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Fish and invertebrate bycatch and discards in New Zealand ling longline fisheries from 1992–93 until 2011–12

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Commercial catch-effort data and fisheries observer records of catch and discards by species provided by the Ministry for Primary Industries were used to estimate the rate and level of fish bycatch and discards in the ling longline fishery for each fishing year from 1992–93 to 2011–12. Separate estimates, along with estimates of precision, were made for three general categories of catch and discards; all QMS species combined, all non-QMS species combined, and all invertebrate species combined. In addition, estimates were made of the annual bycatch of a wide range of individual species.

Linear mixed-effect models (LMEs) were used to identify key factors influencing variability in the observed rates of bycatch and discarding in order to provide appropriate stratification for scaling up from the sampled component of the fishery to the entire commercial ling longline fishery. These models consistently identified the agreed separate fishery areas as having the greatest influence on these rates, therefore area was used to stratify the calculation of annual bycatch and discard totals in each catch category.

A rate estimator, based on the bycatch or discards per number of hooks deployed, was used to calculate bycatch and discard rates in each area and catch category for each fishing year. These rates were then multiplied by the total number of hooks deployed in each stratum, as determined from the commercial catch-effort data, to make annual estimates for the target ling longline fishery as a whole. Multi-step bootstrap methods, taking into account the effect of auto-correlation between sets for the same observed vessel and area stratum, were used to estimate the variance in the rates and provide confidence intervals for the annual bycatch and discard estimates.

Since 1992–93, when the observer programme began to cover this fishery, ling have accounted for about 68% of the total estimated catch weight recorded by observers. The remainder of the observed catch was comprised mainly of two QMS species, spiny dogfish (13% of total catch weight), and ribaldo (3%). Invertebrate species made up only a very small fraction of the overall catch (about 0.2%), with echinoderms (especially starfish) the main group caught. All but a few edible invertebrates (crustaceans and molluscs) were discarded.

Total annual bycatch in the ling longline fishery ranged from about 2000 t to 4000 t, with a slight decreasing trend over time. The majority of bycatch comprised QMS species, which, as a combined group, ranged from about 1400 t to 3200 t. Annual catches of combined non-QMS species were mostly 600–800 t and invertebrate species reached a maximum of about 30 t per year.

Estimated total annual discards ranged from about 1150 t to 2460 t and showed no trend over time. The majority of discards were QMS bycatch species (about 65% over all years), followed by non-QMS species (29%), ling (6%), and invertebrate species (1%). Discards showed no major increases or decreases over time in these categories, although linear regression models indicated significant decreasing trends in discards of ling and non-QMS species and an increasing trend in invertebrate discards but at low volumes. The species discarded in the greatest amounts were spiny dogfish and smooth skate.

The level of annual discards in the ling longline fishery, calculated as a fraction of the ling target catch, increased between 1992–93 and 2001–02 from 0.18 kg to 0.4 kg of discarded fish for every 1 kg of ling caught, and has subsequently remained at an average of 0.35 kg.

The annual catch of 116 individual bycatch species was estimated using the same methods as for the combined species categories, and trends examined. A total of 14 species showed a decreasing trend and 21 species an increasing trend in bycatch *levels* over time, although in some cases detection of trends was confounded by apparent changes over time in the species codes used by observers. Trends in bycatch *rates* of the main bycatch species were also examined and compared with published trends in relative biomass from trawl survey time series. There were few strong trends in either case, although increasing bycatch rates of spiny dogfish on the Chatham Rise were supported by an increasing trend in relative biomass for this species estimated from the Chatham trawl survey time-series.

1. INTRODUCTION

The Ministry for Primary Industries (MPI) National Deepwater Plan includes the following Environment Outcome related management objective: MO2.4. Identify and avoid or minimise adverse effects of deepwater and middle-depth fisheries on incidental bycatch species. This project partially addresses this objective by quantifying the level of bycatch of species or groups of species not managed separately in the Quota Management System (QMS). This project (DAE2010-02) highlights taxa where catch has changed over time, these changes may require additional investigation or potentially remediation measures. In this context recorded data is considered accurate, this may not be true in all cases, but this will need to be investigated on a case-by-case basis and is outside the remit of this project. The scampi (*Metanephrops challengeri*) and arrow squid (*Nototodarus* spp.) trawl fisheries were assessed in the first two years of the programme (Anderson 2012, 2013a), and the ling (*Genypterus blacodes*) bottom longline fishery is the subject of this report. Similar analyses will be made in subsequent years for each of the other MPI Deepwater Tier 1 fisheries, in the following order: hoki (*Macruronus novaezelandiae*)/hake (*Merluccius australis*)/ling trawl, jack mackerel (*Trachurus* spp.) trawl, southern blue whiting (*Micromesistius australis*) trawl, and orange roughy (*Hoplostethus atlanticus*)/oreo (Oreosomatidae) trawl.

Ling are widely distributed around New Zealand at depths of 200–800 m, especially south of 40° S. Line fishing is the method used most often when ling is targeted, with much of the effort on pre-spawning and spawning aggregations, especially on the Chatham Rise and Campbell Plateau. Other important line fisheries for ling exist on the west and east coasts of the South Island, off Southland, and on the Bounty Plateau (Anderson et al. 2000, Ballara 1997, Horn 2007). Line methods other than bottom longline account for only 1% of the total line catch (Horn 2007), although a fifth of the Cook Strait line catch between 1990 and 2005 was taken on dahn lines, with trot lining sometimes used. These two methods differ from bottom longlining in the vertical (vs horizontal) configuration of the hooks, and their use has declined in this fishery (Dunn et al 2013),

The New Zealand ling fishery reported annual landings have declined from the peak of 20 000–23 000 t in the second half of the 1990s to 12 000–14 000 t in the four years up to and including 2012–13 (Ministry for Primary Industries 2014). Export earnings of ling were NZD 45M in 2013 (http://www.seafoodnewzealand.org.nz/), making it New Zealand's third most valuable finfish fishery after hoki and tuna (*Thunnus* spp.). Longlining accounted for a quarter to a third of the annual catch of ling between 1989–90 and 2010–11 (Dunn et al 2013), the remainder being largely caught by trawlers. However, with between 16 and 35 million hooks deployed each year in this fishery, there remains considerable potential to make significant catches of both ling and non-target species that are unwanted due to species, size, damage, fish hold storage limitations, or which are lost and moribund due to operational inefficiencies and the actions of predators and scavengers

Observer and commercial catch-effort data have previously shown that ling account for between 68% and 77% of the total catch in the ling longline fishery, with the principal bycatch species previously listed as spiny dogfish (*Squalus acanthias*), red cod (*Pseudophycis bachus*), ribaldo (*Mora moro*), rough skate (*Zearaja nasuta*), and smooth skate (*Dipturus innominatus*) (Anderson 2008).

The most recent analysis of bycatch and discards in the ling longline fishery (Anderson 2008) used a number of hooks-based estimator and covered the period 1998–1999 to 2005–06; an earlier analysis, limited by a lack of observer data, used single bycatch and discard rates based on all observed sets to provide annual estimates for 1990–91 to 1997–98 (Anderson et al. 2000). These reports estimated total annual bycatch in the ling longline fishery for the combined period (1990–91 to 2005–06) to have ranged from about 1000 t to about 5000 t and total annual discards from about 400 t to about 2400 t. Annual estimates of the rate of discarding ranged from 0.22–0.39 kg of discards for every 1 kg of ling landed. In this assessment, new estimates of annual bycatch and discards were made for all years from 1992–93 to 2011–12, using a revised estimator, and the methods used in previous work were built on by examining temporal trends in more detail.

This report was prepared as an output from the MPI project DAE2010-02 "Bycatch monitoring and quantification of deepwater stocks" which has the following objectives.

Overall objective:

To estimate the level of non-target fish catch and discards of target and non-target fish species in New Zealand deepwater fisheries.

Specific objectives for year-3

1. To estimate the quantity of non-target fish species caught, and the target and non-target fish species discarded in the ling longline fishery, for the fishing years since the last review, using data from Ministry for Primary Industries Observers and commercial fishing returns.

2. To compare estimated rates and amounts of bycatch and discards from this study with previous projects on bycatch in the ling longline fishery.

3. To compare any trends apparent in bycatch rates in the ling longline fishery with relevant fishery independent trawl surveys.

4. To provide annual estimates of bycatch for nine Tier-1 species fisheries (SQU, SCI, HAK, HOK, JMA, ORH, OEO, LIN, SBW). This objective is reported on in a separate report (Anderson 2014), and repeated here for LIN (longline) only.

2. METHODS

2.1 Observer data

MPI observers have been making detailed set by set records of catch by species or species group for a portion of the ling longline fleet in each year since 1992–93. The allocation of observers on commercial vessels takes into account a range of data collection requirements and compliance issues for multiple fisheries, as well as the capacity for the vessel to accommodate additional personnel. It has therefore not always been possible to achieve a representative or random spread of observer effort in each fishery (see Section 3.1 for more details). Observer coverage in the ling longline fishery has varied through time but in most years, especially before 1999–2000 and after 2005–06, it represented less than 15% of the total target species catch from the fishery and was generally low relative to most of the offshore trawl fisheries observed. For a period of several years in the early 2000s, however, a high level of coverage was achieved, frequently representing over 20% (and up to a maximum of 52%) of the total target species catch from the fishery.

Overall, there has been a large amount of observer data collected, representing nearly 10 000 longline sets, by 24 vessels, and 13% of the total longline catch of ling.

2.1.1 Data preparation and grooming

For the analysis of the ling longline fishery, a dataset was prepared from the MPI observer database *cod*, based on all observed bottom longline sets targeting ling up to and including the 2011–12 fishing year. This dataset contains a complete set of catch by species for all relevant sets. Catches in various categories were removed from the initial extract; e.g., seaweed, birds, marine mammals, reptiles, and rubbish. The mean fish or invertebrate weight for each species was calculated from records where both weight and number of fish were recorded, and these values used to estimate catch weights where this was missing but number of fish was not.

As well as recording the catch weight (and, usually, the number of fish) for each species caught in each set, observers also usually record the discard status (discarded or retained). Discarded fish in this fishery fall into the following categories: unwanted non-QMS species, unwanted QMS species legally discarded under the 6th schedule of the Fisheries Act 1996 (e.g., spiny dogfish, smooth and rough skates), unwanted QMS species legally discarded under observer authorisation, fish of any species that are lost from the hook during landing or taken by marine predators (e.g., fur seals), fish smaller than the minimum legal size (e.g. red cod, 25 cm). However, due to procedural issues, this information has been entered into *cod* for only about a third of all observed sets. This is not a constant fraction over time and affects the earlier and later years most strongly. Before 1999–2000 there were no discard data available for any sets entered into *cod* and although there was an improvement after 1999–2000, so that by 2005–06 discards were entered for all sets, this did not last and in the last four years of the series discards were entered for less than 30% of sets (Figure 1).

Where discard status was recorded, it was used to determine the amount of discards by species, and these in turn were used to estimate discards for the remaining records, by calculating overall individual species discard rates and applying them to the recorded catch. These discard rates were calculated separately for numbers of fish and weights of fish where possible and an average taken. A separate set of discard rates were produced for two vessels for which landings records showed they had produced large amounts of fish meal from non-QMS species, suggesting that discards would be less. This procedure gave estimated discard weights for each species formulated as a constant fraction of the catch of that species. Discard information was not available from this source to calculate discard fractions for all catch species recorded by observers, but most species without any direct discard data were either clearly non-commercial species and assigned a discard fraction of 1, or were a quota species which must be retained. These quota species were assigned a discard fraction of 0.012, the value calculated from the available discard data for ling, to account for the small amount of unavoidable discarding due to lost or scavenged fish.

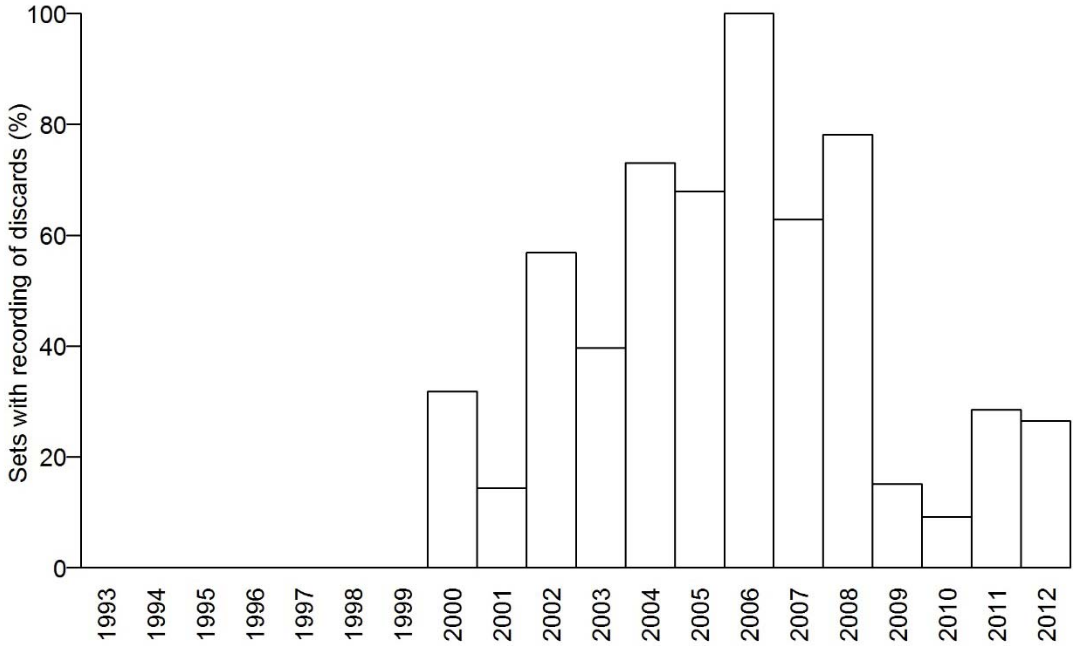

Figure 1: Percentage of sets in each fishing year for which discards were recorded by observers *and* entered in the *cod* database.

All records in the observer data were run through a set of checks and operations to ensure consistency, to correct or aid correction of erroneous values where possible, to remove records with missing values in critical fields, and to derive additional variables with the potential to describe patterns in variability of bycatch and discards.

- The bottom depth was calculated from the average of the recorded start and finish bottom depths. There were 14 records where number of hooks was missing for a set, and these were deleted.
- The length of each set, in kilometres, was calculated from the recorded start and finish positions. These can be considered minimum values, as sets are not always laid in a straight line, and were used primarily for identifying errors in recorded position. Records for which the start or finish position was incompletely recorded, or where the calculated distance was greater than 50 km were identified and groomed using median imputation to substitute approximate values. This process substitutes the missing value with the median start or finish latitude or longitude for other sets by the vessel on the same day. Set lengths were then recalculated from the corrected positions. Position data were completely missing for 44 records, which were deleted.
- The soak time for each set was derived from the difference between the recorded start time (when the first hook enters the water) and finish time (when the first hook leaves the water). Errors resulting from confusion between 12 and 24 h clock systems were identified and rectified where possible.
- Each record was assigned to an area (see Figure 2) as defined in Anderson (2008). Because of the patchy distribution of observer sampling, these areas were intentionally broad and based on known stock divisions or management areas, as well as the geographical distribution of observer sampling. Records from outside the defined areas (mostly outside the EEZ on the Challenger Plateau) were assigned as “OTHR”. The number of sets observed in each area in each year is shown in Table 1.
- Observer data were available from 24 vessels ranging in length from 14 to 54 m. Twelve of these were autoliners (generally larger vessels able to set over 20 000 hooks per day) and were identified as such in the dataset; no vessel is identified in this report, and alphanumeric vessel codes are presented where necessary.
- Other variables were also available from observer records, such as bait type and bottom topography, and these were groomed for errors and then included in the dataset, but not subsequently used.

Using the dataset described above, the weights of species caught and discarded in each set were calculated for the following species categories.

- All QMS species combined, excluding ling (QMS). Observers recorded 50 QMS species in total, excluding ling.
- All non-QMS species combined, excluding invertebrates (non-QMS).
- All non-QMS invertebrate species combined (INV).
- Individual species (bycatch only).

The above abbreviations (QMS, non-QMS, and INV) are used throughout the remainder of this report. Bycatch and discards were estimated separately for each of the combined species categories.

Summaries of the observed catch and percentage discarded of individual species, broad taxa, and species categories are tabulated in Appendices 1–4.

Table 1: Number of observed longline sets targeting ling by area (see Figure 2 for area boundaries) and fishing year.

	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	OTHR	PUYS	All areas
1992–93	78	0	0	0	0	0	88	0	0	0	166
1993–94	0	4	0	0	0	0	0	0	0	110	114
1994–95	90	81	0	0	0	56	176	0	2	0	405
1995–96	106	207	0	0	0	3	57	0	0	0	373
1996–97	0	13	0	0	0	0	249	0	0	0	262
1997–98	0	118	0	0	0	88	101	0	0	0	307
1998–99	0	328	0	0	0	0	131	0	25	0	484
1999–00	189	160	0	0	0	18	22	0	1	116	506
2000–01	111	259	49	0	1	0	4	0	0	320	744
2001–02	20	64	0	0	0	4	842	0	5	157	1 092
2002–03	548	73	31	0	0	68	654	8	0	221	1 603
2003–04	309	42	0	0	0	8	210	19	1	173	762
2004–05	31	90	0	29	0	7	110	0	0	57	324
2005–06	0	0	132	0	28	10	223	0	0	170	563
2006–07	0	0	85	95	42	54	50	0	0	88	414
2007–08	173	0	1	9	0	83	163	0	1	31	461
2008–09	67	77	0	0	0	61	294	0	0	0	499
2009–10	0	111	0	0	0	0	0	0	2	84	197
2010–11	0	67	0	0	0	87	109	0	0	0	263
2011–12	0	181	0	0	0	0	0	35	3	0	219
All years	1 722	1 875	298	133	71	547	3 483	62	40	1 527	9 758

2.2 Commercial longline fishing return data

Catch records from commercial fishing returns were obtained from MPI catch-effort databases for all bottom longline sets in which ling was the stated target species, for the period matching the available observer data, i.e., 1 October 1992 to 30 September 2012. This included all fishing events recorded on Catch, Effort and Landing Retrns (CELRs), Lining Catch, Effort Returns (LCERs), and Lining Trip Catch, Effort Returns (LTCERs). Data were groomed for errors using checking and imputation algorithms developed in the statistical software package R version 2.15.2 (R Core Team 2012). Set position, length, duration, depths, and number of hooks were all groomed in this manner, primarily employing median imputation and range checks to identify and deal with missing or unlikely values and outliers (see Dunn et al. 2013 and Horn & Ballara 2012 for more details on the procedures used).

These records, representing 114 074 sets, were assigned to the areas defined in Figure 2, as was done for the observer data, using the recorded position coordinates.

It is possible to use these commercial catch data to directly estimate the total annual non-target catch in this fishery, as for each set or group of sets the total catch (as well as the catch of the target species) is recorded, unless it is outside of the top five species by weight and therefore generally small. Such estimates are provided here for comparison with the observer-based estimates and are somewhat appealing because, in contrast to the observer-based estimates, no scaling is required. However, a study of this fishery, comparing commercial catch reports between observed and unobserved vessels, indicated that under-reporting and non-reporting of bycatch species had been common; for example only a quarter of the catch of the main bycatch species (spiny dogfish) was reported between 2001 and 2004 (Burns & Kerr 2008). This method also has the limitation that because only the top five species by weight were recorded (eight species after January 2004 (LCER forms) and October 2007 (LTCER forms)) it is not possible to properly estimate the bycatch of individual species or groups of species.

2.3 Analysis of factors influencing discards and bycatch

Regression analyses were used to identify the most useful strata for the calculations to scale up from the observer records to the whole fishery. Several potentially influential variables are recorded by observers for each observed set, but not all are useful for stratification of commercial data. For example, *vessel* and *trip* have been shown in previous analyses to be useful factors for predicting rates of bycatch and discards. But, since only a subset of the vessels and trips in any fishery are observed, it is problematic to calculate rates for those that were not. This potential source of bias was mitigated by employing linear mixed-effects models (LMEs), in which *trip* was treated as a random effect, and other variables treated as fixed effects. The fixed effect variables considered in the models for each species category were: fishing year (1992–93 to 2011–12); autoliner (y/n); month or fishing day (day of the fishing year, 1 to 366 starting on 1st October); area (see Figure 2); vessel tonnage (GRT); number of hooks set; meal-plant (y/n) (for those vessels mealing non-QMS species, see Section 2.1.1).

Each species category (QMS, non-QMS, INV, and LIN (discards)) was examined separately using log-linear and, where appropriate, binomial mixed-effect regression models. Binomial regression models were used only where there was a large proportion of zero values in the data (over 10%). This combined approach enabled an examination of factors influencing both the *probability* and the *level* of a bycatch or discard. The response variable in the binomial models comprised a binomial vector assigned "0" if no bycatch/discard was recorded and "1" otherwise. The log-linear model was fitted to positive records of bycatch/discards only.

From these regressions, summary tables were produced to show the order of variable selection in each model. Variables used to stratify data for bycatch and discard calculations were determined from these summaries.

2.4 Calculation of discard and bycatch rates

For each species category, the observed weights of catch and discards were summed within each stratum determined from regression analysis. From this, the discard rate, $\widehat{DR}$, and bycatch rate, $\widehat{BR}$ were derived, with the following forms,

$$\widehat{DR} = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} t_i} \quad \text{and} \quad \widehat{BR} = \frac{\sum_{i=1}^{m} b_i}{\sum_{i=1}^{m} t_i}$$

where m sets were sampled from a stratum, b_i is the weight of the catch from the ith set sampled, d_i the weight of the discarded catch from the ith set sampled, and t_i the number of hooks in the ith set.

Initially, the analysis used an estimator based on the number of sets rather than number of hooks. Comparison of the precision of the two alternatives using trial data indicated there was little difference between the two. However, the Aquatic Environment Working Group suggested that data errors may have arisen with the introduction of the LCER and LTCER forms in the 2000s which might have introduced a bias if the set-based estimator was used. In addition, the over-representation of large vessels in the observed part of the fishery may also have led to the overestimation of bycatch and discards when using a set-based estimator due to the greater number of hooks per set deployed by the larger vessels.

Using this rate estimator, estimates of $\widehat{BR}$ and $\widehat{DR}$ were derived for each stratum in each fishing year and variances were estimated by a multi-step bootstrapping procedure that allowed for correlation between sets within individual vessels. Specific rates were calculated for each fishing year/strata with 25 records or more. For strata with less than 25 records in the year, additional records were taken from the adjacent two years (the previous and subsequent year) or single year if at the start or end of the series. If there were still less than 25 records the next two adjacent years were included, and this process was continued until 25 records or more were available. The rate calculated was then multiplied by the total number of hooks set in that fishing year and stratum from commercial catch records for the target ling longline fishery, to estimate total bycatch $\widehat{B}$ and discards $\widehat{D}$.

$$(1) \qquad \widehat{B} = \sum_j \widehat{BR}_j \times T_j \quad \text{and} \quad \widehat{D} = \sum_j \widehat{DR}_j \times T_j$$

Where T_j is the number of hooks set in fishing year/strata cell j.

To obtain a 95% confidence interval for the total discards that takes into account vessel to vessel differences, variability in the total amount of fishing effort between vessels, and allows for correlation between sets by the same vessel, 1000 bootstrap samples were generated from the sets within each cell using a three-step sequential sampling procedure.

First a vessel was chosen at random, then a bootstrap sample was taken of the sets from that vessel that were in the cell. These steps were repeated until the effective number of sets was approximately equal to the effective number of observed sets for the cell. The effective number of vessels in the bootstrap sample was then calculated. If this was within 5% of the effective number of observed vessels in the cell, 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 sets and the effective number of vessels were calculated from the effort (number of hooks) and reflected the contributions to the variance of the bycatch/discard rate from the variance of the bycatch/discards and the covariance between pairs of bycatch/discard values for the same vessel and cell. Matching a bootstrap sample to the cell on these criteria ensured that the variation in the bootstrap sample estimate matched the sampling variation of $\widehat{B}$ or $\widehat{D}$. An empirical distribution for the total was obtained by summing the bootstrap estimates across all strata within a fishing year, and the 95% confidence interval was obtained from the 2.5% and 97.5% quantiles.

Bootstrapping procedures were carried out using the statistical software package R (R Core Team, 2012).

2.5 Analysis of temporal trends in bycatch and discards

Annual estimates of bycatch and discards in each species category and overall (with confidence intervals) were plotted for the whole time-series. Locally weighted regression lines were calculated and shown on the plots to highlight overall patterns of change over time.

In addition, to provide an indication as to the long-term trend in annual amounts, linear regressions (with lognormal errors and weighted by 1/variance) were also produced. The direction and steepness of the slopes of these lines were determined and the significance of the difference of these slopes from a slope of zero (indicating no trend) was tested.

2.6 Comparison of trends in bycatch rates with data from trawl surveys

Although this is a potentially valuable exercise where the research survey fishing method matches that of the commercial fishery (see Anderson 2012), no attempt was made to compare bycatch rate estimates for the combined species categories with any from trawl surveys. Differences in the relative catchability among species and fish sizes between the two methods are too difficult to resolve and no time series of longline research surveys exist with which to make useful comparisons between like methods.

However it may be useful to compare the estimated annual bycatch rates of individual non-target species in this fishery (from Specific Objective 4) with relative biomass estimates for the same species from the time series of middle-depth species surveys on the Chatham Rise (O'Driscoll et al. 2011) and sub-Antarctic (Bagley et al. 2013). These survey time-series both date from the early 1990s and also overlap substantially with the depth range and the spatial extent of a large part of the ling longline fishery. A summary of such comparisons was made for the bycatch species identified under Objective 4 as being caught in the greatest amounts.

2.7 Annual bycatch by individual species

For Objective 4, annual bycatch rates for individual QMS and non-QMS species (fish and invertebrates) in the ling longline fishery were calculated from observer records for the period 1992–93 to 2011–12. Species for which less than 10 kg of catch or less than 6 captures were recorded across all 20 years were ignored, as it was considered that either the capture of such species was so rare as to be irrelevant, or the species code may have been incorrectly recorded by the observer. Other non-informative species codes (e.g., FIS, unidentified fish; UNI, unidentified; and MIX, mixed fish) were also ignored, although these codes accounted for less than 0.1% of the total observed catch.

Annual species specific bycatch rates were multiplied by the annual effort (number of hooks) in the fishery to produce estimates of total annual bycatch in the same way as described for the combined species categories (QMS, non-QMS, and INV) in Section 2.4. Precision was estimated using the same bootstrapping procedure and stratification used for the combined species categories also as described in Section 2.4.

An indication of whether the bycatch of each species increased, decreased, or stayed relatively unchanged over time was calculated in the form of a slope coefficient for a loglinear regression fitted to the data. These slopes are provided only as a simple indicator of general changes over time, as the relationships may be non-linear and some trends may be strongly influenced by changes in observer recording of species over time.

3. RESULTS

3.1 Distribution and representativeness of observer data

The positions of all observed sets in the target ling longline fishery between 30 March 1993 (the date of the earliest observed set) and 30 September 2012 are shown, along with all sets recorded with position data on commercial fishing returns from the same period, in Figures 2 and 3.

