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## EXECUTIVE SUMMARY

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Auto-longline fisheries targeting ling developed on the Chatham Rise, the Campbell Plateau, and the Bounty Plateau from 1989 to 1992. CPUE series for the fisheries in these three areas are important relative abundance inputs to assessments of the ling stocks. This analysis of data collected by observers from these fisheries aimed to identify any factors that may have changed the catchability of ling over the observed time period, and, hence, biased CPUE series. Observer coverage in these fisheries did not begin until 1993, and was at low levels before 1999. The areal distribution of observed sets varied markedly between years. Like the CPUE series, the available observer data were analysed by area and year.

Several of the recorded variables showed no consistent trends over time in any of the areas. They were the bottom topography fished on, the bottom depth at the start position, the bait species used, and the rate of ling discard or loss.

A positive trend over time was apparent in the efficiency of the automatic baiters. However, much of this variance is explained by a vessel effect (which would already be incorporated into the CPUE analysis process), and the remaining variance is wide. Bait species has been ruled out as a cause of this variance, as have differences in hook type. However, bait quality and baiting technology have both improved over the time analysed.

A reduction over time in proportions of hooks lost per set probably partially indexes learning by fishing skippers on where and how they should best set gear to minimise hook loss. However, stronger gear used since the development of the toothfish fishery will also have influenced this variable. No steady trend is apparent; median hook loss was about 8% in 1994 and 1995, and about 1% from 1998 to 2003. Data before 1998 were too sparse to allow the estimation of a confident correction factor.

There is no indication that hook saturation has occurred at any time or in any area of the fishery. However, hook saturation in subsections of some lines cannot be ruled out. Ling rarely take more than 15% of the hooks, even during times of peak aggregation. On the Chatham Rise and Bounty Plateau, about 4% of hooks are, on average, taken by ling; the value is about 7% on the Campbell Plateau. Only on very rare occasions have more than half the baited hooks in a set been taken by any fish or invertebrate, but it is acknowledged that the level of bait loss after the hooks leave the vessel is unknown.

There were some apparent reported changes in the bycatch composition of the fishery over the time analysed. Some of these are almost certainly a result of change in observer practice (e.g., the more complete reporting of invertebrates caught in recent years), while others are very likely to be real biological effects (e.g., the increased abundance of spiny dogfish on the Chatham Rise). The extent of any changes (either positive or negative) in total bycatch abundance has been slight.

In summary, this analysis of available observer data has indicated no changes in auto-longline fishing practice that are likely to have been unaccounted for in current CPUE analyses, and, hence, biased the estimated series by altering the catchability of ling.

## 1. INTRODUCTION

This document reports the results of Project LIN2003/01, Objective 3, to collate the available information from scientific observer logbooks on the operation of the ling longline fishery up to 2002–03.

CPUE series calculated for the target longline fisheries for ling are important relative abundance indices in the ling stock modelling (Horn 2002b, 2004a). They are the only abundance series available for some of the ling stocks. Data for the CPUE analyses are derived from the MFish catch and effort database, from both smaller 'inshore' line vessels and larger 'auto-longline' vessels (e.g., Horn 2004b). The auto-longline data dominate the CPUE analyses of ling stocks on the Chatham Rise, Campbell Plateau, and Bounty Plateau.

The CPUE analyses assume that, for an individual vessel, the catchability of ling remains constant between years. Any change in the CPUE is assumed to reflect a relative change in the abundance of ling. Horn (2002a) provided basic analyses indicating that hook saturation had never occurred in the fishery, and concluded that there were no apparent sources of bias likely to strongly perturb the relationship between CPUE and ling abundance. He also showed that longline CPUE trends for the Chatham Rise and Campbell Plateau stocks matched trends in abundance derived from research trawl surveys.

Although trends from fishery-dependent and fishery-independent relative abundance series are similar, it is still possible that catchability may have changed over time, hence biasing CPUE. For example, fishing practices could become more efficient (raising catchability), or non-commercial bycatch species could become more abundant and take more of the baited hooks (lowering catchability of ling). Some of the auto-longline trips have carried observers, and data collected by them may enable any changes in catchability to be quantified. This report summarises the data collected by observers, and examines them for any trends that may have biased CPUE.

## 2. METHODS

Observer data are available from auto-longliner trips targeting ling since 1993, and are archived on the *obs_lfs* database administered by NIWA for MFish.

For each observed set, observers can collect the following data on fishing effort and practice:

- position (latitude and longitude)
- depth of set
- number of hooks set
- bait type (i.e., species code)
- percentage of hooks baited
- number of hooks missing after recovery of set
- bottom topography
- catch of each species (by weight and/or number)
- fate of the catch by species (generally 'retained', 'discarded', or 'lost')

All available data from observed ling longline trips up to the end of the 2003 calendar year were extracted from the *obs_lfs* database. Because, CPUE series are analysed by calendar year and area, similar strata were used in this analysis of the observer data (see figure 1 of Horn 2004b). The area strata are:

- the Chatham Rise and coastal waters between Kaikoura and the Otago Peninsula
- the Campbell Plateau and Stewart-Snares shelf, including Puysegur Bank and the Solander Corridor, and coastal waters south of the Otago Peninsula

- the Bounty Plateau

Data from four trips in other areas were available (two in LIN 2, one in LIN 7, and one outside the New Zealand EEZ on the Challenger Plateau), but were not included in this analysis.

Positions of all sets were plotted to depict the geographical distribution of the observed sets. Each recorded variable was plotted by year in a format deemed the most applicable to demonstrate any trends over time (e.g., as means with 95% confidence intervals, percentage bar plots). The plots were then examined visually for trends (and regression lines were fitted to estimates of percentage of hooks baited). The likely influences on the CPUE series of any apparent changes over time were postulated.

## 3. RESULTS and DISCUSSION

### 3.1 Observed trips

A summary of observed trips, by year and area, is presented in Table 1. Although 53 trips were observed, many of these visited more than one of the area strata. Consequently, the sum of the number of trips from 'All areas' in Table 1 is less than the sum of the totals from the individual areas combined. The distribution of observed trips over time is shown in Figure 1. As noted previously, 4 of the 53 observed trips occurred outside the areas of interest, and, except for of their listing in Table 1, are not included in the analysis.

Observation of ling auto-longliner trips began in 1993. However, coverage was at a low level of less than five trips annually until 1999 (with the exception of 1995). No trips were observed in 1996. From 1999 to 2001, 5–6 trips and about 5 million hooks were observed annually. In 2002 and 2003, observation effort approximately doubled relative to the three previous years. Trips to the Chatham Rise and Campbell Plateau have been observed in most years, but there is a 4-year mid-series gap in data from the Bounty Plateau. There is no clear pattern in the time of year of the observed trips in any of the areas (see Figure1).

The areal distribution of observed sets varied markedly between years (Figures 2a and 2b). The observed fishing on the Chatham Rise in 1993 and 1994 occurred in areas that were seldom or never observed in later years. On the Campbell Plateau, observed fishing in 1993, 2001, and 2002 was confined to a small area in the Solander Corridor, but in some other years this area was unobserved.

### 3.2 Baiting of hooks

Baiting of hooks on auto-longline vessels is done (almost exclusively) in automatic baiting machines. The hooks are dragged through a container of bait, with the intention that a piece of bait will be pierced and retained by each hook. Any changes in the efficiency of this baiting process will influence catching ability (in terms of catch per total number of hooks set) because if more hooks are baited, more ling are likely to be caught.

Estimates of the percentage of hooks retaining bait were first made in 1994, and have been made on most trips since then. Estimates were seldom made for all observed sets on a trip; most commonly this was done once each day, or every few days. On about three trips it appears likely that the baiting efficiency was calculated once (or perhaps from a very small number of sets) as all sets had the same reported percentage. From each of these three trips, 10 data points were retained for the following analyses. All reported estimates were used to calculate the mean percentage of hooks baited (with 95% confidence intervals), by year and area. The estimates for each set ranged from 50 to 99% baiting efficiency, but 98% of these estimates were in the range 70–95%.

There is a trend of increasing mean baiting efficiency over time on the Chatham Rise and Campbell Plateau, and for all areas combined (Figure 3). A 5% increase in efficiency between 1994 and 2003 is indicated from the regression to the means, but if all individual data points are regressed the likely increase reduces to about 2%. Confidence intervals around means for each year are narrow, often because the variance of estimates for an individual trip is very low and the index for each year is often derived from only one or two trips. An examination of the data by vessel over time is presented in Figure 4. This analysis is confounded by the relatively few trips each vessel has been observed on, and also that three vessels fished only up to 1998 and five vessels fished only from 1999. Some vessels exhibit an increasing trend over time (i.e., vessels 7 and 9), but most show no clear trend, and variation within vessel can be high. It is also possible that baiting efficiency may vary between vessels. Vessels 6 and 9 both fished from 1999 to 2002 (Figure 4), and their mean baiting efficiencies over this time were 80% and 90% respectively.

To examine the vessel effect on the *percentage baited* variable, data were fitted to a lognormal linear model using a forward stepwise multiple regression fitting algorithm. The *year* variable was forced into the model, and other variables (*vessel, bait type, total number of hooks set*) were offered. Only *vessel* entered the model, and it explained 27% of the total variance. The model assumptions are mainly satisfied, and there are no marked patterns in the residuals (Figure 5). The poorly estimated points (i.e., those with residuals less than –0.2) make up a very small fraction of the data set. The standardised year effects (Figure 5) are relatively constant over the examined time period, and have relatively wide confidence bounds.

The bait species used has remained relatively constant throughout the fishery. All observed trips used jack mackerel as the primary bait. Seven trips (most before 1999) also used squid. Three trips in 2002 used barracouta, and blue mackerel was used on one trip in 2003. The dominance of jack mackerel as bait indicates that bait species is unlikely to have influenced catching ability over the period that the fishery has been observed.

There is an industry view that bait quality has improved over time, leading to improved baiting efficiency as the hooks leave the vessel, and more baits still being on the hooks when the line reaches the bottom. Some vessels have also made recent improvements to their autobaiting technology. Longline operators maintain that baiting efficiency has improved over the duration of the ling longline fishery.

