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S. L. Ballara
O. F. Anderson

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S. L. Ballara
O. F. Anderson

NIWA
Private Bag 14901
Wellington 6241

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EXECUTIVE SUMMARY

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Fish bycatch and discard levels in the arrow squid and scampi trawl fisheries from 1999–2000 to 2005–06 were estimated, using trawl catch and discard data from the Ministry of Fisheries Observer Programme and commercial catch data, and estimates of non-target catch were derived. Estimates were made for several categories of catch, including the target species, QMS species, non-QMS species, and commonly caught individual species.

Bootstrapping techniques were used to choose the better of two ratio estimators, one based on tow duration and the other on target species catch, to be used for scaling up observed discard and bycatch rates to the total fishery. For arrow squid, the tow duration estimator had a slightly smaller coefficient of variation (c.v.), so this estimator was used in all calculations. For scampi, the tow duration-based estimator provided a higher c.v. than the catch based estimator, although the tow duration-based estimator was used as regressions showed much better fits to tow duration than to scampi catch.

Regression analyses were used to determine which factors had the most influence on bycatch and discard quantities, in order to select the best stratification for calculation of these values. In both the squid and scampi fisheries bycatch and discards the most influential factors were *area*, *fishing duration,* and *company*; *gear code* or *headline height* were also influential for the squid and scampi discards respectively. The variable *fishing year* was influential only in a few models. The *vessel* effect was of lower importance in most models, and was probably confounded with the *company* effect. Because observer data were not available from all vessels or companies, *vessel* and *company* could not be used to scale up ratio estimates and so only *area* and *fishing year* were used. There were not enough data to partition year into *month* or *species specific periods* for stratification.

Total bycatch in the arrow squid fishery ranged from about 16 550 to 26 730 t per year (compared to the total landed trawled squid catch of 19 000 to 82 000 t). About 82–90% of this consisted of QMS species with main bycatch species including barracouta, silver warehou, and spiny dogfish. Total annual discard estimates ranged from about 2840 to 6740 t with main species including spiny dogfish, rattails, silver warehou, javelinfish, and crabs. Discarding of squid was minimal at 0.21% of total discards and an average of 0.2 kg of total discards per kilogram of squid caught

In the scampi fishery, bycatch accounted for a much greater proportion of the total catch, with total annual bycatch estimates ranging from 2910 to 8070 t, compared to total landed trawled scampi catches of 791–1045 t. Main bycatch species included ling, hoki, sea perch, red cod, silver warehou, and giant stargazer. Total annual discard estimates ranged from about 1540 to 5140 t and were dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish, and sea perch. Discarding of scampi was minimal at 0.3% of total discards and discards averaged 2.5 kg of total discards per kilogram of scampi caught.

The precision of the estimates of bycatch and discard levels is strongly linked to the coverage of the fishery by observers. Observer programme coverage in the squid trawl fishery was 20–54% of the annual target fishery catch, which although considered sufficient is misleading as most of the coverage was on the Snares Shelf and around the Auckland Islands with other areas under-represented in some years. Observer programme coverage in the scampi trawl fishery has been patchy over time and between areas and less than 10% of the annual target fishery catch was observed in three of the seven years. Care therefore needs to be taken over interpretation of estimates of bycatch and discards for both squid and scampi.

1. INTRODUCTION

Some level of non-target species catch and discarding is common in virtually every commercial fishery. 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, i.e., thrown back into the sea. Discards in commercial fisheries have become an increasingly important issue in fisheries management over the last decade or two as the world fishery harvest approaches theoretical maximum sustainable yields (Pascoe 1997), and studies on levels of discarding have revealed the magnitude of the problem. There is an extensive literature after a surge in interest in this field in the 1990s (Hall & Mainprize 2005), prompted by a number of scientific workshops which focussed on bycatch and discard issues, e.g., the Technical Consultation on Reduction of Wastage in Fisheries in Japan (Clucas & James 1996), and a comprehensive "how to" book on methods of reducing bycatch (Kennelly 2007).

On a global scale, annual discards are in the millions of metric tonnes. Annual discards in commercial fisheries in 1988–90 were estimated to have been 27 million tonnes, with bycatch of non-target species amounting to about 29 million tonnes, out of a total harvest of about 80 million tonnes (Alverson et al. 1994). Alverson (1998) admitted this may have been an overestimate and suggested that a significant reduction in global discards occurred in the early 1990s, due mostly to the actions of fishery managers and to better use of bycatch. A recalculation of this figure gave a revised estimate of 20 million tonnes (FAO 1999). Considerable progress has been made in the last decade or two in the reduction and better use of bycatch (Kennelly 2007), and an updated figure for the early 2000s of 6.8 million tonnes was calculated by Kelleher (2005). Although Kelleher used a completely different methodology from the earlier study, this suggests that a considerable reduction in wastage has occurred.

The worst discarding has been associated with shrimp trawl fisheries (Clucas & James 1996), which have a very low ratio of retained to discarded catches, and an estimated 1.8 million tonnes of discards per year worldwide (Kelleher 2005). Bottom trawling for fish (together with longline and pot fisheries) were ranked second by Clucas & James (1996), followed by drift-net and seine fisheries, with pelagic trawls and targeted purse-seine having the lowest ratios of discard to target catch.

Information on the level of non-target fish catch and discards in commercial fisheries is important for fisheries management. Successful stock assessment requires good data on the true catch and mortality of fish species. This applies to both target and non-target species, where the latter are other commercial species or non-commercial ones. Such data can also contribute to an improved understanding of fish communities, and the possible impact of fishing on the long-term sustainability of exploited ecosystems.

In New Zealand, the Ministry of Fisheries has the responsibility for determining impacts of fishing on both target species that are discarded and non-target species taken during normal fishing operations. The work undertaken here follows on from a recent study carried out by NIWA to estimate the level of discards in the arrow squid fishery for the 1998–99 to 2000–01 fishing years and scampi trawl fisheries for the 1990–91 to 2000–01 fishing years (Anderson 2004). It also complements other studies investigating bycatch and discards in New Zealand trawl fisheries: e.g., discards in the southern blue whiting, orange roughy, hoki, and oreo fisheries (Clark et al. 2000), and discards and non-target catch in the orange roughy and hoki fisheries (Anderson et al. 2001, Anderson & Smith 2005). This research is helping to increase our understanding of the more general effects of commercial fisheries on fish species and the aquatic environment in New Zealand.

Non-target fish catch and discards in selected New Zealand fisheries

The specific objectives of these projects require estimates to be made of the catch of non-target fish species, and the discards of target and non-target fish species in two important New Zealand trawl fisheries: arrow squid (*Nototodarus sloanii* & *N. gouldi*) and scampi (*Metanephrops challengeri*).

The overall objective for both ENV200701 and ENV200702 was:
To estimate the level of non-target fish catch and discards of target and non-target fish species in selected New Zealand fisheries.

The specific ENV200701 objective was:
To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for scampi for the fishing years 2000–01 to 2005–06 using data from MFish Observers and commercial fishing returns.

The specific ENV200702 objective was:
To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded, in the trawl fisheries for squid for the fishing years 2001–02 to 2005–06 using data from MFish Observers and commercial fishing returns.

Total reported catches in 2005–06 for arrow squid were 72 400 t, and for scampi were 871 t (Ministry of Fisheries 2007). Fisheries of this scale have considerable potential to catch large amounts of non-target species, or of the target species that are of unwanted size or are damaged.

Squid fisheries are based on two species: *Nototodarus sloanii* in or south of the Subtropical Convergence, and *N. gouldi* occurring north of the convergence zone (Smith et al. 1987). Both species are found over the continental shelf in water up to 500 m depth, though they are more common in water less than 300 m depth (Ministry of Fisheries 2007). The trawl fishery accounts for most of the squid catch in most years, with most trawling effort from water depths of 160–200 m between December and May. The main areas of trawling are on the Snares Shelf, off the Auckland Islands, and near Banks Peninsula (Figure 1, Appendix A1). Based on observer data, squid accounts for 67% of the total catch in the target trawl fishery, with bycatch principally of barracouta, jack mackerel (*Trachurus declivis, T. murphyi, T. novaezelandiae*), silver warehou (*Seriolella punctata),* and spiny dogfish (*Squalus acanthias*) (Ministry of Fisheries 2007).

Scampi are widely distributed around the New Zealand coast, mainly in depths of 200 to 500 m (Ministry of Fisheries 2007). The main fisheries are in the Bay of Plenty, off the Wairarapa coast, around the Chatham Rise, and in the Sub-Antarctic, in particular around the Auckland Islands (Figure 2, Appendix B1). Some fishing has been recorded on the Challenger Plateau, especially outside the Exclusive Economic Zone (EEZ) (Annala et al. 2002). Vessels are mainly 20–40 m, and trawl using multiple nets with low headline heights in depths of 300–500 m (Ministry of Fisheries 2007). A small amount of scampi bycatch is taken in middle depth trawl fisheries (Ministry of Fisheries 2007). Scampi trawlers take a substantial bycatch of QMS and non-QMS fish species (Cryer et al. 1999, Hartill et al. 2006), the amount and composition of which varies both within and between QMAs (Cryer & Coburn 2000). Most of the non-QMS bycatch is discarded on the grounds. The major commercial bycatch species include sea perch (*Helicolenus* spp.), ling (*Genypterus blacodes*), hoki (*Macruronus novaezelandiae*), red cod (*Pseudophycis bachus*), silver warehou (*Seriolella punctata*), and giant stargazer (*Kathetostoma giganteum*) (Ministry of Fisheries 2007). Observer programme coverage in the scampi trawl fishery has been patchy (Hartill & Cryer 2000).

There has been observer coverage in each of these fisheries for more than 10 years. In most years, between 5 and 20% of the target fishery catch has been observed in these fisheries. Observers record the catch and discards from each trawl or group of trawls, as well as details of the fishing gear used, location and depth, and various other incidental information. Fishers themselves are required to record catch and effort from all commercial fishing for these species. Details of fishing activity, including total catch and target species catch (per tow or per day), are recorded on Trawl, Catch, Effort, and Processing Returns (TCEPRs) and Catch, Effort and Landing Returns (CELRs) and provided to the Ministry of Fisheries.

Previous research on bycatch and discards in arrow squid and scampi estimated total annual discards for the years 1998–89 to 2000–02 at about 2200–4300 t for squid and for the years 1990–91 to 2000–01 at 1400–5300 t for scampi (Anderson 2004). The main factors influencing discards appeared to be vessel, area, and fishing year for both arrow squid and scampi.

Although not an objective in this project, an examination of the influence of various factors on the levels of bycatch and discards is made for stratification of data to estimate bycatch and discards.

2. METHODS

2.1 Definition of terms

For the purposes of this study, *non-target fish species catch* is equivalent to *bycatch*, all fish caught that were not the stated target species for that tow, whether or not they were discarded (McCaughran 1992). He further defined *discarded catch* (or *discards*) as "all the fish, both target and non-target species, which are returned to the sea whole as a result of economic, legal, or personal considerations". *Discarded catch* in this report includes estimates of any fish lost from the net at the surface.

A summary of methods in Sections 2.2–2.5 follows.

1. Commercial data were examined to see what dataset definition encompassed the most data. In the scampi fishery, core vessels were defined as vessels which had participated in all trips targeting scampi in a fishing year. The optimum squid dataset was chosen as target squid. Two optimum scampi datasets were chosen: trips that target scampi, and core vessels that only target scampi in a year.

2. Observer dataset was chosen based on the dataset definition chosen for commercial data. Observer data with mixed targeting in a process group were removed from the dataset.

3. Discard and bycatch estimator was chosen. The tow-duration-based estimator was selected for all bycatch and discard calculations.

4. Factors influencing bycatch and discards were chosen based on both tree regression and linear and binomial regression for stratification of discard and bycatch. Stratification for bycatch and discard estimates was restricted to *area*. Where there were insufficient records within an area and fishing-year, a bycatch ratio was calculated based on data for all years for that area.

2.2 Commercial fishing return data

Catch records from commercial fishing returns were obtained from Ministry of Fisheries databases for each fishery during the period. All data were extracted from any trip in which scampi or squid were targeted or caught. The data extracts included all fishing recorded on TCEPRs, CELRs, and high seas versions of both.

Data were groomed for errors, using simple checking and imputation algorithms (from Dunn & Livingston 2004) and further analysis and range checks were defined for each attribute to identify outliers in the data. Tow locations, tow speed, net depth, bottom depth, gear width, and headline height were checked in this manner and, where possible, errors were corrected using median imputation. Duration was calculated from the difference in time between the start and finish time of the tow. Where this was zero or more than 10 hours (less than 0.5% of all records), it was replaced by a value estimated from the tow distance (calculated from start and finish positions) and the recorded tow speed. Where large discrepancies remained, the median tow duration was assigned to the record. Records were assigned to the areas defined in Figures 1–2. Catch weights were checked for unusual values. For CELR data, missing tow durations were assigned the median of all other tow durations. A few records in the TCEPR data from each fishery showed a larger target species catch than the total catch from a tow. These were assumed to be errors of transposition, and were corrected accordingly.

TCEPR, CELR, and Catch Landing Returns (CLR) and CELR landings data were examined to work out the appropriate observer squid or scampi datasets to analyse based most of the catches for each either squid or scampi. TCEPR data for scampi or squid were defined in several potential targeting categories based on squid or scampi targeting. In either the squid or scampi dataset "target category" was defined for each vessel and fishing year as follows:

Target category (SPP is SQU or SCI)	Description (SPP is SQU or SCI)
1. Vessel-year target SPP	all trips target SPP in a fishing year (except ≤ 3 tows non-target SPP)
2. Partial vessel-year target SPP trip	trips that target only SPP in a fishing year
3. Partial vessel-year target MIX trip	trips that target mixed species in a fishing year a. partial trip - target SPP b. partial trip - target mixed species
4. Vessel-year non target SPP	trips that have no SPP targeting in a fishing year

For the scampi dataset, a proportion of the fleet that participated in the fishery over the study period had been involved only for a limited period or conducted only a limited number of tows or scampi targeting. Core scampi vessels were thus defined as those which had participated in the fishery for at least 4 years and had all recorded tows in each fishing year in target category 1.

There was no portion of the squid data set that could be attributed in a similar way to a core category (see Appendix A4).

2.3 Observer data

Two datasets were prepared for each fishery, one comprising discard data, and the other bycatch data. Observer records of catch and discards were extracted from the Ministry of Fisheries database '*obs'* for the fishing years being examined. Records were extracted for all tows from a trip where scampi or arrow squid were caught or recorded as the target species. Species codes included SQU, ASQ, NOS, NOG (arrow squid), or SCI (scampi).

For all records, the tow distance was calculated from recorded start and finish positions. Records in which a start or finish position was incompletely recorded, or where the calculated distance was more than 60 km, were identified and groomed using median imputation to substitute approximate values for those missing. This process substitutes the missing value with the median latitude or longitude for other trawls by the vessel on the same day. Trawl distances were then recalculated from the corrected positions.

Duration of tow was calculated from start and finish times as for the commercial data with a similar grooming process. Individual vessel data (gross registered tonnage (GRT) and company) were obtained from a combination of sources due to incomplete records in any single source; the *obs* database, observer trip reports, and TCEPR catch-effort data for matching vessels. Observer data were available by vessel and company, however no vessel or company is identified in this report, and alphanumeric codes are presented where necessary.

To create the dataset used to estimate discards, the weights of each species retained and discarded in each "processing group" were obtained from the MFish *obs* database. The processing group is the level at which observers record discard information, and although usually represented by a single tow, the discards from two or more trawls are frequently combined into one processing group. This grouping of processing data stems from the difficulty of keeping track of the catch from individual trawls in the factory of a vessel. In order to examine how discard levels varied with fishing depth, area, season, etc., it was necessary to summarise these data over all trawls within each processing group. Hence the catch and discards of each species, and trawl lengths and durations, were summed within each processing group. Some variables, such as fishing year, processing type, and company, were always constant between trawls within a processing group, but frequently trawls in a group spanned two months or two areas, and a range of trawl depths. For this reason depth of trawl was assigned to each processing group as a categorical variable. Examination of individual trawl data showed that the mean depth of all observed trawls (where the depth of each trawl was taken as the average of the depth of the groundline at the start and end of the trawl) was about 160 m for arrow squid and 450 m for scampi. Therefore processing groups made up of trawls which were all shallower than these depths were assigned "shallow", those made up of trawls deeper than this depth were assigned "deep", and those with a mixture of tow depths were set to "NULL". If a set of tows belonging to a processing group had more than one target species, a processing group target species "MIX" was assigned, and these processing groups were removed from the dataset (48 from arrow squid and 3 from scampi).

The extraction of bycatch data was more straightforward because observers estimated or measured the weight of all species caught in each trawl. Bycatch could therefore be estimated and related to trawl parameter data for each tow.

A season variable was assigned to each processing group and tow, based on the main fishing season for the target species. The high season was defined as December–April for arrow squid, and September–February for scampi. 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 (Figures 1 and 2). For both arrow squid and scampi these areas differed slightly from those used by Anderson (2004).

From the datasets the weights of fish caught and fish discarded were calculated for the following species categories:

- the "target" species (arrow squid (SQU) or scampi (SCI))
- QMS species combined (QMS)
- all non-QMS species combined (non-QMS)
- selected QMS or non-QMS individual species with enough non-zero catch data

Summaries by species of the overall observed catch and percentage discarded are tabulated for each fishery in Appendices A2 and B2. Species included in QMS were defined as all species managed under the New Zealand's Quota Management System (QMS) before 1 April 2008, 96 species.

When fish were lost from the net before it was brought aboard, observers estimated the amount lost by recording "total greenweight on surface" and "total greenweight on board". These losses came about through a mixture of burst codends, burst windows/escape panels, and rips in the belly of the net, either below the sea surface or at the surface, or on the stern ramp of the vessel. Obvious errors in these values were corrected, for example, where the recorded value for "total greenweight on board" was greater than "total greenweight on surface" the weight of fish lost was set to zero unless an obvious typographical error could be uncovered and corrected by comparing greenweight totals from species by species tallies with the two total greenweight figures. In addition, differences in the recorded values for "total greenweight on surface" and "total greenweight on board" were accepted as valid fish losses only if they were accompanied by a code identifying the cause of the loss. After these corrections, real cases of observed fish losses were very few, and so were ignored for the remaining analyses.

A total of 11 279 tows and 10 381 processing groups targeting arrow squid, and 2645 tows and 2542 processing groups targeting scampi were used in the analysis.

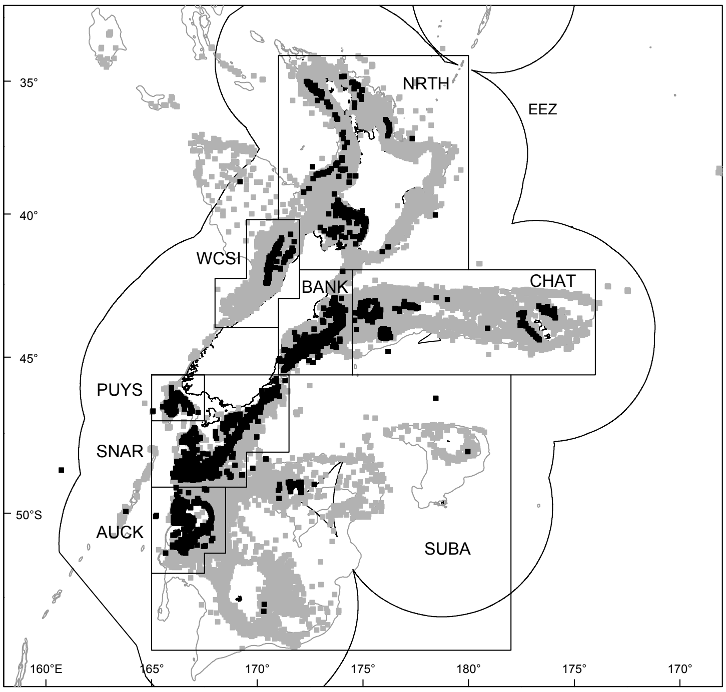

Figure 1: Distribution of all TCEPR tows from trips which caught or targeted squid between 1 October 1999 and 30 September 2006 (grey squares), and target squid TCEPR tows in the same period (grey squares). Area divisions are those used in the squid analysis.

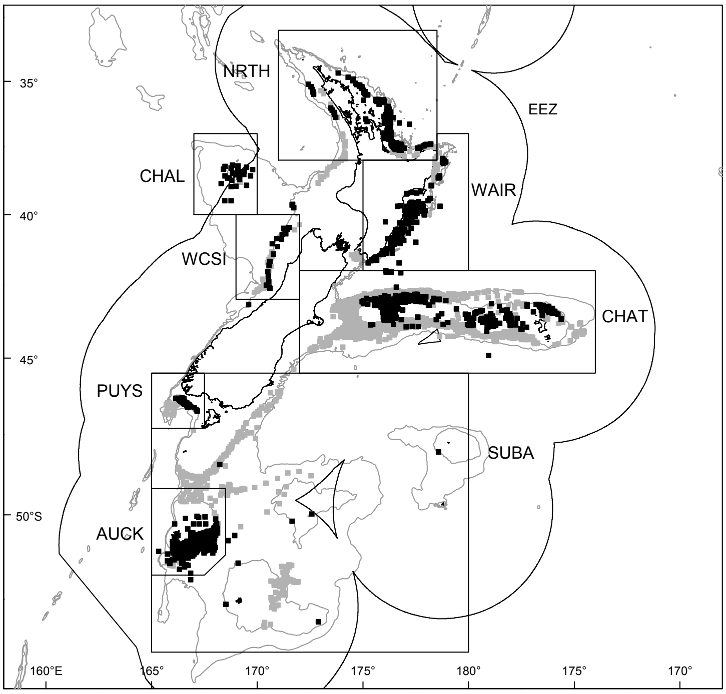

Figure 2: Distribution of all TCEPR tows from trips which caught or targeted scampi between 1 October 1999 and 30 September 2006 (grey squares), and TCEPR target scampi tows from target categories 1 and 2 in the same period (grey squares). Area divisions are those used in the scampi analysis.

2.4 Examination of factors influencing bycatch and discards

A number of regression analyses were carried out to investigate stratification of discard and bycatch calculations. Each species group was examined separately in each fishery and one or two regressions were run on each group: (1) a linear regression for tows/processing groups recording a positive catch/discard of the species in the group; (2) a binomial regression on the presence/absence of catch/discards of the species in the group. The binomial regression uses a response variable which is a binomial vector of discards in two categories. For each record this variable was assigned “1” if bycatch/discard was recorded and “0” otherwise. These two regressions enabled an examination of factors influencing both the *probability* and the *level* of a bycatch/discard.

The response variable for the linear regressions was determined from the outcome of a selection process as described by Anderson (2004) and repeated below (see Section 2.5), and a log transformation was made to provide an approximately normal distribution. The log transformation was found to be the most appropriate in each case, after visual examination of histograms and normal probability plots of untransformed and transformed data. The variables tested in the models are shown in Table 1. Because tows were combined within processing groups for discards analysis, the influence of variables such as *headline height* and vessel *speed* could not be tested.

Variables were added to the model until the model stopped at 1% improvement, and only vessel or vessel length and tonnage were allowed into the model. Regressions were run in turn for discards of the target species (for SQU only), bycatch and discards of other QMS species (QMS), non-QMS species (non-QMS), and frequently caught individual species. A few individual species were also examined for comparison with those examined by Anderson (2004) even though they were not so frequently caught (e.g., scampi: discards of hoki, ling, and red cod).

Each of the variables selected as significant by the model process was examined closely using model predictions. The intention was to use variables with a strong influence in the model and for which the models made sensible predictions to stratify data for bycatch and discard calculations. However, because of the uneven spread or lack of observer data, and for consistency between species groups, stratification of ratios to use for bycatch and discard estimates for each species group was restricted to a single influential factor, area. Separate estimates of ratios for an area stratum were made where there were at least 2 vessels and 50 records available in the stratum. Where there was not enough data to create a stratum, i.e., if there were not at least 2 vessels and 50 records in a stratum, this was defined as a "null" stratum. Null strata bycatch ratios were calculated for an area if the area variable was more influential in the models than fishing year, otherwise bycatch ratios were calculated for that fishing-year.

Table 1: Summary of variables tested in the models (b, bycatch; d, discard models).

Variable	Type	Description
Year (b,d)	categorical	fishing year
Vessel (b,d)	categorical	vessel key
Company (b,d)	categorical	company owning or chartering vessel
Area (b,d)	categorical	area in which tow occurred
Month (b,d)	categorical	fishing year month of tow
Season (b,d)	categorical	high or low
Depth (d)	categorical	depth of tow (deep or shallow, see text)
Depth (b)	continuous	depth of tow (m)
Depth (b)	continuous	average depth of tow (m)
Duration (b,d)	continuous	duration of tow (hours))
Headline height (b)	continuous	recorded headline height of tow (m)
Towtype (b,d)	categorical	bottom or midwater gear (squid only)
Core vessel (b,d)	categorical	core/noncore vessel (scampi fishery only)

2.5 Calculation of discard and bycatch ratios

The observer catch and discards data were summed within each species category for each stratum determined from regression analysis. Similarly, trawl durations were summed within strata. From this the "Discard ratio", $\hat{DR}$, was derived. Initially two versions of the ratio were calculated for several subsets of the data, one based on the total catch of the target species, the other on the total trawl duration. The estimators had the following form,

$$\hat{DR}_1 = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} l_i} \quad \text{and} \quad \hat{DR}_2 = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} t_i}$$

where m processing groups were sampled from a stratum; d_i is the weight of discarded catch from the ith processing group sampled; l_i is the weight of the target species caught in the ith processing group sampled; and t_i is the total towing time for the ith processing group. Variances of these estimates were calculated using standard bootstrap techniques. This involved sampling at random (with replacement) 1000 sets of pairs of ratio values from each data subset. Each of the sets was the same length as the number of records in each subset. This resulted in 1000 estimates of $\hat{DR}$ from which variances and confidence intervals were calculated. A comparison was made between the two estimators of the ratio variances derived from each of the initial subsets tested, with the intention of using the estimator with the lowest variance overall for all subsequent calculations.

The standard bootstrap assumes that all tows were sampled with equal probability. This assumption about the assignment of observers to tows is not true, but the spread of observed tow positions compared with all recorded tow positions from each fishery (see Figures 1 and 2) showed that there was fairly representative coverage of the spatial extent of each fishery, with at least the main fishing grounds well covered.

Once the best estimator was chosen, estimates of $\hat{DR}$ were derived for each stratum in each fishing year, where possible, and variances were derived by a more sophisticated bootstrapping procedure that allowed for correlation of discards between sample units, in this case processing groups, within an observed trip. Separate ratios were calculated only for strata with 50 records or more, and overall ratios (e.g., for all areas within a year) were substituted for strata with fewer than 50 records. The discard ratio calculated for each stratum was then multiplied by either the total estimated catch of arrow squid or scampi or the total tow duration in the stratum (depending on the version of the estimator chosen), from commercial catch records, to estimate total discards $\hat{D}$:

$$(1) \qquad \hat{D} = \sum_j \hat{DR}_j \times L_j \text{ (or } T_j \text{)}$$

where L_j is the total catch of arrow squid or scampi in stratum j and T_j is the total tow duration in the stratum.

To obtain a 95% confidence interval for the total discards that allows for correlation between sampling units within a trip, 1000 bootstrap samples were generated from the sampling units within each stratum using a three-step sequential sampling procedure. First a trip was chosen at random, then a bootstrap sample of the processing groups that were from that trip in the stratum. These steps were repeated until the effective number of discard groups was approximately equal to the effective number of observed discard groups for the stratum. At step 3 the effective number of trips in the bootstrap sample was calculated. If this was within 5% of the effective number of observed trips in the stratum then the bootstrap sample was accepted. Otherwise a new bootstrap sample was drawn until 1000 samples in all had been accepted. The effective number of discard groups and the effective number of trips was calculated from the effort (either catch or duration) and reflected the contributions to the variance of the discard rate $\hat{DR}$ from the variance of the discards and the covariance between pairs of discards within the same trip and stratum. Matching a bootstrap sample to the stratum on these criteria ensured that the variation in the bootstrap sample estimate matched the sampling variation of $\hat{D}$. An empirical distribution for the total discards was obtained by totalling the bootstrap estimates across the strata, and the 95% confidence interval was obtained from the 2.5% and 97.5% quantiles.

Bycatch estimates were calculated in a similar manner to discards but, because catch estimates are not pooled across tows, it was possible to use tow-by-tow data and hence a different (and slightly larger) set of records for comparing estimators and calculating ratios. Bootstrapping was carried out using the statistical software package R (Ihaka & Gentleman 1996).

3. RESULTS

3.1 Commercial data

3.1.1 Arrow squid

Most of the landings are encompassed by the TCEPR data (Appendix A3), with the CELR data making up very little of the overall estimated catch of squid. Appendix A4 shows the TCEPR data for squid by "target category". Most tows and catches fell within target categories 2 and 3. There was not much data in target category 1, as there were no vessels which targeted only squid in each year. A lot of squid was caught in target category 3 where squid and many other species are targeted. Examination of target category 3 showed most of the squid catch was from target squid tows (Appendix A4).

As most of the squid catch was caught in target categories 1, 2, and 3a which encompasses only squid target fishing (*see* Appendix A4), the squid dataset chosen for analysis was the target squid observer dataset as for Anderson (2004).

3.1.2 Scampi

Most of the landings are encompassed by the TCEPR data (Appendix B3), with the CELR data making up very little of the overall estimated catch of scampi. Appendix B4 shows the TCEPR data for scampi by "target category". Most tows and catches fall within target category 1. There was not much data in target categories 3 and 4, most likely because scampi are under-represented in the top five species in the TCEPR estimated form.

The TCEPR datasets categories 1 and 2 combined to make up 98–99% of the TCEPR data and 85–90% of the overall scampi landings. There were 11 vessels which targeted only scampi for at least 4 years and had all recorded tows in each year in "target category" 1 (see Table 3), and these were defined as the "scampi core vessel" dataset

As most of the scampi catches came from trips that only targeted scampi (see Appendix B4), two scampi observer datasets were chosen to be analysed:

- trips that targeted only scampi (i.e., target categories 1 and 2)
- core vessels from trips that targeted only scampi in a year (i.e., 11 vessels that target only scampi in a year and participated in the fishery for at least 4 years in target category 1).

Anderson (2004) used all tows where scampi were targeted. The target categories 1 and 2 dataset is a pruned down version of the dataset used by Anderson (2004) with the mixed targeting trips data removed.

3.2 Distribution and representativeness of observer data

3.2.1 Arrow squid

The positions of all observed tows in the target arrow squid fishery, from 1999–2000 to 2005–06, with the TCEPR commercial tows from the same period and dataset definition, are shown in Figure 3. The grey indicates target squid areas fished but unobserved, and show the AUCK and SNAR areas are well covered and that there is under-sampling in the NRTH, WCSI, and CHAT areas, as well as southern parts of BANK.

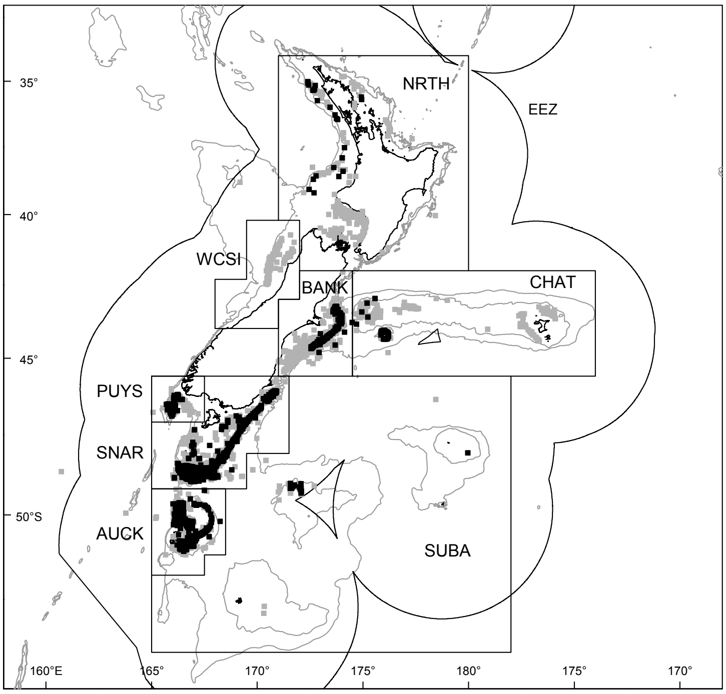

Figure 3: Distribution of tows targeting squid recorded by observers on vessels used in the analysis between 1 October 1999 and 30 September 2006 (black squares), and all commercial tows with recorded position from the same dataset definition and period (grey squares). Area divisions are those used in the squid analysis.

The annual number of observed tows ranged from 867 to 2859 and the percentage of the fishery observed has ranged from 18 to 30% during the period, except for 2000–01 where 54% of target tows were observed (Table 2a). The percentage coverage for each year was well above the nominal 10% usually considered sufficient to be representative of a fishery, although this is slightly misleading as most of the coverage is on the Snares shelf region (SNAR) and Auckland Islands (AUCK) areas, with BANK and PUYS under-represented in some years (Table 2b, Appendix A1). Forty-four vessels were observed during the 7-year period. Total target fishery catch has fluctuated, from a low of 17 184 t in 1999–2000 to a high of 76 034 t in 2003–04.

Observer coverage was spread over the geographical range of this fishery, with sampling throughout all the main fishing grounds (Table 2b). The Auckland Islands fishery (AUCK) has very high observer coverage due to management measures imposed for the protection of New Zealand sea lions. Fishing for arrow squid in that area was confined to the summer and autumn months and observers recorded catch and discards from 27 to 36% of all target tows from 1999–2000 to 2005–06 except for 98% in 2000–01, and 16% in 2003–04. The SNAR area was also well covered and Puysegur Bank (PUYS) was well sampled only in 2001–02 and 2002–03. In the east coast South Island and western Chatham Rise (BANK) area coverage was patchy, and the rest of the Chatham

Islands fishery (CHAT) was not covered. Fishing along the west coast of the North Island between Cape Egmont and North Cape was not well covered. Tows recorded as areas WCSI, PUYS, CHAT, SUBA, NRTH, and in areas outside those defined by boxes in Figure 3 (including outliers with probable position errors) were combined into a single OTHR area category.

Examination of density plots (Figure 4a) shows that the observed tows were distributed throughout the spatial range of the fishery in each of the seven years. Longitudinally 165–170° E was well sampled each year but west of this was generally under-sampled. By latitude, south of 47° S was well sampled in most years although sampling north of 47° S was under-represented.

Table 2a: Number of TCEPR vessels, tows, total catch and squid catch, and number of observed vessels, tows and squid catch and percentage of squid observed catch to squid target trawl fishery, by year.

	Fishing year						
	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
TCEPR							
Number of vessels	37	41	39	44	40	44	45
Number of trips	190	281	267	281	255	258	264
Number of tows	5 473	7 334	7 264	8 084	8 221	10 076	8 072
Total catch (t)	29 663	44 250	57 080	50 628	90 553	86 009	75 495
Squid catch (t)	17 184	30 177	43 126	37 380	76 034	72 726	61 374
Observer							
Number of vessels	12	24	12	18	20	24	22
Number of tows	867	2 859	1 483	1 302	1 163	2 254	1 307
Squid catch (t)	3 463	16 417	11 565	8 146	15 242	20 823	11 060
% of TCEPR catch	20.2	54.4	26.8	21.8	20.0	28.6	18.0

Table 2b: Number of observed squid tows and catches by area for the target squid dataset.

		Fishing year						
	Area	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
Number of tows	NRTH	18	-	-	4	1	-	1
	BANK	9	70	52	50	2	48	10
	CHAT	51	5	-	1	1	9	1
	AUCK	438	565	563	418	409	782	667
	SNAR	351	2 222	735	497	733	1352	622
	PUYS	-	-	125	312	-	62	6
	SUBA	-	-	4	20	17	1	-
	NULL	-	1	-	-	-	-	-
Squid catch (t)	NRTH	1	-	-	<1	<1	-	<1
	BANK	20	247	192	74	2	264	47
	CHAT	380	3	-	<1	<1	33	0
	AUCK	2 167	3 248	4 309	2 266	6 865	7 558	4 892
	SNAR	895	12 925	5 991	3 415	8 332	12 549	6 073
	PUYS	-	-	1 068	2 317	-	419	49
	SUBA	-	-	1	75	44	<1	-
	NULL	-	0	-	-	-	-	-

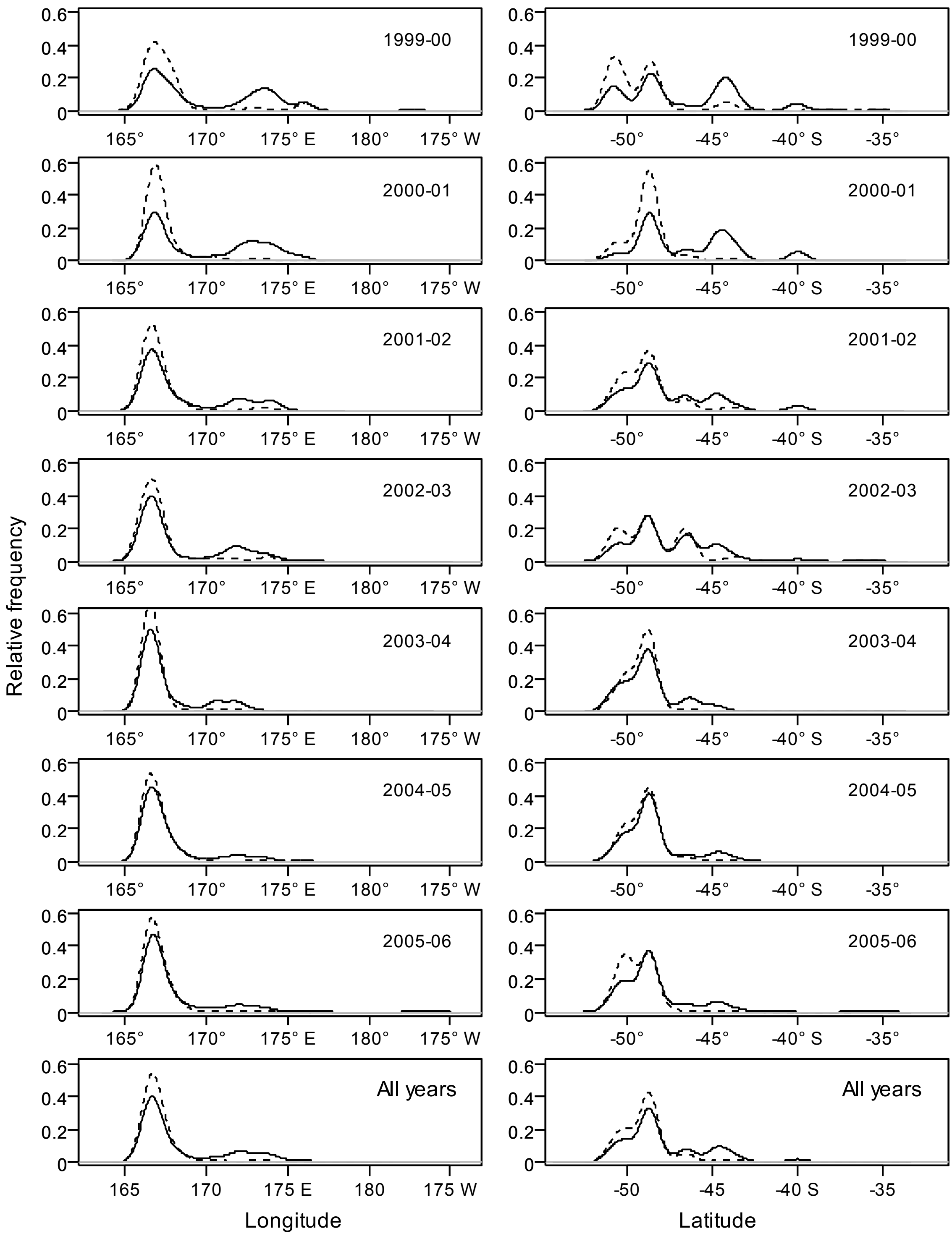

Figure 4a: Comparison of position (latitude and longitude) of squid observed trawls (dashed lines) versus all trawls captured on TCEPR forms (solid line) for each fishing year from 1999–2000 to 2005–06, and for all seven fishing years combined. The relative frequency was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

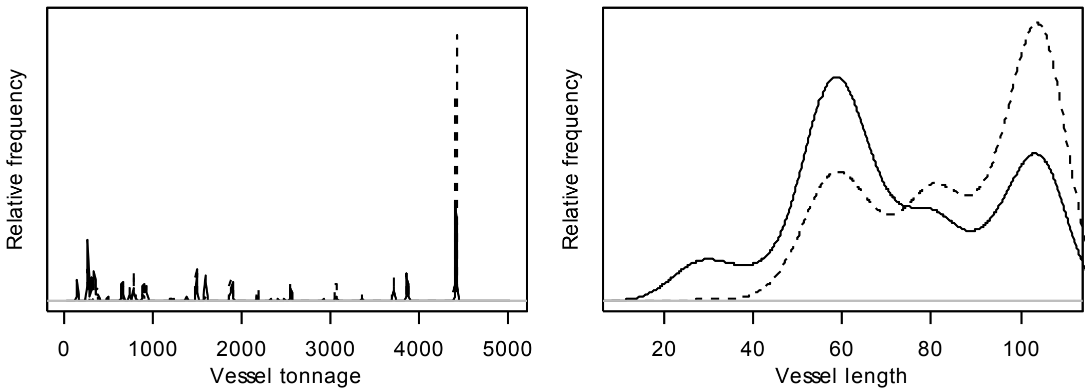

Figure 4b: Comparison of vessel sizes (gross registered tonnage and overall length (m)) in observed squid trawls (dashed lines) versus all trawls captured on TCEPR forms (solid line) for all fishing years combined. The relative frequency was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

The spread of observer effort over the range of vessel sizes was compared to the spread of vessel sizes over the entire target fishery using density plots (Figure 4b). These plots indicate that there was a very wide range of vessel sizes operating in this fishery, from 200 t to over 4400 t, with most observer coverage on vessels over 4000 t and that the most active vessels were all well covered by observers (e.g., the spike at about 4400 t). Vessels over 80 m were over-sampled and therefore well represented. The very small vessels (< 30 m) were not covered, and vessels of 40–80 m were covered although under-sampled. Such large differences in vessel size, and therefore power, are likely to be reflected in the mixture of bycatch species caught.

