Bycatch and discards in trawl fisheries for jack mackerel and arrow squid, and in the longline fishery for ling, in New Zealand waters

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NIWA Technical Report 74
2000

Published by NIWA
Wellington
2000

Inquiries to:
Publication Services, NIWA,
PO Box 14-901, Wellington, New Zealand

ISSN 1174-2631
ISBN 0-478-23201-2

Citation: Anderson, O. F., Clark, M. R., & Gilbert, D. J. 2000:
Bycatch and discards in trawl fisheries for jack mackerel and arrow squid, and in the longline fishery for ling, in New Zealand waters.
NIWA Technical Report 74. 44 p.

Cover: A large catch of spiny dogfish. This species is a regular bycatch in the jack mackerel and squid trawl fisheries. (Photo by Neil Bagley)

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Contents

Abstract

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Catch and discard data from the Scientific Observer Programme for the fishing years 1990–91 to 1997–98 for the jack mackerel (*Trachurus* spp.) and arrow squid (*Nototodarus* spp.) trawl fisheries and catch data for the ling (*Genypterus blacodes*) longline fishery were extracted from MFish databases. Commercial landings data were also obtained from MFish for each of the three fisheries.

Observer data with appropriate stratification were used to produce estimates of the ratio of discard and incidental catch to the total catch. Variances for these ratios were calculated using bootstrapping methods for the jack mackerel and arrow squid trawl fisheries. These ratios were applied to commercial landings data to produce estimates of total annual bycatch and discards.

Discards and bycatch levels varied between years. Total annual discards were generally about 1000–2000 t for the jack mackerel and arrow squid fisheries, and 300–1500 t for the ling fishery. Total annual bycatch was estimated at 5000–13 000 t for the jack mackerel fishery, 9000–20 000 t for the arrow squid fishery, and 1300–5000 t for the ling fishery.

Observer data were found to be of limited use for analysis of discards in the ling longline fishery. However, a trip by trip comparison of observer catch and commercial landing records allowed some provisional estimates of annual bycatch and discards to be produced (without any estimates of variance).

Estimates of discards and bycatch levels were also made from summaries of bycatch records in commercial catch effort data, as a check on the general level of values obtained from the main analyses based on observer data. These estimates were within expected ranges.

Bycatch data from several trawl surveys were compared with observed commercial trawls for sections of the jack mackerel and arrow squid fisheries. These comparisons revealed some marked differences in relative catch composition between research and commercial data, suggesting that research survey data may be of limited use in analysis of bycatch in trawl fisheries.

Introduction

Bycatch and discarding occurs in almost all commercial fisheries. Target and non-target marketable species are retained for sale, and species for which there is no market, or which cannot economically be brought to market, are discarded (thrown back into the sea). Discards in commercial fisheries have become an increasingly important issue in fisheries management, as the world fishery harvest approaches theoretical maximum sustainable yields, and studies on levels of discarding have revealed the magnitude of the problem. A number of scientific workshops have focussed on bycatch and discard issues (e.g., Sissenwine & Daan 1991, Murawski 1992, Boddeke 1992, Weber 1995, Mace 1997). The issues have been most emphasised in shrimp trawl and drift-net fisheries, which have been widely publicised, but the same problems exist with finfish trawling and lining. The extensive literature was summarised by Alverson *et al.* (1994).

On a global scale, the most recent summary indicated annual discards in commercial fisheries of 27 million t, and a bycatch of non-target species of about 29 million t, out of a total harvest of around 80 million t (Alverson *et al.* 1994). Most of this was attributed to shrimp fisheries. Bottom trawls (together with longline and pot fisheries) ranked second, then drift-net and seine fisheries, with pelagic trawls and targeted purse-seine having the lowest ratios of discard to target catch.

The Ministry of Fisheries (MFish) is responsible for determining the impacts on associated or dependent species, including non-target fish species, taken as bycatch during normal fishing operations. This extends a number of current MFish research projects investigating bycatch and discards in New Zealand fisheries. A detailed analysis of the fisheries for southern blue whiting (*Micromesistius australis*), oreos (*Pseudocyttus maculatus* and *Allocyttus niger*), hoki (*Macruronus novaezelandiae*), and orange roughy (*Hoplostethus atlanticus*) (Clark *et al.* 2000) found discard levels to be relatively low in these fisheries, with most discarding occurring as a result of gear failure with very large catches. Some aspects of bycatch and discards have been examined for hoki fisheries off the west coast of the South Island (Ballara & Hurst 1997) and for orange roughy in Challenger Plateau and Chatham Rise fisheries (e.g., Robertson 1986, Clark 1991, Francis *et al.* 1993). Bycatch in tuna longline fisheries was dominated by a few species, with blue shark (*Prionace glauca*) and albacore tuna (*Thunnus alalunga*) accounting for more than 60% of the total catch (Francis *et al.* 1999). There are no known studies on fish bycatch or discards in New Zealand fisheries for jack mackerel, squid, or ling.

The fisheries examined in this report are important for New Zealand. Catches in 1997–98 were about 45 000 t for arrow squid, 37 000 t for jack mackerels, and 23 000 t for ling (Annala *et al.* 1999). Fisheries on this scale have considerable potential to catch large amounts of non-target species, or of target species that are damaged or of unwanted size.

Jack mackerel fisheries occur around much of New Zealand. There is a major purse-seine fishery in the Bay of Plenty and off the northeast coast of the North Island. There are trawl fisheries for jack mackerel in areas of the Chatham Rise, Southland/Subantarctic, and off the west coast of the North Island around Taranaki. The fishery is based on two New Zealand species, *Trachurus declivis* and *T. novaezelandiae*, and from the early 1990s the Peruvian jack mackerel, *T. murphyi*. The three species are generally not distinguished on catch records. The trawl fisheries occur mainly between 75 and 150 m with a maximum depth of about 300 m. Catches can be mixed, with arrow squid (*Nototodarus* spp.), barracouta (*Thyrsites atun*), blue mackerel (*Scomber australasicus*), trevally (*Pseudocaranx dentex*), tarakihi (*Nemadactylus macropterus*), frostfish (*Lepidopus caudatus*), Ray's bream (*Brama brama*), and redbait (*Emmelichthys nitidus*) frequently caught depending on the type of trawl (bottom or midwater) and the area of the fishery (e.g., Jones 1990, Horn 1991).

Squid fisheries are based on *Nototodarus sloanii* in or south of the Subtropical Convergence, and *N. gouldi* north of the convergence zone (Smith *et al.* 1987). Two fishing methods are used: jigging for both species at mostly shallower depths, and trawling almost exclusively for *N. sloanii.* The depth range for trawling is 80–300 m, with most effort at about 200 m (Gibson 1995). The main areas of trawling are the southern Taranaki Bight, Puysegur Bank-Snares Shelf, off the Auckland Islands, and near Banks Peninsula. Frostfish, slender tuna (*Allothunnus fallai*), and Ray's bream are amongst the bycatch taken by the midwater trawl fishery, and a wide range of middle depth species is caught in the bottom trawl fishery.

Ling are widely distributed throughout the EEZ at depths of 200–800 m. The fishery uses both bottom trawl and longline. Bottom longlining takes place primarily on the Chatham Rise, around the southern parts of the South Island, and on the Southern Plateau (Horn 1993, Ballara 1997). Fish species taken on ling longlines include bluenose (*Hyperoglyphe antarctica*), spiny dogfish (*Squalus acanthias*), ribaldo (*Mora moro*), ghost sharks (*Hydrolagus* spp.), and school shark (*Galeorhinus galeus*).

This report was prepared under the MFish project ENV9804 "Estimation of bycatch and discards in selected New Zealand fisheries" and addresses the following objectives.

1. To estimate the quantity of target and non-target fish species **bycatch** in squid trawl, jack mackerel trawl, and ling longline fisheries between the fishing years 1990–91 and 1997–98, using data from Scientific Observers, commercial fishing returns, and research trawl surveys.

2. To estimate the quantity of target and non-target fish species **discarded** in squid trawl, jack mackerel trawl, and ling longline fisheries between the fishing years 1990–91 and 1997–98, using data from Scientific Observers, commercial fishing returns, and research trawl surveys.

Methods

The terms 'bycatch' and 'discards' have a history of being confused. *Discarded catch* (referred to as "discards") are all the fish, both target and non-target species, that are returned to the sea as a result of economic, legal, or personal considerations (*after* McCaughran 1992). It does not include *incidental catch* (retained catch of non-target species) and contributes to *bycatch* (which is discarded catch plus incidental catch). To estimate bycatch in these fisheries, therefore, requires an estimate of discards as well as an estimate of incidental catch.

Tow-by-tow and set-by-set records from commercial fishing returns were obtained from MFish databases for each fishery. For the jack mackerel and squid trawl fisheries this included all fishing recorded on Trawl Catch and Effort Processing Returns (TCEPRs) and Catch Effort Landing Returns (CELRs), and for the ling longline fishery all CELR data. The recorded target species was used to define each fishery: JMA, JMM, JMD, JMN for jack mackerel; SQU, NOS, NOG, ASQ for arrow squid; LIN for ling.

Jack mackerel and arrow squid

Observer records of catch and discards in the two trawl fisheries were extracted separately from the MFish database '*obs*' (Mackay 1995) for the fishing years 1990–91 to 1996–97. Discard data for the 1997–98 fishing year could not be provided by MFish, so that although estimates of discards are made for this year, they are based on discard information from other years.

Tow-by-tow records for each fishery were extracted and attributes assigned for fishing year, area, tow type (midwater or bottom), depth (shallow or deep), season (high or low), and nation.

Tows were designated bottom tows if the net used was a bottom trawl, if the tow was on the bottom throughout the tow, and if the headline height was less than 20 m. Tows were designated midwater if a midwater trawl was used, the tow was in midwater throughout, and the headline height was 20 m or greater. Tows that satisfied neither set of criteria were assigned a NULL value.

The high and low seasons were derived from the spread of effort over the year as recorded by observers and from historical fishing practices: jack mackerel – high, November to April; low, May to October; arrow squid – high, December to May; low, April to November.

The distribution of tow depths was bimodal for both fisheries, so they fell naturally into deep and shallow groupings: jack mackerel – deep, over 120 m; shallow, less than or equal to 120 m; arrow squid – deep, over 160 m; shallow, less than or equal to 160 m.

Each fishery was divided into a number of areas based on natural breaks in the fishery or known stock divisions and tows were assigned to one of these areas.

Jack mackerel		Arrow squid	
West coast central NZ	(WEST)	Auckland Islands	(AUCK)
Chatham Rise	(CHAT)	Stewart-Snares shelf	(SNAR)
Stewart-Snares shelf	(SNAR)	Banks Peninsula	(BANK)

The database table *new_observer_processed* was used to determine the weight retained and discarded for each species. This table contains calculated catch weights and discard weights from processing data for all species caught, but has the disadvantage that it is structured on a processing 'groupnumber' rather than on the station number, and stations are frequently combined or split. In order to examine how discard levels varied with depth, area, fishing method, and season it was necessary to link the information in the tow-by-tow records to the processing data. This was achieved by summarising the station data over all stations within a processing groupnumber and inserting a null value where a variable differed between stations. Usually fishing year, area, season, and nation were constant between stations within a groupnumber, but often there was a mixture of tow types and a mixture of depths resulting in more null values for these variables.

From the resultant summarised data, weights of fish caught and fish discarded were calculated in each fishery for three groups: the target species (JMA/SQU); other main commercial species combined (COM); and all other species combined (OTH).

Summaries by species of the overall observed catch and percentage retained are tabulated for each fishery in Appendices 1 to 3. Species included in COM were defined as those non-target species which constituted more than 1% of the total observed catch over the 8 year period and were either a quota species or a species of which more than 75% by weight was retained.

Fishery	Commercial species (ordered by decreasing percentage of total catch)
JMA	barracouta, blue mackerel, frostfish, arrow squid, hoki, red cod (*Pseudophycis bachus*), blue warehou (*Seriolella brama*), tarakihi, silver warehou (*Seriolella punctata*), school shark, john dory (*Zeus faber*), dark ghost shark (*Hydrolagus novaezealandiae*), Ray's bream, gurnard (*Chelidonichthys kumu*), sea perch (*Helicolenus* spp.), ling, giant stargazer (*Kathetostoma giganteum*), slender tuna, snapper (*Pagrus auratus*), gemfish (*Rexea solandri*), silver dory (*Cyttus novaezealandiae*), rig (*Mustelus lenticulatus*), hapuku and bass (*Polyprion oxygeneios* and *P. americanus*), trevally, hake (*Merluccius australis*), kahawai (*Arripis trutta*).
SQU	barracouta, jack mackerel, blue warehou, silver warehou, hoki, red cod, Ray's bream, redbait, slender tuna, ling, gemfish, hapuku and bass, giant stargazer, smooth skate (*Raja innominata*), dark ghost shark, white warehou (*Seriolella caerulea*), sea perch, crested bellowsfish* (*Notopogon lilliei*), hake, school shark.

