Inshore trawl survey of the Bay of Plenty, North Island, February 1999 (KAH9902)

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NIWA Technical Report 89
ISSN 1174-2631
2000

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Published by NIWA
Wellington
2000

Inquiries to:
Science Communication, NIWA,
PO Box 14-901, Wellington, New Zealand

ISSN 1174-2631
ISBN 0-478-23216-0

Citation:
Morrison, M. & Parkinson, D. 2000:
Inshore trawl survey of the Bay of Plenty, North Island, February 1999 (KAH9902).
NIWA Technical Report 89. 31 p.

Cover photograph by Mark Morrison

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Introduction

Since 1983, trawl surveys have been conducted from RV *Kaharoa* in the Bay of Plenty, with the primary objective of determining snapper (*Pagrus auratus*) relative abundance, population size structure, and year class strength. For the 1999 survey, snapper was dropped as a target species, in favour of species previously assessed as secondary target species: red gurnard (*Chelidodonichthys kumu*), John dory (*Zeus faber*), and tarakihi (*Nemadactlyus macropterus*). These species support commercial fisheries in the Bay of Plenty, as either target species (tarakihi) or bycatch (red gurnard, John dory), and the trawl survey programme may monitor trends in their relative abundance and population structure.

Tarakihi was specified as a target species for the first time in the 1996 survey and the depth range of the survey extended from 150 to 250 m to include its distribution. Thus sampling intensity has shifted overall from the shallower to the deeper strata of the survey area.

Length-weight and reproductive data for the target species and snapper were collected in the present survey; this information has not been collected previously (with the exception of female snapper staging). Otoliths were also collected and archived for the three target species and snapper.

Previous trawl surveys have been documented by Drury & McKenzie (1992), Drury & Hartill (1993), and Morrison (1997). This report presents the results of the Bay of Plenty trawl survey conducted in February 1999, and was funded by the Ministry of Fisheries through contract INT9803.

The objectives of the survey were as follows.

1. To determine the relative abundance and distribution of John dory, red gurnard, and tarakihi in the Bay of Plenty by carrying out a trawl survey. The target coefficients of variation (*c.v.*s) of the biomass estimates for these species were John dory, 20%; red gurnard, 15%; tarakihi, 30%.

2. To determine the length frequency, length-weight relationship, and reproductive condition of John dory, red gurnard, snapper, and tarakihi.

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

4. To determine the length frequencies of all other Quota Management System (QMS) species, and frostfish (*Lepidopus caudatus*), leatherjacket (*Parika scaber*), kahawai (*Arripis trutta*), and kingfish (*Seriola lalandi*).

Methods

Survey area and design

A trawl survey was conducted between 3 and 13 February 1999 from RV Kaharoa in an area extending from Mercury Island to Cape Runaway in the 10–250 m depth range. The 1996 survey used 14 depth and area strata based on the catch rate of pre-recruit snapper (under 25 cm fork length (FL)) from previous trawl surveys. Since the current survey did not target juvenile snapper, 10 of these strata were combined into 4 larger strata, reducing the overall number of strata to be surveyed to 8 (Figure 1, Table 1).

A simulation study of precision versus number of stations was undertaken using data from the 1996 survey (the only previous survey with sufficient data for tarakihi biomass estimation) for the three target species. From this, a survey consisting of 78 trawl stations (50 phase 1, 28 phase 2) was chosen as most appropriate for achieving the target *c.v.*s.

The survey was of a two phase stratified random design (*after* Francis 1984), in which the second phase involved the allocation of trawl shots to strata so as to maximise the anticipated reduction in the *c.v.*s of the three target species. 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 estimates of the target species. 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 individual species *c.v.*s, for each possible stratum allocation. The station was then assigned to the stratum giving the greatest improvement across all *c.v.*s and the process repeated until all stations available had been allocated. A summary of the station allocation is given in Table 1.

Vessel and gear specifications

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

Trawling procedure

All trawls were carried out in daylight between 0530 and 1700 hours (NZST). Trawls were conducted from the randomly selected start position unless untrawlable ground was encountered, when a search was made for suitable ground within a 2 n. mile (3.7 km) radius of the start position. If no suitable ground was located, the station was abandoned and another random position substituted. Towing speed was between 3.0 and 3.3 knots, and tow direction was generally in a direction that maintained the same water depth throughout the tow. Distance towed was constant at 0.7 n. mile for shallower stations and 1 n. mile for deeper stations, measured using Magnavox GPS. Warp to depth ratios ranged from 13.3:1 at the shallowest stations to 2.2:1 for the deepest trawls. Trawl door spread was estimated using Scanmar gear. When the Scanmar gear was not attached to the doors for a particular tow, trawl door spread was estimated using the average from other tows for which door spread was available. A summary of gear parameters is given in Appendix 2.

Catch and biological sampling

The catch from each trawl was sorted by species and weighed to the nearest 0.1 kg on Seaway motion-compensating scales. A sample of all commercially important fish and squid 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. Red gurnard, John dory, snapper, and tarakihi were sexed and staged using appropriate gonad development scales (Appendices 3–5). A range of sizes of red gurnard, John dory, tarakihi, and

snapper was also individually measured and weighed to determine the length-weight relationships. To ensure representative samples were collected, up to a maximum of five fish per sex were measured for each 1 cm size interval, haphazardly collected from across the full spatial extent of the survey area.

Otoliths were collected from measured red gurnard, John dory, tarakihi, and snapper (up to a target of 10 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 most of the trawl stations: sea surface temperature, air temperature, bottom temperature, wind direction and speed, cloud cover, bottom type and contour, barometric pressure, sea condition and colour, and swell height and direction.

Data analysis

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

1. The area swept was the distance between the doors multiplied by the distance towed.
2. The vertical availability was 1.0. This assumes that all fish within the area swept were below the headline height of the net.
3. The vulnerability was 1.0. 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.

Only the length frequencies of the target species are presented.

Results

Eighty stations were completed during the survey, but two were dropped from analysis because of poor gear performance (stations 18 and 77). This left 50 phase 1 and 28 phase 2 successfully completed stations. The areal distribution of trawl shots is shown in Figure 2 and individual station information is given in Appendix 6. Almost all of the phase 2 allocations were made to deeper strata (7085, 808CNE, 909CNE) to reduce the *c.v.* of tarakihi, which was the most variable of the target species.

Catch composition

Sixty-two species were caught during the survey (Table 2). Snapper accounted for 37.5% of the total catch by weight, followed by red gurnard 7.8%, jack mackerel (*Trachurus novaezealandiae*) 7.0%, frostfish 5.7%, jack mackerel (*T. declivis*) 5.3%, trevally 4.6%, and John dory 4.4% (Table 2). Tarakihi accounted for only 2.1% of the catch, even though most of the second phase sampling was targeted at this species. A summary of catch by station of the more important target species for this survey is given in Appendix 7.

Distribution and catch rates

Red gurnard were caught throughout the Bay of Plenty (Figure 3), with relatively large individual catches occurring in the 10–100 m depth range. John dory were less common, with scattered larger catches (Figure 4). Relatively few tarakihi were encountered; most of the tows catching these fish were in deeper water in the middle of the survey area (Figure 5). Snapper were found throughout the bay, and most areas had broadly comparable catch rates (Figure 6).

Biological data

The numbers of fish and squid from which biological data were collected are summarised in Table 3. Male and female red gurnard had broadly similar population length frequencies, though females reached a larger size and had a lower proportion in the 20–30 cm range (Figure 7). A small mode of juvenile fish was evident in the 12–19 cm range, which probably represented 1+ fish.

Length frequencies for John dory were composed of two size modes, from 20 to 30 cm and from 30 to 45 cm (to 50 cm for females). The smaller size mode is likely to have been composed of 1+ fish. Females displayed a broader size range of fish in the second mode, and were on average larger (Figure 8).

Tarakihi were caught in modest numbers compared to the other target species, and had a dominant mode at 30–40 cm. No fish less than 19 cm were caught (Figure 9).

Snapper length frequencies were the same for both sexes, with a mode at about 22–27 cm, followed by a descending limb of larger sized fish to 45 cm (Figure 10). The mode at 22–27 cm was likely to be composed of 3–5+ fish, based on previous age-length keys produced for snapper in this area. A modest mode of 1+ snapper were present (11–15 cm), and the 2+ cohort (15–21 cm) also appeared to be weak, compared to the 1996 survey.