The spread of observer effort over each fishing year was determined and compared with the spread of effort for the whole fishery, by applying a density function to numbers of trawls per day (Figure 4c). These plots show a very similar pattern of effort from year to year, with good observer coverage in February and March, after which effort drops off steadily. Coverage is under-representative in January and, in some years, April–June. This pattern is caused by the high observer coverage in the AUCK (SQU 6T) fishery. There is very little effort outside January to May.

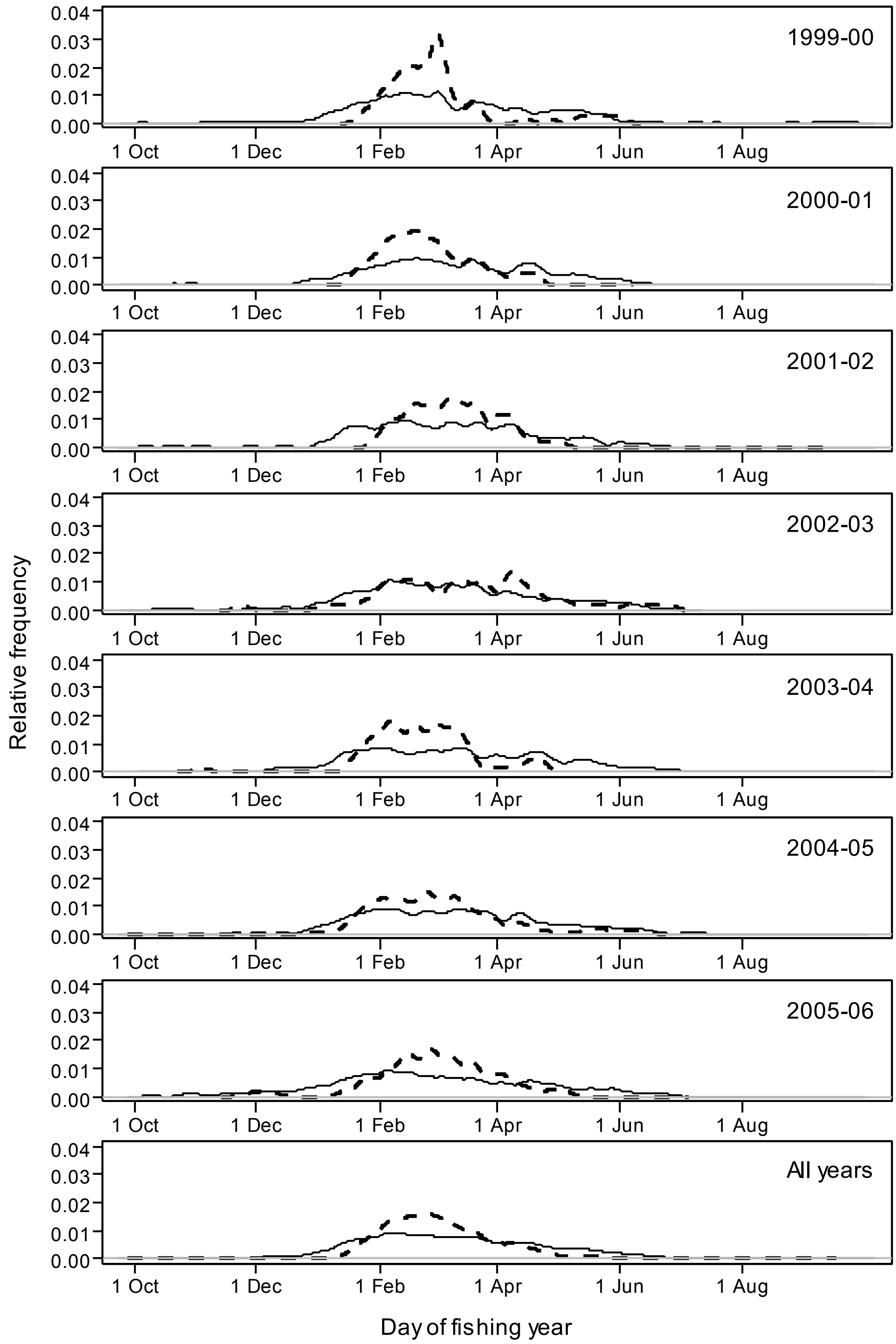

Figure 4c: Comparison of the temporal spread of observed squid trawls (dashed lines) with all squid trawls recorded on TCEPR forms (solid line) for each fishing year from 1999–2000 to 2005–06, and for all seven fishing years combined. The relative frequency of the numbers of trawls was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

3.2.2 Scampi

The positions of observed tows in the scampi dataset (trips that targeted only scampi), from 1999–2000 to 2005–06, are shown in comparison with the TCEPR commercial tows from the same period and dataset definition in Figure 5. The grey indicates areas fished but unobserved and doesn't reveal any major fisheries that were overlooked, although observed distribution is patchy particularly through the middle of the Chatham Rise (CHAT).

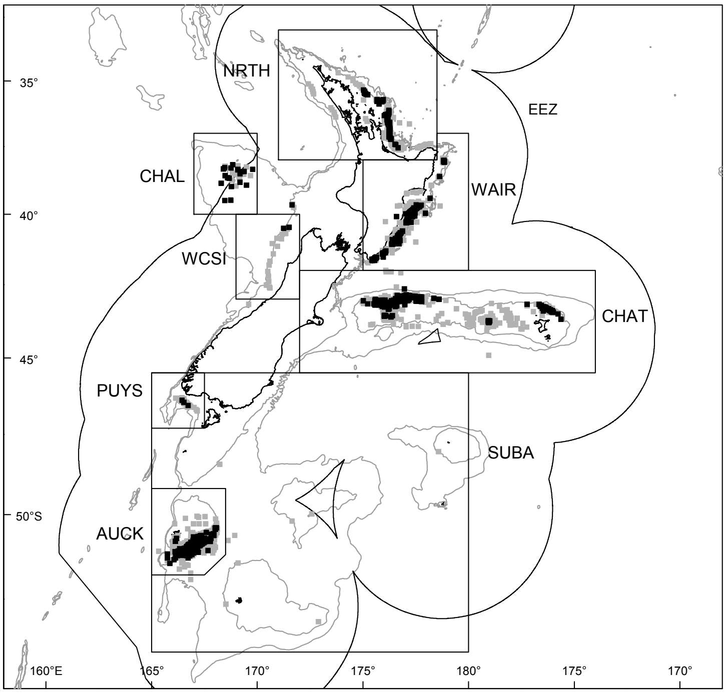

Figure 5: Distribution of tows recorded by observers on scampi vessels used in the analysis (trips that targeted only scampi) between 1 October 1999 and 30 September 2006 (black dots), and all commercial tows with recorded position from the same dataset definition and period (grey dots). Area divisions are those used in the scampi analysis.

This fishery has had observers present for 143–564 tows per year in the years covered by this analysis (Table 3a) with less than 10% of the fishery catch observed in 3 of the 7 years, although over all years the total coverage was about 10.6% with 13 out of 20 vessels observed during this period. (In a year, 10% is the level of coverage considered sufficient to be representative of a fishery.) Hartill & Cryer (2000) noted that observer coverage in the scampi trawl fishery is patchy and under-representative.

Observer coverage for the scampi fisheries was mainly off the east coast of the North Island, on the Chatham Rise, and around the Auckland Islands, and was variably covered by area and year (Table 3b). The Auckland Island's area was not covered at all in 2004–05, and in 2000–01 only 36 tows on the Chatham Rise were observed. The small fishery around the EEZ boundary on the Challenger Plateau was not well covered. The tows recorded on the west coast of the South Island are in conflict with recorded landings from that area, which are negligible (see Annala et al. 2002), and may be the result of incorrect recording of target species. Tows recorded in CHAL, PUYS, WCSI, and NULL were combined into a single OTHR area category.

Table 3a: Number of TCEPR vessels, tows, total catch and scampi catch, and number of observed vessels, tows and scampi catch and percentage of scampi observed catch to scampi target trawl fishery, by year in target categories 1 and 2 (trips that target only scampi) and core vessels from target category 1 (scampi core vessel) datasets.

	Fishing year						
	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
TCEPR Trips that target scampi							
Number of vessels	10	10	13	16	16	9	9
Number of trips	94	102	172	98	56	83	79
Number of tows	4545	4715	6 467	4549	3 397	4 580	4 863
Total catch (t)	1997.8	2308.1	862.5	3497.9	2827.3	2618.5	2371.1
Scampi catch (t)	912.6	888.3	862.5	745.0	651.9	828.1	794.1
TCEPR Scampi core vessels							
Number of vessels	10	10	10	11	10	9	9
Number of trips	94	102	89	70	46	83	79
Number of tows	4545	4715	5 398	3771	2 835	4 580	4 863
Total catch (t)	1997.8	2308.1	767.6	2174.9	1963.7	2618.5	2371.1
Scampi catch (t)	912.6	888.3	767.6	558.7	466.7	828.1	794.1
Observer Trips that target scampi							
Number of vessels	6	5	6	8	6	3	6
Number of tows	418	266	564	511	412	143	331
Scampi catch (t)	100.1	48.2	108.4	136.0	116.7	32.2	60.5
% of commercial scampi catch	11.0	5.4	12.6	18.3	17.9	3.9	7.6
Observer Scampi core vessels							
Number of vessels	6	5	6	7	3	3	6
Number of tows	418	266	564	451	144	143	331
Scampi catch (t)	100.1	48.2	108.4	121.9	45.4	32.2	60.5
% of commercial scampi catch	11.0	5.4	14.1	21.8	9.7	3.9	7.6

Table 3b: Number of observed scampi tows and catches (t) by area for target categories 1 and 2 (trips that target only scampi) dataset.

		Fishing year						
	Area	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
Number of tows	AUCK	74	84	160	149	169	-	118
	CHAT	90	36	111	327	238	77	97
	NRTH	82	-	43	-	5	51	114
	WAIR	172	146	230	32	-	15	-
	CHAL	-	-	17	-	-	-	2
	PUYS	-	-	-	3	-	-	-
	WCSI	-	-	2	-	-	-	-
	NULL	-	-	1	-	-	-	-
Scampi catch (t)	AUCK	13.5	15.7	26.8	30.2	45.3	-	23.9
	CHAT	43.3	13.7	50.2	100.6	70.4	26.6	21.0
	NRTH	19.1	-	6.6	-	1.0	4.2	15.5
	WAIR	24.2	18.7	24.7	4.9	-	1.5	-
	CHAL	-	-	6	-	-	-	10
	PUYS	-	-	-	0.2	-	-	-
	WCSI	-	-	<0.1	-	-	-	-
	NULL	-	-	<0.1	-	-	-	-

Examination of density plots (Figure 6a) shows that the observed tows were distributed throughout the spatial range of the fishery in each of the seven years. The spread of observer coverage generally matched that of the commercial fishery, although observer coverage tended to be more concentrated into narrower ranges in some years, e.g., longitude in 2004–05 and latitude in 2003–04 and 2004–05, and over-sampled in some areas while under-sampling in other areas in some years. The "All years" panel in Figure 6a showed a reasonable match of observer coverage to commercial effort for longitudinal ranges of the fishery but not for the latitudinal range where coverage was low around 38–42 ° S.

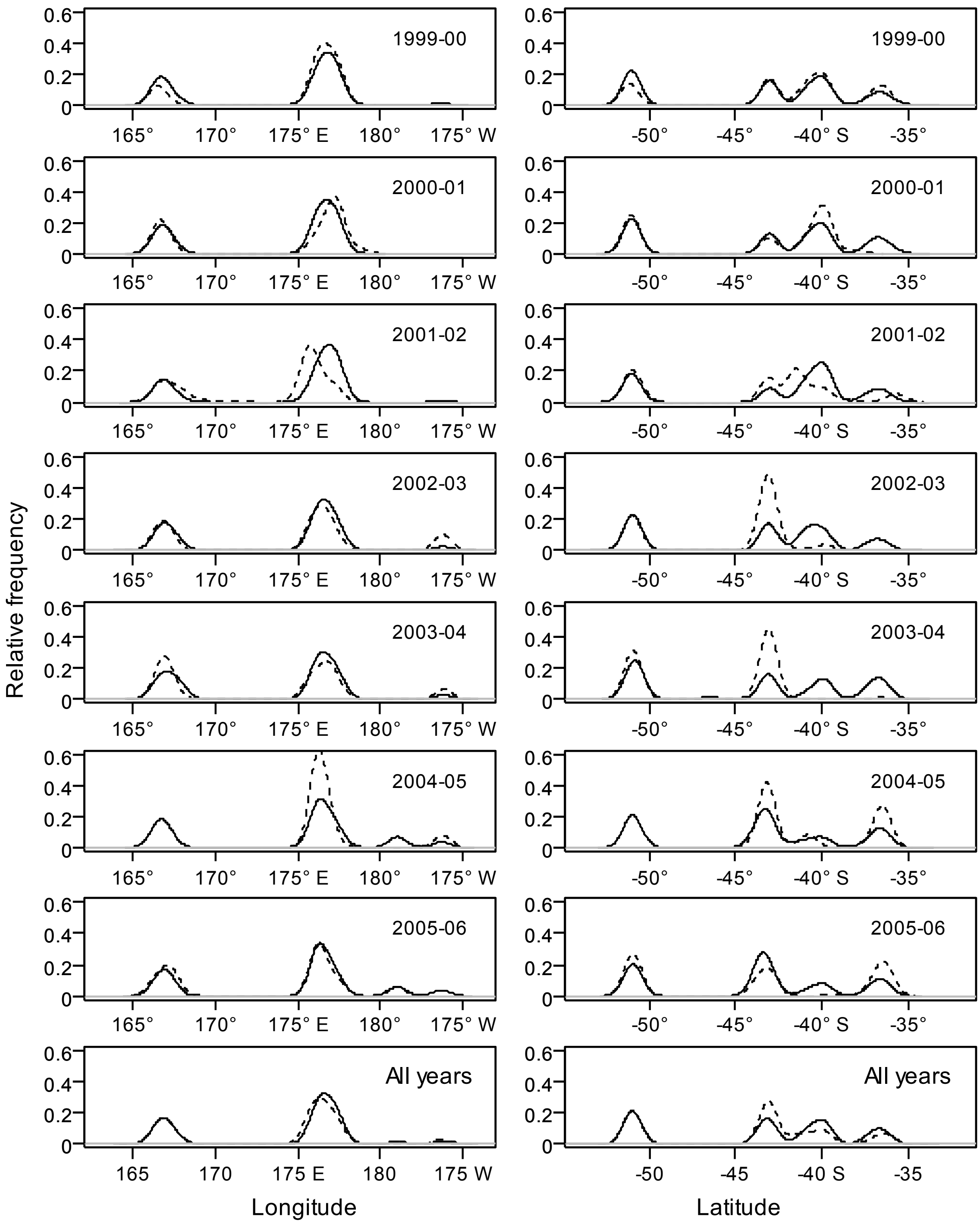

Figure 6a: Comparison of position (latitude and longitude) of observed scampi trawls (dashed lines) versus scampi trawls captured on TCEPR forms (solid line) for each fishing year from 1999–2000 to 2005–06, and for all seven fishing years combined. The relative frequency was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

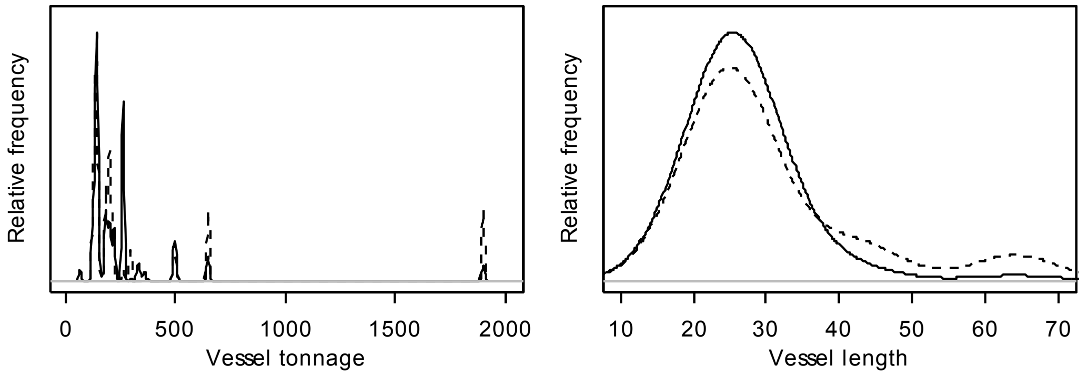

Figure 6b: Comparison of vessel sizes (overall length and gross registered tonnage) in observed scampi trawls (dashed lines) versus scampi trawls captured on TCEPR forms (solid line) for all fishing years combined. The relative frequency was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

The spread of observer effort over the range of vessel sizes was compared to the spread of vessel sizes over the entire target fishery using density plots (Figure 6b). These plots indicate that most vessels were 20–40m and generally less than 700 t. Two vessels were over 60 m at about 1900 t. The observers covered much of the range of vessel sizes with slight under-representation of the 20–40 m vessels and slight over-representation of the large vessels. Such large differences in vessel size (20–40 m versus >60m) and therefore power, are likely to be reflected in the mixture of bycatch species caught.

The spread of observer effort over each fishing year was determined and compared with the spread of effort for the whole fishery by applying a density function to numbers of trawls per day (Figure 6c). These plots show a very similar pattern of effort from year to year, with more effort from October to December, although there were periods of over-sampling and under-sampling in these months in some years. From January to May there generally was under-representation of effort, and for the rest of the year it was variable with patches of over-representation of observer coverage. Overall, observer effort was more variable within each year, but similar over all years.

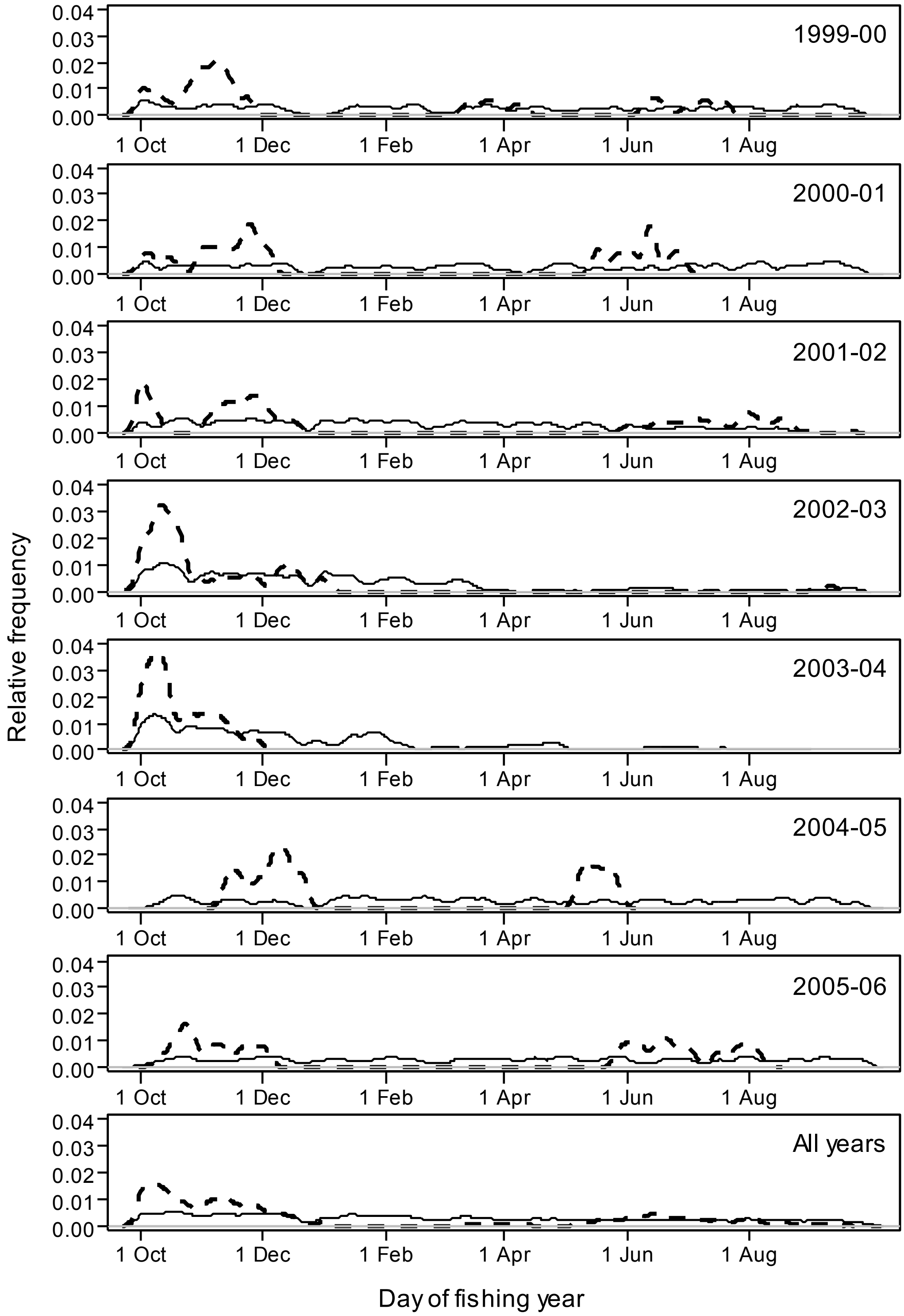

Figure 6c: Comparison of the temporal spread of observed scampi trawls (dashed lines) with scampi trawls recorded on TCEPR forms (solid line) for each fishing year from 1999–2000 to 2005–06, and for all seven fishing years combined. The relative frequency of the numbers of trawls was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

3.3 Comparison of estimators

Using observer data, the arrow squid and scampi estimated catch-based and tow duration-based forms of the bycatch and discard ratio estimators were examined and compared with the aim of selecting and using the one which would provide ratios with the least amount of associated error. For each of the two forms in turn, ratios were calculated for the bycatch and discards in the QMS and non-QMS species categories, without any stratification, and c.v.s estimated by bootstrapping. Individual species categories (including discards of arrow squid or scampi) were not considered as they were represented by far fewer non-zero value observations, and would carry less weight.

Coefficients of variation for the arrow squid fishery were small for bycatch of both species categories and for discards of non-QMS species, for both forms of the estimator (range 2.4% to 6.2%) (Table 4). The estimated c.v.s for bycatch were smaller than for discards, especially in the QMS category. The estimated c.v.s for bycatch in the QMS species category was lower than for the non-QMS species category, while for the discards the QMS species category c.v. was higher than the non-QMS species category c.v. Differences in c.v.s between the two forms were small (range 0.09% to 0.18%), and for the four comparisons the tow duration-based estimator provided a lower c.v. than the arrow squid catch based estimator. On the basis of these comparisons, the tow-duration-based estimator was selected for all bycatch and discard calculations for arrow squid.

Coefficients of variation for the scampi fishery were small for bycatch and discards of both species categories for both forms of the estimator (range 1.8% to 3.2%) (Table 4). The estimated c.v.s were smaller for bycatch than for discards. C.v.s were similar for bycatch in the QMS and non-QMS species categories, and larger for QMS and non-QMS discard species category. Differences in c.v.s between the two forms were small (range 0.09% to 0.17%), and in three out of the four comparisons the tow duration-based estimator provided a higher c.v. than the catch-based estimator. Although the scampi-catch-based estimator had lower c.v.s in most cases, the tow duration-based estimator was used as regressions showed much better fits to tow duration than for scampi catch (see Table 8).

Table 4: Comparison of bycatch and discard estimators.

Fishery	Bycatch/discard	Species category	Estimator	Bycatch ratio	c.v. (%)
Arrow squid	Bycatch	QMS	SQU catch	0.225	2.47
		QMS	Tow duration	438.8	2.36
		non-QMS	SQU catch	0.031	5.01
		non-QMS	Tow duration	60.5	4.92
	Discards	QMS	SQU catch	0.024	6.20
		QMS	Tow duration	46.2	6.04
		non-QMS	SQU catch	0.020	5.73
		non-QMS	Tow duration	40.2	5.55
Scampi	Bycatch	QMS	SCI catch	1.968	1.85
		QMS	Tow duration	75.4	1.96
		non-QMS	SCI catch	2.361	1.77
		non-QMS	Tow duration	90.4	1.94
	Discards	QMS	SCI catch	0.491	2.88
		QMS	Tow duration	18.8	3.18
		non-QMS	SCI catch	1.960	2.67
		non-QMS	Tow duration	75.1	2.58

3.4 Arrow squid observer bycatch data

3.4.1 Overview of raw bycatch data

Arrow squid accounted for 80% of the total estimated catch from all observed trawls targeting arrow squid between 1 October 1999 and 30 September 2006. The remaining 20% mostly comprised other commercial species, especially barracouta (9.2%), silver warehou (2.9%), and jack mackerel (1.1%). Overall 97.5% of the observed catch was QMS species, and only 2.5% non-QMS species.

About 310 species or species groups were identified by observers, the great majority of which were non-QMS species caught in low numbers. Dogfish and sharks, often unspecified but including spiny dogfish and basking shark, accounted for much of the non-commercial catch. Echinoderms, squids, crustaceans, and other unidentified invertebrates were also well represented among the main bycatch species groups caught in this fishery (see Appendix A2 for a list of the top 50 bycatch species).

Exploratory plots were prepared to examine total bycatch per tow (plotted on a log scale) with respect to the available variables (Figure 7a). Total bycatch was highly variable between trawls, ranging from 0 to 70 t, and increased with increasing tow duration and increasing bottom depth. Most tows were between 1 and 8 hours long, but ranged from a few minutes to 12 hours long, and most tows were 100–300 m deep. There was variability in bycatch among the 16 companies and 44 vessels ranging from 0.1 to 2.9 $t.tow^{-1}$.

There was little trend in total bycatch by fishing-year, and it did not vary much between areas (0.7–2.5 $t.tow^{-1}$), except AUCK which had a much lower bycatch level (median 0.2 $t.tow^{-1}$). Bycatch levels were at similar levels for all months (0.4–1.8 $t.tow^{-1}$), except in September and October when they were much higher (5.5 and 2.9 $t.tow^{-1}$ respectively), although these months are based on few tows.

QMS bycatch generally followed similar trends to total bycatch (Figure 7b). Non-QMS species bycatch also followed similar trends to total bycatch (Figure 7c), although the SNAR bycatch level was lower than in AUCK.

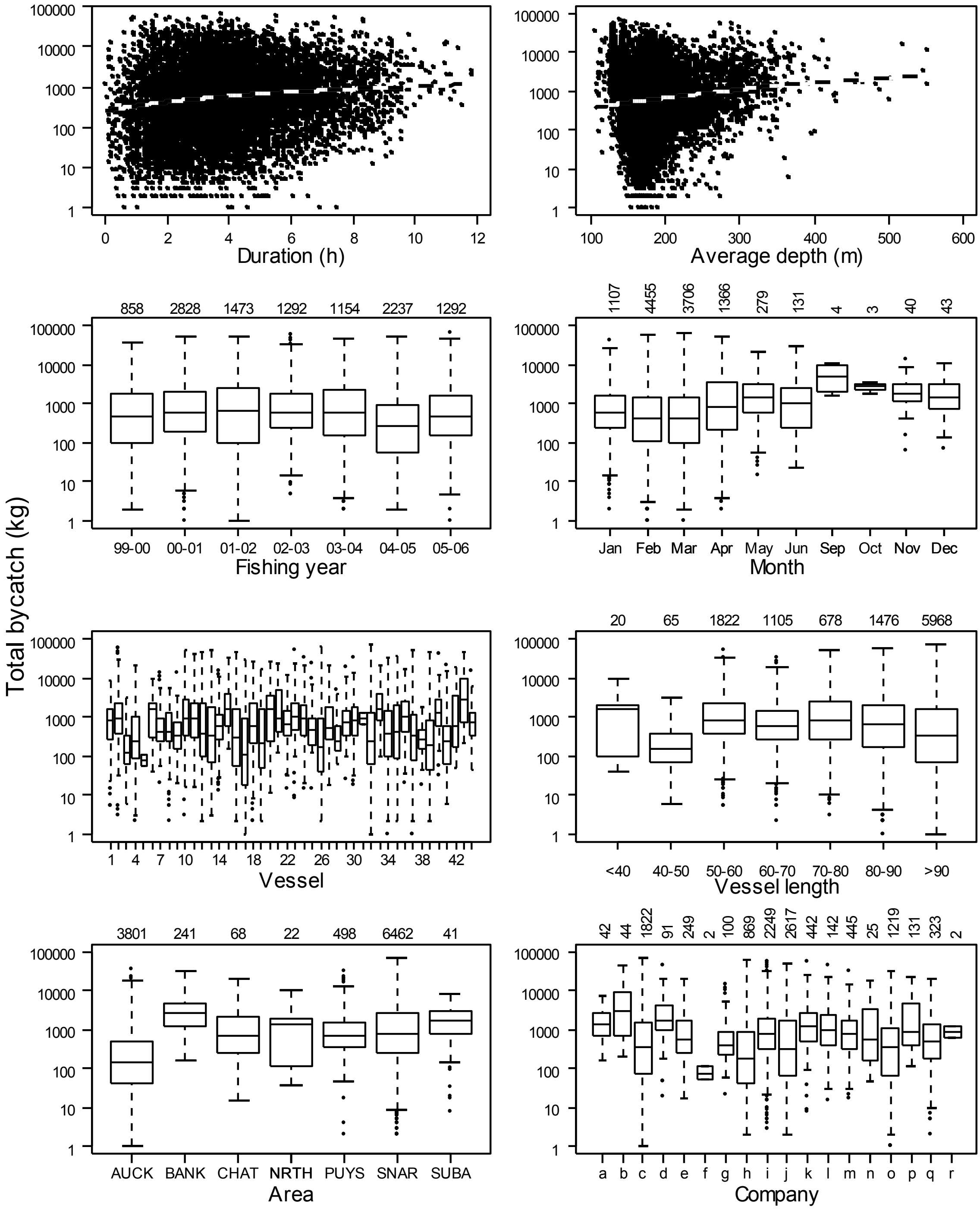

Figure 7a: Total observed bycatch per tow plotted against some of the available variables for the squid fishery. Total bycatch is plotted on a log scale. The dashed lines in the top two panels represent mean fits (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. The numbers above each plot indicate the number of records associated with that level of the variable. Average depth is the average of the start and finish gear depths. See Figure 1 for area codes.

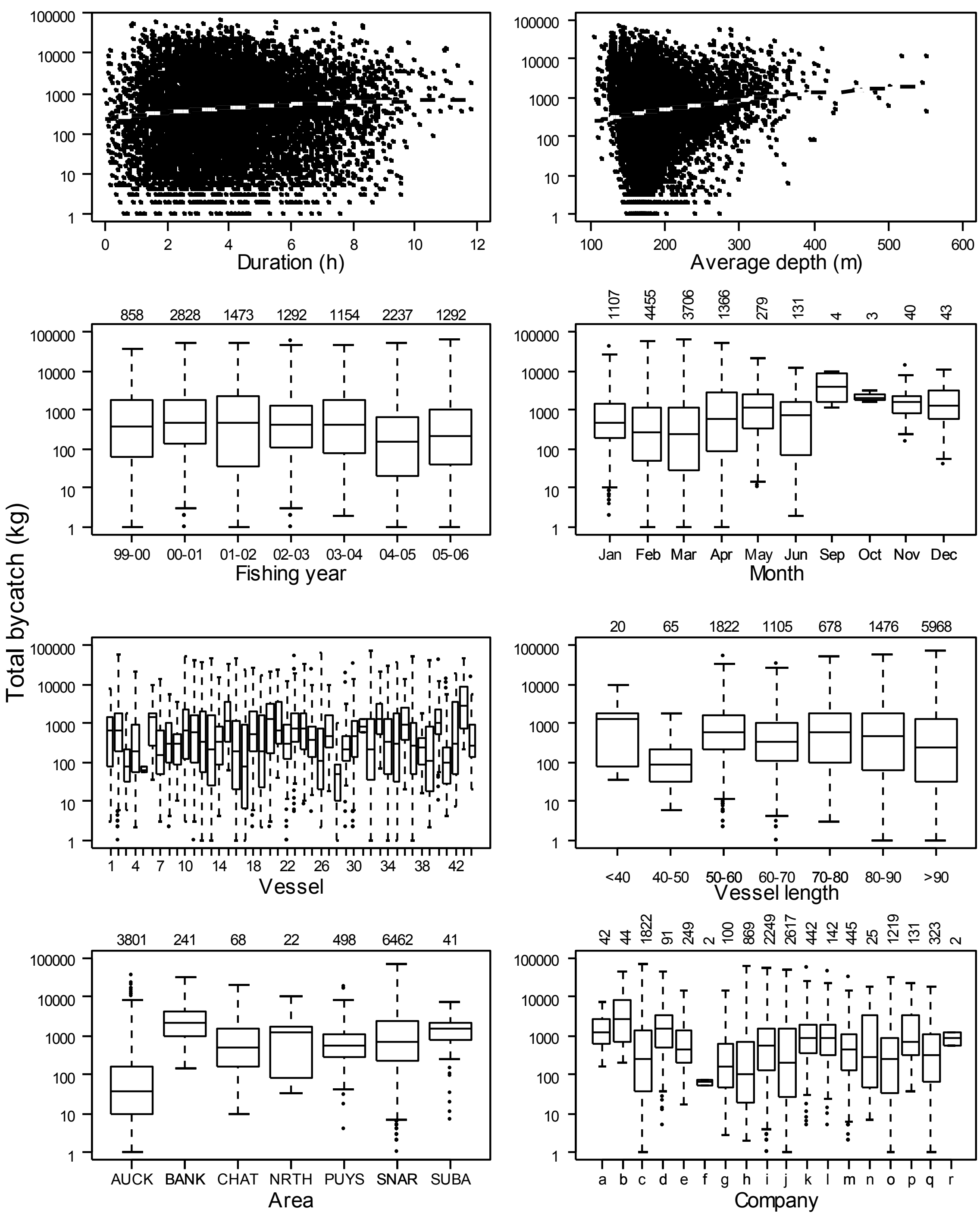

Figure 7b: Observed QMS species bycatch per tow plotted against some of the available variables for the squid fishery. Total bycatch is plotted on a log scale. The dashed lines in the top two panels represent mean fits (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. The numbers above each plot indicate the number of records associated with that level of the variable. Average depth is the average of the start and finish gear depths. See Figure 1 for area codes.

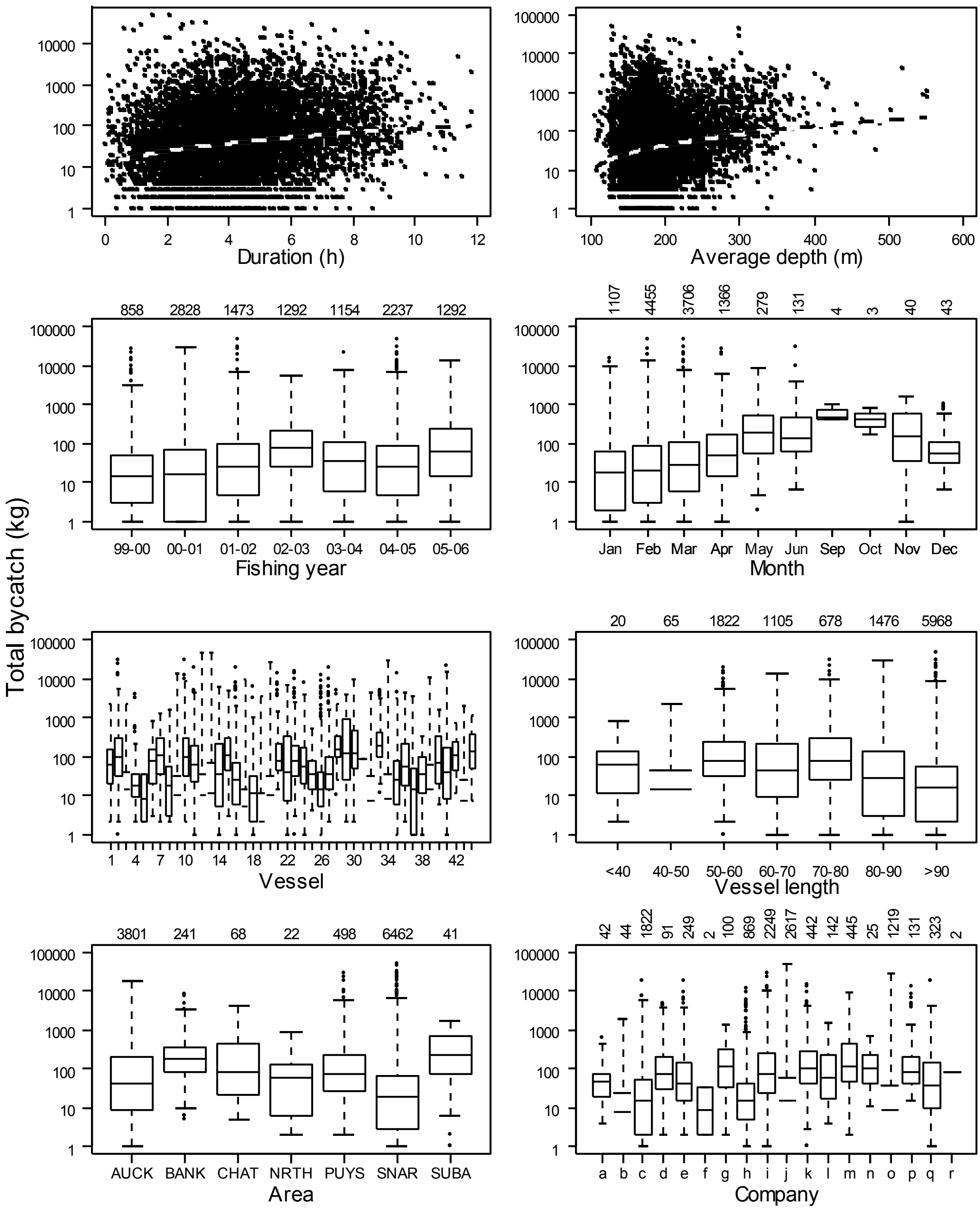

Figure 7c: Observed non-QMS species bycatch per tow plotted against some of the available variables for the squid fishery. Total bycatch is plotted on a log scale. The dashed lines in the top two panels represent mean fits (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. The numbers above each plot indicate the number of records associated with that level of the variable. Average depth is the average of the start and finish gear depths. See Figure 1 for area codes.