* Included mainly because of a single large catch of this species which was recorded as having been retained.

Available for analysis were 3029 trawls and 2206 processing groups in the jack mackerel fishery and 7268 trawls and 4778 processing groups in the arrow squid fishery.

The total weights discarded in each group were estimated as the calculated weight discarded from the vessel plus a proportion of any fish recorded as lost at the surface, based on the relative fractions landed in each group.

A stepwise linear regression procedure in SYSTAT (Systat 1997) was used to determine the influence of nation, tow type, area, depth, season, and fishing year on discards of the target species, COM, and OTH categories, and on incidental catches in order to determine whether any stratification was required. A log-linear transformation was used to deal with some of the strongly skewed discard distributions.

Ling

Set-by-set records of catches in the ling longline fishery were extracted from the MFish database '*obs_lfs*' (Sanders & Mackay 1999) for the fishing years 1990–91 to 1997–98.

Estimation of discards in this fishery was difficult because only 14 trips targeting ling with this method were observed during these 8 years and only records of fish caught (and not of fish discarded or retained) were made by observers.

The only way to determine what was discarded was to compare the observed catch for each trip (where weights of all species caught are recorded) with the catch landing records for the same trips (which record species and species weights of all fish retained). This method is dependent on three assumptions: the fish landed at the end of an observed trip are all and only the fish caught from that trip, all sets on the trip were observed, and all sets made during the trip targeted ling.

Calculation of discard ratios

Discard ratios were calculated for the target species, commercial species, and non-commercial species.

Observed data were combined, so the discards and the total catch were summed within each stratum. This gives the "discard ratio" (R) which is defined as the ratio of discarded catch to total catch:

$$\hat{R} = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} l_i}$$

where m processing groups are sampled from a stratum, d_i is the weight of the species discarded from the ith processing group sampled, and l_i is the weight of the target species caught in the ith processing group sampled. Ideally, the discard ratio calculated for the commercial species category would have used the total catch of that category as the denominator. However, good estimates of total catch of this category are unavailable from commercial fishing returns, which record estimated landed weights of only the top five species in each tow. All discard ratios are therefore based on the total catch of the target species. Assumptions are made that all trips are sampled with equal probability, and that all shots in the trip are observed. Both assumptions are reasonable.

The discard ratio calculated for each of the three categories was then multiplied by the total estimated catch of the target species in the stratum (L) to estimate total discards (D):

$$\hat{D} = \hat{R} \times L$$

For the two trawl fisheries, estimates of $\hat{R}$ for each stratum were derived from the summarised observed processing data, as described above. Variance of the estimates of discards was derived from bootstrap analysis of the same dataset. This involved sampling at random (with replacement) 500 or

1000 sets of pairs (depending on computing limitations) of ratio values from each stratum. Each of the sets was the same length as the number of records in each stratum. This resulted in estimates of $\hat{R}$ from which, providing they were approximately normally distributed, variances and confidence intervals could be calculated.

Bootstrapping used procedures in "New S" (Becker *et al.* 1988).

Estimates of $\hat{R}$ for the ling longline fishery were calculated from the comparison of observer and landings records, derived from the ratio of landed catch to observed catch. No stratification was used and the two non-target categories were combined due to the small amount of data. Confidence intervals could not be calculated for these estimates.

Calculation of incidental catch ratios

Incidental catch ratios were obtained in a similar manner to the discard ratios in each fishery by calculating the ratio of retained non-target species catch to the estimated target species catch. For the jack mackerel and arrow squid fisheries confidence intervals were calculated using the same bootstrapping methods used for discard estimation. The incidental catch ratio was then multiplied by the total estimated landed catch of the target species in the stratum to estimate total incidental catch.

Estimation of discards and bycatch from TCEPR bycatch records

To check whether the estimates of discards and bycatch for these fisheries appeared reasonable, a comparison was made with species catch totals available from commercial landings.

Bycatch data from TCEPR/CELR records were extracted and annual catch totals calculated by species. Observer data from all eight years were used to produce an overall discard ratio for each species in the target fishery, calculated as the total recorded discards of the species during the period divided by the total recorded catch of that species. This ratio was then applied to the annual TCEPR/CELR catch total for that species to provide an estimate of retained and discarded catch. Where observer data were not available for a species a mean ratio was calculated from data for all species except the target species. Observer data were too sparse for too many species for any stratification to be applied for calculation of the ratios.

This method has the advantage that it uses bycatch data from all commercial landings records for the period and thus avoids the scaling up required from just the observed part of the fishery used in the first method. Hence, between year variation in bycatch may be more clearly shown. However, only the top five species are recorded on TCEPR/CELR forms and many of the species caught regularly but in smaller amounts (particularly non commercial species) are overlooked. Observers in the jack mackerel fishery recorded up to 30 species per tow, with an average of about 11. In the arrow squid fishery the equivalent figures were 25 and 6.3, and in the ling longline fishery 14 and 5.8. Because of these limitations in the data confidence bounds could not be estimated.

Bycatch information from trawl surveys

Research surveys are of little use for estimation of discards, as discarding practices during a survey are unlikely to reflect commercial practice. However, trawl survey data may provide some additional information on bycatch species composition and catch levels where location, timing, gear type, and fishing methods are similar to those in commercial fishing operations. Survey data can help to reveal the true variety of bycatch species taken in the fishery because of the more thorough approach taken to species identification, and can help verify relative catch composition data from observer records. To this end we summarised bycatch from several trawl surveys that were comparable to parts of the jack mackerel and arrow squid trawl fisheries.

Results

Jack mackerel trawl fishery

Distribution of data

The positions of observed tows in the jack mackerel fishery, the positions of all commercial tows, and the area boundaries used in the analyses are shown in Figure 1. This shows a good spread of observer coverage over the fishery. Inevitably there were a few positional errors, as evidenced by some tow positions plotted over land and some that may have been recorded as west instead of east. For the analyses, all positions that fell outside the three main areas were treated collectively in an "other" category.

The observed processing groups were dominated by vessels of five nations, primarily Japan, with Russia, New Zealand, Ukraine, and Korea. About 80% of observed fishing took place inside the November–April high season. Many tows were difficult to define as bottom or midwater tows because of the way fishing gear was used close to the sea floor, and the data were further complicated when catches from more than one tow were combined into a single processing group. Where it was possible to classify the tows, bottom tows were about twice as common as midwater tows.

Fishing effort was spread over three main areas: CHAT, 251 groups; SNAR, 257 groups; WEST, 1697 groups; and OTHER, 1 group.

In most years more than 200 observed processing groups were available for analysis.

Fishing year	Groups
1990–91	140
1991–92	228
1992–93	316
1993–94	585
1994–95	399
1995–96	212
1996–97	326

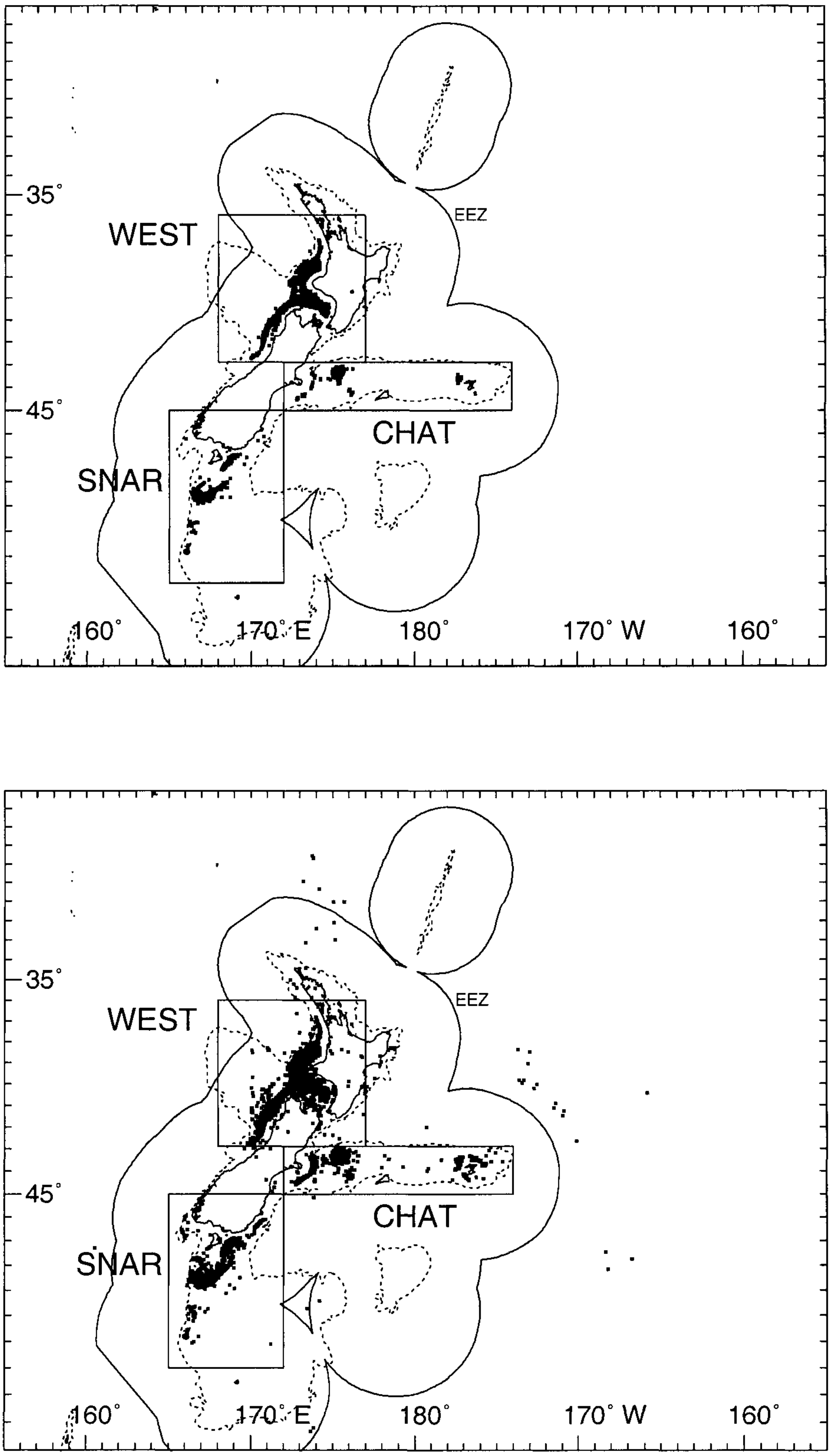

Figure 1: **Distribution of tows (start position) recorded by scientific observers on vessels fishing for jack mackerel between 1 Oct 1990 and 30 Sep 1998 (*top*); distribution of all tows where position was recorded by vessels fishing for jack mackerel during the same period (*bottom*). Area divisions are those used in the analyses; some positions to the east of 180° in the lower panel may reflect eastern hemisphere tows recorded as west.**

Calculation of discards

The GLM analysis indicated that area and tow type were more important than the other variables. Tow type was particularly influential on discards of OTH, which probably reflected a much smaller catch of discard species in midwater trawling. Despite limiting stratification to just area and tow type, there were some combinations of these categories which had very few data. This was partly due to the difficulty in categorising a tow as entirely midwater or entirely bottom, and partly due to a mixture of tow types in the tows which made up the processing groups.

Raw discard values were examined for each species group, in each area, and by gear type where more than 100 processing groups were recorded. Generally JMA and COM were not discarded at all, with medians and 0.75 quantiles of zero in each area and both tow types examined (Table 1). In these categories there were many zero discards with an occasional large discard event. Large discards are likely to have been due to a gear problem resulting in fish loss at the surface or an inability to process the catch: examples from observers include freezer breakdowns and chemical contamination. The largest discard of JMA recorded for one processing group was 72 t, and the largest discard of COM was 15 t.

Non-commercial species were regularly discarded with median values generally non-zero. Maximum discards of OTH were up to 24 t in CHAT and WEST and all quantiles in each area were higher in the mixed category of gear type than in midwater tows.