The efficiency of a particular auto-baiter may vary with different hook types. Details of hook style and size are not recorded by observers. However, hook style has remained relatively constant throughout the fishery, although hook size has increased on some vessels as a result of a change to using larger and heavier toothfish gear to target ling (longline operators, pers. comm.).

## 3.3 Topography

The type of bottom where the gear was set was recorded from 1994 on most trips. The proportions of sets fished on different topographies are shown, by year and area, in Figure 6. As is apparent from Figures 2a and 2b, the localities fished varied markedly between years, and these data on topography should be interpreted bearing this in mind. Most of the fishing on the Chatham Rise occurs on smooth and flat or undulating ground, with less frequent sets on hillocks or rugged areas. The one exception to this occurred in 1998, when all observed sets were in canyons. In that year, the observed fishing in the Chatham Rise area was all at the southern end of the Canterbury Bight (see Figure 2a) in canyons where the continental shelf slopes steeply. Fishing was not observed in this area in any other year. Most fishing in the Campbell Plateau area was also classified as being on smooth and flat or undulating ground. This is a little surprising given that there was fishing on the steep eastern edge of the Stewart-Snares shelf in 1998, and fishing in the canyons of the Puysegur Bank and Solander Corridor in several years (see Figures 2a and 2b). The highest levels of rough bottom classification occurred in 2001 (18% rugged) and 2002 (60% canyon); in both these years observed fishing had been confined to the Solander Corridor. Bottom classification on the Bounty Plateau also varied markedly between years, even from 2000 to 2003 when fishing occurred in almost identical areas (see Figure 2b).

It appears likely that different observers have interpreted bottom topography in different ways. The operation of the vessel and the sounder can markedly influence an interpretation gleaned from an occasional view of a sounder screen. For example, steaming along a depth contour can make a very steep slope appear flat, and sounder settings or a fast vessel speed can visually flatten a rough bottom. The topographic data collected by observers are considered to be relatively uninformative, with no apparent changing trends.

### 3.4 Depths fished

Bottom depth at the start of the set was recorded on over 99% of observed sets. Mean depth fished (Figure 7) should also be interpreted bearing in mind the between-year differences in observed localities fished. On the Chatham Rise, mean depth fished is consistently in the narrow range from 430 to 475 m, except in 1998, when it was much shallower. The exception in 1998 is because observed fishing in that year occurred only on the shelf edge in the southern Canterbury Bight, rather than on the Rise (see Figure 2a). Mean fished depth on the Campbell Plateau is also very consistent (520–580 m), except in 1993 when fishing was generally shallower. In that year the observed trip fished in the Solander Corridor (see Figure 2a), but at depths slightly shallower than were generally fished in the same area in later years. On the Bounty Plateau, the range of mean depths fished was broader and more variable than in the other two areas, but with no consistent trend (Figure 7). Fishing here was also generally shallower (150–300 m) than in the other areas. No consistent trend changes in bottom depth fished are apparent in any of the three area strata.

### 3.5 Hooks lost per set

This variable was recorded on most trips from 1994. However, it may be relatively unreliable for some trips. At times it was recorded in detail for each set. In these situations, some hooks (usually less than 2%) are lost from almost every set, but sometimes zero losses are recorded. Other trips have records for only some of the sets; it is unknown whether the blank records indicate zero losses or no record made. Some trips record zero losses for almost every set, but with occasional non-zero losses, generally when large numbers of hooks were lost (e.g., when a line broke and part of it was not retrieved). Occasionally, a constant non-zero value was applied to most of the sets from a trip.

It is likely that some hooks will be lost on every set, and that occasional sets will have large hook losses. Many of the recorded zero values will be underestimates (although will generally be indicative of relatively slight hook losses), and some of the 'constant' values will be rough estimates probably based on a perceived average level of hook loss. Values of the percentage of hooks set that were lost (where a value of 0 or higher for hooks lost was reported) were binned into five categories: 0–2%, 2.01–5%, 5.01–10%, 10.01–20%, and 20.01–75%.

Proportions per bin, by area and year, are presented in Figure 8. In recent years on the Chatham Rise, levels of hook loss have been low, almost always 5% or less. However, in some years, particularly 1995, more than 40% of observed sets lost more than 5% of their hooks. Hook loss in the Campbell Plateau area has been consistently low since 1998 (i.e., almost always 5% or less), but data from 1995 indicate a slightly greater level of loss. Observed hook loss on the Bounty Plateau exhibited similar trends to the Campbell Plateau, with consistently low levels of hook loss since 2000, but quite high levels in 1995.

There is an indication of an overall trend in hook loss; losses in 1994 and 1995 tended to be greater than losses since 1998. (There are no data from 1996 and 1997.) For all observed sets where hook loss was recorded, 26% of sets in 1994 and 1995 lost more than 10% of their hooks, with the median value being 8% lost. Since 1998, only 2.5% of sets have experienced a similar level of hook loss; the median hook loss during that period was 1%. Assuming that the number of hooks recorded on the CELR forms has been the number set rather than the number recovered, a change in the rate of hooks lost could bias CPUE. If 8% of hooks were lost up to 1995, and 1% of hooks have been lost since 1998, then CPUE from the earlier period has been biased downwards by about 7%.

Longline operators agreed that there had been a decrease in the proportion of hooks lost per set, for two reasons. First, vessel crews are now better trained and are more dedicated to maintaining the gear in good condition. Less weak or worn gear fished equates to fewer hook losses. Second, some of the auto-longliners targeting ling also fish for toothfish, and the same gear is used in both fisheries. The gear used for toothfish has to be stronger than that initially used in the ling fishery; gear losses in the ling fishery have decreased since this upgrade.

### 3.6 Catch composition

Some aspects of the catch from all observed sets have been recorded. At the most complete level, for each set, the total weight and number of each species caught, and the fate of that species (generally 'retained', 'discarded', or 'lost'), has been recorded. Hence, for some sets, there may be three entries for ling: the weight of ling retained and processed, the weight discarded (e.g., because of damage by seals or sea lice), and the estimated weight lost (i.e., brought to the surface but detached from the hook before recovery). The species recorded included commercial and non-commercial teleosts and elasmobranchs, invertebrates, birds, seaweed, and rubbish.

The amount of data recorded per set varied widely. Sometimes only weight or number of a catch species was recorded. The fate of all catch components was often incomplete. It is also apparent that some species (presumably non-commercial, discarded ones) were not recorded in any way on some trips. Species identification can also be confusing. For example, although many sharks and dogfishes were identified to species, large numbers were simply coded as 'deepwater dogfish', 'shark', or 'other sharks and dogfish'.

Because this project aims to look for changes in the fishery over time that may have biased CPUE, and CPUE is based on catch per hook, it is important to know the number of hooks taken by ling (and other species). Consequently, where the catch of species from a particular set had been recorded only as weight, it was necessary to convert that weight to a likely number of individuals (i.e., the number of hooks taken by that species). Conversion factors (by area) for each catch species were created by estimating a mean species weight for every set where both catch weight and number were recorded, and then calculating a grand mean from all these mean weights. Appendix 1 lists these conversion factors. The recorded catch from each set could then be expressed in terms of the number of hooks taken by individual species. The total number of hooks fished to produce the catch from each set was taken as the number of hooks set, less any hooks reported lost (i.e., observed retrieved hooks).

From the 49 trips observed in the three areas of this analysis, 160 species codes were used and about 56 000 species landings were recorded, comprising an estimated 4.6 million items. As might be expected, a few species made up most of the catch: 60% of the species landings records were ling, spiny dogfish, red cod, sea perch, ribaldo, rattails, smooth skates, or ghost sharks. To examine trends in catch over time, 14 species groups were established as follows.

- Ling
- Spiny dogfish (mainly southern, but also northern spiny dogfish)
- Red cod
- Sea perch
- Ribaldo
- Skates (mainly smooth and rough, but also deepsea, and unspecified)
- Ghost sharks (mainly pale and dark, but also giant and longnose chimaeras)
- Non-commercial teleosts (mainly notothenid cod, conger eels, and rattails)
- Commercial teleosts (mainly bluenose, hapuku, bass, and Ray's bream)
- 'Commercial' elasmobranchs (school shark, rig, seal shark, shovelnose dogfish)
- All other sharks and dogfish not noted above
- Hagfish
- Invertebrates (mainly starfish and anemones)
- Other items (birds, seaweed, rubbish, unidentified items)

The distinction between species classified as commercial and non-commercial is a little blurred; sometimes non-commercial species were retained, and occasionally commercial species were discarded. The proportions of observed retrieved hooks occupied by each of these species groups, by area and year, are shown in Figure 9, and the volume of data is summarised in Table 2. It should be remembered that hooks that were set and recorded as lost have been removed from these totals, but unbaited hooks are still included. About 14–19% of retrieved hooks would have been set unbaited (see section 3.2).

On the Chatham Rise, the proportion of hooks with ling is relatively constant at about 2–5%, with no apparent trend over time. Ling were generally the most abundant species in the catch. Total hooks occupied ranged from 6 to 15%, also without any clear trend. Spiny dogfish were particularly abundant in the 2002 and 2003 catches (6–7%), and in those years were more prevalent than ling. Catches of spiny dogfish in years up to 2001 were generally 3% or less. Hooks holding sea perch were relatively constant at about 0.5 to 2%. Ribaldo occupied about 1–2% of hooks up to 2001, but less than 0.3% of hooks since then. Invertebrates seldom appear in the observer data before 2001, probably because they were not recorded rather than not caught. There is an industry perception that the abundance of spiny dogfish has markedly increased over time on the Chatham Rise, and that ribaldo abundance may have declined.

On the Campbell Plateau, ling was clearly the most abundant species in the catch every year, generally occupying 5–9% of the hooks. Total hooks occupied by all species ranged from 6 to 13%, and the percentage of hooks taken by all bycatch species has remained relatively constant over the years examined. Spiny dogfish consistently accounted for about 0.5 to 1.7% of hooks. Red cod were a notable bycatch in 1993 and 1999–2003; these were the years when the Solander Corridor fishery was observed (see Figures 2a and 2b). There has been an observed increase in the numbers of hooks taken by commercial and non-commercial sharks since 1999. It is not known whether this is a real biological effect, or owing to incomplete recording of the catch in earlier years. Invertebrates have seldom been recorded in the Campbell Plateau catch in any year.

