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# Catch per unit effort (CPUE) analyses and characterisation of the South Island commercial freshwater eel fishery, 1990–91 to 2012–13

New Zealand Fisheries Assessment Report 2015/30

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ISSN 1179-5352 (online)
ISBN 978-0-908334-03-2 (online)

April 2015

New Zealand Government

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## EXECUTIVE SUMMARY

**Beentjes, M.P.; Dunn, A. (2015). Catch per unit effort (CPUE) analyses and characterisation of the South Island commercial freshwater eel fishery, 1990–91 to 2012–13.**

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The results of a catch-per-unit-effort (CPUE) analysis for the South Island commercial freshwater eel fishery (*Anguilla australis*, shortfin; *A. dieffenbachii*, longfin) for the fishing years 1991 to 2013 (1990–91 to 2012–13) are presented, updating previous analyses by three years. Analyses were carried out individually for ten South Island eel statistical areas (ESAs Nelson AN, Marlborough AP, south Marlborough AQ, north Canterbury AR, Te Waihora AS, south Canterbury AT, Waitaki AU, Otago AV, Southland AW, and Westland AX) , except AP and AQ which were combined. CPUE analyses were carried out for all areas for the period before introduction of South Island eels into the Quota Management System (pre-QMS, 1990–91 to 1999–2000), and post-QMS for areas with sufficient data and fishers (i.e., ESAs AX, AV, AW, and AS1). Additional predictor variables, to those used previously, were included in the standardised CPUE analyses: target species (reconstructed), catcher (=fisher) for post-QMS data after 2001 (distinct from permit holder), water quality data for key rivers, river flow data for more key rivers, Te Waihora lake level and periods when the lake was open or closed. In addition to the routine standardised CPUE analyses carried out using estimated catch from ECERs, trial analyses were carried out linking landings data collected from the MPI project 'Monitoring commercial eel fisheries' with the ECER effort data to model standardized CPUE of eels in the largest size category. Also presented for the first time, are detailed fyke net specifications and methods of deployment.

### Catch summary

Overall, total groomed estimated catch used in the CPUE analyses was 90% of the total reported landed catch for the South Island. The shortfall was a result of removing 6 and 11% of records with errors and 5% of records that reported estimated catch as EEU before 2002. The trends in estimated and landed eel catch are similar, indicating that estimated catch is likely to be proportional to total landed catch, and hence suitable for CPUE analysis.

The reported estimated catch over 23 years was 51% shortfin (average of about 170 t per year), 45% longfin (average of about 150 t per year), and 5% unidentified (EEU). Shortfin and longfin catches were made in all South Island ESAs, but 60% of the shortfin catch was from Te Waihora (AS) and 76% of longfin from three ESAs (Otago AV, Southland AW, and Westland AX). Catch rates (kg per lift) of total catch were generally similar across all areas, and most commonly were between 4 and 6 kg per lift with no trends with time.

The trend of declining estimated eel catch of all South Island eels from 1992 to about 2000 is mostly due to the decrease in longfin catch as shortfin catch was reasonably stable from 1991 to 2013. The declining estimated eel catch in the 1990s is evident in all ESAs except Te Waihora which maintained a reasonably stable catch over the 23 year time series. The decline in longfin catch cannot be attributed to the introduction of the QMS in 2001 because there were no quotas set for individual eel species and the ANG South Island quota was never caught.

There was a trend of declining estimated catch of all South Island eels from 1992 to about 2000, after which catch was comparatively stable up to 2013. The estimated catch of shortfin has remained about the same over the 23 year time series, however landed catch indicates a clear decline from the early 1990s to 2001 after which is has been stable or increasing. The different trends in the shortfin data sets may result from data grooming deletions of shortfin from estimated catch and coding catch to EEU rather than shortfin. Catch of longfin catch in both the landed and estimated catch data sets declined from the early 1990s to 2003 and has since been stable or increasing, with the exception of 2009. Longfin catches are often related to fluctuating market demands.

### CPUE analyses

Standardised and unstandardised CPUE analyses were carried out on core fishers' estimated catch for individual species (longfin and shortfin), except AS1 which was restricted to shortfin. Standardised

CPUE analyses used a Generalised Linear Model (GLM) ignoring zero catches, where the response variable was daily catch. The four variables permit, target, lifts, and month were included in nearly all pre-QMS models, with month generally explaining the least variability of the four in the models. The variable ‘catcher’ tended to replace the variable ‘permit’ in the post-QMS models. The target species variable is new to these analyses and accounts for differences in fishing gear and deployment when targeting one or the other species. Sensitivity analyses restricted records to target shortfin or longfin, and although they had less data, showed similar and in many cases identical trends indicating that offering target species as a predictor variable was adequate to explain the effects of targeting on CPUE. The results indicated that catch rates were very dependent on fisher experience and/or ability, target species, number of nets used, and season.

Trial CPUE analyses using merged and groomed landed catch of large eels from processors, and effort data from ECERs resulted in considerable loss of data because either the landing data could not be matched with catch-effort records, or the resulting merge resulted in a substantial difference in the landed and estimated catch, and required outliers to be removed. The CPUE results were for three years only (2009–10, 2010–11 and 2011–12) and comments on trends are premature. The validity of these indices is unknown.

### Shortfin CPUE summary

For the data-poor areas (AN, AP-AQ, AR, AT, and AU), with the exception of AN all pre-QMS indices showed a declining trend in CPUE from 1991 to 2000, most marked in AP-AQ.

For the data-rich areas (AX, AV, AW, and AS1), indices showed clear declines in pre-QMS CPUE for AV and AW, but in AX there was an overall increase in CPUE. Post-QMS indices showed clear trends of increasing CPUE in all areas, most marked in AW and particularly AS1 until 2011, after which it levelled off.

### Longfin CPUE summary

For the data-poor areas (AN, AP-AQ, AR, AT, and AU), the pre-QMS indices in AP-AQ showed a strong and consistent decline in CPUE from 1991 to 2000, whereas the other areas tended to show slight declines followed by slight increases in CPUE.

For the data-rich areas (AX, AV, and AW), indices showed clear declines in pre-QMS CPUE for AV and AW, but in AX the CPUE increased over time. Post-QMS indices showed clear trends of increasing CPUE in AX and AV, and to a lesser extent in AW over the last five years

# 1. INTRODUCTION

This report presents the results of a catch-per-unit-effort analysis (CPUE) for freshwater eels (*Anguilla australis* and *A. dieffenbachii*) for ten South Island eel statistical areas (ESA) for the fishing years 1990–91 to 2012–13 (23 years), and updates previous similar analyses (Beentjes & Bull 2002, Beentjes & Dunn 2003, 2008, 2013).

## 1.1 Commercial fishery

The commercial freshwater eel fishery in New Zealand developed in the late 1960s and landings consist of both the endemic longfin eel (*Anguilla dieffenbachii*), and the shortfin eel (*A. australis*) which is also found in southeast Australia, Tasmania, New Caledonia, Lord Howe and Norfolk Islands (McDowall 2000). Landings from the north of the North Island can include the occasional spotted eel (*A. reinhardtii*). Total New Zealand eel catches peaked in 1972 at about 2100 t and from 1972 to 1998–99 catch fluctuated with no clear trend with an annual average catch of about 1300 t (Figure 1). Catches then progressively declined to a low of 560 t in 2009–10 before increasing to reach 712 t in 2012–13 (Ministry for Primary Industries 2014). South Island catches showed a similar decline for both species with shortfin increasing after 2001–02 and longfin after 2008–09 (Figure 1). Over the last ten years the South Island has contributed 42%, on average, of the total New Zealand eel catch.

The South Island eel fishery was introduced into the Quota Management System (QMS) in 2000–01, with five Quota Management Areas (ANG 11 to ANG 16) and Total Allowable Commercial Catches (TACC) set for both species combined (Table 1, Figure 2). TACCs were consistently under-caught in all South Island QMAs, with the exception of ANG 13 (Te Waihora), which was 100% caught between 2003–04 and 2008–09 (Ministry for Primary Industries 2014). The combined South Island TACC (421 t) was 66% caught, on average, since being introduced into the QMS with the highest catches in 2012–13, the most recent year (85% of TACC) (Figure 1). The Chatham Island eel fishery was introduced into the QMS in 2003–04 with single QMAs for each species (SFE 17, and LFE 17). Subsequently, the North Island eel fishery was introduced into the QMS in 2004–05 with four separate QMAs each for shortfin and longfin (LFE 20–23 and SFE 20–23).

South Island shortfin and longfin catches were of similar magnitude with the exception of the period between 2003–04 and 2010–11 when the longfin catches were substantially lower. Longfin are widespread throughout the South Island, but largest catches were from Southland, south Otago, northern Westland, and Marlborough (Wairau River catchment). The bulk of the South Island shortfin landings were from Te Waihora and Lake Brunner, but also from coastal lakes, lower river reaches, and estuaries (Beentjes & Chisnall 1997, 1998, Beentjes 1999, 2011, 2013). By contrast, shortfin was the dominant species in North Island catches representing more than three quarters of landed catch weight between 2003–04 and 2008–09 (Beentjes 2011).

## 1.2 Reporting

The introduction of the Catch Effort Landing Return (CELR) in October 1989 replaced the Fisheries Statistics Unit (FSU) eel returns. Data quality for the first two years of the CELR system was poor (Jellyman 1993), and the data from 1989–90 were not suitable for inclusion in this analysis. The CELR form was replaced by an Eel Catch Effort Return (ECER) and an Eel Catch Landing Return (ECLR) on 1 October 2001. Changes to the new forms included dedicated fields for shortfin and longfin estimated catch, the removal of target species and EEU (unidentified) as a valid species code. Before this last change, the proportion of total eel catch recorded as EEU ranged from about 0% (Te Waihora, ESA 21 and AS) to 83% (AD, Waikato), although the EEU code tended to be used more often in the North Island. The ECER and ECLR forms provided the only means to record the individual catch of longfin and shortfin separately in the South Island, as either species were reported as ANG on Quota Management Returns (QMR) and Monthly Harvest Returns (MHR).

The data used in the CPUE analyses presented in this report include data from CELR (1990–91 to 1999–2000) and ECER (2001–02 to 2012–13) forms. Eel statistical areas for reporting catch effort data were changed from numeric codes (1–23) to alpha codes (AA–AZ) in July 2000; ESA boundaries were virtually unchanged except ESA 14 which was divided into Marlborough and South Marlborough (AP and AQ) (Figure 3, Table 1). In this report we refer to ESAs by the current alpha codes, although some previous analyses used the numeric codes. Table 1 provides a useful key for relating ESAs (numeric and alpha), QMAs, and area names.

### 1.3 Specific objective

To analyse CPUE trends in the South Island commercial eel fisheries (ANG 11, ANG 12, ANG 13, ANG 14, ANG 15, and ANG 16) using data up to the end of the fishing year 2012/13.

## 2. METHODS

### 2.1 Catch effort data extraction

Estimates of catch and effort for each day's fishing were recorded on CELR forms up to 30 September 2001, and then on ECERs after this time, although there was a transition period in early 2001–02 when either form was accepted. The catch effort data used in this report were extracted from the Ministry for Primary Industries Catch Effort Database *Warehou*, and for each daily record from fishing years (1 October to 30 September) 1990–91 to 2012–13 for all South Island ESAs. The following variables were extracted.

CELR (1990–91 to 2001–02)

- Date nets were lifted
- Permit number (encrypted)
- Vessel registration number
- Location landed
- Method
- Form number
- Eel statistical area (ESA)
- Number of net lifts
- Nets in the water at midnight
- Target species
- Total weight (weight of shortfin, SFE; longfin, LFE; unidentified, EEU; and bycatch)
- Weight of individual species (includes SFE, LFE, EEU, and bycatch species)

ECER (2001–02 to 2011–12)

- Date nets were lifted
- Permit number (encrypted*)
- Method
- Eel statistical area (ESA)
- Number of net lifts
- Estimated catch weight of shortfin (SFE)
- Estimated catch weight of longfin (LFE)
- Catcher ID

The encrypted permit number represents the Ministry for Primary Industries *Permit Holder FIN Number* (CELR) and *Client Number of Permit Holder* (ECER). A permit holder is entitled to employ others to fish on their permit, and hence one permit number may have catch landed from more than one fisher. It is more usual, however, for the permit holder to also be the person listed as the catcher on ECERs. The catcher was only recorded since 2001–02 when ECERs were introduced and this is the first time this variable was extracted. Identity of the catcher (=fisher) is recorded on ECERs by entering the first letter of the fisher's first name and the first four letters of the surname, e.g., Joe Bloggs would be correctly recorded as JBLOG in the field 'Name of Fisher'. Inspection of the data showed that there was considerable inconsistency by fishers recording the correct or a consistent format and often a single fisher would use several abbreviation variations (e.g., JBLOC, BLOGG, JOBLO). Further the spelling/writing was sometimes ambiguous and incorrectly punched by FishServe. This was also complicated by fishers with the same surnames. All possible variations for a single fisher were identified, primarily by reference to permit number and frequency used, and these were recoded to the presumed correct code. In this process the initial number of catchers was reduced from 182 to 133 after grooming and recoding. There is no guarantee that the assignment was correct in all cases.

In the current analyses we extracted all ECER data for the years 2001–02 to 2012–13 (twelve years) for all South Island ESAs, groomed for errors or missing data, and appended these to the existing groomed data sets from CELR data, creating a time series for each ESA from 1990–91 to 2012–13 (23 years) (Table 2). We did not re-extract the CELR data as there were considerable effort and resources applied to the original manual error checking and grooming of these data (Beentjes & Willsman 2000, Beentjes & Bull 2002, Beentjes & Dunn 2003). For the current analyses there were very few deletions and virtually all ECER data were retained in the analyses.

In this report, henceforth, fishing years are referred to by the second year, e.g., 1990–91 is referred to as 1991.

## 2.2 Environmental variables

Mean daily river flow data for some key rivers from each ESA, were obtained from regional councils and the NIWA hydrological database (NIWA Water Resources and Climate Archive) with nine additional rivers included in the current analyses (Appendix 1). When river flow data from more than one river per ESA were used in standardised CPUE analyses, they were treated as separate variables.

In addition, for the first time, freshwater water quality data were included in the CPUE analyses. These water quality data originate from the National Rivers Water Quality Network (NRWQN) operated by NIWA in which 77 sites from 35 rivers spread throughout New Zealand have been sampled monthly since 1998 (Davies-Colley et al. 2011, Ballantine & Davies-Colley 2014). These data were obtained from a number of sites throughout the South Island, at the same locations that mean river flow is recorded (Appendix 1). The water quality variables extracted from this database were water temperature, dissolved oxygen, water clarity, pH, dissolved nitrates, and dissolved phosphates. Because these data are collected monthly, for each catch record within a month the same values of these variables were used (e.g., water temperature could be 15°C for all December catch records). For missing data, when water quality data were not recorded, the median value from the preceding or following two months was used, otherwise the median value from preceding or following four months. When water quality from more than one site per ESA were used in standardised CPUE analyses, they were treated as separate variables.

Moon phase was included as a possible explanatory term to account for changes in catchability with changes in the lunar cycle. The relative phase (0–1) of the moon (moon cycle) was determined for each record in the data set based on the date of each record, using an algorithm from Meeuse (1998).

For Te Waihora two new variables (lake level and time of lake opening) were included in the standardised CPUE analyses. These data were provided by Environment Canterbury.

## 2.3 Reconstructed target species

Target species is recorded in CELR forms but not in ECER forms. Target species was reconstructed for all records from recorded CELR target species and species proportions using a simple optimisation to evaluate the best proportion to use (Cohen's kappa coefficient). The resulting level of concordance was a measure of how well the constructed target species matched that recorded in CELRs. Target species was reconstructed for all records, including those from CELR data. We used a 'common sense' default minimum value of 80% in some cases because higher values tended to assign too many records to the category 'either', when kappa was above 80%.

## 2.4 CPUE analyses

### 2.4.1 Pre- and post-QMS data analyses

Analyses for shortfin and longfin separately were carried out for pre-QMS and post-QMS datasets for four key areas with sufficient data and fishers (i.e., ESAs AX, AV, AW, and AS1). For the remaining five areas (ESAs AN, AP-AQ, AR, AU, and AT) CPUE analyses were restricted to pre-QMS (1991 to 2000), but the characterisation of the fishery was carried out for all years. Analyses for Te Waihora were restricted to shortfin eels in AS1 (outside the concession area) from 2001 onwards when the codes AS1 and AS2 were introduced enabling reporting of catches from inside and outside the concession area.

South Island CPUE analyses were carried out on the continuous time series up until 2005–06 (Beentjes & Dunn 2008) after which analyses were split into pre- and post-QMS (Beentjes & Dunn 2013). The rationale for this was that following the introduction of South Island eels into the QMS in 2000–01, there was generally a reduction in both numbers of fishers and catch. Further, it was suspected that some of the post-QMS new entrants had previously fished for existing permit holders under a fishing agreement and hence were not, strictly speaking, new entrants. It was not possible to link the identity of South Island fishers pre- and post-QMS because the ECER form, which includes a field identifying fishers that landed the catch, did not come into effect until 2001–02, a year after South Island eels were introduced into the QMS. This permit linking approach was used in the North Island CPUE analyses where eels were introduced into the QMS in 2004–05, three years after reporting by the ECER form came into effect (Beentjes & Dunn 2010).

### 2.4.2 Unstandardised CPUE analyses

Unstandardised CPUE analyses were carried out for SFE and LFE separately. It is presented as total catch/total lifts per year (where shortfin and longfin sum to the total eel catch, excluding zeros associated with EEU catch) for all raw data, and for core fishers which is plotted alongside the standardised CPUE indices.

### 2.4.3 Standardised CPUE analyses

#### Core fishers

For each ESA standardised CPUE analyses were conducted separately for SFE and LFE. A selection criterion was applied to each dataset restricting data analysis to core fishers (identified by permit number). Core fishers were defined as those that recorded a total catch (all eels) of 1000 kg or more over all years, and landed eel catch in at least three years. These selection criteria identified fishers that had a long-term commitment to the fishery.

#### The GLM model

Estimates of year effects and associated standard errors were obtained using a forward stepwise Generalised Linear Model (GLM) (McCullagh & Nelder 1989), with daily catch modelled as the response variable. Using daily catch as the response variable and lift as a possible predictor allows the model to consider non-linear relationships between catch and effort. Records with a catch of zero were not included in the analyses. Whilst zero catches can provide useful information in some fisheries, it is generally not so in eel fisheries for the following reasons:

1. Fishers that record zero for one species are often fishing habitat preferred by the other, and without including habitat or target species as explanatory variables the models are unable to account for this behaviour. Unfortunately habitat is not recorded on the catch effort forms, however target species has been reconstructed and included for the first time in the current analyses (see below). These are valid zeros.
2. Where catches comprise a mix of the two eel species, small proportions of one species are likely to be recorded as zeros since fishers tend to estimate catches based on a visual inspection of unsorted catches. These are invalid zeros.
3. There are many records before 2002 where eels were reported as EEU (unspecified species) and hence for these records shortfin and longfin catch are given a value of zero in the input data even though it is clearly not zero but unknown. These are invalid zeros.

The GLM model used the log-normal transformation of positive daily catch. This implies a multiplicative model, i.e., the combined effect of two predictors is the product of their individual effects. The predictor variables used in the model were fishing year, permit number, catcher (from 2002 onward), number of lifts, month (season), river flow (for selected rivers within each ESA analysis), lake level and lake open/closed status (Te Waihora only), water quality (water temperature, dissolved oxygen, clarity, pH, dissolved nitrates and dissolved phosphates), target species (reconstructed) and moon phase. Variables were treated as categorical, except number of lifts, daily mean river flow, water quality, and moon phase, which were entered as continuous variables. Continuous variables were typically fitted as a 3-degree polynomial in log space.

A stepwise regression procedure was used to fit the GLM of CPUE (daily catch) on these predictor variables. The relative year effect from the model was then interpreted as the CPUE index, and presented using the canonical form, scaled to have a mean of 1.0. Model fits were investigated using standard residual diagnostics. Plots of model residuals and fitted values were investigated for evidence of departure from model assumptions. Influence step plots and coefficient-distribution-influence plots (CDI), were used to interpret the standardisation effects of explanatory variables (Bentley et al. 2012).

The stepwise fitting method began with a basic model in which the only predictor was the year, and iteratively included predictors until there was insufficient improvement in the model. For all analyses, the improvement in the residual deviance, i.e., (new deviance – old deviance) / (saturated deviance – null deviance), and termed $R^2$ was used as the criterion for including predictors. At each step, the predictor with the greatest improvement in $R^2$ was included, providing that its inclusion resulted in an improvement in $R^2$ of at least 0.5%.

The inclusion of first order interaction terms was considered, but it was found that they generally required many additional degrees of freedom and often appeared to have a spurious significance. Interactions tended to be between permit number (typically the most important predictor) and the other variables. These interactions appeared to be a reflection of variability in predictor variables among fishers rather than relative changes in the CPUE index.

In addition to using reconstructed target species as a predictor variable, sensitivity analyses were carried out restricting records to those where target species was shortfin for shortfin CPUE analyses, and target species was longfin for longfin CPUE analyses.

### 2.4.4 Te Waihora analyses

The migration area (concession area) was introduced in 1996 in Te Waihora to allow fishers to legally harvest undersized migrating male shortfin eels during the months February and March each year. However, catches for this area were not distinguished from those caught elsewhere in the lake until 2001 when specific area codes were introduced for the migration area (AS2) and the lake excluding the migration area (AS1). Consequently, CPUE analyses for Te Waihora were carried out from 2001 onward, and only for shortfin eels which make up more than 99% of the catch. Before 2001 there was no accurate way to identify catches that were from AS1 or AS2. Analyses were carried out only for AS1 because of the seasonal nature of the AS2 fishery for which indices are unlikely to be reliable. Lifts was included as a predictor variable, because, although the fishers progressively moved to using fewer larger shortfin fyke nets, the transition had largely been completed by 2001.

## 2.5 Trial CPUE analyses from landed catch data

In addition to the routine standardised CPUE analyses carried out for South Island eels using estimated catch from ECERs, the Eel Working Group (EELWG-2-13-39) recommended that analyses be trialled to link the landings data collected from the MPI project ‘Monitoring commercial eel fisheries’ (EEL201202) with the catch effort data to model standardized CPUE of longfin eels in the largest size category. The data collected from this project included landed weights of each species, and a breakdown of weights by size grade as well as location of the catch at the level of ESA sub area which were essentially catchment based (Beentjes 2013) (Figure 4). The South Island size grade data capture began in 2006–07, but was restricted to ANG15 (ESAs 19 and 20 with no subarea breakdown), and collection for the entire South Island (by subarea) began in 2010–11. Hence, CPUE analyses were carried out using three years of data (2010–11 to 2012–13).

### Landings data

South Island eel species specific size grade landings data by ESA and sub-area were collected from 2010–11 to 2012–13. Longfin size grades were 1000 g and below (small) and over 1000 g (large). Shortfin size grades were 800 g and below (small) and over 800 g (large). A landing can include from one to multiple days fishing. These data were provided to MPI voluntarily by fishers and processors and required considerable grooming to ensure that details such as permit number, landing date, and area caught were correct as there were no official database error checking business rules for these data.

### Catch effort data

Effort and estimated catch data were extracted from ECERs (daily record). Equivalent data were used for the routine standardised CPUE analyses on estimated catch (see section 2.1).

### Merging effort and landings data

The size grade landings data were merged with the catch-effort data using permit number and matching dates. The effort and estimated catch associated with the landing was assumed to be the sum of all effort and estimated catch from after the date of the last landing, up to and including the current landing date. As a check the merged landing weights were compared with those from the sum of the estimated catch for the same period and outliers were removed from the analyses. Outliers were defined as being where estimated and landed catch (all eels) differed by more than 30% and or 120 kg.

### CPUE analyses

Unstandardised CPUE analyses were carried out for SFE and LFE separately (total catch/total lifts per year) for the large size grades using the groomed and merged data sets. No core fisher restriction was applied because the data were only for the last three years data which included the current active fishers. Estimates of year effects and associated standard errors were then obtained using a forward stepwise Generalised Linear Model (GLM) (McCullagh & Nelder 1989), with total landed catch and landed catch of the large size grade modelled as the response variables (See Section 2.4.3 on the GLM model). For each key South Island ESA (AX, AV, AW and AS1) the predictor variables in the GLM model were permit, month, lifts, and subarea. The standardised CPUE from the total landed catch was compared with that from the estimated catch over the same period to test for consistency in trends.

### 2.6 Fyke net specifications

There are no known published specification plans or descriptions of the fishing gear used in the commercial eel fishery and the aim was to address this gap in knowledge. The first author visited Victor Thompson on 18th February 2014 at Mossburn Enterprises, Invercargill, and photographed and obtained specifications of shortfin and longfin fyke nets set up at the factory on land. In addition, the method of deployment, and locations and situations where nets are used was described by Mr Thompson.

## 3. RESULTS

### 3.1 Descriptive analyses

#### 3.1.1 Groomed data versus landed catch

A comparison of groomed total estimated catch for the South Island from CELRs/ECERs with the reported landed catch is shown in Figure 5. The total groomed estimated catch was less than the landed catch (table 2 of the plenary report, MPI 2014) for all years up to 2004, with the exception of 2001 when they were virtually the same, and overall was 86% of landed catch over this period. From 2005 onward estimated catch was 99% of landed catch. The QMR/MHR landed catch data from 2001 onward are more similar to the estimated catch than the landed catch from the plenary table 2 data. The expectation is that the QMR/MHR data are a more accurate record of landed catch. Grooming of estimated catch data before 2001 resulted in the deletion of between 6 and 11% of records because of uncertainty in the key variables landing location, effort, or validity of the catch (Beentjes & Dunn 2003). This resulted in an underestimate of the total estimated catch over this period, however the total estimated and landed catches had the same declining trend over time.

In general, the quality of the eel fishery catch effort data has improved over time to the extent that virtually all records over the period 2000 to 2013 were retained after grooming and included in the CPUE analyses.

#### 3.1.2 Spatial and temporal distribution of species catch

The number of records and aggregate catch by species for each of the nine ESAs over the 23 year time series are shown in Table 2 and Figure 6. The proportions of estimated catch reported as SFE, LFE, or EEU in each ESA for all years combined are shown in Table 3. Overall, the total South Island catch from 1991 to 2013 was 45% longfin, 51% shortfin, and 5% EEU (Table 3). Northern South Island ESAs had relatively high proportions of annual catch recorded as EEU compared to the west coast and southern South Island where it was low to negligible. In Te Waihora (ESA 21, AS) no catch was reported as EEU (Table 3, Figure 6). From 2001 onward, EEU was not recorded in any ESA with all catches reported by species (LFE or SFE); this pre-dates the introduction of the ECER by one year, after which EEU was no longer a valid code (Figure 7). Ignoring EEU, within each ESA shortfin were the dominant species in northern South Island ESAs (AP and AQ, AR, AT), and in Te Waihora (AS) virtually all the catch was shortfin (Table 3, Figure 6). In contrast, longfin dominated the species mix in Nelson (AN), the West Coast (AX), the southern ESAs Waitaki and Otago (AU and AV), and particularly Southland (AW). Among ESAs, most shortfin (60%) was taken from Te Waihora (ESA AS), and most longfin from Southland (AW), Westland (AX), and Otago (AV) with contributions of 36%, 21% and 19% respectively (Table 3, Figure 6).

There was a trend of declining estimated catch of all South Island eels from 1992 to about 2000, after which catch was comparatively stable up to 2013 (Figure 7). The estimated catch of shortfin has remained about the same over the 23 year time series, however landed catch indicates a clear decline from the early 1990s to 2001 after which is has been stable or increasing (Figures 1 and 7). The different trends in the shortfin catch data sets may result from data grooming deletions of shortfin from estimated catch and coding catch to EEU rather than shortfin. Catch of longfin catch in both the landed and estimated catch data sets declined from the early 1990s to 2003 and has since been stable or increasing, with the exception of 2009 (Figures 1 and 7). Longfin catches are often related to fluctuating market demands.

## 3.2 Fishery characterisation and CPUE analyses by ESA

The number of records (including those with zero catch), and estimated catch of shortfin, longfin, and unidentified eels are presented in Table 2. For the data-poor areas (ESAs AN, AP-AQ, AR, AT, and AU), for each ESA the characterisation of the fishery was updated to 2013 and standardised pre-QMS CPUE analyses updated as these may have changed with the inclusion of target species as a predictor variable since the last analyses. In addition, more rivers and in some cases water quality data were included (Appendices A to E). For the data-rich key areas (ESAs AX, AV, AW, and AS1 shortfin) the characterisation of the fishery was updated to 2013, followed by the CPUE analyses (pre and post-QMS) and diagnostics for shortfin, and longfin, in that order (Appendices F to I).

### 3.2.1 Nelson (ESA AN)

#### Fishery characteristics 1991–2013

Reported annual eel catches in were variable with little or no catch in some years, but declined sharply after 1996 (Appendix A - Figure A1). A high proportion of catch (33%) was reported as unidentified (EEU), particularly before 1996 when it was about half, but the EEU code was not used after 2000 (Table 3, Appendix A - Figure A1). Nelson contributed 1% of the total South Island shortfin catch and 4% of the longfin catch over the 23 year time series (Table 3). Longfin were the dominant species in the catch (LFE 49%, SFE 17%), although in recent years the mix was more even (Appendix A - Figure A1).

The Nelson eel fishery for both species is seasonal, with few catches in the winter months June to August (Appendix A - Figures A2 and A3).

Target species was roughly evenly divided between shortfin and longfin in recent years, when EEU was not used (Appendix A - Figure A4). The optimal species proportion estimated by Cohen's Kappa to assign target species was 76% or more of one species in the catch and this resulted in a concordance of 27% in the CELR data where target species was recorded. The low concordance is related to the high incidence of EEU reporting.

The median number of lifts per day was variable but overall the number of nets used halved in the last 10 years (Appendix A - Figure A5).

There were very few zero records for total catch, which suggests that there were few trips where eels were not caught (Appendix A - Figure A6). The very high proportion of zeros for shortfin before 1996 indicates that either it was not caught, or it was not reported, although there were no trends in the proportion of zeros for total catch, shortfin, and longfin.

Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers showed no clear trends for all eels or for longfin (Appendix A - Figure A7). The shortfin time series trend was weakened by the lack of shortfin catch before 1996 and the years with little or no catch, however despite this, shortfin catch rates showed an upward trend. Overall the all-eel catch rate was about 5 kg per lift, with the notable exception of 2009 when it was about 14 kg per lift.

### Shortfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data used in the CPUE analyses retained most of the catch, but lost all but one from six original fishers.

The standardised CPUE index for pre-QMS shortfin differed markedly from the unstandardised catch rates (kg per lift) (Appendix A - Figure A8), which is not surprising as the standardised indices were based on a single core fisher and the unstandardized catch rates came from six fishers. Very large confidence intervals around some indices, combined with inadequate data in the model for several years, are indicative of the paucity of fishers and catches in these analyses. The variables target, month, lifts, Buller River flow, moon phase, Buller clarity, and Wairau River flow were included in the model and explained 49% of the variation in CPUE (Appendix 3).

### Longfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data used in the CPUE analyses retained most of the catch and four of the six original fishers

The standardised CPUE index for pre-QMS longfin followed the same general trend as the unstandardised catch rates (kg per lift) with indications of decline in the first and an increase in the last few years (Appendix A - Figure A9). Very large confidence intervals around some indices, combined with inadequate data in the model for several years, are indicative of the paucity of fishers and catches in these analyses. The variables lifts, permit, target, month, lifts, Buller phosphate, Buller River flow, and Buller pH were included in the model and explained 44% of the variation in CPUE (Appendix 3).

## 3.2.2 Marlborough (ESAs AP and AQ)

### Fishery characteristics 1991–2013

Reported annual eel catches were variable, but declined sharply after 1999 (Appendix B – Figure B1). A high proportion of catch (36%) was reported as unidentified (EEU), but EEU was not used after 2000 (Table 3, Appendix B – Figure B1). Marlborough contributed 4% of the total South Island shortfin catch and 3% of the longfin catch over the 23 year time series (Table 3). Shortfin was the dominant species in the catch (SFE 40%, LFE 29%), although in some years the catch was a more even mix (Table 3, Appendix B – Figure B1).

The Marlborough eel fishery for both species was seasonal, with few catches in the winter months June to August (Appendix B – Figures B2 and B3).

Target species was masked by the high reporting of EEU before 2001, but after this time target was roughly evenly divided between shortfin and longfin, and the high proportion of the target category “either”, supports this observation (Appendix B – Figure B4). The optimal species proportion estimated by Cohen’s Kappa to assign target species was 81% or more of one species in the catch.

The median number of lifts per day was stable over the time series at about 25 lifts per day (Appendix B – Figure B5).

There were no zero records for total catch, indicating that eels were caught on all trips (Appendix B – Figure B6). The variable proportions of zeros for both species tends to reflect the target behaviour. When one species was the dominant target species the proportion of zeros declined for that species, and vice versa. There were no trends in the proportion of zeros for total catch, shortfin, and longfin.

Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers showed general increasing trends for all eels, shortfin and longfin after about 1998 (Appendix B – Figure B7). In recent years the all-eel catch rate was about 7 kg per lift.

#### Shortfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data retained virtually all of the catch, but lost half of the six original fishers.

The standardised CPUE index for pre-QMS shortfin followed the same general pattern as the unstandardised catch rates (kg per lift) (Appendix B – Figure B8). The variables target, lifts, month, permit, and Wairau River flow were included in the model and explained 69% of the variation in CPUE (Appendix 3).

#### Longfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The longfin core data used in the CPUE analyses retained most of the catch and three of the seven original fishers.

The standardised CPUE index for pre-QMS longfin differs from the unstandardised index (kg per lift) with a generally declining trend from 1991 to 2000 (Appendix B – Figure B9). Large confidence intervals around some values are indicative of the paucity of fishers and catches in these analyses. The variables target, permit, lifts, and month were included in the model and explained 54% of the variation in CPUE (Appendix 3).

### 3.2.3 North Canterbury (ESA AR)

#### Fishery characteristics 1991–2013

Reported annual eel catches were variable, but have gradually declined since the peak in 1995 until 2009 when the catch of either species was less than one tonne (Appendix C – Figure C1). Catches progressively increased since 2009. A high proportion of catch (11%) was reported as unidentified (EEU), but EEU was not used after 2000 (Table 3, Appendix C1). North Canterbury contributed 7% of the total South Island shortfin catch and 6% of the longfin catch over the 23 year time series (Table 3). Shortfin was the dominant species in the catch (SFE 50%, LFE 39%), although in a few years longfin catch was greater than shortfin (Table 3, Appendix C – Figure C1).

The north Canterbury eel fishery for both species was seasonal, with few catches in the winter months June to August (Appendix C – Figures C2 and C3).

Target species was roughly evenly divided between shortfin and longfin, and the high proportion of the target category “either”, supports this observation (Appendix C – Figure C4). The optimal species proportion estimated by Cohen’s Kappa to assign target species was 94% or more of one species in the catch so a default value of 80% was used in this case.

The median number of lifts per day was stable over the time series at about 20 lifts per day (Appendix C – Figure C5).

There were very few zero records for total catch, which suggests that there were few trips where eels were not caught (Appendix C – Figure C6). The variable proportions of zeros for both species tends to reflect the target behaviour. When one species was the dominant target species the proportion of zeros declined for that species, and vice versa. There were no trends in the proportion of zeros for total catch, shortfin, and longfin. Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers showed no trends for all eels, or by species (Appendix C – Figure C7). The all eel catch rate was variable but most often was about 6 kg per lift.

### Shortfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data retain virtually all of the catch, and nine of the seventeen original fishers.

The standardised CPUE index for pre-QMS shortfin differed from the unstandardised catch rates (kg per lift) (Appendix C – Figure C8) and showed a slight trend of declining CPUE. The variables permit, lifts, target, and month were included in the model and explained 61% of the variation in CPUE (Appendix 3).

### Longfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data used in the CPUE analyses retain most of the catch and eight of the 22 original fishers.

The standardised CPUE index for pre-QMS longfin followed the same general pattern as the unstandardised catch rates (kg per lift) with no clear trend (Appendix C – Figure C9). The variables permit, target, lifts, and month were included in the model and explained 55% of the variation in CPUE (Appendix 3).

## 3.2.4 South Canterbury (ESA AT)

### Fishery characteristics 1991–2013

Reported annual eel catches were variable, but declined markedly after 1996 and, apart from the low catches in 2009 to 2011, showed no trend since the decline (Appendix D – Figure D1). Only 3% of the catch was reported as unidentified (EEU), and EEU was not used after 1999 (Table 3, Appendix D1). South Canterbury contributed 4% of the total South Island shortfin catch and 5% of the longfin catch over the 23 year time series (Table 3) and the species mix was roughly even (SFE 49%, LFE 48%) (Table 3, Appendix D – Figure D1).

The north Canterbury eel fishery for both species was seasonal, with few catches from May to September (Appendix D – Figures D2 and D3).

Target species was roughly evenly divided between shortfin and longfin, and the high proportion of the target category “either”, supports this observation (Appendix D – Figure D4). The optimal species proportion estimated by Cohen’s Kappa to assign target species was 90% or more of one species in the catch so a default value of 80% was used in this case.

The median number of lifts per day, while variable up to 2001, generally declined from about 25 a day up to 2001, to about 15 a day after that time (Appendix D – Figure D5).

There were very few zero records for total catch, which suggests that there were few trips where eels were not caught and the proportion of zeros was similar for shortfin and longfin (Appendix D – Figure D6). The variable proportions of zeros for both species tends to reflect the target behaviour. When one species is the dominant target species the proportion of zeros declined for that species, and vice versa. There were no clear trends in the proportion of zeros for total catch, shortfin, and longfin.

Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers showed a trend of increasing catch rates for both species (Appendix D – Figure D7). Catch rates were similar for both species and the all-eel catch rate over the last ten years ranged from about 7 to 11 kg per lift.

### Shortfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained nearly all the catch, and nine of the eleven original fishers

The standardised CPUE index for pre-QMS shortfin generally followed the same general pattern as the unstandardised catch rates (kg per lift) (Appendix D – Figure D8) with a decline in the first few years after which it was generally flat. The variables permit, lifts, target, month, and Waitaki River pH were included in the model and explained 55% of the variation in CPUE (Appendix 3).

### Longfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data used in the CPUE analyses retained most of the catch and eight of the seventeen original fishers.

The standardised CPUE index for pre-QMS longfin followed the same general pattern as the unstandardised catch rates (kg per lift) and was generally flat with the exception of a marked decrease between 1991 and 1992 and an increase between 1999 and 2000 (Appendix D – Figure D9). The variables target, permit, lifts, and month were included in the model and explained 52% of the variation in CPUE (Appendix 3).

## 3.2.5 Waitaki (ESA AU)

### Fishery characteristics 1991–2013

Reported annual eel catches were highly variable, marked by a sustained ten year period between 2001 and 2011 when catches were relatively low, with no catch in 2010 and negligible catch in 2005. In the last two years catches were higher than in all but four years in the 23 time series (Appendix E – Figure E1). Only 2% of the catch was reported as unidentified (EEU), and this was only in two years (1996 and 1997) (Table 3, Appendix E – Figure E1). Waitaki contributed 1% of the total South Island shortfin catch and 4% of the longfin catch over the 23 year time series (Table 3). Longfin was the dominant species in the catch (LFE 71%, SFE 27%), although in 2000 shortfin catch was greater than that of longfin and in 2009 only shortfin was landed (Table 3, Appendix E – Figure E1).

The Waitaki eel fishery for both species was seasonal, with few catches in the winter months June to August as well as early spring (Appendix E – Figures E2 and E3).

Target species was dominated by longfin except in 2009 when only shortfin were caught (Appendix E – Figure E4). The optimal species proportion estimated by Cohen's Kappa to assign target species was 86% or more of one species in the catch and this value was used to assign target species.

The median number of lifts per day was variable but no trend was apparent over the time series and averaged about 30 lifts per day (Appendix E – Figure E5).

There were very few zero records for total catch, which suggests that there were few trips where eels were not caught (Appendix E – Figure E6). The variable proportions of zeros for both species tends to reflect the fisher targeting behaviour. When one species was the dominant target species the proportion of zeros declined for that species, and vice versa. There were no trends in the proportion of zeros for total catch, shortfin, and longfin.

Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers were variable, reflecting the low or zero catch of either species in a few years. Despite the variability, longfin catch rates appeared to have an upward trend. Shortfin showed no clear trend, although the two highest catch rates were recorded in the last five years (Appendix E – Figure E7). The all-eel catch rate was variable but most often was about 5 kg per lift.

### Shortfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data retained virtually all of the catch, and seven of the thirteen original fishers.

The standardised CPUE index for pre-QMS shortfin differed from the unstandardised catch rates (kg per lift) (Appendix E – Figure E8) and showed a trend of declining CPUE. The variables permit, target, lifts, month, and Waitaki River temperature were included in the model and explained 73% of the variation in CPUE (Appendix 3).

### Longfin pre-QMS CPUE indices

The original number of records (positive catches only), fishers, longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The core data used in the CPUE analyses retained most of the catch and nine of the seventeen original fishers.

The standardised CPUE index for pre-QMS longfin followed the same general pattern as the unstandardised catch rates (kg per lift) with a slight upward trend (Appendix E – Figure E9). The variables lifts, permit, month, target, Waitaki River pH, and moon phase were included in the model and explained 54% of the variation in CPUE (Appendix 3).

## 3.2.6 Westland (ESA AX)

### Fishery characteristics 1991–2013

Reported annual eel catches were variable and, overall, declined from 90 t in 1991 to 25 t in 2003 after which they were variable but stable, ranging from about 30 to 50 t per year (Appendix F – Figure F1). Only 4% of the catch was reported as unidentified (EEU), but EEU was not used after 1998 (Table 3, Appendix F – Figure F1). Westland contributed 8% of the total South Island shortfin catch and 21% of the longfin catch over the 23 year time series (Table 3). Longfin was the dominant species in the catch (LFE 66%, SFE 29%), although from 2009 to 2011 more shortfin than longfin was caught (Table 3, Appendix F – Figure F1).

The Westland eel fishery for both species was seasonal, with few catches in the winter months of June to August (Appendix F – Figures F2 and F3).

Longfin was the dominant target species every year, although in the last few years the proportion of fishing records with shortfin as the target increased (Appendix F – Figure F4). The optimal species proportion estimated by Cohen's Kappa to assign target species was 75% or more of one species in the catch and this value was used to assign target species.

The median number of lifts per day was stable over the time series at about 20 lifts per day (Appendix F – Figure F5).

There were few zero records for total catch, indicating that eels were caught on nearly all fishing events (Appendix F – Figure F6). The proportion of records with zero longfin catch increased, whereas that for shortfin decreased. For both species, this reflected the target behaviour. With the move to increased targeting of shortfin relative to longfin, the proportion of zeros declined and the opposite applies for longfin.

Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers showed general increasing trends for all eels and for shortfin, but for longfin there was no trend. In recent years the all eel catch rate was about 7 kg per lift.

### Shortfin pre-QMS CPUE indices (1991–2000)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained nearly all the catch, and six of the fifteen original fishers (Appendix F – Figure F8, Appendix 2).

The standardised CPUE for pre-QMS shortfin was generally flat until 1997 after which it rose sharply (Appendix F – Figure F9). Catch from core fishers mirrors the unstandardised index pattern, but did not follow the pattern of the standardised indices. The variables permit, target, lifts, month, and Buller River phosphate were included in the model and explained 78% of the variation in CPUE (Appendix 3).

Residual diagnostics are shown in Appendix F – Figure F10, influence step plots in Appendix F – Figure F11, and CDI plots for the top two model predictor variables in Appendix F – Figures F12 and F13. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### Shortfin post-QMS CPUE indices (2002–2013)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained nearly all the catch, and seven of the twelve original fishers (Appendix F – Figure F14, Appendix 2).

The standardised CPUE for post-QMS shortfin showed an overall trend of increased CPUE, although it was flat for the last four years (Appendix F – Figure F15). The unstandardised index tends to mirror the catch from core fishers more than the pattern of the standardised indices. The variables catcher, target, lifts, and Grey River flow were included in the model and explained 79% of the variation in CPUE (Appendix 3). Because catcher entered the model, the year 2001 could not be included in the analyses because catcher was not recorded before 2002.

Residual diagnostics are shown in Appendix F – Figure F16, influence step plots in Appendix F – Figure F17, and CDI plots for the top two model predictor variables in Appendix F – Figures F18 and F19. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### Longfin pre-QMS CPUE indices (1991–2000)

The original number of records (positive catches only), fishers, and longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The longfin core data used in the CPUE analyses retained nearly all the catch, and eleven of the sixteen original fishers (Appendix F – Figure F20, Appendix 2).

Standardised and unstandardised CPUE for pre-QMS longfin both showed general trends of increasing CPUE (Appendix F – Figure F21). Catch from core fishers, in contrast, showed a declining trend. The variables permit, lifts, target, and month were included in the model and explained 64% of the variation in CPUE (Appendix 3).

Residual diagnostics are shown in Appendix F – Figure F22, influence step plots in Appendix F – Figure F23, and CDI plots for the top two model predictor variables in Appendix F – Figures F24 and F25. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### Longfin post-QMS CPUE indices (2002–2013)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The longfin core data used in the CPUE analyses retained nearly all the catch, and eight of the sixteen original fishers (Appendix F – Figure F26, Appendix 2).

The standardised CPUE for post-QMS longfin showed an overall trend of increasing CPUE over the time series (Appendix F – Figure F27). The unstandardised index tends to mirror the catch from core fishers more than the pattern of the standardised indices and shows no clear trend. The variables catcher, lifts, and target were included in the model and explained 69% of the variation in CPUE (Appendix 3). Because catcher entered the model, the year 2001 could not be included in the analyses because catcher was not recorded before 2002.

Residual diagnostics are shown in Appendix F – Figure F28, influence step plots in Appendix F – Figure F29, and CDI plots for the top two model predictor variables in Appendix F – Figures F30 and F31. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### 3.2.7 Otago (ESA AV)

#### Fishery characteristics 1991–2013

Reported annual eel catches were variable and dropped off markedly after 1996 from about 60 to 90 t to catches averaging about 30 t after this time, with the exception of 2009 and 2010 when catches were only 8 t and 14 t respectively (Appendix G – Figure G1). Only 0.8% of the catch was reported as unidentified (EEU), but EEU was not used after 1999 (Table 3, Appendix G – Figure G1). Otago contributed 6% of the total South Island shortfin catch and 19% of the longfin catch over the 23 year time series (Table 3). Longfin was the dominant species in the catch (LFE 73%, SFE 26%), although in 2009 and 2011, more shortfin than longfin was caught (Table 3, Appendix G – Figure G1).

The Otago eel fishery for both species was seasonal, with few catches in the winter months June to August, and the months either side of winter (May and September) (Appendix G – Figures G2 and G3).

Longfin was the dominant target species every year except in 2009 when catches were low, and in 2011 when they were similar (Appendix G – Figure G4). The optimal species proportion estimated by Cohen's Kappa to assign target species was 99% or more of one species in the catch so a default value of 80% was used in this case. The relatively high proportion of target category 'either' indicated that many catches were not dominated by either species.

The median number of lifts per day was stable over the time series at about 30 lifts per day (Appendix G – Figure G5).

There were few zero records for total catch, indicating that eels were caught on nearly all fishing events (Appendix G – Figure G6). The proportion of records with zero longfin catch increased, whereas that for shortfin was stable. For both species, this is a reflection of the target behaviour. With the move to increased targeting of shortfin relative to longfin, the proportion of zeros increased for longfin.

Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers showed a decrease following by an increased for all eels and longfin, but for shortfin there was a sharp increase after 2007 (Appendix G – Figure G7). In recent years the all eel catch rate was about 5 kg per lift.

#### Shortfin pre-QMS CPUE indices (1991–2000)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained nearly all the catch, and 17 of the 22 original fishers (Appendix G – Figure G8, Appendix 2).

The standardised CPUE for pre-QMS shortfin showed a progressive decline until 1999 after which it increased (Appendix G – Figure G9). Catch from core fishers mirrored the unstandardised index pattern, but did not follow the pattern of the standardised indices. The variables permit, lifts, month, and moon phase phosphate were included in the model and explained 54% of the variation in CPUE (Appendix 3).

Residual diagnostics are shown in Appendix G – Figure G10, influence step plots in Appendix G – Figure G11, and CDI plots for the top two model predictor variables in Appendix G – Figures G12–G13. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### Shortfin post-QMS CPUE indices (2002–2013)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained most of the catch (80%), and eight of the 21 original fishers (Appendix G – Figure G14, Appendix 2).

The standardised CPUE for post-QMS shortfin was variable and generally increased until 2011, after which it declined in the following two years (Appendix G – Figure G15). The unstandardised index and catch tends to broadly mirror the standardised indices. The variables catcher, lifts, target, month, and Taieri River flow were included in the model and explained 77% of the variation in CPUE (Appendix 3). Because catcher entered the model, the year 2001 could not be included in the analyses because catcher was not recorded before 2002.

Residual diagnostics are shown in Appendix G – Figure G16, influence step plots in Appendix G – Figure G17, and CDI plots for the top two model predictor variables in Appendix G – Figures G18–G19. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### Longfin pre-QMS CPUE indices (1991–2000)

The original number of records (positive catches only), fishers, and longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The longfin core data used in the CPUE analyses retained nearly all the catch, and 19 of the 26 original fishers (Appendix G – Figure G20, Appendix 2).

Standardised and unstandardised CPUE for pre-QMS longfin both showed declines until 1996 after which indices were stable (Appendix G – Figure G21). Catch from core fishers followed a broadly similar trend. The variables permit, lifts, target, and month were included in the model and explained 61% of the variation in CPUE (Appendix 3).

Residual diagnostics are shown in Appendix G – Figure G22, influence step plots in Appendix G – Figure G23, and CDI plots for the top two model predictor variables in Appendix G – Figures G24–G25. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### Longfin post-QMS CPUE indices (2002–2013)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The longfin core data used in the CPUE analyses retained most (90%) of the catch, and eight of the 27 original fishers (Appendix G – Figure G26, Appendix 2).

The standardised CPUE for post-QMS longfin showed a slight trend of increasing CPUE over the time series (Appendix G – Figure G27). The unstandardised index tends to mirror the catch from core fishers more than the pattern of the standardised indices and showed no clear trend. The variables catcher, target, lifts, month, and moon were included in the model and explained 68% of the variation in CPUE (Appendix 3). Because catcher entered the model, the year 2001 could not be included in the analyses because catcher was not recorded before 2002.

Residual diagnostics are shown in Appendix G – Figure G28, influence step plots in Appendix G – Figure G29, and CDI plots for the top two model predictor variables in Appendix G – Figures G30–G31. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### 3.2.8 Southland (ESA AW)

#### Fishery characteristics 1991–2013

Reported annual eel catches were 90–120 t per year until 1995 after which they declined and were stable at about 60–70 t, with the exception of 2013 when catches increased to 84 t (Appendix H – Figure H1). Only 0.3% of the catch was reported as unidentified (EEU), but EEU was not used after 2000 (Table 3, Appendix H – Figure H1). Southland contributed 7% of the total South Island shortfin catch and 36% of the longfin catch over the 23 year time series (Table 3). Longfin was the dominant species in the catch in all years (LFE 82%, SFE 18%) (Table 3, Appendix H – Figure H1).

The Southland eel fishery for both species was seasonal, with few catches in late autumn to early spring (May to September) (Appendix H – Figures H2 and H3).

Longfin was the dominant target species every year (Appendix H – Figure H4). The optimal species proportion estimated by Cohen's Kappa to assign target species was 95% or more of one species in the catch so a default value of 80% was used in this case.

The median number of lifts per day was stable over the time series at about 30 lifts per day (Appendix H – Figure H5).

There were few zero records for total catch, indicating that eels were caught on nearly all fishing events (Appendix H – Figure H6). There were no trends in the proportion of records with zero catch for either species.