***Table 1*: Quantiles of discards (kg) of jack mackerel (JMA), other commercial species (COM), and non-commercial species (OTH) by area and tow type, from observer data; N, number of processing groups**

Species	Area	Tow type	N	Median	0.75 quantile	0.95 quantile	Maximum
JMA	CHAT	mixed	132	0	0	61	72 668
JMA	CHAT	midwater	117	0	0	5	24 500
JMA	SNAR	mixed	161	0	0	0	20 000
JMA	SNAR	midwater	93	0	0	14	1 053
JMA	WEST	mixed	610	0	0	0	8 000
JMA	WEST	bottom	861	0	0	30	28 774
JMA	WEST	midwater	226	0	0	3	9 974
COM	CHAT	mixed	132	0	0	13	490
COM	CHAT	midwater	117	0	0	0	189
COM	SNAR	mixed	161	0	0	10	169
COM	SNAR	midwater	93	0	0	34	300
COM	WEST	mixed	610	0	0	41	9 100
COM	WEST	bottom	861	0	0	235	3 008
COM	WEST	midwater	226	0	0	47	15 000
OTH	CHAT	mixed	132	93	376	2 121	24 500
OTH	CHAT	midwater	117	7	80	1 142	3 500
OTH	SNAR	mixed	161	10	100	1 846	11 600
OTH	SNAR	midwater	93	0	6	376	3 500
OTH	WEST	mixed	610	53	305	2 220	17 292
OTH	WEST	bottom	861	300	750	2 840	16 310
OTH	WEST	midwater	226	5	45	634	24 500

Discard ratios and variances were calculated for each species group from bootstrap analyses for each area and tow type combination where more than 100 values were available, and the resultant distributions examined. For JMA discards some of these distributions were strongly skewed to the right and bimodal. This is because most of the time there are no discards at all and occasionally there is a large discard value. Similarly for COM species, strongly non-normal distributions were shown for some area/tow type combinations. Bootstrap distributions of OTH discard ratios were all close to normal due to a much higher level of non-zero discard values in the raw data. This indicates that, as might be expected, non-commercial species are often caught and generally discarded.

As a result of these non-normal distributions, a single overall ratio was calculated for discards of JMA with no stratification by area or year. This overall bootstrap showed a more normal distribution, which was acceptable for calculating variances. For discards of COM, ratios were calculated for each area with no tow type separation, and again produced acceptably normal distributions of ratios. For OTH, stratification was by area and tow type where more than 100 values were available. For both COM and OTH analyses, where a stratum had too few values or ratio distributions were non-normal, the overall ratio for the group was used to provide a complete set of ratios to apply to the fishery totals for each year. The strata and discard ratios used for each species group are summarised in Table 2. Discard ratios varied between 0.0008 and 0.0789, and were lowest in the COM categories.

***Table 2*: Summary of sample sizes, discard ratios and associated *c.v.*s used to calculate total discards in the jack mackerel fishery; N, number of processing groups**

Species group	Area	Tow type	N	$\hat{R}$	*c.v.* (%)
JMA	ALL	all	2 206	0.0140	34.9
COM	CHAT	all	251	0.0010	48.0
COM	SNAR	all	257	0.0008	31.2
COM	WEST	all	1 697	0.0043	25.8
COM	ALL	all	2 206	0.0036	25.1
OTH	ALL	all	2 206	0.0503	5.9
OTH	ALL	mid	436	0.0243	35.7
OTH	ALL	bot	866	0.0779	6.4
OTH	CHAT	mid	117	0.0128	31.6
OTH	SNAR	mid	93	0.0153	42.3
OTH	WEST	mid	226	0.0334	47.6
OTH	WEST	bot	861	0.0789	6.2

Jack mackerel are frequently caught as bycatch in other trawl fisheries and these catches make up a significant fraction of the total landed catch. Yearly totals of estimated catches from the target fishery were prepared from TCEPR data (where the target species is recorded) and compared with QMS landings (Table 3). The target fishery catch estimates range from 36 to 64% of the reported landings. This comparison is shown here because the bycatch estimates presented in this document relate to only the target fishery. Additional discarding will have occurred in fishing where jack mackerel was caught as bycatch, but discard ratios are likely to be different and are best accounted for in separate analyses of those fisheries. Observers covered up to 22% of the annual target fishery, with a low of 9% in 1991–92.

***Table 3*: Estimated catch totals of jack mackerel from the target trawl fishery and all reported landings from the QMS by year**

Fishing year	Target fishery estimated catch (t) TCEPR	QMS reported landings (t)*	Observed catch (% of TCEPR total)
1990–91	11 054	30 661	19
1991–92	22 308	38 676	9
1992–93	23 483	47 778	22
1993–94	18 806	45 748	21
1994–95	17 781	38 264	12
1995–96	15 297	38 947	15
1996–97	16 420	34 655	21
1997–98	24 252	37 439	–

* QMS figures from Annala *et al.* (1999).

Landings data were stratified by area and tow type and the associated discard ratios from observer data applied to each stratum to estimate discards in each category (Table 4). Discards were dominated by species in the OTH category, with COM species consistently discarded least. Total discards ranged from 937–1845 t per annum. Although discards were estimated for all fishing years, including 1997–98, the observer data used to provide these estimates did not include any from that year.

***Table 4*: Estimates of discards in the JMA trawl fishery for 1990–91 to 1997–98 (rounded to the nearest t), with 95% confidence intervals in parentheses**

Fishing year	JMA	COM	OTH	TOT
1990–91	155 (68–262)	46 (28–73)	735 (644–835)	937 (740–1 170)
1991–92	313 (137–529)	95 (57–150)	1 398 (1 212–1 608)	1 806 (1 407–2 286)
1992–93	329 (145–557)	88 (52–140)	1 457 (1 242–1 707)	1 875 (1 439–2 404)
1993–94	264 (116–446)	71 (42–114)	1 136 (962–1 344)	1 471 (1 120–1 903)
1994–95	249 (109–421)	61 (35–98)	811 (607–1 091)	1 121 (752–1 610)
1995–96	215 (94–363)	40 (23–65)	750 (611–926)	1 005 (727–1 354)
1996–97	230 (101–389)	46 (26–75)	812 (662–1 005)	1 089 (789–1 470)
1997–98	340 (149–575)	68 (40–109)	1 436 (1 240–1 664)	1 845 (1 428–2 348)

Calculation of incidental catch

The GLM analysis showed tow type to be the most influential factor on retained non-target catch, with area also important. These were the same factors important in describing the variability in discard levels, so the stratification used in the discard calculations was repeated here, with stratum-specific ratios used where bootstrap distributions were acceptable and an overall ratio used where they were not. Table 5 shows the catch ratios calculated for JMA. These ranged from 0.104 to 0.751 and were highest in area SNAR and lowest in area CHAT. Where midwater and bottom tows were analysed separately, midwater tows had a slightly lower ratio.

Table 5: **Summary of sample sizes, catch ratios, and associated *c.v.*s used to calculate total incidental catch in the jack mackerel fishery; N, number of processing groups**

Area	Tow type	N	$\hat{R}$	*c.v.*(%)
ALL	all	2 206	0.4007	4
ALL	mid	436	0.3626	11
ALL	bot	866	0.4262	4
CHAT	all	251	0.2435	18
CHAT	mid	117	0.1044	27
SNAR	all	257	0.5706	12
SNAR	mid	93	0.7506	19
WEST	all	1 697	0.4030	4
WEST	mid	226	0.3472	16
WEST	bot	861	0.4146	4

The estimates of $\hat{R}$ from Table 5 were applied to landings data to produce estimates of total incidental catch for the jack mackerel target fishery (Table 6). Annual estimates of incidental catch ranged from 4462 to 10 794 t.

Table 6: **Estimates of incidental catch in the JMA trawl fishery for 1990–91 to 1997–98 (rounded to the nearest t), with 95% confidence intervals in parentheses**

Fishing year	Incidental catch (t)
1990–91	4 462 (4 058–4 931)
1991–92	9 127 (8 272–10 108)
1992–93	8 734 (7 698–9 999)
1993–94	7 074 (6 215–8 122)
1994–95	6 226 (5 101–7 636)
1995–96	6 417 (5 146–7 987)
1996–97	6 236 (5 123–7 642)
1997–98	10 794 (9 014–12 829)

Bycatch was calculated separately for JMA and non-target species (Table 7). For JMA, bycatch is the discarded part of the JMA catch, and for non-target species bycatch is the sum of the incidental catch and the discarded portion of the non-target species catch. These estimates were derived from Tables 4 and 6. Non-target bycatch dominated the total annual bycatch and ranged from 5399 to 12 639 t.

Table 7: **Estimates of bycatch in the JMA trawl fishery for 1990–98 (rounded to the nearest t), with 95% confidence intervals in parentheses**

Fishing year	JMA bycatch	Non-target bycatch	Total bycatch
1990–91	155 (68–262)	5 244 (4 730–5 839)	5 399 (4 798–6 101)
1991–92	313 (137–529)	10 620 (9 542–11 866)	10 932 (9 679–12 395)
1992–93	329 (145–557)	10 279 (8 992–11 846)	10 609 (9 136–12 403)
1993–94	264 (116–446)	8 282 (7 218–9 580)	8 546 (7 334–10 025)
1994–95	249 (109–421)	7 207 (5 743–8 825)	7 347 (5 852–9 247)
1995–96	215 (94–363)	7 207 (5 780–8 978)	7 422 (5 874–9 341)
1996–97	230 (101–389)	7 122 (5 811–8 722)	7 352 (5 912–9 111)
1997–98	340 (149–575)	12 299 (10 293–14 602)	12 639 (10 442–15 176)

Estimation of discards and bycatch from TCEPR bycatch records

A total of 93 species or species groups were recorded on commercial landings forms, with discard ratios from observer data available for 73 of them. Annual discard totals were calculated for commercial and non-commercial categories (Table 8), but not for the target species because the method in this case is simply a less refined version of that already used. Estimates of annual bycatch were calculated for all non-target species combined. Discards of commercial species varied from 28 to 66 t per annum. These values are much lower than calculated using the previous method (*see* Table 4) for the first four years, and broadly similar for the final four years. Discards of non-commercial species increased over time from a low of 308 t in 1990–91 to a high of 845 t in 1997–98. As expected these values are much lower than those estimated in the main analysis (*see* Table 4) due to a lower likelihood of these species being recorded on the TCEPR forms. Estimates of total non-target bycatch range from 3580 to 12 957 t. Like the discard estimates, these values are lower than those estimated by the first method for the first four years, but are quite similar for the last four years, falling within the 95% confidence intervals calculated for those estimates (*see* Table 7).

***Table 8*: Estimates of discards and bycatch in the JMA trawl fishery for 1990–91 to 1997–98 (rounded to the nearest t), derived from TCEPR totals**

Fishing year	COM Discards	OTH Discards	Non-target Bycatch
1990–91	28	308	3 580
1991–92	51	415	8 438
1992–93	32	530	5 797
1993–94	29	640	5 705
1994–95	48	690	7 212
1995–96	42	701	6 366
1996–97	52	613	8 487
1997–98	66	845	12 957

Bycatch information from trawl survey data

A trawl survey was carried out from a chartered commercial vessel in the Taranaki Bight in 1990 during the main part of the jack mackerel season (Horn 1991). The aim was to provide an index of jack mackerel biomass in the area where most of the stock was thought to occur. The survey used bottom trawl gear only and 220 random trawls were made. In general, trawl gear and fishing methods were similar to those used by the commercial fleet. All catch was identified and weighed to the nearest 100 g, except for catches over 150 kg when species weights were usually back-calculated from frozen block weights.

A few comparisons are possible between these trawl survey data and observed commercial fishery data from this area and with this tow type. A total of 86 bycatch species or species groups was recorded from the research survey. A total of 61 t of jack mackerel (42 t *Trachurus novaezelandiae*, 19 t *T. declivis*) was caught with 76 t of bycatch, mainly barracouta, spiny dogfish, school shark, and snapper (Table 9). The top nine species listed in this table accounted for over 80% of the total bycatch from the survey.

Coincidentally, observers in this area (WEST, *see* Figure 1) also recorded 220 bottom trawls the following season which caught 1700 t of jack mackerel and 500 t of bycatch species. The considerably greater catches of both jack mackerel and bycatch species in the commercial tows compared with the same number of survey tows is not unexpected because the former target concentrations of fish and the latter are based on random positions. The observers recorded 52 species or species groups. The composition of the main bycatch species was markedly different to that from the research survey data, with eight species providing more than 96% of the total bycatch (*see* Table 9). Although barracouta was again the main bycatch species, it had almost twice the contribution to bycatch at 35.7%. Blue mackerel also made up a large proportion of the observed bycatch (33.9%) compared with only 0.5 % in the survey. Spiny dogfish, school shark, and snapper were more common in bycatch from the survey than from the observed commercial tows.

