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# Fishery characterisation and setnet catch-per-unit-effort indices for rig in SPO1 and SPO 8, 1989–90 to 2009–10

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## EXECUTIVE SUMMARY

**Kendrick, T.H.; Bentley, N. (2012). Fishery characterisation and setnet catch-per-unit-effort indices for rig in SPO 1 and SPO 8, 1989–90 to 2009–10.**

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This study was contracted as MFish project SPO2010-01 with the specific objectives: To characterise the fisheries and update the standardised CPUE indices for SPO 1 and SPO 8 using data up to the end of the 2009–10 fishing year.

This study updates the characterisation of the fishery and confirms that most of the catch of SPO 1 and SPO 8 continues to be taken by targeted setnet and reported on the daily Catch Effort Landing Return (CELR). A developing trend of increasing storage of catch ashore has serious implications for CPUE indices of abundance.

Rig in SPO 1 and SPO 8 is monitored using standardised CPUE for a core fleet of inshore vessels that target rig using the setnet method. Most catch is taken in harbours and although it is thought unlikely that rig comprise separate substocks, the harbour fisheries operate with some independence and are considered to be vulnerable to local depletion, so abundance is monitored at that scale. Six set net fisheries have historically been monitored, but most rig are landed from Manukau and Kaipara Harbours, and the Firth of Thames, while the other three are coastal fisheries that combine sparse data across disparate harbours and statistical areas. These series were last updated to 2006–07 (Manning 2008). This study updates the previously defined series with an additional four years of data.

An exploration of CPUE indices from bottom trawl was also done for each of SPO 1E, SPO 1W, and SPO 8. Rig is not well-reported in bottom trawl as it is a bycatch of a wide range of target species and often not among the top eight species in the catch. Trawl is also not considered likely to monitor the whole population as larger fish are able to avoid the net; nevertheless, trawl indices are used in other rig stocks to index pre-adult abundance and are produced here to provide corroboration or insights into trends in setnet CPUE. For the east coast substock of SPO 1, trawl fishing is more spatially representative than set net, taking rig from most statistical areas with the exception of Area 007 (Firth of Thames). In contrast, the set net fishery operates almost entirely in Area 007. For the west coast substock of SPO 1, most set netting is done in the Kaipara and Manukau Harbours, and they are closed to trawl. The trawl series in this substock therefore also covers quite different spatial aspects of the population to the series based on set net.

There are quite serious data issues for rig that have implications for the choice of methodology used to standardise CPUE, particularly the measure of catch to use. Estimated catch is not generally used for elasmobranchs because they are processed (usually trunked) as soon as possible to avoid spoiling, and fishers have often wrongly recorded the processed weight rather than the whole (green) weight in the catch/effort part of the form. In trawl fisheries, rig is a bycatch, and often not among the top eight species in the catch so that it may not be estimated at all. There is a third problem with estimated catches that was particular to the Northland set net fisheries for a period during the 1990s, and resulted in false zeros (of estimated catch of rig) in up to 10% of records. The estimated catch of the target species was often reported in the total catch field, but not repeated in the species field due to a misunderstanding of the form. This was first described for grey mullet set net fisheries but many of the same vessels fish for flatfish and rig using set net, and the problem is common, although it is also relatively straightforward to correct.

To bypass the problems inherent with estimated catch, it has become standard practice in the analysis of most New Zealand inshore fisheries to use the verified landed greenweight, available at the end of the fishing trip, by allocating it to effort strata (Starr 2007).

Landed weight is problematic for rig because the conversion factors used to back calculate greenweight from the processed state have been refined over time and care must be taken to re-convert all landings using the most recent (and presumably most accurate) conversion factors. Care must also be taken not to double count fish when it is landed in more than one processed state such as when fins are removed. In this study we describe a new evolving problem that seriously compromises the utility of the Starr (2007) methodology, and we describe a potential solution that also has application to other fisheries, notably the rock lobster fisheries, where this problem is known as the "holding pot problem".

There are an increasing proportion of landings coded to destination "Q" in the Northland set net fisheries. This practise of holding catch ashore for subsequent landing to a LFRR effectively breaks the linkage between effort and landings, and the increasing use of this code contaminates both catch rate and success rate signals. The Starr methodology recognises the problem and drops landings that are retained (either on board or ashore) to avoid double counting them when they are eventually sold, and generally the proportion of catch involved is so small that this treatment is considered adequate because the landings are correct at annual resolution.

At the level of detail required for CPUE analysis, however, landings are not correctly linked to the effort and in some Northland set net fisheries, about a third of landings are now coded to "Q". The most defensible approach is to drop all trips for those vessels reporting "Q" destination landings, but the consequent loss of data in this case, especially in the most recent years, is too great (almost 50% of rig in 2009–10).

The increasing trend in the proportion of catch landed to destination "Q" also manifests as false zeros (when there is no "L" coded landed catch to allocate), and elevated CPUE in trips that subsequently land those previously caught fish. A declining success rate, that is in contrast to a flat or increasing catch rate in positive trips could be misinterpreted as hyper stability, and must be comprehensively explored at data preparation stage.

Options for correcting for this were explored in preliminary work for this study and included; 1) rolling up data to a coarser resolution, for example, a vessel/month (after dropping "Q" landings), in an attempt to match relevant landed and estimated catches, 2) allocating "Q" landings to effort and subtracting them from subsequent landings, and 3) using the estimated catches. However, a high proportion of zero catches remained to indicate that a monthly roll-up was not adequate to smooth out the discrepancies, the reporting behaviour with respect to "Q" landings varied too greatly among vessels for a correction algorithm to be effective, and the Working Group considered that the problems inherent in estimated catch for this species are too great for that measure of catch to be used unmodified.

Our proposed adjustment to estimated catches is based on having reliable annual landed catch totals for each vessel (because all catch must be landed at the end of a fishing year), and comparing that to the total estimated catch of rig. The annual ratios of estimated catch to landed catch were bimodal with modes at 1.0 (for those vessels on which greenweight was correctly estimated) and at 1.5 (for those vessels on which estimated catch consistently represented the processed weight).

We selected vessel-years in which the ratio was between 0.75 and 2.0 and pro-rated the estimated catches by that ratio. We refer to these values as "adjusted catches", and the standardised CPUE analyses for set net documented in this report are based on them.

The Working Group was uncertain about adjusting estimated catches on the basis of the annual ratio of landed/estimated catch, and did not accept the set net series for SPO 1. This was largely because the groomed landings in our analysis datasets are markedly in excess of QMR totals during the 1990s, and compromise the reliability of the ratio. This problem will need further exploration and consideration before the adjusted catches can be considered useful for monitoring abundance of rig in the set net fisheries of SPO 1. There may be a wider acceptance of the “adjusted catches” if the range of ratio was narrowed so that records included in the analyses were those in which either the greenweight (ratio centred tightly on 1.0) or the processed weight (ratio centred tightly on 1.5) had been consistently and accurately reported. This would be more of a selection than a correction procedure and would need to be accompanied by a characterisation of reporting practice that demonstrates that these “good estimators” are reasonably representative of the fishery. Destination “Q” landings did not affect data for the set net series in SPO 8, and that series, which fluctuated without trend, with recent indices near the long-term average, was accepted.

The trawl analyses were done using allocated landed catch. The Working Group accepted that the trawl series in SPO 1 E and SPO 1 W are probably monitoring some part of the rig population, but felt that the trawl series for SPO 8 was based on too few data to be reliable.

The bottom trawl series all show a decline to low points in the mid 2000s, but agree on recent recoveries.

# 1 INTRODUCTION

## 1.1 The fishery

Following the introduction of rig to the QMS in 1986, landings of both SPO 1 and SPO 8 were constrained by their TACCs until they were increased by 20% for the 1991–92 fishing year under the Adaptive Management Programme (AMP). Catches of rig have declined steadily in SPO 1 since 1991-92 and for five consecutive years after 1995–96 in SPO 8, and they were removed from the AMP in July 1997. The TACCs for SPO1 and SPO 8 reverted to the pre-AMP levels in the 1997–98 fishing year, but catches have remained well below TACCs since then (Figure 1).

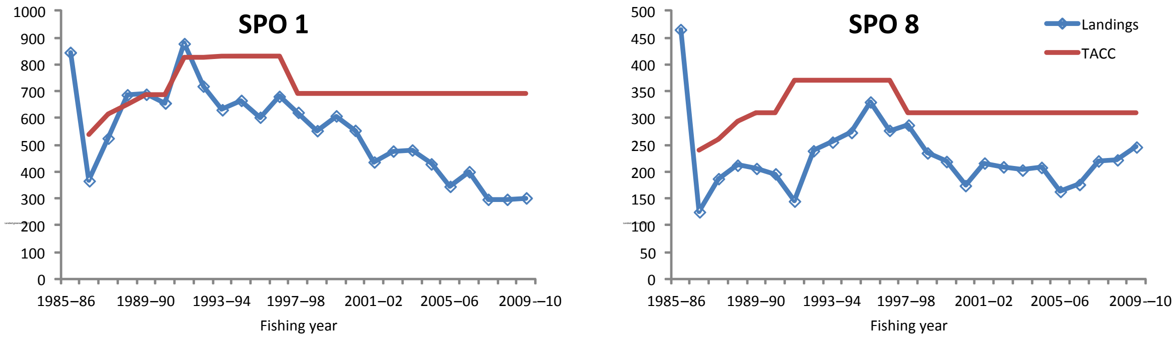



**Figure 1: Landings (t) and TACC for SPO 1 and SPO 8.**

## 1.2 Previous work

Rig has previously (Blackwell et al. 2006, Manning 2008) been monitored in discrete set net fisheries in sub-stock areas SPO 1E Thames, SPO 1E coast, Kaipara, Manukau, SPO1W coast, and SPO 8. The analyses were done on positive catches from targeted fishing and were last updated to the 2006–07 fishing year. CPUE indices in each sub-area had showed no trend in most areas except for the Manukau Harbour series, which declined steadily until the early 2000's and then showed some recovery, and the SPO 1E Thames series which was increasing steeply at the time of the last assessment (Figure 2). There is no report available from the previous project and it is appropriate that all decisions made at that time about fisheries in which rig might best be monitored are re-examined and documented.

## 1.3 This study

There are long time series of data for set net in SPO 1 and SPO 8, but they are based on fishing that targets aggregations of rig in spring and summer, and may be insensitive to any changes in underlying abundance, especially if only positive catches are modelled, as has been the case. A regime shift as the result of closures to all recreational and commercial set net fishing in WCNI inshore areas will also have affected these time series. We have widened the fishery definitions to include bycatch of rig when other shark species are targeted by set net; in particular, spiny dogfish and school shark. This definition of effective effort allows a separate standardisation of encounter rate to be attempted, and although this approach is not usually informative for CELR format data (because zero catches are subsumed into the daily totals) it should nevertheless be examined for any gross signals that might indicate that the lognormal indices of catch rate are hyperstable.

Time series of bycatch from bottom trawl may have utility for monitoring juveniles in the dispersed population (adult rig are thought able to avoid trawls). There are precedents for monitoring rig from bycatch of bottom trawl fisheries in other rig Fishstocks; SPO 3 (Starr et al. 2008), and SPO 2 (Bentley

& Kendrick 2011), and the problems and potentials for the monitoring of this species in bycatch trawl have been exhaustively examined. Trawl surveys are considered to adequately monitor part of the rig population in SPO 7 (Starr et al. 2010). The main problem with monitoring bycatch of rig in bottom trawl is that it is not a well-reported species for this fishing method and is rarely estimated among the top catch species. This potentially compromises the procedure that allocates landed catch to effort strata which is normally done on the basis of estimated catch. The alternative approach of allocating landed catch on the basis of effort is problematic and can result in distributions that reflect the distribution of effort rather than catch.

The set net series established in the previous study (Manning 2008) are updated here with a further four years of data. The two main fisheries on the west coast are based in the Kaipara and Manukau harbours (Statistical Areas 043 and 044). The main fishery on the east coast is based in Statistical Area 007 (Firth of Thames). Other areas in SPO 1 are combined and described as SPO 1W (coast) and SPO 1E (coast). All statistical areas in SPO 8 (where there are no major harbour fisheries) are combined into one coastal fishery. Additionally, three new series are presented that are based on bottom trawl; east and west of Northland and further south in QMA 9 (SPO 8).

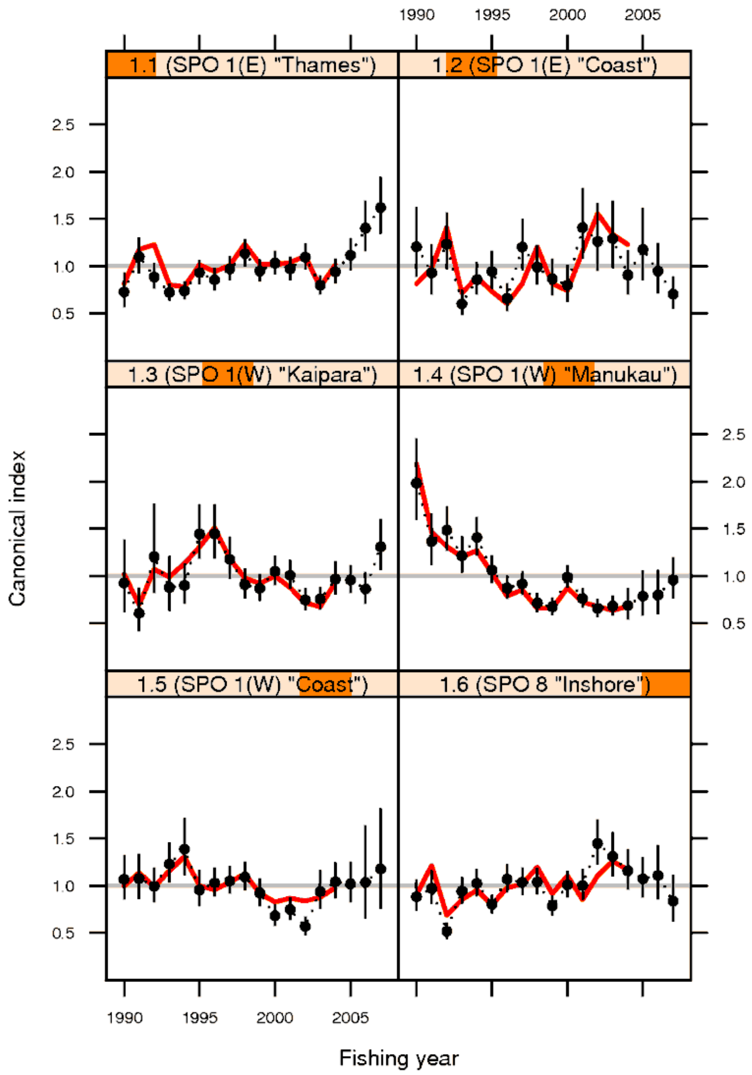



**Figure 2: Unpublished CPUE indices to 2006–07 for six defined setnet fisheries in SPO 1 and SPO 8 (Manning 2008). Error bars represent 95% confidence intervals and the solid line represents the previous indices from Blackwell et al. (2006).**

## 2 DATA SOURCES AND METHODS

Catch and effort data extracted from the research database '*warehou*' were defined by trips that landed to Fishstock SPO 1 or SPO 8 OR that used the setnet (SN), bottom trawl (BT), or bottom pair trawl (BPT) methods in any statistical area valid for SPO 1 and SPO 8 (FMAs 1 and 9) with the exception of tows targeted at the deepwater species (ORH, OEO, SOE, SOR, SSO, BOE, WOE, CDL, BYX, HOK, SBW, SCI, SQU, HAK). All data for the trips thus defined were obtained with no restriction on fishing method, statistical area, or target species. All landings data for rig associated with the defined trips (from the bottom part of the CELR or from CLRs) were also obtained.

The fishery characterisation and the CPUE analyses for the bottom trawl method in this study were done on *allocated landings*; the landed greenweight of SPO 1and SPO 8 as reported at the end of the fishing trip, either on the bottom part of the general Catch Effort Landing Returns (CELR) or, where fishing was reported on the more detailed Trawl Catch Effort (TCEPR/TCE) or Net Catch Effort (NCE) returns; on the associated Catch Landing Return (CLR). The CELR form summarises the estimated catch and effort for a day or part day of fishing. It may therefore generalise the species targeted for the day. The TCEPR/TCE/NCE forms report catch and effort for each individual tow or set and may detail the target species more accurately, with potential consequences for the amalgamation of data to effort strata.

Landed greenweight of rig was linked to effort strata (unique combinations of trip, method, target species and statistical area) in proportion to estimated catch using the method of Starr (2007). This requires that landings, estimated catch, and effort data are all groomed and error checked separately before the allocation is done and those steps are described below.

### 2.1 Landed greenweight versus estimated catch

The weight for only the top five species (top eight species on the more recently introduced formtypes) in the catch is required to be estimated and reported for each unit of effort on Catch Effort Returns. The total estimated catch for a trip is often therefore an underestimate, and zero catches within an effort stratum within a trip are as likely to mean the species was caught, but was not among the top five species, as that it wasn't caught at all. The shortfall was first acknowledged as a serious problem for monitoring bycatch species, but with the trend towards monitoring many species in mixed target fisheries, it is becoming acknowledged as a more general problem

The degree to which the estimated catch is representative of the actual landed catch depends on the consistency of the reporting rate (the proportion of the landed catch that was estimated among the top five species caught), and bias can result if the shortfall comes from specific parts of the fleet or varies between target fisheries. Any variation from year to year in the reporting rate will compromise an annual index based on estimated catch, and the problem is more serious, and more obvious, when there is a trend in the reporting rate over time. Also, the estimated catch of well reported, or even targeted, species is still biased towards large catches, with smaller catches making the top five species less often. This is a potentially serious source of bias that could mask the magnitude of a decline in abundance.

For elasmobranchs, there is an additional problem because the fish spoil quickly and are partly processed at sea rather than being landed green. This often results in the fisher wrongly estimating the processed weight instead of the greenweight, with significant underestimation a consequence because the difference in weight between green and dressed rig is more than 33%.

Only the landings values, reported at the end of the fishing trip represent actual total catches. These values are trip-based (available only), and are not directly linkable to individual fishing events or even to a single day's fishing. The linkage can be simulated by apportioning the landed catch at the end of each trip to effort strata within the corresponding trip using procedures that were comprehensively described by Starr (2007).

The Starr (2007) methodology, which allocates landed catch to effort data is the preferred approach for collating catch effort data in New Zealand inshore fisheries because it uses verified greenweight reported by the permit holder against quota, and provides an elegant method for combining data across form types.

The main assumption made in this allocation procedure is that the reporting of estimated catch is consistent across statistical areas and target species within a trip. In contrast, if estimated catches were used directly, the assumption must be made that reporting rates are constant across the entire fleet and all statistical areas for all years.

Another advantage to using landed, rather than estimated catch, is that the catches from ambiguous statistical areas (statistical areas shared by more than one Fishstock) can often be assigned to a Fishstock and retained in the analysis dataset. Without the benefit of Fishstock information, all data from straddling areas must be excluded.

During the grooming process, however, it was discovered that landings of rig could not be linked to effort strata when landings were reported to destination code "Q", meaning they were held in receptacle ashore (eg. a freezer) for subsequent sale to a licensed fish receiver (destination code "L"), a practice that has become widespread in the set net fishery. An alternative measure of catch, referred to as "adjusted" catch, was used for the CPUE analyses based on the set net method. Allocated landings were used to characterise the fisheries and also for the standardised CPUE based on the trawl method.

## 2.2 Grooming and collation of MFish catch and effort data

Estimated catch, associated effort, and landings were all groomed separately. Outlier values in the landings data were identified by finding the trips with very high landings for rig based on verified maximum values supplied by the Ministry of Fisheries (now Ministry for Primary Industries) data unit. The effort data for these trips were then used to calculate the trip CPUE and the associated estimated catch was also examined. Trips which had a ratio of landed to estimated catch which exceeded 4 and a CPUE which exceeded two times the 95$^{th}$ percentile of the trip CPUE distribution for the entire dataset were excluded from the analysis.

Occasional outlier values (input errors) in the effort data were identified by comparison with empirical distributions derived from the effort variable (duration or number of sets) and, where the values were in the extreme upper and lower tails of the distribution (a multiple of the 95$^{th}$ percentile value), they were replaced with the median value for the effort field for the affected vessel. Missing effort data were treated similarly. Missing values for statistical area, method, or target species within any trip were substituted with the predominant (most frequent) value for that field over all records for the trip. Trips with all fields missing for one of these descriptors were dropped entirely.

### 2.2.1 Grooming estimated catch for false zero (estimated) catches

A well determined target fishery would normally include few genuine zero catch records, but the data for many northland setnet fisheries; including flatfish and grey mullet, include anomalous peaks of zero catches (about 10% of records) of the target species during the mid 1990s. These were identified as false zeros during an analysis of grey mullet catch effort data by McKenzie & Vaughan (2008). In these records, there were no estimated catches recorded in the columns for the top five species caught yet there was a positive value reported in the 'total catch' field. It appears that fishers were entering the weight of the target species in the total catch field, and felt that duplicating that value in the species catch columns was unnecessary. The same pattern is evident in set net targeted at rig, involving many of the same vessels on the east and west coasts of Northland (SPO 1) and to a lesser extent in SPO 8 (Figure 3).

The consequence is a loss of data when positive catches based on either estimated catch or on allocated landings are analysed, and an unexplained pattern in the success rate (Figure 3).

To correct for this misunderstanding of the form the estimated catch of rig was corrected to equal the total catch where the method was set net, the target species was SPO, and the estimated catch for rig was zero, but the total catch was not zero.

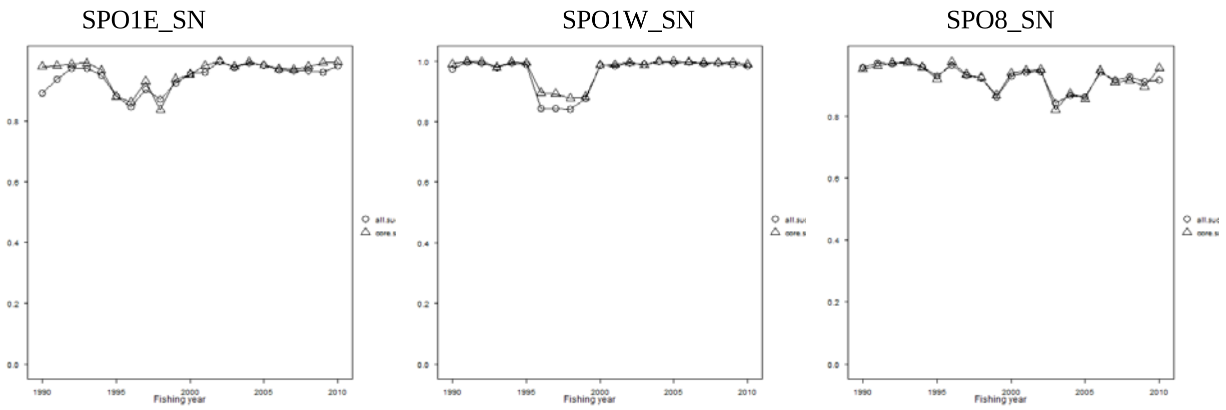



**Figure 3: The success rate (proportion of strata in which a positive catch of rig was estimated) from rig target set net fisheries in the three main substock areas indicating false zeros. Circles, all vessels in defined fishery; triangles, core vessels. SPO1E_SN, set net from east coast of SPO 1; SPO1W_SN, set net from the west coast of SPO 1; SPO8_SN, set net in SPO 8.**

### 2.2.2 Grooming landed catch for changes in conversion factors

Almost all rig in SPO 1 and 8 are landed partly processed, either dressed (DRE) or headed and gutted (HGU) although these two codes appear to describe the same cut as they have the same conversion factor. The conversion factors that were used to back-calculate greenweight from landed (processed) weights changed from 2 to 1.75 in 1992–93 and to 1.55 in 2000–01 (Table 1). Greenweights calculated using earlier conversion factors are not changed in the database, and are therefore overestimated prior to 2000–01 (assuming that the changes represent improved estimates and not changes in processing efficiency). To correct for changes in conversion factors, greenweights in the dataset were corrected using the most recent conversion factor for the processed state.

**Table 1: The median conversion factor in each fishing year for the main processed states, total landed greenweight (t) of SPO in the unedited file by processed state (this is the whole data extract including other rig Fishstocks). DRE, dressed; GRE, green; HGU, head and gutted; FIL, filleted: 0, less than 0.5 t.**

| | Conversion factor | | | | Landed SPO (t) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fishing year | DRE | GRE | HGU | FIL | DRE | GRE | HGU | FIL | Other |
| 89/90 | | 1 | 2 | 2.7 | | 99 | 133 | 0 | 48 |
| 90/91 | 2 | 1 | 2 | 2.7 | 349 | 448 | 209 | 0 | 48 |
| 91/92 | 2 | 1 | 2 | 2.7 | 345 | 191 | 317 | 0 | 52 |
| 92/93 | 1.75 | 1 | 1.75 | 2.3 | 427 | 206 | 267 | 0 | 23 |
| 93/94 | 1.75 | 1 | 1.75 | 2.1 | 478 | 255 | 210 | 0 | 16 |
| 94/95 | 1.75 | 1 | 1.75 | 2.1 | 492 | 212 | 267 | 0 | 9 |
| 95/96 | 1.75 | 1 | 1.75 | | 575 | 147 | 237 | | 6 |
| 96/97 | 1.75 | 1 | 1.75 | 2.1 | 560 | 104 | 267 | 0 | 16 |
| 97/98 | 1.75 | 1 | 1.75 | 2.1 | 556 | 97 | 270 | 0 | 13 |
| 98/99 | 1.75 | 1 | 1.75 | 2.1 | 491 | 78 | 169 | 0 | 19 |
| 99/00 | 1.75 | 1 | 1.75 | 2.1 | 555 | 96 | 112 | 1 | 25 |
| 00/01 | 1.55 | 1 | 1.55 | 2.1 | 530 | 65 | 90 | 2 | 29 |
| 01/02 | 1.55 | 1 | 1.55 | | 571 | 42 | 71 | | 5 |
| 02/03 | 1.55 | 1 | 1.55 | 2.1 | 589 | 46 | 98 | 0 | 3 |
| 03/04 | 1.55 | 1 | 1.55 | | 620 | 60 | 97 | | 4 |
| 04/05 | 1.55 | 1 | 1.55 | 2.1 | 611 | 54 | 81 | 0 | 20 |
| 05/06 | 1.55 | 1 | 1.55 | 2.1 | 498 | 38 | 52 | 0 | 3 |
| 06/07 | 1.55 | 1 | 1.55 | | 608 | 51 | 55 | | 2 |
| 07/08 | 1.55 | 1 | 1.55 | 2.1 | 552 | 46 | 42 | 0 | 7 |
| 08/09 | 1.55 | 1 | 1.55 | | 573 | 31 | 47 | | 2 |
| 09/10 | 1.55 | 1 | 1.55 | | 610 | 27 | 60 | | 15 |

### 2.2.3 Grooming landed catch for valid destination codes

Most rig is landed to destination code “L” meaning that it is landed to a licensed fish receiver, but there has been an increasing proportion of SPO landings recorded to destination code “Q” since 2003–04 (Table 2). The use of this code signals that fish are held in a receptacle ashore (for example a freezer) and ‘landed’ to a Licensed Fish Receiver (LFR) at a later date for example, with a truck coming to pickup fish occasionally. The landing is then recorded again using destination code “L”, and is not identified as having been caught on a previous trip. To prevent double counting of catches the standard grooming ignores Qs and uses Ls. Small amounts of catch landed to one of the “held-over” codes (Q, or R) can be excluded from the dataset before the merging procedure that allocates landed catch to effort with little consequence, and the annual landings should sum correctly. Allocated landings were used for the characterisation part of this study although should be interpreted with some caution.

Apart from the obvious potential for double counting, however, this practice means that the landed catch for vessels that report “Q” destination landings (on CELR forms) cannot be associated with any particular fishing trip with confidence, and the data are not reliable for inclusion in standardised CPUE analysis.

Examination of the distribution of this code showed the practice to be confined to the setnet method, but, within that method, to be widespread across operators and areas.

**Table 2: Number of landings and tonnes of landed SPO 1 and SPO 8 in the unedited landings file by destination code and fishing year. L, landed to an LFRR; Q, held in a receptacle onshore. R, retained onboard; W, wharf sale; Note this is all landings across all methods and including some landings to other SPO Fishstocks.**

| | Number of landings | | | | | Landed SPO (t) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fishing year | L | Q | R | W | Other | L | Q | R | W | Other |
| 89/90 | 5 984 | | 23 | 46 | 48 | 646 | | 9 | 1 | 3 |
| 90/91 | 7 144 | | 24 | 78 | 49 | 1192 | | 1 | 2 | 2 |
| 91/92 | 8 316 | | 23 | 44 | 34 | 1179 | | 2 | 1 | 4 |
| 92/93 | 9 905 | | 34 | 56 | 34 | 1132 | | 1 | 2 | 1 |
| 93/94 | 8 658 | | 27 | 82 | 35 | 1466 | | 2 | 1 | 3 |
| 94/95 | 8 521 | | 33 | 56 | 16 | 1567 | | 3 | 1 | 2 |
| 95/96 | 8 492 | | 9 | 68 | 27 | 1427 | | 0 | 0 | 4 |
| 96/97 | 8 978 | | 28 | 93 | 18 | 1816 | | 7 | 1 | 1 |
| 97/98 | 8 645 | | 101 | 33 | 18 | 1352 | | 4 | 1 | 4 |
| 98/99 | 8 538 | | 149 | 53 | 6 | 939 | | 1 | 1 | 3 |
| 99/00 | 8 975 | | 193 | 50 | 9 | 983 | | 4 | 1 | 0 |
| 00/01 | 8 455 | 9 | 286 | 70 | 40 | 745 | 0 | 14 | 1 | 4 |
| 01/02 | 7 430 | 281 | 172 | 63 | 15 | 698 | 6 | 1 | 1 | 2 |
| 02/03 | 7 141 | 871 | 233 | 43 | 31 | 710 | 40 | 0 | 1 | 3 |
| 03/04 | 6091 | 1306 | 229 | 62 | 25 | 703 | 83 | 0 | 1 | 0 |
| 04/05 | 6015 | 1482 | 229 | 93 | 37 | 670 | 97 | 1 | 1 | 2 |
| 05/06 | 5247 | 1335 | 173 | 51 | 64 | 520 | 70 | 1 | 1 | 1 |
| 06/07 | 5689 | 1781 | 142 | 87 | 29 | 590 | 121 | 2 | 1 | 1 |
| 07/08 | 5061 | 1400 | 25 | 66 | 41 | 553 | 91 | 0 | 2 | 0 |
| 08/09 | 5339 | 1579 | 43 | 59 | 60 | 541 | 110 | 1 | 1 | 0 |
| 09/10 | 5741 | 2016 | 61 | 61 | 53 | 579 | 131 | 2 | 1 | 0 |

### 2.2.4 Linking and allocating landed catch to effort

The allocation of landed catch to effort is done by first summarising effort and estimated catch data for a fishing trip, for every unique combination of fishing method, statistical area, and target species (referred to as an "effort-stratum"). This reduces both CELR and TCEPR format records to lower resolution "amalgamated" data, giving fewer records per trip, but retains the original method, area, and target species recorded by the skipper. The landed greenweight, declared at the end of the trip, is then allocated to the effort strata in proportion to the estimated catch. Where there are no estimated catches during the trip, the allocation is in proportion to the amount of effort.

Trips that fished in straddling statistical areas (016, 036, 037, 039, 040 or 041) and landed to fishstocks of rig other than SPO 1 or SPO 8, or that used multiple fishing methods with incompatible measures of effort, were entirely dropped. All catches of rig from Area 041, which is shared by SPO 1 and SPO 8, were retained without regard to Fishstock.

The data available for each trip included estimated and landed catch of rig, total hours fished, total number of tows/sets/hooks (depending on fishing method), fishing year, statistical area, target species, month of landing, and a unique vessel identifier. Data retained in the analysis dataset might not represent an entire fishing trip, but just those portions of it that qualified, but the amount of landed catch assigned to the part of the trip that was kept would be proportional to the total landed catch for the trip. Trips were not dropped because they targeted more than one species or fished in more than one statistical area.

For the entire dataset, since 1989–90, there was a total of 11 821 t of estimated catches and 16 861 t of landings (excluding those data dropped by error checks) for SPO. A total of 15 934 t (94.5%) of these landings were able to be allocated to fishing events. Overall 64.4% of allocations were made on the basis of estimated catches, 30.5% on the basis of effort and 5.1% were made equally to all fishing events on the trip.

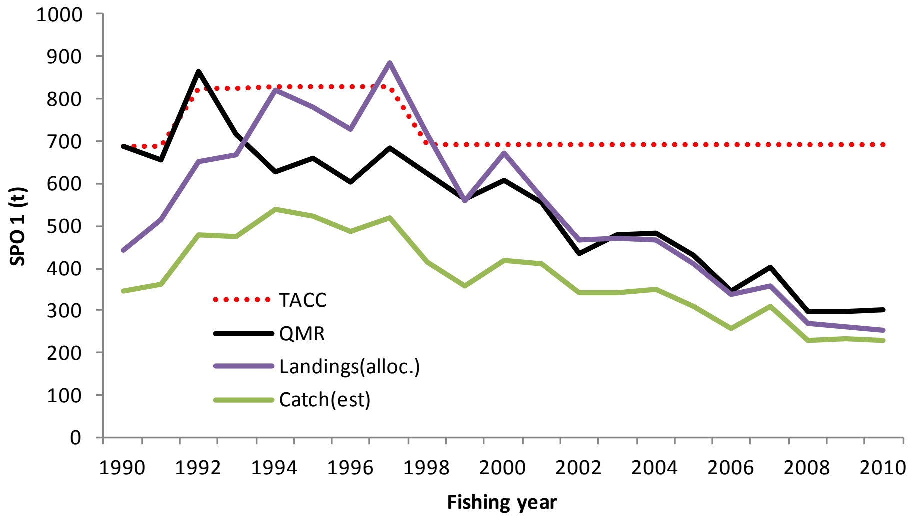



**Figure 4: Landings of SPO 1 and TACC (tonnes) from 1989–90 to 2009–10 from Ministry of Fisheries (2010), compared to the groomed landed catch from the "warehou" extract, and annual estimated catches. Year is fishing year (e.g. 99 = 1 Oct 1998 to 30 Sep 1999).**

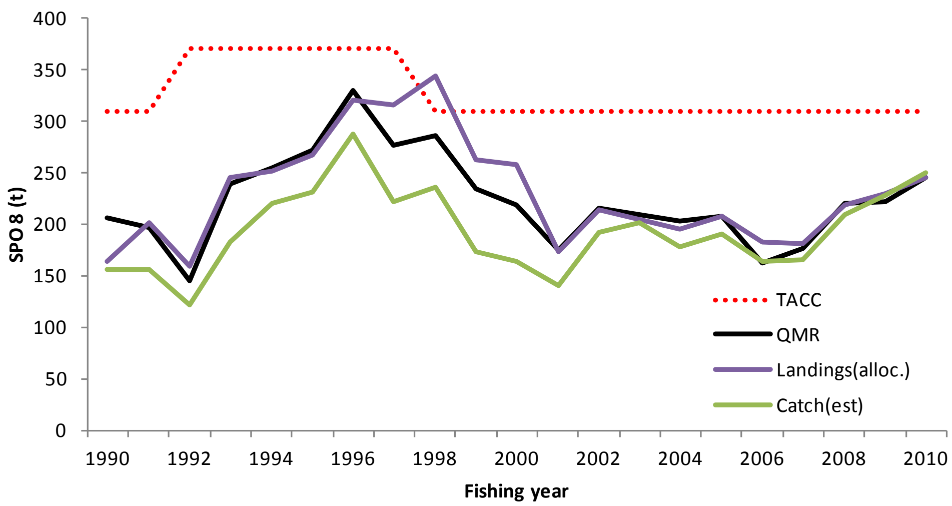



**Figure 5: Landings of SPO 8 and TACC (tonnes) from 1989–90 to 2009–10 from Ministry of Fisheries (2010), compared to the groomed landed catch from the "warehou" extract, and annual estimated catches. Year is fishing year (e.g. 99 = 1 Oct 1998 to 30 Sep 1999).**

The total landed greenweight available from the bottom of the form and obtained in the "*warehou*" extract usually differs from the total landings reported to the QMS due to different error checking routines used, but in this study the correspondence was particularly poor. Even after grooming, the allocated landings for SPO 1 show a shortfall of up to 30% in the early 1990s and are up to 30%

greater than the QMS annual totals during the mid to late 1990s (Figure 4, Table 3). The allocated landings of SPO 8 are also inflated by up to 20% during the late 1990s (Figure 5, Table 4). This may be due to the misuse of the destination code “L” leading to double counting of “held over” landings, but that could not be established, nor could it be corrected.

Allocated landings were re-scaled in the dataset to equal the verified totals from Monthly Harvest Returns (MHR) or, before October 2001, from Quota Management Returns (QMR).

**Table 3: Comparison of catch totals for SPO 1. TACC and landed greenweight (t) reported to the Quota Management System (QMS), landed greenweight from the bottom of the form as extracted from “warehou” database groomed to exclude some destination coded landings, landed greenweight after more extensive grooming (analysis dataset), estimated catch in the analysis dataset, percent of QMS landings retained, estimated catch as a percent of QMS landings, and as a percentage of the landed catch in the analysis dataset by fishing year. Estimated catch of SPO has been corrected for false zero catches.**

| Fishing year | TACC | QMS/ HMR Landings | "Warehou" extract Landings | Landed catch for analysis | Estimated catch in dataset | % analysis catch of QMR | % estimated catch of QMR | % estimated catch of analysis |
|---|---|---|---|---|---|---|---|---|
| 89/90 | 687 | 689.1 | 470.0 | 444.3 | 344.2 | 64.5 | 49.9 | 77.5 |
| 90/91 | 688 | 655.6 | 984.0 | 514.8 | 360.2 | 78.5 | 54.9 | 70.0 |
| 91/92 | 825 | 865.1 | 869.0 | 650.4 | 478.5 | 75.2 | 55.3 | 73.6 |
| 92/93 | 825 | 714.6 | 877.0 | 666.7 | 474.8 | 93.3 | 66.4 | 71.2 |
| 93/94 | 829 | 626.9 | 1 190.0 | 818.4 | 537 | 130.5 | 85.7 | 65.6 |
| 94/95 | 829 | 660.8 | 1 292.0 | 779.0 | 523.4 | 117.9 | 79.2 | 67.2 |
| 95/96 | 829 | 602.1 | 1 087.0 | 729.5 | 485.1 | 121.2 | 80.6 | 66.5 |
| 96/97 | 829 | 683.8 | 1 440.0 | 884.3 | 518.8 | 129.3 | 75.9 | 58.7 |
| 97/98 | 692 | 621.4 | 973.0 | 717.6 | 415.1 | 115.5 | 66.8 | 57.8 |
| 98/99 | 692 | 563.7 | 647.0 | 559.3 | 357.8 | 99.2 | 63.5 | 64.0 |
| 99/00 | 692 | 608.3 | 718.0 | 671.5 | 416.5 | 110.4 | 68.5 | 62.0 |
| 00/01 | 692 | 553.9 | 583.0 | 568.8 | 408.8 | 102.7 | 73.8 | 71.9 |
| 01/02 | 692 | 436.2 | 472.0 | 464.9 | 342.4 | 106.6 | 78.5 | 73.7 |
| 02/03 | 692 | 476.6 | 516.0 | 471.8 | 341.9 | 99.0 | 71.7 | 72.5 |
| 03/04 | 692 | 481.4 | 554.0 | 464.9 | 348.2 | 96.6 | 72.3 | 74.9 |
| 04/05 | 692 | 431.2 | 528.0 | 411.4 | 309.2 | 95.4 | 71.7 | 75.2 |
| 05/06 | 692 | 345.8 | 418.0 | 337.5 | 258.1 | 97.6 | 74.6 | 76.5 |
| 06/07 | 692 | 400.3 | 525.0 | 356.6 | 311.4 | 89.1 | 77.8 | 87.3 |
| 07/08 | 692 | 297.2 | 397.0 | 270.3 | 230.3 | 90.9 | 77.5 | 85.2 |
| 08/09 | 692 | 297.6 | 404.0 | 261.4 | 232.3 | 87.8 | 78.1 | 88.9 |
| 09/10 | 692 | 302.1 | 437.0 | 254.5 | 228.6 | 84.2 | 75.7 | 89.8 |

**Table 4: Comparison of catch totals for SPO 8. TACC and landed greenweight (t) reported to the Quota Management System (QMS), landed greenweight from the bottom of the form as extracted from "warehou" database, landed greenweight after grooming (analysis dataset), estimated catch in the analysis dataset, percent of QMS landings retained, estimated catch as a percent of QMS landings, and as a percentage of the landed catch in the analysis dataset by fishing year. Estimated catch of SPO has been corrected for false zero catches.**

| Fishing year | TACC | QMS/ HMR Landings | "Warehou" extract Landings | Landed catch for analysis | Estimated catch in dataset | % analysis catch of QMR | % estimated catch of QMR | % estimated catch of analysis |
|---|---|---|---|---|---|---|---|---|
| 89/90 | 310 | 206.2 | 170.3 | 164.3 | 156.4 | 79.7 | 75.8 | 95.2 |
| 90/91 | 310 | 196.4 | 205.5 | 201.3 | 156 | 102.5 | 79.4 | 77.5 |
| 91/92 | 370 | 145.4 | 170.6 | 160.0 | 122 | 110.0 | 83.9 | 76.3 |
| 92/93 | 370 | 238.7 | 246.2 | 245.6 | 182.7 | 102.9 | 76.5 | 74.4 |
| 93/94 | 370 | 255 | 254.2 | 252.2 | 220.9 | 98.9 | 86.6 | 87.6 |
| 94/95 | 370 | 272.6 | 277.8 | 266.8 | 231.6 | 97.9 | 85.0 | 86.8 |
| 95/96 | 370 | 329.8 | 325.3 | 321.0 | 287.1 | 97.3 | 87.1 | 89.4 |
| 96/97 | 370 | 277.4 | 375.9 | 316.3 | 222.4 | 114.0 | 80.2 | 70.3 |
| 97/98 | 310 | 286.9 | 373.3 | 344.7 | 236.8 | 120.1 | 82.5 | 68.7 |
| 98/99 | 310 | 234.4 | 288.8 | 263.3 | 173.5 | 112.3 | 74.0 | 65.9 |
| 99/00 | 310 | 219.1 | 259.1 | 257.2 | 164.2 | 117.4 | 74.9 | 63.8 |
| 00/01 | 310 | 174.3 | 168.4 | 173.1 | 140.2 | 99.3 | 80.4 | 81.0 |
| 01/02 | 310 | 215.7 | 217.5 | 214.0 | 192.3 | 99.2 | 89.2 | 89.9 |
| 02/03 | 310 | 208.6 | 221.5 | 204.3 | 202 | 97.9 | 96.8 | 98.9 |
| 03/04 | 310 | 203 | 219.3 | 195.7 | 178.6 | 96.4 | 88.0 | 91.3 |
| 04/05 | 310 | 208.3 | 221.5 | 207.8 | 190.9 | 99.8 | 91.6 | 91.9 |
| 05/06 | 310 | 162.6 | 167.4 | 182.4 | 163.2 | 112.2 | 100.4 | 89.5 |
| 06/07 | 310 | 175.9 | 180.4 | 180.4 | 165.6 | 102.6 | 94.1 | 91.8 |
| 07/08 | 310 | 219.9 | 225.1 | 218.8 | 208.7 | 99.5 | 94.9 | 95.4 |
| 08/09 | 310 | 221.8 | 223.8 | 229.6 | 228.1 | 103.5 | 102.8 | 99.3 |
| 09/10 | 310 | 245.5 | 250.6 | 245.2 | 250.2 | 99.9 | 101.9 | 102.0 |

### 2.2.5 Alternative approach needed for monitoring rig in set net

Initial exploratory work for this study used allocated landings, as detailed in Starr (2007), to update the standardised CPUE series for SPO 1 and SPO 8. Normally, small amounts of catch landed to one of the "held-over" codes (Q, R) can be excluded from the dataset before the merging procedure that allocates landed catch to effort, with little consequence. The magnitude of held-over catch in this fishery, however, manifested as an increasingly large proportion of zero catches (Figure 6) (from trips with no "L" landed catch to allocate). Genuine zero catches usually occur only rarely in target fisheries and the trend in the probability of capture drew attention to the inappropriateness of the standard methodology.

The standard approach avoids double counting landed catch, but ignores the greater problem that, for vessels that employ this practice, no landed catch can be associated with any particular fishing trip with confidence. The most defensible approach is to drop all trips for those vessels reporting "Q" destination landings, but the consequent loss of data in this case (almost 50% of rig in 2009–10) as well as the potential for introducing bias was considered unacceptable.

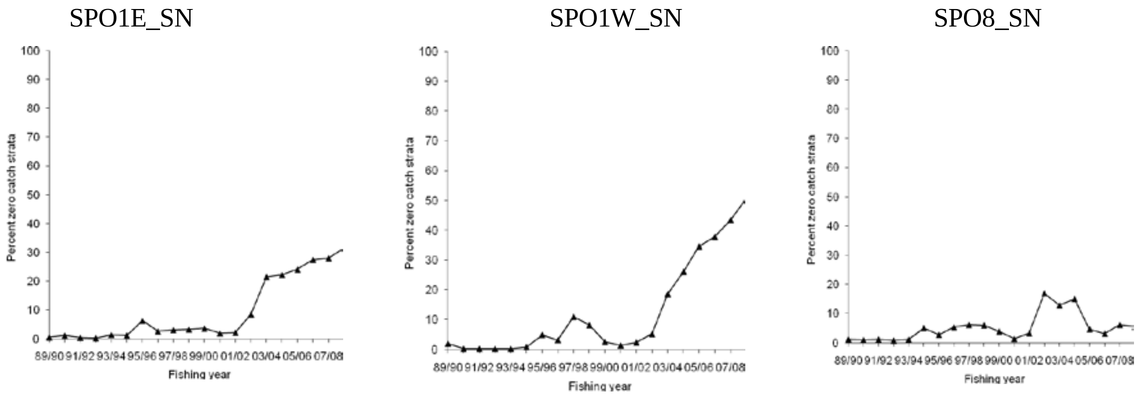



**Figure 6: Trends in zero catches that are a manifestation of allocating groomed (excluding destination Q) landed catch to effort strata in target setnet fisheries for the three main substock areas.**

Other potential solutions were explored including rolling-up records over a month to blend out the mismatch between effort and landings, but did not remove the problem, possibly indicating that fish are commonly held over for longer periods.

An investigation of whether it was possible to instead ignore the Ls and use the Qs to link landings with effort for each day was also made by tracking accumulated held-over landings. Ideally, in order to use the Qs only, we would see holdings rise and then fall back to zero with each L. While this pattern was approximated much of the time there were many vessel years where this was not the case. Some examples for individual vessels are shown in Figure 7. Note the differing recording behaviours. For 4068 the Ls seems to be bigger than the preceding Qs. For 20906 the Ls are similar in magnitude to the preceding Qs. For 21053 the pattern looks right.