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

Male red gurnard were predominantly in the spermatogenic phase of ovarian development (56%) (Table 5). Female red gurnard were mainly in the regressed (26%), vitellogenic (25%), or spent (25%) state. For John dory males, 64% were in a developing-resting state, 20% in a developing state, and 11% in the ripe-spawning state (Table 5). Female John dory were predominately in a maturing virgin state (36%), with the remainder being mainly in developing (12%), developed (17%), or gravid states (17%) (Table 5).

Tarakihi males were predominately in a developing state (50%), with the remainder being in a virgin (24%), developing (15%), or partially spent (9%) state (Table 5). Tarakihi females were mainly in a developing (67%), resting (24%), or advanced developing (15%) state. Snapper males were predominately spermatogenic (58%), with the remainder being mainly immature (22%), partially spermiated (10%), or spent (8%). Female snapper were predominately regressed (71%), with the remainder being mainly immature (12%) or vitellogenic (14%).

Otolith collections were made for the three target species and snapper, and a summary of what was collected is given in Appendix 8.

Biomass estimates

Biomass estimates for red gurnard, John dory, tarakihi, snapper, jack mackerel (*T. novaezealandiae*), and trevally are given in Table 6. Coefficients of variation for the three target species were 14.1% for red gurnard, 14.1% for John dory, and 27% for tarakihi, all less than the project objective targets (15%, 20%, and 30% respectively). Red gurnard biomass was distributed across most of the shallow to mid-depth strata, but was low in the deepest strata of 150–250 m water depth (909CNE). John dory biomass was concentrated in stratum 7085 (61%), with the remaining biomass occurring across both shallower (1096, 6085) and deeper (808CNE) strata. Tarakihi were most abundant in the deepest strata (808CNE, 909CNE) and were not present in water depths of less than 50 m.

Snapper were relatively abundant in the shallow to mid-depth strata, and jack mackerel (*T. novaezealandiae*) biomass was concentrated in strata 4085 (31%) and 808CNE (33%). Trevally were found mainly in shallow (1096/2096, 4085, 5187/5287) to intermediate depth (7085) strata.

Discussion

All objectives for this programme were successfully met, and the *c.v.*s on biomass estimates were all lower than the target *c.v.*s. The *c.v.* for tarakihi, predicted from survey simulations to be the most variable of the target species, was an improvement on the 1996 survey results (the only other survey to include the deeper strata where tarakihi are dominantly found). However, tarakihi biomass was modest at 50 t (*c.v.* of 27%) (*c.f.* 35 t, *c.v.* 46% in 1996), suggesting that the current survey series may not be sampling a large proportion of the tarakihi stock.

Coefficients of variation for the other target species were towards the lower end of the range that has been achieved (red gurnard current 14%, past range 9–28%; John dory current 14%, past range 12–44%).

A reasonable *c.v.* on snapper biomass was obtained (18%), although this species is no longer a target species of the surveys. Other commercial species were not particularly abundant.

Acknowledgments

Thanks go to the captain and crew of *Kaharoa*, and the scientific staff during the voyage, Kevin MacKay, Matt Smith, Glen Carbines, Nick Davies, and Jim Drury. Otolith sampling was organised and conducted by Bruce Hartill and Cameron Walsh. Mike Beentjes provided comments on a draft of the report, and Mike Beardsell provided editorial assistance. Original coastline data wassourced from LINZ. This work was funded by MFish contract INT9803.

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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		Station density (per km^2)
				Phase 1	Phase 2	
1096/2096	Whale Island – Cape Runaway Waihi – Town Point	10–25	432	7	1	1:54
5187/5287	Mt Manganui – Whale Island Hot Water Beach – Mt Manganui	25–50	629	3		1:210
32NH	Te Ororoa – Opoutere	10–25	26	3		1:9
6085	Whale Island to Cape Runaway	50–100	740	3		1:25
7085	Mercury Island – Whale Island	50–100	1 696	14	11	1:68
808CNE	Mercury Island – Cape Runaway	100–150	1 304	6	7	1:100
909CNE	Mercury Island – Cape Runaway	150–250	897	10	9	1:47
4085	Whale Island – Cape Runaway	25–50	486	3		1:162
			6 210	50	28	

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

Common name	Species code	Scientific name	Total weight (kg)	Percentage of catch by weight	Occ
Snapper	SNA	*Pagrus auratus*	2 358.1	37.5	76.9
Red gurnard	GUR	*Chelidonichthys kumu*	491.9	7.8	74.4
Jack mackerel	JMN	*Trachurus novaezealandiae*	438.3	7.0	50.0
Frostfish	FRO	*Lepidopus caudatus*	357.0	5.7	34.6
Jack mackerel	JMD	*Trachurus declivis*	331.9	5.3	37.2
Trevally	TRE	*Pseudocaranx dentex*	291.2	4.6	38.5
John dory	JDO	*Zeus faber*	276.4	4.4	66.7
Cucumberfish	CUC	*Chlorophthalmus nigripinnis*	161.2	2.6	17.9
Sea perch	SPE	*Helicolenus* spp.	144.5	2.3	35.9
Barracouta	BAR	*Thyrsites atun*	144.0	2.3	32.1
Tarakihi	TAR	*Nemadactylus macropterus*	132.0	2.1	23.1
Silverside	SSI	*Argentina elongata*	131.1	2.1	19.2
Rough skate	RSK	*Raja nasuta*	123.9	2.0	24.4
Leatherjacket	LEA	*Parika scaber*	106.1	1.7	43.6
Snipefish	SNI	*Macrorhamphosus scolopax*	72.0	1.1	14.1
Eagle ray	EGR	*Myliobatus tenuicaudatus*	66.1	1.0	7.7
Stingray	STR	*Allothunnus fallai*	65.7	1.0	6.4
Arrow squid	SQU	*Nototodarus sloanii*	61.1	1.0	34.6
Japanese gurnard	JGU	*Pterygotrigla picta*	60.8	1.0	28.2
Kahawai	KAH	*Arripis trutta*	48.0	0.8	16.7
Thresher shark	THR	*Alopias vulpinus*	45.0	0.7	1.3
Silver dory	SDO	*Cyttus novaezealandiae*	41.7	0.7	15.4
Kingfish	KIN	*Seriola lalandi*	41.1	0.7	9.0
Shorttailed stingray	BRA	*Dasyatis brevicaudatus*	40.0	0.6	1.3
Scaly gurnard	SCG	*Lepidotrigla brachyoptera*	31.5	0.5	35.9
Rig	SPO	*Mustelus lenticulatus*	24.0	0.4	7.7
School shark	SCH	*Galeorhinus australis*	22.1	0.4	3.8
Smooth skate	SSK	*Raja innominata*	21.8	0.3	5.1
Hammerhead shark	HHS	*Sphyrna zygaena*	21.2	0.3	5.1
Mirror dory	MDO	*Zenopsis nebulosus*	20.2	0.3	11.5
Electric ray	ERA	*Torpedo fairchildi*	18.9	0.3	5.1
Jack mackerel	JMM	*Trachurus murphyi*	18.2	0.3	7.7
Red cod	RCO	*Pseudophycis bachus*	11.3	0.2	6.4
Bollons's rattail	CBO	*Caelorinchus bollonsi*	9.9	0.2	1.3
Hapuku	HAP	*Polyprion oxyceneios*	9.3	0.1	3.8
Yellow boarfish	YBO	*Pentaceros decacanthus*	7.3	0.1	2.6
Octopus	OCT	*Octopus* sp.	6.6	0.1	1.3
Sand flounder	SFL	*Rhombosolea plebeia*	5.2	0.1	7.7
Rattail	RAT	Macrouridae	4.8	0.1	3.8
Lemon sole	LSO	*Pelotretis flavilatus*	4.1	0.1	15.4
Witch	WIT	*Arnoglossus scapha*	3.3	0.1	21.8
Southern boarfish	SBO	*Pseudopentaceros richardsoni*	3.1	0.0	2.6
Brown stargazer	BRZ	*Xenocephalus armatus*	2.7	0.0	3.8
Gemfish	SKI	*Rexea solandri*	2.5	0.0	1.3
Ghost shark	GSH	*Hydrolagus novaezealandiae*	2.3	0.0	2.6
Spotted stargazer	SPZ	*Genyagnus monopterygius*	2.2	0.0	6.4
Blue mackerel	EMA	*Scomber australasicus*	2.1	0.0	3.8
Yellow-eyed mullet	YEM	*Aldrichetta forsteri*	2.1	0.0	1.3
Paddle crab	PAD	*Ovalipes catharus*	1.8	0.0	1.3

