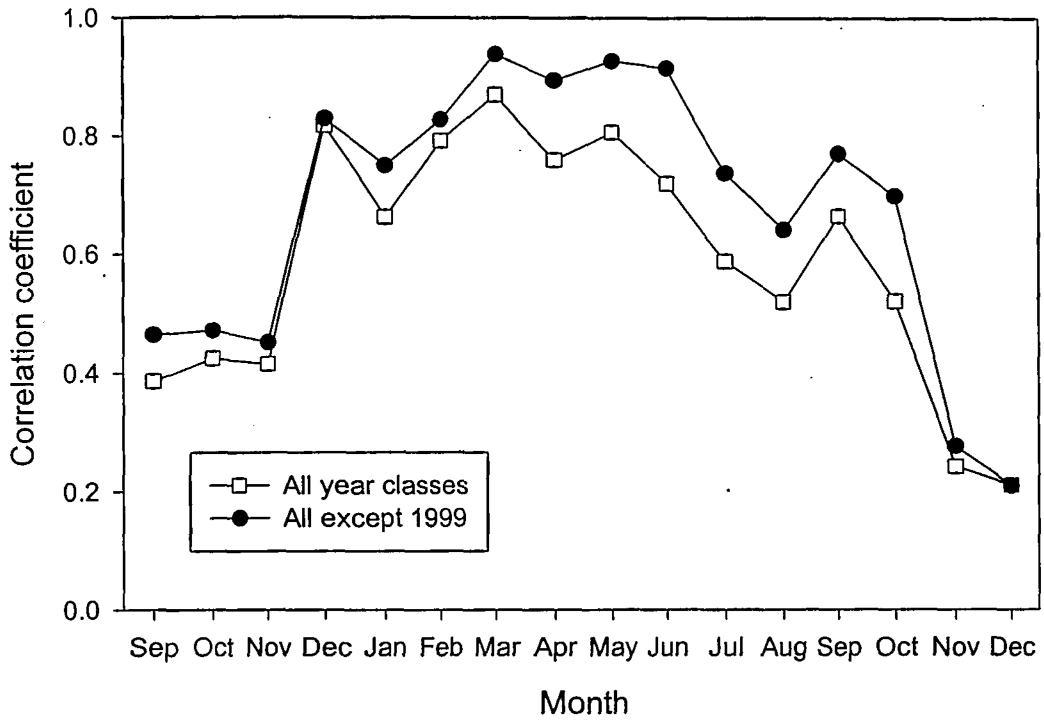


Figure 21: Correlations between 1+ snapper year class strength and monthly Leigh sea surface temperature, both with and without inclusion of the 1999 year class.