On the Bounty Plateau, ling consistently occupied 2.5 to 5% of the hooks, and was the most abundant species in the catch in all years except 1993 and 1994. Total hooks occupied by all species ranged from 7 to 13%, and appears to have exhibited a declining trend over time. Non-commercial teleosts (almost exclusively notothenid cod and rattails) was the second most abundant species group, accounting for about 6% of hooks in 1993 and 1994, but then declining to about 1% in recent years. Hooks with skate have been relatively constant at 1–2% annually. Spiny dogfish are seldom caught in the Bounty fishery. There has been an increase in the reported numbers of non-commercial sharks and invertebrates since 2001. Again, it is not known whether this is a real biological effect, or owing to incomplete recording of the catch in earlier years.

The data in Figure 9 indicate that the ling auto-longline fishery is reasonably effective at targeting ling; numerically, about 45% of the catch is the target species. It is also very clear that, on average, the fishery does not approach hook saturation. For every 100 hooks set and retrieved, about 17 would have been unbaited, 5 will catch ling, and 6 will catch some other species. That leaves 72 baited hooks in the water with no catch. Even if an allowance of 40 hooks is made to account for baits that fall off the hook before the line reaches the ling fishing depth or baits that are removed by fish and invertebrates too small to take the hook, this still leaves one-third of the hooks baited, but ignored or not encountered by ling.

The data in Figure 9 indicate that, on average, hook saturation is not approached. However, catch and catch rates vary seasonally (Horn 2001), so hook occupancy levels of individual sets need to be examined to determine whether saturation occurs at times of peak catch rates. Frequency distributions of hook occupancy by ling, and total hook occupancy, for individual sets by area are presented in Figure 10. Because hook saturation is more likely to occur at times when ling aggregate to spawn, data from the longline fishery in the Puysegur Bank and Solander Corridor areas from October to December have been shown separately to data from the rest of the 'Campbell' area. The maximum number of observed retrieved hooks occupied by ling was 32% in a set in the Solander Corridor in 2000. The next highest ling occupancy rate was 21%, also from a Solander Corridor set. It is clear from Figure 10 that most sets on the Chatham Rise, Bounty Plateau, and the Campbell Plateau, excluding the Puysegur and Solander areas, have less than 7% of hooks taken by ling. In the Puysegur and Solander areas, the number of hooks taken by ling generally ranges from 7 to 14% per set. Over all areas, 96% of sets have 12% or fewer hooks taken by ling.

Total hook occupancy by set tends to range between 4 and 18% (Figure 10). The highest occupancy was 58% for a set on the Bounty Plateau where a large proportion of the hooks had sea anemones attached. Only 2% of all sets had a total occupancy rate of more than 40%; half of these were from a single trip on the Bounty Plateau producing high catch rates of sea anemones, spiny dogfish, and deepwater dogfish. Over all areas, 95% of sets have 23% or fewer hooks occupied. In most areas, the rate seldom exceeds 16%, although the Chatham Rise appears to have a higher rate of bycatch than the other three areas.

### 3.7 Fate of the catch

Of the 49 observed trips included in this analysis, only 22 reported on the fate of the ling catch, and only one of these before 1999. (Even fewer reported information on the fate of other species.) Five trips split the ling catch into the three categories: the weight of ling retained and processed, the weight discarded (e.g., because of damage by seals or sea lice), and the estimated weight lost (i.e., brought to the surface but detached from the hook before recovery). The remaining 17 trips reported the retained catch, and either lost or discarded catch (but not both). This is indicative that, at times, the latter two categories were confused and/or combined. Hence, for each trip, the number of ling classified as discarded and lost were combined and expressed as a percentage of the number of ling retained (Figure 11). There is no apparent trend over time in the data. In most trips where losses and discards were recorded they amounted to less than 2% of the retained ling catch.

There is an industry view that damage to ling by seals (necessitating discard) has increased in recent years, particularly on the Chatham Rise. It is also possible that attraction of seals to longliners is vessel-specific and related to the sound generated by particular vessels. Discarded ling are (theoretically) recorded as part of the catch, so any changes in discard rates should not bias CPUE.

## 4. CONCLUSIONS

The ling auto-longline fishery developed on the Chatham Rise in the 1989–90 fishing year, on the Campbell Plateau in 1990–91, and on the Bounty Plateau in 1991–92 (Horn 2001). CPUE series for line fisheries in these three areas began in calendar years 1990, 1991, and 1992, respectively (Horn 2004b). Observer coverage in these fisheries did not brgin until 1993, and coverage was sporadic and light before 1999. The geographical distribution of the observed sets varies markedly between years. The relatively light and variable coverage in space and time means that any apparent trends should be considered with caution. A single 'abnormal' trip could have a strong influence on any of the examined time series of data.

Several of the data categories showed no consistent trends over time in any of the areas. They were the bottom topography fished on, the bottom depth at the start position, the bait species used, and the rate of ling discard or loss.

A positive trend over time was apparent in the efficiency of the automatic baiters, a view corroborated by longline operators. This was a variable where it is logical to combine data from all areas; baiting efficiency is dependent on the on-board technology and operators, and independent of locality. A vessel effect explained 27% of the variance in baiting efficiency, and the standardised annual indices of expected percentage of hooks baited had very wide confidence intervals (see Figure 5). During 1997 to 1999, the composition of the auto-longliner fleet changed, with some vessels retiring from the fishery and others entering (see figure 2 of Horn 2004b). As noted above, of the vessels producing data for this analysis, three fished only up to 1998 and five fished only from 1999. Hence, the improvement in apparent overall baiting efficiency over time could partially be a function of newer vessels having better baiting technology. In a CPUE analysis, this technological advance would be largely explained in the vessel effect, which has been one of the variables entering the CPUE model in every ling longline analysis (Horn 2004b). The explanation by a vessel effect of much of the variance in baiting efficiency, and the wide confidence bounds around the standardised indices, indicates that there is probably no need to specifically compensate CPUE analyses for any changes in this variable.

A decrease over time was apparent in the proportion of hooks lost per set in all three areas. Over all areas combined, a median of 8% was lost in 1994 and 1995, compared with a median of 1% since 1998. Assuming number of hooks set is recorded on the CELR forms, then this change would have the effect of biasing CPUE downwards in the earlier years because the actual number of hooks fished (i.e., retrieved) would be about 8% lower than reported. However, the worth of this data set is diminished because it contains no data before 1994, or from 1996 and 1997, and the data volume from 1994 and 1995 is small. Hence, any estimation of a hook loss time series is complicated. The Middle Depth Fisheries Working Group concluded that there were insufficient data to conclude that any adjustments of the CPUE series were necessary.

There are probably two categories of hook loss; high proportion loss when gear malfunction or line snagging results in the loss of much of a longline, and low proportion loss when a few hooks are snagged or the snoods are broken off by hooked fish. High percentage losses (defined as those of more than 20% of hooks) usually occur on less than 2% of sets in any year and have shown no changing trend in frequency over time. The low proportion losses (which may have decreased over time) may be partially indexing learning; fishing skippers learn how and where to set gear to minimise hook loss.

Analyses in Section 3.6 have indicated that hook saturation is unlikely to have occurred at any time or in any area of the ling auto-longline fishery. Only on very rare occasions have more than half the baited hooks set been taken by a fish or invertebrate. Ling rarely take more than 15% of the hooks, even during times of peak aggregation. Mean hook occupancy by ling was highest in the Puysegur/Solander region, and lowest on the Chatham Rise. However, it is not possible to completely rule out the occurrence of hook saturation. Ling are unlikely to be homogenously distributed on the bottom. So even when setting a line through an area known to contain spawning ling aggregations, some sections of the line may be exposed to low ling densities, while other sections may be set in areas where there are many more ling than baited hooks. Overall, the catch from that line would indicate non-saturation of the hooks, but some sections of the line may have experienced hook saturation. It is also acknowledged that bait loss between the hook leaving the vessel and arriving at the seabed cannot be measured and may be significant. The extent of bait loss due to fish or invertebrates too small to be hooked is also unknown.

There were some apparent reported changes in the bycatch composition of the fishery over the time analysed. Some of these are almost certainly a result of change in observer practice, e.g., the more complete reporting of invertebrates (mainly starfish and anemones) caught in recent years. It is uncertain whether recent increases in reported catches of 'non-commercial sharks and dogfish' on the Campbell and Bounty Plateaus reflect more complete reporting or a real biological change. The reduction in catches of notothenid cod and rattails on the Bounty Plateau is probably not an artefact of reporting. However, an increase in hook size on some vessels since the development of the toothfish fishery may have led to a reduced catch of small rattails and notothenids. The apparent abundance of spiny dogfish increased on the Chatham Rise, but remained relatively constant on the Campbell Plateau. Similar trends were apparent in comprehensive series of spiny dogfish CPUE derived from the target ling bottom longline fisheries in these two areas separately (Manning et al. 2004), and on the Chatham Rise from a series of research trawl surveys (Livingston et al. 2002).

In summary, this analysis has indicated no changes in auto-longline fishing practice that are likely to have biased estimated series of CPUE by altering the catchability of ling. A small reduction in the proportion of hooks lost over time is indicated, but the available data are too sparse to confidently estimate a correction factor. There has probably also been an improvement in baiting efficiency, but the analysis indicates it will be largely explained by the vessel effect currently incorporated in the CPUE analysis process. Hook saturation is considered unlikely to have occurred on most sets, but cannot be completely ruled out.

It is apparent that there is a degree of inconsistency in data recording by observers, so it may be advantageous to have more detailed instructions available. For example, it is probably unnecessary to record the percentage of hooks baited for every set, but when that parameter is estimated it should be recorded only against the set from which it was derived. Guidelines for species identification should ensure that codes like SKA (unspecified skates) or OSD (unspecified sharks and dogfish) are not used. It may be useful to collect data on hook style and size, and on mean spacing between snoods. Both those factors are known to influence CPUE.