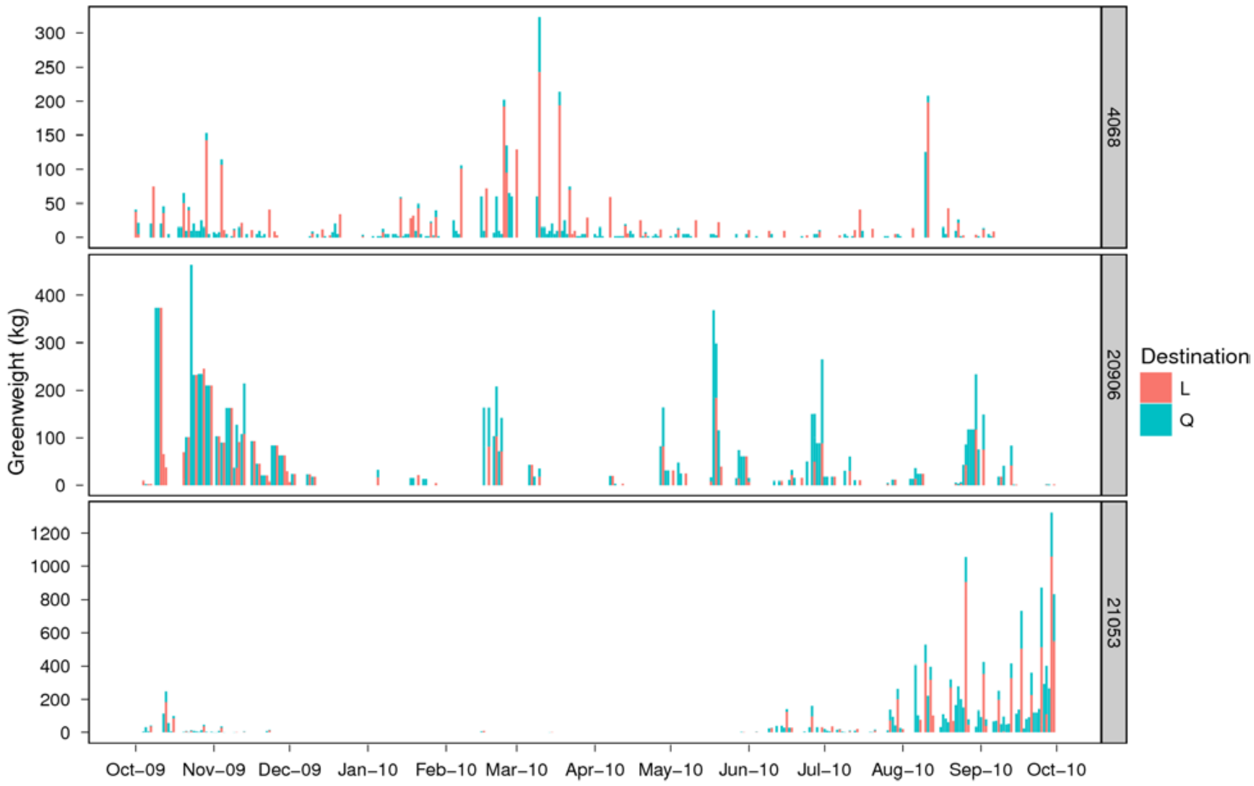



**Figure 7: Plot of landings by date and destination code for some example vessels in 2009/10.**

Analyses that used estimated catch were rejected by the working group because that measure of catch is notoriously unreliable for species that are processed at sea, however, the annual ratios of estimated to landed catch give us some information about how the catch for each vessel has been reported, and led the authors to propose that we use the ratio of landings to estimated catches for each vessel in each fishing year as a means of adjusting estimated catches.

### 2.2.6 Adjusting estimated catches

The distribution of the ratio of annual landings to annual estimated catches of rig for setnet are shown for each fishing year in Figure 8. There are a substantial number of vessel years in which the landed catch is about 1.5 times the estimated catch which suggests that the vessel is reporting estimated catches on the basis of dressed weight (the conversion factor is 1.55). There is clear bi-modality in the distribution of the ratio with some vessels reporting estimated catches based on whole weight and others based on dressed weight. However in recent years there are some vessels that have landed relatively large amounts of SPO but who have a low ratio sometimes less than 0.5. We suspect there are instances where the vessel has incorrectly recorded landings using the Q code, or perhaps do not subsequently land to L.

The approach proposed in this study calculates the ratio of total landed greenweight to total estimated catch for each vessel in each fishing year to establish the reporting practice used. A range of between 0.75 and 2 is explainable as the skipper estimating either greenweight or processed weight and these vessel/years were retained for analysis. Estimated weights were adjusted (usually upwards) by the ratio for that vessel/year and used in CPUE standardisation. Vessel/years in which the ratio was outside of this range were excluded from the analysis.

The effect of this grooming step on the data available for analysis is shown in Figure 9 for SPO 1 and SPO 8. The adjusted estimated catches are proportional to the landed catch and make up about half of the shortfall in SPO 1 and most of the shortfall in SPO 8. This approach shows considerable promise but is nevertheless compromised by the poor correspondence between the total landed greenweight available from the bottom of the form and obtained in the "*warehou*" extract and the total landings reported to the QMS as described in the previous section.

The effect of this grooming step on the annual indices for each set net fishery relative to indices based on unadjusted estimated catch is described in Appendix H.

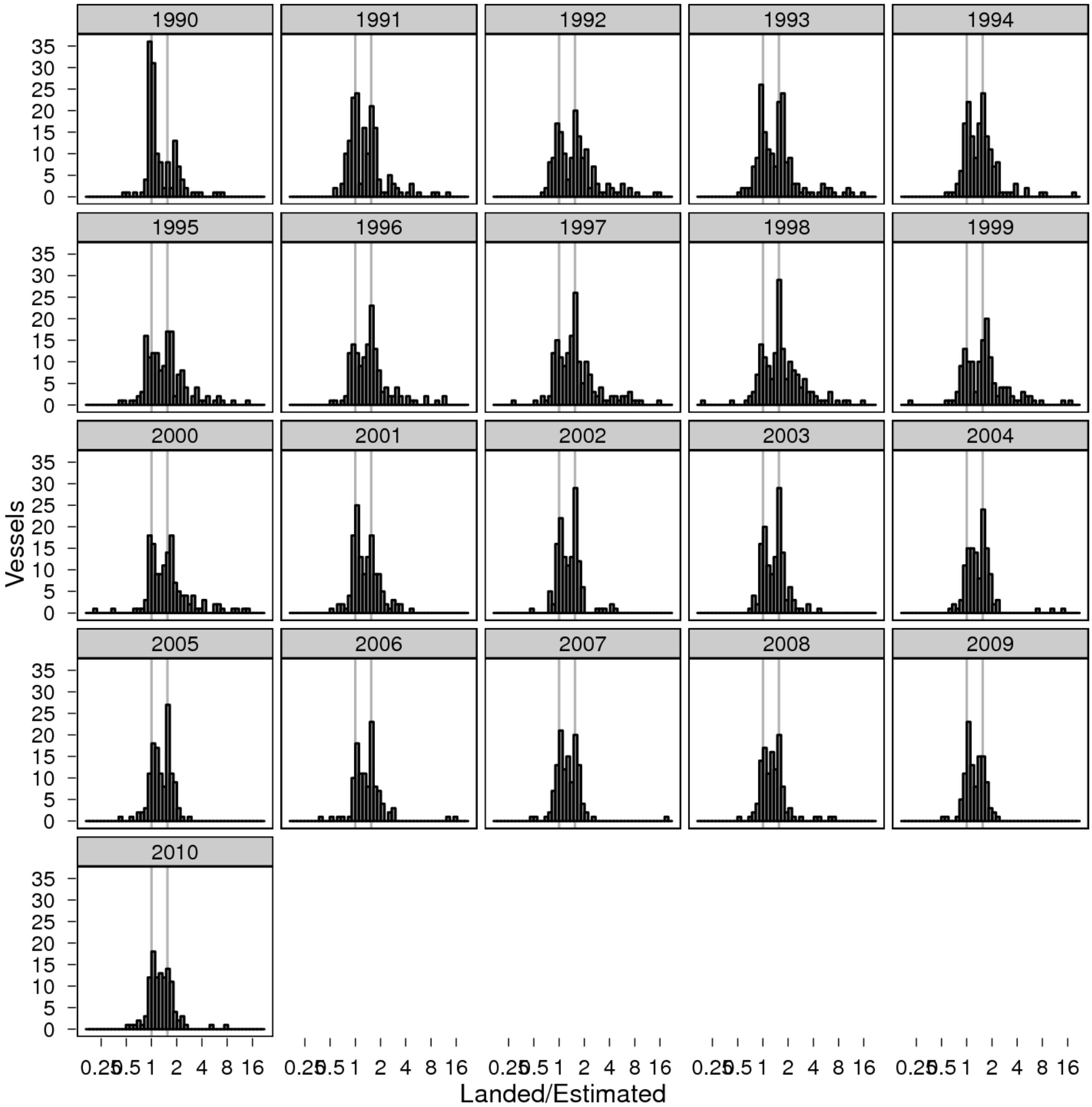



**Figure 8: Frequency distribution of the ratio of total landed catch over total estimated catch of rig for set net by fishing year. The vertical lines are at 1.0 and 1.55 reflecting estimated catches reported using whole weight and dressed weight respectively.**

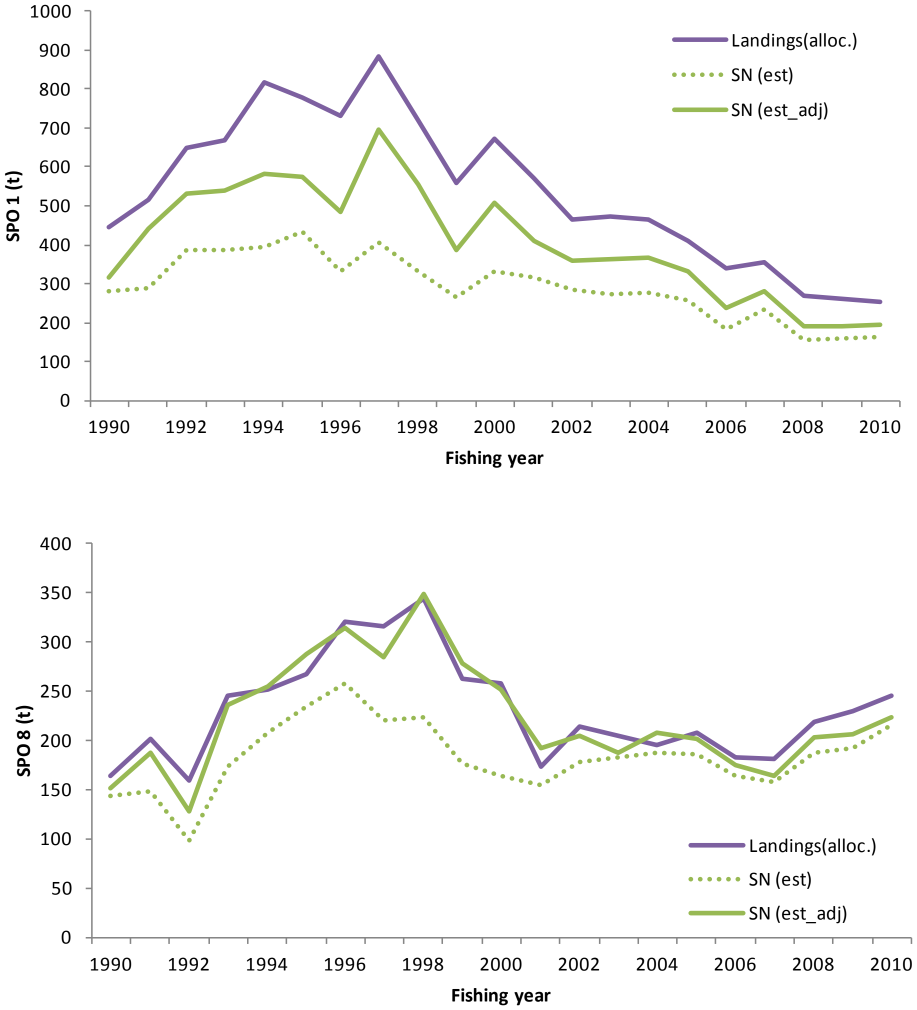



**Figure 9: Effect of adjusting the set net estimated catches for SPO 1 [upper] and SPO 8 [lower] in the analysis dataset by the ratio of total annual landed catch/total annual estimated catch by vessel.**

## 2.3 Methods used for catch-per-unit-effort analysis

### 2.3.1 Core fleet definitions

The data sets used for the standardised CPUE analyses were further restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables: the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed rig retained in the dataset and on the number of core vessels was plotted and examined visually (Appendix A).

The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of rig. This selection process generally reduced the number of vessels in the dataset by about 70% while reducing the amount of landed rig catch by about 20%. Note that the vessels thus selected are not necessarily the top vessels with respect to catching rig. The number of trips in each fishing year for the selected vessels and the distribution of the length of participation for the core vessels in each fishery are examined for adequate overlap across years and consistency of coverage through the time series (Appendix A).

### 2.3.2 Models

There are few zero catch records for rig in the (mainly target) set net fisheries, and lognormal linear models were fitted to positive estimated catches of rig excluding zero catches. For the bottom trawl fisheries which catch rig as a bycatch, a binomial model which predicted success or failure of rig catch was also fitted to the total dataset, including records that reported a zero catch of rig. These two models were combined into a single set of indices using the method of Vignaux (1994).

Data were amalgamated to effort strata that mimic the coarse resolution of the CELR form. The dependent variable for the lognormal models was the log of catch per record, based on **adjusted estimated** catch for set net, and **allocated landed catch** for bottom trawl, and were standardised for variance in the explanatory variables using a stepwise multiple regression procedure, selecting until the improvement in model $R^2$ was less than 0.01. The explanatory variables offered to the model were: *fishing year* (always forced as the first variable), and *month* (of catch), *statistical area*, *target species*, and a unique *vessel* identifier. The logs of the total *length of net* and of *duration* were offered as alternative measures of effort to explain catch as a catch rate. Continuous effort variables were offered as third order polynomials. The year effects were extracted as canonical coefficients (Francis 1999) so that confidence bounds could be calculated for each year.

# 3 RESULTS

## 3.1 Characterisation of SPO 1 and SPO 8 fisheries

In the early 1990s catch of rig from SPO 1 exceeded that from the adjacent SPO 8 almost four-fold but has declined steadily over the study period and in 2009–10 landings were less than half of their peak of 865 t in 1991–92. Landings from the adjacent SPO 8 have been more consistent and now almost equal the catch from SPO 1 (Figure 10).

Most SPO 1 and SPO 8 have been caught by setnet (SN, 75–89 % annually) with the balance largely taken by bottom trawl (BT, 6–18 % annually). Small amounts in each year are also taken by bottom longline (BLL), Danish seine (DS) and bottom pair trawl (BPT) (Table 5).

Set net is the dominant method along the west coast of the north Island (Areas 037 to 047), and in the Firth of Thames (Area 007). The west coast harbours (Areas 043 and 044) are closed to commercial trawl, but rig is caught by that method throughout the remainder of two QMAs. Bottom longline (BLL) catches rig on the Northland east coast, and Danish seine (DS) and bottom pair trawl (BPT) catch rig throughout QMAs 1 and 9 (Figure 11).

There has been reasonable uptake of the new Net Catch Effort and Landing Return form (NCE) which records information for individual sets, since it was introduced in 2006–07, but there continues to be a considerable amount of set net data captured at daily resolution on CELRs from vessels that are under 6 m length. A switch made during the mid 1990s by the main operator in the trawl fishery from reporting on the CELR to the more detailed TCEPR form is evident, but some daily reporting persisted until the introduction of the new TCE in 2007–08 (Figure 12).

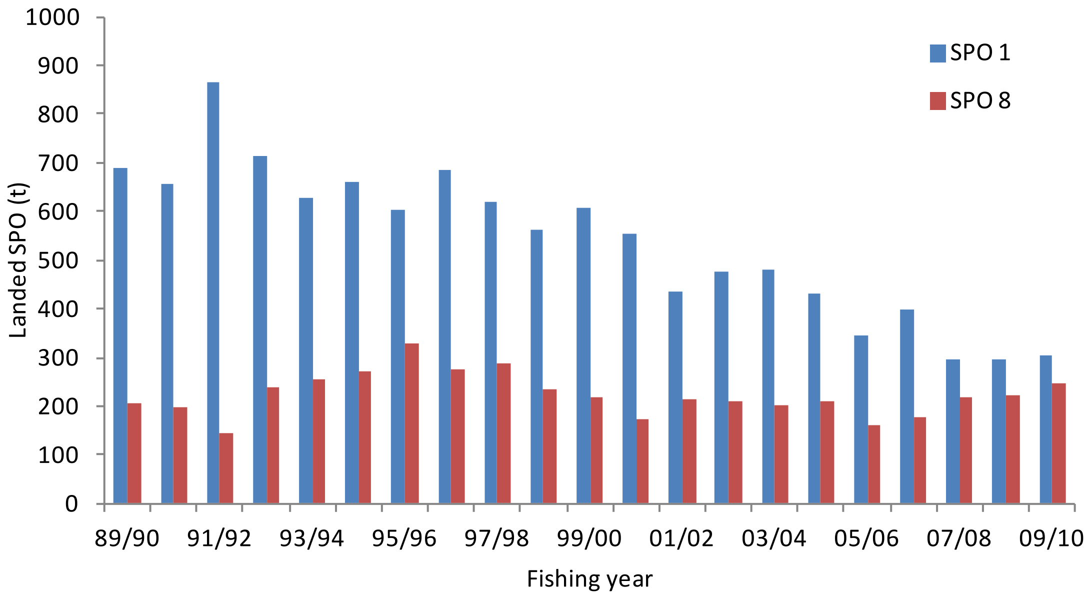



**Figure 10: Landed catch (t) of rig from SPO 1 and SPO 8 by fishing year. QMS totals.**

**Table 5: Landed catch of rig in SPO 1 and SPO 8 by method and fishing year in tonnes, and in percent of annual landings. Catches are raised to the annual QMR catch. 0, less than 0.5 t.; SN, setnet; BT, bottom trawl; BLL, bottom longline; DS, Danish seine; BPT, bottom pair trawl.**

| Fishing | Fishing method (t) | | | | | | Fishing method (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | SN | BT | BLL | DS | BPT | Other | SN | BT | BLL | DS | BPT | Other |
| 89/90 | 678 | 158 | 13 | 17 | 29 | 1 | 76 | 18 | 1 | 2 | 3 | 0 |
| 90/91 | 674 | 116 | 13 | 22 | 26 | 1 | 79 | 14 | 2 | 3 | 3 | 0 |
| 91/92 | 796 | 137 | 22 | 28 | 24 | 3 | 79 | 14 | 2 | 3 | 2 | 0 |
| 92/93 | 766 | 113 | 24 | 29 | 20 | 2 | 80 | 12 | 3 | 3 | 2 | 0 |
| 93/94 | 736 | 69 | 48 | 14 | 15 | 1 | 83 | 8 | 5 | 2 | 2 | 0 |
| 94/95 | 823 | 64 | 21 | 10 | 15 | 1 | 88 | 7 | 2 | 1 | 2 | 0 |
| 95/96 | 783 | 79 | 48 | 14 | 8 | 1 | 84 | 8 | 5 | 1 | 1 | 0 |
| 96/97 | 851 | 62 | 12 | 11 | 19 | 7 | 89 | 6 | 1 | 1 | 2 | 1 |
| 97/98 | 802 | 78 | 17 | 8 | 1 | 2 | 88 | 9 | 2 | 1 | 0 | 0 |
| 98/99 | 642 | 111 | 25 | 11 | 7 | 3 | 80 | 14 | 3 | 1 | 1 | 0 |
| 99/00 | 674 | 107 | 27 | 9 | 6 | 3 | 81 | 13 | 3 | 1 | 1 | 0 |
| 00/01 | 594 | 89 | 24 | 11 | 10 | 2 | 82 | 12 | 3 | 1 | 1 | 0 |
| 01/02 | 533 | 94 | 13 | 8 | 1 | 1 | 82 | 14 | 2 | 1 | 0 | 0 |
| 02/03 | 552 | 103 | 11 | 8 | 9 | 3 | 81 | 15 | 2 | 1 | 1 | 0 |
| 03/04 | 576 | 80 | 8 | 11 | 9 | 1 | 84 | 12 | 1 | 2 | 1 | 0 |
| 04/05 | 537 | 81 | 7 | 7 | 6 | 1 | 84 | 13 | 1 | 1 | 1 | 0 |
| 05/06 | 407 | 73 | 8 | 11 | 8 | 2 | 80 | 14 | 1 | 2 | 2 | 0 |
| 06/07 | 453 | 74 | 10 | 24 | 12 | 2 | 79 | 13 | 2 | 4 | 2 | 0 |
| 07/08 | 387 | 78 | 8 | 32 | 11 | 1 | 75 | 15 | 1 | 6 | 2 | 0 |
| 08/09 | 398 | 81 | 6 | 27 | 4 | 3 | 77 | 16 | 1 | 5 | 1 | 1 |
| 09/10 | 428 | 81 | 5 | 24 | 7 | 3 | 78 | 15 | 1 | 4 | 1 | 1 |

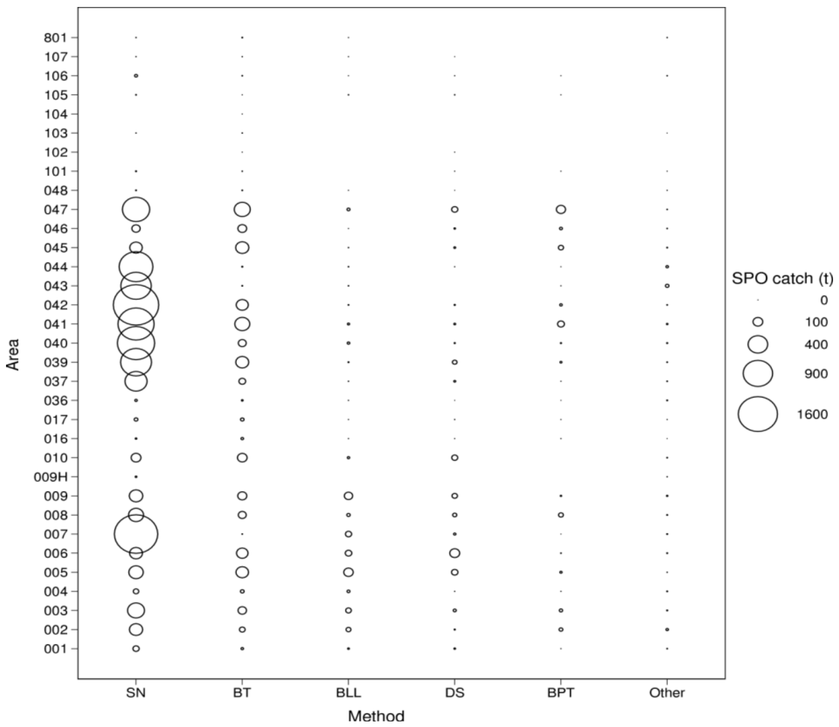



**Figure 11: Rig catch (t) by method and statistical area. All years 1989–90 to 2009–10 combined.**

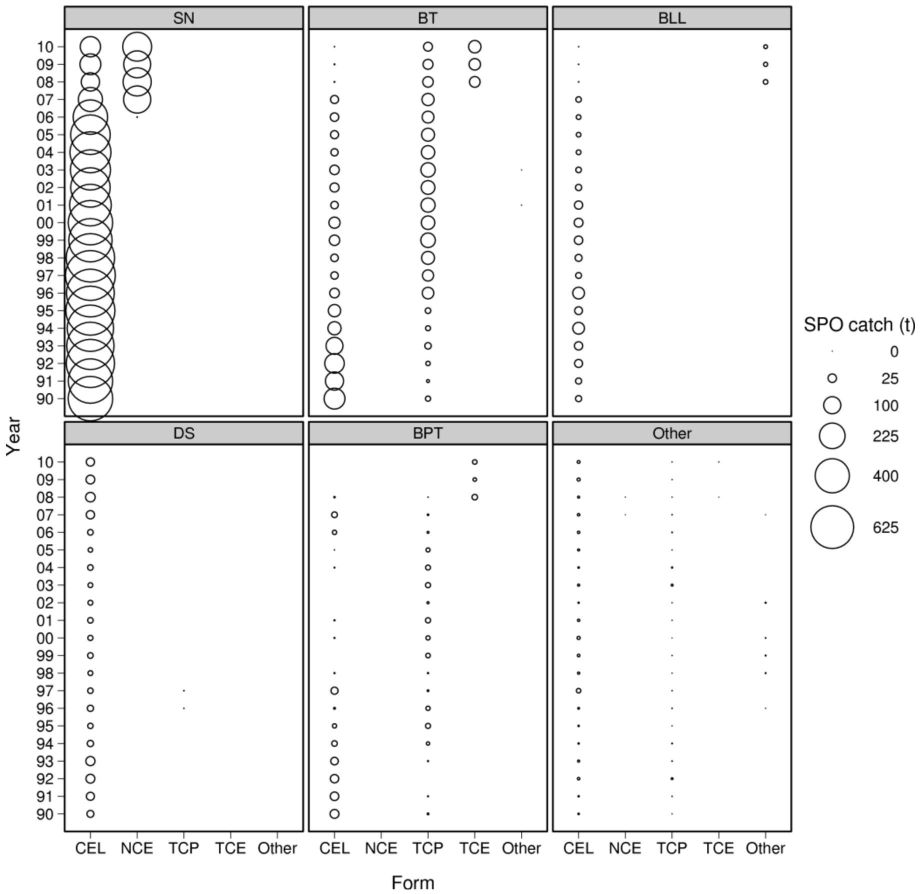



**Figure 12: Reporting of landed rig (t) by form type, fishing method, and fishing year.**

### 3.1.1 Description of the SPO 1 and SPO 8 setnet fisheries

The setnet effort in which catches of rig are reported is mostly targeted at rig (79–91% annually), but some is reported as a bycatch of snapper (SNA), red gurnard (GUR), trevally (TRE) and school shark (SCH) (Table 6). There are mesh size differences that make it indefensible to combine data across all setnet fisheries, but effort targeted at school shark uses similar gear and methods to set net targeted at rig.

The time series of set net catches of rig by statistical area is shown in Figure 13 and emphasises the relative importance of the inner Hauraki Gulf (Statistical Area 007) on the east coast, with consistently smaller amounts taken from other coastal areas of east Northland and Bay of Plenty. On the west coast the main area is around the mouth of the Waikato River (Area 042); and inside the large harbours; Manukau (Statistical Area 043) and Kaipara (Statistical Area 044). Consistent catches have also been landed from the coastal areas of SPO 8 that are south of the Waikato River, but catches from the coastal areas north of the Kaipara (045–047) have been smaller and less consistent. There was a marked shift away from Area 042 after 1997–98. Offshore areas (Statistical Area numbers 100 and above and also Statistical Area 001) are unlikely to have supported genuine setnet effort and the catch recorded for those areas is probably misreported. Fishers sometimes mistakenly enter the QMA in the statistical area field giving a false reference to Area 001.

The seasonal distribution of rig catches (Figure 14) shows a consistent focus on the spring months, from September to November. There are differences among areas, however, with catches being strongly seasonal in the main harbours of SPO 1, as well as the lower Waikato (area 042) but reported more consistently throughout the year, and peaking in January in other coastal areas and in SPO 8 (Figure 15).

**Table 6: Distribution of setnet caught rig, by target species (SPO, rig; SNA, snapper; GUR, red gurnard; TRE, trevally; SCH, school shark and other) as a percentage of the combined annual catch of SPO 1 and SPO 8 by fishing year.**

| Fishing | Target species (%) | | | | | |
|---|---|---|---|---|---|---|
| year | SPO | SNA | GUR | TRE | SCH | Other |
| 89/90 | 79 | 6 | 1 | 2 | 7 | 6 |
| 90/91 | 82 | 5 | 1 | 4 | 4 | 4 |
| 91/92 | 82 | 6 | 2 | 3 | 4 | 4 |
| 92/93 | 84 | 4 | 2 | 4 | 2 | 5 |
| 93/94 | 91 | 1 | 1 | 2 | 1 | 4 |
| 94/95 | 92 | 1 | 2 | 1 | 1 | 2 |
| 95/96 | 89 | 1 | 3 | 2 | 2 | 4 |
| 96/97 | 91 | 0 | 2 | 3 | 2 | 2 |
| 97/98 | 85 | 1 | 4 | 3 | 3 | 4 |
| 98/99 | 86 | 1 | 3 | 3 | 3 | 4 |
| 99/00 | 88 | 1 | 3 | 2 | 2 | 5 |
| 00/01 | 86 | 1 | 5 | 2 | 2 | 5 |
| 01/02 | 88 | 1 | 3 | 1 | 2 | 4 |
| 02/03 | 84 | 1 | 8 | 1 | 2 | 5 |
| 03/04 | 80 | 2 | 9 | 2 | 3 | 4 |
| 04/05 | 82 | 1 | 6 | 3 | 3 | 6 |
| 05/06 | 81 | 2 | 7 | 2 | 3 | 6 |
| 06/07 | 86 | 1 | 2 | 2 | 4 | 6 |
| 07/08 | 88 | 1 | 0 | 1 | 4 | 6 |
| 08/09 | 86 | 0 | 0 | 1 | 5 | 8 |
| 09/10 | 84 | 0 | 0 | 2 | 6 | 9 |

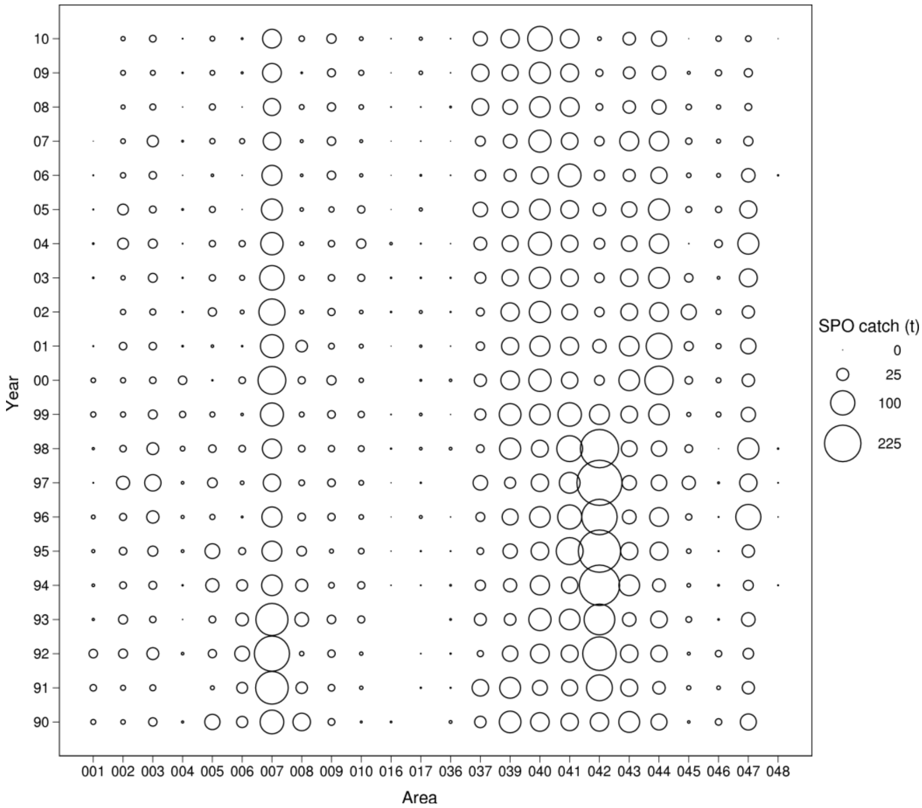



**Figure 13: Catch of rig (t) (SPO 1 or SPO 8) by set net (regardless of target species), statistical area and fishing year. Years are fishing years (e.g. 99 = 1 Oct 1998 to 30 Sep 1999).**

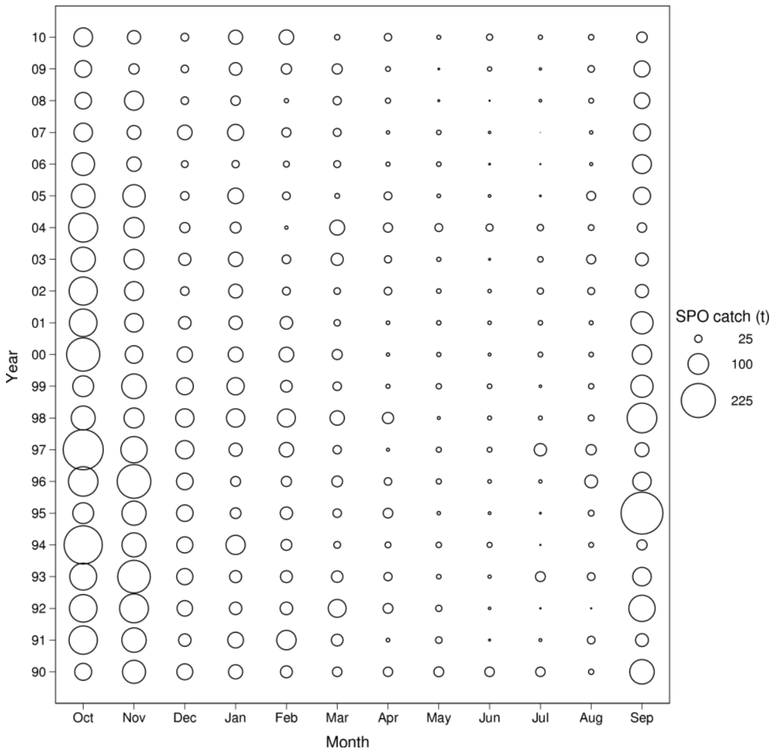



**Figure 14: Catch (t) of rig (SPO1 and SPO 8 combined) by month and year for method setnet (regardless of target species).**

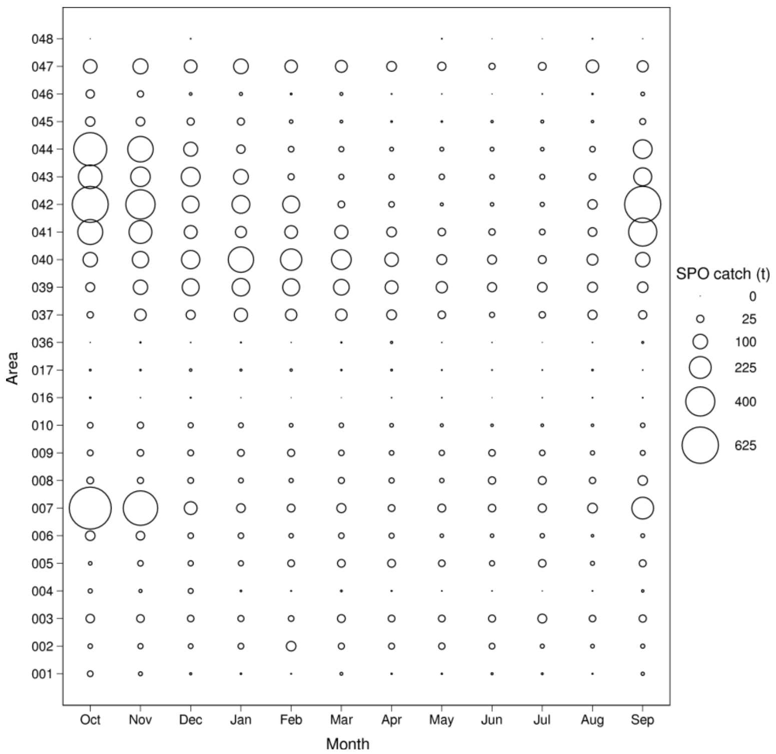



**Figure 15: Catch (t) of rig (SPO1 or SPO 8) by area and month for method SN (regardless of target species).**

### 3.1.2 Description of the SPO 1 and SPO 8 bottom trawl fisheries

Rig are caught by bottom trawl as a bycatch of mainly snapper and John dory in SPO 1 East, but also gurnard, and trevally in SPO 1 West and SPO 8, as well as tarakihi throughout both QMAs (Figure 16). There were significant landings of rig from trawl fisheries operating in the Hauraki Gulf during the early 1990s but they declined sharply after 1992–93. Similarly, Area 041 on the west coast was important in the early 1990s after which catches declined. Rig is caught by trawl in all the inshore areas valid for SPO 1 and SPO 8, although trawl is not permitted in the large west coast harbours and therefore the small amounts reported from Area 043 and 044 are presumably errors (Figure 17). Trawl catches of rig are generally greatest in the summer months of January to April (Figure 18), especially from open coast areas, but there is also a peak during spring from areas such as 042 and 045 which are adjacent to large harbours and estuaries (Figure 19).

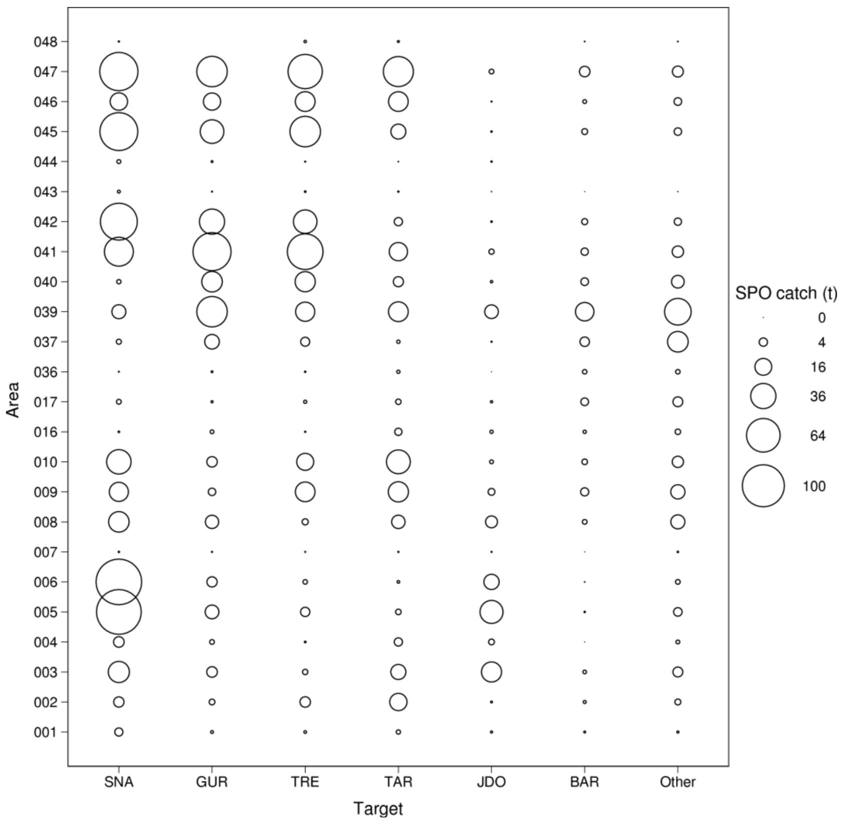



**Figure 16: Catch (t) of rig (SPO1 or SPO 8) by area and target species for method bottom trawl.**

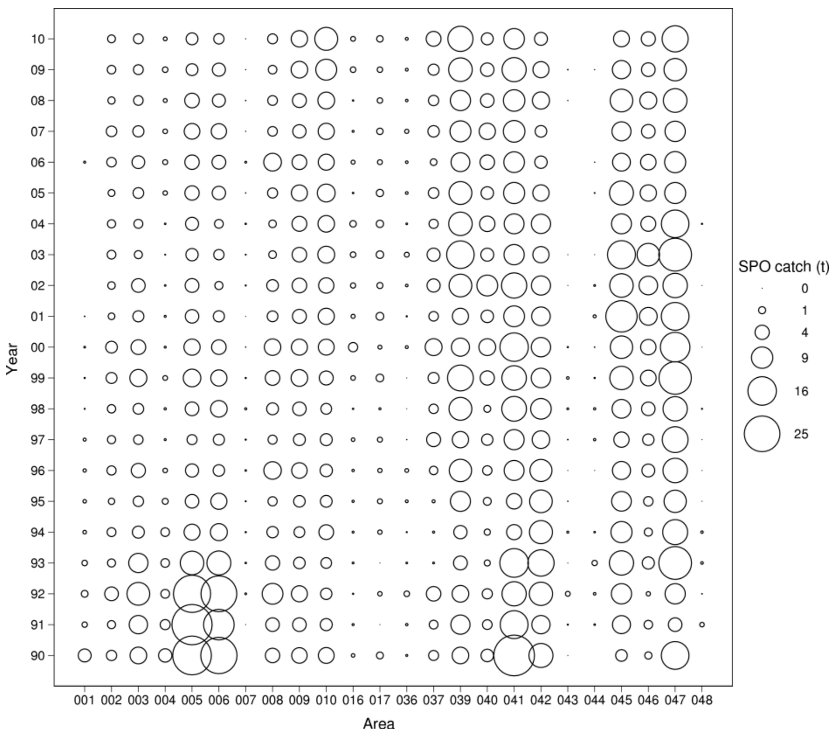



**Figure 17: Catch of rig (t) (SPO 1 or SPO 8) for bottom trawl (regardless of target species), by statistical area and fishing year. Years are fishing years (e.g. 99 = 1 Oct 1998 to 30 Sep 1999).**

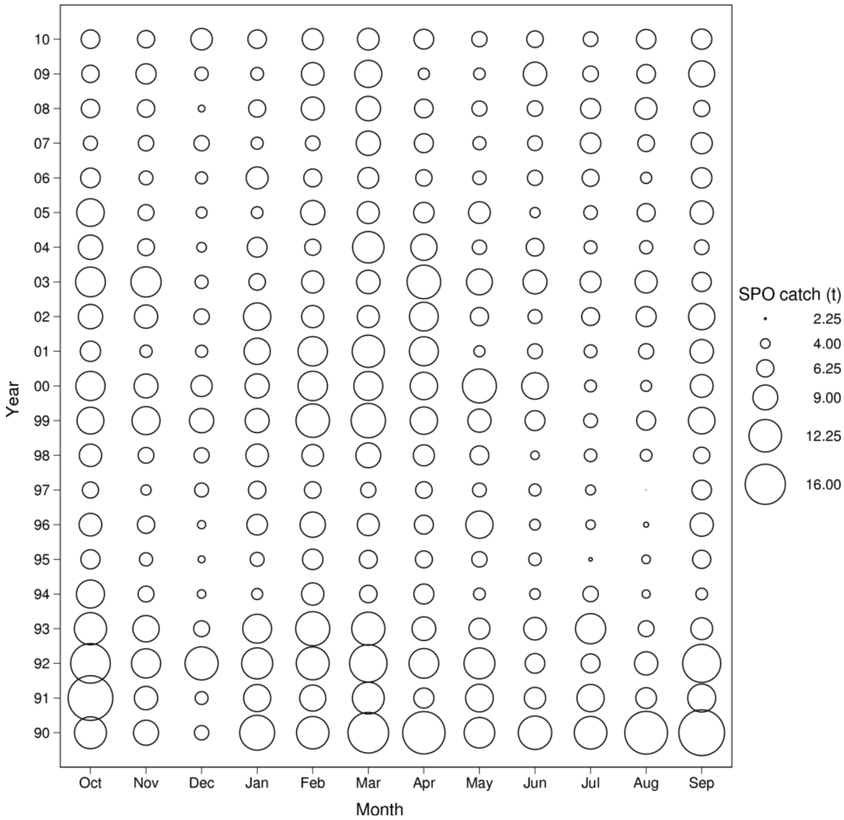



**Figure 18: Catch (t) of rig (SPO1 and SPO 8 combined) for bottom trawl (regardless of target species), by month and year.**

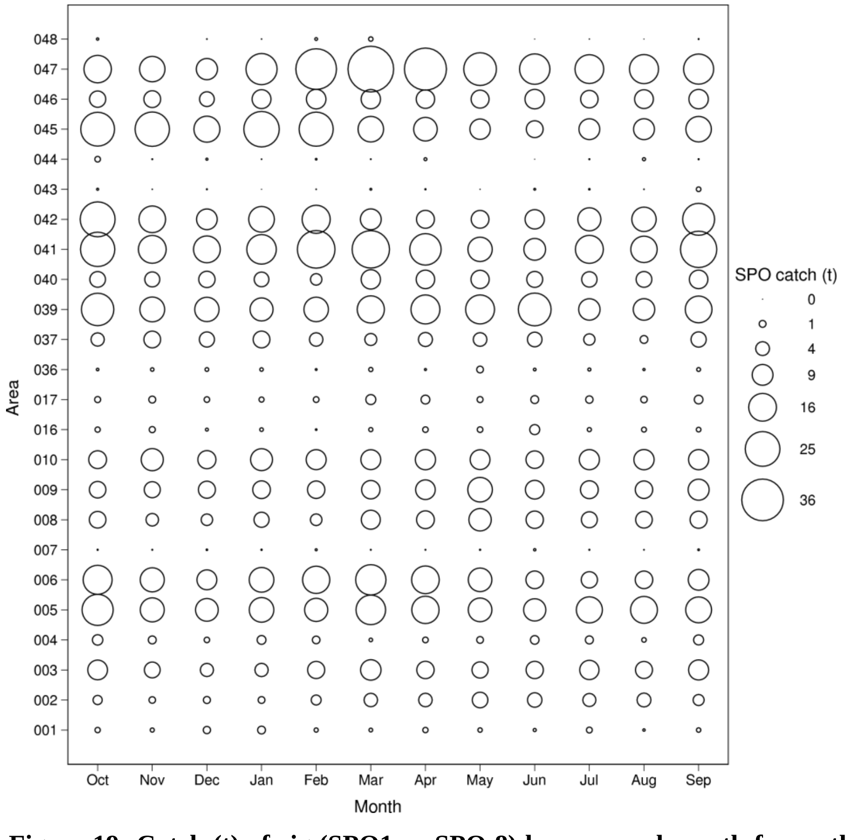



**Figure 19: Catch (t) of rig (SPO1 or SPO 8) by area and month for method bottom trawl (regardless of target species).**

### 3.1.3 Fishery definitions for CPUE

The SPO 1 fishstock can be divided into two sub-regions (Paul 2003), SPO 1 East, and SPO 1 West. SPO 1 East includes inshore statistical areas 001–010 off the east coast of the North Island. Important fisheries operate in the Hauraki Gulf (areas 005 and 006), and Firth of Thames (Area 007). The SPO 1 West sub-stock includes the coastal inshore Statistical Areas 042–048 off the west coast of the North Island, and locally important fisheries operate off Ninety-mile beach (area 047), in Kaipara Harbour (Area 044), and the Manukau Harbour (Area 043).The SPO 8 Fishstock includes the coastal inshore Statistical areas 037–041 off the lower west coast of the North Island, with no major harbours.

Six set net fisheries that operate with some independence have previously been defined for CPUE analysis and those analyses are updated with little change except that the range of target species is expanded to include other shark set net fisheries (Table 7). They include the three main harbour fisheries (Thames, Kaipara, and Manukau) and three coastal fisheries that cover the remaining coastal statistical areas in each substock. Only positive catches were retained for analysis and the small proportion of zero catch records was excluded. Additionally, a bottom trawl fishery in each of the three substocks is defined (Table 7). The main set net fisheries operate in the large west coast harbours while trawl operates offshore and is not legal inside harbour limits. The trawl fisheries therefore cover distinctly different spatial aspects of the stock, and probably also a different part of the underlying population. Rig is a bycatch of trawl fisheries and both the catch rate in successful trips and the success rate (probability of capture) were examined for signals of any change in abundance. The binomial models of the probability of capture did not provide very much additional signal and only the lognormal models of catch rate in successful strata are described in detail.

The fisheries and the resultant CPUE series are described by the substock code suffixed by the fishing method and an indication of the subarea included. For example SPO1W_SN(043) means adjusted estimated catches of rig from the setnet fishery in Statistical Area 043 (Manukau Harbour) of the west coast substock of SPO 1.