***Table 9*: Bycatch species and percentage of the total bycatch from a random trawl survey of jack mackerel and from commercial trawls targeting jack mackerel in the Taranaki Bight; *see* Appendix 4 for an explanation of the species codes**

Species code	Survey data (% of total bycatch)	Commercial data (% of total bycatch)
BAR	19.5	35.7
SPD	13.9	2.5
SCH	11.5	1.5
SNA	10.8	0.1
TRE	7.2	< 0.1
TAR	5.5	0.7
FRO	5.3	13.3
LEA	3.8	0.2
SQU	3.0	4.0
RBT	2.2	3.1
EMA	0.5	33.9
THR	0.5	2.2

Arrow squid trawl fishery

Distribution of data

The distribution of observed tows in the arrow squid fishery for comparison with all commercial tows, and the area boundaries used in the analyses, are shown in Figure 2. The data show a good spread of observer coverage in the Auckland Islands and Stewart-Snares shelf fisheries, with less coverage in the fishery off Banks Peninsula. There are a few positional errors, which were treated in the same manner as those found in the jack mackerel data. Almost all samples (98.8%) were taken from the December–May "high" season.

The observed fishery was dominated by Russian flagged vessels (about 65% of all processing groups), and vessels from Japan, Korea, Poland, Ukraine, and China provided most of the remainder of the data.

Only 20% of processing groups could be separated into bottom and midwater trawls. Where it was possible to do this, bottom trawls were almost ten times as common as midwater trawls.

Fishing occurred mainly in SNAR (2451 groups) and AUCK (2071) with 242 groups in BANK and 14 in OTHER.

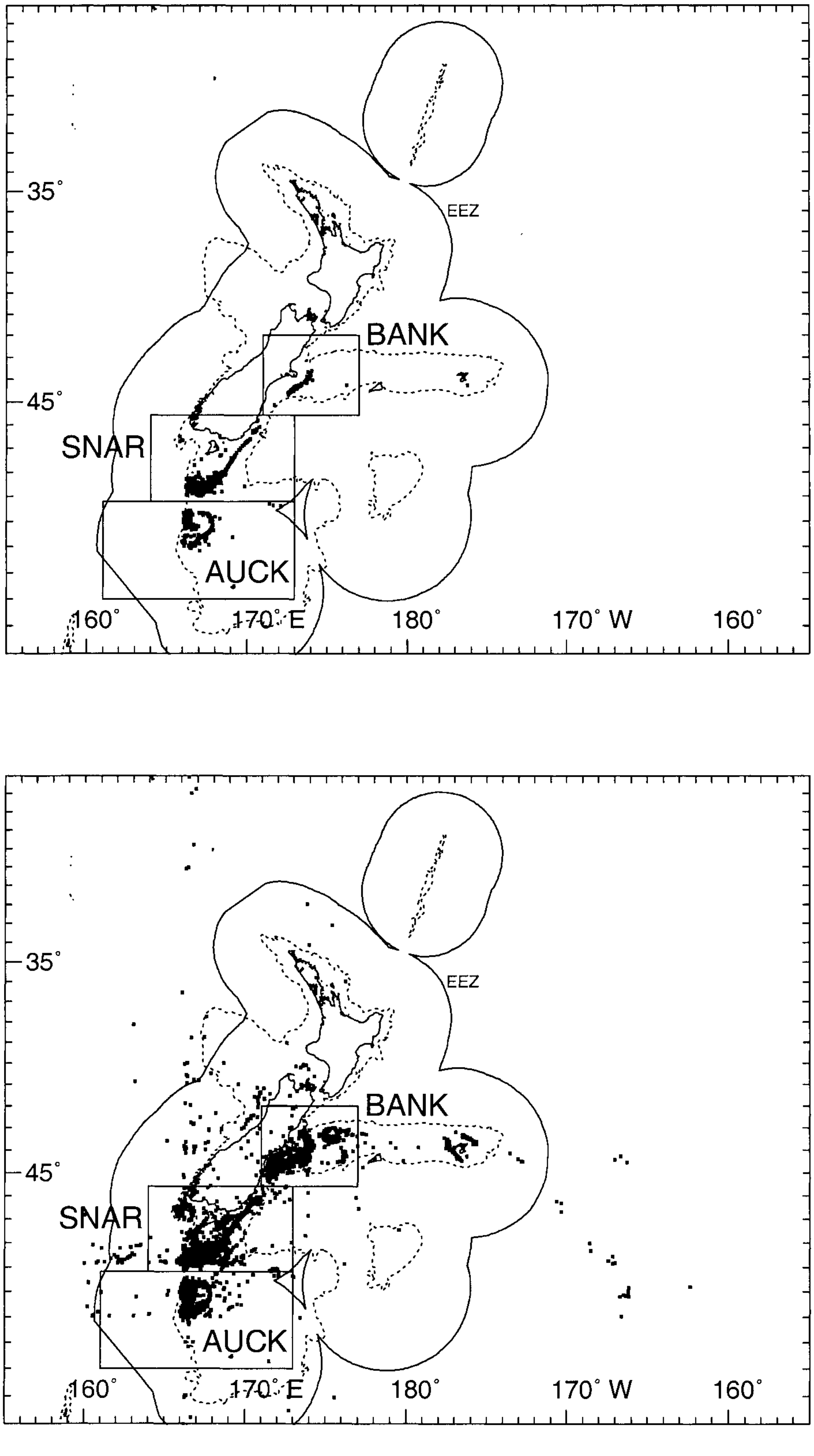

Figure 2: **Distribution of tows (start position) recorded by scientific observers on vessels fishing for arrow squid between 1 Oct 1990 and 30 Sep 1998 (*top*); distribution of all tows where position was recorded by vessels fishing for arrow squid during the same period (*bottom*). Area divisions are those used in the analyses; some positions to the east of 180° in the lower panel may reflect eastern hemisphere tows recorded as west.**

In most years more than 600 observed processing groups were available for analysis, with lower sampling effort in 1991–92.

Fishing year	Groups
1990–91	712
1991–92	344
1992–93	813
1993–94	753
1994–95	639
1995–96	690
1996–97	827

Calculation of discards

The stepwise GLM indicated that nation and area were important in each species category with tow type also important in discards of OTH. Stratification was limited to nation and area and discard ratios were estimated for combinations of these variables where there were over 100 values. For the BANK area only three nations recorded more than 20 processing groups and two nations, New Zealand and Faroe Islands, recorded less than 50 groups in total.

Raw discard values were examined for each species group, in each area, and by nation where more than 100 processing groups were recorded (Table 10). The distribution of raw discard weights showed a similar pattern to that of JMA discards in that, for discards of the target species, most groups had no discarding at all and discards were dominated by occasional large events. The maximum recorded discard of SQU in a single processing group was 29.9 t by a Russian vessel in the SNAR area. In contrast, no discards of SQU were recorded in 106 groups processed by Chinese registered vessels in the same area. Other commercial species were only slightly more regularly discarded with 0.75 quantiles generally zero or only a few tonnes. An exception was Chinese registered vessels in SNAR and AUCK, which recorded discards of COM more regularly. The greatest recorded discard of COM was 14.8 t by a Russian registered vessel in SNAR. Discards of OTH were more regular, but still occurred in less than 50% of groups in some nation/area combinations. The maximum discard of OTH was 25 t in SNAR by a Russian registered vessel.

Bootstrap analyses were done initially for all species group, area, and nation combinations where enough data were available (over 100 groups). Because of the nature of some of the distributions of discards in these groups, bootstrapping produced a highly non-normal distribution of ratios. The most extreme example was the analysis for SQU/CHINA/AUCK. This was based on 157 records, 156 of which had zero discards and one a discard of 24 t. Also many of these groupings were not represented by enough data to make a separate estimate, with the effort by nation unevenly spread over the three areas. For these reasons bootstrapping was carried out on an area by area basis for each species group, and nation was ignored. This gave enough data for bootstrapping to produce near-normal distributions from which variances could be calculated in all but one case. For this case, and for the purposes of applying the ratios to the yearly fishery totals where the fish were caught outside of any of the areas used, an overall discard ratio and variance was estimated for each species group.

The discard ratios used for each species group and area range from 0.0009 to 0.0592 and are lowest in the COM categories. There were low discard ratios for COM and OTH categories in the AUCK area (Table 11).

***Table 10*: Quantiles of discards (kg) of arrow squid, other commercial species, and non-commercial species by area and tow type; N, number of processing groups**

Species	Nation	Area	N	Median	0.75 quantile	0.95 quantile	Maximum
SQU	China	AUCK	157	0	0	0	23 983
SQU	China	SNAR	106	0	0	0	0
SQU	Japan	SNAR	344	0	0	437	1 567
SQU	Korea	AUCK	210	0	3	17	60
SQU	Korea	SNAR	165	0	4	34	727
SQU	Poland	AUCK	148	0	0	0	20
SQU	Poland	BANK	125	0	0	0	9
SQU	Ukraine	SNAR	173	0	0	0	1 800
SQU	USSR	AUCK	1 414	0	0	90	26 858
SQU	USSR	SNAR	1 604	0	0	119	29 914
COM	China	AUCK	157	9	24	92	366
COM	China	SNAR	106	29	115	518	10 149
COM	Japan	SNAR	344	0	5	78	4 519
COM	Korea	AUCK	210	0	2	17	607
COM	Korea	SNAR	165	0	5	42	1 610
COM	Poland	AUCK	148	0	0	0	30
COM	Poland	BANK	125	0	0	0	150
COM	Ukraine	SNAR	173	0	0	1	900
COM	USSR	AUCK	1 414	0	0	25	520
COM	USSR	SNAR	1 604	0	0	15	14 795
OTH	China	AUCK	157	0	1	265	1 818
OTH	China	SNAR	106	0	4	111	270
OTH	Japan	SNAR	344	126	352	2 180	8 500
OTH	Korea	AUCK	210	7	180	1 313	14 346
OTH	Korea	SNAR	165	20	100	1 031	11 060
OTH	Poland	AUCK	148	0	4	37	500
OTH	Poland	BANK	125	150	350	1 140	2 570
OTH	Ukraine	SNAR	173	0	2	105	9 500
OTH	USSR	AUCK	1 414	0	0	80	688
OTH	USSR	SNAR	1 604	0	10	257	25 000

***Table 11*: Summary of sample sizes, discard ratios and associated *c.v.*s used to calculate total discards in the arrow squid fishery; N, number of processing groups**

Species group	Area	N	$\hat{R}$	*c.v.* (%)
SQU	ALL	4 778	0.0091	21
SQU	AUCK	2 071	0.0090	35
SQU	SNAR	2 451	0.0095	27
SQU	BANK	242	0.0070	24
COM	ALL	4 778	0.0043	31
COM	AUCK	2 071	0.0009	11
COM	SNAR	2 451	0.0057	26
COM	BANK	242	–	–
OTH	ALL	4 778	0.0213	8
OTH	AUCK	2 071	0.0072	18
OTH	SNAR	2 451	0.0295	11
OTH	BANK	242	0.0592	14

The target fishery for arrow squid accounts for most of the total landed catch, with only a small fraction caught as bycatch in other target fisheries. Yearly totals of estimated catches from the target fishery were prepared from TCEPR data and compared with QMS landings figures (Table 12). The target fishery catch estimates range from 89 to 94% of the reported landings.

***Table 12*: Estimated catch totals of arrow squid from the target trawl fishery and all reported landings from the trawl fishery from the QMS, by year**

Fishing year	Target fishery estimated catch (t) TCEPR	QMS reported landings (t)*	Observed catch (% of TCEPR total)
1990–91	27 564	29 338	12
1991–92	43 727	47 514	7
1992–93	28 855	32 413	20
1993–94	62 459	67 968	10
1994–95	61 197	65 700	6
1995–96	28 495	31 864	8
1996–97	41 103	44 612	12
1997–98	30 769	36 031	11

* QMS figures from Annala *et al.* (1999).

Estimated catch data were stratified by area and the associated discard ratios from the observer data applied to these strata to estimate discards in each category (Table 13). Discards of OTH were considerably higher than of SQU and COM.