## 5. ACKNOWLEDGMENTS

I thank Mike Stevenson for preparing Figure 2, representatives of auto-longline fishing operations for useful discussions on changes that have occurred in the fishery, and Keith

Michael for comments on a draft of this manuscript. This research was funded by the Ministry of Fisheries under Project LIN2003/01.

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Manning, M.J.; Hanchet, S.M.; Stevenson, M.L. (2004). A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks. Final Research Report for Ministry of Fisheries Research Project SPD2002/01, Objective 1. 142 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Table 1: Summary of observed trips, sets, and hooks set, by year and area. Analysed data were from the Chatham Rise, Campbell Plateau, and Bounty Plateau only; data from trips in other areas are included in the "All areas" totals. WCSI, west coast South Island; ECNI, east coast North Island.

| Area | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
| Chatham Rise | trips | 1 | 1 | 4 | 0 | 3 | 1 | 2 | 0 | 3 | 7 | 7 |
| | sets | 86 | 66 | 225 | | 398 | 41 | 171 | | 144 | 750 | 693 |
| | hooks | 302 400 | 288 300 | 1 202 716 | | 2 346 763 | 220 718 | 851 200 | | 796 789 | 5 124 123 | 5 422 306 |
| Campbell Plateau | trips | 1 | 0 | 3 | 0 | 1 | 1 | 3 | 3 | 4 | 2 | 4 |
| | sets | 114 | | 287 | | 13 | 119 | 439 | 482 | 477 | 221 | 288 |
| | hooks | 442 800 | | 1 421 800 | | 81 600 | 738 241 | 3 764 065 | 3 129 617 | 3 428 609 | 1 318 559 | 2 129 194 |
| Bounty Plateau | trips | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 4 |
| | sets | 77 | 20 | 177 | | | | | 293 | 32 | 336 | 337 |
| | hooks | 294 400 | 67 200 | 760 221 | | | | | 1 915 305 | 197 600 | 2 196 958 | 2 398 974 |
| Analysed data | trips | 2 | 1 | 5 | 0 | 4 | 1 | 5 | 5 | 5 | 11 | 11 |
| | sets | 277 | 86 | 689 | | 411 | 160 | 610 | 775 | 653 | 1 307 | 1 318 |
| | hooks | 1 039 600 | 355 500 | 3 384 737 | | 2 428 363 | 958 959 | 4 615 265 | 5 044 922 | 4 422 998 | 8 639 640 | 9 950 474 |
| WCSI | trips | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | sets | | | | | | | | | | | 8 |
| | hooks | | | | | | | | | | | 7 256 |
| ECNI | trips | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | sets | | | | | | | | | 50 | | 31 |
| | hooks | | | | | | | | | 369 681 | | 267 000 |
| Extra-territorial | trips | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| | sets | | | | | | | 24 | | | | |
| | hooks | | | | | | | 152 574 | | | | |
| All areas | trips | 2 | 1 | 5 | 0 | 4 | 1 | 6 | 5 | 6 | 11 | 12 |
| | sets | 277 | 86 | 689 | | 411 | 160 | 634 | 775 | 703 | 1 307 | 1 357 |
| | hooks | 1 039 600 | 355 500 | 3 384 737 | | 2 428 363 | 958 959 | 4 767 839 | 5 044 922 | 4 792 679 | 8 639 640 | 10 224 730 |

**Table 2: Summary of observed retrieved hooks taken by all species combined, and by ling only (by year and area).**

| Area | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
| **Chatham Rise** | | | | | | | | | | | |
| Number of hooks observed | 302 400 | 273 946 | 1 165 217 | 0 | 2 346 763 | 219 418 | 839 700 | 0 | 791 761 | 5 014 418 | 5 358 377 |
| Number of hooks occupied | 33 618 | 29 440 | 153 474 | | 236 920 | 16 835 | 52 843 | | 88 238 | 731 816 | 711 314 |
| Hooks occupied (%) | 11.1 | 10.7 | 13.2 | | 10.1 | 7.7 | 6.3 | | 11.1 | 14.6 | 13.3 |
| Hooks taken by ling (%) | 2.7 | 4.1 | 5.1 | | 3.4 | 4.8 | 2.1 | | 2.4 | 3.6 | 3.6 |
| **Campbell Plateau** | | | | | | | | | | | |
| Number of hooks observed | 442 800 | 0 | 1 374 331 | 0 | 81 600 | 737 441 | 3 718 620 | 3 112 777 | 3 389 724 | 1 314 357 | 2 088 467 |
| Number of hooks occupied | 50 421 | | 114 838 | | 5 996 | 44 219 | 380 853 | 395 975 | 372 249 | 149 611 | 225 354 |
| Hooks occupied (%) | 11.4 | | 8.4 | | 7.3 | 6.0 | 10.2 | 12.7 | 11.0 | 11.4 | 10.8 |
| Hooks taken by ling (%) | 8.1 | | 6.1 | | 5.2 | 5.2 | 6.2 | 8.5 | 7.3 | 9.3 | 6.0 |
| **Bounty Plateau** | | | | | | | | | | | |
| Number of hooks observed | 294 400 | 59 424 | 684 261 | 0 | 0 | 0 | 0 | 1 896 975 | 196 999 | 2 151 855 | 2 368 591 |
| Number of hooks occupied | 36 823 | 5 775 | 78 612 | | | | | 140 635 | 23 153 | 257 499 | 199 558 |
| Hooks occupied (%) | 12.5 | 9.7 | 11.5 | | | | | 7.4 | 11.8 | 12.0 | 8.4 |
| Hooks taken by ling (%) | 3.3 | 2.5 | 5.3 | | | | | 4.6 | 3.9 | 4.8 | 4.3 |

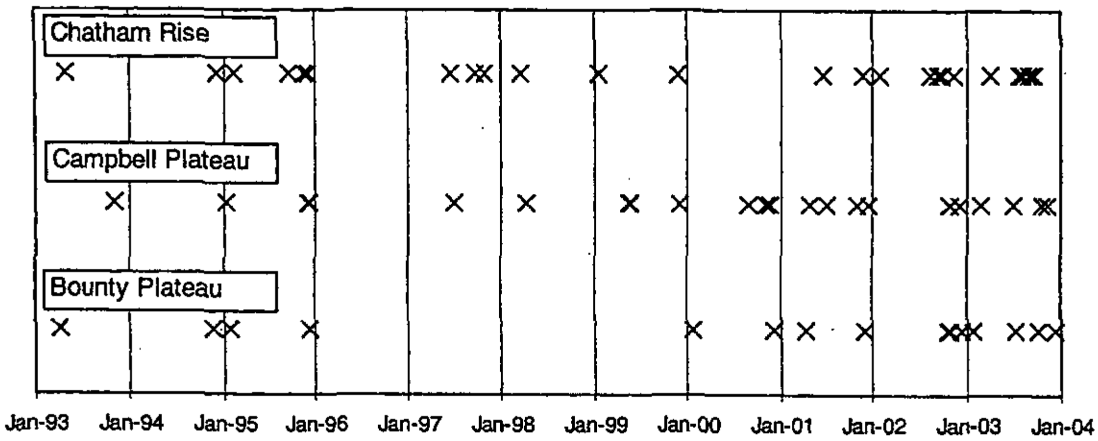


**Figure 1: Distribution of observer ling longline trips, by area and date. The Xs mark the midpoint of the trip.**

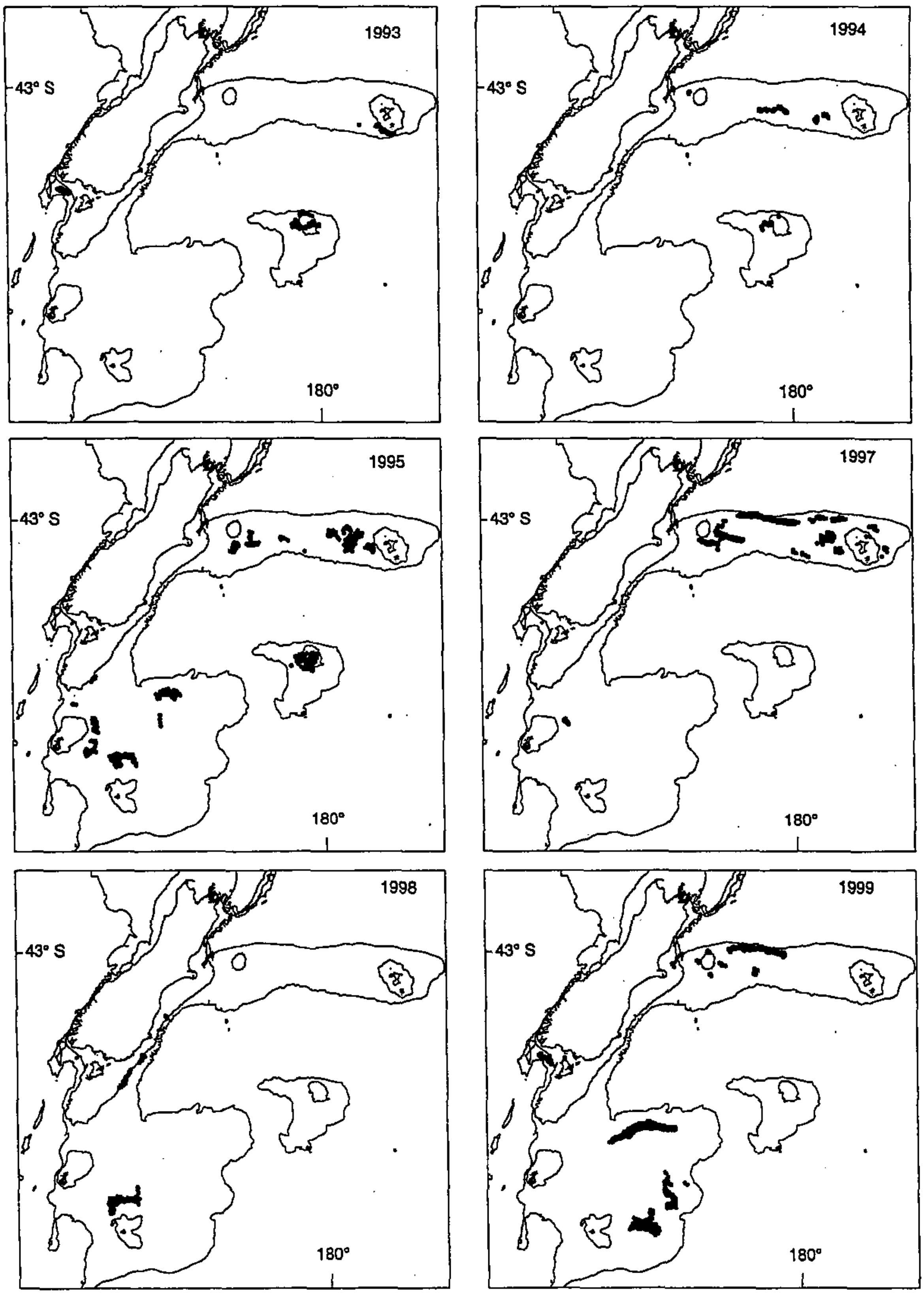


**Figure 2a: Distribution of observed sets (●), 1993 to 1999 (no trips were observed in 1996). Plotted depth contours are 200 and 1000 m.**