Observer coverage has been reasonably well spread over the spatial extent of this fishery, especially within the main fisheries on the north and east Chatham Rise, the Bounty Plateau, the Pukaki, Auckland, and Campbell Rises on the Campbell Plateau, and the Puysegur Banks. Within the commercially fished areas on the western Chatham Rise (LIN 3) and the smaller fisheries around the North Island north of Hawke Bay (LIN 1 and LIN 2) and the west coast of the South Island (LIN 7) coverage was relatively poor. In general these areas with poorer coverage were fished by smaller vessels that would not normally carry observers (Table 2) and commercial effort data returned for them frequently lacked position data (as they used CELR forms which do not require it) and therefore were not fully represented in Figure 2. Effort data from the COOK, LIN 1, and LIN 7 fisheries, in particular, were lacking recorded position. The smaller COOK fishery received the most coverage overall, relative to its size, with observers present for about one third of all hooks set between 1992–93 and 2011–12. The largest fisheries (LIN 4, and CAMP) received a moderate amount of coverage, 13% and 16% respectively, but the next largest (LIN3) received quite low coverage (4.6%); the similar sized Bounty fishery received about six times the coverage of LIN 3.

The distribution of commercial effort changed over time in some areas. This was most noticeable in the fisheries of the Campbell Plateau, where the spread of effort declined after 2002–03 and fishing became more restricted to the Pukaki Rise region (Figure 3). Lower commercial effort in the Bounty area in more recent years was due to the departure from the fishery of a vessel which had been the mainstay of this fishery. Observer effort generally covered the main regions in each block of time examined (Figure 3), although it was entirely restricted to the Chatham Rise, Campbell Plateau, and Bounty Plateau in 1992–93 to 1996–97, and the Puysegur, southern Campbell Plateau, and east Coast fisheries were only sporadically observed during this period.

Table 2: Summary statistics for the ling longline fishery, by fishery area, for the period 1992–93 to 2011–12, including observer coverage and aspects of data quality (e.g. number of sets with positional data).

		Total effort				
Area	Median vessel length (m)	Number of sets	Number of hooks (millions)	Percent observed	Effort (sets) with position data (%)	Effort (sets) by vessels never observed (%)
LIN7	16.2	13 868	21.5	0.3	35.7	64.9
LIN1	17.6	7 146	10.9	0.9	29.5	68.3
LIN2*	18.3	13 565	24.6	1.5	41.7	60.7
COOK	19.2	2 214	5.8	34.5	41.8	11.2
LIN3	33.1	14 982	51.9	4.6	70.2	12.4
OTHR**	33.1	692	3.0	5.2	36.6	8.0
LIN4	35.4	33 408	178.5	13.2	93.9	4.5
CAMP	41.3	14 573	86.3	16.1	97.5	0.2
PUYS	46.5	6 798	43.9	24.8	95.3	1.7
BNTY	53.6	6 828	40.6	28.0	99.7	2.8

* excluding area COOK
** mainly ET and LIN5 outside of PUYS

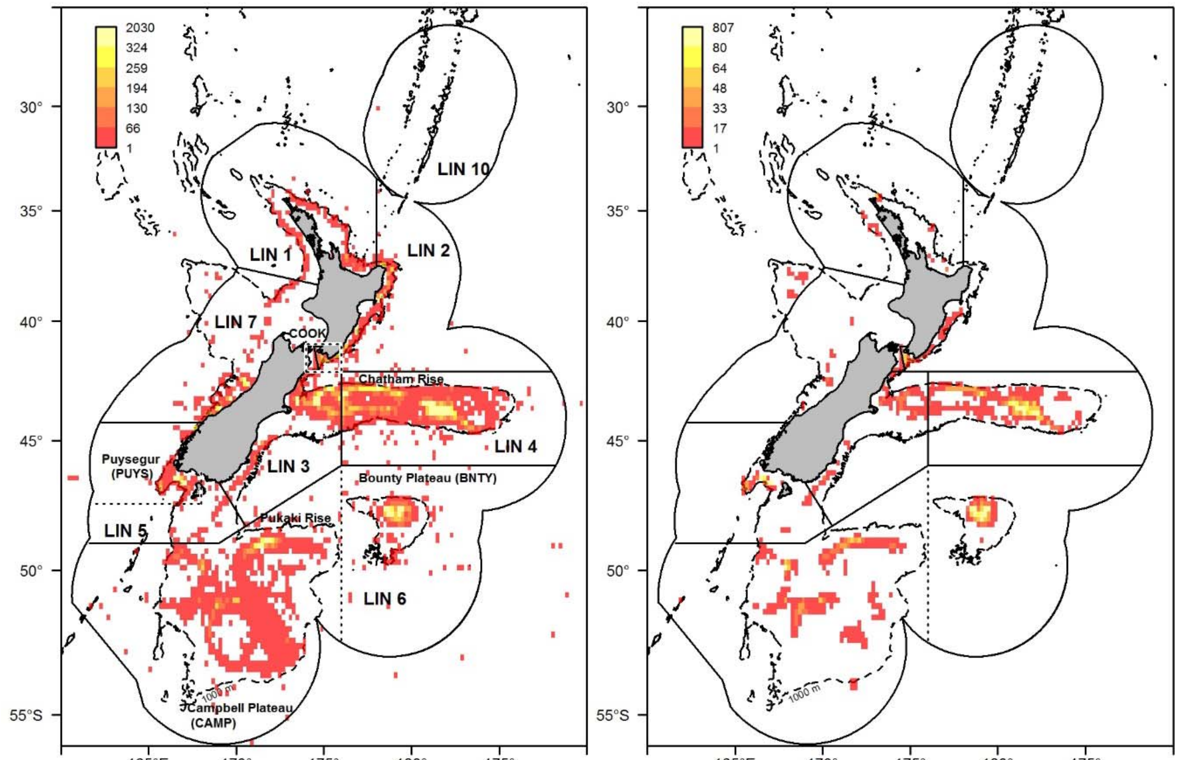

Figure 2: Density plots showing the distribution of all commercial longline sets with recorded position data targeting ling (left) and all sets recorded by observers on vessels targeting ling (right), for 1992–93 to 2011–12. The legend indicates the number of sets in each cell; solid lines mark the boundary of the EEZ and ling QMAs; dotted lines delineate other named areas used in the analyses (e.g. BNTY, COOK); dashed lines indicates the approximate 1000 m isobaths.

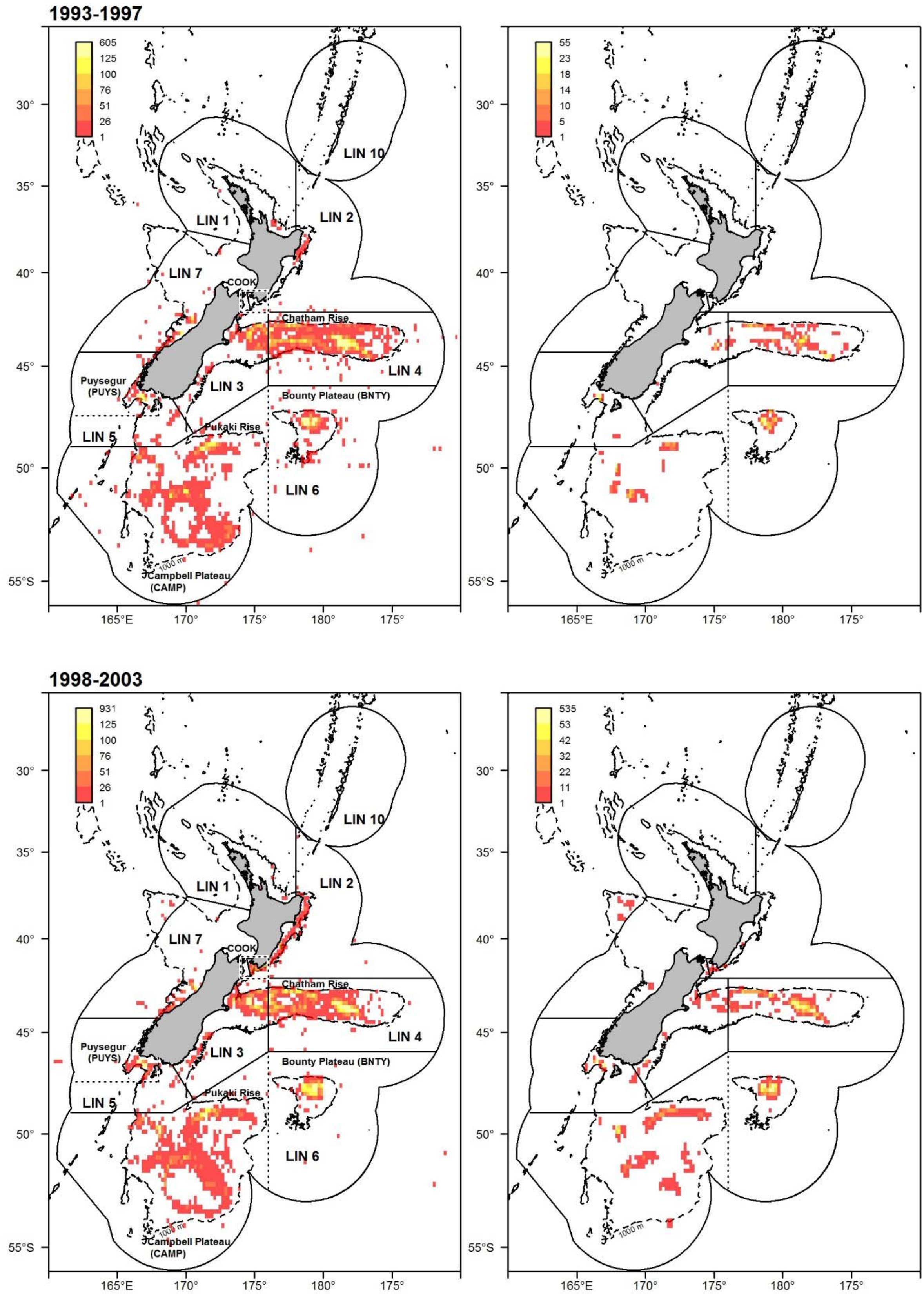

Figure 3: Density plots showing the distribution of all commercial longline sets with recorded position data targeting ling (left) and all sets recorded by observers on vessels targeting ling (right), by blocks of years. In the titles, 1993 = fishing year 1992–93, thus panel 1998–2003 represents fishing years 1997–1998 to 2002-2003. See Figure 2 caption for more details.

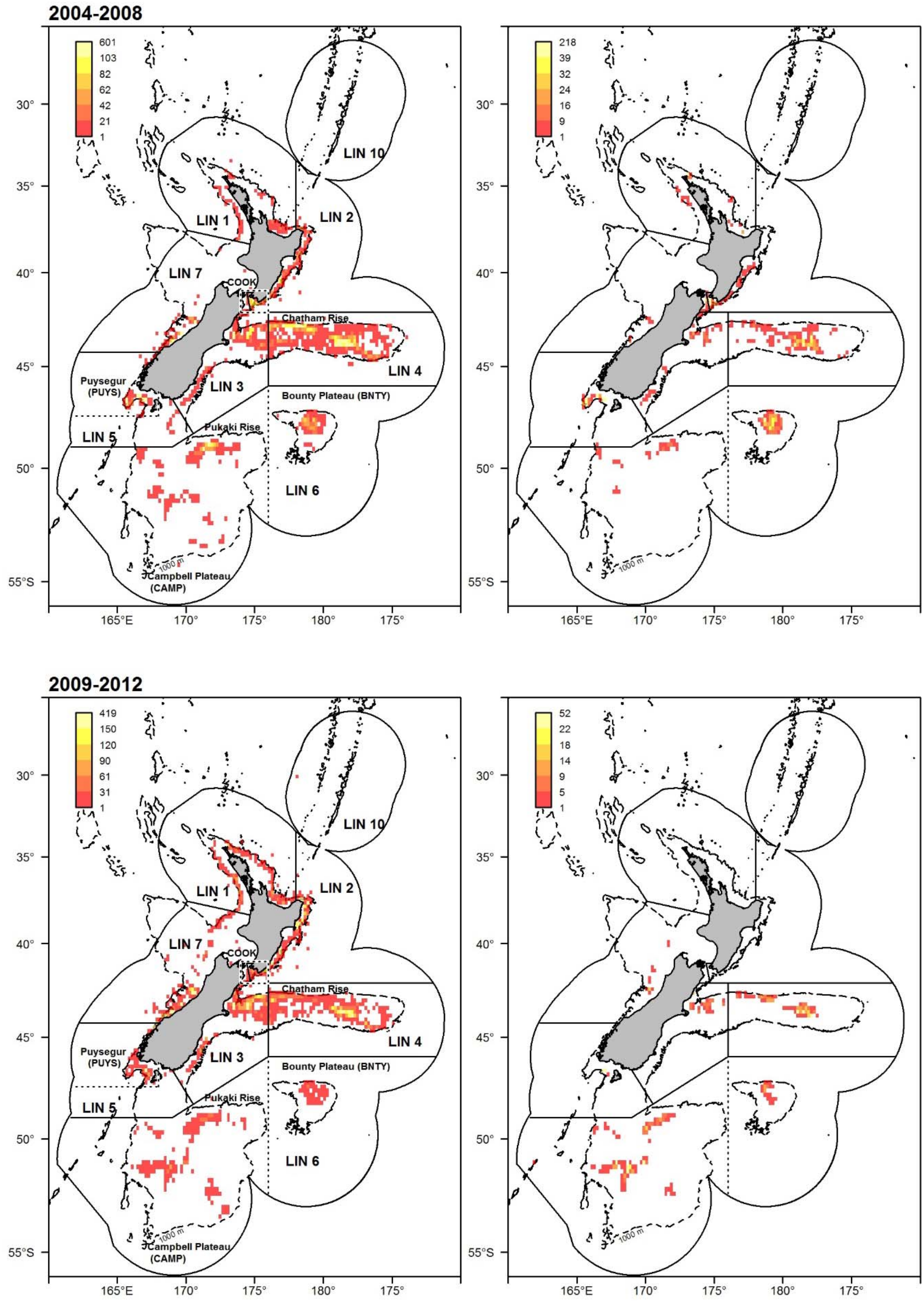

Figure 3—*Continued*

To more objectively assess the spatial observer coverage, a comparison of the latitude and longitude of observed sets with all commercial sets recorded with position data was produced using density plots (Figure 4).

The spread of observed sets over much of the spatial extent of the fishery was well matched to the spread of commercial sets throughout much of the 20-year period being assessed, particularly in the years before 2006–07. After this there were a few regions which stood out as having been under or over sampled. Undersampling occurred between 42° S and 45° S (the Chatham Rise) in 2006–07, in northern regions (north of about 39° S) in all subsequent years, and in areas east of about 172° in 2009–10 and 2011–12. Oversampling is seen in eastern regions in 2007–08 and 2008–09 and in western and southern regions in 2009–10 and 2011–12. This uneven sampling balanced out across years to a large extent, however, with coverage well matched to the total fishery when all years are considered. Only a slight oversampling of the southern fisheries at the expense of the Chatham Rise fisheries is evident from the plots.

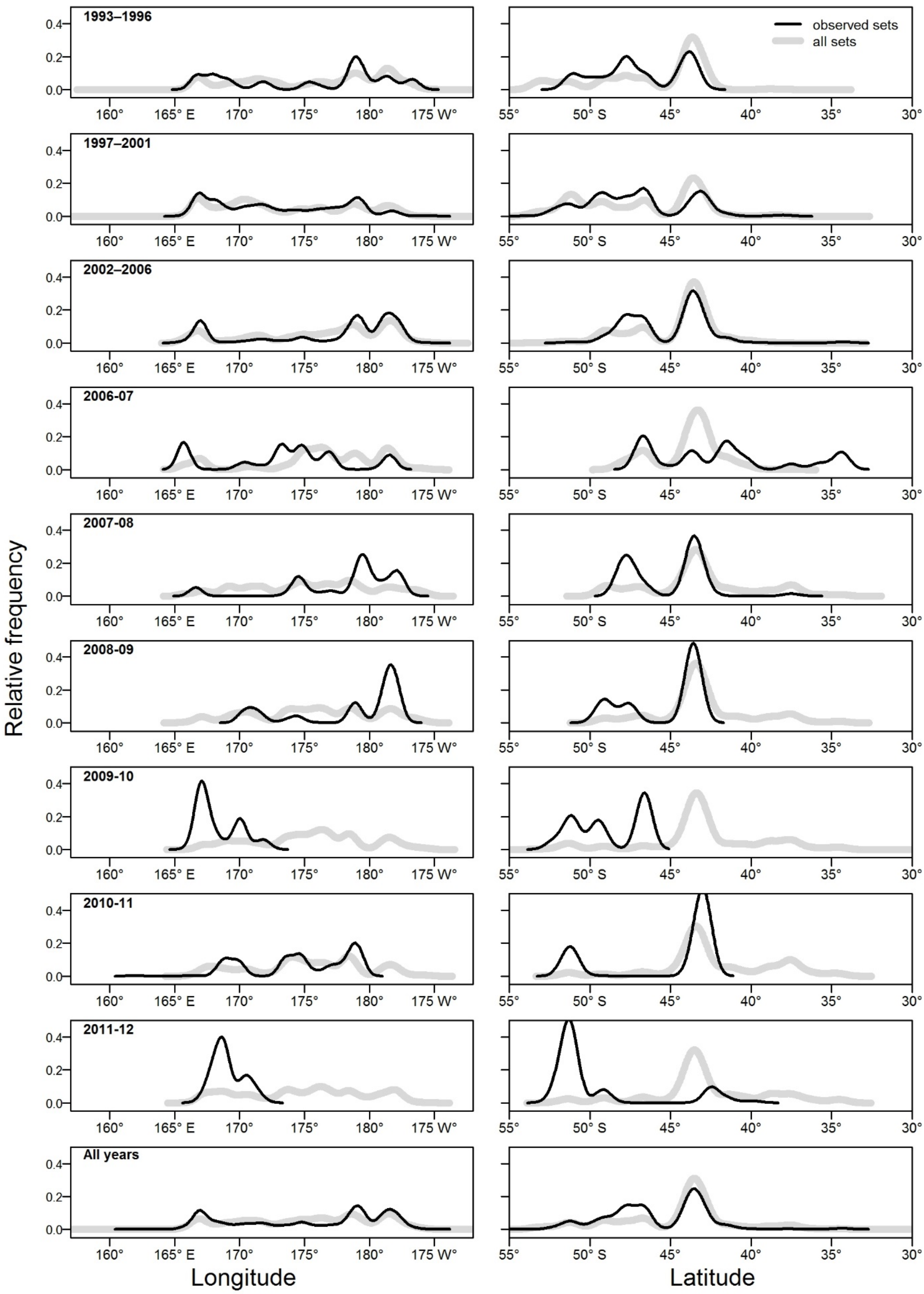

Figure 4: Comparison of start positions (latitude and longitude) of observed sets with those of all commercial sets in the ling longline target fishery. Fishing years 1992–93 to 2005–2006 are shown in blocks of 4 or 5 years, fishing years 2006–07 to 2011–12 are shown by individual year and, in the bottom panel, all years are shown combined. The relative frequency was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

Observer coverage of the ling longline fishery began in March 1993. The annual number of observed sets since then has ranged from 114 to 1603, but apart from a period of high coverage centred around 2001–02, has been about 200–500 sets in most years (Table 3). The number of observed hooks followed the same pattern as observed sets, with the peak in observer coverage lagging behind the peak in total fishery effort which occurred in the mid-1990s. The number of vessels observed in each year ranged from 1 to 8 (equivalent to 1.4–14.3% of the fleet), with a peak in the early 2000s. The number of trips observed each year also peaked at this time, with a maximum of 17 in 2002–03. The observed catch (and number of sets and hooks) accounted for substantially less than 10% of the total in most years before 1999–2000, but was substantially greater than 10% in most of the following years, reaching a peak of 52% (catch), 33% (sets), and 60% (hooks) in 2002–03. Observer coverage has been lower in more recent years, less than 10% of the catch in 2010–11 and 2011–12, but for the 20 year period as a whole represented 13% of the total catch. The fishery is relatively discrete, with ling being the exclusive target species in 75% of all trips (observed and un-observed) in which ling were targeted at least once.

Table 3: Summary of effort and estimated catch in the target longline fishery for ling, for observed sets and overall, by fishing year. Trips include those with any recorded targeting of ling.

Fishing year	Number of sets		Number of hooks ('000)		Number of vessels		Number of trips		Ling total catch (t)		Percentage observed		
	Obs	All	Obs	All	Obs	All	Obs	All	Obs	All	Catch	Sets	Hooks
1992–93	166	5 661	606	16 323	1	72	1	605	168	6 518	2.6	2.9	3.7
1993–94	114	6 531	443	20 450	1	62	1	591	150	7 384	2.0	1.7	2.2
1994–95	405	7 566	1 974	24 459	3	73	3	722	577	9 817	5.9	5.4	8.1
1995–96	373	6 748	1 771	24 838	4	73	5	795	604	7 754	7.8	5.5	7.1
1996–97	262	7 704	1 644	32 245	2	59	3	696	247	8 311	3.0	3.4	5.1
1997–98	307	7 441	1 730	33 711	3	54	3	658	524	7 697	6.8	4.1	5.1
1998–99	484	7 013	3 213	32 691	3	49	4	543	552	7 182	7.7	6.9	9.8
1999–00	506	6 372	3 611	31 572	4	49	4	506	905	6 962	13.0	7.9	11.4
2000–01	744	5 259	5 033	26 714	4	41	6	430	1 329	6 542	20.3	14.1	18.8
2001–02	1 092	5 534	7 566	27 659	4	42	9	453	1 648	5 765	28.6	19.7	27.4
2002–03	1 603	4 791	11 299	18 704	8	56	17	573	2 572	4 909	52.4	33.5	60.4
2003–04	762	4 861	5 707	24 047	8	57	11	463	1 189	4 906	24.2	15.7	23.7
2004–05	324	5 132	2 646	22 746	4	46	5	542	582	4 943	11.8	6.3	11.6
2005–06	563	4 000	3 615	16 411	2	48	5	375	924	3 526	26.2	14.1	22.0
2006–07	414	4 615	2 180	16 865	7	50	8	524	502	3 744	13.4	9.0	12.9
2007–08	461	5 044	3 233	18 998	7	59	8	544	761	4 834	15.7	9.1	17.0
2008–09	499	4 543	3 714	17 558	4	56	6	501	983	4 064	24.2	11.0	21.2
2009–10	197	4 785	1 718	18 360	1	54	2	492	511	4 521	11.3	4.1	9.4
2010–11	263	5 814	1 391	18 294	4	58	4	573	205	3 852	5.3	4.5	7.6
2011–12	219	4 660	1 704	16 998	3	52	4	513	418	4 235	9.9	4.7	10.0
All years	9 758	114 074	64 797	459 643	24	259	99	11 030	15 354	117 465	13.1	8.6	14.1

Comparisons made between vessel sizes in the commercial fleets and the observed portion showed that although a wide size range of vessels operate in this fishery, from about 50 t GRT (Gross Registered Tonnage) to over 1500 t, most fishing is by vessels of either 300–600 t or 1000–1200 t (Figure 5). Apart from the very smallest of these vessels, this range was well covered by observers, although the largest vessels which were more able to accommodate observers were somewhat oversampled compared to the smaller vessels.

This lack of coverage of smaller vessels was most evident in LIN 1, LIN 2, and LIN 7, where over 60% of the effort over the 20 years examined was by vessels which never had an observer on board. In contrast, in those fisheries with generally larger vessels (BNTY, CAMP, LIN 4, PUYS) less than 5% of the effort was by vessels which had never carried an observer (see Table 2).

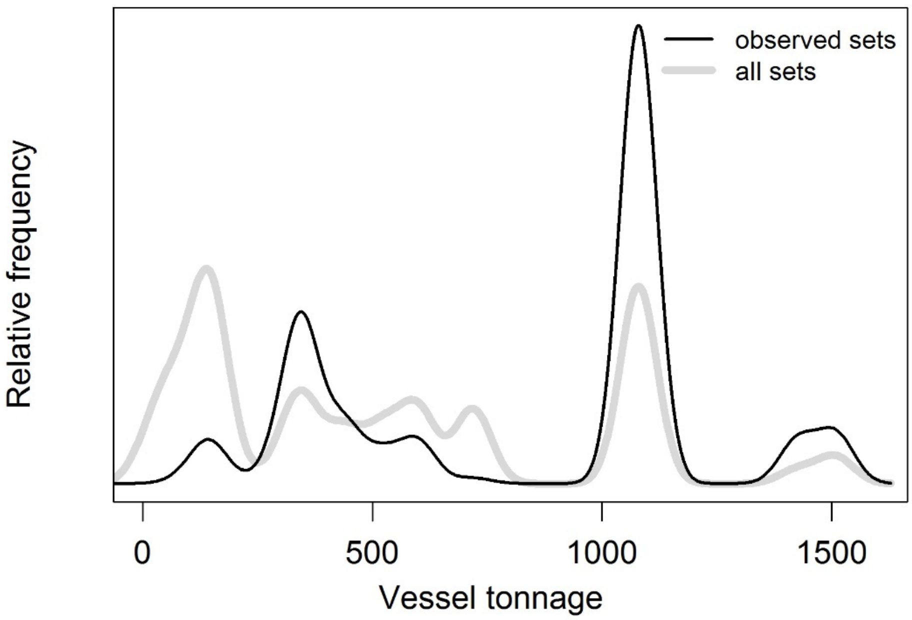

Figure 5: Comparison of vessel sizes (gross registered tonnage) in observed sets versus all recorded commercial sets, standardised for the number of hooks per set, for the period 1 October 1992 to 30 September 2012, in the ling longline fishery. The relative frequency was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

The spread of observed effort throughout each fishing year was compared with the spread of total effort in the fishery by applying a density function to the numbers of sets per day (Figure 6). The commercial ling longline fishery has been evenly spread over the fishing year, but with usually slightly more effort at the beginning and end of the year. When observers first began to cover this fishery (in 1992–93 and 1993–94) their efforts were restricted to a single, short period in each year. As the number of observer days increased over the next several years coverage gradually extended to include a greater part of the year, with different periods covered in each year. By 2002–03 and 2003–04, when the annual number of observed sets was peaking, coverage was spread over most of the year and, in 2002–03 in particular, matched closely the distribution of total commercial effort. After 2003–04 coverage again became more uneven, but generally included several periods in each year but these periods differed between years. For all years combined the observer coverage closely matched the overall temporal spread of the commercial fishery.