Annual unstandardized catch rates (total catch / total number of lifts in each year) for all fishers showed general increasing trends for all eels and longfin since about 2000, with no trend for shortfin (Appendix H – Figure H7). In recent years the all eel catch rate was about 6 kg per lift.

#### Shortfin pre-QMS CPUE indices (1991–2000)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained most of the catch, and 12 of the 25 original fishers (Appendix H – Figure H8, Appendix 2).

The standardised CPUE for pre-QMS shortfin generally declined until 1997 after which it increased slightly (Appendix H – Figure H9). With the exception of 1991, both catch from core fishers and the unstandardised index mirrors the pattern of the standardised indices. The variables permit, lifts, target species, and month were included in the model and explained 74% of the variation in CPUE (Appendix 3).

Residual diagnostics are shown in Appendix H – Figure H10, influence step plots in Appendix H – Figure H11, and CDI plots for the top two model predictor variables in Appendix H – Figures H12–H13. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

#### Shortfin post-QMS CPUE indices (2002–2013)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained most (92%) of the catch, and eight of the 25 original fishers (Appendix H – Figure H14, Appendix 2).

The standardised CPUE for post-QMS shortfin, although variable, showed a clear trend of increasing CPUE (Appendix H – Figure H15). The unstandardised index tends to mirror the catch from core fishers more than the pattern of the standardised indices. The variables target, lifts, catcher, Mataura River nitrogen, month and moon phase were included in the model and explained 66% of the variation in

CPUE (Appendix 3). Because catcher entered the model, the year 2001 could not be included in the analyses because catcher was not recorded before 2002.

Residual diagnostics are shown in Appendix H – Figure H16, influence step plots in Appendix H – Figure H17, and CDI plots for the top two model predictor variables in Appendix H – Figures H18–H19. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

**Longfin pre-QMS CPUE indices (1991–2000)**

The original number of records (positive catches only), fishers, and longfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The longfin core data used in the CPUE analyses retained nearly all the catch, and 16 of the 28 original fishers (Appendix H – Figure H20, Appendix 2).

Standardised CPUE for pre-QMS longfin declined steadily until 1999 after which it increased steeply (Appendix H – Figure H21). Catch from core fishers, and unstandardised CPUE show similar patterns. The variables permit, lifts, month, and target were included in the model and explained 50% of the variation in CPUE (Appendix 3).

Residual diagnostics are shown in Appendix H – Figure H22, influence step plots in Appendix H – Figure H23, and CDI plots for the top two model predictor variables in Appendix H – Figures H24–H25. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

**Longfin post-QMS CPUE indices (2002–2013)**

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the CPUE model core data following the restrictions are shown in Appendix 2. The longfin core data used in the CPUE analyses retained most (83%) of the catch, and 10 of the 30 original fishers (Appendix H – Figure H26, Appendix 2).

The standardised CPUE for post-QMS longfin showed no trend from 2002 to 2010, but the indices for the last three years are the highest in the time series (Appendix H – Figure H27). The unstandardised index follows a similar pattern and the catch from core fishers the same to a lesser degree. The variables lifts, target, catcher, and month were included in the model and explained 67% of the variation in CPUE (Appendix 3). Because catcher entered the model, the year 2001 could not be included in the analyses because catcher was not recorded before 2002.

Residual diagnostics are shown in Appendix H – Figure H28, influence step plots in Appendix H – Figure H29, and CDI plots for the top two model predictor variables in Appendix H – Figures H30–H31. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

### 3.2.9 Te Waihora

**ESAs 21, AS1, and AS2 fishery characteristics (1991–2013)**

ESA 21 included the entire lake before codes AS1 and AS2 were introduced in 2001. Thereafter, AS1 includes the fishery within the entire lake outside the migration concession area, and AS2 the portion of the lake inside the migration area which operates only for the months of February and March. Te Waihora is essentially a shortfin fishery and in recent years longfin were voluntarily released by fishers. In the 23 years of the time series shortfin was by far the dominant species in the catch (SFE 99%, LFE 1%) (Appendix I – Figure I1, Table 3). No catch in Te Waihora was reported as unidentified (EEU). Catches were especially low in 1994, the year a minimum legal size (MLS) of 140 g was introduced, increasing by 10 g per year until 2002 when it reached the national MLS of 220 g (Appendix I – Figure I2). Reported estimated annual eel catches in ESA combined AS1 and AS2 were 82–148 t over the time series and averaged about 112 t (Appendix I – Figure I2).

The median number of lifts per day steadily declined, initially as fishers changed to using larger but fewer nets. More recently with catch rates increasing, even fewer of the large nets were used. Over the entire 23 year time series the median number of nets declined from about 40 to only a few lifts per day (Appendix I – Figure I3). The change to large nets occurred before 2001 when the AS1 CPUE time series began.

### AS1 fishery characteristics (2001–2013)

AS1 includes the Te Waihora fishery outside the migration area (AS2) which was established in 1996, but separate reporting codes were not introduced until 2001 and hence the beginning of our time series is taken from 2001 when catch location could be positively identified. This also coincides with the year that South Island eels, including Te Waihora, were introduced into the QMS.

Reported annual eel catches in ESA AS1 averaged 65 t per year, ranging from 45 to 92 t (Appendix I – Figure I4) with no trend. In all 13 years of the time series shortfin was the dominant species in the catch (SFE 99%, LFE 1%) with no trend in species proportions.

The AS1 shortfin fishery was seasonal, with few catches in late autumn to early spring (April to September) (Appendix I – Figure I5).

The median number of lifts per day in AS1 declined from about 20 in 2001 to a few in 2013. The decline was not due to a change in net type but the deployment of fewer nets to ensure that daily catches were manageable (Appendix I – Figure I6).

There were very few zero records for total catch or shortfin in AS1, which suggests that there were few trips where eels, including shortfin, were not caught (Appendix I – Figure I7). There were substantially more catches that had little or no reported longfin in the catch. Although legal sized longfin are voluntarily released by fishers, they are still required to be recorded on ECERs and recorded against destination ‘X’ on ECLRs if they are not landed.

There was a strong trend of increasing annual unstandardized shortfin catch rates (total catch / total number of lifts in each year) in AS1 (Appendix I – Figure I8). Overall the all eel catch rate ranged from about 5 kg per lift in 2001 to 180 kg per lift in 2013.

### AS1 shortfin post-QMS CPUE indices (2002–2013)

The original number of records (positive catches only), fishers, and shortfin catch, and those included in the AS1 CPUE model core data following the restrictions are shown in Appendix 2. The shortfin core data used in the CPUE analyses retained nearly all the catch, and seven of the 11 original fishers (Appendix I – Figure I9, Appendix 2).

The standardised CPUE for post-QMS shortfin in AS1, with the exception of the drop in 2010, showed a steady and progressive increase in CPUE until 2011 after which it was flat, and this is closely mirrored by the unstandardised catch rates until 2011 (Appendix I – Figure I10). Catch, however, shows no relationship to either of these indices. The variables lifts, month, catcher and lake level were included in the model and explained 46% of the variation in CPUE (Appendix 3). Because catcher entered the model, the year 2001 could not be included in the analyses because catcher was not recorded before 2002. Target species was not included as a predictor variable because shortfin was always the target species.

Residual diagnostics are shown in Appendix I – Figure I11, influence step plots in Appendix I – Figure I12, and CDI plots for the model predictor variables in Appendix I – Figures I13–I16. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

## 3.3 CPUE analyses from landed catch data

The merging and grooming of landed catch from processors and effort data from ECERs resulted in considerable loss of data because either the landing data could not be matched with catch-effort records or the resulting merge resulted in a substantial difference in the landed and estimated catch requiring outliers to be removed.

### 3.3.1 Westland (AX)

#### Shortfin

The shortfin landed catch was 15–21 t per year and about one-third to one half of this included eels over 800 g (Appendix J – Figure J1 and J2). After the outliers were removed the CPUE analyses retained 62% of the original shortfin catch (Appendix J – Figure J3).

Standardised CPUE and unstandardised catch rates for shortfin large size grades are shown in Appendix J – Figure J4. With only three years data it is not appropriate to comment on trends. The variables subarea, month, lifts and permit were included in the model in that order explaining 78% of the variation in CPUE. Comparison of standardised CPUE from estimated catch and CPUE from landed catch for all shortfin sizes, notwithstanding that there were only three overlapping years, showed a poor match (Appendix J – Figure J5).

#### Longfin

The longfin landed catch was 49–63 t per year and about one-third to two-thirds of this included eels over 1000 g (Appendix J – Figures J1 and J2). After the outliers were removed the CPUE analyses retained 76% of the original longfin catch (Appendix J – Figure J3).

Standardised CPUE and unstandardised catch rates for longfin large size grades are shown in Appendix J – Figure J6. With only three years data it is not appropriate to comment on trends. The variables lifts, month, permit, and subarea were included in the model in that order explaining 74% of the variation in CPUE. Comparison of standardised CPUE from estimated catch and CPUE from landed catch for all longfin sizes, notwithstanding that there were only three overlapping years, showed a good match (Appendix J – Figure J5).

### 3.3.2 Otago (AV)

#### Shortfin

The shortfin landed catch was 7–14 t per year and about half of this included eels over 800 g (Appendix K – Figures K1 and K2). After the outliers were removed the CPUE analyses retained 54% of the original shortfin catch (Appendix K – Figure K3).

Standardised CPUE and unstandardised catch rates for shortfin large size grades are shown in Appendix K – Figure K4. With only three years data it is not appropriate to comment on trends. The variables subarea, month, permit, and lifts were included in the model in that order explaining 82% of the variation in CPUE. Comparison of standardised CPUE from estimated catch and CPUE from landed catch for all shortfin sizes, notwithstanding that there were only three overlapping years, showed a reasonable match (Appendix K – Figure K5).

#### Longfin

The longfin landed catch was 22–26 t per year and about 20–50% of this included eels over 1000 g (Appendix K – Figures K1 and K2). After the outliers were removed the CPUE analyses retained 47% of the original longfin catch (Appendix K – Figure K3).

Standardised CPUE and unstandardised catch rates for longfin large size grades are shown in Appendix K – Figure K6. With only three years data it is not appropriate to comment on trends. The variables lifts, subarea, permit, and month were included in the model in that order explaining 61% of the variation in CPUE. Comparison of standardised CPUE from estimated catch and CPUE from landed catch for all longfin sizes, notwithstanding that there were only three overlapping years, showed a good match (Appendix K – Figure K5).

### 3.3.3 Southland (AW)

#### Shortfin

The shortfin landed catch was 8–10 t per year and about half of this included eels over 800 g (Appendix L – Figures L1 and L2). After the outliers were removed the CPUE analyses retained 66% of the original shortfin catch (Appendix L – Figure L3).

Standardised CPUE and unstandardised catch rates for shortfin large size grades are shown in Appendix L – Figure L4. With only three years data it is not appropriate to comment on trends. The variables permit, month, subarea and lifts were included in the model in that order explaining 38% of the variation in CPUE. Comparison of standardised CPUE from estimated catch and CPUE from landed catch for all shortfin sizes, notwithstanding that there were only three overlapping years, showed a poor match (Appendix L – Figure L5).

#### Longfin

The longfin landed catch was 49–63 t per year and about one-quarter to over one-third of this included eels over 1000 g (Appendix L – Figures L1 and L2). After the outliers were removed the CPUE analyses retained 57% of the original longfin catch (Appendix L – Figure L3).

Standardised CPUE and unstandardised catch rates for longfin large size grades are shown in Appendix L – Figure L6. With only three years data it is not appropriate to comment on trends. The variables subarea, permit, lifts and month were included in the model in that order explaining 41% of the variation in CPUE. Comparison of standardised CPUE from estimated catch and CPUE from landed catch for all longfin sizes, notwithstanding that there were only three overlapping years, showed a reasonable match (Appendix L – Figure L5).

### 3.3.4 Te Waihora (AS)

#### Shortfin

The shortfin landed catch was 40–60 t per year in AS1 and about half to three-quarters of this included eels over 800 g (Appendix M – Figures M1 and M2). After the outliers were removed the CPUE analyses retained 39% of the original shortfin catch (Appendix M – Figure M3).

Standardised CPUE and unstandardised catch rates for shortfin large size grades are shown in Appendix M – Figure M4. With only three years data it is not appropriate to comment on trends. The variables lifts, month, and permit were included in the model in that order explaining 73% of the variation in CPUE. Comparison of standardised CPUE from estimated catch and CPUE from landed catch for all shortfin sizes, notwithstanding that there were only three overlapping years, showed a poor match (Appendix M – Figure M5).

## 3.4 Fyke net specifications

The South Island commercial eel fishery (excluding Te Waihora) used fyke nets exclusively to catch both shortfin and longfin eels. The type of fyke net varied, however, for the species being targeted. Schematic drawings of both the shortfin and longfin fyke nets are shown in Figure 8 and photographs of nets in Figures 9 and 10 respectively, with a comparison of the two net types side by side, in Figure 11. Te Waihora fishers, changed from the standard South Island shortfin net in about 2000, to a larger modified version of this net (Figure 8).

### General characteristics of standard South Island shortfin fyke net

1. The 'D' ring determines the catch and if it too small the net will be ineffective. The standard 'D' is 600 mm high and 700 mm wide.
2. Leader is normally 6 m long except when fishing in narrow streams or creeks when a long leader is impractical and a 3 m leader is used. The leader has floats and is staked at the end so it stands up as a rectangle.
3. Nets have three valves leading into the codend which has two 31 mm escape tubes. Valves prevent eels escaping through the entrance and escape tubes allow eels less than about 300 g to escape.
4. Mesh is 'Rochelle' nylon diamond mesh. 30 mm in first section between 'D' and first hoop, and then reducing to 25 mm (measured tight). 25 mm mesh prevents eels from pushing tails through.
5. After the 'D' there are five hoops (diameters = 500 mm, 450 mm, 400 mm, 400 mm, and 350 mm).
6. Net length is 3 m from 'D' to end of codend.
7. Net is set to capture eels that follow the leader into the net.
8. Nets are never baited and more commonly used in ponds, lagoons, and receding flood waters. The long leader tends to guide or direct eels into the net as they travel along river banks or out of flooded backwaters, i.e., there is no attractant.
9. Shortfin fyke nets capture little longfin, even if present.

### General characteristics of standard South Island longfin fyke net

1. The 'D' ring determines the catch and if it too small the net will be ineffective. The standard 'D' is 400 mm high and 450 mm wide.
2. The leader is 1.5 m long on average and is rectangular is shape, but when set it is gathered at the far end so the shape is a triangle.
3. Nets have two valves leading into a codend which has two 31 mm escape tubes.
4. Mesh is generally 25 mm 'Rochelle' nylon diamond mesh throughout (measured tight). 25 mm prevents eels from pushing tails through.
5. After the 'D' there are four hoops (diameter = 350 mm, 300 mm, 250 mm, and 200 mm)
6. Net length is 2 m long from 'D' to end of codend.
7. Net is set with the entrance facing downstream to capture eels that follow the bait plume. Most common bait is paua viscera or mackerel contained in 400 ml plastic 'snifter' pottles.
8. Longfin fyke nets are commonly used in streams, rivers and lakes and catch little shortfin, even if present.

### General characteristics of Te Waihora large shortfin fyke net

Specifications of Te Waihora shortfin fyke net can vary among fishers but most often a large modified version of the standard South Island fyke net in used (Figure 8) and this is described below. However, less often smaller nets, similar to the standard South Island fyke net, are used in shallow water.

1. The 'D' is rectangular with a floating top-bar that can restrict the height of the entrance in shallow water. Normally 1000 mm wide by 1000 mm high if water is over 1 m deep.
2. Leader can vary from 30 to 50 m in length and is staked at the end so it stands up as a rectangle.
3. Wings extend from either side of the net ( about 5 to 10 m in length) staked at the ends
4. Nets have three valves leading into the codend which has two 31 mm escape tubes.

5. Mesh is 'Rochelle' nylon diamond mesh, 30 mm in first section between 'D' and last valve, and then reducing to 25 mm (measured tight).
6. After the 'D' there are seven hoops (diameters reducing from 900 to 600 mm).
7. Net length is 10 m from 'D' to end of codend.
8. Nets are often set with the 30 to 50 m leaders staked on shore and running out perpendicularly from the shore.
9. Nets are never baited. The long leader tends to guide or direct eels into the net as they travel along lake shore.
10. Nets can be modified to capture migrating shortfin by sewing a mesh into the front valve to prevent large eels from entering and reducing the length of the leader. In addition the codend is often enlarged and only two valves will be incorporated into the nets.

# 4. DISCUSSION

This report presents catch per unit effort analyses for the South Island commercial freshwater eel fishery from 1991 to 2013 carried out at the level of statistical area, with the exception of the analyses for ESAs AP and AQ (Marlborough) which were combined. For Te Waihora, analyses were carried out only for AS1 (the lake) from 2001 onward when codes were introduced to distinguish catches from AS2 (migration area). Analyses were split between pre- and post-QMS to be consistent with the previous analyses up to 2010 (Beentjes & Dunn 2013a).

The current analyses differed from the previous study (Beentjes & Dunn 2013) in the following ways:

1. Additional predictor variables were included in the standardised CPUE analyses: target species (reconstructed), catcher for post-QMS data after 2001 (distinct from permit holder), water quality data for key rivers, river flow data for more key rivers, Te Waihora lake level and periods when lake was open or closed.
2. Sensitivity analyses were carried restricting data to target species shortfin or longfin.
3. CPUE analyses were carried out on the landed catch of large longfin and shortfin (last three years data only) linked with effort data from ECERs.

In addition fyke nets used in the South Island shortfin and longfin eel fisheries are illustrated and described for the first time.

## 4.1 Estimated catch used in CPUE analyses

In the freshwater eel fishery, the catch of each species is estimated by visual inspection of catches in the fyke nets or in holding bags, and not using standard fish bins containing separated species. There is therefore the possibility that in catches dominated by one species, the minor catch may be overlooked or underestimated. Overall, total groomed estimated catch used in the CPUE analyses was 90% of the total reported landed catch for the South Island (see Figure 5). The data before 2002 had 6–11% of records removed because of errors in CELR reporting (Beentjes & Dunn 2003a) and 5% of records that reported estimated catch as EEU were also lost from the analyses. From 2001–02 onward with the introduction of the ECER, very few records were removed from the analyses during grooming and estimated catch increased to 96% of landed catch (Ministry for Primary Industries 2014)(MPI (2014) plenary table 2 landed catch) for the post 2001 period. The trends in estimated and landed eel catch were similar, indicating that estimated catch is likely to be proportional to total landed catch, and hence suitable for CPUE analysis.

## 4.2 Reporting of released legal sized eels

A potential issue relating to reporting of the estimated catch is the release of legal sized eels. Fishers are entitled to return eels of legal size (220 g to 4000 g) to the water, but are still legally required to complete the catch effort section of the ECER including estimates of released legal sized eels, and to report the released estimated catch as 'Destination X' in the ECLR destination field. This may occur when there is no market for a particular species and/or size grade, as was the case in the North Island from 2008–09 to 2010–11 when there was no market for medium sized longfin eels and fishers were discouraged from landing these sized eels into the North Island processors. This may also occur if the fisher has no quota. Initially North Island fishers were not always compliant in reporting of legal sized released eels in ECERs, but our understanding is that this has improved and fishers are now reporting correctly. In the South Island this is not considered to be an issue, but in 2013–14 and 2014–15 the demand for large (up to 4 kg) longfin eels declined and fishers were discouraged from landing this category. Hence, we expect that many legal sized longfin (under 4 kg) were caught and released and assume that they were correctly reported on ECERs and also on ECLRs as 'Destination X'. There is also a voluntary code of practice to release longfin eels caught that are in a migratory condition and similarly if these are of legal size we assume that they were included on both ECERs and ECLRs.

The implications of non-reporting for CPUE are that the effort (i.e., number of fyke nets) would be fully recorded, but not always the total amount of catch associated with that effort. If non-reporting of released legal sized eels is significant then we would expect estimated catch and CPUE indices to be conservative.

## 4.3 Release of eels over the legal size (4 kg)

Also missing from the estimated catch are longfin eels over 4 kg which since 1996 in the South Island have been legally required to be returned to the water on capture. These eels were not required to be reported on ECERs or ECLRs because they do not fall within the legal size limit (220 g to 4000 g). The full extent of these over 4 kg longfin eel releases is unknown but voluntary recording of these data by South Island eel fishers showed that over 1400 longfins over 4 kg were caught and released in 2013–14 (Bill Chisolm, pers. comm.), some of which were as large as 16 kg. This equates conservatively to about 6 tonnes of longfin eels which would correspond to about 4% of the 2012–13 longfin landed catch. CPUE has therefore been underestimated for longfins since 1996. An electronic logbook (joint project by South Island Eel Industry and NIWA) was trialled by key South Island fishers in 2014 and it is planned to roll this out initially to all South Island fishers and then subsequently to the North Island. The logbook captures data on the release of longfin eels over 4 kg as well as other information such as finer scale catch location details and it is envisaged that it will eventually provide New Zealand wide coverage. Since eels over 4 kg have not been recorded since 1996, this would not have influenced trends in post-QMS CPUE, which essentially depict relative abundance of exploitable eels.

## 4.4 Escape-tube modifications

The legal escape-tube size in the South Island was increased from 25 mm to 31 mm in 1996–97. The 25 mm diameter tube was designed to allow eels smaller than 220 g (minimum legal size, MLS) to escape from fyke nets if captured (see Figure 8), although in practice eels below the MLS were often caught. A 31 mm escape tube can be expected to retain eels larger than about 300 g, hence the South Island pre-QMS CPUE for both species may be conservative for a few years after 1996–97 because eels that were previously retained as catch, were able to escape. This change in regulations should not have influenced trends in post-QMS CPUE as the time to grow from 220 to 300 g is about 2 years, based on average length increments of 2.5 cm per year.

## 4.5 Fyke net specifications

It is important in any fishery being monitored to understand the type of fishing gear being used, the specifications of the gear, and how the gear operates to catch fish. Any changes to gear that might affect the catchability and hence CPUE should be documented and be considered during any presentation of results that use catch and effort data. Although fishing method is recorded on ECERs, it is limited to entering fyke net, eel pot, fish trap or other — options for method 'other' are set net, ring net, cod pot or inshore drift net, and of these only set net is occasionally used in the Firth of Thames for targeting freshwater eels. Fyke net method was recorded on nearly all South Island ECERs. The fyke net fishing gear as described in Section 3.8, as far we know and have been informed by the eel industry, has remained unchanged over the time series of CPUE, with the exception of Te Waihora where larger modified nets replaced the standard shortfin fyke net around 2000. Further we assume that this is the same gear (i.e., standard South Island shortfin and longfin fyke nets) used in the North Island eel fishery, but this remains unresolved until North Island gear is physically examined and compared with that from the South Island. Although the shortfin and longfin fyke nets are broadly similar, each net is specifically designed and deployed to target a different species. While there is bycatch of longfin in shortfin nets and vice versa, a fisher would never use a shortfin net to target longfin or a longfin net to target shortfin. If there are changes to these net specifications in the future it will be important to have this documented. It also highlights the need to record target species on ECER forms which is currently absent.

## 4.6 Catch and species distribution

The estimated eel catch of all South Island eels from 1992 to about 2000 has declined and while it appears to be mostly due to the decrease in longfin estimated catch, the landed catch of both shortfin and longfin shows a clear decline in the 1990s (Figures 1 and 7). This difference may have resulted from data grooming deletions of shortfin from estimated catch and coding catch to EEU rather than shortfin. The general trend of declining estimated eel catch in the 1990s is evident in all ESAs except Te Waihora which has maintained a reasonably stable catch over the 23 year time series (see Appendices A1 to I1). The decline in eel catch cannot be attributed to the introduction of the QMS in 2001 because there were no quotas set for individual eel species and the ANG quota was never caught (Figure 1).

All South Island ESAs have both shortfin and longfin reported catches, but in general shortfin was the dominant species in Te Waihora and north east areas (AP–AQ, AR) whereas longfin was dominant everywhere else, particularly in the south and west (see Figure 6). The bulk of the shortfin catch in ESA AX is from Lake Brunner on the Grey River, the next most important shortfin fishery in the South Island after Te Waihora (Beentjes 2013).

Reported catch of EEU before 2001 presents problems in catch effort analyses for individual species. The extent to which EEU, rather than LFE or SFE, was recorded by fishers varied between regions and overall 5.3% of South Island records had zero estimated catch for both species, but eels were caught and landed (Figure 7). A high proportion of the catch was recorded by species where one species was dominant, e.g., Southland and Te Waihora. In these ESAs, catches were predominantly longfin or shortfin respectively, compared to other areas where a mixture of both species made it more difficult for fishers to estimate the true proportion. Fortunately, for the key areas where pre- and post-QMS CPUE was carried out (AX, AV, AW and AS) the proportion of records with zeros for both species was low (i.e., 4.8%, 1.1%, 0.3% and 0% respectively). The introduction of South Island freshwater eels into the Quota Management System in October 2000 required fishers to be more diligent in completing the CELR form resulting in improved quality of catch effort data, e.g., there are no records of EEU being used in 2001 with all catches being identified to species. Replacement of the CELR form with the ECER and ECLR on 1 October 2001 did not give the option of recording EEU and there were no records of EEU in the catch effort data since 2000.

### 4.6.1 Te Waihora catch

Te Waihora catches from 1991 to 2013 were variable but there is no trend. There was a very large catch in 1992 (exceeding the controlled fishery limit of 121 t), and sharp drops in catch in 1994, when the minimum legal size was introduced to the lake (140 g increasing by 10 g a year until 220 g) and in 2000, the year before the fishery was introduced into the QMS. There appears to be a reciprocal relationship between catches from the migration area (AS2) and outside the migration area (AS1), i.e., high catches in AS2 coincided with low catches in AS1 and vice versa, an outcome of having the total catch capped (controlled fishery until 2000, then a TACC from 1 October 2000, under the QMS). The estimated catches in Te Waihora for AS1 and AS2 combined are not always well matched with the landed catch. This is partly because of the 1 February to 31 January fishing year that was in effect in Te Waihora since 2002, whereas our analyses were structured on the standard 1 October to 30 September fishing year. The catch mismatch was discussed in the Te Waihora CPUE analyses up to 2011–12 (Beentjes & Dunn 2014).

## 4.7 CPUE analyses

### Standardised CPUE analyses

South Island eel CPUE analyses up to 2006 (Beentjes & Bull 2002, Beentjes & Dunn 2003, 2008) were carried out as continuous time series beginning in 1991 for each of the ESAs (Beentjes & Dunn 2008). This produced some equivocal results for areas with sparse data and few fishers in the core data set. For these areas, CPUE exhibited high annual variation and had very large confidence intervals around the indices with the result that indices of abundance were spurious. This was compounded by the reduction in total numbers of fishers following the introduction of eels into the QMS in 2000 after which the number of core fishers in the analyses frequently dropped away dramatically. Further, many of the existing fishers were replaced by new entrants after 2001. Given this, the Eel Working Group (EELWG-2012-05) recommended splitting the 1991 to 2010 series CPUE analyses into pre- and post-QMS time series with post-QMS CPUE analyses only required for areas with sufficient data and fishers (ESAs AX, AV, AW and AS1) (Beentjes & Dunn 2013). This approach was also adopted in the current analyses.

Standardised CPUE indices summary plots with lowess fitted trend lines, for areas in which only pre-QMS analyses were carried out, are shown in Figure 12 (ESAs AN, AP-AQ, AR, AT and AU), and for areas where both pre- and post-QMS analyses (ESAs AX, AV, AW) were carried out are shown in Figure 13. The latter also includes sensitivity analyses where only records with shortfin or longfin target species were included. For AS1 only post-QMS analyses was carried out (Figure 14).

The standardised CPUE analyses take into account the effects that the variables lifts, permit, catcher, season (month), moon phase, river flow, water quality, and target species may have had on the raw catch rates (see Appendix 3). The four variables permit, target, lifts, and month were included in nearly all pre-QMS models, with month generally explaining the least variability of the four in the models (see Appendix 3). The variable catcher tended to replace the variable permit in the post-QMS models, but came at the cost of losing the 2001 fishing year from the GLM analyses as catcher was not recorded until 2002. The target species variable is new to these analyses but is clearly important as a predictor which is not surprising given the differences in fishing gear and deployment when targeting one or the other species. The sensitivity analyses restricting records to target shortfin or longfin, while having less data, showed similar and in many cases identical trends (Figure 13) indicating that offering target species as a predictor variable is adequate to explain the effects of targeting on CPUE. The finding that month affects catch rates is understandable since water temperature varies seasonally and eel catch rates have been found to decline markedly in winter (Jellyman 1991, 1997) and there is little or no fishing and processing of eels in the South Island in the winter months. The inclusion of permit or catcher in all models also indicates the importance of fisher experience and/or ability on catch rates and this is shown in the influence plots. Lifts was included because it is the key indicator of relative effort. River flow, water quality variables, and moon phase entered some models, but these were generally the last variables to be included. Despite the inclusion of explanatory variables into the model there was little difference between the plotted trends of the unstandardised and the standardised CPUE indices for about half of the models.

In Te Waihora, lifts, month, catcher and lake level were accepted as model predictors. Target species was not relevant in this case because the fishery is 100% shortfin target. The environmental variables lake level and time of lake opening were new to the variables offered to the AS1 shortfin model, but only lake level was accepted.

### Shortfin CPUE summary

For the data-poor areas (AN, AP-AQ, AR, AT, and AU), with the exception of ESA AN (Nelson) all pre-QMS shortfin indices showed some indications of a declining trend in CPUE from 1991 to 2000, and this was most marked in ESA AP-AQ (Figure 12). Nelson (AN) has little data and few fishers, and the resulting indices were not reliable as is shown by the relatively large confidence intervals and coefficients of variation (CV) (Figure 12, Appendix A8).

For the data-rich areas (AX, AV, AW, and AS1), shortfin indices showed clear declines in pre-QMS CPUE for ESAs AV and AW, but in AX there was an overall increase in CPUE (Figure 13). Post-QMS shortfin showed clear trends of increasing CPUE in all areas and this was most marked in AW and particularly AS1 up to 2011, after which it levelled off (Figures 13 and 14).

### Longfin CPUE summary

For the data-poor areas (AN, AP-AQ, AR, AT, and AU), the pre-QMS longfin indices AP-AQ showed a strong and consistent decline in CPUE from 1991 to 2000, whereas the other areas tended to show slight declines followed by slight increases in CPUE (Figures 12).

For the data-rich areas (AX, AV, and AW), longfin indices showed clear declines in pre-QMS CPUE for ESAs AV and AW, but in AX the CPUE increased over time (Figure 13). Post-QMS longfin showed clear trends of increasing CPUE in AX and AV, and to a lesser extent in AW over the last five years (Figure 13).

### Overall CPUE trends

The pre-QMS CPUE and the overlapping post-QMS analyses CPUE have remained largely unchanged from the previous analyses (Beentjes & Dunn 2013a) and the overall trends post QMS have not changed despite the addition of more predictor variables, and three years more data (2010–11 to 2012–13).

Overall, for both shortfin and longfin in the key areas Otago (AV) and Southland (AW) (excluding Te Waihora) CPUE increased since about 2000 following declines. Westland (AX) CPUE for both species, however steadily increased throughout both the pre- and post QMS periods. Te Waihora shortfin in AS1 showed a strong and steady increase in CPUE over the post-QMS time series.

Increases in CPUE post-QMS may partially be a result of the introduction of TACCs that were set well below previous catches and were only 67–85% caught each year, although the highest total eels (ANG includes both species combined) catch occurred in the last two years (see Figure 1). Further catches of both species that comprise the ANG total peaked in the most recent years shown (2012–13). High annual catches are, however, often more related to market demands than catchability. Since the introduction of eels to the QMS, numbers of fishers and hence effort declined substantially in all ESAs, and there was a transition in the fishery from long term existing fishers to 'new entrants'. Many of these new entrants are now established fishers having been in the fishery for over 13 years. The most recent commercial catch sampling programme for Southland in 2004 showed that mean size of eels from inland river strata was about 5 cm larger than from 1996 to 1998 (Beentjes 2005), a finding consistent with reduced effort and increasing CPUE.

### Te Waihora

Shortfin CPUE in AS1, more than any other area, increased dramatically from 2002 to 2011, but appears to be levelling off in 2012 and 2013. The new variables lake level and catcher were both accepted by the model as a predictor variables. Te Waihora was managed as a controlled fishery with a capped catch limit of 136.5 t, fished by 11 permit holders, before the introduction of the QMS regime in 2001. The TACC was reduced to 122 t (Ministry for Primary Industries 2014) following introduction of the QMS and in the first three years the TACC was under-caught by 11–43% and thereafter was most often caught or close to it. Fisher numbers also declined as quota was purchased and aggregated and only about five fishers were active in recent years.

A standalone CPUE analysis for Te Waihora shortfin in AS1 was carried out up to 2011–12 and the Fisheries Assessment Report included sections on ecology of the lake, history of management, and eel fishery characterisation (Beentjes & Dunn 2014). Plausible reasons for the dramatic increase in CPUE in AS1 are also discussed in detail and the reader is referred to this report. In summary it was suggested that the fishery has experienced a progressive improvement in yield per recruit as the MLS incrementally increased over time. Beentjes & Dunn (2014) also analysed eel size in the lake in the 1990s compared with that in recent years demonstrating that the size of commercially caught eels has substantially increased over time, supporting the concept of an improved yield per recruit. The reason that the MLS was introduced at just 140 g in 1994, compared to the national MLS of 220 g, was because there were few large eels in the lake at that time. It was considered that an initial MLS set any higher would have essentially closed the fishery. The small size of eels at that time was a result of high fishing pressure before 1978 (i.e., unrestricted access, no MLS, and no catch limits), followed by the introduction of large TACCs before being set at 122 t in 2001 under the QMS. The lake also experienced enhanced nutrient loading from the growing number of dairy farms surrounding the lake. The short term effect may be increased productivity of phytoplankton and benthic epiphytic algae. The impact of this on the lake and fishery in the long-term is unknown.

A discussion with a commercial fisher (pers. comm. Clem Smith) confirms that catches are strikingly better in recent years, consistent with the steep increase in CPUE. It was reported that nets were sometimes ‘tied-off’ several hours after setting to reduce the catch which can be unmanageable from a single net landed into a small vessel.

### 4.8 Trial CPUE from landed catch

The merging and grooming of landed catch from processors and effort data from ECERs resulted in considerable loss of data because either the landing data could not be matched with catch-effort records or the resulting merge resulted in a substantial difference in the landed and estimated catch requiring outliers to be removed. The landed data with location of the catch provided voluntarily by fishers and collated by the processor had a high incidence of errors in the landing dates and permit numbers. Considerable time was spent grooming the landings data set and in conjunction with some catch effort data misreporting, the match between catch from the two data sets overall was poor. However, despite the high proportion of outliers that were removed, comparison of CPUE from catch-effort data and landings data showed a good correlation in the trend of CPUE for longfins of all sizes which indicates that the CPUE for large eels may have some validity (see Appendices J5 to L5). Shortfin correlation, however, was poor overall and the validity of the CPUE for large size grade is therefore questionable. An improvement in the match between the data sets is required before these alternative CPUE indices can be accepted.

## 5. ACKNOWLEDGMENTS

This research was carried out by NIWA under contract to the Ministry for Primary Industries (Project EEL2013/01). We thank the Eel Working Group for discussion of the preliminary analyses, Peter McMillan (NIWA) and Marc Griffiths (Ministry for Primary Industries) for comments on the manuscript, and Marianne Vignaux for editorial comments. We also thank Canterbury Regional Council, Environment Southland, and Otago Regional Council for river flow data, Kathy Walters

(NIWA) for NIWA river flow data, and Rob Davies-Colley (NIWA) for water quality data. Thanks to Victor Thompson and Clem Smith for discussions around fyke net specifications and operation.

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**Table 1: Eel Quota Management Areas (QMAs) for longfin (LFE) and shortfin (SFE) eel stocks and both species combined (ANG), current Eel Statistical Areas (ESA, from October 2001), and the associated historical numeric Eel Statistical Areas (ESA, up to September 2001).**

| Area | QMA LFE | QMA SFE | ESA (alpha) (after 1 Oct 2001) | | ESA (numeric) (before 1 Oct 2001) |
|---|---|---|---|---|---|
| Northland | LFE 20 | SFE 20 | AA | | 1 |
| Auckland | LFE 20 | SFE 20 | AB | | 2 |
| Hauraki | LFE 21 | SFE 21 | AC | | 3 |
| Waikato | LFE 21 | SFE 21 | AD | | 4 |
| Bay of Plenty | LFE 21 | SFE 21 | AE | | 5 |
| Poverty Bay | LFE 21 | SFE 21 | AF | | 6 |
| Hawke's Bay | LFE 22 | SFE 22 | AG | | 7 |
| Rangitikei-Wanganui | LFE 23 | SFE 23 | AH | | 8 |
| Taranaki | LFE 23 | SFE 23 | AJ | | 9 |
| Manawatu | LFE 22 | SFE 22 | AK | | 10 |
| Wairarapa | LFE 22 | SFE 22 | AL | | 11 |
| Wellington | LFE 22 | SFE 22 | AM | | 12 |
| Nelson | ANG 11 | ANG 11 | AN | | 13 |
| Marlborough | ANG 11 | ANG 11 | AP | } | 14 |
| South Marlborough | ANG 12 | ANG 12 | AQ | } | 14 |
| Westland | ANG 16 | ANG 16 | AX | | 15 |
| North Canterbury | ANG 12 | ANG 12 | AR | | 16 |
| South Canterbury | ANG 14 | ANG 14 | AT | | 17 |
| Waitaki | ANG 14 | ANG 14 | AU | | 18 |
| Otago | ANG 15 | ANG 15 | AV | | 19 |
| Southland | ANG 15 | ANG 15 | AW | | 20 |
| Te Waihora (outside-migration area) | ANG 13 | ANG 13 | AS1 | } | 21 |
| Te Waihora migration area | ANG 13 | ANG 13 | AS2 | } | 21 |
| Chatham Islands | LFE 17 | SFE 17 | AZ | | 22 |
| Stewart Island | ANG 15 | ANG 15 | AY | | 23 |

**Table 2: ESAs, regions, and the number of groomed records (equivalent to the number of fisher days), and estimated catch for shortfin, longfin, and unidentified eels from 1991 to 2013.**

| | | | Estimated catch (t) | | | |
|---|---|---|---|---|---|---|
| ESA | Region | Records | Shortfin | Longfin | Unidentified | Total |
| 13 (AN) | Nelson | 2 408 | 51 | 147 | 99 | 298 |
| 14 (AP and AQ) | Marlborough | 3 269 | 164 | 122 | 127 | 414 |
| 15 (AX) | Westland | 9 336 | 323 | 729 | 44 | 1 096 |
| 16 (AR) | North Canterbury | 4 125 | 287 | 223 | 65 | 575 |
| 17 (AT) | South Canterbury | 3 426 | 176 | 170 | 11 | 358 |
| 18 (AU) | Waitaki | 1 432 | 53 | 138 | 4 | 194 |
| 19 (AV) | Otago | 8 331 | 235 | 659 | 7 | 901 |
| 20 (AW) | Southland | 9 720 | 279 | 1 262 | 4 | 1 545 |
| 21 (AS1 and AS2) | Te Waihora (lake and migration area) | 8 882 | 2 393 | 25 | 0 | 2 418 |
| Totals | | 50 929 | 3 961 | 3 475 | 361 | 7 799 |

**Table 3: Percent of estimated species catch within and among ESAs from combined years 1991 to 2013. Groomed data used in the CPUE analyses. LFE, longfin; SFE, shortfin; EEU, unclassified.**

| | Percent species catch within areas | | | | Percent species catch among area | | | |
|---|---|---|---|---|---|---|---|---|
| ESA | SFE | LFE | EEU | | Total | SFE | LFE | EEU |
| 13 (AN) | 17.2 | 49.5 | 33.3 | 100 | 3.8 | 1.3 | 4.2 | 27.4 |
| 14 (AP and AQ) | 39.7 | 29.5 | 30.8 | 100 | 5.3 | 4.1 | 3.5 | 35.2 |
| 15 (AX) | 29.5 | 66.5 | 4.0 | 100 | 14.1 | 8.2 | 21.0 | 12.2 |
| 16 (AR) | 49.9 | 38.8 | 11.3 | 100 | 7.4 | 7.2 | 6.4 | 18.0 |
| 17 (AT) | 49.3 | 47.6 | 3.1 | 100 | 4.6 | 4.4 | 4.9 | 3.0 |
| 18 (AU) | 27.2 | 70.8 | 2.1 | 100 | 2.5 | 1.3 | 4.0 | 1.1 |
| 19 (AV) | 26.1 | 73.1 | 0.8 | 100 | 11.6 | 5.9 | 19.0 | 1.9 |
| 20 (AW) | 18.1 | 81.7 | 0.3 | 100 | 19.8 | 7.0 | 36.3 | 1.1 |
| 21 (AS1 and AS2) | 99.0 | 1.0 | 0.0 | 100 | 31.0 | 60.4 | 0.7 | 0.0 |
| Overall | 50.8 | 44.6 | 4.6 | 100 | 100 | 100 | 100 | 100 |

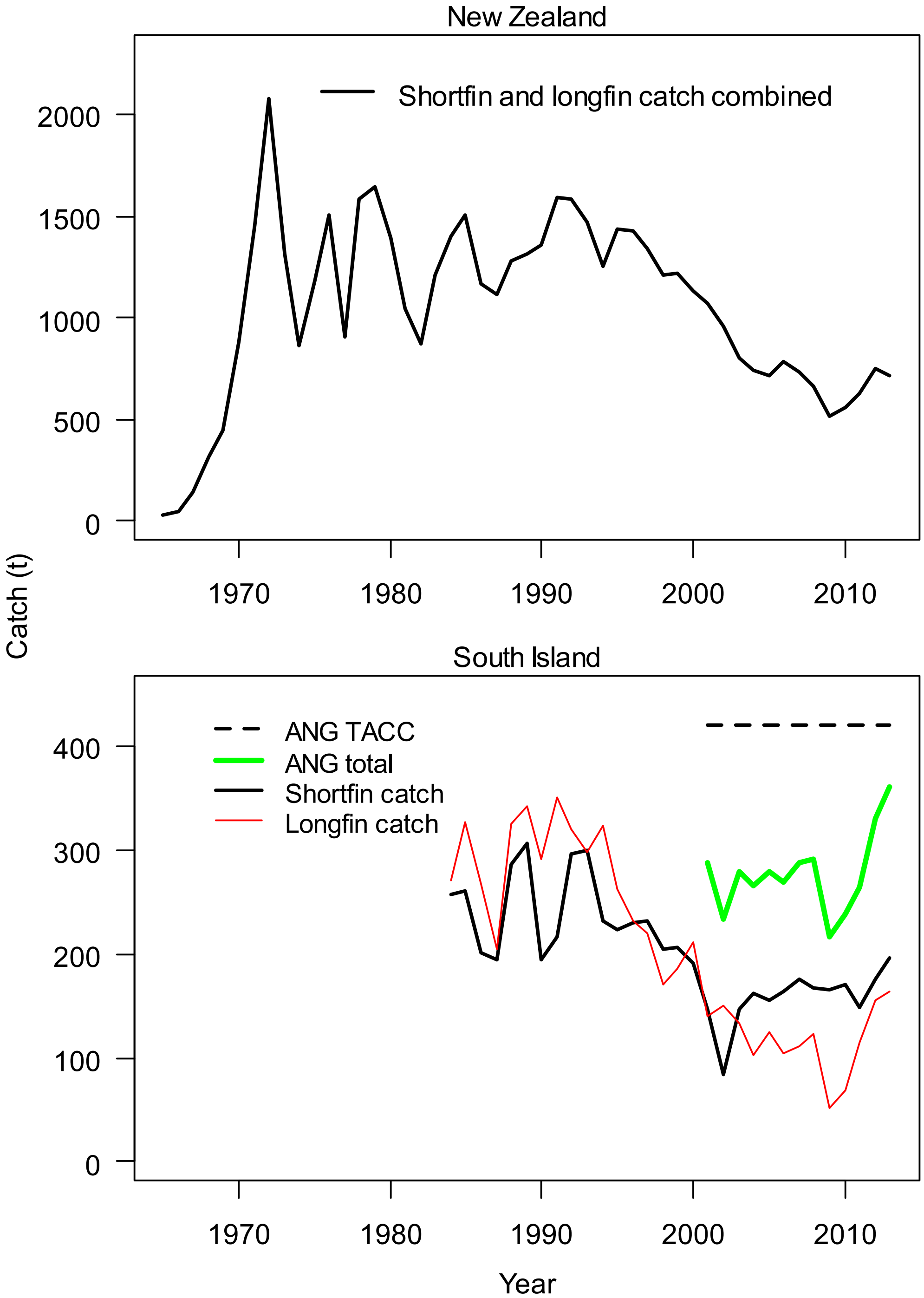



**Figure 1: Top panel: Landed catches of eels from New Zealand from 1965 to 2012–13 by calendar year up until 1988 and by fishing year from 1988–99 onward (Data from Ministry for Primary Industries 2014; Table 1). These catches are based on MAF Fisheries Statistics Unit (FSU), Licensed Fish Receiver Returns (LFRR), Quota Management Reports (QMR), and Monthly Harvest Returns (MHR). Bottom panel: South Island landed catches for shortfin and longfin eels individually, combined (ANG total), and the ANG TACC. South Island data were taken from ECLR data (Ministry for Primary Industries 2014; table 4) from 2000–01 onward and before that were estimated from species proportions from catch effort (CELR) estimated catches.**

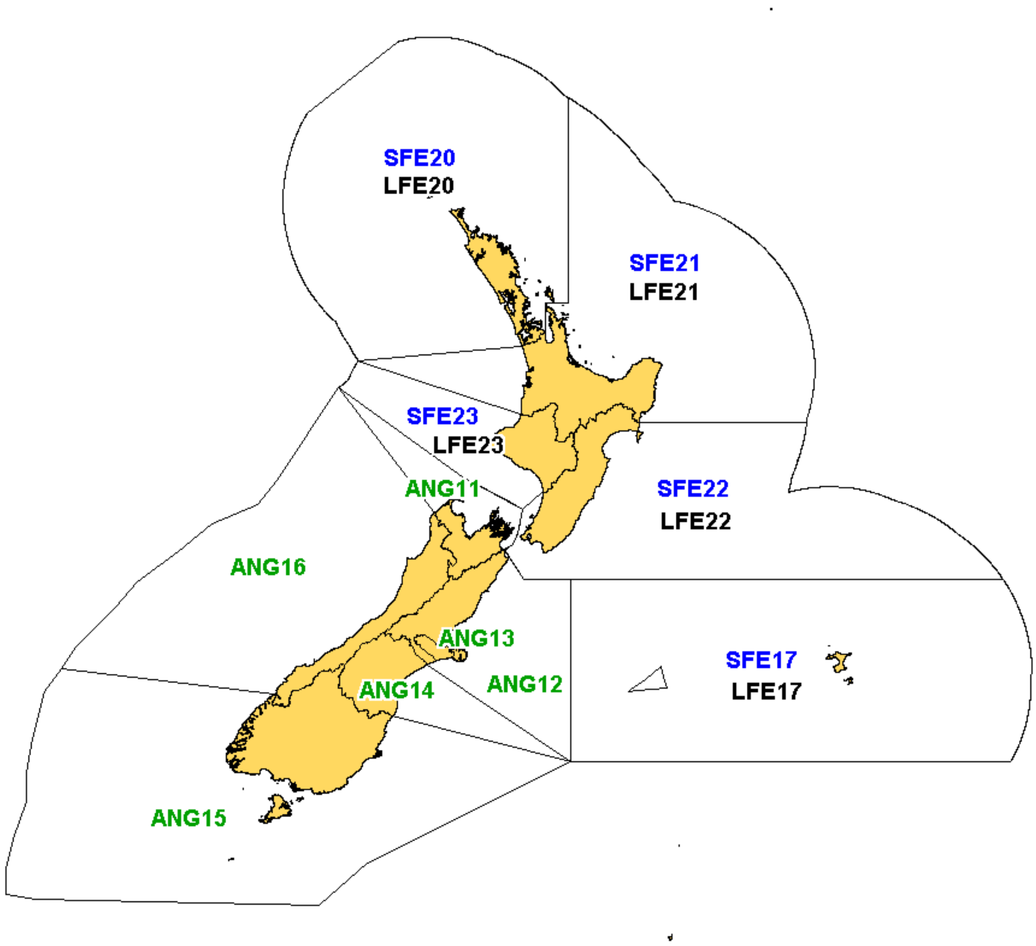



**Figure 2: Quota Management Areas for the New Zealand eel fishery (see Table 1 for breakdown by eel statistical areas). Shortfin stocks are denoted by the prefix SFE, and longfin by LFE. ANG comprises both shortfin and longfin combined. (Figure from Ministry for Primary Industries 2014).**


**Figure 3: South Island eel statistical areas (ESAs). See Table 1 for old ESA numeric codes 13 to 23.**

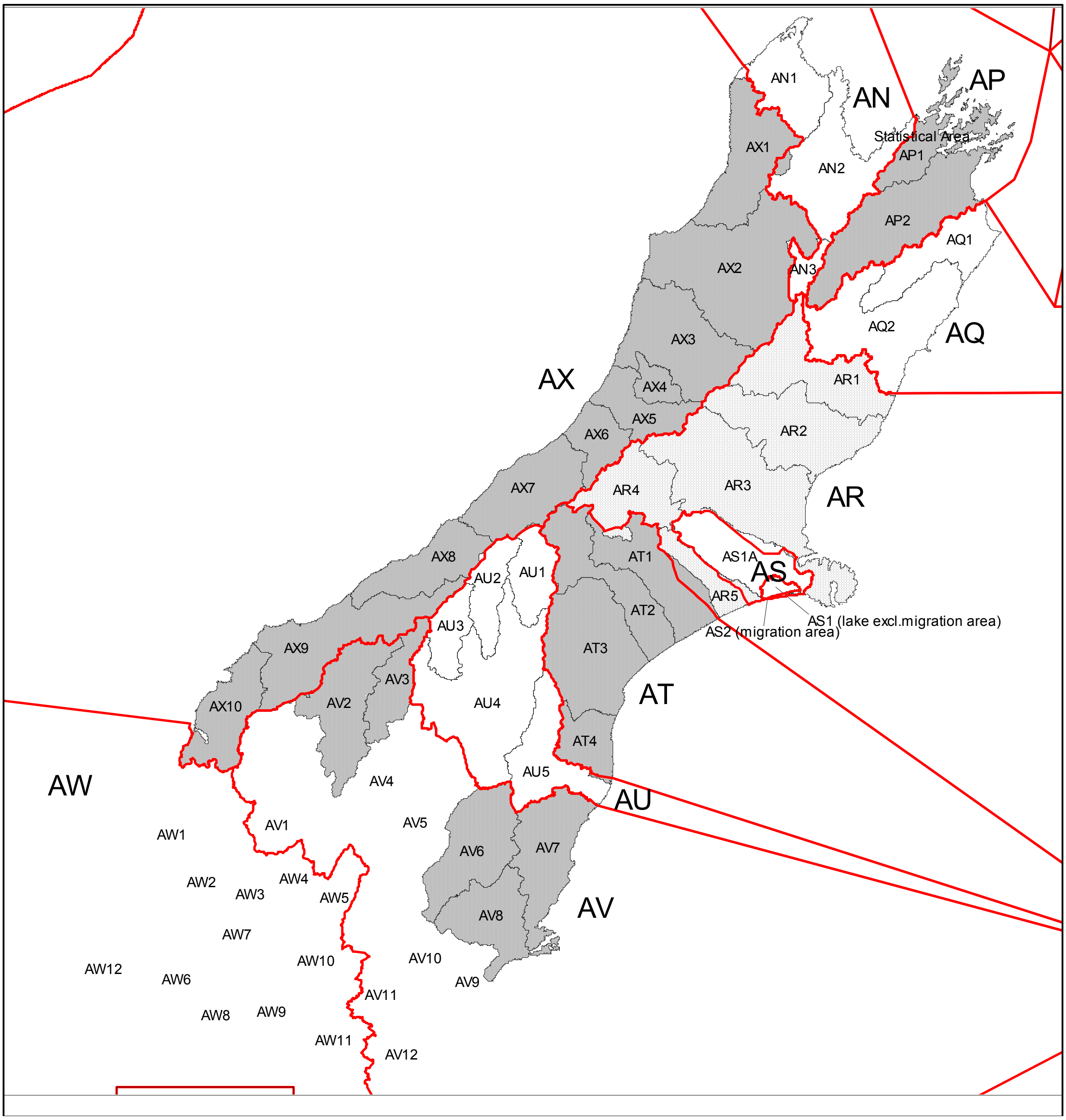



**Figure 4: South Island eel statistical areas and subareas, shaded to contrast contiguous ESAs.**

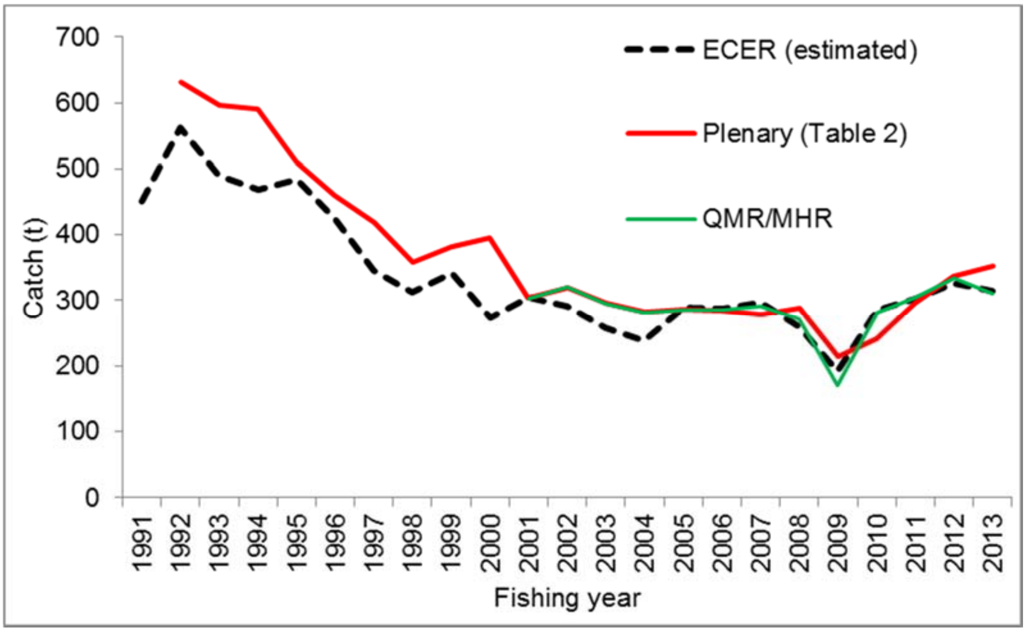



**Figure 5: South Island estimated commercial catch of all eels (shortfin, longfin, and unclassified) from 1991 to 2013, and landed catch from 1992 to 2013 and 2001 to 2013. Estimated catches are from CELR and ECER (after 2001) and represent the groomed data used in the current CPUE analyses. The landed catches are from table 2 of the plenary document sourced from processors (1992–2000) and LFRR/QMR (2001–2013) (Ministry for Primary Industries 2014, table 2). Landed catch is also shown from QMR/MHR data from 2001 to 2013. 1991 represents the 1990–91 fishing year.**

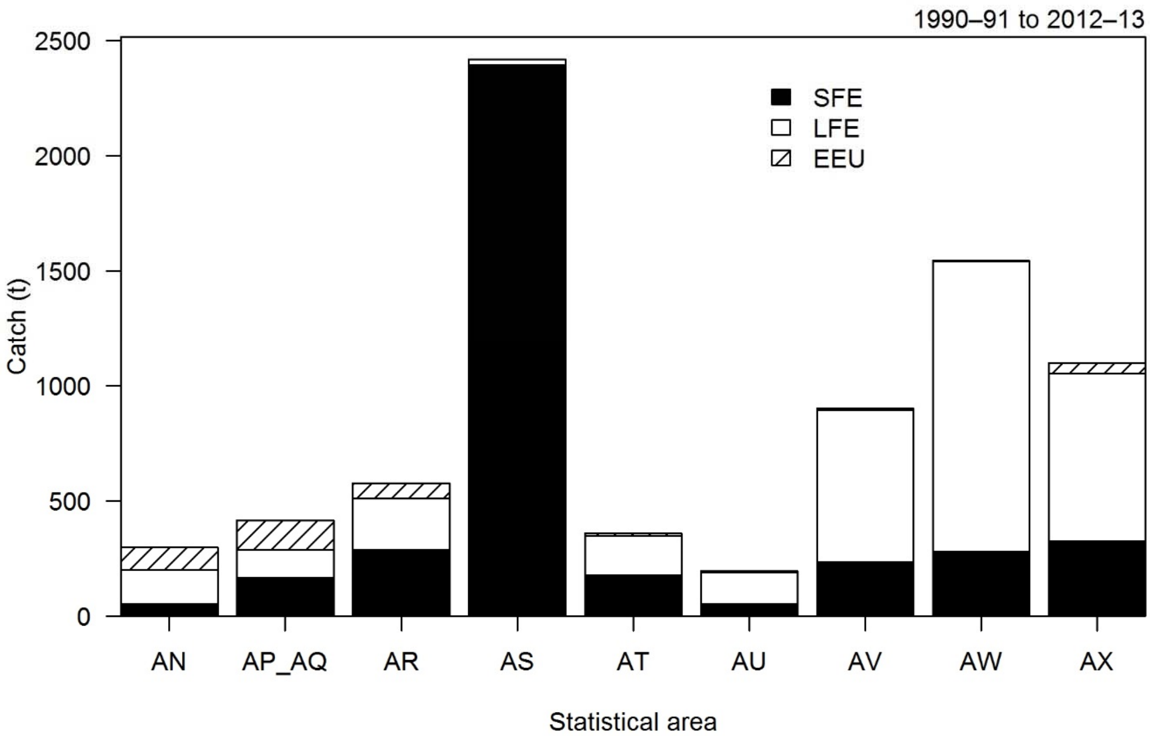



**Figure 6: South Island total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) by statistical area for the years 1990–91 to 2012–13**.