**Table 7: Summary of fisheries defined for standardised CPUE analysis in this study.**

| Fishstock (substock) | Fishery Label | Fishing method | Statistical Area(s) | Target species | Update or new |
|---|---|---|---|---|---|
| SPO 1E | SPO1E-SN(007) | Set net | 007 | SPO, SCH, SPD, NSD | U |
| | SPO1E-SN(coast) | Set net | 003–006, 008–010 | SPO, SCH, SPD, NSD | U |
| | **SPO1E-BT** | Bottom trawl | 002–010 | SNA, TRE, GUR, JDO,BAR, TAR | **New** |
| SPO 1W | SPO1W-SN(044) | Set net | 043 | SPO SCH, SPD, NSD | U |
| | SPO1W-SN(043) | Set net | 044 | SPO SCH, SPD, NSD | U |
| | SPO1W-SN(coast) | Set net | 042, 045–047 | SPO SCH, SPD, NSD | U |
| | **SPO1W-BT** | Bottom trawl | 042, 045–048 | SNA, TRE, GUR, JDO, BAR, TAR | **New** |
| SPO 8 | SPO8-SN | Set net | 037–041 | SPO SCH, SPD, NSD | U |
| | **SPO8-BT** | Bottom trawl | 037–041 | SNA, TRE, GUR, JDO, BAR, TAR | **New** |

### 3.1.4 Unstandardised catch and effort in defined fisheries

Set net effort in the Hauraki Gulf (Area 007) peaked in the early 1990s at almost 1000 vessel-days targeting rig. It declined by more than half over the following two years, and was relatively stable at that level until the early 2000s. Catches mirrored the pattern of effort closely, peaking at about 160 tonnes in 1992–93 and declining to nearer 70 tonnes by 1999–00. Effort and then catch peaked again in the early 2000s before declining steadily over 5–6 consecutive years to the lowest point in the fishery in 2007–08 when less than 50 t of rig was caught in about 200 vessel-days of set net effort. The two most recent years have seen some increase in activity from that low. Set net effort in the rest of east Northland also peaked in 1993–94 at about 100 tonnes of rig from about 400 vessel-days but then declined and the fishery has operated at less than half that level of activity since then. The east Northland fishery is widely spread across several discrete harbours and coastal areas (Mangonui, Whangaroa, Houhora, Rangaunu Harbour, Karikari Peninsula and Doubtless Bay).

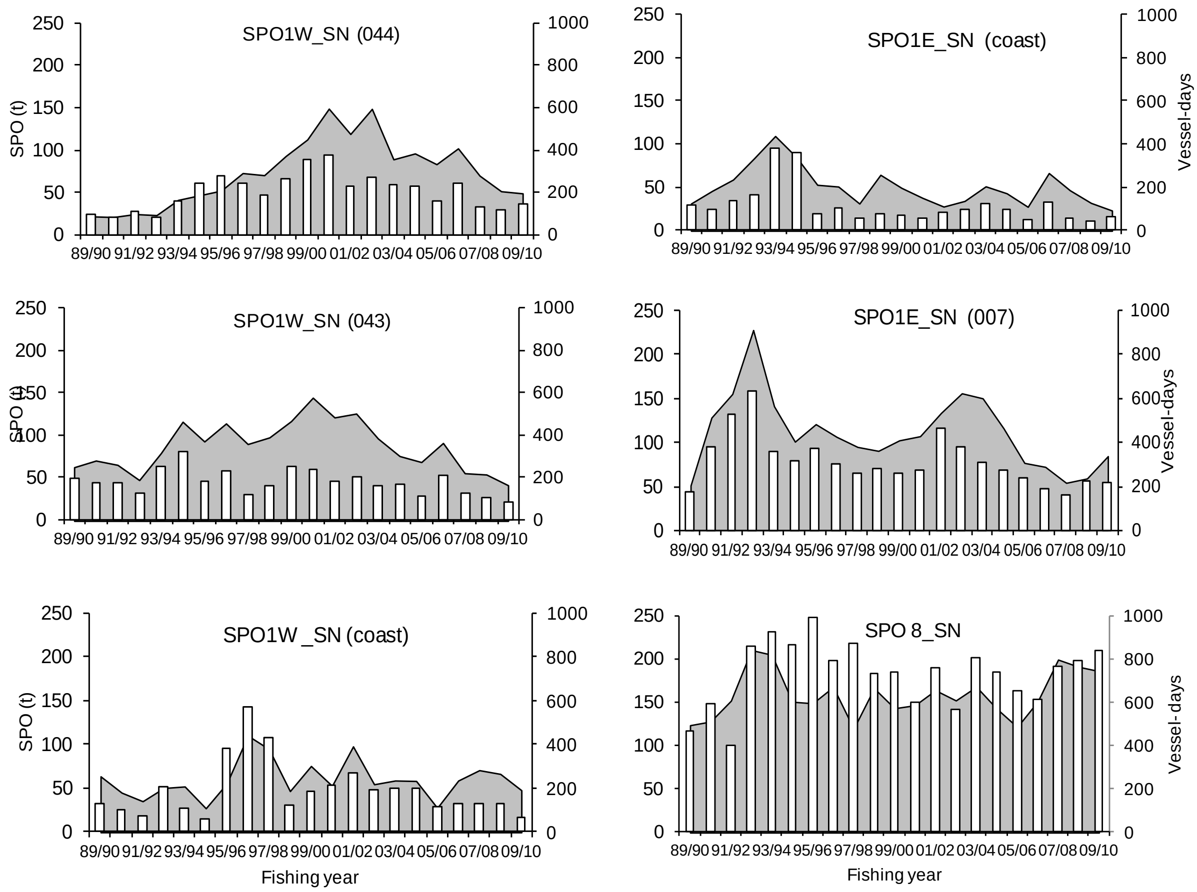



**Figure 20: Effort (vessel-days, shaded area, right-hand axis) for setnet fishing targeted at rig and other shark species, and landed catch (tonnes, bars, left-hand axis) of rig in defined set net fisheries for SPO 1 and SPO 8.**

On the west coast, the Kaipara Harbour (Area 044) fishery for rig increased steadily during the 1990s to peak at more than 600 vessel-days in 2000–01, but has declined almost as steadily since then, with catches also declining from a peak of about 100 t to less than 50 t in most years since then. Further south in the Manukau Harbour the pattern and magnitude of effort and catches is similar, although effort was initially higher than in the Kaipara. Catches have declined over the last decade, and in 2009–10 were the lowest for the study period. On the coast, there has been more cyclical variability in effort. Catches peaked in the mid 1990s but then declined to reach the lowest level for the series in 2009–10. The setnet fishery in SPO 8 is the largest, with effort maintained at around 800 vessel-days per year since the early 1990s, and landings of about 200 t of rig annually with no obvious decline in effort or catches (Figure 20).

The bycatch of rig from the inshore bottom trawl fisheries declined in proportion to effort in the west coast fishery of SPO 1, peaking in the early 1990s and declining steadily since then. Further south in SPO 8, catch and effort peaked in the late 1990s before declining to their lowest level by 2007–08. On the east coast, catches declined more steeply than effort during the 1990s and then stabilised at a new lower level during the 2000s (Figure 21).

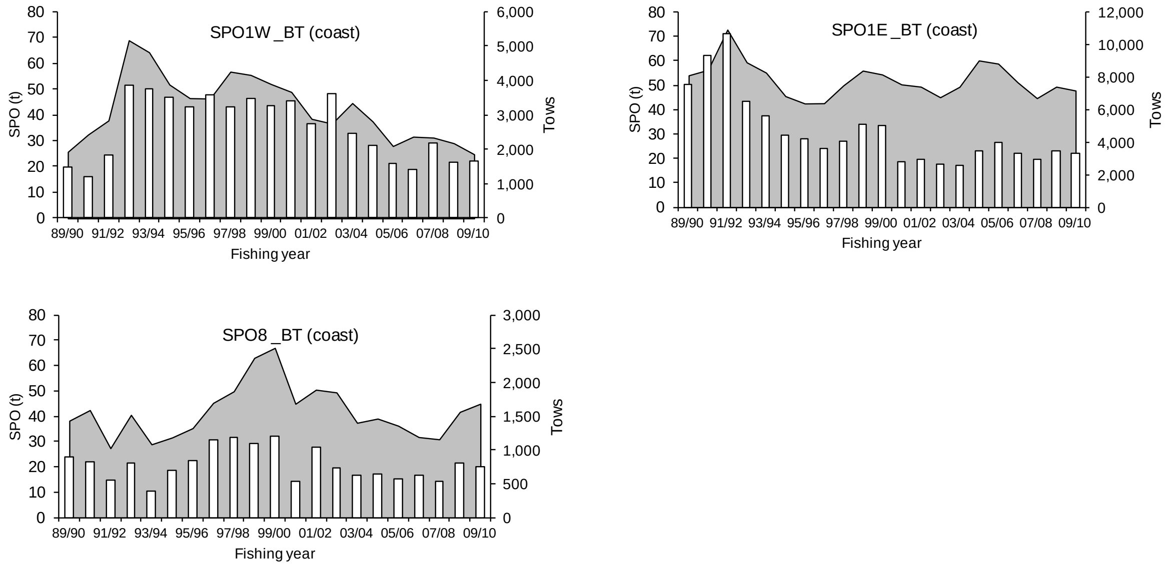



**Figure 21: Effort (Number of tows, shaded area, right-hand axis) for bottom trawl targeted at snapper, trevally, gurnard, John dory, barracouta or tarakihi, and landed catch (tonnes, bars, left-hand axis) of rig in defined bottom trawl fisheries for SPO 1 and SPO 8.**

### 3.1.5 Core fleets selected

These fisheries typically consist of a large number of small vessels and the selection of core fleets from each fishery is described in Appendix A. The participation of the resultant core fleet over time shows that in most fisheries there has been consistent participation across the time series by many vessels, and an influx of new entrants from the early 2000s. An adequate overlap of vessels across years is demonstrated in each fishery.

SPO1E_SN (coast): Vessels that had fished for at least three trips in each of at least three years. These criteria resulted in a core fleet size of 32 vessels which took 77% of the catch.

SPO1E_SN (007): Vessels that had fished for at least five trips in each of at least four years. These criteria resulted in a core fleet size of 34 vessels which took 74% of the catch.

SPO1E_BT: Vessels that had fished for at least five trips in each of at least four years. These criteria resulted in a core fleet size of 60 vessels which took 93% of the catch.

SPO1W_SN (044): Vessels that had fished for at least five trips in each of at least four years. These criteria resulted in a core fleet size of 25 vessels which took 88% of the catch.

SPO1W_SN (043): Vessels that had fished for at least five trips in each of at least four years. These criteria resulted in a core fleet size of 24 vessels which took 84% of the catch.

SPO1W_SN coast): Vessels that had fished for at least three trips in each of at least three years. These criteria resulted in a core fleet size of 26 vessels which took 75% of the catch.

SPO1W_BT: Vessels that had fished for at least five trips in each of at least four years. These criteria resulted in a core fleet size of 35 vessels which took 94% of the catch.

SPO8_SN: Vessels that had fished for at least five trips in each of at least four years. These criteria resulted in a core fleet size of 37 vessels which took 86% of the catch.

SPO8_BT: Vessels that had fished for at least five trips in each of at least four years. These criteria resulted in a core fleet size of 31 vessels which took 77% of the catch.

### 3.1.6 Model selection, diagnostics, and year effects

The final models selected for each fishery are described in Tables 8 to 16. These tables include those explanatory variables that met the AIC criteria and are not necessarily a complete list of the variables that were offered. The variables that met the acceptance criteria based on a 1% improvement in $R^2$ are indicated with asterisks in the table, along with the amount of deviance they explained.

The models generally explained 40 to 50% of the variance in catch and included vessel ID as the factor with greatest explanatory power followed by a measure of effort; variously net length or duration (soak time). Month was also accepted into most models, target species had explanatory power in the coastal set net fisheries, and area was only accepted into the model of the west coast trawl fishery.

Variables that explain the most deviance are not necessarily the ones responsible for most of the difference between standardised and observed series of CPUE. The influence of an explanatory variable is a combination of its GLM coefficients and its distributional changes over years, and is examined in more detail with the aid of Coefficient-Distribution-Influence (CDI) plots (Bentley et al. (2011), given in Appendix B.

Diagnostic plots of the residuals from each final model fit are given in Appendix C and show reasonable fits through the range in which most of the data occur. Potentially confounding interactions between fishing year and statistical area (for those fisheries that include more than one statistical area) were investigated by plotting residual implied coefficients for each area in each year and are given in Appendix D.

The time series of year effects from the models are plotted, along with the unstandardised geometric mean of the catch per strata (not adjusted for effort) for the core fleets (Figure 22 to Figure 30). For most set net fisheries, annual CPUE indices are spiky with considerable interannual variance and relatively large error bars. The exception is the series for the Manukau Harbour which is well determined, with small confidence intervals around each point and changes in direction that are sustained over consecutive years rather than manifesting as inter-annual variance. The bottom trawl series show better determined trends than the set net series, and some promise for indexing the underlying abundance of part of the population. Binomial and combined models were also fit to the bottom trawl datasets but were not additionally informative (Appendix G).

Final datasets standardised by the models are tabulated in Appendix E and the unstandardised and standardised CPUE indices with 95% confidence intervals are given in Appendix F.

The two east coast set net series show no trend but have considerable interannual variance. The effect of standardisation is to smooth each series without changing its overall trend. The east coast bottom trawl series falls into two periods of relative stability at 50% higher than the mean during the 1990s, followed by a steep decline to a new level well below the mean during the 2000s. The effect of standardisation was to remove a large peak in the early 1990s by adjusting for a shift towards fewer tows per trip-stratum at about the time that the northern inshore trawl fleet changed from reporting daily to reporting for individual tows. Standardisation also lifts points in the last half of the series as an adjustment for changes in the core fleet towards poorer performing vessels with respect to rig.

Series for the set net fisheries in the two west coast harbours are similar in describing steady declines to the lowest levels of the series in the early 2000s. The Kaipara harbour series then becomes somewhat erratic, while the Manukau Harbour series is quite flat thereafter. The effect of standardisation in both cases is not great, but does lower and flatten points in the second half of the series for Manukau, removing the hint of recovery in the unstandardised series. The coastal set net series also suggests a sharp decline of about 50% between decades that coincides with a shift away from targeting school shark in Area 042, and standardisation removes some spikes that were due to anomalous data. The series for bottom trawl along the east coast also falls into two parts with higher catches in the 1990s falling by about 50% to a new level in the 2000s. A very large spike in 2003 coincides with a shift away from Area 042 and into adjacent areas with higher predicted catches.

The series for set net in SPO 8 is spiky with no overall trend up or down. Indices for four consecutive years after 2003–04 decline by about 50% to the lowest point in 2008–09, and then show two consecutive years of increase. The effect of standardisation was to remove some very high and low points, but does not convincingly improve the credibility of the series. Bottom trawl on the same coast, however, demonstrates a strong decline that standardisation emphasises by lifting early points and lowering recent points.

## 3.2 Standardised CPUE for SPO1 E

### 3.2.1 Firth of Thames setnet SPO1E_SN (007)

**Table 8: Summary of final lognormal model for the SPO1E_SN (007) fishery based on the vessel selection criteria of at least five trips per year in at least four or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 9 413 | 0.00 | 20 383 | |
| fyear | 21 | 9 089 | 3.44 | 20 203 | * |
| vessel | 54 | 6 060 | 35.63 | 17 720 | * |
| month | 65 | 5 476 | 41.83 | 17 105 | * |
| poly(log(netlength), 3) | 68 | 5 159 | 45.19 | 16 737 | * |
| poly(log(duration), 3) | 71 | 5 073 | 46.10 | 16 637 | |
| poly(log(days), 3) | 74 | 5 064 | 46.21 | 16 631 | |
| target | 76 | 5 060 | 46.25 | 16 630 | |

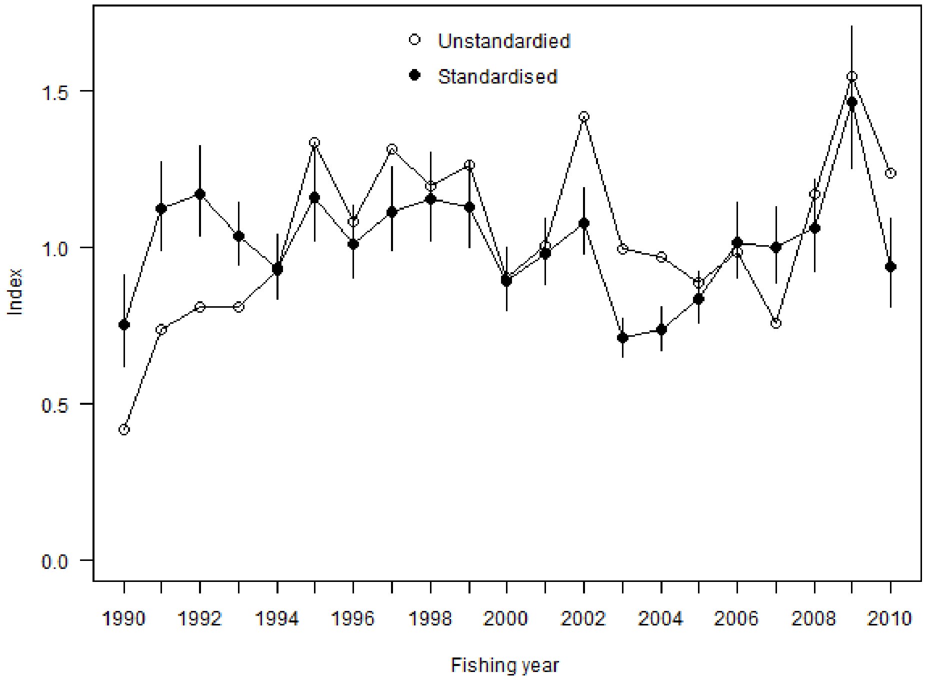



**Figure 22: Overall standardization effect of the model for the SPO1E_SN(007) fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

### 3.2.2 East coast setnet SPO1E_SN (coast)

**Table 9: Summary of final lognormal model for the SPO1E_SN (coast) fishery based on the vessel selection criteria of at least three trips per year in at least 3 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 4 667 | 0.00 | 9 401 | |
| fyear | 21 | 4 565 | 2.18 | 9 380 | * |
| vessel | 52 | 3 248 | 30.40 | 8 485 | * |
| poly(log(duration), 3) | 55 | 2 876 | 38.37 | 8 150 | * |
| target | 57 | 2 837 | 39.21 | 8 115 | |
| month | 68 | 2 778 | 40.46 | 8 079 | |
| area | 73 | 2 742 | 41.24 | 8 052 | |
| poly(log(netlength), 3) | 76 | 2 724 | 41.63 | 8 039 | |

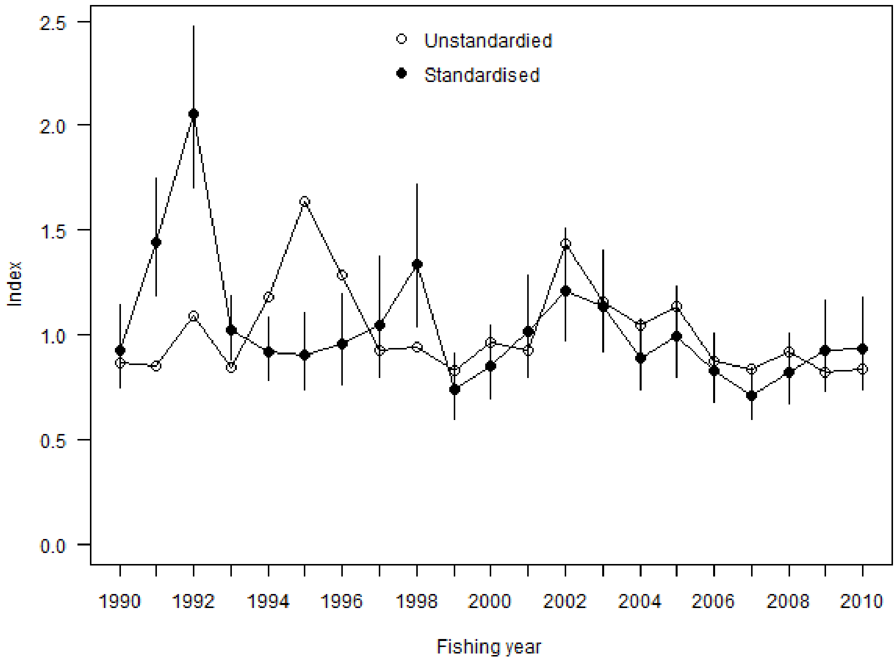



**Figure 23: Overall standardization effect of the model for the SPO1E_SN fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

### 3.2.3 East coast bottom trawl SPO1E_BT

**Table 10: Summary of final lognormal model for the SPO1E_BT fishery based on the vessel selection criteria of at least five trips per year in at least 4 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 55 874 | 0.00 | 89 914 | |
| fyear | 21 | 49 158 | 12.02 | 86 808 | * |
| poly(log(num) 3) | 24 | 38 666 | 30.80 | 80 915 | * |
| vessel | 83 | 33 645 | 39.78 | 77 616 | * |
| area | 91 | 33 144 | 40.68 | 77 263 | |
| month | 102 | 32 937 | 41.05 | 77 131 | |
| target | 106 | 32 892 | 41.13 | 77 106 | |
| poly(log(duration) 3) | 109 | 32 846 | 41.21 | 77 077 | |

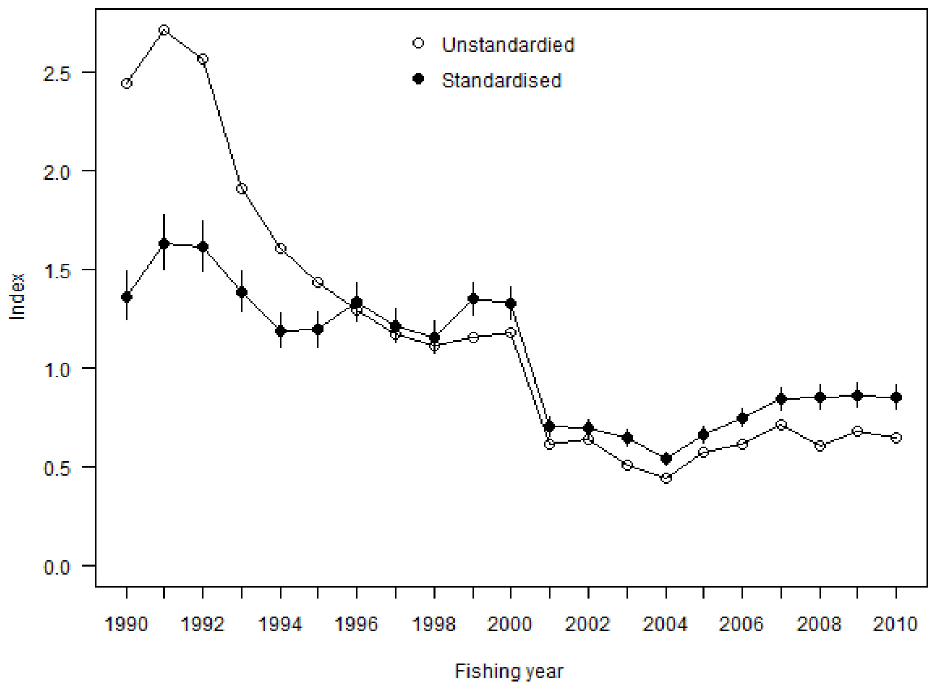



**Figure 24: Overall standardization effect of the model for the SPO1E_BT fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

## 3.3 Standardised CPUE in SPO1 W

### 3.3.1 Kaipara Harbour setnet SPO1W_SN(044)

**Table 11: Summary of final lognormal model for the SPO1W_SN(044) fishery based on the vessel selection criteria of at least five trips per year in at least 4 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 4 551 | 0.00 | 11 724 | |
| fyear | 21 | 4 235 | 6.95 | 11 481 | * |
| poly(log(netlength), 3) | 24 | 2 886 | 36.59 | 9 982 | * |
| month | 35 | 2 663 | 41.50 | 9 688 | * |
| vessel | 59 | 2 367 | 47.99 | 9 273 | * |
| poly(log(days), 3) | 62 | 2 264 | 50.27 | 9 104 | * |
| poly(log(duration), 3) | 65 | 2 213 | 51.38 | 9 022 | * |
| target | 67 | 2 211 | 51.43 | 9 021 | |

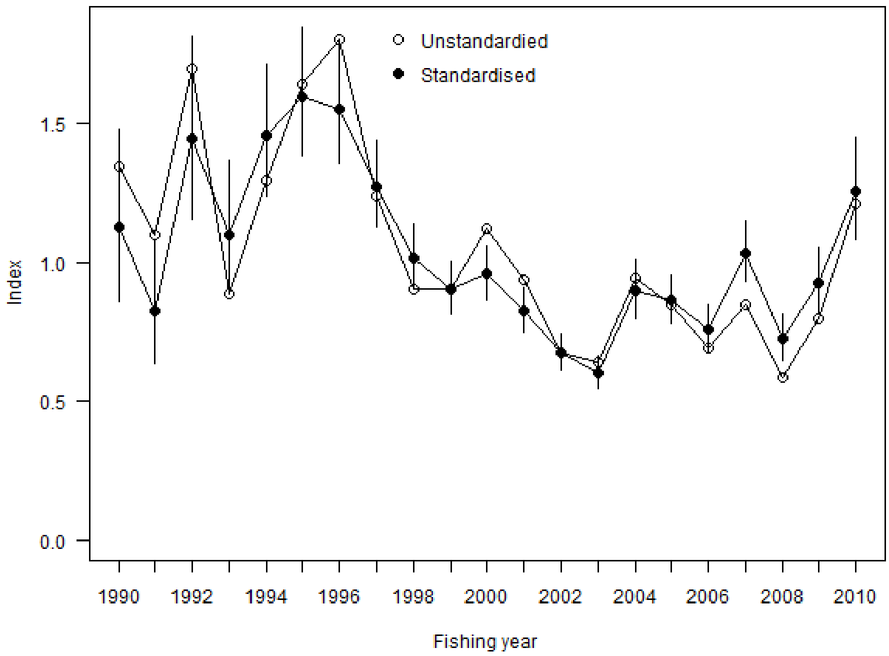



**Figure 25: Overall standardization effect of the model for the SPO1W_SN(044) fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

### 3.3.2 Manukau Harbour setnet SPO1W_SN(043)

**Table 12: Summary of final lognormal model for the SPO1W_SN(043) fishery based on the vessel selection criteria of at least five trips per year in at least 4 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 6 771 | 0.00 | 15 984 | |
| fyear | 21 | 6 480 | 4.30 | 15 799 | * |
| vessel | 44 | 4 572 | 32.48 | 14 056 | * |
| poly(log(netlength), 3) | 47 | 3 950 | 41.66 | 13 312 | * |
| month | 58 | 3 507 | 48.20 | 12 724 | * |
| poly(log(duration), 3) | 61 | 3 392 | 49.91 | 12 559 | * |
| poly(log(days), 3) | 64 | 3 366 | 50.30 | 12 525 | |

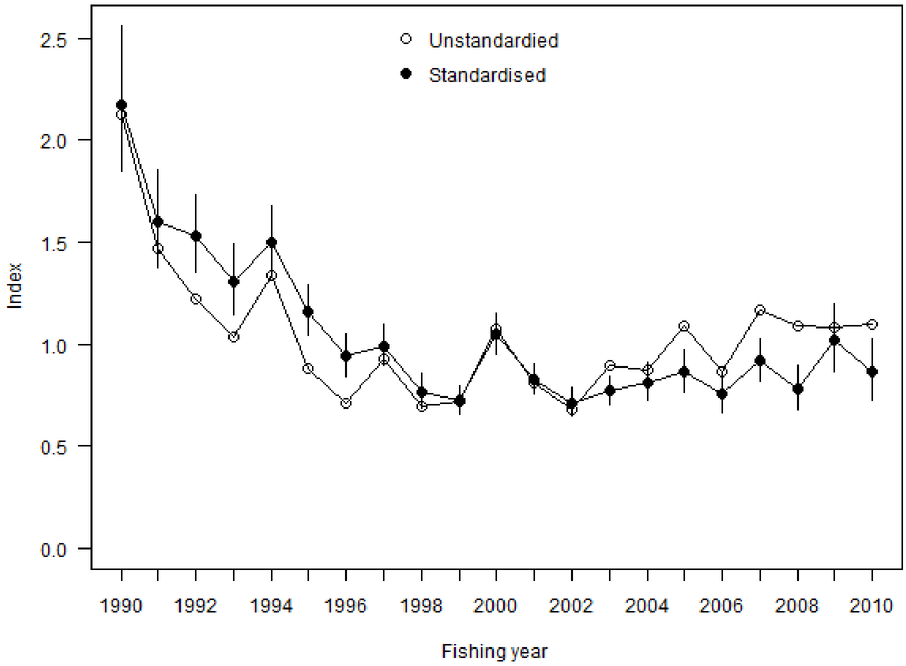



**Figure 26: Overall standardization effect of the model for the SPO1W_SN(043) fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

### 3.3.3 West coast setnet SPO1W_SN (coast)

**Table 13: Summary of final lognormal model for the SPO1W_SN (coast) fishery based on the vessel selection criteria of at least five trips per year in at least 4 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 5 194 | 0.00 | 11 197 | |
| fyear | 21 | 4 652 | 10.44 | 10 858 | * |
| vessel | 47 | 3 754 | 27.72 | 10 171 | * |
| month | 58 | 3 329 | 35.91 | 9 778 | * |
| poly(log(netlength), 3) | 61 | 3 027 | 41.72 | 9 457 | * |
| target | 63 | 2 854 | 45.06 | 9 257 | * |
| poly(log(days), 3) | 66 | 2 809 | 45.92 | 9 209 | |
| poly(log(duration), 3) | 69 | 2 793 | 46.23 | 9 195 | |
| area | 72 | 2 780 | 46.47 | 9 186 | |

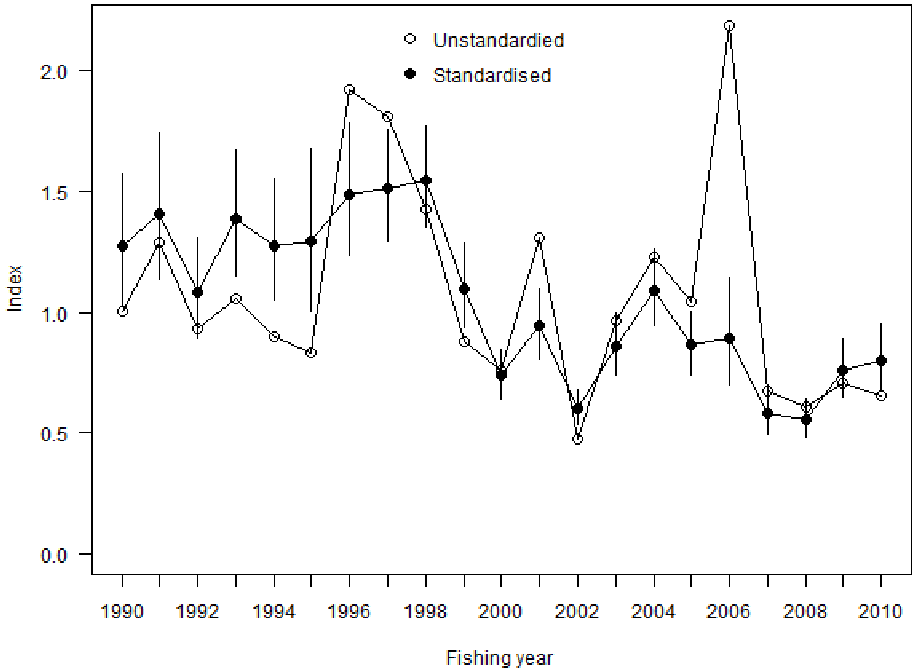



**Figure 27: Overall standardization effect of the model for the SPO1W_SN fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

### 3.3.4 West coast bottom trawl SPO1W_BT

**Table 14: Summary of final lognormal model for the SPO1W_BT fishery based on the vessel selection criteria of at least 10 trips per year in at least 4 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 22 102 | 0.00 | 37 589 | |
| fyear | 21 | 21 360 | 3.36 | 37 270 | * |
| poly(log(duration) 3) | 24 | 16 331 | 26.11 | 34 460 | * |
| vessel | 58 | 13 994 | 36.68 | 32 909 | * |
| month | 69 | 13 299 | 39.83 | 32 396 | * |
| area | 72 | 13 004 | 41.17 | 32 167 | * |
| poly(log(num) 3) | 75 | 12 824 | 41.98 | 32 027 | |

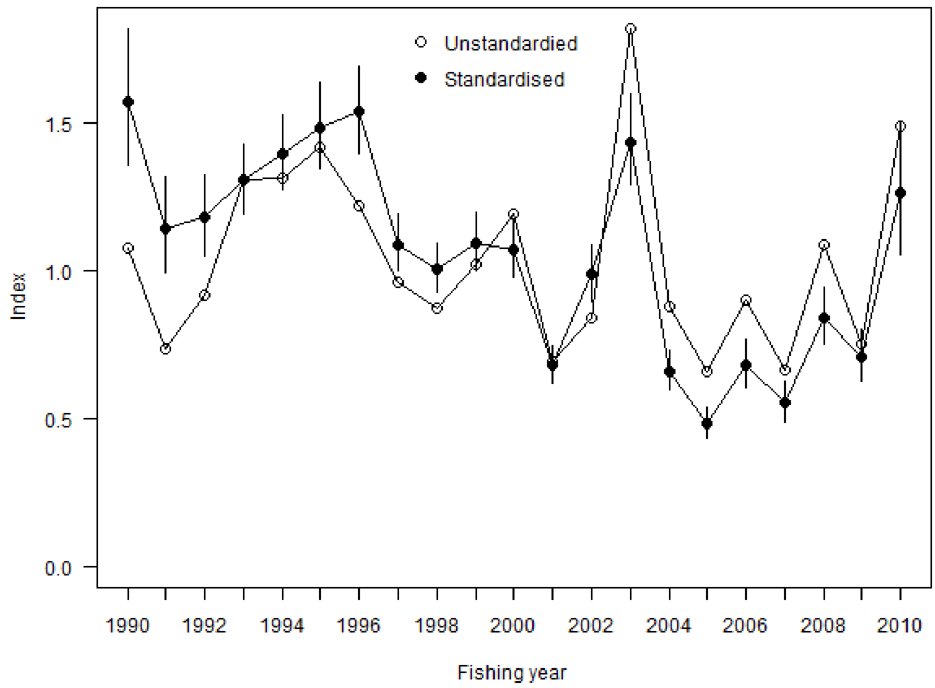



**Figure 28: Overall standardization effect of the model for the SPO1W_BT fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

## 3.4 Standardised CPUE in SPO 8

### 3.4.1 Setnet SPO8_SN

**Table 15: Summary of final lognormal model for the SPO8_SN fishery based on the vessel selection criteria of at least five trips per year in at least 4 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| fyear | 21 | 17 607 | 2.66 | 26 773 | * |
| vessel | 57 | 11 860 | 34.43 | 24 020 | * |
| target | 60 | 10 045 | 44.46 | 22 839 | * |
| poly(log(netlength), 3) | 63 | 8 981 | 50.35 | 22 045 | * |
| month | 74 | 8 706 | 51.87 | 21 845 | * |
| area | 77 | 8 537 | 52.80 | 21 710 | |
| poly(log(days), 3) | 80 | 8 487 | 53.08 | 21 674 | |
| poly(log(duration), 3) | 83 | 8 465 | 53.20 | 21 662 | |

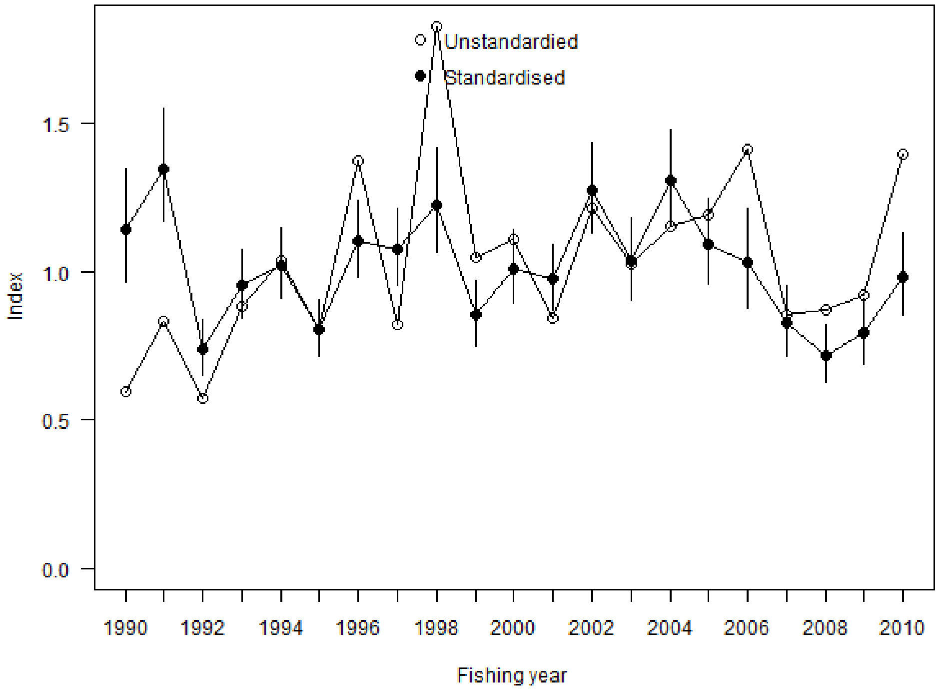



**Figure 29: Overall standardization effect of the model for the SPO8_SN fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

### 3.4.2 Bottom trawl SPO8_BT

**Table 16: Summary of final lognormal model for the SPO8_BT fishery based on the vessel selection criteria of at least five trips per year in at least 4 or more fishing years. Independent variables are listed in the order of acceptance to the model. DF: Degrees of freedom, AIC: Akaike Information Criterion, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.**

| Lognormal Term | DF | Deviance | Deviance explained (%) | AIC | Final |
|---|---|---|---|---|---|
| None | 0 | 10 856 | 0.00 | 18 335 | |
| fyear | 21 | 10 633 | 2.05 | 18 270 | * |
| vessel | 51 | 7 465 | 31.24 | 16 524 | * |
| poly(log(duration) 3) | 54 | 6 097 | 43.84 | 15 498 | * |
| month | 65 | 5 873 | 45.90 | 15 329 | * |
| target | 69 | 5 813 | 46.45 | 15 284 | |
| poly(log(num) 3) | 72 | 5 791 | 46.66 | 15 271 | |
| area | 75 | 5 783 | 46.73 | 15 270 | |

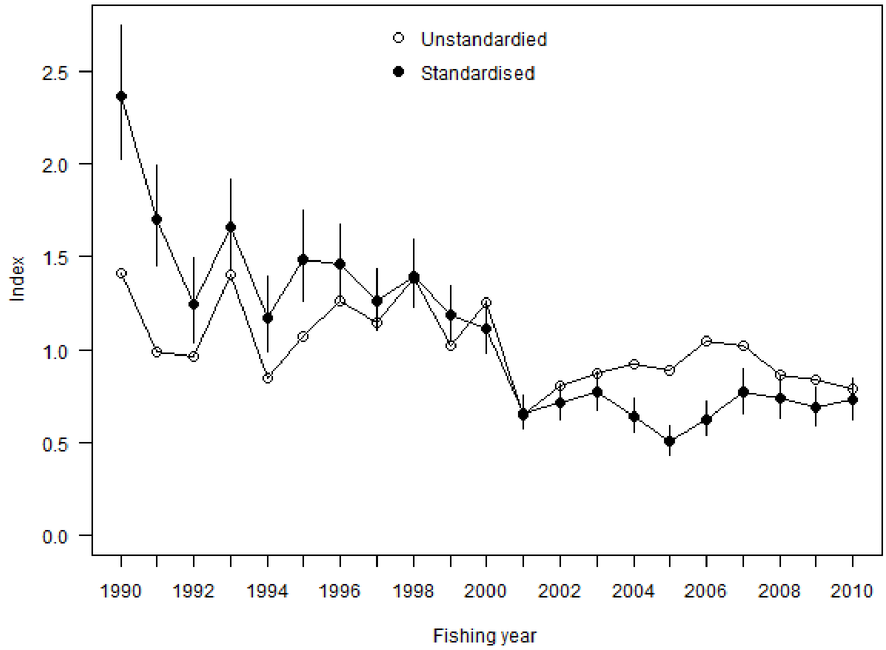



**Figure 30: Overall standardization effect of the model for the SPO8_BT fishery. The year effects from the lognormal model are shown ± 2 SE. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.**

## 3.5 Comparison of set net fisheries

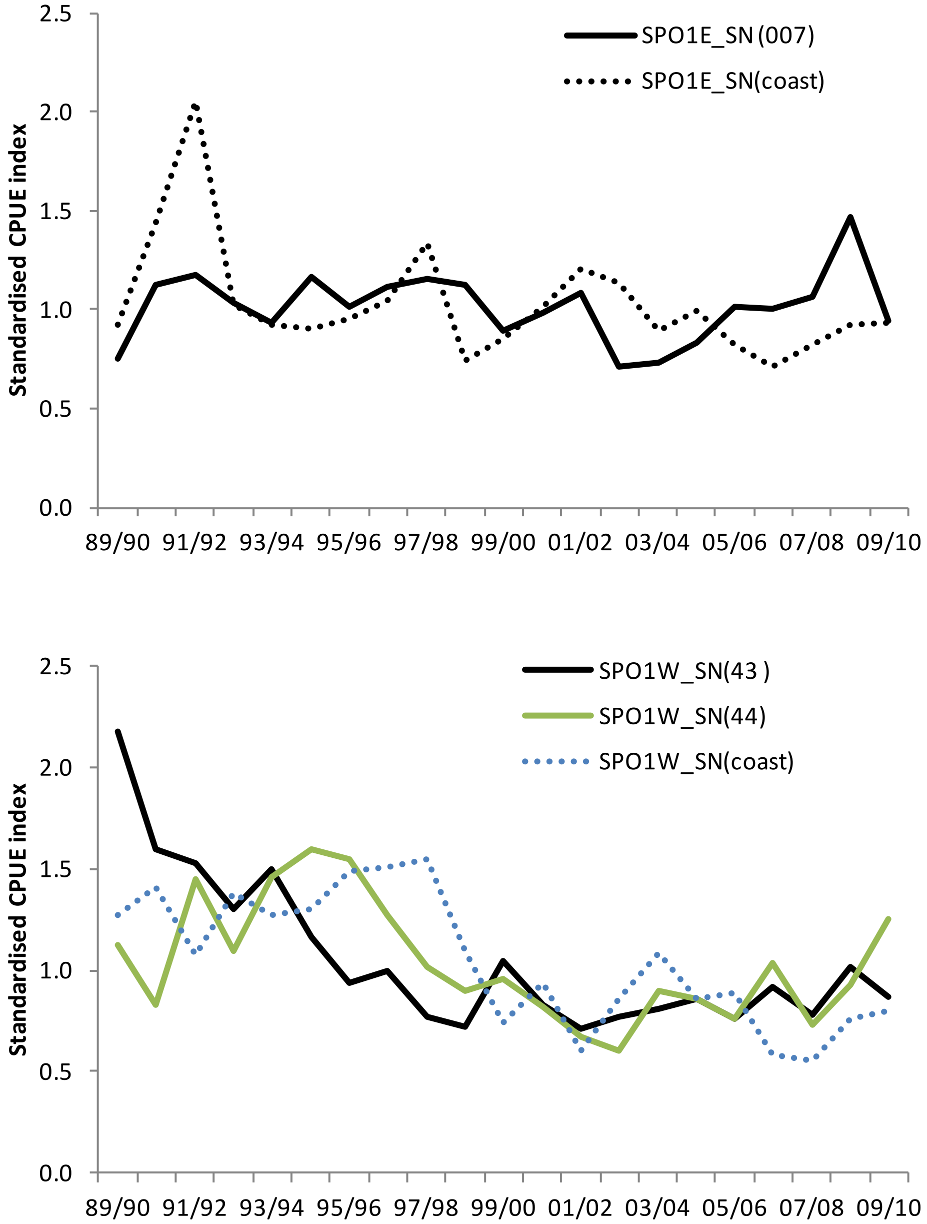
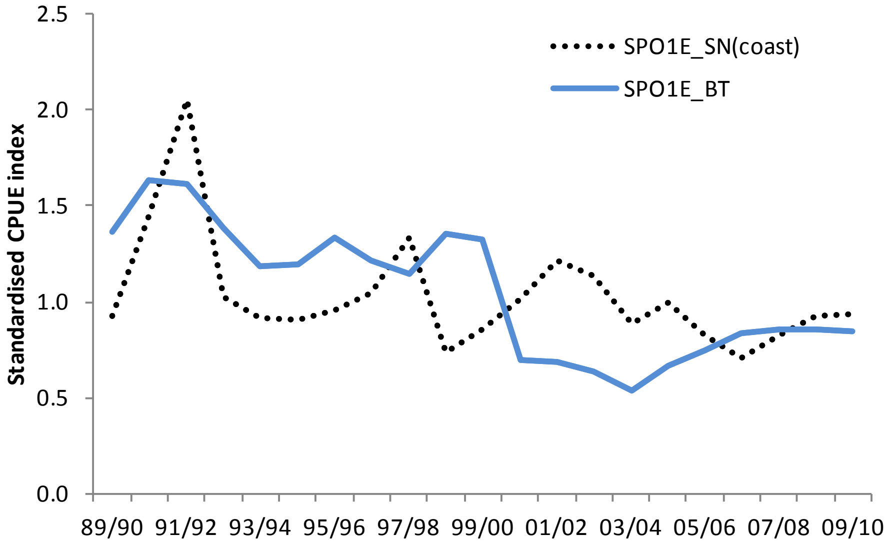
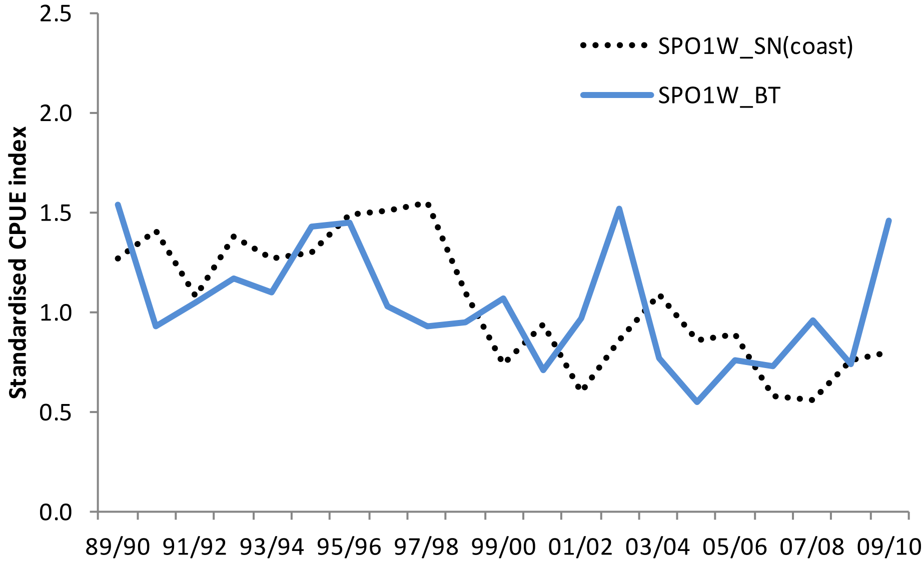



**Figure 31: Comparison of standardised CPUE indices for set net fisheries within each substock of SPO 1; SPO 1 East [upper panel], and SPO 1 West [lower panel].**

## 3.6 Comparison across fishing methods



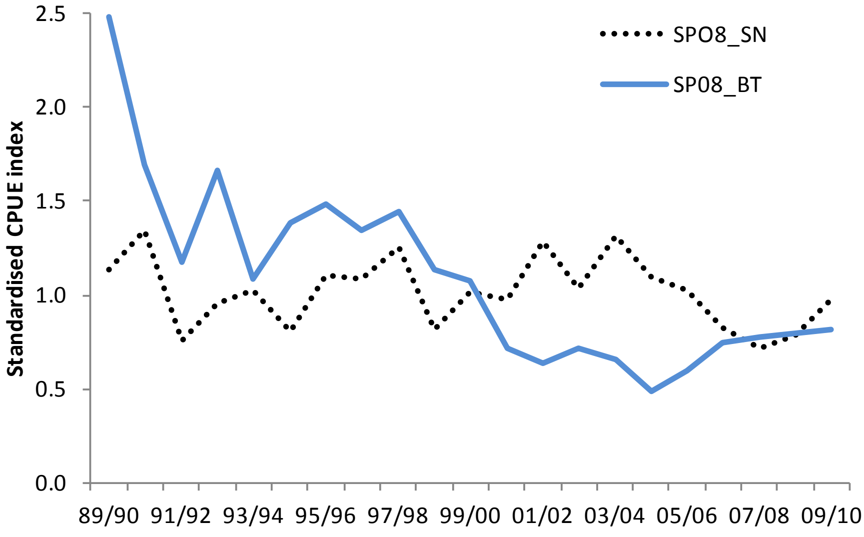




**Figure 32: Comparison of standardised CPUE indices for coastal set net and trawl fisheries in each substock; SPO 1 West [top], SPO 1 East [centre], and SPO 8 [bottom]. The set net indices are based on adjusted estimated catches and the bottom trawl indices are based on allocated landed catches.**

# 4 DISCUSSION

Catch and effort recorded for rig fishing in New Zealand is plagued with problems that have been methodically worked through over many iterations and analyses of rig stocks. Estimated catch is compromised by under reporting when rig is a bycatch species, and, because it spoils quickly and is therefore generally trunked as soon as possible, by the common mistake of recording processed weight rather than green weight. In the Northland set net fisheries, a poor understanding of the form also led to false zero catches being recorded for a period in the 1990s, particularly when the target species comprised the entire catch. The allocation of landed catch goes some way towards solving these issues but still requires that the systematic errors in estimated catches be corrected. Landed catch is also compromised by changes to conversion factors that have been used to back-estimate greenweight, and, in the Northland set net fisheries, by a developing trend of holding catch ashore for selling at a later date. The destination "Q" landings break the link between catch and effort and renders allocated landings unreliable for calculating CPUE. Initial work presented to the Working Group was therefore done using estimated catches, which the Working Group agreed was a reasonable decision, but unlikely to yield acceptable indices. Additional work was requested to investigate methods for correcting the estimated catches based on annual total landings.