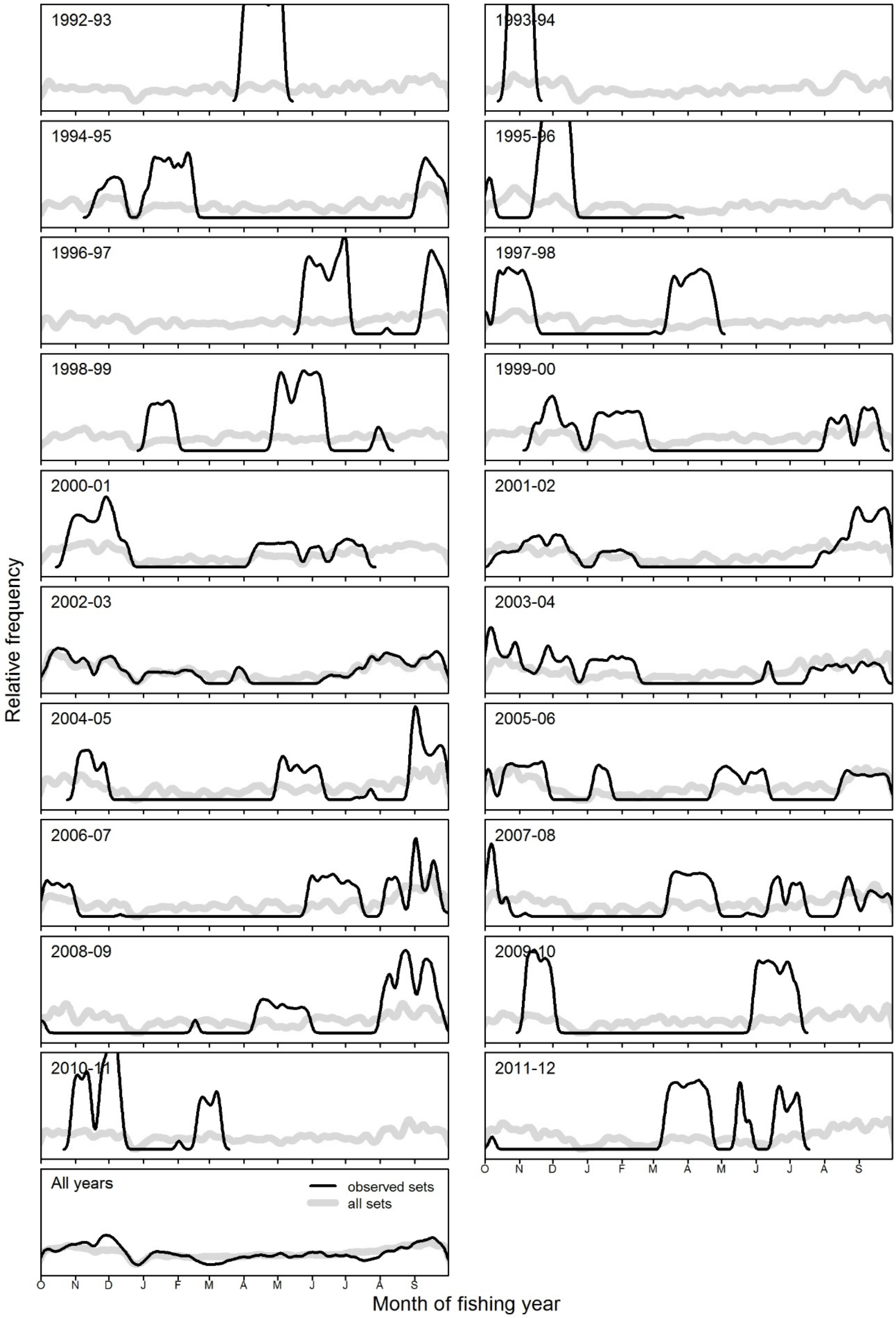

Figure 6: Comparison of the temporal spread of observed sets with all recorded commercial sets for 1992–93 to 2011–12, and for all fishing years combined. The relative frequency of the numbers of sets was calculated from a density function which used linear approximation to estimate frequencies at a series of equally spaced points.

3.2 Bycatch data

3.2.1 Overview of raw bycatch data

More than 230 bycatch species or species groups were identified by observers in the ling longline target fishery, most being non-commercial species, including invertebrate species, caught in low numbers (see Appendices 1–3). Ling accounted for about 68% of the total estimated catch from all observed sets targeting ling between 1 October 1992 and 30 September 2012. The main bycatch species by weight were spiny dogfish (13%), ribaldo (2.9%), smooth skate (1.8%), rough skate (1.8%), red cod (1.7%), black cod (*Paranotothenia magellanica*) (1.4%), and sea perch (*Helicolenus* spp.) (1.2%); of these only spiny dogfish were mostly discarded. Several of the main QMS bycatch species can legally be discarded under Schedule 6 of the Fisheries Act (1996), or (in the case of red cod shorter than 25 cm) *must* be discarded under the Fisheries (Commercial Fishing) Regulations 2001 (Figure 7). When combined into broader taxonomic groups, sharks and dogfish contributed the most bycatch (16.8% of the total catch) and most of these were discarded. Other fish (excluding also rays, skates, chimaeras, eels, and rattails) accounted for a further 8.5% of the catch and these were mostly retained. Rays and skates were the next largest group (4% of the catch); a quarter of these were discarded. Of the invertebrates, only echinoderms (mainly starfish) were caught in substantial amounts. About 39 t of echinoderms were caught, and all were discarded. Crustaceans, molluscs, and sponges were caught in smaller amounts.

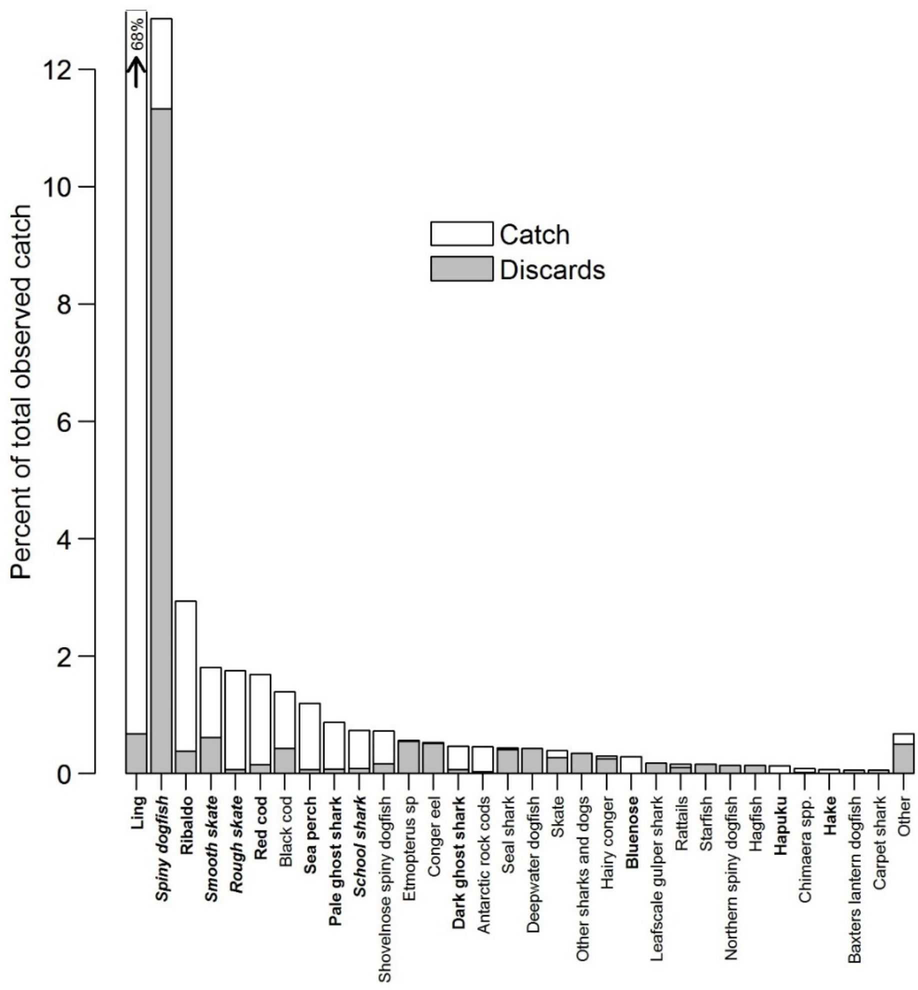

Figure 7: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the ling longline fishery between 1992–93 and 2011–12, and the percentage discarded. The "Other" category is the sum of all bycatch species representing less than 0.05% of the total catch. Names in bold are QMS species, names in italics are QMS species which can be legally discarded under Schedule 6 of the Fisheries Act (1996). In addition, red cod shorter than 25 cm must be returned to the sea under the Fisheries (Commercial Fishing) Regulations 2001.

Many invertebrates, in particular corals, echinoderms, and crustaceans, were identified to species, especially in the more recent records. This is due to improving knowledge of the New Zealand marine invertebrate fauna, both in general and specifically by fisheries scientists and observers, and the use of invertebrate identification guides (e.g. Tracey et al 2011) which have become available to observers. See Appendices 1 and 2 for a list of the main observed bycatch species and Appendix 3 for a summary by higher taxonomic group.

Exploratory plots were prepared to examine bycatch per hook (plotted on a log scale) with respect to other relevant available variables, including depth, number of hooks, vessel, fishing year, month, area, seabed topography and bait type (Figures 8–10). Plots were prepared separately for QMS species, non-QMS species, and for total bycatch.

Total bycatch per hook was highly variable between sets, ranging from 0 kg to 4.1 kg (Figure 8). Lines were mostly set at depths of 350–600 m but there was also a significant fraction of effort at 150–250 m, mostly related to the shallower fishing grounds around the Bounty Plateau. Total bycatch levels tapered off slightly with average bottom depth greater than about 500 m. The number of hooks in the set had little influence on bycatch rates, although the slight decrease in bycatch with very large numbers of hooks may indicate that the ends of long sets may sometimes end up outside the main targeted area. There were some differences in total bycatch rates between vessels and between months. The ratio of highest to lowest monthly bycatch rate was about 2.3:1 (highest in September, lowest in November), and the ratio of highest to lowest vessel bycatch rate was about 3.6:1. There were some differences in median bycatch rates between fishing years (range 0.04–0.22 kg per hook), and although there was no apparent trend over time, the highest rate was in the first year of the series and the lowest rate in the most recent year. Greater differences in bycatch were observed between areas, with PUYS and CAMP (both about 0.05 kg per hook) the lowest and LIN 7 (0.23 kg per hook) the highest, and the ratio of highest to lowest catch rates was about 5.3:1. By far the most common bait species were jack mackerels (JMD, JMA, JMN), with barracouta (*Thyrsites atun*, BAR) and blue mackerel (*Scomber australasicus*, EMA) associated with relatively high bycatch relative to JMA, and arrow squid (SQU) relatively lower bycatch. Most lines were set over flat or undulating sea-bed and there was relatively little difference in total bycatch rates between these observer-recorded bottom types (ratio of highest to lowest bycatch rate 2:1), although lines recorded as being set in canyons (mostly in the Puysegur area, LIN 5) had lower rates (0.06 kg per hook).

Patterns of bycatch for QMS species in relation to these variables were mostly very similar to those for total bycatch, as QMS species have accounted for the majority of the catch (Figure 9), as might have been expected given that the majority of the bycatch were QMS species.

Patterns of bycatch for non-QMS species, however, differ for several variables (Figure 10). These include, a decrease in bycatch with increasing number of hooks is more pronounced for non-QMS species; the relative levels of bycatch among the 15 vessels with more than 50 records differs, with a few vessels that had a high total bycatch having a relatively low non-QMS bycatch; there is a seasonal pattern of decreased non-QMS bycatch over the winter months; and bycatch is lower in LIN 4 relative to the other areas for non-QMS species than for all species.

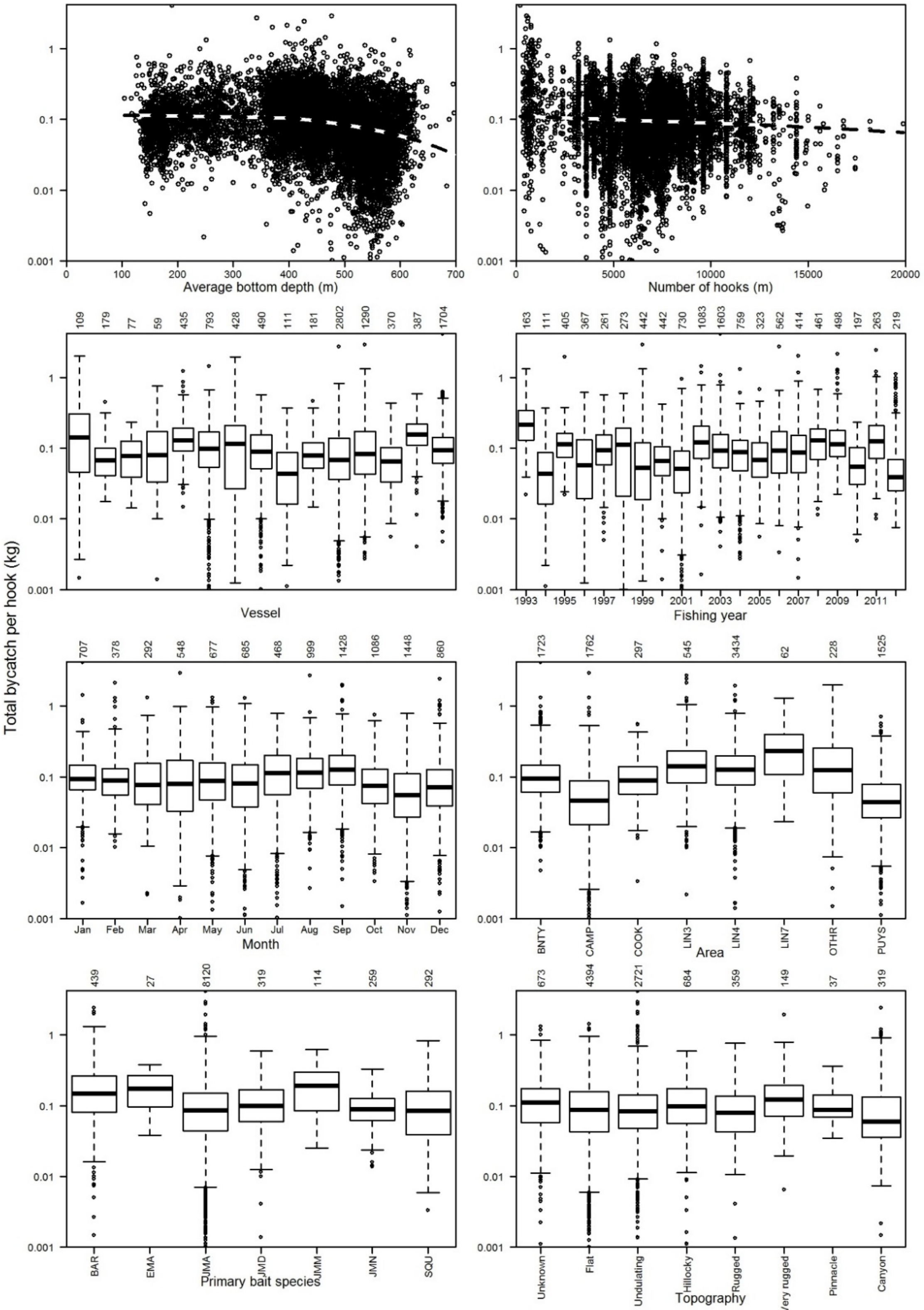

Figure 8: Total bycatch (all species) in kg per hook plotted against selected variables in the ling longline target fishery. Total bycatch is plotted on a log scale (with zero values of bycatch excluded). The dashed lines in the top panels represent mean fits (using a locally weighted regression smoother) 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. The numbers above the plots indicate the number of (non-zero) records (sets) associated with that level of the variable. In the vessel plot, vessels are ordered by size, from shortest to longest; and vessels represented by fewer than 50 records (including zeros) were not plotted. Average depth is the average of the depths at each end of the set. See Figure 2 for area codes.

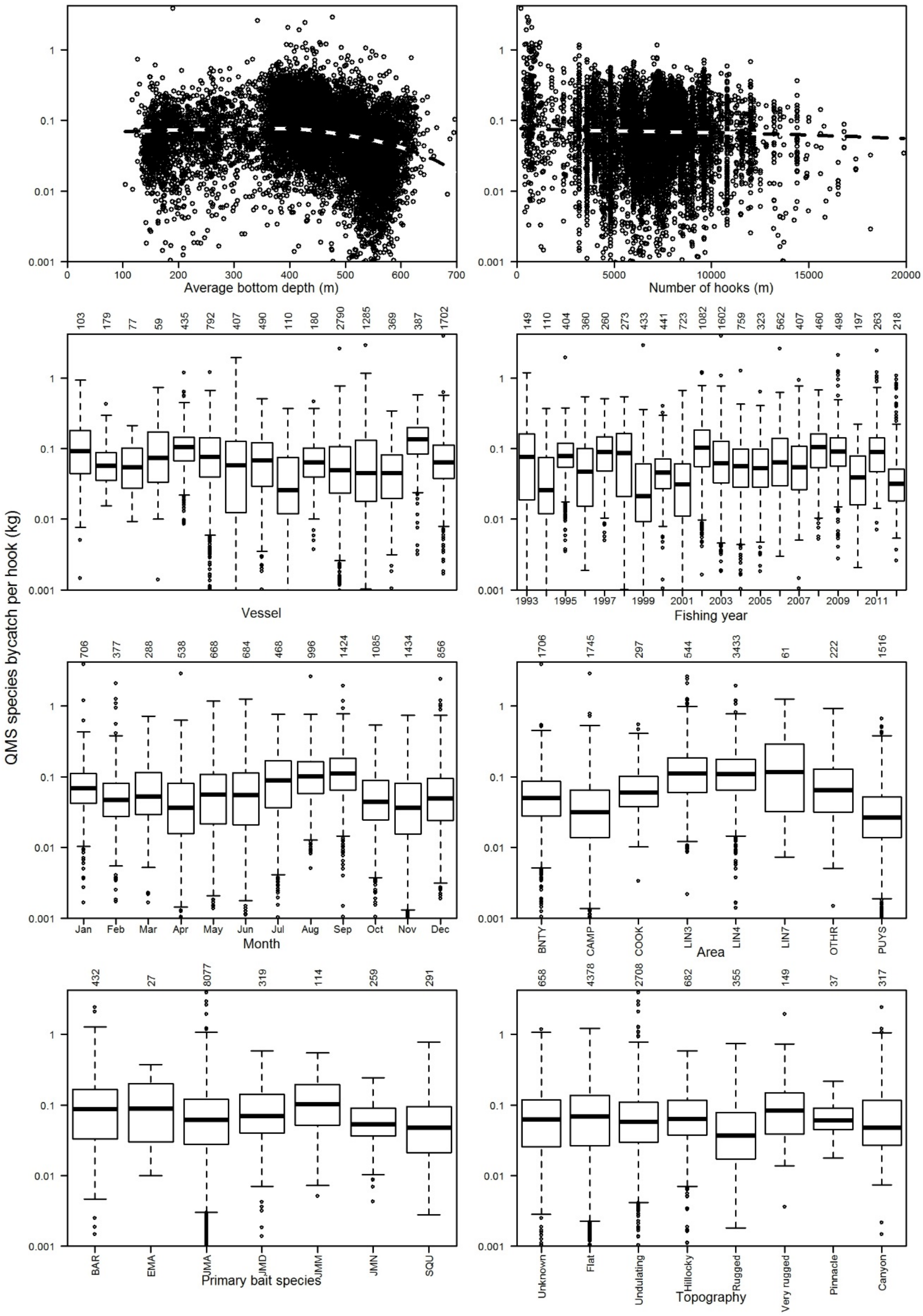

Figure 9: QMS species bycatch per hook plotted against selected variables in the ling longline target fishery. See Figure 8 for further details.

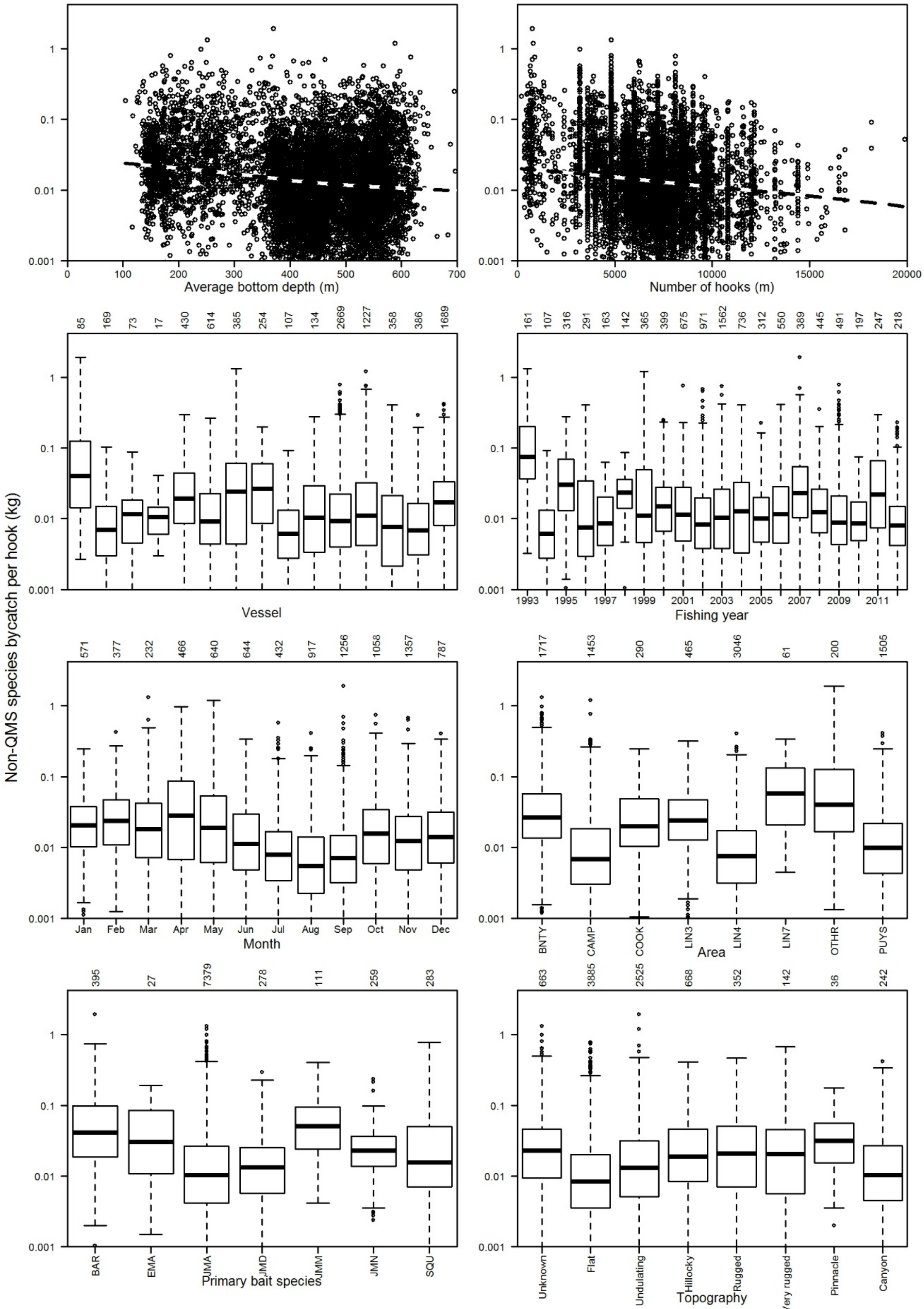

Figure 10: Non-QMS species bycatch per hook plotted against selected variables in the ling longline target fishery. See Figure 8 for further details.

3.2.2 Regression modelling and stratification of bycatch data

The dependent variable in the LME models was the bycatch rate, expressed as the log of catch (kg) per hook. There was a substantial fraction of records with no bycatch of non-QMS species and invertebrate species, and so for these groups both log-linear and binomial models were constructed. For the QMS species category the fraction of records with no bycatch was less than 3%, and so a binomial model was not constructed.

In each model, *area* was the most influential variable, with *month* the next most important overall, followed by *fishing year* (Table 4). The variable *number of hooks* was third or fourth chosen in the log-linear models, but was not selected in either of the binomial models. Other variables tested had only a small influence on bycatch rates.

Although *month* clearly has an influence on catch rates in each species category, the quantity of available observer data in this fishery limits the amount of stratification that can practically be used in the calculation of bycatch estimates. If a stratification including *month* in addition to *area* and f*ishing year* were considered, only 125 (5%) of the 2400 individual strata would meet the criteria used here for calculating an independent bycatch ratio (i.e., over 25 observed sets). Therefore, due to the consistent and generally greater influence of *area* in each of the bycatch categories, this variable alone was used to stratify all bycatch calculations, as it was in the previous assessment of bycatch in this fishery (Anderson 2008).

Table 4: Summary of LME modelling of bycatch in the ling longline fishery. The numbers denote the order in which the variable entered the model. Variables: *n.hooks*, number of hooks; *autoline*, vessel is an autoliner (y/n) *fday*, day of fishing year; *fyr*, fishing year; *grt*, vessel tonnage; *MPvess*, vessel operates a mealplant (y/n).

Species cat.	Model type	Variable							
		area	*month*	*fyr*	*fday*	*n.hooks*	*MPvess*	*grt*	*autoline*
QMS	Normal	1	2	4	6	3	–	5	7
Non-QMS	Normal	1	2	–	–	3	–	–	–
Non-QMS	Binomial	1	2	4	3	–	–	–	–
INV	Normal	1	2	3	6	4	–	5	–
INV	Binomial	1	3	2	4	–	5	–	–

3.3 Discard data

3.3.1 Overview of raw discard data

The individual species most discarded in the ling longline fishery was spiny dogfish, which was introduced into the QMS in October 2004 but at the same time added to the 6th schedule of the Fisheries Act 1996, allowing it to be legally discarded (dead or alive) at sea (see also Section 3.5.5 for a discussion of observer-authorised QMS species discards). Spiny dogfish was also the most common bycatch species and an estimated 88% of the 2900 t of the observed catch was discarded (Figure 7, Appendix 1). The next four most commonly caught species (ribaldo, smooth and rough skates, and red cod) are also QMS species, and these were mostly retained (Figure 7). These two skate species are also in the 6th schedule of the Fisheries Act 1996 but can only be discarded if done immediately and if there is a reasonable chance that they will survive. About a third of the observed catch of smooth skate was discarded, but only 4% of rough skates. Of the observed (and recorded) discards of smooth skates 17% were coded as lost from the line – compared to 79% for rough skates and 3% for all species combined. These fish are treated as discarded in this analysis and no attempt is made to estimate the likelihood of their survival. The non-QMS species caught most, black cod, was mostly retained (Figure 7). The amount of observed catch of this species is surprising, as it is considered relatively rare and restricted to the southern plateaux (McMillan et al 2011b). These cods may be especially vulnerable to longlines or there may be some confusion between this species and the more abundant smallscaled cod (*Notothenia microlepidota*) (McMillan et al. 2011a), a species never recorded by observers in this fishery. Of the other frequently caught non-QMS species, *Etmopterus* species and conger eels (97%), seal sharks (*Dalatias licha*) (93%), and deepwater dogfish and sharks (99–100%) were usually discarded (Figure 7, Appendix 1). Of the main QMS invertebrate species caught, the giant spider crab (*Jacquinotia edwardsii*), queen scallop (*Zygochlamys delicatula*), and king crabs (*Lithodes aotearoa* & *Neolithodes brodiei*) were 99% retained. Other invertebrate species were generally fully discarded (Appendix 2).

The variability in the level of discards per hook for QMS species, non-QMS species and all species combined, with respect to some of the available variables are explored in Figures 11, 12 and 13.