Northern spiny dogfish	NSD	*Squalus mitsukurii*	1.3	0.0	1.3
Blue cod	BCO	*Parapercis colias*	1.0	0.0	1.3
Conger eel	CON	*Conger* spp.	0.9	0.0	1.3
Ling	LIN	*Genypterus blacodes*	0.8	0.0	1.3
Estuarine stargazer	ESZ	*Leptoscopus macropygus*	0.7	0.0	1.3
Yellow-belly flounder	YBF	*Rhombosolea leporina*	0.7	0.0	1.3
Unidentified	UNI		0.6	0.0	3.8
Prawn killer	PRK	*Ibacus alticrenatus*	0.5	0.0	3.8
Spotty	STY	*Notolabrus celidotus*	0.5	0.0	1.3
Capro dory	CDO	*Capromimus abbreviatus*	0.4	0.0	3.8
Broad squid	BSQ	*Sepioteuthis australis*	0.3	0.0	1.3
Pipefish	PIP	Syngnathidae	0.2	0.0	2.6
Stargazer	STG		0.2	0.0	1.3
Redbait	RBT	*Emmelichthys nitidus*	0.1	0.0	1.3
		Total	6 295.8		

Table 3: **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
Snapper	60	3 884	1 633	1 910	341
Red gurnard	58	1 790	696	995	99
John dory	52	380	207	172	2
Jack mackerel (*Trachurus novaezelandiae*)	39	2 576	–	–	2 576
Leatherjacket	34	437	–	1	436
Trevally	30	326	132	193	1
Jack mackerel (*T. declivis*)	29	884	1	–	883
Scaly gurnard	28	48	–	–	48
Sea Perch	28	17	–	–	17
Frostfish	27	550	6	4	540
Arrow squid	27	389	19	13	357
Barracouta	25	266	20	23	223
Japanese gurnard	22	20	–	–	20
Rough skate	19	8	1	7	0
Tarakihi	18	172	103	69	0
Witch	17	5	–	–	5
Kahawai	13	50	26	16	8
Lemon sole	12	13	1	1	11
Silver dory	12	2	–	2	0
Kingfish	7	8	1	7	0
Eagle ray	6	5	3	2	0
Jack mackerel (*T. murphyii*)	6	16	1	–	15
Sand flounder	6	12	4	1	7
Rig	6	6	3	2	1
Red cod	5	34	1	3	30
Spotted stargazer	5	6	2	2	2
Brown stargazer	3	3	–	1	2
Blue mackerel	3	17	–	–	17
Hapuku	3	3	1	–	2
School shark	3	2	–	2	0
Ghost shark	2	2	–	–	2
Southern Boarfish	2	3	–	–	3
Blue cod	1	1	1	–	0
Broad squid	1	2	–	–	2
Estuarine stargazer	1	2	–	–	2
Ling	1	1	–	–	1
Gemfish	1	2	1	1	0
Yellowbelly flounder	1	2	–	–	2
Yellow-eyed mullet	1	11	–	–	11

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)**

	Sex	n	Length range (cm)	a	b	r
Red gurnard	Male	498	20–42	0.0048	3.2075	0.98
	Female	631	14–48	0.0031	3.3272	0.96
	All fish	1 184	13–48	0.0038	3.2770	0.97
John dory	Male	102	19–46	0.0185	2.9531	0.92
	Female	162	20–54	0.0084	3.1864	0.96
	All fish	265	19–54	0.0067	3.2454	0.95
Tarakihi	Male	101	19–46	0.0127	3.0944	0.96
	Female	54	20–48	0.0075	3.2414	0.96
	All fish	155	19–48	0.0098	3.1665	0.96
Snapper	Male	512	19–62	0.0468	2.7655	0.99
	Female	672	15–58	0.0426	2.7949	0.98
	All fish	1 222	12–62	0.0445	2.7809	0.98

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

Species		No. of fish	Gonad stage								
			0	1	2	3	4	5	6	7	8
Red gurnard	Males	504	–	71	283	62	11	76	1	–	–
	Females	633	–	92	163	156	56	10	156	–	–
John dory	Males	186	–	8	119	37	21	1	–	–	–
	Females	163	–	3	59	20	28	28	12	10	3
Tarakihi	Males	100	–	24	50	15	1	1	9	–	–
	Females	54	–	11	36	6	1	–	–	–	–
Snapper	Males	556	–	122	325	53	10	46	–	–	–
	Females	776	–	91	549	105	10	8	13	–	–

–, not applicable

Table 6: **Estimated biomass (t) and coefficient of variation (in parentheses) by stratum and all strata combined, of red gurnard (GUR), John dory (JDO), tarakihi (TAR), snapper (SNA), jack mackerel (JMN, *Trachurus novaezealandiae*), and trevally (TRE)**

Stratum	GUR	JDO	TAR	SNA	JMN	TRE
1096/2096	46.1 (25)	10.9 (59)	0.0	463.9 (45)	15.8 (47)	47.2 (28)
32NH	2.9 (35)	0.6 (10)	0.0	31.66 (15)	0.0	2.03 (52)
4085	24.5 (67)	7.9 (80)	0.0	182.1 (29)	114.7 (74)	89.4 (6)
5187/5287	64.2 (34)	7.2 (11)	0.0	360.2 (47)	4.4 (81)	78.4 (84)
6085	40.1 (57)	15.7 (72)	2.3 (52)	166.1 (19)	59.7 (45)	2.90 (100)
7085	150.5 (21)	107.4 (17)	9.1 (85)	404.2 (20)	40.5 (70)	46.31 (40)
808CNE	33.5 (33)	22.6 (29)	13.4 (43)	30.8 (25)	123.6 (64)	0.0
909CNE	1.7 (69)	3.2 (72)	25.6 (38)	6.31 (43)	15.5 (69)	0.0
Total	363.5 (14)	175.5 (14)	50.4 (27)	1 645.4 (18)	374.1 (33)	266.4 (26)

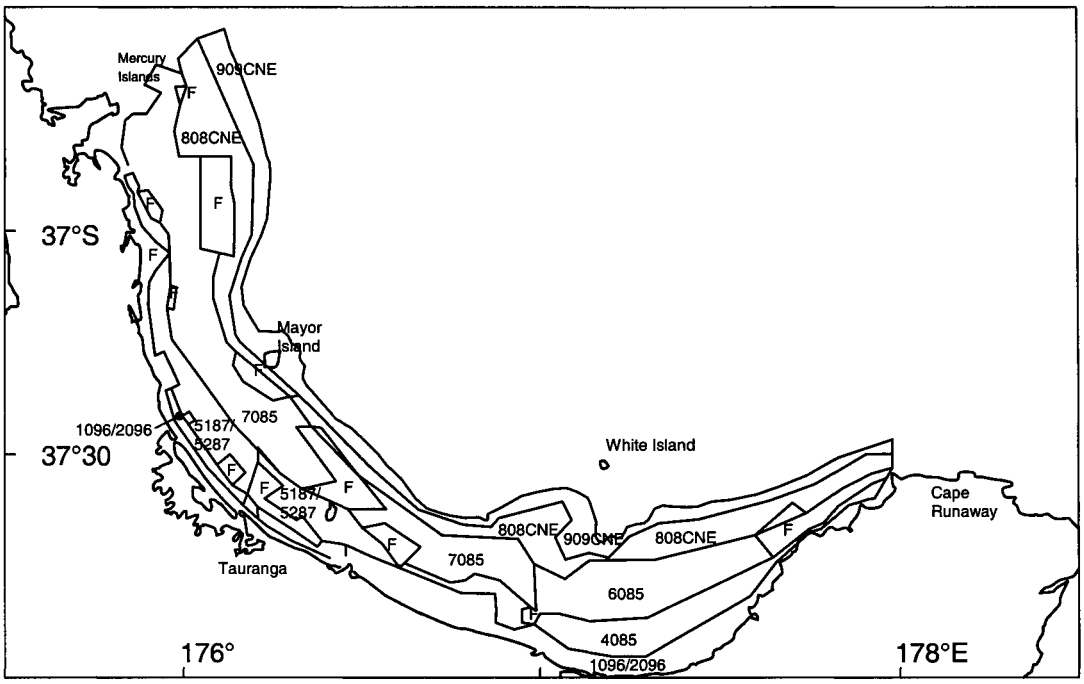

Figure 1: **Survey area and stratum boundaries (F, foul ground area). Alphanumeric codes are stratum designations.**