The adjustment proposed in this study for correcting estimated catches has considerable promise and has been adopted in the analysis of rock lobster CPUE for dealing with the similar " holding pot problem". However, in the set net fisheries of Northland, the effect of the proposed adjustment on annual indices was not great (See Appendix G), and did not result in marked smoothing of the trajectories. Most of them remain spiky and unconvincing as indices of underlying abundance. Poor correlation between landed weights from the bottom part of the catch effort form, and that reported to the QMS in the 1990s also reduces the credibility of the procedure. There may be a wider acceptance of the "adjusted catches" if the range of ratio was narrowed so that records included in the analyses were those in which either the greenweight (ratio centred tightly on 1.0) or the processed weight (ratio centred tightly on 1.5) had been consistently and accurately reported. This would be more of a selection than a correction procedure and would need to be accompanied by a characterisation of reporting practice that demonstrates that these "good estimators" are reasonably representative of the fishery.

Initial exploratory work for this project included residual diagnostics for alternative analyses done at QMA level that showed similar annual and seasonal effects among areas, and supported monitoring the stock at that scale. However, the Working Group felt that as set net fishers tended to operate at the scale of individual harbours, the fisheries should continue to be monitored at that scale. Residual diagnostics for the analyses presented here show no marked contradictory trends for constituent statistical areas (See Appendix D).

The two east coast set net series show no trend, and the three west coast set net series all decline during the late 1990s to new levels below the mean for the series at which they have been relatively stable through the 2000s. An early divergence in trends for the two main harbours on the west coast was not maintained, and they have tracked each other closely for the later part of the study period (Figure 31).

The trawl series are better determined, but trawl is not likely to adequately sample the entire population of rig as large fish are thought to be able to avoid the net. The series may be useful for indexing the abundance of juveniles, and there are precedents in other rig Fishstocks for using trawl to monitor part of the population. All three trawl series decline to their lowest level in the early 2000s, but show some subsequent recovery. When compared to the coastal set net series for the relevant QMA it is possible to see similarities with a lag of between one and two years separating them (Figure 32).

There is a general pattern of catch rates in the 2000s being lower than those in the 1990s, with a disturbingly abrupt delineation between the two periods that may indicate the effect of other factors that are not being standardised for. There have been regime shifts associated with a shift in reporting of trawl catch effort in the mid 1990s, and with the closures of some coastal habitat to set net in the early 2000s that will have had both tangible and intangible effects on both fisher behaviour and the population dynamics of rig, that may be beyond the resolution of the CELR form to describe.

**The NINS Working Group concluded:**

The standardised CPUE analyses for the set-net fisheries in SPO 1 were rejected with further detailed investigation of the new methodology required before acceptance.

CPUE standardisations based on SPO 1 bottom trawl data were accepted as indices of abundance Bottom trawl did not exhibit the behaviour of landing to temporary holding receptacles that is problematic for set net, however catches are likely to be comprised of sub-adult fish in contrast to set-net catches which consist mainly of adults.

The SPO 8 landing data, regardless of the method of capture, also did not exhibit the behaviour of landing to temporary holding receptacles. Consequently, the NINSWG accepted the standardized set net CPUE for SPO 8, which fluctuated without trend with recent indices near the long-term average.

The SPO 8 bottom trawl CPUE indices were not considered to be reliable as they were based on very small data sets.

## 5 ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries as project SPO2010-01. Thanks to members of the Northern Inshore Stock Assessment Working Group, in particular Paul Starr and Malcolm Francis, for helpful advice and suggestions.

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## APPENDIX A CORE FLEET SELECTION

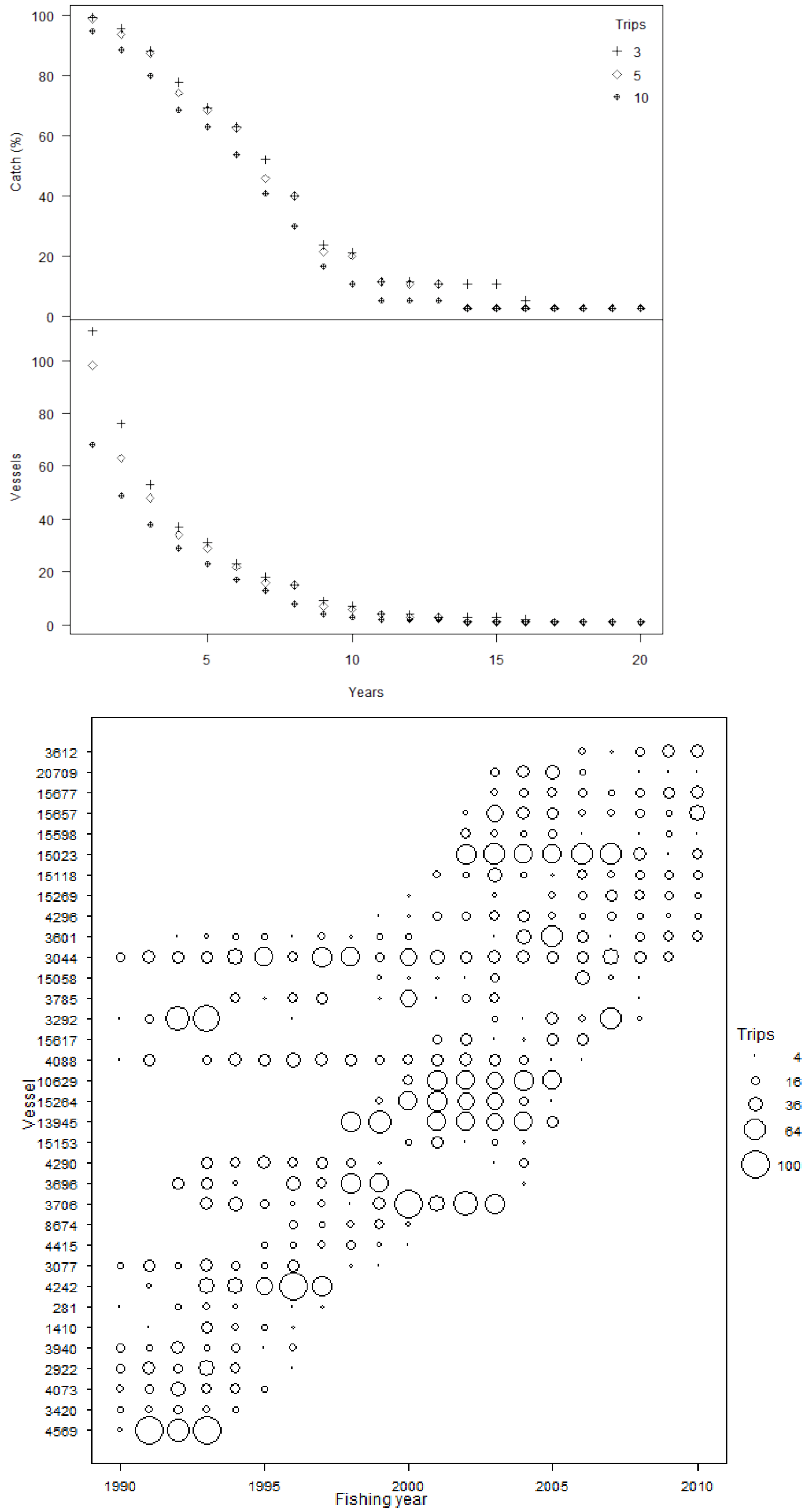



**Figure A1: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO1E_SN(007) dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least five trips per year in at least four years); number of trips for each vessel in each fishing year [bottom].**

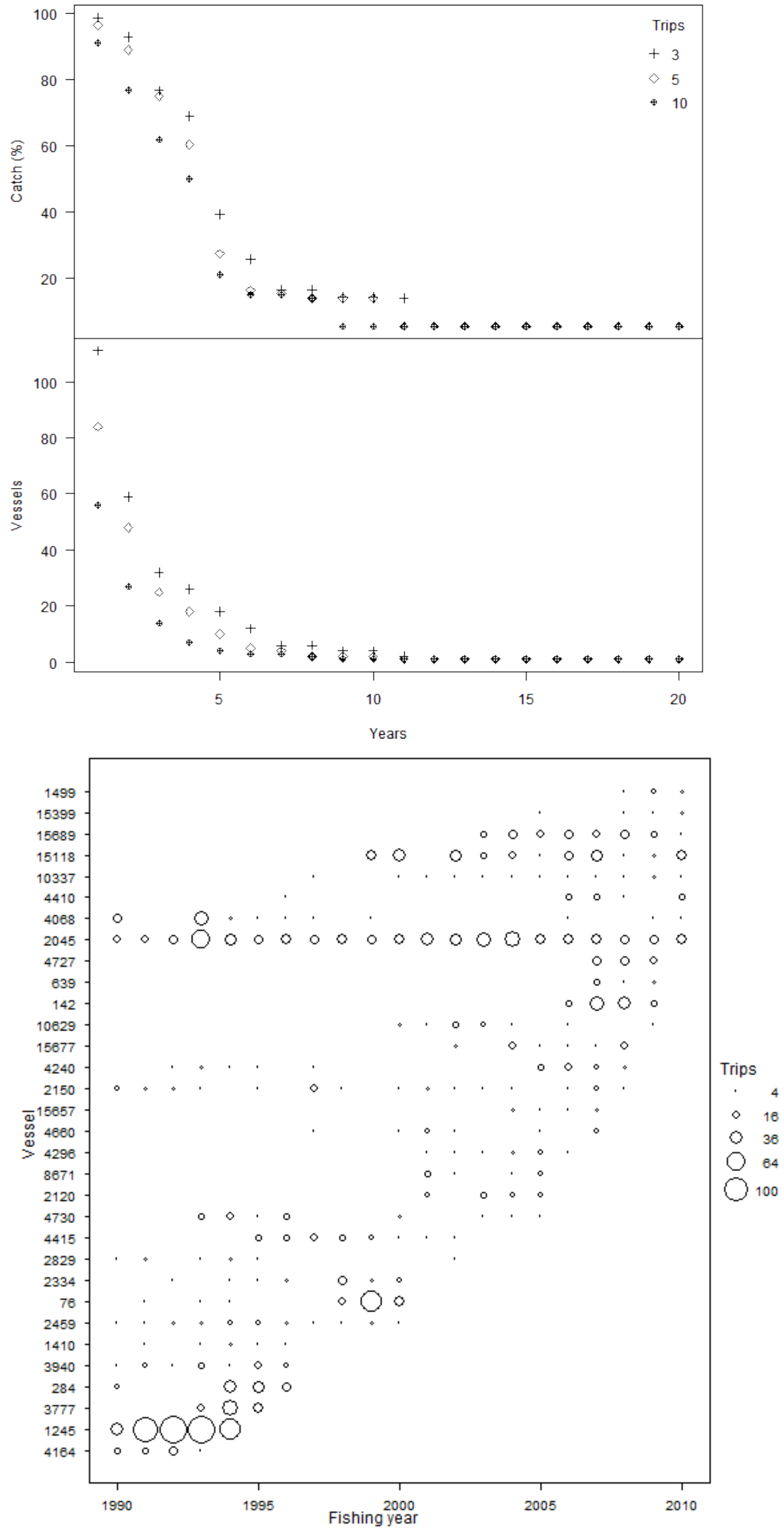



**Figure A2: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO1E_SN(coast) dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least three trips per year in at least three years); number of trips for each vessel in each fishing year [bottom].**

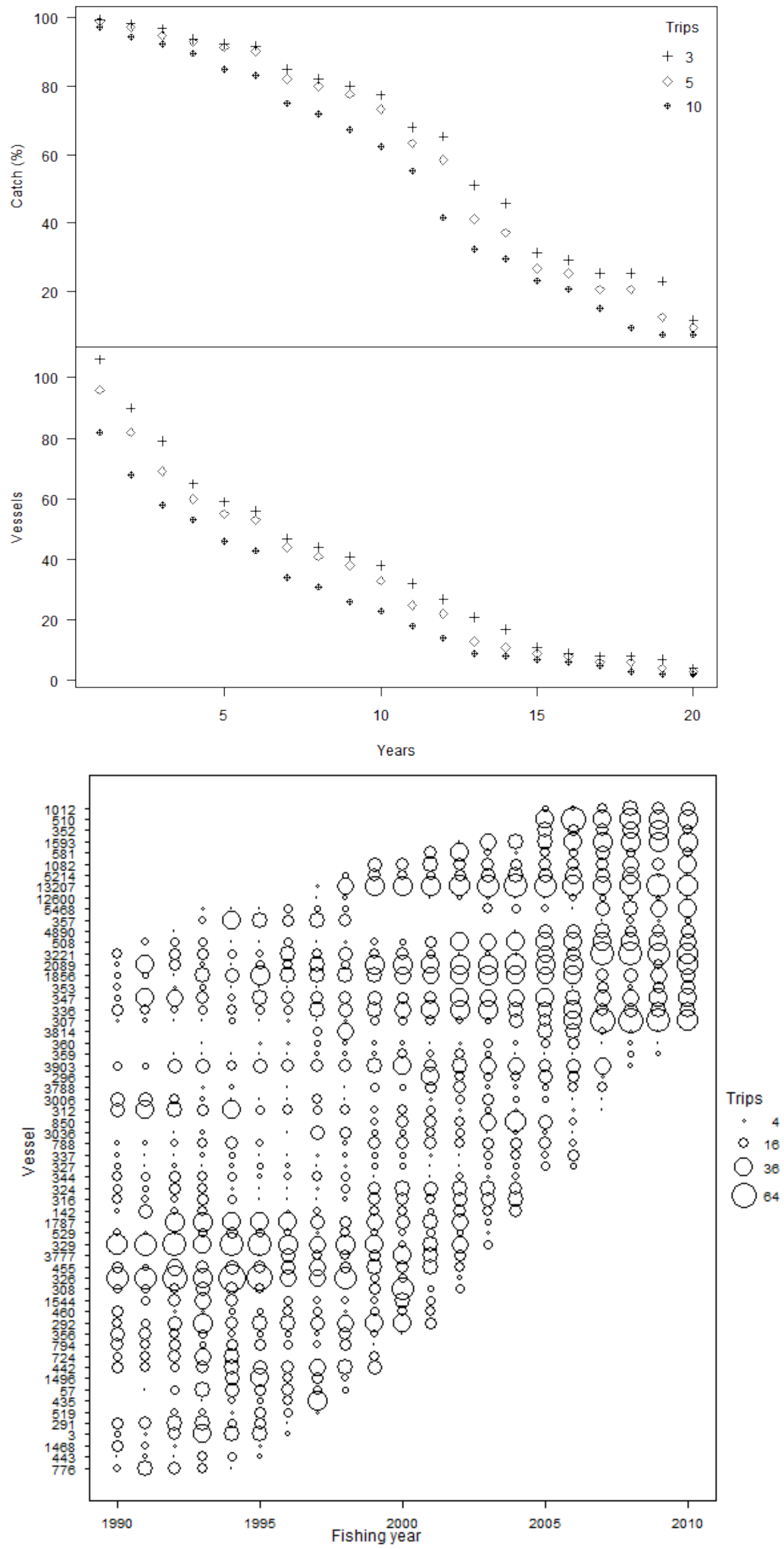



**Figure A3: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO1E_BT dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least five trips per year in at least four years); number of trips for each vessel in each fishing year [bottom].**

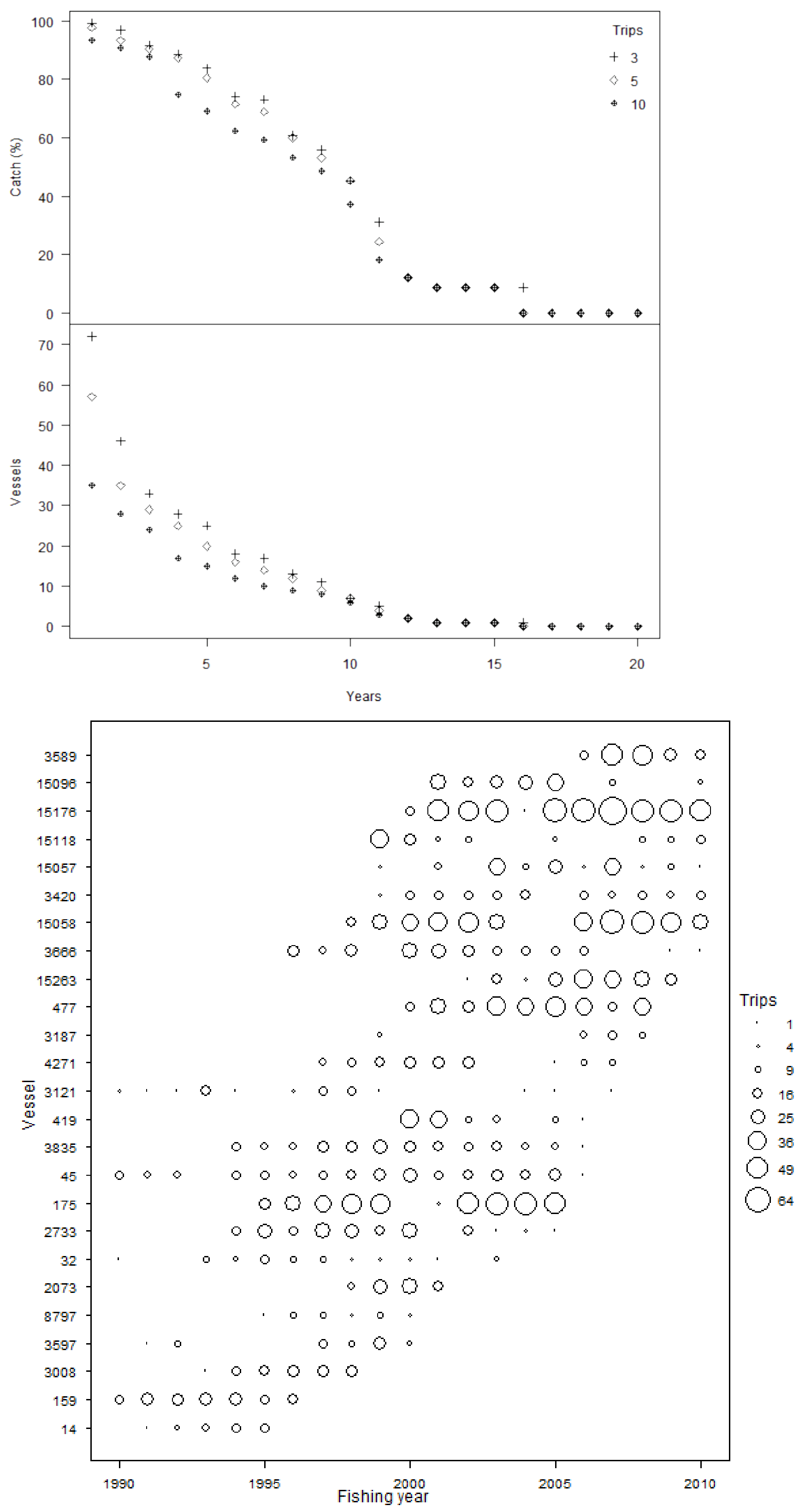



**Figure A4: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO1W_SN(044) dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least five trips per year in at least four years); number of trips for each vessel in each fishing year [bottom].**

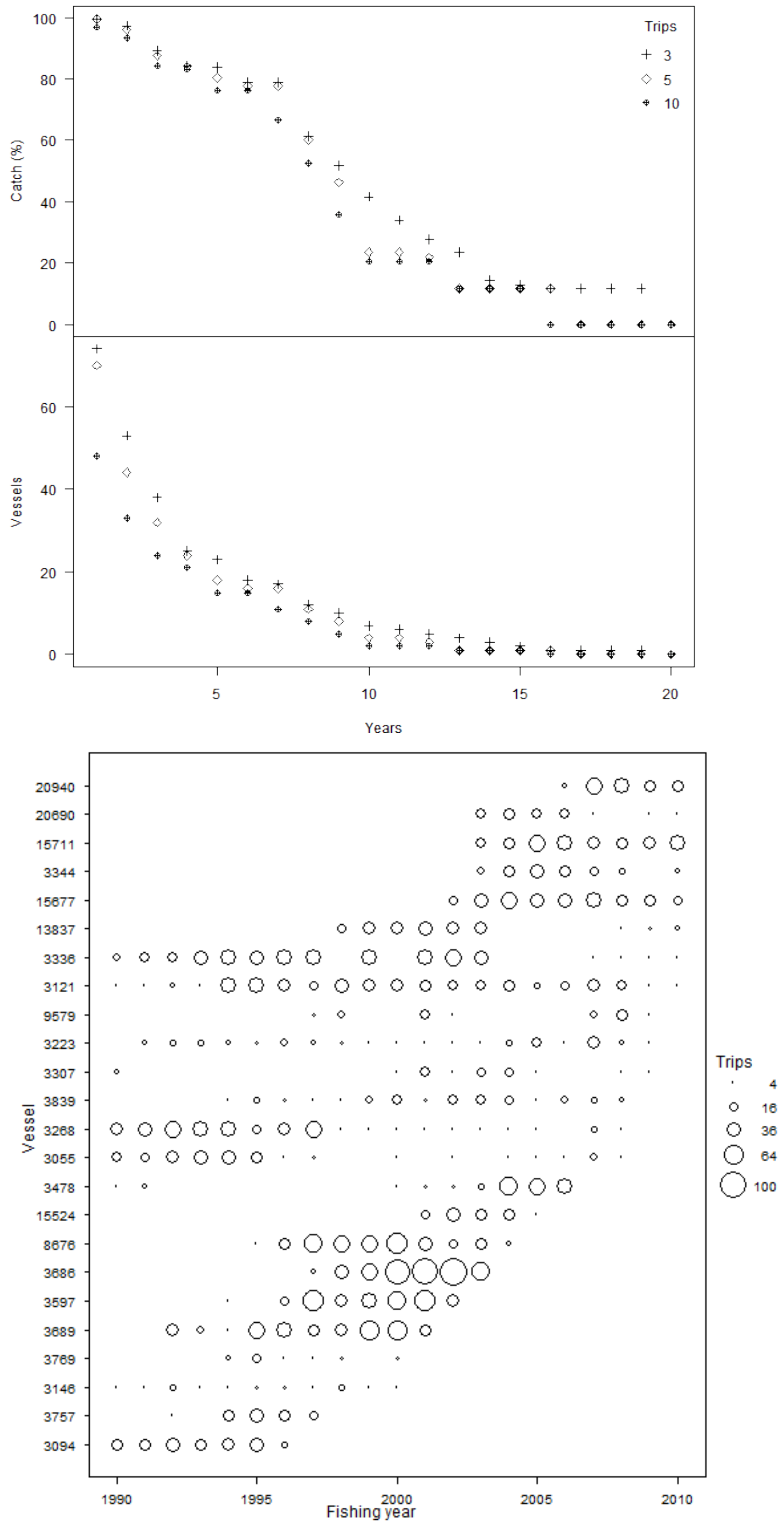



**Figure A5: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO1W_SN(043) dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least five trips per year in at least four years); number of trips for each vessel in each fishing year [bottom].**

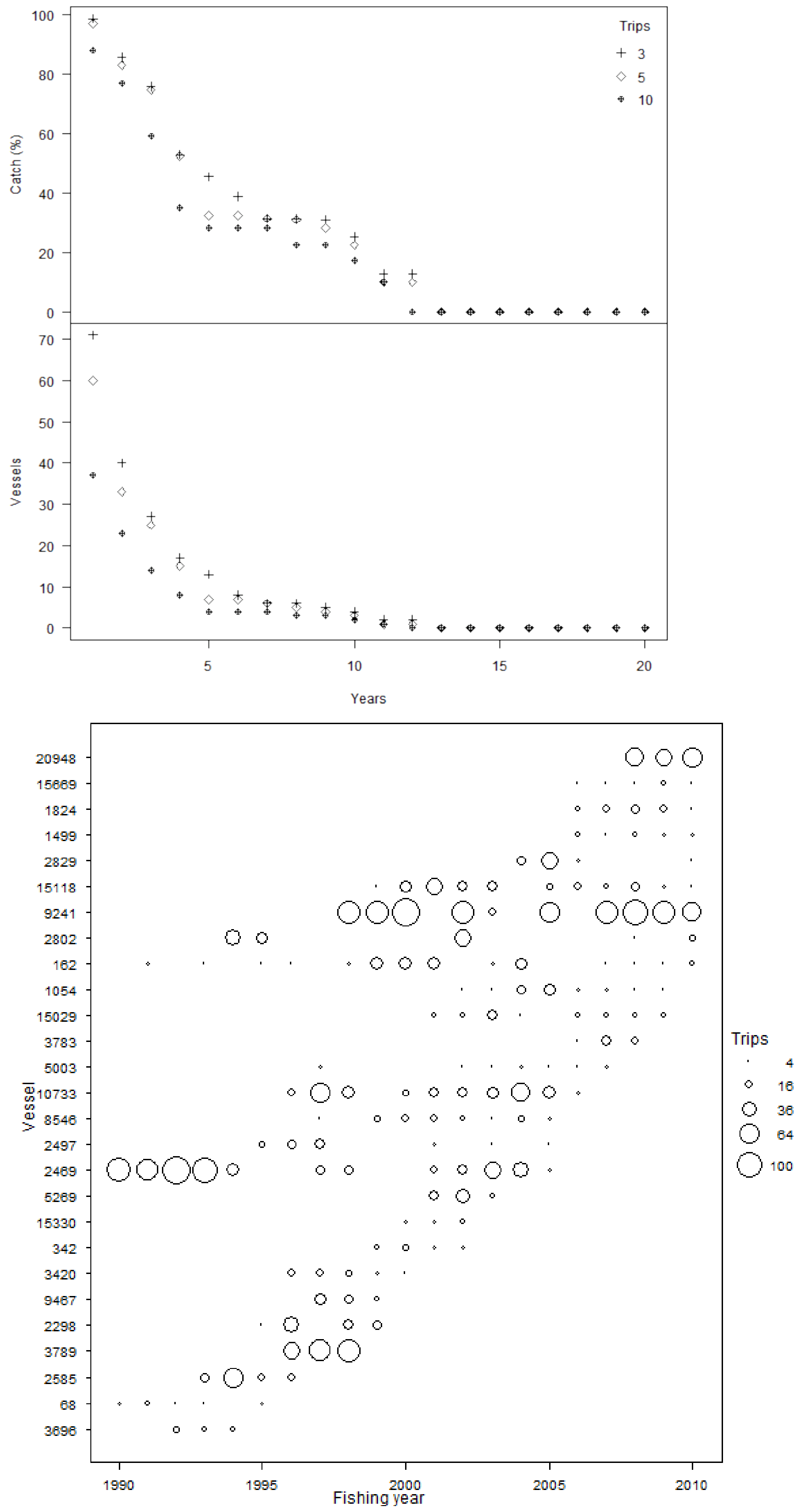



**Figure A6: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO1W_SN(coast) dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least three trips per year in at least three years); number of trips for each vessel in each fishing year [bottom].**

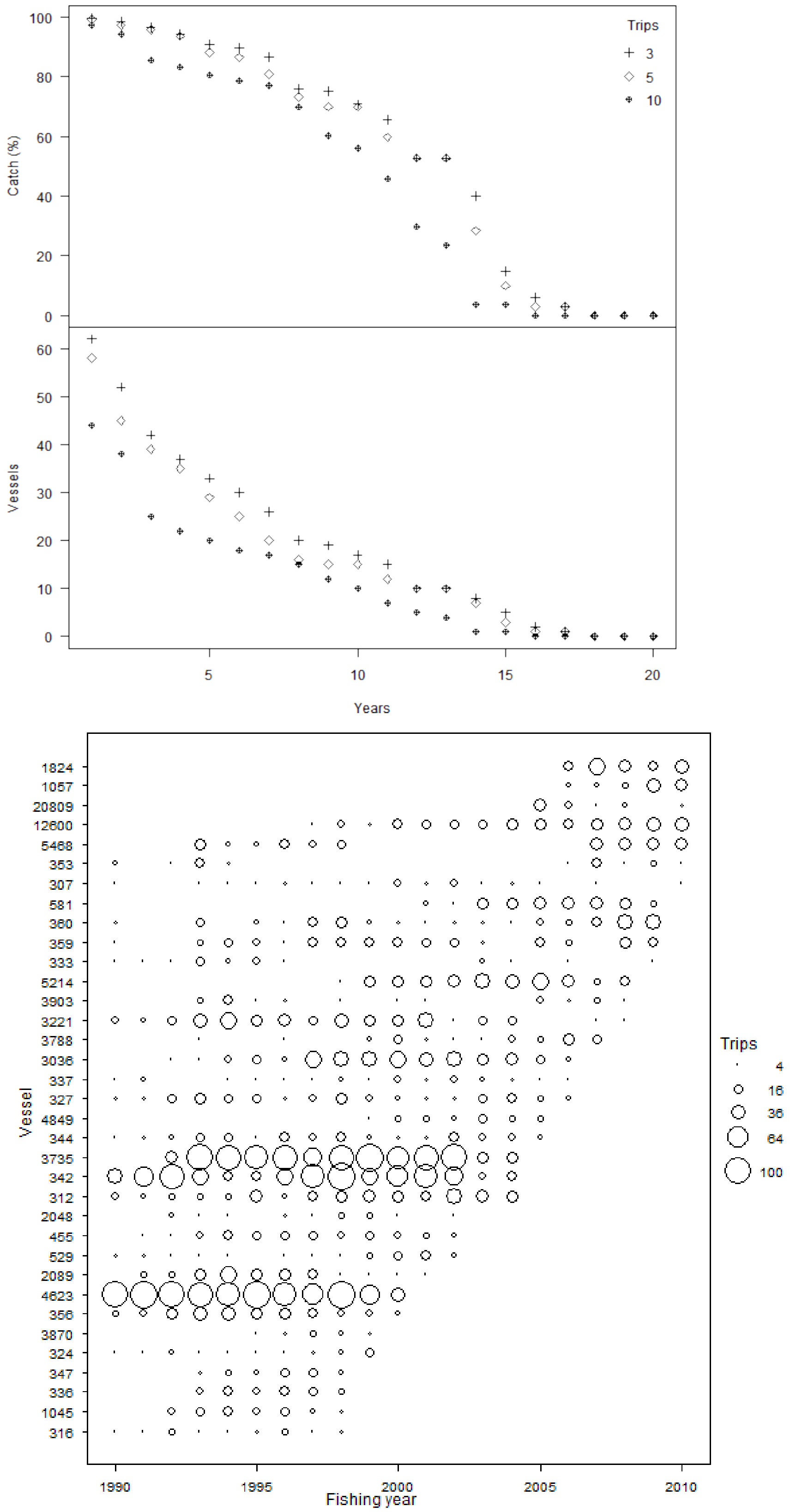



**Figure A7: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO1W_BT dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least five trips per year in at least four years); number of trips for each vessel in each fishing year [bottom].**

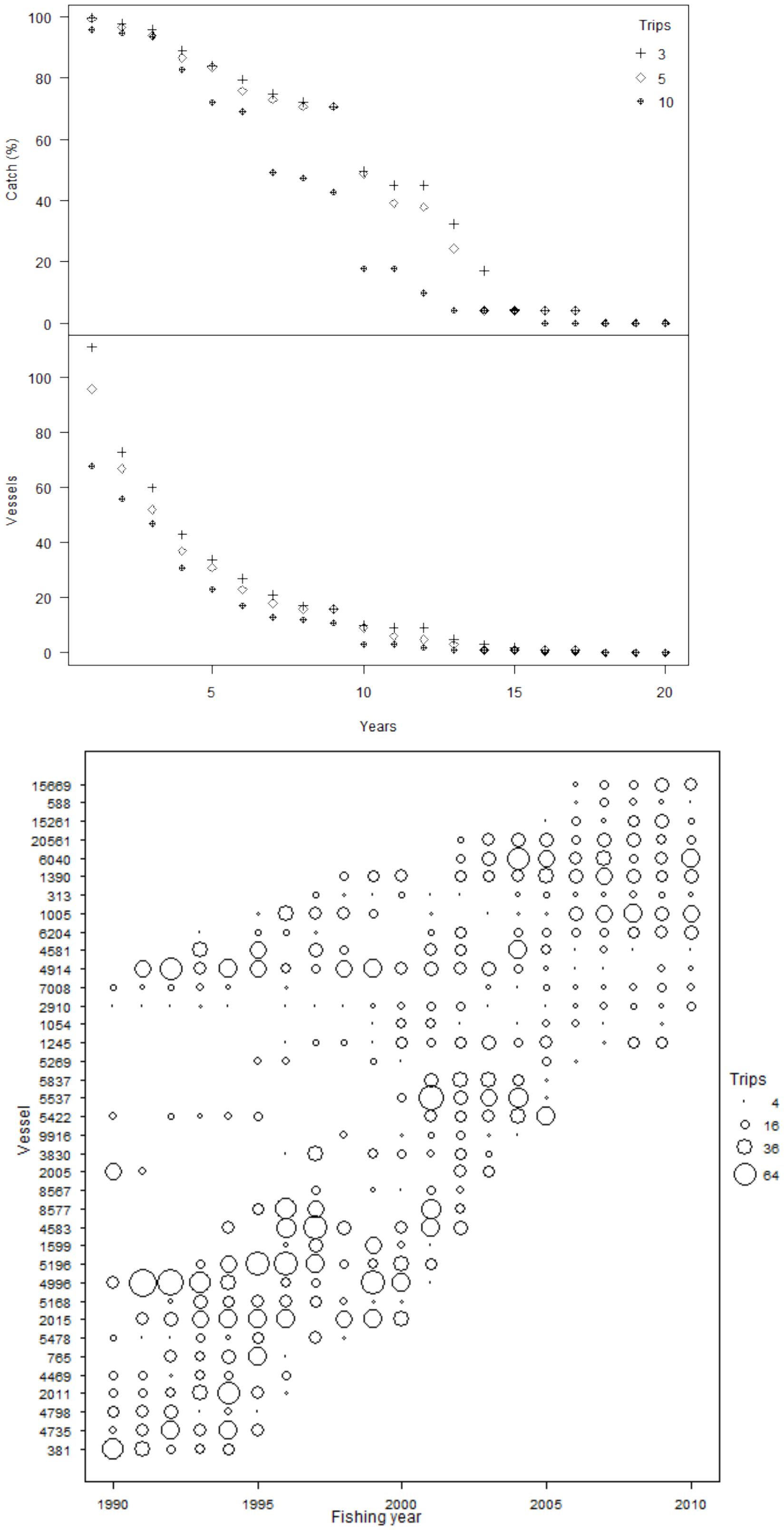



**Figure A8: The total landed catch (t) [top] and the number of vessels [middle] retained in the SPO8_SN dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least five trips per year in at least four years); number of trips for each vessel in each fishing year [bottom].**

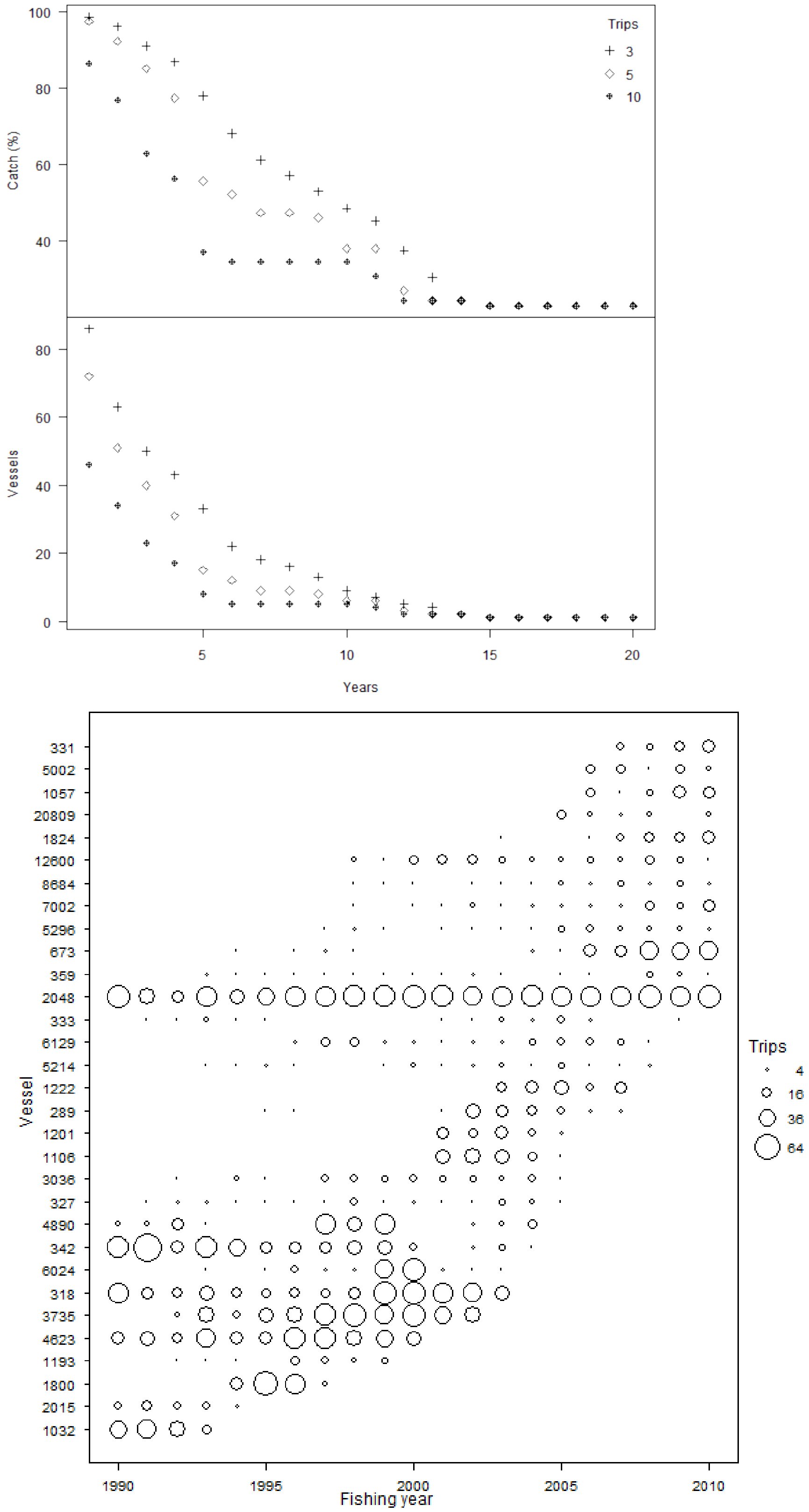



**Figure A9: The total landed catch (t) [top] and the number of vessels [bottom] retained in the SPO8_BT dataset depending on the minimum number of trips per year used to define a qualifying year and the number of qualifying years used to define core vessels. The participation of selected core vessels (based on at least five trips per year in at least four years); number of trips for each vessel in each fishing year [bottom].**

## APPENDIX B  COEFFICIENT- DISTRIBUTION-INFLUENCE PLOTS

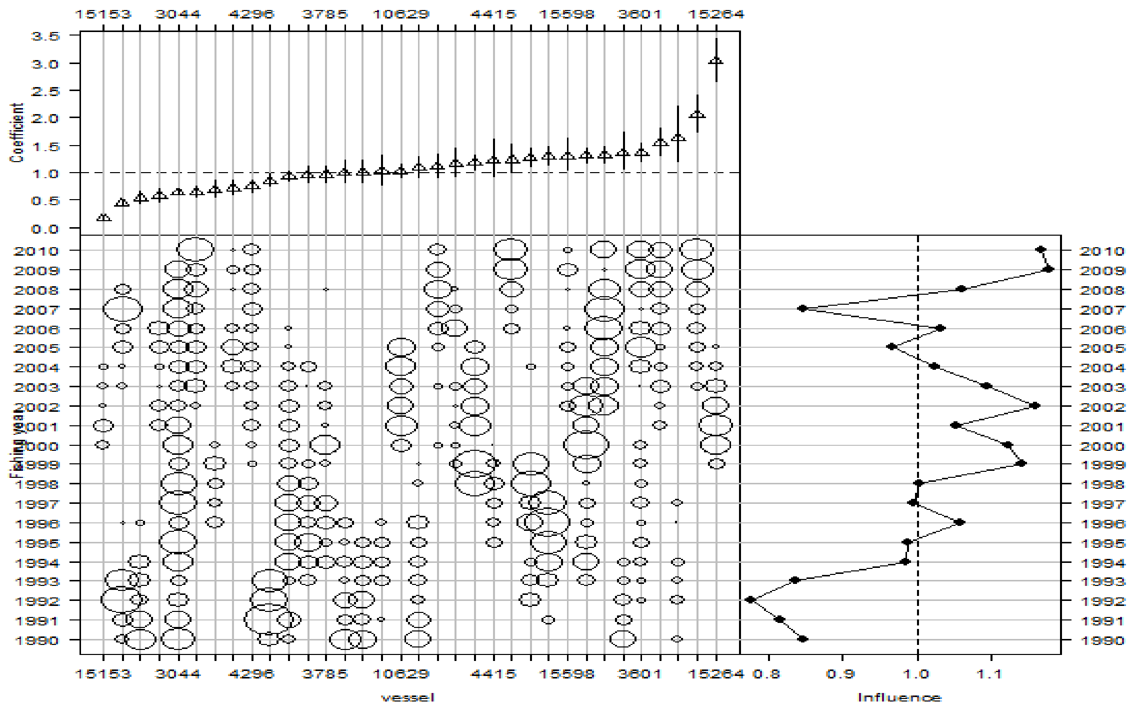



**Figure B1: Effect and influence of *vessel* in the SPO1E_SN (007) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

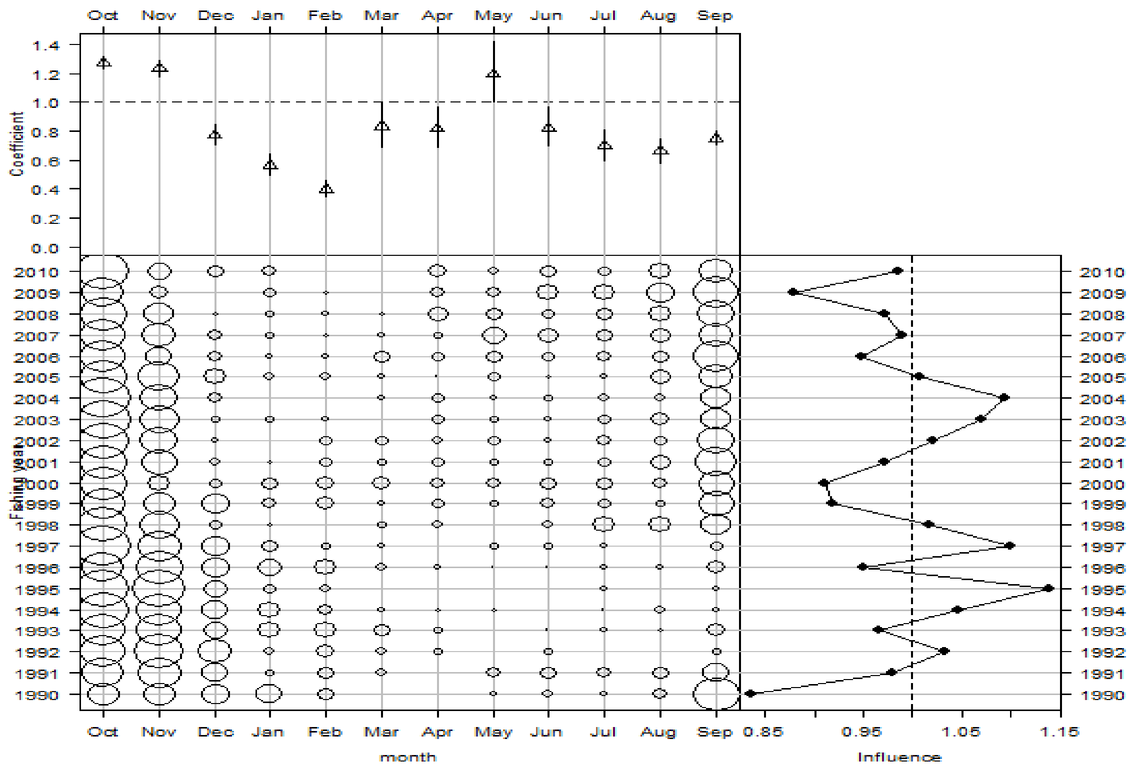



**Figure B2: Effect and influence of *month* in the SPO1E_SN (007) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

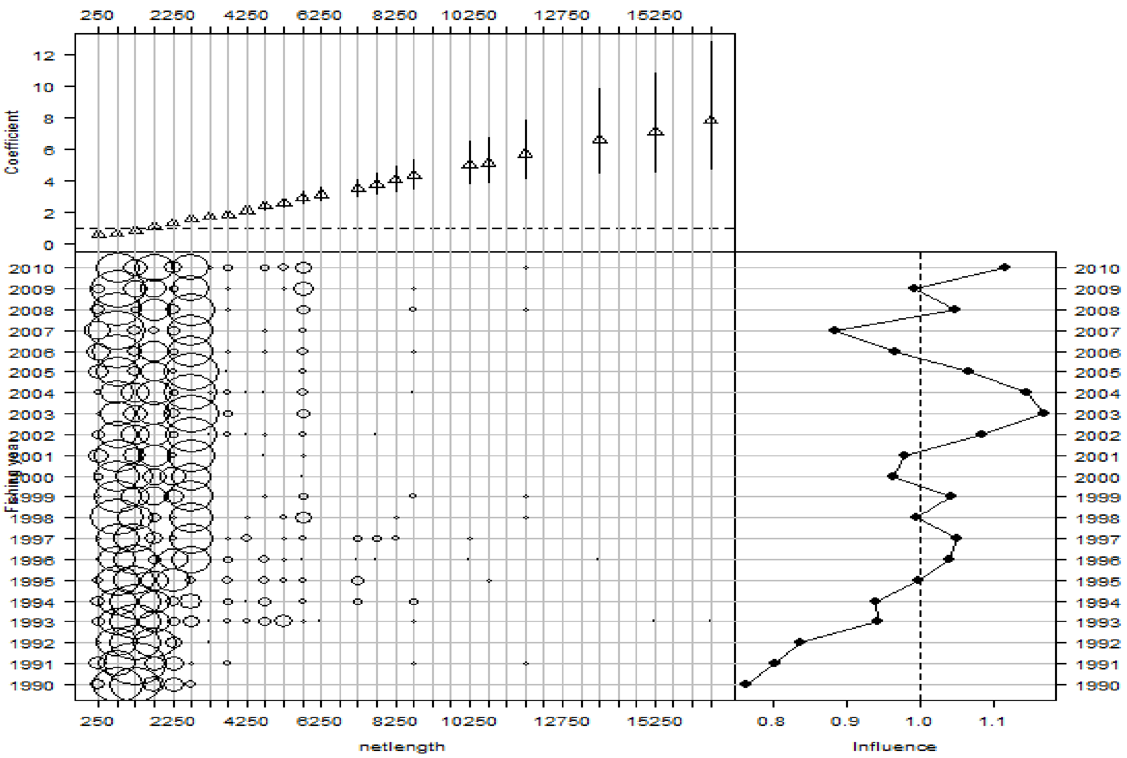



**Figure B3: Effect and influence of *netlength* in the SPO1E_SN (007) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