The level of total discards was highly variable, ranging from 0 to 1.9 kg per hook (Figure 11). The quantity of total discards and QMS discards decreased slightly with increasing bottom depth beyond about 400 m, and more steadily throughout the depth range of the fishery for non-QMS species. The number of hooks set had no overall influence on discard rates, but for non-QMS species the discard rate decreased slightly with increasing number of hooks.

The differences in bycatch rates among vessels, areas, months, and primary bait species were similar to those described for bycatch, substantially due to the constant-fraction method of estimating discards in the portion of the observer data without direct recording of discard amounts (which results in about 2/3 of the discards being calculated simply as a fraction of the bycatch – see Section 2.1.1).

There was a small difference in discard rates between vessels with recorded landings of fishmeal made from non-QMS species (see Section 2.1.1) and those without. For QMS species (medians of 0.012 $kg.hook^{-1}$ and 0.023 $kg.hook^{-1}$) as well as non-QMS species (medians of 0.006 $kg.hook^{-1}$ and 0.012 $kg.hook^{-1}$) discards were less on vessels making fishmeal (Figures 11, 12 and 13).

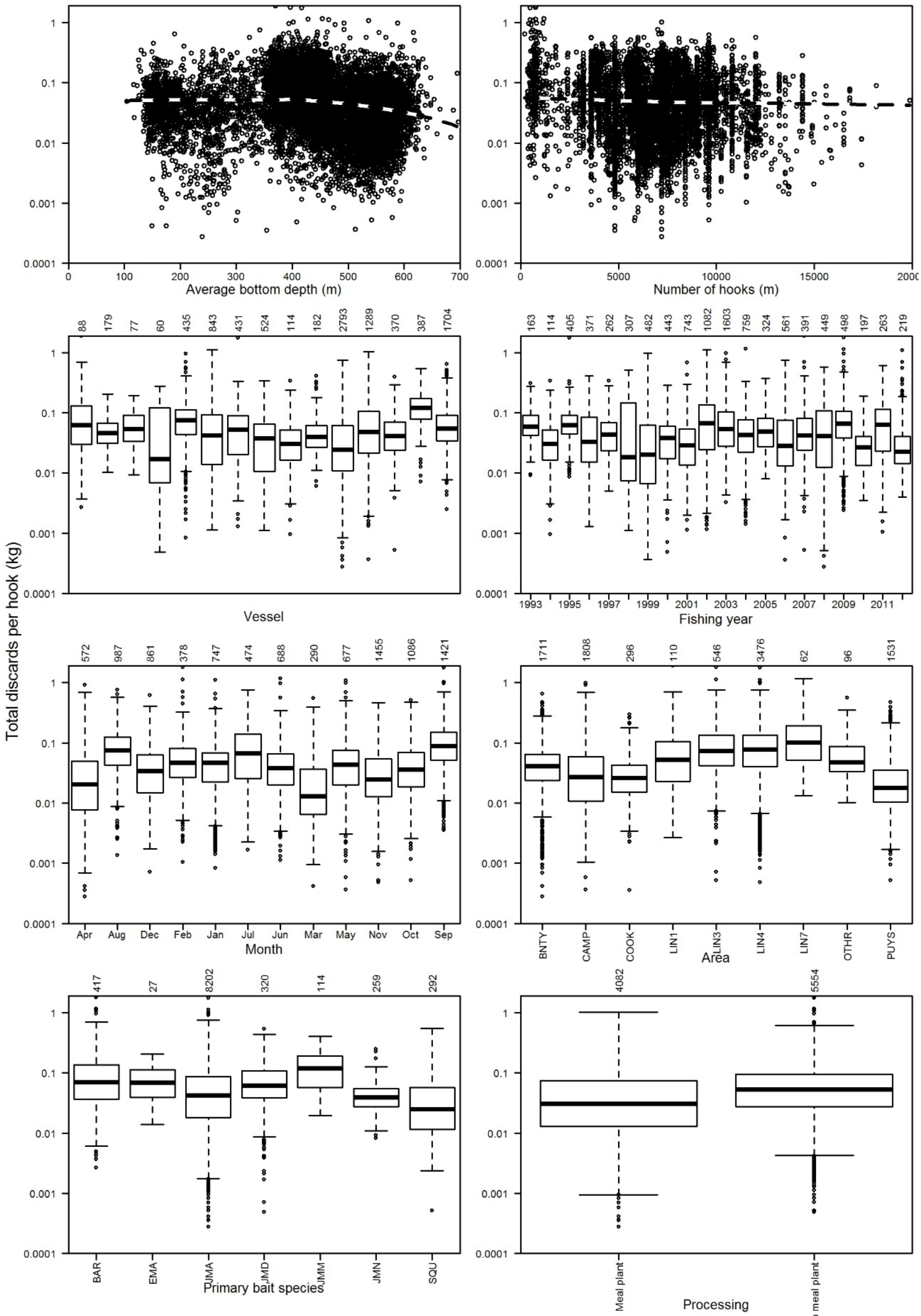

Figure 11: Total discards (all species) per hook plotted against selected variables in the ling longline target fishery. Total discards are plotted on a log scale. See Figure 8 for further details.

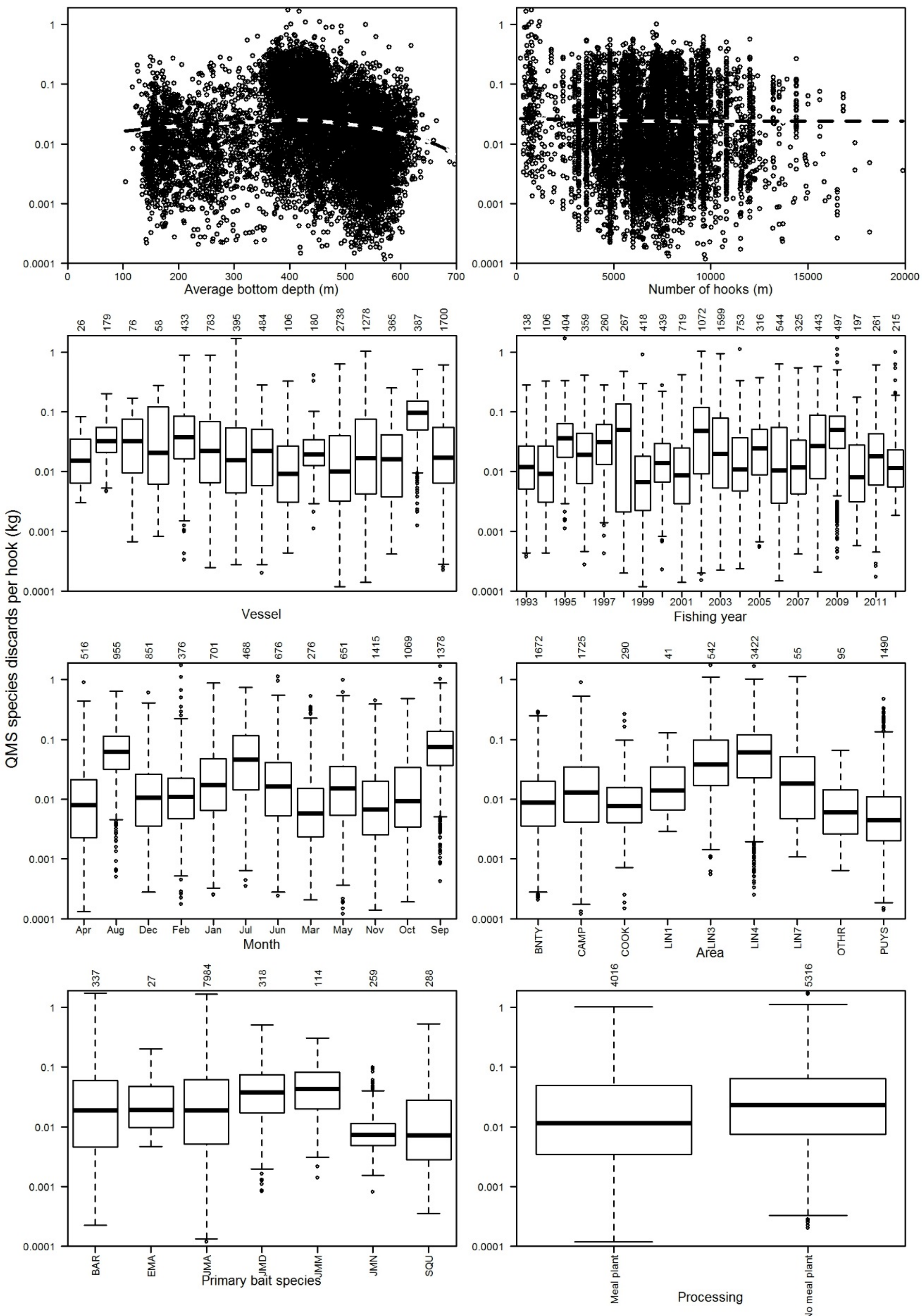

Figure 12: QMS species discards per hook plotted against selected variables in the ling longline target fishery. See Figure 8 for further details.

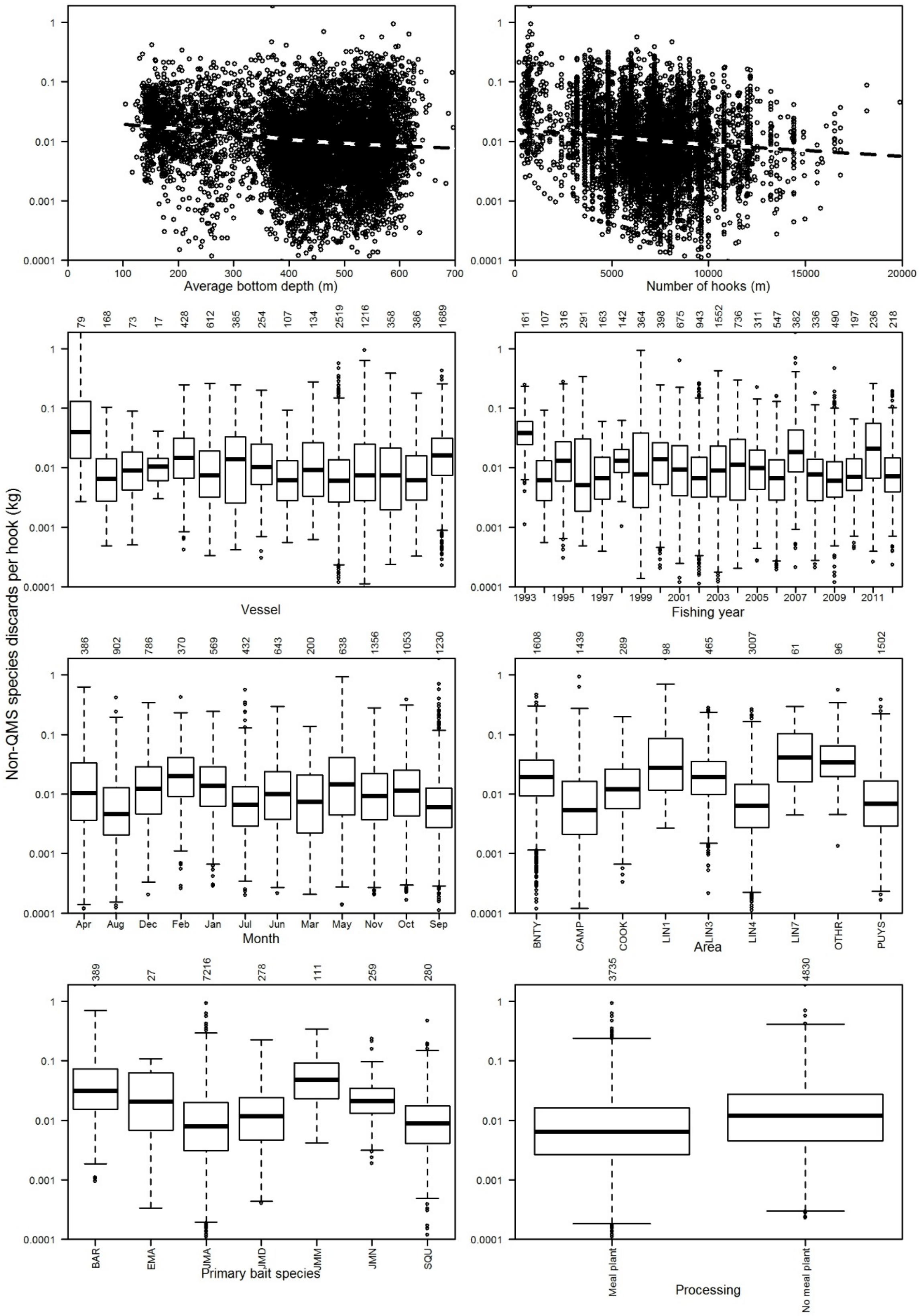

Figure 13: Non-QMS species discards per hook plotted against selected variables in the ling longline target fishery. See Figure 8 for further details.

3.3.2 Regression modelling and stratification of discard data

The dependent variable in the discard LME models was the discard rate, expressed as the log of discards (kg) per hook.

Only log-linear models were constructed as binomial models were not usable here because real zero values occurred only within the fraction of observed sets where discards were recorded in *cod*. For the other sets, a small amount of discards was assigned for species where none had been recorded, to take account for fish lost off hooks (see Section 2.1.1).

As with the bycatch models *area* was also the most influential variable in each of the discard models and month the next most important overall (Table 5). The variable *n.hooks* also had a similar amount of influence in these models as in the bycatch models being the third or fourth variable selected in three of the four models. The other variables tested, *fyr*, *autoline*, *grt*, *MPvess*, and *fday* had only a minor influence in one or two of the models.

For the same reasons that *area* was used as the sole stratification in the calculation of bycatch estimates (see Section 3.2.2), and to be consistent with those calculations, this variable alone was used in the discard calculations.

Table 5: Summary of LME modelling of discards in the ling longline fishery. The numbers denote the order in which the variable entered the model. Variables: *n.hooks*, number of hooks; *autoline*, vessel is an autoliner (y/n) *fday*, day of fishing year; *fyr*, fishing year; *grt*, vessel tonnage; *MPvess*, vessel operates a mealplant (y/n).

Species cat.	Model type								Variable
		area	*month*	*n.hooks*	*fyr*	*autoline*	*grt*	*MPvess*	*fday*
LIN	Normal	1	4	3	–	–	–	2	–
QMS	Normal	1	2	3	–	–	–	–	–
Non-QMS	Normal	1	2	–	–	–	–	3	–
INV	Normal	1	2	4	3	–	5	–	6

3.4 Estimation of bycatch

3.4.1 Bycatch rates

Bycatch rates by area and year were calculated for each species category from the observer data. Average bycatch rates across all areas in each year were calculated to apply to the small amount of fishing effort in areas outside of these nine main areas. The variance associated with these estimates was calculated using the bootstrap methods described in Section 2.4.

As well as providing the basis from which annual bycatch can be determined, by application to target fishery effort totals, these rates also provide some insight as to how bycatch rates vary between the different regions of the ling longline fishery (Figure 14, Appendices 4 and 5). Limitations in the data, especially in the spread of observer effort across areas in each year, meant that calculation of bycatch ratios for several year/area combinations included data from adjacent years, as described in Section 2.4. The total number of years of data required for each stratum is shown in Table 6. The areas in which greater numbers of years were often required, LIN 1, LIN 2, LIN 7, were the smaller fisheries which typically had less observer coverage (see Tables 1 and 2. About a third of the rates were based on data solely from the year concerned, and about two thirds of the rates were based on data from three or less years.

Table 6: Number of years of observer data required to provide more than 25 records for bycatch and discard rate calculations.

Fishing year									Area
	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	PUYS
1992–93	1	3	9	13	14	3	1	12	2
1993–94	3	3	9	13	14	3	3	12	1
1994–95	1	1	9	13	14	1	1	12	3
1995–96	1	1	9	13	14	3	1	12	5
1996–97	3	3	9	13	14	3	1	12	7
1997–98	5	1	7	13	14	1	1	12	5
1998–99	3	1	5	13	14	3	1	11	3
1999–00	1	1	3	11	13	5	3	9	1
2000–01	1	1	1	9	11	3	3	7	1
2001–02	3	1	3	7	9	3	1	5	1
2002–03	1	1	1	5	7	1	1	3	1
2003–04	1	1	3	3	5	3	1	3	1
2004–05	1	1	3	1	3	3	1	5	1
2005–06	3	3	1	3	1	3	1	7	1
2006–07	3	5	1	1	1	1	1	9	1
2007–08	1	3	3	3	3	1	1	9	1
2008–09	1	1	5	5	5	1	1	7	3
2009–10	3	1	6	6	6	3	3	5	1
2010–11	4	1	6	6	6	1	1	2	3
2011–12	4	1	6	6	6	2	2	2	3

Median bycatch rates of QMS species were highest in LIN 1 and LIN 7, although data limitations in these smaller fisheries meant that bycatch rates for them were mostly calculated using average data from two or more years, and therefore rates varied less over time. Of the main fishing areas, with more data, bycatch rates of QMS species were highest on the Chatham Rise (LIN 3 and LIN 4), and lowest in the southern areas (CAMP and PUYS).

Bycatch rates of non-QMS species were in general lower than those of QMS species and in most areas less than 0.05 kg per hook in most years. Higher rates were estimated for some years in LIN 1, LIN 2, LIN 7, and BNTY (Figure 14).

Bycatch rates of invertebrates were highly variable and very low, never more than 0.004 kg per hook in any area/year, but are likely to have been inconsistently recorded by observers and underestimated in earlier years. No invertebrate bycatch was recorded before 1998–99, with any non-zero estimates for these years based on average data from adjacent years. Invertebrate species bycatch rates were consistently low in LIN 1, LIN 2, LIN 3, and LIN 7, and highest in BNTY, LIN 4, and COOK.

Regression modelling was used to identify areas with trends in bycatch rates in each species category, with the models weighted by $1/n$, where n is the number of years of observer records combined to achieve a minimum of 25 records (see Table 6). Despite this weighting the calculated trends are partially influenced by these combinations and are presented as only a general indicator of temporal changes in bycatch rates. Results indicated a mixture of increasing and decreasing bycatch rates over time across the three species categories and areas (Table 7). Significant decreasing trends ($p<0.01$) were shown for all species categories in LIN 2, QMS species in LIN 1, non-QMS and INV species in COOK, and INV species in LIN 7; increasing trends were indicated for QMS and non-QMS species in LIN 7, and non-QMS species in LIN 1 (Table 7).

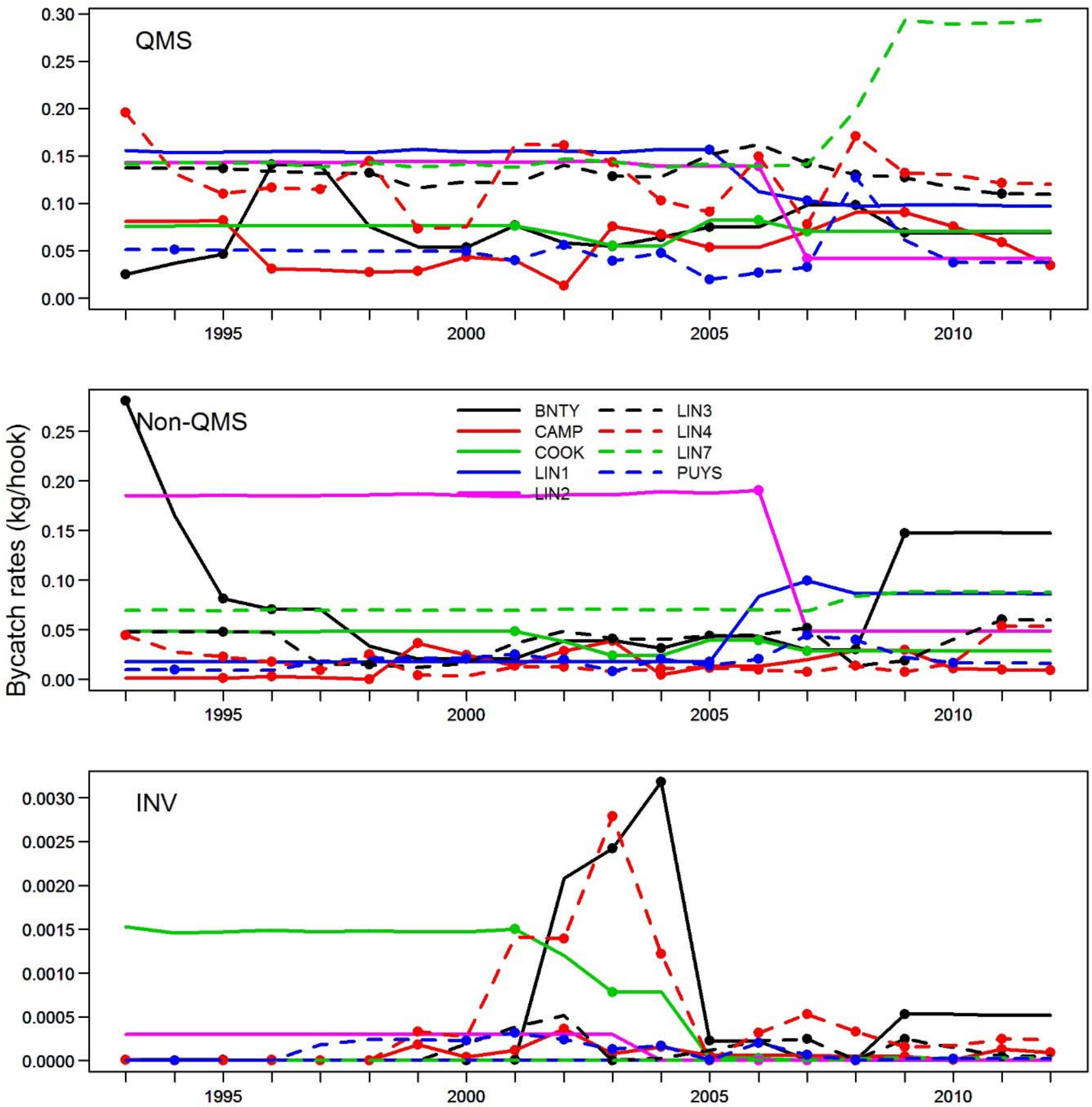

Figure 14: Annual bycatch rates by species category and areas used for stratification, in the ling longline fishery. Bycatch rates are the median of the bootstrap sample of 1000. Dots indicate years in which there were sufficient observed sets (>25) to calculate an individual bycatch rate for the area; for years with no dot bycatch rates were calculated using additional records from between 2 and 14 adjacent years (average 4, see Table 6) as required to obtain at least 25 records.

Table 7: Summary of results of regression analyses for trends in annual bycatch rates, by species category and area. The *p* values indicate how significantly the slopes differed from zero. Those results where *p* values are less than 0.01 (generally considered highly significant) are shown in bold; –, no bycatch recorded.

Species category	Area	Slope	*p*
QMS	BNTY	0.029	0.099
QMS	CAMP	0.022	0.310
QMS	COOK	-0.002	0.795
QMS	**LIN1**	**-0.038**	**<0.001**
QMS	**LIN2**	**-0.097**	**0.001**
QMS	LIN3	-0.006	0.067
QMS	LIN4	-0.004	0.748
QMS	**LIN7**	**0.052**	**<0.001**
QMS	PUYS	-0.010	0.595
Non-QMS	BNTY	-0.028	0.421
Non-QMS	CAMP	0.129	0.040
Non-QMS	**COOK**	**-0.039**	**0.005**
Non-QMS	**LIN1**	**0.141**	**0.001**
Non-QMS	**LIN2**	**-0.105**	**0.002**
Non-QMS	LIN3	0.009	0.692
Non-QMS	LIN4	-0.007	0.817
Non-QMS	**LIN7**	**0.017**	**<0.001**
Non-QMS	PUYS	0.047	0.030
Invertebrates	BNTY	0.169	0.049
Invertebrates	CAMP	-0.015	0.700
Invertebrates	**COOK**	**-0.288**	**<0.001**
Invertebrates	LIN1	0.001	0.104
Invertebrates	**LIN2**	**-0.194**	**<0.001**
Invertebrates	LIN3	-0.029	0.449
Invertebrates	LIN4	0.105	0.044
Invertebrates	**LIN7**	**-0.090**	**<0.001**
Invertebrates	PUYS	-0.099	0.030

3.4.2 Annual bycatch levels

Annual bycatch in each species category was estimated by multiplying the rates calculated from observer data for each area and year stratum by the total number of hooks set in the target ling longline fishery for the equivalent stratum, as described in Section 2.4. The precision of the estimates was determined from the variability in the bootstrap samples of 1000 ratios (Table 8, Figure 15).

The annual bycatch of QMS species ranged from 1420 t (in 2006–07) to 3150 t (in 2001–02) (Table 8). There are no strong patterns or trends in the amounts of bycatch of QMS species over time, the annual estimates being strongly determined by year to year changes in relative effort between areas along with differences in bycatch rates between areas.

The estimated annual bycatch of non-QMS species was much lower than that of QMS species, and in most years was 600–800 t. Maximum bycatch occurred in 1992–93 (1230 t), and catch was also relatively high in 1993–94, 1998–99 and 2010–11.

Invertebrate species were only a very small component of the total annual bycatch, amounting to from less than 1 t to 31 t per year, but less than 10 t in most years. The greatest amounts were caught in the middle part of the period, from 1998–99 to 2003–04 when 5–30 t per year were caught.

Total bycatch (all categories combined) showed a similar pattern to QMS species bycatch—as it was dominated by that category and inter-annual variability was relatively low in the other categories. However a slight decrease, or step-change, occurs after 2001–02 with only one subsequent year having greater bycatch than that of the lowest previous year. Total annual bycatch ranged from 1994 t in 2006–07 to 4068 t in 2001–02. The total bycatch estimates of Anderson (2008) are mostly similar to the current estimates for the same years (i.e. within 10%), not consistently higher or lower, and with overlapping confidence intervals in each year (Figure 15). Total bycatch is highly correlated with effort (correlation coefficient = 63%), as may be expected, with effort having generally decreased in this fishery after 2001–02. However, there is little correlation between total bycatch and the total estimated catch of ling from the target fishery—the latter having shown a strong decline over time.

Table 8: Estimates of total annual bycatch rounded to the nearest 10 t (except for invertebrates, rounded to the nearest tonne) in the ling longline fishery for the species categories QMS, non–QMS, invertebrates, and overall, based on observed catch rates; 95% confidence intervals in parentheses.