3.4.2 Regression modelling and stratification of squid bycatch data

Of the 11 235 observed trawls examined, 94.7% tows recorded bycatch of QMS species, and 81.9% recorded bycatch of non-QMS species. Individual species categories were present in 9–73% of tows (Table 5). Using regression tree analysis each species category was split into one and four time intervals over the fishing year (Table 5).

Table 5: Results of regression tree analyses on non-zero tows on the optimal stratification of fishing day variable for describing rates of squid bycatch. Split points are "day of the fishing year" where 1 = 1 October and 365 = 30 September. See Appendix A2 for definition of species codes.

Species category	Percentage of non-zero tows (11 235 tows)	Number of periods (split points)
QMS	94.7	2 (195.5)
Non-QMS	81.9	3(122.5, 195.5)
BAR	72.5	4 (141.5, 196.5, 209.5)
SWA	66.9	3 (131.5, 209.5)
SPD	53.5	2 (179.5)
JMA	24.4	2 (159.5)
WAR	8.8	2 (159.5)
RBT	23.7	none
RCO	39.1	2 (210.5)
HOK	11.5	none
LIN	21.5	2 (193.5)

The dependent variable in the GLM models was the bycatch ratio, expressed as the log of species category catch per hour trawled (kg/h). In each case, because of the fraction of trawls with no bycatch, both the linear and binomial models were run

In initial models the variable *trip* had a low to mid explanatory power in some cases, but is of no use in stratification as not all trips were observed. When removed from consideration in the models it made little difference to the models' explanatory power.

In model runs excluding the variable *trip*, variables *area*, *duration,* and *company* were often the most influential variables in the linear models, although some other variables were often important too (Table 6).

Trawl *duration* also was often important in the bycatch, with longer trawls producing more bycatch per hour than shorter trawls, especially for non-QMS species (Figure 7). This could be because longer trawls tended to be more speculative than short trawls, used mainly to explore unfamiliar grounds, or were perhaps trawls that missed the targeted fish mark but continued on for a period. Trawl *duration* had a marked influence on the bycatch rates of the QMS, non-QMS, BAR, SWA, JMA, WAR, RBT, RCO, LIN, and HOK species categories. The variable *headline height* had little influence in most models except for the QMS category. The time of year factors, (*period*, *season,* and *fishing month*) had only a small influence in most models but a large influence on the bycatch of WAR species category. The depth variables (*start depth*, *average depth,* or *depth category*) also were of lower importance in most of the models, but had a larger influence on the BAR, JMA, WAR, HOK, and LIN species categories. The variable *company* entered most regressions and was often relatively important in most models (in the top three linear variables for SWA, SPD, RBT, RCO, HOK, and LIN species categories). The variable *vessel* was of low importance in all models (less than 1% improvement in R^2), and vessel information was captured only as *vessel tonnage* for RCO species category.

Because of the uneven spread or lack of observer data, stratification of ratios to use for bycatch estimates for each species group was restricted to a single factor *area*. Null strata bycatch ratios were calculated across an area rather than fishing-year, as in all cases except one, the *area* was more important than *fishing-year*.

Table 6: Summary of GLM modelling of bycatch in the squid fishery using the bycatch ratio log(catch/duration) up to 1% improvement. The numbers denote the order in which the variable entered the model; –, not selected; *area*: squid areas; *fyear*, fishing year*; h.ht,* headline height; *co,* company; *duration* and *depth* are logged; Depth variables: s, start depth; a, average depth; c, depth category; Period variables: sp, species specific period; m, month; Vessel size: l, length; t, tonnage. See Appendix A2 for species codes.

													Variable
Species category	Model type	Model R^2 (%)	*area*	*duration*	*h.ht*	*fyear*	*fday*	*co*	*vessel size*	*depth*	*period*	*gear*	*vessel*
QMS	Normal	37.7	1	2	3	4	-	-	-	-	-	-	-
	Binomial	19.8	1	2	4	-	-	3	-	-	-	-	-
non-QMS	Normal	19.8	2	3	-	-	5	4	-	-	-	1	-
	Binomial	13.3	-	2	-	-	3	1	-	-	-	-	-
BAR	Normal	29.3	1	2	-	5	-	-	-	3a	4sp	-	-
	Binomial	17.4	1	-	-	-	-	2	-	3a	-	-	-
SWA	Normal	21.3	1	3	-	-	-	2	-	-	4sp	-	-
	Binomial	12.3	1	2	-	-	4	3	-	5a	-	-	-
SPD	Normal	38.7	2	4	-	5	-	3	-	-	6sp	1	-
	Binomial	43.5	1	3	-	-	-	-	-	-	-	2	-
JMA	Normal	32.5	3	1	-	5	-	4	-	2a	6sp	-	-
	Binomial	29.5	1	-	-	3	-	2	-	4a	-	-	-
WAR	Normal	14.8	4	2	-	-	-	-	-	3s	1sp	-	-
	Binomial	27.8	1	-	-	-	3	4	-	2s	-	-	-
RBT	Normal	20.3	-	2	-	-	3	1	-	-	-	-	-
	Binomial	23.0	1	-	-	-	-	2	-	-	-	-	-
RCO	Normal	22.9	2	3	-	-	-	1	4t	-	5m	-	-
	Binomial	9.7	3	2	-	-	-	-	-	-	-	1	-
HOK	Normal	28.6	4	2	-	-	-	3	-	1a	-	-	-
	Binomial	12.2	-	3	-	-	-	2	-	1a	-	-	-
LIN	Normal	38.1	2	3	-	-	-	1	-	4a	6sp	5	-
	Binomial	18.6	2	4	-	-	-	1	-	-	3sp	-	-

3.5 Scampi observer bycatch data

3.5.1 Overview of raw scampi bycatch data

Scampi accounted for 18.6% of the total estimated catch from all trips that targeted scampi only between 1 October 1999 and 30 September 2006, and just over half of the observed total catch of QMS species. The main QMS species were sea perch (10.2% of total catch), ling (6.3%), hoki (5.2%), red cod (2.2%), silver warehou (2.0%), giant stargazers (2.0%), ghost sharks (1.9%), hake (1.0%), gemfish (0.4%), arrow squid (0.5%), and bluenose (0.3%).

About 292 species or species groups were identified by observers, the great majority of which were non-QMS species caught in low numbers. The main non-QMS species included javelinfish (16.3% of total catch), rattails (12.1%), deep sea flatheads (2.4%), unspecified crabs (1.6%), skates (1.5%), spiny dogfish (1.4%), and starfish (1.1%). Dogfish and sharks, echinoderms, crustaceans, and other invertebrates were also well represented among the bycatch species groups caught in this fishery (see Appendix B2 for a list of the top 56 bycatch species).

Exploratory plots were prepared to examine total bycatch per tow (plotted on a log scale) with respect to the available variables (Figure 8a). Total bycatch was highly variable between trawls; it decreased slightly with increasing tow duration but did not change with increasing bottom depth. Most tows were about 3–10 hours long and 300–500 m deep. There was variability in bycatch among the companies and vessels ranging from 0.4 to1.6 $t.tow^{-1}$ for companies and 0.4 to1.2 $t.tow^{-1}$ for vessels. Bycatch was more consistent between fishing years, with slightly lower levels in 2005–06, and varied more among areas, with lower levels in the NRTH and AUCK areas (0.5 and 0.6 $t.tow^{-1}$ respectively) and higher levels in PUYS, CHAT, and CHAL (median 2.6, 1.1 and 1.0 $t.tow^{-1}$ respectively). Bycatch levels increased from May (0.3 $t.tow^{-1}$) to September (1.5 $t.tow^{-1}$), and then decreased to December (0.6 $t.tow^{-1}$). March and April bycatch levels were higher (1.1 $t.tow^{-1}$).

QMS and non-QMS bycatch per tow variables showed similar trends to the total bycatch (Figure 8b and 8c).

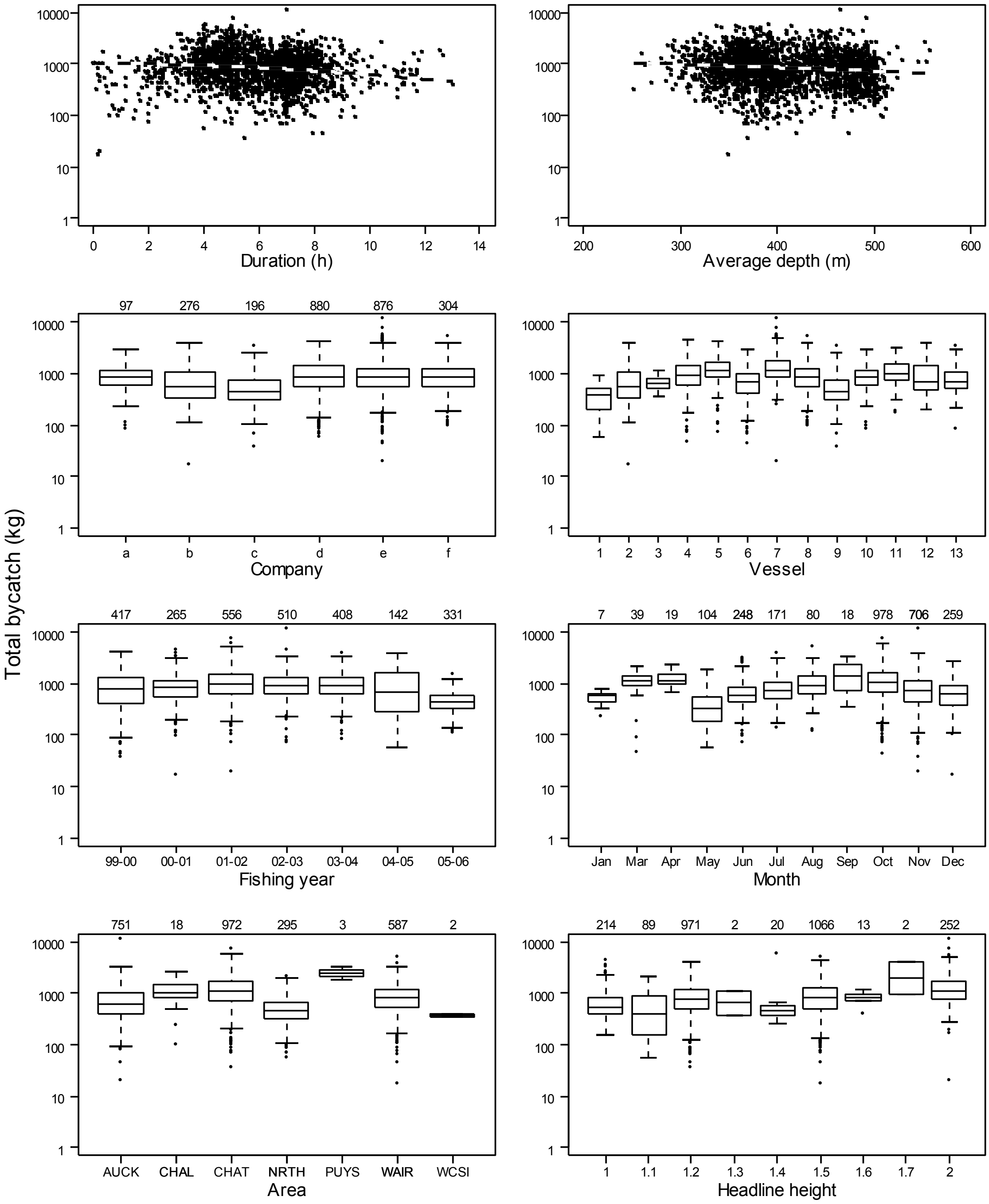

Figure 8a: Total observed bycatch per tow plotted against some of the available variables for the scampi fishery. Total bycatch is plotted on a log scale. The dashed lines in the top two panels represent mean fits (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. The numbers above each plot indicate the number of records associated with that level of the variable. Average depth is the average of the start and finish gear depths. See Figure 2 for area codes.

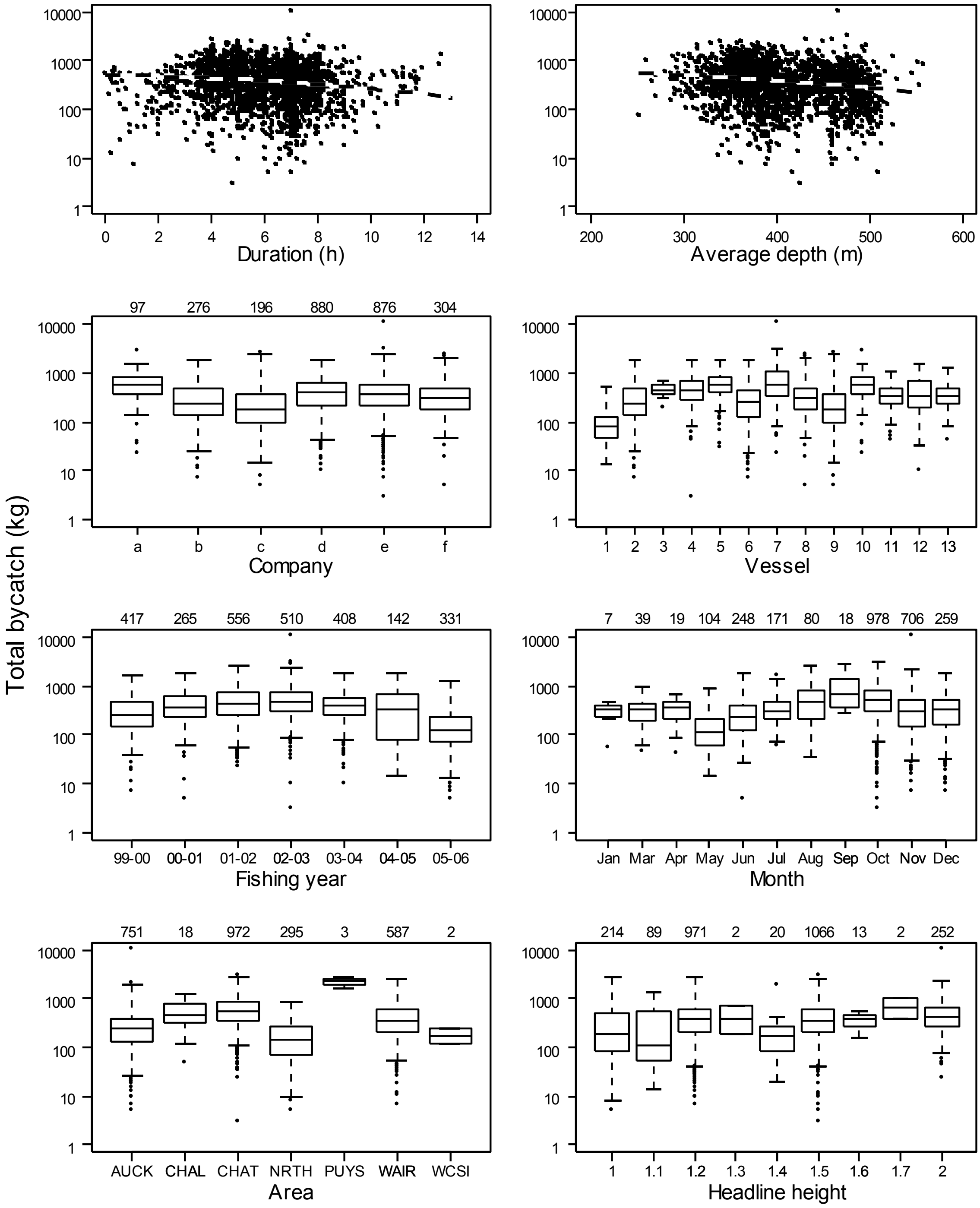

Figure 8b: Observed QMS species bycatch per tow plotted against some of the available variables for the scampi fishery. Total bycatch is plotted on a log scale. The dashed lines in the top two panels represent mean fits (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. The numbers above each plot indicate the number of records associated with that level of the variable. Average depth is the average of the start and finish gear depths. See Figure 2 for area codes.

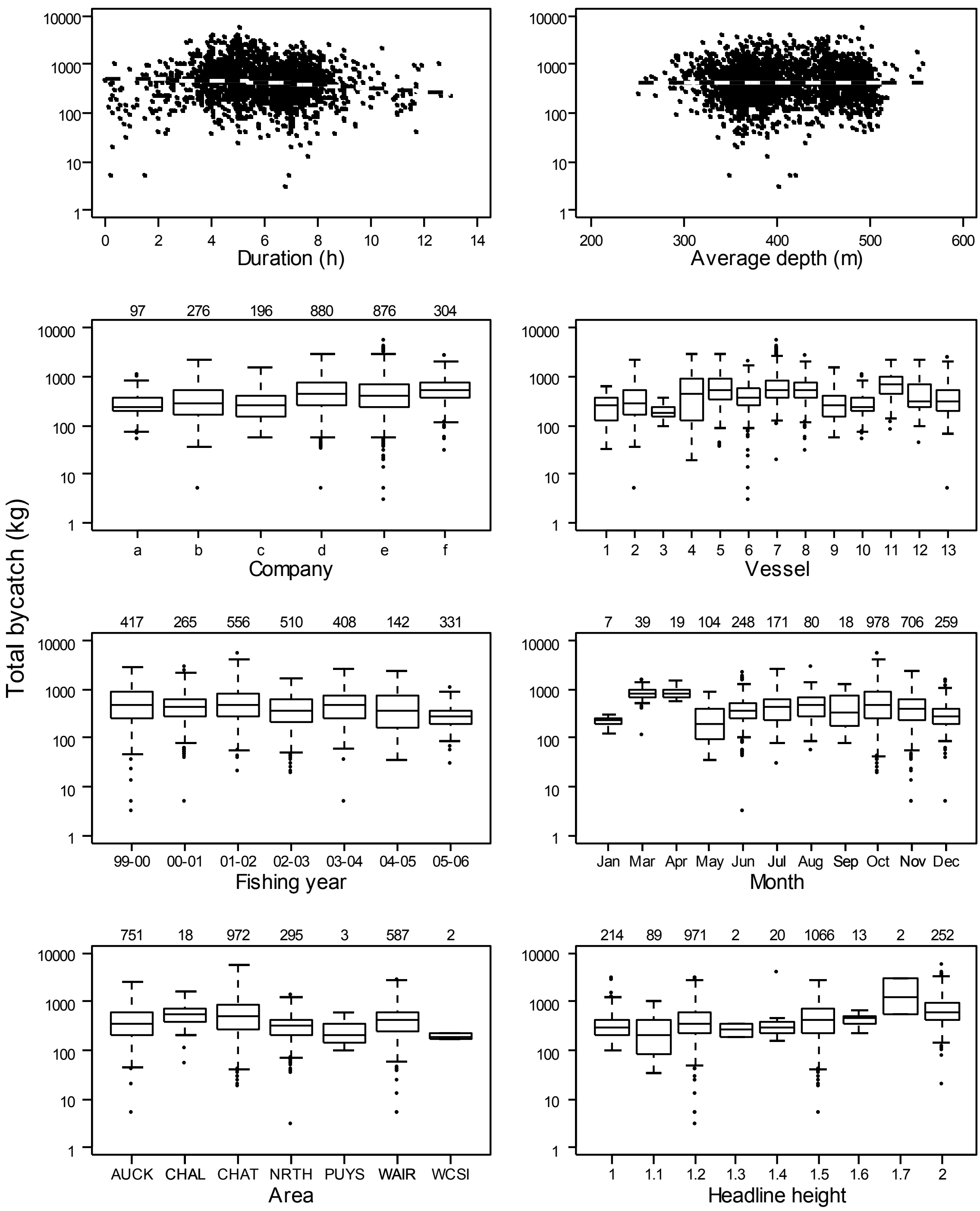

Figure 8c: Observed non-QMS species bycatch per tow plotted against some of the available variables for the scampi fishery. Total bycatch is plotted on a log scale. The dashed lines in the top two panels represent mean fits (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. The numbers above each plot indicate the number of records associated with that level of the variable. Average depth is the average of the start and finish gear depths. See Figure 2 for area codes.]

3.5.2 Regression modelling and stratification of scampi bycatch data

Of the 2645 observed trawls examined, 99.2% tows recorded bycatch of QMS species, and 98.3% recorded bycatch of non-QMS species. Individual species categories were present in 14–85% of tows (Table 7). Each species category was grouped into between one and five time intervals over a fishing year using regression tree analysis (Table 7).

Table 7: Results of regression tree analyses on non-zero tows on the optimal stratification of the fishing day variable for describing rates of scampi bycatch. Split points are "day of the fishing year" where 1 = 1 October and 365 = 30 September. See Appendix B2 for species codes.

Species category	Percentage of non-zero tows (2645 tows)	Number of periods (split points)
QMS	99.2	3 (24.5, 317.5)
Non-QMS	98.3	5 (39.5, 129, 208, 257.5)
SPE	69.3	4 (24.5, 152.5, 296.5)
LIN	85.0	3 (24.5, 265.5)
HOK	84.3	3 (174.5, 255.5)
RCO	54.7	4 (206,265.5,303.5)
SWA	35.8	3 (36.5, 298)
STA	53.4	3 (24.5, 319.5)
GSH	53.7	3 (56.5, 296.5)
HAK	36.4	3 (212.5, 297)
SQU	43.8	2 (19.5, 50.5, 302.5)
SKI	18.8	2 (220.5)
BNS	13.8	2 (23.5)
WWA	21.5	1 (-)

The dependent variable in GLM models was the bycatch ratio, expressed as the log of species category catch per duration (kg/h). For individual species, because of the high fraction of trawls with no bycatch, both the linear and binomial models were run.

In initial models, the variable *trip* had a high explanatory power in most cases, but is of no use in stratification as not all trips were observed. When removed from the models it was often replaced by *area*, with little loss in the models' explanatory power.

In model runs excluding the variable *trip*, variables *area*, *duration,* and *company* were often the most influential variables in the linear models, although some other variables were often important too (Table 8). The variable *area* was often an influential variable.

Trawl *duration* also was important in the bycatch, with longer trawls producing less bycatch per hour than shorter trawls (see Figure 8). This could happen if longer trawls tended to move away from relatively restricted productive areas for bycatch species. Trawl *duration* had a marked influence on the bycatch of the QMS, non-QMS, STA, GSH, HAK, SQU, and WWA species categories. H*eadline height* had a small influence some models, especially SKI and BNS. The time of year factors (*period*, *season,* and *month of fishing year*) had a small influence in most models but a large influence on the bycatch of non-QMS, STA, and SKI species categories. The depth variables (*start depth*, *average depth,* or *depth category*) also were of lower importance in most of the models, but had a greater influence on the SPE, RCO, GSH, HAK, and WWA species categories.

The variable *company* entered most regressions and was often relatively important in the models (in the top three linear variables for non-QMS, RCO, SWA, HAK, SQU, and BNS categories). The variable *vessel* was of lower importance, except to explain the presence or absence of SQU and BNS species categories as bycatch species. The variable *core vessel* was not important in most models, but did help to explain presence or absence of hoki as a bycatch species.

Because of the uneven spread or lack of observer data, stratification for bycatch estimates for each species group was restricted to a single factor *area*. Where there were insufficient records within an area and fishing-year, a bycatch ratio was calculated based on data for all years for that area.

Table 8: Summary of GLM modelling of bycatch in the scampi fishery. The numbers denote the order in which the variable entered the model to 1% improvement; –, not selected; *area*, scampi areas; *fyear*, fishing year; *h.ht*, headline height; *co*, company; *duration* and *depth* are logged; Depth variables: s, start depth; a, average depth; c, depth category; Period variables: sp, species specific period; s, season; m, month of fishing year. See Appendix B2 for species codes.

Species category	Model type	Bycatch ratio	Model R^2 (%)	Variable: *area*	*duration*	*fyear*	*h.ht*	*period*	*co*	*depth*	*vessel*	*core vessel*
QMS	Normal	catch/duration	49.8	1	2	3	4	5_{sp}	6	-	-	-
		catch	40.6	1	6	2	3	5_{sp}	4	7_s	-	-
		catch/SCI catch	28.1	1	-	6	4	2_{sp}	3	5_s	-	-
non-QMS	Normal	catch/duration	40.2	4	1	5	6	2_{sp}	3	7_a	-	-
		catch	21.5	1	-	3	4	-	2	5_a	-	-
		catch/SCI catch	19.6	1	4	-	3	-	2	5_a	-	-
SPE	Normal	catch/duration	55.8	1	3	-	-	5_{sp}, 6_m	4	2_s, 7_c	-	-
	Binomial	catch/duration	87.5	1	2	-	-	-	3	-	-	-
LIN	Normal	catch/duration	33.6	1	3	2	-	5_{sp}	-	6_c	4	-
	Binomial	catch/duration	20.4	4	5	1	-	-	2	3_c, 6_a	-	-
HOK	Normal	catch/duration	36.3	2	3	1	5	7_{sp}	4	-	-	6
	Binomial	catch/duration	17.7	3	4	-	-	5_m	1	6_c	-	2
RCO	Normal	catch/duration	47.4	1	4	-	5	-	3	2_a,6_c	-	-
	Binomial	catch/duration	15.6	1	-	6	-	4_{sp},5_m	2	3_a	-	-
SWA	Normal	catch/duration	56.7	1	6	3	-	4_{sp}	2	5_s	-	7
	Binomial	catch/duration	32.3	1	-	2	-	4_{sp}	3	-	-	-
STA	Normal	catch/duration	48.5	1	2	-	5	3_{sp}	6	-	4	-
	Binomial	catch/duration	13.7	1	-	-	-	3_{sp}	2	-	4	5
GSH	Normal	catch/duration	25.6	1	2	-	-	-	4	3_a	-	-
	Binomial	catch/duration	16.8	1	-	-	-	-	2	-	-	-
HAK	Normal	catch/duration	46.2	4	1	6	-	5_{sp}, 8_m	2	3_a	7	-
	Binomial	catch/duration	38.5	1	-	3	-	-	4	2_s	-	-
SQU	Normal	catch/duration	55.9	1	2	4	-	5_{sp},6_m	3	-	-	-
	Binomial	catch/duration	23.9	1	-	-	-	-	3	-	2	-
SKI	Normal	catch/duration	24.1	5	-	3	2	1_{sp}	4	-	-	-
	Binomial	catch/duration	59.1	1	-	-	-	-	2	-	-	-
BNS	Normal	catch/duration	35.7	-	3	-	2	4_{sp}, 5_m	1	-	-	6
	Binomial	catch/duration	34.2	1	5	2	-	-	4	-	3	-
WWA	Normal	catch/duration	35.9	-	1	-	3	-	4	2_s	6	5
	Binomial	catch/duration	13.4	1	-	-	-	-	2	-	-	-

3.6 Observer arrow squid discard data

3.6.1 Overview of raw discard data

QMS species accounted for 51% of observed discards, particularly spiny dogfish which made up 41.6% of discards. Other main QMS species observed discarded included arrow squid (4.5%), silver warehou (3.7%), barracouta (1.5%), hoki (1.1%), and red cod (1%).

Non-QMS species made up 44.5% of discards and included various crab species (18.6%), rattails (5.4%), javelinfish (1.1%), and various sharks (3.5%). Other groups frequently discarded included various fish species, echinoderms, squids, crustaceans, and other unidentified invertebrates (see Appendix A2 for details).

Exploratory plots were prepared to examine the variability in the total level of discards per processing group with respect to available factors (Figure 9). The quantity of discards increased slightly with increasing trawl duration, and the duration of most processing groups was less than 8 hours. Processing groups with trawls deeper than 160 m had slightly more discards than groups with shallower tows, although this small difference is unlikely to be significant.

The factors showing the most variability were *company* and *vessel*, for which median discard levels were 19–360 kg.tow^{-1} and 2–643 kg.tow^{-1}, respectively. Discard levels were lower on the smaller and largest vessels (median 200 kg.tow^{-1} for vessels under 40 m, 87 kg.tow^{-1} for vessels 40–50 m, and 30 kg.tow^{-1} for vessels over 90 m). The total discards by fishing year were variable, with lower discard rates in 1999–2000 (24 kg.tow^{-1}), medium discard rates in 2000–01, 2003–04, and 2004–05 (76–90 kg.tow^{-1}), and higher discard rates in 2001–02, 2002–03, and 2005–06 (131–143 kg.tow^{-1}). Discards varied between areas, with lower levels in AUCK and SNAR and higher levels of discards in BANK and SUBA. Discards were lowest in January, increased between January and May (60–282 kg.tow^{-1}), and then levelled off.

Discards for QMS and non-QMS species generally showed similar trends to total discards (Figures 9b and 9c).

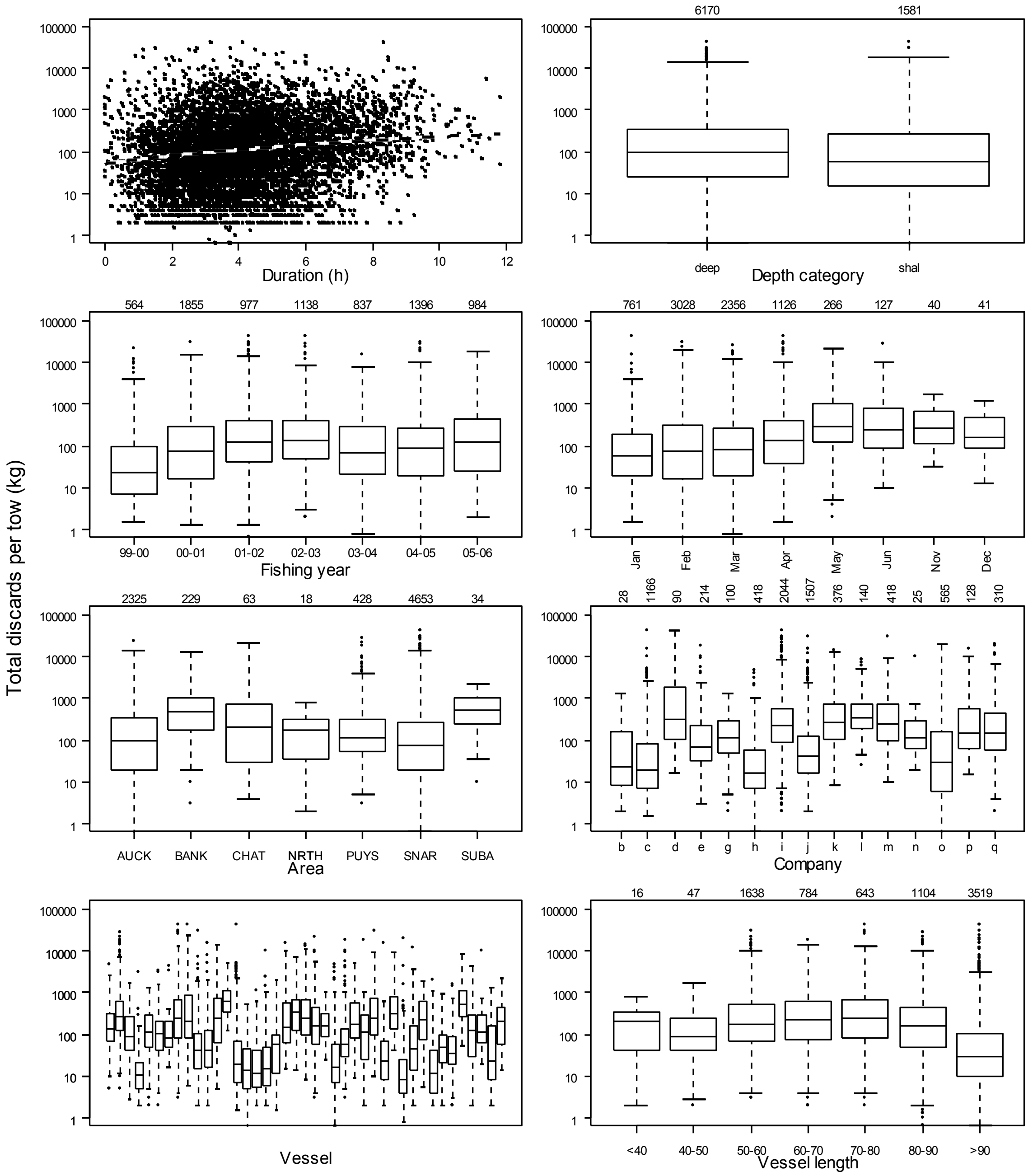

Figure 9a: Total discards per tow for the squid dataset (total discards per processing group divided by the number of tows in the group) plotted against some of the available variables (records with no discards excluded). Discards are plotted on a log scale. The dashed line in the top left panel represents a mean fit (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. Levels of variables represented by fewer than 20 records were not plotted. See Figure 1 for area codes; deep, tows 160 m or deeper; shal, tows shallower than 160 m.

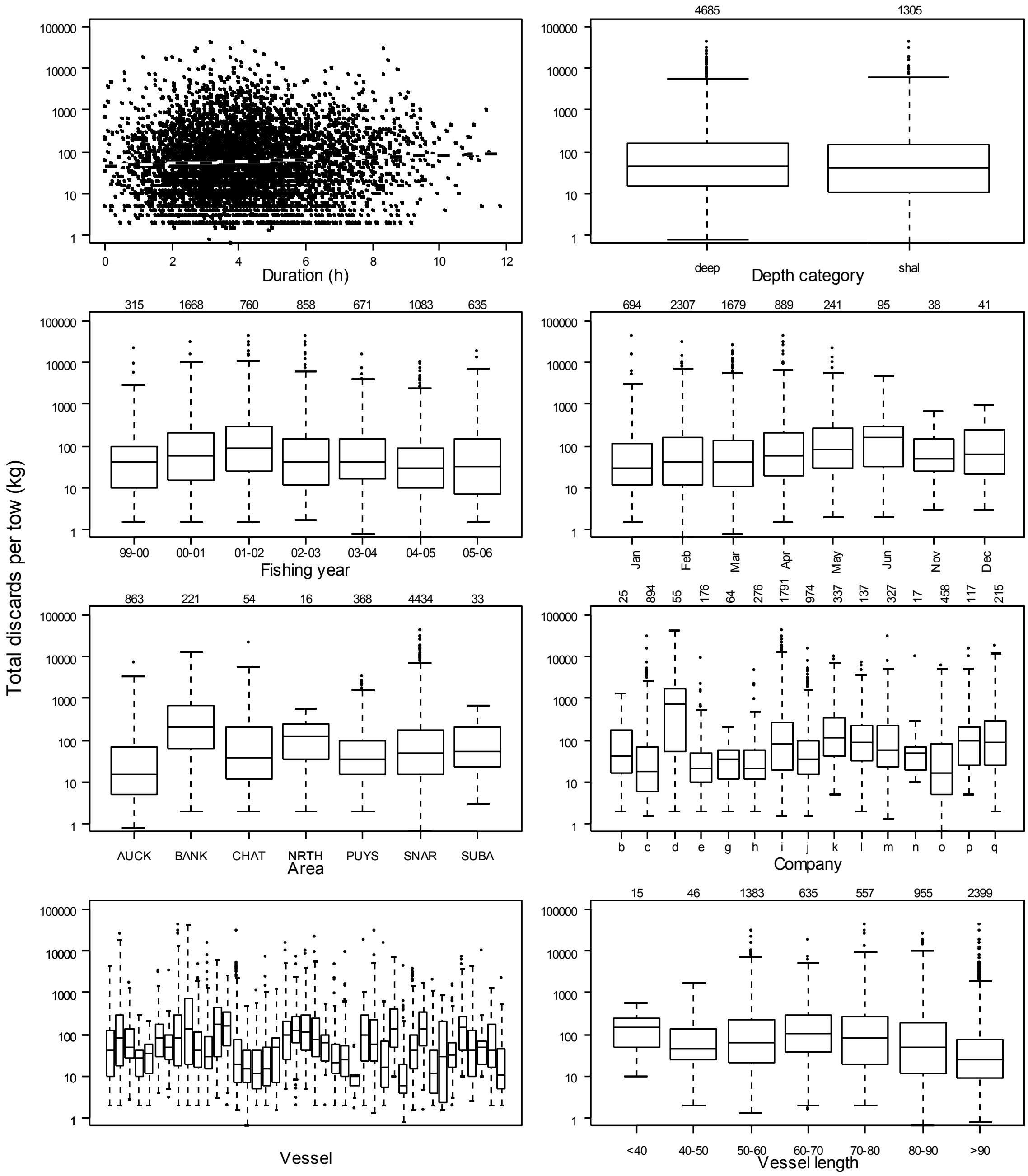

Figure 9b: QMS species discards per tow for the squid dataset (total discards per processing group divided by the number of tows in the group) plotted against some of the available variables (records with no discards excluded). Discards are plotted on a log scale. The dashed line in the top left panel represents a mean fit (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. Levels of variables represented by fewer than 20 records were not plotted. See Figure 1 for area codes; deep, tows 160 m or deeper; shal, tows shallower than 160 m.

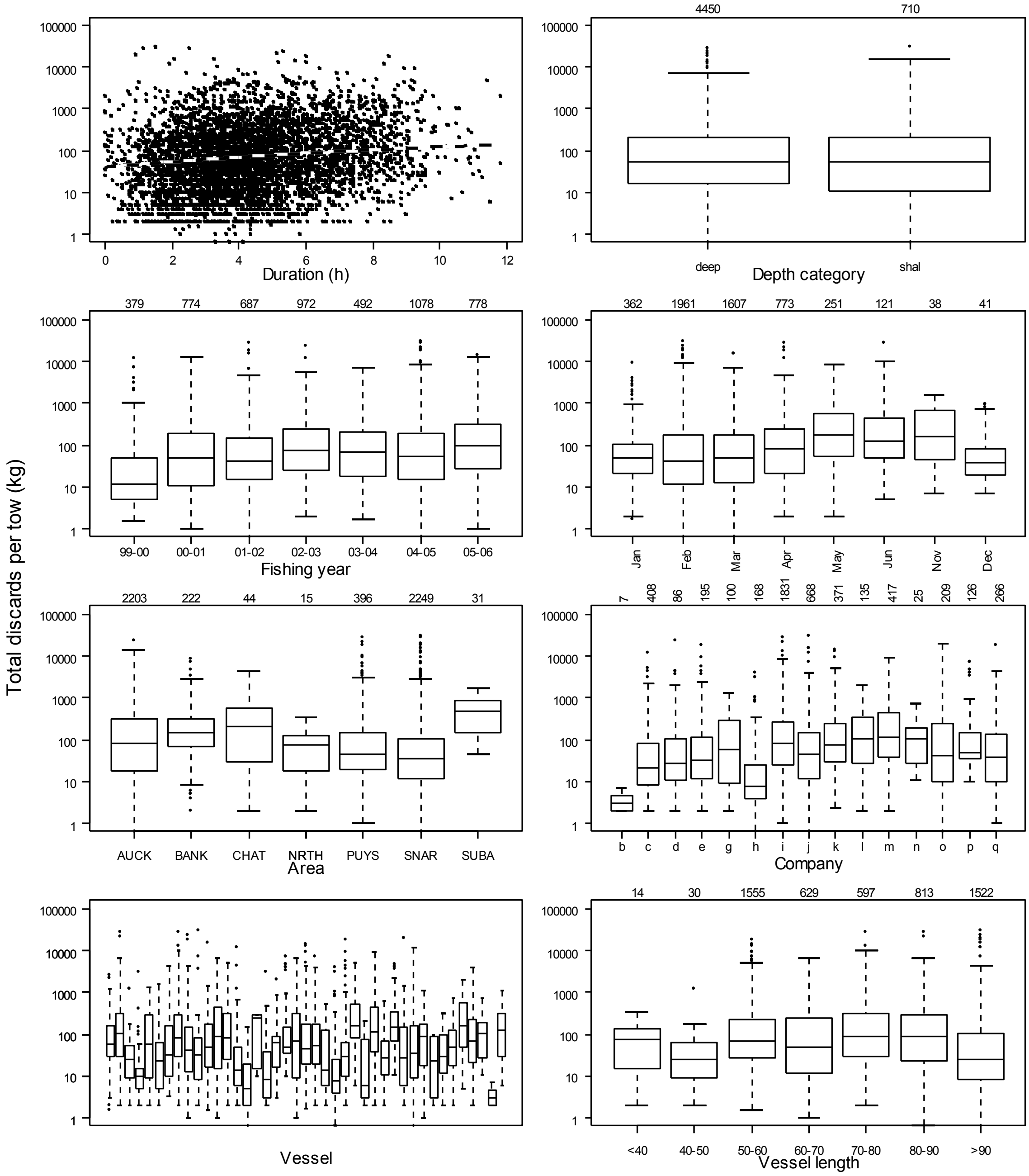

Figure 9c: Non-QMS species discards per tow for the squid dataset (total discards per processing group divided by the number of tows in the group) plotted against some of the available variables (records with no discards excluded). Discards are plotted on a log scale. The dashed line in the top left panel represents a mean fit (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. Levels of variables represented by fewer than 20 records were not plotted. See Figure 1 for area codes; deep, tows 160 m or deeper; shal, tows shallower than 160 m.