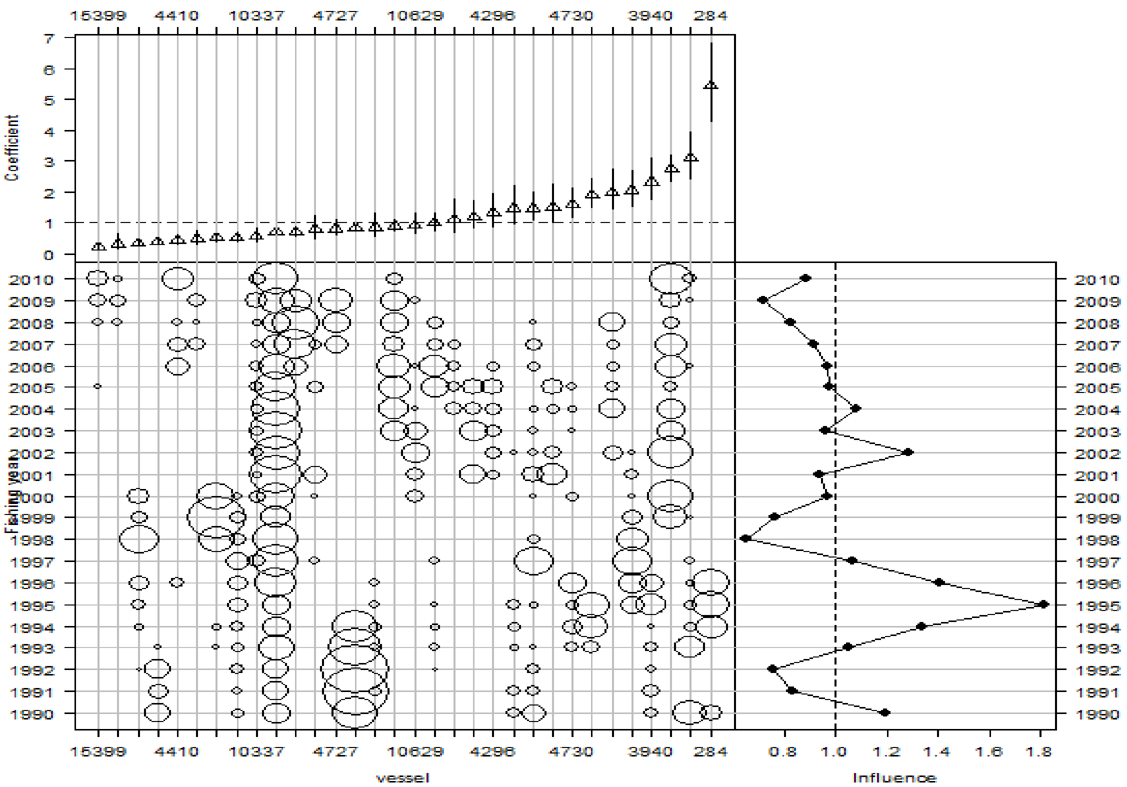



**Figure B4: Effect and influence of *vessel* in the SPO1E_SN (coast) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

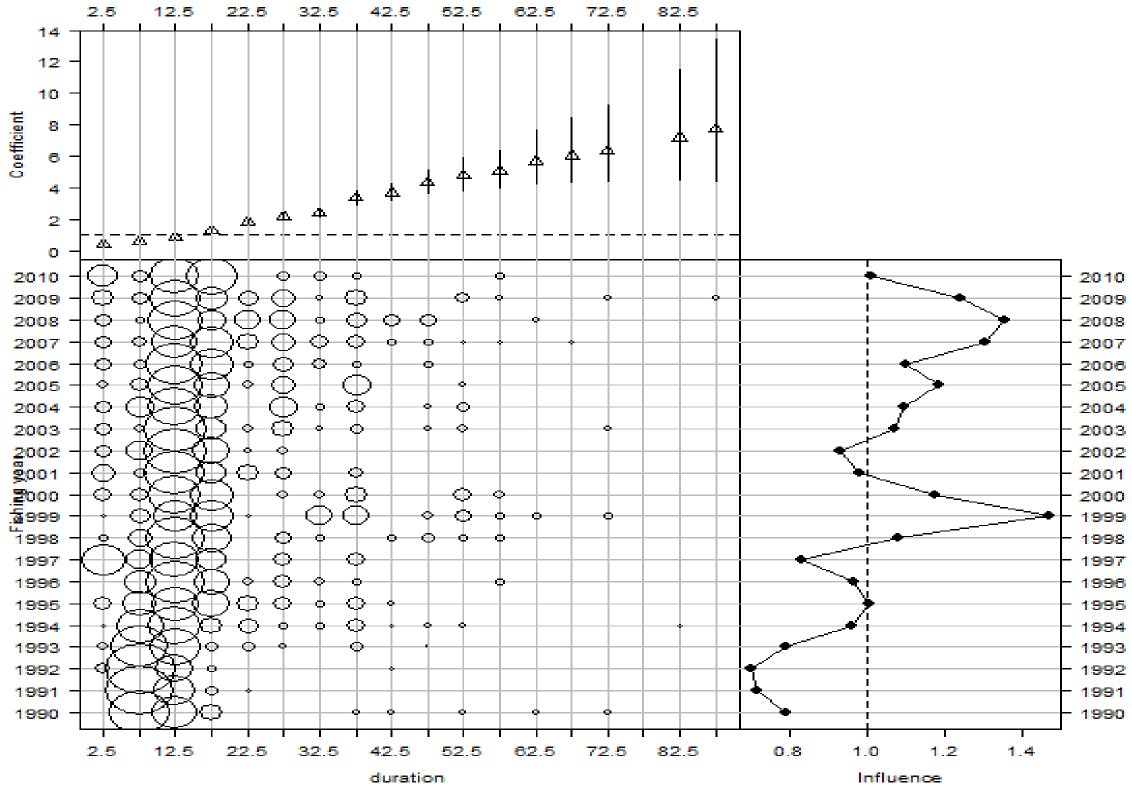



**Figure B5: Effect and influence of *duration* in the SPO1E_SN (coast) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

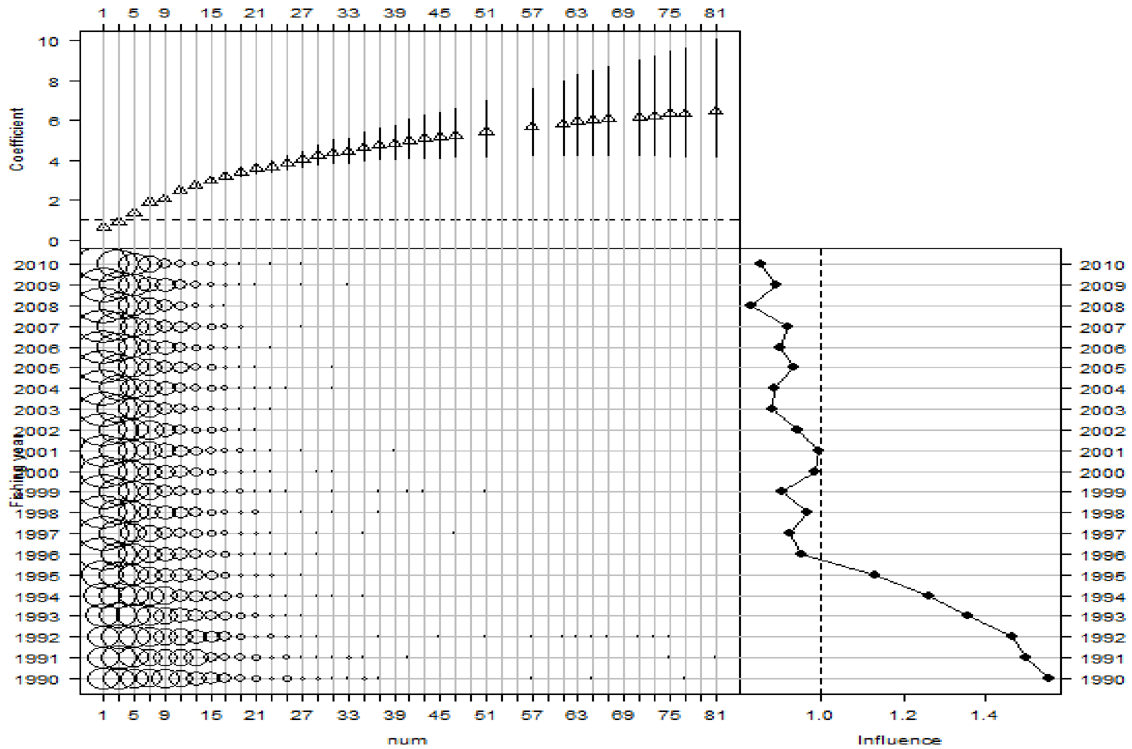



**Figure B6: Effect and influence of *tows* in the SPO1E_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

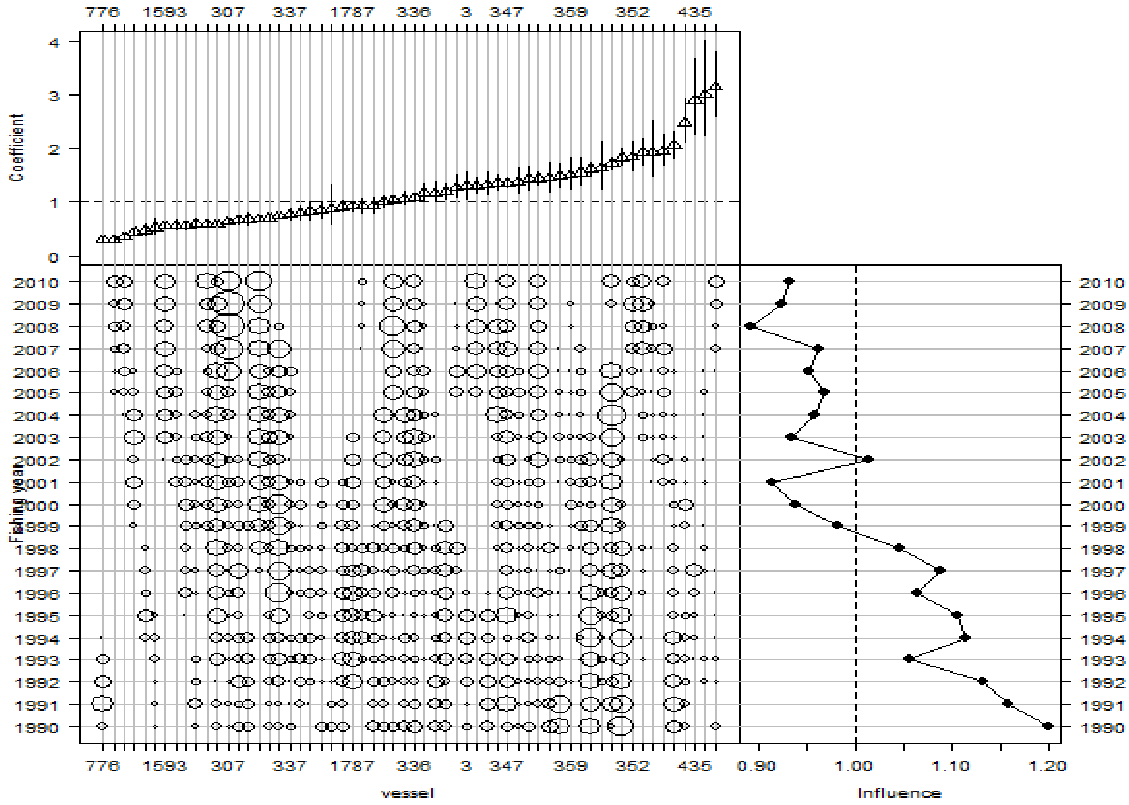



**Figure B7: Effect and influence of *vessel* in the SPO1E_BT (coast) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

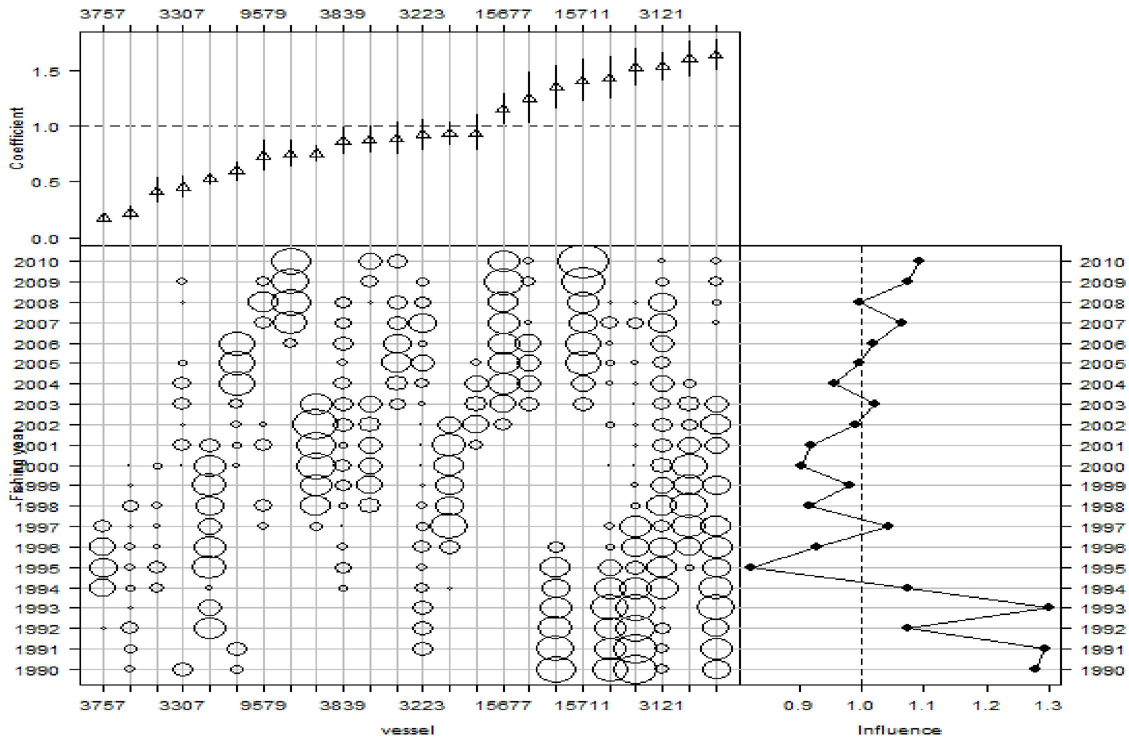



**Figure B8: Effect and influence of *vessel* in the SPO1W_SN (043) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

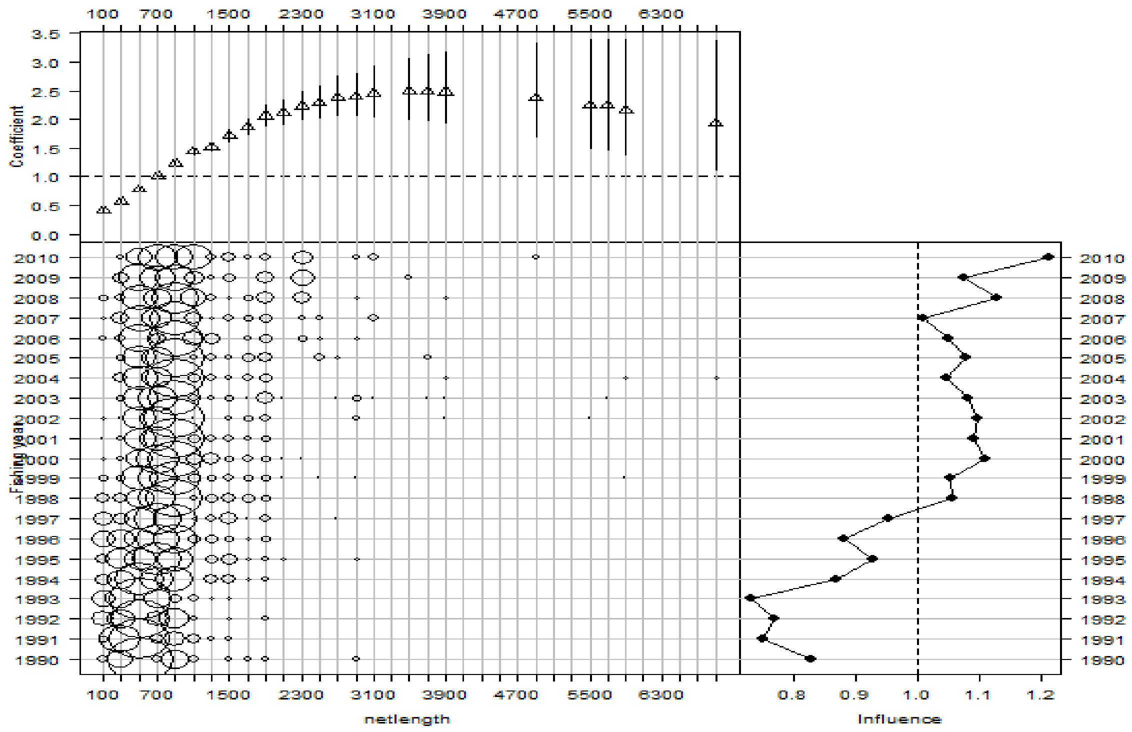



**Figure B9: Effect and influence of *netlength* in the SPO1W_SN (043) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

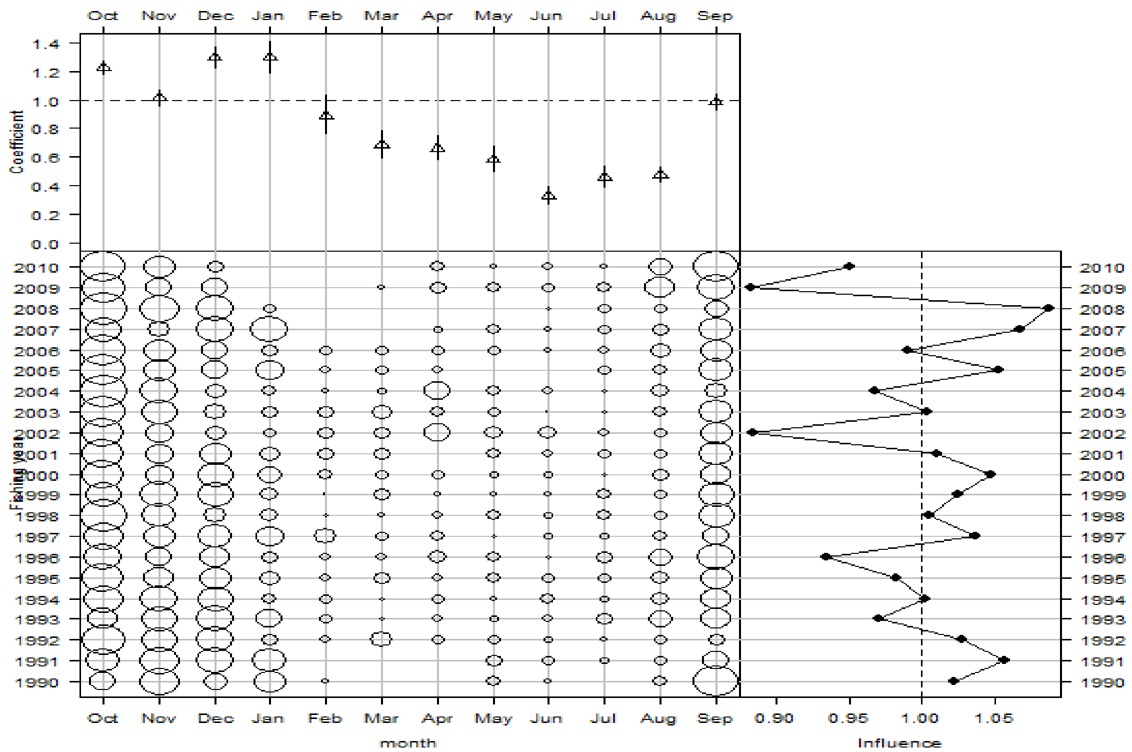



**Figure B10: Effect and influence of *month* in the SPO1W_SN (043) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

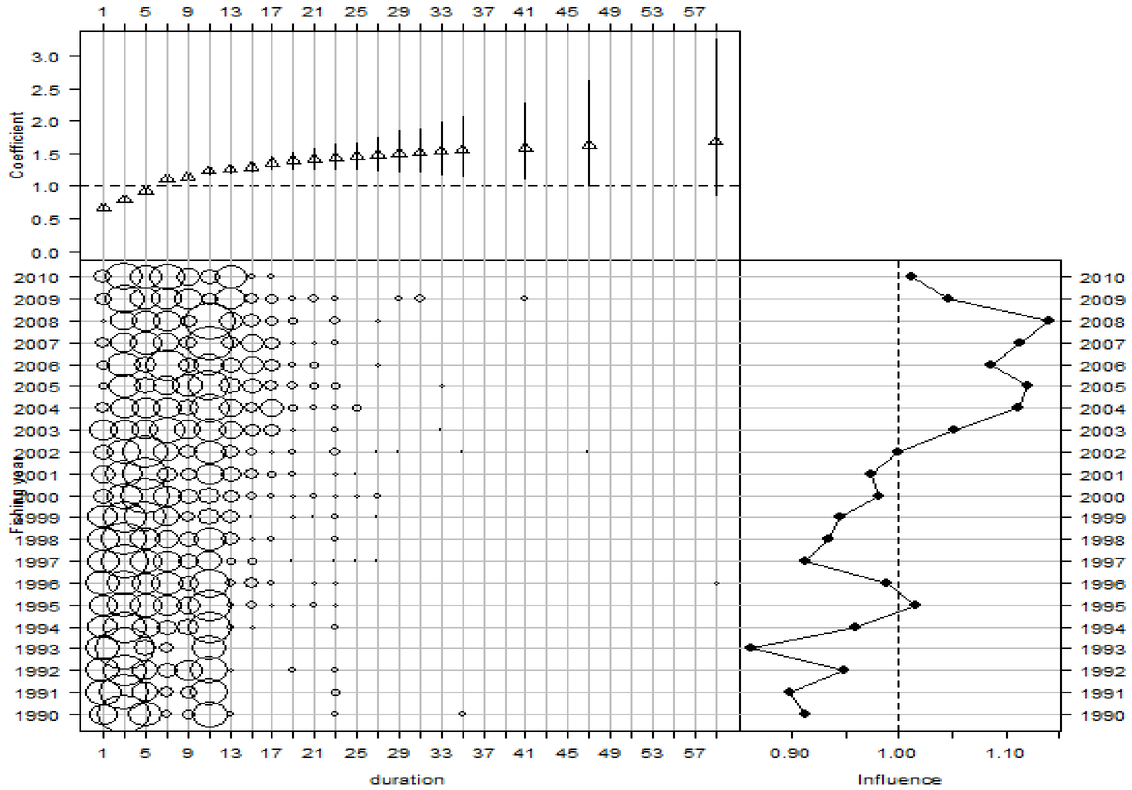



**Figure B11: Effect and influence of *duration* in the SPO1W_SN (043) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

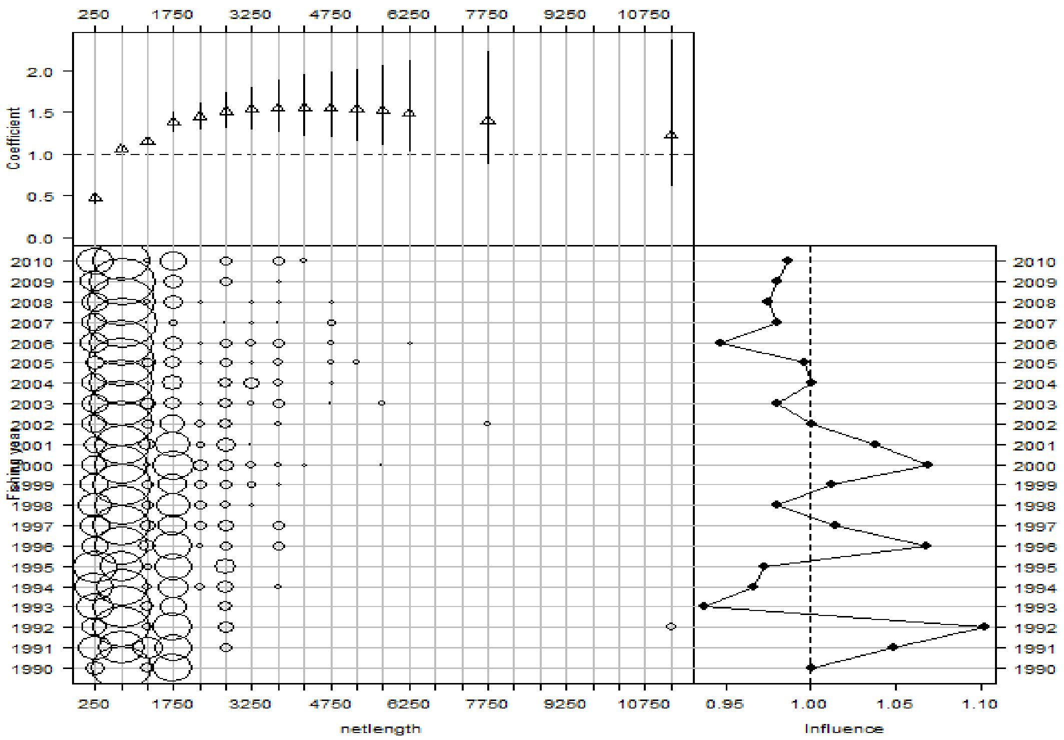



**Figure B12: Effect and influence of *netlength* in the SPO1W_SN (044) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

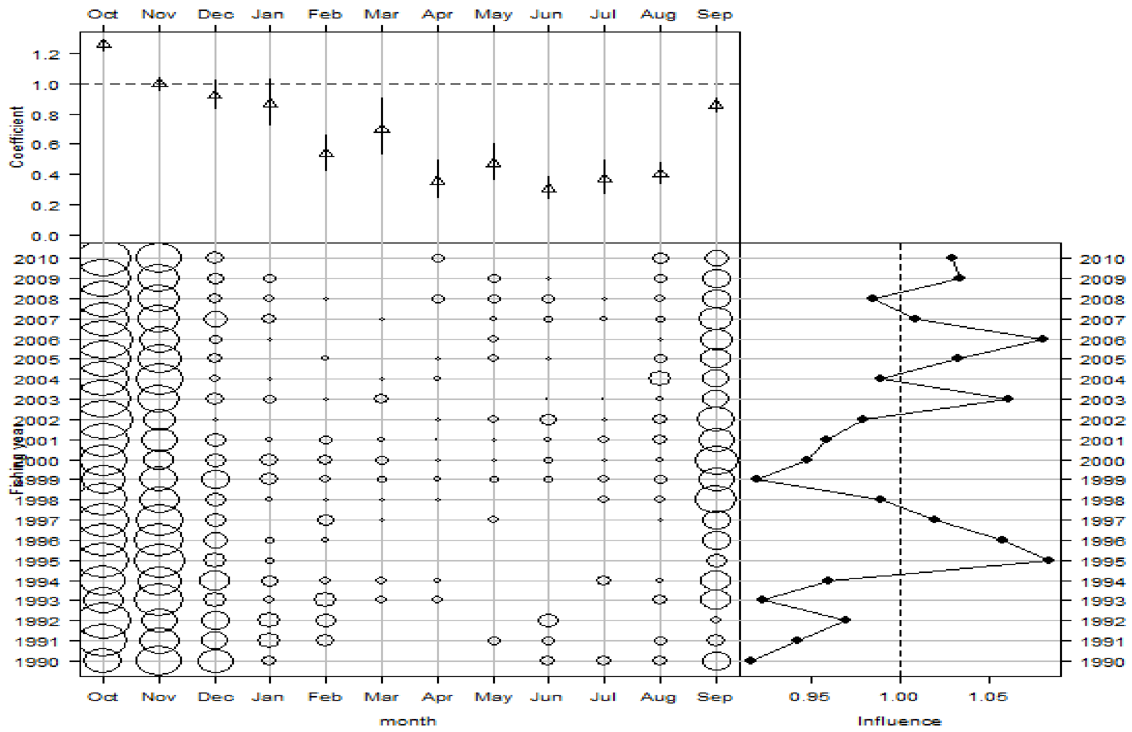



**Figure B13: Effect and influence of *month* in the SPO1W_SN (044) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

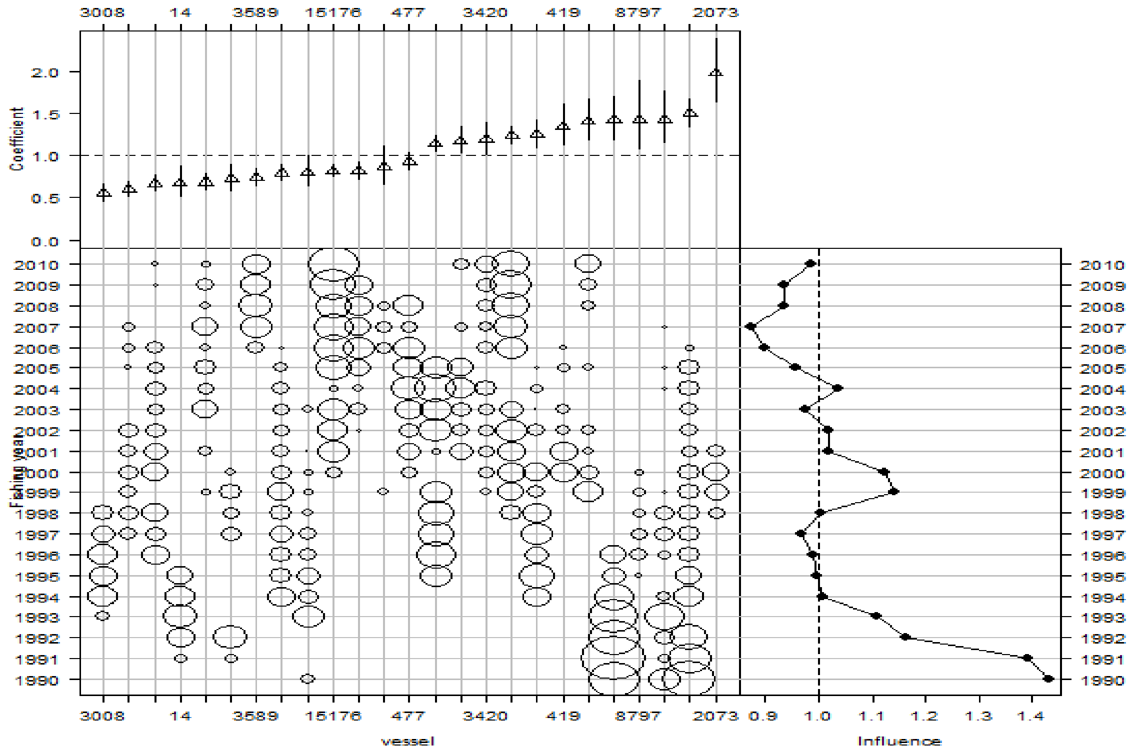



**Figure B14: Effect and influence of *vessel* in the SPO1W_SN (044) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

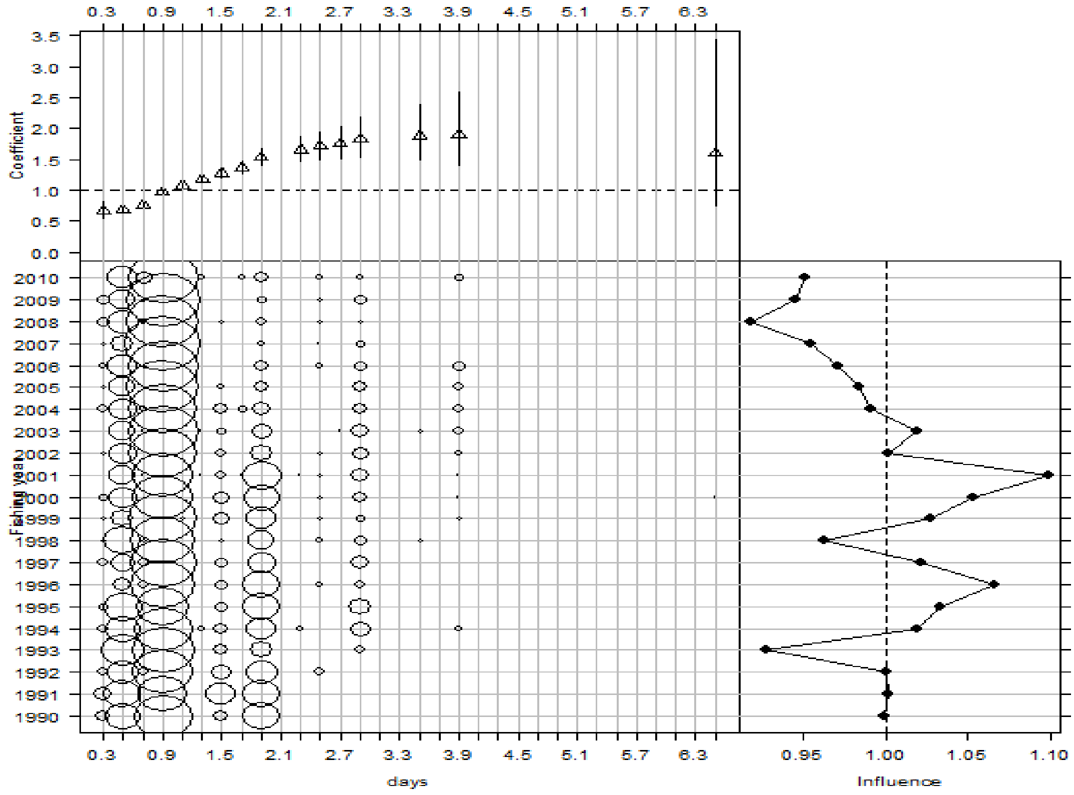



**Figure B15: Effect and influence of *days* in the SPO1W_SN (044) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

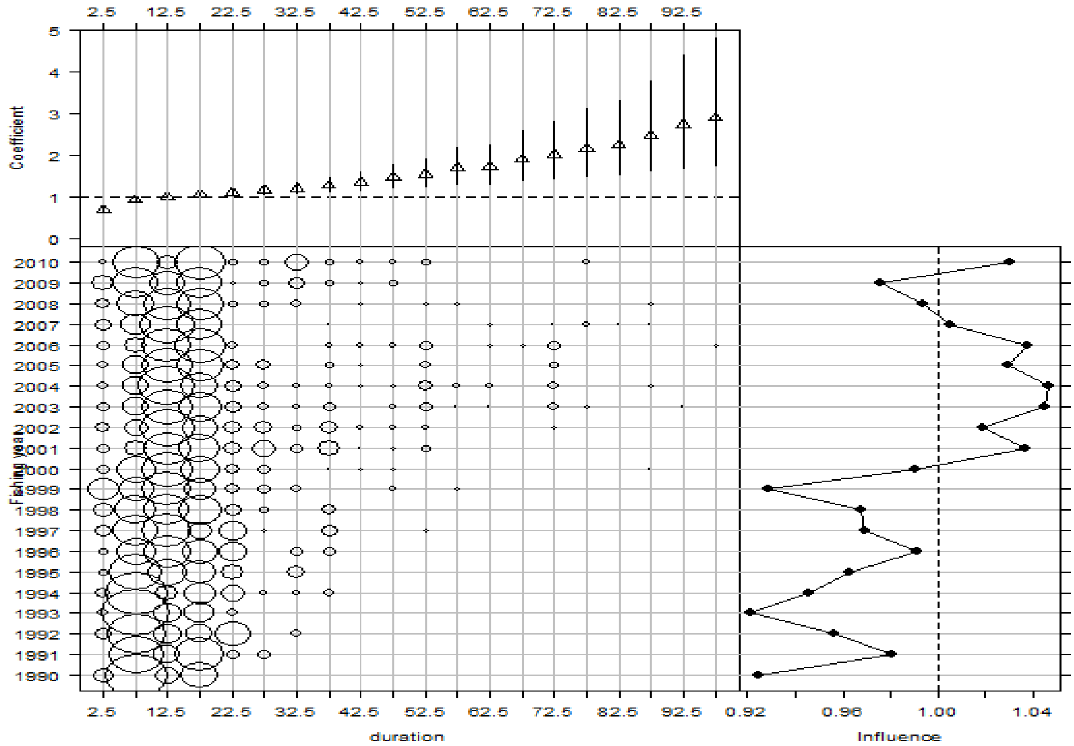



**Figure B16: Effect and influence of *duration* in the SPO1W_SN (044) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

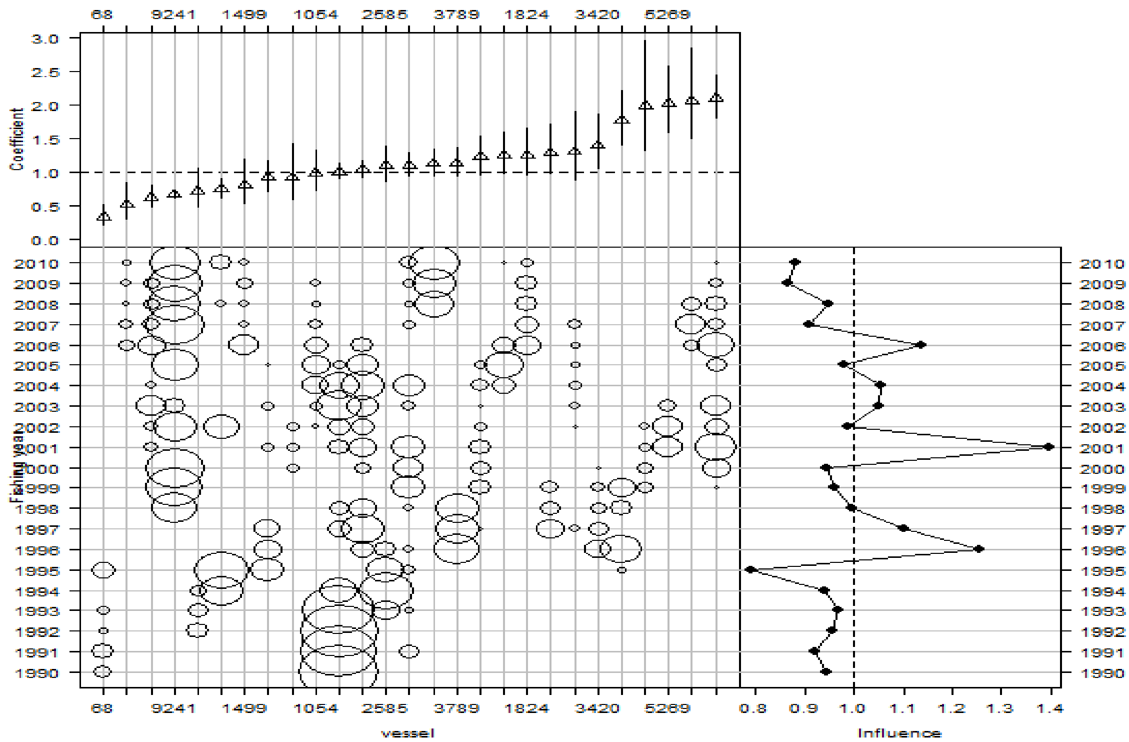



**Figure B17: Effect and influence of *vessel* in the SPO1W_SN (coast) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

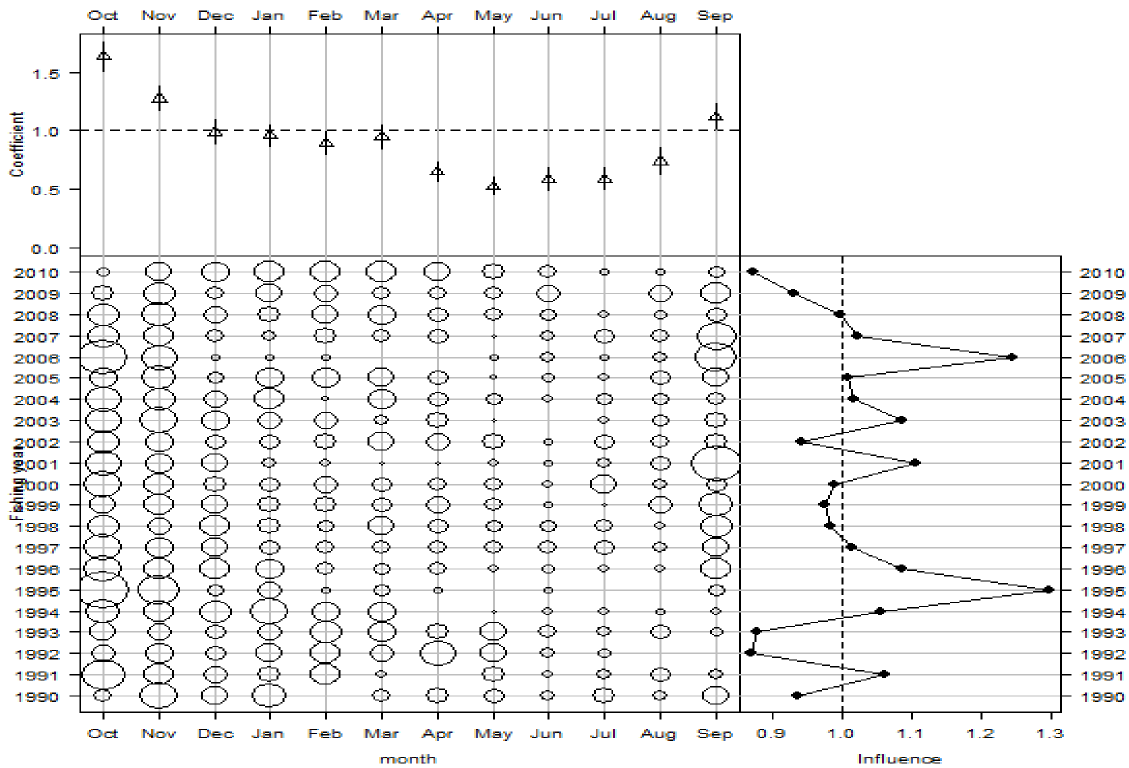



**Figure B18: Effect and influence of *month* in the SPO1W_SN (coast) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

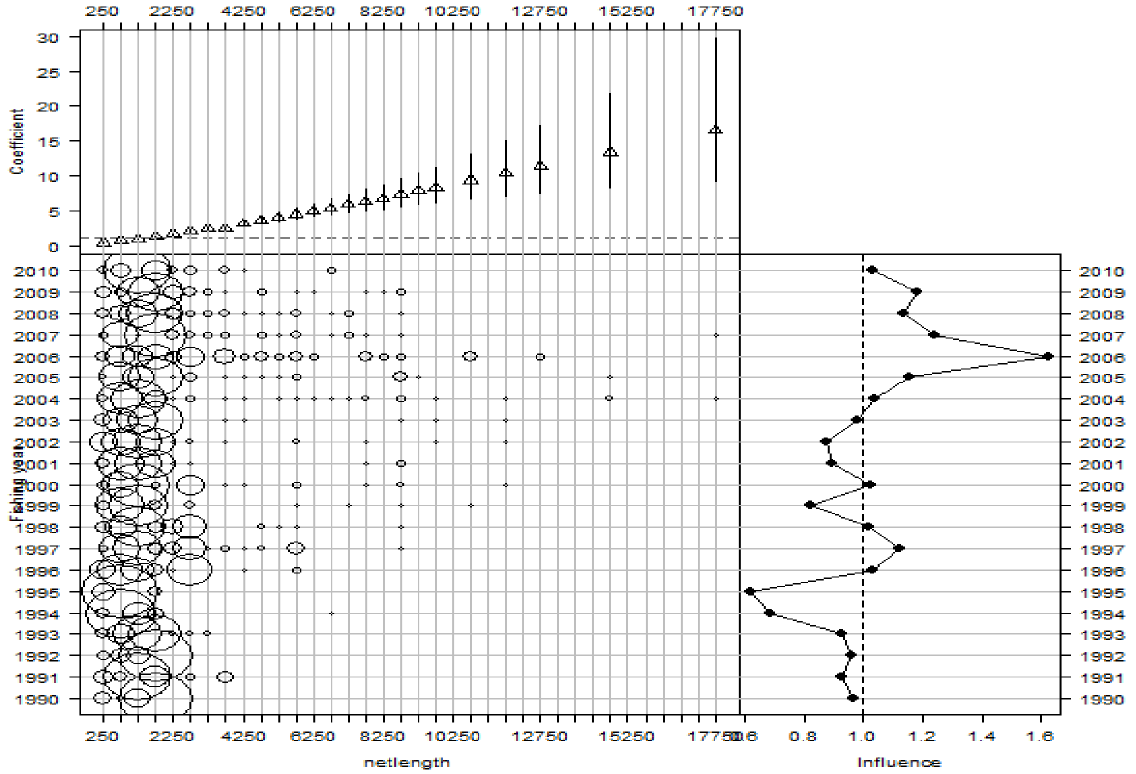



**Figure B19: Effect and influence of *netlength* in the SPO1W_SN (coast) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