	QMS		Non-QMS		Invertebrate		Total bycatch	
1992–93	2 080	(1 820–2 370)	1 230	(1 100–1 390)	<1	(0–1)	3 310	(2 920–3 761)
1993–94	2 150	(1 970–2 340)	1 170	(820–1 610)	<1	(0–1)	3 320	(2 790–3 951)
1994–95	2 510	(2 340–2 730)	670	(600–750)	<1	(0–1)	3 180	(2 940–3 481)
1995–96	2 590	(2 270–2 960)	750	(650–860)	<1	(0–1)	3 340	(2 920–3 821)
1996–97	2 970	(2 580–3 400)	590	(490–710)	1	(0–1)	3 561	(3 070–4 111)
1997–98	3 000	(2 640–3 410)	770	(670–880)	2	(1–2)	3 772	(3 311–4 292)
1998–99	2 060	(1 650–2 470)	890	(510–1 220)	7	(4–10)	2 957	(2 164–3 700)
1999–00	2 390	(1 980–2 750)	680	(570–810)	5	(3–10)	3 075	(2 553–3 570)
2000–01	2 870	(2 500–3 330)	880	(760–1 030)	17	(5–30)	3 767	(3 265–4 390)
2001–02	3 150	(2 700–3 660)	890	(790–1 000)	28	(12–45)	4 068	(3 502–4 705)
2002–03	1 980	(1 670–2 310)	600	(530–670)	31	(19–43)	2 611	(2 219–3 023)
2003–04	2 120	(1 890–2 340)	710	(620–890)	24	(15–30)	2 854	(2 525–3 260)
2004–05	1 980	(1 790–2 210)	670	(580–750)	<1	(0–1)	2 650	(2 370–2 961)
2005–06	2 040	(1 850–2 230)	630	(540–720)	3	(2–5)	2 673	(2 392–2 955)
2006–07	1 420	(1 250–1 640)	570	(480–660)	4	(2–7)	1 994	(1 732–2 307)
2007–08	2 420	(2 210–2 630)	610	(520–700)	2	(1–3)	3 032	(2 731–3 333)
2008–09	2 050	(1 900–2 210)	660	(580–750)	3	(2–4)	2 713	(2 482–2 964)
2009–10	2 120	(1 790–2 450)	550	(420–700)	2	(1–3)	2 672	(2 211–3 153)
2010–11	1 960	(1 790–2 150)	950	(840–1 080)	2	(2–3)	2 912	(2 632–3 233)
2011–12	1 690	(1 530–1 860)	760	(680–840)	2	(2–3)	2 452	(2 212–2 703)

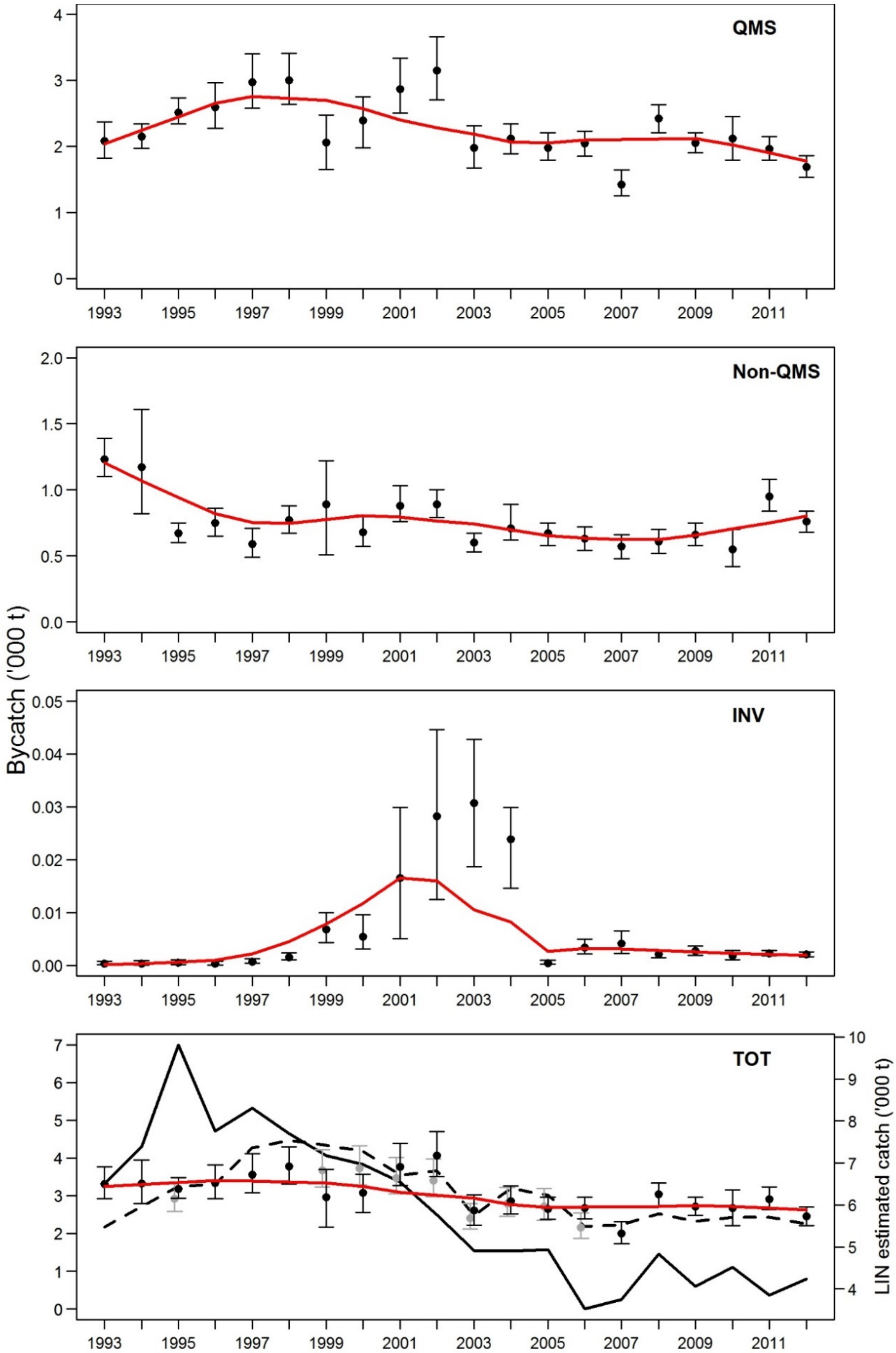

Figure 15: Annual estimates of bycatch in the ling longline fishery, for QMS species, non-QMS species, invertebrates (INV), and overall for 1992–93 to 2011–12. Also shown (in grey) are earlier estimates of total bycatch calculated for 1994–95 and 1998–99 to 2005–06 (Anderson 2008). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual bycatch. In the bottom panel the solid black line shows the total annual estimated commercial longline-catch of ling, and the dashed line shows annual effort (number of hooks), scaled to have mean equal to that of total bycatch.

Total annual bycatch calculated directly from commercial catch records (by summing the difference between the recorded total catch and ling catch for each set (LCE and LTC type forms) or group of sets (CEL type forms)) was substantially lower than the observer data-based estimate in all but one year (1993–94), and except for this year and 1998–99 was also outside of the 95% confidence intervals of the observer data-based estimates (Figure 16, Table 9). Overall, the total catch record-based annual bycatch for the 21-year period was about 65% of the observer data-based bycatch. However, the general pattern over time was similar between the two estimates, with a correlation of about 49%.

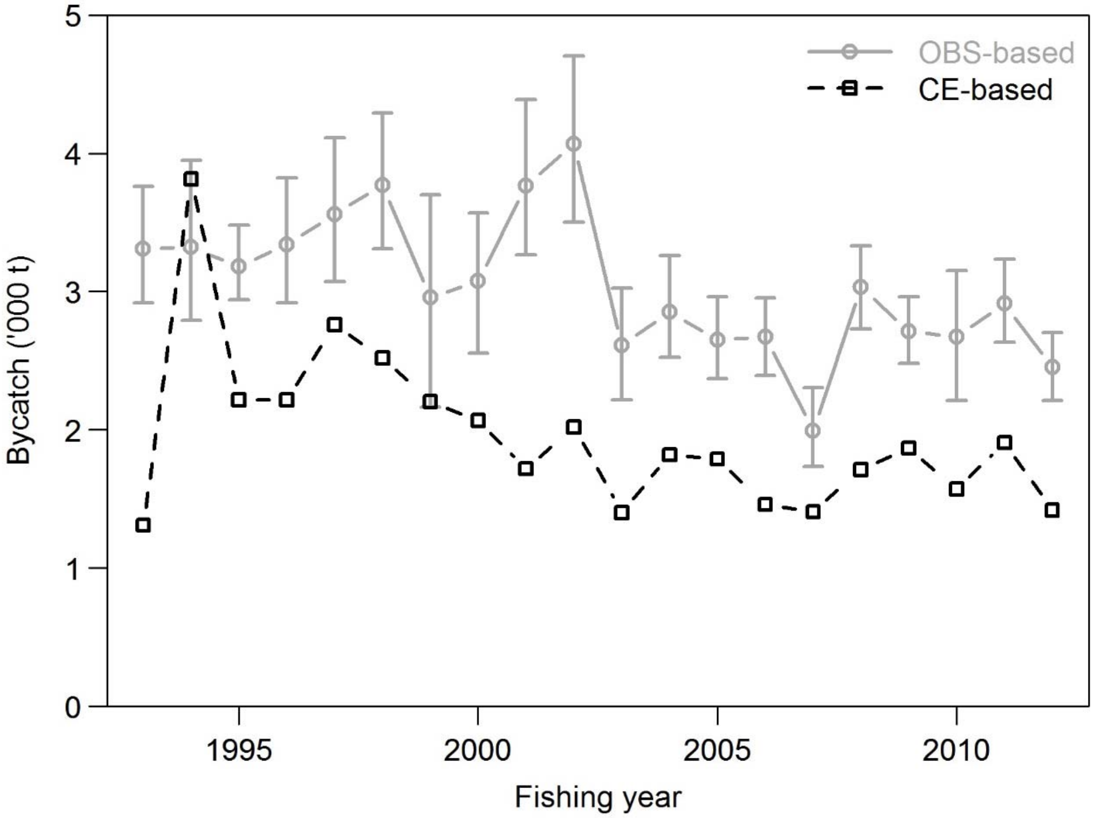

Figure 16: Total annual bycatch in the ling longline fishery from scaled up observer catch rates and commercial catch effort records.

Table 9: Total annual bycatch estimates for the ling longline fishery, based on catch effort records, compared with the observer-based estimates. Estimates are derived by summing the difference between the recorded total catch and ling catch for each set (LCE and LTC type forms) or group of sets (CEL type forms).

Fishing year	Total bycatch (t)	% of observer-based estimate
1992–93	1 311	40
1993–94	3 815	115
1994–95	2 216	70
1995–96	2 218	66
1996–97	2 762	78
1997–98	2 519	67
1998–99	2 203	75
1999–00	2 069	67
2000–01	1 719	46
2001–02	2 019	50
2002–03	1 402	54
2003–04	1 820	64
2004–05	1 789	67
2005–06	1 461	55
2006–07	1 408	71
2007–08	1 713	56
2008–09	1 868	69
2009–10	1 571	59
2010–11	1 907	65
2011–12	1 418	58

3.4.3 Trends in annual bycatch

A significant trend of increasing bycatch over time was shown for invertebrate species, and a significant trend of decreasing bycatch was shown for total bycatch (Table 10). Although changes in annual bycatch in these species categories are not necessarily strongly linear these regressions are useful, in conjunction with the locally weighted polynomials fitted to the plots in Figure 15, for drawing attention to any short term or long-term trends. The increased invertebrate catch over time may indicate an increased abundance of invertebrate species vulnerable to the fishery, a change in the operation of the fishery which has increased catch rates of these species, or improvements in the recording of invertebrate catch by observers. The decrease in bycatch in the other categories is strongly linked to decreasing overall effort in the fishery and, for QMS species at least, also the result of predominantly decreasing bycatch rates in most areas (see Table 7).

Table 10: Summary of results of regression analyses for trends in annual bycatch, by species category. The *p* values indicate whether the slopes differed significantly from zero. Those results where *p* values are less than 0.01 (generally considered highly significant) are shown in bold.

Species category	Slope	*p*
QMS	-0.015	0.015
Non-QMS	-0.006	0.418
Invertebrate	**0.089**	**<0.001**
Total	**-0.016**	**0.005**

3.5 Estimation of discards

3.5.1 Discard rates

Discard rates by area and year were calculated for each species category from the observer data (Figure 17, Appendices 6 and 7). The variance associated with the discard estimates was calculated using the bootstrap methods described above.

As with bycatch, the limited spread of observer effort required discard rates for several year/area combinations to include data from adjacent years, as described in Section 2.4.

Median discard rates of ling were generally less than 0.01 kg per hook and variable between years and areas although mostly constant in COOK, LIN 1, LIN 2, and LIN 7 due to insufficient data for calculating rates for individual years in these areas. In the larger fisheries, discard rates of ling were higher in BNTY and LIN 3 than in other areas and were generally higher before 2000–01.

Discard rates of QMS species ranged from close to zero to about 0.12 kg per hook, and as with bycatch tended to be highest on the Chatham Rise (LIN 3 and LIN 4) and lower in the southern regions. QMS species discard rates were consistently low in COOK, PUYS, LIN 1, and LIN 2. High rates in LIN 7 were based on data from multiple years.

Discard rates of non-QMS species were generally lower than those of QMS species, mostly less than 0.08 kg per hook. The highest rates were generally in LIN 1, LIN 2, and LIN 7, with rates mostly less than 0.03 kg per hook in other areas.

Discard rates for invertebrates are almost identical to bycatch for this group (see Figure 15), because the great majority of invertebrates were discarded. As with bycatch of invertebrates, patterns of discard rates may have been influenced by changes in observer recording practices over time.

Regression modelling was used to examine trends in discard rates in the same way (and with the same limitations) as described for bycatch (see Section 3.4.1). Results indicated a mixture of increasing and decreasing discard rates over time among areas in each species category (Table 11). Statistically significant decreases ($p<0.01$) were shown for ling in BNTY, CAMP, COOK, LIN 1, LIN 3, and LIN 7; for QMS species in BNTY, LIN 1, LIN 2, and LIN 7; for non-QMS species in COOK and LIN 2; and for INV species in COOK, LIN 2, and LIN 7. Significant increases were shown for QMS species in COOK, non-QMS species in LIN 1 and LIN 7, and INV species in BNTY.

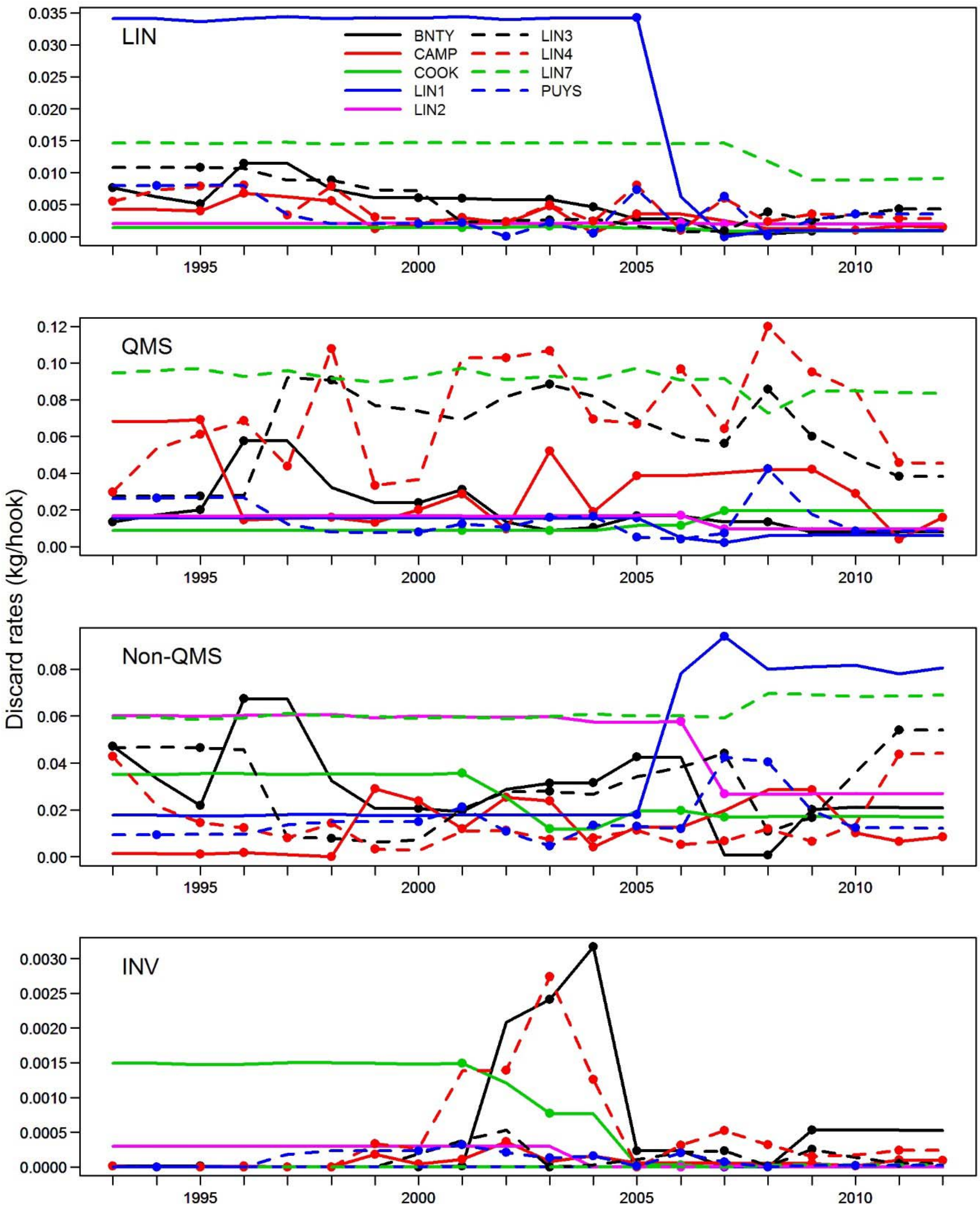

Figure 17: Annual discard rates by species category and areas used for stratification, in the ling longline fishery. Discard rates are the median of the bootstrap sample of 1000. Dots indicate years in which there were sufficient observed sets (>25) to calculate an individual discard rate for the area; for years with no dot discard rates were calculated using additional records from between 2 and 14 adjacent years (average 4, see Table 6) as required to obtain at least 25 records.

Table 11: Summary of results of regression analyses for trends in annual discard rates, by species category and area. The *p* values indicate how significantly the slopes differed from zero. Those results where *p* values are less than 0.01 (generally considered highly significant) are shown in bold; –, no discards recorded.

Species category	Area	Slope	*p*
LIN	**BNTY**	**-0.156**	**<0.001**
LIN	**CAMP**	**-0.075**	**0.005**
LIN	**COOK**	**-0.044**	**0.001**
LIN	**LIN1**	**-0.360**	**0.003**
LIN	LIN2	-0.003	0.200
LIN	**LIN3**	**-0.086**	**0.003**
LIN	LIN4	-0.048	0.035
LIN	**LIN7**	**-0.035**	**<0.001**
LIN	PUYS	-0.060	0.475
QMS	**BNTY**	**-0.065**	**0.005**
QMS	CAMP	-0.032	0.293
QMS	**COOK**	**0.067**	**<0.001**
QMS	**LIN1**	**-0.105**	**0.009**
QMS	**LIN2**	**-0.043**	**0.002**
QMS	LIN3	0.014	0.431
QMS	LIN4	0.026	0.131
QMS	**LIN7**	**-0.009**	**<0.001**
QMS	PUYS	-0.044	0.133
NONQMS	BNTY	-0.102	0.037
NONQMS	CAMP	0.133	0.031
NONQMS	**COOK**	**-0.061**	**0.003**
NONQMS	**LIN1**	**0.134**	**0.001**
NONQMS	**LIN2**	**-0.063**	**0.001**
NONQMS	LIN3	0.019	0.513
NONQMS	LIN4	-0.002	0.952
NONQMS	**LIN7**	**0.011**	**<0.001**
NONQMS	PUYS	0.040	0.109
INV	**BNTY**	**0.216**	**0.004**
INV	CAMP	-0.019	0.622
INV	**COOK**	**-0.288**	**<0.001**
INV	LIN1	0.000	0.104
INV	**LIN2**	**-0.187**	**0.006**
INV	LIN3	-0.030	0.420
INV	LIN4	0.103	0.049
INV	**LIN7**	**-0.090**	**<0.001**
INV	PUYS	-0.098	0.028

3.5.2 Annual discard levels

The level of annual discards in each species category was estimated by multiplying the ratios calculated from observer data for each area and year stratum by the total number of hooks set in the target ling longline fishery for the equivalent stratum, and precision of the estimates was determined from the variability in the bootstrap samples of 1000 ratios, as described in Section 2.4 (Table 12, Figure 18).

Discarding of ling was generally low, less than 250 t per year in all years except for 1997–98, and 100 t or less in half of the years examined; annual levels decreased over time, with 40–70 t of ling discards per year after 2004–05.

Discards of QMS species were in most years greater than discards of other categories, but were somewhat variable—ranging from a low of 580 t in 2011–12 to a high of 1800 t in 1997–98 (Table 12). Overall, QMS species discards showed a slight trend of increasing then decreasing levels over time.

Discards of non-QMS species were generally much lower than those of QMS species, although they were slightly higher in 2010–11 and 2011–12, ranging from 360 t in 2005–06 to 750 t in 2010–11. The fitted line in Figure 18 shows no clear trend in discard levels over time.

Annual discards of invertebrates were virtually identical to bycatch (as almost all of the catch in this category is discarded), ranging from less than 1 t to 30 t and generally greater in the middle years of the period, between 1998–99 and 2003–04.

Estimates of total annual discards ranged from 1230 in 2006–07 to 2510 t in 1997–98 and, like bycatch, generally show lower values for years after 2001–02 than for earlier years. The estimates for 1994–95 and 1998–99 to 2005–06 generally match well with those of Anderson (2008) for the same years (within 15% in all but two years), are not consistently higher or lower, and have overlapping confidence intervals in each year (Figure 18).

Table 12: Estimates of total annual discards (except for invertebrates, rounded to the nearest 10 t) in the ling longline fishery for the species categories LIN, QMS, non-QMS, invertebrates, and overall, based on observed discard rates; 95% confidence intervals in parentheses.

	LIN		QMS		Non-QMS		Invertebrate		Total discards	
1992–93	120	(110–130)	590	(510–700)	550	(500–610)	<1	(0–1)	1 260	(1 120–1 440)
1993–94	170	(160–190)	870	(760–990)	520	(420–640)	<1	(0–1)	1 560	(1 340–1 820)
1994–95	190	(180–210)	1 370	(1 220–1 540)	400	(350–460)	<1	(0–1)	1 960	(1 750–2 210)
1995–96	230	(220–240)	1 240	(980–1 540)	560	(480–680)	<1	(0–1)	2 030	(1 680–2 460)
1996–97	220	(200–240)	1 270	(920–1 660)	430	(350–530)	1	(0–1)	1 920	(1 470–2 430)
1997–98	250	(230–260)	1 800	(1 430–2 150)	460	(390–570)	2	(1–2)	2 510	(2 050–2 980)
1998–99	120	(110–130)	930	(570–1 320)	630	(350–910)	7	(4–10)	1 690	(1 030–2 370)
1999–00	130	(110–150)	1 120	(690–1 540)	480	(400–570)	5	(3–10)	1 740	(1 200–2 270)
2000–01	110	(100–120)	1 520	(1 230–1 860)	550	(460–640)	16	(5–31)	2 200	(1 790–2 650)
2001–02	80	(70–90)	1 720	(1 320–2 110)	570	(510–640)	28	(12–45)	2 400	(1 910–2 880)
2002–03	100	(80–110)	1 170	(890–1 470)	380	(330–430)	30	(12–42)	1 680	(1 310–2 050)
2003–04	70	(60–70)	970	(770–1 130)	430	(380–530)	24	(15–30)	1 490	(1 230–1 760)
2004–05	160	(140–190)	1 160	(980–1 370)	440	(380–500)	<1	(0–1)	1 760	(1 500–2 060)
2005–06	40	(30–40)	1 030	(900–1 200)	360	(310–420)	3	(2–5)	1 430	(1 240–1 660)
2006–07	70	(60–90)	730	(600–900)	430	(370–510)	4	(2–6)	1 230	(1 030–1 510)
2007–08	50	(40–50)	1 220	(1 090–1 390)	440	(390–520)	2	(1–3)	1 710	(1 520–1 960)
2008–09	50	(50–60)	1 020	(920–1 130)	370	(330–420)	3	(2–4)	1 440	(1 300–1 610)
2009–10	60	(50–70)	1 000	(710–1 220)	450	(330–570)	2	(1–3)	1 510	(1 090–1 860)
2010–11	60	(50–70)	600	(490–720)	750	(660–840)	2	(2–3)	1 410	(1 200–1 630)
2011–12	50	(50–60)	580	(470–690)	620	(560–690)	2	(2–3)	1 250	(1 080–1 440)

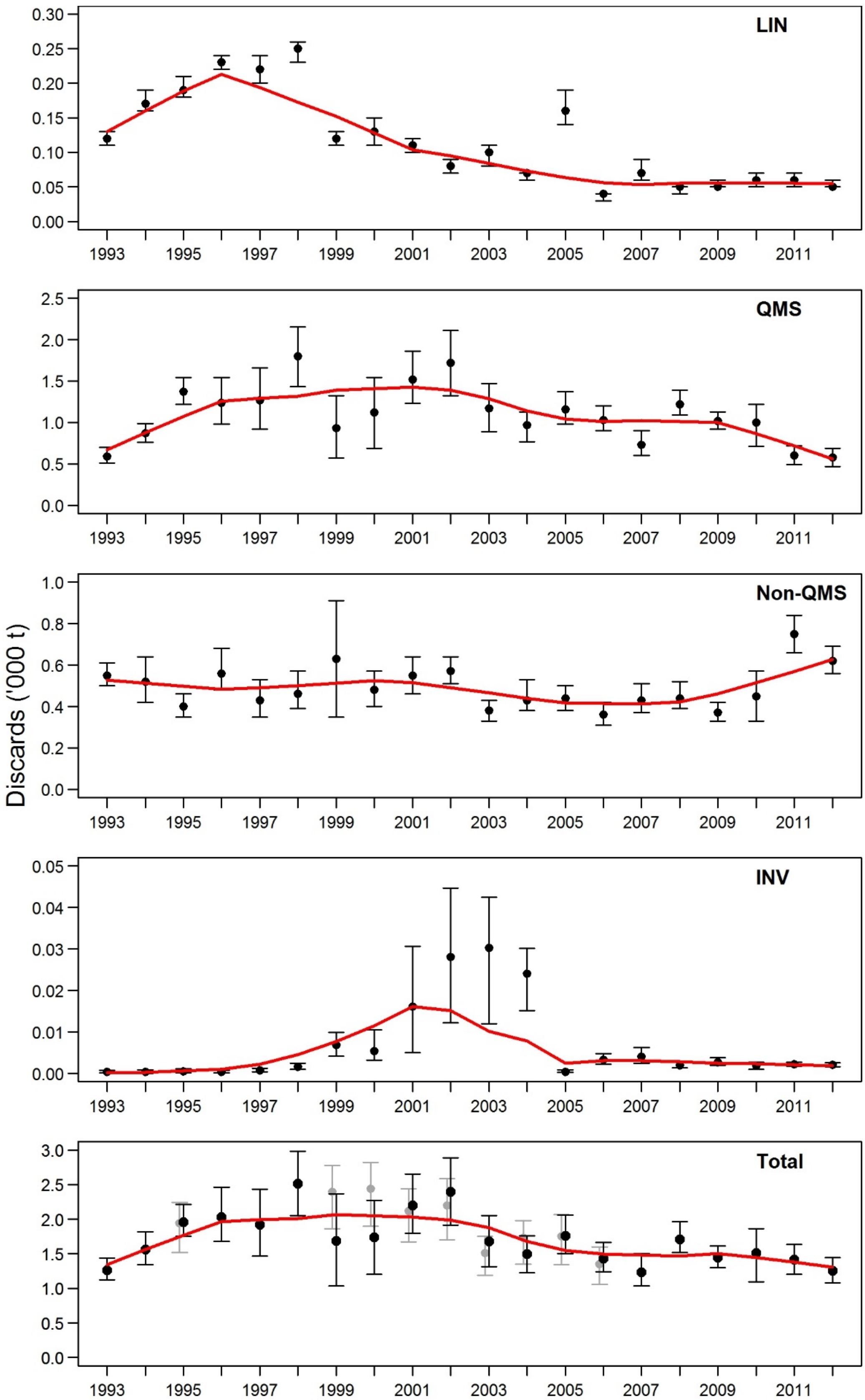

Figure 18: Annual estimates of discards in the ling longline fishery, for ling (LIN), QMS species, non-QMS species, invertebrates (INV), and overall for 1992–93 to 2011–12. Also shown (in grey) are earlier estimates of total discards calculated for 1994–95 and 1998–1999 to 2005–06 (Anderson 2008). Error bars indicate 95% confidence intervals. The red lines show the fit of a locally-weighted polynomial regression to annual discards.