***Table 13*: Estimates of discards in the SQU trawl fishery for 1990–91 to 1997–98 (rounded to the nearest t), with 95% confidence intervals in parentheses**

Fishing year	SQU		COM		OTH		TOT	
1990–91	255	(125–414)	105	(60–164)	606	(481–760)	966	(667–1 339)
1991–92	396	(203–634)	190	(107–301)	1 238	(972–1 560)	1 824	(1 282–2 495)
1992–93	267	(143–420)	154	(85–245)	903	(719–1 120)	1 324	(947–1 786)
1993–94	537	(256–885)	177	(102–275)	1 606	(1 218–2 089)	2 320	(1 577–3 249)
1994–95	549	(263–903)	193	(112–299)	1 348	(1 047–1 726)	2 091	(1 422–2 929)
1995–96	252	(120–414)	86	(50–133)	663	(510–855)	1 000	(680–1 402)
1996–97	372	(179–610)	135	(78–209)	891	(696–1 135)	1 397	(953–1 954)
1997–98	281	(144–450)	137	(77–216)	850	(671–1 066)	1 268	(892–1 732)

Calculation of incidental catch

The GLM analysis showed area to be the only variable with any influence on levels of incidental catch so, as in the discard calculations, this was the only stratification applied. The incidental catch ratios calculated for SQU show a wide variation between area (Table 14). The ratio for area AUCK, like the discard ratios in Table 11, was low compared with the other two areas.

***Table 14*: Summary of sample sizes, catch ratios and associated *c.v.*s used to calculate total incidental catch in the arrow squid fishery; N, number of processing groups**

Area	N	$\hat{R}$	*c.v. (%)*
ALL	4 778	0.354	4
AUCK	2 071	0.111	8
SNAR	2 451	0.588	5
BANK	242	0.256	19

The estimates of $\hat{R}$ from Table 14 were applied to landings data to produce estimates of total incidental catch for the arrow squid target fishery (Table 15). Annual estimates of incidental catch ranged from 8165 to 19 101 t.

***Table 15*: Estimates of incidental catch in the SQU trawl fishery for 1990–91 to 1997–98 (rounded to the nearest t), with 95% confidence intervals in parentheses**

Fishing year	Incidental catch
1990–91	10 844 (9 779–12 001)
1991–92	18 593 (16 533–20 913)
1992–93	15 324 (13 820–16 964)
1993–94	15 766 (13 154–18 951)
1994–95	19 101 (16 790–21 756)
1995–96	8 165 (7 051–9 476)
1996–97	13 516 (11 977–15 259)
1997–98	13 566 (12 139–15 151)

Bycatch was calculated separately for SQU and non-target species (Table 16). For SQU, bycatch is the discarded part of the SQU catch and for non-target species bycatch is the sum of the incidental catch and the discarded portion of the non-target species catch. These estimates were derived from Tables 12 and 14. Bycatch of SQU was in all years only a small fraction of the total bycatch, which ranged from 9165 to 21 192 t.

***Table 16*: Estimates of bycatch in the SQU trawl fishery for 1990–98 (rounded to the nearest t), with 95% confidence intervals in parentheses**

Fishing year	SQU bycatch	Non-target bycatch	Total bycatch
1990–91	255 (125–414)	11 554 (10 321–12 925)	11 809 (10 446–13 340)
1991–92	396 (203–634)	20 021 (17 612–22 773)	20 417 (17 815–23 407)
1992–93	267 (143–420)	16 381 (14 624–18 330)	16 648 (14 767–18 750)
1993–94	537 (256–885)	17 549 (14 475–21 315)	18 086 (14 731–22 200)
1994–95	549 (263–903)	20 643 (17 949–23 781)	21 192 (18 212–24 684)
1995–96	252 (120–414)	8 913 (7 611–10 464)	9 165 (7 731–10 879)
1996–97	372 (179–610)	14 542 (12 751–16 603)	14 914 (12 930–17 213)
1997–98	281 (144–450)	14 553 (12 887–16 433)	14 834 (13 031–16 883)

Estimation of discards and bycatch from TCEPR bycatch records

A total of 126 species or species groups were recorded on commercial landings forms, with discard ratios from observer data available for 86 of them. Annual discard and bycatch totals were calculated for commercial and non-commercial categories (Table 17). Discards of commercial species varied from 93 to 295 t per annum. Discards of non-commercial species varied widely between years, being highest in the first year (1226 t) and lowest in the last year (107 t). The high level of discards in 1990–91 was caused by larger catches of spiny dogfish than in subsequent years. More than 1000 t of spiny dogfish was caught in 1990–91 and with a discard rate of over 80% this species had a large influence on non-commercial species discards. This may explain why for this year the estimate of non-commercial discards was higher with this method than estimated in the main analysis (*see* Table 13). In all other years the estimates of non-commercial species discards were considerably lower with this second method. Estimates of bycatch of all non-target species ranged from 8379 to 15 867 t (*see* Table 17). These values are generally much lower than those estimated with the first method (*see* Table 16), except in the 1990–91 fishing year where the figure is higher and in 1996–97 where values are similar.

***Table 17*: Estimates of discards and bycatch in the SQU trawl fishery for 1990–91 to 1997–98 (rounded to the nearest t), derived from TCEPR totals**

Fishing year	COM discards	OTH discards	Non-target bycatch
1990–91	93	1 226	15 867
1991–92	168	437	12 189
1992–93	227	519	15 988
1993–94	126	539	9 190
1994–95	118	219	8 379
1995–96	183	283	14 255
1996–97	295	481	14 104
1997–98	223	107	8 610

Bycatch information from trawl survey data

Four trawl surveys using R.V. *Tangaroa* were carried out between 1993 and 1996 in the Stewart-Snares shelf/Puysegur Bank area (Hurst & Bagley 1997), an area very similar to area SNAR in this report. This time series was designed to monitor changes in distribution, abundance, and size structure of a number of (mostly commercial) species associated with the arrow squid fishery, including barracouta, ling, silver warehou, blue warehou, red cod, stargazer, and jack mackerel (*T. murphyi*). The surveys used bottom trawl gear and, although trawling locations were random and stratified by area and depth, gear and fishing methods were similar to those used by commercial vessels. Catch was identified and weighed accurately.

We summarised all survey trawls within the depth range of the commercial arrow squid fishery (80–300 m) for comparison with all observed bottom trawls in area SNAR. A total of 391 trawls were made, and 111 species or species groups recorded. A total of 18 t of arrow squid (*N. sloanii*) were caught, with 411 t of bycatch. Spiny dogfish was the most common bycatch species, accounting for 53.7% of the total bycatch (Table 18). Jack mackerel (mostly *T. murphyi)*, barracouta, silver warehou, and red cod were the next most important bycatch species. These five species contributed 80% of the total bycatch from the survey tows.

From 1990–91 to 1997–98 observers recorded 899 bottom tows in the area covered by the research surveys, taking 3579 t of arrow squid and 1327 t of bycatch species. The catch rates of arrow squid in the commercial tows were clearly far greater than in the survey, which was not unexpected, because the survey tows were not targeting concentrations of fish. The amount of bycatch caught per tow was also greater for the commercial tows. The observers recorded 102 species or species groups, with the top five species accounting for 74% of the total bycatch, similar to the survey figure. The composition of the main bycatch species in the observed tows had some striking differences from the research data. The main bycatch species in the observed tows was barracouta (31.1%) with spiny dogfish, so dominant in the research bycatch, accounting for only 19.9% (Table 18). Conversely, hoki was much more common in the commercial bycatch than in the survey bycatch.

***Table 18*: Bycatch species and percentage of the total bycatch from a time series of four random trawl surveys and from commercial trawls targeting arrow squid, on the Stewart-Snares shelf; *see* Appendix 4 for an explanation of the species codes**

Species code	Survey data (% of total bycatch)	Commercial data (% of total bycatch)
SPD	53.7	19.9
JMA	9.8	5.7
BAR	7.5	31.1
SWA	5.4	9.4
RCO	4.1	4.0
STA	3.4	1.2
WAR	3.3	3.7
LIN	2.4	4.0
SCH	1.3	0.2
HAP	1.0	0.9
RSK	0.9	0.4
GSH	0.8	0.5
TAR	0.8	< 0.1
SKI	0.7	2.3
HOK	< 0.1	7.7

Ling longline fishery

Distribution of data

The distribution of observed sets in the ling longline fishery for comparison with all commercial sets is shown in Figure 3. This fishery is focused on the Chatham Rise, the Bounty Platform, and the Campbell Plateau, with a scattering of effort off the east coast of the North Island and the west coast of the South Island. Although the level of observer coverage was low, the three main areas were all covered. As in the other two fisheries, some positional errors are evident, but have no effect, as no area stratification was applied.

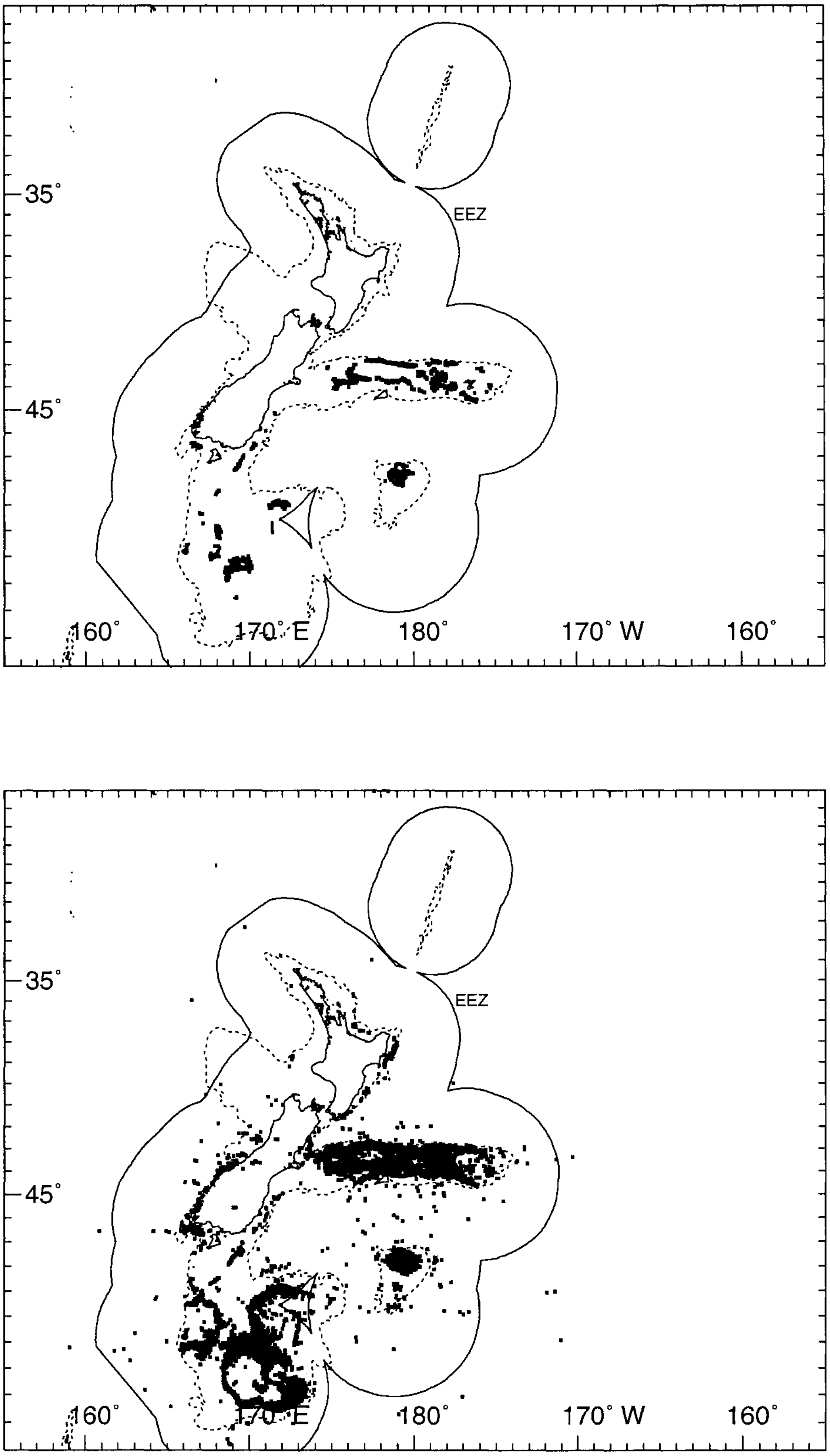

***Figure 3*: Distribution of longline sets (start position) recorded by scientific observers on vessels fishing for ling between 1 Oct 1990 and 30 Sep 1998 (*top*); distribution of all longline sets where position was recorded by vessels fishing for ling during the same period (*bottom*). Some positions to the east of 180° in the lower panel may reflect eastern hemisphere tows recorded as west.**

Calculation of discards and incidental catch

Discard ratios calculated from matched observer records and commercial landings are presented in Table 19. Ratios were calculated separately for discards of ling and for all other species combined.