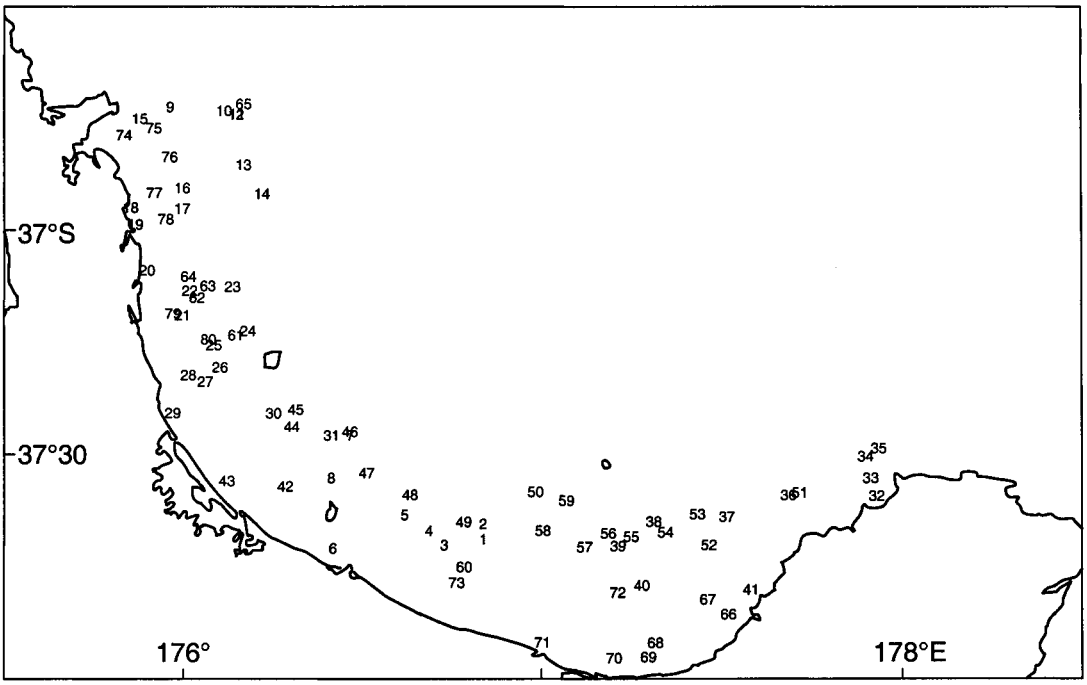

Figure 2: **Station position and numbers.**

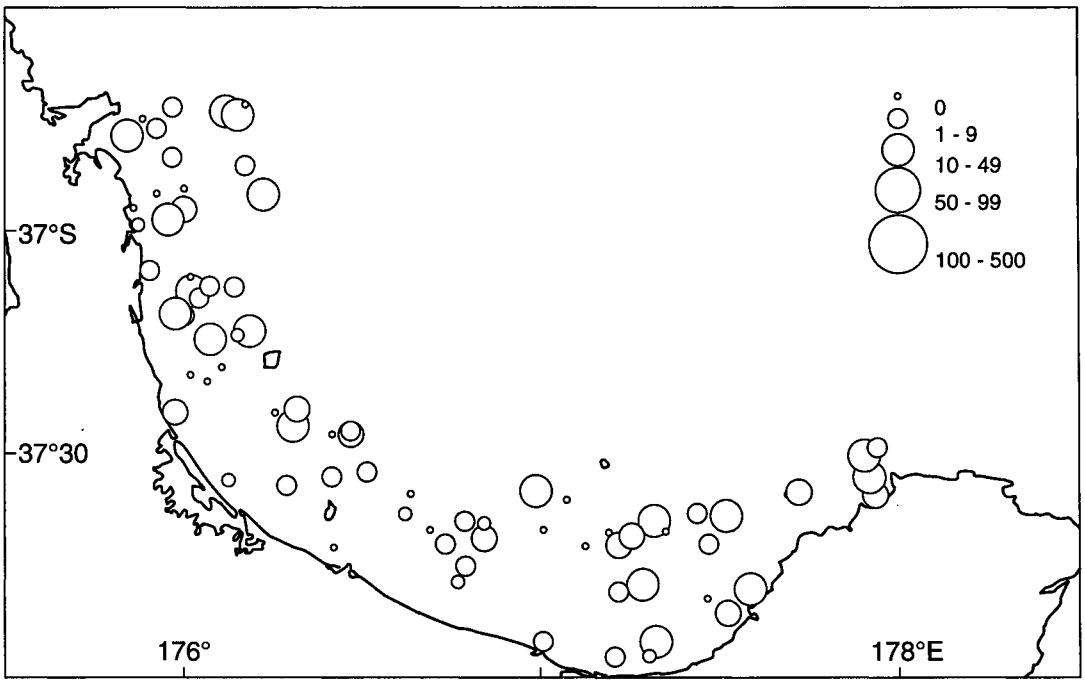

Figure 3: Catch rates (kg.km^{-2}) of red gurnard.

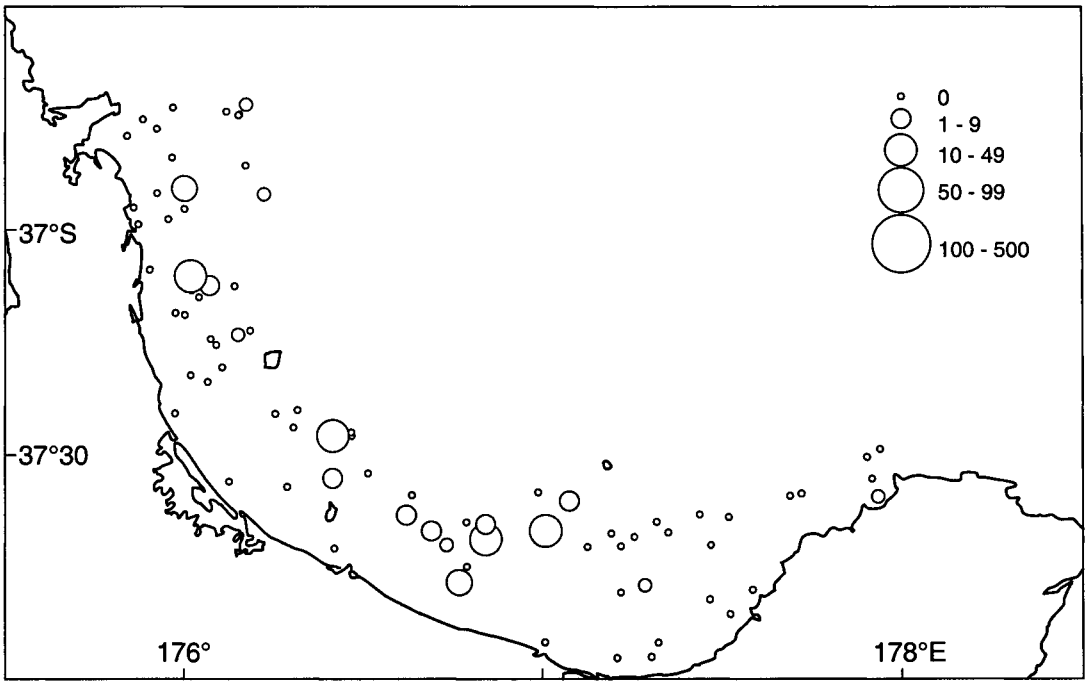

Figure 4: Catch rates (kg.km^{-2}) of John dory.

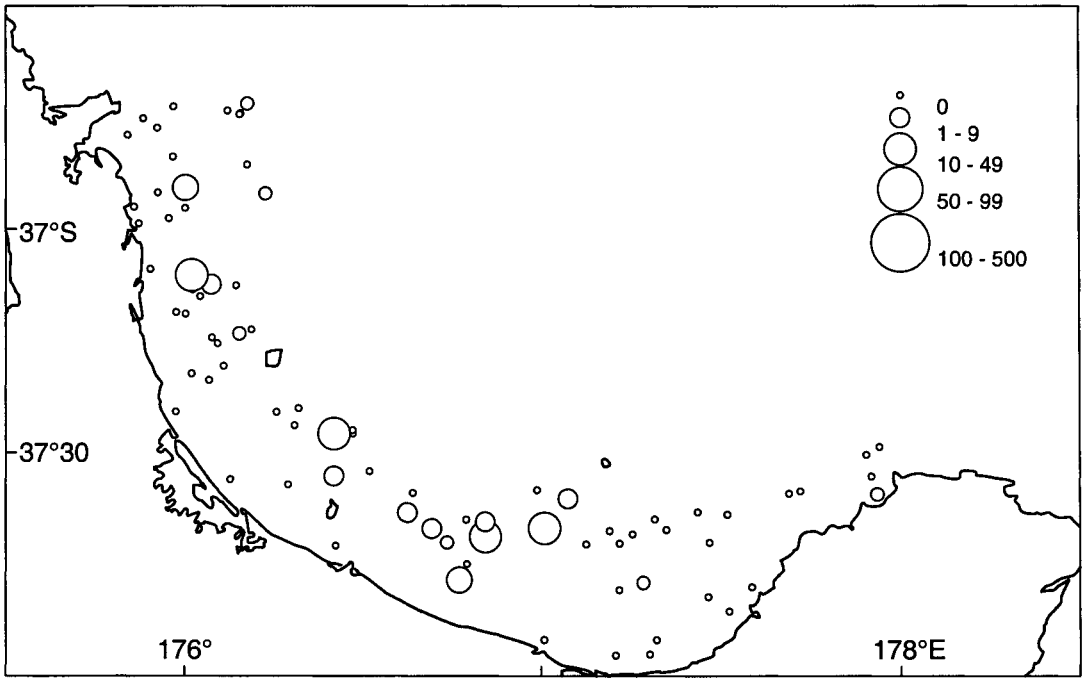

Figure 5: Catch rates (kg.km^{-2}) of tarahiki.