3.5.3 Trends in annual discards

Linear trends in annual discards are not strongly suggested in any of the categories examined (see fitted regression lines in Figure 18); however, linear regressions can be useful for indicating long-term changes. A significant positive slope (indicating increasing discards over time) was shown for invertebrates, and a negative slope (indicating decreasing discards over time) was shown for ling (Table 13).

Table 13: Summary of results of regression analyses for trends in annual discards, by species category. The *p* values indicate whether the slopes differed significantly from zero. Those results where *p* values are less than 0.01 (generally considered highly significant) are shown in bold.

Species category	Slope	*p*
LIN	**-0.077**	**<0.001**
QMS	0.004	0.714
Non-QMS	-0.003	0.682
Invertebrate	**0.086**	**<0.001**
Total	-0.005	0.349

3.5.4 Discard information from Catch Landing Returns

The disposal of all catch taken by vessels in the ling longline fishery is recorded on Catch Landing Returns (CLRs). Codes used on this form under *destination_type* which may provide information on discarding include:

A	Accidental loss
D	Discarded (non-QMS)
M	QMS species returned to sea (those in Part 6A of the Fisheries (Reporting) Regulations 2001, this code currently only applies to spiny dogfish).
X	QMS species returned to sea (those listed in Schedule 6 of the Fisheries Act (1996) but excluding those in Part 6A of the Fisheries (Reporting) Regulations 2001 (i.e., spiny dogfish).

Although these returns are designed to capture information on the disposal of all catch recorded in catch/effort forms, in reality there appears to have been more of a focus on fish physically landed onshore, with discarded bycatch not fully recorded in all cases. A summary of this information is made in any case, to gauge the level of reported discarding, in particular the discarding of QMS species, which is permitted for species listed in Schedule 6 of the Fisheries Act (1996) and for species not so listed when an observer is on board the vessel and approves it.

Catch Landing Return data were examined from all bottom longlining trips on which ling were targeted in any set. Unfortunately these returns relate to the catch from several days or from whole trips rather than from individual sets, and so they may relate to more than one target fishery. Ling was the target species in only about 75% of the sets on these trips, therefore the discard quantities derived in this way are overestimated.

Recorded accidental losses of fish ranged from 1–101 t per year and discarding of non-QMS species ranged from 104–1083 t per year (Table 14). Accidental losses were variable but generally increased over time (at least up until 2006–07), while non-QMS discards were highest between 1995–96 and 2003–04 and have been at a relatively low and constant level since 2005–06. Destination types M and X are more recent codes, introduced in 2004–05 and 2007–08 respectively. These show little recorded discarding of Schedule 6 QMS species but larger amounts of Part 6A (spiny dogfish) discards (up to 480 t per year). The codes listed in Table 14 are the only destination type codes available for recording discards, and there is no code provided to record observer/fishery officer approved discards. Such discards are therefore unaccounted for by Catch Landing Records. The total discards calculated from these returns are much lower than estimated from observer records, less than half in most years, but excluding the first few years represent a relatively constant fraction of them.

Table 14: Summary of discard and loss weights (t) by destination type and fishing year, from ling longline fishery Catch Landing Returns. A, Accidental loss; D, Discarded (Non-QMS); M, QMS species returned to sea (Part 6A, currently only spiny dogfish); X, QMS species returned to sea (not Part 6A, i.e., excluding spiny dogfish but including species with size limits, e.g. red cod).

	Destination type					
	A	D	M	X	Total	% of observer-based estimate
1992–93	2	250	0	0	252	20
1993–94	6	319	0	0	325	21
1994–95	1	222	0	0	223	11
1995–96	11	1001	0	0	1012	50
1996–97	41	901	0	0	941	49
1997–98	10	889	0	0	900	36
1998–99	8	755	0	0	763	45
1999–00	22	600	0	0	622	36
2000–01	4	769	0	0	773	35
2001–02	30	914	0	0	943	39
2002–03	38	1 083	0	0	1 121	67
2003–04	35	773	0	0	808	54
2004–05	95	255	437	0	787	45
2005–06	52	104	367	0	523	37
2006–07	101	146	438	0	686	56
2007–08	57	174	482	6	718	42
2008–09	46	189	432	2	668	46
2009–10	48	149	430	21	648	43
2010–11	48	199	422	18	687	49
2011–12	26	169	269	25	489	39

3.5.5 Observer-authorised discarding

Section 72 of the Fisheries Act (1996) allows for the legal discarding of QMS species not listed in Schedule 6 if authorised by an observer (or fishery officer) who is present at the time. Such discarding is recorded at sea on an "Authority to return or abandon fish to the sea" form. These forms are returned to MPI where they are stored, but not recorded in any electronic database. In addition, observers provide a summary of all approved discarding for each trip in their trip report, but again this is not recorded in a database. A complicating factor with the data from both of these sources (if they were to have been incorporated into this study) is that usually the records relate to the combined discards from several sets, or the entire trip, and there may have been issues in reconciling these data with the catch from individual sets.

An examination was made of the trip reports from a random selection of 15 of the 99 observed trips in this study. Four of these trips recorded authorised discarding of QMS species of between about 0.350 t and 4 t per trip, and the remaining trips recorded none. Most of these discards comprised ling and ribaldo which were considered too damaged by lice, predators or scavengers to process.

Observer authorised discarding clearly has the potential to bias estimation of discards which are based on observed discard ratios. Ideally such discards would be ignored in the calculation of these ratios but this could be done only by assuming that all QMS species discards in the observer databases were properly approved. Disregarding these discards would lead to a discard ratio of zero and infer zero discarding of (non-Schedule 6, or fish smaller then MLS) QMS species in the unobserved portion of the fishery. The annual QMS species discard estimates presented in this report therefore make the assumption that the level of discarding of QMS species not listed in Schedule 6 and MLS of the Fisheries Act 1996 is unaffected by the presence of an observer on the vessel.

3.6 Efficiency of the ling longline fishery

Annual discard estimates in the ling longline fishery were divided by the estimated annual catch of ling and the total annual bycatch, to provide measures of the efficiency of the fisheries (Table 15).

The annual discard fraction (kg of discards/kg of ling catch) ranged from 0.19 in 1992–93 to 0.42 in 2001–02, with an overall value for the 20-year period of 0.29. Although variable from year to year, the discard fraction increased up to 2001–02, and has shown no trend since. Between 38% and 67% of the annual bycatch was discarded, with no obvious pattern over time.

Table 15: Estimated annual ling catch (t), total bycatch (t), and total discards (t) in the target ling longline fishery; discard fraction (kg of total discards per kg of ling caught); and discards as a fraction of bycatch.

Fishing year	Ling estimated catch	Total bycatch	Total discards	Discard fraction	Discards/ bycatch
1992–93	6 518	3 310	1 260	0.19	0.38
1993–94	7 384	3 320	1 560	0.21	0.47
1994–95	9 817	3 180	1 960	0.20	0.62
1995–96	7 754	3 340	2 030	0.26	0.61
1996–97	8 311	3 561	1 920	0.23	0.54
1997–98	7 697	3 772	2 510	0.33	0.67
1998–99	7 182	2 957	1 690	0.24	0.57
1999–00	6 962	3 075	1 740	0.25	0.57
2000–01	6 542	3 767	2 200	0.34	0.58
2001–02	5 765	4 068	2 400	0.42	0.59
2002–03	4 909	2 611	1 680	0.34	0.64
2003–04	4 906	2 854	1 490	0.30	0.52
2004–05	4 943	2 650	1 760	0.36	0.66
2005–06	3 526	2 673	1 430	0.41	0.53
2006–07	3 744	1 994	1 230	0.33	0.62
2007–08	4 834	3 032	1 710	0.35	0.56
2008–09	4 064	2 713	1 440	0.35	0.53
2009–10	4 521	2 672	1 510	0.33	0.57
2010–11	3 852	2 912	1 410	0.37	0.48
2011–12	4 235	2 452	1 250	0.30	0.51

3.7 Annual bycatch by individual species in the ling longline fishery

A table of annual bycatch estimates for individual species, and regression slopes indicating general trends in abundance, is given in Appendix 11. In some cases the apparent increase or decrease in bycatch of a species is likely to be due to improvements in species identification, or changes in recording habits, over time. For example, observers may have switched from the genus-level code CON (*Conger* spp.) to the more specific code HCO (hairy conger, *Bassanago hirsutus*) resulting in an apparent increase in HCO catch and a decrease in CON catch over time; and a change from SKA (skate) to the more specific RSK (rough skate) and SSK (smooth skate) may be responsible for the apparent decrease in bycatch of SKA.

Based on these estimates, the most commonly caught bycatch species over the entire commercial fishery were (in decreasing order) spiny dogfish (SPD), ribaldo (RIB), smooth skate (SSK), sea perch (SPE), bluenose (BNS), and red cod (RCO). Of the 116 bycatch species examined, 14 have shown a significant decrease in catch over time and 21 an increase in catch over time (the remaining species showing no change at the 1% level of significance). Among the species showing significant declines were bluenose (*Hyperoglyphe antarctica*, BNS), Ray's bream (*Brama brama*, RBM), and hapuku (*Polyprion oxygeneios*, HAP). Species showing significant increases included hairy conger (HCO), hagfish (*Eptratretus cirrhatus*, HAG), and pale ghost shark (*Hydrolagus bemisi*, GSP) (Figure 19).

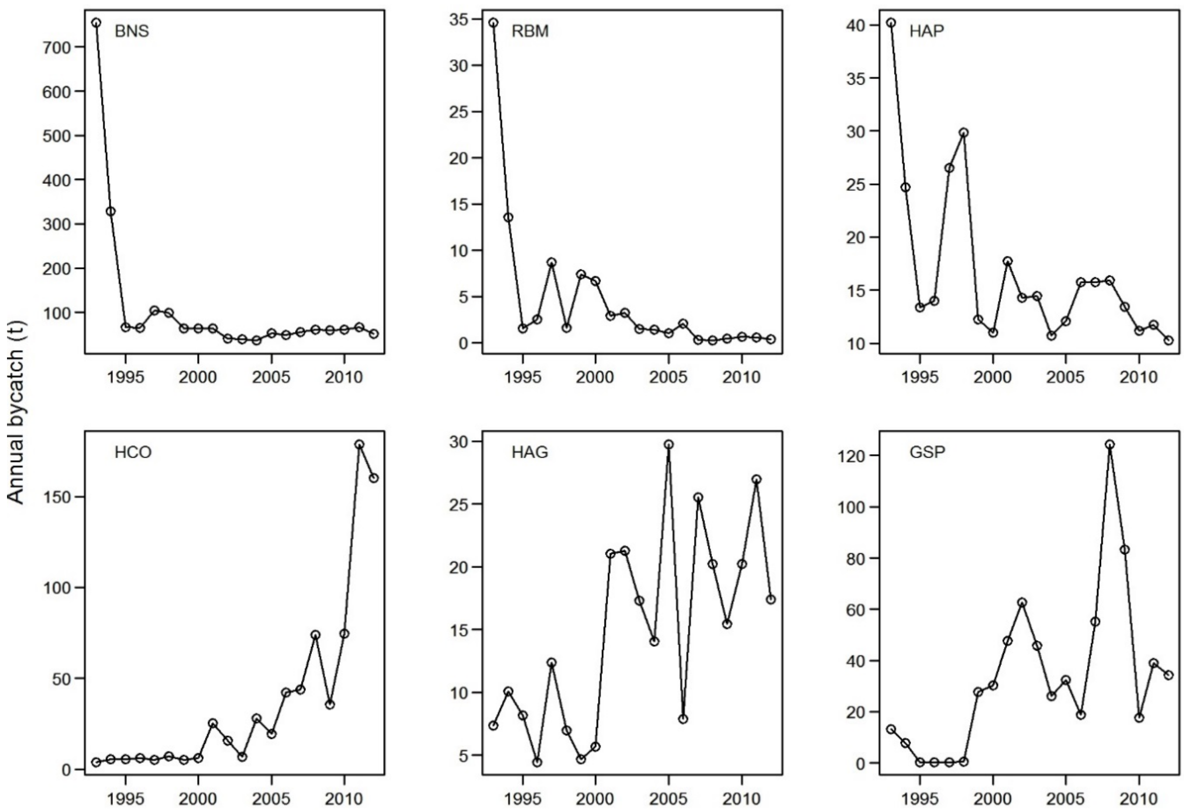

Figure 19: Annual bycatch estimates in the ling longline fishery for species which have shown a significant decrease (top) or increase (bottom) between 1990–91 and 2010–11. See text above for explanation of the species codes.

3.7.1 Comparison of trends in individual species bycatch in the ling longline fishery with relevant trawl surveys

The time-series of trawl surveys in the sub-Antarctic (Bagley et al. 2013) and on the Chatham Rise (O'Driscoll et al. 2011) overlap substantially with the depth range and the spatial extent of the ling longline fishery. The sub-Antarctic surveys include the Campbell Plateau (CAMP) stratum of this study in depths of 300–800 m; the Chatham Rise surveys cover the Chatham Rise (LIN 3 and LIN 4) strata of this study in depths of 200–800 m. Although the fishing methods are quite different, preventing comparison of catch rates of combined species categories due to differences in the relative catchability of individual species between methods, it may be useful to compare trends in catch rates of the main bycatch species with survey relative biomass estimates.

Annual relative biomass estimates were calculated for a wide range of species in each survey time-series and summarised in two comprehensive reports; these cover the years 1991 to 2009 in the sub-Antarctic (Bagley et al. 2013), and 1992 to 2010 on the Chatham Rise (O'Driscoll et al. 2011). The confidence in the biomass estimates in these reports was defined as follows: **very well** estimated, mean CV < 20%; **well** estimated, mean CV 20–30%; **moderately well** estimated, mean CV 30–40%, **poorly** estimated, mean CV > 40% (O'Driscoll et al. 2011). Definitions of trends used a bootstrapping technique based on ranks for survey data split into three time periods (see O'Driscoll et al. 2011 for full details). Trends in bycatch rates from this study were identified using linear regression models, with annual bycatch rates weighted by 1/n, where n is the number of years of observer records combined to achieve a minimum of 25 records (see Table 6).

Spiny dogfish (SPD)
According to the present study, spiny dogfish was the most caught bycatch species (by weight) in the ling longline fishery; no trend in bycatch rates was identified in this study for the Campbell Plateau, but significant increasing trends were indicated for both Chatham Rise areas (LIN 3 and LIN 4). This species was reported as being **well** estimated in the survey area of the sub-Antarctic survey and **very well** estimated in the survey area of the Chatham Rise surveys; relative biomass showed **no clear trend** in the sub-Antarctic survey time-series, but **increased** in the Chatham Rise surveys.

Ribaldo (RIB)
Ribaldo was the second most caught bycatch species (by weight) in the fishery; a significant increasing trend in bycatch rate was identified in this study for the Campbell Plateau but not for the Chatham Rise. This species was reported as being **very well** estimated in the survey areas of both the sub-Antarctic surveys and the Chatham Rise surveys and relative biomass has showed **no clear trend** in either time-series.

Shovelnose dogfish (SND)
Shovelnose dogfish was the third most caught bycatch species (by weight) in the fishery; a significant increasing trend in bycatch rate was identified in this study for the western Chatham Rise (LIN 3), with no trends in the other areas. This species was reported as being **well** estimated in the survey areas of both the sub-Antarctic surveys and the Chatham Rise surveys; relative biomass has showed **no clear trend** in the Chatham Rise time-series, but **decreased** then **increased** in the sub-Antarctic time-series.

Smooth skate (SSK)
Smooth skate was the fourth most caught bycatch species (by weight) in the fishery; no significant trends in bycatch rate were identified in this study for any of the areas. This species was reported as being **poorly** estimated in the survey area of the sub-Antarctic survey but **well** estimated in the survey area of the Chatham Rise surveys; relative biomass showed **no clear trend** in the sub-Antarctic time-series, but **increased** in the Chatham Rise time-series.

Sea perch (SPE)
Sea perch was the fifth most caught bycatch species (by weight) in the fishery; no significant trends in bycatch rate were identified in this study for any of the areas. This species was reported as being **poorly** estimated in the survey area of the sub-Antarctic surveys but **very well** estimated in the survey area of the Chatham Rise surveys; relative biomass showed **no clear trend** in the sub-Antarctic time-series, but **increased** in the Chatham Rise time-series.

Bluenose (BNS)
Bluenose was the sixth most caught bycatch species (by weight) in the fishery; a significant increasing trend in bycatch rate was identified in this study for the western Chatham Rise, but a decreasing trend for the eastern Chatham Rise (LIN 4). This species was reported as being **poorly** estimated in the survey areas of both the sub-Antarctic surveys and the Chatham Rise surveys and relative biomass has showed **no clear trend** in either time-series.

4. SUMMARY AND DISCUSSION

The annual estimates of bycatch and discards in the fishery are based on observed bycatch and discard rates and, as such, the precision of these estimates is strongly dependent on the level and spread of observer coverage as well as the quality of this coverage.

The level of observer coverage in the ling longline fishery has been lower than most of the other deepwater fisheries for which bycatch and discard levels are assessed. The long-term level of observer coverage in most of the other deepwater fisheries has been greater than 18% (and over 40% for southern blue whiting) by weight of the target fishery catch, and for the ling longline fishery the level is about 13%. Other fisheries for which a similarly low level of coverage has been reported are the jack mackerel and scampi fisheries (Anderson 2004, 2007, 2012), at about 11–12% of the target fishery catch. Coverage in the ling longline fishery has been highly variable, although for most of the 2000s was well over 15% and as much as 52%, and has recently declined to below 10%. The 5.3% coverage achieved in 2010–11 was the lowest since 1996–97.

The distribution of observer effort has been fairly representative of total commercial effort across the variables shown in the models to influence rates of bycatch and discards. The main longline fisheries for ling on the Chatham Rise, Bounty Plateau, Campbell Plateau, and Puysegur Banks were all well sampled by observers in most years and although there was a degree of under- and over-sampling in some regions after 2005–06, coverage was mostly in proportion to total effort throughout the 20 years examined. The smaller vessels in the fishery were poorly sampled compared to the large vessels, and although large fractions of the ling catch in areas fished mainly by small vessels were taken by vessels that never hosted observers, these were the smaller (by volume) ling longline fisheries (LIN 1, LIN 2, LIN 7). Observer coverage in this year-round fishery was restricted to one or a few short periods in each year but over the 20-year period examined coverage the seasonal changes in total effort were well matched by observer effort.

The number of hooks-based rate estimator used in the analysis was ultimately preferred over initial methods based on a number of sets-based estimator. The number of sets-based estimator was initially chosen due to the reduced possibility of measurement error, and of because of potential bias in the hooks-based method due to the lack of information in the percentage of hooks baited on non-observed sets (data from this study show that greater than 20% of hooks are unbaited in 15% of observed sets), and difficulties in reconciling errors in recording of hook numbers. Hook numbers were less than 20 000 in over 99% of sets, but occasionally larger vessels deploy longer sets with more than 20 000 hooks, up to a maximum of about 35 000 hooks. For the outliers, median imputation was used to substitute median hook numbers for the vessel/trip in question but the choice of a cut-off value (in this case 20 000) is somewhat arbitrary and, because of the numbers involved, has the potential to affect the amount of effort attributed. However, these concerns were outweighed by the bias and over-estimation that may result from the number of sets-based estimator due to the lack of observer coverage on smaller vessels for which the mean set length is considerably shorter.

Overall, the *area* fished was the most critical factor influencing bycatch and discard rates in this fishery and although *month* was also important, there was insufficient observer data to stratify by more than two variables, i.e., *area* and *fishing year*—the same as used in the previous assessment (Anderson 2008).

Estimation of bycatch and discards focussed on three broad categories of catch; QMS species, non-QMS species, and invertebrates. These categories do not match the “commercial” and “non-commercial” species categories previously assessed, limiting comparisons between studies to total bycatch and total discards. The repeated estimates of total annual bycatch and discards were very similar to the earlier estimates for most years. The small differences observed are due to slight differences in data grooming methods and the revised procedure used for dealing with data poor strata.

Eight of the top ten bycatch species are QMS species, and therefore direct controls exist to limit their overall catch. Spiny dogfish is by far the main bycatch species and, despite being a QMS species, is mostly discarded. Although individual species discards were not estimated, annual bycatch of spiny dogfish was 500–1800 t and observer data show an overall discard rate of 88% for this species. Spiny dogfish are also a major component of the bycatch and discards in the arrow squid, scampi, hoki, hake, ling, southern blue whiting, and jack mackerel trawl fisheries (Anderson 2007, 2009, 2012, 2013a, Ballara et al. 2010), and indeed much of the total annual catch of this species has historically been discarded due to its low commercial value (Manning et al. 2004). Despite this, there is no evidence that spiny dogfish abundance has declined, and stock sizes may actually be increasing (Ministry for Primary Industries 2014).

The non-QMS bycatch species observed in the greatest amount was the black cod, a species very rarely caught in research trawls (McMillan et al. 2011b), and considered most likely to have been confused with the much more common smallscaled cod (*Notothenia microlepidota*) (Andrew Stewart, Te Papa, pers. comm.). However, the observer records of black cod were mainly from around the Bounties, where the fishery is much shallower and well overlapped with the depth range of this species (0–250 m), with very few records from other areas where the fishing is mostly deeper than this. Interestingly, most of the observed catch of black cod was retained by the vessel, and it was the 16th most reported bycatch species by weight in landings records for long longline trips during the period, at an average of 45 t per year since 1995–96. Verification of the identification of black cod from this fishery should be addressed. The next most observed non-QMS bycatch species, the shovelnose dogfish (*Deania calcea*), is a widespread species in depths of 400–1400 m (McMillan et al. 2011a). Shovelnose dogfish were also one of the main bycatch and discard species in the hoki, hake, and ling trawl fishery (Ballara et al. 2010) and orange roughy fishery (Anderson 2011). A recent summary has shown that, across all eight of the deepwater fisheries monitored, there is a mixture of increasing and decreasing bycatch of shovelnose dogfish (Anderson 2013b, Anderson 2014). The overall impact of the deepwater fisheries on this species should be assessed.

Of the next ten bycatch species, eight were non-QMS species and were mostly discarded; together these accounted for nearly 4% of the total fishery catch. The catch of invertebrates in this fishery is small compared to most trawl fisheries and, combined, rank as only the 21st most observed taxa caught in the fishery. Asteroids (starfishes) dominate this category and are particularly vulnerable to baited hooks as they feed by either swallowing food whole or by everting their stomachs to engulf food externally to their body. Observers may have become more diligent over time, or been more diligent at times, in recording of invertebrates, but this cannot be assessed. Observers have always been required to record invertebrate catch and the main improvement in this area is likely to have been in the taxonomic resolution of the catch species.

Bycatch in both of the combined fish species categories, non-QMS species discards, and total bycatch and total discards, all showed a decreasing trend over the 20-year period, and although this trend was statistically significant in most cases, the decrease was not substantial (e.g., total bycatch went from about 3300 t in 1992–93 to about 2400 t in 2011–12, see Figure 15). Similarly, bycatch and discards of invertebrates increased only slightly over time and may have been partly due to a generally increasing observer focus on this part of the catch over the period. Total bycatch determined from commercial catch-effort records, while much lower than those estimated from observer data, showed a similar decreasing trend.

The current rate of discarding in this fishery is similar to the long-term average, with recent values of 0.30–0.37 kg of discards per kilogram of ling caught compared with a 20-year average of 0.29 kg. This current rate is higher than that seen in the southern blue whiting (0.005 kg), oreo (0.03 kg), orange roughy (0.04 kg), jack mackerel (0.06 kg), arrow squid (0.06 kg), and hoki, hake, ling trawl (0.06 kg) fisheries, and is lower only than that of the scampi (4.2 kg) fishery (Anderson 2007, 2009, 2011, 2012, 2013a, Ballara & Anderson 2009).

Worthwhile comparisons of bycatch rate estimates for the combined QMS species, Non-QMS species, and invertebrate species categories from this study with relative abundance estimates from time series of research surveys were not possible, but comparisons of annual estimates of bycatch rates for the main individual bycatch species with relative biomass estimates from Chatham Rise and sub-Antarctic trawl survey time series were made.

The estimation of bycatch levels for a wide range of species in the ling longline fishery fisheries has provided an initial overview of the level of annual catch and enabled the highlighting of taxa where catch has changed over time, and may require additional investigation. Patterns in relative biomass estimates for individual bycatch species from trawl survey time series in the sub-Antarctic and the Chatham Rise showed little support for species identified in this study as having significantly declining or increasing catch rates over time; the exception to this was spiny dogfish which showed a significant increasing trend in bycatch rate in both Chatham Rise areas, supported by increasing relative biomass in the Chatham Rise trawl survey time series. Biomass of most of the other species compared was either poorly estimated in the surveys (mean CV > 40%), showed no clear trend over time, or both.

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APPENDICES

Appendix 1: Observed fish bycatch. Species codes, common and scientific names, estimated catch, percentage of total catch, and overall percentage discarded of the top 100 fish species or species groups by weight from observer records for the ling longline target fishery from 1 Oct 1992 to 30 Sep 2012. Records are ordered by decreasing percentage of catch. Codes in bold are QMS species; 1 = Schedule 6 QMA species; 2 = species with a minimum legal size. Estimated catches are based on all observed target ling longline sets; discards are based on recorded discards and species discard ratios calculated from sets where discards were recorded.