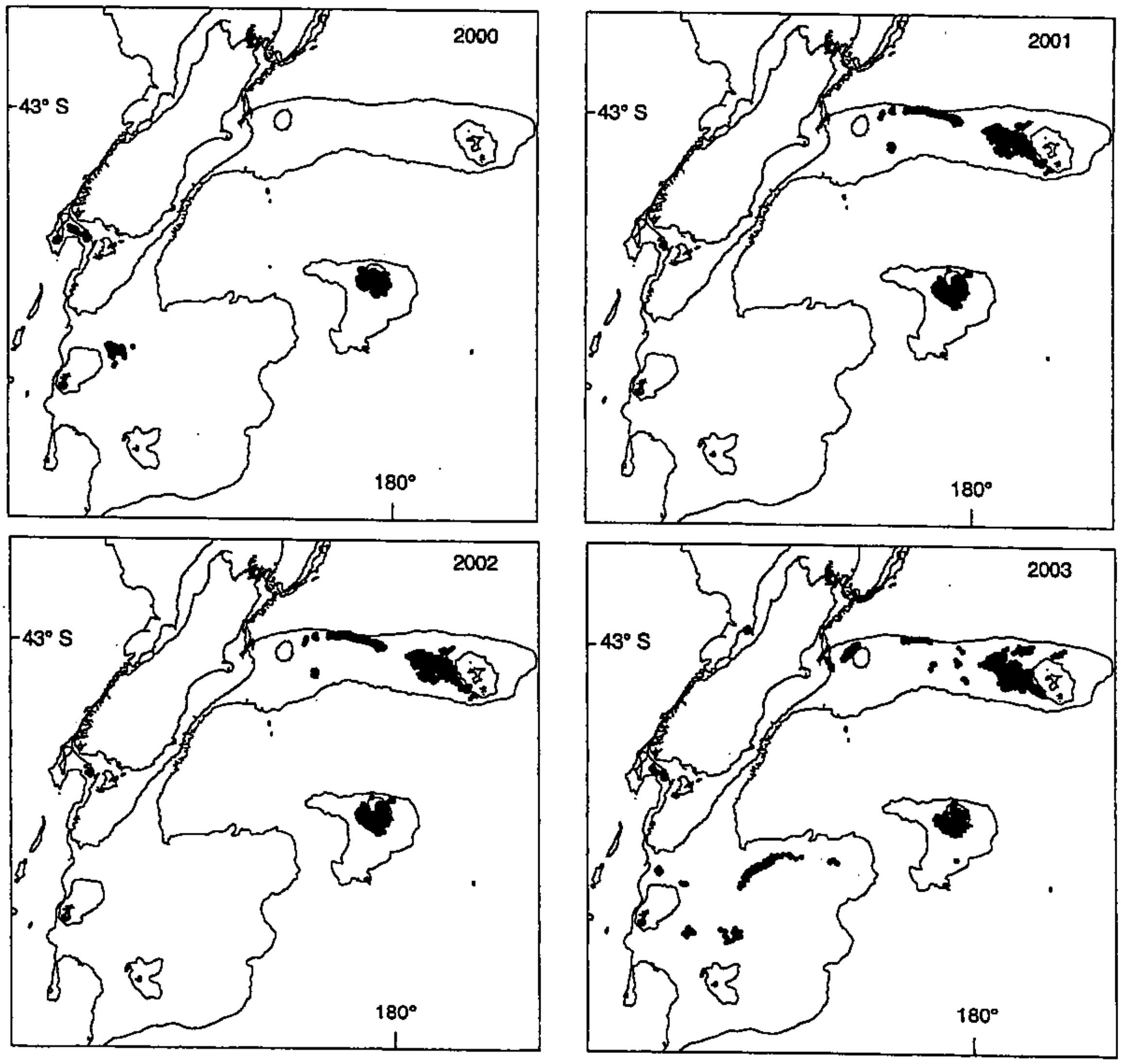


**Figure 2b: Distribution of observed sets (●), 2000 to 2003. Plotted depth contours are 200 and 1000 m.**

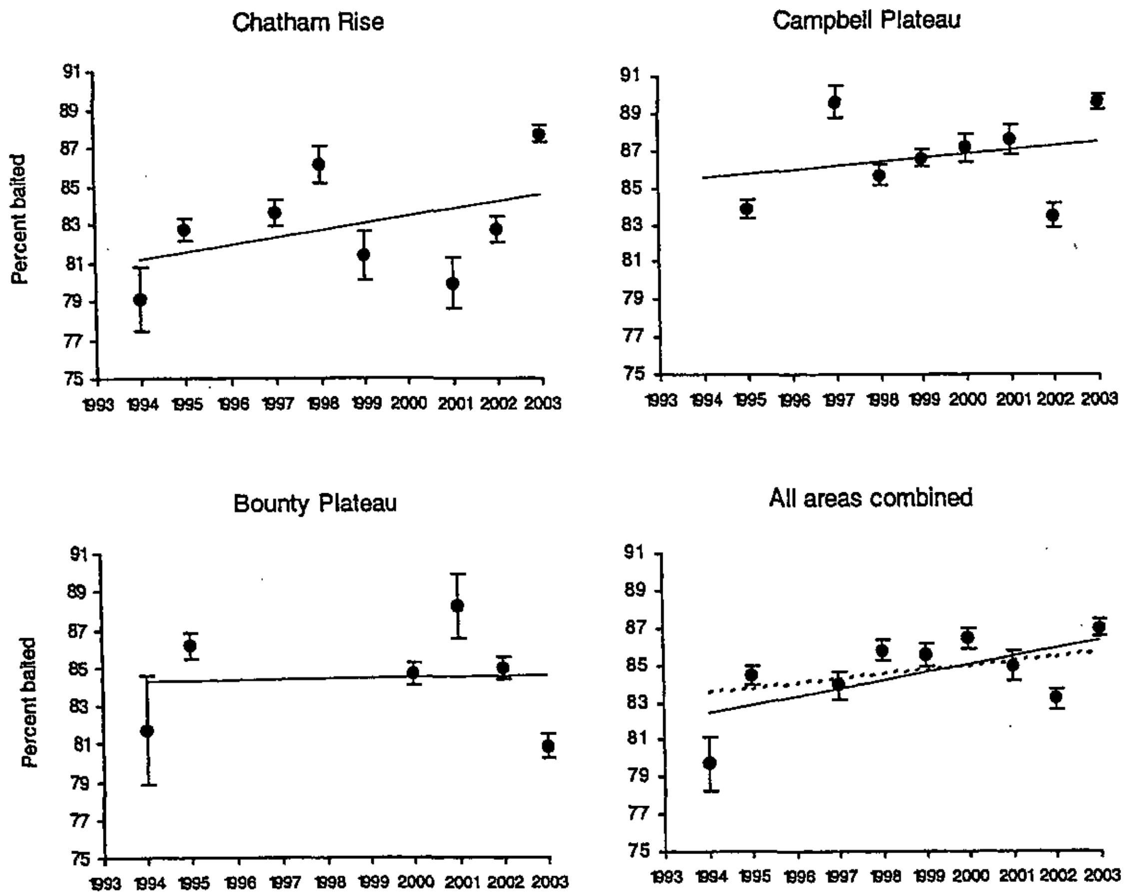


**Figure 3: Mean percentage of hooks baited (with 95% confidence intervals), by year and area, and for all areas combined. Linear regressions to each set of means are shown on each plot (solid lines). On the 'All areas combined' plot, the regression fitted to all individual data points (i.e., each set having an estimate of baiting efficiency) is shown as a broken line.**