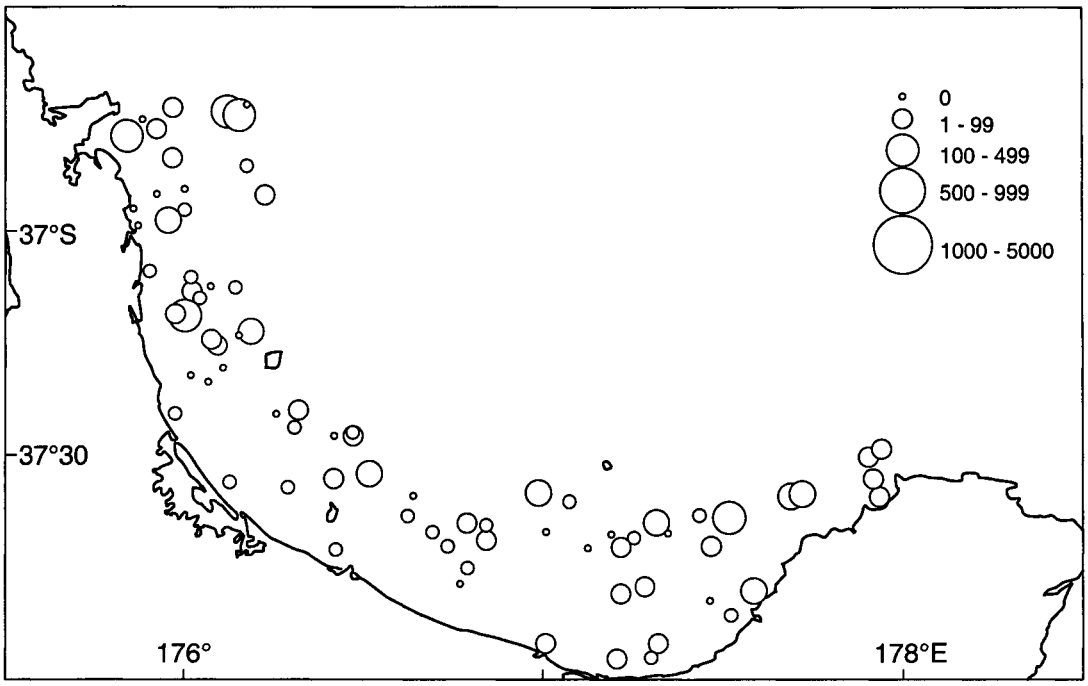

Figure 6: Catch rates (kg.km^{-2}) of snapper.

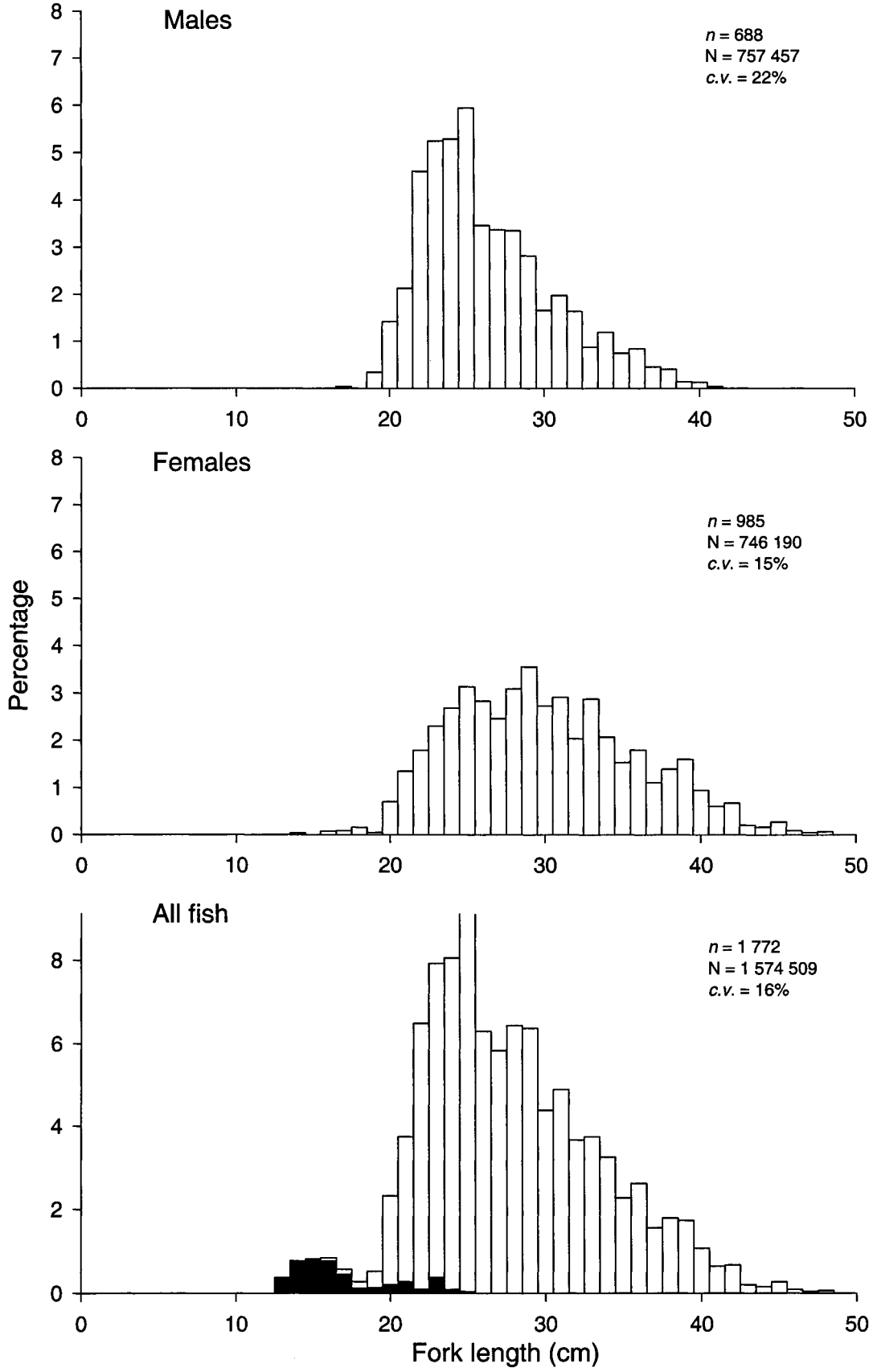

Figure 7 : Scaled length frequency distributions of male, female, and all red gurnard. *n*, number of fish measured; N, estimated number of fish in the survey area; *c.v.*, coefficient of variation of the survey estimate. Unsexed fish are shown as dark bars.