3.6.2 Regression modelling and stratification of arrow squid discard data

Discarding of arrow squid occurred in 12% of processing groups observed. Discarding of QMS and non-QMS species occurred in 50–60% of processing groups (Table 9), although most individual species had much lower incidences of discarding. The number of species category month groupings varied from 0 to 3 with similar patterns of discard (Table 9) using regression tree analysis. Month of fishing year was used instead of fishing day as processing groups often ran for two or more days.

Table 9: Results of regression tree analyses on non-zero groups for the optimal stratification of the month of the fishing year variable for describing rates of discards in some species categories in the arrow squid trawl fishery. See Appendix A2 for species codes; all-CRB and all-shark are combined crab or shark codes respectively.

Species category	Percentage of non-zero groups (total 10333)	Month groupings
QMS	59.7	-
non-QMS	51.3	Oct-Apr, May-Sep
SQU	12.3	-
SPD	51.2	Oct-Jan, Feb-Mar, Apr-Sep
RCO	9.1	Oct-May, Jun-Sep
RAT	20.2	Oct-Dec, Jan-Mar, Apr-Sep
SWA	6.7	-
HOK	1.9	-
JAV	3.7	Oct-Feb, Mar-Sep
BAR	3.4	-
SDO	12.4	Oct-Jan, Feb-Sep
RBT	10.8	-
All-shark	89.5	Oct-Dec, Jan-Sep
All-CRB	73.4	Oct-Dec, Jan-Sep

The dependent variable in the regression analyses was the discard ratio, expressed as the log of discards (kg) per hour. Both linear and binomial regressions were run on the discards of some individual species (a total of 259 species observed were discarded). *Area*, *company*, *gear code* (MW or BT), and trawl *duration* were the key factors in these regressions (Table 10). The variable *area* was often the most influential variable. The variable *company* was often influential (in the top three linear variables for all species categories except all-CRB, all-shark, BAR, and HOK categories). The variables *vessel*, *vessel length,* and *vessel tonnage* were generally of lower importance except for BAR. Clearly there are differences in the way that vessels and companies treat discards of non-target species, but these differences are difficult to correlate with characteristics that are recorded by observers or reported by fishers. *Gear code* was often important in the discards, clearly also a proxy for headline height and fishing method.

Trawl *duration* was often important in the discard models, with longer trawls producing more discards per hour than shorter trawls (see Figure 9). Trawl *duration* had the most influence on the discards of the RCO, SWA, and HOK species categories and was important for all other species categories.

The time of year factors, *period*, *season,* and *month* had some influence in most models and a larger influence on the discards of RCO, RAT, HOK, and JAV species categories. The depth variable (*depth category*) was of lower importance in most of the models.

Table 10: Summary of regression modelling for discards in the squid fishery. The numbers denote the order in which the variable entered the model to 1% improvement; –, not selected; *area*, squid areas; *fyear*, fishing year; *Duration* is logged; Variable subscripts—Period variables: sp, species specific period; s, season; m, month of fishing year; Vessel variables: v, vessel; l, vessel length; t, vessel tonnage. See Appendix A2 for species codes; all-CRB and all-shark are combined crab or shark codes respectively.

Species category	Model type	Model R^2 (%)	Variable *area*	*company*	*gear code*	*fyear*	*duration*	*period*	*depth*	*vessel*
QMS	Normal	32.8	1	2	3	4	5	-	-	-
	Binomial	30.4	1	2	-	-	-	-	-	-
non-QMS	Normal	23.3	2	3	1	-	4	-	-	-
	Binomial	44.7	2	1	3	-	-	-	-	-
SQU	Normal	36.7	3	1	-	5	2	6_s	-	4_v
	Binomial	46.7	-	1	-	-	4	5_s	-	2_t, 3_l
RCO	Normal	27.1	5	2	-	-	1	3_m	-	4_t
	Binomial	22.0	4	1	3	2	-	-	-	-
SDO	Normal	25.5	1	3	-	-	2	4_m	-	-
	Binomial	47.0	2	3	1	-	-	-	-	-
all-CRB	Normal	45.9	1	4	2	5	3	6_{sp}	-	-
	Binomial	32.6	2	1	-	-	-	-	-	3_t
SPD	Normal	34.0	2	1	3	5	4	-	6	-
	Binomial	35.5	1	-	2	-	4	-	-	-
RBT	Normal	27.0	-	1	-	4	2	5_s	-	3_t
	Binomial	41.2	2	1	3	-	-	-	-	-
RAT	Normal	30.9	1	3	-	-	4	2_{sp}	-	-
	Binomial	53.0	2	1	3	5	-	4_{sp}	-	-
all-shark	Normal	44.9	4	5	2	1	3	6_{sp}	-	-
	Binomial	19.2	1	2	3	-	-	-	-	-
BAR	Normal	30.6	3	5	-	4	2	6_s	-	1_t
	Binomial	38.0	3	1	-	5	-	-	-	2_t, 4_l
SWA	Normal	31.4	3	2	-	-	1	-	-	4_v
	Binomial	40.8	3	2	1	-	-	-	-	4_t
HOK	Normal	17.7	-	-	3	-	1	2_m	-	-
	Binomial	35.3	4	2	1	5	-	3_m		6_v
JAV	Normal	22.9	5	1	-	-	3	2_m	-	4_l
	Binomial	26.5	-	1	-	-	-	2_m	-	3_t

As for bycatch, stratification by *area* became the obvious option for discards as species *period* was an influential variable in only one discard model and it makes sense to use the same factor to stratify all ratio estimates. Fishing year (*fyear*) was important in a few linear and binomial models, but estimates will, in any case, be made separately for each year. As in the bycatch calculations, separate ratios were calculated only where there were at least 50 tows and at least two vessels were represented in a stratum.

3.7 Observer scampi discard data

3.7.1 Overview of raw scampi discard data

QMS species accounted for 20% of observed discards, the main species being sea perch (13.7%) and spiny dogfish (2.7%). Scampi made up only 0.3% of discards.

Non-QMS species made up nearly 80% of discards and included various crab species (3.5%), rattails (20.7%), and javelinfish (28.6%). Other groups frequently discarded included numerous fish species, echinoderms, squids, crustaceans, and other unidentified invertebrates (see Appendix B2 for details). A total of 485 species were discarded.

Exploratory plots were prepared to examine the variability in the total level of discards per processing group with respect to some of the available factors (Figure 10). The quantity of discards had a slight decreasing trend with increasing trawl duration, and total duration for most processing groups was less than 9 hours. Processing groups with trawls deeper than 450 m had similar discard levels to groups with shallower tows.

The *company* and *vessel* factors showed some variability, with median discard levels of 0.3–0.6 t.tow^{-1} and 0.1–0.7 t.tow^{-1}, respectively. Discard levels were lower on the largest vessels (median 0.1 t.tow^{-1} for vessels over 50 m and 0.4–0.5 t.tow^{-1} for other vessel length classes). "Core" vessels (0.5 t.tow^{-1}) had higher levels of discards than "non-core" vessels (0.2 t.tow^{-1}). The total discards by fishing year increased from 1999–2000 to 2002–03 (0.3–0.6 kg.tow^{-1}), then dropped off slightly in 2003–04 and 2004–05 (0.5 and 0.4 t.tow^{-1}), and again in 2005–06 (0.3 t.tow^{-1}).

Discards varied between areas, with lower levels in PUYS, AUCK and NRTH, and higher levels of discards in CHAT and CHAL. Discards varied by month with a slight increasing trend seen from May to August and a levelling off from August to December. Higher discards were seen in March and April.

Discards showed similar trends for QMS and non-QMS species categories (Figures 10b and 10c), except QMS discards had a larger decreasing trend with increasing trawl duration, the fishing year discard level dropped in 2005–06 for QMS species, and more QMS species were discarded in shallower water.

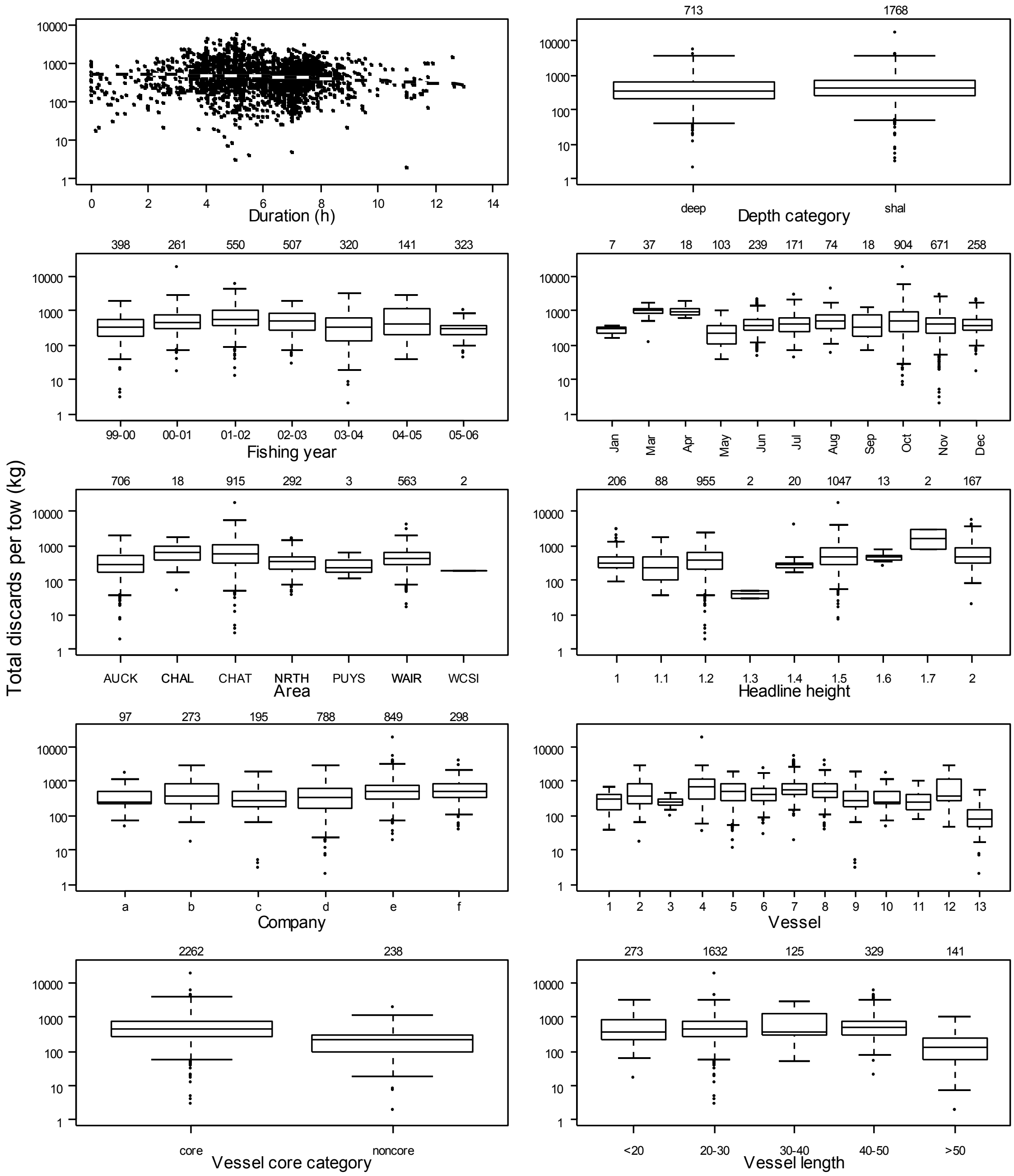

Figure 10a: Total discards per tow for the scampi dataset (total discards per processing group divided by the number of tows in the group) plotted against some of the available variables (records with no discards excluded). Discards are plotted on a log scale. The dashed line in the top left panel represents a mean fit (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. Levels of variables represented by fewer than 20 records were not plotted. See Figure 2 for area codes; deep, tows 450 m or deeper; shal, tows shallower than 450 m.

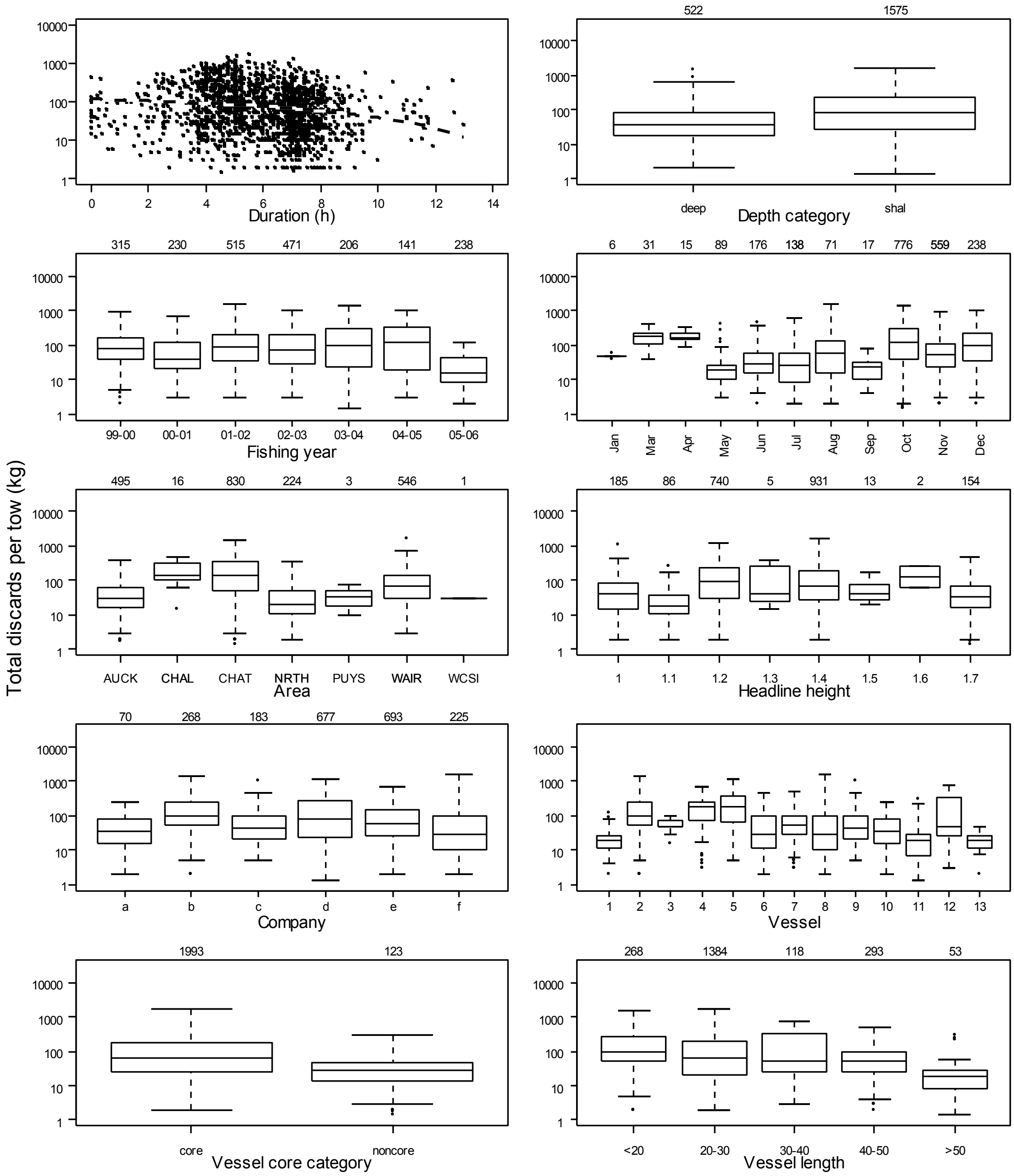

Figure 10b: QMS species discards per tow for the scampi dataset (total discards per processing group divided by the number of tows in the group) plotted against some of the available variables (records with no discards excluded). Discards are plotted on a log scale. The dashed line in the top left panel represents a mean fit (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. Levels of variables represented by fewer than 20 records were not plotted. See Figure 2 for area codes; deep, tows 450 m or deeper; shal, tows shallower than 450 m.

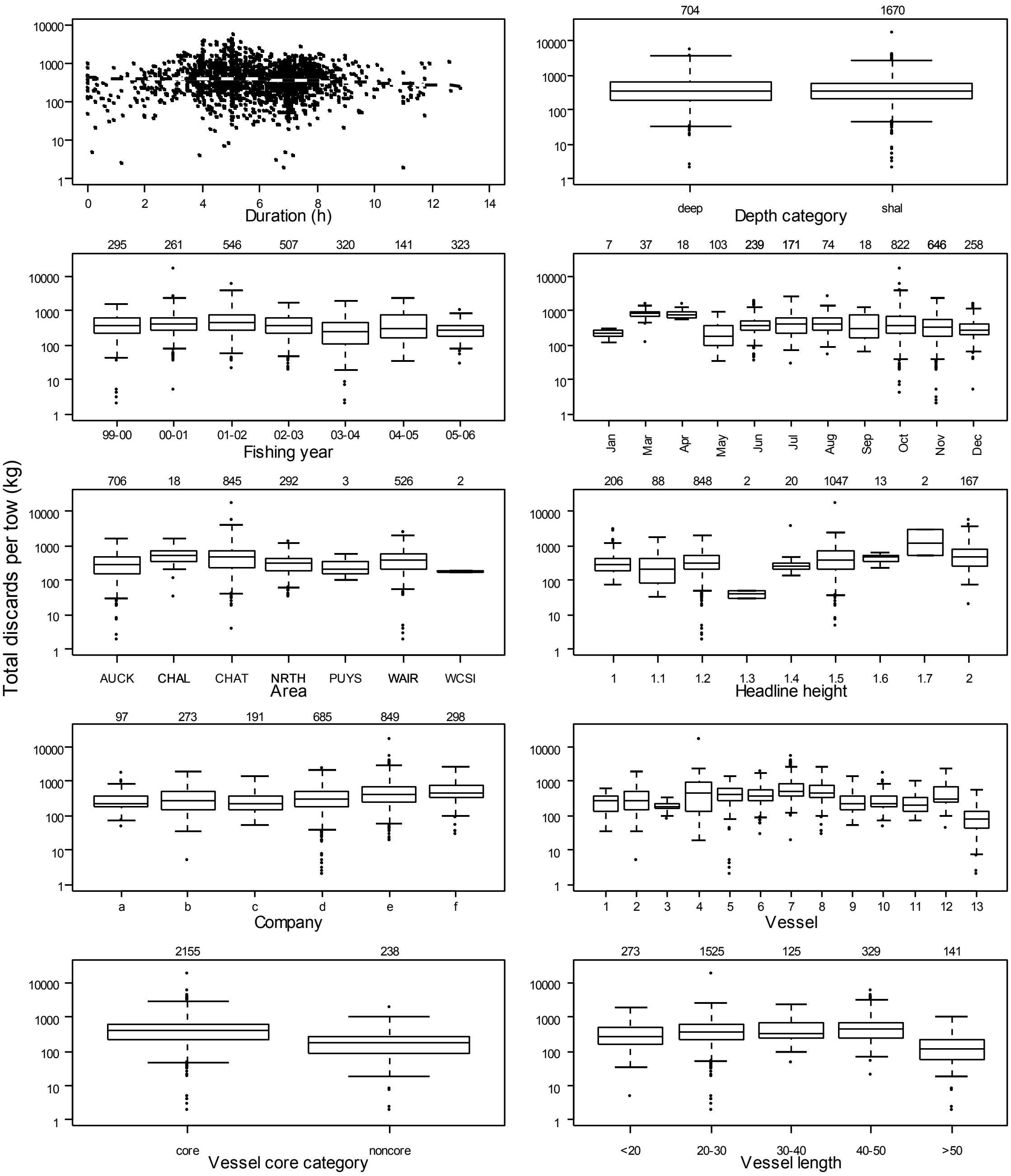

Figure 10c: Non-QMS species discards per tow for the scampi dataset (total discards per processing group divided by the number of tows in the group) plotted against some of the available variables (records with no discards excluded). Discards are plotted on a log scale. The dashed line in the top left panel represents a mean fit (using a locally weighted regression smoother) to the data. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5x the interquartile range, and outliers individually plotted beyond the whiskers. Levels of variables represented by fewer than 20 records were not plotted. See Figure 2 for area codes; deep, tows 450 m or deeper; shal, tows shallower than 450 m.

3.7.2 Regression modelling and stratification of scampi discard data

Discarding of scampi occurred in 19% of processing groups observed. Discarding of QMS and non-QMS species occurred in most processing groups (Table 11), although some species had lower incidences of discarding, e.g., LIN, HOK, and RCO. Regression tree analysis, using the log of the discard ratio as the dependent variable, showed that species category month groupings varied from one to four with similar patterns of discard (Table 11). Month of fishing year was used instead of fishing day as processing groups often ran for two or more days.

Table 11: Results of regression tree analyses on non-zero groups for the optimal stratification of the month of fishing year variable for describing rates of discards in some species categories in the scampi trawl fishery. See Appendix B2 for species codes; all-CRB are combined crab codes.

Species category	Percentage of non-zero groups (total 2542)	Month groupings
QMS	84.5	Oct; Nov; Dec-Apr; May-Jul; Aug-Sep
non-QMS	94.3	Oct; Nov-Jan; Feb-Apr; May; Jun-Sep
SPE	44.7	Oct; Nov-Feb; Mar-May; Jun-Sep
SPD	37.0	Oct; Nov-Jan; Feb-Apr; May-Sep
JAV	86.9	Oct; Nov-Jan; Feb-Apr; May; Jun-Jul; Aug-Sep
RAT	83.7	Oct; Nov-Apr; May; Jun-Sep
SKA	32.9	Oct-Sep
all-CRB	56.5	Oct; Nov-Jan; Feb-Apr; May-Sep
TOA	36.1	Oct-Nov; Dec-Jan; Feb-Apr; May-Sep
SFI	47.1	Oct-Jan; Feb-Apr; May-Sep
FHD	51.7	Oct; Nov-Feb; Mar-May; Jun-Sep
HOK	17.1	Oct-Sep
LIN	8.0	Oct-Sep
RCO	13.6	Oct-Nov; Dec-Sep

The dependent variable in the regression analyses was the discard ratio, expressed as the log of discards (kg) per hour. Both linear and binomial regressions were run for a small range of species categories discarded (485 species observed were discarded). *Area*, *company*, *trawl duration,* and *species specific period* were the key factors in these regressions (Table 12) but, as for bycatch, initial models including *trip* as a factor found this variable to be a key factor in some model runs.

Area was often the most influential variable except for SPD. *Trawl duration* also was often important in the discards, with longer trawls producing fewer discards per hour than shorter trawls (see Figure 10). *Trawl duration* had the most influence on the discards of the QMS, non-QMS, SPD, SFI, HOK, RAT, and SKA species categories. The time of year factors (*period*, *season,* and *fishing month*) had varying influence in most models and a larger influence on the discards of SPE, SPD, RAT, CRB, FHD, and RCO species categories.

The variable *company* entered most regressions and was often relatively important in the models (in the top three linear variables for QMS, SPE, SPD, JAV, SKA, SFI, FHD, HOK, LIN, and RCO categories), and the variables *vessel, vessel length,* and *vessel tonnage* were of lower importance except to explain the presence or absence of several species categories as discard species. The variable *core vessel* was not important in most models, but did help to explain presence or absence of QMS species and crabs in the discards from a group. Clearly there are differences in the way that vessels and companies treat the catch of non-target species, but these differences are difficult to correlate with characteristics that are recorded by observers or reported by fishers.

Table 12: Summary of regression modelling for discards in the scampi fishery. The numbers denote the order in which the variable entered the model to 1% improvement; –, not selected; *area*, scampi areas; *fyear*, fishing year, *Duration* and *depth* are logged; Variable subscripts—Period variables: sp, species specific period; s, season; m, month of fishing year; Vessel variables: v, vessel; l, vessel length; t, vessel tonnage. See Appendix B2 for species codes; all-CRB are combined crab codes.

Species	Model	Model									Variable
		R^2 (%)						*core*			*headline*
category	type		*area*	*duration*	*company*	*period*	*fyear*	*vessel*	*vessel*	*depth*	*height*
QMS	Normal	49.5	1	2	3	5_{sp}, 6_{s}	4	-	-	-	-
	Binomial	30.1	1	-	2	5_{s}	-	3	6_{l}	-	4
non-QMS	Normal	41.7	2	1	6	5_{sp}	-	4	-	7	3
	Binomial	62.7	3	-	2	6_{sp}, 8_{m}	1	4	7_{l}	-	5
SPE	Normal	59.8	1	4	2	5_{m}, 3_{sp}	8	-	-	6	7
	Binomial	64.8	1	-	2	3_{sp}	-	-	4	5	-
SPD	Normal	56.7	5	3	2	1_{sp}, 6_{m}	7	-	4_{l}	-	-
	Binomial	20.3	1	-	2	3_{sp}	-	-	4_{l}	-	-
JAV	Normal	47.9	1	4	3	6_{sp}	2	-	5_{t}	7	-
	Binomial	61.5	6	-	3	5_{sp}	2	5	1_{t}	-	4
RAT	Normal	42.1	2	1	4	3_{sp}	5	-	6_{t}	7	-
	Binomial	50.3	-	-	3	5_{sp}	2	4	1_{t}	-	-
SKA	Normal	28.4	3	1	2	-	-	-	-	-	4
	Binomial	22.0	-	-	2	-	1	-	4_{v}	-	3
all-CRB	Normal	37.8	1	5	4	3_{sp}	-	-	-	6	2
	Binomial	15.8	-	-	1	4_{sp}, 5_{m}	-	3	2_{l}	-	-
TOA	Normal	52.4	1	4	5	8_{sp}	2	3	-	6	7
	Binomial	24.5	1	-	4	2_{sp}, 5_{s}	3	-	-	-	-
SFI	Normal	48.6	8	3	1	4_{sp}	7	5	6_{t}	-	2
	Binomial	23.5	2	-	1	3_{m}, 4_{sp}	-	6	5_{l}	-	-
FHD	Normal	54.7	1	4	3	2_{sp}	-	-	6_{t}	5	-
	Binomial	43.0	1	-	2	5_{sp}, 6_{m}	4	-	3_{l}	-	-
HOK	Normal	33.5	2	3	1	-	-	-	-	-	-
	Binomial	44.0	2	6	1	-	7	5	4_{v}	-	3
LIN	Normal	55.2	2	-	1	-	5	-	4_{t}	3	6
	Binomial	42.9	4	-	1	3_{m}	2	-	-	5	-
RCO	Normal	39.0	-	-	3	2_{sp}, 4_{m}	-	-	6_{v}	1	5
	Binomial	14.3	2	4	1	-	-	-	-	-	3

The variable *headline height* had an influence in most models, especially non-QMS, CRB, and SFI. The depth variable (*depth category*) was of lower importance in most of the models, although, had larger influence on LIN and RCO species categories.

As for bycatch, stratification by area became the obvious option for discards. Although species *period* was sometimes influential overall, in some discard models there was not enough data to split the data into further strata using this variable. Fishing year (*fyear*) was important in a few linear and binomial models, but estimates will, in any case, be made separately for each year. As in the bycatch calculations, separate ratios were calculated only where there were at least 50 tows and at least two vessels represented in a stratum.

3.8 Calculation of arrow squid bycatch

3.8.1 Arrow squid bycatch rates

Bycatch ratios for some species categories were calculated from the observer data separately for each area and each fishing year. The variance in these bycatch rates was calculated using the bootstrap methods described in Section 2.5. These ratios provide the basis from which total bycatch can be determined from target fishery effort totals, and also a guide to the rate at which bycatch species were caught in each of the areas used for stratification, and how this may have changed over time.

Annual median bycatch rates of QMS species in the four areas ranged from 21 to 1137 kg.h^{-1} (Figure 11, Appendix A5), with SNAR and BANK having the higher bycatch rates in most years. PUYS also had higher bycatch rates in 2001–02 and 2004–05. High bycatch rates of barracouta, jack mackerel, silver warehou, and spiny dogfish were seen in the SNAR and BANK areas; common warehou and redbait were also seen in the SNAR area; red cod, hoki, and ling in BANK area; and spiny dogfish, redbait, hoki, and ling in the PUYS area in some years. Low catch rates were seen for all species categories in the AUCK area. Annual bycatch rates of non-QMS species ranged from 27 to 437 kg.h^{-1} and were also the greatest in the PUYS area especially in 2004–05 (Figure 11, Appendix A5).

3.8.2 Annual arrow squid bycatch levels

Annual bycatch was determined by multiplying the ratios calculated for each stratum by the target fishery tow duration totals for the equivalent stratum, and precision of the estimates was determined from the variability in the bootstrap samples of 1000 ratios (Table 13, Figures 12 & 13).

Bycatch of QMS species was lower in 1999–2000, and 2002–03 to 2004–05 at 14 810–17 940 t, with higher bycatch levels in 2000–01 and 2005–06 and highest bycatch levels in 2001–02 of 24 190 t. The 95% confidence intervals around the QMS bycatch overlap between all years (Figure 12) and show a similar range for each year, although years with higher annual bycatch levels have wider ranges suggesting that these figures were influenced by a few large values.

Bycatch of commercial and non-commercial species in the squid fishery from 1998–99 to 2000–01 was estimated by Anderson (2004). There is an overlap of two years for 1999–2000 and 2000–01 between the Anderson (2004) and current analysis, and bycatch estimates differ. The estimates between the two studies should not be compared directly for several reasons. Anderson (2004) used different areas and the “COM” species category comprised 10 species rather than all QMS species. Spiny dogfish are also included in the QMS species, whereas they would have been incorporated in the “other” category by Anderson (2004). For both studies the ratio estimator was based on effort, although the precision was calculated differently. The Anderson (2004) estimates also are based on simpler strata definitions, e.g., area for “COM” and “OTH”. The Anderson (2004) confidence intervals are narrower (Figure 12 and 13) and the overlapping years show different annual bycatch estimates for species categories. These differences are greatest for the QMS and non-QMS categories, and least for the estimates of total bycatch and for the species examined individually in both studies (JMA and SWA) which are quite similar, especially for 2000–01.

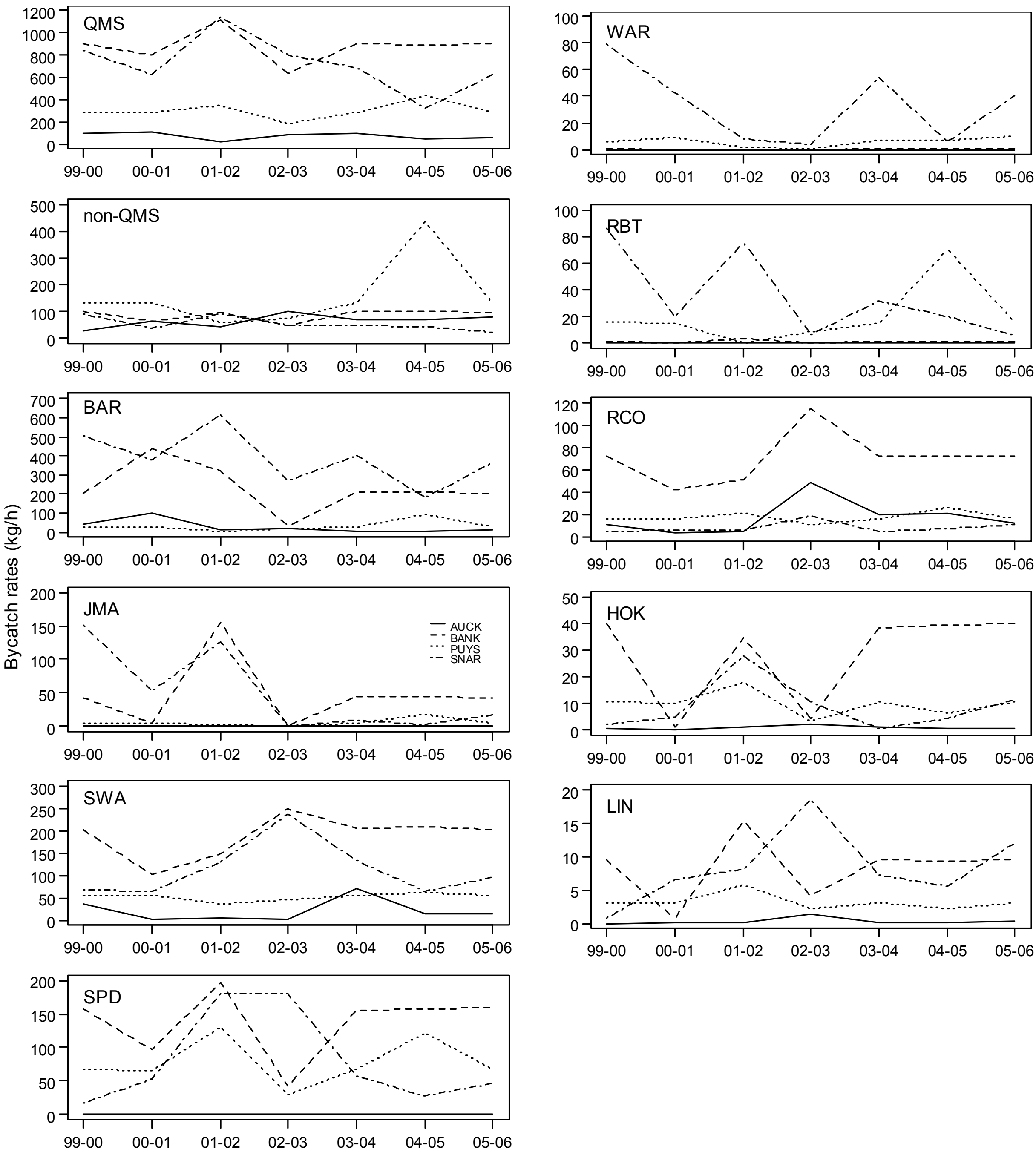

Figure 11: Annual bycatch rates by the areas used for stratification for selected species categories in the squid trawl fishery. Bycatch rates shown are the median of the bootstrap sample of 1000.

Overall total bycatch increased between 1999–2000 and 2000–01, decreased to 2003–04, and then increased to 2005–06 (see Figure 12), and appears to have been highest in 2001–02 because of increased levels of both QMS and non-QMS species bycatch.

The estimates of individual QMS species bycatch show the annual bycatch of most species were all at their highest level in 2001–02 (Table 13), although the estimates for this year had wider confidence intervals (Figure 13). Barracouta was one of the main bycatch species in all years (4250–10 670 $t.y^{-1}$), followed by silver warehou (2250–5450 $t.y^{-1}$) and spiny dogfish (1550–4120 $t.y^{-1}$). Bycatch of non-QMS species was large each year, 1740–3450 t, with the lowest value in 1999–2000. Non-QMS species bycatch was much lower than QMS species bycatch in all years.

Table 13: Estimates of bycatch (rounded to the nearest 10 t) in the target squid trawl fishery by fishing year and species categories, with 95% confidence intervals in parentheses. See Appendix A2 for species codes.

					Species category	
	QMS		Non-QMS)		TOT	
1999–00	14810	(10340-20660)	1740	(970-2760)	16550	(11310-23420)
2000–01	20270	(13780-28010)	2090	(1230-3060)	22360	(15010-31070)
2001–02	24190	(17140-31650)	2540	(1130-4460)	26730	(18270-36110)
2002–03	17940	(12120-24790)	2240	(1380-3170)	20180	(13500-27960)
2003–04	16720	(11220-24490)	2420	(1070-4340)	19140	(12290-28830)
2004–05	15830	(11310-21270)	3450	(1910-5640)	19280	(13220-26910)
2005–06	20710	(14160-28450)	2590	(1460-4020)	23300	(15620-32470)

					Species category	
	BAR		SWA		SPD	
1999–00	5870	(3700-8280)	2250	(1130-3720)	1550	(590-3010)
2000–01	10330	(6240-15860)	2320	(1530-3470)	2280	(1070-3830)
2001–02	10670	(5030-16850)	2950	(1380-5200)	4120	(1890-7180)
2002–03	4250	(1540-7900)	5450	(1990-10100)	3070	(1390-5120)
2003–04	7720	(4080-12980)	3910	(2430-5730)	1610	(900-2590)
2004–05	6510	(3460-10150)	3350	(1130-6610)	1920	(1000-3160)
2005–06	9950	(5270-15360)	3650	(1870-6060)	2000	(1040-3290)

					Species category	
	WAR		RBT		RCO	
1999–00	720	(270-1580)	730	(280-1430)	960	(510-1660)
2000–01	640	(290-1080)	320	(120-660)	1060	(500-1950)
2001–02	150	(40-300)	1160	(280-2490)	630	(360-1000)
2002–03	100	(0-230)	140	(60-270)	1660	(970-2820)
2003–04	1040	(270-2160)	610	(140-1350)	720	(340-1250)
2004–05	190	(30-400)	730	(130-1920)	1070	(520-1880)
2005–06	1170	(90-3070)	150	(30-360)	890	(430-1550)

					Species category	
	LIN		HOK		JMA	
1999–00	100	(30-180)	360	(80-900)	1670	(660-3100)
2000–01	230	(90-440)	280	(30-320)	820	(430-1500)
2001–02	270	(120-480)	750	(230-1480)	2780	(1090-4740)
2002–03	380	(140-670)	310	(70-490)	50	(0-130)
2003–04	210	(60-540)	190	(40-330)	300	(80-610)
2004–05	230	(90-440)	450	(70-980)	430	(50-1110)
2005–06	370	(170-620)	550	(90-1270)	700	(160-1430)

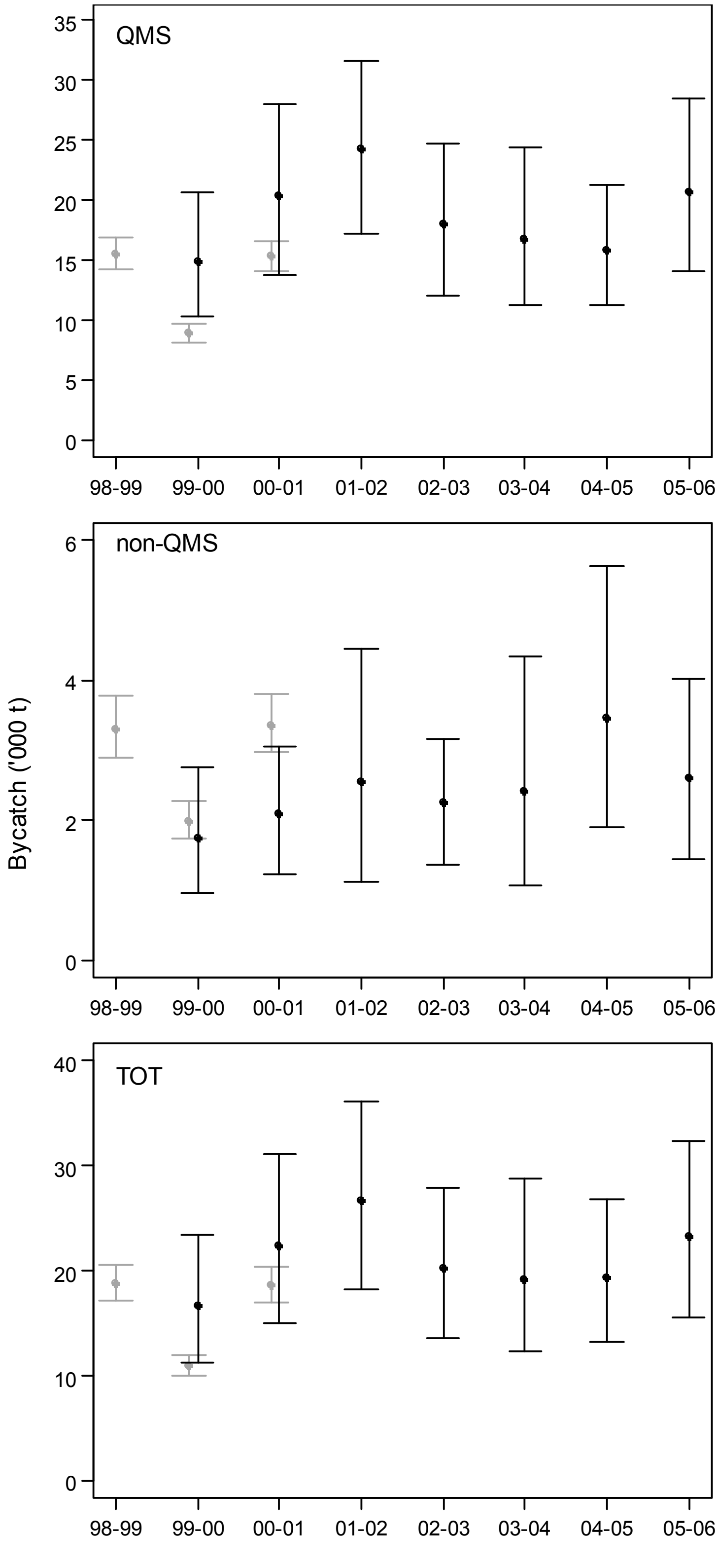

Figure 12: Annual estimates of fish bycatch in the target squid trawl fishery, calculated for commercial species (QMS), non-commercial species (non-QMS), and overall (TOT) 1999–2000 to 2005–06 for all target squid trips (black). Also shown (in grey) are the COM, OTH and TOT bycatch estimates calculated for 1998–99 to 2000–01 by Anderson (2004). Error bars show the 95% confidence intervals.