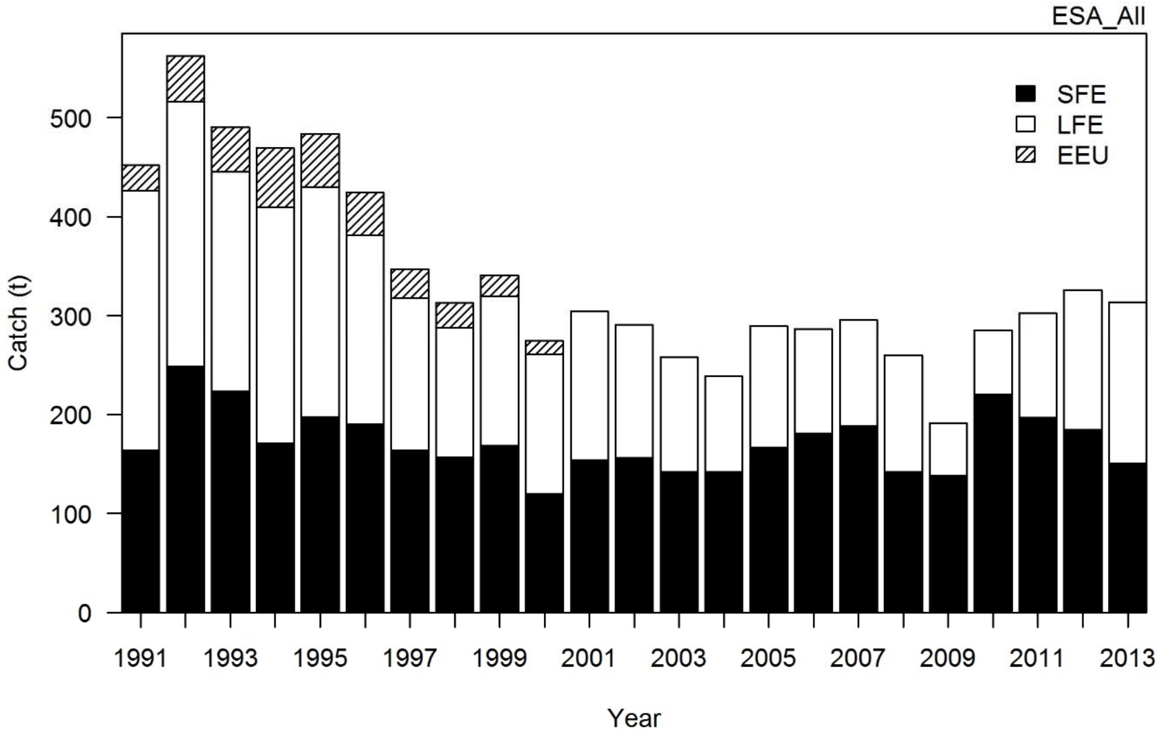
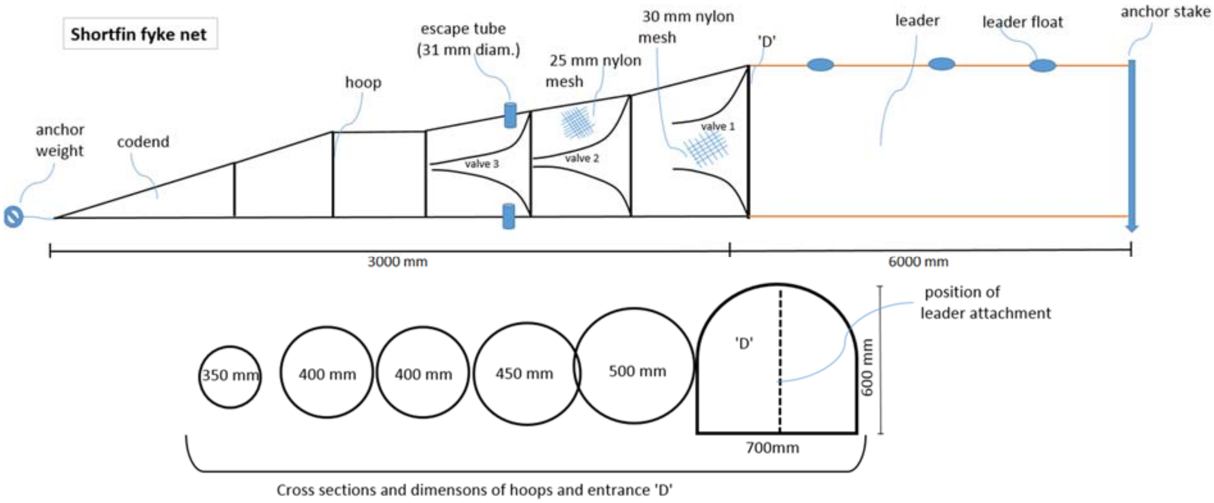



**Figure 7: South Island total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13.**



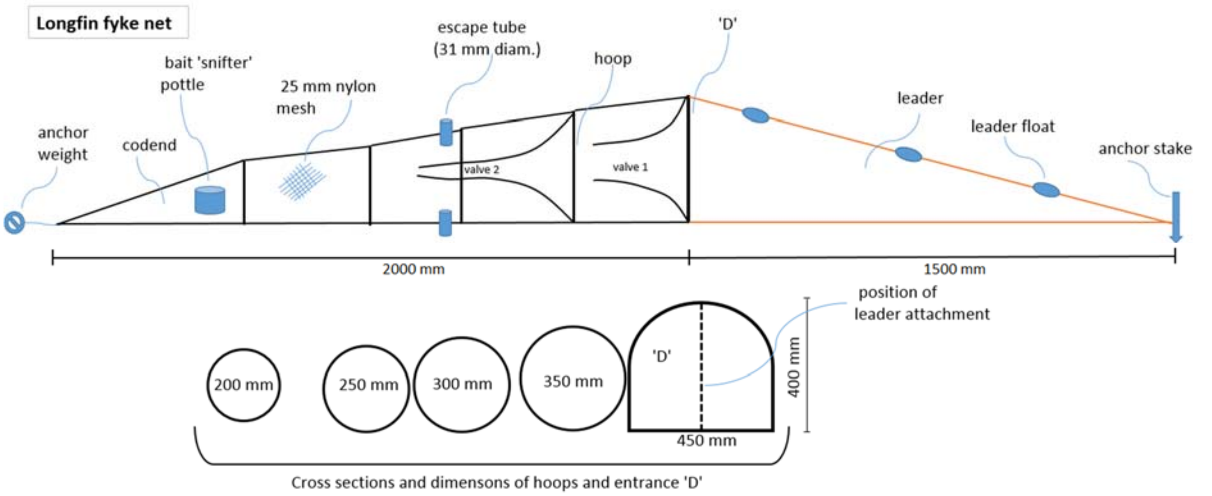




**Figure 8: Schematic drawings of standard South Island shortfin and longfin fyke nets, and the large Te Waihora shortfin fyke net (next page). The scale among the three net types varies and for the shortfin nets the leaders and wings are not to scale relative to the net dimensions.**

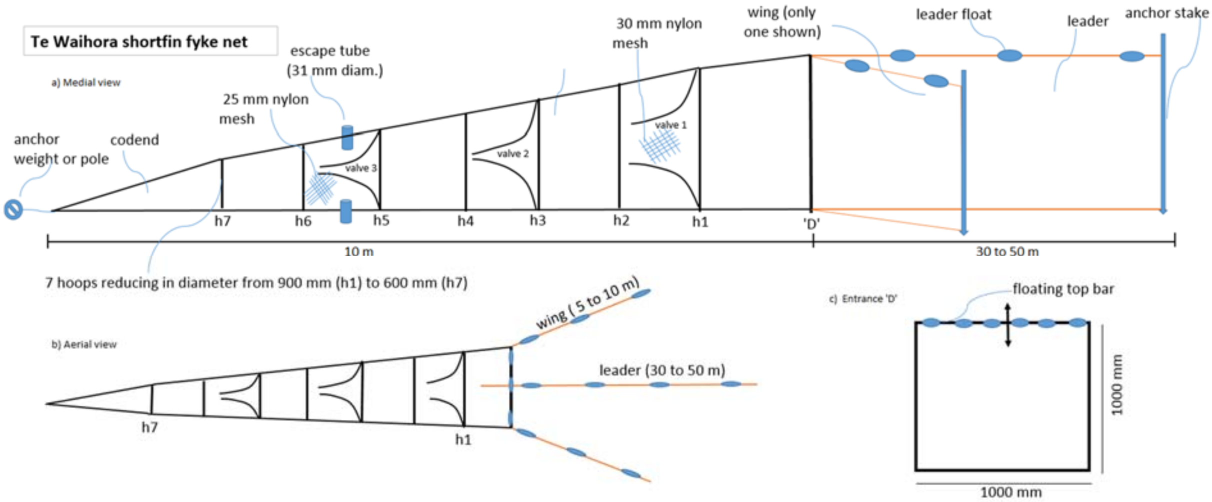



**Figure 8 – *continued***


**Figure 9: Photographs of a standard South Island shortfin eel fyke net (foreground. a) Full view of net fully extended; b) Net entrance and first valve between the 'D' and first hoop. Mesh size between 'D' and first hoop is 30 mm reducing to 25 mm thereafter; c) Second and third valves with escape tubes inserted behind the third valve; d) Entrance 'D' with leader attachment shown; e) 6 m leader extending away from the 'D'; f) Codend from which eels are removed from the net. Photos by Mike Beentjes taken at Mossburn Enterprises, Invercargill (February 2014).**

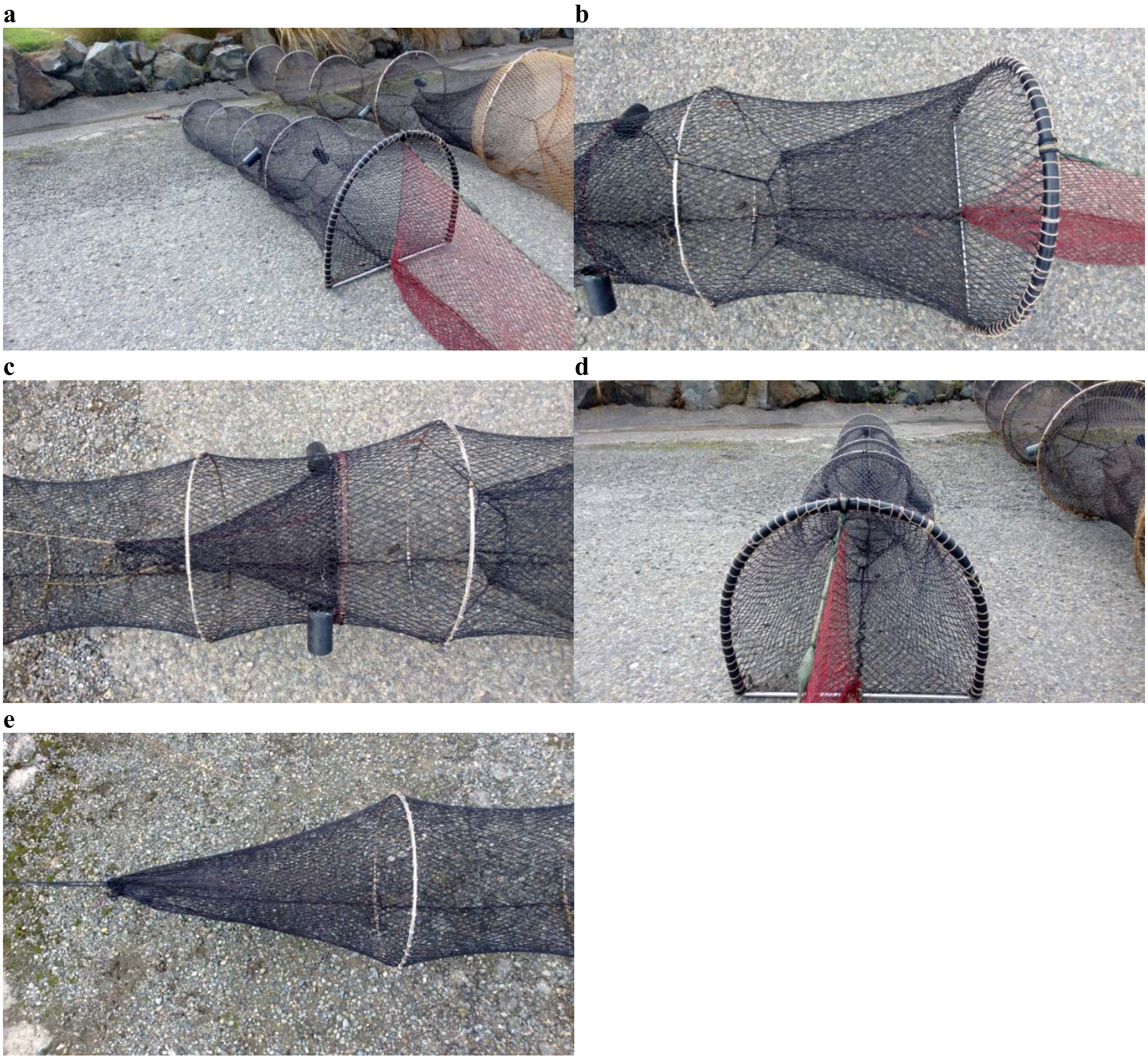



**Figure 10: Photographs of a standard South Island longfin eel fyke net (foreground). a) Full view of net fully extended; b) Net entrance and first valve between the 'D' and first hoop. Mesh size throughout is 25 mm; c) First and second valve with escape tubes inserted behind the second valve; d) Entrance 'D' with leader attachment shown. Leader is 1.5 m leader and tapers as it extends away from the 'D'; e) Codend from which eels are removed from the net. Photos by Mike Beentjes taken at Mossburn Enterprises, Invercargill (February 2014).**

**Figure 11: Photograph of standard South Island longfin (foreground) and shortfin (background) eel fyke nets side by side. Photos by Mike Beentjes taken at Mossburn Enterprises, Invercargill (February 2014).**

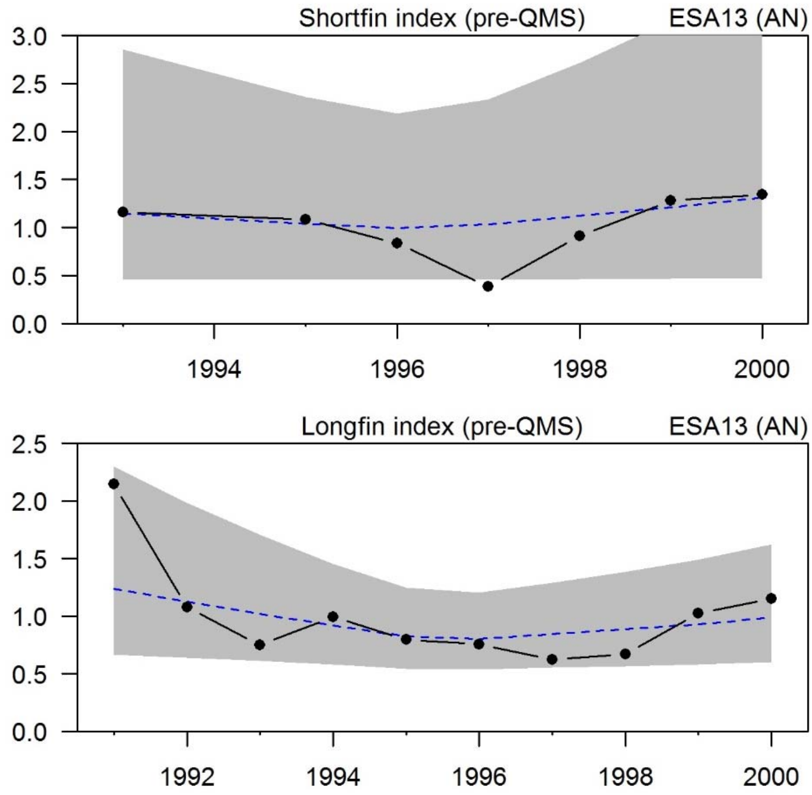



**Figure 12: Standardised CPUE indices for shortfin and longfin eel for the years 1991–2000 (pre-QMS) for data-poor areas (AN, AP-AQ, AR, AU, AT). A lowess fit (dashed line) to the index is plotted along with the CVs (shaded).**

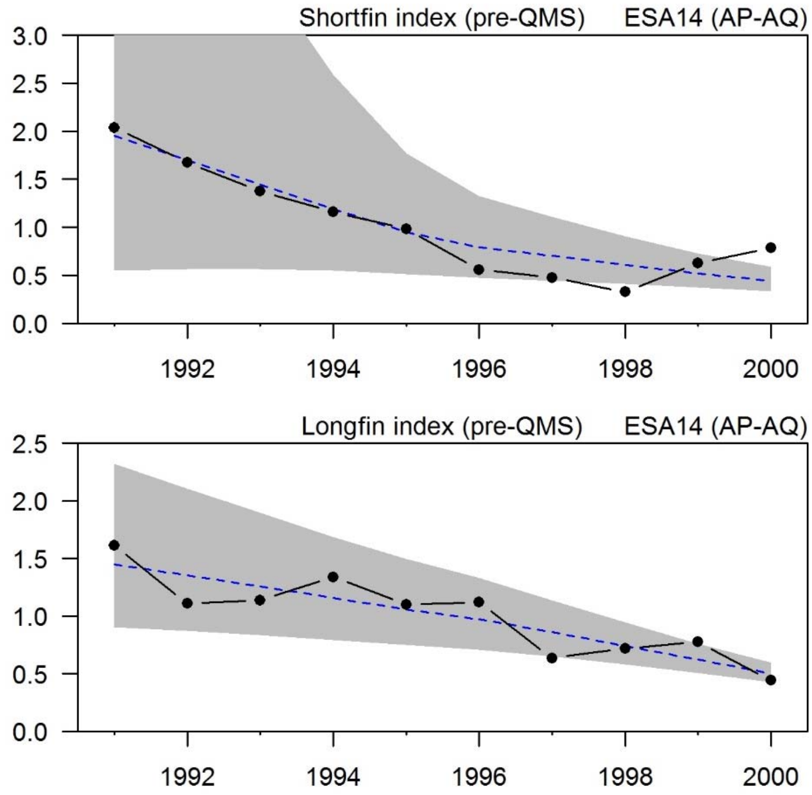



**Figure 12 –** ***continued***

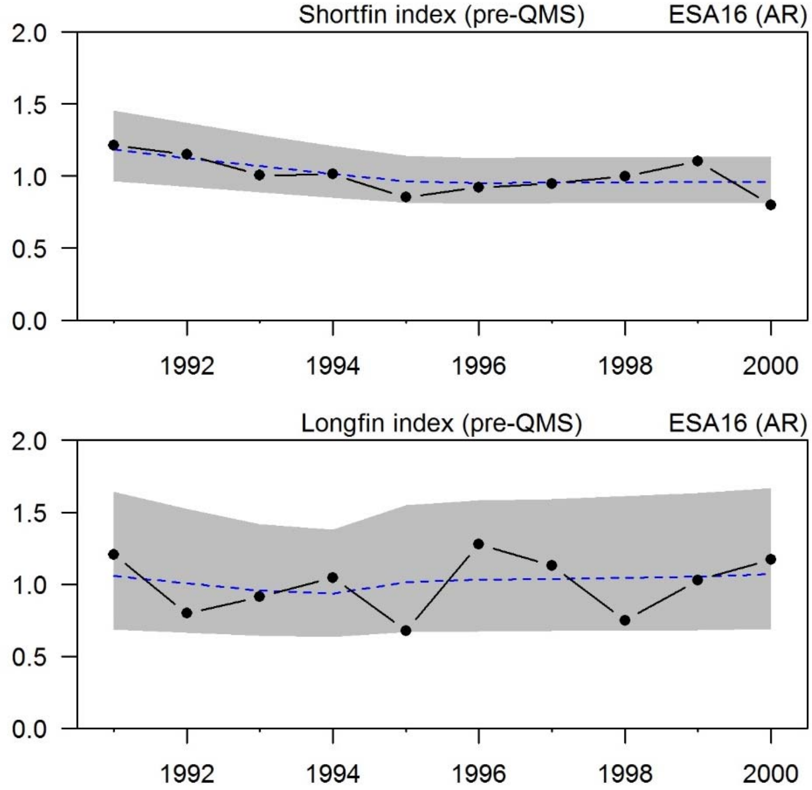



**Figure 12 – *continued***

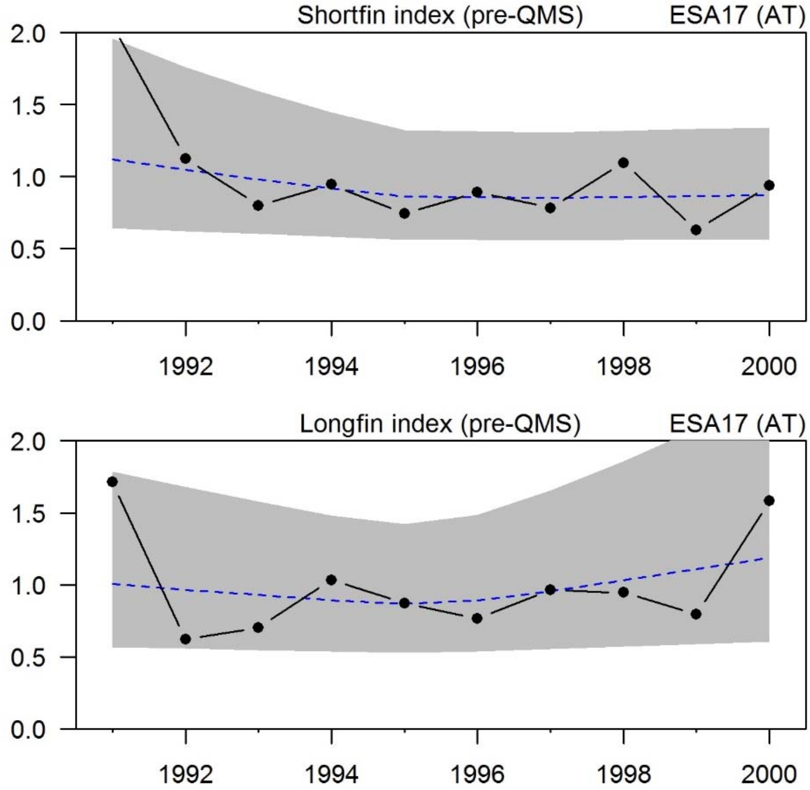



**Figure 12 –** ***continued***

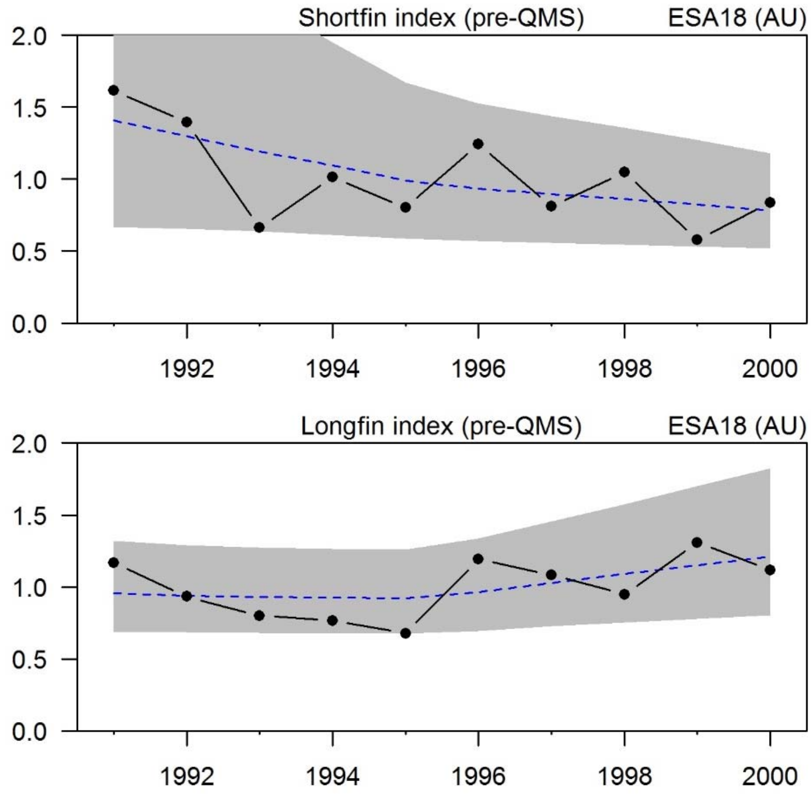



**Figure 12–** ***continued***

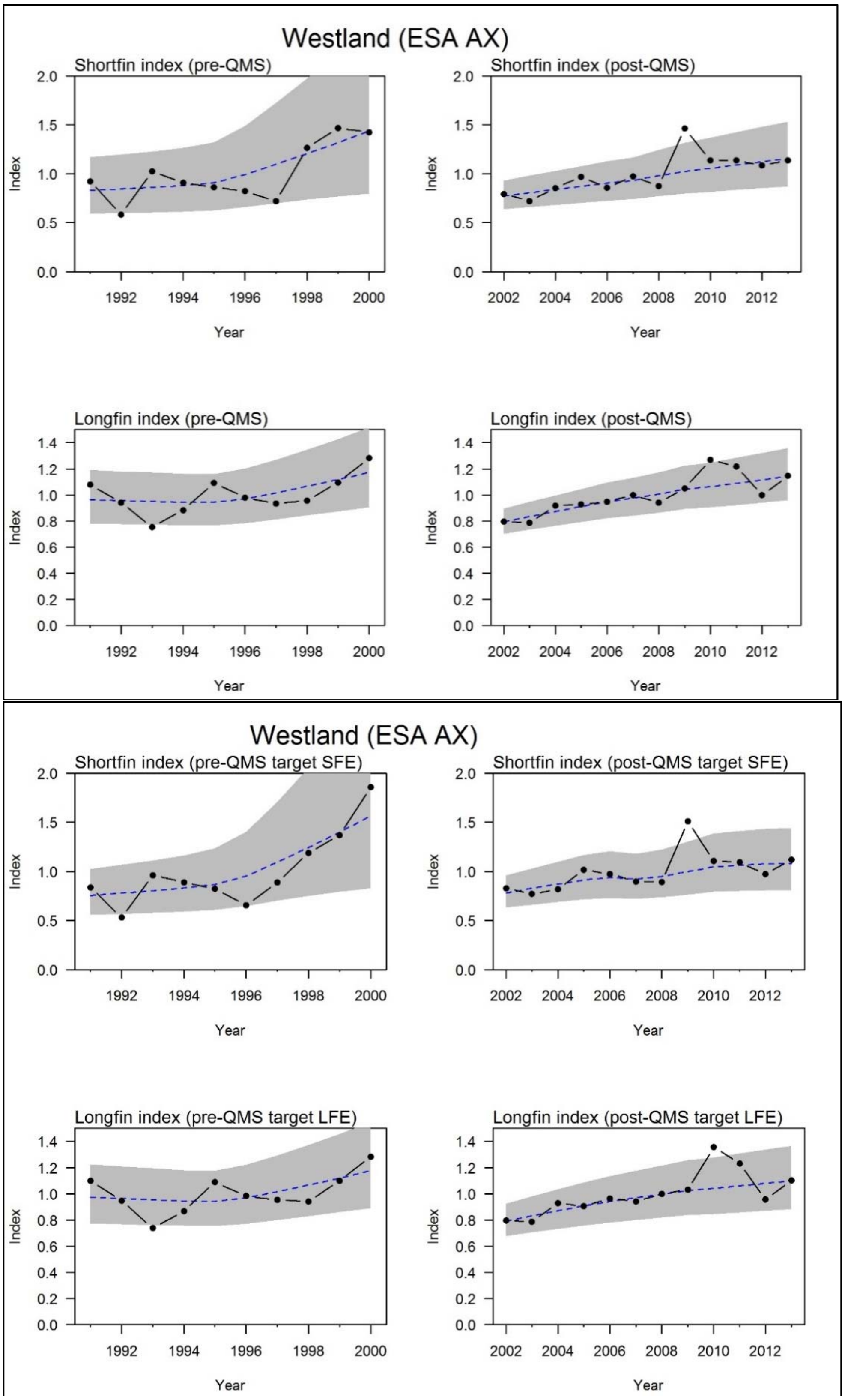
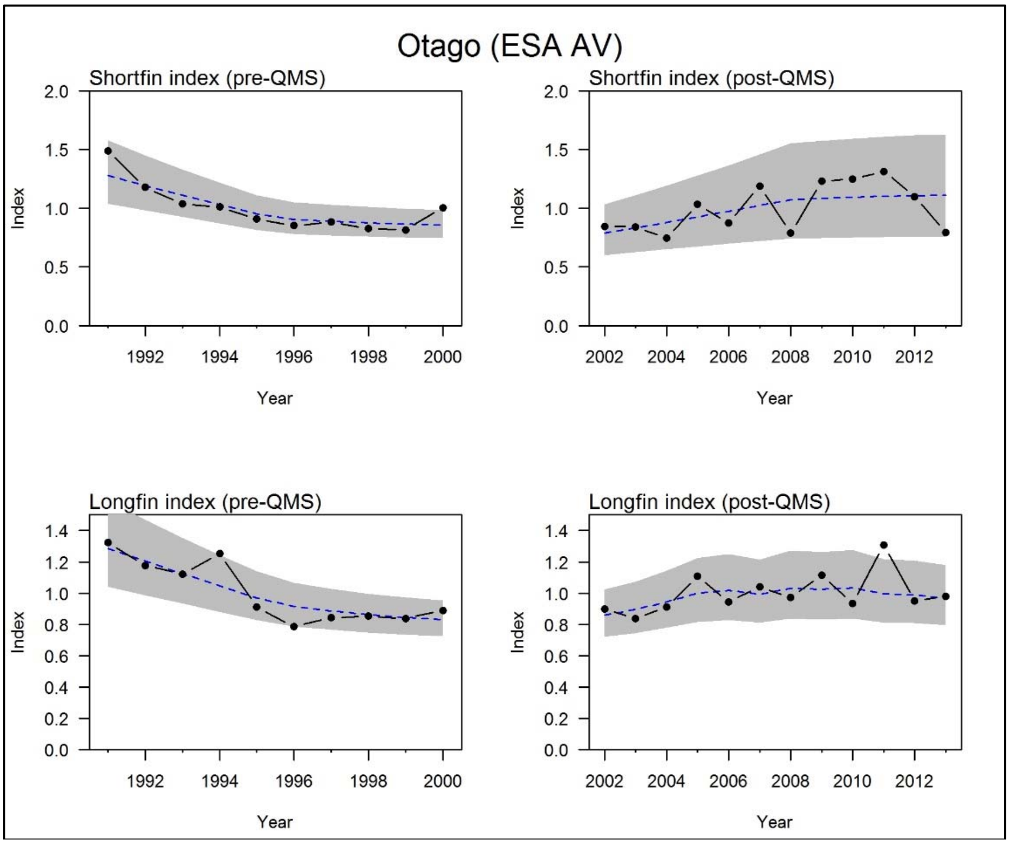



**Figure 13: Standardised CPUE indices for shortfin and longfin eel for the years 1991–2000 (pre-QMS) and 2002 to 2013 for data-rich areas (AX, AV, AW, AS1-shortfin only). A lowess fit (dashed line) to the index is plotted along with the CVs (shaded). The four plots in the top panel are the base analyses and those in the bottom panel are sensitivity analyses where only records with target species shortfin or longfin were included.**



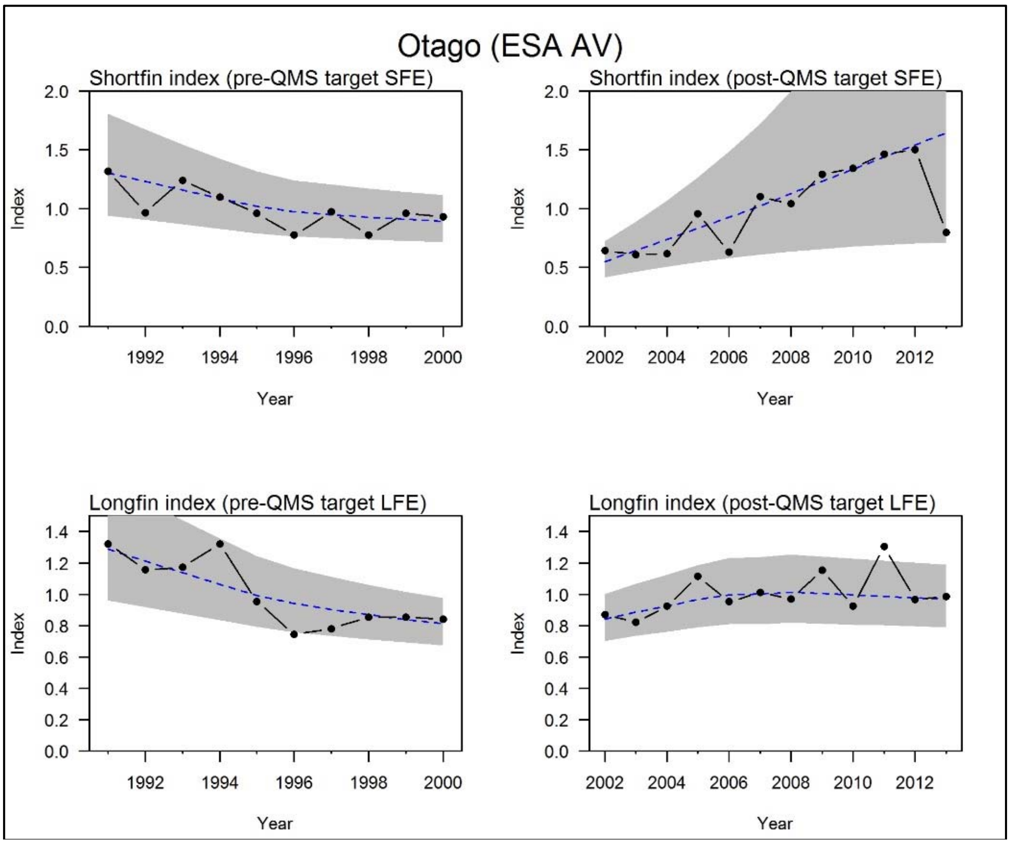
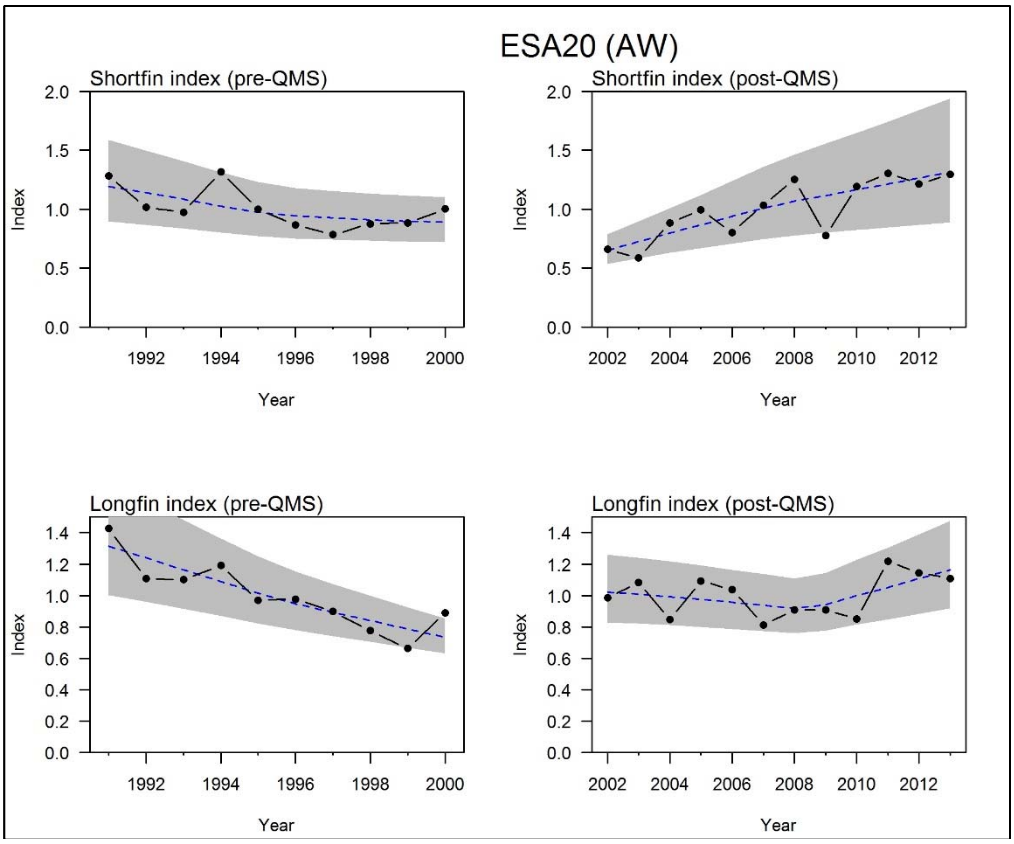




**Figure 13 –** ***continued***



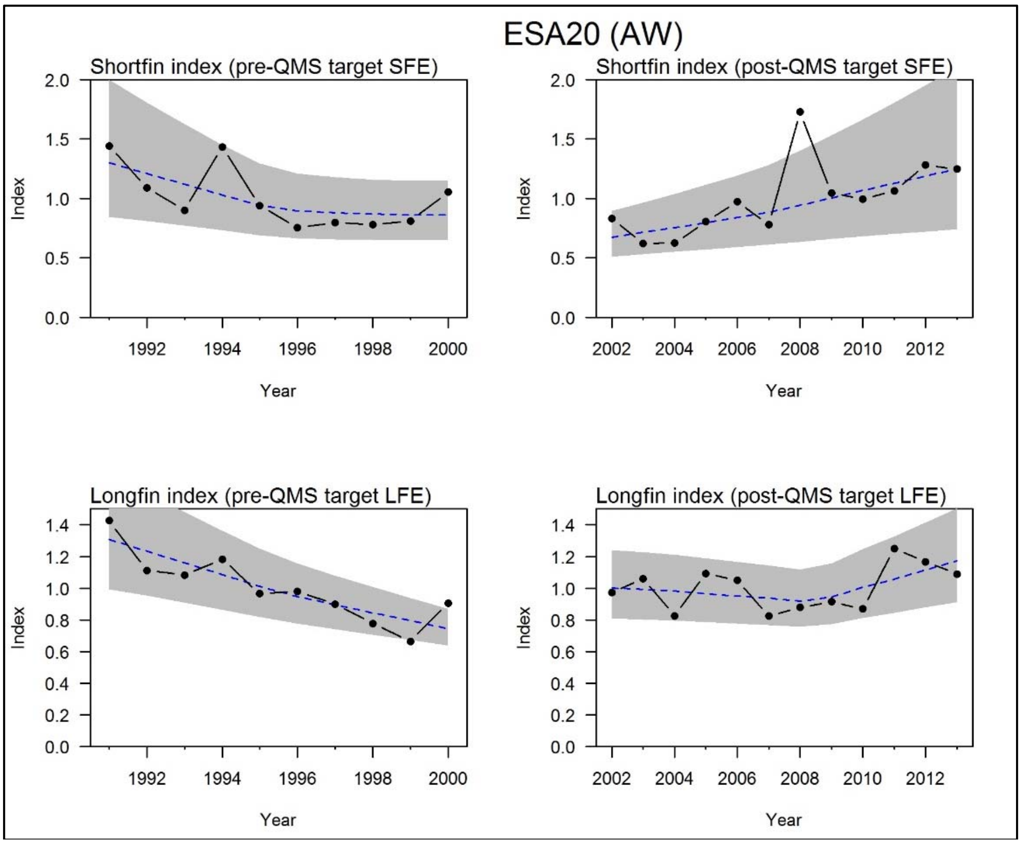




**Figure 13 – *continued***

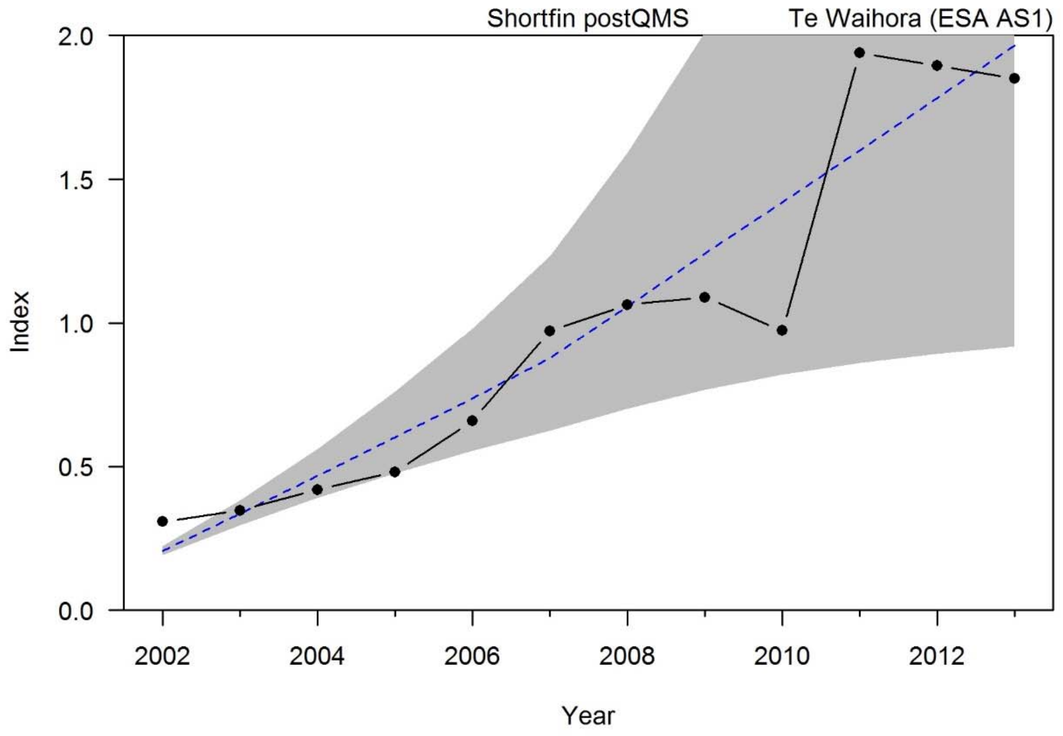



**Figure 14: Standardised CPUE indices for shortfin in AS1 for the years 2002–2013 (post-QMS). A lowess fit (dashed line) to the index is plotted along with the CVs (shaded).**

**Appendices A to E: Plots of eel fishery characterisation and pre-QMS CPUE analyses by ESA for data-poor ESAs (AN, AP-AQ, AR, AT, and AU).**