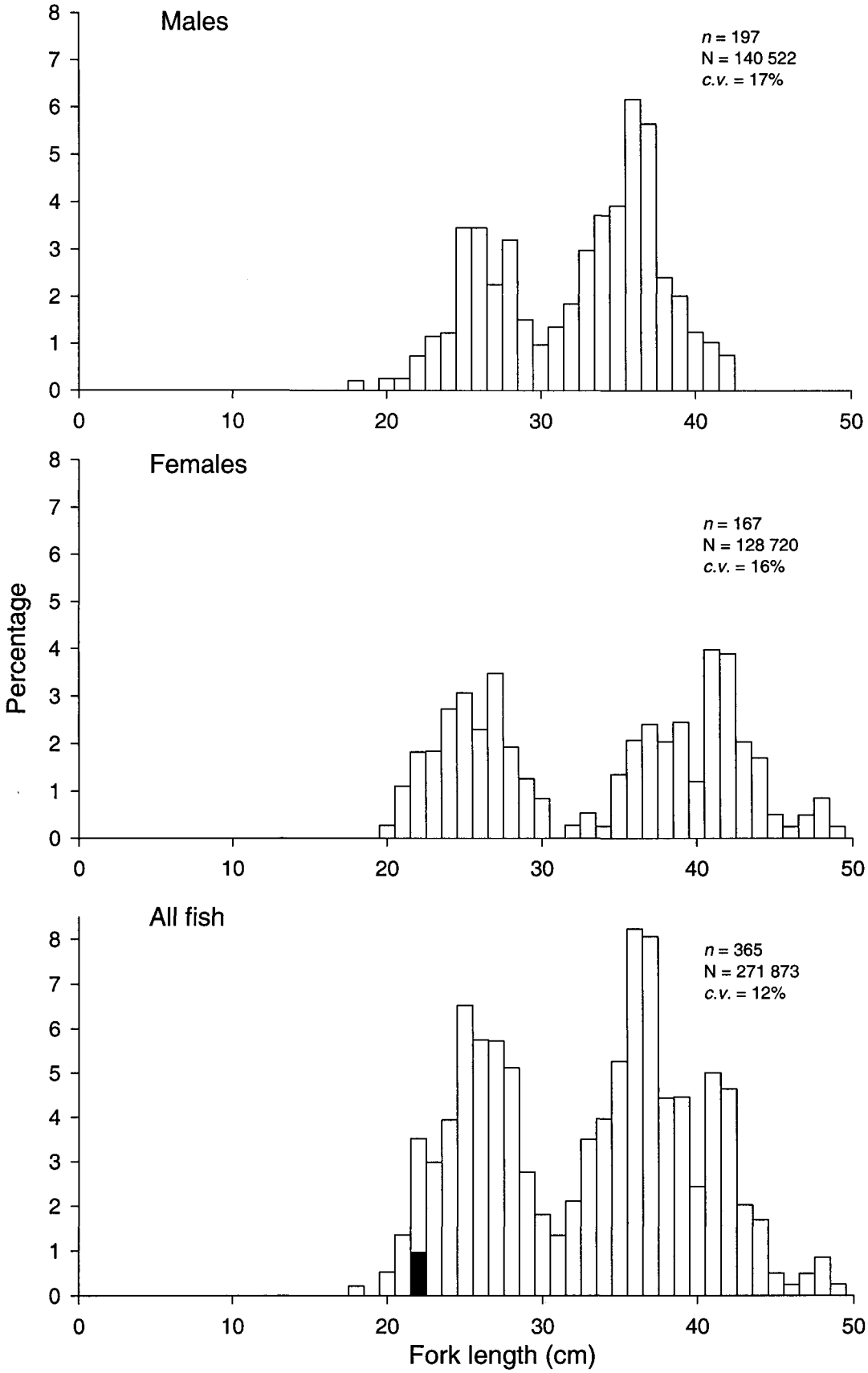

Figure 8: **Scaled length frequency distributions of male, female, and all John dory. *n*, number of fish measured; N, estimated number of fish in the survey area; *c.v.*, coefficient of variation of the survey estimate. Unsexed fish are shown as dark bars.**

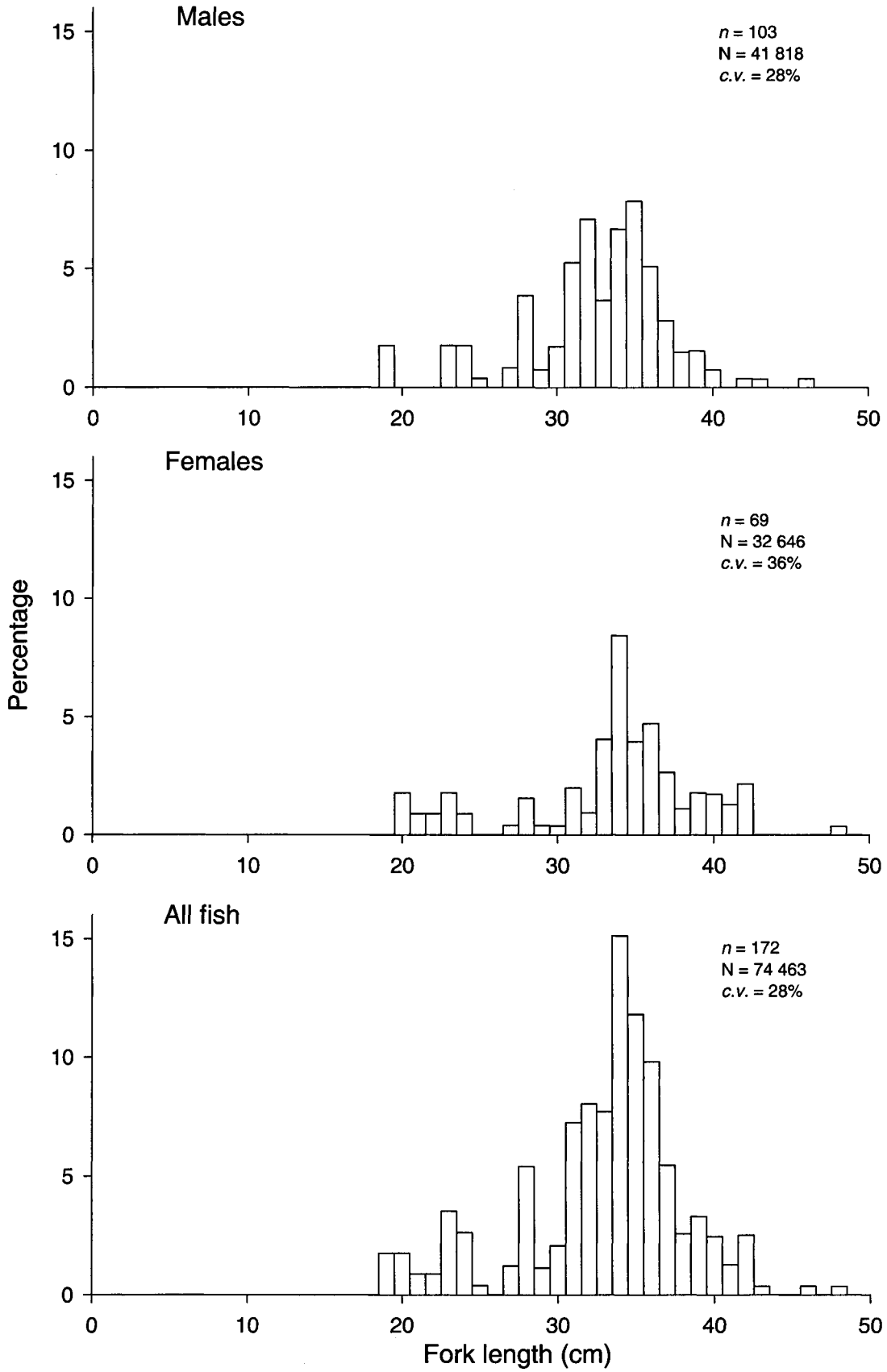

***Figure 9*: Scaled length frequency distributions of male, female, and all tarakihi. *n*, number of fish measured; N, estimated number of fish in the survey area; *c.v.*, coefficient of variation of the survey estimate.**