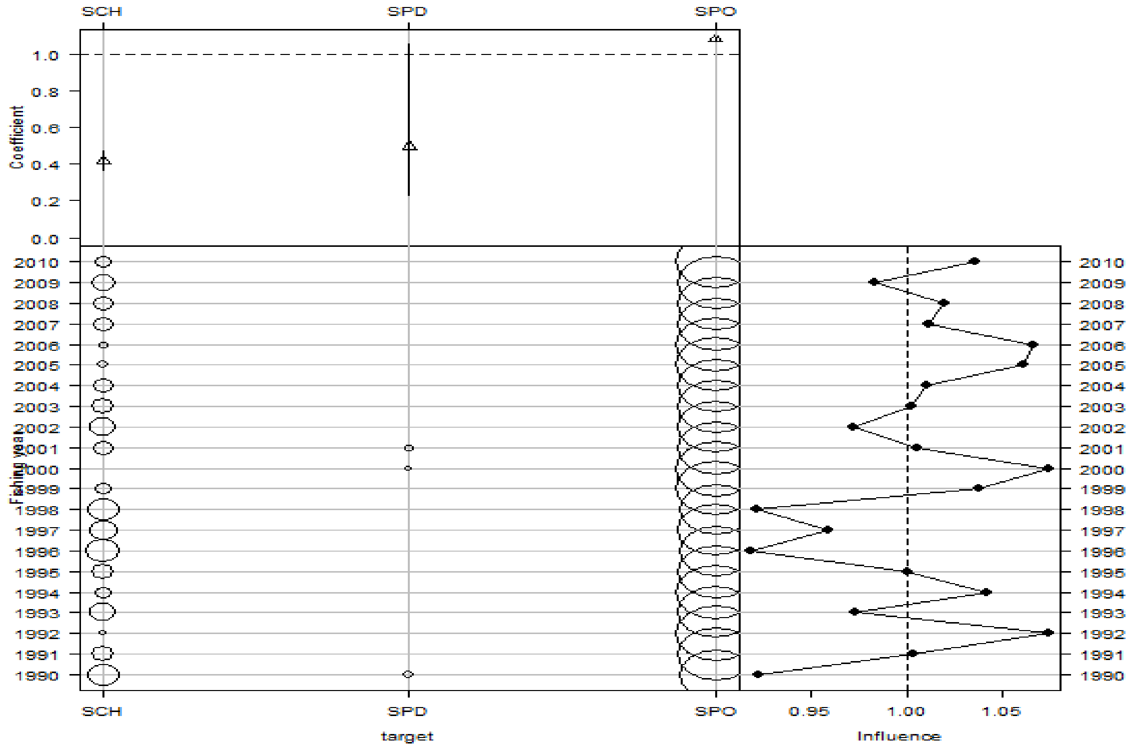



**Figure B20: Effect and influence of *target* in the SPO1W_SN (coast) lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

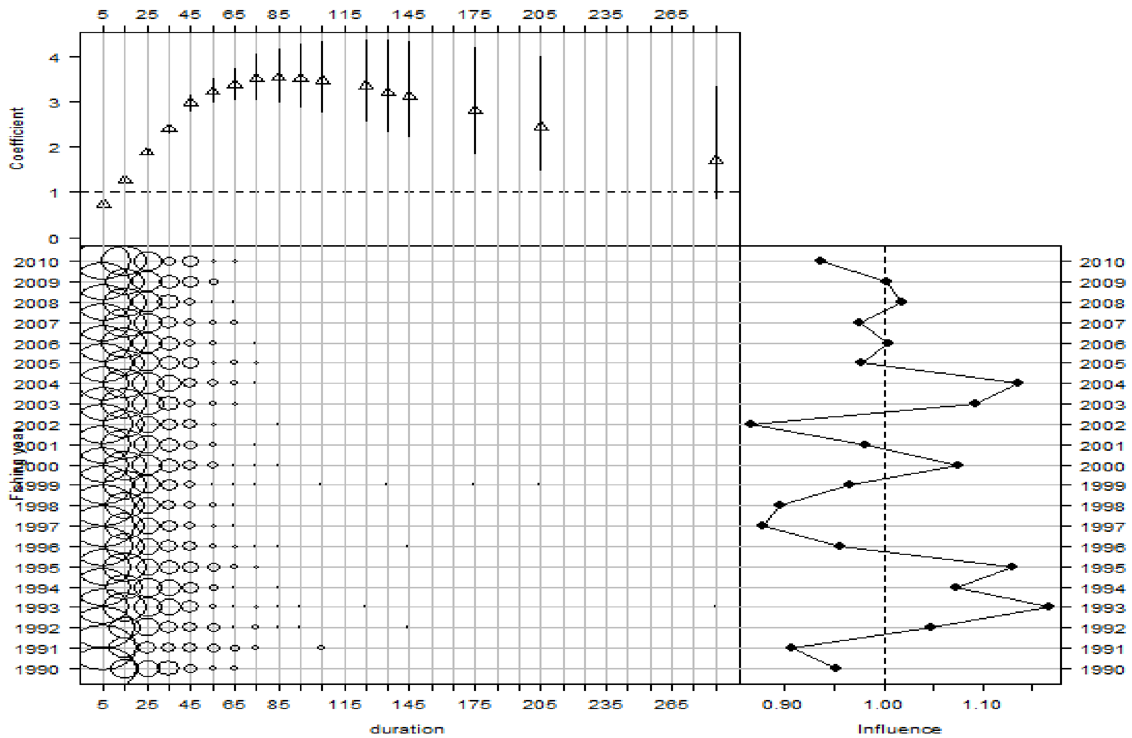



**Figure B21: Effect and influence of *duration* in the SPO1W_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

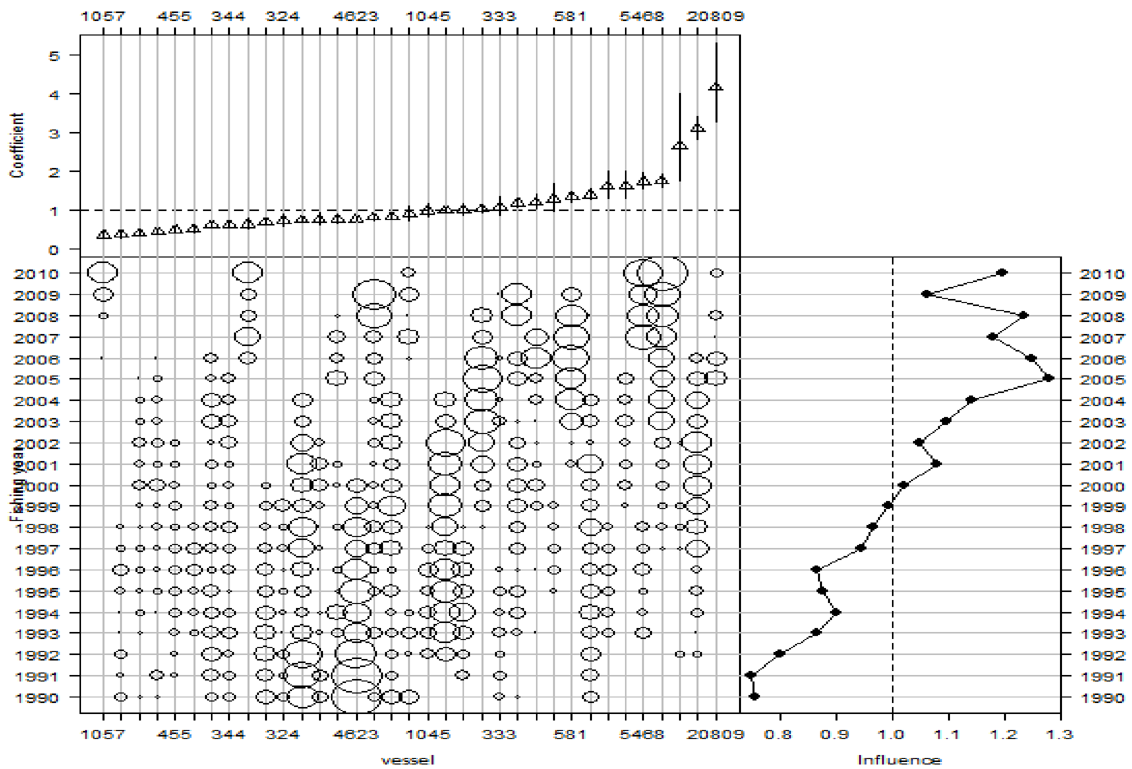



**Figure B22: Effect and influence of *vessel* in the SPO1W_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

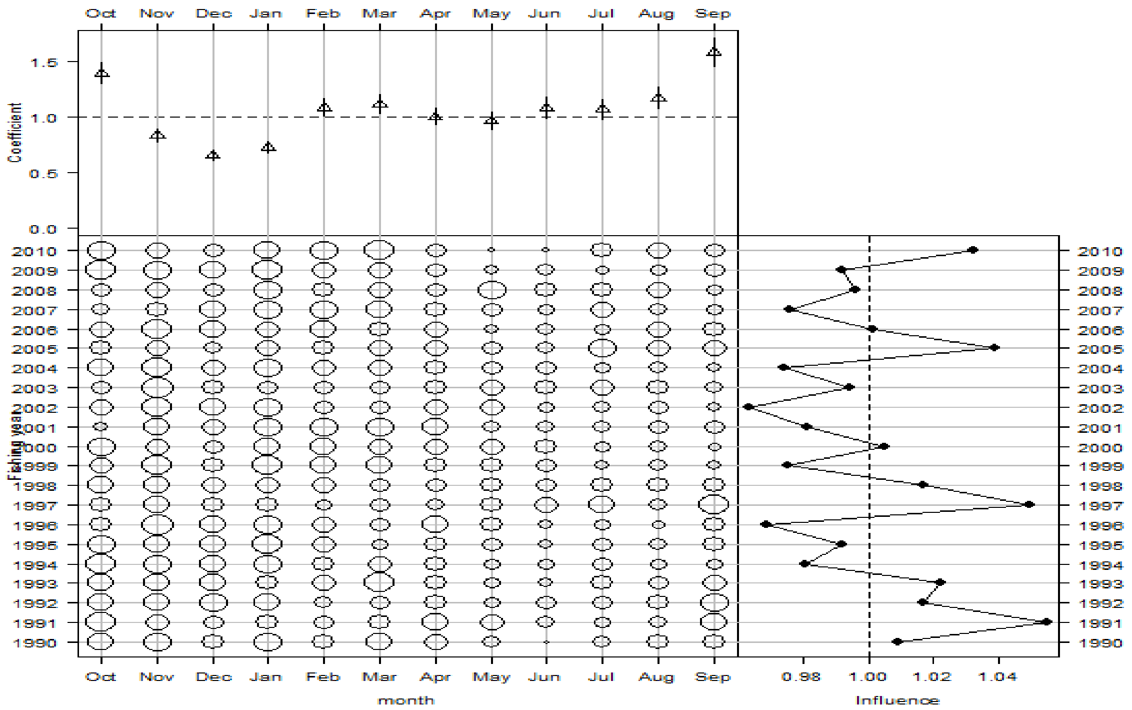



**Figure B23: Effect and influence of *month* in the SPO1W_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

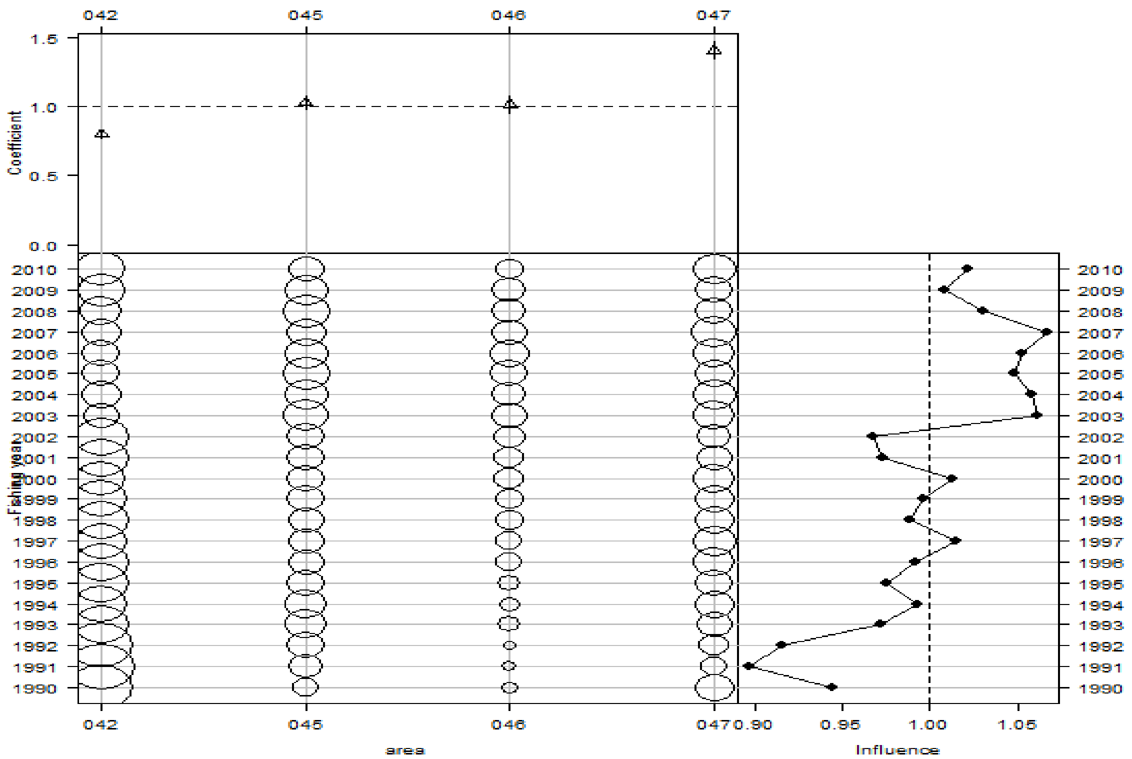



**Figure B24: Effect and influence of *area* in the SPO1W_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

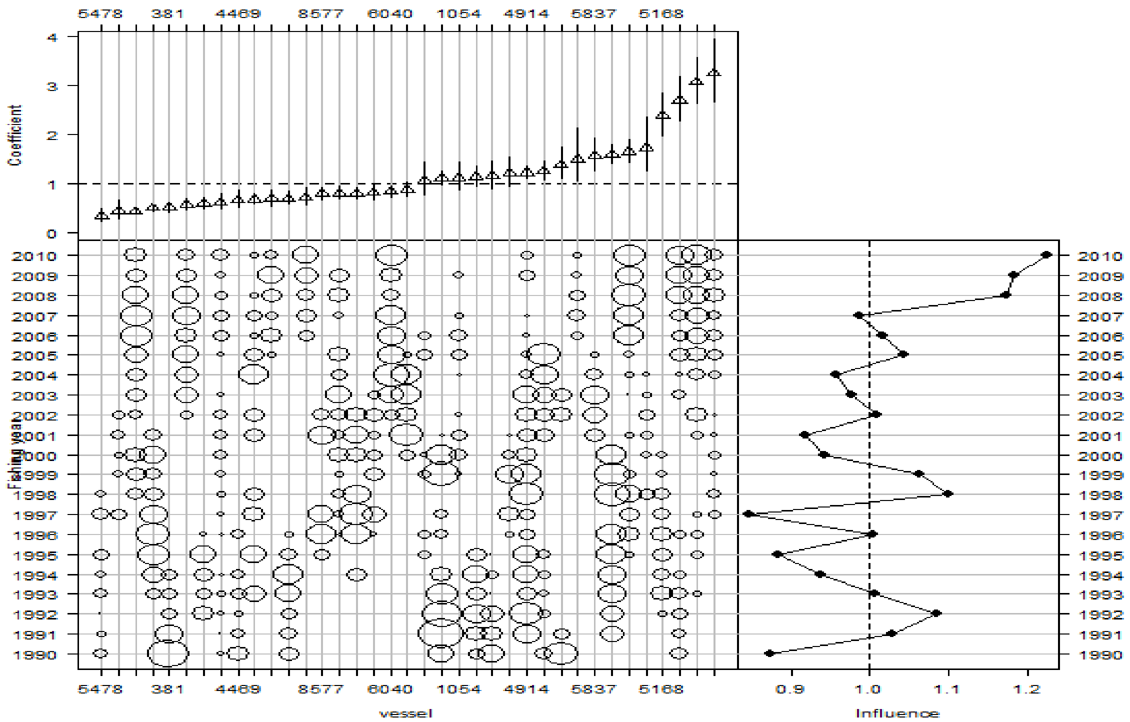



**Figure B25: Effect and influence of *vessel* in the SPO8_SN lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

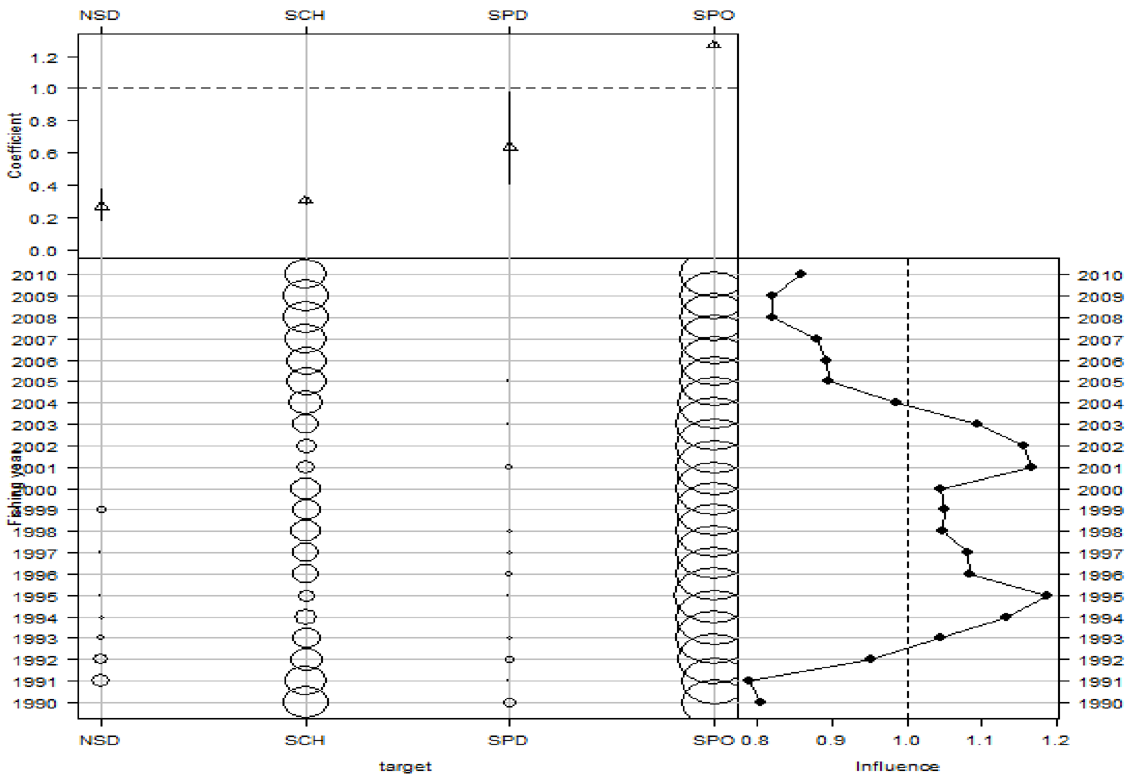



**Figure B26: Effect and influence of *target* in the SPO8_SN lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

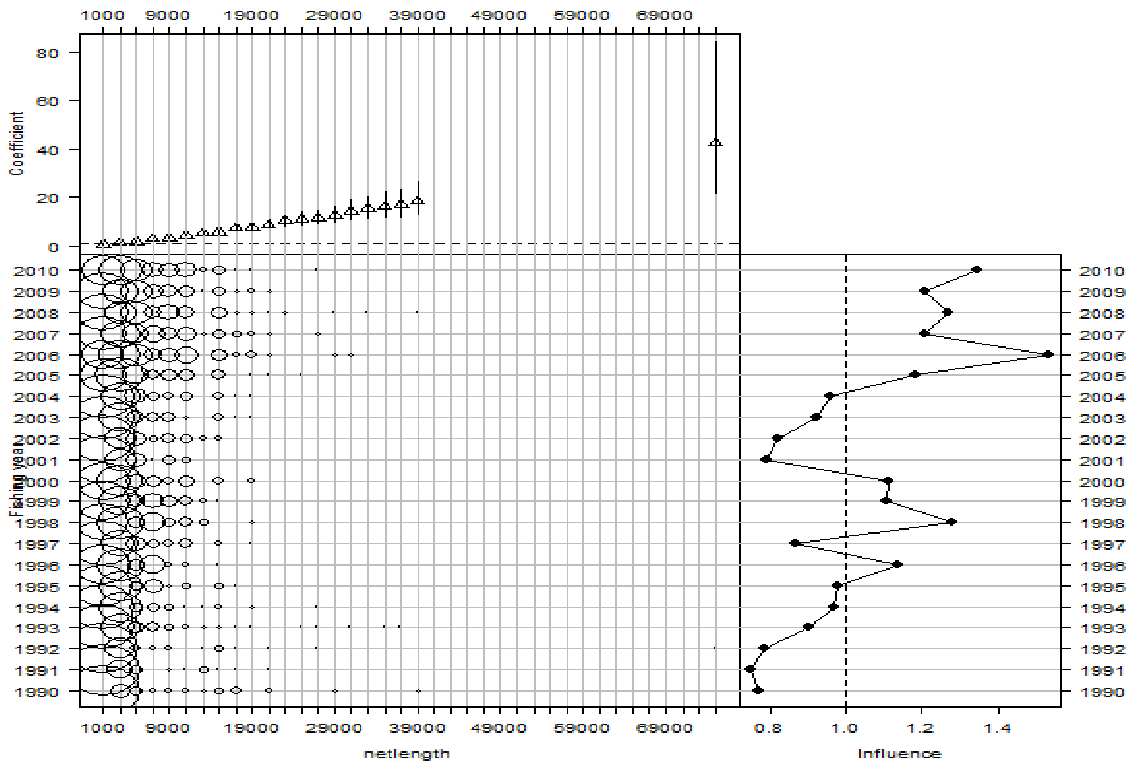



**Figure B27: Effect and influence of *netlength* in the SPO8_SN lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

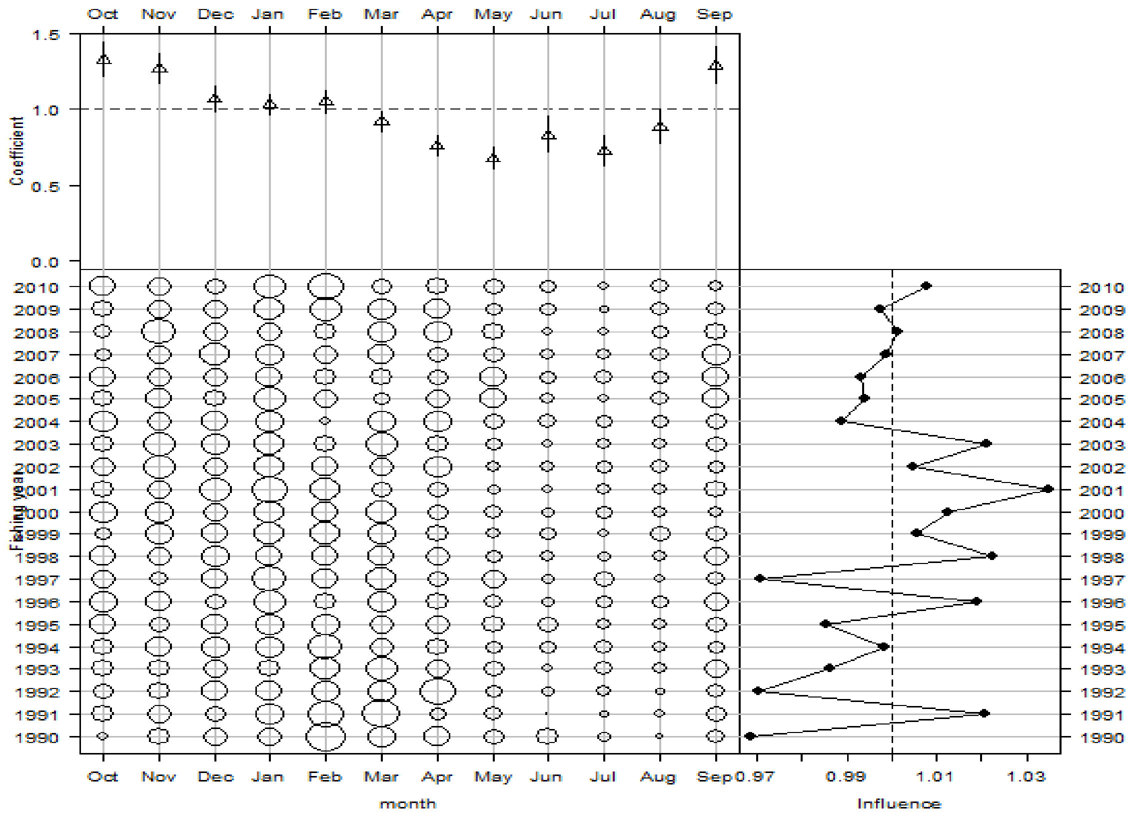



**Figure B28: Effect and influence of *month* in the SPO8_SN lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

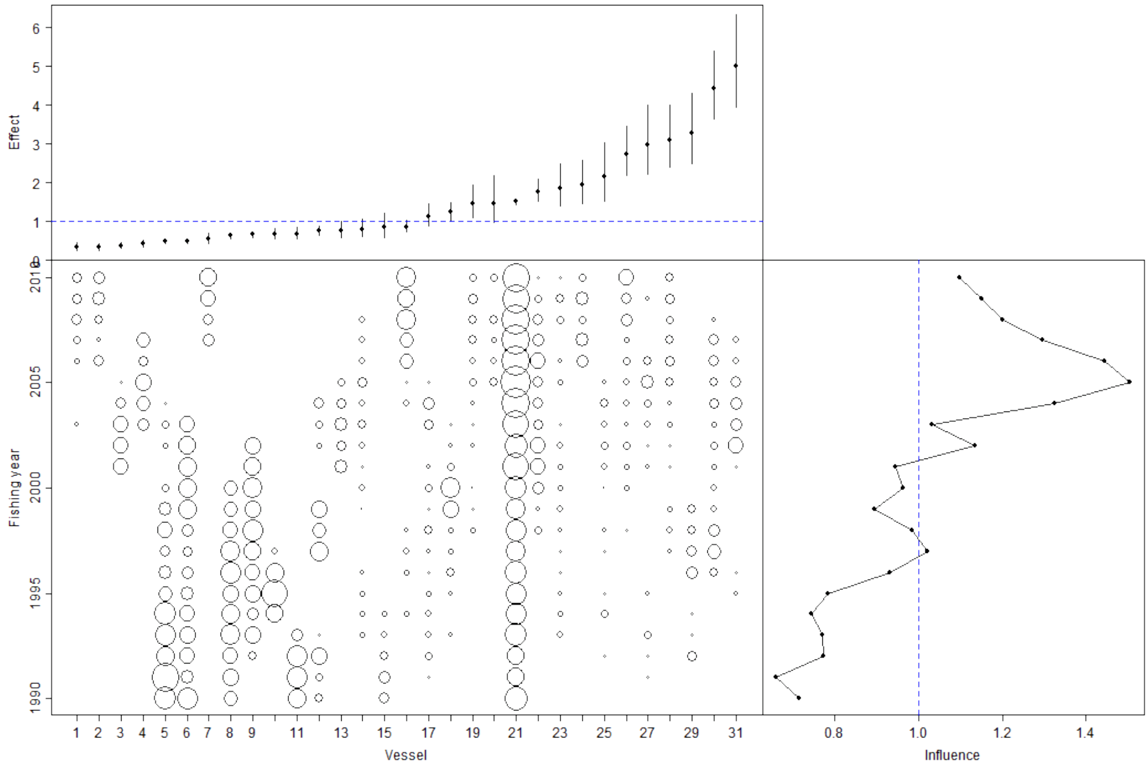



**Figure B29: Effect and influence of *vessel* in the SPO8_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

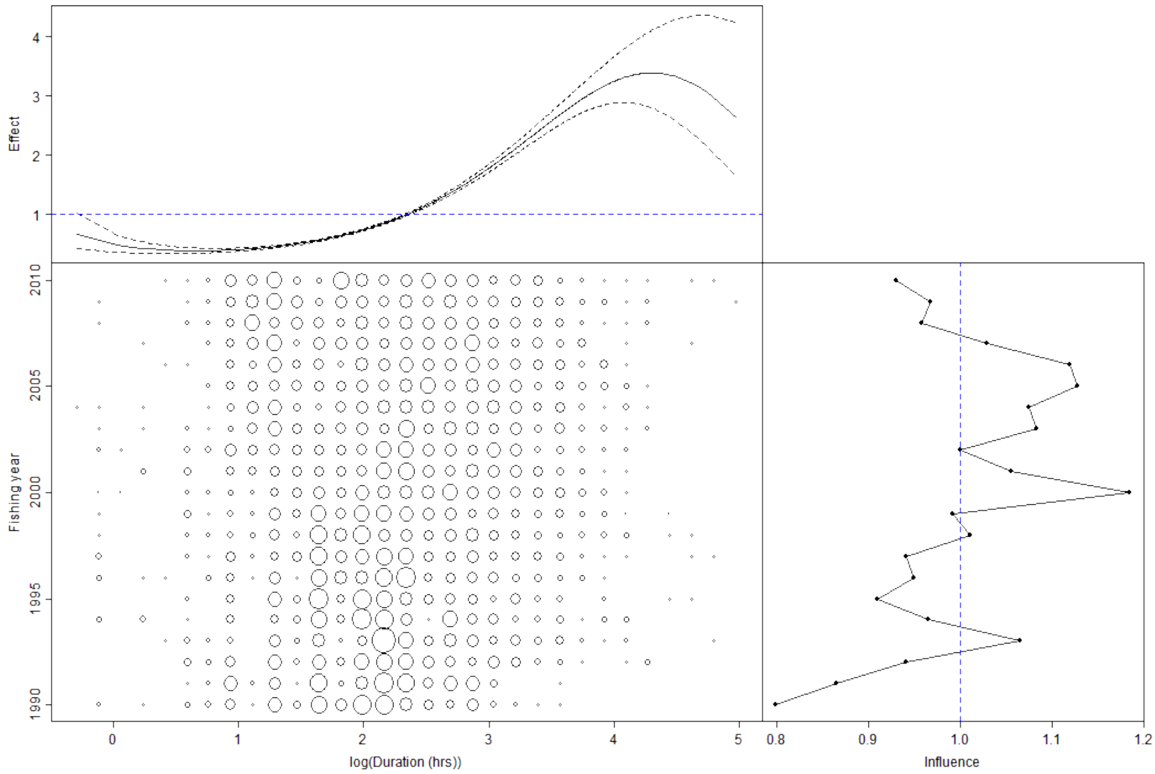



**Figure B30: Effect and influence of *duration* in the SPO8_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

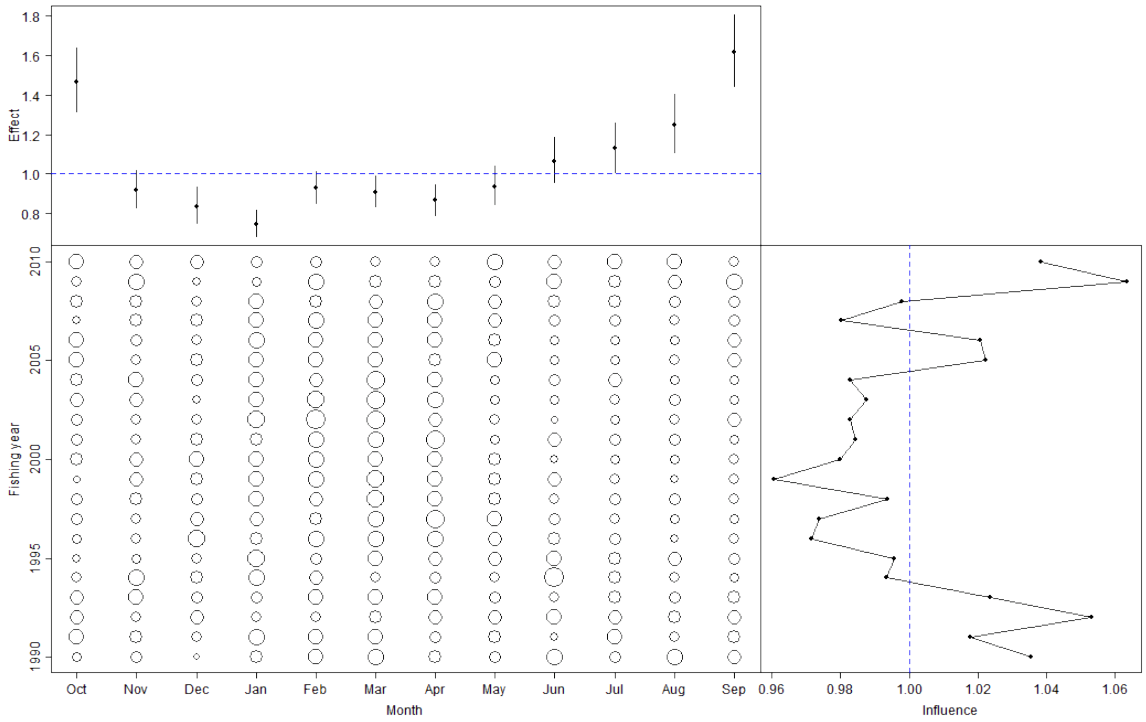



**Figure B31: Effect and influence of *month* in the SPO8_BT lognormal model. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

## APPENDIX C MODEL RESIDUAL DIAGNOSTIC PLOTS

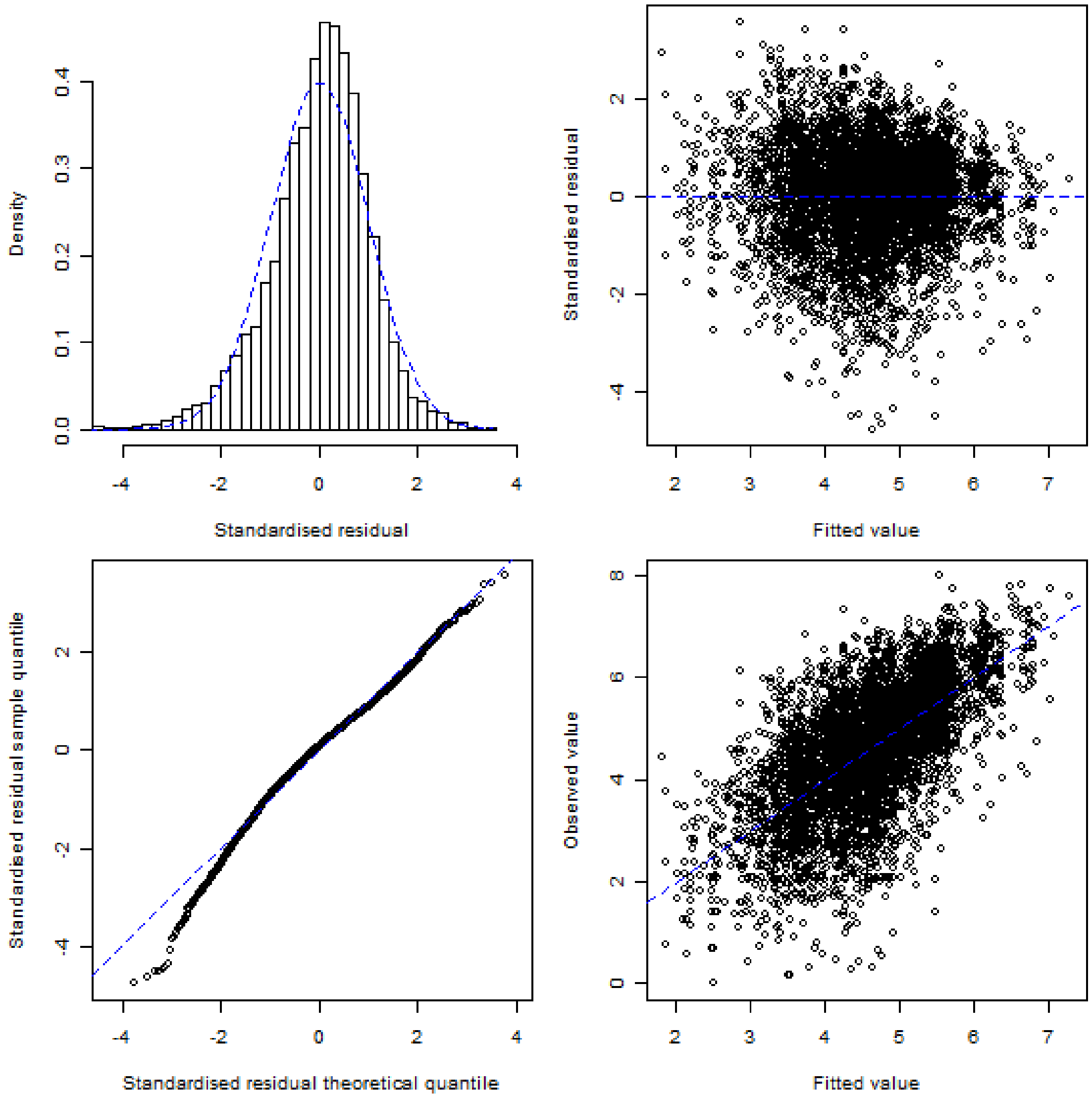



**Figure C1: Plots of the fit of the final standardised CPUE model to positive catches in the SPO1E_SN (007) fishery assuming a log logistic error distribution. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: standardised residuals versus fitted values. Bottom right: observed values versus fitted values.**