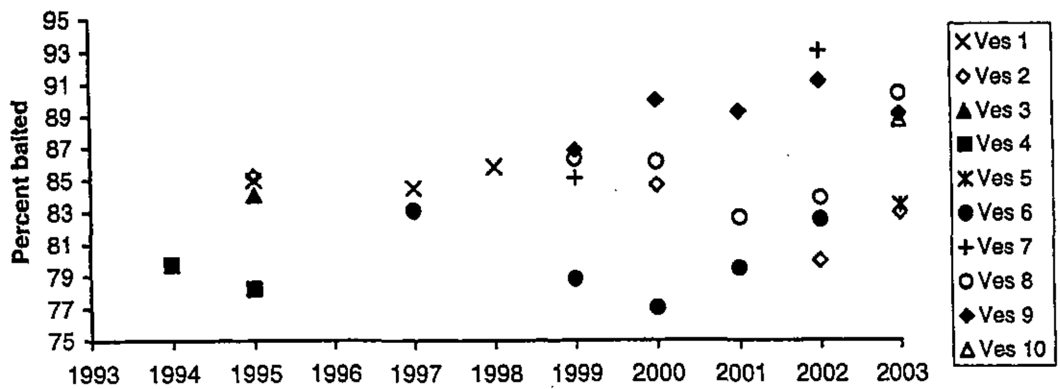


**Figure 4: Mean percentage of hooks baited, by vessel by year.**

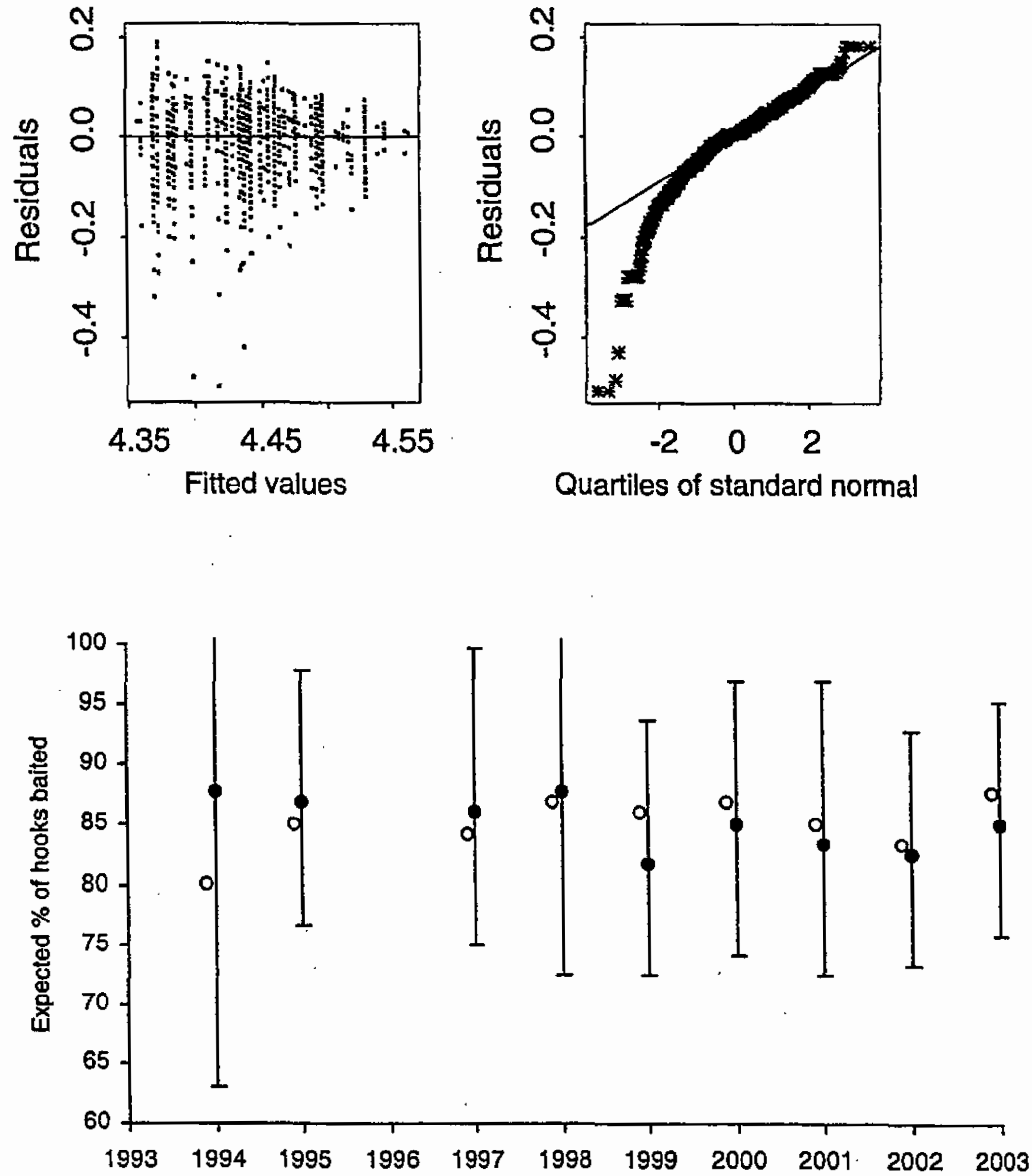


**Figure 5: Diagnostic plots for the model relating percentage of hooks baited to year, after standardising the vessel effect. The standardised indices of expected percentage of hooks baited (solid circles with 95% confidence intervals) are plotted with the unstandardised indices (open circles).**

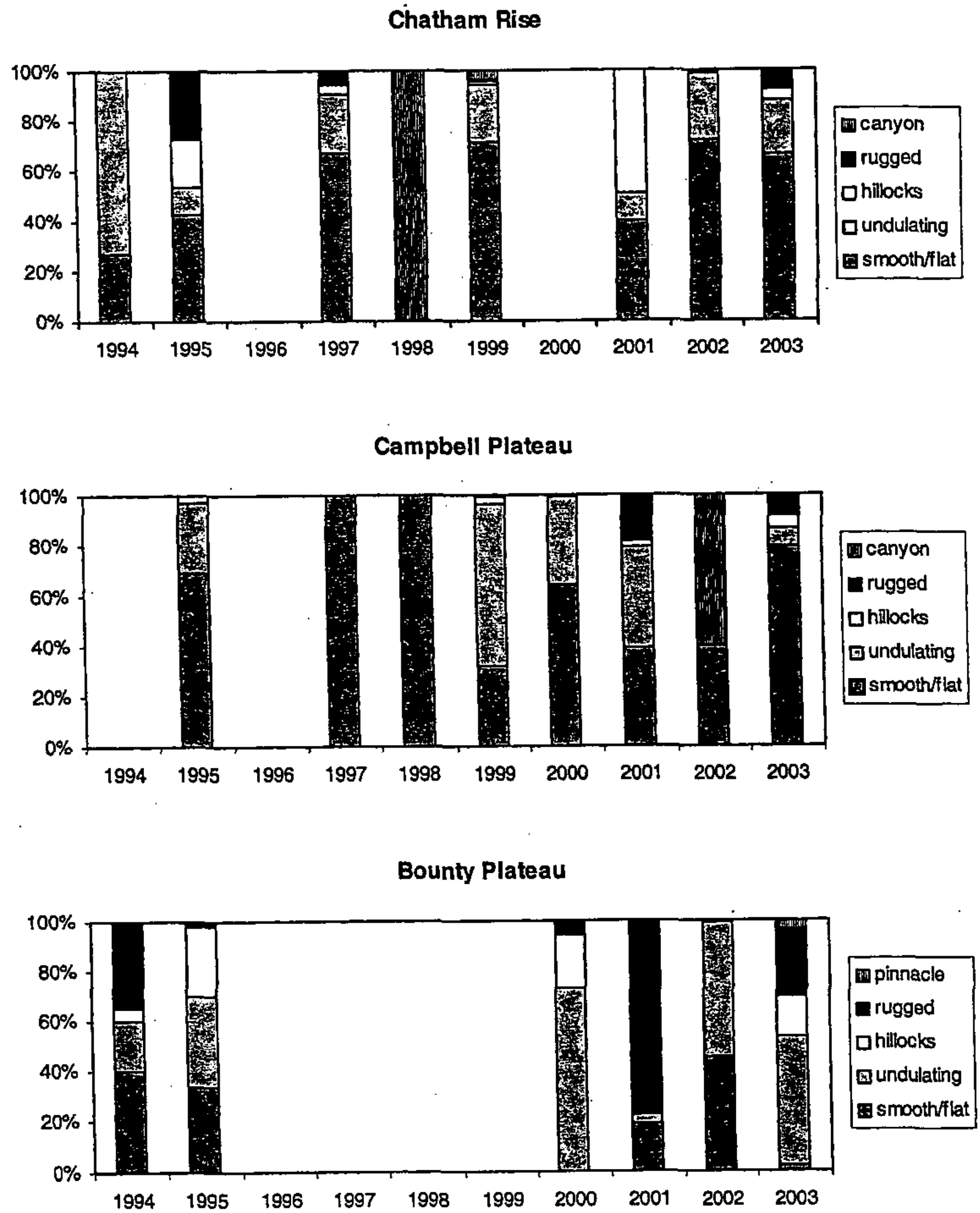


**Figure 6: Proportions of bottom type fished on, by year and area.**

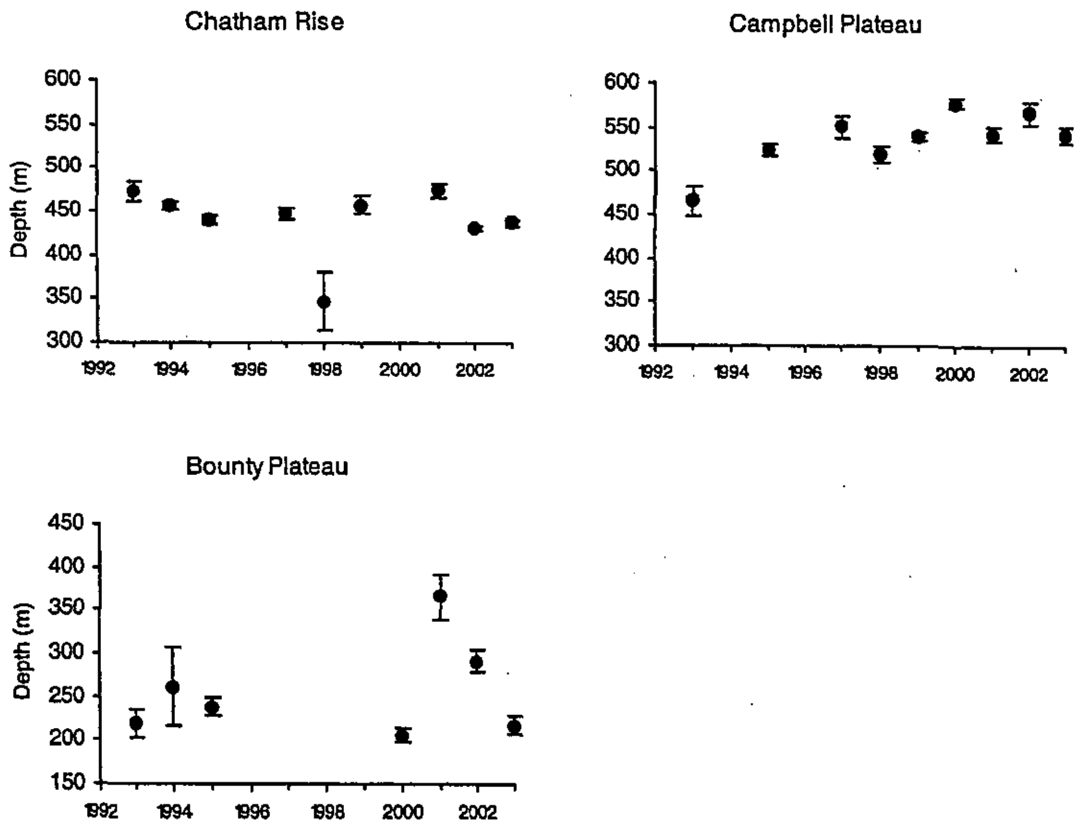


**Figure 7: Mean depth of the seabed under the vessel at the start of each set (with 95% confidence intervals), by year and area.**