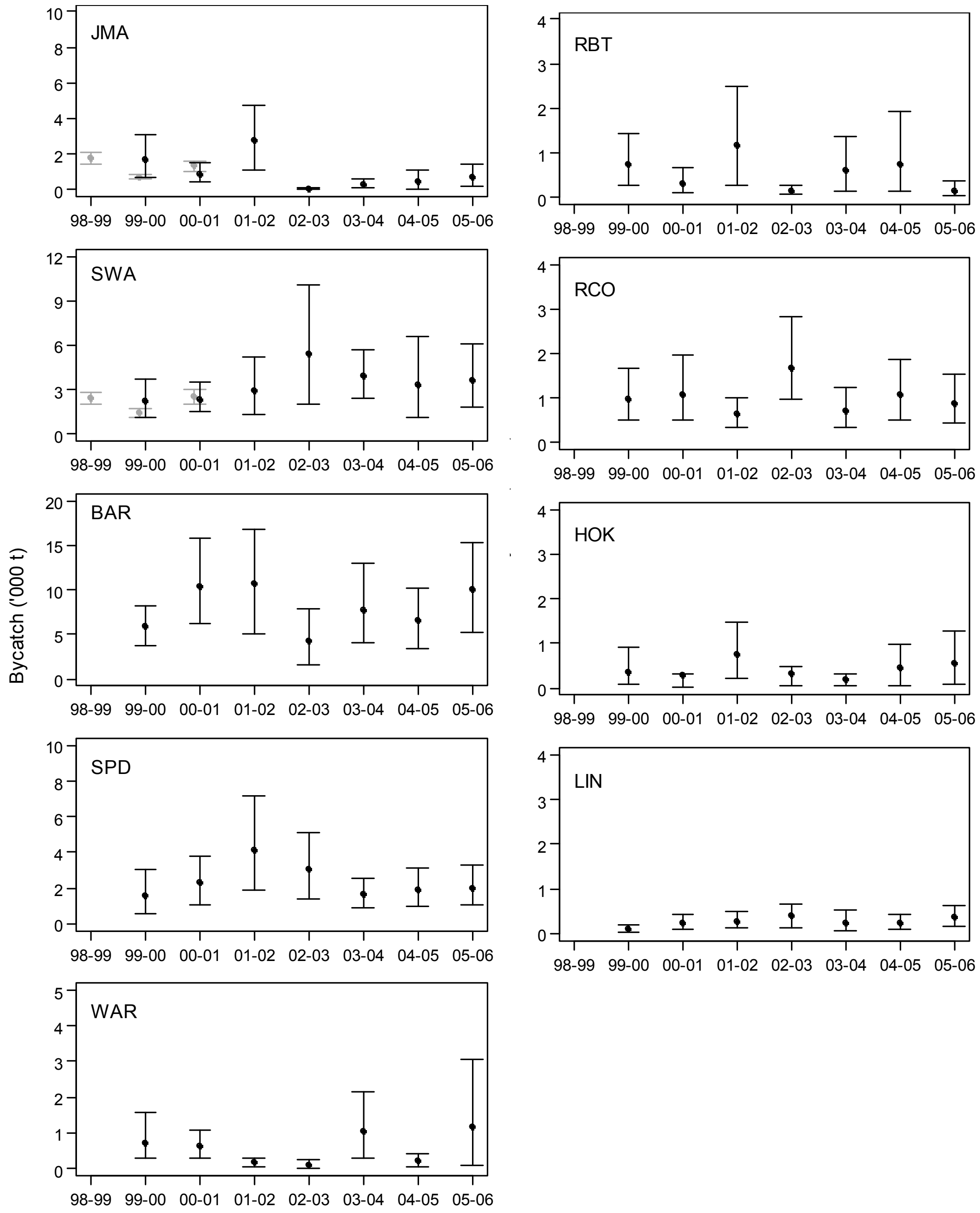

Figure 13: Annual estimates of fish bycatch in the target squid trawl fishery, calculated for selected species categories for 1999–2000 to 2005–06 (in black). Also shown (in grey) are the bycatch estimates for 1998–99 to 2000–01 by Anderson (2004). Error bars show the 95% confidence intervals.

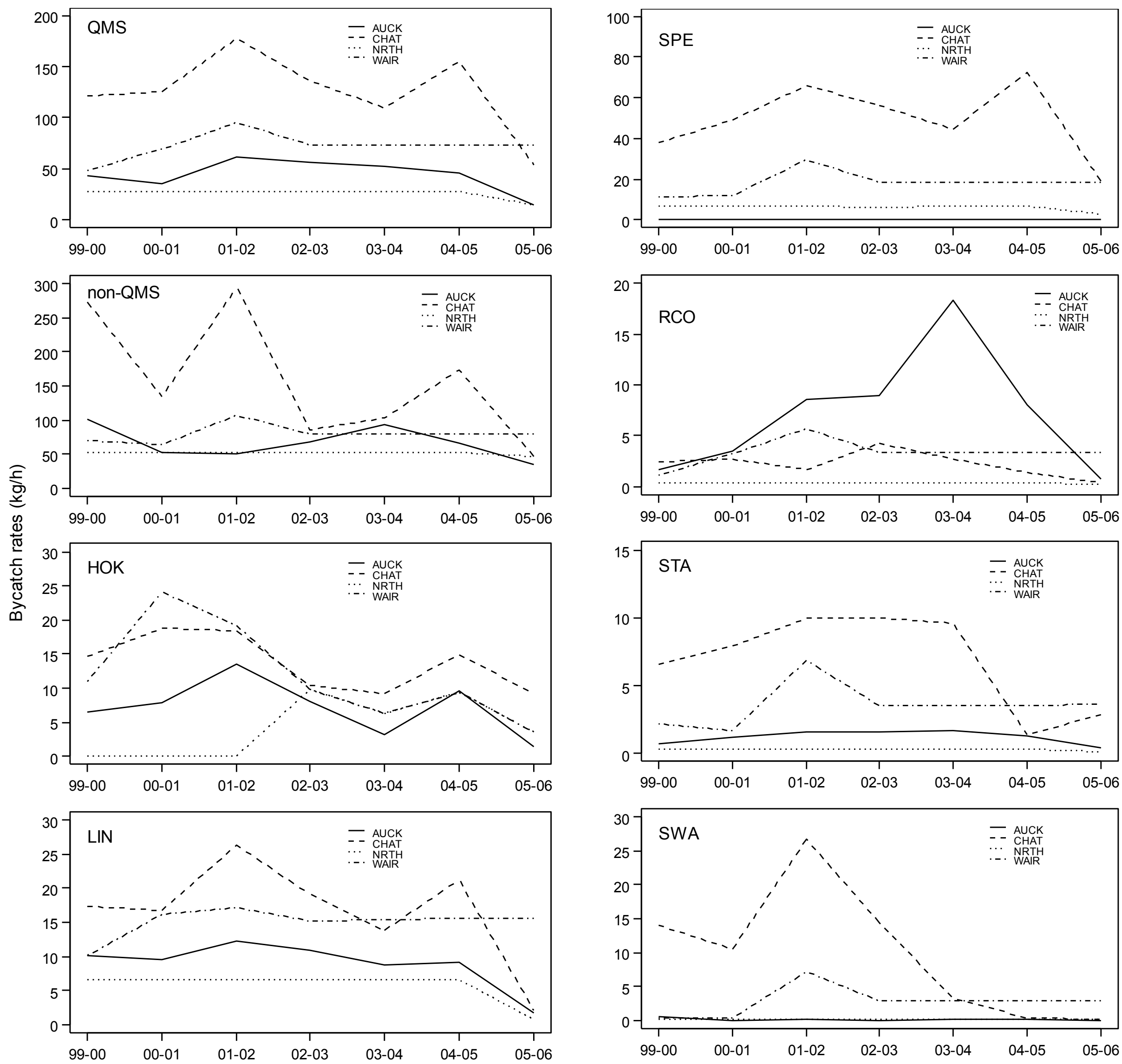

Figure 14: Annual bycatch rates by the areas used for stratification for eight species categories, in the scampi trawl fishery. Bycatch rates shown are the median of the bootstrap sample of 1000.

3.9 Calculation of scampi bycatch

3.9.1 Scampi bycatch rates

Bycatch ratios for various species categories were calculated from the observer data separately for each area and each of the seven fishing years. The variance in these bycatch rates was calculated using the bootstrap methods described in Section 2.5. These ratios provide the basis for calculating total bycatch from target fishery effort and a guide to the rate at which bycatch species were caught in each of the areas used for stratification, and how this may have changed over time.

Annual median bycatch rates of QMS species in the four areas ranged from 14 to 173 $kg.h^{-1}$ (Figure 14, Appendix B5), with CHAT having the highest bycatch rates in all years except 2005–06. High bycatch rates of sea perch, hoki, ling, and giant stargazer were seen in the CHAT area; hoki and ling in WAIR; red cod in AUCK; and silver warehou in the species-area AUCK and NRTH. Annual bycatch rates of non-QMS species were 35–273 kg.h^{-1} and were also greatest in the CHAT area (Figure 14, Appendix B5).

3.9.2 Annual scampi bycatch levels

Bycatch of QMS species (Table 14, Figures 15) was lower in 1999–2000, 2000–01, 2003–04, and 2005–06 ranging from 1290 to 1850 t, but higher in 2000–01, 2002–03, and 2004–05 to 3630 t. The 95% confidence intervals around the QMS bycatch overlap between most years (Figure 15) but were wider for years when bycatch was higher, suggesting variability in bycatch.

The bycatch estimates for core vessels (Figure 15) are almost identical to those for the whole dataset because the datasets are almost the same except for 2002–03 and 2003–04 when there were fewer tows for the core vessels (*see* Table 3a).

Bycatch of QMS and non-QMS species in the scampi fishery in 1990–91 to 2000–01 was estimated by Anderson (2004). There is an overlap of two years for 1999–00 and 2000–01 between the Anderson (2004) and current analysis, and bycatch estimates are not the same. The estimates should not be compared directly for several reasons. In Anderson (2004) there were area differences and the "COM" species category comprised 16 species rather than all QMS species. For both studies the ratio estimator was based on effort, although the precision was calculated differently. The Anderson (2004) estimates also are based on simpler strata definitions. The Anderson (2004) values confidence intervals are narrower (Figures 15 and 16) and the overlapping years show different annual bycatch estimates for species categories. These differences are greater for the QMS category, partly due to differences in the species composition between studies, and less for the estimates of non-QMS and total bycatch (at least for 1999–2000). Differences between studies for the individual species were more variable, with very similar results for HOK, RCO, and SPE, and larger differences for LIN and STA.

Further comparison with Anderson's (2004) results were made by re-estimating bycatch for QMS, non-QMS, and total bycatch categories for 1999–2000 to 2005–06, using the same area strata definitions (see Figure 15). Anderson's (2004) estimates were different from those calculated in this study, although all are within the 95% confidence intervals, except 2005–06 which is well above the bycatch estimates. This indicates that the selection and definition of strata can have a considerable influence on estimates of bycatch. It is almost certain that the confidence intervals around the estimates of Anderson (2004) were underestimated, and if they were to be recalculated with the methods used in this study there would likely have been more overlap between the repeated estimates.

Overall, although total bycatch may have declined slightly from the levels of the 1990s (see Figure 15), it has been highly variable during the recent period, being greater than in any other year in 2001–02 (with increased levels of both QMS and non-QMS species bycatch) and lower than in any other year in 2005–06.

The estimates of individual QMS species bycatch show the annual bycatch of most species were all at their highest level in 2001–02 (Table 14), although the estimates for this year were less precise with wider confidence intervals (Figure 16). Sea perch was the main bycatch species in all years (330–940 t.y^{-1}), followed by ling (120–660 t.y^{-1}) and hoki (130–640 t.y^{-1}). Bycatch of other species was variable and usually less than 300 t.y^{-1}. Bycatch of non-QMS species was large each year, ranging from 1620 t to 4440 t and was lowest in 2005–06. Non-QMS species bycatch was much greater than QMS species bycatch in all years.

Table 14: Estimates of bycatch (rounded to the nearest 10 t) in the target scampi trawl fishery by fishing year and species categories, with 95% confidence intervals in parentheses.

	Species category					
	QMS		Non-QMS)		TOT	
1999–00	1640	(1280-2030)	3290	(2750-3850)	4930	(4030-5880)
2000–01	1850	(1510-2160)	2150	(1750-2520)	4000	(3260-4680)
2001–02	3630	(2660-4670)	4440	(2200-6330)	8070	(4860-11000)
2002–03	2400	(1670-3230)	2480	(1650-3350)	4880	(3320-6580)
2003–04	1480	(1120-1830)	2010	(1440-2650)	3490	(2560-4480)
2004–05	2500	(1470-3400)	3060	(1740-4340)	5560	(3210-7740)
2005–06	1290	(1130-1520)	1620	(1340-1930)	2910	(2470-3450)

	Species category							
	HOK		LIN		SPE		SWA	
1999–00	250	(150-360)	320	(220-420)	330	(230-430)	80	(60-100)
2000–01	430	(380-500)	380	(290-480)	380	(220-540)	40	(20-80)
2001–02	640	(350-1020)	660	(390-920)	940	(690-1210)	270	(70-440)
2002–03	330	(250-390)	440	(320-560)	590	(380-830)	120	(40-230)
2003–04	130	(80-180)	270	(160-330)	320	(200-440)	30	(10-60)
2004–05	330	(160-530)	410	(160-640)	870	(400-1280)	10	(0-40)
2005–06	170	(130-250)	120	(90-150)	370	(300-440)	10	(0-50)

	Species category							
	RCO		STA		SQU		GSH	
1999–00	40	(20-50)	60	(30-90)	10	(10-20)	50	(30-80)
2000–01	80	(50-160)	60	(40-80)	40	(30-40)	80	(60-110)
2001–02	230	(110-370)	210	(50-380)	50	(40-90)	110	(30-230)
2002–03	150	(90-220)	120	(70-180)	20	(10-30)	90	(30-160)
2003–04	200	(150-250)	70	(40-120)	10	(10-10)	70	(50-100)
2004–05	100	(60-150)	40	(30-70)	30	(20-40)	200	(140-280)
2005–06	30	(10-50)	60	(40-100)	30	(20-60)	140	(110-180)

	Species category			
	HAK		BNS	
1999–00	40	(30-50)	10	(10-20)
2000–01	30	(20-40)	30	(10-40)
2001–02	100	(60-150)	60	(10-110)
2002–03	50	(30-60)	20	(10-30)
2003–04	50	(30-50)	10	(10-20)
2004–05	50	(20-80)	10	(10-20)
2005–06	0	(0-0)	10	(10-10)

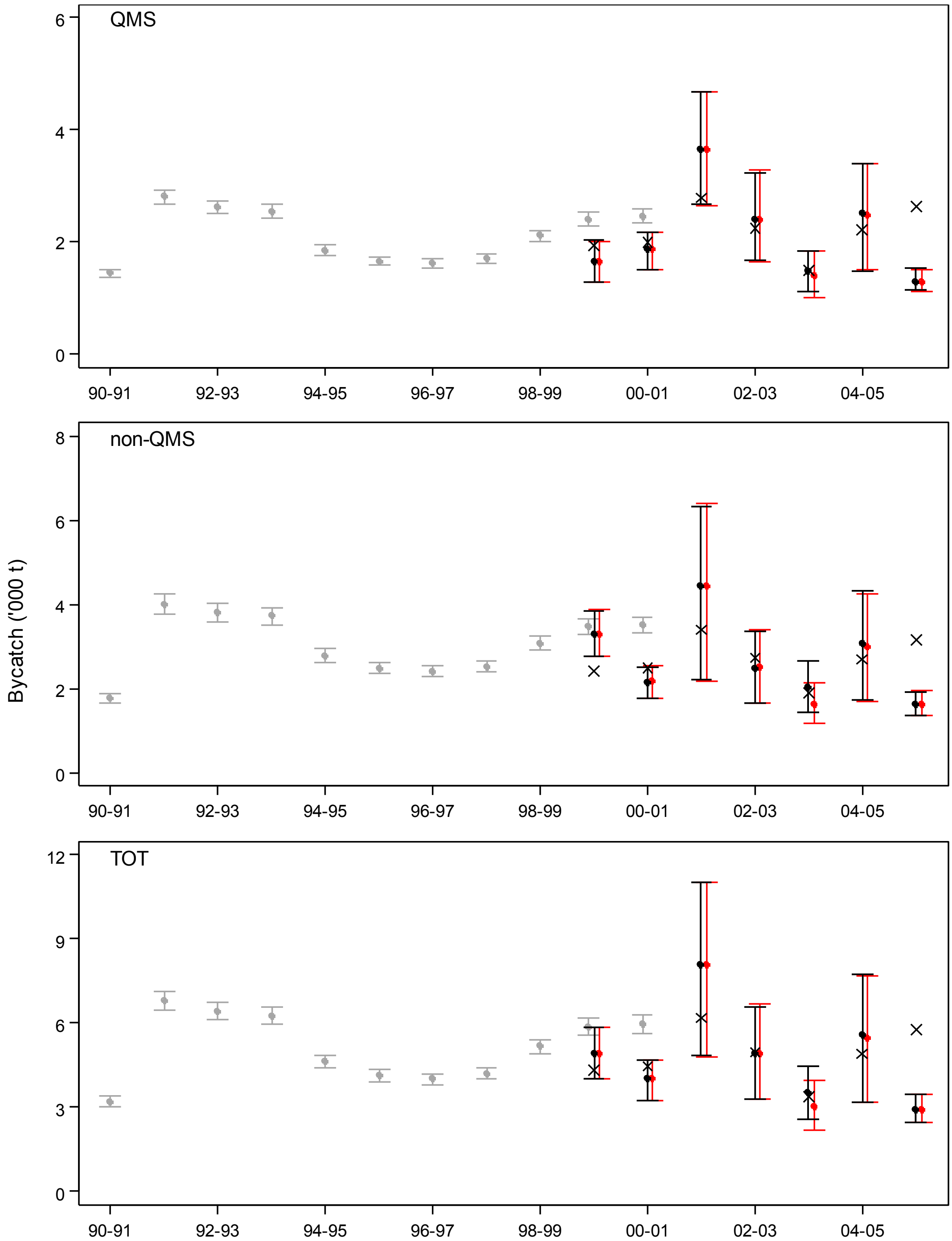

**Figure 15: Annual estimates of fish bycatch in the target scampi trawl fishery, calculated for commercial species (QMS), non-commercial species (non-QMS), and overall (TOT) for 1999–2000 to 2005–06 for all target scampi trips (black) and scampi core vessels (grey). Point estimates (x) for QMS, non-QMS and overall are also calculated using strata as in Anderson (2004). Also shown (in light grey) are the COM, OTH, and TOT bycatch estimates calculated for 1990–91 to 2000–01 by Anderson (2004). Error bars show the
95% confidence intervals.**

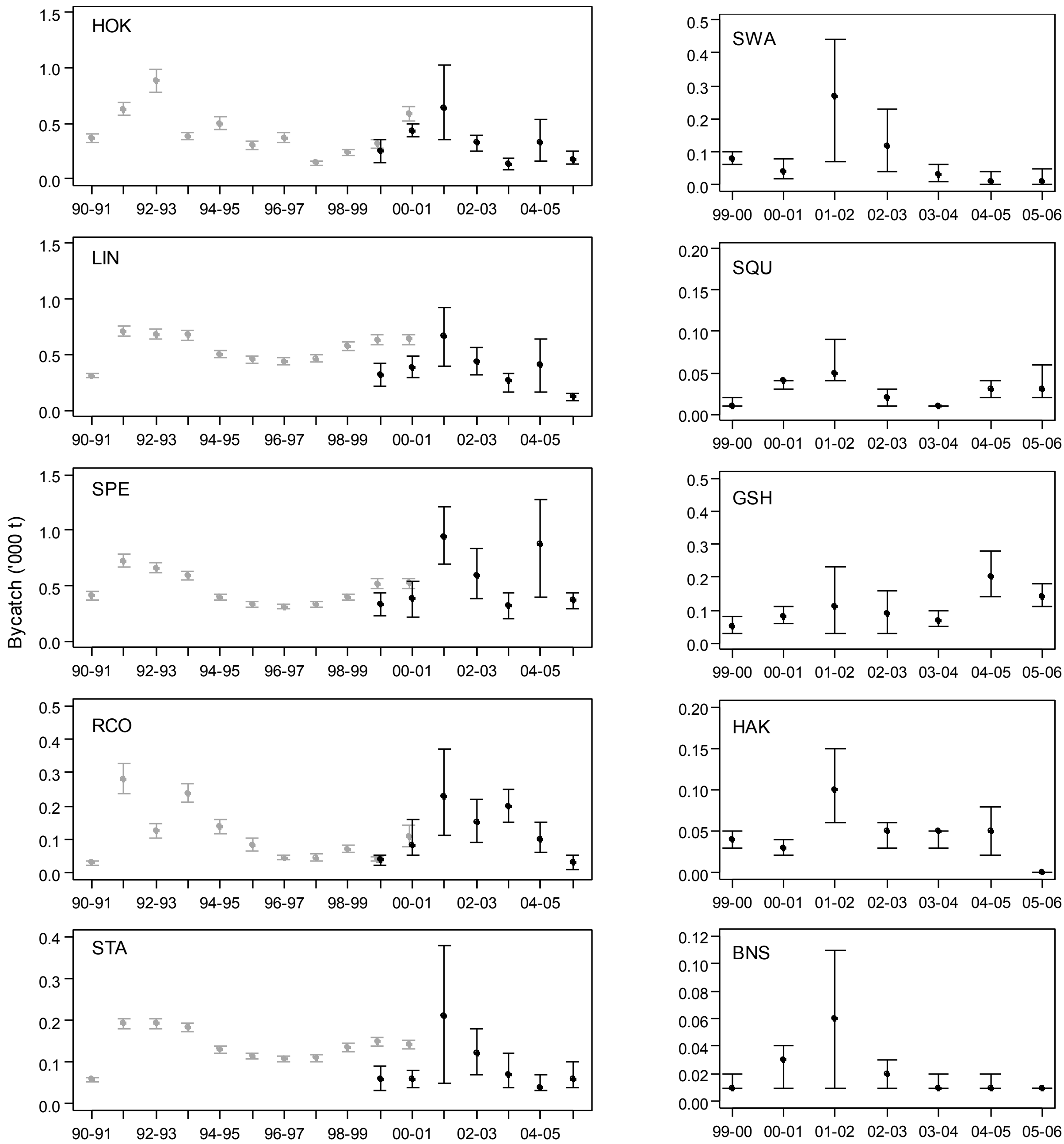

Figure 16: Annual estimates of fish bycatch in the target scampi trawl fishery, calculated for selected species categories for 1999–2000 to 2005–06 (in black). Also shown (in grey) are the bycatch estimates for 1990–91 to 2000–01 by Anderson (2004). Error bars show the 95% confidence intervals.

3.10 Calculation of arrow squid discards

3.10.1 Arrow squid discard rates

Discard ratios for some species categories were calculated from the observer data separately for each area and each of the seven fishing years. The variance in these discard rates was calculated using the bootstrap methods described in Section 2. Discards of QMS and non-QMS species were sufficient in both AUCK and SNAR to calculate separate discard ratios for each year in these areas. For the areas BANK, PUYS, and NULL, where there were not enough observer data within a year, discards were calculated across all years. Discards were calculated for a few of the individual species, although for some of these there were few discard events recorded by observers and calculated ratios may not be reliable.

Annual median discard rates of QMS species in the four areas ranged from 2 to 204 $kg.h^{-1}$ (Figure 17, Appendix A6), with BANK having the highest discard rates in all years (165–204 $kg.h^{-1}$). The SNAR and PUYS areas had lower discard rates (20–166 $kg.h^{-1}$ and 89–132 $kg.h^{-1}$ respectively), and the AUCK area had the lowest (2–12 $kg.h^{-1}$).

Annual discard rates of non-QMS species ranged from 15 to 102 $kg.h^{-1}$ with both these range values coming from the AUCK area (Figure 17a, Appendix A6). Generally the annual discard rates were lower for the non-QMS species than the QMS-species except in AUCK.

High discard rates of spiny dogfish, rattails, silver warehou, javelinfish, sharks, and hoki were seen in the BANK area; spiny dogfish, squid, redbait, silver dory, barracouta, and hoki in SNAR; spiny dogfish, rattails, and crabs in PUYS; and lower levels of discards for most species in AUCK except crabs, squid, sharks, and red cod.

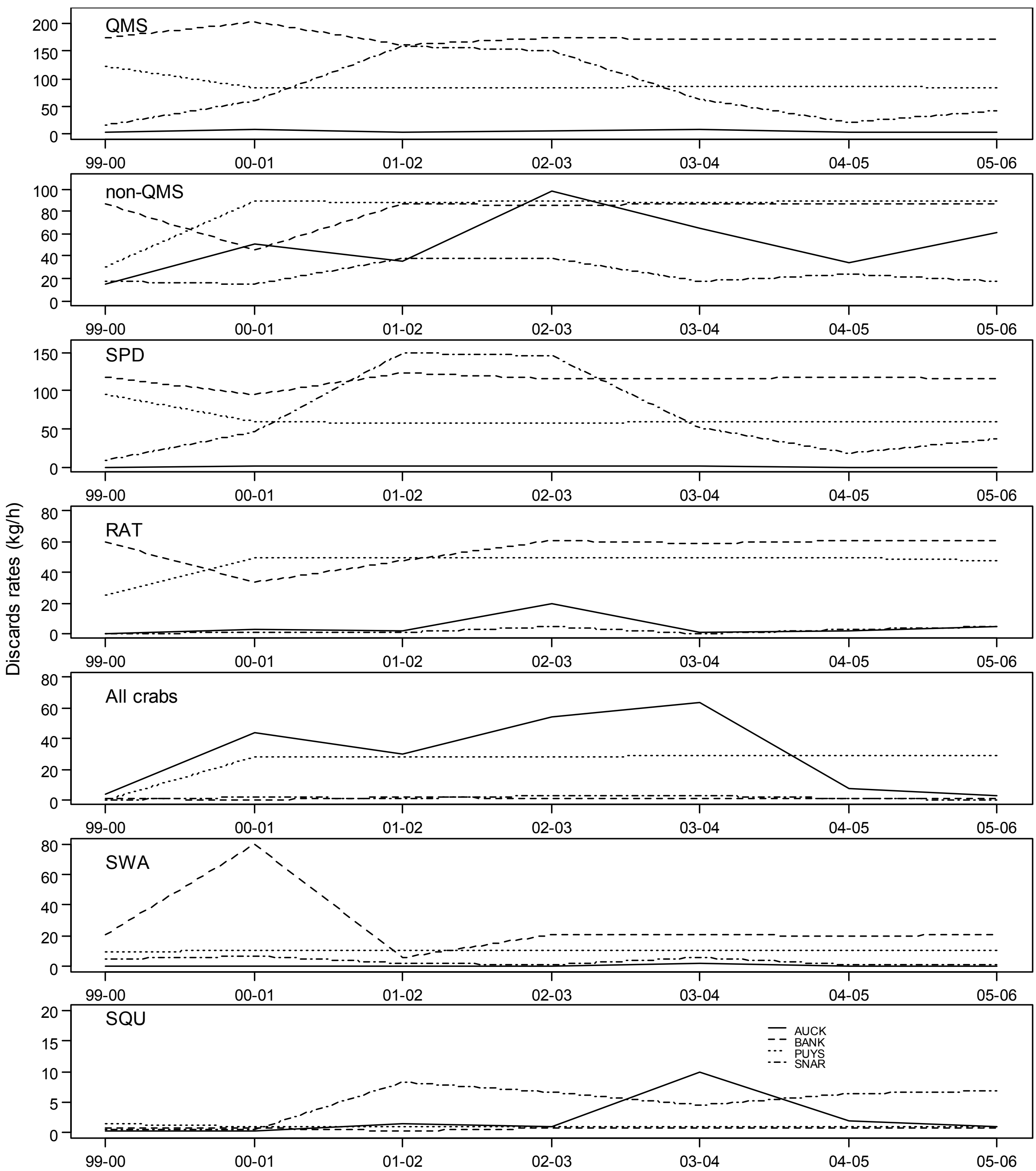

Figure 17a: Annual discard rates of QMS species (QMS), non-QMS species (non-QMS), SPD, RAT, combined crabs, SWA, and SQU in the squid trawl fishery. Discard rates shown are the median of the bootstrap sample of 1000.

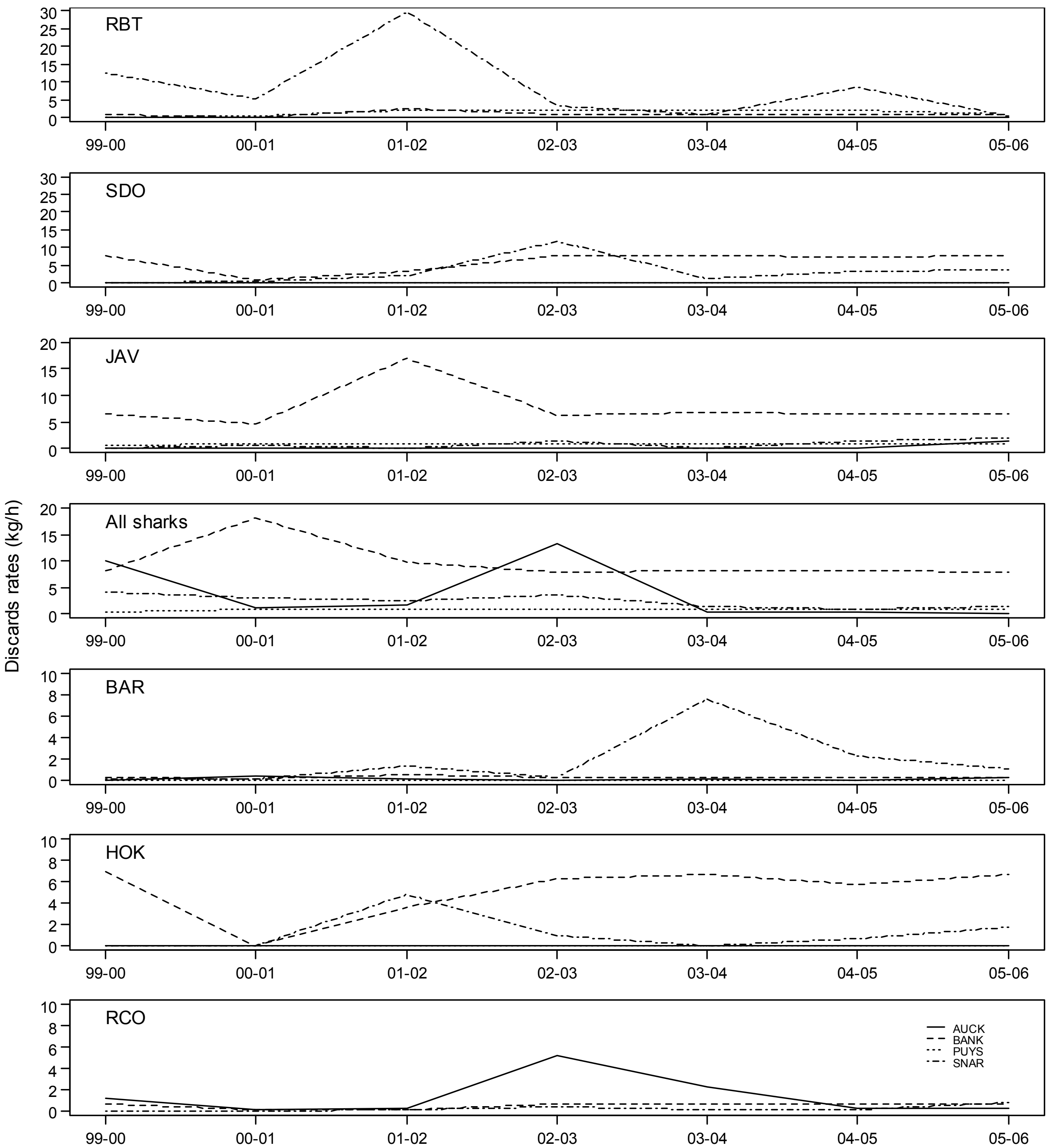

Figure 17b: Annual discard rates for RBT, SDO, JAV, combined sharks, BAR, HOK, and RCO in the squid trawl fishery. Discard rates shown are the median of the bootstrap sample of 1000.

3.10.2 Arrow squid annual discard levels

Annual discard levels were determined by multiplying the ratios calculated for each stratum by the target fishery tow duration totals for the equivalent stratum, as described in Section 2.5. Discards of commercial and non-commercial species in the squid fishery in the period 1998–99 to 2000–01 were estimated by Anderson (2004). There is an overlap of two years for 1999–2000 and 2000–01 between the Anderson (2004) analysis and the current study. As for the bycatch, the estimates between the two studies should not be compared directly for several reasons. In Anderson (2004) there were area differences and the "COM" species category comprised 10 commercial species rather than all QMS species. However, for both studies the ratio estimator was based on tow duration and was estimated similarly, although the precision was calculated differently. The confidence intervals around the Anderson (2004) values are much tighter (Figure 18) in part due to the less sophisticated bootstrap methods used for calculating variance compared to the current study. In some cases the overlapping years show different annual bycatch estimates for species categories.

Discard levels of QMS species were variable from 1999–2000 to 2005–06, ranging from 1830 t to 3750 t (Table 15, Figure 18a). Four years had similar, lower discards of QMS species (1999–00 and 2003–04 to 2005–06) and three years had similar, higher discards of QMS species (2000–01 to 2002–03). The 95% confidence intervals around the QMS discards are overlapping across all years. Annual discards of QMS species between 1999–2000 and 2005–06 were at the high end of discard levels compared to those estimated by Anderson (2004) (Figure 18a), and the 1999–2000 QMS species discards estimated by Anderson (2004) were well below that produced in this analysis. This is likely to be mainly due to spiny dogfish being incorporated into the QMS species category, as the two estimates of total discards for the two overlapping years were quite similar (Figure 18a).

The annual discards of spiny dogfish have ranged from 1200 to 3200 $t.y^{-1}$ for 1999–2000 to 2005–06 and are a major contributor to the QMS species discard total, especially on BANK and SNAR and for 2000–01 to 2002–03 (Table 15, Figure 18b). The annual discards of silver warehou were low although above those calculated by Anderson (2004) (Table 15, Figure 18b) and the annual discards of squid are low (20–340 $t.y^{-1}$). These differences may be due to the differences in dataset chosen compared with Anderson (2004), with no mixed target species *process group* data, therefore less targeting of middle depth species incorporated into the dataset. The annual discards for some of the individual species are unlikely to have been very well estimated as some species had very low incidences of discarding (see Table 9).

Discards of non-QMS species were large each year, ranging from 1010 to 3050 $t.y^{-1}$ (Table 15, Figure 18a), and were lower than the QMS species totals for 1999–2000 to 2002–03, and only slightly above the QMS annual estimates for the other years. Discards of non-QMS species were variable over the last seven years, with wide confidence intervals, and there appears to be a similar amount of discards compared with the 1998–99 to 2000–01 discards calculated by Anderson (2004). The main non-QMS species discarded were rattails (250–890 $t.y^{-1}$) and crabs (50–1270 $t.y^{-1}$), although many other species contributed significantly to non-QMS discards.

Overall, total discards have been relatively constant and our estimates were similar to Anderson's (2004) for the overlapping years. Discards appeared somewhat higher for 2000–01 to 2002–03, although the wide confidence intervals allow for no clear patterns or trends to be discerned. The best estimates of current total annual discards are in the range 2840–6740 $t.y^{-1}$, compared with 2174–4280 $t.y^{-1}$ for 1998–99 to 2000–01 (Anderson 2004). The total 2003–04 to 2005–06 discards appear have been similar (3930–4620 $t.y^{-1}$), and lower compared with the previous 3 years (5630–6740 $t.y^{-1}$), reflecting the fluctuating discards of the major contributing species spiny dogfish.

Table 15: Estimates of discards (rounded to the nearest 10 t) in the target squid trawl fishery by year, for various species categories with 95% confidence intervals in parentheses.