**Appendix A: ESA 13 (AN).**

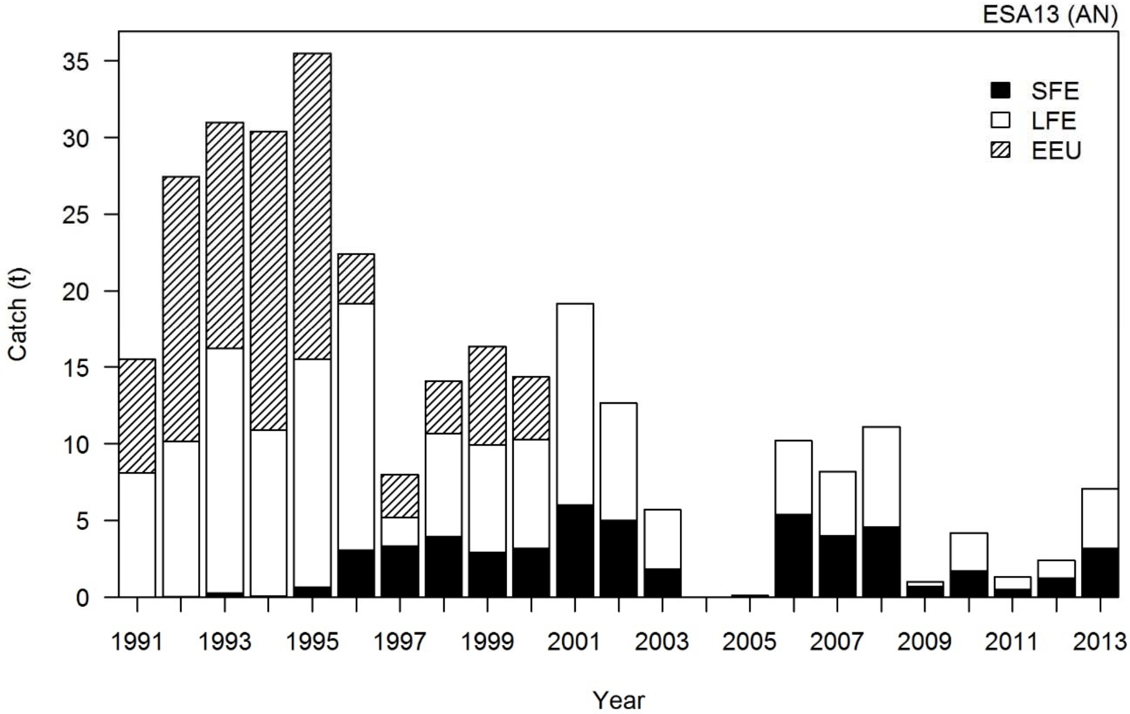



**Figure A1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (ESA13 (AN)).**

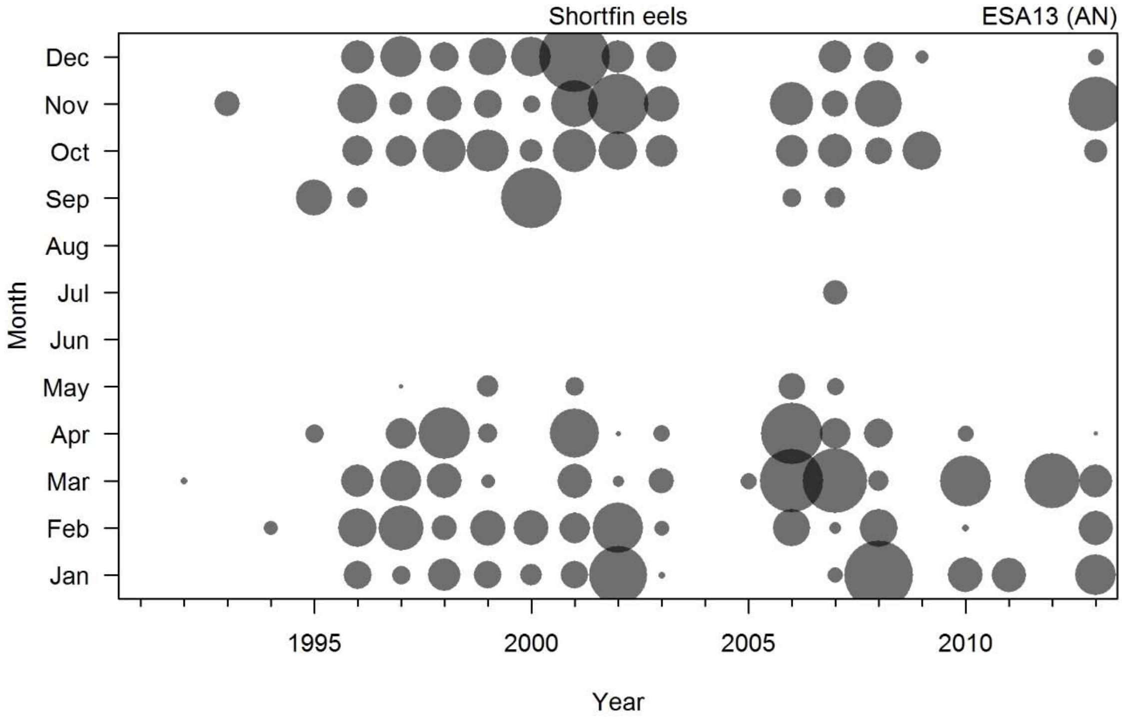



**Figure A2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (ESA13 (AN)).**

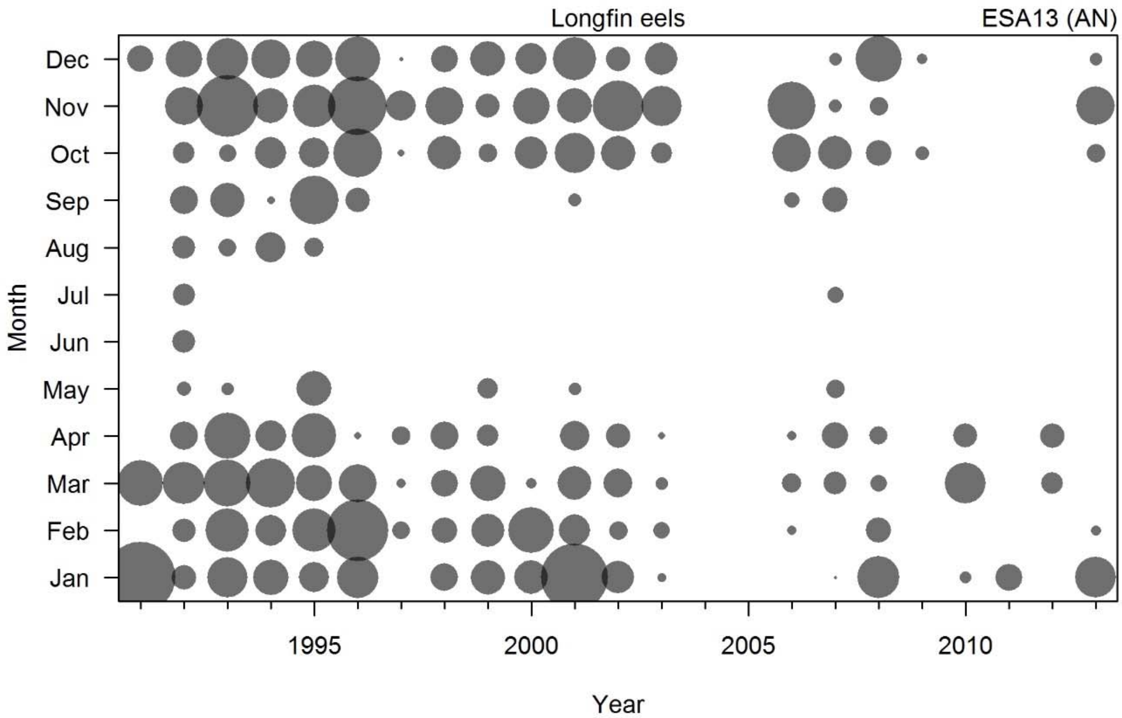



**Figure A3: Longfin eel catch by month for the years 1990–91 to 2012–13 (ESA13 (AN)).**

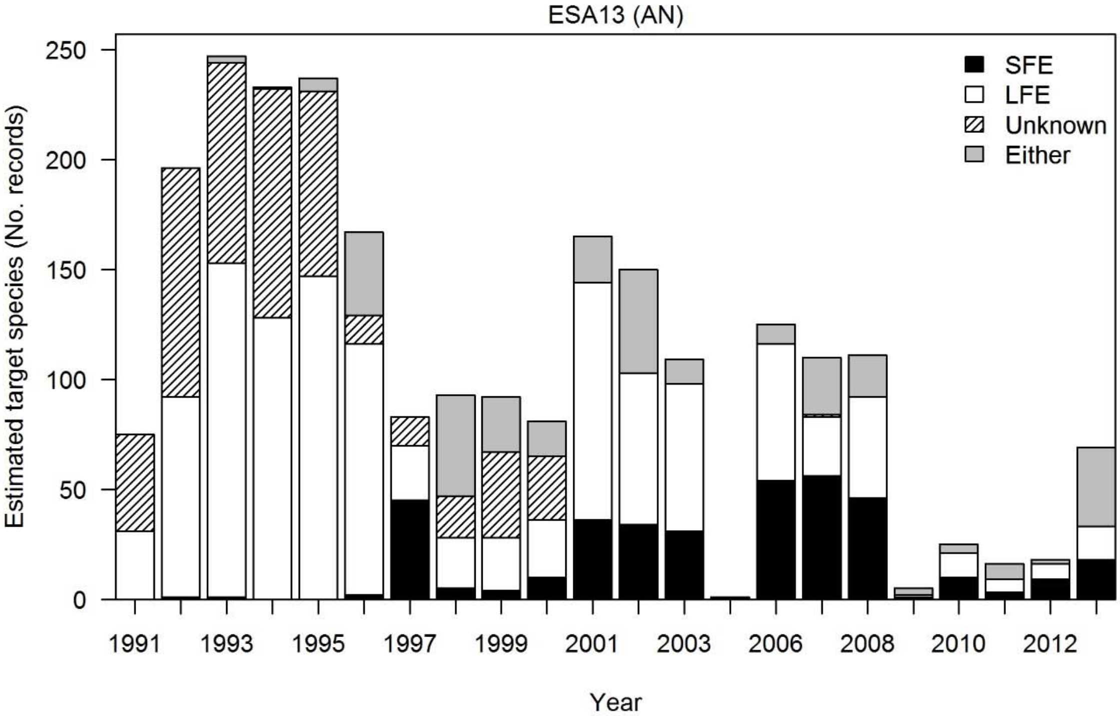



**Figure A4: Reconstructed target species for the years 1990–91 to 2012–13 (ESA13 (AN)).**

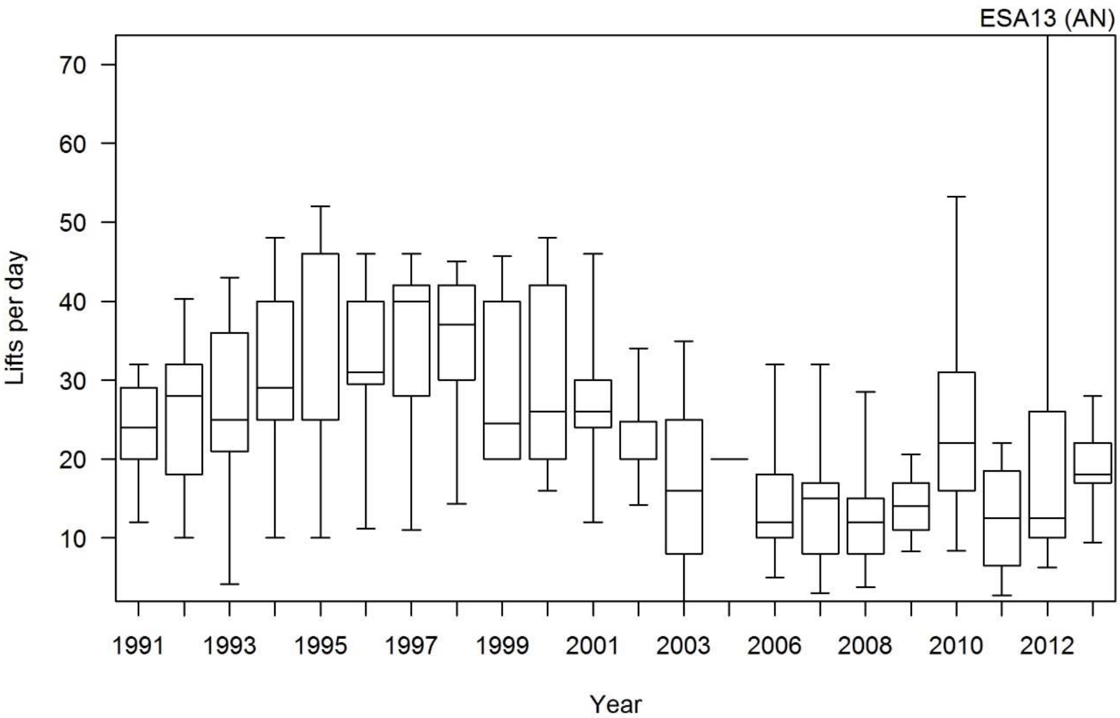



**Figure A5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (ESA13 (AN)).**

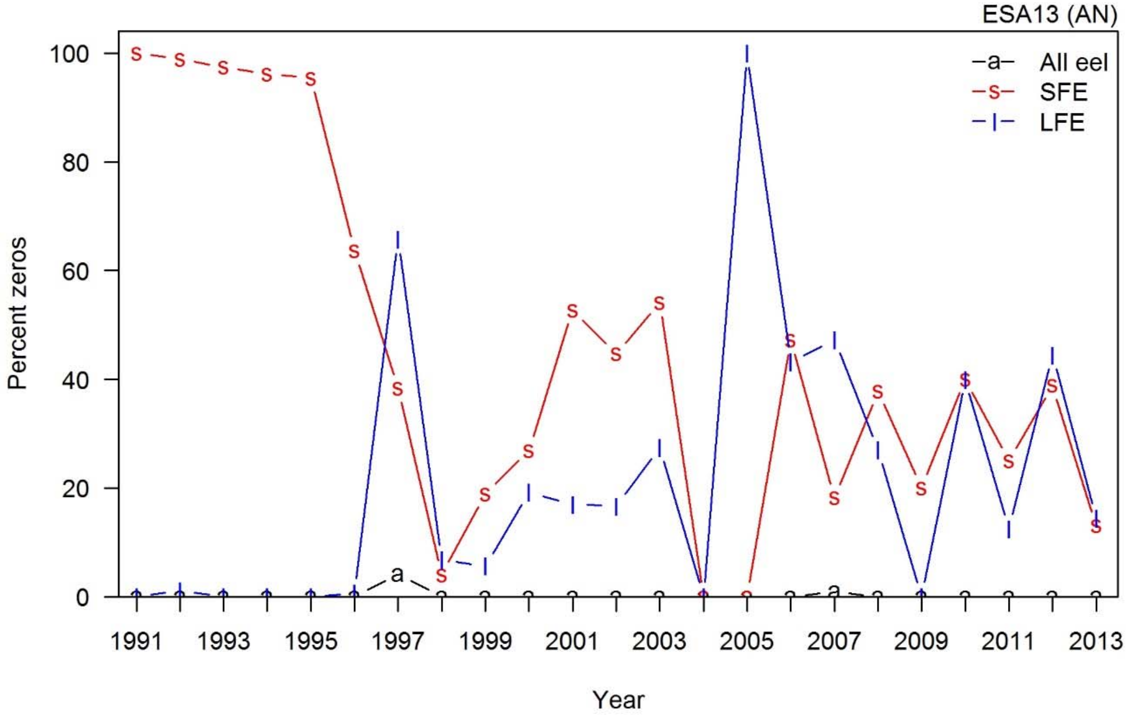



**Figure A6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) catch for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (ESA13 (AN)).**

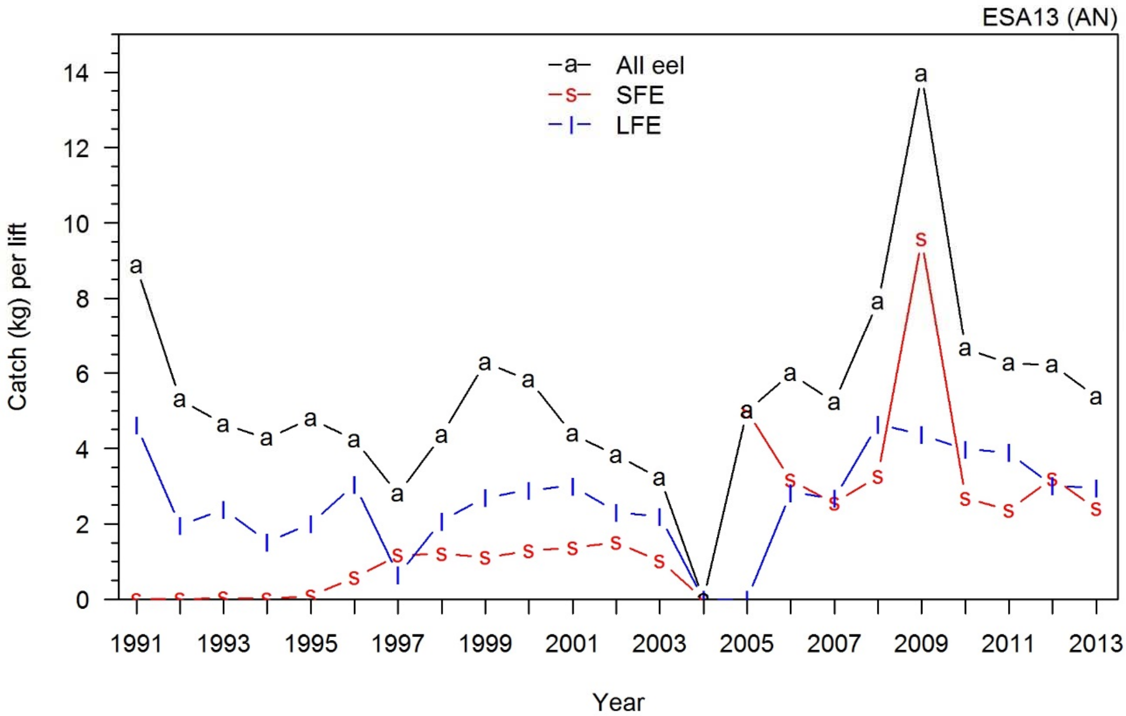



**Figure A7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (ESA13 (AN)).**

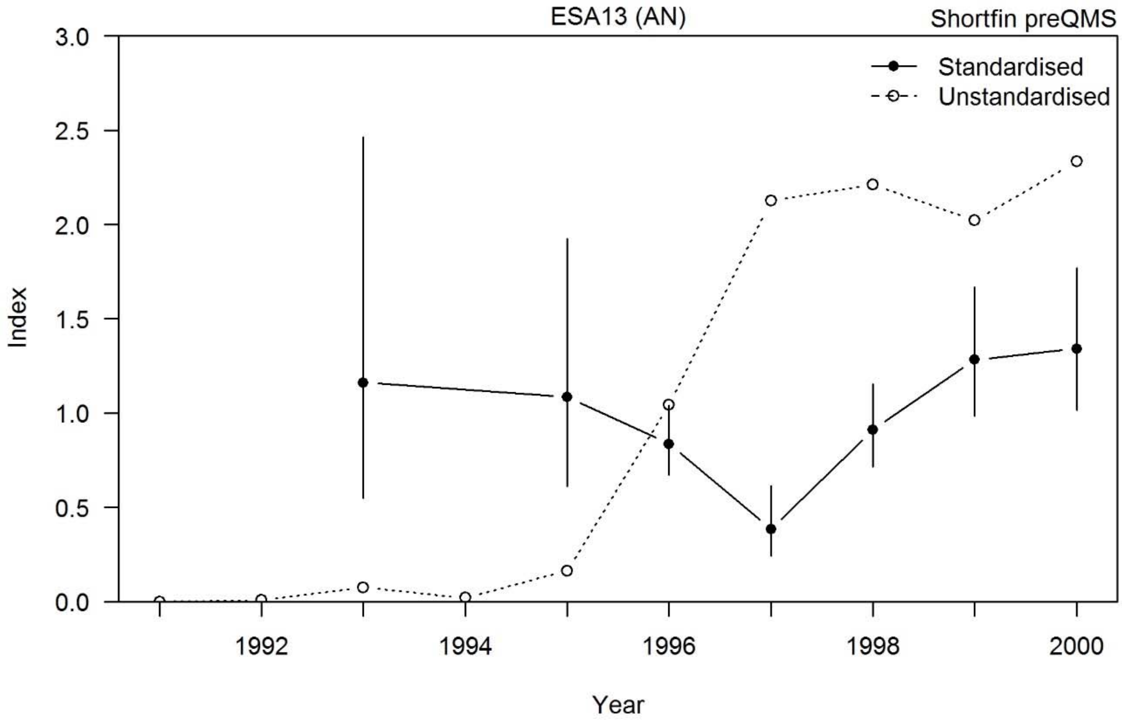



**Figure A8: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA13 (AN)).**

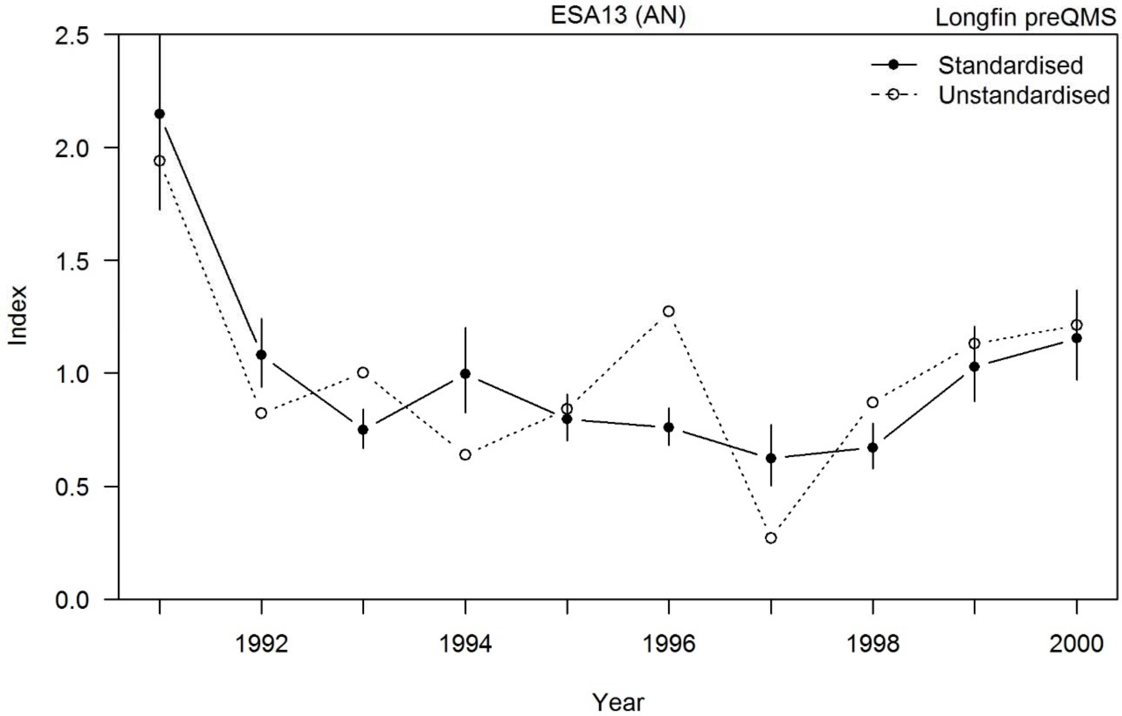



**Figure A9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA13 (AN)).**

**Appendix B: ESA 14 (AP-AQ).**

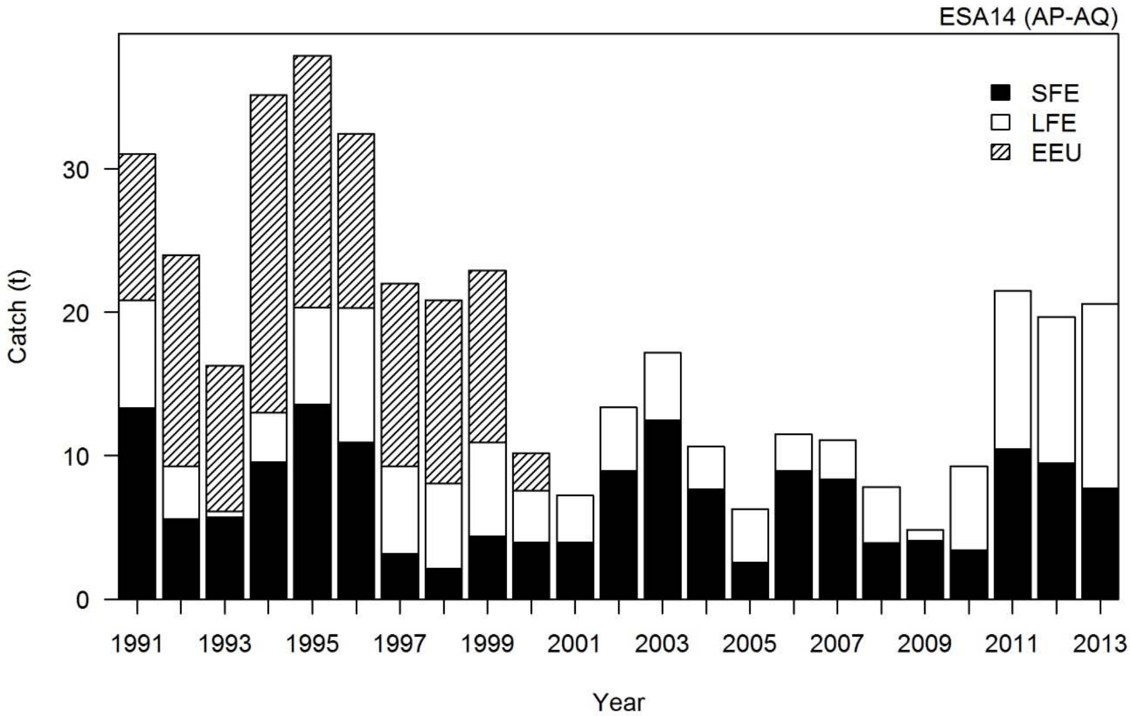



**Figure B1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (ESA14 (AP-AQ)).**

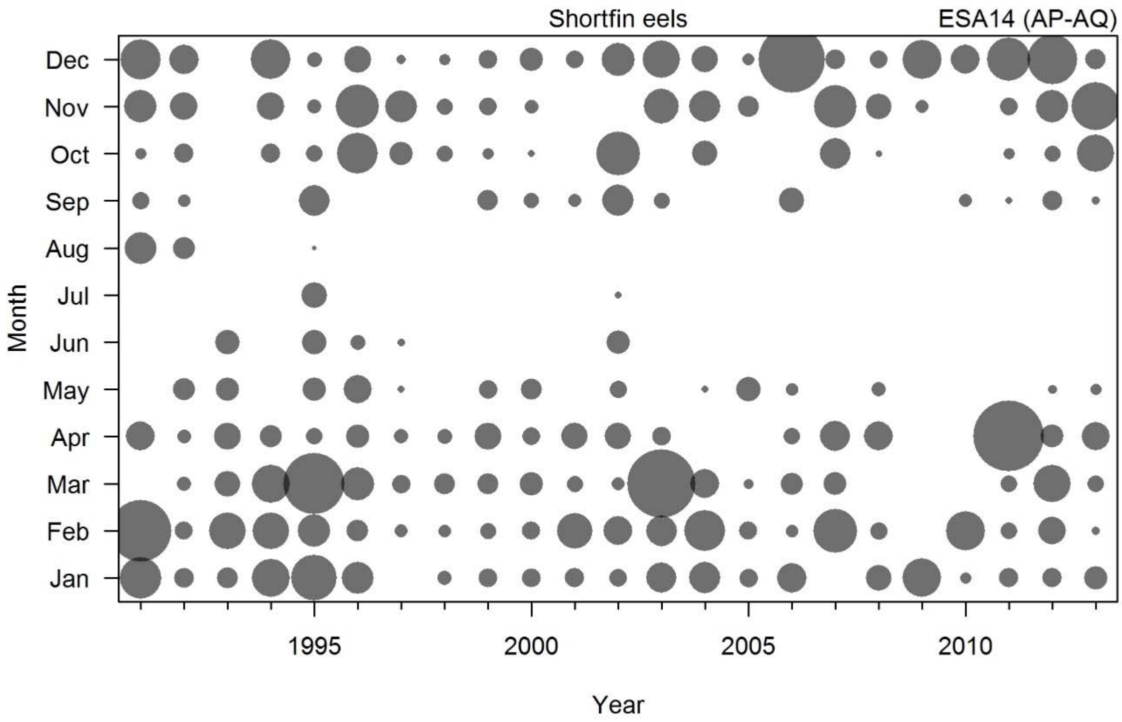



**Figure B2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (ESA14 (AP-AQ)).**

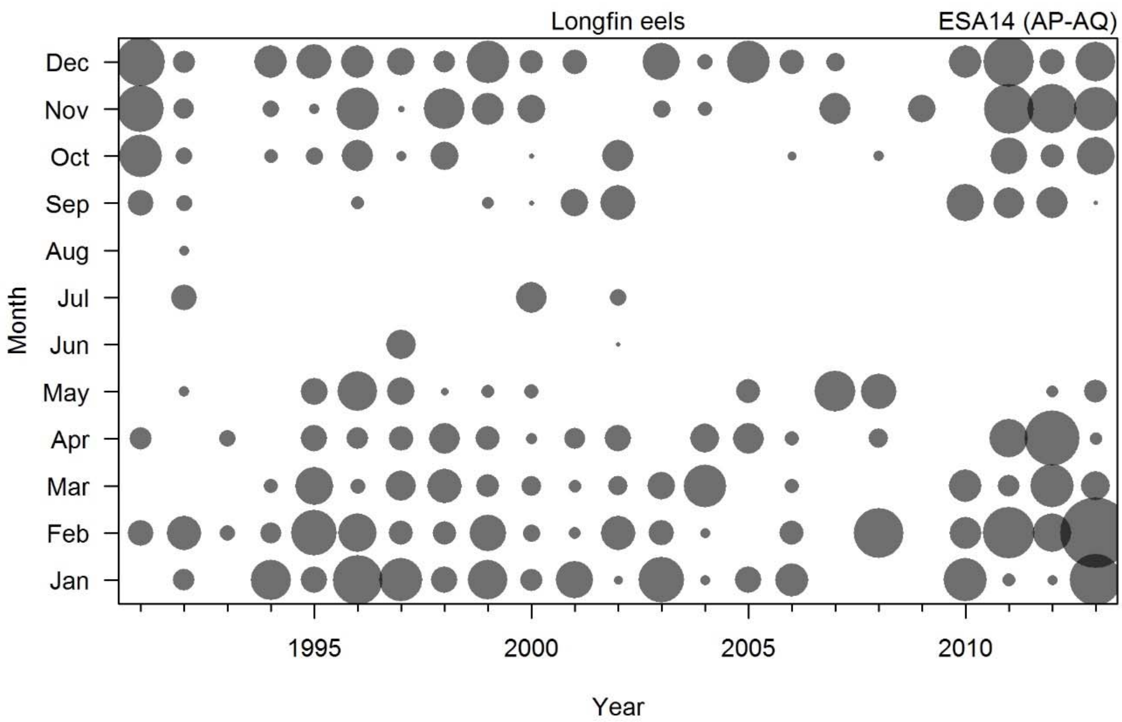



**Figure B3: Longfin eel catch by month for the years 1990–91 to 2012–13 (ESA14 (AP-AQ)).**

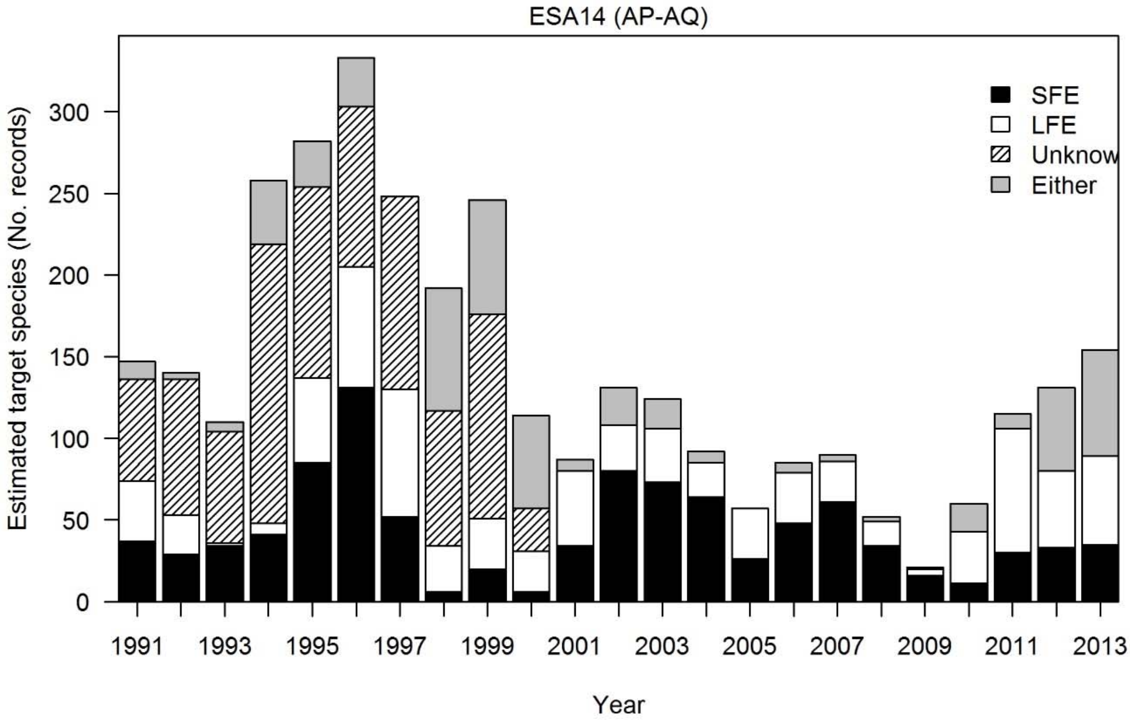



**Figure B4: Reconstructed target species for the years 1990–91 to 2012–13 (ESA14 (AP-AQ)).**

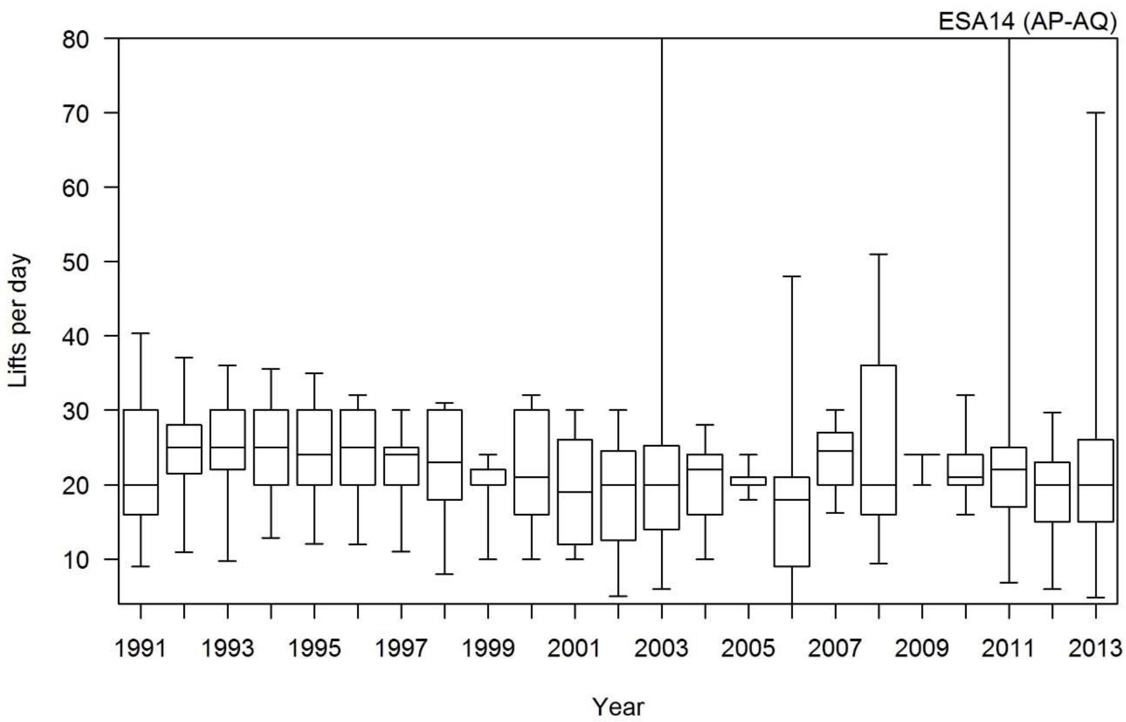



**Figure B5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (ESA14 (AP-AQ)).**

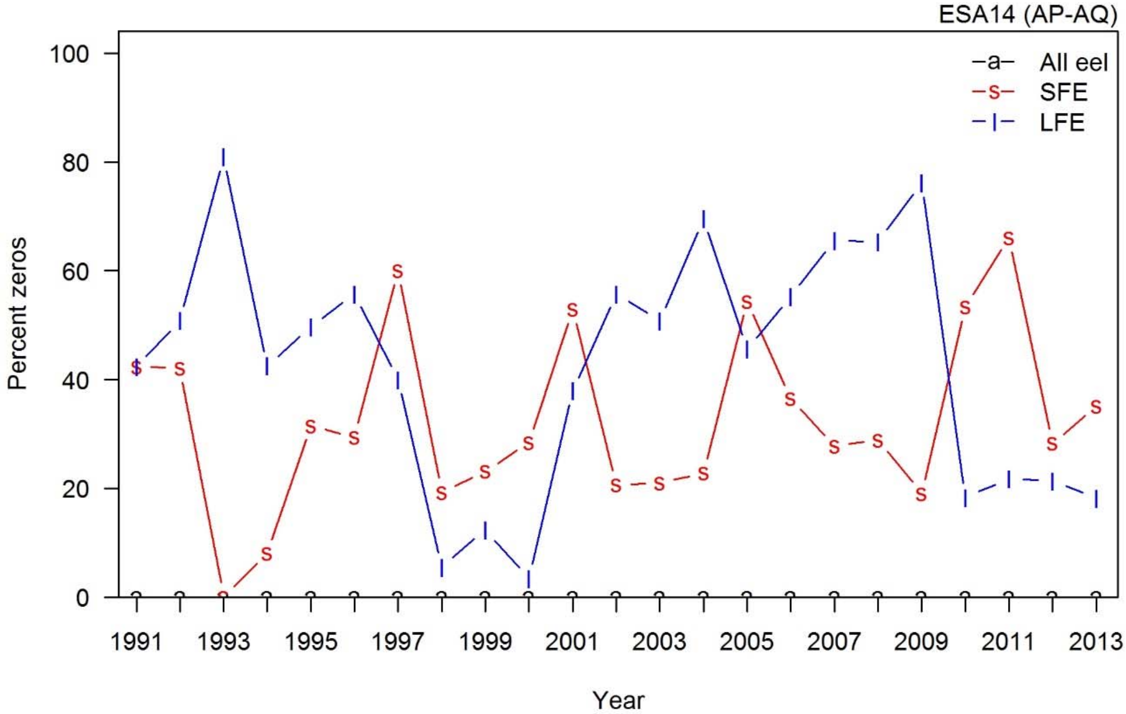



**Figure B6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) catch for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (ESA14 (AP-AQ)).**