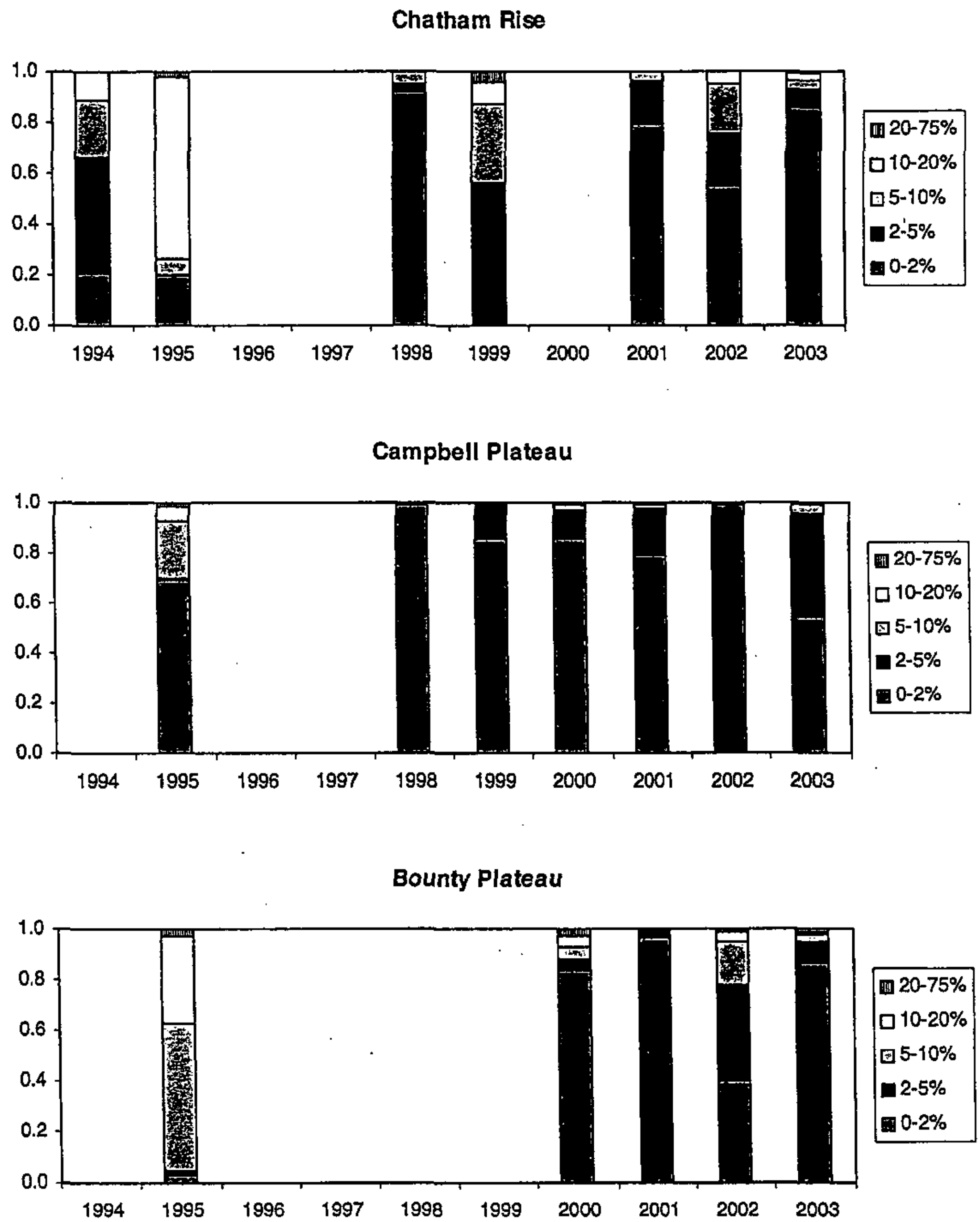


**Figure 8: Proportions of hook loss per set, by year and area. Percentage hook loss has been binned into five categories.**

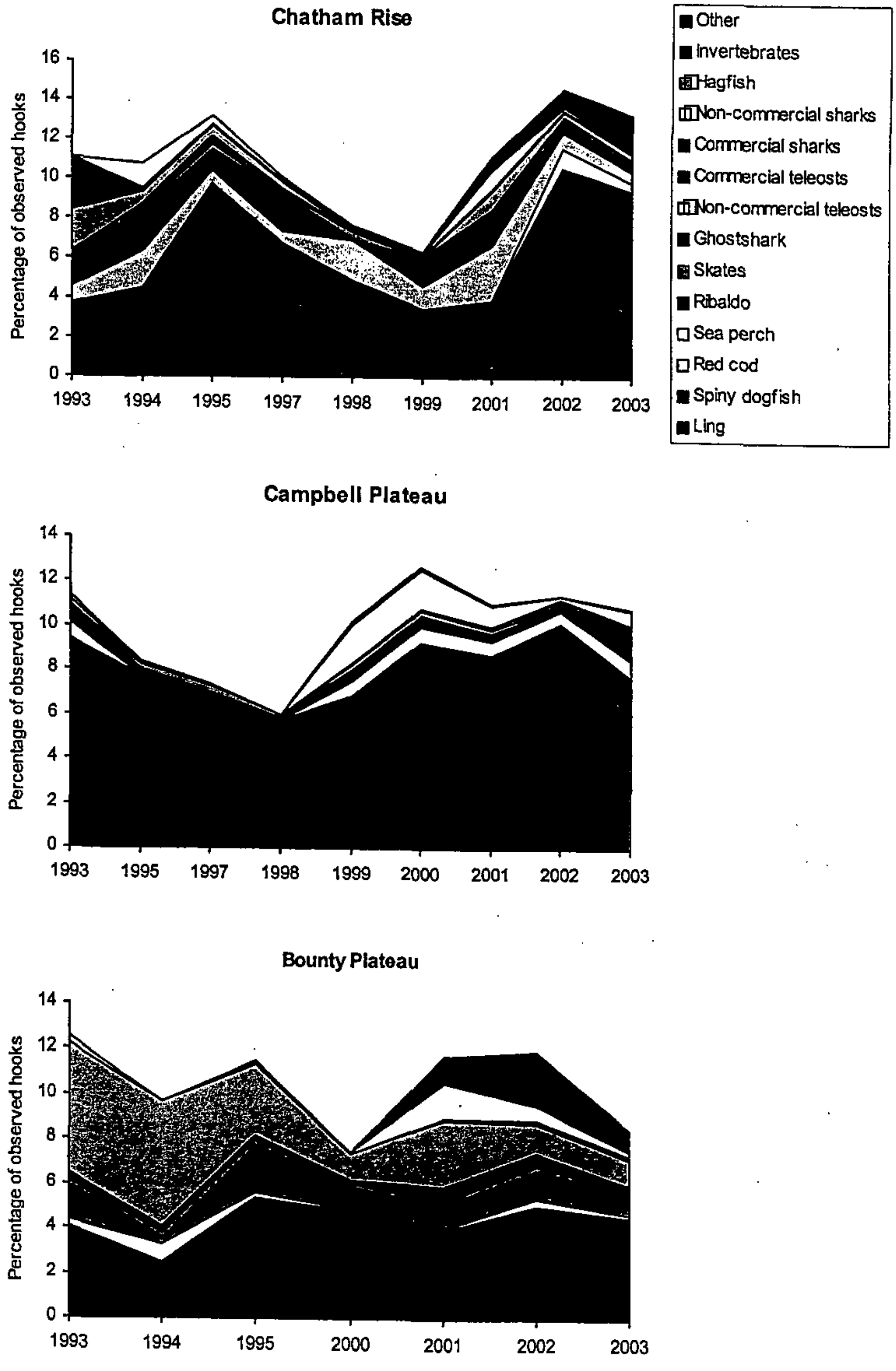


**Figure 9: Percentage of observed retrieved hooks occupied by the various species groups, by area and year.** ***Note that the years on the x-axes are not consecutive as there were no data from some years in some areas.***