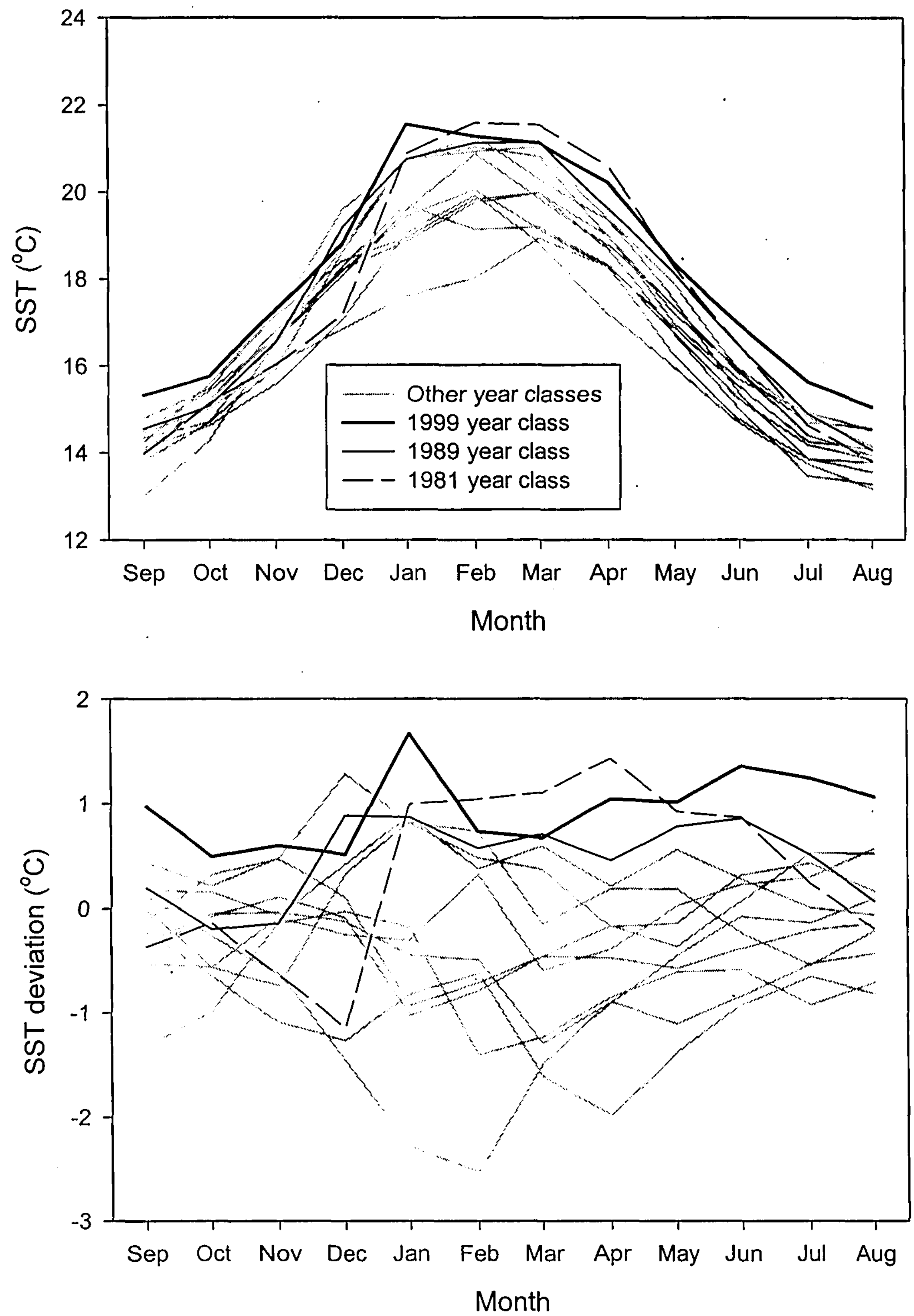


Figure 22: Comparison of sea surface temperatures (SST), and SST deviations from the long-term monthly means, experienced by the 1999 year class with those experienced by the strong 1981 and 1989 year classes, and other year classes surveyed by *Kaharoa*.

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 flotation :	217 kgf
Codend mesh :	40 mm

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

	10–50			50–100			100–150			Total
	n	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*
Headline height (m)	38	6.4	0.5	9	6.4	0.5	1	6.5	-	48
Tow speed (knots)	38	3.3	0.1	9	3.3	0.1	1	3.1	-	48
Doorspread (m)	38	74.8	5.1	9	74.9	4.0	1	85.6	-	48
Distance towed (n.m.)	38	0.74	0.21	9	0.99	0.1	1	0.99	-	48
Warp/depth ratio	38	8.71	4.28	9	3.87	0.48	1	3.14	-	48

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

Stage	Macroscopic condition
Males	
1	Immature; testis white threads
2	Spermatogenic; testis firm and ivory white in colour
3	Partially spermiated; testis firm, ivory white in colour with viscous milt in spermaduct
4	Fully spermiated; testis firm, ivory white in colour with free flowing milt in spermaduct
5	Spent; testis spent and bloody in colour and flaccid
Females	
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 red gurnard (after Clearwater 1992)

Stage	Macroscopic condition
Males	
1	Immature; testis translucent, angular threads
2	Spermatogenic; testis white, no milt in spermaducts
3	Partially spermiated; testis white, viscous milt in spermaducts
4	Mature (fully spermiated); testis white, plump, fluid milt expressable from spermaduct
5	Spent; testis bloody/grey, no milt expressable
Females	
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 among 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 colour. Oocytes if present are unevenly dispersed. Dark brown specks or material sometimes visible

Appendix 5: Macroscopic condition stages of gonads of John dory (after Hore 1982)