					Species category	
		QMS		Non-QMS		TOT
1999–00	1830	(750-3390)	1010	(550 1760)	2840	(1300-5150)
2000–01	3750	(1900-6100)	2080	(960 3510)	5830	(2860-9610)
2001–02	3670	(1690-6250)	1960	(840 3500)	5630	(2530-9750)
2002–03	3690	(1720-6270)	3050	(1770 4830)	6740	(3490-11100)
2003–04	1900	(960-3310)	2030	(710 4160)	3930	(1670-7470)
2004–05	1830	(860-3060)	2840	(1310 4790)	4670	(2170-7850)
2005–06	2020	(880-3540)	2600	(1120 4470)	4620	(2000-8010)

							Species category	
		SQU		RCO		SDO		SPD
1999–00	20	(0-40)	80	(0-270)	70	(20-170)	1220	(360-2350)
2000–01	40	(0-70)	60	(0-180)	130	(50-260)	2070	(880-3830)
2001–02	200	(0-650)	20	(0-90)	160	(30-400)	3220	(1380-5540)
2002–03	150	(20-310)	100	(20-260)	330	(70-720)	3100	(1100-5430)
2003–04	340	(0-1190)	120	(0-530)	120	(40-280)	1390	(740-2280)
2004–05	250	(30-650)	30	(0-170)	610	(130-1440)	1290	(550-2200)
2005–06	210	(0-530)	40	(0-90)	210	(40-550)	1560	(610-2830)

							Species category	
		CRB		all-crabs		GON		WIT
1999–00	40	(10-100)	50	(10-100)	0	(0-0)	10	(0-20)
2000–01	540	(130-1160)	770	(200-1510)	0	(0-0)	0	(0-10)
2001–02	450	(180-810)	510	(180-930)	0	(0-0)	0	(0-0)
2002–03	720	(360-1210)	880	(500-1420)	0	(0-10)	20	(0-30)
2003–04	1070	(170-2500)	1270	(330-2960)	0	(0-20)	20	(0-40)
2004–05	210	(0-550)	290	(40-650)	10	(0-10)	10	(0-30)
2005–06	30	(0-70)	100	(10-200)	10	(0-30)	10	(0-30)

							Species category	
		RBT		RAT		all-shark		BAR
1999–00	150	(10-460)	480	(310-740)	170	(70-360)	0	(0-0)
2000–01	130	(10-330)	720	(350-1250)	310	(150-490)	20	(0-40)
2001–02	530	(30-1400)	420	(190-730)	130	(50-220)	20	(0-50)
2002–03	110	(20-240)	860	(380-1460)	430	(70-1180)	80	(0-380)
2003–04	80	(0-260)	250	(100-460)	70	(20-120)	150	(0-460)
2004–05	410	(20-1480)	540	(260-950)	90	(40-160)	70	(0-180)
2005–06	40	(0-160)	550	(230-940)	80	(40-150)	40	(0-90)

					Species category	
		SWA		HOK		JAV
1999–00	270	(50-660)	50	(0-220)	40	(10-120)
2000–01	1050	(320-1830)	0	(0-10)	80	(0-240)
2001–02	100	(10-270)	130	(0-430)	100	(20-240)
2002–03	190	(50-430)	60	(0-270)	60	(10-180)
2003–04	240	(20-710)	20	(0-90)	20	(0-90)
2004–05	190	(40-470)	80	(0-260)	90	(10-240)
2005–06	150	(40-330)	90	(0-280)	130	(0-410)

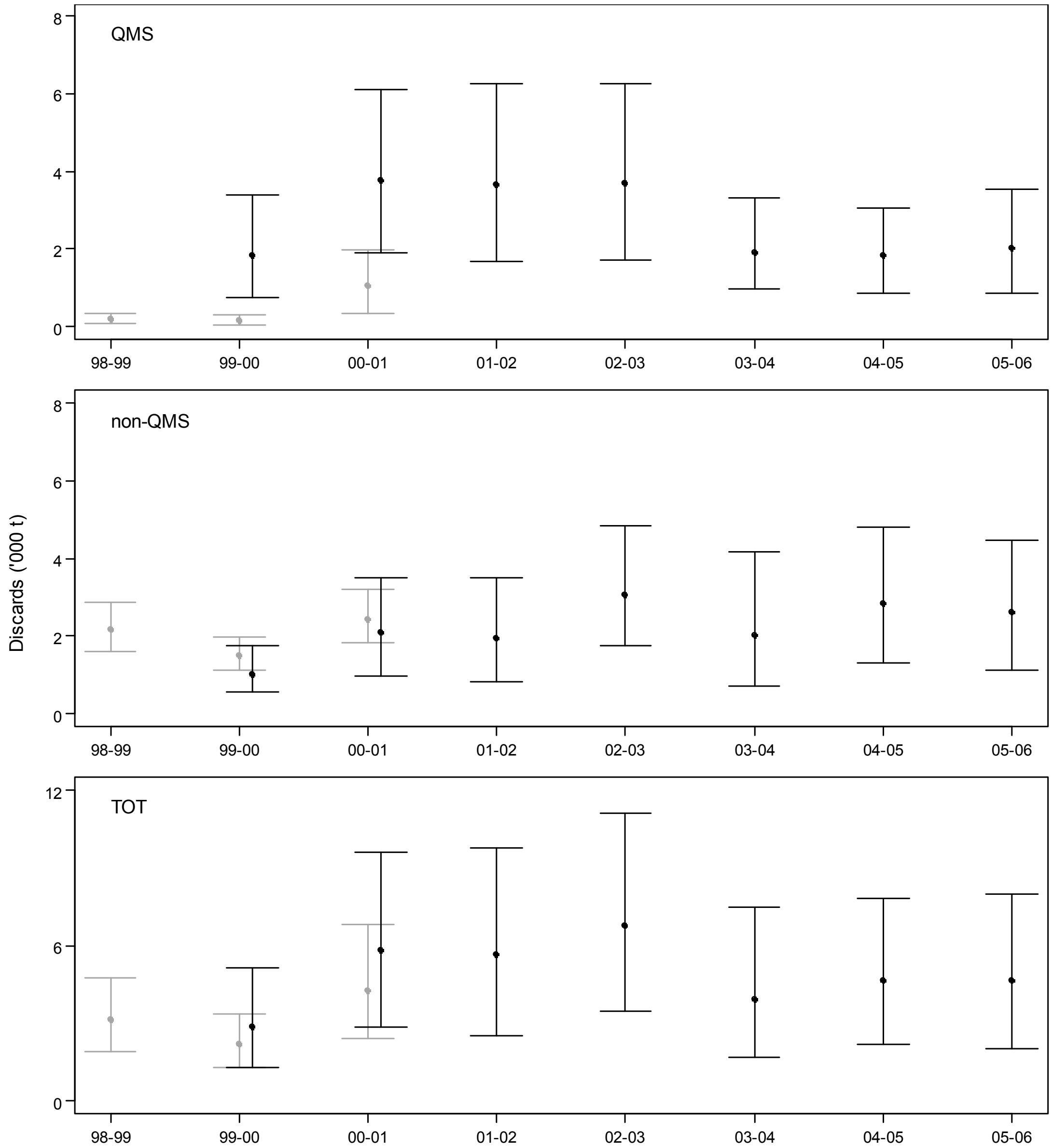

Figure 18a: Annual estimates of fish discards in the target squid trawl fishery, calculated for QMS species (QMS), non-QMS species (non-QMS), and overall (TOT) for 1999–2000 to 2005–06 for all target squid trips (black). Also shown (in grey) are the COM, OTH and TOT bycatch estimates calculated for 1998–99 to 2000–01 by Anderson (2004). Error bars show the 95% confidence intervals.

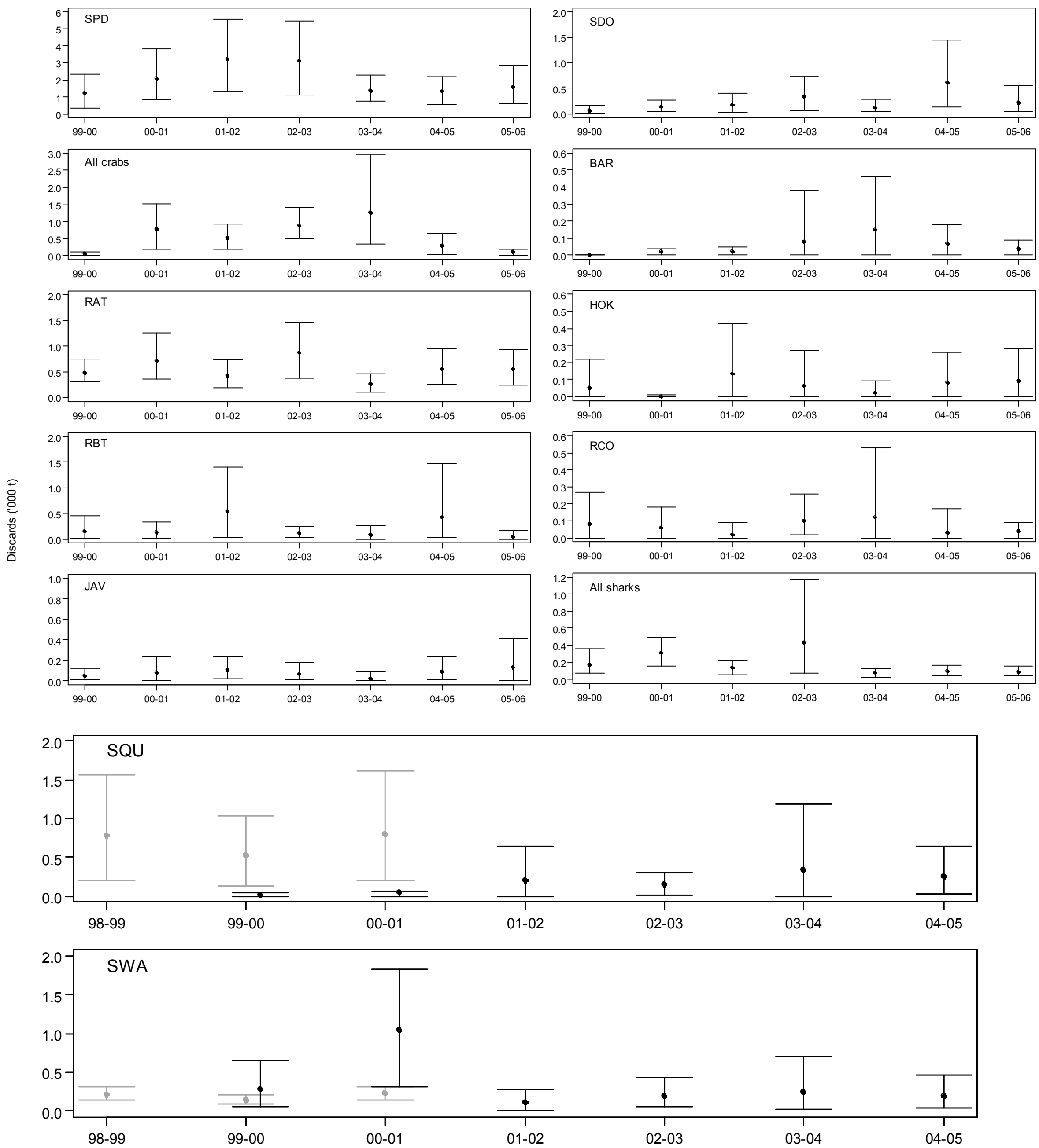

Figure 18b: Annual estimates of fish discards in the target squid trawl fishery, calculated for several species categories for 1999–2000 to 2005–06 (in black). Also shown (in grey) are estimates of discards for SQU and SWA calculated for 1998–99 to 2000–01 by Anderson (2004). Error bars show the 95% confidence intervals.

3.11 Calculation of scampi discards

3.11.1 Scampi discard rates

Discard ratios for some species categories were calculated from the observer data separately for each area and each of the seven fishing years. The variance in these discard rates was calculated using the bootstrap methods described in Section 2. Discards of QMS and non-QMS species were sufficient in some areas and years to calculate separate discard ratios for each year in each of areas. For species categories where there was not enough observer data, discards were calculated across years or areas depending on whether *fyear* or *area* were more important in the regression. Discards were calculated for some species for which few discard events were recorded by observers and the calculated ratios may not be reliable.

Annual median discard rates of QMS species in the four areas ranged from 1 to 74 $kg.h^{-1}$ (Figure 19a, Appendix B6), with CHAT having the highest discard rates in all years (range 38–74 $kg.h^{-1}$), except 2005–06 (4.2 $kg.h^{-1}$). The area WAIR had moderate discard rates (11–26 $kg.h^{-1}$), and AUCK and NRTH had the lowest discard rates (1–16 $kg.h^{-1}$).

Annual discard rates of non-QMS species were higher and ranged from 29–271 $kg.h^{-1}$ and were also markedly higher in the CHAT area, except in 1999–2000, 2003–04 and 2005–06 (Figure 19a).

High discard rates of javelinfish, rattails, sea perch, deep-sea flathead, spiny dogfish, and sometimes hoki, ling and red cod were seen in the CHAT area; rattails, red cod, and skates in WAIR; crabs, toadfish, and sometimes skates, ling, and red cod in AUCK; and lower levels of discards for most species in NRTH.

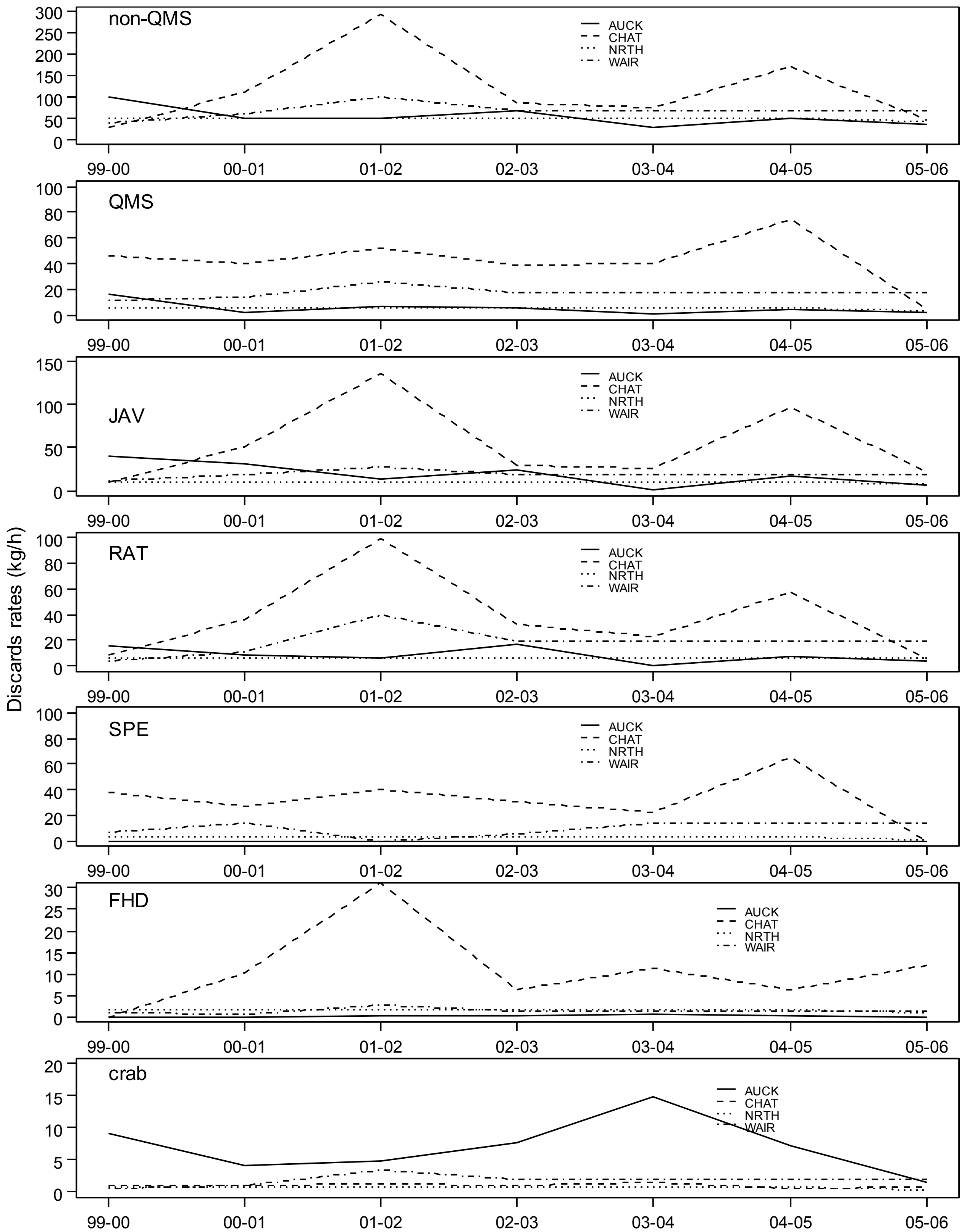

Figure 19a: Annual discard rates of QMS species (QMS), non-QMS species (non-QMS), JAV, RAT, SPE, FHD and crab (combined crab species) in the scampi trawl fishery. Discard rates shown are the median of the bootstrap sample of 1000.

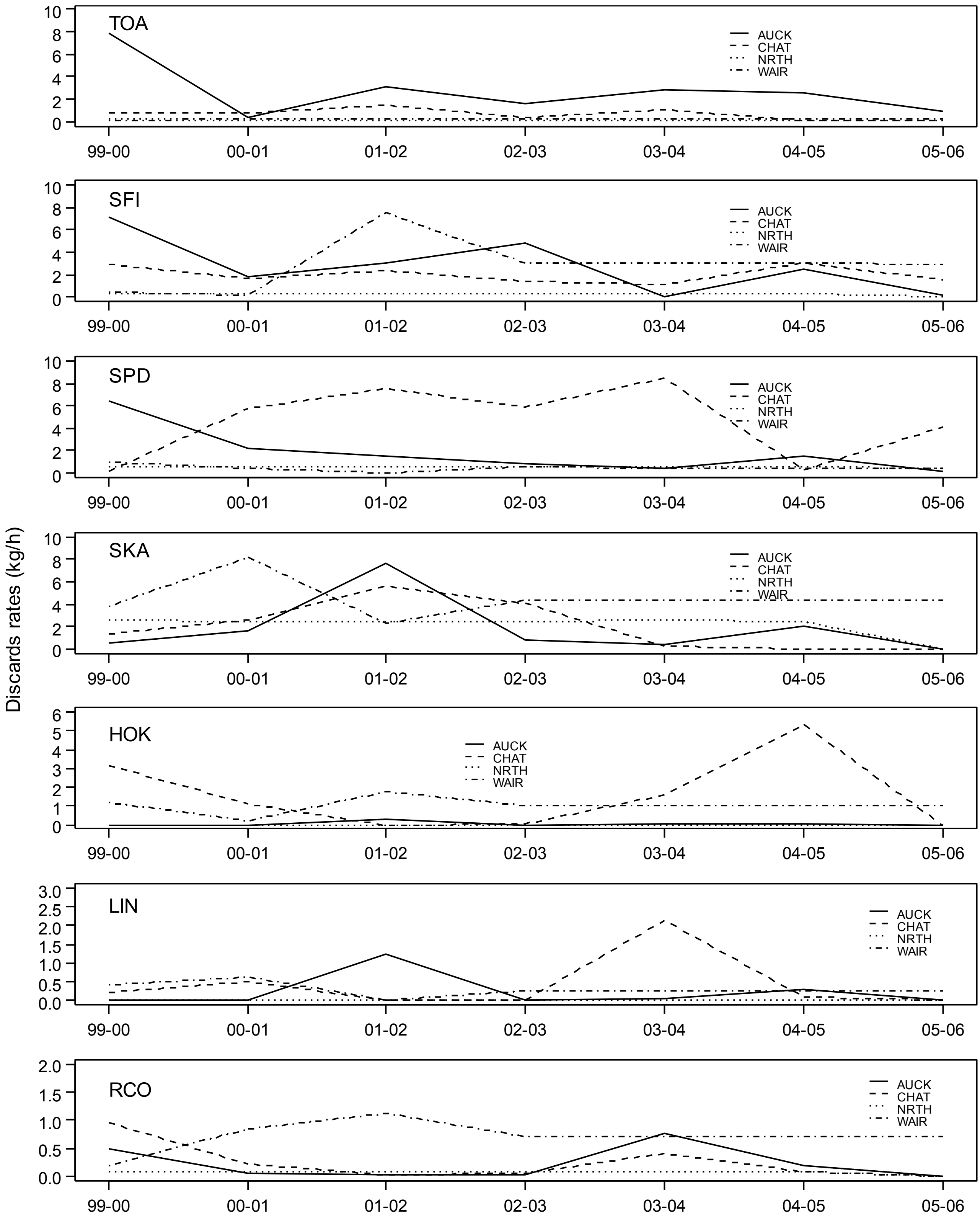

Figure 19b: Annual discard rates for TOA, SFI, SPD, SKA, HOK, LIN, and RCO in the scampi trawl fishery. Discard rates shown are the median of the bootstrap sample of 1000.

3.11.2 Scampi annual discard levels

Annual discard levels were determined by multiplying the ratios calculated for each stratum by the target fishery tow duration totals for the equivalent stratum, as described in Section 2.5. Discards of commercial and non-commercial species in the scampi fishery for 1990–91 to 2000–01 were estimated by Anderson (2004) and our analysis overlaps that study in 1999–2000 and 2000–01. As for the bycatch, the estimates between the two studies should not be compared directly for several reasons. In Anderson (2004) there were area differences and the "COM" species category comprised 16 commercial species rather than all QMS species. However, for both studies the ratio estimator was based on tow duration and was estimated similarly, although the precision was calculated differently. The Anderson (2004) confidence intervals are much tighter (Figure 20), due partly to the less sophisticated bootstrap methods used for calculating variance compared to the current study. For some of the species categories the overlapping years show different annual bycatch estimates.

Discards of QMS species were variable from 1999–2000 to 2005–06, ranging from 180 t (in 2005–06) to 970 t (2004–05) (Table 16, Figure 20). The 95% confidence intervals around the QMS discards overlap across most years. Annual discards of QMS species between 1999–2000 and 2004–05 were mostly greater than those estimated by Anderson (2004) (Figure 20), but the 2005–06 discards were the lowest ever. Core vessels had very similar discard levels to the main data set. Estimates of discards from 1999–2000 to 2005–06 using the area strata definitions of Anderson (2004) are different from those calculated in this study, although all fall within the 95% confidence intervals except 2005–06 which is well above the bycatch estimates. This shows definitions of strata are important in calculating discard levels, and is a result of the low, patchy, and non-representative observer coverage.

The annual discards of sea perch were similar to the previous years, except 2004–05 which had high discards particularly on the Chatham Rise (see figure 19). The annual discards of hoki, ling, and sea perch were very low and mostly below Anderson's (2004) estimates (Table 16, Figure 20), which may be due to the differences in dataset chosen (no mixed target trip data, therefore less targeting of middle depth species incorporated into the dataset). The annual discards of spiny dogfish have ranged from 10 to 70 $t.y^{-1}$ for 1999–2000 to 2005–06, most of which was on the Chatham Rise (see Figure 19). The annual discard of individual species may not be representative as some species had lower incidences of discarding (*see* Table 11).

Discards of non-QMS species were large each year, ranging from 1230 to 4270 $t.y^{-1}$ (Table 16, figure 20). Non-QMS species discards were much higher than QMS species discards in all years. Discards of non-QMS species were variable over the seven years, although broadly similar to the 11 years estimated by Anderson (2004). The main non-QMS discard species included javelinfish (270–1370 $t.y^{-1}$) and rattails (250–1380 $t.y\text{-}^{1}$), much of which were on the Chatham Rise (see Figure 19).

Total discards are variable between years, but similar to the range of estimates given by Anderson (2004) (1540–5140 $t.y^{-1}$ compared with 1561–5057 $t.y^{-1}$ for 1990–91 to 2000–01).

Intentional discarding of quota species (which include all species in the QMS category) is not permitted (under Section 72 of the 1996 Fisheries Act) and so discards for most species should be limited to fish accidentally lost. One major exception to this is spiny dogfish, which was introduced into the QMS in October 2004 but added to the list of QMS species in Schedule 6 of the Fisheries Act 1996. The Schedule 6 listing allows spiny dogfish to be discarded at sea, as long as the catch is reported. This change in status for spiny dogfish (within this study period) should not have affected reporting behaviour of fishers for the species, as discarding of the species has remained legal throughout.

There is also debate about whether discards are greater when observers are present (and quota species can be legally discarded in certain circumstances) or when they are not present and illegal discarding can take place unseen. A recent study comparing commercial catch reports in the New Zealand ling longline fishery between observed and unobserved vessels indicated that under-reporting and non-reporting of bycatch species was common in this fishery, and only a quarter of the catch of spiny dogfish (the most commonly caught bycatch species) was reported (Burns & Kerr 2008).

Table 16: Estimates of discards (rounded to the nearest 10 t) in the target scampi trawl fishery by year, for various species categories with 95% confidence intervals in parentheses.

	Species category					
	QMS		Non-QMS		TOT	
1999–00	530	(360-700)	1770	(1320-2190)	2300	(1680-2890)
2000–01	370	(180-570)	2040	(1690-2420)	2410	(1870-2990)
2001–02	870	(650-1160)	4270	(2120-6100)	5140	(2770-7260)
2002–03	520	(280-740)	2340	(1490-3150)	2860	(1770-3890)
2003–04	310	(130-520)	1230	(870-1720)	1540	(1000-2240)
2004–05	950	(500-1280)	2850	(1450-4130)	3800	(1950-5410)
2005–06	180	(130-220)	1530	(1250-1830)	1710	(1380-2050)

	Species category							
	SPE		SPD		JAV		RAT	
1999–00	270	(160-390)	70	(50-120)	610	(460-760)	260	(180-360)
2000–01	280	(160-420)	40	(30-80)	820	(660-1010)	400	(300-520)
2001–02	180	(130-350)	50	(10-100)	1370	(700-1960)	1380	(410-2130)
2002–03	270	(100-460)	50	(20-100)	710	(540-910)	640	(260-1120)
2003–04	190	(80-320)	30	(10-80)	270	(160-370)	250	(100-410)
2004–05	760	(370-1080)	10	(10-50)	1270	(630-1810)	790	(180-1410)
2005–06	60	(50-100)	60	(50-60)	480	(410-600)	270	(180-380)

	Species category							
	SKA		crab		TOA		SFI	
1999–00	70	(0-150)	110	(80-140)	80	(60-100)	80	(60-120)
2000–01	150	(90-190)	60	(30-90)	0	(0-0)	30	(10-30)
2001–02	180	(30-360)	140	(50-240)	50	(0-110)	200	(20-370)
2002–03	100	(30-160)	120	(50-180)	20	(10-20)	90	(20-190)
2003–04	30	(10-70)	150	(100-340)	30	(10-40)	20	(0-50)
2004–05	60	(10-90)	100	(30-130)	20	(10-40)	60	(30-110)
2005–06	20	(10-30)	30	(10-60)	10	(10-10)	30	(20-70)

	Species category							
	FHD		HOK		LIN		RCO	
1999–00	20	(0-30)	20	(10-40)	0	(0-10)	0	(0-20)
2000–01	60	(30-70)	0	(0-20)	10	(0-20)	10	(0-20)
2001–02	200	(100-290)	40	(20-70)	10	(0-30)	20	(0-60)
2002–03	70	(30-100)	10	(10-20)	0	(0-10)	10	(0-10)
2003–04	70	(30-100)	20	(0-30)	10	(0-30)	10	(0-30)
2004–05	80	(50-100)	60	(40-90)	0	(0-10)	0	(0-10)
2005–06	180	(150-200)	10	(0-10)	0	(0-0)	0	(0-10)

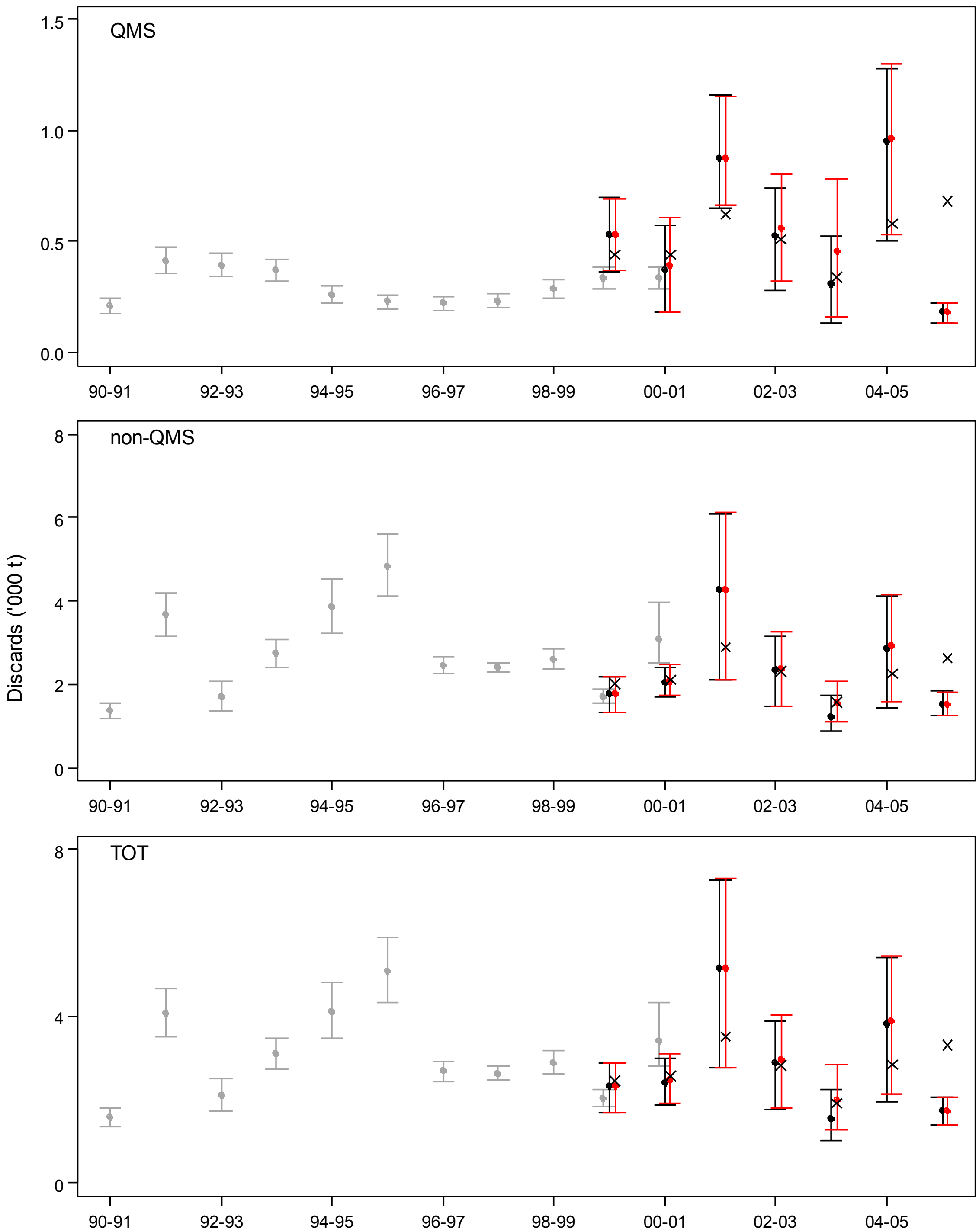

Figure 20a: Annual estimates of fish discards in the target scampi trawl fishery, calculated for QMS species (QMS), non-QMS species (non-QMS), and overall (TOT) 1999–2000 to 2005–06 for all target scampi trips (black) and scampi core vessels (grey). Point estimates (x) for QMS, non-QMS and overall are also calculated using strata as in Anderson 2004 for the all target scampi trip dataset. Also shown (in light grey) are the COM, OTH and TOT bycatch estimates calculated for 1990–91 to 2000–01 by Anderson (2004). Error bars show the 95% confidence intervals.

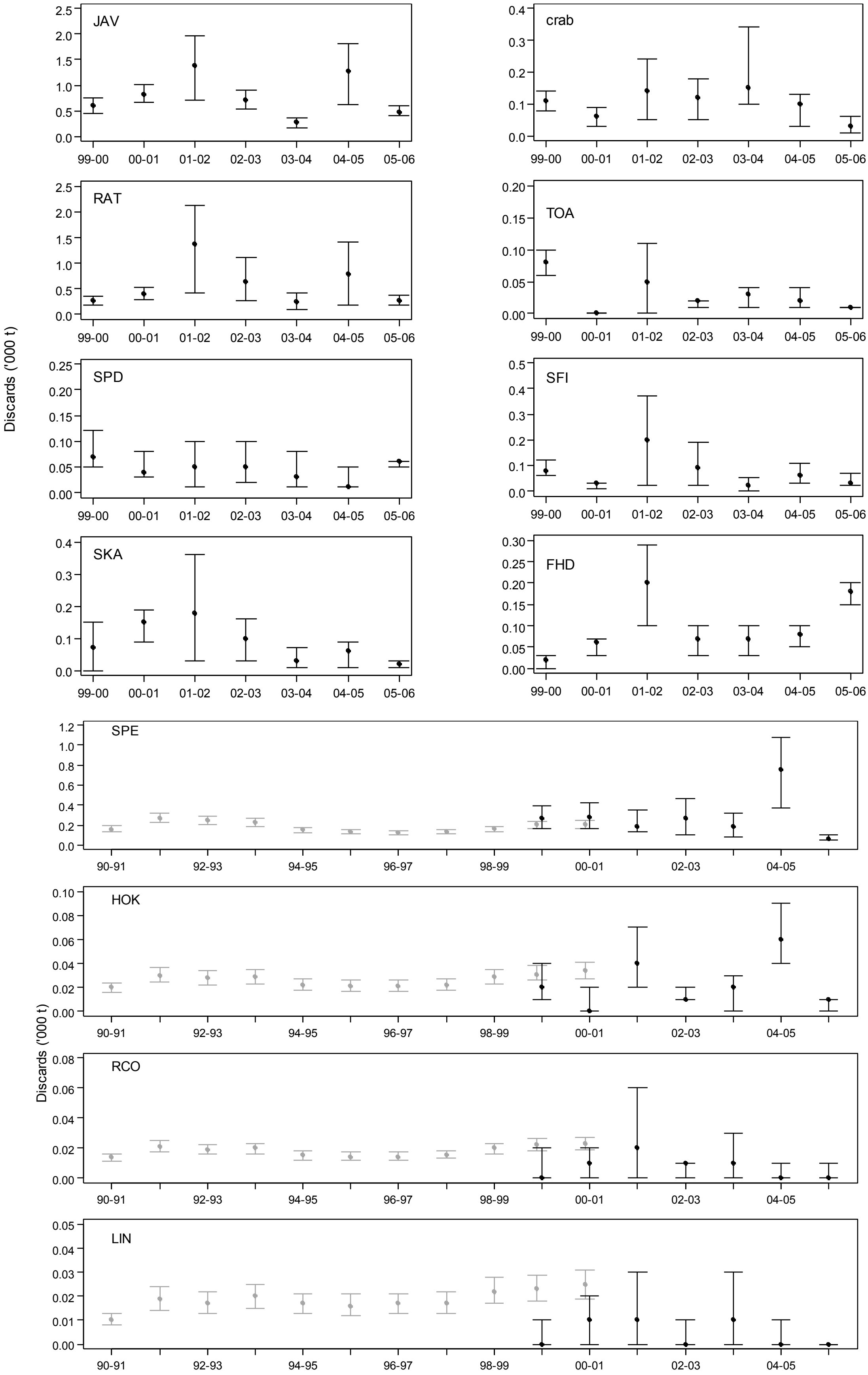

Figure 20b: Annual estimates of fish discards in the target scampi trawl fishery, calculated for several species categories for 1999–2000 to 2005–06 (in black). Also shown (in grey) are estimates of discards for SPE, HOK, LIN, and RCO calculated for 1990–91 to 2000–01 by Anderson (2004). Error bars show the 95% confidence intervals.

3.12 Fraction of the fishery represented by the target trawl fishery

Estimated annual catches used in the scampi and squid analysis represent 86–92% of the total annual trawled landings of arrow squid and 82–90% of the total annual trawled landings of scampi during the period examined (see Appendix Tables A3 and B3). Discards associated with squid or scampi caught (and subsequently landed) while trawling for other species is likely to contribute only a small fraction of the total squid or scampi trawl fishery discards.

4. DISCUSSION

The precision of the estimates of bycatch and discard levels using these methods is strongly linked to the coverage of the fishery achieved by observers. Precise estimates require a reasonable fraction of the target fishery be observed and a good spatial spread of observer placements across the spatial extent of the fishery, the different types of vessels, and times of the year.

The multi-level bootstrap methods we used to calculate precision provided more realistic estimates than previous analyses because they took into account the effect of correlation between tows in the same trip and area stratum. The difference between the methods can be judged by comparing confidence intervals from the two methods in Figures 15, 16, 18a , 18b, 20a, 20b. These usually show considerably wider confidence limits for our method and therefore better estimates of uncertainty.

The effect of the individual vessels on the variability in bycatch rates as well as target species catch rates has been well documented in many New Zealand fisheries (see, e.g., Clark & Anderson 2001, O'Driscoll 2003, Horn 2004, Anderson & Smith 2005) and was acknowledged in the methods used here by ensuring that a minimum number of vessels were included in each stratum for which rates were calculated separately. Clearly some vessels (and companies, through fishing strategies) are better at avoiding unwanted bycatch and minimising discards than others, demonstrating that there is potential for reducing discards in these two fisheries.

The definition of strata is important in calculating bycatch and discard levels, and sensitivity of bycatch and discard estimates to the stratification used may be a result of low, patchy, and non-representative observer coverage in some areas, and suggests that estimates (and trends) might be quite unreliable. Observer programme coverage in the squid trawl fishery was 20–54% of the annual target fishery catch, which although considered sufficient is misleading as most of the coverage was on the Snares Shelf and around the Auckland Islands with other areas under-represented in some years. Observer programme coverage in the scampi trawl fishery has been patchy over time and between areas, and less than 10% of the annual target fishery catch was observed in three of the seven years. Care therefore needs to be taken over interpretation of estimates of bycatch and discards for both squid and scampi.

4.1 Squid

Observer effort in the squid fishery was variable both over time and between areas with 20–54% of the annual target fishery catch observed in seven years. This is a level, which, if appropriately spread, should be representative of the fishery. This is somewhat misleading as most of the coverage was in the SNAR and AUCK areas with BANK and PUYS under-represented in some years, and therefore care needs to be taken over conclusions of estimates of bycatch and discards. Large vessels were well covered by observers, especially for SNAR and AUCK. Temporal coverage, of fishing effort by observers was ideal, with peaks in coverage from January to April, although most of this was again from the AUCK and SNAR areas where most of the fishing effort occurred, with little coverage at other times or places.

Modelling of bycatch and discards showed that the most influential factors were *area*, *fishing duration,* and *company*, and for discards *gear code* was also influential, and hence the probability of occurrence and the amount of bycatch and discards in a tow were highly dependent on these. The area effect could sometimes be directly related to the known distribution of a particular bycatch species, such as the northern distribution of common mackerel, and the scarceness of barracouta south of the Stewart-Snares Shelf. Bycatch and discards of all species groups was especially low in the AUCK area, and particularly high in the BANK fishery.

Company was also influential in most of the models, but the use of this factor in stratification of the calculations is also difficult. *Vessel*, *vessel length,* and *vessel tonnage* were less influential, but, the vessel effect was probably confounded with the *company* effect. The variable *period* (as determined from regression tree partitioning) proved to be of limited value in explaining variability, and so ultimately *area* was used to stratify all calculations of bycatch and discards. The *species-area* strata, derived from areas combined through regression tree analysis, were not used as there was not enough data to split the dataset into further strata using this variable, and often non-adjacent areas were grouped which did not make sense. *Gear code* was often important with discards and was clearly confounded with *fishing method* and *headline height*.

Overall, total bycatch appears to have increased from 1999–2000 to 2000–01, decreased to 2003–04, remained at this level until 2004–05, and then increased slightly in 2005–06. Bycatch levels were high for both QMS and non-QMS species in 2001–02. Bycatch in the squid fishery was composed mainly of the QMS species, at about 82–90% of the total annual bycatch, with main bycatch species including barracouta, silver warehou, and spiny dogfish. Total annual bycatch ranged from 16 550 to 26 730 t.

Discards included both QMS and non-QMS species, with the main discard species being spiny dogfish, rattails, silver warehou, javelinfish, and crabs. Discarding of squid was minimal at 0.21% of total discards. An average of 0.2 kg of total discards per kilogram of squid caught was calculated for the 7 years examined in this study, slightly higher than the 0.14 kg figure calculated by Anderson (2004) for the previous three years. Total discards in this study have been variable (2840–6740 $t.y^{-1}$) and are close to the range (2174–4280 $t.y^{-1}$) calculated by Anderson (2004), although the upper bound of the range in the current analysis is higher, probably reflecting the quantity of spiny dogfish discarded from 2000–01 to 2002–03. The total 2005–06 discard level appears to be similar to the two previous years for both QMS and non-QMS species.