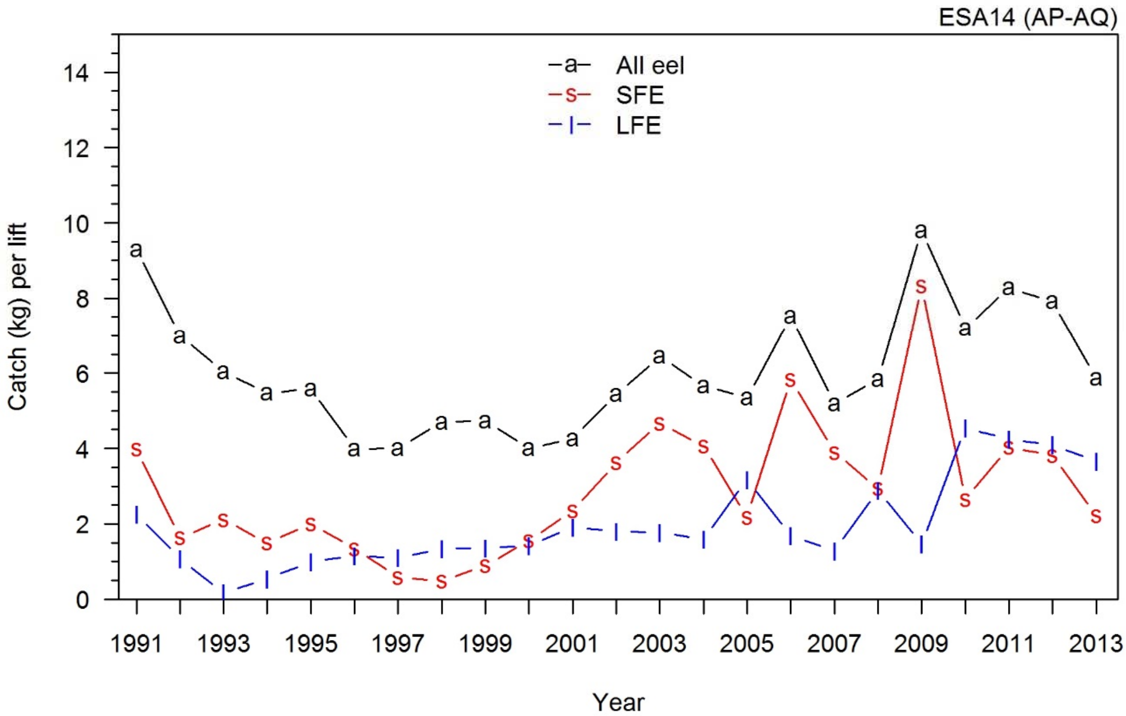



**Figure B7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (ESA14 (AP-AQ)).**

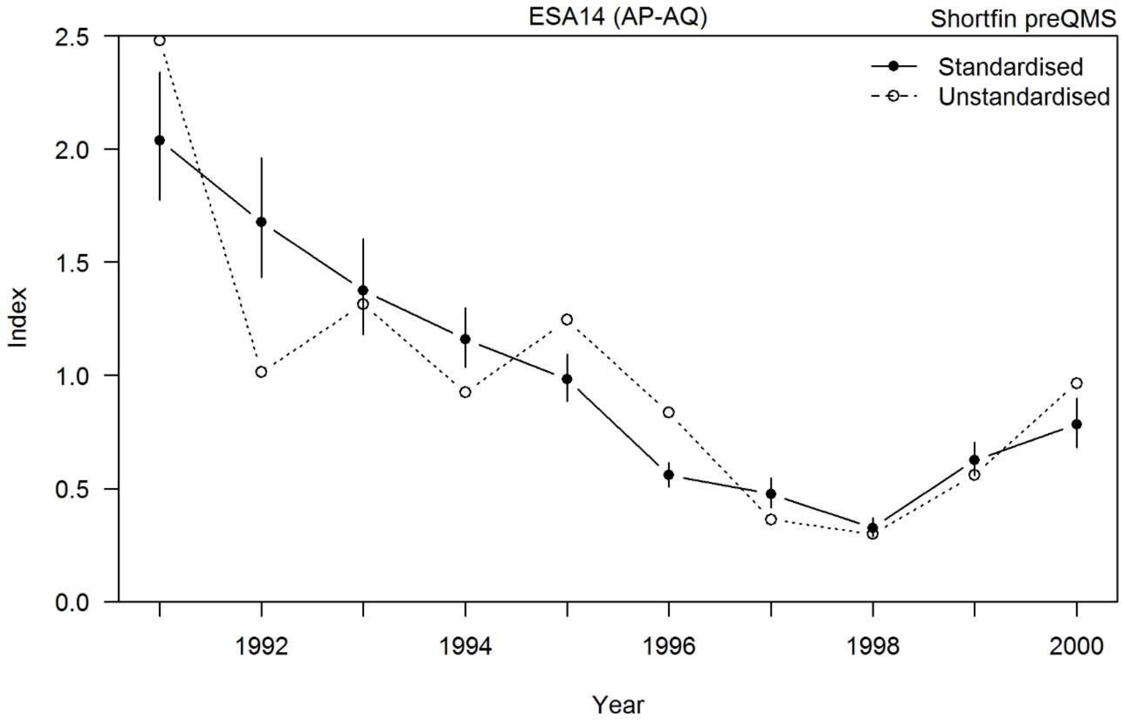



**Figure B8: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA14 (AP-AQ)).**

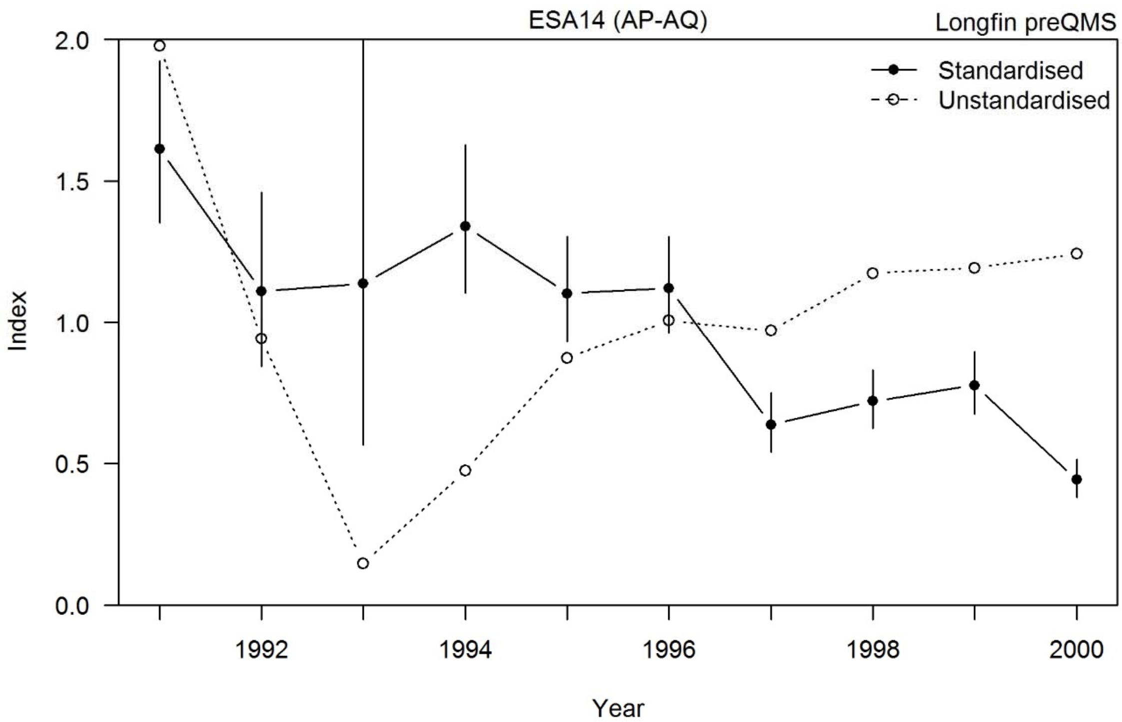



**Figure B9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA14 (AP-AQ)).**

**Appendix C: ESA 16 (AR)**

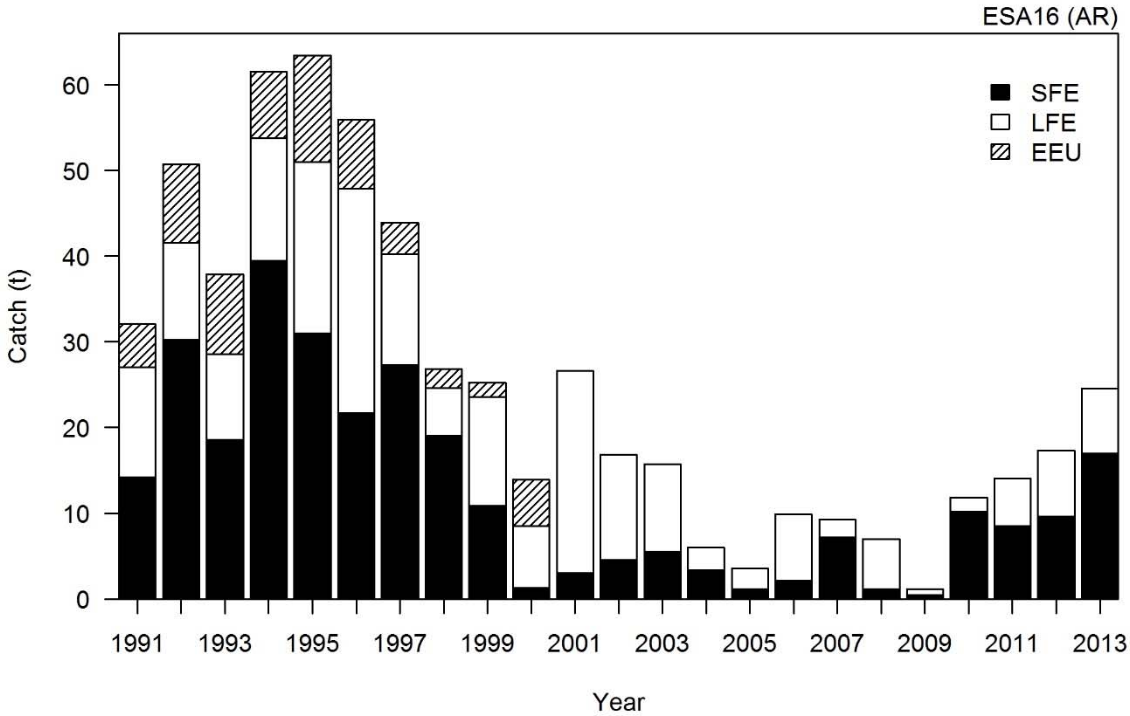



**Figure C1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (ESA16 (AR)).**

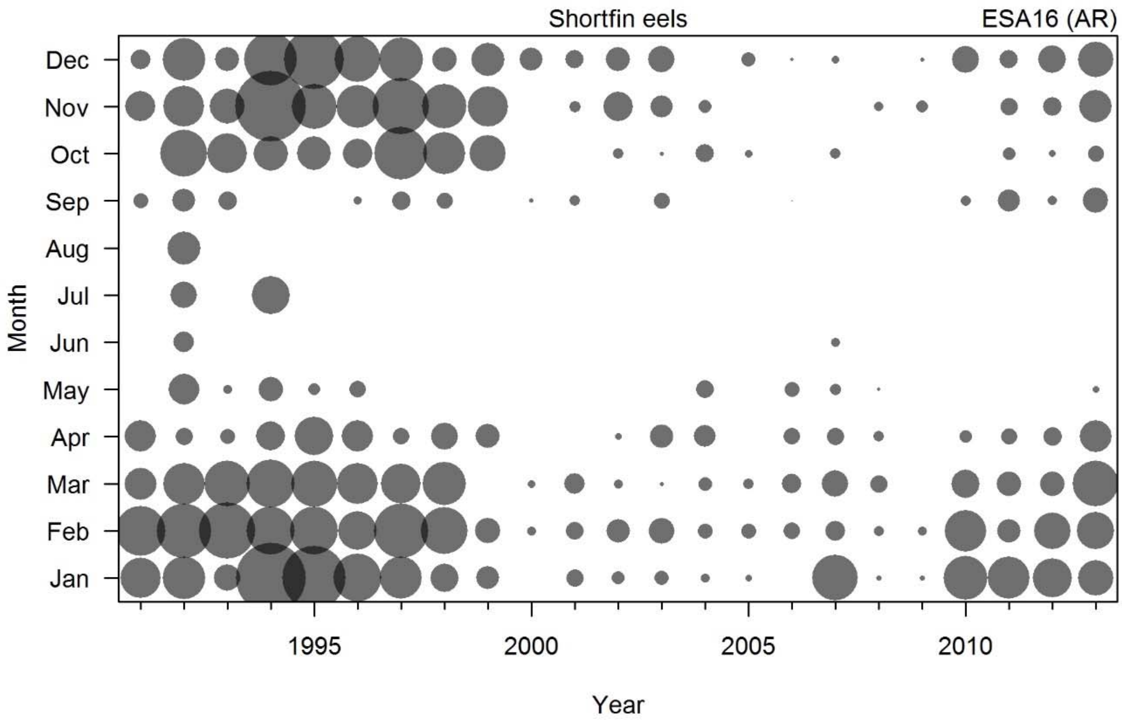



**Figure C2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (ESA16 (AR)).**

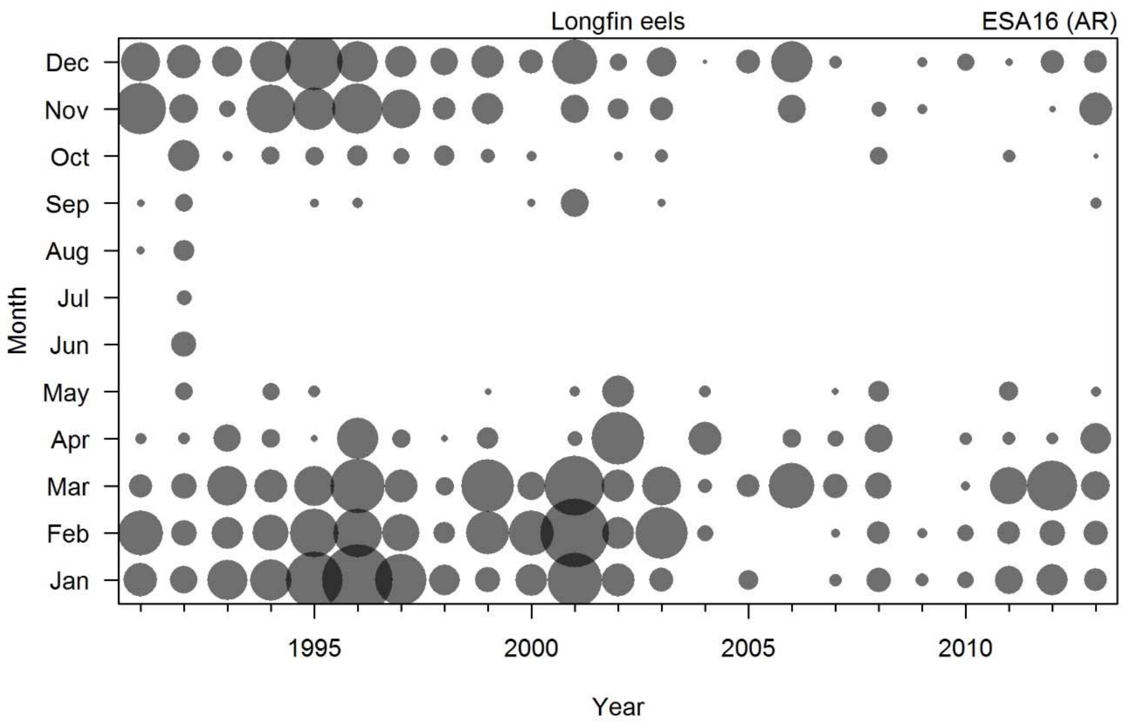



**Figure C3: Longfin eel catch by month for the years 1990–91 to 2012–13 (ESA16 (AR)).**

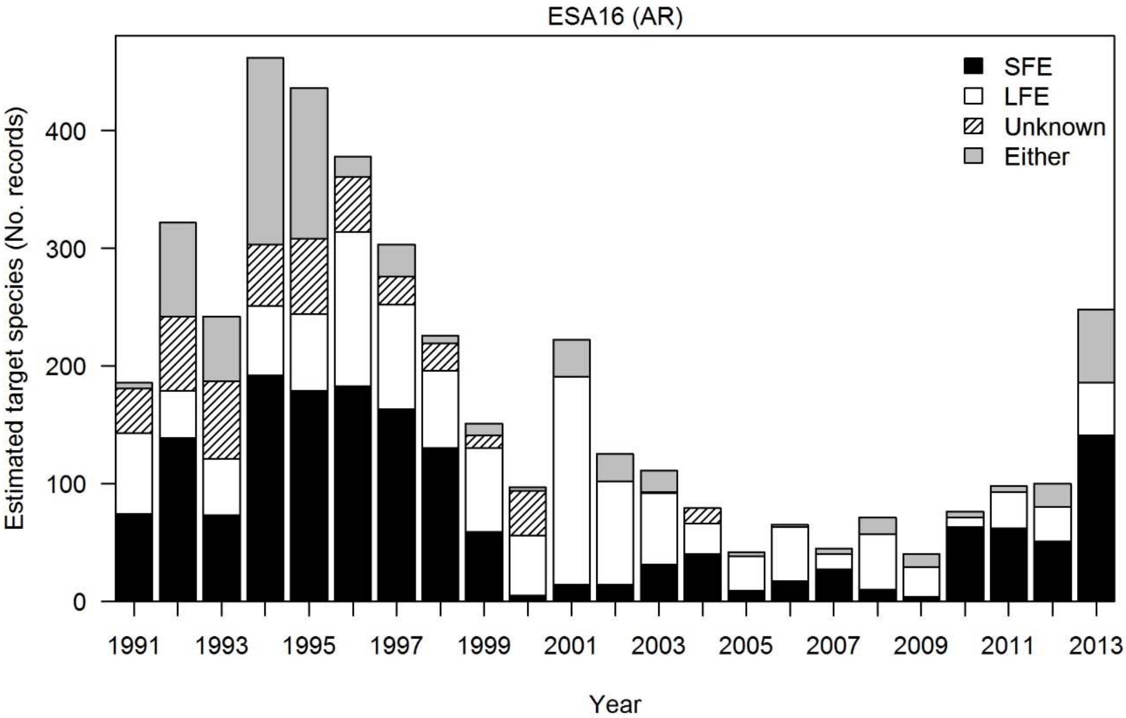



**Figure C4: Reconstructed target species for the years 1990–91 to 2012–13 (ESA16 (AR)).**

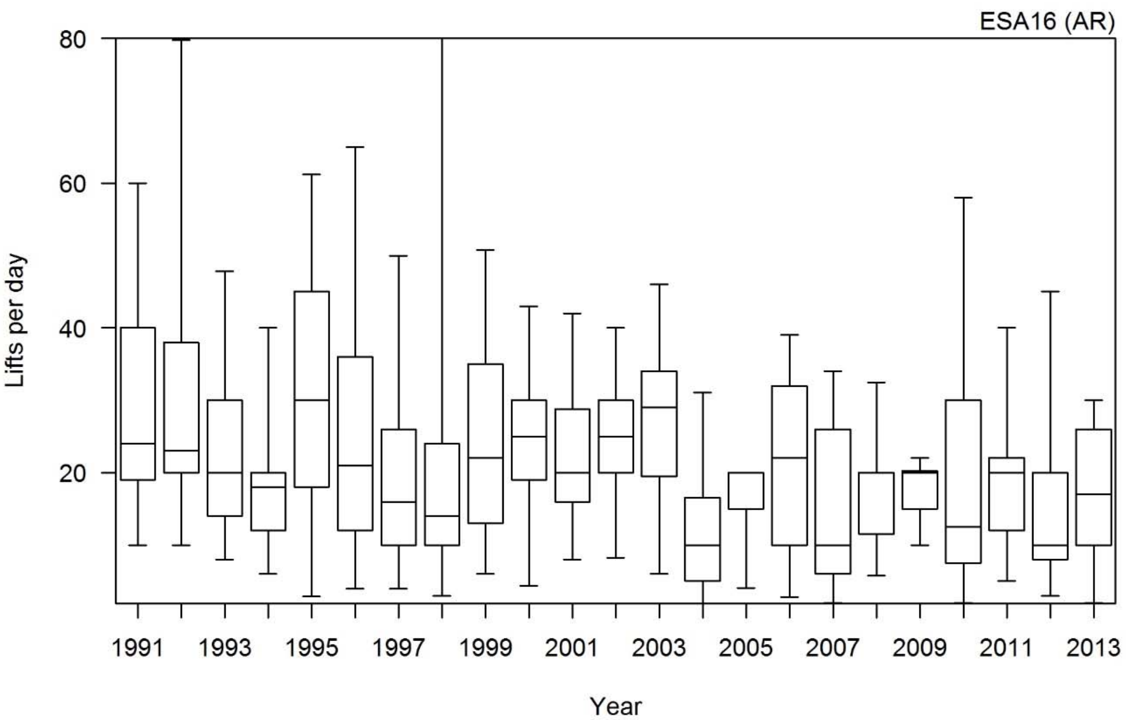



**Figure C5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (ESA16 (AR)).**

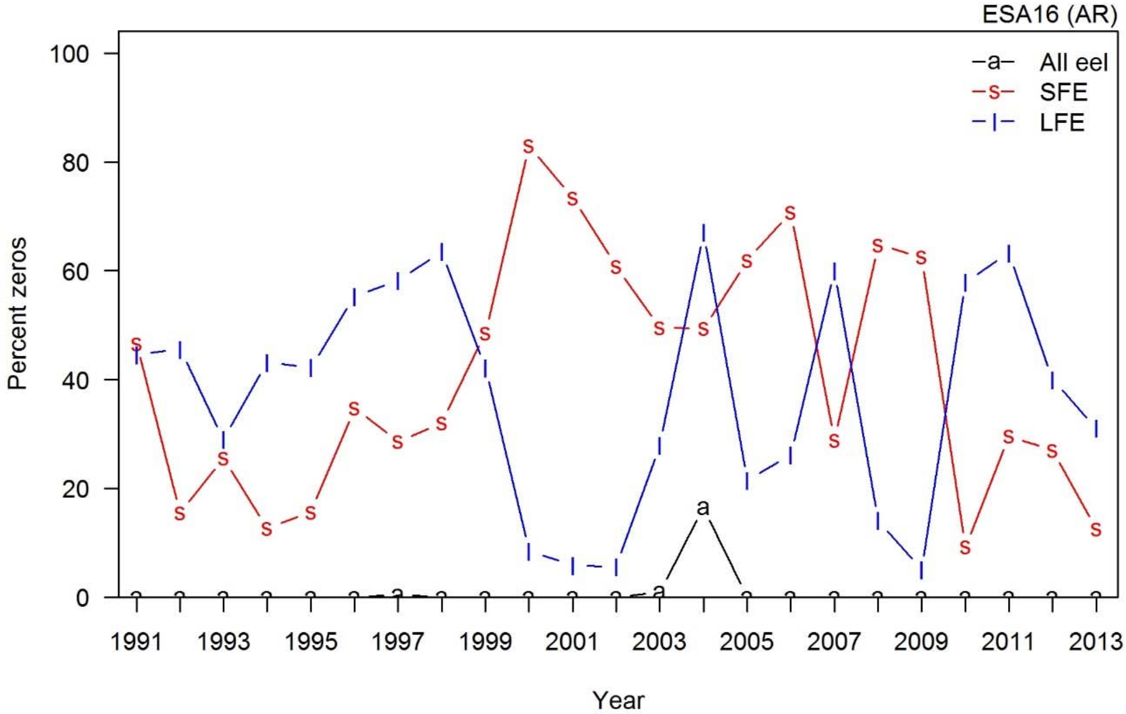



**Figure C6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) catch for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (ESA16 (AR)).**

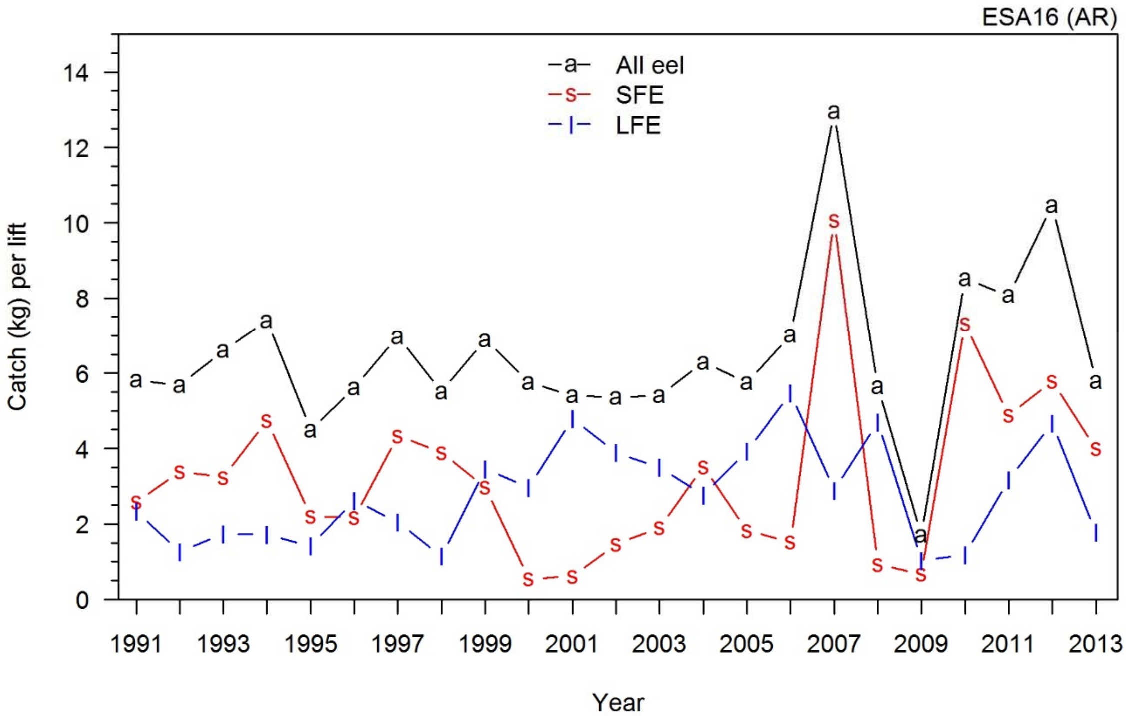



**Figure C7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (ESA16 (AR)).**

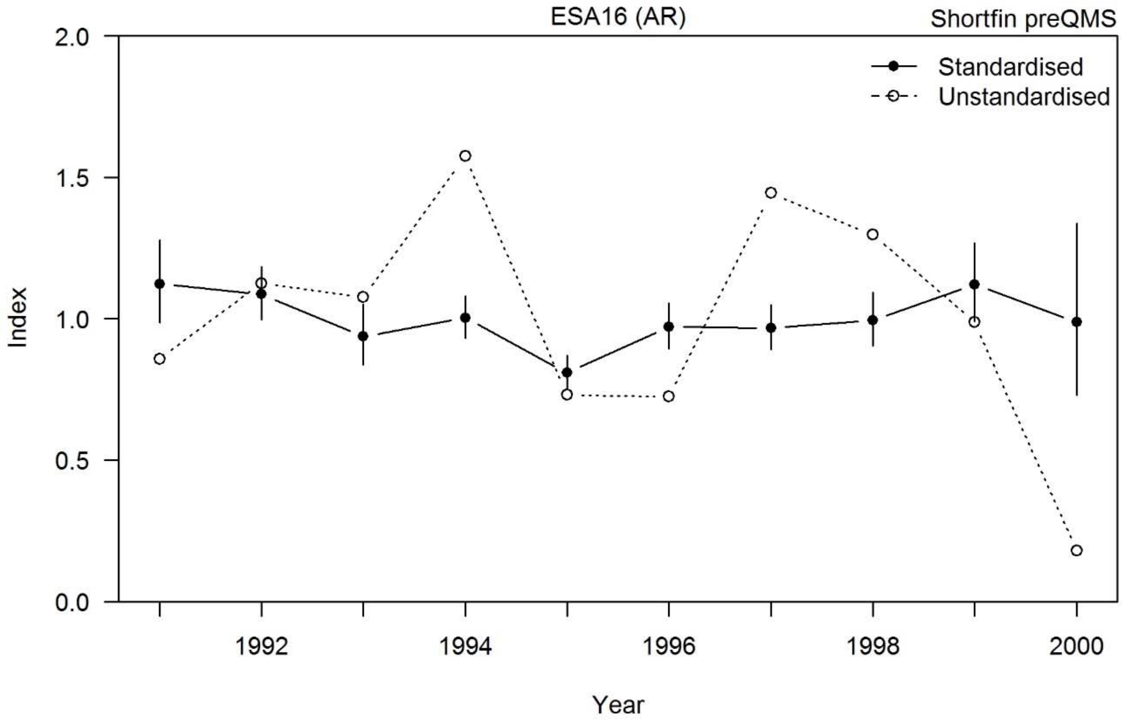



**Figure C8: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA16 (AR)).**

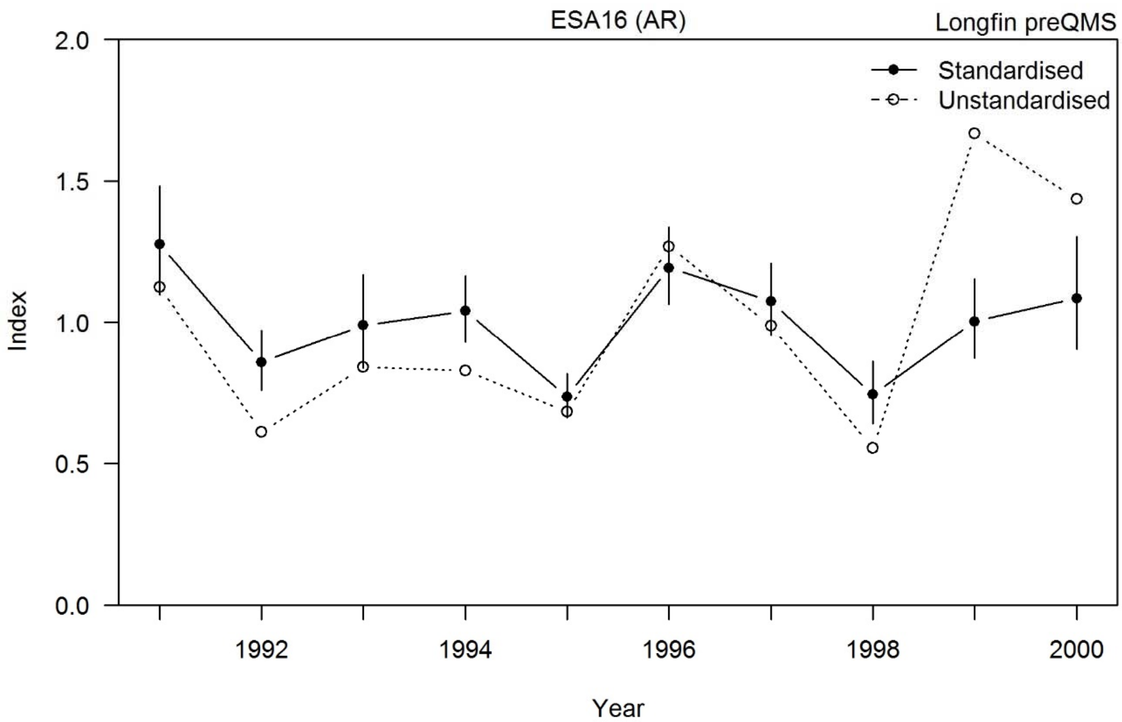



**Figure C9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA16 (AR)).**

## Appendix D: ESA 17 (AT)

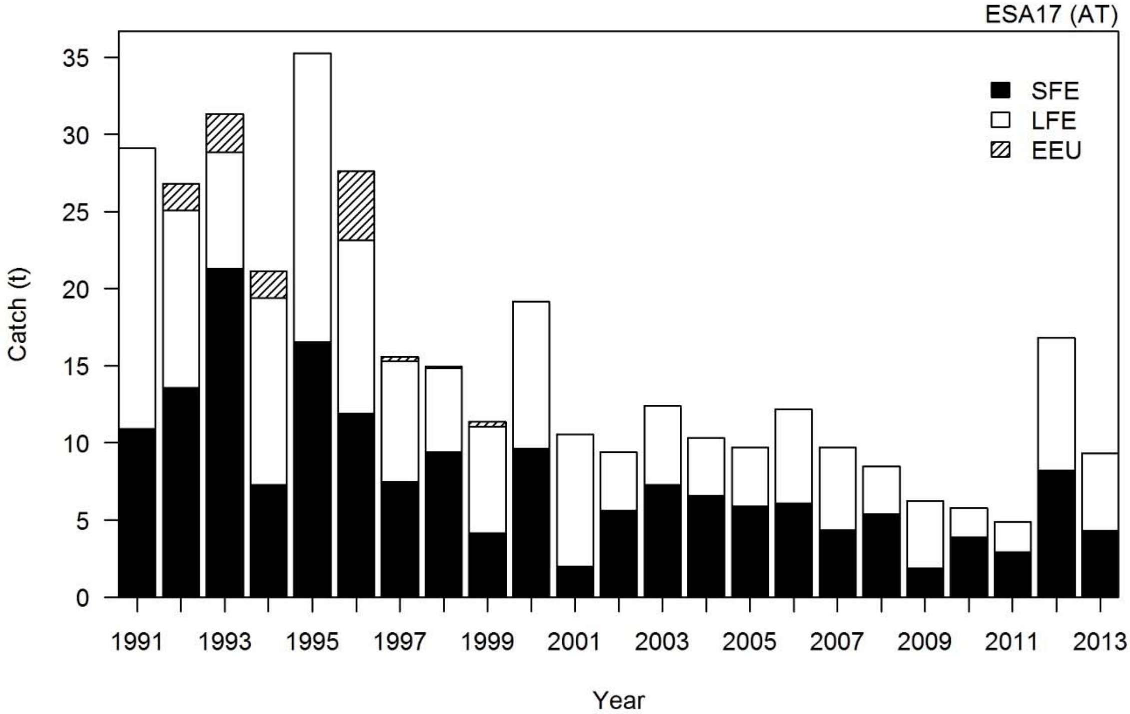



**Figure D1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (ESA17 (AT)).**

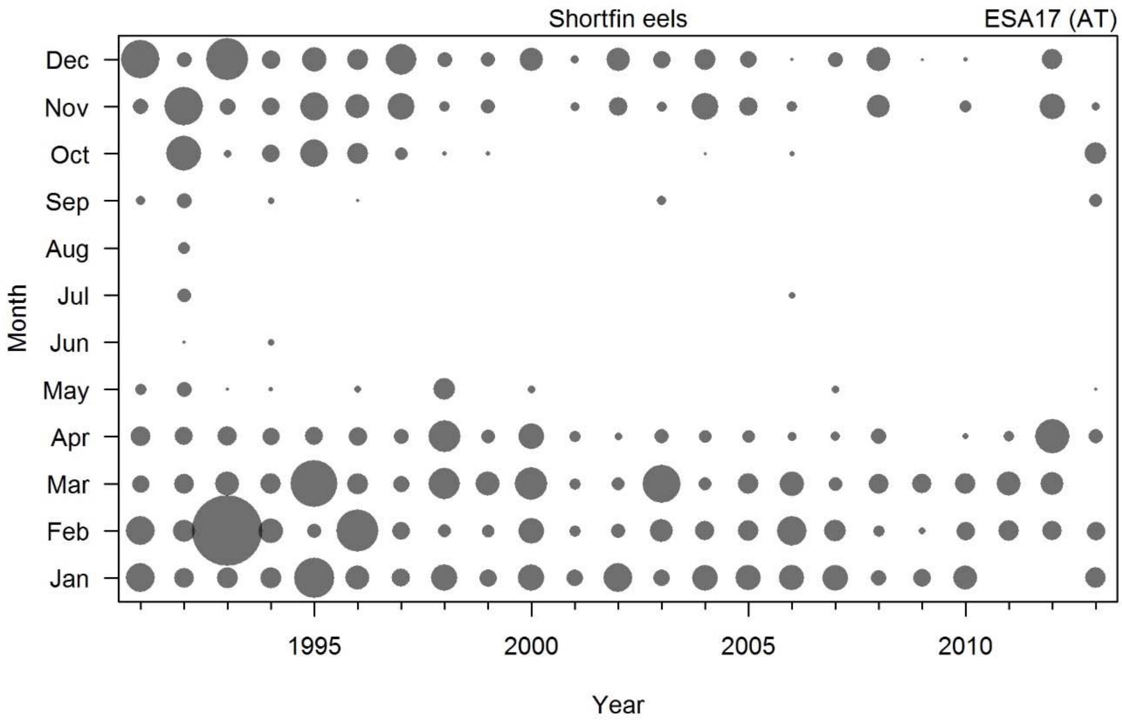



**Figure D2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (ESA17 (AT)).**

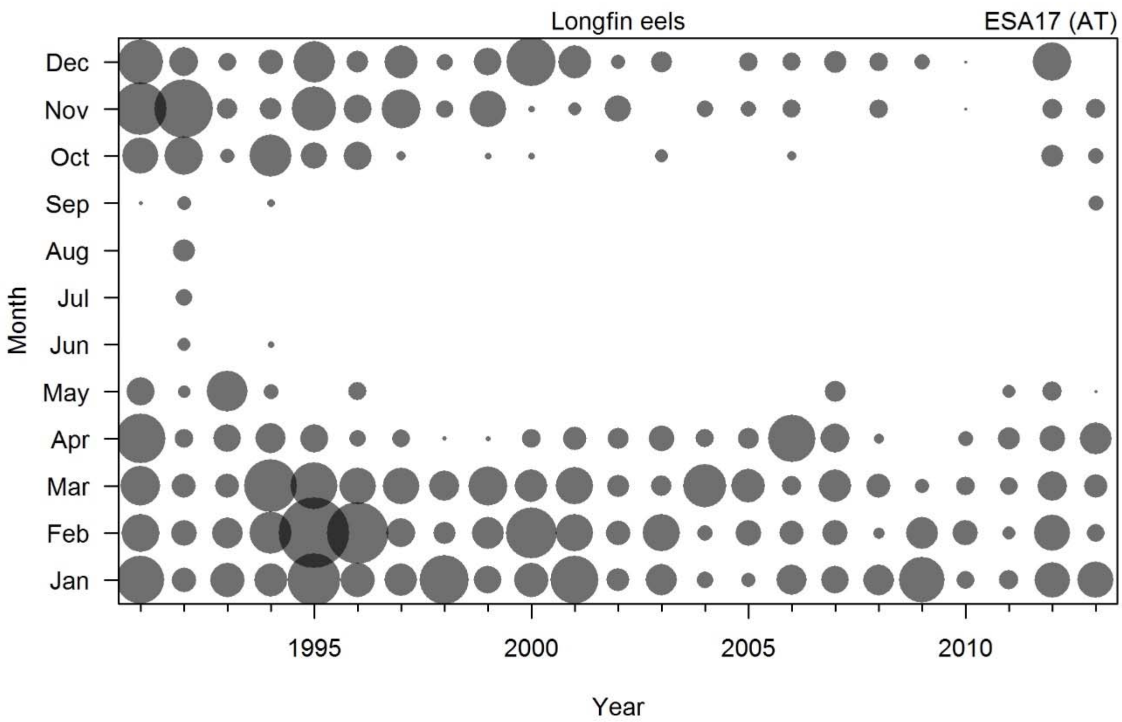



**Figure D3: Longfin eel catch by month for the years 1990–91 to 2012–13 (ESA17 (AT)).**

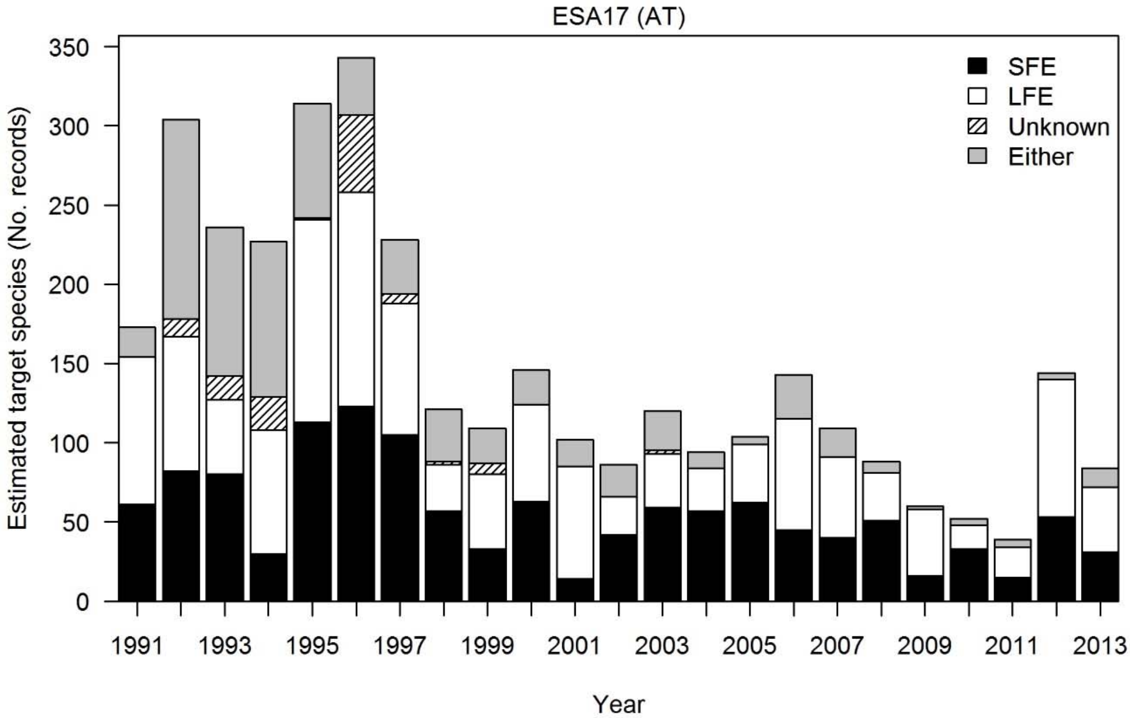



**Figure D4: Reconstructed target species for the years 1990–91 to 2012–13 (ESA17 (AT)).**

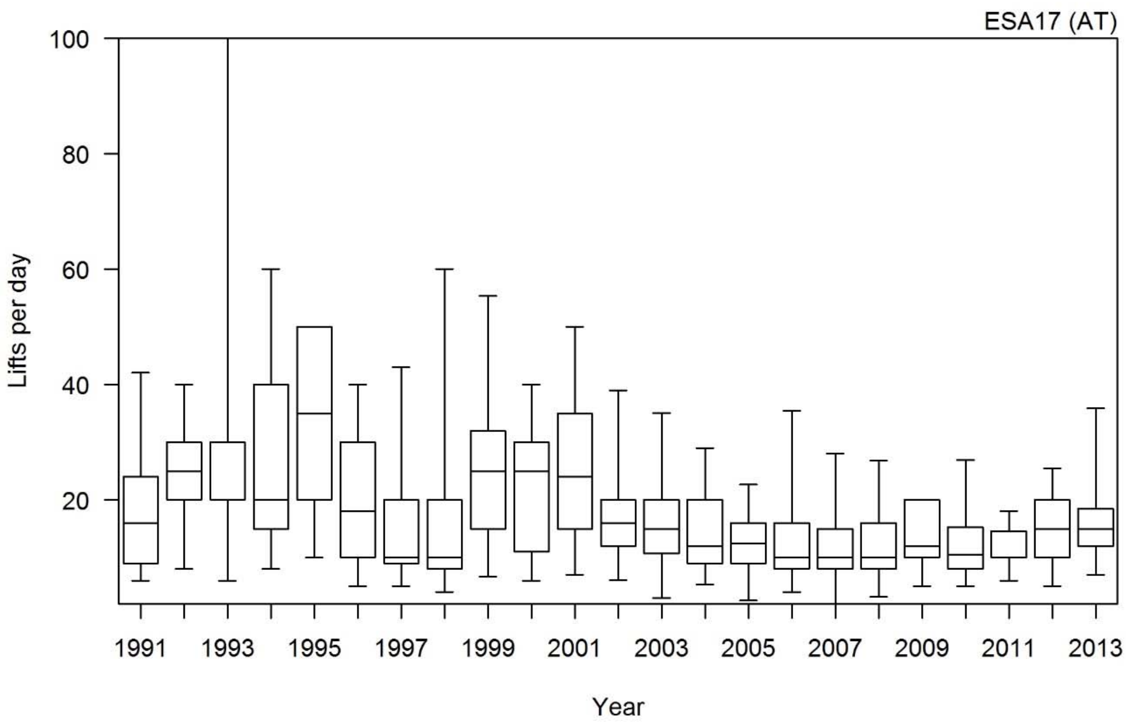



**Figure D5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (ESA17 (AT)).**

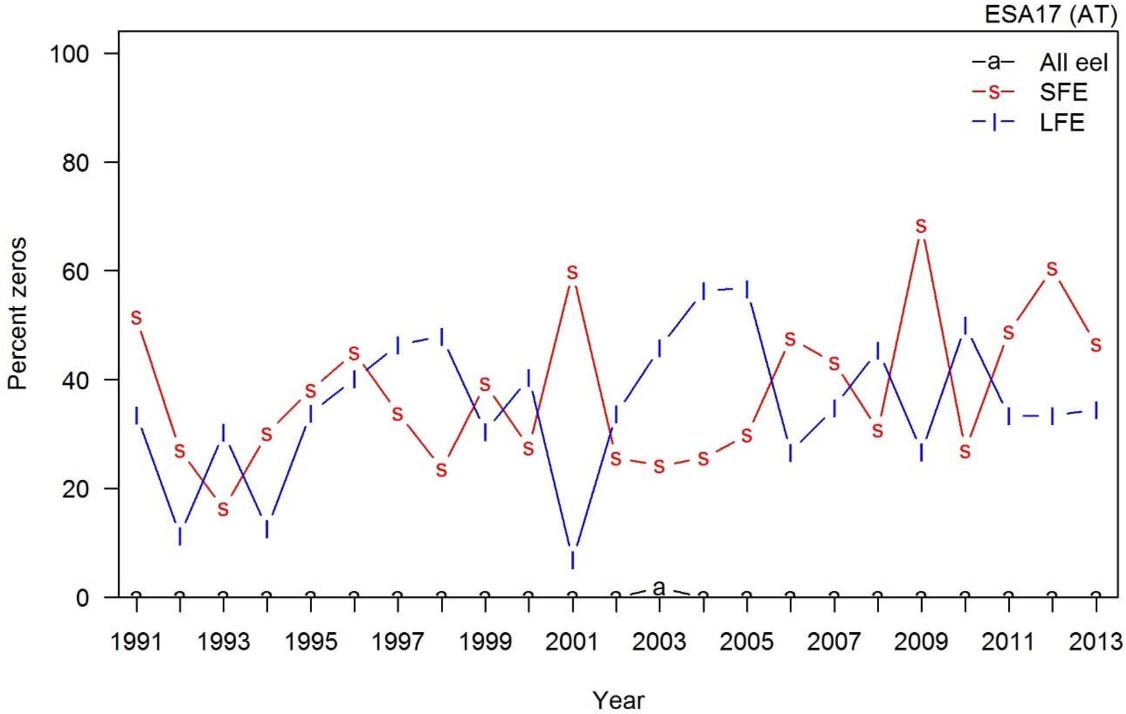



**Figure D6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) catch for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (ESA17 (AT)).**

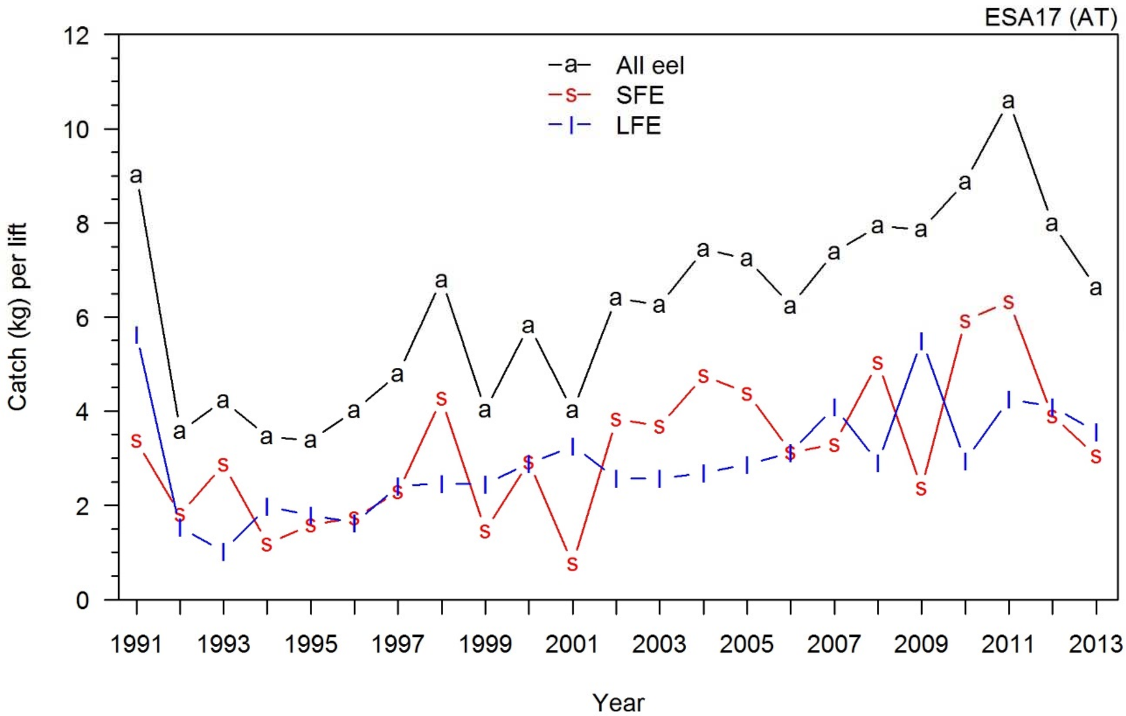



**Figure D7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (ESA17 (AT)).**

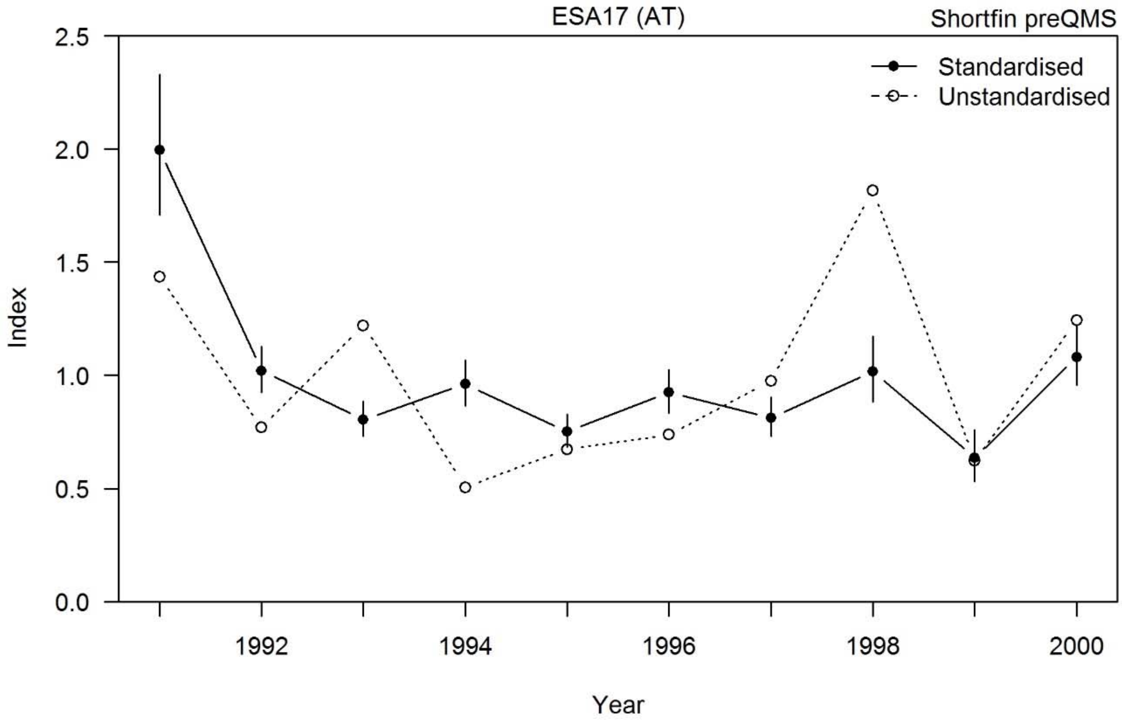



**Figure D8: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA17 (AT)).**

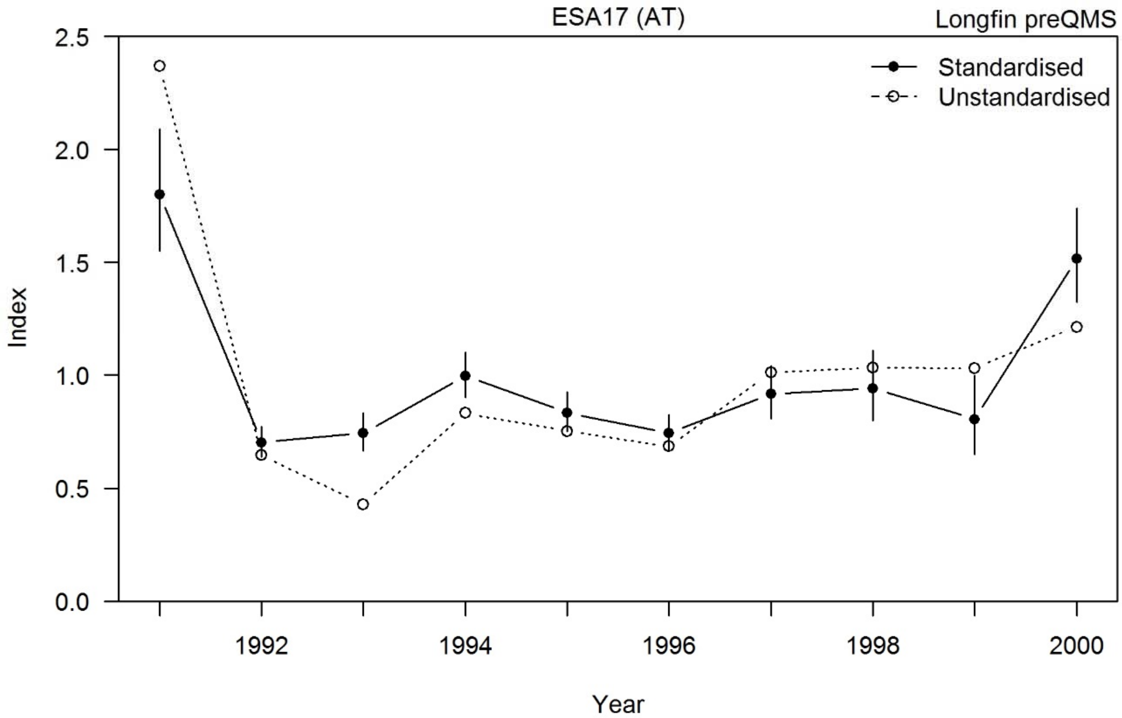



**Figure D9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA17 (AT)).**

## Appendix E: ESA 18 (AU)

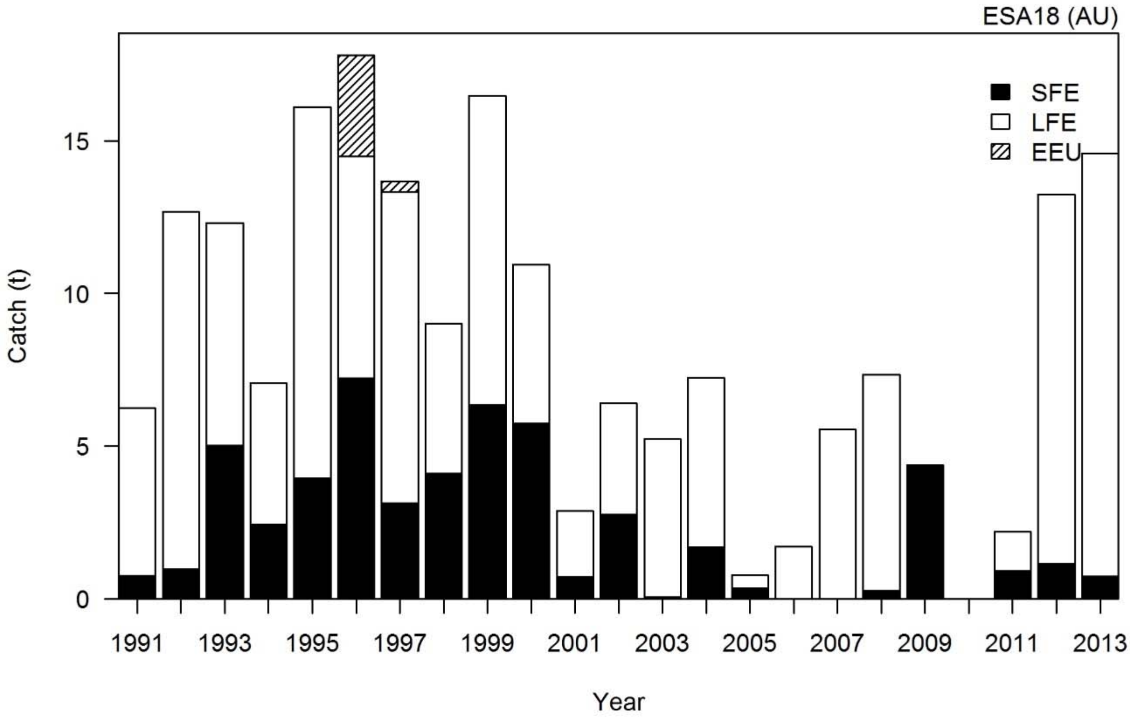



**Figure E1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (ESA18 (AU)).**

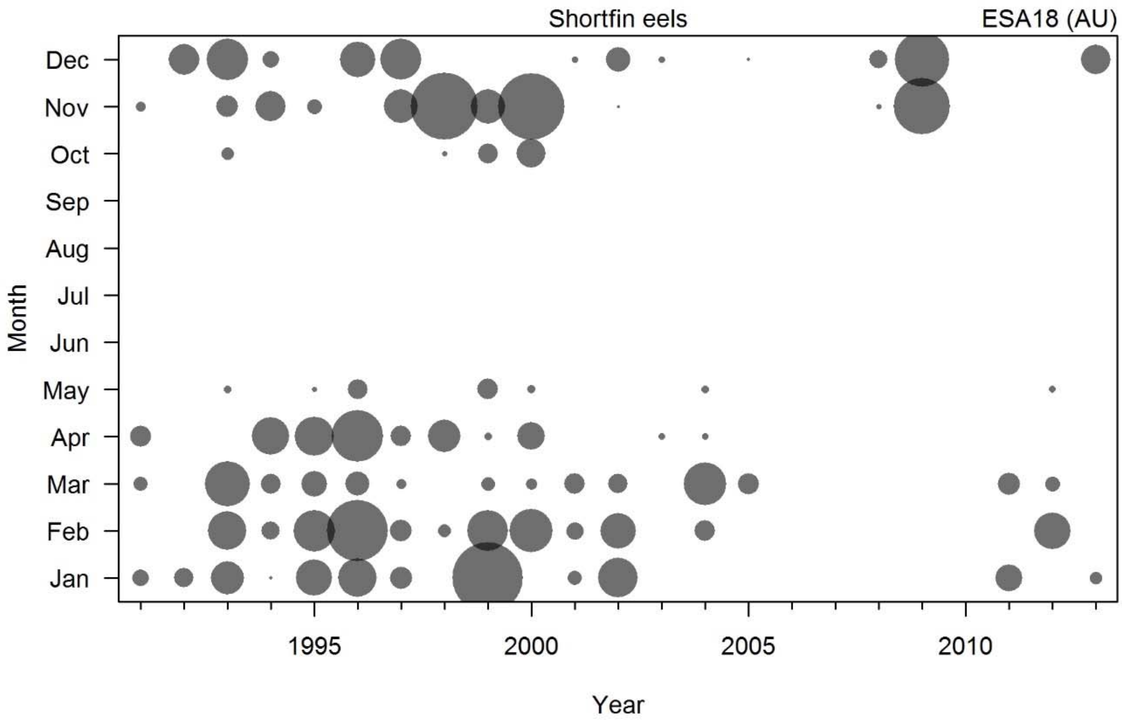



**Figure E2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (ESA18 (AU)).**

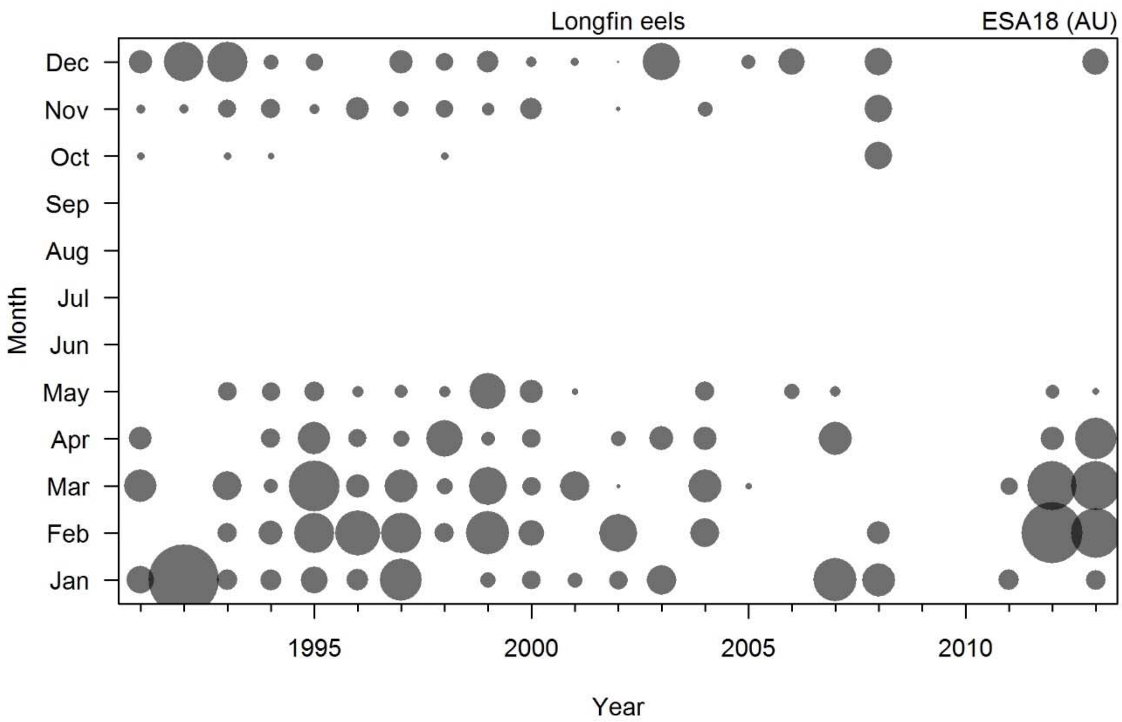



**Figure E3: Longfin eel catch by month for the years 1990–91 to 2012–13 (ESA18 (AU)).**

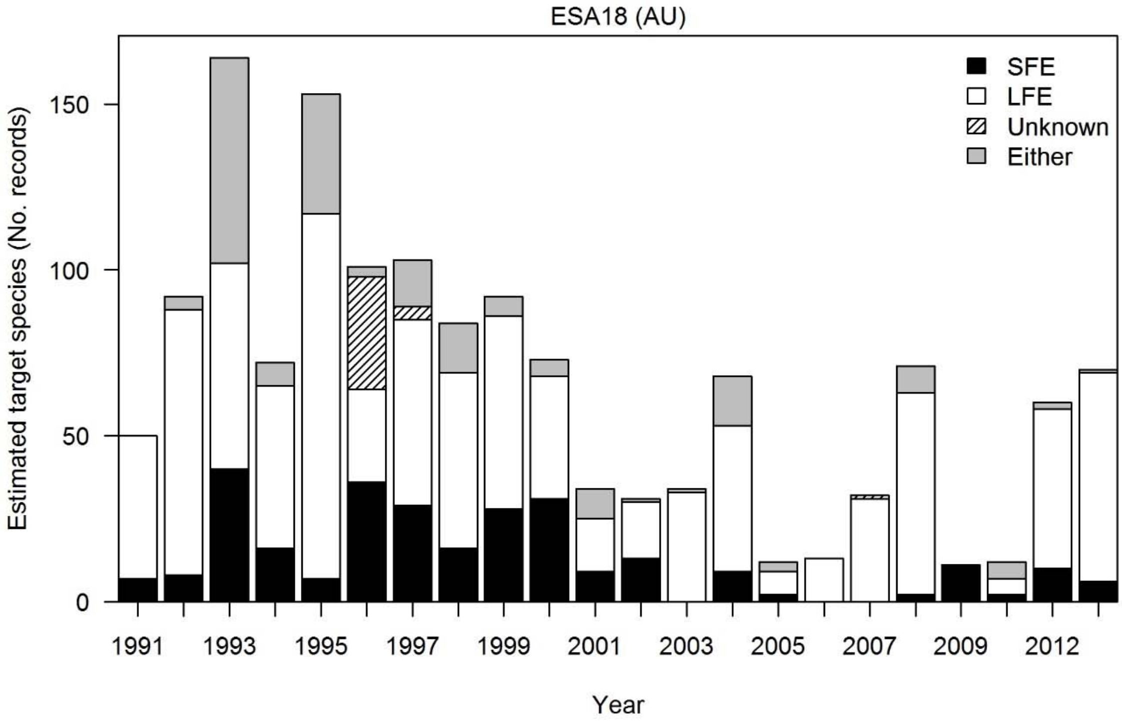



**Figure E4: Reconstructed target species for the years 1990–91 to 2012–13 (ESA18 (AU)).**

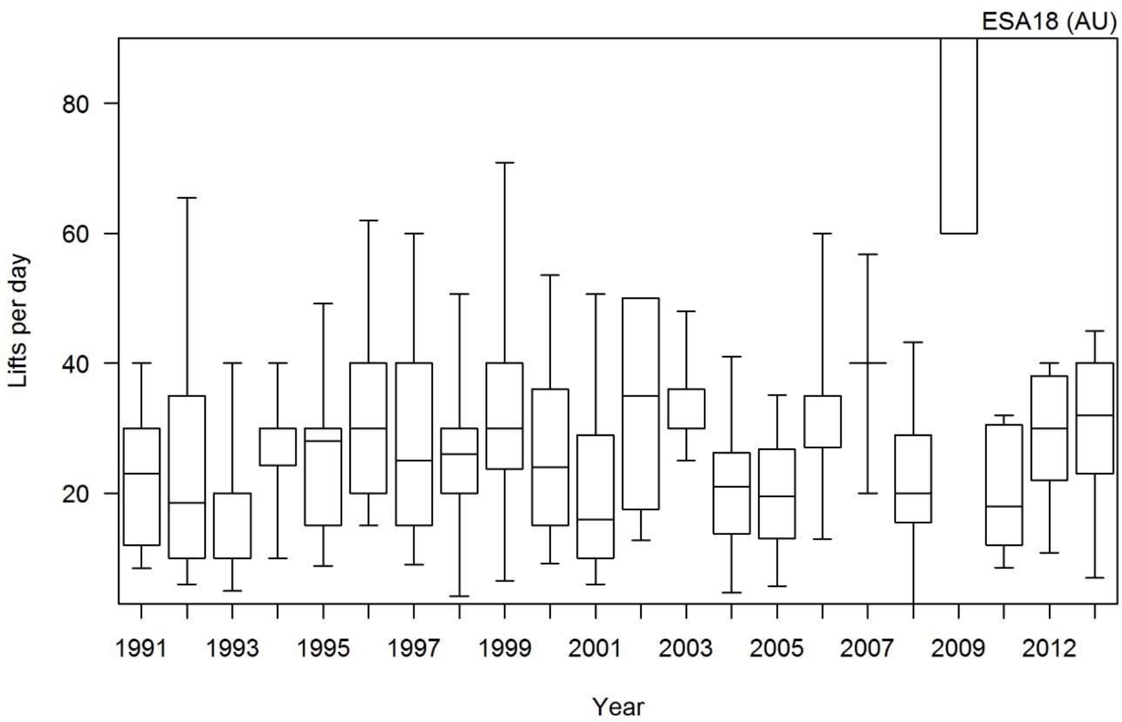



**Figure E5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (ESA18 (AU)).**

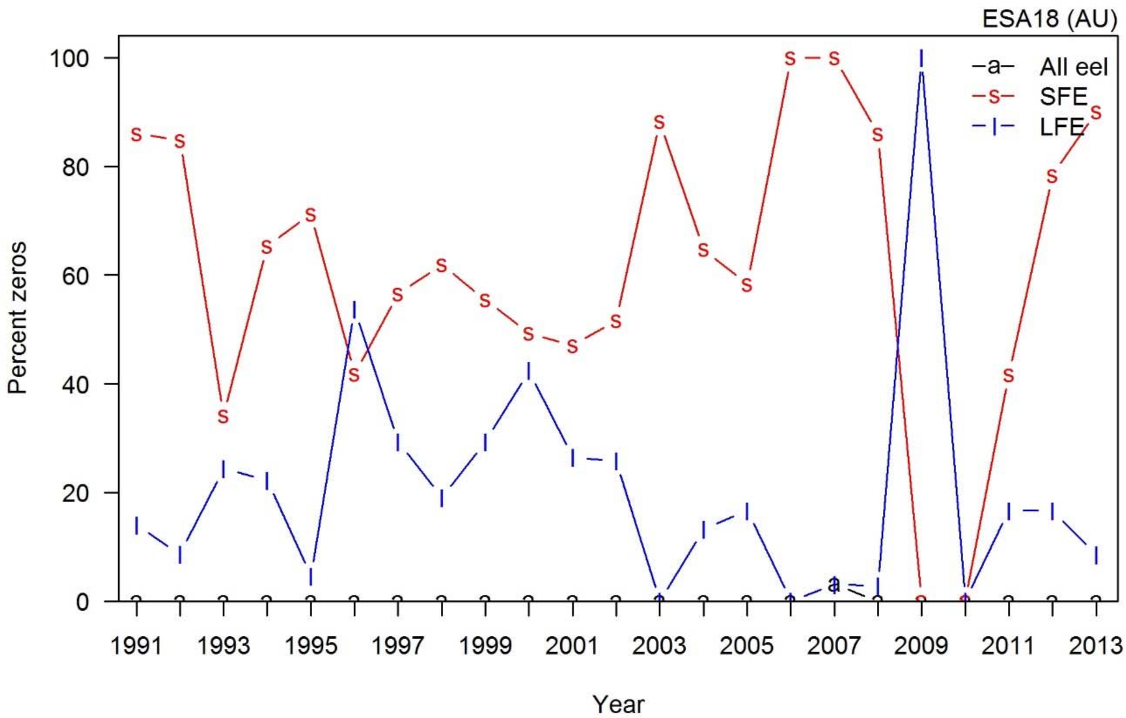



**Figure E6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) catch for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (ESA18 (AU)).**