Stage	Macroscopic condition
Males	
1	Virgin; testis thin and ribbon like, pale white in colour with a smooth surface
2	Developing-resting; convoluted surface, grey in colour
3	Developing; convolutions more prominent, network of blood vessels over surface, no milt runs when cut, milky white in colour
4	Ripe-spawning; convolutions of surface marked, firm to touch, pure white, prominent blood vessels, milt runs when testis is cut
5	Spent; flaccid, brown/white, no milt runs when cut
Females	
1	Virgin; ovaries thin, lie along posterior edge of ventral cavity, orange
2	Maturing virgin; ovaries enlarged, no eggs visible to the eye, orange
3	Developing; eggs visible to eye, orange with reddish tinge, network of blood vessels developing
4	Developed; eggs clearly discernable, 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 in colour

Appendix 6: **Individual station data**

Station no.	Stratum	Date (Nov 00)	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	1149	8	0550	36 52 23	175 06 09	6	0.73	100	-	57
2	1268	8	0840	36 48 26	175 15 21	30	-	200	5.2	79
3	1268	8	1030	36 51 24	175 13 64	25	1.00	200	5.4	76
4	1887	8	1340	36 56 41	175 21 53	25	1.00	200	8.0	79
5	1887	8	1502	36 59 90	175 26 66	13	0.76	200	-	68
6	1887	8	1606	37 02 05	175 22 51	18	0.69	200	6.1	76
7	1268	9	0550	36 48 21	175 19 17	31	0.99	200	6.0	82
8	9292	9	0747	36 38 49	175 23 74	18	0.71	200	6.6	76
9	9292	9	0903	36 36 21	175 21 12	25	0.69	200	6.2	81
10	1219	9	0946	36 36 05	175 18 71	38	0.99	200	6.6	79
11	9292	9	1147	36 33 69	175 20 27	29	1.00	200	6.9	83
12	2229	9	1324	36 40 29	175 12 43	41	0.99	200	6.1	79
13	2229	9	1423	36 41 79	175 09 72	38	1.00	200	6.2	75
14	2229	9	1513	36 43 71	175 12 04	41	0.99	200	6.3	80
15	2229	10	0512	36 43 18	175 04 55	34	1.03	200	6.1	71
*16	2229	10	0619	36 43 36	175 00 70					
17	1386	11	0543	36 42 13	174 50 06	21	0.71	200	6.2	79
18	1386	11	0638	36 39 46	174 47 77	19	0.70	200	6.2	72
19	1386	11	0754	36 41 81	174 54 24	26	0.69	250	5.7	73
20	1518	12	0525	36 03 41	175 17 69	84	1.00	300	6.4	79
*21	1518	12	0759	36 05 47	175 35 26					
22	4492	13	0534	36 36 33	175 36 91	45	1.00	200	6.0	75
23	4492	13	0716	36 32 34	175 37 86	51	1.00	200	7.0	73
24	4492	13	0829	36 29 07	175 43 74	66	1.00	250	6.4	78
25	1518	13	1027	36 24 85	175 55 67	143	0.99	450	6.5	86
26	4492	13	1313	36 25 02	175 30 89	56	1.00	200	7.0	70
27	4492	13	1522	36 22 09	175 11 19	47	1.00	200	6.1	71
28	4492	14	0517	36 03 80	175 02 62	70	1.00	300	6.3	73
29	1518	14	0745	35 51 29	174 46 39	91	1.01	300	5.6	74
30	1449	14	0941	35 56 29	174 33 59	35	0.70	200	6.8	72
31	1449	14	1216	35 55 97	174 30 29	18	0.70	200	6.7	75
32	1449	14	1347	36 04 45	174 38 53	42	0.70	200	6.5	73
33	4492	14	1550	36 13 53	174 54 77	53	0.99	250	6.9	83
34	1219	15	0508	36 18 51	174 52 46	48	1.01	200	6.7	75
35	2229	15	0701	36 33 20	174 51 11	30	0.50	200	6.3	72
36	1284	15	0756	36 34 38	174 49 29	24	0.50	200	6.8	72
37	1284	15	0902	36 31 90	174 48 39	25	0.49	200	6.5	75
38	1284	15	1010	36 33 71	174 46 53	20	0.50	200	6.4	75
39	1284	15	1135	36 34 98	174 44 06	12	0.51	200	6.5	76
40	1149	16	0745	36 47 19	174 57 80	23	0.50	200	5.4	78
41	1149	16	0834	36 44 83	174 59 30	17	0.52	200	6.4	69
42	2229	16	1004	36 39 76	174 59 55	32	0.50	200	6.4	74
43	1219	16	1137	36 31 67	175 01 81	46	1.00	250	6.8	82
44	1219	16	1239	36 26 55	175 04 33	47	1.00	250	6.7	82
45	1268	17	0504	36 46 10	175 15 38	29	0.50	200	6.2	75
46	1268	17	0628	36 52 94	175 18 69	31	0.71	200	6.2	68
47	1268	17	0813	36 53 09	175 15 01	21	0.50	200	6.7	70
48	1268	17	0924	36 56 69	175 20 48	26	0.50	200	6.3	70
49	1887	17	1044	37 03 39	175 27 34	9	0.49	200	6.8	70
50	1887	17	1142	37 03 80	175 24 07	10	0.50	200	6.6	74