4.2 Scampi

Observer effort in the scampi fishery was variable both over time and between areas. Less than 10% of the annual target fishery catch was observed in three of the seven years, a level which may not be sufficient to be representative of the fishery. Estimates of bycatch and discards may therefore be less reliable for those years. Graphical analysis showed that observer coverage was variable in the major fisheries, with better coverage in the southern areas, although it was sometimes patchy, and patchy and often low coverage in the northern areas. The size range of the vessels was well covered by observers. Temporal coverage of fishing effort by observers was less ideal, with peaks at certain times of the year, and virtually no coverage at other times.

Modelling of discards and bycatch showed that the most influential factors were *area*, *fishing duration,* and *company*, as well as headline height for discards, and hence the probability of occurrence and the amount of discards and bycatch in a tow were highly dependent on these. For some of the individual species examined, the *area* effect could be directly related to the known distribution of that species. Bycatch of all species groups was especially low in the northern area (NRTH), and particularly high in the Chatham Rise scampi fishery.

The *company* variable was also influential in most of the models, but the use of this factor in stratification of the calculations is also difficult. *Vessel* was a lesser influential variable, but the *vessel* effect was probably confounded with the *company* effect. *Period* proved to be of limited value in explaining variability, and so ultimately *area* was used to stratify all calculations of bycatch and discards. The *species-area* strata, derived from areas combined through regression tree analysis, were not used as derived species areas did not produce patterns that were repeated strongly across species, and in several cases grouped areas that were not adjacent and thus it did not make sense to combine these groups.

Although *trip* was identified as being the primary influence on bycatch and discards in most of the initial regression models, this factor could not easily be used to stratify the calculations, and when removed from consideration, it was generally replaced by *area* with little loss in explanatory power.

Overall, total bycatch may have declined slightly from the levels of the 1990s, and appears to have been high in 2001–02 and at its lowest level in 2005–06. Bycatch in the scampi fishery was composed mostly of non-QMS species, at about 56% of the total annual bycatch. Total annual bycatch ranged between 1500 and 5140 t. Main bycatch species included ling, hoki, sea perch, red cod, silver warehou, and giant stargazer.

Total discards were dominated by non-QMS species such as rattails, javelinfish, skates, and crabs although significant discards of QMS species such as ling, red cod, hoki, spiny dogfish, and sea perch were also recorded. The main discard species included javelinfish, rattails, and sea perch. Discards of scampi was minimal at 0.3% of total discards. An average of 2.5 kg of total discards per kilogram of scampi caught was calculated for the 7 years examined in this study, slightly less than estimated by Anderson (2004). Total discards in this study were variable (1540–5140 $t.y^{-1}$) but similar to Anderson's (2004) estimates (1561–5057 $t.y^{-1}$). The total 2005–06 discards appear to be low for both QMS and non-QMS species. This may be a result of an overall decline in the availability of many fish species, as well as improvements in methods for avoiding unwanted bycatch or utilisation of low value species (Zeller & Pauly 2005).

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Appendix A1: Number of TCEPR vessels, tows, total catch and squid total catch and squid target catch by fishing year, area and target category. Numbers in parentheses are percentage of squid catch to total catch for each category, e.g., percentage of Squid target catch in category 1 to total catch in category 1.

								Fishing year
Area	Target category	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
AUCK	Number of vessels	45	44	49	46	42	45	41
	Number of tows	3138	2556	4104	3153	4311	4358	3778
	Total Catch (t)	12619	8516	19352	12234	40058	32277	19742
	Total squid catch (t)	6112 (48.4)	3124 (36.7)	11033 (57.0)	6860 (56.1)	32370 (80.8)	25872 (80.2)	16687 (84.5)
	1. Squid catch (t) SQU target	666 (95.0)	585 (93.3)	1652 (96.4)	1583 (90.2)	24646 (95.1)	13851 (95.8)	11497 (94.9)
	2. Squid catch (t) MIX target	5434 (82.6)	2506 (74.1)	9362 (78.5)	5273 (68.4)	7721 (65.0)	12012 (71.4)	5182 (73.1)
	2a.Squid catch (t) MIX target (SQU target only)	5430 (94.6)	2503 (92.2)	9351 (97.9)	5219 (91.2)	7718 (97.3)	11964 (96.9)	5180 (95.4)
	2b.Squid catch (t) MIX target (no target SQU)	3 (0.4)	3 (0.5)	11 (0.5)	55 (2.8)	3 (0.1)	48 (1.1)	2 (0.1)
	3. Squid catch (t) none SQU target	13 (0.2)	32 (0.7)	18 (0.3)	3 (0.1)	3 (0.1)	10 (1.0)	7 (1.4)
BANK	Number of vessels	50	46	44	47	36	43	37
	Number of tows	4068	4696	3784	3791	2957	2700	2648
	Total Catch (t)	22420	24044	20018	19757	18395	19976	17649
	Total squid catch (t)	4536 (20.2)	6075 (25.3)	2422 (12.1)	2718 (13.8)	1194 (6.5)	3578 (17.9)	1762 (10.0)
	1. Squid catch (t) SQU target	423 (56.0)	1175 (59.2)	590 (38.8)	429 (40.3)	534 (42.5)	1643 (57.3)	743 (44.1)
	2. Squid catch (t) MIX target	4105 (27.4)	4899 (28.2)	1832 (12.3)	2287 (15.6)	475 (6.5)	1933 (12.7)	1018 (7.5)
	2a.Squid catch (t) MIX target (SQU target only)	3687 (54.8)	4069 (58.2)	1464 (35.7)	1853 (41.1)	245 (29.6)	1557 (50.7)	931 (32.7)
	2b.Squid catch (t) MIX target (no target SQU)	418 (5.0)	830 (8.0)	367 (3.4)	434 (4.3)	230 (3.6)	376 (3.1)	87 (0.8)
	3. Squid catch (t) none SQU target	9 (0.1)	2 (0.0)	1 (0.0)	2 (0.0)	185 (1.9)	0.3 (0.0)	0.2 (0.0)
CHAT	Number of vessels	45	47	44	44	37	42	43
	Number of tows	4317	4549	3756	3175	3002	3673	3948
	Total Catch (t)	27149	26784	19540	16645	15935	17325	18884
	Total squid catch (t)	2491 (9.2)	1737 (6.5)	15 (0.1)	66 (0.4)	15 (0.1)	726 (4.2)	94 (0.5)
	1. Squid catch (t) SQU target	1018 (87.3)	12 (41.5)	1 (29.4)	3 (70.7)	2 (13.5)	533 (84.4)	0 (0.0)
	2. Squid catch (t) MIX target	1471 (10.7)	1711 (8.9)	10 (0.1)	61 (0.7)	11 (0.2)	187 (1.5)	78 (0.5)
	2a.Squid catch (t) MIX target (SQU target only)	1426 (82.8)	1668 (57.9)	5 (5.4)	40 (12.1)	1 (4.3)	161 (58.1)	33 (17.4)
	2b.Squid catch (t) MIX target (no target SQU)	45 (0.4)	42 (0.3)	5 (0.0)	20 (0.2)	10 (0.2)	26 (0.2)	45 (0.3)
	3. Squid catch (t) none SQU target	2 (0.0)	13 (0.2)	4 (0.0)	3 (0.0)	2 (0.0)	6 (0.1)	17 (0.5)
NRTH	Number of vessels	53	72	63	69	48	47	45
	Number of tows	5773	8062	6807	6782	5226	7967	7727
	Total Catch (t)	9411	14067	17492	23986	14820	29895	33641
	Total squid catch (t)	43 (0.5)	105 (0.8)	51 (0.3)	78 (0.3)	33 (0.2)	67 (0.2)	115 (0.3)
	1. Squid catch (t) SQU target	17 (2.9)	25 (3.7)	16 (2.6)	3 (2.5)	0 (0.0)	0 (0.0)	0 (0.0)
	2. Squid catch (t) MIX target	10 (0.3)	30 (0.4)	7 (0.1)	38 (0.2)	9 (0.1)	11 (0.1)	57 (0.2)
	2a.Squid catch (t) MIX target (SQU target only)	5 (2.2)	3 (25.9)	1 (11.7)	11 (6.0)	2 (22.7)	0 (16.7)	2 (24.9)
	2b.Squid catch (t) MIX target (no target SQU)	5 (0.1)	27 (0.4)	6 (0.1)	27 (0.2)	7 (0.1)	11 (0.1)	55 (0.2)
	3. Squid catch (t) none SQU target	17 (0.3)	50 (0.8)	28 (0.5)	37 (0.7)	24 (0.6)	57 (0.8)	58 (1.3)

Appendix A1: continued.

		Fishing year						
Area	Category	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
PUYS	Number of vessels	23	33	31	33	25	30	20
	Number of tows	703	1195	1196	1919	574	718	570
	Total Catch (t)	3860	10244	10468	15601	4426	7545	3982
	Total squid catch (t)	115 (3.0)	3059 (29.9)	4133 (39.5)	9808 (62.9)	1545 (34.9)	1620 (21.5)	1163 (29.2)
	1. Squid catch (t) SQU target	0 (0.0)	0 (0.0)	1287 (87.9)	5625 (95.1)	1298 (80.6)	920 (72.4)	154 (58.4)
	2. Squid catch (t) MIX target	110 (5.5)	3041 (42.0)	2840 (44.3)	4165 (61.6)	243 (12.3)	700 (11.9)	1009 (27.1)
	2a.Squid catch (t) MIX target (SQU target only)	65 (35.0)	2909 (90.4)	2790 (86.2)	4140 (91.1)	227 (61.2)	670 (59.3)	942 (71.0)
	2b.Squid catch (t) MIX target (no target SQU)	45 (2.5)	132 (3.3)	50 (1.6)	25 (1.1)	17 (1.0)	29 (0.6)	66 (2.8)
	3. Squid catch (t) none SQU target	5 (0.3)	18 (0.6)	5 (0.2)	18 (0.6)	3 (0.4)	0.3 (0.1)	0 (0.0)
SNAR	Number of vessels	41	40	43	44	39	41	38
	Number of tows	5563	5737	6424	5620	6562	7777	6695
	Total Catch (t)	41758	42965	58237	45552	68790	67044	75613
	Total squid catch (t)	4640 (11.1)	17573 (40.9)	26748 (45.9)	18192 (39.9)	40803 (59.3)	41548 (62.0)	42484 (56.2)
	1. Squid catch (t) SQU target	411 (39.5)	2744 (68.7)	7985 (82.6)	5411 (74.7)	25403 (85.0)	26397 (89.5)	22558 (87.3)
	2. Squid catch (t) MIX target	4178 (13.8)	14802 (45.4)	18732 (49.0)	12765 (36.1)	15380 (44.4)	15148 (41.4)	19927 (40.0)
	2a.Squid catch (t) MIX target (SQU target only)	3985 (37.6)	14474 (69.0)	1794 9 (71.6)	12415 (68.3)	14916 (69.8)	14923 (74.8)	19082 (75.0)
	2b.Squid catch (t) MIX target (no target SQU)	193 (1.0)	320 (2.8)	783 (6.0)	350 (2.0)	464 (3.5)	226 (1.4)	845 (3.5)
	3. Squid catch (t) none SQU target	51 (0.5)	27 (0.4)	31 (0.3)	16 (0.5)	21 (0.5)	2 (0.2)	0 (0.0)
SUBA	Number of vessels	26	25	36	28	25	29	21
	Number of tows	1147	1153	2618	1186	1552	888	519
	Total Catch (t)	13214	14412	19083	7718	10160	9750	8746
	Total squid catch (t)	34 (0.3)	4 (0.0)	85 (0.4)	651 (8.4)	1020 (10.0)	93 (1.0)	222 (2.5)
	1. Squid catch (t) SQU target	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	2. Squid catch (t) MIX target	27 (0.6)	4 (0.1)	80 (1.0)	650 (11.6)	1020 (12.0)	92 (1.0)	222 (3.4)
	2a.Squid catch (t) MIX target (SQU target only)	5 (11.0)	2 (12.3)	11 (43.2)	606 (66.1)	909 (81.6)	76 (36.2)	175 (85.6)
	2b.Squid catch (t) MIX target (no target SQU)	22 (0.5)	1 (0.0)	69 (0.8)	44 (1.0)	111 (1.5)	16 (0.2)	47 (0.7)
	2b.Squid catch (t) MIX target (no target SQU)	22 (0.5)	1 (0.0)	69 (0.8)	44 (1.0)	111 (1.5)	16 (0.2)	47 (0.7)
WCSI	Number of vessels	25	50	44	39	41	35	31
	Number of tows	1985	4787	4342	4377	4499	3620	2932
	Total Catch (t)	22368	49710	51376	38742	33518	33207	28029
	Total squid catch (t)	10 (0.1)	110 (0.2)	139 (0.3)	282 (0.7)	439 (1.3)	146 (0.4)	192 (0.7)
	1. Squid catch (t) SQU target	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	2. Squid catch (t) MIX target	8 (0.1)	87 (0.3)	123 (0.4)	231 (0.9)	392 (1.6)	126 (0.4)	178 (0.7)
	2a.Squid catch (t) MIX target (SQU target only)	0 (0.0)	4 (4.0)	0 (0.0)	43 (31.8)	78 (49.9)	30 (10.8)	25 (38.5)
	2b.Squid catch (t) MIX target (no target SQU)	8 (0.1)	83 (0.3)	123 (0.4)	188 (0.8)	314 (1.3)	95 (0.3)	153 (0.6)
	3. Squid catch (t) none SQU target	2 (0.0)	23 (0.1)	17 (0.1)	52 (0.4)	47 (0.6)	20 (0.6)	14 (1.0)

Appendix A2: Species codes, common and scientific names, estimated catch weight, percentage of the total catch, and percentage of species catch discarded (to the nearest 0.01percent), of the top species by weight down to 0.01% of the catch from all observer records for the squid fishery from 1 Oct 1999 to 30 Sep 2006. Records are ordered by decreasing percentage of catch. These are calculated from summed raw records, and may be unreliable if coverage is not representative.

Species code	Common name	Scientific name	Estimated catch (t)	% of catch	% Discarded
SQU	Arrow squid	*Nototodarus sloanii, N. gouldi*	87213.8	79.53	0.21
BAR	Barracouta	*Thyrsites atun*	10091.6	9.20	0.62
SWA	Silver warehou	*Seriolella punctata*	3192.3	2.91	4.81
SPD	Spiny dogfish	*Squalus acanthias*	2147.4	1.96	80.88
JMA	Jack mackerel	*Trachurus declivis, T. s. murphyi, T. novaezelandiae*	1198.7	1.09	0.05
WAR	Common warehou	*Seriolella brama*	883.5	0.81	0.47
RBT	Redbait	*Emmelichthys nitidus*	809.8	0.74	35.40
RCO	Red cod	*Pseudophycis bachus*	653.2	0.60	6.05
CRB	Crab general	Decapoda	388.0	0.35	97.15
NCB	Smooth red swimming crab	*Nectocarcinus bennetti*	323.3	0.29	84.71
HOK	Hoki	*Macruronus novaezelandiae*	321.3	0.29	14.72
RAT	Rattails	Macrouridae	259.2	0.24	85.58
LIN	Ling	*Genypterus blacodes*	247.9	0.23	0.62
SDO	Silver dory	*Cyttus novaezealandiae*	246.1	0.22	87.71
STU	Slender tuna	*Allothunnus fallai*	154.0	0.14	10.40
GSH	Ghost shark	*Hydrolagus novaezealandiae*	118.5	0.11	14.23
RBM	Ray's bream	*Brama brama*	103.0	0.09	22.57
HAP	Hapuku	*Polyprion oxygeneios*	100.7	0.09	0.65
STA	Giant stargazer	*Kathetostoma giganteum*	86.1	0.08	2.08
SSK	Smooth skate	*Dipturus innominatus*	75.3	0.07	3.84
SKI	Gemfish	*Rexea solandri*	73.6	0.07	1.09
SCH	School shark	*Galeorhinus galeus*	70.1	0.06	2.13
FRO	Frostfish	*Lepidopus caudatus*	59.0	0.05	0.16
BSK	Basking shark	*Cetorhinus maximus*	57.9	0.05	100.00
JAV	Javelinfish	*Lepidorhynchus denticulatus*	52.8	0.05	91.39
WWA	White warehou	*Seriolella caerulea*	46.7	0.04	0.25
TAR	Tarakihi	*Nemadactylus macropterus*	42.3	0.04	1.28
GSC	Giant spider crab	*Jacquinotia edwardsii*	40.7	0.04	50.25
SPE	Sea perch	*Helicolenus* spp	40.1	0.04	3.68
ROK	Rocks and stones	-	38.1	0.03	56.54
RSK	Rough skate	*Dipturus nasutus*	35.3	0.03	1.74
POS	Porbeagle shark	*Lamna nasus*	32.3	0.03	67.87
SPI	Spider crab	-	25.1	0.02	98.96
SWC	Swimming crab	-	23.4	0.02	93.83
NCA	Red swimming crab	*Nectocarcinusantarcticus*	23.0	0.02	97.20
SPO	Rig	*Mustelus lenticulatus*	20.4	0.02	63.81
CDO	Capro dory	*Capromimus abbreviatus*	18.9	0.02	63.47
PAD	Paddle crab	*Ovalipes catharus*	18.8	0.02	82.09
CAR	Carpet shark	*Cephaloscyllium isabellum*	17.5	0.02	99.94
CBE	Crested bellowsfish	*Notopogon lilliei*	15.5	0.01	90.63
MAK	Mako shark	*Isurus oxyrinchus.*	13.5	0.01	82.82
SSI	Silverside	*Argentina.elongata*	12.1	0.01	79.31
SAL	Salps	-	11.4	0.01	97.59
HPB	Hapuku and bass	*Polyprion oxygeneios, P. americanus*	9.4	0.01	3.49
GMU	Grey mullet	*Mugil cephalus*	9.3	0.01	100.00
WIT	Witch	*Arnoglossus scapha*	9.3	0.01	88.76
BCO	Blue cod	*Parapercis colias*	9.2	0.01	4.33
BEL	Bellowsfish	*Centriscops spp.*	8.9	0.01	23.83
SBW	Southern blue whiting	*Micromesistius australi*	8.7	0.01	0.43
BWS	Blue shark	*Prionace glauca*	8.5	0.01	81.70
GON	Gonorynchus forsteri & G. Greyi	*Gonorynchus forsteri, G. greyi*	7.0	0.01	93.99

Appendix A2 continued.

Species code	Common name	Scientific name	Estimated catch (t)	% of catch	% Discarded
MUD	Mud	-	6.9	0.01	100.00
BSH	Seal shark	*Dalatias licha*	6.4	0.01	82.87
SNA	Snapper	*Pagrus auratus*	5.6	0.01	0.47

Appendix A3: Number of vessels, trips, total greenweight (all species) and squid greenweight processed weights by fishing year.

		Fishing year						
Data set		1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
TCEPR data	Number of vessels	97	107	99	101	90	89	85
	Number of trips	722	896	842	808	789	846	832
	Total catch weight (t)	153127	191494	215822	180426	206649	217482	206615
	Squid catch weight (t)	18035	31790	44651	38655	77476	73654	62769
CELR data	Number of vessels	90	98	84	85	85	91	93
	Number of trips	601	859	561	610	747	978	867
	Total catch weight (t)	5183	8430	5165	6724	6886	8065	8278
	Squid catch weight (t)	441	1543	509	603	462	766	918
Landing data	Number of vessels	184	201	182	183	174	179	176
(trips associated with TCEPR	Number of trips	1322	1750	1411	1418	1532	1822	1691
and CELR above)	Total green weight (t)	171377	219174	248070	211157	233433	244019	237969
	Squid green weight (t)	19446	34878	47766	40690	81932	76235	66657
	Squid processed weight (t)	17728	29819	40640	36402	70890	69343	58381
Landing data	Number of vessels	256	263	241	238	244	224	220
(all trips where SQU landed)	Number of trips	4409	4640	4183	4193	4294	4500	4196
	Total green weight (t)	389293	408717	435015	388772	376048	370490	359770
	Squid green weight (t)	19702	35049	47932	40868	82080	76382	66795
	Squid processed weight (t)	17978	29985	40907	36589	71056	69504	58533

Appendix A4: Number of TCEPR vessels, tows, total catch and squid total catch and squid target catch by fishing year and target category

		Fishing year						
	Target category	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
Number of vessels	1. Vessel-year target SQU	1	3	1	1	0	4	2
	2. Partial vessel-year target SQU trip	14	14	20	22	29	29	28
	3. Partial vessel-year target MIX trip	36	38	38	43	40	40	43
	4. Non target SQU	60	66	60	57	50	45	40
	Total	97	107	99	101	90	89	85
Number of tows	1. Vessel-year target SQU	5	546	317	6	0	882	112
	2. Partial vessel-year target SQU trip	921	1 272	1 864	2 157	4 738	4 773	3 976
	3. Partial vessel-year target MIX trip	12 864	16 822	17 013	17 829	14 479	16 049	15 587
	4. Non target SQU	13 028	14 378	13 959	10 126	9 726	10 165	9 240
	Total	26 818	33 018	33 153	30 118	28 943	31 869	28 915
Total catch (t)	1. Vessel-year target SQU	4.6	734.8	624.7	0.2	0	6 037.3	688.3
	2. Partial vessel-year target SQU trip	4 239.7	6 637.8	14 367.0	16 113.3	58 748.1	42 721.5	39 294.9
	3. Partial vessel-year target MIX trip	87 037.9	126 494.6	136 247.8	122 601.0	106418.6	149 522.0	152 017.2
	4. Non target SQU	61 845.1	57 626.5	64 582.8	41 711.0	41482.6	19 201.4	14 614.3
	Total	1 531 27.3	191 493.7	215 822.2	180 425.5	206 649.4	217 482.2	206 614.7
Squid catch (t)	1. Vessel-year target SQU	0.2	25.4	15.9	0.0	0.0	5 042.5	515.1
	2. Partial vessel-year target SQU trip	2 535.4	4 516.6	11 516.8	13 053.6	51939.4	38 304.7	34 488.5
	3. Partial vessel-year target MIX trip	15 393.4	27 083.0	33 008.0	25 470.2	25251.2	30 209.4	27 669.5
	3a. Target SQU tows	14 648.5	25 635.1	31 592.7	24 326.0	24 094.8	29 381.7	26 370.6
	3b. Non target SQU tows	744.9	1438.5	1415.2	1144.3	1156.2	827.7	1298.8
	4. Non target SQU	105.5	164.7	119.9	131.1	285.1	96.9	96.3
	Total	18 034.5	31 789.6	44 650.6	38 654.9	77475.5	73 653.5	62 769.4
Percent squid catch	1. Vessel-year target SQU	4.7	3.4	2.6	0.0	0.0	83.5	74.8
	2. Partial vessel-year target SQU trip	59.8	68.0	80.2	81.0	88.4	89.7	87.8
	3. Partial vessel-year target MIX trip	17.7	21.4	24.2	20.8	23.7	20.2	18.2
	4. Non target SQU	0.2	0.3	0.2	0.3	0.7	0.5	0.7
	Total	11.8	16.6	20.7	21.4	37.5	33.9	30.4

Appendix A5: Bycatch rates in the squid fishery by fishing year and area for species categories examined. Standard deviations calculated from bootstrap samples are shown in parentheses. See Figure 1 for area boundaries.

QMS (All QMS species)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	91.78 (13.47)	897.30 (174.99)	282.71 (48.78)	836.00 (131.31)
2000–01	113.57 (15.08)	795.46 (194.40)	281.57 (49.19)	626.71 (67.01)
2001–02	21.45 (4.62)	1118.12 (141.16)	350.34 (44.31)	1137.05 (187.76)
2002–03	83.73 (30.74)	633.47 (151.01)	187.83 (36.58)	797.28 (121.59)
2003–04	95.96 (31.49)	901.94 (179.20)	282.54 (49.38)	684.20 (140.88)
2004–05	47.86 (13.64)	891.87 (181.67)	441.06 (42.14)	319.76 (45.43)
2005–06	53.68 (15.74)	895.35 (177.73)	281.98 (49.11)	629.96 (105.41)

Non-QMS (All non-QMS species)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	27.40 (9.66)	98.50 (16.01)	130.69 (31.56)	90.67 (34.84)
2000–01	62.35 (18.70)	61.13 (12.16)	130.27 (30.97)	38.13 (8.44)
2001–02	43.91 (12.27)	97.16 (22.89)	58.33 (26.93)	87.52 (40.53)
2002–03	97.42 (13.71)	48.41 (7.94)	71.27 (18.77)	45.56 (9.63)
2003–04	68.06 (28.78)	97.87 (16.24)	129.18 (32.21)	48.44 (18.26)
2004–05	68.97 (14.09)	98.83 (16.10)	437.85 (175.23)	41.29 (14.36)
2005–06	80.86 (25.94)	97.11 (16.59)	130.52 (31.35)	23.84 (5.92)

BAR (Barracouta)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	40.48 (8.90)	205.78 (59.94)	27.18 (7.89)	500.46 (77.41)
2000–01	96.53 (13.80)	437.75 (160.84)	26.96 (8.02)	379.02 (38.67)
2001–02	9.35 (2.66)	316.52 (78.93)	6.96 (1.29)	611.46 (184.73)
2002–03	17.43 (6.87)	32.26 (8.36)	18.38 (3.98)	269.35 (107.34)
2003–04	1.00 (0.30)	208.02 (61.64)	27.52 (8.02)	400.64 (119.22)
2004–05	5.72 (1.75)	210.32 (61.62)	90.75 (16.72)	183.75 (49.67)
2005–06	13.77 (11.37)	205.10 (60.02)	27.41 (8.02)	363.61 (87.97)

SWA (Silver warehou)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	36.16 (10.83)	204.58 (64.97)	54.13 (17.44)	66.65 (18.73)
2000–01	1.64 (0.72)	103.60 (22.95)	54.55 (16.03)	63.38 (10.19)
2001–02	3.39 (1.14)	148.36 (74.61)	35.38 (18.68)	129.75 (36.95)
2002–03	1.75 (0.67)	251.27 (139.04)	45.56 (18.33)	237.34 (81.87)
2003–04	69.63 (29.25)	205.67 (64.73)	54.32 (16.52)	134.82 (16.79)
2004–05	15.18 (5.08)	210.40 (68.55)	61.33 (22.67)	66.06 (35.18)
2005–06	15.12 (7.83)	202.66 (68.18)	54.92 (15.39)	97.46 (27.33)

Appendix A5: Bycatch rates continued.

SPD (Spiny dogfish)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.08 (0.05)	158.25 (51.18)	67.28 (15.21)	16.44 (6.63)
2000–01	0.61 (0.55)	96.80 (32.26)	65.66 (15.72)	52.65 (10.01)
2001–02	0.28 (0.42)	196.55 (58.07)	129.86 (22.01)	179.84 (66.37)
2002–03	1.02 (0.51)	42.90 (10.79)	28.53 (7.16)	180.36 (55.29)
2003–04	0.89 (0.42)	154.96 (49.10)	66.99 (15.61)	57.73 (12.66)
2004–05	0.20 (0.09)	156.70 (49.67)	121.68 (23.03)	27.11 (6.76)
2005–06	0.32 (0.23)	160.58 (51.05)	67.39 (15.62)	46.40 (12.36)

JMA (Jack mackerel)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.08 (0.05)	42.56 (31.02)	3.63 (1.37)	150.41 (50.47)
2000–01	0.05 (0.03)	4.55 (5.71)	3.62 (1.40)	51.86 (14.07)
2001–02	0.05 (0.02)	156.17 (57.10)	1.61 (0.50)	126.65 (44.52)
2002–03	0.01 (0.01)	0.32 (0.23)	0.69 (0.29)	1.08 (0.77)
2003–04	0.02 (0.03)	44.42 (32.14)	3.65 (1.40)	8.98 (3.27)
2004–05	0.02 (0.02)	43.87 (31.85)	17.79 (5.04)	2.64 (2.73)
2005–06	0.01 (0.01)	42.10 (29.23)	3.62 (1.36)	17.28 (8.98)

WAR (Common warehou)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.00 (0.00)	0.08 (0.05)	5.41 (13.80)	78.87 (42.16)
2000–01	0.00 (0.00)	0.00 (0.00)	9.20 (13.20)	42.07 (13.30)
2001–02	0.00 (0.00)	0.00 (0.00)	1.39 (0.67)	8.41 (4.41)
2002–03	0.01 (0.01)	0.00 (0.00)	0.09 (0.05)	4.03 (4.67)
2003–04	0.00 (0.00)	0.08 (0.05)	7.00 (13.13)	53.98 (25.93)
2004–05	0.02 (0.02)	0.08 (0.05)	7.17 (2.93)	5.70 (3.34)
2005–06	0.01 (0.02)	0.08 (0.05)	10.24 (13.40)	40.85 (34.19)

RBT (Redbait)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.03 (0.01)	0.76 (0.58)	15.86 (15.17)	86.13 (35.62)
2000–01	0.17 (0.11)	0.01 (0.01)	14.96 (15.84)	20.08 (7.94)
2001–02	0.04 (0.21)	2.85 (1.33)	0.41 (0.23)	75.72 (41.72)
2002–03	0.06 (0.09)	0.02 (0.02)	8.81 (3.92)	5.93 (1.81)
2003–04	0.00 (0.01)	0.74 (0.61)	14.60 (16.17)	31.17 (16.17)
2004–05	0.01 (0.01)	0.80 (0.60)	70.28 (94.97)	19.51 (13.18)
2005–06	0.00 (0.00)	0.75 (0.60)	15.95 (16.65)	5.01 (2.79)

RCO (Red cod)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	10.57 (3.96)	72.02 (12.26)	15.32 (3.43)	4.48 (2.72)
2000–01	3.64 (1.81)	42.11 (14.81)	15.58 (3.33)	6.06 (2.25)
2001–02	4.08 (1.95)	50.94 (8.41)	20.50 (5.63)	6.23 (2.02)
2002–03	48.03 (29.09)	115.67 (16.29)	10.61 (3.56)	18.25 (7.28)
2003–04	19.70 (8.35)	72.91 (12.29)	15.36 (3.34)	5.00 (1.91)
2004–05	20.55 (12.75)	72.06 (11.91)	26.50 (15.19)	7.23 (2.21)
2005–06	11.80 (6.82)	71.98 (12.20)	15.50 (3.30)	10.93 (4.25)

Appendix A5: Bycatch rates continued.

HOK (Hoki)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.73 (0.24)	40.09 (27.11)	10.51 (4.75)	2.00 (2.08)
2000–01	0.02 (0.02)	1.04 (1.32)	10.22 (4.63)	4.79 (2.62)
2001–02	1.13 (0.81)	34.82 (9.85)	18.12 (12.80)	27.66 (15.84)
2002–03	2.02 (1.85)	4.26 (1.62)	2.99 (2.39)	10.44 (4.85)
2003–04	0.94 (0.57)	38.11 (25.76)	10.54 (4.67)	0.51 (0.18)
2004–05	0.48 (0.19)	39.30 (25.74)	6.39 (12.06)	4.09 (2.80)
2005–06	0.72 (0.28)	40.11 (26.33)	10.46 (4.83)	11.74 (7.01)

LIN (Ling)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.01 (0.01)	9.58 (3.24)	3.12 (0.90)	0.78 (0.58)
2000–01	0.03 (0.02)	0.78 (0.40)	3.13 (0.88)	6.73 (2.61)
2001–02	0.09 (0.11)	15.55 (3.33)	5.71 (1.49)	8.20 (4.02)
2002–03	1.31 (0.94)	4.03 (1.15)	2.22 (0.68)	18.65 (6.83)
2003–04	0.13 (0.32)	9.49 (3.20)	3.15 (0.90)	7.24 (5.59)
2004–05	0.03 (0.01)	9.38 (3.16)	2.14 (1.08)	5.54 (1.99)
2005–06	0.24 (0.14)	9.49 (3.23)	3.16 (0.93)	12.18 (4.02)

Appendix A6: Discard rates in the squid fishery by fishing year and area for species categories examined. Standard deviations calculated from bootstrap samples are shown in parentheses. See Figure 1 for area boundaries.

QMS (All QMS species)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	3.29 (1.14)	177.65 (51.94)	131.83 (79.59)	20.11 (10.49)
2000–01	8.53 (6.32)	203.37 (50.58)	92.75 (47.92)	60.61 (12.30)
2001–02	3.54 (2.41)	165.02 (51.94)	91.47 (45.20)	165.66 (52.60)
2002–03	7.25 (1.61)	176.38 (50.24)	89.88 (43.65)	154.62 (52.15)
2003–04	11.59 (8.39)	173.30 (50.08)	91.35 (44.25)	63.12 (14.81)
2004–05	2.93 (1.20)	176.52 (53.02)	92.51 (46.04)	21.68 (5.93)
2005–06	3.42 (1.77)	171.59 (48.75)	91.66 (47.34)	43.23 (15.84)

Non-QMS (All non-QMS species)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	15.54 (6.81)	87.79 (17.05)	30.39 (6.36)	20.40 (14.33)
2000–01	52.70 (20.61)	46.64 (11.57)	91.01 (29.90)	15.48 (4.91)
2001–02	36.16 (10.87)	89.35 (21.80)	90.56 (28.59)	40.39 (19.38)
2002–03	101.81 (22.72)	86.87 (16.97)	91.54 (30.36)	39.34 (13.48)
2003–04	69.89 (33.51)	87.33 (17.01)	90.22 (29.90)	18.65 (8.36)
2004–05	34.32 (7.63)	87.71 (16.85)	90.95 (28.42)	25.62 (10.40)
2005–06	64.10 (23.84)	87.18 (17.06)	89.50 (28.08)	19.09 (8.00)

SQU (Arrow squid)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.22 (0.14)	0.91 (0.48)	1.57 (1.09)	0.68 (0.53)
2000–01	0.41 (0.25)	0.80 (0.73)	1.02 (0.57)	0.49 (0.21)
2001–02	1.69 (1.15)	0.27 (0.14)	1.02 (0.58)	12.29 (11.90)
2002–03	1.25 (0.92)	0.93 (0.51)	1.04 (0.63)	6.77 (3.52)
2003–04	11.61 (9.19)	0.92 (0.48)	1.01 (0.58)	7.84 (8.47)
2004–05	2.17 (1.61)	0.95 (0.51)	1.04 (0.59)	7.20 (4.66)
2005–06	1.15 (0.93)	0.95 (0.49)	1.00 (0.58)	7.45 (5.21)

Appendix A6: Discard rates continued.

RCO (Red cod)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	1.26 (0.84)	0.81 (0.60)	21.37 (21.25)	0.05 (0.02)
2000–01	0.10 (0.10)	0.11 (0.08)	12.14 (11.31)	0.08 (0.06)
2001–02	0.34 (0.29)	0.07 (0.05)	11.26 (10.84)	0.12 (0.07)
2002–03	5.19 (2.02)	0.76 (0.58)	12.04 (11.89)	0.36 (0.21)
2003–04	5.66 (7.10)	0.78 (0.60)	11.80 (11.43)	0.19 (0.10)
2004–05	0.78 (0.89)	0.79 (0.60)	12.26 (11.60)	0.10 (0.05)
2005–06	0.25 (0.17)	0.78 (0.61)	12.13 (11.64)	0.87 (0.46)

SDO (Silver dory)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.00 (0.00)	7.81 (4.87)	0.00 (0.00)	0.00 (0.00)
2000–01	0.03 (0.04)	1.01 (0.29)	0.15 (0.10)	0.50 (0.30)
2001–02	0.00 (0.00)	3.37 (0.86)	0.15 (0.10)	2.26 (1.65)
2002–03	0.00 (0.00)	8.05 (5.07)	0.14 (0.10)	11.98 (6.52)
2003–04	0.00 (0.00)	8.00 (5.02)	0.15 (0.10)	1.37 (0.64)
2004–05	0.00 (0.00)	7.89 (5.20)	0.15 (0.11)	3.34 (2.43)
2005–06	0.00 (0.00)	8.03 (4.97)	0.15 (0.11)	4.38 (3.29)

CRB (Crab general)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	3.93 (2.35)	1.19 (0.67)	0.00 (0.00)	0.07 (0.06)
2000–01	37.65 (18.03)	0.16 (0.10)	5.97 (6.29)	1.42 (1.00)
2001–02	29.88 (9.68)	1.92 (1.50)	6.90 (6.74)	0.95 (0.72)
2002–03	48.73 (13.47)	1.18 (0.63)	6.02 (6.03)	2.80 (1.64)
2003–04	58.46 (32.66)	1.18 (0.64)	6.14 (6.18)	2.29 (1.18)
2004–05	6.35 (5.28)	1.17 (0.62)	6.13 (6.21)	0.46 (0.17)
2005–06	0.41 (0.36)	1.18 (0.64)	6.01 (6.42)	0.27 (0.19)

All-CRB (All crab codes combined)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	4.45 (2.45)	1.29 (0.66)	0.00 (0.00)	0.08 (0.07)
2000–01	45.23 (17.99)	0.23 (0.11)	28.79 (18.43)	2.46 (1.22)
2001–02	30.45 (10.08)	2.29 (1.52)	29.55 (17.77)	1.03 (0.71)
2002–03	55.20 (11.84)	1.29 (0.65)	29.74 (18.29)	3.02 (1.77)
2003–04	68.80 (34.47)	1.27 (0.66)	30.70 (18.41)	2.48 (1.13)
2004–05	7.87 (4.96)	1.27 (0.67)	30.06 (18.05)	0.78 (0.25)
2005–06	2.61 (1.45)	1.28 (0.66)	30.63 (18.73)	0.39 (0.22)

Appendix A6: Discard rates continued.

SPD (Spiny dogfish)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.07 (0.04)	117.99 (40.23)	96.79 (81.20)	8.28 (2.52)
2000–01	0.81 (0.61)	97.02 (34.38)	64.39 (46.12)	46.19 (10.02)
2001–02	2.31 (2.30)	125.45 (46.91)	61.32 (42.23)	153.65 (50.67)
2002–03	1.09 (0.52)	116.87 (39.63)	61.01 (44.57)	148.96 (54.67)
2003–04	1.42 (0.76)	115.89 (39.80)	64.08 (44.31)	53.94 (12.04)
2004–05	0.20 (0.09)	118.66 (40.84)	62.50 (42.92)	17.92 (4.62)
2005–06	0.20 (0.14)	118.08 (40.46)	61.96 (42.90)	38.30 (14.38)

GON (*Gonorhynchus forsteri* & *Gonorhynchus greyi*)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.01 (0.00)	0.04 (0.03)	0.00 (0.00)	0.00 (0.00)
2000–01	0.00 (0.00)	0.00 (0.00)	0.07 (0.08)	0.10 (0.08)
2001–02	0.01 (0.01)	0.02 (0.02)	0.07 (0.08)	0.06 (0.03)
2002–03	0.19 (0.09)	0.05 (0.03)	0.07 (0.08)	0.38 (0.18)
2003–04	0.15 (0.12)	0.05 (0.03)	0.07 (0.08)	0.18 (0.07)
2004–05	0.05 (0.02)	0.05 (0.03)	0.08 (0.08)	0.28 (0.09)
2005–06	0.14 (0.07)	0.05 (0.03)	0.07 (0.08)	0.37 (0.14)

WIT (Witch)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.00 (0.00)	1.58 (0.78)	0.00 (0.00)	0.00 (0.00)
2000–01	0.10 (0.10)	0.40 (0.18)	0.03 (0.02)	0.11 (0.06)
2001–02	0.01 (0.01)	0.15 (0.13)	0.03 (0.02)	0.12 (0.06)
2002–03	0.03 (0.01)	1.58 (0.77)	0.03 (0.02)	0.51 (0.22)
2003–04	0.38 (0.21)	1.55 (0.77)	0.03 (0.02)	0.32 (0.13)
2004–05	0.08 (0.03)	1.56 (0.75)	0.03 (0.02)	0.14 (0.05)
2005–06	0.07 (0.03)	1.57 (0.76)	0.03 (0.02)	0.21 (0.10)

RBT (Redbait)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.00 (0.00)	0.77 (0.56)	0.05 (0.02)	16.17 (13.48)
2000–01	0.05 (0.05)	0.01 (0.01)	2.25 (2.86)	5.83 (3.26)
2001–02	0.00 (0.00)	2.40 (1.13)	2.51 (2.99)	31.88 (19.47)
2002–03	0.10 (0.09)	0.79 (0.56)	2.43 (2.80)	3.64 (1.81)
2003–04	0.00 (0.00)	0.78 (0.55)	2.43 (2.89)	2.26 (2.66)
2004–05	0.00 (0.00)	0.79 (0.57)	2.54 (2.95)	10.56 (8.77)
2005–06	0.00 (0.00)	0.77 (0.57)	2.47 (2.92)	16.17 (13.48)

RAT (Rattails)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.20 (0.11)	60.66 (13.29)	25.50 (6.17)	0.28 (0.19)
2000–01	2.58 (1.22)	34.66 (7.30)	52.70 (24.87)	1.30 (0.73)
2001–02	1.93 (1.16)	48.80 (12.42)	52.94 (26.14)	0.70 (0.53)
2002–03	19.03 (6.57)	60.90 (13.75)	52.91 (25.21)	4.58 (1.93)
2003–04	0.99 (0.74)	59.91 (13.70)	52.13 (24.23)	0.09 (0.06)
2004–05	2.05 (0.83)	60.64 (13.14)	52.37 (24.57)	2.93 (1.92)
2005–06	4.70 (2.06)	60.93 (13.56)	52.05 (25.52)	4.67 (2.56)

Appendix A6: Discard rates continued.