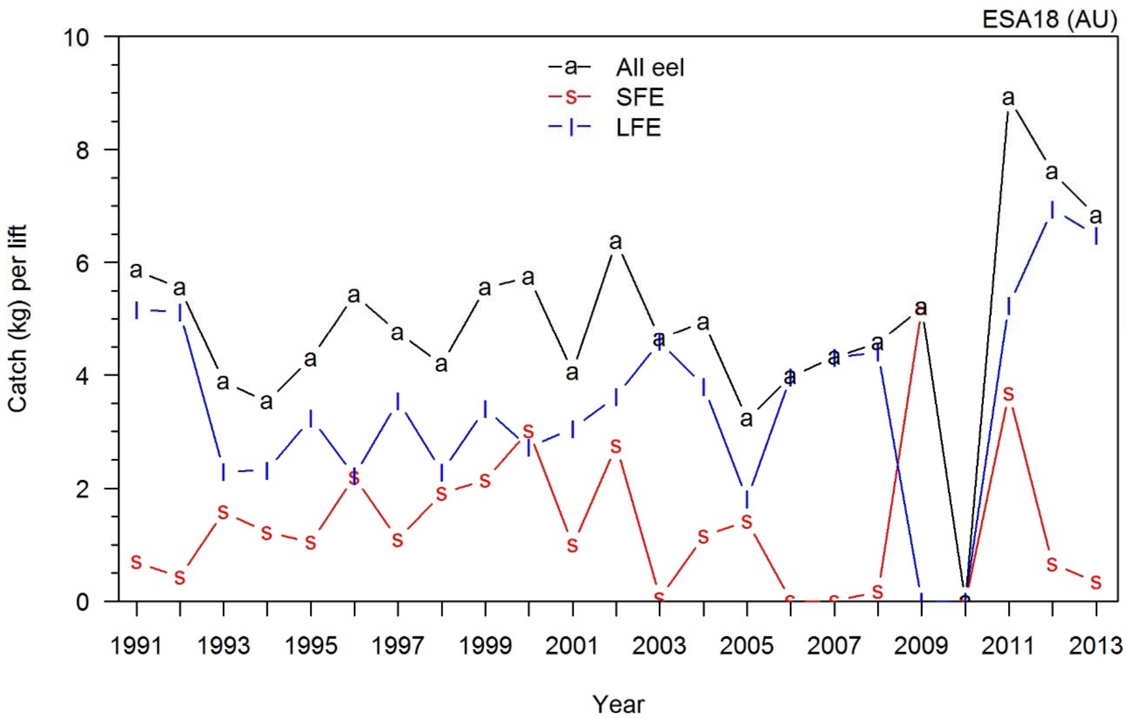



**Figure E7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (ESA18 (AU)).**

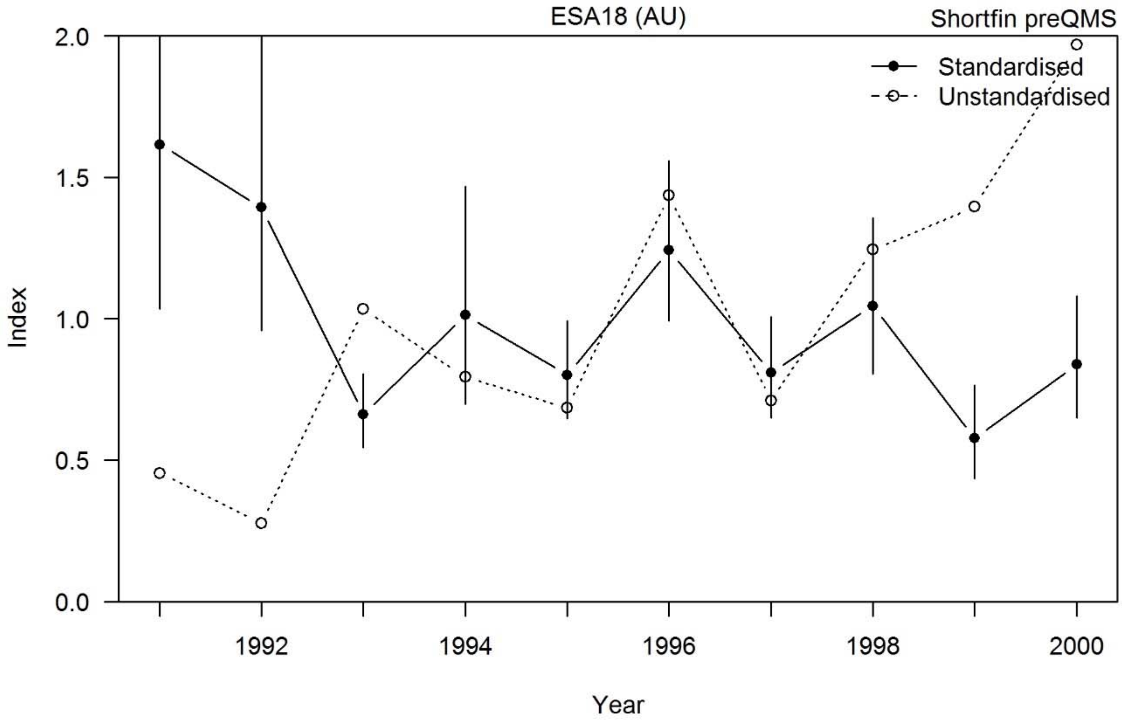



**Figure E8: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA18 (AU)).**

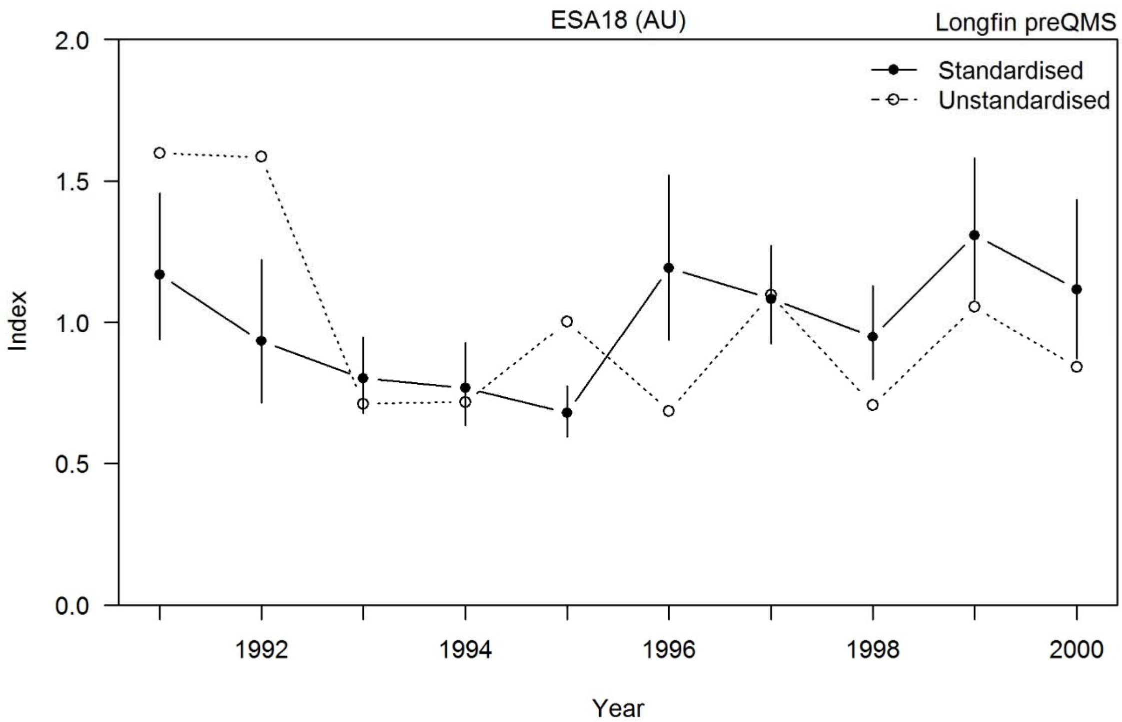



**Figure E9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000 (ESA18 (AU)).**

**Appendices F to I: Plots of eel fishery characterisation and CPUE analyses for data rich ESAs (AX, AV, AW and AS1). The fishery characterisation plots are shown first followed by those for shortfin eel pre-QMS, shortfin post QMS, longfin pre-QMS, and lastly longfin post-QMS.**

**Appendix F: ESA 15 (AX)**

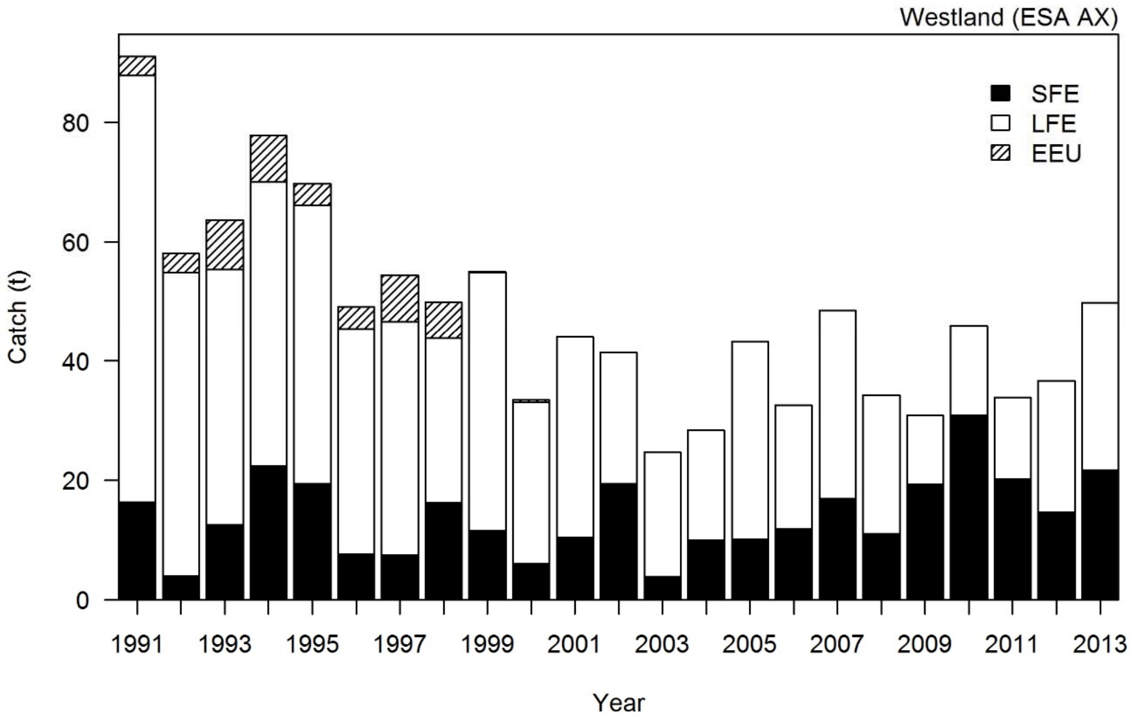



**Figure F1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (Westland (ESA AX)).**

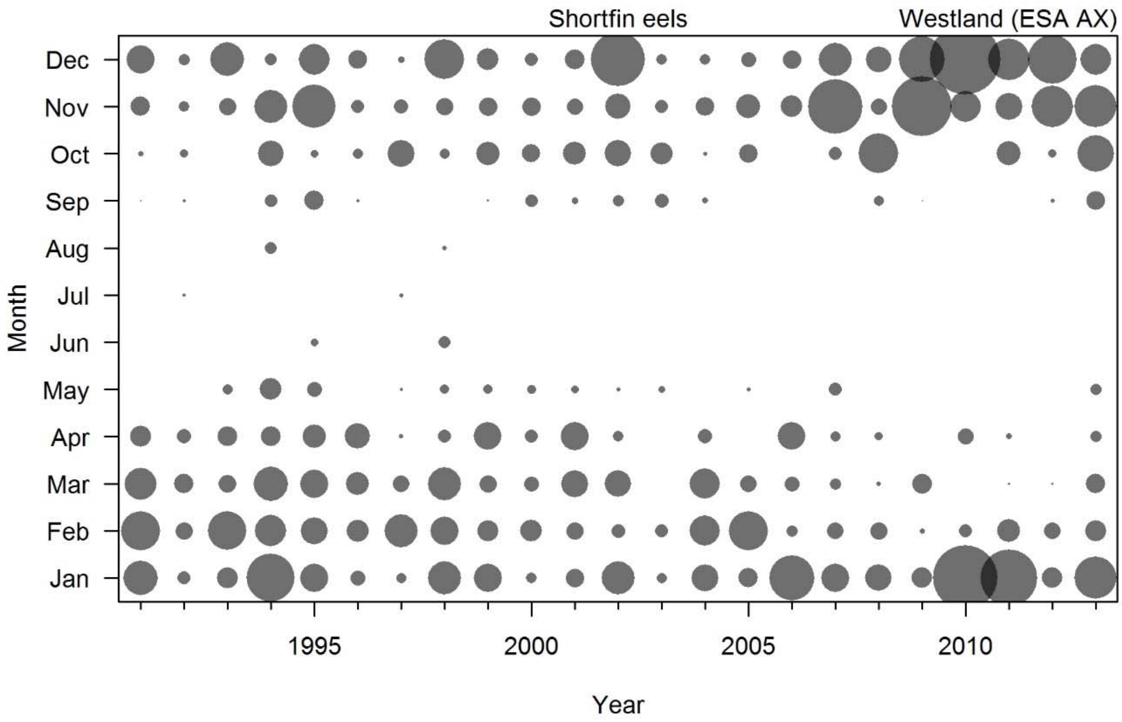



**Figure F2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (Westland (ESA AX)).**

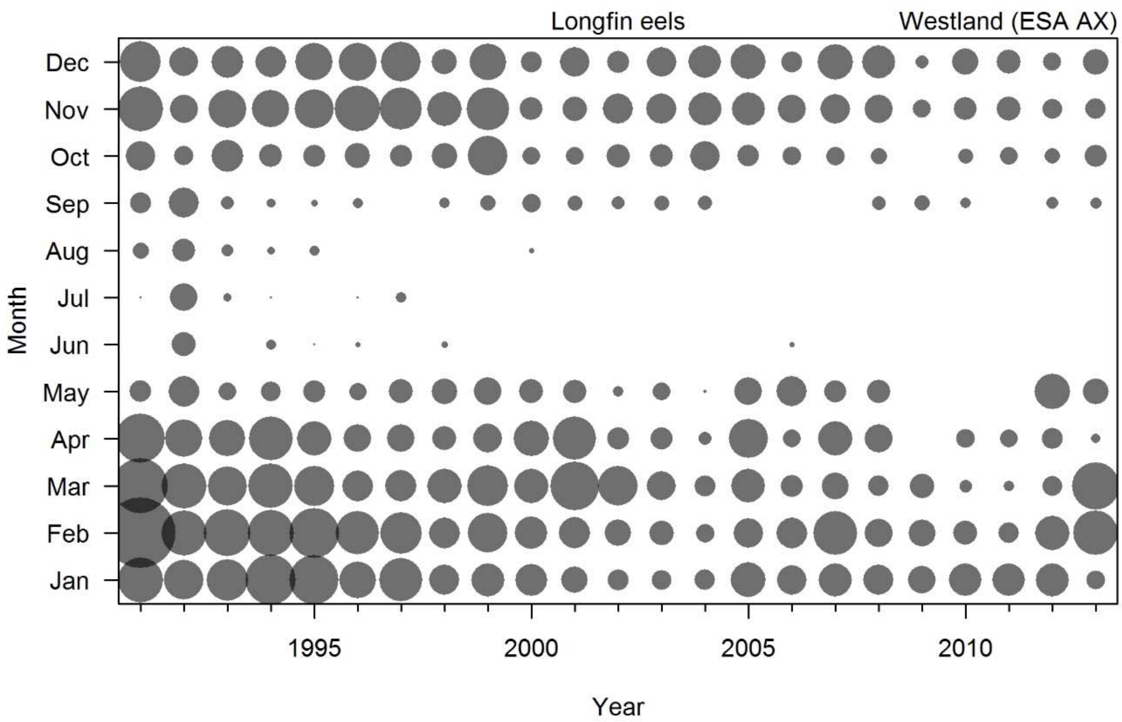



**Figure F3: Longfin eel catch by month for the years 1990–91 to 2012–13 (Westland (ESA AX)).**

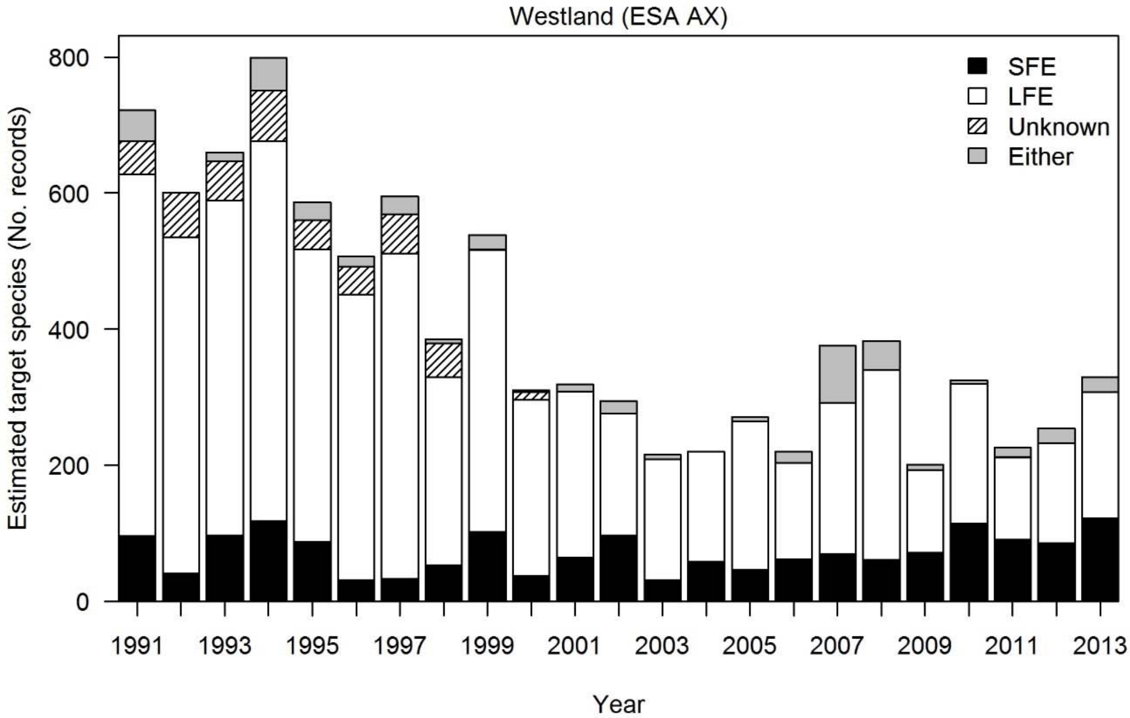



**Figure F4: Reconstructed target species for the years 1990–91 to 2012–13 (Westland (ESA AX)).**

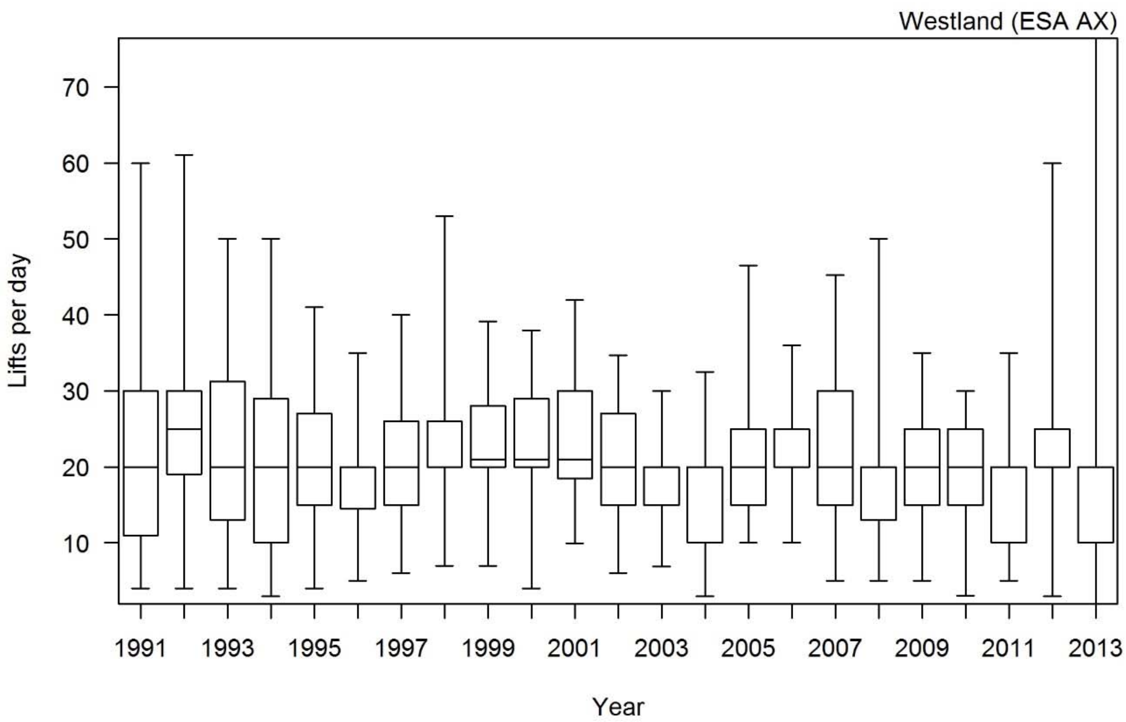



**Figure F5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (Westland (ESA AX)).**

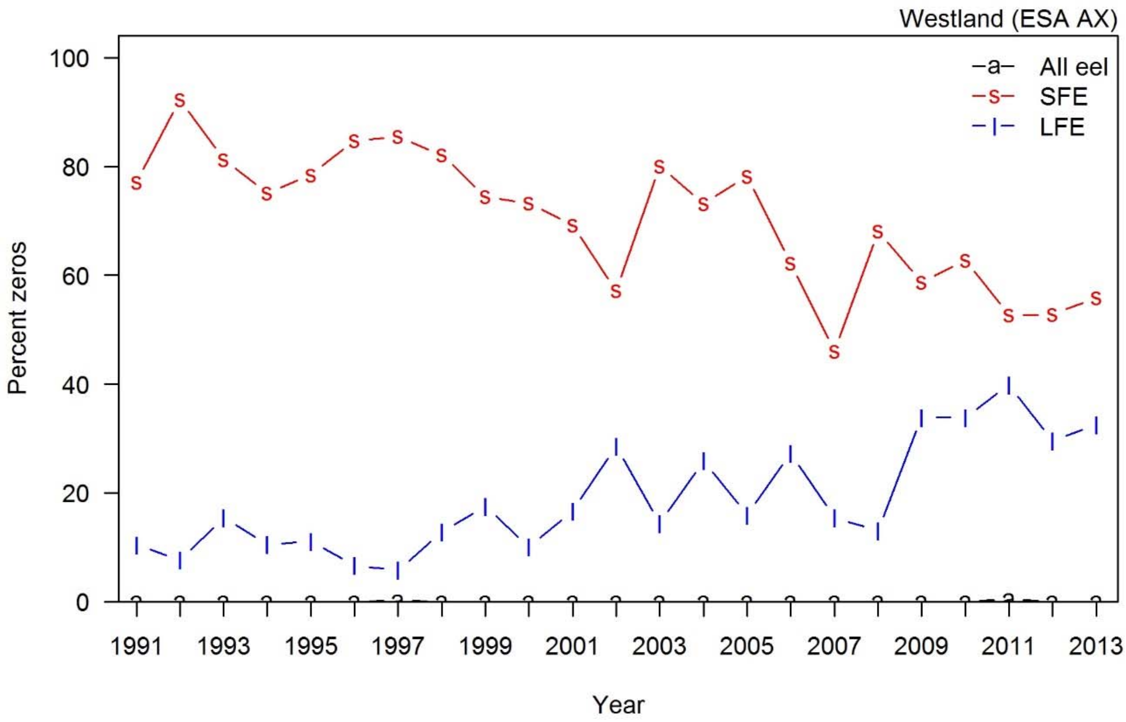



**Figure F6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (Westland (ESA AX)).**

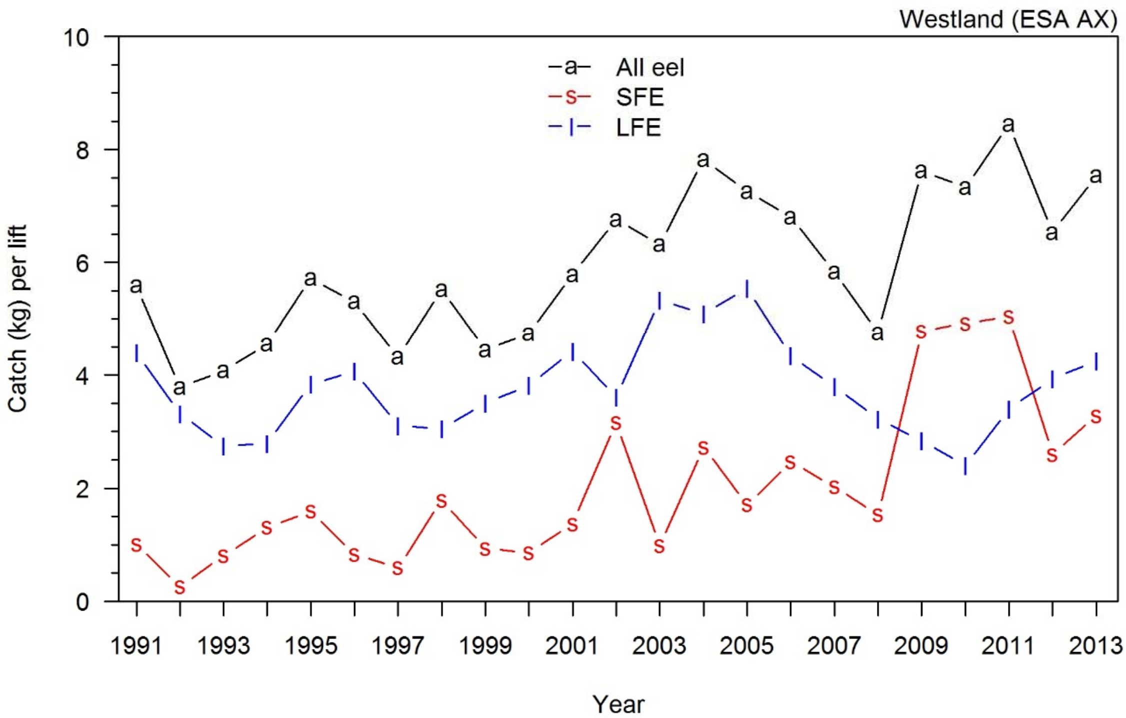



**Figure F7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (Westland (ESA AX)).**

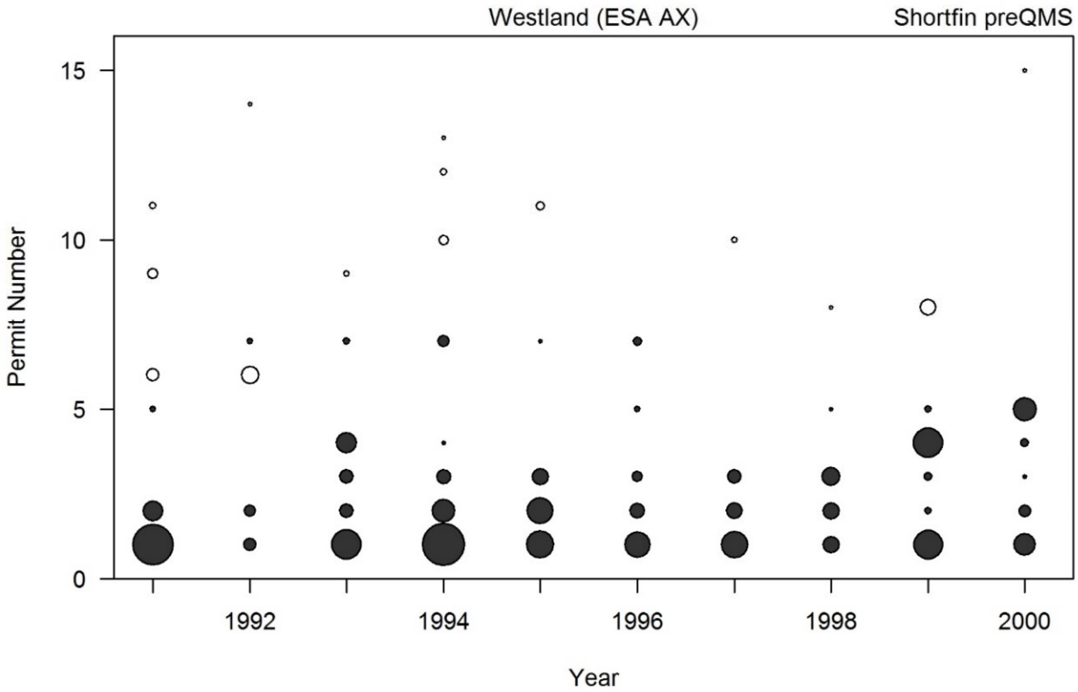



**Figure F8: Relative shortfin catch from all fishers (all circles) for the years 1990–91 to 1999–2000 (pre-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses (Westland (ESA AX)).**

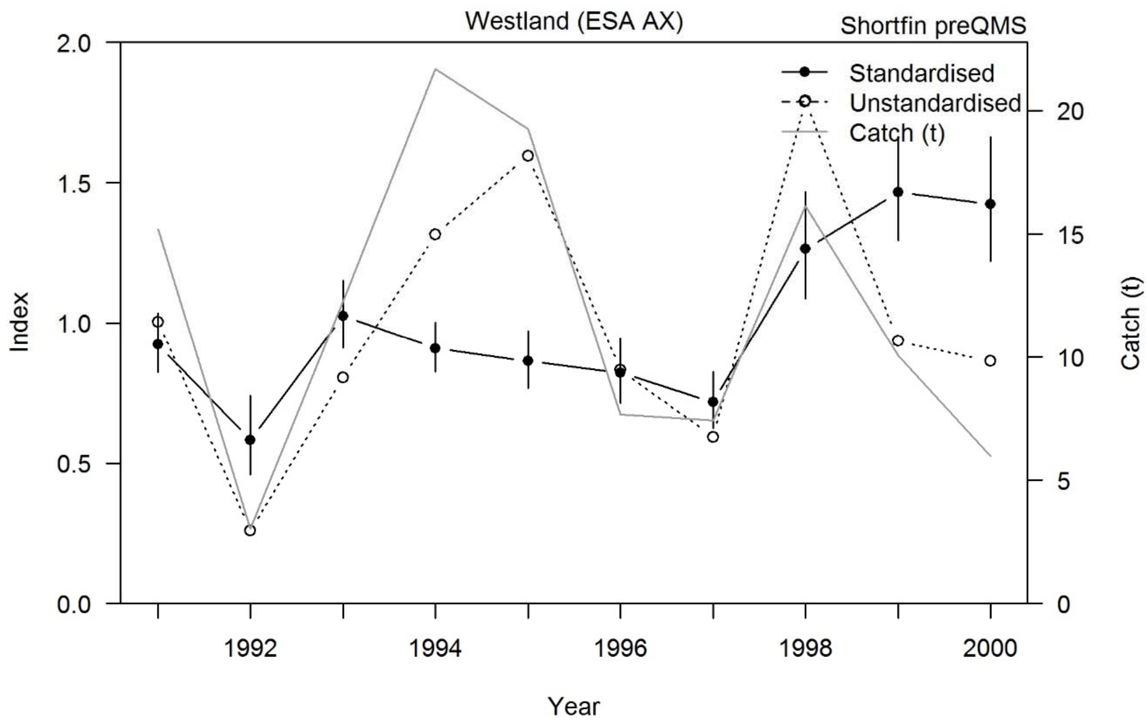



**Figure F9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000. The catch by core fishers is also plotted (Westland (ESA AX)).**

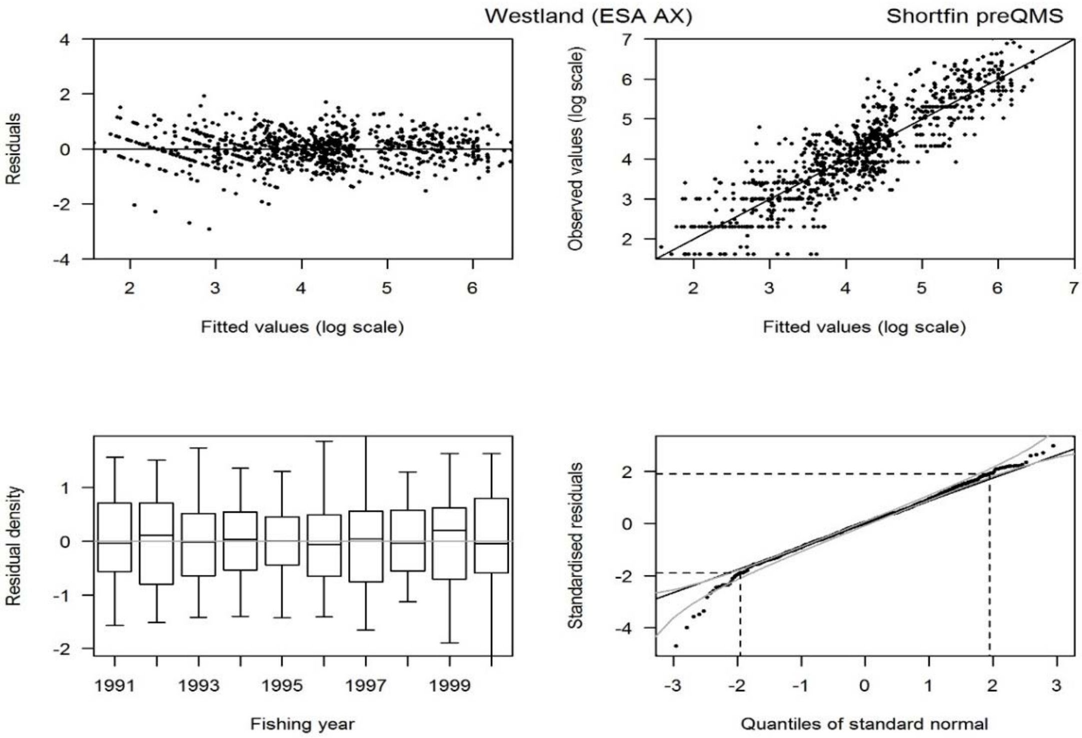



**Figure F10: Residual diagnostic plots for the shortfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution (Westland (ESA AX)).**

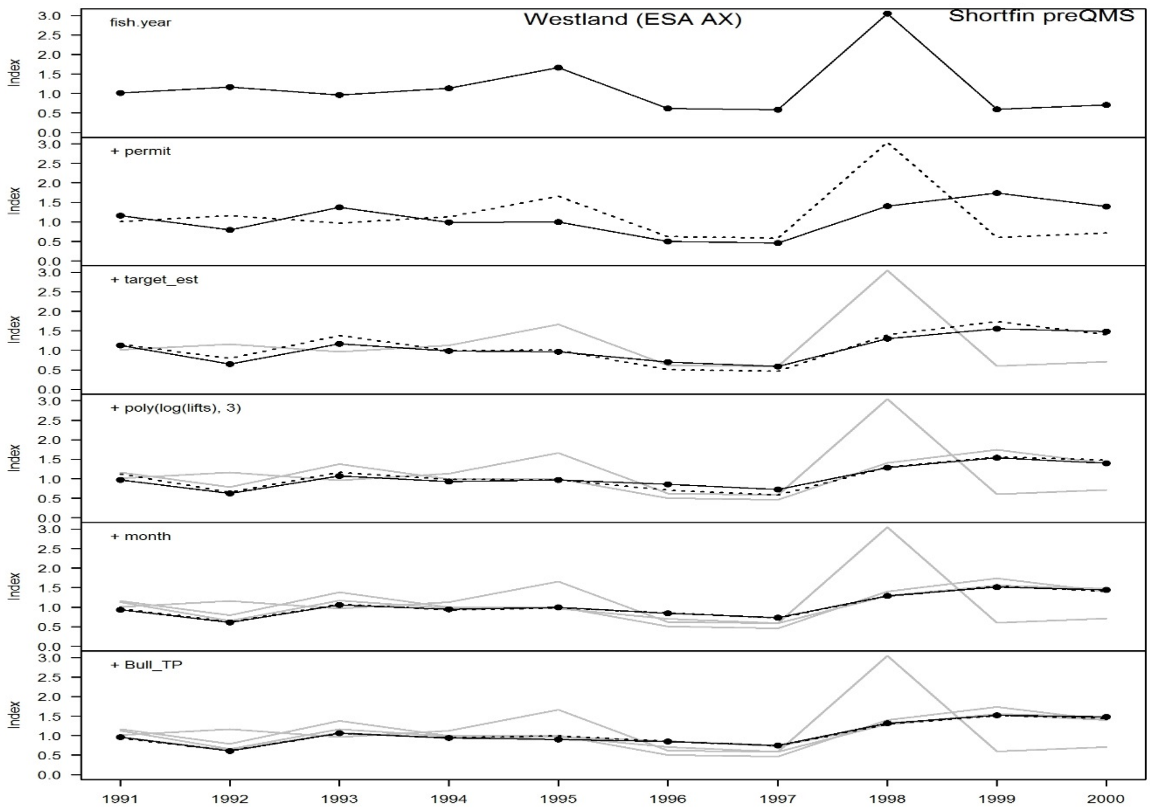



**Figure F11: Step plot for the shortfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that (Westland (ESA AX)).**

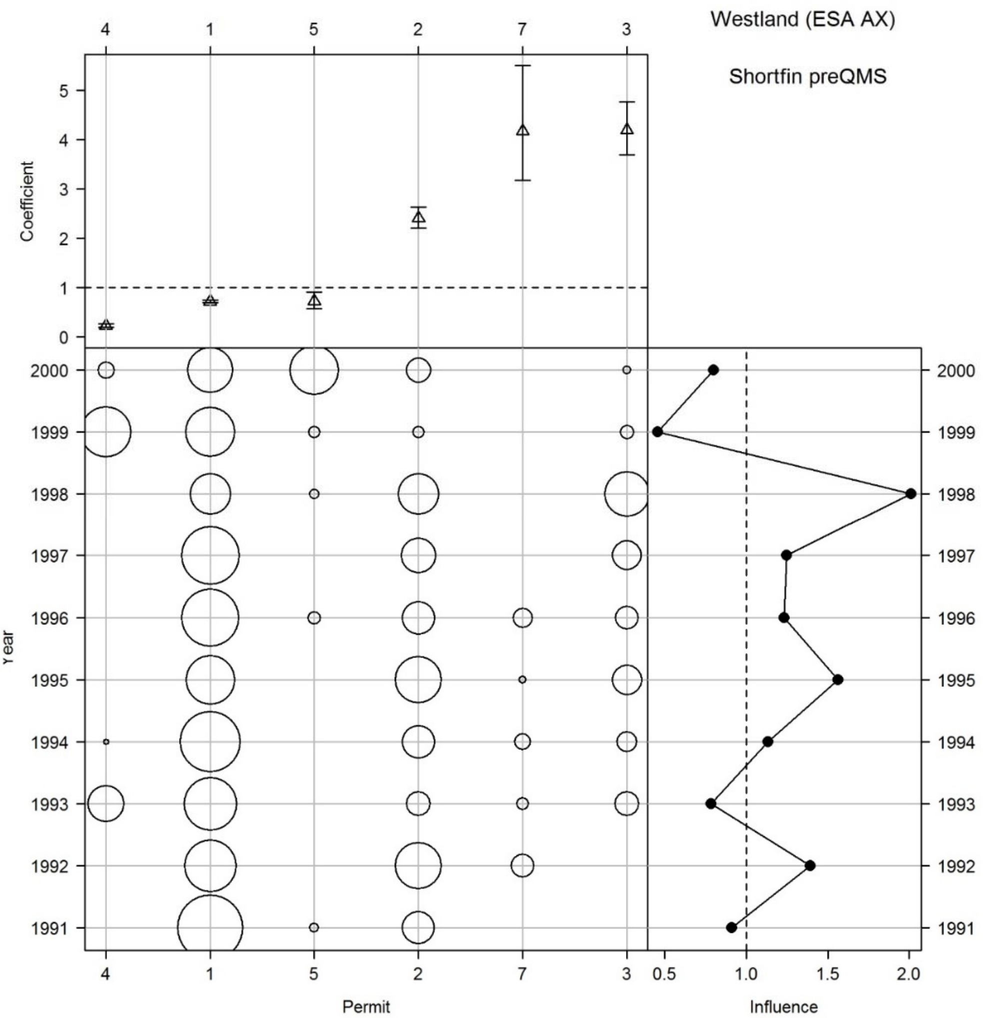



**Figure F12: Influence of permit for the shortfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Westland (ESA AX)).**

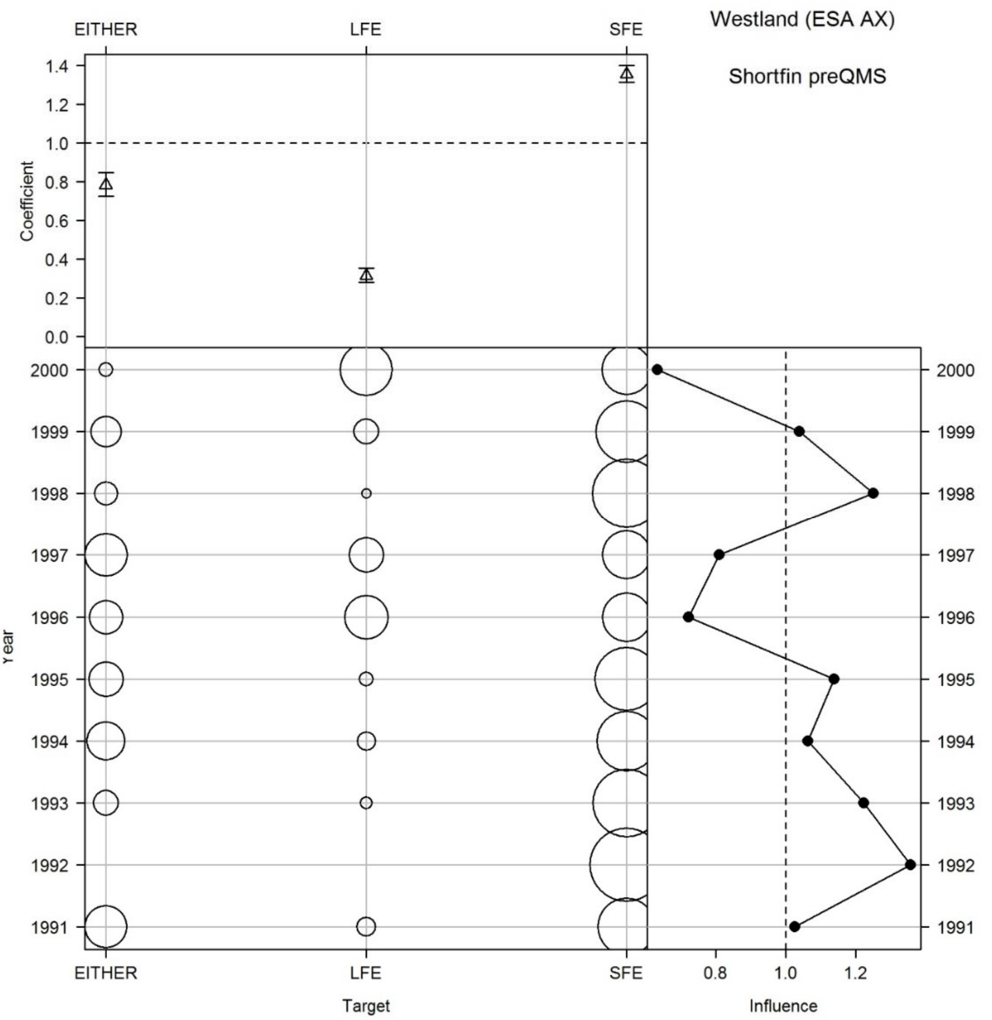



**Figure F13: Influence of target species for the shortfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Westland (ESA AX)).**

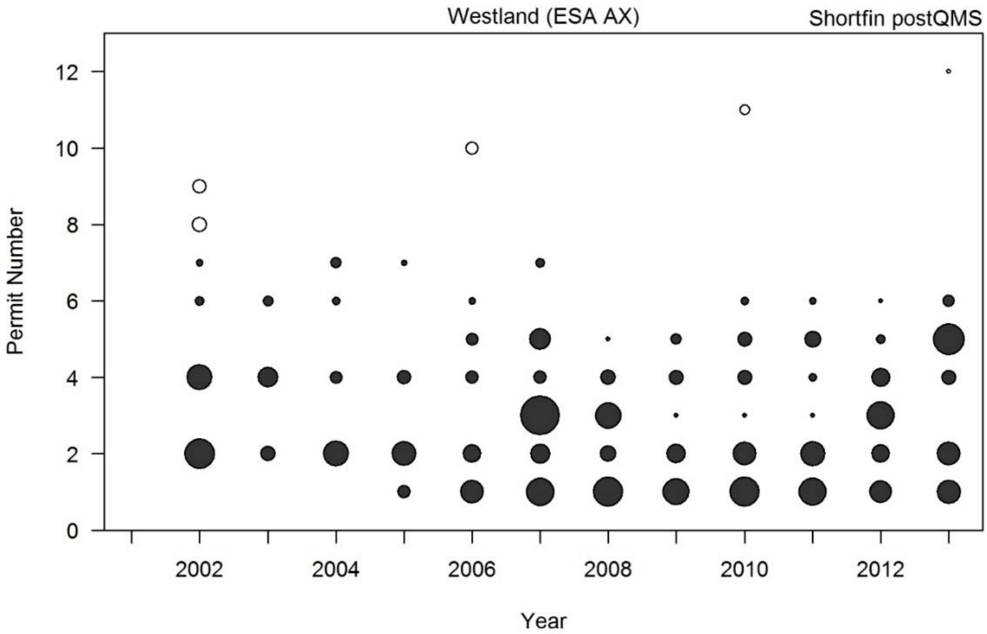



**Figure F14: Relative shortfin catch from all fishers (all circles) for the years 2001–02 to 2012–13 (post-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

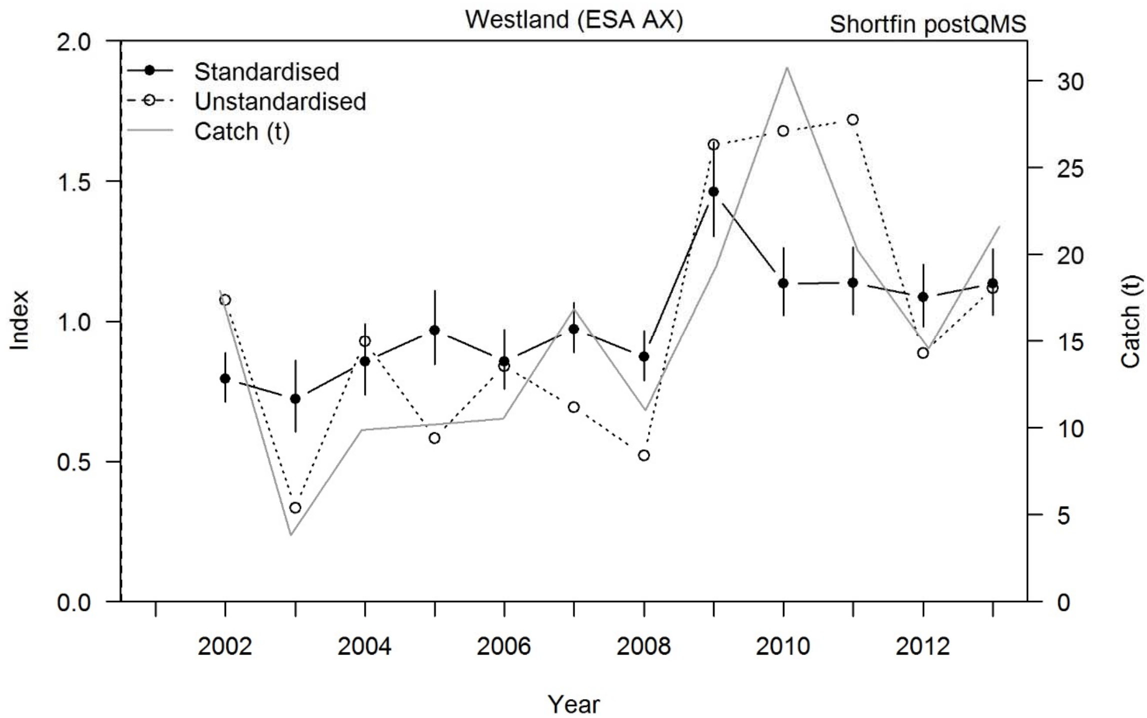



**Figure F15: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) post-QMS for the years 2001–02 to 2012–13. The catch by core fishers is also plotted. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