A single incidental catch ratio was calculated from the same data, as the total retained weight of all non-target catch divided by the total catch weight of ling.

***Table 19*: Total and retained catch, discards, and discard and incidental catch ratios from matched observer and landings records for the ling longline fishery**

	Total catch weight (t)	Total retained weight (t)	Total discards (t)	Discard ratio	Incidental catch ratio
Ling	1 320	—	52	0.039	—
All non-target	—	593	189	0.143	0.450

The target longline fishery accounted for between 14 and 46% of the total reported catch of ling from all fishing methods for the 1990–91 to 1997–98 fishing years. However, only in 1990–91 was less than one third of the total catch taken by longliners. With the introduction of large autoliners came increases in longline catch and overall catch from 1991–92 onwards. There was no observer coverage before 1992–93 and since then observer coverage has been only sporadic, with observed catch representing less than 10% of the annual longline catch in all but one year (Table 20).

***Table 20*: Estimated catch totals of ling from the target longline fishery and all reported landings from the entire fishery from the QMS, by year**

Fishing year	Target fishery estimated catch (t) CELR	QMS reported catch (t)*	Observed catch (% of CELR total)
1990–91	1 953	13 506	0
1991–92	5 897	17 778	0
1992–93	6 518	19 065	5
1993–94	7 384	15 961	1
1994–95	8 762	19 841	12
1995–96	7 680	21 428	0
1996–97	8 306	22 522	7
1997–98	7 604	22 884	3

* QMS figures from Annala *et al.* (1999).

Total annual discards were derived by applying discard ratios from Table 19 to the target fishery catch of ling in Table 20 (Table 21). Ling discards accounted for about 20% of the total discards in each year, which ranged from 356 to 1387 t. Because of the limited amount of usable data and unknown levels of error associated with the methods used in this analysis, these estimates should be treated as indicative only.

Table 21: **Estimates of discards, incidental catch, and bycatch in the ling longline fishery for the 1990–91 to 1997–98 fishing years (rounded to the nearest t)**

Fishing year	Ling discards	All other discards	Incidental catch	Total non-target bycatch
1990–91	76	280	878	1 158
1991–92	230	845	2 651	3 496
1992–93	255	934	2 930	3 864
1993–94	288	1 058	3 319	4 377
1994–95	342	1 256	3 939	5 194
1995–96	300	1 101	3 452	4 553
1996–97	324	1 190	3 734	4 924
1997–98	297	1 090	3 418	4 508

Estimation of discards and bycatch from CELR bycatch records

A total of 131 species or species groups was recorded on commercial landings forms, but discard ratios were available for only 43 of them. Annual discard and bycatch totals were calculated for all non-target species combined (Table 22). The method of calculating discards of ling does not differ from that used above, but the analysis was used to estimate all other discards and the total non-target bycatch. Discards of non-target species varied from 74 to 693 t per annum, with a general increase over time. These values are much lower than those estimated by the first method (*see* Table 21), mainly due to many of these species not being recorded on CELR forms. Estimates of bycatch of non-target species ranged from 290 to 2652 t. These values also are generally much lower than those estimated by the first method, for the same reason.

Table 22: **Estimates of discards and bycatch in the ling longline fishery for 1990–91 to 1997–98 (rounded to the nearest t), derived from CELR totals**

Fishing year	Ling discards	All other discards	Total non-target bycatch
1990–91	76	74	290
1991–92	230	210	1 014
1992–93	255	242	1 131
1993–94	288	409	1 761
1994–95	342	393	1 749
1995–96	300	526	2 059
1996–97	324	693	2 652
1997–98	297	540	1 991

Discussion

Observer data proved to be the most useful source for estimating discards in the jack mackerel and arrow squid trawl fisheries because, although coverage varied from year to year, records of catch and discard weights had generally been recorded in some detail. Lack of discard data for the 1997–98 season resulted in some loss of accuracy for the jack mackerel and arrow squid discard estimates, but, with no stratification of discard ratios by year, precision is at least no different for this year. Estimated catches from TCEPR data, although not describing the entire catch composition, were useful for validating the general level of incidental catch. Research trawl surveys are, by design, very different to the structure of a commercial fishing operation and give limited discard information

Total discards were similar for the jack mackerel and arrow squid trawl fisheries (about 1000–2000 t per annum), but with the arrow squid target fishery catch generally two to three times that of the jack mackerel target fishery it is a much 'cleaner' fishery. Discarding in the jack mackerel fishery was at a similar level to that estimated in the hoki fishery by Clark *et al.* (2000). Discards in the arrow squid fishery were at a similar level to those estimated for orange roughy in the same study. Discard levels estimated by Clark *et al.* (2000) for oreos were lower still and lower again in the southern blue whiting fishery where averaged annual discards were about 300 t from a catch of about 20 000 t per year.

Analysis of discards in the ling longline fishery was constrained by a lack of data and the overall level of discards was not well estimated. However, the discard ratios calculated suggest a high rate of discarding compared with the trawl fisheries examined in this study and by Clark *et al.* (2000). Without any direct recording of discarded catch by observers, discard estimation in this fishery will continue to rely on comparison of observed catch with landed catch, as was done here. Alternatively discards may be estimated by making some assumptions regarding which species have commercial value and applying this to the observed catch to calculate discard ratios. Neither method is ideal, and the best solution is to change observer practices on longliners so that details of discarded catch are recorded in future.

On a global scale, all these fisheries have very low levels of discarding. Alverson (1996) cited the Trinidadian shrimp trawl fishery as being the world's most wasteful with 14.71 kg of discards for every 1 kg landed, and the North West Atlantic hake trawl fishery as the least wasteful with just 0.011 kg of discards per kg landed. The equivalent values for the fisheries studied in this project and by Clark *et al.* (2000) are about 0.07 for jack mackerel, 0.04 for arrow squid, 0.18 for ling, 0.015 for southern blue whiting, 0.036 for orange roughy, 0.054 for hoki, and 0.028 for oreos.

By relating the discard ratios to total catch, instead of to retained catch as was done by Clark *et al.* (2000), and applying them to estimated catch totals from the commercial fishery, some stratification was possible. To achieve this, factors affecting discards were briefly examined. Although log transformations improved the symmetry of the distributions of discards, they were dominated by zero values. Final models had generally low R^2 values, but some variables stood out repeatedly and the importance of these was borne out by the variation in the resultant discard ratios. Area and tow type were influential factors in discards in both trawl fisheries, with nation having some influence on discards in the arrow squid fishery. Midwater trawling is an important part of both fisheries and can be linked with lower discard rates. For non-commercial species in the jack mackerel fishery, discard ratios were considerably lower for midwater tows than for bottom tows overall and for the WEST area. In the arrow squid fishery, discard ratios estimated for the Auckland Islands fishery (area AUCK) were considerably lower than for other areas in both the COM and OTH species groups. In each fishery, annual discards were based directly on total catches so that annual variation in discard rates was not estimated. Limited data allowed stratification by only one or two factors and fishing year was generally not an influential variable in the GLM analyses.

Some sources of fishing mortality are difficult to measure. Fish loss through gear damage while trawling at depth and ghost fishing by lost gear cannot be accounted for with this sort of study and contributes an unknown amount to the total fishing mortalities of the target and non-target species. Estimation of fish loss from burst codends and ripped trawls at the surface provide another source of error. Fish loss from the net at the surface is difficult to quantify, except occasionally when the change in volume of the net can be observed. Whether these estimates have any bias is unknown, but such losses form a large proportion of the discards in both trawl fisheries examined.

Bias may occur in observer-based data if the presence of an observer causes a change in fishing practices on a vessel, though an Australian study of a multispecies trawl fishery off the coast of NSW (Liggins *et al.* 1997) found no significant bias. There is some anecdotal evidence of altered behaviour and of "hiding things" when observers are present on vessels in New Zealand fisheries, but these practices are difficult to examine formally.

In each of the fisheries examined by Clark *et al.* (2000), the non-target-fishery catch was negligible and no stratification was applied, allowing discard ratios to be reasonably applied to the entire fishery. Portions of both the arrow squid and jack mackerel fishery catch come either from methods other than trawling and/or from incidental catches in other trawl fisheries. It is important to note, therefore, that all discard estimates in this document relate to only the target fishery catch. It would be inappropriate to apply the ratios presented here to the remainder of the landed catch for which fishing methods are likely to be different.

The summaries of TCEPR and CELR data served as a useful means of cross checking the discards and bycatch estimates from the main analyses, and provided a second measure of the inter-annual variation in levels of discards and bycatch. As expected, discard and bycatch totals were usually considerably lower with the second method due to a maximum of five species being recorded on the catch effort forms.

The comparisons between trawl survey and commercial fishing data showed some obvious differences in bycatch composition even though they were using similar gear at similar times of the year and at similar depths. These comparisons suggest that the species composition and level of bycatch may vary greatly depending on how the fishing is conducted. Targeted fishing catches greater quantities of both the target species and bycatch species. This may be due to either an association between the target and bycatch species or a result of commercial fishing targeting marks that at times are not the target species. The results of these comparisons lead us to conclude that research data may be useful in determining species composition in an area, but they might not reflect species composition taken by the commercial fishery. Hence observer data are a more reliable source of bycatch information.

Acknowledgments

We thank the numerous scientific observers whose efforts and attention to detail made this type of analysis possible. We are also grateful to Suze Baird who provided a valuable review of the manuscript. This research was funded by the Ministry of Fisheries (Project ENV9804).

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Appendix 1: Species codes, total catch weight, percentage of the total catch, and overall percentage retained from all observer records for the jack mackerel target fishery from 1990 to 1998. Records are ordered by decreasing percentage of catch; codes in bold are those species combined in the COM category (*see* Appendix 4 for species names)

Species code	Total catch (t)	Percent of catch	% kept
JMA	21 032	68.643	99.17
BAR	2 868	9.359	99.51
EMA	1 561	5.094	99.28
FRO	1 153	3.762	99.59
SPD	812	2.650	14.44
SQU	787	2.568	98.92
RBT	516	1.685	67.35
HOK	326	1.065	93.59
RCO	243	0.793	99.31
WAR	230	0.751	99.89
TAR	218	0.711	98.85
SWA	175	0.572	99.70
SCH	140	0.459	97.64
JDO	87	0.284	99.87
MIX	64	0.210	13.29
GSH	41	0.134	98.09
RBM	39	0.126	98.51
GUR	33	0.108	99.22
SPE	30	0.098	96.66
POP	29	0.096	0.73
THR	25	0.082	20.40
SKA	16	0.052	13.98
LIN	16	0.051	99.01
STA	15	0.048	98.03
LEA	15	0.048	14.64
STU	13	0.043	93.50
SSK	12	0.040	33.62
CAR	11	0.037	0.40
SNA	10	0.032	99.53
SKI	10	0.032	99.74
SDO	10	0.032	88.00
RAT	10	0.031	36.19
SPO	9	0.029	82.48
HPB	8	0.027	97.91
RSK	8	0.027	2.85
TRE	7	0.022	99.61
HAK	6	0.020	97.58
KAH	6	0.020	92.40
SUN	4	0.012	1.57
NSD	4	0.012	33.48
MAK	3	0.011	22.60
BPE	3	0.010	97.66
KIN	3	0.009	99.31
POS	3	0.009	3.31
ERA	3	0.009	0.22
SSI	2	0.007	96.04
CSH	2	0.006	7.93
OSD	2	0.005	0.20
RBY	1	0.005	100.00