* = 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), tarakihi (TAR), John dory (JDO), barracouta (BAR), leatherjacket (LEA), and red gurnard (GUR).**

Station	SNA	JMN	TAR	JDO	BAR	LEA	GUR
1	244.3	21.7	0.0	3.7	0.0	0.0	0.0
2	404.4	18.6	0.0	9.9	0.0	0.0	5.5
3	520.3	9.5	0.0	31.4	0.0	0.0	0.0
4	413.6	20.8	0.0	11.2	0.0	0.0	1.3
5	247.5	5.4	0.0	6.4	0.0	0.0	0.0
6	166.5	10.3	0.0	9.9	0.0	0.0	0.0
7	609.2	9.0	0.0	8.3	0.1	0.0	1.0
8	222.2	1.3	0.0	3.0	0.0	0.0	0.3
9	14.3	3.9	0.0	0.0	0.0	0.0	0.0
10	31.9	25.4	0.0	2.0	0.1	0.0	0.0
11	110.1	0.3	0.0	9.0	0.0	1.0	0.0
12	78.0	12.9	0.0	3.5	0.6	0.8	1.0
13	41.1	21.3	0.0	7.4	10.1	0.0	0.4
14	225.4	37.0	0.0	1.8	4.0	1.6	3.9
15	108.1	34.2	0.0	3.6	0.1	0.0	0.0
*16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	325.2	4.2	0.0	0.0	0.0	0.0	0.0
18	90.3	7.6	0.0	0.8	0.0	0.0	0.0
19	3 975.6	1.2	0.0	7.8	0.0	0.0	0.0
20	6.1	0.2	0.0	3.2	3.1	0.0	0.0
*21	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	146.5	30.5	0.0	10.2	38.3	1.0	0.0
23	0.6	0.0	0.0	0.0	0.0	2.4	0.0
24	21.8	0.0	0.0	6.4	7.4	18.9	1.2
25	1.0	0.0	0.7	0.0	0.0	0.0	0.0
26	722.3	0.0	245.4	1.3	2.2	1.9	0.0
27	63.2	15.3	0.0	0.0	0.1	0.3	0.0
28	39.8	0.6	7.1	21.8	0.0	3.7	0.0
29	4.4	8.1	9.0	5.8	7.3	0.0	0.0
30	4.0	0.1	0.0	0.2	1.6	4.3	0.0
31	249.3	0.0	0.0	0.0	0.0	7.6	0.0
32	23.2	29.1	0.0	0.9	1.5	3.5	0.0
33	14.5	21.7	0.0	1.1	0.2	11.2	4.1
34	45.6	5.8	0.0	1.2	0.1	0.7	3.7
35	66.4	20.1	0.0	1.9	0.1	0.0	0.0
36	261.5	15.2	0.0	0.0	0.0	0.0	0.0
37	145.8	0.1	0.0	4.6	0.0	0.0	0.0
38	109.4	0.1	0.0	5.0	0.0	0.0	0.0
39	163.4	0.1	0.0	1.7	0.0	0.0	0.0
40	46.0	20.3	0.0	4.6	0.0	0.0	0.0
41	632.4	31.2	0.0	4.1	0.0	0.0	0.0
42	153.6	20.2	0.0	1.0	0.0	0.0	0.0
43	95.7	47.8	0.0	2.6	0.9	1.6	0.3
44	77.2	70.7	0.0	0.4	3.7	1.4	0.0
45	688.3	6.5	0.0	6.2	0.0	0.1	0.0
46	843.2	49.4	0.0	10.3	0.2	0.0	0.0
47	207.7	54.4	0.0	2.3	0.0	0.0	0.0
48	304.5	16.4	0.0	5.6	5.7	0.0	0.0
49	60.9	48.4	0.0	5.4	0.0	0.0	0.0
50	70.0	42.7	0.0	6.2	0.0	0.0	0.0
Total	13 096.3	799.6	262.2	233.7	87.4	62.0	22.7