Species code	Common name	Scientific name	Observed catch (t)	% of catch	% discarded
LIN	Ling	*Genypterus blacodes*	15 371	67.93	1
SPD[1]	Spiny dogfish	*Squalus acanthias*	2 909	12.86	88
RIB	Ribaldo	*Mora moro*	665	2.94	13
SSK[1]	Smooth skate	*Dipturus innominatus*	409	1.81	34
RSK[1]	Rough skate	*Zearaja nasuta*	395	1.75	4
RCO[2]	Red cod	*Pseudophycis bachus*	382	1.69	9
BCD	Black cod	*Paranotothenia magellanica*	315	1.39	31
SPE	Sea perch	*Helicolenus* spp.	272	1.20	6
GSP	Pale ghost shark	*Hydrolagus bemisi*	197	0.87	9
SCH[1]	School shark	*Galeorhinus galeus*	168	0.74	12
SND	Shovelnose spiny dogfish	*Deania calcea*	165	0.73	24
ETM	(Dogfishes)	*Etmopterus* sp.	130	0.57	97
CON	Conger eel	*Conger* spp.	120	0.53	97
GSH	Ghost shark	*Hydrolagus novaezealandiae*	106	0.47	14
NOT	Antarctic rock cods	Nototheniidae	103	0.46	8
BSH	Seal shark	*Dalatias licha*	100	0.44	93
DWD	Deepwater dogfish		97	0.43	99
SKA	Skate	Rajidae Arhynchobatidae	89	0.39	71
OSD	Other sharks and dogs	Selachii	78	0.35	100
HCO	Hairy conger	*Bassanago hirsutus*	68	0.30	86
BNS	Bluenose	*Hyperoglyphe antarctica*	67	0.29	3
CSQ	Leafscale gulper shark	*Centrophorus squamosus*	40	0.18	100
RAT	Rattails	Macrouridae	37	0.16	67
NSD	Northern spiny dogfish	*Squalus griffini*	32	0.14	100
HAG	Hagfish	*Eptatretus cirrhatus*	31	0.14	100
HAP	Hapuku	*Polyprion oxygeneios*	29	0.13	1
CHI	Chimaeras	*Chimaera* spp.	19	0.09	21
HAK	Hake	*Merluccius australis*	15	0.07	11
ETB	Baxters lantern dogfish	*Etmopterus baxteri*	15	0.06	100
CAR	Carpet shark	*Cephaloscyllium isabellum*	13	0.06	100
BAS	Bass groper	*Polyprion americanus*	12	0.05	1
SCO	Swollenhead conger	*Bassanago bulbiceps*	12	0.05	97
ETL	Lucifer dogfish	*Etmopterus lucifer*	10	0.05	79
SSH	Slender smooth-hound	*Gollum attenuatus*	10	0.04	100
PLS	Plunket's shark	*Proscymnodon plunketi*	9	0.04	100
DWE	Deepwater eel		7	0.03	100
SEE	Silver conger	*Gnathophis habenatus*	7	0.03	100
DSK	Deepwater spiny skate	*Amblyraja hyperborea*	6	0.03	100
POS[1]	Porbeagle shark	*Lamna nasus*	6	0.03	63
CHP	Chimaera brown	*Chimaera* sp.	6	0.03	100
CHG	Giant chimaera	*Chimaera lignaria*	6	0.02	12
RBM	Rays bream	*Brama brama*	5	0.02	21
HPB	Hapuku & bass	*Polyprion oxygeneios & P. americanus*	4	0.02	2
HEX	Sixgill shark	*Hexanchus griseus*	4	0.02	100
CYO	Smooth skin dogfish	*Centroscymnus owstoni*	3	0.02	100
SQA	(Dogfishes)	*Squalus* spp.	3	0.01	100
BWS[1]	Blue shark	*Prionace glauca*	3	0.01	15
SCM	Largespine velvet dogfish	*Centroscymnus macracanthus*	2	0.01	80

Appendix 1 — *Continued*

Species code	Common name	Scientific name	Observed catch (t)	% of catch	% discarded
STA	Giant stargazer	*Kathetostoma* spp.	1	0.01	70
BCO[2]	Blue cod	*Parapercis colias*	1	0.01	4
HOK	Hoki	*Macruronus novaezelandiae*	1	0.01	23
JAV	Javelin fish	*Lepidorhynchus denticulatus*	1	0.01	95
WPS	White pointer shark	*Carcharodon carcharias*	1	<0.01	100
TRU	Trumpeter	*Latris lineata*	1	<0.01	1
SPO[1]	Rig	*Mustelus lenticulatus*	1	<0.01	100
CEN	Deepsea sharks	Squalidae	1	<0.01	100
CYP	Longnose velvet dogfish	*Centroscymnus crepidater*	1	<0.01	100
HYD	Hydrolagus	*Hydrolagus* sp.	1	<0.01	100
RCK	Rockfish	Acanthoclinidae	1	<0.01	100
SHA	Shark		1	<0.01	100
EEL	Eels marine		1	<0.01	100
PTO[1]	Patagonian toothfish	*Dissostichus eleginoides*	1	<0.01	1
TOA	Toadfish	*Neophrynichthys* sp.	1	<0.01	99
MAK[1]	Mako shark	*Isurus oxyrinchus*	<1	<0.01	59
DCS	Dawson's catshark	*Bythaelurus dawsoni*	<1	<0.01	32
BRC	Northern bastard cod	*Pseudophycis breviuscula*	<1	<0.01	100
SBR	Southern bastard cod	*Pseudophycis barbata*	<1	<0.01	90
HYB	Black ghost shark	*Hydrolagus homonycteris*	<1	<0.01	100
AST	Snaggletooths	Astronesthinae	<1	<0.01	100
SEV	Broadnose sevengill shark	*Notorynchus cepedianus*	<1	<0.01	68
CSH	Catshark	Scyliorhinidae	<1	<0.01	99
PSK	Longnosed deepsea skate	*Bathyraja shuntovi*	<1	<0.01	100
BTH	Bluntnose skates	*Notoraja* spp.	<1	<0.01	100
SKI	Gemfish	*Rexea* spp.	<1	<0.01	11
BYS	Alfonsino	*Beryx splendens*	<1	<0.01	2
APR	Catshark	*Apristurus* spp.	<1	<0.01	100
HEP	Sharpnose sevengill shark	*Heptranchias perlo*	<1	<0.01	100
TAR[2]	Tarakihi	*Nemadactylus macropterus & N. sp.* (King tarakihi)	<1	<0.01	10
SNR	Rough shovelnose dogfish	*Deania histricosa*	<1	<0.01	89
FHD	Deepsea flathead	*Hoplichthys haswelli*	<1	<0.01	100
ELT	(Lanternfish)	*Electrona* spp.	<1	<0.01	100
SWA	Silver warehou	*Seriolella punctata*	<1	<0.01	100
TOP	Pale toadfish	*Ambophthalmos angustus*	<1	<0.01	32
WWA	White warehou	*Seriolella caerulea*	<1	<0.01	1
ETP	Smooth lanternshark	*Etmopterus pusillus*	<1	<0.01	100
THR	Thresher shark	*Alopias vulpinus*	<1	<0.01	100
SOP	Pacific sleeper shark	*Somniosus pacificus*	<1	<0.01	100
OFH	Oilfish	*Ruvettus pretiosus*	<1	<0.01	38
SPR	Sprats	*Sprattus antipodum & S. muelleri*	<1	<0.01	100
VCO	Violet cod	*Antimora rostrata*	<1	<0.01	100
BYX	Alfonsino & long-finned beryx	*Beryx splendens & B. decadactylus*	<1	<0.01	1
WIT	Witch	*Arnoglossus scapha*	<1	<0.01	100
TOD	Dark toadfish	*Neophrynichthys latus*	<1	<0.01	100
ODO	Smalltooth sand tiger shark	*Odontaspis ferox*	<1	<0.01	33
SBO	Southern boarfish	*Pseudopentaceros richardsoni*	<1	<0.01	1
HGB	Giant black ghost shark	*Hydrolagus* sp. d	<1	<0.01	100
LCH	Long-nosed chimaera	*Harriotta raleighana*	<1	<0.01	100
ROC	Rock cod	*Lotella rhacinus*	<1	<0.01	100
MOR	Moray eel	Muraenidae	<1	<0.01	100
SPP	Splendid perch	*Callanthias* spp.	<1	<0.01	100
MOD	Morid cods	Moridae	<1	<0.01	100

Appendix 2: Observed invertebrate catch. Species codes, common and scientific names, estimated catch, percentage of total catch, and overall percentage discarded of all invertebrate species or species groups by weight from observer records for the ling longline target fishery from 1 Oct 1992 to 30 Sep 2012. Records are ordered by decreasing percentage of catch. Codes in bold are QMS species; 1 = Schedule 6 QMA species; 2 = species with a minimum legal size.. Estimated catches are based on all observed target ling longline sets; discards are based on recorded discards and species discard ratios calculated from sets where discards were recorded.

Species code	Common name	Scientific name	Observed catch (t)	% of catch	% discarded
SFI	Starfish	*Asteroidea & Ophiuroidea*	37	0.16	100
ANT	Anemones	Anthozoa	6	0.03	100
CRB	Crab		1	0.01	97
ASR	Asteroid (starfish)	Asteroidea	1	<0.01	100
ONG	Sponges	Porifera	1	<0.01	100
SPI	Spider crab		<1	<0.01	89
COU	Coral (unspecified)		<1	<0.01	100
OCT	Octopus	*Pinnoctopus cordiformis*	<1	<0.01	92
GSC[1]	Giant spider crab	*Jacquinotia edwardsii*	<1	<0.01	1
GAS	Gastropods	Gastropoda	<1	<0.01	99
PSI	Geometric star	*Psilaster acuminatus*	<1	<0.01	100
PKN	Abyssal star	*Plutonaster knoxi*	<1	<0.01	100
PNE		*Proserpinaster neozelanicus*	<1	<0.01	100
QSC[1]	Queen scallop	*Zygochlamys delicatula*	<1	<0.01	1
HMT	Deepsea anemone	Hormathiidae	<1	<0.01	100
MOL	Molluscs	Mollusca	<1	<0.01	100
ECN	Echinoid (sea urchin)	Echinoidea	<1	<0.01	100
CPA	Pentagon star	*Ceramaster patagonicus*	<1	<0.01	100
ECH	Echinoderms	Echinodermata	<1	<0.01	100
SOT		*Solaster torulatus*	<1	<0.01	100
DMG		*Dipsacaster magnificus*	<1	<0.01	27
COR	Hydrocorals	Stylasteridae	<1	<0.01	100
MSL	Starfish	*Mediaster sladeni*	<1	<0.01	100
ZOR	Rat-tail star	*Zoroaster* spp.	<1	<0.01	100
VOL	Volute	Volutidae	<1	<0.01	100
FMA		*Fusitriton magellanicus*	<1	<0.01	100
KIC[1]	King crab	*Lithodes aotearoa & Neolithodes brodiei*	<1	<0.01	1
ACS	Deepsea anemone	Actinostolidae	<1	<0.01	100
CBB	Coral rubble		<1	<0.01	100
WHE	Whelks		<1	<0.01	100
SCC[1]	Sea cucumber	*Stichopus mollis*	<1	<0.01	100
URO	Sea urchin (unspecified)	Echinoidea	<1	<0.01	100
HTH	Sea cucumber	Holothurian unidentified	<1	<0.01	100
ATR	Sea anemones	Actiniaria	<1	<0.01	100
BOO	Bamboo coral	*Keratoisis* spp.	<1	<0.01	100
SCA[1,2]	Scallop	*Pecten novaezelandiae*	<1	<0.01	1
SCI	Scampi	*Metanephrops challengeri*	<1	<0.01	100
GPA		*Goniocidaris parasol*	<1	<0.01	100
JFI	Jellyfish		<1	<0.01	100
SMO	Cross-fish	*Sclerasterias mollis*	<1	<0.01	100
SIA	Stony corals	Scleractinia	<1	<0.01	100
SUA	Fleshy club sponge	*Suberites affinis*	<1	<0.01	100
HTR	Trojan starfish	*Hippasteria phrygiana*	<1	<0.01	100
PSL		*Paralomis dosleini*	<1	<0.01	100
SQU	Arrow squid	*Nototodarus sloanii & N. gouldi*	<1	<0.01	100
OPH	Ophiuroid (brittle star)	Echinodermata???	<1	<0.01	100
PRU		*Pseudechinaster rubens*	<1	<0.01	100
CJA	Sun star	*Crossaster multispinus*	<1	<0.01	100
DPP		*Diplopteraster* sp.	<1	<0.01	100
BHE		*Bathypectinura heros*	<1	<0.01	100

Appendix 2 — *Continued*

Species code	**Common name**	**Scientific name**	**Observed catch (t)**	**% of catch**	**% discarded**
NCB	Smooth red swimming crab	*Nectocarcinus bennetti*	<1	<0.01	100
NUD	Nudibranch	Nudibranchia	<1	<0.01	100
PAD[1]	Paddle crab	*Ovalipes catharus*	<1	<0.01	1
PAO		*Pillsburiaster aoteanus*	<1	<0.01	100
PZE	Prickly king crab	*Paralomis zealandica*	<1	<0.01	100
SMK	Spiny masking crab	*Teratomaia richardsoni*	<1	<0.01	100
SQX	Squid		<1	<0.01	100
VSQ	Violet squid	*Histioteuthis* spp.	<1	<0.01	100
BES		*Benthopecten* spp.	<1	<0.01	100
COV		*Comitas onokeana vivens*	<1	<0.01	100
DDI		*Desmophyllum dianthus*	<1	<0.01	100
GYS	Siboga sea pen	*Gyrophyllum sibogae*	<1	<0.01	100
AWI		*Alcithoe wilsonae*	<1	<0.01	100
HDR	Hydroid	Hydrozoa	<1	<0.01	100
BNO		*Benthoctopus* spp.	<1	<0.01	100
CDY		*Cosmasterias dyscrita*	<1	<0.01	100
COC[1]	Cockle	*Austrovenus stutchburyi*	<1	<0.01	100
CRU	Crustacea	Crustacea	<1	<0.01	100
GMC	Garrick's masking crab	*Leptomithrax garricki*	<1	<0.01	100
GOR		*Gorgonocephalus* spp.	<1	<0.01	100
GVO	Golden volute	*Provocator mirabilis*	<1	<0.01	100
LLC	Long-legged masking crab	*Leptomithrax longipes*	<1	<0.01	100
OPI	Umbrella octopus	*Opisthoteuthis spp.*	<1	<0.01	100
OSP	Pacific oyster spat	*Crassostrea gigas*	<1	<0.01	100
PHB	Grey fibrous massive sponge	*Phorbas* spp.	<1	<0.01	100
SSC	Giant masking crab	*Leptomithrax australis*	<1	<0.01	100
STP	Solitary bowl coral	*Stephanocyathus platypus*	<1	<0.01	100
SUR	Kina	*Evechinus chloroticus*	<1	<0.01	100
SVA		*Solenosmilia variabilis*	<1	<0.01	100
TLO	Encrusting long polyps coral	*Telesto* spp.	<1	<0.01	100
ARO		*Anthomastus (Bathyalcyon) robustus*	<1	<0.01	100
GDU	Bushy hard coral	*Goniocorella dumosa*	<1	<0.01	100
HYA	Floppy tubular sponge	*Hyalascus* sp.	<1	<0.01	100
HOR	Horse mussel	*Atrina zelandica*	<1	<0.01	100
PLN	Chipped fibreglass matt sponge	*Poecillastra laminaris*	<1	<0.01	100
BOC	Deepsea anemone	*Bolocera* spp.	<1	<0.01	100
BRN	Barnacle	Cirripedia	<1	<0.01	100
PAB	Bubblegum coral	*Paragorgia arborea*	<1	<0.01	100
CMT	Feather star	*Comatulida*	<1	<0.01	100
DSO	Demosponges	Demospongiae	<1	<0.01	100
HIS		*Histocidaris* spp.	<1	<0.01	100
LAG		*Laetmogone* spp.	<1	<0.01	100
SOC	Soft coral	Alcyonacea	<1	<0.01	100
THO	Bottlebrush coral	*Thouarella* spp.	<1	<0.01	100

Appendix 3: Observed bycatch by species group. Estimated catch, percentage of total catch, and overall percentage discarded from observer records for ling longline target fishery from 1 Oct 1992 to 30 Sep 2012. Estimated catches are based on all observed target ling longline sets; discards are based on recorded discards and species discard ratios calculated from sets where discards were recorded.

Group	Observed catch (t)	% of catch	% discarded
Invertebrates			
Echinoderms	39	0.17	100
Cnidaria	7	0.03	100
Crustaceans	2	0.01	89
Molluscs	1	<0.01	80
Sponges	1	<0.01	100
Elasmobranchs			
Sharks & dogfish	3 805	16.82	83
Rays & skates	900	3.98	25
Chimaeras	335	1.48	13
Other fish			
Fish (other)	1 914	8.46	15
Eels	214	0.94	94
Rattails	38	0.17	68

Appendix 4: Observed bycatch by species category. Estimated catch, percentage of total catch, and overall percentage discarded from observer records for ling longline target fishery from 1 Oct 1992 to 30 Sep 2012. Estimated catches are based on all observed target ling longline sets; discards are based on recorded discards and species discard ratios calculated from sets where discards were recorded.

Species category	Observed catch	% of catch	% discarded
QMS (excluding ling)	21 023	92.91	15
Non-QMS	1 555	6.87	66
Invertebrate	48	0.21	100

Appendix 5: Bycatch rates (kg/hook) of QMS fish species in the ling longline fishery, by area and fishing year, based on observed catch data. Bycatch rates are the median of the bootstrap sample of 1000, rounded to the nearest whole number. Some rates based on additional records from adjacent years (see Table 6).

	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	PUYS
1992–93	0.02	0.08	0.08	0.16	0.14	0.14	0.20	0.14	0.05
1993–94	0.04	0.08	0.08	0.15	0.14	0.14	0.13	0.14	0.05
1994–95	0.05	0.08	0.08	0.15	0.14	0.14	0.11	0.14	0.05
1995–96	0.14	0.03	0.08	0.15	0.14	0.13	0.12	0.14	0.05
1996–97	0.14	0.03	0.08	0.15	0.14	0.13	0.11	0.14	0.05
1997–98	0.08	0.03	0.08	0.15	0.14	0.13	0.14	0.14	0.05
1998–99	0.05	0.03	0.08	0.16	0.14	0.12	0.07	0.14	0.05
1999–00	0.05	0.04	0.08	0.15	0.14	0.12	0.08	0.14	0.05
2000–01	0.08	0.04	0.08	0.16	0.14	0.12	0.16	0.14	0.04
2001–02	0.06	0.01	0.07	0.16	0.14	0.14	0.16	0.15	0.06
2002–03	0.05	0.08	0.06	0.15	0.14	0.13	0.14	0.14	0.04
2003–04	0.06	0.07	0.06	0.16	0.14	0.13	0.10	0.14	0.05
2004–05	0.08	0.05	0.08	0.16	0.14	0.15	0.09	0.14	0.02
2005–06	0.07	0.05	0.08	0.11	0.14	0.16	0.15	0.14	0.03
2006–07	0.10	0.07	0.07	0.10	0.04	0.14	0.08	0.14	0.03
2007–08	0.10	0.09	0.07	0.10	0.04	0.13	0.17	0.20	0.13
2008–09	0.07	0.09	0.07	0.10	0.04	0.13	0.13	0.29	0.06
2009–10	0.07	0.08	0.07	0.10	0.04	0.12	0.13	0.29	0.04
2010–11	0.07	0.06	0.07	0.10	0.04	0.11	0.12	0.29	0.04
2011–12	0.07	0.03	0.07	0.10	0.04	0.11	0.12	0.29	0.04

Appendix 6: Bycatch rates (kg/hook) of non-QMS fish species in the ling longline fishery, by area and fishing year, based on observed catch data. Bycatch rates are the median of the bootstrap sample of 1000, rounded to the nearest whole number. Some rates based on additional records from adjacent years (see Table 6).

	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	PUYS
1992–93	0.28	<0.01	0.05	0.02	0.19	0.05	0.04	0.07	0.01
1993–94	0.17	<0.01	0.05	0.02	0.19	0.05	0.03	0.07	0.01
1994–95	0.08	<0.01	0.05	0.02	0.19	0.05	0.02	0.07	0.01
1995–96	0.07	<0.01	0.05	0.02	0.18	0.05	0.02	0.07	0.01
1996–97	0.07	<0.01	0.05	0.02	0.19	0.02	0.01	0.07	0.02
1997–98	0.03	<0.01	0.05	0.02	0.19	0.02	0.03	0.07	0.02
1998–99	0.02	0.04	0.05	0.02	0.19	0.01	<0.01	0.07	0.02
1999–00	0.02	0.02	0.05	0.02	0.19	0.02	<0.01	0.07	0.02
2000–01	0.02	0.01	0.05	0.02	0.18	0.04	0.01	0.07	0.03
2001–02	0.04	0.03	0.04	0.02	0.19	0.05	0.01	0.07	0.02
2002–03	0.04	0.04	0.02	0.02	0.19	0.04	0.01	0.07	0.01
2003–04	0.03	<0.01	0.02	0.02	0.19	0.04	0.01	0.07	0.02
2004–05	0.04	0.01	0.04	0.02	0.19	0.04	0.01	0.07	0.01
2005–06	0.04	0.01	0.04	0.08	0.19	0.04	0.01	0.07	0.02
2006–07	0.03	0.02	0.03	0.10	0.05	0.05	0.01	0.07	0.04
2007–08	0.03	0.03	0.03	0.09	0.05	0.01	0.01	0.08	0.04
2008–09	0.15	0.03	0.03	0.09	0.05	0.02	0.01	0.09	0.02
2009–10	0.15	0.01	0.03	0.09	0.05	0.04	0.02	0.09	0.02
2010–11	0.15	0.01	0.03	0.09	0.05	0.06	0.05	0.09	0.02
2011–12	0.15	0.01	0.03	0.09	0.05	0.06	0.05	0.09	0.02

Appendix 7: Bycatch rates (g/hook) of invertebrate species in the ling longline fishery, by area and fishing year, based on observed catch data. Bycatch rates are the median of the bootstrap sample of 1000, rounded to the nearest whole number. NOTE DIFFERENT UNITS. Some rates based on additional records from adjacent years (see Table 6).

	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	PUYS
1992–93	0.01	<0.01	1.53	<0.01	0.30	<0.01	0.01	<0.01	<0.01
1993–94	0.01	<0.01	1.46	<0.01	0.30	<0.01	<0.01	<0.01	<0.01
1994–95	0.01	<0.01	1.47	<0.01	0.30	<0.01	<0.01	<0.01	<0.01
1995–96	<0.01	0.01	1.49	<0.01	0.30	<0.01	<0.01	<0.01	<0.01
1996–97	<0.01	<0.01	1.47	<0.01	0.30	<0.01	<0.01	<0.01	0.18
1997–98	<0.01	<0.01	1.48	<0.01	0.30	<0.01	<0.01	<0.01	0.24
1998–99	<0.01	0.18	1.47	<0.01	0.30	<0.01	0.33	<0.01	0.24
1999–00	<0.01	0.04	1.47	<0.01	0.30	0.19	0.27	<0.01	0.23
2000–01	0.01	0.12	1.50	<0.01	0.30	0.38	1.41	<0.01	0.32
2001–02	2.08	0.36	1.20	<0.01	0.30	0.52	1.39	<0.01	0.24
2002–03	2.42	0.08	0.78	<0.01	0.30	<0.01	2.79	<0.01	0.13
2003–04	3.18	0.16	0.79	<0.01	<0.01	0.03	1.22	<0.01	0.17
2004–05	0.23	0.06	0.03	<0.01	<0.01	0.12	<0.01	<0.01	0.01
2005–06	0.22	0.06	0.03	<0.01	<0.01	0.23	0.32	<0.01	0.20
2006–07	0.01	0.06	<0.01	<0.01	<0.01	0.25	0.53	<0.01	0.07
2007–08	0.01	0.05	<0.01	<0.01	0.01	0.01	0.33	0.02	<0.01
2008–09	0.53	0.05	<0.01	<0.01	0.01	0.25	0.16	0.03	0.02
2009–10	0.53	0.01	<0.01	<0.01	0.01	0.15	0.17	0.03	0.02
2010–11	0.52	0.13	<0.01	<0.01	<0.01	0.05	0.25	0.03	0.02
2011–12	0.52	0.09	<0.01	<0.01	0.01	0.05	0.24	0.03	0.02

Appendix 8: Discard rates (kg/hook) of QMS fish species in the ling longline fishery, by area and fishing year, based on observed discard data. Discard rates are the median of the bootstrap sample of 1000, rounded to the nearest whole number. Some rates based on additional records from adjacent years (see Table 6).

	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	PUYS
1992–93	0.01	0.07	0.01	0.02	0.02	0.03	0.03	0.09	0.03
1993–94	0.02	0.07	0.01	0.02	0.02	0.03	0.05	0.10	0.03
1994–95	0.02	0.07	0.01	0.02	0.02	0.03	0.06	0.10	0.03
1995–96	0.06	0.01	0.01	0.02	0.02	0.03	0.07	0.09	0.03
1996–97	0.06	0.02	0.01	0.02	0.02	0.09	0.04	0.10	0.01
1997–98	0.03	0.02	0.01	0.02	0.02	0.09	0.11	0.09	0.01
1998–99	0.02	0.01	0.01	0.02	0.02	0.08	0.03	0.09	0.01
1999–00	0.02	0.02	0.01	0.02	0.02	0.07	0.04	0.09	0.01
2000–01	0.03	0.03	0.01	0.02	0.02	0.07	0.10	0.10	0.01
2001–02	0.01	0.01	0.01	0.02	0.02	0.08	0.10	0.09	0.01
2002–03	0.01	0.05	0.01	0.02	0.02	0.09	0.11	0.09	0.02
2003–04	0.01	0.02	0.01	0.02	0.02	0.08	0.07	0.09	0.02
2004–05	0.02	0.04	0.01	0.02	0.02	0.07	0.07	0.10	0.01
2005–06	0.02	0.04	0.01	<0.01	0.02	0.06	0.10	0.09	<0.01
2006–07	0.01	0.04	0.02	<0.01	0.01	0.06	0.06	0.09	0.01
2007–08	0.01	0.04	0.02	0.01	0.01	0.09	0.12	0.07	0.04
2008–09	0.01	0.04	0.02	0.01	0.01	0.06	0.10	0.08	0.02
2009–10	0.01	0.03	0.02	0.01	0.01	0.05	0.09	0.08	0.01
2010–11	0.01	<0.01	0.02	0.01	0.01	0.04	0.05	0.08	0.01
2011–12	0.01	0.02	0.02	0.01	0.01	0.04	0.05	0.08	0.01

Appendix 9: Discard rates (kg/hook) of non-QMS fish species in the ling longline fishery, by area and fishing year, based on observed discard data. Discard rates are the median of the bootstrap sample of 1000, rounded to the nearest whole number. Some rates based on additional records from adjacent years (see Table 6).

	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	PUYS
1992–93	0.05	<0.01	0.04	0.02	0.06	0.05	0.04	0.06	0.01
1993–94	0.03	<0.01	0.04	0.02	0.06	0.05	0.02	0.06	0.01
1994–95	0.02	<0.01	0.04	0.02	0.06	0.05	0.01	0.06	0.01
1995–96	0.07	<0.01	0.04	0.02	0.06	0.05	0.01	0.06	0.01
1996–97	0.07	<0.01	0.04	0.02	0.06	0.01	0.01	0.06	0.01
1997–98	0.03	<0.01	0.04	0.02	0.06	0.01	0.01	0.06	0.01
1998–99	0.02	0.03	0.04	0.02	0.06	0.01	<0.01	0.06	0.02
1999–00	0.02	0.02	0.04	0.02	0.06	0.01	<0.01	0.06	0.02
2000–01	0.02	0.01	0.04	0.02	0.06	0.02	0.01	0.06	0.02
2001–02	0.03	0.03	0.03	0.02	0.06	0.03	0.01	0.06	0.01
2002–03	0.03	0.02	0.01	0.02	0.06	0.03	0.01	0.06	<0.01
2003–04	0.03	<0.01	0.01	0.02	0.06	0.03	0.01	0.06	0.01
2004–05	0.04	0.01	0.02	0.02	0.06	0.03	0.01	0.06	0.01
2005–06	0.04	0.01	0.02	0.08	0.06	0.04	0.01	0.06	0.01
2006–07	<0.01	0.02	0.02	0.09	0.03	0.04	0.01	0.06	0.04
2007–08	<0.01	0.03	0.02	0.08	0.03	0.01	0.01	0.07	0.04
2008–09	0.02	0.03	0.02	0.08	0.03	0.02	0.01	0.07	0.02
2009–10	0.02	0.01	0.02	0.08	0.03	0.04	0.01	0.07	0.01
2010–11	0.02	0.01	0.02	0.08	0.03	0.05	0.04	0.07	0.01
2011–12	0.02	0.01	0.02	0.08	0.03	0.05	0.04	0.07	0.01

Appendix 10: Discard rates (g/hook) of invertebrate species in the ling longline fishery, by area and fishing year, based on observed discard data. Discard rates are the median of the bootstrap sample of 1000, rounded to the nearest whole number. NOTE DIFFERENT UNITS. Some rates based on additional records from adjacent years (see Table 6).