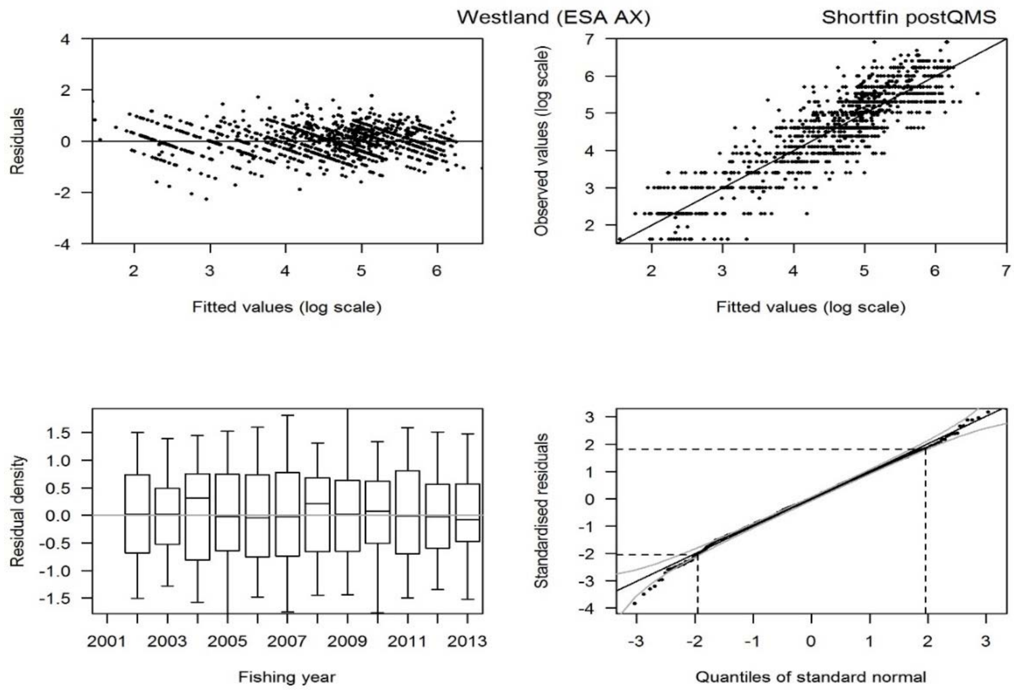



**Figure F16: Residual diagnostic plots for the shortfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

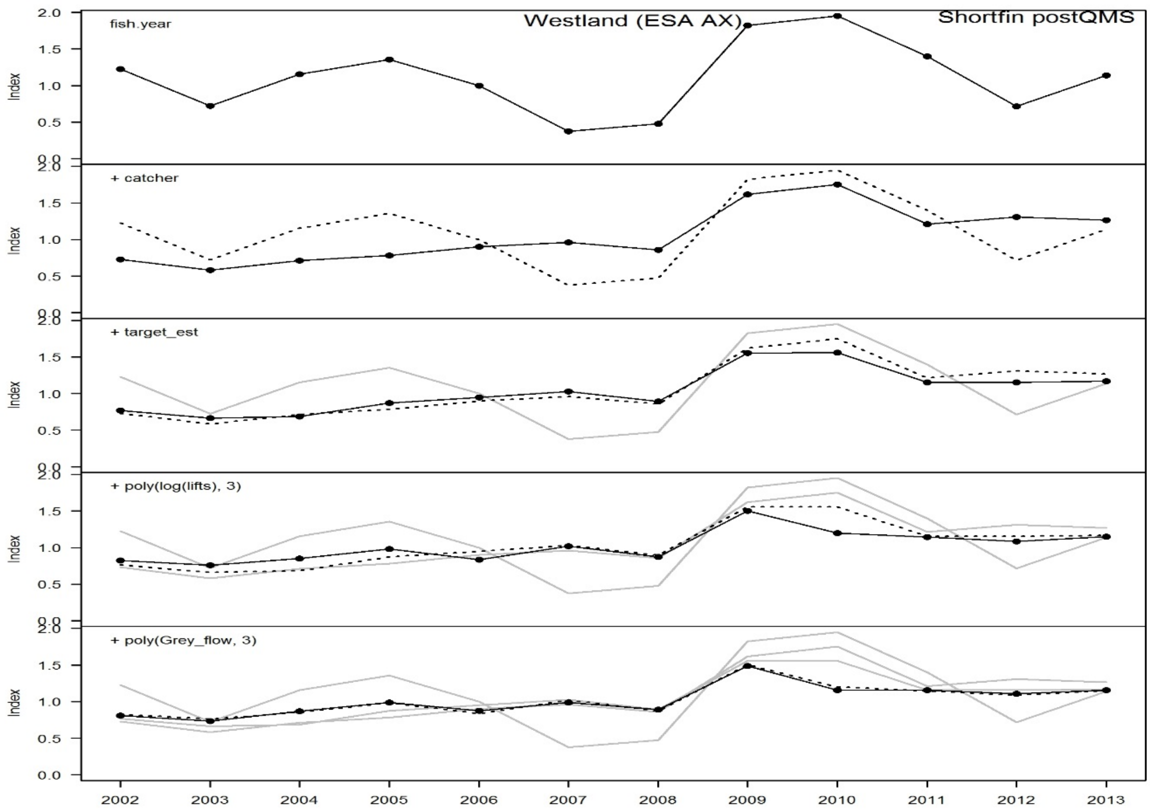



**Figure F17: Step plot for the shortfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

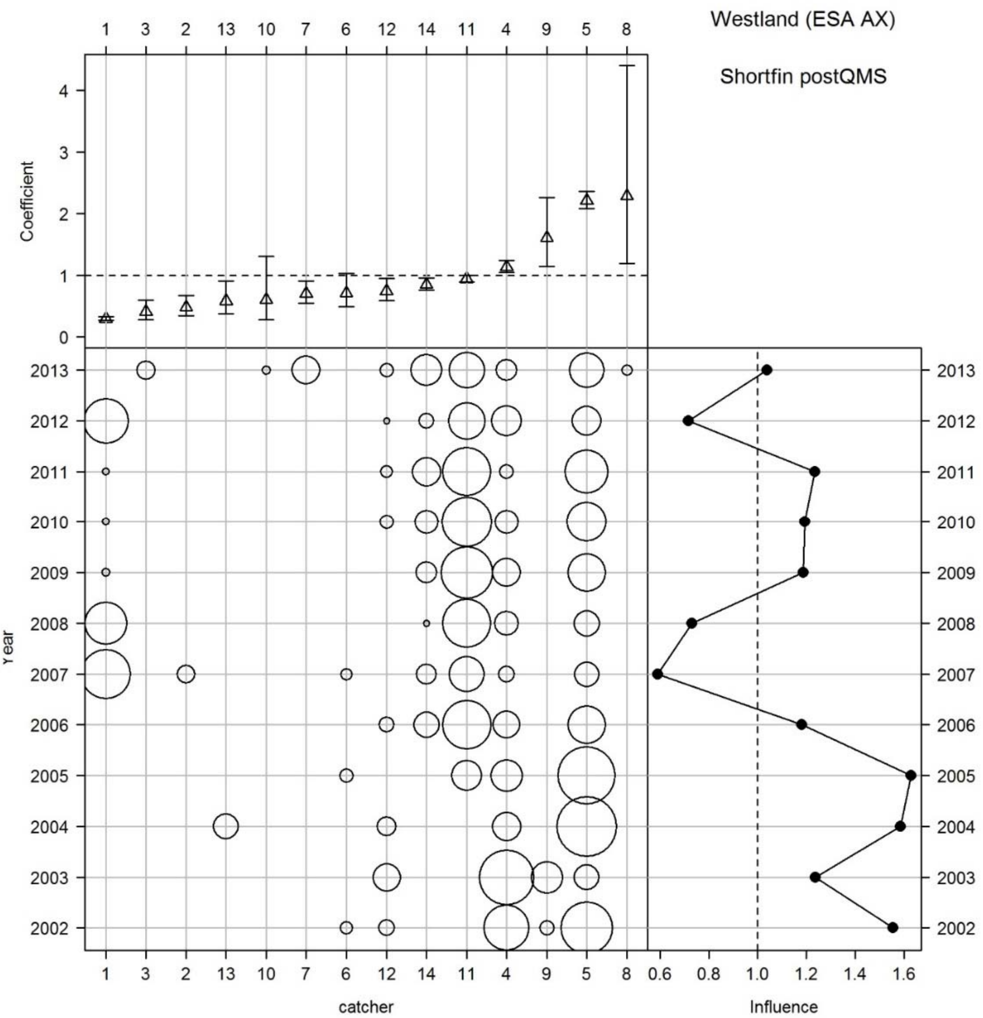



**Figure F18: Influence of catcher for the shortfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

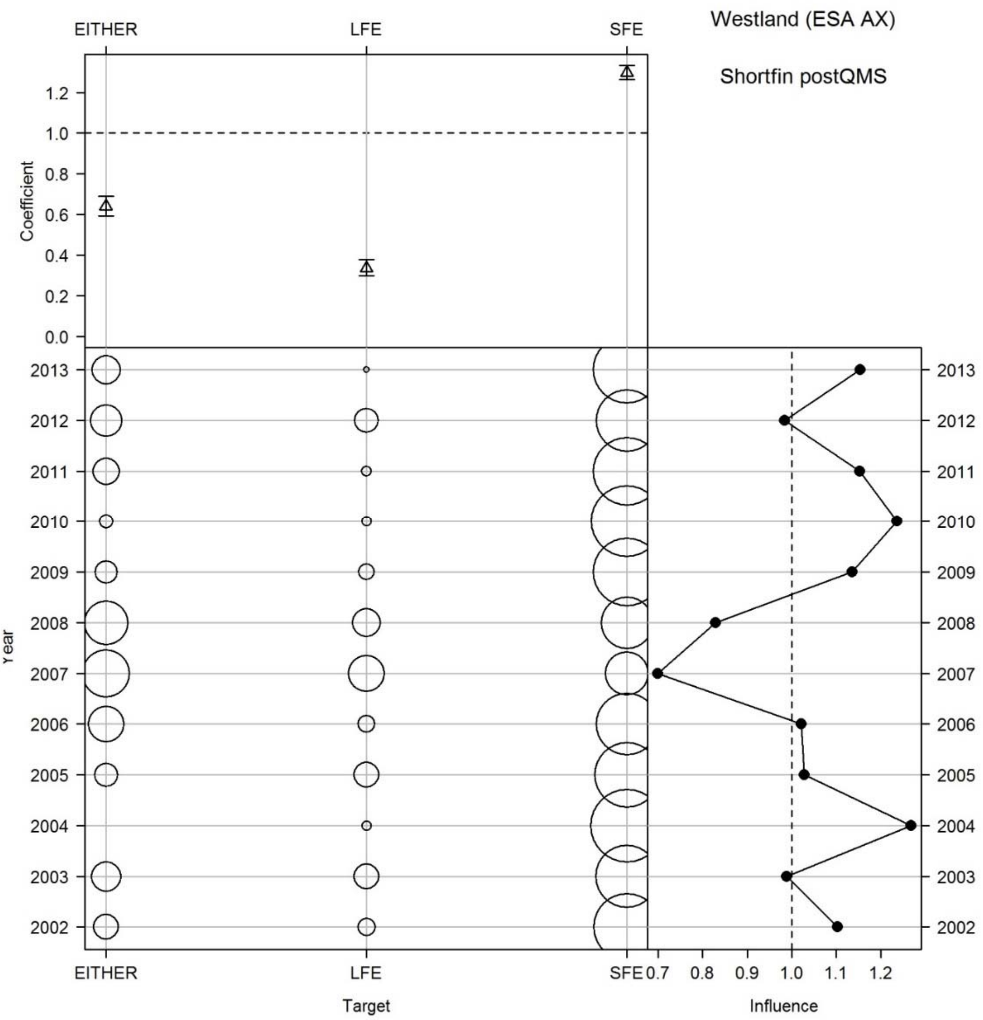



**Figure F19: Influence of target species for the shortfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

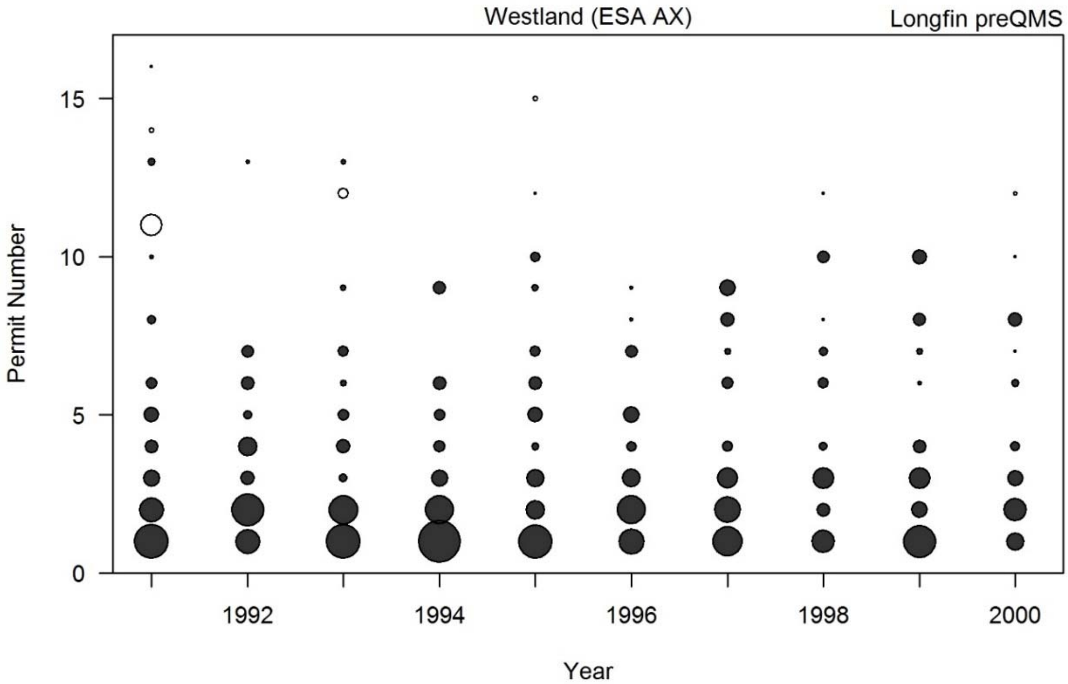



**Figure F20: Relative longfin catch from all fishers (all circles) for the years 1990–91 to 1999–2000 (pre-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses (Westland (ESA AX)).**

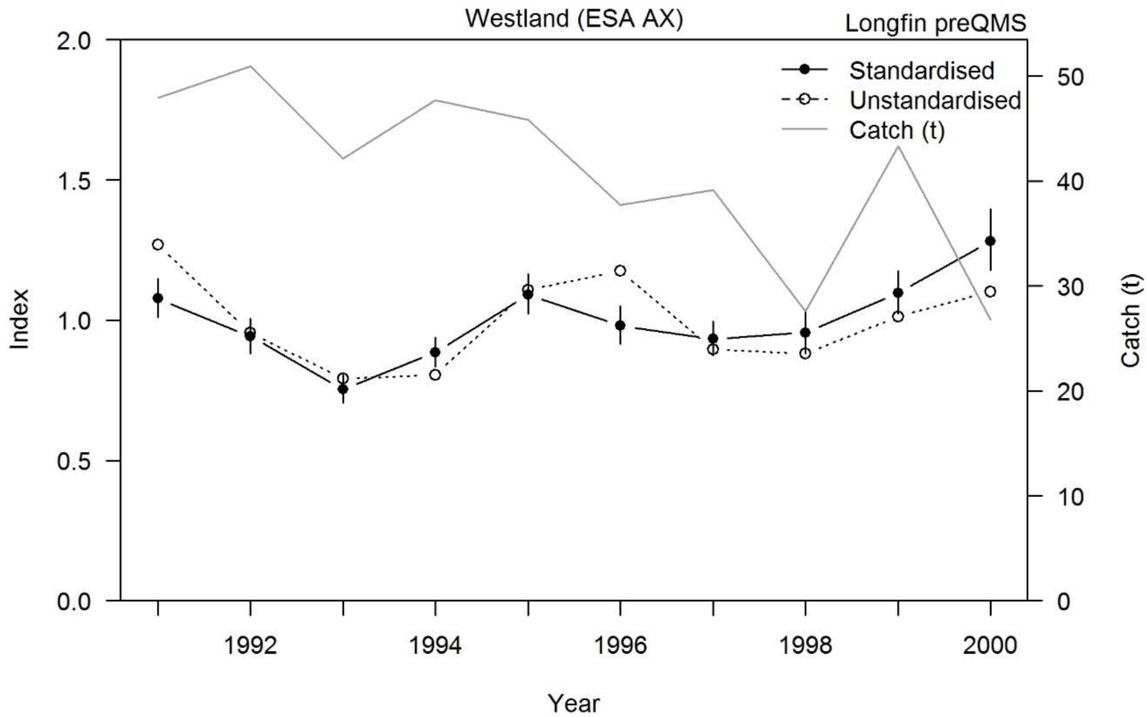



**Figure F21: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000. The catch by core fishers is also plotted (Westland (ESA AX)).**

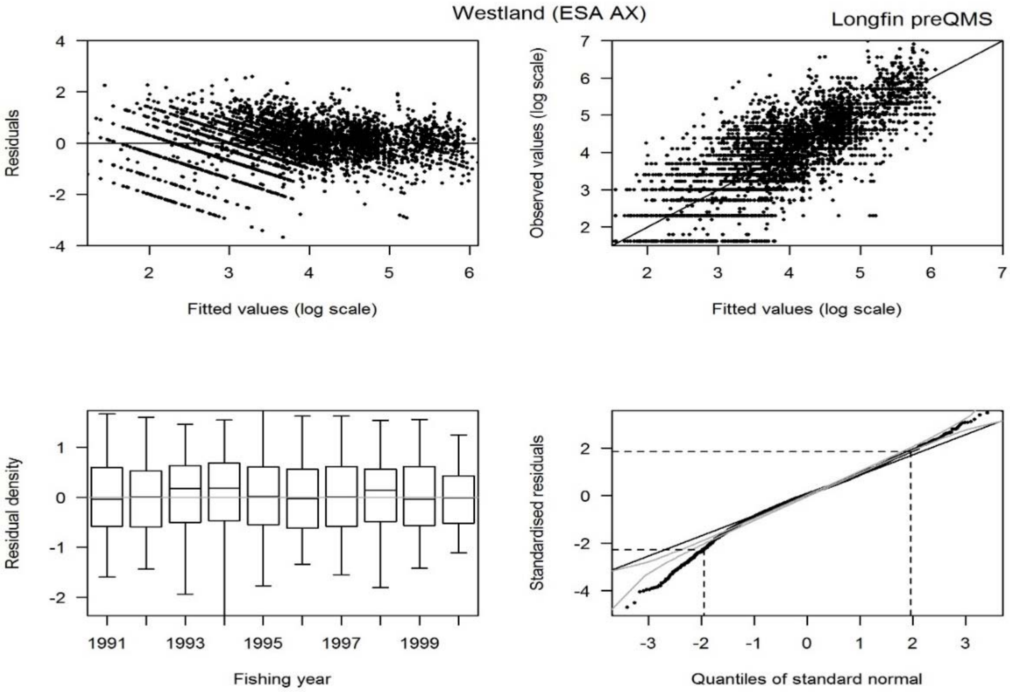



**Figure F22: Residual diagnostic plots for the longfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution (Westland (ESA AX)).**

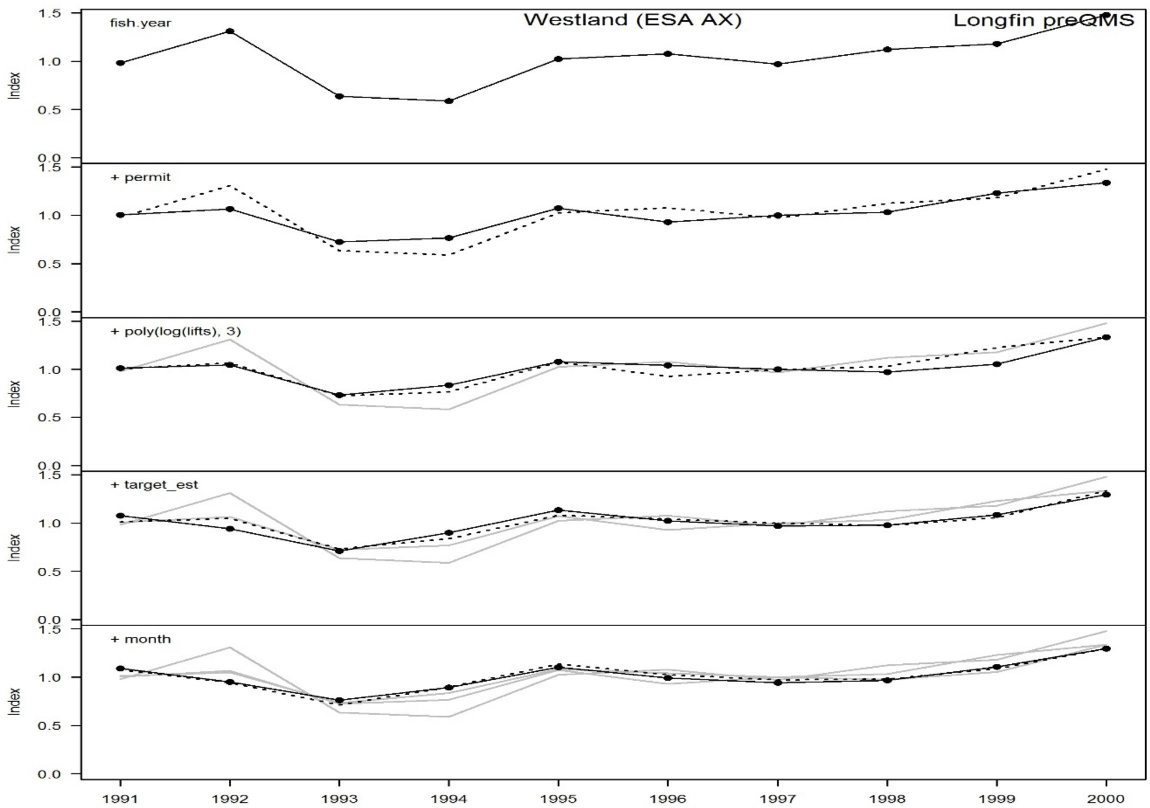



**Figure F23: Step plot for the longfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that (Westland (ESA AX)).**

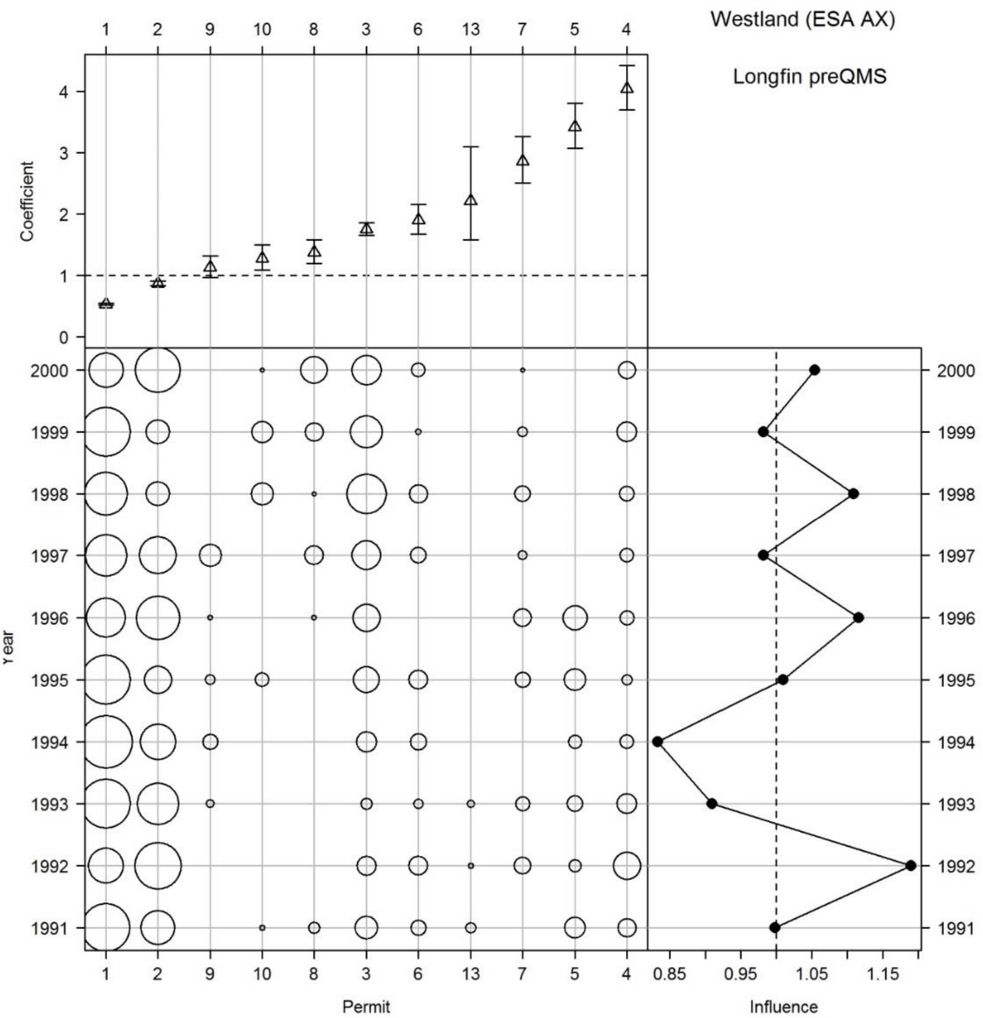



**Figure F24: Influence of permit for the longfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Westland (ESA AX)).**

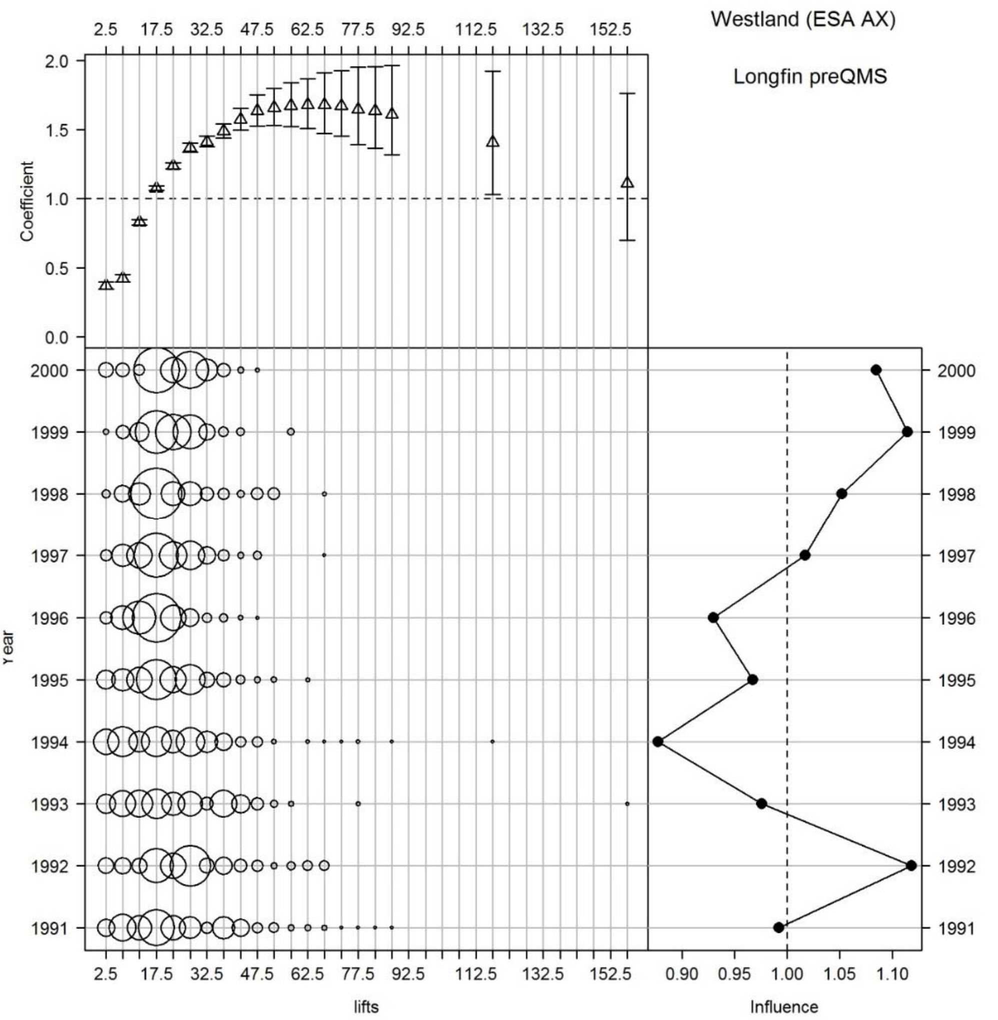



**Figure F25: Influence of lifts for the longfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Westland (ESA AX)).**

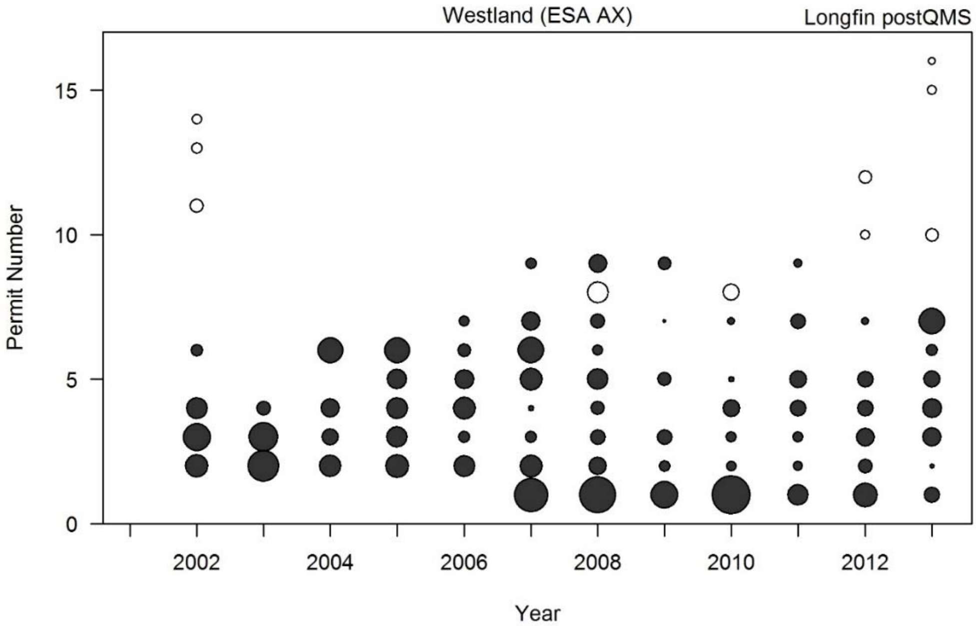



**Figure F26: Relative longfin catch from all fishers (all circles) for the years 2001–02 to 2012–13 (post-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

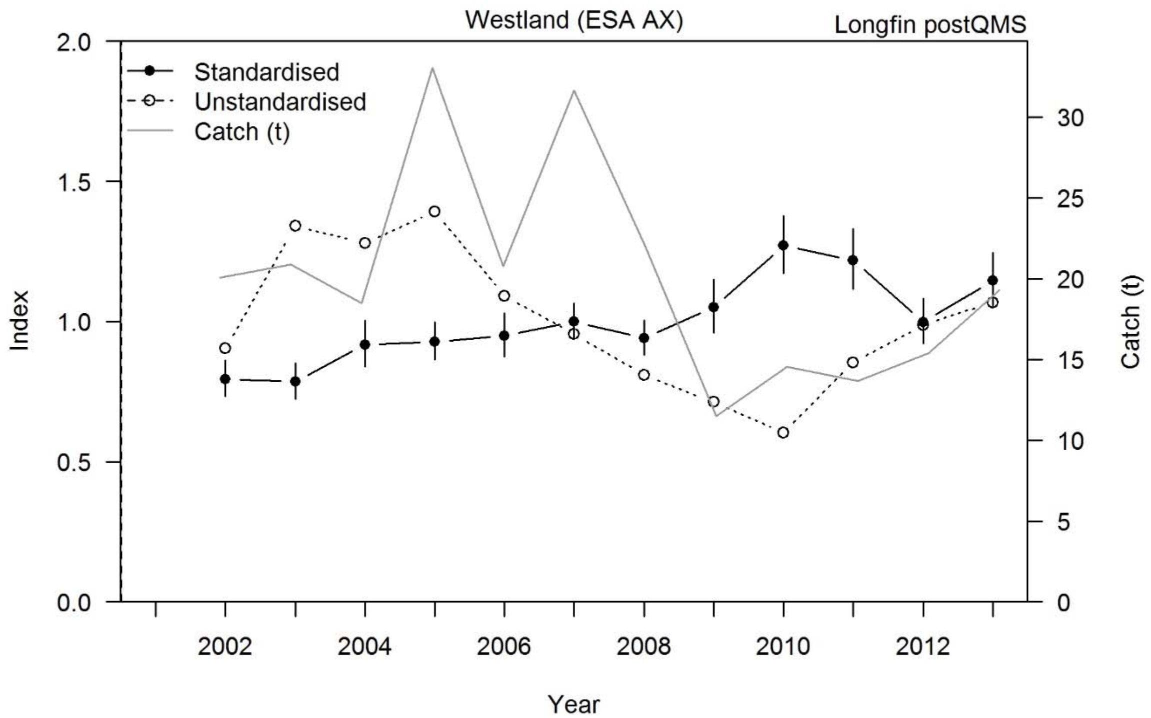



**Figure F27: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) post-QMS for the years 2001–02 to 2012–13. The catch by core fishers is also plotted. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