Species code	Total catch (t)	Percent of catch	% kept
BWS	1	0.005	7.93
OPE	1	0.005	98.60
JGU	1	0.004	85.21
SWO	1	0.004	70.04
SCG	1	0.004	67.48
SOR	1	0.004	100.00
BRA	< 1	0.003	0.00
BNS	< 1	0.003	98.59
STR	< 1	0.003	5.34
RHY	< 1	0.003	25.71
JAV	< 1	0.003	100.00
SBK	< 1	0.002	100.00
RUD	< 1	0.002	100.00
EGR	< 1	0.002	0.69
MOO	< 1	0.002	66.72
RSN	< 1	0.002	96.85
BWH	< 1	0.002	0.00
CON	< 1	0.002	20.92
ALB	< 1	0.001	100.00
RAY	< 1	0.001	3.94
SEV	< 1	0.001	0.00
PIL	< 1	0.001	50.39
BSK	< 1	0.001	0.00
BCO	< 1	< 0.001	96.00
BYX	< 1	< 0.001	89.83
RPI	< 1	< 0.001	69.83
OCT	< 1	< 0.001	48.21
DEA	< 1	< 0.001	97.87
SND	< 1	< 0.001	0.00
WRA	< 1	< 0.001	0.00
HEX	< 1	< 0.001	0.00
LDO	< 1	< 0.001	93.33
HEP	< 1	< 0.001	0.00
WSE	< 1	< 0.001	53.03
TRU	< 1	< 0.001	100.00
EEL	< 1	< 0.001	1.54
SRH	< 1	< 0.001	6.67
LAN	< 1	< 0.001	0.00
MDO	< 1	< 0.001	0.00
TOA	< 1	< 0.001	98.00
SBW	< 1	< 0.001	100.00
WIT	< 1	< 0.001	74.19
CMO	< 1	< 0.001	100.00
SSH	< 1	< 0.001	0.00
BSH	< 1	< 0.001	60.00
CUC	< 1	< 0.001	60.00
LFE	< 1	< 0.001	0.00
BRZ	< 1	< 0.001	78.95
SHO	< 1	< 0.001	100.00
MOK	< 1	< 0.001	100.00
SPF	< 1	< 0.001	100.00
CDO	< 0.01	< 0.001	88.89
AGR	< 0.01	< 0.001	100.00

Species code	Total catch (t)	Percent of catch	% kept
SQX	< 0.01	< 0.001	14.29
SBR	< 0.01	< 0.001	42.86
SDR	< 0.01	< 0.001	85.71
NCA	< 0.01	< 0.001	0.00
SWC	< 0.01	< 0.001	0.00
ELE	< 0.01	< 0.001	20.00
PIG	< 0.01	< 0.001	60.00
SHL	< 0.01	< 0.001	100.00
BEN	< 0.01	< 0.001	0.00
FLA	< 0.01	< 0.001	0.00
BRC	< 0.01	< 0.001	75.00
WSQ	< 0.01	< 0.001	100.00
HAG	< 0.01	< 0.001	0.00
YEM	< 0.01	< 0.001	0.00
JFI	< 0.01	< 0.001	33.33
YBO	< 0.01	< 0.001	33.33
WWA	< 0.01	< 0.001	100.00
BER	< 0.01	< 0.001	0.00
BOA	< 0.01	< 0.001	0.00
LAM	< 0.01	< 0.001	0.00
TOD	< 0.01	< 0.001	0.00
UNI	< 0.01	< 0.001	0.00
YCO	< 0.01	< 0.001	0.00
FOX	< 0.01	< 0.001	100.00
LFB	< 0.01	< 0.001	100.00
SOL	< 0.01	< 0.001	100.00
BBE	< 0.01	< 0.001	0.00
BSP	< 0.01	< 0.001	0.00
CEP	< 0.01	< 0.001	0.00
DCS	< 0.01	< 0.001	0.00
FHD	< 0.01	< 0.001	0.00
PSK	< 0.01	< 0.001	0.00
SNI	< 0.01	< 0.001	0.00
SPG	< 0.01	< 0.001	0.00
TOP	< 0.01	< 0.001	0.00
ANC	< 0.01	< 0.001	100.00
CBE	< 0.01	< 0.001	100.00
CRU	< 0.01	< 0.001	100.00
KOH	< 0.01	< 0.001	100.00

Appendix 2: Species codes, total catch weight, percentage of the total catch, and overall percentage retained, from all observer records for the arrow squid target fishery from 1990 to 1998. Records are ordered by decreasing percentage of catch, codes in bold are those species combined in the COM category (*see* Appendix 4 for species names)

Species code	Total catch (t)	Percent of catch	% kept
SQU	30 136	72.511	99.55
BAR	4 553	10.955	99.62
JMA	3 305	7.951	99.75
WAR	1 044	2.512	99.99
SWA	630	1.515	96.71
SPD	513	1.233	18.49
HOK	303	0.729	97.24
RCO	205	0.493	98.89
RBM	144	0.346	98.41
RBT	137	0.329	76.12
STU	80	0.192	91.98
MIX	75	0.181	13.48
LIN	73	0.175	99.74
CRB	69	0.165	4.12
SKI	55	0.133	99.72
RAT	37	0.089	25.98
HPB	32	0.077	99.82
STA	17	0.040	99.27
PAD	16	0.039	26.75
SSK	15	0.036	78.58
GSH	15	0.035	96.16
WWA	7	0.018	99.34
SPE	7	0.018	98.02
CBE	6	0.014	99.17
RSK	5	0.012	0.43
HAK	5	0.011	98.67
POS	4	0.011	14.99
SCH	4	0.010	66.70
SSC	4	0.010	3.73
SWC	4	0.009	15.73
BCO	3	0.008	98.45
BOE	3	0.007	100.00
CSQ	3	0.006	0.00
SPO	3	0.006	17.37
MAK	2	0.006	9.44
OCT	2	0.006	63.91
RIB	2	0.005	21.18
STN	2	0.005	99.68
SUN	2	0.004	11.59
THR	2	0.004	0.00
JAV	2	0.004	13.16
WIT	1	0.003	9.29
NCA	1	0.003	6.34
SSI	1	0.003	18.99
BEL	1	0.003	99.92
FRO	1	0.003	93.07
BNS	1	0.003	100.00
SBW	1	0.003	77.57
BSH	1	0.002	0.19

Species code	Total catch (t)	Percent of catch	% kept
DWD	1	0.002	0.00
BSK	1	0.002	0.00
SSO	< 1	0.002	100.00
JFI	< 1	0.002	2.42
SKA	< 1	0.002	27.73
FLA	< 1	0.001	72.28
NOT	< 1	0.001	98.06
SBK	< 1	0.001	0.00
UNI	< 1	0.001	4.31
CBO	< 1	0.001	100.00
SPI	< 1	0.001	1.57
YEM	< 1	0.001	100.00
LDO	< 1	0.001	97.33
API	< 1	0.001	1.23
TOA	< 1	0.001	29.94
OSD	< 1	0.001	0.00
ETM	< 1	0.001	0.00
ETL	< 1	0.001	3.53
YFN	< 1	0.001	78.34
GSC	< 1	0.001	89.74
BWS	< 1	0.001	2.13
PIG	< 1	0.001	64.35
TAR	< 1	0.001	95.56
LCH	< 1	< 0.001	0.00
SHA	< 1	< 0.001	12.37
CAR	< 1	< 0.001	0.00
STG	< 1	< 0.001	100.00
YCO	< 1	< 0.001	72.09
MOK	< 1	< 0.001	100.00
BIG	< 1	< 0.001	76.67
TOD	< 1	< 0.001	65.75
GSP	< 1	< 0.001	88.10
WSQ	< 1	< 0.001	10.48
RUD	< 1	< 0.001	65.04
POR	< 1	< 0.001	0.00
SDO	< 1	< 0.001	77.59
DEA	< 1	< 0.001	65.22
SNA	< 1	< 0.001	100.00
SSH	< 1	< 0.001	0.00
BRC	< 1	< 0.001	18.52
OAR	< 1	< 0.001	0.00
LUC	< 1	< 0.001	0.00
SEV	< 1	< 0.001	0.00
GON	< 1	< 0.001	42.11
TUN	< 1	< 0.001	100.00
ERA	< 1	< 0.001	11.76
LAN	< 1	< 0.001	0.00
MIQ	< 1	< 0.001	4.35
MOO	< 1	< 0.001	33.33
OPE	< 1	< 0.001	84.44
CRU	< 1	< 0.001	100.00
SND	< 1	< 0.001	2.38
BWH	< 1	< 0.001	0.00

Species code	Total catch (t)	Percent of catch	% kept
SEE	< 1	< 0.001	0.00
COD	< 1	< 0.001	0.00
HAG	< 1	< 0.001	0.00
RSQ	< 1	< 0.001	0.00
CUC	< 1	< 0.001	0.00
SCG	< 1	< 0.001	100.00
ETB	< 1	< 0.001	0.00
SBO	< 1	< 0.001	96.43
NCB	< 1	< 0.001	100.00
EMA	< 1	< 0.001	100.00
PDG	< 1	< 0.001	0.00
GUR	< 1	< 0.001	89.47
FBA	< 1	< 0.001	27.78
BYX	< 1	< 0.001	100.00
OPA	< 1	< 0.001	82.35
TOP	< 1	< 0.001	6.25
CDO	< 1	< 0.001	81.25
JGU	< 1	< 0.001	100.00
GPF	< 1	< 0.001	85.71
KIC	< 1	< 0.001	16.67
BBE	< 1	< 0.001	20.00
MAN	< 1	< 0.001	100.00
PSY	< 0.01	< 0.001	55.56
BSQ	< 0.01	< 0.001	12.50
FTU	< 0.01	< 0.001	100.00
RPE	< 0.01	< 0.001	100.00
CHI	< 0.01	< 0.001	100.00
CRA	< 0.01	< 0.001	16.67
RAY	< 0.01	< 0.001	0.00
TRU	< 0.01	< 0.001	0.00
BCD	< 0.01	< 0.001	100.00
TEW	< 0.01	< 0.001	100.00
YBF	< 0.01	< 0.001	100.00
POT	< 0.01	< 0.001	100.00
CON	< 0.01	< 0.001	0.00
RDO	< 0.01	< 0.001	0.00
MDO	< 0.01	< 0.001	33.33
WSE	< 0.01	< 0.001	33.33
PHO	< 0.01	< 0.001	66.67
BER	< 0.01	< 0.001	0.00
HCO	< 0.01	< 0.001	0.00
SBR	< 0.01	< 0.001	0.00
BPF	< 0.01	< 0.001	100.00
JDO	< 0.01	< 0.001	100.00
SPZ	< 0.01	< 0.001	100.00
AFO	< 0.01	< 0.001	0.00
BCA	< 0.01	< 0.001	0.00
DCS	< 0.01	< 0.001	0.00
MOL	< 0.01	< 0.001	0.00
MIC	< 0.01	< 0.001	100.00

Appendix 3: Species codes, total catch weight, percentage of the total catch, and overall percentage retained, from all observer records for the ling target fishery from 1990 to 1998. Values of percentage kept were calculated from the subset of observer trips that could be matched to landings data, hence some missing values (–). Records are ordered by decreasing percentage of catch, codes in bold are those species combined in the COM category (*see* Appendix 4 for species names)

Species code	Total catch (t)	Percent of catch	% kept
LIN	2 277	69.445	96.09
SPD	312	9.527	59.80
RIB	169	5.167	93.61
SSK	104	3.188	82.48
NOT	90	2.743	87.16
SKA	51	1.566	97.52
SPE	41	1.261	54.62
BNS	40	1.227	91.05
CON	37	1.132	53.48
BCD	32	0.967	68.75
GSH	26	0.782	68.65
SCH	19	0.580	87.09
RCO	13	0.396	47.89
RSK	12	0.357	—
OSD	7	0.212	100.00
BSH	7	0.199	63.17
DWE	5	0.161	0.00
HAP	4	0.126	76.89
ETL	4	0.109	0.00
SCO	4	0.108	0.00
DWD	3	0.103	59.68
HAG	3	0.090	11.93
RBM	3	0.085	75.71
SND	3	0.080	0.91
RAT	2	0.059	0.00
HPB	2	0.058	4.76
GSP	2	0.050	95.42
BAS	1	0.036	0.00
WPS	1	0.034	0.00
NSD	< 1	0.026	11.25
CHP	< 1	0.021	100.00
SPO	< 1	0.020	0.00
PLS	< 1	0.017	—
HAK	< 1	0.014	80.56
BWS	< 1	0.010	9.88
HEX	< 1	0.009	0.00
BCO	< 1	0.008	0.00
CAR	< 1	0.006	0.00
HCO	< 1	0.005	0.00
POS	< 1	0.004	0.00
SWA	< 1	0.003	0.00
WWA	< 1	0.003	100.00
GSC	< 1	0.001	0.00
BYX	< 1	0.001	77.50
MAK	< 1	0.001	0.00
SEV	< 1	0.001	0.00
BSP	< 1	0.001	0.00
CSQ	< 1	0.001	0.00