*, fouled or poor performance shot

Appendix 8: Snapper age-length key for survey

Length																				Age (years)		No.
(cm)	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	>19+	aged
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
7	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
8	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
9	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
10	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22
11	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22
12	0.95	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
13	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
14	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17
15	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26
16	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
17	-	0.75	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24
18	-	0.30	0.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
19	-	0.17	0.78	0.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
20	-	-	0.91	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22
21	-	-	0.76	0.14	0.05	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
22	-	-	0.67	0.14	0.14	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
23	-	-	0.27	0.23	0.36	0.09	-	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	22
24	-	-	0.16	-	0.64	0.12	0.04	0.04	-	-	-	-	-	-	-	-	-	-	-	-	-	25
25	-	-	-	0.14	0.36	0.18	0.23	-	0.05	0.05	-	-	-	-	-	-	-	-	-	-	-	22
26	-	-	-	0.06	0.39	0.11	0.06	0.22	0.06	0.11	-	-	-	-	-	-	-	-	-	-	-	18
27	-	-	-	-	0.06	0.25	0.31	-	0.06	0.06	-	0.13	0.06	-	0.06	-	-	-	-	-	-	16
28	-	-	-	-	0.24	0.18	0.12	0.24	0.06	0.12	-	-	0.06	-	-	-	-	-	-	-	-	17
29	-	-	-	-	-	0.08	0.08	0.25	-	0.25	0.08	0.17	0.08	-	-	-	-	-	-	-	-	12
30	-	-	-	-	-	0.36	0.18	0.18	0.18	-	-	0.09	-	-	-	-	-	-	-	-	-	11
31	-	-	-	-	-	0.09	0.18	0.18	-	0.36	-	0.18	-	-	-	-	-	-	-	-	-	11
32	-	-	-	-	-	0.11	0.22	0.22	0.11	0.11	0.22	-	-	-	-	-	-	-	-	-	-	9
33	-	-	-	-	-	0.13	0.25	0.25	0.13	-	-	0.13	-	-	-	-	-	0.13	-	-	-	8
34	-	-	-	-	-	-	0.20	0.20	0.20	0.20	-	0.10	-	-	-	0.10	-	-	-	-	-	10
35	-	-	-	-	-	-	0.09	0.09	0.18	0.36	-	0.09	-	-	-	0.09	0.09	-	-	-	-	11
36	-	-	-	-	-	-	0.08	0.25	0.17	0.25	0.08	0.17	-	-	-	-	-	-	-	-	-	12
37	-	-	-	-	-	-	0.10	-	-	0.20	0.20	0.20	0.20	-	-	-	-	-	-	0.10	-	10
38	-	-	-	-	-	-	-	-	0.10	0.30	-	0.30	0.20	0.10	-	-	-	-	-	-	-	10
39	-	-	-	-	-	-	-	0.11	0.11	0.11	0.11	0.22	-	0.11	0.22	-	-	-	-	-	-	9
40	-	-	-	-	-	-	-	0.09	0.09	0.18	-	0.18	0.09	-	0.18	0.09	0.09	-	-	-	-	11
41	-	-	-	-	-	-	-	0.13	-	0.13	0.13	0.25	-	-	0.13	0.13	-	-	-	0.13	-	8
42	-	-	-	-	-	-	-	-	0.10	0.10	-	0.40	0.10	-	0.10	-	0.10	0.10	-	-	-	10
43	-	-	-	-	-	-	-	-	-	0.10	0.10	0.20	0.10	-	0.40	0.10	-	-	-	-	-	10
44	-	-	-	-	-	-	-	-	-	0.10	-	0.50	0.20	-	0.10	-	0.10	-	-	-	-	10
45	-	-	-	-	-	-	-	-	-	0.09	0.09	0.09	0.18	0.18	0.18	0.09	0.09	-	-	-	-	11
46	-	-	-	-	-	-	-	-	-	0.17	-	-	0.33	0.17	0.33	-	-	-	-	-	-	6
47	-	-	-	-	-	-	-	-	-	0.14	0.29	-	0.29	-	-	0.14	-	0.14	-	-	-	7
48	-	-	-	-	-	-	-	-	0.17	0.17	-	0.33	-	-	0.33	-	-	-	-	-	-	6
49	-	-	-	-	-	-	-	-	-	-	0.22	0.11	0.22	-	0.22	0.11	0.11	-	-	-	-	9
50	-	-	-	-	-	-	-	-	-	-	-	-	0.25	0.25	-	0.25	0.25	-	-	-	-	4
51	-	-	-	-	-	-	-	-	-	-	-	0.25	0.25	-	-	-	0.25	-	-	-	0.25	4
52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	-	-	0.50	-	2
53	-	-	-	-	-	-	-	-	-	-	-	-	-	0.25	-	0.25	-	0.25	-	0.25	-	4
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.67	-	0.33	-	-	-	-	3
55	-	-	-	-	-	-	-	-	-	-	-	-	0.25	-	-	-	0.25	-	-	0.50	-	4
56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	1
57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	-	0.50	-	-	-	-	2
58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33	-	-	0.67	-	3
61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-	1
62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	1
63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1
65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	1
66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	2
Total																						651