Shark (Shark combined species)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	10.95 (6.42)	8.17 (1.56)	0.42 (0.25)	4.11 (1.06)
2000–01	1.28 (0.63)	18.67 (4.87)	1.07 (0.56)	3.14 (0.71)
2001–02	1.92 (1.70)	10.00 (2.92)	1.08 (0.61)	2.59 (0.59)
2002–03	17.87 (16.90)	8.06 (1.54)	1.05 (0.59)	3.63 (0.92)
2003–04	0.46 (0.31)	8.18 (1.57)	1.07 (0.58)	1.63 (0.52)
2004–05	0.39 (0.26)	8.21 (1.55)	1.08 (0.60)	1.11 (0.53)
2005–06	0.18 (0.13)	8.10 (1.54)	1.09 (0.60)	1.46 (0.53)

BAR (Barracouta)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.00 (0.00)	0.24 (0.13)	0.00 (0.00)	0.04 (0.05)
2000–01	0.47 (0.49)	0.11 (0.06)	0.00 (0.00)	0.43 (0.52)
2001–02	0.02 (0.02)	0.55 (0.23)	0.00 (0.00)	1.30 (0.68)
2002–03	0.01 (0.01)	0.23 (0.13)	0.00 (0.00)	6.40 (8.52)
2003–04	0.05 (0.05)	0.23 (0.13)	0.00 (0.00)	8.88 (7.13)
2004–05	0.02 (0.02)	0.23 (0.13)	0.00 (0.00)	2.53 (1.81)
2005–06	0.23 (0.17)	0.24 (0.13)	0.00 (0.00)	1.18 (0.98)

SWA (Silver warehou)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.05 (0.07)	22.21 (9.80)	10.66 (7.94)	8.35 (9.19)
2000–01	0.04 (0.04)	79.22 (25.65)	11.66 (7.46)	7.37 (2.80)
2001–02	0.02 (0.02)	6.44 (4.51)	11.33 (7.01)	2.46 (2.50)
2002–03	0.01 (0.02)	22.24 (9.79)	11.60 (7.54)	1.09 (0.95)
2003–04	3.12 (3.15)	22.20 (9.71)	11.29 (7.28)	6.89 (5.45)
2004–05	0.05 (0.04)	21.90 (10.20)	11.04 (7.03)	1.94 (1.81)
2005–06	0.57 (0.54)	21.76 (9.70)	11.35 (7.32)	0.78 (0.53)

HOK (Hoki)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.00 (0.00)	8.23 (9.18)	0.00 (0.00)	0.00 (0.00)
2000–01	0.00 (0.00)	0.00 (0.01)	0.02 (0.02)	0.01 (0.01)
2001–02	0.00 (0.00)	3.87 (1.79)	0.02 (0.02)	6.56 (6.51)
2002–03	0.00 (0.00)	8.03 (9.12)	0.02 (0.02)	0.97 (0.85)
2003–04	0.08 (0.11)	8.29 (9.39)	0.02 (0.02)	0.00 (0.00)
2004–05	0.00 (0.00)	8.00 (9.26)	0.02 (0.02)	0.62 (0.49)
2005–06	0.04 (0.04)	8.41 (9.41)	0.02 (0.02)	1.96 (1.37)

JAV (Javelinfish)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	BANK	PUYS	SNAR
1999–00	0.00 (0.00)	7.26 (4.61)	0.58 (0.37)	0.00 (0.00)
2000–01	0.02 (0.02)	4.94 (5.35)	0.91 (0.38)	0.72 (0.69)
2001–02	0.03 (0.03)	18.10 (8.87)	0.91 (0.39)	0.14 (0.13)
2002–03	0.15 (0.06)	6.96 (4.47)	0.92 (0.39)	1.52 (0.95)
2003–04	0.63 (0.80)	7.31 (4.57)	0.90 (0.39)	0.01 (0.01)
2004–05	0.07 (0.05)	7.00 (4.38)	0.93 (0.41)	1.58 (1.46)
2005–06	1.57 (1.16)	7.17 (4.51)	0.93 (0.41)	2.46 (2.48)

Appendix B1: Number of TCEPR vessels, tows, total catch and scampi total catch and scampi target catch by fishing year, area, and target category. Numbers in brackets are percentage of catch to total catch for each area.

		Fishing year						
Area	Category	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
AUCK	Number of vessels	11	11	12	9	10	6	6
	Number of tows	1346	1429	1604	1396	1254	1276	1329
	Total Catch (t)	681	753	871	1161	1123	721	643
	Total scampi catch (t)	299 (44.0)	281 (37.3)	239 (27.5)	249 (21.4)	227 (20.2)	281 (38.9)	273 (42.4)
	Scampi catch (t) scampi target trips	299 (50.7)	281 (42.9)	239 (31.8)	249 (21.4)	212 (21.2)	281 (38.9)	273 (42.4)
WAIR	Number of vessels	10	9	11	9	8	8	8
	Number of tows	1561	1736	3119	1539	736	675	695
	Total Catch (t)	536	740	1364	647	411	375	324
	Total scampi catch (t)	190 (35.4)	191 (25.8)	230 (16.8)	114 (17.6)	56 (13.7)	62 (16.4)	70 (21.7)
	Scampi catch (t) scampi target trips	190 (35.6)	178 (24.5)	229 (16.8)	114 (17.6)	56 (14.0)	61 (16.4)	70 (21.7)
CHAT	Number of vessels	16	12	13	18	18	8	8
	Number of tows	1443	1267	1015	1118	1244	1718	2002
	Total Catch (t)	3223	2833	2476	2100	3077	1223	1134
	Total scampi catch (t)	308 (9.6)	314 (11.1)	285 (11.5)	286 (13.6)	265 (8.6)	386 (31.5)	357 (31.5)
	Scampi catch (t) scampi target trips	302 (50.1)	313 (52.8)	284 (30.8)	286 (21.2)	264 (27.3)	385 (31.5)	357 (31.5)
NRTH	Number of vessels	8	9	10	6	9	5	3
	Number of tows	683	861	1025	564	791	894	835
	Total Catch (t)	261	343	329	313	697	295	269
	Total scampi catch (t)	115 (44.2)	117 (34.3)	110 (33.5)	96 (30.7)	116 (16.6)	100 (34.0)	94 (35.0)
	Scampi catch (t) scampi target trips	115 (44.2)	117 (35.4)	110 (34.4)	96 (30.7)	116 (26.8)	100 (34.0)	94 (35.0)
PUYS	Number of vessels	2	2	1	4	1	2	1
	Number of tows	38	14	21	32	49	12	1
	Total Catch (t)	121	69	232	482	25	5	0.2
	Total scampi catch (t)	3 (2.4)	0 (0.1)	-	0.2 (0.0)	4 (15.5)	1 (12.3)	0.1 (42.9)
	Scampi catch (t) scampi target trips	3 (44.7)	0 (0.7)	-	0.2 (0.6)	4 (15.5)	1 (12.3)	0.1 (42.9)
SUBA	Number of vessels	4	3	3	4	4	-	-
	Number of tows	99	60	48	73	124	-	-
	Total Catch (t)	711	315	140	1963	1839	-	-
	Total scampi catch (t)	0.2 (0.0)	-	-	0.4 (0.0)	-	-	-
	Scampi catch (t) scampi target trips	0.2 (83.8)	-	-	0.3 (29.9)	-	-	-

Appendix B1: continued.

		Fishing year						
Area	Category	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
WCSI	Number of vessels	2	-	1	2	1	1	-
	Number of tows	13	-	2	30	14	4	-
	Total Catch (t)	1	-	1	115	125	1	-
	Total scampi catch (t)	0.3 (37.3)	-	-	-	-	-	-
	Scampi catch (t) scampi target trips	-	-	-	-	-	-	-
CHAL	Number of vessels	1	-	1	-	-	1	1
	Number of tows	6	-	17	-	-	5	2
	Total Catch (t)	0.2	-	17	-	-	1	1
	Total scampi catch (t)	0.0 (5.2)	-	-	-	-	0 (2.7)	-
	Scampi catch (t) scampi target trips	0.0 (5.2)	-	-	-	-	0 (2.7)	-

Appendix B2: Species codes, common and scientific names, estimated catch weight, percentage of the total catch, and percentage of species catch discarded (to the nearest 0.01 percent), of the top species by weight down to 0.1 % of the catch from all observer records for the scampi fishery from 1 Oct 1999 to 30 Sep 2006. Records are ordered by decreasing percentage of catch. These are calculated from summed raw records, and may be unreliable if coverage is not representative.

Species code	Common name	Scientific name	Estimated catch (t)	% of catch	% Discarded
SCI	Scampi	*Metanephrops challengeri*	602.5	18.59	0.6
JAV	Javelinfish	*Lepidorhynchus denticulatus*	527.1	16.26	93.7
RAT	Rattails	Macrouridae	391.4	12.07	84.5
SPE	Sea perch	*Helicolenus* spp.	331.7	10.23	59.3
LIN	Ling	*Genypterus blacodes*	202.9	6.26	2.7
HOK	Hoki	*Macruronus novaezelandiae*	168.4	5.20	5.7
FHD	Deepsea flathead	*Hoplichthys haswelli*	78.7	2.43	98.8
RCO	Red cod	*Pseudophycis bachus*	69.5	2.16	7.0
SWA	Silver warehou	*Seriolella punctata*	66.3	2.04	0.9
STA	Giant stargazer	*Kathetostoma giganteum*	65.5	2.02	2.5
GSH	Ghost shark	*Hydrolagus novaezealandiae*	60.8	1.87	6.2
CRB	Crab	Decapoda	51.0	1.57	99.8
SKA	Skate families	Rajidae and Arhynchobatidae	49.1	1.51	89.4
SPD	Spiny dogfish	*Squalus acanthias*	44.0	1.36	91.7
SSK	Smooth skate	*Dipturus innominatus*	43.3	1.34	35.4
SFI	Starfish	Asteroidea & Ophiuroidea	34.5	1.06	100.0
BBE	Banded bellowsfish	*Centriscops humerosus*	31.8	0.98	100.0
HAK	Hake	*Merluccius australis*	31.5	0.97	1.2
TOA	Toadfish	*Neophrynichthys* sp.	21.6	0.67	93.1
WWA	White warehou	*Seriolella caerulea*	19.8	0.61	0.5
SQU	Arrow squid	*Nototodarus sloanii, N. gouldi*	17.4	0.54	0.3
LDO	Lookdown dory	*Cyttus traverse*	17.0	0.52	64.2
RHY	Common roughy	*Paratrachichthy trailli*	14.9	0.46	97.6
BEL	Bellowsfish	*Centriscops* spp.	14.4	0.44	100.0
SKI	Gemfish	*Rexea solandri*	13.8	0.43	1.7
SSI	Silverside	*Argentina elongate*	13.4	0.41	68.2
ERA	Electric ray	*Torpedo fairchildi*	10.6	0.33	100.0
SRH	Silver roughy	*Hoplostethus mediterraneus*	9.6	0.30	100.0
CRU	Crustacea	*Crustacea*	9.4	0.29	100.0
RSK	Rough skate	*Dipturus nasutus*	9.3	0.29	27.3
ANT	Anemones	Anthozoa	9.1	0.28	98.9
BNS	Bluenose	*Hyperoglyphe antarctica*	8.8	0.27	0.0
CDO	Capro dory	*Capromimus abbreviatus*	7.3	0.23	100.0
SMK	Spiny masking crab	*Teratomaia richardsoni*	7.2	0.22	100.0
CAR	Carpet shark	*Cephaloscyllium.isabellum*	7.2	0.22	100.0
OCT	Octopus	*Pinnoctopus cordiformis*	7.1	0.22	95.3
CON	Conger eel	*Conger* spp.	6.9	0.21	100.0
HAG	Hagfish	*Eptatretus cirrhatus*	6.6	0.20	100.0
BER	Numbfish	*Typhlonarke* spp.	5.8	0.18	100.0
MDO	Mirror dory	*Zenopsis nebulosus*	5.7	0.18	75.2
SDO	Silver dory	*Cyttus novaezealandiae*	5.5	0.17	94.7
WSQ	Warty squid	*Moroteuthis spp*	5.4	0.17	100.0
FLA	Flatfish	-	5.2	0.16	100.0
SCH	School shark	*Galeorhinus galeus*	4.8	0.15	6.4
EEL	Marine eels	-	4.6	0.14	99.5
HAP	Hapuku	*Polyprion oxygeneios*	4.5	0.14	0.0
SND	Shovelnose dogfish	*Deania calcea*	4.2	0.13	99.5
SCC	Sea cucumber	*Stichopus mollis*	4.2	0.13	84.0
COU	Coral unspecified	-	3.9	0.12	100.0
ECH	Echinodermata	Echinodermata.	3.9	0.12	100.0

Appendix B2: continued.

Species code	Common name	Scientific name	Estimated catch (t)	% of catch	% Discarded
BSH	Seal shark	*Dalatias licha*	3.5	0.11	100.0
RIB	Ribaldo	*Mora moro*	3.3	0.10	22.0
YBO	Yellow boarfish	*Pentaceros decacanthus*	3.2	0.10	100.0
PSK	Longnosed deep sea skate	*Bathyraja shuntovi*	3.1	0.10	100.0
HIS	Jackknife prawn	*Haliporoides sibogae*	3.0	0.09	86.2
OPI	Umbrella octopus	*Opisthoteuthis* spp	2.9	0.09	100.0

Appendix B3: Number of vessels, trips, total greenweight (all species) and scampi greenweight processed weights by fishing year.

		Fishing year						
Data set		1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
TCEPR data	Number of vessels	17	15	18	19	21	9	9
	Number of trips	104	109	178	101	63	83	79
	Total catch (t)	5 648	5 051	5 430	6 780	7 779	2 622	2 371
	Scampi catch (t)	919	903	864	745	668	829	794
CELR data	Number of vessels	1	2	1	3	1	1	1
	Number of trips	26	25	16	50	4	1	1
	Total catch (t)	95	118	62	267	56	13	18
	Scampi catch (t)	9	12	24	38	7	0.1	0.1
Landing data	Number of vessels	18	17	19	22	22	10	10
(trips associated with TCEPR	Number of trips	130	134	194	151	67	82	79
and CELR above)	Total green weight (t)	6 548	5 857	7 493	8 022	11 494	2 950	2 804
	Scampi green weight (t)	1 031	985	994	882	767	907	895
	Scampi processed weight (t)	1 001	971	893	798	692	876	830
Landing data	Number of vessels	45	48	48	56	49	40	38
(all trips where SCI landed)	Number of trips	237	275	322	313	217	202	191
	Total green weight (t)	113 935	137 511	110 437	126 505	127 526	98 432	103 115
	Scampi green weight (t)	1 045	1 013	1 014	907	791	917	901
	Scampi processed weight (t)	1 013	992	906	817	707	882	834

Appendix B4: Number of TCEPR vessels, tows, total catch and scampi total catch and scampi target catch by fishing year and category

		Fishing year						
	Target category	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
Number of vessels	1. Vessel-year target SCI	9	9	13	16	14	9	9
	2. Partial vessel-year target SCI trip	1	1	-	-	2	-	-
	3. Partial vessel-year target MIX trip	1	1	1	-	2	-	-
	4. Non target SCI	7	5	4	3	5	-	-
	Total	17	15	18	19	21	9	9
Number of tows	1. Vessel-year target SCI	4 015	4 343	6 477	4 549	3 117	4 587	4 864
	2. Partial vessel-year target SCI trip	532	374	0	0	280	-	-
	3. Partial vessel-year target MIX trip	38	81	62	-	277	-	-
	4. Non target SCI	634	569	315	203	554	-	-
	Total	5 219	5 367	6 854	4 752	4 228	4 587	4 864
Total catch (t)	1. Vessel-year target SCI	1888.3	206.1	3378.3	3497.9	2506.7	2621.7	2371.4
	2. Partial vessel-year target SCI trip	109.6	104.7	-	-	320.6	-	-
	3. Partial vessel-year target MIX trip	9.7	20.6	190.8	-	903.7	-	-
	4. Non target SCI	3639.9	2719.7	860.9	3282.4	4048.3	-	-
	Total	5647.5	5051.1	5430.1	6780.2	7779.3	2621.7	2371.4
Scampi catch (t)	1. Vessel-year target SCI	820.8	810.5	863.5	744.9	568.4	829.0	794.2
	2. Partial vessel-year target SCI trip	91.8	77.7	-	-	83.5	-	-
	3. Partial vessel-year target MIX trip	3.7	13.9	0.8	-	14.9	-	-
	4. Non target SCI	2.5	0.7	0.2	0.1	1.0	-	-
	Total	918.9	902.9	864.5	745.0	667.9	829.0	794.2
Percent scampi catch	1. Vessel-year target SCI	43.5	36.7	25.6	21.3	22.7	31.6	33.0
	2. Partial vessel-year target SCI trip	83.8	74.2	-	-	26.0	-	-
	3. Partial vessel-year target MIX trip	38.4	67.2	0.4	-	1.6	-	-
	4. Non target SCI	0.1	<0.1	<0.1	<0.1	<0.1	-	-
	Total	16.3	17.9	15.9	11.0	8.6	31.6	33.5

Appendix B5: Bycatch rates in the scampi fishery by fishing year and area for species categories examined. Standard deviations calculated from bootstrap samples are shown in parentheses. See Figure 2 for area boundaries

QMS (All QMS species)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	42.82 (3.12)	122.07 (6.60)	26.41 (5.10)	49.71 (10.68)
2000–01	35.79 (2.02)	125.21 (16.95)	26.34 (5.13)	69.61 (3.40)
2001–02	63.64 (19.62)	172.53 (25.70)	26.15 (5.12)	94.48 (8.48)
2002–03	54.97 (16.46)	135.99 (19.43)	26.41 (5.06)	73.50 (8.09)
2003–04	52.05 (5.58)	109.10 (15.51)	26.39 (4.98)	73.59 (8.11)
2004–05	46.08 (4.77)	152.11 (38.98)	26.44 (5.24)	73.29 (8.24)
2005–06	14.37 (2.70)	54.14 (2.39)	14.74 (0.92)	73.45 (8.07)

Non-QMS (All non-QMS species)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	100.26 (4.47)	272.97 (12.88)	51.85 (5.66)	70.19 (13.61)
2000–01	51.08 (6.13)	135.66 (19.35)	51.91 (5.76)	63.45 (3.34)
2001–02	52.67 (17.28)	269.44 (63.64)	51.89 (5.67)	103.51 (32.41)
2002–03	66.90 (17.10)	85.80 (13.76)	51.77 (5.57)	80.75 (15.60)
2003–04	95.26 (16.90)	103.43 (13.89)	52.26 (5.71)	79.25 (15.08)
2004–05	66.47 (8.55)	173.87 (49.42)	51.91 (5.60)	80.06 (15.47)
2005–06	34.94 (4.44)	47.28 (2.40)	46.42 (1.75)	80.00 (14.93)

SPE (Sea perch)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.00 (0.00)	37.93 (4.53)	6.21 (1.88)	11.24 (1.69)
2000–01	0.00 (0.00)	48.66 (7.56)	6.24 (1.85)	12.47 (2.51)
2001–02	0.00 (0.00)	65.36 (10.12)	6.24 (1.86)	29.69 (3.81)
2002–03	0.00 (0.00)	55.98 (11.23)	6.08 (1.93)	18.70 (3.47)
2003–04	0.00 (0.00)	44.05 (7.75)	6.25 (1.81)	18.58 (3.43)
2004–05	0.00 (0.00)	71.68 (20.53)	6.18 (1.86)	18.72 (3.34)
2005–06	0.00 (0.00)	19.43 (1.23)	2.75 (0.16)	18.73 (3.41)

LIN (Ling)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	10.08 (1.34)	17.36 (1.37)	6.16 (1.90)	10.28 (2.40)
2000–01	9.44 (1.06)	16.82 (2.35)	5.99 (2.01)	16.28 (1.03)
2001–02	12.64 (3.91)	26.27 (2.34)	6.10 (1.99)	16.80 (3.62)
2002–03	10.85 (0.80)	19.31 (2.26)	6.05 (2.06)	15.46 (1.91)
2003–04	8.72 (1.19)	13.92 (1.71)	6.07 (2.03)	15.45 (1.92)
2004–05	9.08 (0.85)	20.98 (9.64)	6.01 (2.11)	15.64 (1.94)
2005–06	1.70 (0.27)	2.08 (0.29)	0.68 (0.09)	15.59 (1.94)

Appendix B5: Bycatch rates continued.

HOK (Hoki)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	6.60 (0.77)	14.71 (1.30)	0.00 (0.00)	11.00 (4.59)
2000–01	7.94 (0.69)	18.95 (1.79)	0.00 (0.00)	24.13 (1.46)
2001–02	14.22 (7.84)	17.18 (5.71)	0.00 (0.00)	19.52 (3.93)
2002–03	8.09 (1.13)	10.35 (1.56)	9.87 (0.83)	9.87 (0.85)
2003–04	3.16 (0.87)	9.33 (1.71)	6.34 (1.01)	6.35 (1.01)
2004–05	9.91 (3.86)	14.91 (2.95)	9.87 (3.97)	9.59 (3.91)
2005–06	1.32 (0.18)	9.10 (0.68)	3.65 (1.82)	3.69 (1.80)

RCO (Red cod)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	1.65 (0.39)	2.49 (0.33)	0.39 (0.06)	1.11 (0.55)
2000–01	3.49 (0.63)	2.79 (0.61)	0.39 (0.06)	3.29 (1.25)
2001–02	8.73 (1.84)	1.77 (0.41)	0.39 (0.06)	5.69 (2.09)
2002–03	8.80 (1.57)	4.27 (1.11)	0.39 (0.06)	3.33 (0.66)
2003–04	18.45 (2.05)	2.75 (0.85)	0.39 (0.06)	3.35 (0.68)
2004–05	8.21 (2.10)	1.40 (0.48)	0.39 (0.06)	3.36 (0.65)
2005–06	0.84 (0.46)	0.31 (0.08)	0.24 (0.04)	3.37 (0.70)

STA (Giant stargazer)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.70 (0.20)	6.55 (0.80)	0.28 (0.09)	2.23 (0.76)
2000–01	1.17 (0.19)	8.01 (1.32)	0.28 (0.09)	1.70 (0.38)
2001–02	1.63 (0.40)	10.03 (1.89)	0.27 (0.09)	6.77 (3.67)
2002–03	1.55 (0.46)	10.01 (1.63)	0.28 (0.09)	3.71 (1.65)
2003–04	1.63 (0.25)	9.78 (2.21)	0.28 (0.09)	3.66 (1.62)
2004–05	1.27 (0.14)	1.44 (0.54)	0.28 (0.09)	3.71 (1.70)
2005–06	0.45 (0.09)	2.86 (0.33)	0.08 (0.03)	3.72 (1.66)

GSH (Ghost shark)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	2.34 (0.44)	5.71 (0.63)	0.77 (0.11)	0.22 (0.16)
2000–01	4.13 (0.65)	6.58 (1.08)	0.76 (0.11)	1.06 (0.28)
2001–02	6.96 (3.79)	4.06 (1.17)	0.76 (0.11)	0.73 (0.56)
2002–03	4.26 (1.47)	5.56 (1.68)	0.77 (0.11)	0.64 (0.18)
2003–04	5.00 (0.51)	5.45 (1.38)	0.76 (0.12)	0.64 (0.17)
2004–05	4.42 (0.50)	15.94 (2.78)	0.77 (0.11)	0.65 (0.17)
2005–06	2.12 (0.32)	9.18 (0.85)	0.79 (0.17)	0.65 (0.17)

HAK (Hake)

	Mean bycatch rate $kg.h^{-1}$			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	2.42 (0.22)	3.81 (0.42)	0.01 (0.01)	0.08 (0.07)
2000–01	1.58 (0.15)	2.91 (0.53)	0.01 (0.01)	0.00 (0.00)
2001–02	6.02 (1.38)	8.88 (2.04)	0.01 (0.01)	0.01 (0.00)
2002–03	3.28 (0.96)	1.92 (0.40)	0.01 (0.01)	0.03 (0.01)
2003–04	4.24 (0.34)	2.06 (0.55)	0.01 (0.01)	0.03 (0.01)
2004–05	3.28 (0.50)	1.97 (0.92)	0.01 (0.01)	0.03 (0.01)
2005–06	0.23 (0.04)	0.09 (0.05)	0.00 (0.00)	0.03 (0.01)

Appendix B5: Bycatch rates continued.

SKI (Gemfish)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.66 (0.20)
2000–01	0.00 (0.00)	2.43 (0.65)	0.00 (0.00)	4.18 (0.57)
2001–02	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.95 (1.34)
2002–03	0.00 (0.00)	0.02 (0.03)	0.23 (0.19)	0.23 (0.20)
2003–04	0.00 (0.00)	0.00 (0.00)	0.04 (0.04)	0.03 (0.04)
2004–05	0.53 (0.23)	0.00 (0.00)	0.53 (0.24)	0.54 (0.23)
2005–06	0.00 (0.00)	0.00 (0.00)	0.64 (0.41)	0.66 (0.40)

BNS (Bluenose)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.00 (0.00)	0.05 (0.04)	0.28 (0.13)	1.37 (0.27)
2000–01	0.00 (0.00)	0.09 (0.03)	0.28 (0.14)	2.30 (0.58)
2001–02	0.00 (0.00)	0.11 (0.08)	0.29 (0.14)	2.64 (1.29)
2002–03	0.00 (0.00)	0.06 (0.02)	0.28 (0.14)	2.04 (0.49)
2003–04	0.00 (0.00)	0.09 (0.05)	0.29 (0.14)	2.05 (0.51)
2004–05	0.00 (0.00)	0.34 (0.17)	0.28 (0.13)	2.05 (0.50)
2005–06	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	2.05 (0.49)

SQU (Arrow squid)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	1.52 (0.14)	1.52 (0.14)	0.28 (0.11)	0.03 (0.02)
2000–01	3.73 (0.27)	3.73 (0.27)	0.28 (0.11)	0.05 (0.02)
2001–02	5.01 (0.79)	5.01 (0.79)	0.27 (0.11)	0.20 (0.10)
2002–03	1.78 (0.71)	1.78 (0.71)	0.27 (0.11)	0.10 (0.05)
2003–04	1.08 (0.25)	1.08 (0.25)	0.28 (0.11)	0.11 (0.05)
2004–05	2.52 (0.40)	2.52 (0.40)	0.28 (0.11)	0.10 (0.05)
2005–06	2.04 (0.91)	2.04 (0.91)	0.04 (0.01)	0.10 (0.05)

SWA (Silver warehou)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.63 (0.15)	14.11 (1.21)	0.17 (0.06)	0.41 (0.31)
2000–01	0.02 (0.01)	10.66 (2.36)	0.16 (0.06)	0.28 (0.09)
2001–02	0.16 (0.05)	26.02 (4.85)	0.17 (0.06)	7.15 (4.11)
2002–03	0.04 (0.03)	15.16 (4.90)	0.17 (0.06)	3.01 (2.04)
2003–04	0.07 (0.04)	3.48 (0.95)	0.17 (0.06)	3.02 (2.08)
2004–05	0.13 (0.06)	0.32 (0.14)	0.17 (0.06)	3.02 (2.09)
2005–06	0.03 (0.01)	0.21 (0.08)	0.06 (0.02)	3.03 (2.12)

WWA (White warehou)

	Mean bycatch rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.04 (0.04)	1.22 (0.21)	0 (0)	0.14 (0.06)
2000–01	1.07 (0.17)	1.02 (0.34)	0 (0)	0.68 (0.25)
2001–02	0.64 (0.13)	0.78 (0.20)	0 (0)	0.18 (0.13)
2002–03	10.24 (11.23)	0.77 (0.39)	0 (0)	0.33 (0.10)
2003–04	0.35 (0.09)	0.65 (0.44)	0 (0)	0.33 (0.10)
2004–05	2.68 (2.19)	5.39 (1.51)	0 (0)	0.33 (0.10)
2005–06	0.14 (0.07)	0.00 (0.00)	0 (0)	0.32 (0.10)

Appendix B6: Discard rates in the scampi fishery by fishing year and area for species categories examined. Standard deviations calculated from bootstrap samples are shown in parentheses. See Figure 2 for area boundaries.

QMS (All QMS species)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	16.47 (1.67)	45.76 (4.53)	5.77 (2.31)	11.73 (3.44)
2000–01	2.43 (0.37)	39.43 (10.16)	5.85 (2.33)	13.76 (2.76)
2001–02	7.04 (1.00)	53.90 (9.16)	5.84 (2.38)	25.62 (3.21)
2002–03	5.61 (1.36)	38.06 (12.40)	5.73 (2.27)	17.41 (2.30)
2003–04	1.35 (0.39)	40.69 (18.73)	5.69 (2.28)	17.43 (2.23)
2004–05	5.03 (1.51)	73.54 (16.37)	5.81 (2.42)	17.37 (2.23)
2005–06	1.97 (1.22)	4.16 (0.31)	3.18 (0.30)	17.40 (2.28)

Non-QMS (All non-QMS species)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	98.48 (5.01)	29.90 (3.78)	50.69 (6.00)	37.88 (13.28)
2000–01	50.78 (5.47)	113.86 (16.58)	50.88 (6.13)	62.57 (3.32)
2001–02	52.45 (17.85)	270.71 (63.17)	50.63 (6.23)	95.80 (30.57)
2002–03	66.55 (18.12)	85.63 (14.10)	50.77 (6.12)	66.71 (14.87)
2003–04	30.50 (5.76)	75.19 (12.89)	50.71 (6.16)	68.34 (15.28)
2004–05	50.65 (9.36)	171.34 (50.19)	50.37 (6.23)	67.16 (14.43)
2005–06	34.39 (4.58)	46.72 (2.50)	43.93 (1.65)	66.81 (14.87)

SPE (Sea perch)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.00 (0.00)	37.55 (4.58)	3.73 (1.89)	6.72 (3.17)
2000–01	0.00 (0.00)	27.01 (9.30)	3.69 (1.92)	13.71 (2.20)
2001–02	0.02 (0.02)	44.55 (11.83)	3.71 (1.93)	0.00 (0.00)
2002–03	0.00 (0.00)	31.20 (12.99)	3.82 (1.93)	5.68 (0.69)
2003–04	0.00 (0.00)	22.04 (9.79)	3.80 (1.90)	13.78 (2.20)
2004–05	0.00 (0.01)	65.27 (16.65)	3.70 (1.92)	13.74 (2.33)
2005–06	0.00 (0.00)	0.00 (0.00)	0.76 (0.09)	13.71 (2.21)

Appendix B6: Discard rates continued.

SPD (Spiny dogfish

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	6.40 (0.85)	0.14 (0.14)	0.63 (0.27)	0.93 (0.76)
2000–01	2.27 (0.38)	5.91 (1.44)	0.61 (0.27)	0.38 (0.23)
2001–02	1.53 (0.34)	6.46 (4.16)	0.62 (0.27)	0.00 (0.00)
2002–03	0.80 (0.48)	5.86 (1.46)	0.61 (0.27)	0.51 (0.48)
2003–04	0.41 (0.15)	8.49 (3.21)	0.63 (0.27)	0.38 (0.21)
2004–05	1.51 (0.61)	0.37 (0.27)	0.62 (0.27)	0.37 (0.21)
2005–06	0.14 (0.07)	4.11 (0.32)	0.43 (0.10)	0.37 (0.22)

JAV (Javelinfish)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	39.87 (2.67)	10.35 (1.38)	9.58 (1.30)	11.11 (3.69)
2000–01	30.82 (4.27)	51.40 (9.38)	9.64 (1.27)	19.47 (0.98)
2001–02	14.93 (7.84)	126.72 (26.35)	9.61 (1.32)	26.74 (7.21)
2002–03	23.76 (2.64)	30.13 (3.99)	9.59 (1.34)	19.45 (3.59)
2003–04	0.02 (0.03)	25.64 (5.76)	9.61 (1.32)	19.19 (3.55)
2004–05	16.05 (4.24)	93.98 (24.64)	9.47 (1.39)	19.40 (3.68)
2005–06	5.61 (0.39)	22.73 (1.95)	7.64 (0.37)	19.15 (3.54)

RAT (Rattails)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	16.10 (2.10)	8.46 (1.52)	0.79 (3.73)	3.73 (1.37)
2000–01	8.19 (0.82)	36.52 (7.11)	0.82 (11.33)	11.33 (1.24)
2001–02	6.08 (0.59)	91.71 (27.02)	0.75 (38.17)	38.17 (16.86)
2002–03	16.71 (7.80)	32.23 (8.03)	0.78 (19.36)	19.36 (8.85)
2003–04	0.21 (0.25)	23.10 (6.33)	0.80 (19.63)	19.63 (8.68)
2004–05	7.78 (1.79)	57.49 (6.38)	0.77 (19.84)	19.84 (8.67)
2005–06	4.15 (0.44)	6.43 (0.42)	0.35 (19.93)	19.93 (9.06)

SKA (Skate families)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.59 (0.16)	1.42 (0.54)	2.42 (1.25)	3.84 (3.02)
2000–01	1.68 (0.33)	2.64 (0.81)	2.30 (1.26)	8.22 (0.60)
2001–02	7.92 (3.56)	4.96 (3.03)	2.36 (1.28)	2.44 (1.79)
2002–03	0.73 (0.33)	4.09 (1.43)	2.40 (1.28)	4.39 (1.23)
2003–04	0.42 (0.19)	0.20 (0.10)	2.41 (1.25)	4.35 (1.20)
2004–05	2.00 (0.79)	0.00 (0.00)	2.36 (1.28)	4.38 (1.23)
2005–06	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.38 (1.23)

Appendix B6: Discard rates continued.

Crabs (All crabs)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	9.20 (0.78)	1.10 (0.54)	0.92 (0.52)	0.63 (0.51)
2000–01	4.02 (0.46)	1.17 (0.24)	0.90 (0.54)	1.07 (0.34)
2001–02	5.01 (1.89)	1.09 (0.57)	0.89 (0.52)	3.42 (1.25)
2002–03	7.50 (2.01)	1.07 (0.39)	0.93 (0.53)	1.95 (0.65)
2003–04	16.60 (5.40)	1.52 (0.43)	0.91 (0.52)	1.93 (0.67)
2004–05	6.98 (2.16)	0.49 (0.14)	0.88 (0.53)	1.94 (0.66)
2005–06	1.67 (0.96)	0.70 (0.08)	0.22 (0.08)	1.95 (0.67)

TOA (Toadfish)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	7.93 (0.80)	0.77 (0.51)	0.16 (0.05)	0.04 (0.03)
2000–01	0.34 (0.05)	0.81 (0.19)	0.16 (0.05)	0.27 (0.07)
2001–02	3.35 (2.42)	1.40 (0.51)	0.15 (0.05)	0.25 (0.17)
2002–03	1.50 (0.43)	0.41 (0.15)	0.16 (0.05)	0.19 (0.05)
2003–04	2.58 (0.82)	1.04 (0.44)	0.16 (0.05)	0.19 (0.05)
2004–05	2.58 (0.69)	0.15 (0.05)	0.16 (0.05)	0.19 (0.05)
2005–06	0.95 (0.06)	0.03 (0.01)	0.12 (0.02)	0.19 (0.05)

SFI (Starfish)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	7.12 (0.95)	2.93 (0.81)	0.33 (0.23)	0.49 (0.19)
2000–01	1.83 (0.28)	1.77 (0.51)	0.33 (0.22)	0.18 (0.06)
2001–02	3.17 (0.86)	2.34 (0.77)	0.34 (0.22)	7.43 (4.13)
2002–03	4.64 (1.69)	1.46 (0.69)	0.33 (0.24)	3.17 (2.15)
2003–04	0.09 (0.04)	1.12 (0.60)	0.34 (0.23)	2.93 (2.02)
2004–05	2.53 (0.77)	3.05 (0.63)	0.34 (0.23)	2.96 (2.08)
2005–06	0.15 (0.10)	1.63 (0.25)	0.02 (0.01)	2.91 (2.05)

FHD (Deepsea flathead)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.00 (0.00)	0.00 (0.00)	1.62 (0.32)	0.93 (0.73)
2000–01	0.00 (0.00)	10.32 (1.99)	1.62 (0.31)	0.46 (0.21)
2001–02	0.08 (0.02)	31.06 (4.39)	1.64 (0.30)	2.65 (1.51)
2002–03	0.08 (0.05)	6.51 (1.65)	1.63 (0.32)	1.43 (0.72)
2003–04	0.42 (0.16)	11.08 (2.20)	1.66 (0.29)	1.40 (0.70)
2004–05	0.15 (0.09)	6.24 (0.94)	1.64 (0.31)	1.38 (0.73)
2005–06	0.04 (0.03)	11.90 (0.95)	1.04 (0.08)	1.43 (0.73)

HOK (Hoki)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.00 (0.00)	3.18 (0.43)	0.01 (0.01)	1.23 (0.56)
2000–01	0.00 (0.00)	1.11 (0.49)	0.00 (0.01)	0.19 (0.11)
2001–02	0.27 (0.20)	0.00 (0.00)	0.00 (0.01)	1.74 (0.60)
2002–03	0.00 (0.00)	0.03 (0.03)	0.00 (0.01)	1.08 (0.34)
2003–04	0.01 (0.01)	1.69 (1.14)	0.01 (0.01)	1.08 (0.33)
2004–05	0.07 (0.06)	5.44 (0.87)	0.00 (0.01)	1.07 (0.33)
2005–06	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.08 (0.32)

Appendix B6: Discard rates continued.

LIN (Ling)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.00 (0.00)	0.22 (0.05)	0.02 (0.01)	0.43 (0.23)
2000–01	0.00 (0.00)	0.58 (0.56)	0.02 (0.01)	0.64 (0.21)
2001–02	1.20 (0.89)	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)
2002–03	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	0.28 (0.21)
2003–04	0.05 (0.05)	2.21 (1.84)	0.02 (0.01)	0.28 (0.21)
2004–05	0.31 (0.28)	0.11 (0.09)	0.02 (0.01)	0.28 (0.20)
2005–06	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)	0.28 (0.21)

RCO (Red cod)

	Mean discard rate kg.h^{-1}			
Fishing year	AUCK	CHAT	NRTH	WAIR
1999–00	0.47 (0.48)	0.97 (0.18)	0.07 (0.05)	0.19 (0.13)
2000–01	0.06 (0.04)	0.22 (0.10)	0.08 (0.05)	0.84 (0.33)
2001–02	0.02 (0.02)	0.02 (0.01)	0.08 (0.05)	1.16 (0.81)
2002–03	0.03 (0.02)	0.04 (0.02)	0.08 (0.05)	0.72 (0.19)
2003–04	0.86 (0.36)	0.47 (0.29)	0.08 (0.05)	0.70 (0.18)
2004–05	0.21 (0.12)	0.09 (0.06)	0.08 (0.05)	0.71 (0.18)
2005–06	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.71 (0.18)