Species code	Total catch (t)	Percent of catch	% kept
SCM	< 1	0.001	—
DCS	< 1	< 0.001	0.00
PLU	< 1	< 0.001	0.00
HOK	< 1	< 0.001	100.00
TAR	< 1	< 0.001	20.00
PDG	< 1	< 0.001	0.00
SKI	< 0.01	< 0.001	—
STA	< 0.01	< 0.001	0.00
OCT	< 0.01	< 0.001	25.00
SOR	< 0.01	< 0.001	0.00
SEE	< 0.01	< 0.001	0.00
SBR	< 0.01	< 0.001	0.00
SPI	< 0.01	< 0.001	0.00
TOA	< 0.01	< 0.001	0.00
ELE	< 0.01	< 0.001	0.00
FHD	< 0.01	< 0.001	0.00
PTO	< 0.01	< 0.001	—
LCH	< 0.01	< 0.001	0.00
SBW	< 0.01	< 0.001	0.00
TOP	< 0.01	< 0.001	0.00
TRU	< 0.01	< 0.001	0.00

Appendix 4: Species codes and their common and scientific names

Species code	Common name	Scientific name
AFO	Royal red prawn	*Aristaeomorpha foliacea*
AGR	Ribbonfish	*Agrostichthys parkeri*
ALB	Albacore tuna	*Thunnus alalunga*
ANC	Anchovy	*Engraulis australis*
API	Alert pigfish	*Alertichthys blacki*
BAR	Barracouta	*Thyrsites atun*
BAS	Bass groper	*Polyprion americanus*
BBE	Banded bellowsfish	*Centriscops humerosus*
BCA	Barracudina	*Magnisudis prionosa*
BCD	Black cod	*Paranotothenia magellanica*
BCO	Blue cod	*Parapercis colias*
BEL		*Centriscops* spp.
BEN	Scabbardfish	*Benthodesmus* spp.
BER	Numbfish	*Typhlonarke* spp.
BIG	Bigeye tuna	*Thunnus obesus*
BNS	Bluenose	*Hyperoglyphe antarctica*
BOA	Sowfish	*Paristiopterus labiosus*
BOE	Black oreo	*Allocyttus niger*
BPE	Butterfly perch	*Caesioperca lepidoptera*
BPF	Banded wrasse	*Notolabrus fucicola*
BRA	Short-tailed black ray	*Dasyatis brevicaudata*
BRC	Northern bastard cod	*Pseudophycis breviuscula*
BRZ	Brown stargazer	*Xenocephalus armatus*
BSH	Seal shark	*Dalatias licha*
BSK	Basking shark	*Cetorhinus maximus*
BSP	Big-scale pomfret	*Taratichthys longipinnis*
BSQ	Broad squid	*Sepioteuthis australis*
BWH	Bronze whaler shark	*Carcharhinus brachyurus*
BWS	Blue shark	*Prionace glauca*
BYX	Alfonsino & long-finned beryx	*Beryx splendens* & *B. decadactylus*
CAR	Carpet shark	*Cephaloscyllium isabellum*
CBE	Crested bellowsfish	*Notopogon lilliei*
CBO	Bollons' rattail	*Caelorinchus bollonsi*
CDO	Capro dory	*Capromimus abbreviatus*
CEP	Red bandfish	*Cepola aotea*
CHI		*Chimaera* spp.
CHP	Brown chimaera	*Chimaera* sp.
CMO	Copper moki	*Latridopsis forsteri*
COD	Any cod	
CON	Conger eel	*Conger* spp.
CRA	Rock lobster	*Jasus edwardsii*
CRB	Any crab	
CRU	Any crustacean	
CSH	Any catshark	
CSQ	Leafscale gulper shark	*Centrophorus squamosus*
CUC	Cucumberfish	*Chlorophthalmus nigripinnis*
DCS	Dawson's catshark	*Halaelurus dawsoni*
DEA	Dealfish	*Trachipterus trachypterus*
DWD	Any deepwater dogfish	
DWE	Any deepwater eel	
EEL	Any marine eel	
EGR	Eagle ray	*Myliobatis tenuicaudatus*
ELE	Elephantfish	*Callorhinchus milii*
EMA	Blue mackerel	*Scomber australasicus*
ERA	Electric ray	*Torpedo fairchildi*
ETB	Baxter's dogfish	*Etmopterus baxteri*

Species code	Common name	Scientific name
ETL	Lucifer dogfish	*Etmopterus lucifer*
ETM		*Etmopterus* spp.
FBA	False barracouta	*Neolatus tripes*
FHD	Deepsea flathead	*Hoplichthys haswelli*
FLA	Any flatfish	
FOX	Foxfish	*Bodianus* sp.
FRO	Frostfish	*Lepidopus caudatus*
FTU	Frigate tuna	*Auxis thazard*
GON		*Gonorynchus gonorynchus*
GPF	Girdled wrasse	*Notolabrus cinctus*
GSC	Giant spider crab	*Jacquinotia edwardsii*
GSH	Dark ghost shark	*Hydrolagus novaezealandiae*
GSP	Pale ghost shark	*Hydrolagus* sp. B2
GUR	Gurnard	*Chelidonichthys kumu*
HAG	Hagfish	*Eptatretus cirrhatus*
HAK	Hake	*Merluccius australis*
HAP	Hapuku	*Polyprion oxygeneios*
HCO	Hairy conger	*Bassanago hirsutus*
HEP	Sharpnose sevengill shark	*Heptranchias perlo*
HEX	Sixgill shark	*Hexanchus griseus*
HOK	Hoki	*Macruronus novaezelandiae*
HPB	Hapuku & bass	*Polyprion oxygeneios & P. americanus*
JAV	Javelinfish	*Lepidorhynchus denticulatus*
JDO	John dory	*Zeus faber*
JFI	Jellyfish	
JGU	Spotted gurnard	*Pterygotrigla picta*
JMA	Jack mackerel	*Trachurus declivis, T. murphyi, T. novaezelandiae.*
KAH	Kahawai	*Arripis trutta*
KIC	King crab	*Lithodes murrayi or Neolithodes brodiei*
KIN	Kingfish	*Seriola lalandi*
KOH	Koheru	*Decapterus koheru*
LAM	Lamprey	*Geotria australis*
LAN	Lanternfish	Myctophidae
LCH	Long-nosed chimaera	*Harriotta raleighana*
LDO	Lookdown dory	*Cyttus traversi*
LEA	Leatherjacket	*Parika scaber*
LFB	Longfinned boarfish	*Zanclistius elevatus*
LFE	Long-finned eel	*Anguilla dieffenbachii*
LIN	Ling	*Genypterus blacodes*
LUC		*Luciosudus* spp.
MAK	Mako shark	*Isurus oxyrinchus*
MAN	Finless flounder	*Neoachiropsetta milfordi*
MDO	Mirror dory	*Zenopsis nebulosus*
MIC	Slender argentine	*Microstoma microstoma*
MIQ	Warty squid	*Moroteuthis ingens*
MIX	Mixed fish	
MOK	Moki	*Latridopsis ciliaris*
MOL	Any mollusc	
MOO	Moonfish	*Lampris guttatus*
NCA		*Nectocarcinus antarcticus*
NCB		*Nectocarcinus bennetti*
NOT		*Paranotothenia* spp.
NSD	Northern spiny dogfish	*Squalus mitsukurii*
OAR	Oarfish	*Regalecus glesne*
OCT	Octopus	*Octopus cordiformis*
OPA	Opalfish	*Hemerocoetes* spp.
OPE	Orange perch	*Lepidoperca aurantia*
OSD	Other sharks and dogs	

Species code	Common name	Scientific name
PAD	Paddle crab	*Ovalipes catharus*
PDG	Prickly dogfish	*Oxynotus bruniensis*
PHO	Lighthouse fish	*Photichthys argenteus*
PIG	Pigfish	*Congiopodus leucopaecilus*
PIL	Pilchard	*Sardinops neopilchardus*
PLS	Plunket's shark	*Centroscymnus plunketi*
PLU		*Physiculus luminosa*
POP	Porcupinefish	*Allomycterus jaculiferus*
POR	Porae	*Nemadactylus douglasi*
POS	Porbeagle shark	*Lamna nasus*
POT	Any parrotfish	
PSK	Longnosed deepsea skate	*Bathyraja shuntovi*
PSY	Psychrolutes	*Psychrolutes* sp.
PTO	Patagonian toothfish	*Dissostichus eleginoides*
RAT	Any rattail	*Macrouridae*
RAY	Any ray	Torpedinidae, Dasyatidae, Myliobatidae, Mobulidae
RBM	Ray's bream	*Brama brama*
RBT	Redbait	*Emmelichthys nitidus*
RBY	Ruby fish	*Plagiogeneion rubiginosus*
RCO	Red cod	*Pseudophycis bachus*
RDO	Rosy dory	*Cyttopsis roseus*
RHY	Common roughy	*Paratrachichthys trailli*
RIB	Ribaldo	*Mora moro*
RPE	Red perch	
RPI	Red pigfish	*Bodianus vulpinus*
RSK	Rough skate	*Raja nasuta*
RSN	Red snapper	*Centroberyx affinis*
RSQ	Red squid	*Ommastrephes bartrami*
RUD	Rudderfish	*Centrolophus niger*
SBK	Spineback	*Notacanthus sexspinis*
SBO	Southern boarfish	*Pseudopentaceros richardsoni*
SBR	Southern bastard cod	*Pseudophycis barbata*
SBW	Southern blue whiting	*Micromesistius australis*
SCG	Scaly gurnard	*Lepidotrigla brachyoptera*
SCH	School shark	*Galeorhinus galeus*
SCM	Roughskin dogfish	*Scymnodon macracanthus*
SCO	Swollenhead conger	*Bassanago bulbiceps*
SDO	Silver dory	*Cyttus novaezealandiae*
SDR	Spiny seadragon	*Solegnathus spinosissimus*
SEE	Silver conger	*Gnathophis habenatus*
SEV	Broadnose sevengill shark	*Notorynchus cepedianus*
SHA	Any shark	
SHL	Shovelnosed lobster	*Scyllarus* sp.
SHO	Seahorse	*Hippocampus abdominalis*
SKA	Skate	Rajidae, Arhynchobatidae
SKI	Gemfish	*Rexea solandri*
SNA	Snapper	*Pagrus auratus*
SND	Shovelnose spiny dogfish	*Deania calcea*
SNI	Snipefish	*Macrorhamphosus scolopax*
SOL	Sole	
SOR	Spiky oreo	*Neocyttus rhomboidalis*
SPD	Spiny dogfish	*Squalus acanthias*
SPE	Sea perch	*Helicolenus* spp.
SPF	Scarlet wrasse	*Pseudolabrus miles*
SPG	Spotted gurnard	*Pterygotrigla picta*
SPI	Spider crab	
SPO	Rig	*Mustelus lenticulatus*
SPZ	Spotted stargazer	*Genyagnus monopterygius*

Species code	Common name	Scientific name
SQU	Arrow squid	*Nototodarus sloanii* & *N. gouldi*
SQX	Any squid	
SRH	Silver roughy	*Hoplostethus mediterraneus*
SSC	Giant masking crab	*Leptomithrax australis*
SSH	Slender smooth-hound	*Gollum attenuatus*
SSI	Silverside	*Argentina elongata*
SSK	Smooth skate	*Raja innominata*
SSO	Smooth oreo	*Pseudocyttus maculatus*
STA	Giant stargazer	*Kathetostoma giganteum*
STG	Stargazer	
STN	Southern bluefin tuna	*Thunnus maccoyii*
STR	Stingray	
STU	Slender tuna	*Allothunnus fallai*
SUN	Sunfish	*Mola mola*
SWA	Silver warehou	*Seriolella punctata*
SWC	Swimming crab	
SWO	Broadbill swordfish	*Xiphias gladius*
TAR	Tarakihi	*Nemadactylus macropterus*
TEW	Sand diver	*Tewara cranwellae*
THR	Thresher shark	*Alopias vulpinus*
TOA	Toadfish	*Neophrynichthys* sp.
TOD	Dark toadfish	*Neophrynichthys latus*
TOP	Pale toadfish	*Neophrynichthys angustus*
TRE	Trevally	*Pseudocaranx dentex*
TRU	Trumpeter	*Latris lineata*
TUN	Any tuna	
UNI	Unidentified	
WAR	Common warehou	*Seriolella brama*
WIT	Witch	*Arnoglossus scapha*
WPS	White pointer shark	*Carcharodon carcharias*
WRA	Longtailed stingray	*Dasyatis thetidis*
WSE	Wrasses	Labridae
WSQ	Warty squid	*Moroteuthis* spp.
WWA	White warehou	*Seriolella caerulea*
YBF	Yellowbelly flounder	*Rhombosolea leporina*
YBO	Yellow boarfish	*Pentaceros decacanthus*
YCO	Yellow cod	*Parapercis gilliesi*
YEM	Yellow-eyed mullet	*Aldrichetta forsteri*
YFN	Yellowfin tuna	*Thunnus albacares*