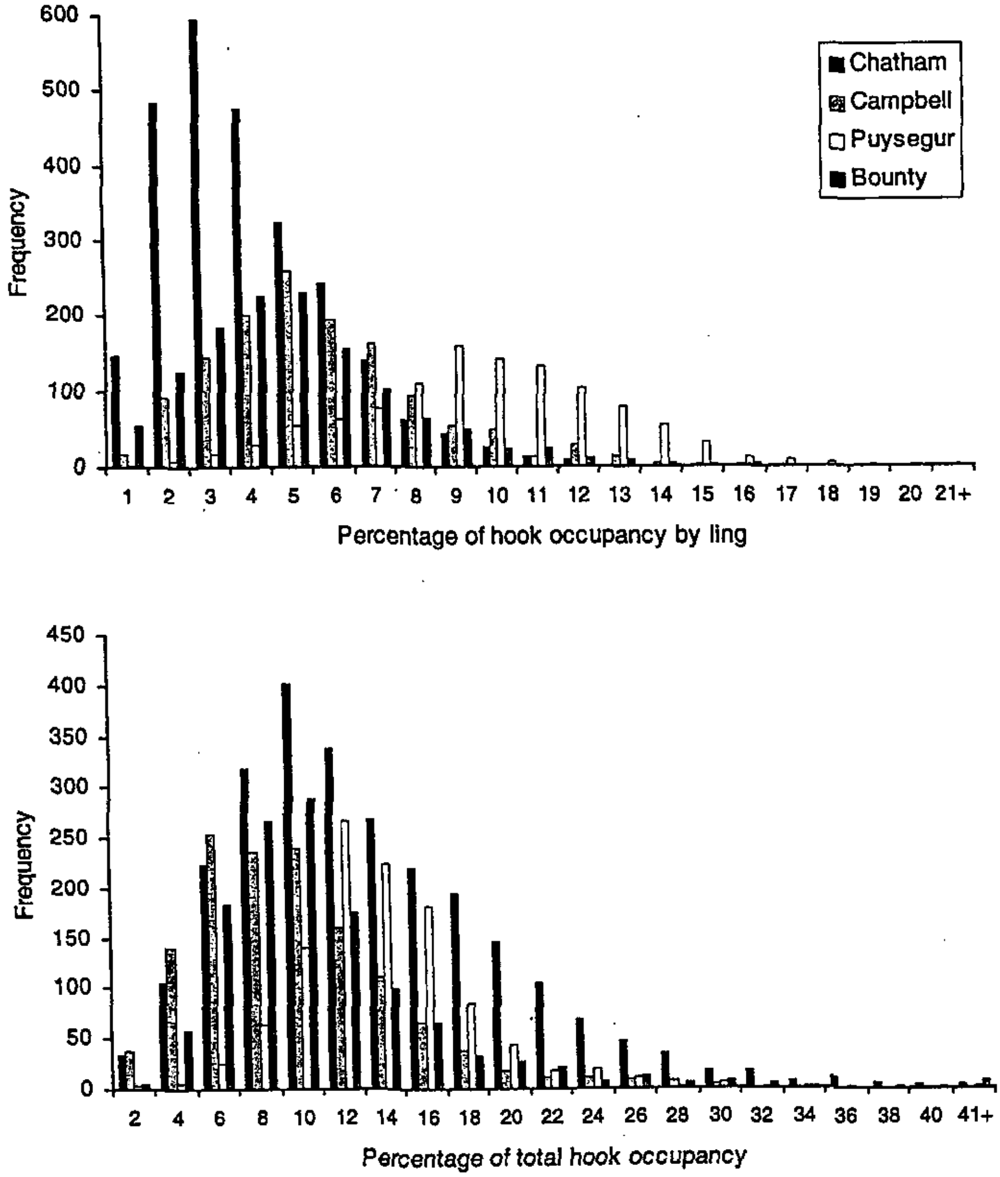


**Figure 10: Frequency distributions of hook occupancy (by ling, and all species combined) by set, by area. 'Campbell' excludes Puysegur Bank and Solander Corridor, 'Puysegur' comprises Puysegur Bank and Solander Corridor. The $x$-axis labels indicate the highest value of that bin, e.g., the bin labelled '18' on the lower graph includes percentages $p$ where $16 < p \leq 18$.**

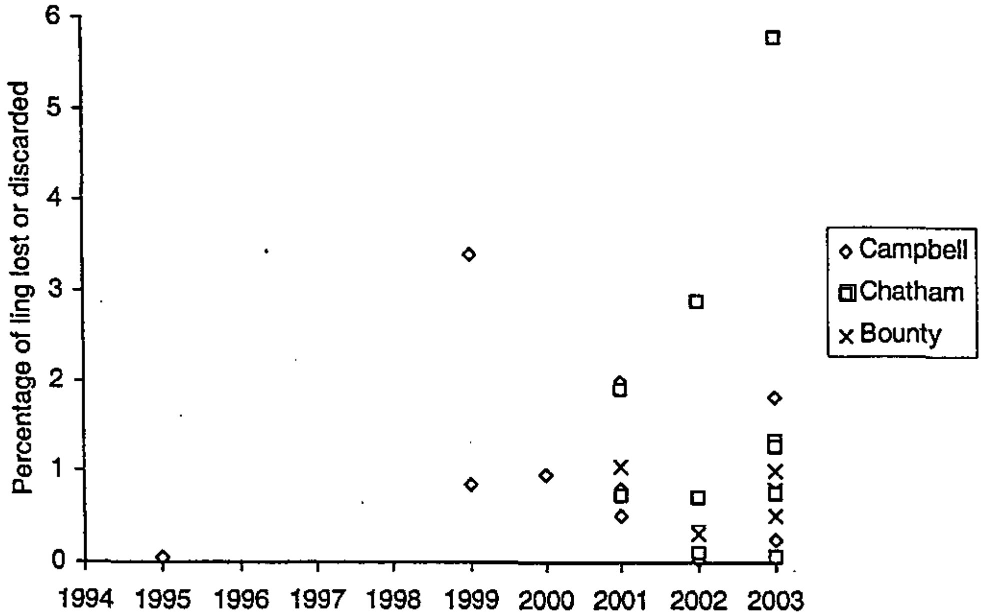


**Figure 11: Ling lost or discarded, as a percentage of the total number of ling retained, by trip, plotted against the year of the trip and distinguished by area.**

## Appendix 1: Mean weights (kg) of species or species groups, by area, recorded in the catch on observed ling auto-longline vessels

| Species group | Chatham | Campbell | Bounty |
|---|---|---|---|
| **Algae** | | | |
| seaweed | | 1.0 | 0.2 |
| **Invertebrates** | | | |
| sponge | 0.8 | 0.7 | 0.3 |
| coral | | 0.7 | 0.2 |
| anemone | 0.7 | 0.4 | 0.2 |
| salp | 0.2 | 0.3 | 0.1 |
| queen scallop | | | 0.2 |
| mollusc (unspecified) | | 0.3 | |
| gastropods | | 0.3 | 0.2 |
| squid | 1.0 | 2.0 | |
| octopus | 3.7 | 2.0 | 2.6 |
| crab | 0.6 | 0.7 | 1.4 |
| starfish | 0.2 | 0.4 | 0.3 |
| sea cucumber | | 0.7 | |
| echinoderms | 0.8 | 0.1 | 0.4 |
| **Agnatha** (jawless fishes) | | | |
| hagfish | 1.3 | 1.2 | |
| **Chondrichthyes** (cartilaginous fishes) | | | |
| sharks & dogfish (unspecified) | 2.5 | 3.8 | 1.8 |
| six-gill shark | 7.8 | 15.0 | |
| seven-gill shark | 9.2 | | 75.0 |
| leafscale gulper shark | | 4.3 | |
| longnose velvet dogfish | | 4.6 | |
| Owston's dogfish | | 10.0 | |
| Plunket's shark | 7.6 | 4.2 | |
| shovelnose dogfish | 3.6 | 5.0 | |
| Baxter's dogfish | 1.2 | 1.5 | 1.3 |
| lucifer dogfish | 0.3 | 0.4 | 0.9 |
| seal shark | 10.5 | 5.2 | 3.0 |
| spiny dogfish | 2.0 | 1.7 | 1.7 |
| northern spiny dogfish | 2.3 | | |
| prickly dogfish | 3.5 | | 2.5 |
| mako shark | 42.5 | 60.0 | 60.0 |
| porbeagle shark | 28.7 | 80.4 | 102.2 |
| thresher shark | 10.5 | | |
| carpet shark | 3.6 | 0.5 | |
| catsharks | 1.2 | 0.3 | |
| rig | 2.0 | 1.9 | |
| slender smoothhound | 0.3 | 0.2 | |
| school shark | 12.3 | 9.0 | 8.5 |
| blue shark | 21.6 | 44.3 | |
| skate (unspecified) | 7.6 | 5.5 | 3.2 |
| deepwater skates | 13.0 | 3.3 | 2.8 |
| smooth skate | 9.9 | 5.4 | 4.5 |
| rough skate | 5.8 | 6.1 | 3.4 |
| giant chimaeras | 8.8 | 9.7 | 10.6 |
| dark ghostshark | 1.7 | 1.8 | 2.1 |
| pale ghostshark | 2.3 | 2.1 | 2.1 |
| longnose chimaera | 2.3 | 1.8 | 2.6 |

## Appendix 1 (continued)

| Species group | Chatham | Campbell | Bounty |
|---|---|---|---|
| **Osteichthyes** (bony fishes) | | | |
| conger eels | 2.0 | 1.6 | 1.7 |
| ribaldo | 2.1 | 2.3 | 1.5 |
| red cod | 1.7 | 1.6 | 1.9 |
| southern bastard cod | 1.5 | 1.7 | |
| hoki | 2.1 | 2.1 | |
| hake | 6.1 | 5.8 | |
| rattail | 1.0 | 0.8 | 0.7 |
| javelinfish | 0.7 | 0.7 | |
| ling | 5.8 | 3.8 | 6.3 |
| alfonsino | 1.6 | | |
| sea perch | 1.2 | 1.2 | 1.7 |
| deepsea flathead | 0.9 | 0.8 | 1.0 |
| toadfish | 2.4 | 1.5 | 2.0 |
| hapuku & bass | 10.2 | 12.7 | 3.7 |
| Ray's bream | 1.8 | 1.6 | 1.0 |
| tarakihi | 1.7 | | |
| trumpeter | 8.3 | | |
| giant stargazer | 4.0 | 4.4 | 3.4 |
| blue cod | 1.4 | 1.3 | 2.2 |
| notothenid cod | | 2.1 | 2.7 |
| parracouta | | 1.8 | |
| gemfish | 2.0 | 6.3 | |
| bluenose | 5.6 | 8.3 | 6.0 |
| white warehou | 3.2 | | 4.0 |
| silver warehou | | 3.0 | |
| flounders | | 1.3 | 0.9 |