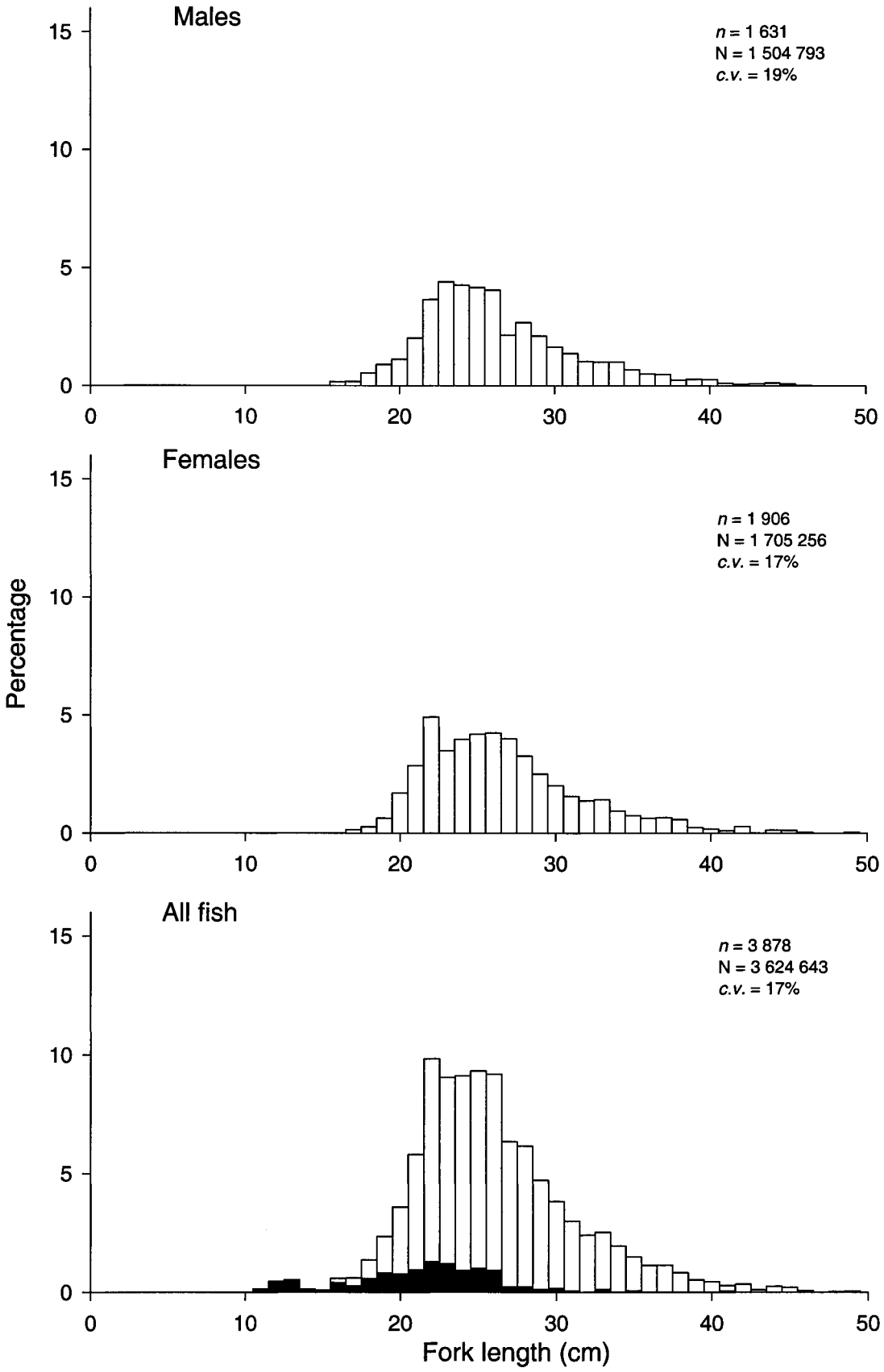

Figure 10: **Scaled length frequency distributions of male, female, and all snapper. *n*, number of fish measured; N, estimated number of fish in the survey area; *c.v.*, coefficient of variation of the survey estimate. Unsexed fish are shown as dark bars.**

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)**

	Depth range (m)															
	10–50			50–100			100–150			150–200			200–250			Total
	n	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*	Mean	*s.d.*	*n*
Headline height (m)	17	6.2	0.2	28	6.2	0.3	12	6.4	0.3	14	6.2	0.4	6	6.1	0.2	77
Tow speed (knots)	17	3.1	0.1	28	3.0	0.1	12	3.1	0.1	14	3.0	0.1	6	3.0	0.0	77
Doorspread (DS) (m)	17	80.8	2.4	28	83.8	3.4	12	84.3	5.1	14	91.2	6.5	6	95.6	8.0	77

Appendix 3: **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 4: **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 5*: 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 6 : Individual station data

Station no.	Stratum	Date (Feb 99)	Start of tow Time	Latitude ° 'S	Longitude ° 'E	Depth (m)	Tow distance (n. mile)	Warp length (m)	Headline height (m)	Door width (m)
1	7085	3	0549	36 43 91	175 58 16	93	0.67	292	6.8	-
2	808C	3	0717	36 44 90	176 07 21	149	1.00	425	6.5	-
3	909C	3	0921	36 44 75	176 09 47	166	1.00	478	5.7	98.6
4	909C	3	1017	36 44 91	176 09 22	163	1.10	426	5.7	93.4
5	808C	3	1135	36 51 53	176 10 60	145	1.00	350	6.0	89.8
6	909C	3	1247	36 55 33	176 13 76	184	1.00	450	5.8	94.9
7	7085	3	1540	36 45 21	175 53 30	59	0.70	200	6.0	83.1
8	7085	4	0543	36 54 72	176 00 14	80	0.73	225	5.9	84.9
9	7085	4	0648	36 57 28	176 00 16	66	0.71	200	6.2	79.8
10	32NH	4	0818	36 57 40	175 51 85	25	0.69	200	6.3	75.4
11	32NH	4	0956	36 59 46	175 52 47	15	0.70	200	6.0	80.6
12	32NH	4	1139	37 50 63	175 54 35	24	0.70	200	6.5	82.4
13	7085	4	1258	37 11 65	176 00 26	62	0.70	200	6.3	83.3
14	7085	4	1415	37 08 14	176 01 53	73	0.70	225	6.0	85.4
15	909C	4	1551	37 07 91	176 08 89	198	0.94	500	6.7	102.0
16	909C	5	0609	37 13 78	176 11 23	223	1.02	550	5.8	97.8
17	7085	5	0730	37 15 59	176 05 78	79	0.70	250	6.3	81.7
* 18	7085	5	0914	37 18 60	176 06 76	69	0.47	200	6.2	81.2
19	7085	5	1000	37 20 45	176 04 03	52	0.70	200	6.2	77.0
20	5C87	5	1119	37 19 68	176 01 22	46	0.70	200	6.2	79.6
21	096C	5	1218	37 24 83	175 58 87	19	0.70	200	6.0	81.4
22	7085	5	1413	37 24 89	176 15 58	77	0.70	225	6.4	87.8
23	808C	5	1558	37 27 77	176 25 13	125	1.00	300	6.5	86.6
24	096C	6	0530	37 35 98	177 56 12	24	0.69	200	6.2	80.7
25	6085	6	0619	37 33 34	177 55 10	74	0.71	225	7.6	73.3
26	808C	6	0716	37 30 54	177 54 38	149	0.95	350	6.2	88.0
26	808C	6	0716	37 30 54	177 54 38	149	0.95	350	6.2	88.0
27	909C	6	0808	37 29 40	177 56 65	193	0.99	450	5.9	93.4
28	808C	6	1023	37 35 87	177 41 79	145	1.00	350	7.2	74.8
29	808C	6	1147	37 38 61	177 31 39	137	0.99	350	6.9	80.2
30	909C	6	1322	37 39 20	177 19 21	161	0.96	400	6.7	91.9
31	909C	6	1456	37 42 44	177 13 26	184	0.99	500	7.0	83.8
32	6085	6	1627	37 47 89	177 17 36	73	0.69	225	6.9	85.1
33	4085	7	0530	37 48 23	177 35 44	30	0.70	200	5.9	81.1
34	096C	7	0619	37 51 68	177 31 88	22	0.70	200	6.4	80.6
35	4085	7	0713	37 49 71	177 28 13	38	0.69	200	6.2	80.0
36	4085	7	0836	37 55 35	177 19 69	31	0.69	200	6.2	84.4
37	096C	7	0915	37 57 19	177 18 46	25	0.69	200	6.2	79.9
38	096C	7	1007	37 57 40	177 12 82	24	0.69	200	6.6	79.1
39	096C	7	1348	37 55 31	177 00 79	21	0.69	200	6.2	79.9
40	6085	7	1536	37 48 83	177 13 23	68	0.69	220	6.0	80.0
41	5C87	8	0541	37 47 31	176 46 25	46	0.69	200	6.1	82.6
42	7085	8	0657	37 41 59	176 50 96	98	0.75	275	6.2	83.7
43	909C	8	0752	37 39 57	176 50 92	160	0.98	375	6.2	88.9
44	7085	8	0902	37 42 21	176 44 07	87	0.69	250	6.2	85.0
45	7085	8	0948	37 40 40	176 41 85	97	0.69	275	6.2	84.5
46	7085	8	1040	37 38 18	176 37 62	97	0.72	275	6.2	86.0
47	096C	8	1233	37 42 94	176 25 54	20	0.70	200	6.2	85.0
48	909C	8	1448	37 27 79	176 28 38	201	0.99	475	6.2	94.3