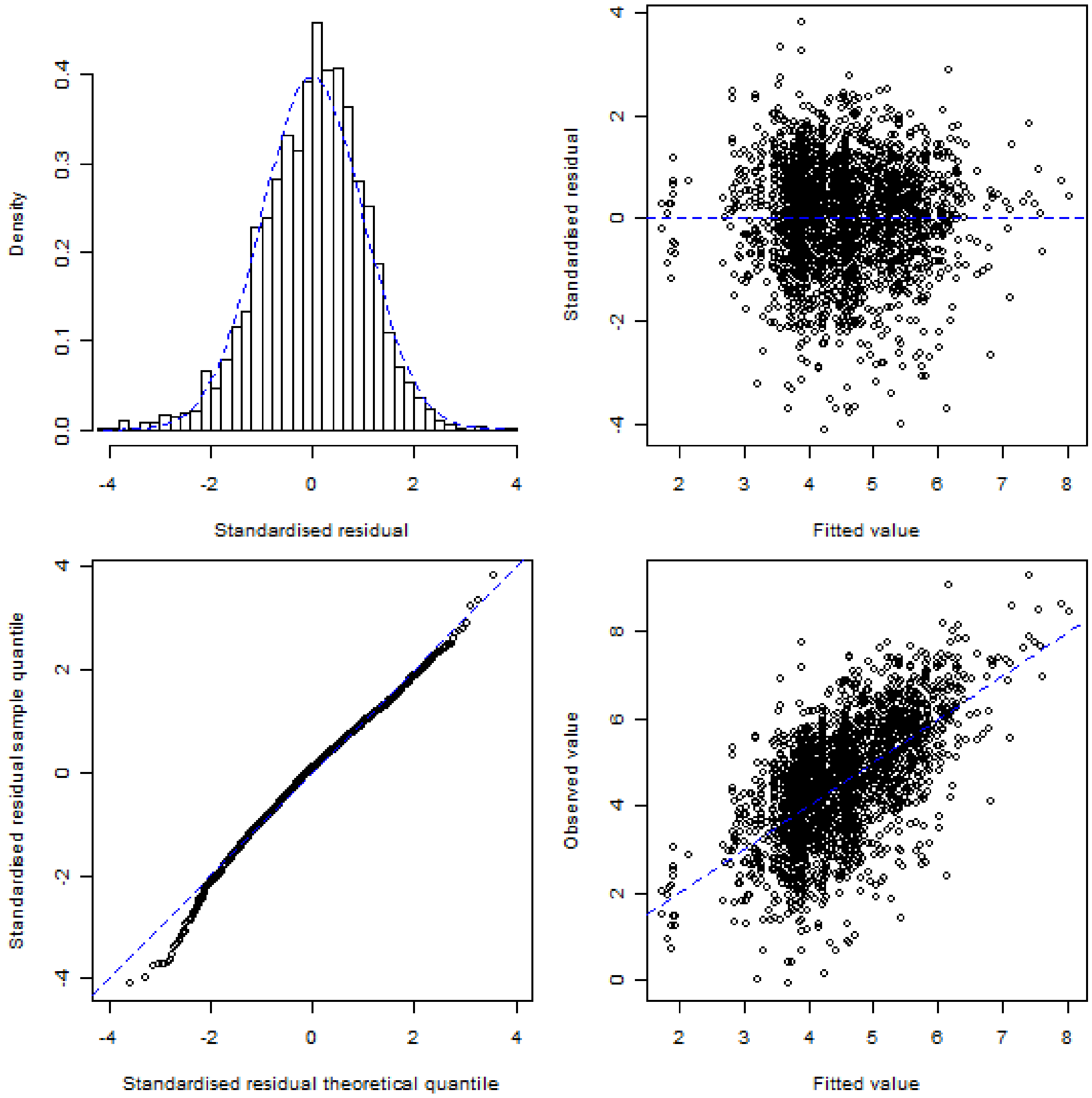



**Figure C2: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO1E_SN (coast).**

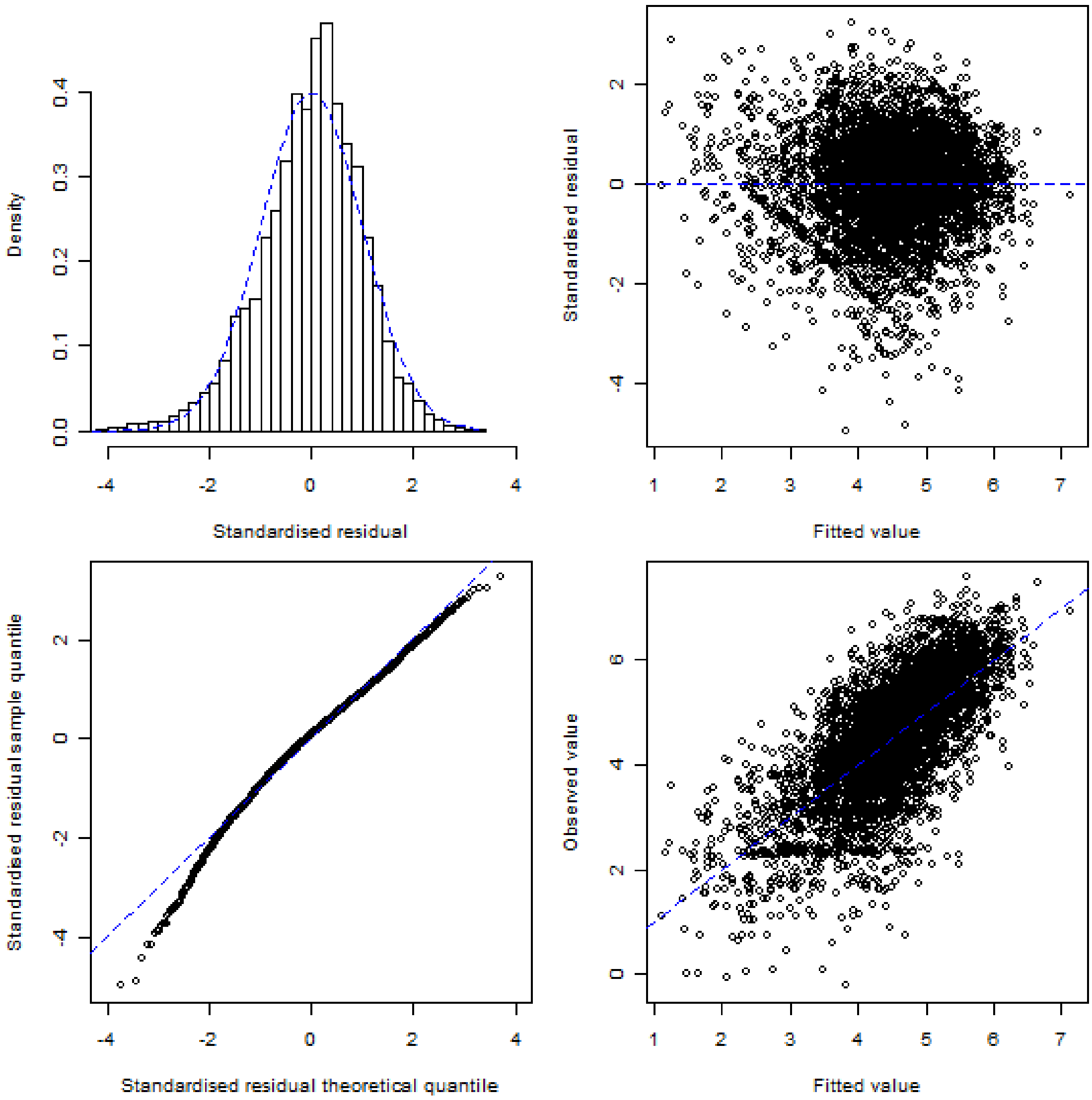



**Figure C3: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO1W_SN (043) fishery.**

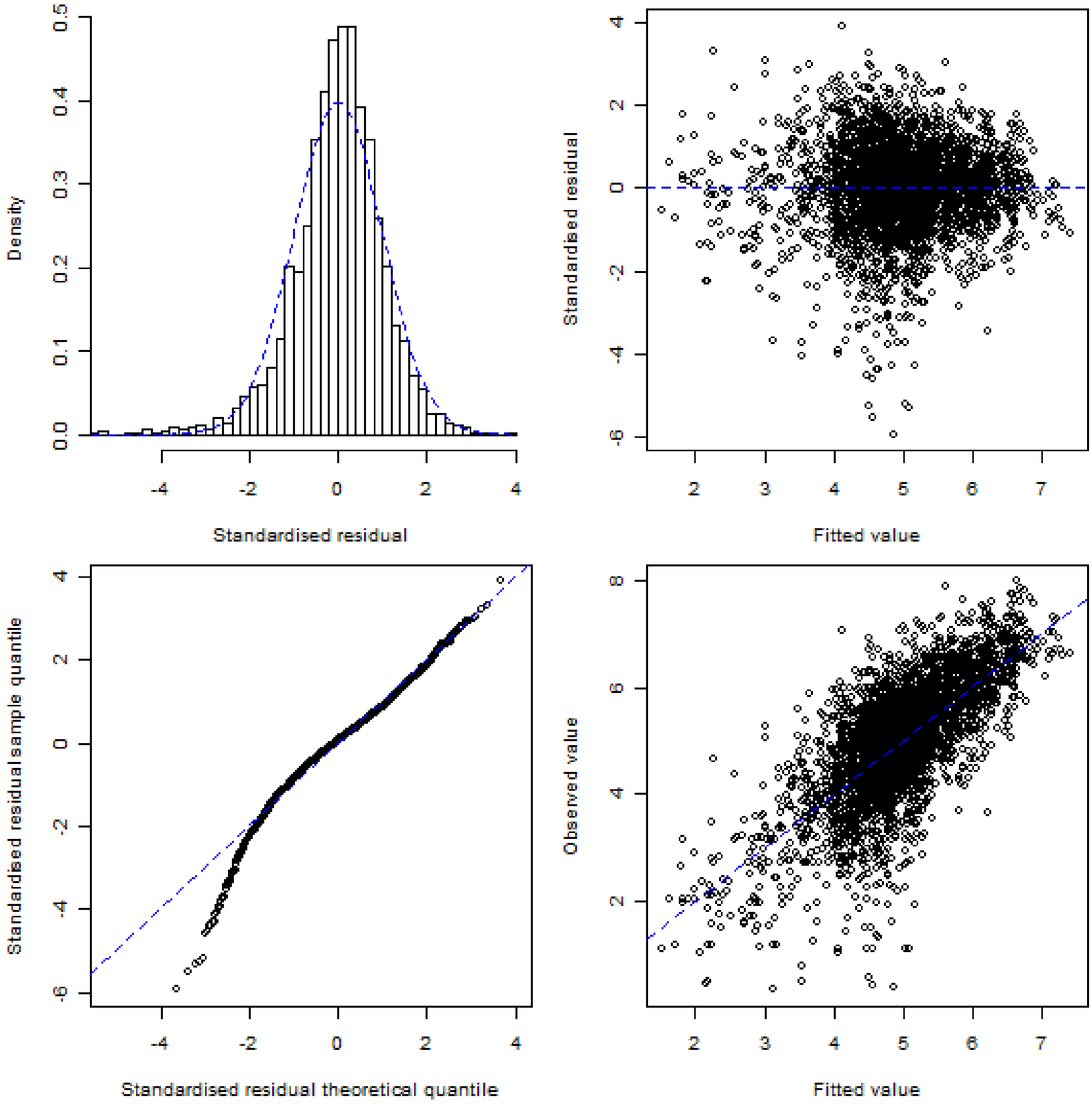



**Figure C4: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO1W_SN (044) fishery.**

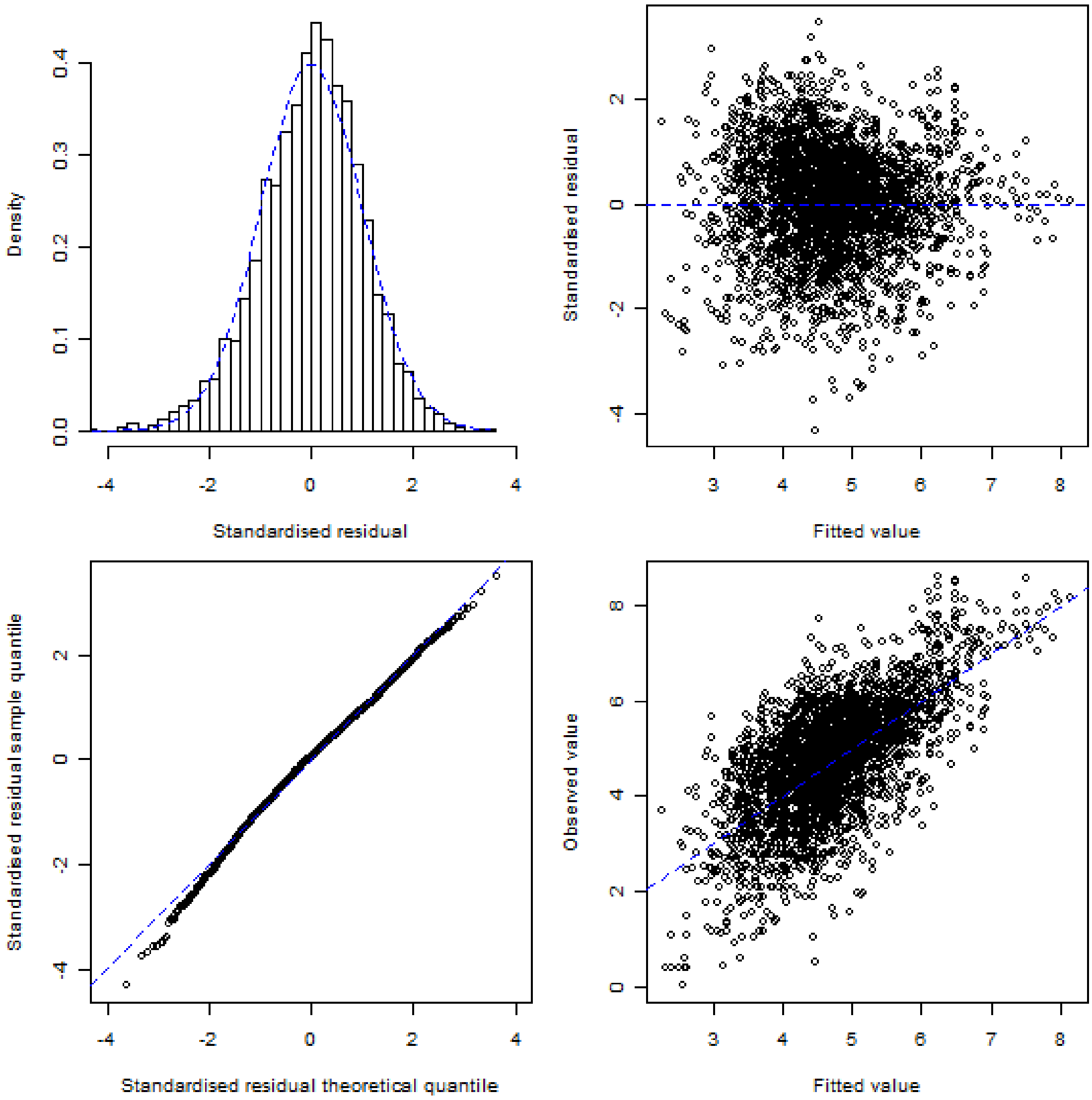



**Figure C5: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO1W_SN (coast) fishery.**

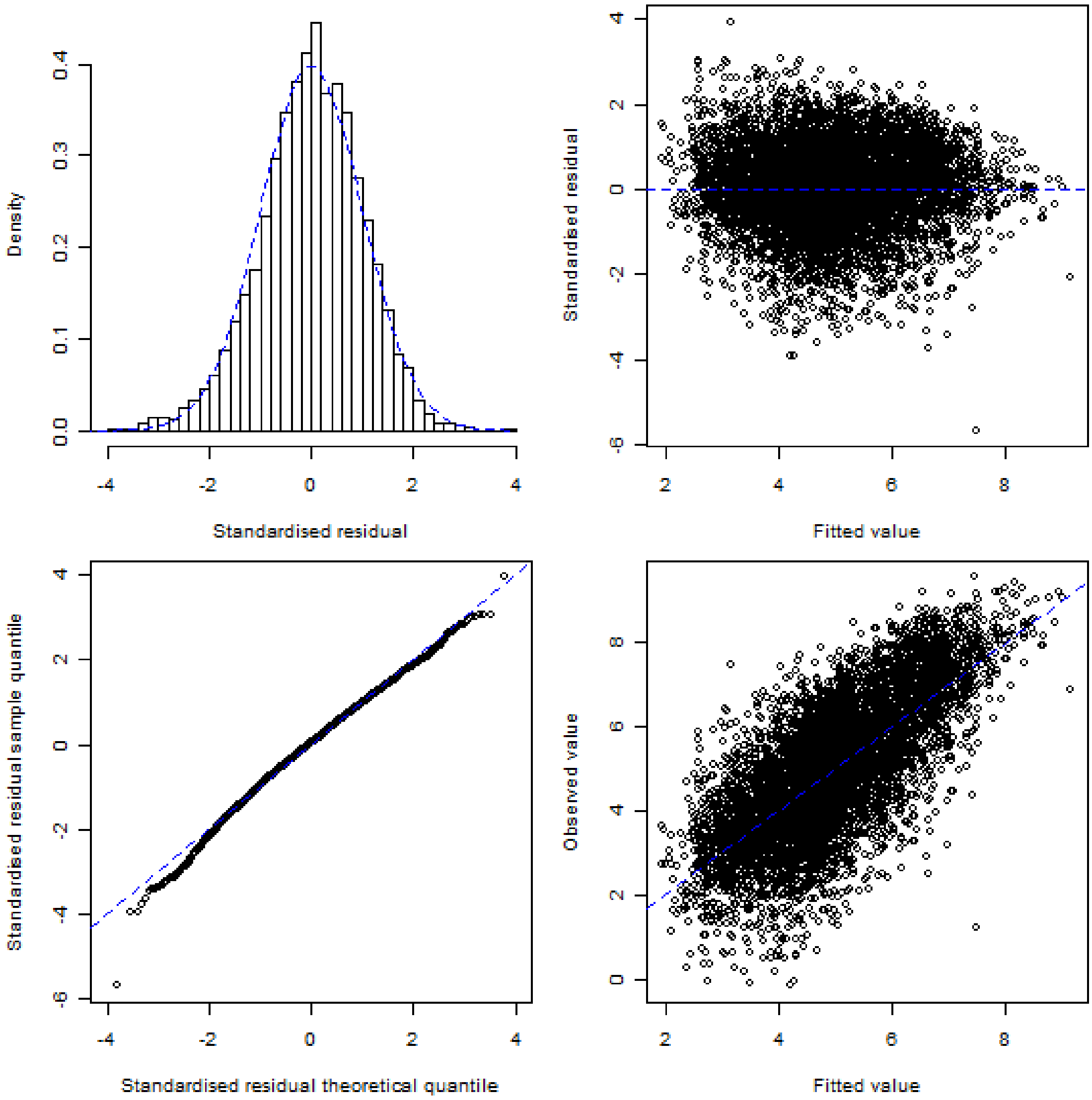



**Figure C6: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO8_SN fishery.**

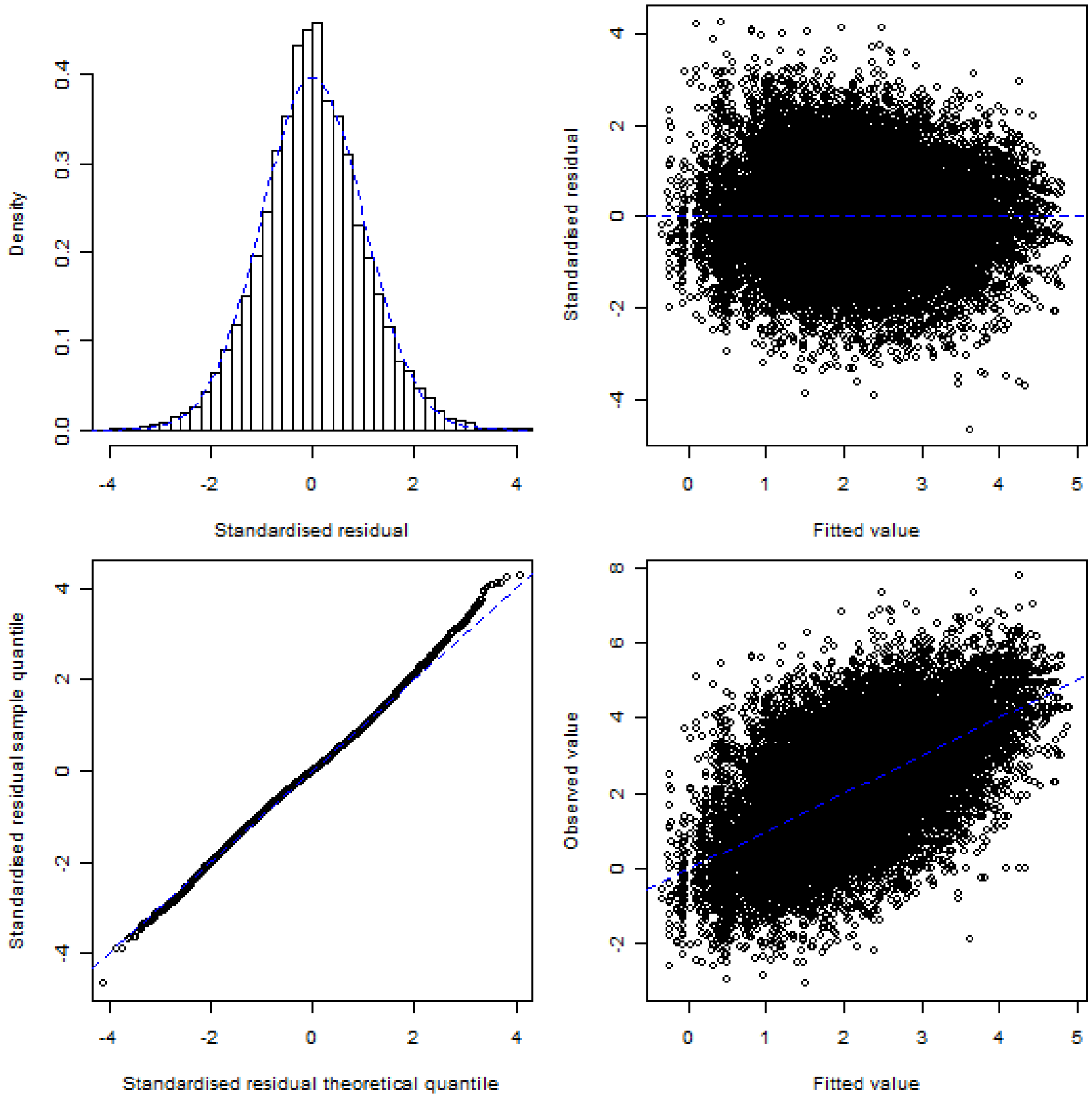



**Figure C7: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO1E_BT fishery.**

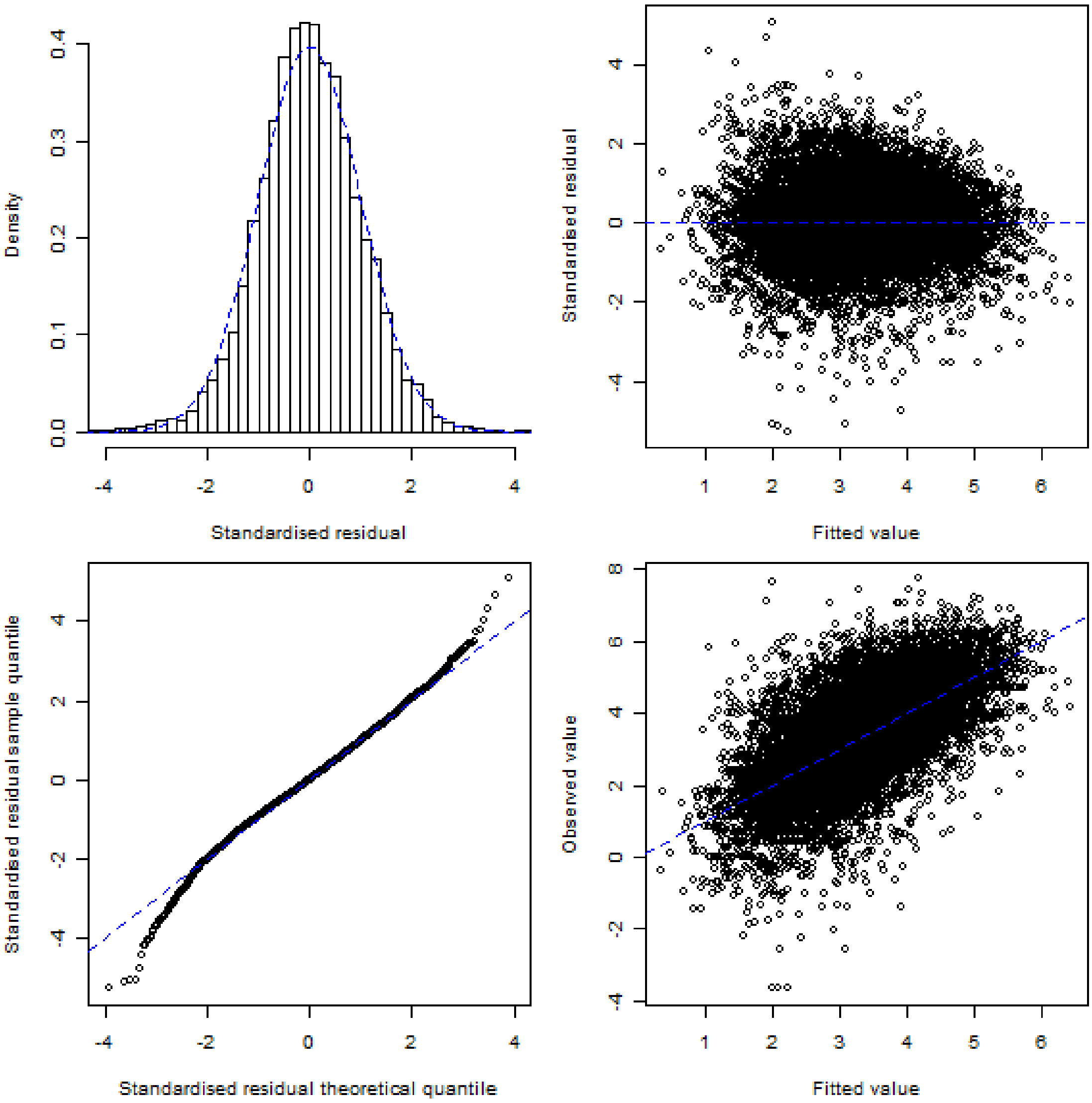



**Figure C8: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO1W_BT fishery.**

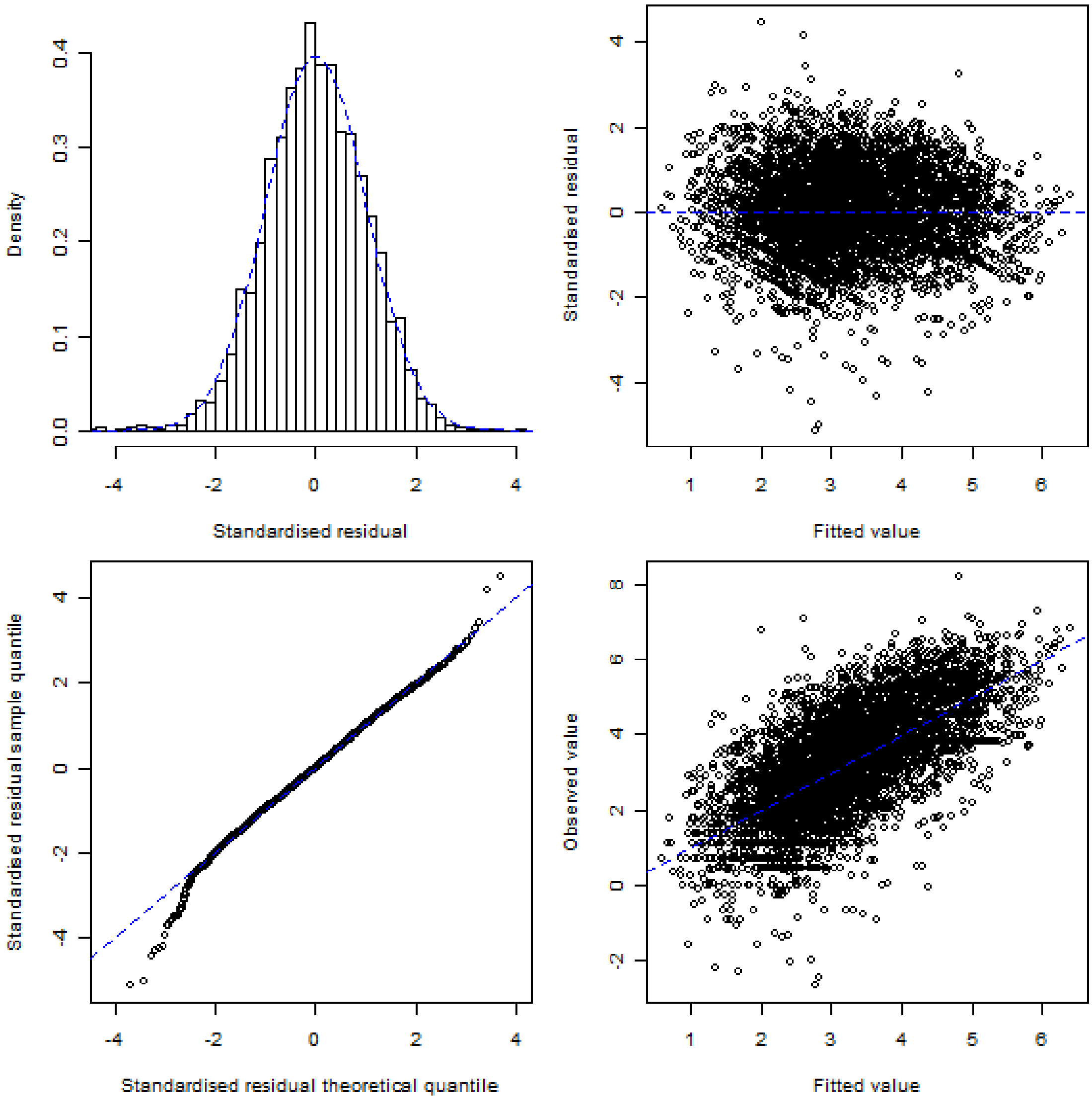



**Figure C9: Plots of the fit of the final lognormal CPUE model to positive catches in the SPO8_BT fishery.**

## APPENDIX D: POTENTIAL INTERACTION TERMS (NOT FITTED)

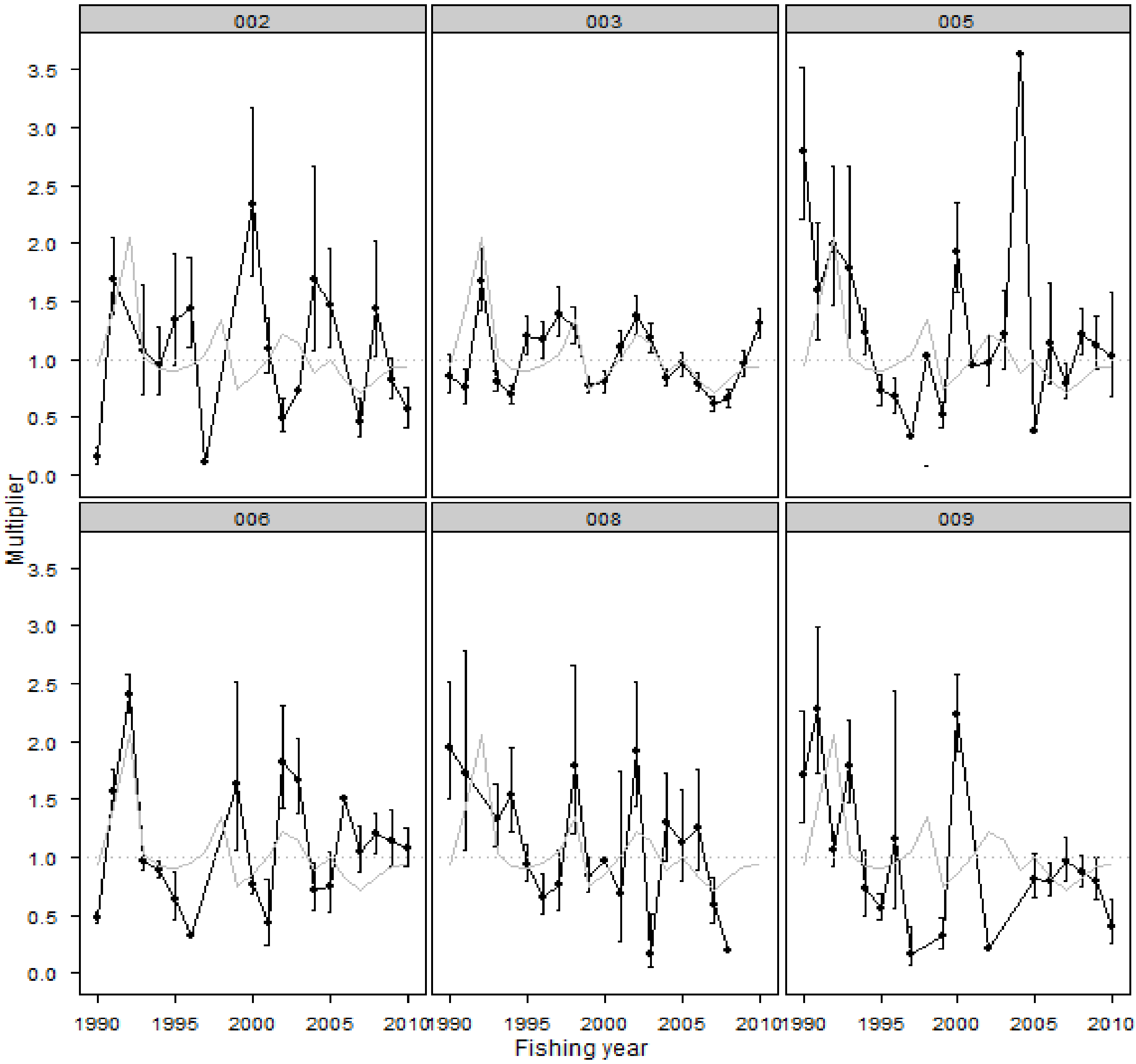



**Figure D1: Residual implied coefficients for each area in each fishing year from the final lognormal model of the SPO1E_SN(coast) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.**

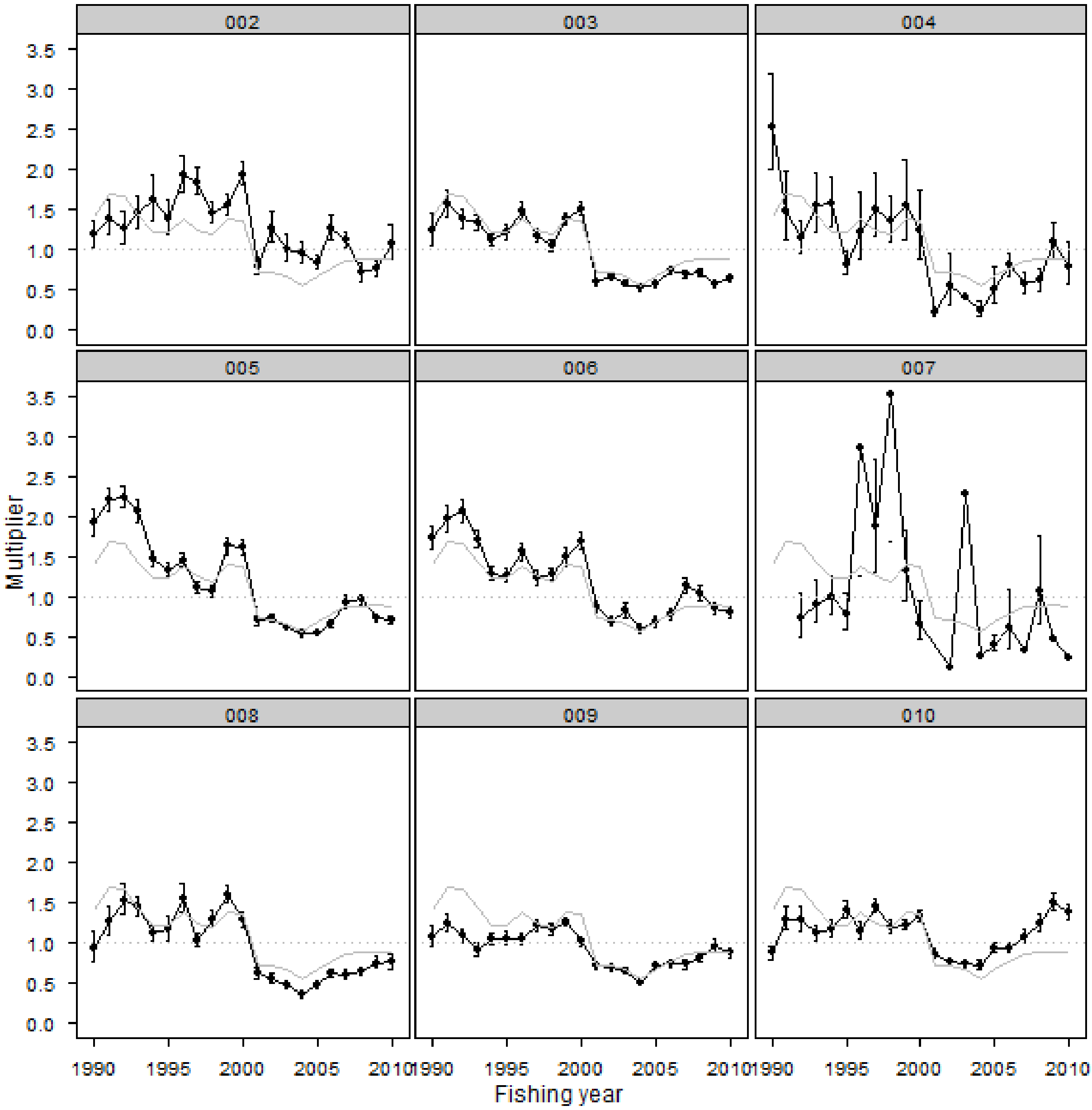



**Figure D2: Residual implied coefficients for each area in each fishing year from the final lognormal model of the SPO1E_BT fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.**

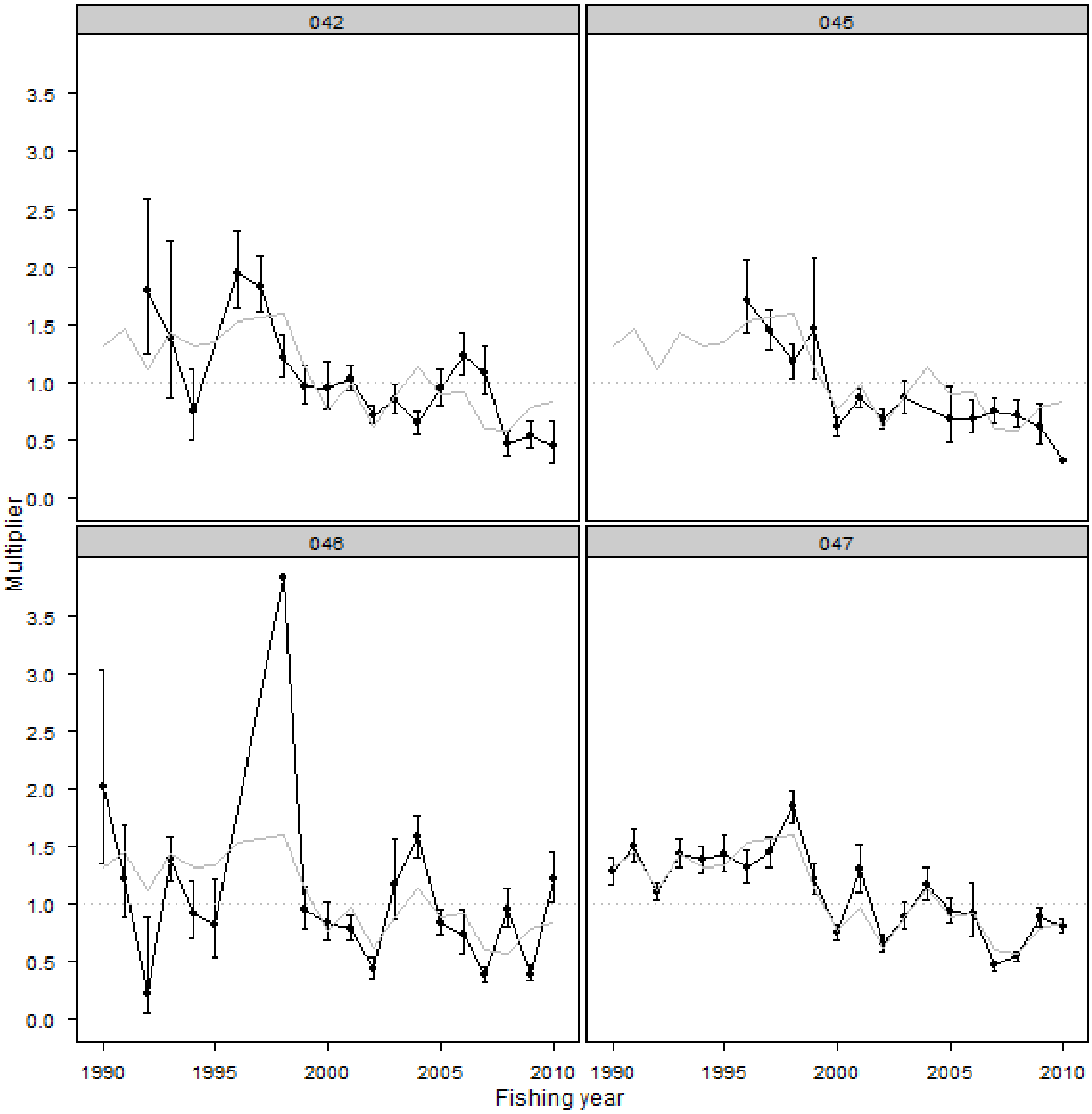



**Figure D3: Implied annual indices for each statistical area in the SPO1W_SN fishery.**

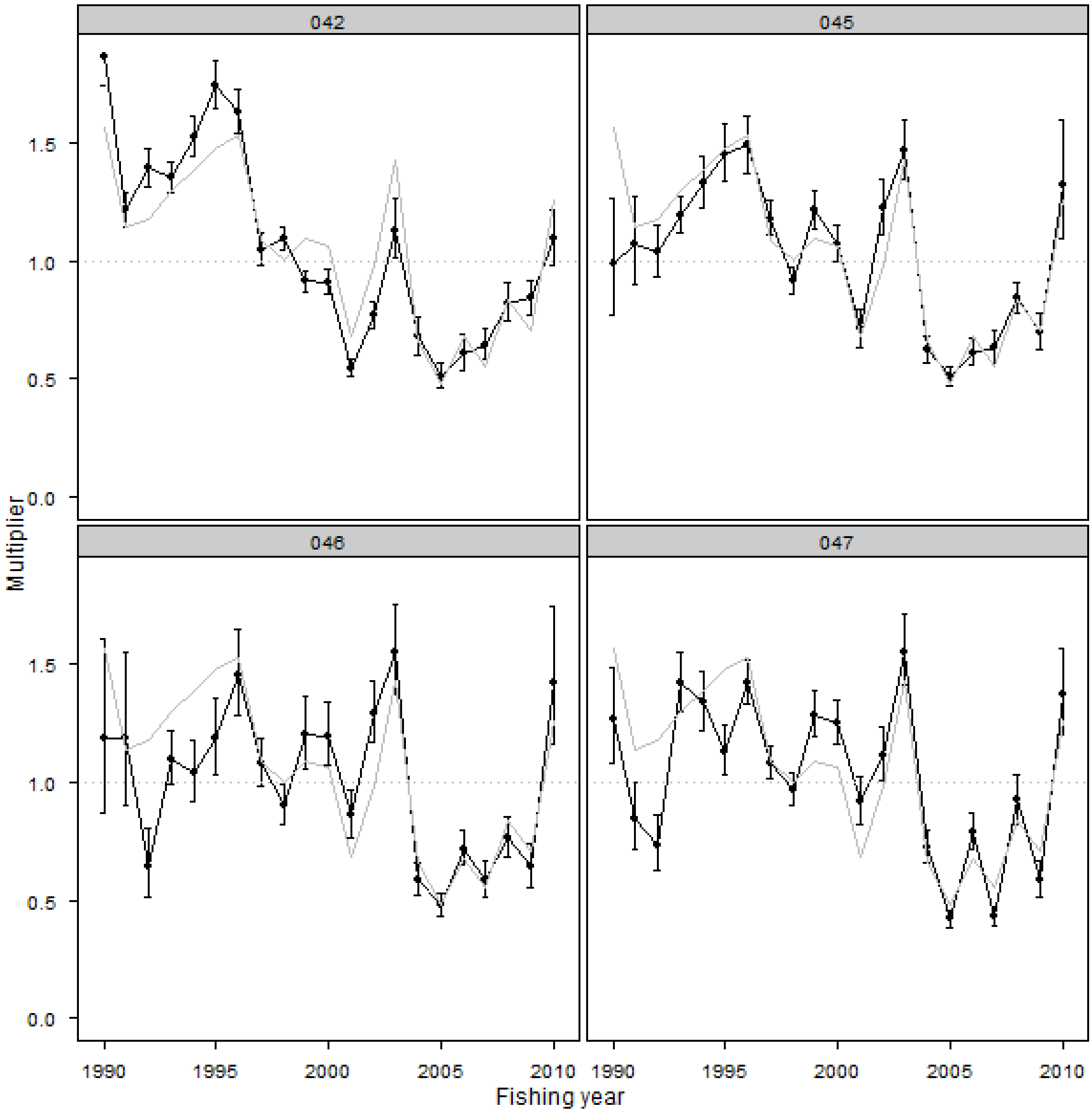



**Figure D4: Implied annual indices for each statistical area in the SPO1W_BT fishery.**

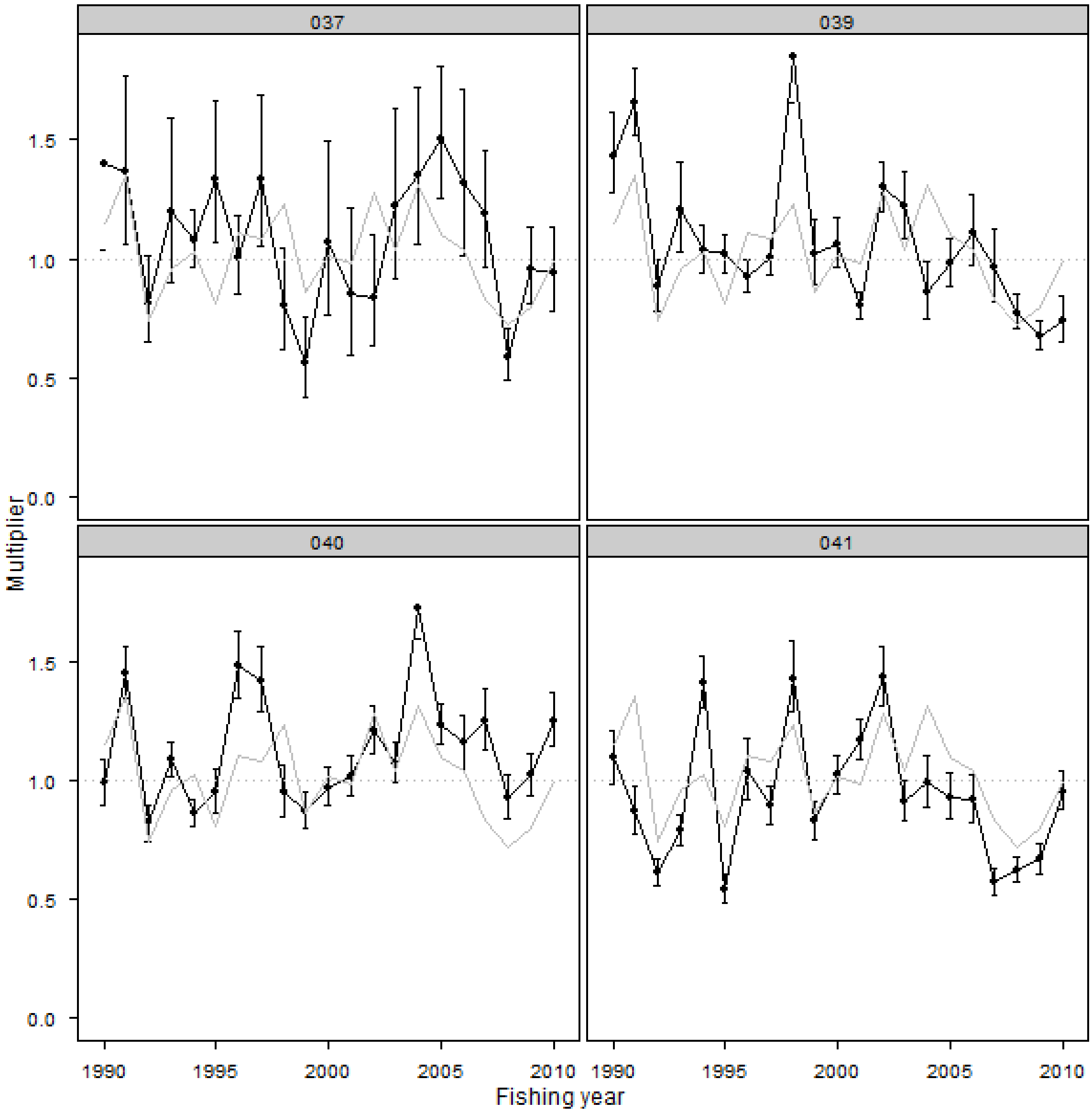



**Figure D5: Implied annual indices for each statistical area in the SPO8_SN fishery.**

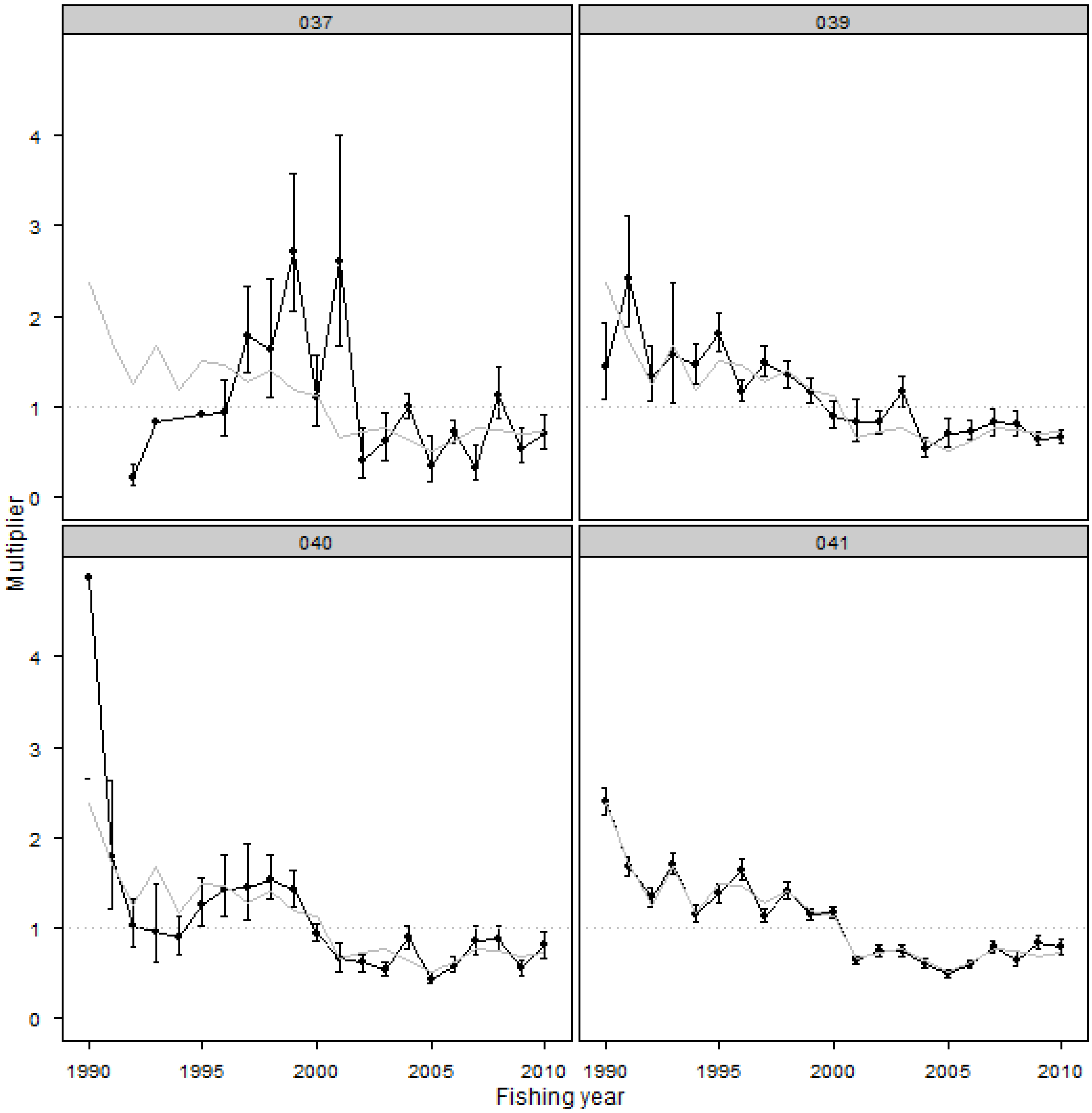



**Figure D6: Implied annual indices for each statistical area in the SPO8_BT fishery.**

## APPENDIX E ANALYSIS DATASETS

**Table E1: Number of vessels, trips, trip strata, events, sum of catch, sum of sets (or tows) and sum of hours fishing for core vessels in the three CPUE analyses for east coast fisheries of SPO 1, by fishing year.**

| | SPO1E_SN(coast) | | | | | | | | SPO1E _SN(007) | | | | | | | | SPO1E_BT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing year | Vessel | Trips | Trip-strata | events | Catch | Sets | Hours | % zero | Vessel | Trips | Trip-strata | events | Catch | Sets | Hours | % zero | Vessel | Trips | Trip-strata | events | Catch | Tows | Hours | % zero |
| 1990 | 9 | 114 | 115 | 130 | 65.0 | 0 | 1 679 | 0.9 | 10 | 96 | 96 | 100 | 8 | 0 | 808 | 0.0 | 33 | 527 | 786 | 1 875 | 43 | 6 789 | 16 115 | 12.9 |
| 1991 | 9 | 165 | 166 | 172 | 20.1 | 0 | 1 769 | 2.4 | 11 | 279 | 279 | 294 | 37 | 0 | 3 056 | 0.0 | 33 | 552 | 949 | 2 054 | 53 | 7 472 | 18 275 | 17.3 |
| 1992 | 8 | 194 | 194 | 212 | 27.3 | 0 | 2 040 | 0.0 | 11 | 315 | 315 | 349 | 54 | 0 | 3 259 | 0.0 | 41 | 699 | 1 207 | 2 645 | 63 | 9 605 | 23 782 | 18.5 |
| 1993 | 13 | 298 | 302 | 334 | 58.2 | 0 | 3 730 | 1.3 | 16 | 503 | 503 | 604 | 97 | 0 | 6 933 | 0.0 | 44 | 765 | 1 296 | 2 496 | 43 | 8 743 | 24 173 | 20.0 |
| 1994 | 13 | 257 | 288 | 414 | 120.2 | 0 | 5 175 | 1.0 | 15 | 304 | 304 | 342 | 50 | 0 | 3 923 | 0.0 | 42 | 751 | 1 306 | 2 867 | 36 | 8 199 | 22 525 | 17.2 |
| 1995 | 13 | 136 | 180 | 352 | 107.3 | 0 | 3 757 | 1.7 | 12 | 223 | 223 | 258 | 55 | 0 | 2 701 | 0.0 | 41 | 682 | 1 183 | 2 972 | 28 | 6 708 | 17 501 | 15.1 |
| 1996 | 10 | 92 | 113 | 170 | 23.2 | 0 | 1 936 | 9.7 | 16 | 327 | 327 | 403 | 70 | 0 | 5 547 | 0.0 | 41 | 593 | 1 289 | 4 846 | 25 | 5 918 | 15 821 | 26.5 |
| 1997 | 8 | 62 | 62 | 71 | 9.9 | 0 | 820 | 6.5 | 11 | 264 | 264 | 322 | 62 | 0 | 3 526 | 0.0 | 41 | 645 | 1 401 | 5 173 | 23 | 5 976 | 14 290 | 24.0 |
| 1998 | 6 | 73 | 74 | 96 | 15.2 | 0 | 1 267 | 0.0 | 10 | 247 | 247 | 278 | 51 | 0 | 2 721 | 0.0 | 40 | 661 | 1 515 | 6 411 | 25 | 6 967 | 16 664 | 23.4 |
| 1999 | 7 | 146 | 153 | 245 | 18.7 | 0 | 3 617 | 1.3 | 14 | 258 | 258 | 274 | 60 | 0 | 2 686 | 0.8 | 38 | 725 | 1 885 | 7 242 | 33 | 8 195 | 21 623 | 22.0 |
| 2000 | 11 | 118 | 120 | 185 | 17.3 | 0 | 2 311 | 4.2 | 13 | 326 | 326 | 334 | 54 | 0 | 3 450 | 0.3 | 34 | 726 | 1 764 | 6 650 | 33 | 8 113 | 22 266 | 23.8 |
| 2001 | 9 | 86 | 87 | 107 | 11.6 | 0 | 1 302 | 3.4 | 12 | 344 | 344 | 375 | 65 | 0 | 3 912 | 0.0 | 37 | 701 | 1 612 | 6 882 | 18 | 7 548 | 20 781 | 22.4 |
| 2002 | 11 | 92 | 92 | 97 | 20.1 | 0 | 1 277 | 1.1 | 15 | 421 | 421 | 478 | 104 | 0 | 5 076 | 0.0 | 36 | 714 | 1 713 | 6 478 | 20 | 7 410 | 20 776 | 22.7 |
| 2003 | 9 | 98 | 98 | 124 | 18.8 | 0 | 1 659 | 0.0 | 21 | 518 | 518 | 566 | 92 | 0 | 6 611 | 0.2 | 33 | 653 | 1 678 | 5 907 | 17 | 6 625 | 17 881 | 21.6 |
| 2004 | 12 | 135 | 135 | 180 | 23.3 | 0 | 2 343 | 0.0 | 18 | 413 | 413 | 485 | 68 | 0 | 5 347 | 0.0 | 31 | 634 | 1 686 | 5 894 | 16 | 6 925 | 18 858 | 24.1 |
| 2005 | 13 | 105 | 106 | 141 | 17.7 | 0 | 1 971 | 2.8 | 16 | 397 | 397 | 418 | 66 | 0 | 4 013 | 0.0 | 30 | 687 | 1 882 | 6 551 | 21 | 8 062 | 23 514 | 24.0 |
| 2006 | 13 | 124 | 124 | 147 | 16.9 | 0 | 2 067 | 0.8 | 15 | 286 | 286 | 298 | 59 | 0 | 3 056 | 0.3 | 32 | 699 | 1 891 | 6 030 | 21 | 7 645 | 21 810 | 26.0 |
| 2007 | 13 | 199 | 210 | 302 | 32.3 | 895 | 4 158 | 1.9 | 11 | 255 | 255 | 259 | 45 | 60 | 2 398 | 0.4 | 26 | 619 | 1 756 | 5 752 | 21 | 7 329 | 19 446 | 31.6 |
| 2008 | 13 | 137 | 149 | 246 | 23.0 | 602 | 3 145 | 2.7 | 14 | 187 | 187 | 204 | 41 | 942 | 2 051 | 0.0 | 23 | 618 | 1 909 | 6 674 | 20 | 6 674 | 20 264 | 31.1 |
| 2009 | 11 | 97 | 103 | 148 | 13.4 | 409 | 2 068 | 10.7 | 11 | 160 | 160 | 176 | 47 | 1 032 | 1 629 | 0.6 | 22 | 597 | 1 904 | 7 363 | 23 | 7 365 | 21 742 | 33.1 |
| 2010 | 8 | 88 | 88 | 96 | 15.8 | 285 | 1 344 | 5.7 | 10 | 176 | 176 | 198 | 41 | 68 | 2 051 | 0.0 | 20 | 603 | 1 944 | 6 870 | 21 | 6 870 | 20 761 | 37.5 |