Appendix 9: Summary of otoliths collected, for snapper, red gurnard, John dory, and tarakihi

Size class	Snapper			Red gurnard			John dory		
(cm)	Male	Female	Unsexed	Male	Female	Unsexed	Male	Female	Unsexed
7	-	-	2	-	-	-	-	-	-
8	-	-	8	-	-	-	-	-	-
9	-	-	15	-	-	-	-	-	-
10	-	-	23	-	-	-	-	-	-
11	-	-	22	-	-	-	-	-	-
12	-	-	20	-	-	-	-	-	-
13	-	-	10	-	-	-	-	-	1
14	-	-	18	-	-	-	-	-	-
15	-	-	26	-	-	-	-	-	-
16	1		20	-	-	-	-	-	3
17	3	4	17	-	-	-	-	-	2
18	9	6	9	-	-	4	-	1	5
19	10	10	4	-	-	1	1	3	3
20	14	8	-	-	-	-	-	-	4
21	11	9	1	1	1	1	-	1	2
22	9	11	1	1	6	-	-	1	-
23	11	11	-	1	3	1	-	-	1
24	16	8	1	1	4	-	1	2	1
25	10	13	-	3	3	-	4	3	-
26	9	9	-	6	4	-	4	2	-
27	7	9	-	1	2	-	2	2	-
28	10	7	-	1	6	-	2	2	1
29	7	5	-	2	6	-	2	3	-
30	6	5	-	-	4	-	4	2	-
31	6	6	-	1	5	-	2	2	-
32	5	6	-	-	2	-	3	2	-
33	4	5	-	-	1	-	2	1	-
34	6	5	-	-	3	-	4	-	-
35	5	6	-	-	-	-	3	1	-
36	7	5	-	-	-	-	5	5	-
37	5	5	-	-	4	-	6	4	-
38	5	5	-	1	2	-	4	5	-
39	5	6	-	-	-	-	5	6	-
40	5	5	-	-	-	-	4	5	-
41	5	5	-	-	-	-	5	5	-
42	5	5	-	-	-	-	3	5	-
43	6	4	-	-	-	-	2	4	-
44	6	4	-	-	-	-	1	6	-
45	5	6	-	-	-	-	3	5	-
46	6	1	-	-	-	-	-	1	-
47	5	2	-	-	-	-	-	5	-
48	5	1	-	-	-	-	-	5	-
49	5	5	-	-	-	-	-	4	-
50	2	2	-	-	-	-	-	1	-
51	2	3	-	-	-	-	-	-	-
52	1	1	-	-	-	-	-	-	-
53	3	1	-	-	-	-	-	-	-
54	1	2	-	-	-	-	-	-	-
55	3	1	-	-	-	-	-	-	-
56	1	-	-	-	-	-	-	-	-
57	1	1	-	-	-	-	-	-	-
58	-	-	-	-	-	-	-	-	-
59	-	-	-	-	-	-	-	-	-
60	1	2	-	-	-	-	-	-	-
61	-	1	-	-	-	-	-	-	-
62	-	1	-	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-
64	1	-	-	-	-	-	-	-	-
65	-	1	-	-	-	-	-	-	-
66	-	-	-	-	-	-	-	-	-
67	1	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-
69	-	-	-	-	-	-	-	-	-
70	2	-	-	-	-	-	-	-	-
Totals	253	218	197	19	56	7	72	94	23