49	7085	9	0551	37 33 27	176 25 08	70	0.69	225	6.2	86.0
50	5C87	9	0703	37 34 52	176 17 55	47	0.69	200	6.2	83.4
51	096C	9	0813	37 33 98	176 07 98	21	0.69	200	6.2	77.0
52	7085	10	0630	37 26 58	176 18 67	81	0.70	225	6.2	82.4
53	7085	10	0727	37 24 07	176 19 12	100	0.72	275	6.4	89.1
54	909C	10	0929	37 27 01	176 28 29	220	0.69	525	6.2	80.0
55	808C	10	1141	37 32 86	176 31 00	117	0.99	300	6.5	79.0
56	909C	10	1259	37 35 74	176 38 52	225	1.06	575	6.2	97.5
57	909C	10	1440	37 39 11	176 47 53	206	0.99	450	6.4	89.9
58	909C	10	1624	37 35 07	176 59 60	235	0.98	550	6.0	96.3
59	808C	11	0540	37 35 35	177 43 57	143	1.00	375	6.2	88.4
60	808C	11	0750	37 42 23	177 28 44	102	0.99	300	6.3	81.7
61	808C	11	0904	37 38 04	177 26 54	172	0.99	425	6.7	87.9
62	808C	11	1015	37 40 71	177 21 15	132	1.00	350	6.2	79.1
63	808C	11	1135	37 41 05	177 15 63	133	1.00	350	6.2	88.5
64	909C	11	1237	37 40 95	177 11 87	209	0.99	550	6.4	99.2
65	909C	11	1339	37 42 68	177 07 96	178	0.99	450	6.2	93.0
66	808C	11	1453	37 40 38	177 00 99	119	0.99	325	6.0	87.0
67	909C	11	1611	37 36 36	177 04 85	163	0.99	375	6.4	74.7
68	7085	12	0534	37 45 11	176 47 67	63	0.70	200	6.1	85.0
69	909C	12	1019	37 14 03	176 09 17	154	1.00	400	5.8	90.2
70	7085	12	1135	37 09 03	176 02 96	84	0.70	250	6.0	88.3
71	7085	12	1223	37 07 73	176 04 66	100	0.71	-	6.1	86.8
72	7085	12	1314	37 06 36	176 01 21	73	0.70	225	6.1	88.1
73	909C	12	1614	36 43 23	176 10 70	200	0.99	540	6.1	103.0
74	7085	13	0536	36 47 58	175 50 69	52	0.69	200	6.0	83.1
75	7085	13	0643	36 46 64	175 55 65	86	0.46	250	6.0	85.8
76	7085	13	0738	36 50 43	175 58 20	95	0.69	275	6.0	85.0
* 77	7085	13	0929	36 55 15	175 55 76	63	-	200	-	-
78	7085	13	1009	36 58 95	175 57 58	57	0.69	200	6.4	85.0
79	7085	13	1144	37 11 25	175 58 97	54	0.70	200	6.1	81.8
80	7085	13	1249	37 14 97	176 04 85	79	0.69	250	6.1	85.2

*, fouled or poor performance shot

Appendix 7: Catch (kg) at each station of the seven more important commercial species : red gurnard (GUR), John dory (JDO), tarakihi (TAR), snapper (SNA), jack mackerel (Trachurus novaezelandiae, JMN; T. declivis, JMD), and trevally (TRE)

Station	GUR	JDO	TAR	SNA	JMN	JMD	TRE
1	6.4	2.9	12.1	13.8	0.0	1.0	1.6
2	1.4	0.3	6.7	6.4	14.2	3.0	0.0
3	4.4	0.0	1.7	5.0	7.2	4.6	0.0
4	0.0	0.2	3.4	3.7	2.9	0.5	0.0
5	0.4	0.0	3.7	8.7	1.1	0.1	0.0
6	0.0	0.0	0.0	7.7	0.0	5.0	0.0
7	10.4	13.2	0.0	52.8	0.0	0.0	1.0
8	1.7	11.2	1.2	54.7	0.0	0.0	0.0
9	3.3	11.1	0.0	28.7	0.0	0.0	0.0
10	10.6	1.9	0.0	107.9	0.0	0.0	15.0
11	4.6	2.8	0.0	100.7	0.0	0.4	1.9
12	18.9	2.9	0.0	167.7	0.0	4.4	6.4
13	5.1	1.0	0.0	3.7	0.1	0.0	0.0
14	26.9	3.5	1.1	34.2	0.3	1.3	9.7
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	15.0	0.0	42.3	108.3	0.0
17	5.9	12.5	0.0	3.2	0.0	0.0	4.3
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.2	1.5	0.0	0.0	0.0	0.3	0.0
20	3.5	1.4	0.0	4.8	0.0	0.1	0.0
21	1.7	12.5	0.0	459.0	0.0	0.0	3.7
22	18.7	13.0	0.0	12.8	0.0	0.0	27.3
23	2.4	1.0	0.0	3.9	0.0	1.9	0.0
24	21.7	0.0	0.0	54.8	0.0	0.0	24.5
25	0.0	0.0	0.0	25.6	2.7	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	110.9	0.0	0.0
29	7.7	6.0	0.0	4.6	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.1	0.0
31	0.0	0.9	18.6	0.0	0.1	0.0	0.0
32	6.0	1.4	0.6	15.0	6.9	0.0	0.0
33	12.0	0.0	0.0	31.6	1.6	0.0	19.6
34	14.9	0.0	0.0	25.8	4.5	0.0	3.9
35	3.8	0.7	0.0	24.3	11.5	0.0	16.7
36	0.0	4.5	0.0	63.2	62.6	0.0	21.8
37	20.1	5.0	0.0	138.3	14.9	0.0	4.2
38	13.7	3.0	0.0	73.1	2.0	0.0	21.3
39	6.2	0.0	0.0	10.4	1.7	0.0	14.0
40	11.0	5.2	0.4	27.6	15.4	0.0	1.2
41	13.0	1.2	0.0	76.9	1.9	0.0	4.4
42	4.7	3.6	0.0	7.8	43.3	0.0	0.0
43	0.7	1.0	0.0	1.3	0.0	146.9	0.0
44	12.3	12.8	0.0	8.3	0.6	0.0	0.0
45	9.4	8.5	0.0	16.8	0.0	0.4	0.0
46	2.5	2.5	0.0	4.2	0.0	0.5	0.0
47	4.0	0.5	0.0	57.7	1.4	0.0	3.0
48	0.0	0.0	0.0	0.0	2.0	2.7	0.0
49	3.5	9.7	0.0	21.9	0.4	0.4	1.5

50	15.9	1.0	0.0	100.5	0.3	0.0	35.4
51	5.5	0.0	0.0	74.8	5.4	0.0	14.6
52	2.4	0.7	0.0	35.9	0.0	0.0	0.0
53	1.3	2.0	0.0	5.6	0.0	0.2	0.0
54	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	14.0	2.0	0.0	7.6	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	1.4	0.1	0.0
58	0.0	0.0	23.2	0.0	0.0	0.0	0.0
59	0.0	7.2	6.8	0.5	21.6	2.1	0.0
60	6.2	4.6	0.0	7.3	21.4	0.3	0.0
61	0.6	0.0	1.2	0.0	0.2	1.5	0.0
62	4.6	3.0	0.0	4.2	6.2	0.0	0.0
63	2.8	7.4	3.3	0.0	0.0	0.6	0.0
64	0.0	0.0	20.9	0.8	0.0	0.0	0.0
65	0.0	0.0	1.1	0.0	2.3	0.5	0.0
66	10.4	3.5	0.0	4.1	2.8	0.9	0.0
67	0.0	0.8	0.0	0.0	0.5	0.0	0.0
68	12.0	0.0	0.0	14.1	0.5	0.0	0.0
69	0.4	8.0	0.0	5.1	0.0	1.0	0.0
70	5.0	14.0	0.0	18.2	0.0	0.0	7.5
71	4.2	3.4	0.0	14.1	0.0	0.0	3.3
72	5.3	5.5	0.0	27.2	0.0	0.0	0.0
73	0.8	0.0	11.0	0.0	1.3	42.8	0.0
74	15.2	9.1	0.0	112.5	0.6	0.0	13.5
75	1.4	0.0	0.0	12.1	0.0	0.0	0.9
76	3.4	8.8	0.0	17.4	0.0	0.0	0.0
77	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	37.3	7.5	0.0	80.0	0.0	0.0	5.7
79	15.3	5.0	0.0	31.4	21.3	0.0	2.1
80	34.2	23.5	0.0	16.1	0.0	0.0	1.2
Total	491.9	276.4	132.0	2 358.1	438.3	331.9	291.2

Appendix 8: Summary of otoliths collected, for red gurnard, John dory, tarakihi, and snapper

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