	BNTY	CAMP	COOK	LIN1	LIN2	LIN3	LIN4	LIN7	PUYS
1992–93	0.01	<0.01	1.49	<0.01	0.30	<0.01	0.01	<0.01	<0.01
1993–94	0.01	<0.01	1.49	<0.01	0.30	<0.01	<0.01	<0.01	<0.01
1994–95	0.01	<0.01	1.47	<0.01	0.30	<0.01	<0.01	<0.01	<0.01
1995–96	<0.01	0.01	1.48	<0.01	0.30	<0.01	<0.01	<0.01	<0.01
1996–97	<0.01	<0.01	1.50	<0.01	0.30	<0.01	<0.01	<0.01	0.18
1997–98	<0.01	<0.01	1.50	<0.01	0.30	<0.01	<0.01	<0.01	0.23
1998–99	<0.01	0.18	1.49	<0.01	0.30	<0.01	0.33	<0.01	0.23
1999–00	<0.01	0.04	1.48	<0.01	0.30	0.19	0.27	<0.01	0.23
2000–01	0.01	0.11	1.49	<0.01	0.30	0.38	1.38	<0.01	0.32
2001–02	2.08	0.36	1.21	<0.01	0.30	0.53	1.39	<0.01	0.21
2002–03	2.41	0.08	0.77	<0.01	0.30	<0.01	2.74	<0.01	0.13
2003–04	3.17	0.16	0.76	<0.01	<0.01	0.03	1.26	<0.01	0.16
2004–05	0.23	0.06	0.03	<0.01	<0.01	0.11	<0.01	<0.01	0.01
2005–06	0.23	0.06	0.03	<0.01	<0.01	0.21	0.31	<0.01	0.20
2006–07	<0.01	0.06	<0.01	<0.01	0.01	0.23	0.52	<0.01	0.07
2007–08	<0.01	0.05	<0.01	<0.01	0.01	0.01	0.32	0.02	<0.01
2008–09	0.53	0.05	<0.01	<0.01	<0.01	0.25	0.15	0.03	0.02
2009–10	0.53	0.01	<0.01	<0.01	0.01	0.14	0.17	0.03	0.02
2010–11	0.53	0.10	<0.01	<0.01	<0.01	0.05	0.24	0.03	0.02
2011–12	0.52	0.09	<0.01	<0.01	<0.01	0.05	0.24	0.03	0.02

Appendix 11: Ling longline fishery. Total annual bycatch estimates (t) (with estimated CVs in parentheses) for individual species, based on observer catch rates. Species are ordered by decreasing total catch. The slope of a regression through the data points is shown in parentheses alongside each species code. See http://marlin.niwa.co.nz for species code definitions).

	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
SPD$^{(0)}$	480(11)	723(9)	1285(7)	938(16)	1030(20)	1808(12)	855(25)	978(26)	1446(14)	1783(15)	1178(14)	923(12)	1117(9)	1125(8)	714(12)	1204(7)	983(6)	947(18)	526(11)	436(14)
RIB$^{(0)}$	466(9)	409(7)	383(8)	520(8)	935(7)	205(10)	416(9)	578(10)	397(13)	373(13)	181(11)	354(10)	216(11)	313(8)	90(13)	247(10)	222(12)	422(16)	636(7)	589(6)
SND$^{(0)}$	97(14)	142(14)	152(14)	132(17)	148(16)	201(14)	156(15)	183(16)	350(13)	306(12)	190(13)	317(13)	267(13)	307(11)	106(23)	122(21)	97(23)	134(24)	270(12)	224(11)
SSK$^{(0)}$	54(6)	173(30)	171(6)	530(8)	272(16)	132(6)	240(29)	227(6)	355(6)	113(10)	70(16)	130(23)	92(11)	73(7)	72(11)	133(9)	132(13)	126(16)	108(18)	89(16)
SPE$^{(0)}$	76(7)	144(5)	202(5)	117(7)	137(10)	124(10)	132(11)	159(12)	156(7)	180(7)	76(18)	111(7)	161(9)	149(6)	104(11)	80(7)	81(7)	98(11)	119(7)	90(6)
BNS$^{(-0.1)}$	755(17)	328(17)	66(26)	64(23)	105(25)	99(23)	63(24)	64(30)	64(33)	41(33)	39(29)	36(32)	53(22)	49(22)	55(20)	60(20)	60(24)	60(22)	66(20)	51(20)
RCO$^{(0)}$	20(15)	38(18)	30(13)	106(33)	74(7)	137(8)	113(9)	108(8)	182(11)	299(7)	95(18)	91(22)	66(18)	96(13)	57(20)	104(20)	65(11)	37(15)	17(13)	20(11)
SCH$^{(0)}$	44(18)	112(16)	151(17)	94(14)	133(16)	155(11)	68(14)	61(22)	111(13)	93(12)	72(12)	79(12)	70(12)	67(12)	41(15)	115(11)	89(10)	79(14)	48(12)	47(11)
RSK$^{(0.2)}$	0.7(0)	0.8(0)	1.2(0)	1.7(61)	61(51)	130(18)	45(53)	45(71)	2.8(36)	98(5)	145(4)	314(9)	41(24)	52(10)	118(6)	149(6)	55(10)	8.7(50)	23(26)	12(29)
CON$^{(-0.1)}$	299(6)	161(7)	85(10)	118(10)	70(11)	8.5(17)	30(14)	25(17)	68(12)	97(11)	36(17)	20(18)	15(23)	9.2(11)	45(15)	43(10)	22(8)	16(47)	4.8(72)	3.7(47)
HAK$^{(0.2)}$	3.4(30)	3.7(27)	4.4(32)	5.9(38)	7(35)	6(37)	5.8(35)	4.1(34)	5.2(27)	5(28)	3.7(27)	3.9(36)	4(36)	3.8(38)	6.7(26)	112(34)	199(25)	246(25)	283(24)	251(23)
SKA$^{(-0.4)}$	196(13)	187(45)	131(14)	82(16)	51(34)	202(10)	38(49)	49(52)	34(20)	65(10)	32(14)	21(31)	5.7(93)	0.4(0)	0.3(0)	0.5(0)	0.3(0)	0.4(0)	0.6(0)	0.4(0)
BCD$^{(0.1)}$	0(–)	32(75)	12(20)	120(9)	78(10)	49(7)	42(7)	74(7)	44(11)	60(5)	82(5)	103(6)	8.2(17)	5.1(20)	35(9)	69(10)	189(12)	4.1(0)	40(12)	4.7(0)
BSH$^{(0)}$	25(20)	41(16)	51(16)	65(20)	54(26)	53(21)	48(20)	45(18)	76(16)	73(13)	96(12)	51(16)	58(15)	76(12)	50(18)	36(23)	27(18)	48(13)	36(17)	32(15)
NOT$^{(-0.5)}$	518(13)	446(32)	53(7)	3(101)	2.5(143)	0(–)	0(–)	0(–)	2.9(34)	7.6(32)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
GSH$^{(-0.1)}$	47(12)	87(11)	124(14)	125(13)	47(10)	64(8)	16(17)	23(19)	39(9)	55(10)	31(30)	14(10)	80(9)	36(15)	62(18)	30(11)	33(13)	29(19)	9.5(21)	5.5(18)
HCO$^{(0.2)}$	3.9(0)	5.5(18)	5.6(18)	6.2(16)	5.2(19)	7.2(14)	5.3(19)	6.1(16)	25(19)	16(11)	7(14)	28(20)	19(26)	42(9)	44(21)	74(14)	36(25)	75(30)	179(9)	160(8)
BAS$^{(0)}$	41(20)	58(21)	51(20)	43(20)	78(20)	75(19)	38(17)	29(17)	34(17)	15(16)	18(18)	17(16)	26(18)	19(14)	18(19)	26(17)	21(24)	30(26)	46(30)	32(27)
DWD$^{(-0.3)}$	20(52)	24(54)	28(56)	37(77)	58(49)	65(44)	66(37)	52(34)	112(32)	48(31)	34(42)	20(78)	68(25)	33(48)	23(67)	16(90)	0.2(0)	0.4(0)	0(–)	0.4(0)
ETM$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	373(53)	155(18)	59(15)	34(27)	5.7(49)	0.4(0)	6.3(71)	17(50)	22(54)	0(0)	0(0)	0(–)	0(–)	0(–)
GSP$^{(0.2)}$	13(49)	7.8(97)	0.4(0)	0.3(0)	0.3(0)	0.5(0)	28(76)	30(9)	48(14)	63(9)	46(13)	26(9)	32(11)	19(5)	55(8)	124(6)	83(16)	18(14)	39(9)	34(6)
NSD$^{(0.1)}$	12(23)	16(23)	14(23)	11(22)	28(21)	17(23)	5.6(25)	3.9(25)	14(37)	12(62)	8(33)	27(50)	52(15)	24(26)	26(37)	63(30)	64(23)	69(25)	83(24)	73(25)
OSD$^{(0.1)}$	31(10)	33(9)	35(11)	50(11)	2.3(0)	0(–)	1.1(89)	0.2(0)	2.6(39)	23(23)	5.7(18)	24(30)	6.8(64)	23(22)	26(25)	53(15)	69(14)	38(21)	60(23)	55(17)
DWE$^{(-0.1)}$	9.7(51)	13(53)	16(49)	27(49)	37(41)	107(14)	30(42)	27(39)	17(49)	13(51)	14(48)	15(49)	16(50)	16(48)	29(35)	21(52)	8.3(75)	7.1(76)	8.1(76)	5(80)
CSQ$^{(0.4)}$	0(–)	0(–)	0(–)	0.1(0)	6.2(23)	13(26)	11(25)	9.7(25)	0(–)	0(–)	0(–)	7(53)	0(–)	0(–)	58(18)	21(31)	16(42)	40(43)	100(20)	89(18)
CAR$^{(0)}$	6.2(49)	8.7(46)	9.9(50)	16(51)	18(49)	19(43)	15(49)	10(44)	21(27)	19(23)	17(26)	16(29)	29(21)	35(26)	42(27)	15(17)	7(32)	15(41)	25(26)	15(25)
HAP$^{(0)}$	40(24)	25(19)	13(20)	14(36)	27(24)	30(13)	12(16)	11(20)	18(16)	14(12)	14(27)	11(19)	12(19)	16(16)	16(18)	16(18)	13(15)	11(20)	12(21)	10(20)
HAG$^{(0.1)}$	7.4(14)	10(14)	8.2(12)	4.4(0)	12(20)	7(20)	4.7(30)	5.7(30)	21(13)	21(9)	17(28)	14(12)	30(12)	7.9(13)	26(12)	20(11)	15(13)	20(24)	27(12)	17(12)
SCO$^{(0.2)}$	0(–)	27(15)	47(14)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	8.9(91)	0(–)	0(0)	0(0)	0(–)	11(40)	23(24)	23(26)	20(30)	21(29)
RAT$^{(0)}$	4.8(59)	7.5(35)	3.1(45)	5.6(47)	4.6(54)	6.1(40)	9.8(23)	8.9(16)	16(12)	16(13)	13(17)	12(11)	6.2(28)	7.9(22)	11(19)	7.2(20)	16(12)	2.7(0)	5(0)	2.9(0)
PLS$^{(0.4)}$	0(–)	0(–)	0(–)	0(–)	4.6(22)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	9.9(44)	2.3(88)	5.9(61)	8.1(63)	0.4(0)	0.8(0)	18(73)	53(37)	26(38)
ETL$^{(0)}$	0(0)	6.5(15)	12(12)	52(43)	6.1(16)	8.7(11)	2.9(0)	2.3(0)	2.1(0)	3.5(29)	3.3(31)	1.1(0)	4.2(0)	1.4(0)	1.8(0)	1.8(0)	1.9(0)	2.5(0)	5.6(0)	3.7(0)
SFI$^{(0.1)}$	0.1(0)	0.1(0)	0.2(0)	0.1(0)	0.3(0)	0.7(0)	5.5(26)	3.5(29)	14(52)	22(44)	25(29)	18(21)	0.2(0)	2.5(0)	1.8(56)	0.1(0)	1(0)	0.7(0)	1.6(0)	1.6(0)
RBM$^{(-0.2)}$	35(16)	14(18)	1.6(0)	2.5(40)	8.7(16)	1.6(0)	7.4(19)	6.7(15)	2.9(0)	3.2(0)	1.5(0)	1.4(0)	1(0)	2.1(0)	0.4(0)	0.2(0)	0.5(0)	0.6(0)	0.6(0)	0.4(0)

Appendix 11—*continued*

	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
ETB$^{(0.3)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	48(19)	1.2(115)	15(42)	0(0)	0(–)	0(–)	4.4(68)	0.7(0)	0.8(0)	1.7(0)	4.3(33)
POS$^{(-0.1)}$	3(68)	4.3(70)	3.6(67)	4(56)	6.3(58)	6(53)	3.4(42)	5.5(41)	4.6(38)	2.9(35)	3.6(28)	1.7(0)	1.5(66)	0.4(0)	1.3(0)	1.1(0)	2(51)	1.3(76)	1.5(0)	0.7(0)
CHI$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	19(60)	0(–)	0.6(0)	9.6(39)	12(39)	1.5(66)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	2.3(99)	0(–)
SKI$^{(0)}$	2.1(0)	2.9(34)	2.9(34)	3.2(31)	4.6(31)	4(36)	2.3(43)	1.6(0)	2.3(44)	1.4(0)	1.5(0)	1.5(0)	2(0)	1.7(0)	1.7(0)	1.6(0)	1.6(0)	1.7(0)	2(0)	1.8(0)
BWS$^{(-0.1)}$	2.4(60)	1.5(66)	1(140)	2.7(91)	4.2(63)	3.2(76)	5.1(44)	4.2(41)	3.4(42)	2.2(46)	1.6(90)	1.3(76)	2.2(64)	1.7(85)	1.8(80)	2(71)	0.9(0)	0.9(0)	1.1(0)	0.8(0)
HPB$^{(-0.1)}$	1.8(0)	5.7(25)	6.3(22)	4.9(54)	4.1(24)	3(34)	0.1(0)	0.2(0)	0.2(0)	0.6(0)	0(0)	0.2(0)	0.9(108)	2.5(69)	5.7(43)	4.8(36)	0.4(0)	0.2(0)	0.3(0)	0.2(0)
SSH$^{(0.2)}$	0.2(0)	0.2(0)	0.2(0)	0.2(0)	0.2(0)	0.3(0)	0.2(0)	0.2(0)	0.4(0)	0.3(0)	0.6(0)	0.2(0)	0.3(0)	0.2(0)	0.3(0)	3.2(55)	5.4(56)	5.7(56)	5.7(58)	5.7(58)
HEX$^{(0.2)}$	0(–)	0(–)	0(–)	0(–)	0(0)	0.1(0)	0(–)	0(–)	1.7(0)	2.5(40)	0.7(0)	0.5(0)	15(16)	0.2(0)	0(–)	1.5(0)	3.7(38)	2.7(52)	0.1(0)	0.1(0)
CHP$^{(0.1)}$	6.7(74)	3(121)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)	14(77)	0.3(0)	3.1(73)	0.3(0)
CSH$^{(0.4)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.6(182)	0.7(0)	0.5(0)	0.6(0)	0.1(0)	0(–)	1.5(115)	3.4(66)	4.8(55)	4.8(55)	4.9(57)	4.8(72)
HOK$^{(0.2)}$	0.5(0)	0.2(0)	0(0)	0(0)	0.1(0)	0.2(0)	0.2(0)	0.2(0)	0.2(0)	0.2(0)	0.1(0)	0.8(0)	0.5(0)	0.5(0)	0.6(0)	1.2(0)	3.5(41)	5.3(54)	7.4(48)	4.6(44)
SCM$^{(-0.1)}$	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(–)	0.5(0)	20(22)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
MAK$^{(-0.1)}$	1.3(78)	1.1(92)	1.1(95)	1.7(118)	1.9(108)	1.7(118)	1.5(117)	1(101)	1.1(124)	1(105)	1.4(74)	1.2(87)	1.2(85)	1.1(92)	1(98)	0(–)	0(–)	0.2(0)	0.7(143)	0.4(0)
CYO$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	16(77)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(0)	0(–)	0(–)	0(–)	0(0)	0(0)	0.1(0)
SEV$^{(-0.1)}$	0.4(0)	0.5(0)	0.7(0)	1.1(93)	1.3(108)	1.1(88)	1(99)	0.8(127)	1.5(66)	1.6(65)	1.1(92)	1.2(82)	0.9(118)	0.6(0)	0.7(152)	0.2(0)	0.2(0)	0.2(0)	0.2(0)	0.2(0)
BYS$^{(0.2)}$	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.2(0)	0.2(0)	0.1(0)	0.1(0)	0.1(0)	1.1(0)	1.5(0)	2.2(47)	1.5(0)	1.7(0)	2.4(42)	1.7(0)
ANT$^{(-0.1)}$	0(–)	0(–)	0(–)	0(–)	0.3(0)	0.5(0)	0.5(0)	0.4(0)	0.5(0)	2.5(0)	3.8(0)	4(25)	0(0)	0.2(0)	0(0)	0(–)	0(0)	0(–)	0(0)	0(–)
UNI$^{(0.2)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0.8(0)	1.5(0)	0.2(0)	1.4(74)	0.9(0)	1.6(0)	0(–)	3.5(41)	2(72)	0(–)	0(–)
CHG$^{(0.2)}$	0(0)	0(0)	0(0)	0(0)	0(0)	0.1(0)	0.3(0)	0(0)	0.1(0)	0.9(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	1.2(0)	2.4(43)	4.7(70)	0.1(0)	1(0)	0.1(0)
DSK$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	3(0)	4.1(0)	3.7(27)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
TAR$^{(0)}$	0.6(0)	0.7(0)	0.6(0)	0.5(0)	0.9(0)	0.7(0)	0.3(0)	0.2(0)	0.4(0)	0.1(0)	0.2(0)	0.1(0)	0.2(0)	0.3(0)	0.5(0)	0.7(0)	0.5(0)	0.5(0)	0.8(0)	0.6(0)
CYP$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0.3(0)	0.6(0)	0.5(0)	0.4(0)	0.1(0)	0(–)	0(–)	0.3(0)	0(–)	0(–)	0(–)	5.9(61)	1.1(0)	0(–)	0(–)	0(–)
JAV$^{(0.2)}$	0(0)	0(0)	0(0)	0(0)	0.2(0)	0.3(0)	0.3(0)	0.4(0)	0.7(0)	1(0)	0.3(0)	0.2(0)	0.8(0)	0.4(0)	0.4(0)	0.2(0)	0.3(0)	0.4(0)	0.8(0)	0.7(0)
ASR$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	1(144)	1.1(130)	1.6(86)	0(–)	0(–)	0.1(0)	0.4(0)	0.5(0)	0(–)	1.2(0)	0.8(0)	0(–)	0(0)
OFH$^{(0.2)}$	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.3(0)	0.3(0)	0.2(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.5(0)	0.5(0)	0.8(122)	0.6(0)	0.6(0)	0.9(108)	0.7(0)
SQA$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	5.4(19)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
SPO$^{(0)}$	0(–)	0(–)	0(–)	0(–)	4.2(106)	0(0)	0(0)	0(0)	0.2(0)	0.4(0)	0(–)	0.2(0)	0(0)	0.1(0)	0.1(0)	0(0)	0(–)	0(–)	0(–)	0(–)
BCO$^{(0)}$	0(–)	0(0)	0(0)	1.3(113)	0.8(122)	0.3(0)	0(–)	0.1(0)	0(–)	0(–)	0.5(204)	0(0)	0.1(0)	0.1(0)	0.4(0)	0.5(0)	0(0)	0(0)	0(0)	0(0)
STA$^{(-0.1)}$	0(0)	0.1(0)	0(0)	0.1(0)	0.1(0)	0.2(0)	0.2(0)	0.1(0)	0.2(0)	1.2(0)	0.4(0)	0.6(0)	0.2(0)	0.5(0)	0(0)	0.1(0)	0(0)	0(0)	0(–)	0(–)
EEL$^{(-0.2)}$	0.2(0)	0.3(0)	0.2(0)	0.2(0)	0.3(0)	0.3(0)	0.1(0)	0.1(0)	1.7(0)	0.1(0)	0.1(0)	0.3(0)	0.2(0)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
CEN$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	1.4(69)	2.4(60)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
COU$^{(-0.2)}$	0.2(0)	0.3(0)	0.3(0)	0.2(0)	0.2(0)	0.3(0)	0.2(0)	0.3(0)	0.5(0)	0.4(0)	0.3(0)	0.3(0)	0(0)	0(0)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)
BRC$^{(0.2)}$	0(–)	0(–)	0(–)	0(–)	0(0)	0.1(0)	0.1(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0.9(0)	0.7(0)	0.5(0)	0.3(0)	0.5(0)	0.3(0)
WWA$^{(0)}$	1.8(56)	0.7(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0.1(0)	0.2(0)	0.3(0)	0.3(0)	0.2(0)
HEP$^{(0.2)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(0)	0.2(0)	0(–)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.7(154)	1.3(107)	0.7(0)
TOA$^{(0.1)}$	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0.6(0)	0.4(0)	0.5(0)	0.4(0)	0.2(0)	0.2(0)	0.1(0)	0.1(0)	0(–)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)
PTO$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(0)	0(0)	0.8(132)	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	2(101)	0(0)

Appendix 11—*continued*

	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
DCS$^{(0.1)}$	0(–)	0.1(0)	0.1(0)	0(–)	0(0)	0(–)	0(–)	0(–)	0(0)	0(0)	0(0)	0(–)	1(0)	0(0)	0(–)	0.3(0)	0.1(0)	0(0)	0.8(0)	0.2(0)
CRB$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(0)	0(0)	0(0)	0(0)	0.2(0)	0.4(0)	0.6(0)	1.2(0)	0(0)	0.1(0)	0(0)	0(–)	0(–)	0(–)	0(–)	0(0)
AST$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	1.1(0)	0.9(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	0.1(0)	0(0)	0(0)	0(0)	0(0)
THR$^{(-0.1)}$	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.1(0)	0.2(0)	0.2(0)	0.1(0)	0.2(0)	0.2(0)	0.2(0)	0(–)	0.3(0)	0(–)	0(–)	0(–)	0(–)
SHA$^{(0.2)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	0.2(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0.3(0)	0.3(0)	0.1(0)	0.8(0)
HYD$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0.5(0)	0.7(0)	0.2(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
SOT$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	1.5(0)	0(–)	0(–)	0(–)	0(0)	0(–)
SBR$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0(–)	0(–)	0(0)	0.3(0)	0.5(0)	0.5(0)	0(0)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)
APR$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.4(0)	0.6(0)	0.1(0)	0.1(0)	0(0)	0(–)	0.1(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
BYX$^{(-0.1)}$	0.8(0)	0.3(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(0)	0(–)	0(–)
ONG$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(0)	0.3(0)	0.4(0)	0.3(0)	0(–)	0(–)	0(–)	0(–)	0(0)	0(0)	0(0)	0(0)
FHD$^{(0)}$	0(–)	0(0)	0(0)	0(–)	0(0)	0(0)	0(0)	0(0)	0.2(0)	0.2(0)	0.1(0)	0(0)	0.2(0)	0(0)	0.1(0)	0(–)	0(–)	0(–)	0(0)	0(0)
HYB$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.3(0)	0.4(0)	0(–)	0.2(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
ELT$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0.1(0)	0(0)	0(–)	0(–)	0(–)	0(–)	0.7(0)	0(–)	0(–)	0(–)	0(–)
OCT$^{(0)}$	0.1(0)	0(0)	0(–)	0(0)	0(0)	0(–)	0(–)	0(0)	0.1(0)	0.1(0)	0(0)	0.1(0)	0(0)	0.1(0)	0.2(0)	0(0)	0(–)	0(–)	0(–)	0(–)
PSK$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0.2(0)	0.1(0)	0.1(0)	0(0)	0(–)	0.1(0)	0(0)	0(0)	0.1(0)	0.1(0)
ETP$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.4(0)	0.3(0)	0(–)	0(–)
GSC$^{(0)}$	0(–)	0(–)	0(–)	0.2(0)	0.1(0)	0(0)	0(–)	0(–)	0(0)	0(0)	0(0)	0(–)	0(–)	0(–)	0(0)	0.1(0)	0.1(0)	0(–)	0(0)	0(–)
SPI$^{(0)}$	0(–)	0(0)	0(0)	0(–)	0(–)	0(–)	0(0)	0(–)	0(0)	0.6(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
TOP$^{(0)}$	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0.4(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0.1(0)
BTH$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.3(0)	0.2(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
PNE$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.5(0)	0(0)	0(0)	0(–)	0(–)
PSI$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.5(0)	0(–)	0(–)	0(–)	0(–)
PKN$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.5(0)	0(–)	0(–)	0(–)	0(–)
BSP$^{(-0.1)}$	0(–)	0(–)	0(–)	0.1(0)	0.2(0)	0(–)	0.1(0)	0.1(0)	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
SNR$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(0)	0.4(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
GAS$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(0)	0.2(0)	0(–)	0.1(0)	0(–)	0(–)	0(0)	0(0)	0(0)	0(0)
TRU$^{(0)}$	0.1(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(0)	0(–)	0.2(707)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
MOL$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	0(–)	0(–)	0(–)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
ODO$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.3(0)	0(–)	0(–)	0(–)	0(–)
ECN$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)
HMT$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	0(–)	0.1(0)	0(0)
ACS$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0.1(0)	0.1(0)
ECH$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.2(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
ROC$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(0)	0(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)
TOD$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
LCH$^{(0)}$	0(0)	0(0)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0.1(0)	0(0)	0(0)	0(–)	0(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)

Appendix 11—*continued*

	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
MOD$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0.1(0)	0(–)
DMG$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(–)	0(–)	0(0)	0(0)
QSC$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0.1(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0(–)
CPA$^{(0.1)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0.1(0)
MSL$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(0)	0(0)	0(–)	0(–)
WHE$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0.1(0)	0(–)	0(–)	0(0)	0(0)	0(0)
WIT$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0(–)	0(–)	0(0)	0(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)
MOR$^{(0)}$	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)	0(0)	0.1(0)	0(–)	0(–)	0(–)	0(–)	0(–)	0(–)