**Table E2: Number of vessels, trips, trip strata, events, sum of catch, sum of sets (or tows) and sum of hours fishing for core vessels in the three CPUE analyses of west coast fisheries of SPO 1, by fishing year.**

| | SPO1W_SN(044) | | | | | | | | SPO1W_SN(043) | | | | | | | | SPO1W_SN(coast) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing year | Vessel | Trips | Trip-strata | events | Catch | Sets | Hours | % zero | Vessel | Trips | Trip-strata | events | Catch | Sets | Hours | % zero | Vessel | Trips | Trip-strata | events | Catch | Tows | Hours | % zero |
| 1990 | 4 | 31 | 31 | 41 | 13 | 0 | 298 | 0.0 | 8 | 107 | 107 | 124 | 32 | 0 | 642 | 0.0 | 2 | 95 | 95 | 96 | 14 | 0 | 2 022 | 1.1 |
| 1991 | 5 | 36 | 36 | 52 | 13 | 0 | 448 | 0.0 | 8 | 125 | 125 | 141 | 27 | 0 | 737 | 0.0 | 3 | 89 | 89 | 99 | 16 | 0 | 1 777 | 0.0 |
| 1992 | 5 | 49 | 49 | 67 | 23 | 0 | 612 | 0.0 | 9 | 198 | 199 | 210 | 41 | 0 | 1 333 | 0.5 | 3 | 125 | 125 | 128 | 17 | 0 | 2 144 | 0.0 |
| 1993 | 5 | 60 | 60 | 70 | 16 | 0 | 556 | 0.0 | 8 | 165 | 165 | 168 | 29 | 0 | 804 | 0.0 | 5 | 128 | 128 | 137 | 21 | 0 | 2 280 | 0.8 |
| 1994 | 8 | 96 | 96 | 134 | 34 | 0 | 1 138 | 0.0 | 12 | 248 | 248 | 257 | 57 | 0 | 1 703 | 0.0 | 4 | 151 | 151 | 151 | 21 | 0 | 1 829 | 0.0 |
| 1995 | 9 | 121 | 121 | 170 | 55 | 0 | 1 521 | 0.0 | 12 | 282 | 282 | 312 | 52 | 0 | 2 209 | 0.4 | 6 | 61 | 61 | 64 | 8 | 0 | 576 | 0.0 |
| 1996 | 10 | 133 | 133 | 177 | 54 | 0 | 1 930 | 0.0 | 13 | 256 | 256 | 277 | 37 | 0 | 2 042 | 0.0 | 7 | 164 | 164 | 181 | 77 | 0 | 2 396 | 3.0 |
| 1997 | 11 | 171 | 171 | 227 | 52 | 0 | 2 349 | 0.0 | 14 | 311 | 311 | 349 | 48 | 0 | 1 820 | 0.3 | 8 | 226 | 226 | 266 | 90 | 0 | 3 786 | 1.8 |
| 1998 | 13 | 205 | 205 | 254 | 45 | 0 | 2 835 | 0.0 | 12 | 244 | 244 | 294 | 27 | 0 | 1 553 | 0.0 | 8 | 277 | 278 | 300 | 84 | 0 | 4 538 | 0.7 |
| 1999 | 15 | 261 | 264 | 339 | 63 | 0 | 3 347 | 1.1 | 11 | 331 | 331 | 374 | 38 | 0 | 2 069 | 0.3 | 8 | 162 | 162 | 176 | 28 | 0 | 2 421 | 0.6 |
| 2000 | 15 | 299 | 301 | 421 | 87 | 0 | 4 172 | 0.7 | 14 | 379 | 379 | 443 | 61 | 0 | 2 603 | 0.3 | 8 | 225 | 225 | 268 | 38 | 0 | 3 432 | 0.4 |
| 2001 | 15 | 305 | 305 | 481 | 84 | 0 | 6 057 | 0.0 | 14 | 421 | 421 | 463 | 49 | 0 | 2 902 | 0.2 | 10 | 178 | 178 | 185 | 47 | 0 | 2 586 | 0.0 |
| 2002 | 14 | 281 | 281 | 370 | 46 | 0 | 4 713 | 0.0 | 15 | 359 | 359 | 391 | 36 | 0 | 2 691 | 0.0 | 12 | 267 | 268 | 288 | 37 | 0 | 3 993 | 0.0 |
| 2003 | 14 | 320 | 321 | 436 | 51 | 0 | 5 831 | 0.3 | 15 | 345 | 345 | 405 | 42 | 0 | 3 032 | 0.0 | 11 | 164 | 164 | 190 | 37 | 0 | 2 599 | 0.0 |
| 2004 | 12 | 189 | 189 | 262 | 46 | 0 | 3 406 | 0.0 | 13 | 286 | 286 | 320 | 34 | 0 | 2 918 | 0.0 | 8 | 182 | 184 | 226 | 49 | 0 | 3 120 | 0.5 |
| 2005 | 14 | 289 | 289 | 349 | 56 | 0 | 4 697 | 0.0 | 12 | 236 | 236 | 272 | 39 | 0 | 2 402 | 0.0 | 9 | 195 | 195 | 226 | 49 | 0 | 2 896 | 0.5 |
| 2006 | 13 | 234 | 234 | 315 | 38 | 0 | 4 278 | 0.0 | 10 | 205 | 205 | 225 | 26 | 0 | 1 894 | 0.5 | 10 | 62 | 63 | 106 | 29 | 0 | 1 287 | 0.0 |
| 2007 | 11 | 310 | 310 | 353 | 56 | 0 | 4 527 | 0.0 | 12 | 252 | 252 | 280 | 49 | 112 | 2 486 | 0.0 | 10 | 155 | 158 | 190 | 27 | 734 | 2 456 | 0.6 |
| 2008 | 9 | 241 | 241 | 269 | 32 | 33 | 3 448 | 0.0 | 13 | 172 | 172 | 192 | 29 | 103 | 1 787 | 0.0 | 11 | 227 | 229 | 266 | 29 | 1 039 | 3 450 | 1.3 |
| 2009 | 8 | 170 | 170 | 194 | 29 | 43 | 2 400 | 0.0 | 10 | 112 | 112 | 140 | 21 | 140 | 1 021 | 0.0 | 9 | 172 | 175 | 200 | 25 | 817 | 2 758 | 1.7 |
| 2010 | 8 | 126 | 126 | 170 | 34 | 81 | 2 298 | 0.0 | 8 | 103 | 103 | 119 | 18 | 163 | 765 | 1.0 | 9 | 155 | 156 | 180 | 16 | 461 | 2 374 | 1.9 |

**Table E3: Number of vessels, trips, trip strata, events, sum of catch, sum of sets (or tows) and sum of hours fishing for core vessels in three CPUE analyses of west coast fisheries in SPO 1 and 8, by fishing year.**

| | SPO1W_BT | | | | | | | | SPO8_SN | | | | | | | | SPO8_BT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing year | Vessel | Trips | Trip-strata | events | Catch | Tows | Hours | % zero | Vessel | Trips | Trip-strata | events | Catch | | Hours | % zero | Vessel | Trips | Trip-strata | events | Catch | Tows | Hours | % zero |
| 1990 | 16 | 211 | 257 | 429 | 14 | 1 188 | 3 441 | 7.4 | 11 | 229 | 237 | 286 | 70 | 0 | 4 804 | 2.5 | 7 | 221 | 226 | 305 | 17 | 744 | 2 084 | 1.3 |
| 1991 | 14 | 234 | 278 | 519 | 10 | 1 453 | 3 989 | 7.2 | 12 | 309 | 316 | 346 | 117 | 0 | 5 925 | 1.6 | 9 | 218 | 231 | 292 | 11 | 798 | 2 326 | 5.6 |
| 1992 | 18 | 351 | 429 | 924 | 22 | 2 375 | 6 863 | 9.6 | 14 | 366 | 379 | 442 | 87 | 0 | 7 037 | 2.1 | 12 | 152 | 171 | 316 | 8 | 762 | 2 122 | 11.7 |
| 1993 | 26 | 529 | 826 | 2 145 | 49 | 5 056 | 14 289 | 21.1 | 17 | 377 | 392 | 511 | 178 | 0 | 8 913 | 1.5 | 14 | 233 | 250 | 510 | 18 | 1 268 | 3 547 | 8.4 |
| 1994 | 25 | 504 | 787 | 1 781 | 49 | 4 716 | 12 783 | 16.6 | 16 | 442 | 464 | 546 | 202 | 0 | 7 999 | 1.1 | 14 | 159 | 171 | 291 | 7 | 742 | 2 239 | 7.0 |
| 1995 | 24 | 458 | 671 | 1 814 | 47 | 3 878 | 11 122 | 18.6 | 15 | 424 | 440 | 526 | 203 | 0 | 7 623 | 0.9 | 13 | 192 | 208 | 377 | 11 | 789 | 2 582 | 6.3 |
| 1996 | 27 | 462 | 813 | 2 468 | 40 | 3 319 | 10 804 | 25.6 | 18 | 403 | 420 | 546 | 227 | 0 | 7 022 | 2.6 | 14 | 243 | 275 | 459 | 20 | 1 036 | 3 270 | 4.7 |
| 1997 | 25 | 487 | 970 | 2 927 | 47 | 3 415 | 10 610 | 28.7 | 16 | 416 | 427 | 575 | 182 | 0 | 7 048 | 2.3 | 15 | 279 | 333 | 728 | 27 | 1 313 | 4 162 | 13.2 |
| 1998 | 27 | 608 | 1 083 | 3 399 | 42 | 4 204 | 12 414 | 23.5 | 13 | 237 | 249 | 386 | 146 | 0 | 4 840 | 2.0 | 17 | 271 | 313 | 869 | 26 | 1 357 | 4 423 | 13.1 |
| 1999 | 23 | 464 | 893 | 3 091 | 43 | 3 921 | 11 399 | 28.6 | 15 | 323 | 339 | 480 | 135 | 0 | 6 216 | 3.5 | 16 | 329 | 375 | 700 | 24 | 1 684 | 5 086 | 9.6 |
| 2000 | 22 | 447 | 943 | 3 048 | 42 | 3 767 | 12 574 | 36.3 | 17 | 329 | 343 | 478 | 139 | 0 | 5 767 | 0.9 | 14 | 301 | 375 | 852 | 26 | 1 952 | 6 097 | 11.2 |
| 2001 | 20 | 405 | 942 | 2 864 | 42 | 3 250 | 11 270 | 34.3 | 19 | 433 | 446 | 546 | 141 | 0 | 7 271 | 0.2 | 16 | 220 | 316 | 827 | 11 | 1 310 | 4 286 | 21.2 |
| 2002 | 19 | 376 | 835 | 2 334 | 33 | 2 562 | 9 183 | 35.3 | 19 | 382 | 402 | 567 | 173 | 0 | 7 755 | 4.5 | 19 | 240 | 359 | 986 | 22 | 1 408 | 4 700 | 18.9 |
| 2003 | 17 | 257 | 804 | 2 379 | 47 | 2 634 | 10 161 | 44.2 | 14 | 300 | 313 | 418 | 108 | 0 | 5 771 | 2.9 | 20 | 216 | 334 | 958 | 16 | 1 408 | 5 009 | 19.2 |
| 2004 | 16 | 262 | 828 | 3 108 | 32 | 3 144 | 11 721 | 38.3 | 15 | 352 | 373 | 529 | 181 | 0 | 7 044 | 1.3 | 17 | 175 | 305 | 922 | 15 | 1 221 | 4 614 | 21.6 |
| 2005 | 14 | 227 | 807 | 2 728 | 28 | 2 728 | 10 491 | 36.4 | 17 | 295 | 330 | 530 | 181 | 0 | 6 944 | 1.8 | 17 | 157 | 291 | 946 | 14 | 1 188 | 4 530 | 25.8 |
| 2006 | 15 | 197 | 526 | 1 791 | 20 | 1 861 | 6 903 | 26.8 | 15 | 200 | 211 | 441 | 157 | 0 | 5 732 | 4.7 | 16 | 166 | 290 | 948 | 13 | 1 157 | 4 396 | 22.4 |
| 2007 | 13 | 214 | 529 | 1 893 | 16 | 2 087 | 7 290 | 27.6 | 15 | 256 | 286 | 551 | 148 | 2 803 | 8 596 | 2.8 | 15 | 160 | 253 | 784 | 13 | 1 015 | 3 699 | 16.6 |
| 2008 | 12 | 219 | 649 | 2 239 | 29 | 2 247 | 8 159 | 34.1 | 13 | 262 | 320 | 682 | 176 | 4 390 | 9 749 | 2.8 | 14 | 185 | 302 | 990 | 12 | 995 | 3 744 | 29.5 |
| 2009 | 9 | 195 | 562 | 1 993 | 21 | 1 993 | 7 360 | 33.5 | 14 | 273 | 319 | 593 | 180 | 3 154 | 8 541 | 4.1 | 12 | 182 | 331 | 1 115 | 15 | 1 171 | 4 266 | 23.9 |
| 2010 | 7 | 131 | 299 | 1 079 | 19 | 1 079 | 3 652 | 38.1 | 13 | 252 | 309 | 590 | 196 | 3 616 | 8 950 | 4.2 | 12 | 203 | 375 | 1 220 | 13 | 1 253 | 4 477 | 29.1 |

## APPENDIX F CPUE INDICES

**Table F1: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for each of the three CPUE models of east coast fisheries in SPO 1.**

| | SPO1E_SN(coast) | | | | SPO1E_SN(007) | | | | SPO1E_BT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing | All | Core | | | All | Core | | | All | Core | | |
| Year | Arithmetic | Arithmetic | Geometric | Standardised | Arithmetic | Arithmetic | Geometric | Standardised | | Arithmetic | Geometric | Standardised |
| 1990 | 1.690 | 2.024 | 0.608 | 0.688 | 0.986 | 0.486 | 0.440 | 0.751 | 1.823 | 1.805 | 1.419 | 1.362 |
| 1991 | 1.011 | 0.924 | 0.997 | 1.201 | 0.995 | 0.723 | 0.742 | 1.122 | 2.008 | 1.931 | 1.671 | 1.631 |
| 1992 | 1.074 | 1.022 | 1.402 | 2.016 | 1.237 | 0.969 | 0.817 | 1.172 | 1.759 | 1.800 | 1.620 | 1.611 |
| 1993 | 0.826 | 0.843 | 0.721 | 0.913 | 0.949 | 0.889 | 0.785 | 1.039 | 1.313 | 1.337 | 1.347 | 1.383 |
| 1994 | 1.293 | 1.430 | 1.136 | 0.804 | 0.882 | 0.807 | 0.857 | 0.933 | 1.273 | 1.239 | 1.242 | 1.189 |
| 1995 | 1.557 | 1.783 | 1.813 | 0.868 | 1.070 | 1.147 | 1.227 | 1.161 | 1.245 | 1.238 | 1.270 | 1.190 |
| 1996 | 0.674 | 1.056 | 1.297 | 1.018 | 1.027 | 0.987 | 0.999 | 1.012 | 1.226 | 1.194 | 1.420 | 1.330 |
| 1997 | 0.952 | 0.678 | 0.903 | 1.268 | 0.988 | 1.100 | 1.188 | 1.116 | 1.083 | 1.117 | 1.341 | 1.212 |
| 1998 | 0.878 | 0.780 | 0.853 | 1.306 | 0.931 | 1.017 | 1.122 | 1.154 | 0.933 | 0.971 | 1.207 | 1.150 |
| 1999 | 0.556 | 0.557 | 0.658 | 0.809 | 1.119 | 1.244 | 1.226 | 1.129 | 1.066 | 1.055 | 1.352 | 1.349 |
| 2000 | 0.728 | 0.780 | 0.847 | 0.816 | 0.863 | 0.902 | 0.872 | 0.894 | 1.017 | 1.036 | 1.243 | 1.323 |
| 2001 | 0.707 | 0.745 | 0.990 | 1.017 | 0.938 | 1.054 | 1.023 | 0.981 | 0.691 | 0.683 | 0.641 | 0.701 |
| 2002 | 1.404 | 1.671 | 1.734 | 1.296 | 1.290 | 1.342 | 1.414 | 1.081 | 0.749 | 0.752 | 0.712 | 0.691 |
| 2003 | 1.386 | 1.197 | 1.300 | 1.188 | 0.846 | 0.916 | 0.963 | 0.709 | 0.677 | 0.653 | 0.620 | 0.642 |
| 2004 | 1.178 | 0.953 | 0.941 | 0.885 | 0.779 | 0.897 | 0.954 | 0.737 | 0.669 | 0.657 | 0.529 | 0.538 |
| 2005 | 1.136 | 0.976 | 1.054 | 1.020 | 0.849 | 0.932 | 0.948 | 0.835 | 0.635 | 0.654 | 0.652 | 0.662 |
| 2006 | 0.863 | 0.852 | 0.908 | 0.892 | 1.126 | 1.188 | 1.126 | 1.016 | 0.778 | 0.747 | 0.730 | 0.746 |
| 2007 | 1.164 | 0.939 | 0.785 | 0.671 | 1.016 | 1.127 | 1.007 | 1.000 | 0.802 | 0.819 | 0.824 | 0.840 |
| 2008 | 0.580 | 0.597 | 0.715 | 0.832 | 1.067 | 1.140 | 1.255 | 1.060 | 0.761 | 0.766 | 0.797 | 0.852 |
| 2009 | 0.886 | 0.930 | 0.872 | 0.970 | 1.332 | 1.502 | 1.544 | 1.464 | 0.871 | 0.885 | 0.819 | 0.860 |
| 2010 | 1.511 | 1.632 | 1.447 | 1.243 | 0.916 | 1.161 | 1.157 | 0.939 | 0.905 | 0.921 | 0.827 | 0.851 |

**Table F2: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for three CPUE models of west coast fisheries in SPO 1.**

| | SPO1W_SN(044) | | | | SPO1W_SN(043) | | | | SPO1W_SN(coast) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing | All | Core | | | All | Core | | | All | Core | | |
| Year | Arithmetic | Arithmetic | Geometric | Standardised | Arithmetic | Arithmetic | Geometric | Standardised | | Arithmetic | Geometric | Standardised |
| 1990 | 1.448 | 1.594 | 1.372 | 1.125 | 1.486 | 1.898 | 2.149 | 2.174 | 0.824 | 0.823 | 1.054 | 1.274 |
| 1991 | 1.389 | 1.442 | 1.138 | 0.827 | 1.198 | 1.355 | 1.594 | 1.599 | 0.860 | 1.006 | 1.304 | 1.410 |
| 1992 | 1.761 | 2.099 | 1.706 | 1.446 | 1.294 | 1.394 | 1.382 | 1.528 | 0.753 | 0.801 | 0.981 | 1.080 |
| 1993 | 1.210 | 1.200 | 1.006 | 1.098 | 1.511 | 1.455 | 1.394 | 1.306 | 1.552 | 0.899 | 1.079 | 1.385 |
| 1994 | 1.344 | 1.331 | 1.256 | 1.455 | 1.707 | 1.730 | 1.509 | 1.497 | 0.707 | 0.798 | 0.930 | 1.274 |
| 1995 | 1.726 | 1.626 | 1.573 | 1.596 | 1.402 | 1.169 | 0.855 | 1.161 | 0.833 | 0.754 | 0.896 | 1.297 |
| 1996 | 1.706 | 1.463 | 1.600 | 1.550 | 0.914 | 0.914 | 0.689 | 0.942 | 2.281 | 2.511 | 1.879 | 1.485 |
| 1997 | 1.217 | 1.211 | 1.184 | 1.270 | 0.976 | 0.967 | 0.908 | 0.992 | 1.915 | 2.081 | 1.696 | 1.510 |
| 1998 | 0.919 | 0.920 | 0.960 | 1.014 | 0.676 | 0.680 | 0.670 | 0.768 | 1.570 | 1.658 | 1.470 | 1.549 |
| 1999 | 0.898 | 0.875 | 0.848 | 0.902 | 0.769 | 0.698 | 0.682 | 0.723 | 0.826 | 0.814 | 0.867 | 1.099 |
| 2000 | 1.083 | 1.079 | 1.024 | 0.956 | 1.095 | 1.019 | 1.031 | 1.049 | 0.779 | 0.769 | 0.747 | 0.736 |
| 2001 | 0.751 | 0.784 | 0.793 | 0.822 | 0.750 | 0.679 | 0.737 | 0.828 | 1.237 | 1.296 | 1.363 | 0.942 |
| 2002 | 0.631 | 0.623 | 0.660 | 0.673 | 0.693 | 0.604 | 0.622 | 0.712 | 0.930 | 0.789 | 0.529 | 0.603 |
| 2003 | 0.540 | 0.536 | 0.603 | 0.601 | 0.703 | 0.652 | 0.768 | 0.769 | 1.117 | 1.080 | 0.994 | 0.860 |
| 2004 | 0.864 | 0.891 | 0.944 | 0.897 | 0.781 | 0.742 | 0.853 | 0.813 | 1.122 | 1.193 | 1.151 | 1.090 |
| 2005 | 0.764 | 0.776 | 0.848 | 0.863 | 1.117 | 1.050 | 1.091 | 0.862 | 1.029 | 1.070 | 0.996 | 0.862 |
| 2006 | 0.661 | 0.623 | 0.710 | 0.757 | 0.744 | 0.776 | 0.884 | 0.756 | 1.647 | 1.765 | 1.782 | 0.892 |
| 2007 | 0.803 | 0.796 | 0.891 | 1.034 | 1.107 | 1.234 | 1.222 | 0.919 | 0.733 | 0.771 | 0.648 | 0.581 |
| 2008 | 0.675 | 0.640 | 0.670 | 0.726 | 1.009 | 1.020 | 1.072 | 0.783 | 0.644 | 0.660 | 0.597 | 0.556 |
| 2009 | 0.788 | 0.765 | 0.868 | 0.925 | 0.935 | 1.078 | 1.033 | 1.019 | 0.727 | 0.717 | 0.728 | 0.760 |
| 2010 | 1.137 | 1.180 | 1.292 | 1.253 | 0.958 | 1.014 | 1.019 | 0.865 | 0.553 | 0.567 | 0.661 | 0.801 |

**Table F3: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for each of the three CPUE models of east coast fisheries in SPO 1.**

| | SPO1W_BT | | | | SPO8_SN | | | | SPO8_BT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing | All | Core | | | All | Core | | | All | Core | | |
| Year | Arithmetic | Arithmetic | Geometric | Standardised | Arithmetic | Arithmetic | Geometric | Standardised | | Arithmetic | Geometric | Standardised |
| 1990 | 1.022 | 1.145 | 0.994 | 1.571 | 0.754 | 0.654 | 0.696 | 1.141 | 1.465 | 1.788 | 1.591 | 2.364 |
| 1991 | 0.692 | 0.691 | 0.665 | 1.145 | 1.011 | 1.018 | 1.009 | 1.346 | 1.064 | 1.044 | 1.029 | 1.702 |
| 1992 | 0.841 | 0.823 | 0.740 | 1.181 | 0.624 | 0.696 | 0.668 | 0.740 | 1.077 | 0.864 | 0.893 | 1.246 |
| 1993 | 0.828 | 0.788 | 0.914 | 1.307 | 0.898 | 1.152 | 0.939 | 0.953 | 1.048 | 1.030 | 1.098 | 1.660 |
| 1994 | 0.942 | 0.910 | 0.953 | 1.395 | 1.049 | 1.224 | 1.160 | 1.023 | 0.821 | 0.721 | 0.799 | 1.173 |
| 1995 | 1.131 | 1.091 | 1.047 | 1.484 | 1.144 | 1.112 | 0.855 | 0.805 | 1.112 | 1.046 | 1.136 | 1.489 |
| 1996 | 1.158 | 1.098 | 1.233 | 1.537 | 1.306 | 1.223 | 1.368 | 1.103 | 1.301 | 1.399 | 1.301 | 1.458 |
| 1997 | 1.071 | 1.036 | 1.086 | 1.091 | 0.900 | 0.874 | 0.842 | 1.078 | 1.407 | 1.460 | 1.177 | 1.260 |
| 1998 | 0.911 | 0.873 | 0.928 | 1.007 | 1.605 | 1.283 | 1.659 | 1.228 | 1.096 | 1.201 | 1.320 | 1.399 |
| 1999 | 1.001 | 0.970 | 0.954 | 1.096 | 0.962 | 0.893 | 0.990 | 0.855 | 0.870 | 0.994 | 0.919 | 1.188 |
| 2000 | 1.109 | 1.082 | 1.130 | 1.071 | 1.086 | 0.918 | 1.046 | 1.012 | 0.931 | 0.936 | 0.942 | 1.112 |
| 2001 | 1.108 | 1.087 | 0.767 | 0.683 | 0.863 | 0.787 | 0.895 | 0.976 | 0.602 | 0.623 | 0.604 | 0.655 |
| 2002 | 1.166 | 1.136 | 1.076 | 0.989 | 0.946 | 0.930 | 1.230 | 1.276 | 1.097 | 1.147 | 0.811 | 0.714 |
| 2003 | 1.535 | 1.507 | 1.927 | 1.437 | 0.899 | 0.969 | 1.156 | 1.035 | 0.922 | 0.934 | 0.827 | 0.769 |
| 2004 | 0.879 | 0.874 | 0.886 | 0.659 | 1.128 | 1.194 | 1.316 | 1.309 | 0.913 | 0.943 | 0.957 | 0.638 |
| 2005 | 0.779 | 0.765 | 0.817 | 0.482 | 1.250 | 1.212 | 1.215 | 1.094 | 0.798 | 0.794 | 0.895 | 0.502 |
| 2006 | 1.031 | 1.045 | 1.061 | 0.682 | 1.203 | 1.209 | 1.107 | 1.033 | 0.784 | 0.803 | 1.059 | 0.621 |
| 2007 | 0.838 | 0.832 | 0.776 | 0.555 | 0.961 | 0.931 | 0.734 | 0.827 | 1.034 | 1.033 | 1.112 | 0.768 |
| 2008 | 1.041 | 1.009 | 1.227 | 0.843 | 0.756 | 0.764 | 0.699 | 0.719 | 1.151 | 1.172 | 1.060 | 0.741 |
| 2009 | 1.037 | 1.057 | 0.866 | 0.707 | 0.941 | 1.071 | 0.814 | 0.794 | 0.994 | 0.862 | 0.969 | 0.686 |
| 2010 | 1.203 | 1.633 | 1.663 | 1.262 | 1.163 | 1.296 | 1.231 | 0.985 | 0.932 | 0.837 | 0.937 | 0.727 |

## APPENDIX G: BINOMIAL AND COMBINED MODELS

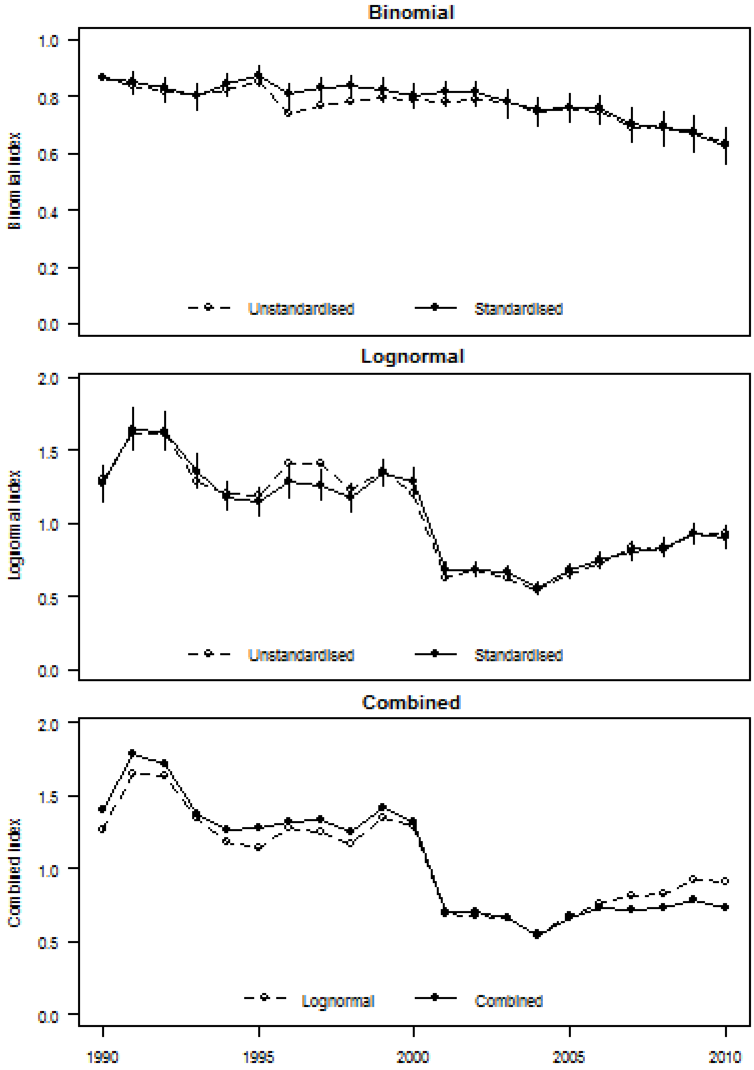



**Figure G1: Different standardised annual CPUE indices for the SPO1E_BT fishery. Top: Binomial index representing probability of capture. Middle: Lognormal index representing magnitude of catch. Bottom: Combined index representing expected catch.**

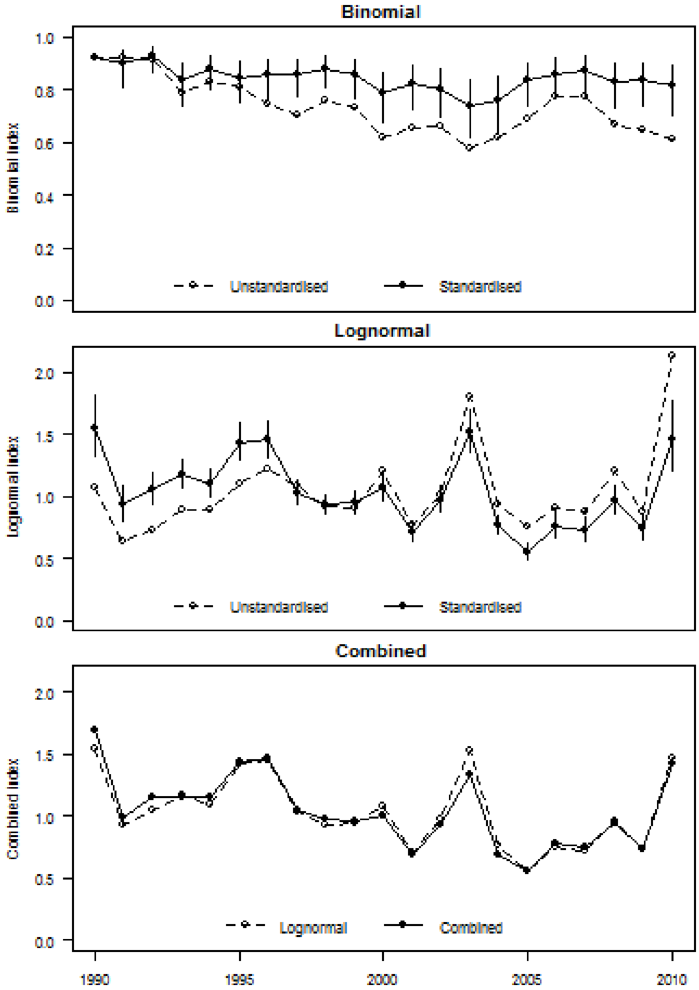



**Figure G2: Different standardised annual CPUE indices for the SPO1W_BT fishery. Top: Binomial index representing probability of capture. Middle: Lognormal index representing magnitude of catch. Bottom: Combined index representing expected catch.**

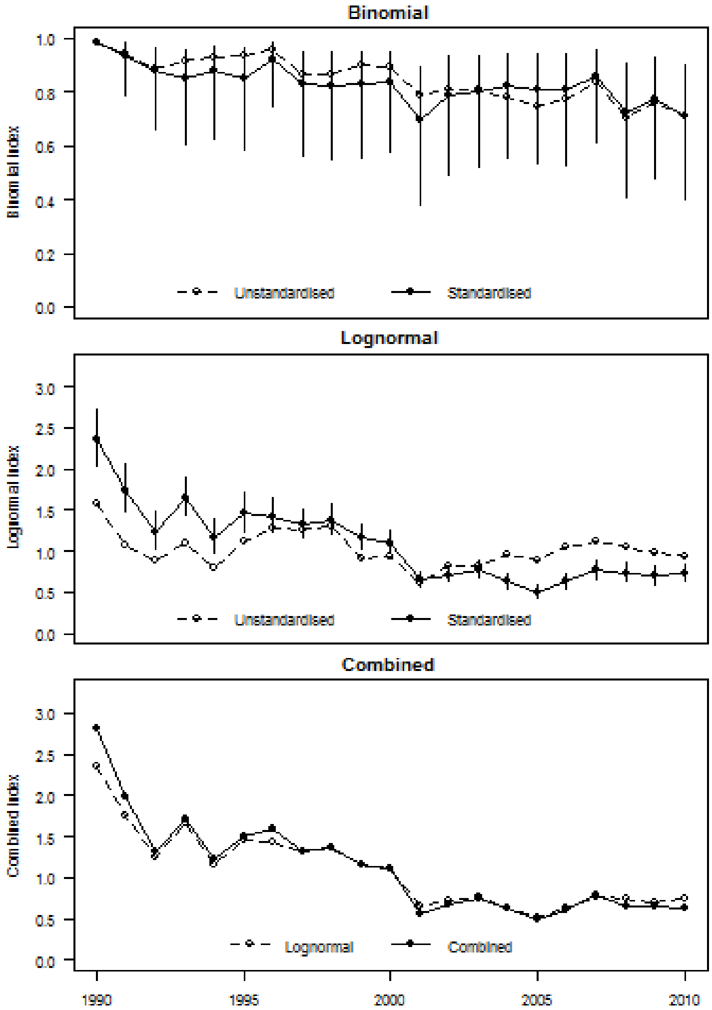
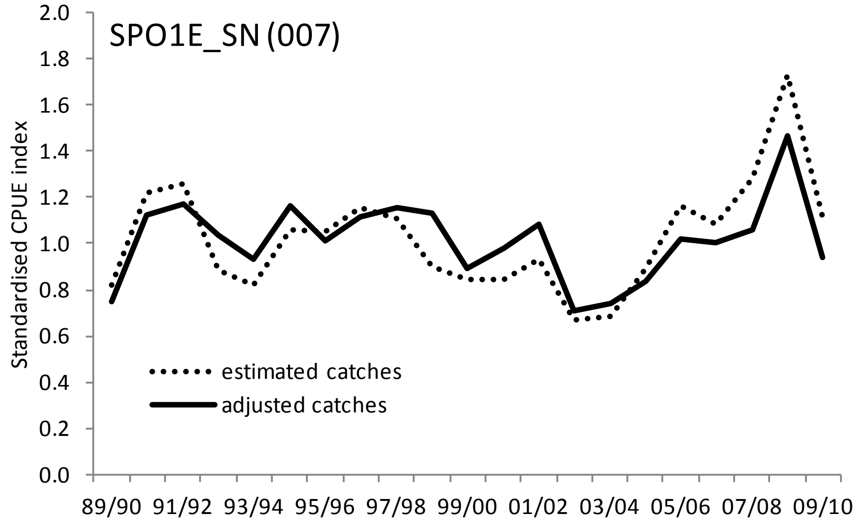
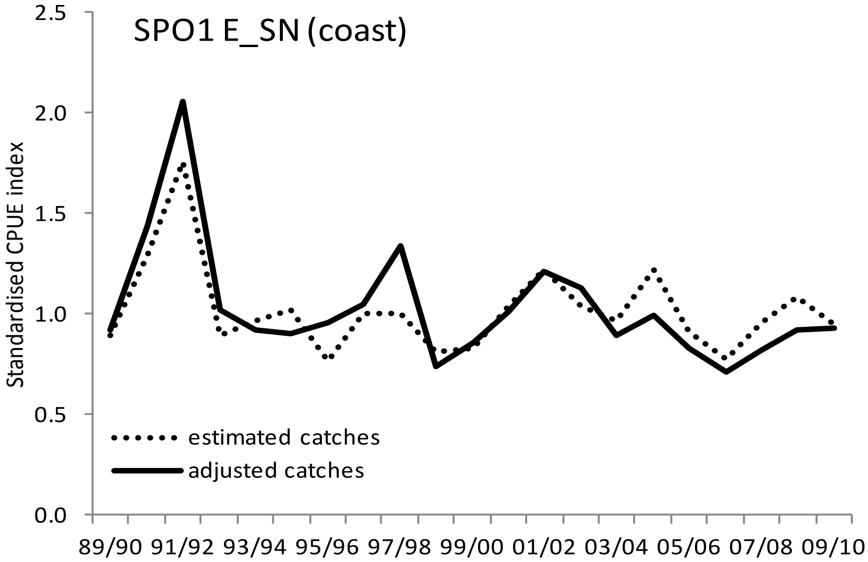
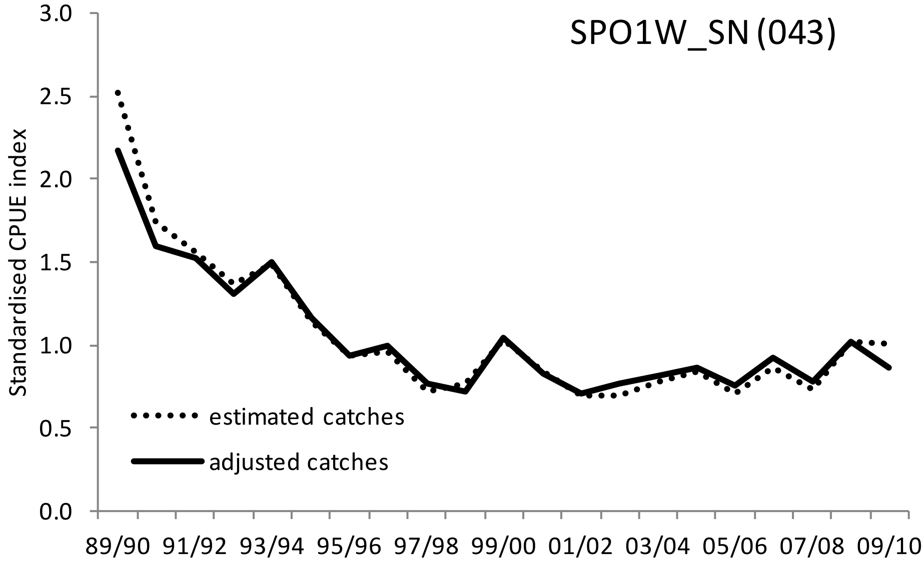


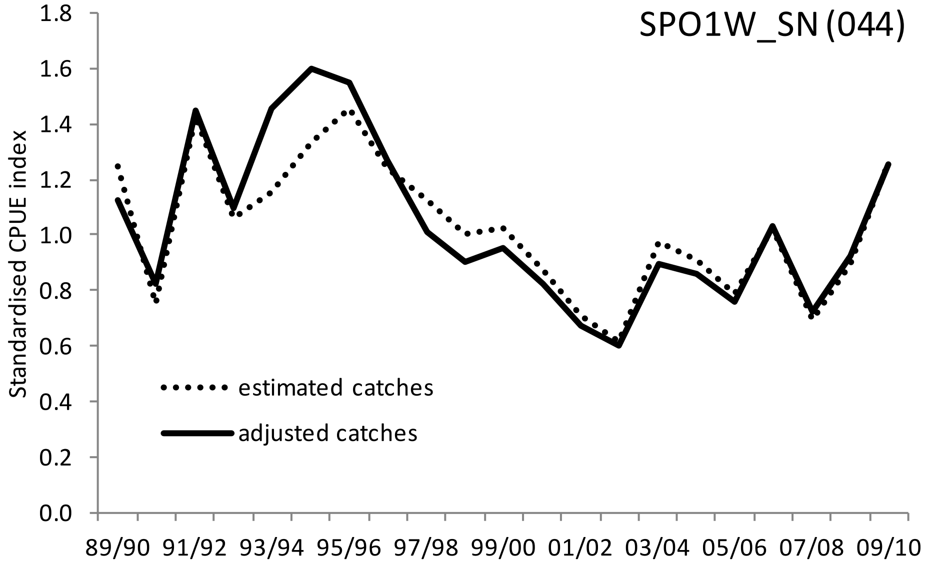

**Figure G3: Different standardised annual CPUE_indices for the SPO8_BT fishery. Top: Binomial index representing probability of capture. Middle: Lognormal index representing magnitude of catch. Bottom: Combined index representing expected catch.**

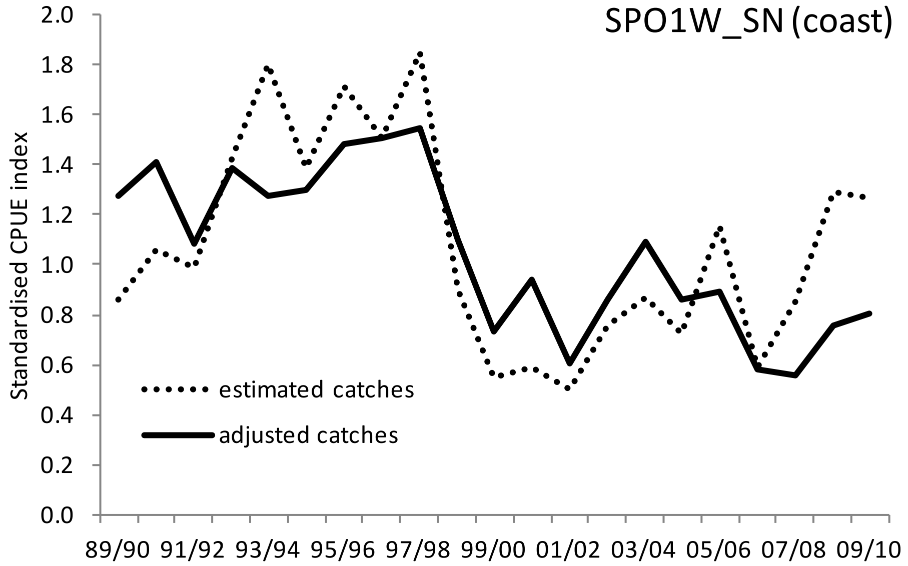
**APPENDIX H: SENSITIVITY OF SET NET INDICES TO ADJUSTING ESTIMATED CATCHES**

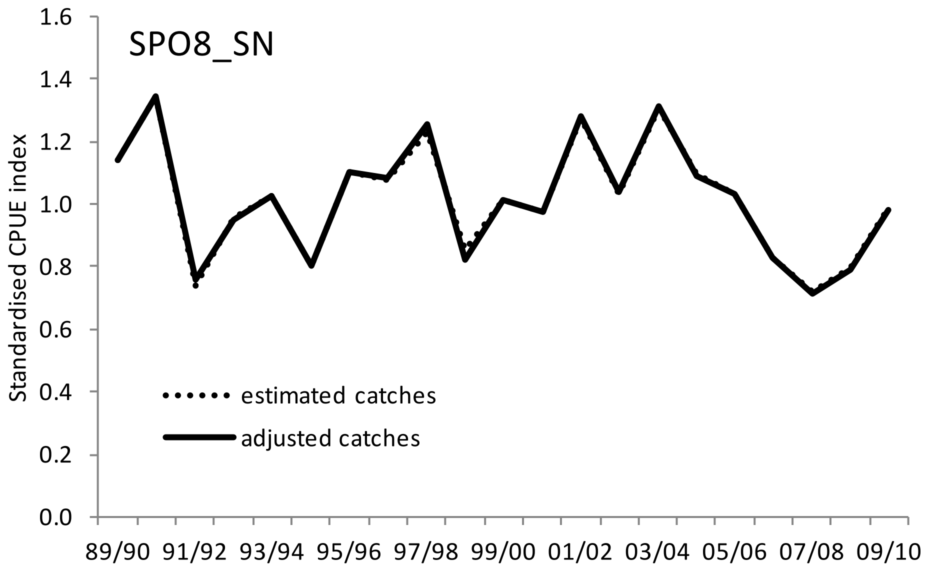



SPO1W_SN (044)
Standardised CPUE index
estimated catches
adjusted catches
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
89/90 91/92 93/94 95/96 97/98 99/00 01/02 03/04 05/06 07/08 09/10


SPO1W_SN (coast)
Standardised CPUE index
estimated catches
adjusted catches
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
89/90 91/92 93/94 95/96 97/98 99/00 01/02 03/04 05/06 07/08 09/10


SPO8_SN
Standardised CPUE index
estimated catches
adjusted catches
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
89/90 91/92 93/94 95/96 97/98 99/00 01/02 03/04 05/06 07/08 09/10