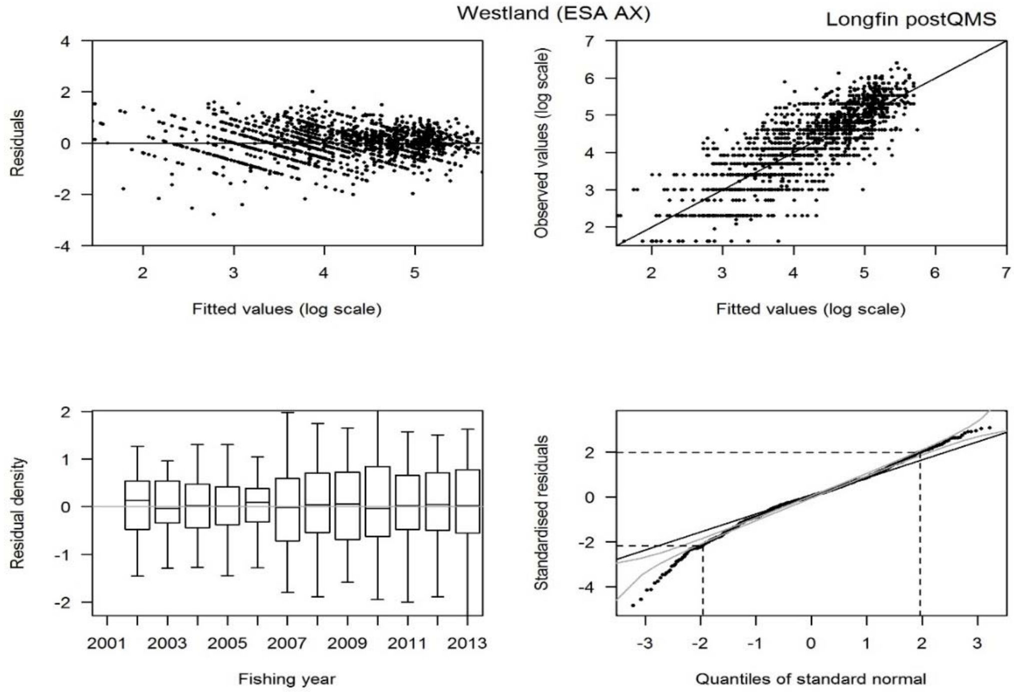



**Figure F28: Residual diagnostic plots for the longfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

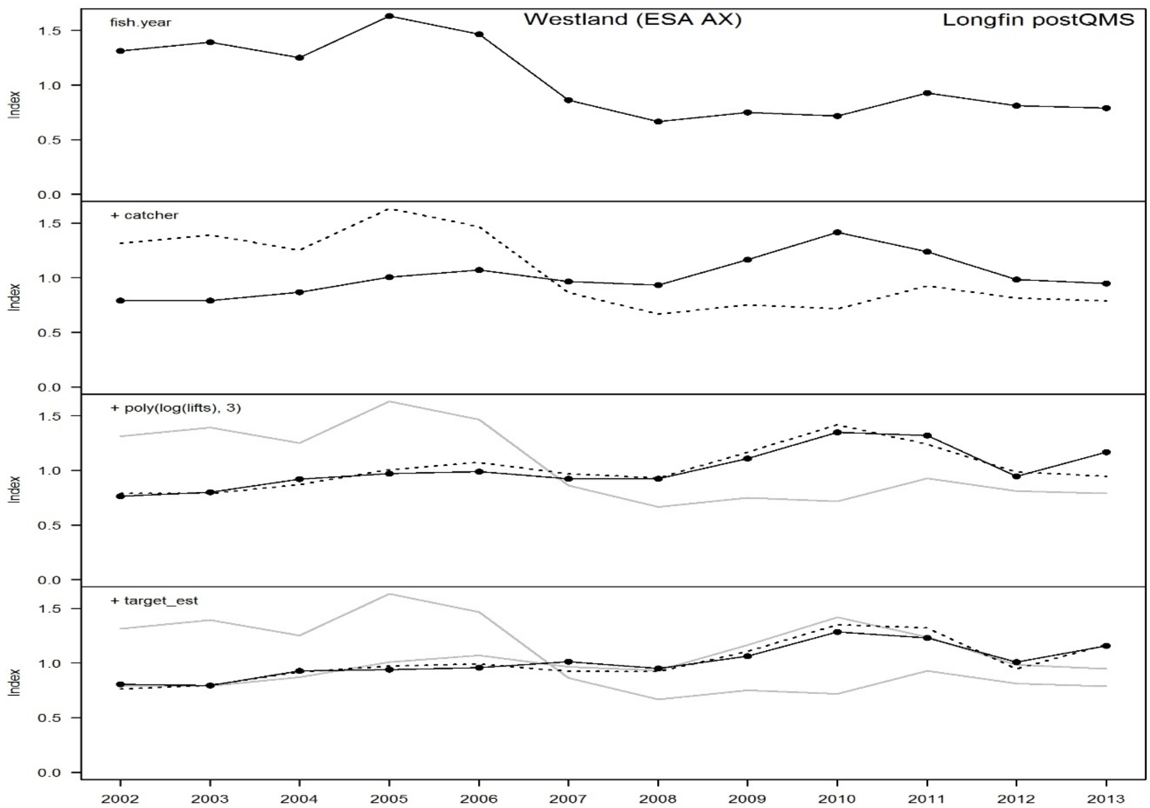



**Figure F29: Step plot for the longfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

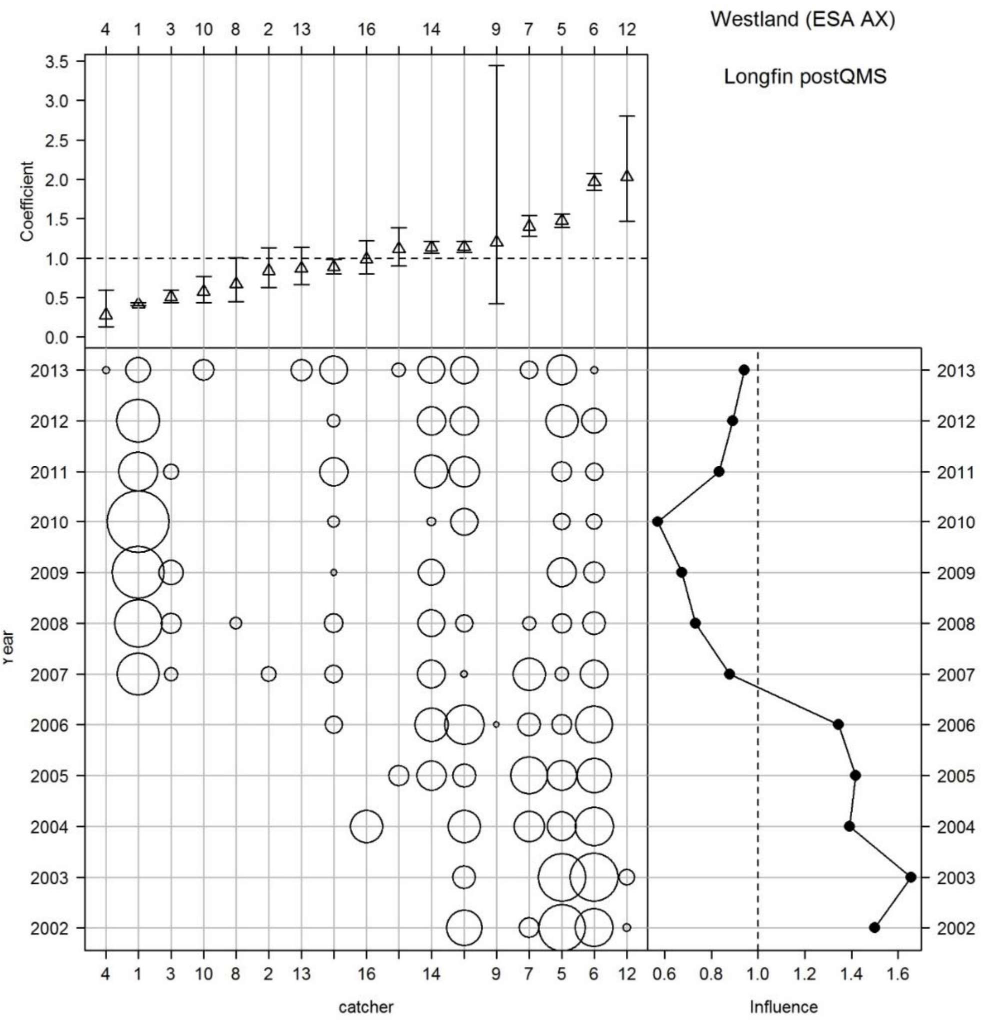



**Figure F30: Influence of catcher for the longfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

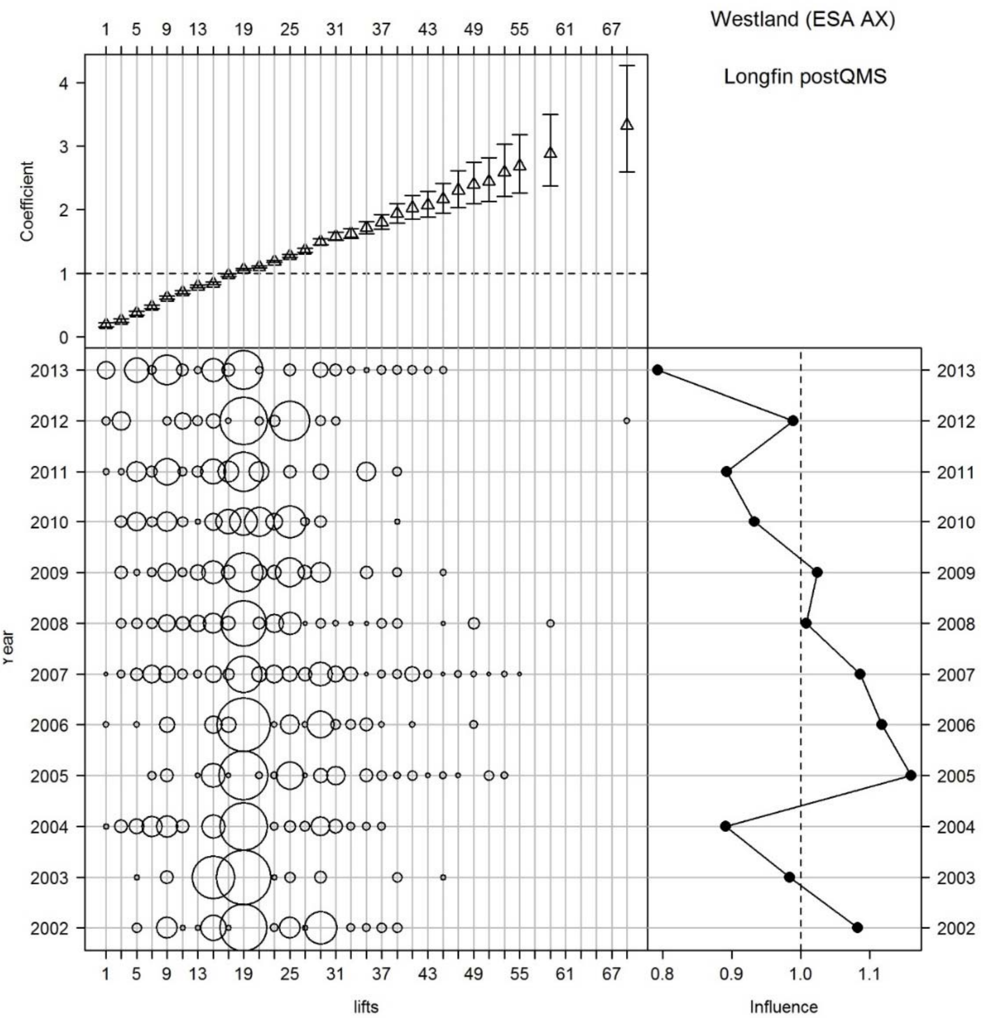



**Figure F31: Influence of lifts for the longfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Westland (ESA AX)).**

**Appendix G: ESA 19 (AV)**

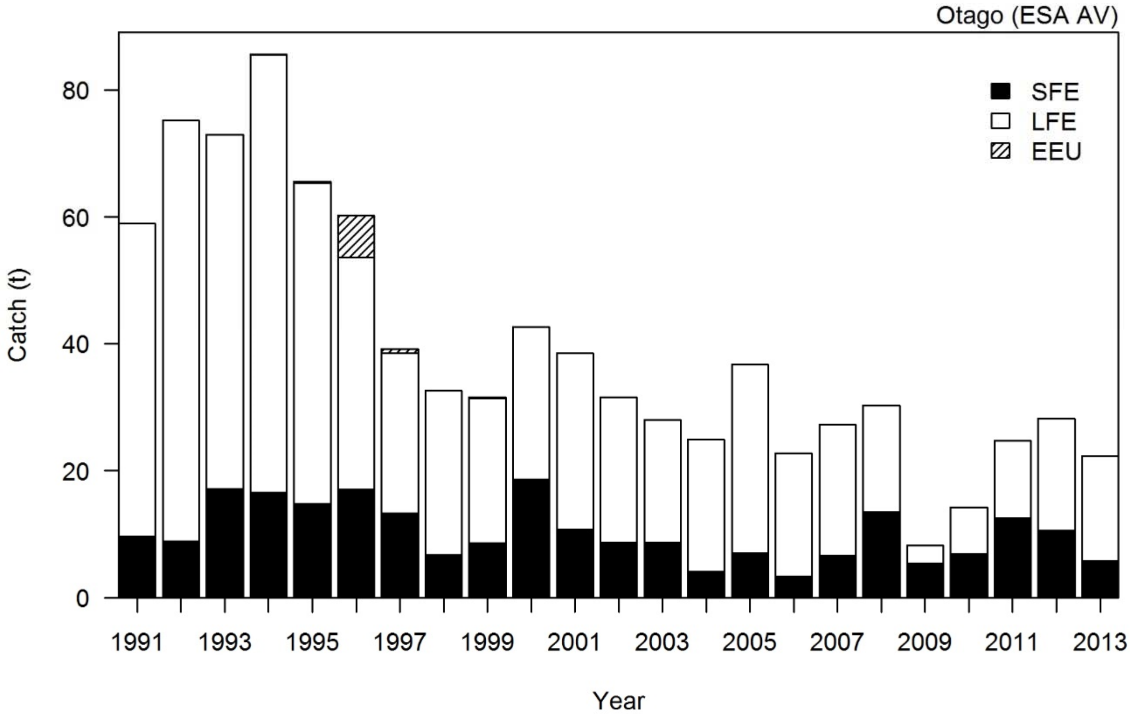



**Figure G1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (Otago (ESA AV)).**

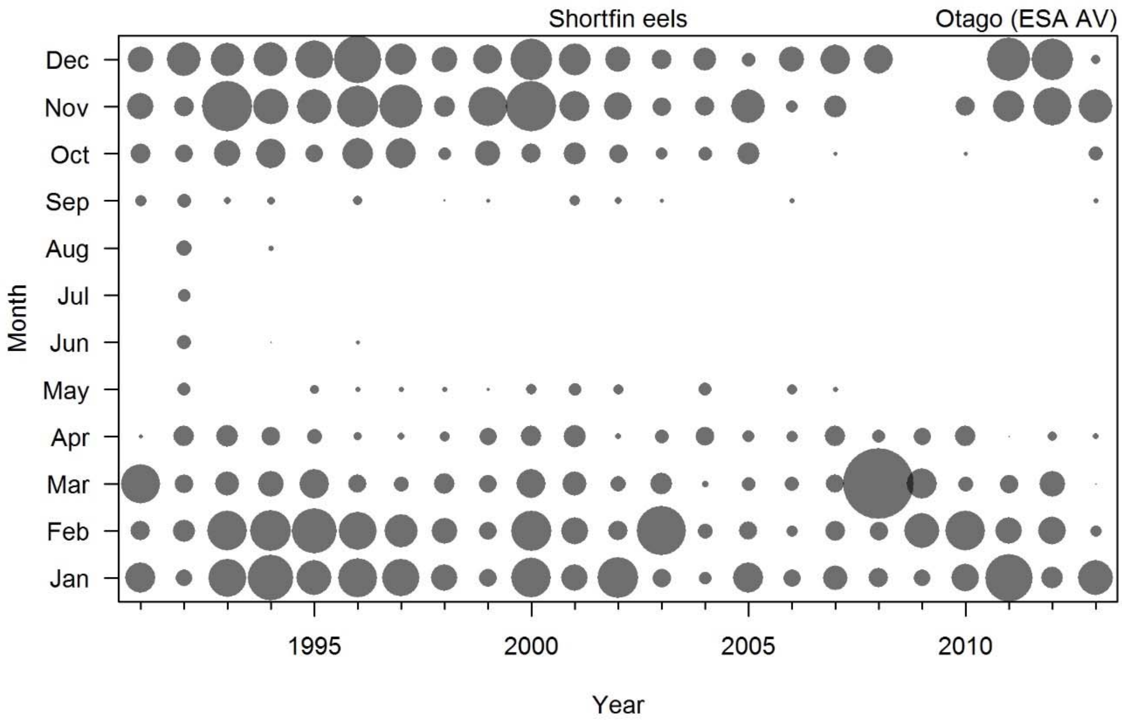



**Figure G2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (Otago (ESA AV)).**

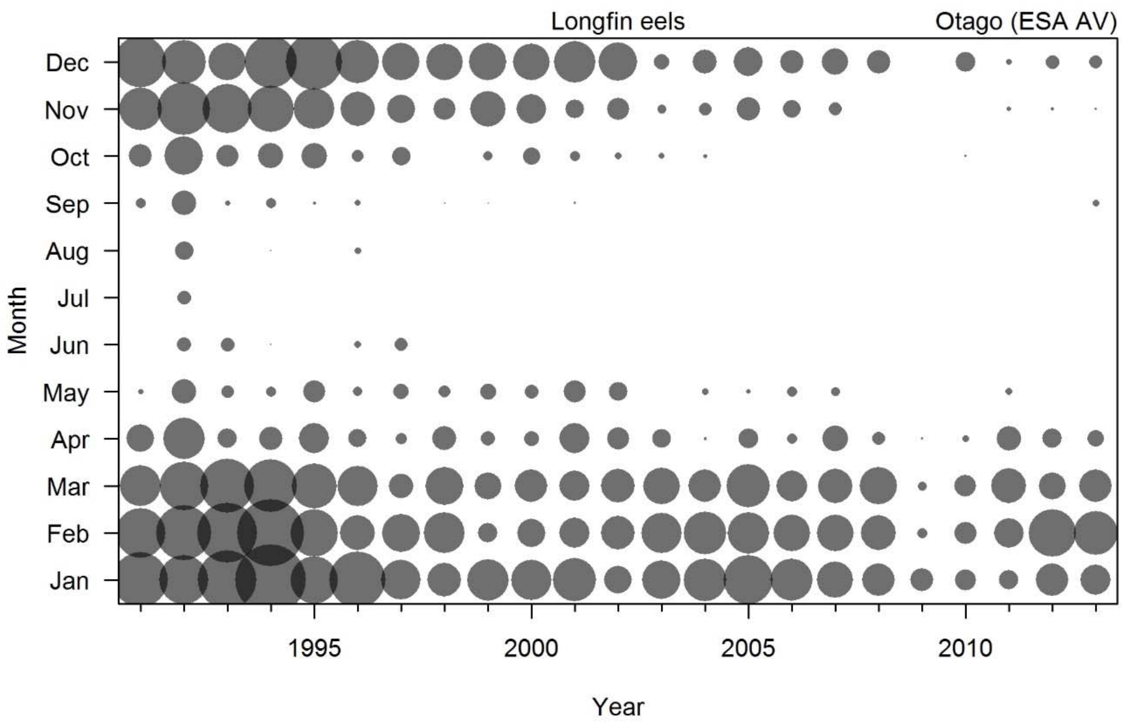



**Figure G3: Longfin eel catch by month for the years 1990–91 to 2012–13 (Otago (ESA AV)).**

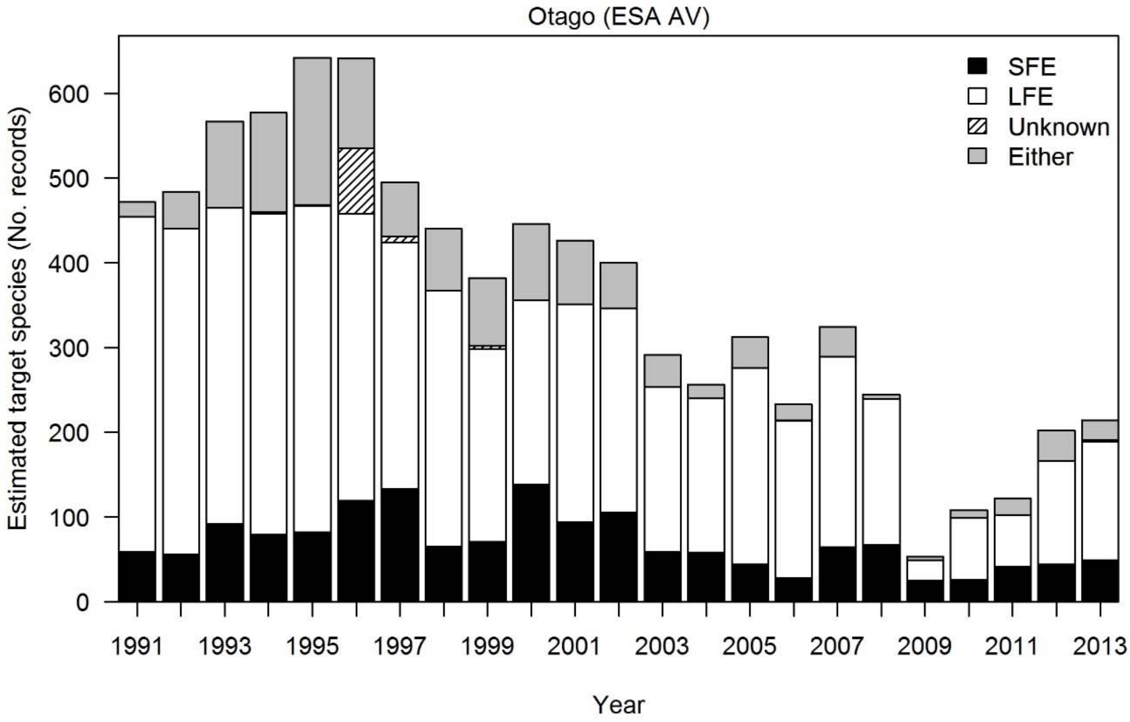



**Figure G4: Reconstructed target species for the years 1990–91 to 2012–13 (Otago (ESA AV)).**

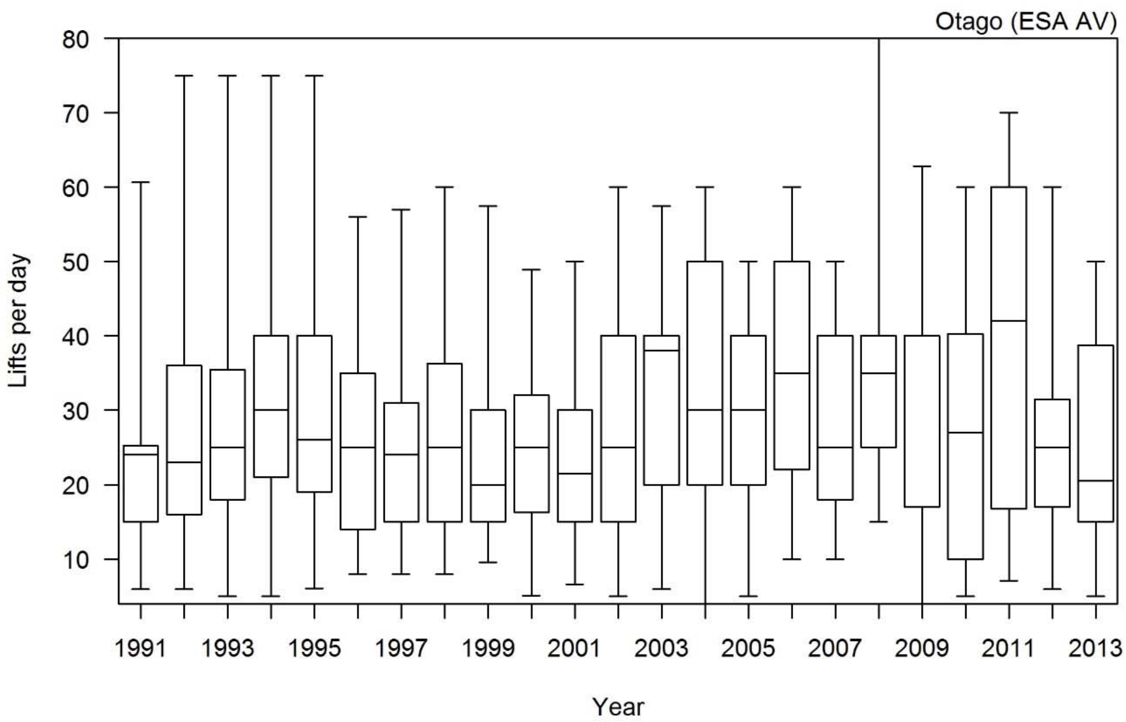



**Figure G5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (Otago (ESA AV)).**

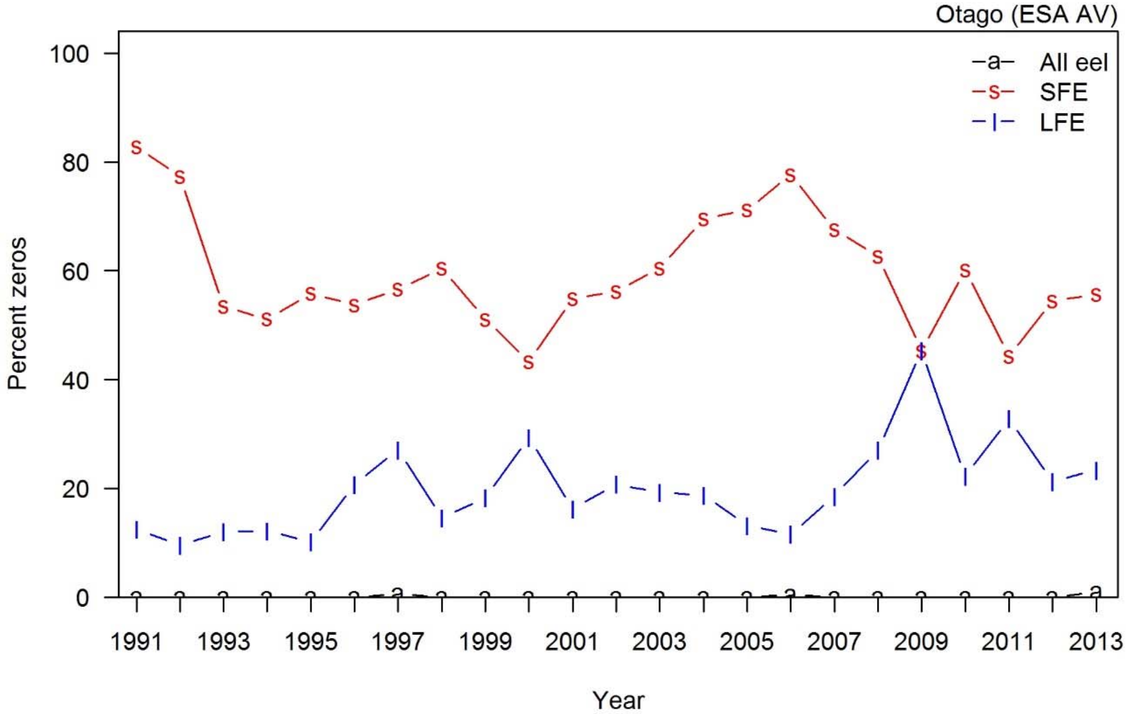



**Figure G6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (Otago (ESA AV)).**

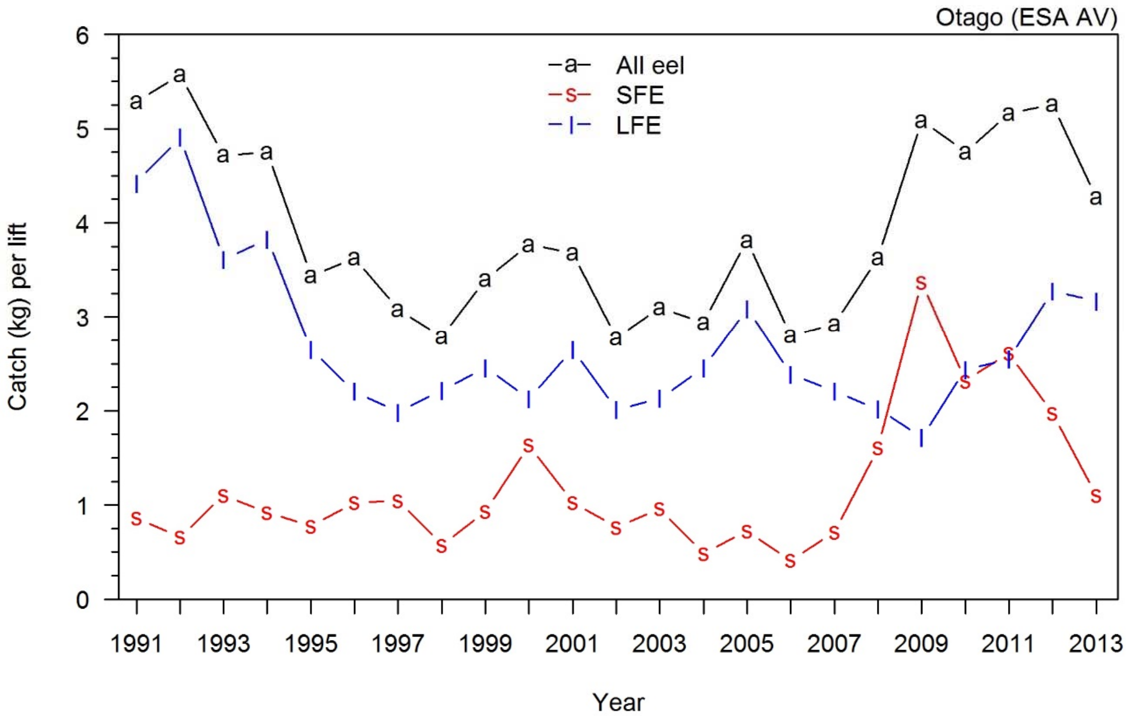



**Figure G7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (Otago (ESA AV)).**

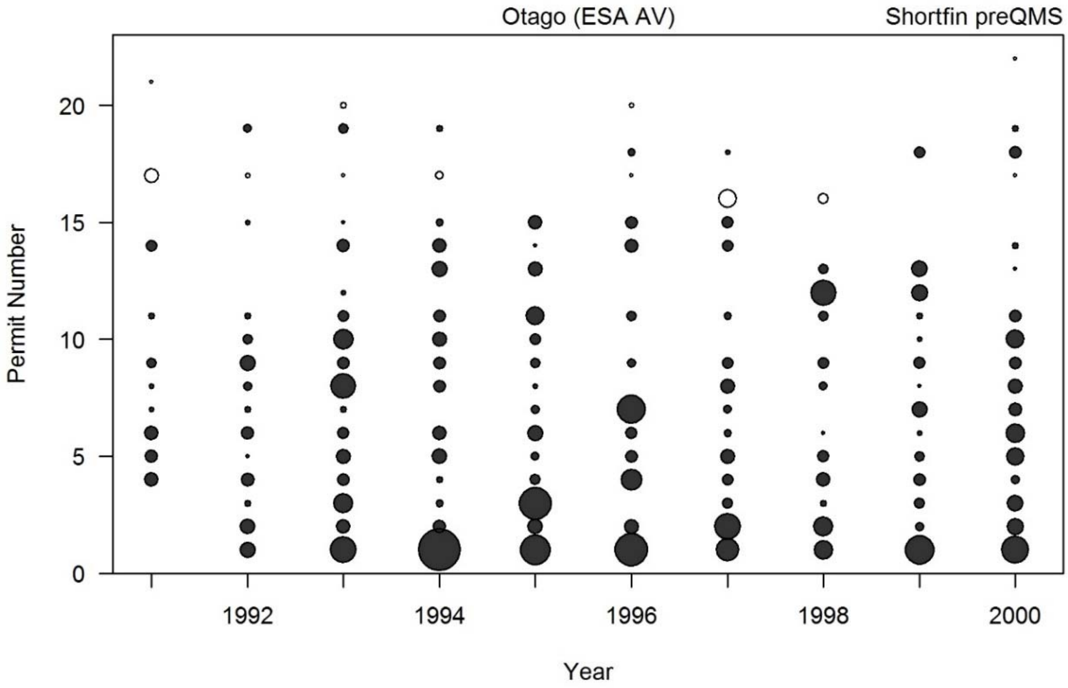



**Figure G8: Relative shortfin catch from all fishers (all circles) for the years 1990–91 to 1999–2000 (pre-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses (Otago (ESA AV)).**

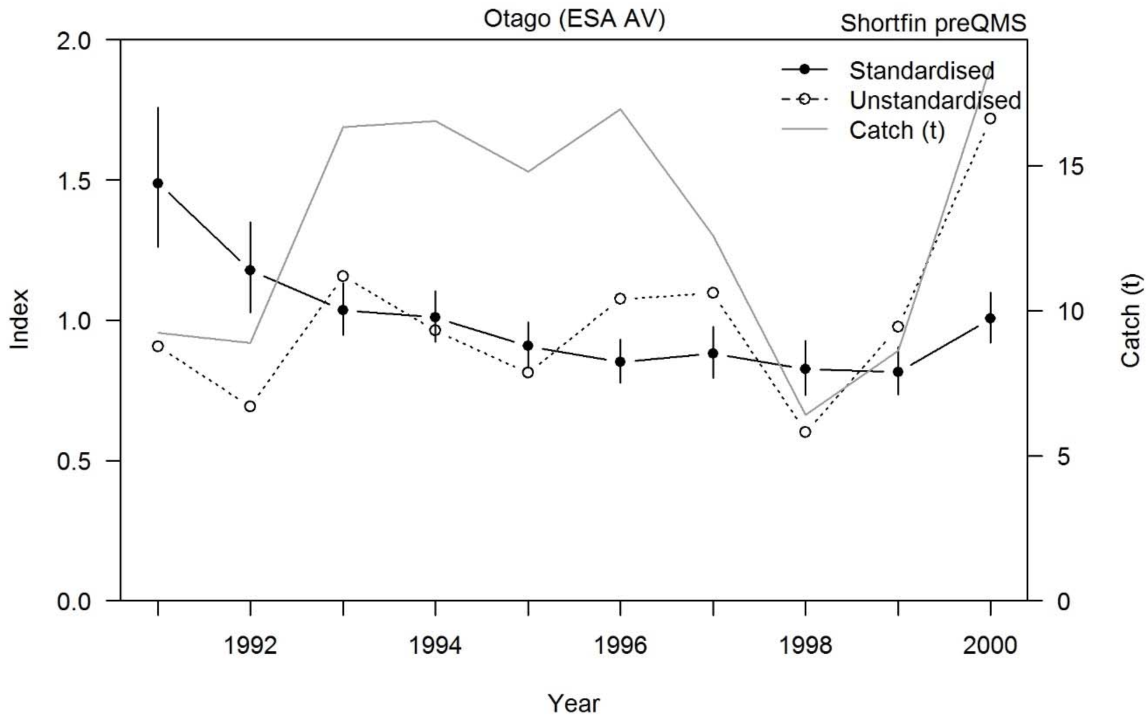



**Figure G9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000. The catch by core fishers is also plotted (Otago (ESA AV)).**

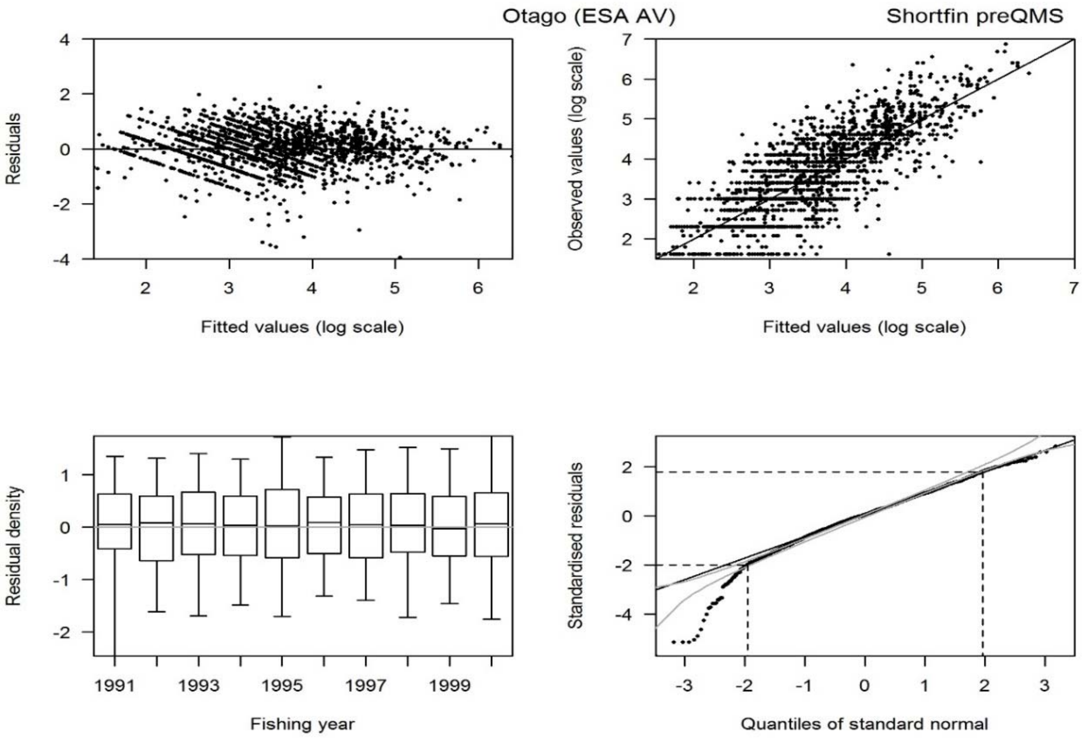



**Figure G10: Residual diagnostic plots for the shortfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution (Otago (ESA AV)).**

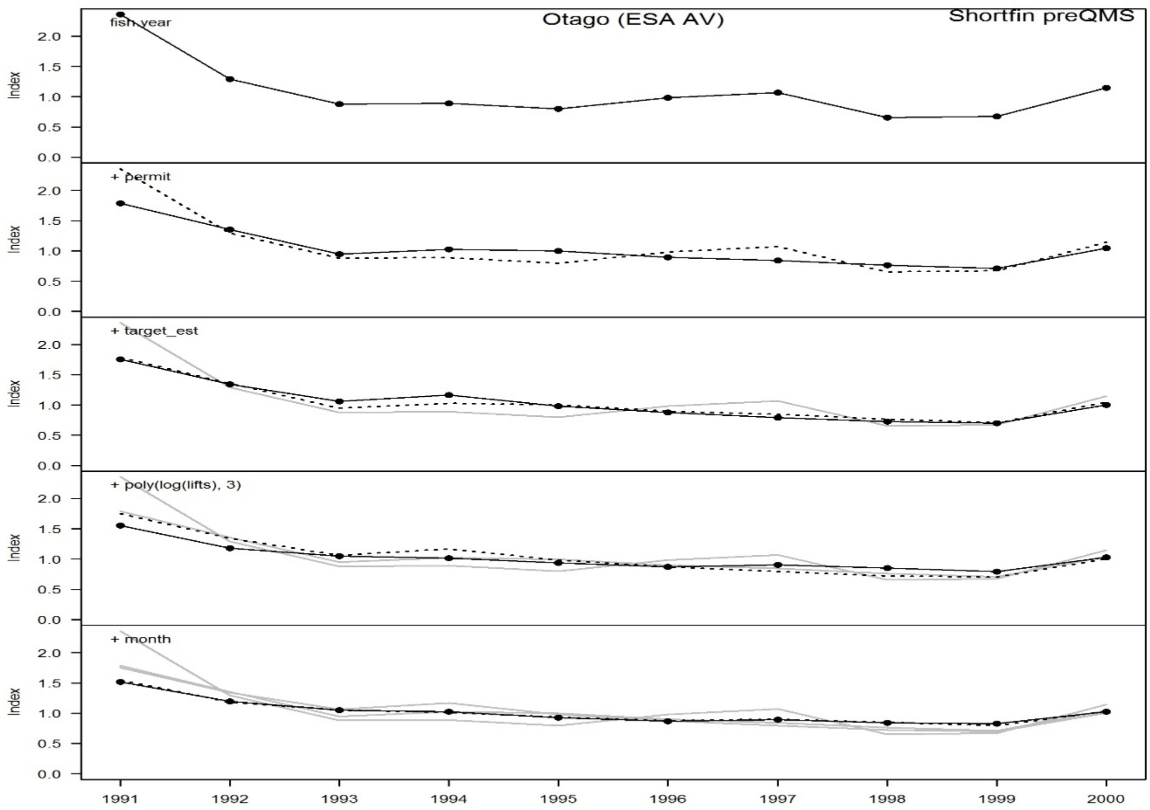



**Figure G11: Step plot for the shortfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that (Otago (ESA AV)).**

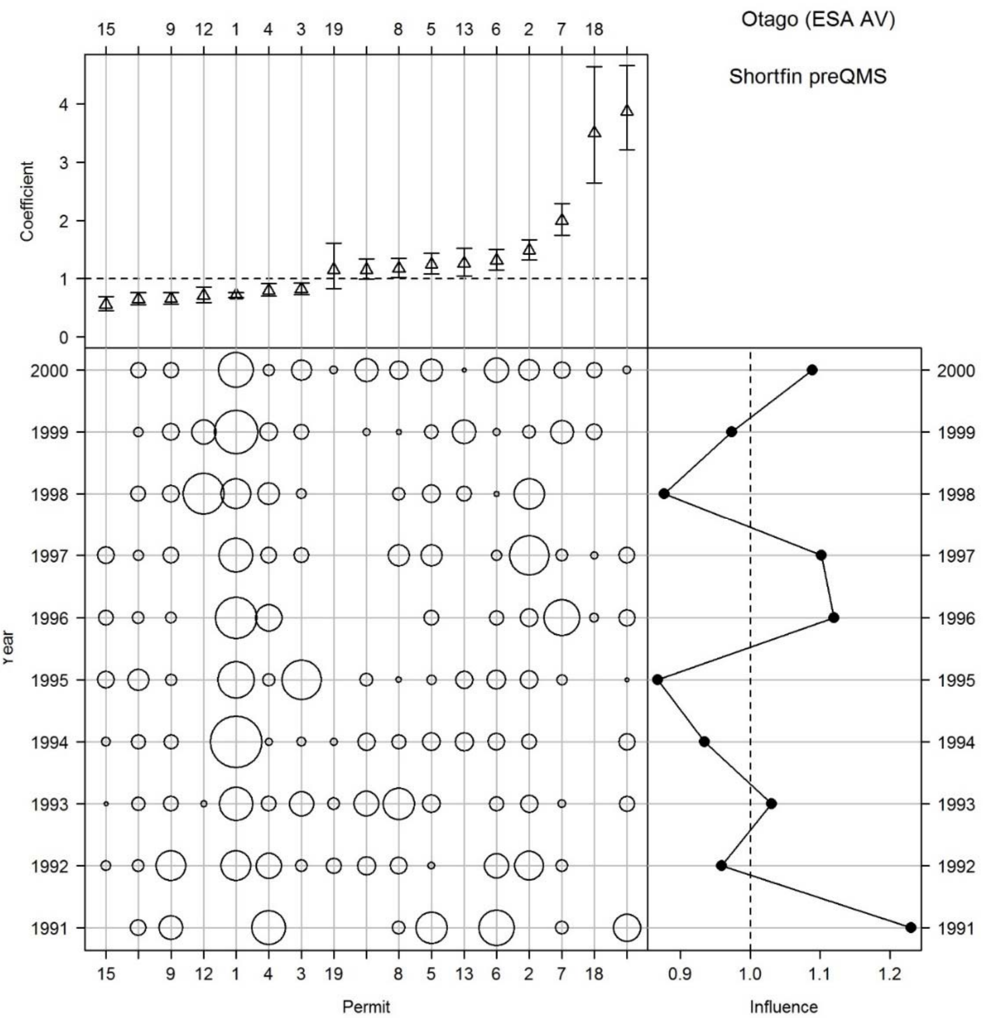



**Figure G12: Influence of permit for the shortfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Otago (ESA AV)).**

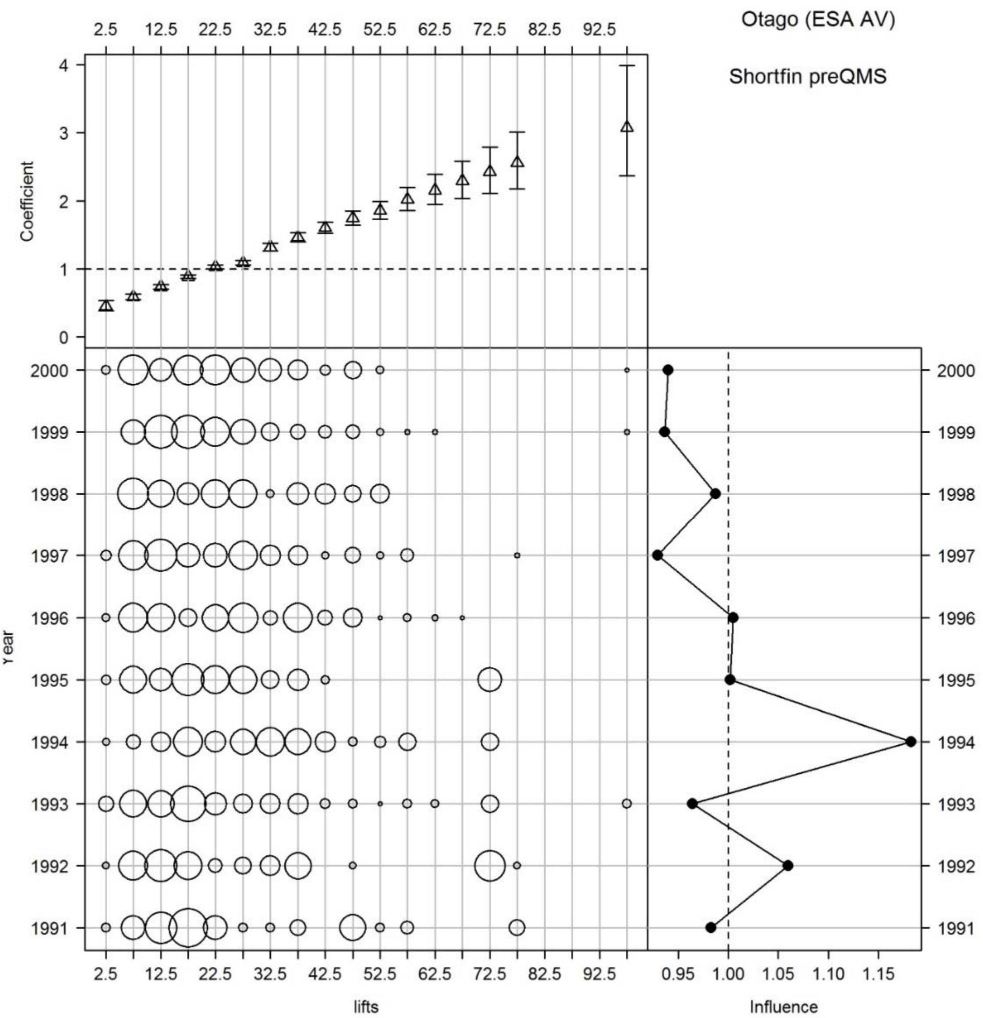



**Figure G13: Influence of lifts for the shortfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Otago (ESA AV)).**

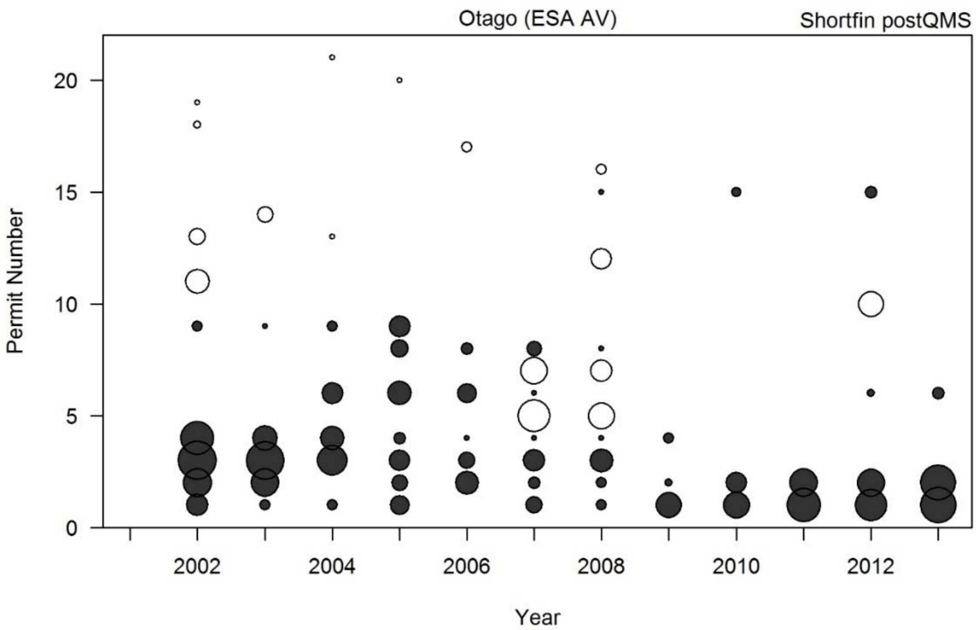



**Figure G14: Relative shortfin catch from all fishers (all circles) for the years 2001–02 to 2012–13 (post-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

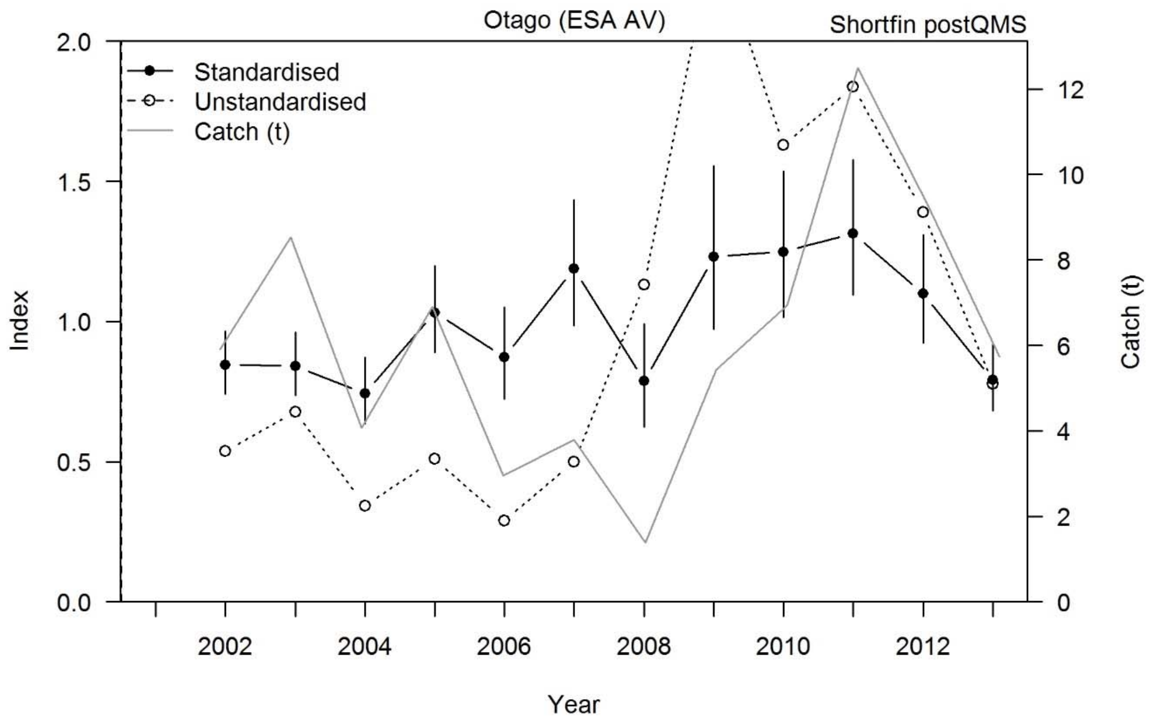



**Figure G15: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) post-QMS for the years 2001–02 to 2012–13. The catch by core fishers is also plotted. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

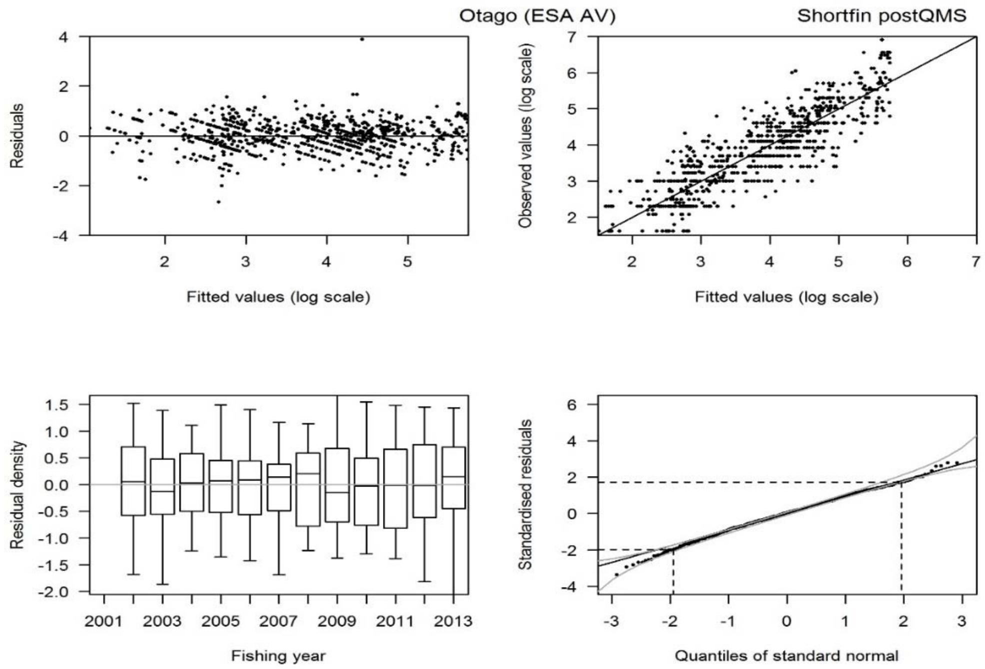



**Figure G16: Residual diagnostic plots for the shortfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

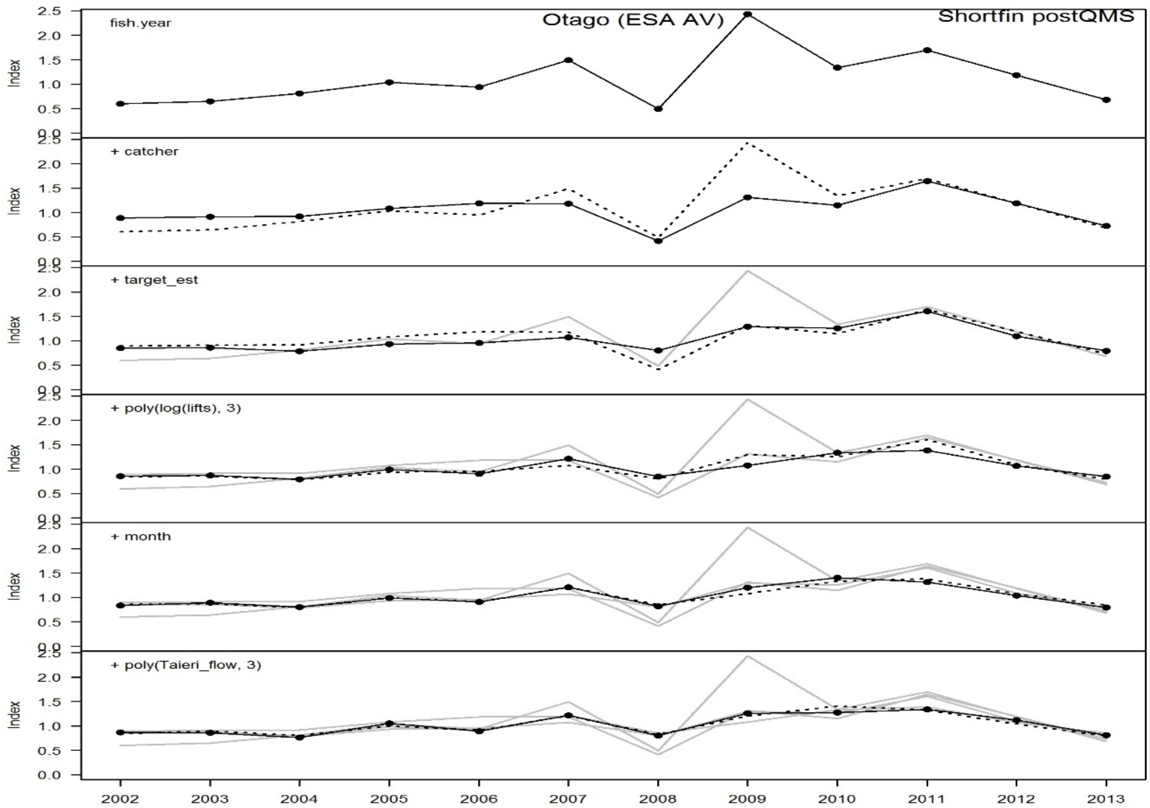



**Figure G17: Step plot for the shortfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

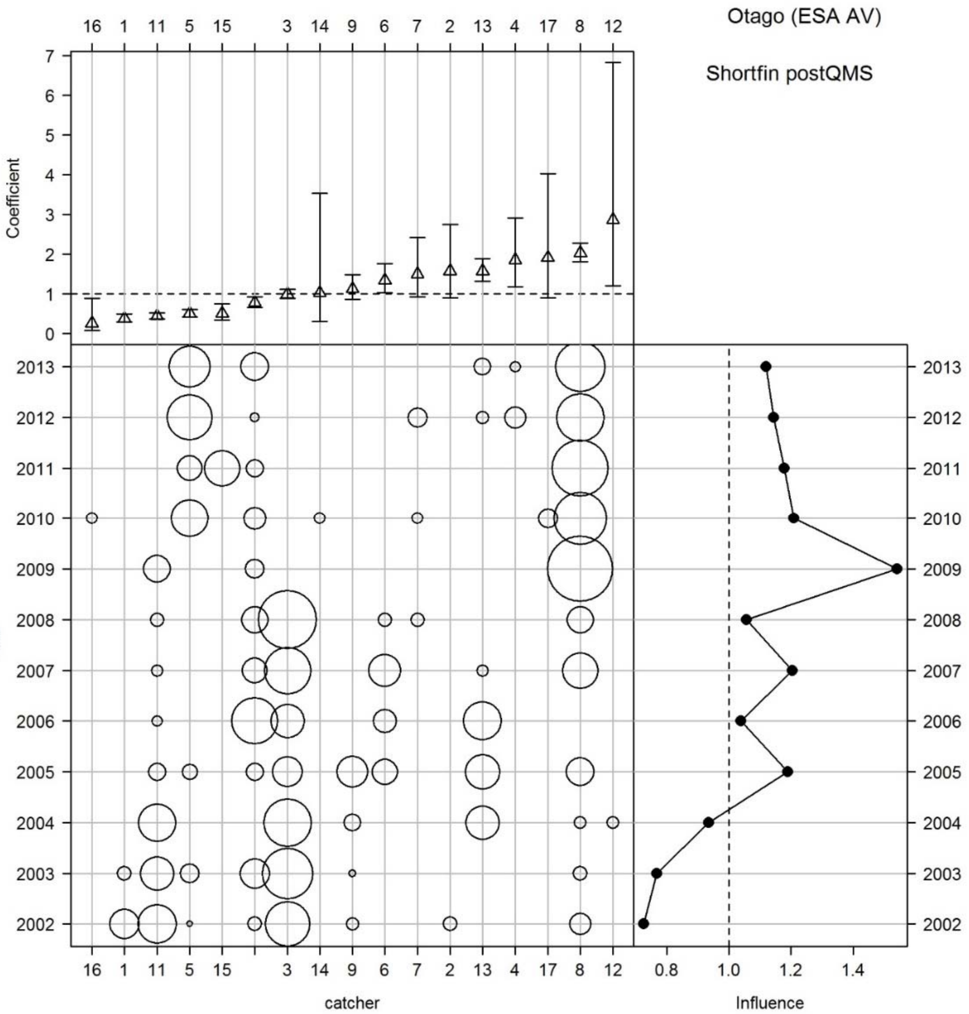



**Figure G18: Influence of catcher for the shortfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

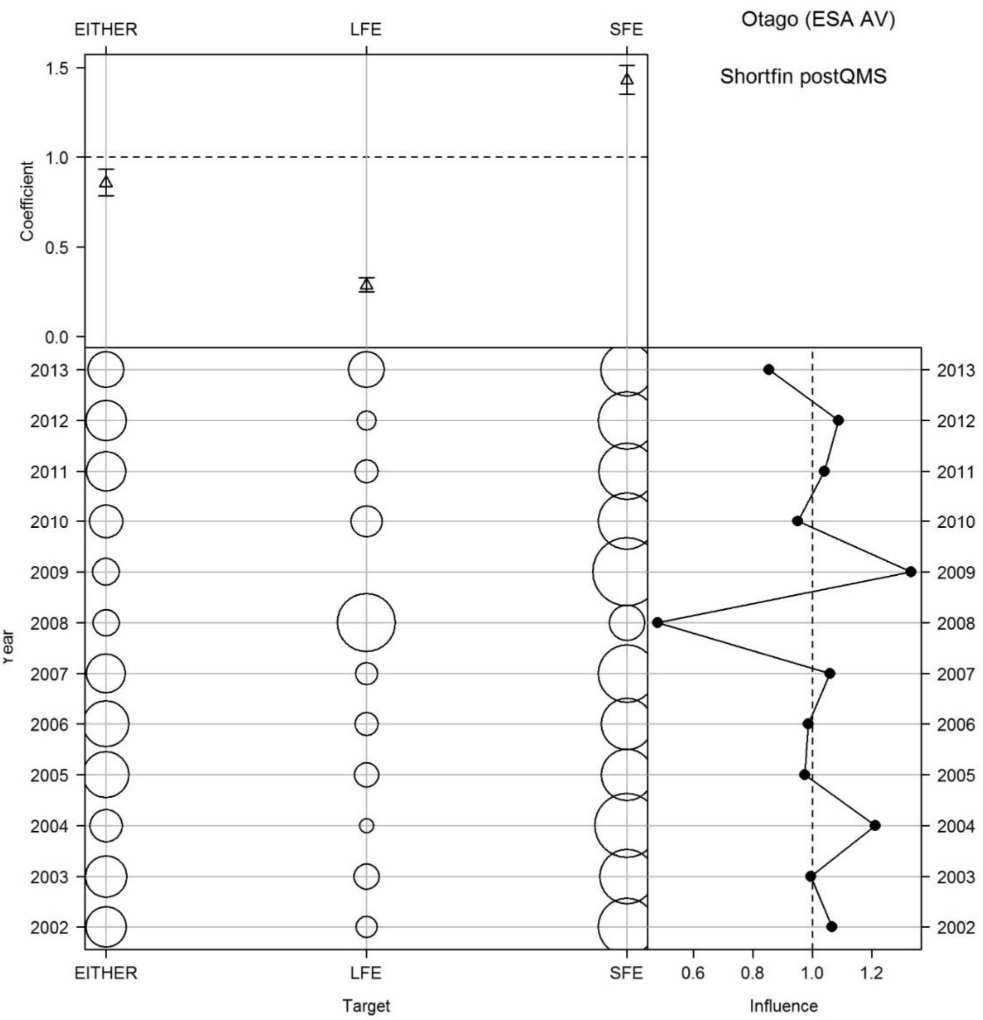



**Figure G19: Influence of target species for the shortfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

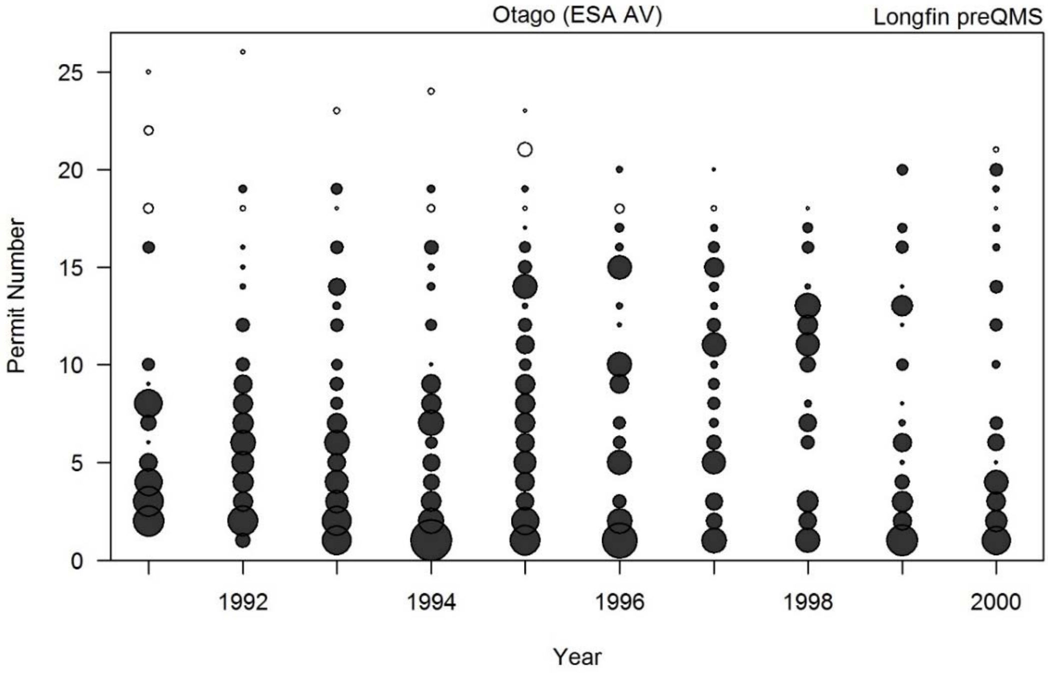



**Figure G20: Relative longfin catch from all fishers (all circles) for the years 1990–91 to 1999–2000 (pre-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses (Otago (ESA AV)).**

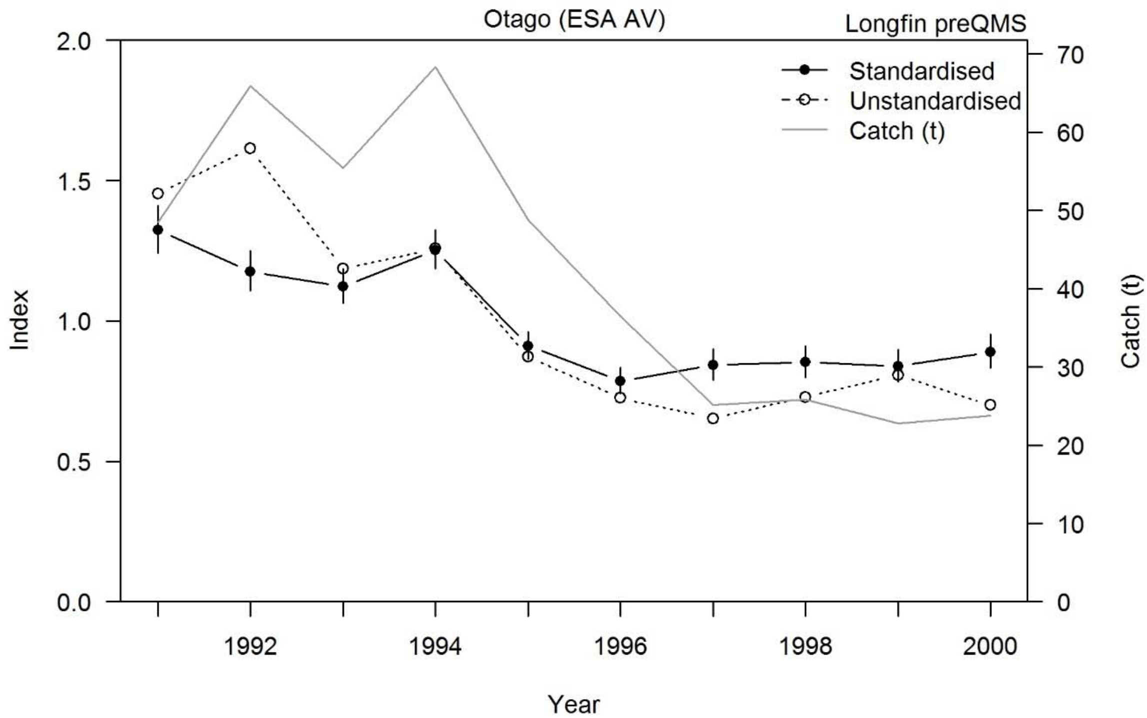



**Figure G21: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000. The catch by core fishers is also plotted (Otago (ESA AV)).**

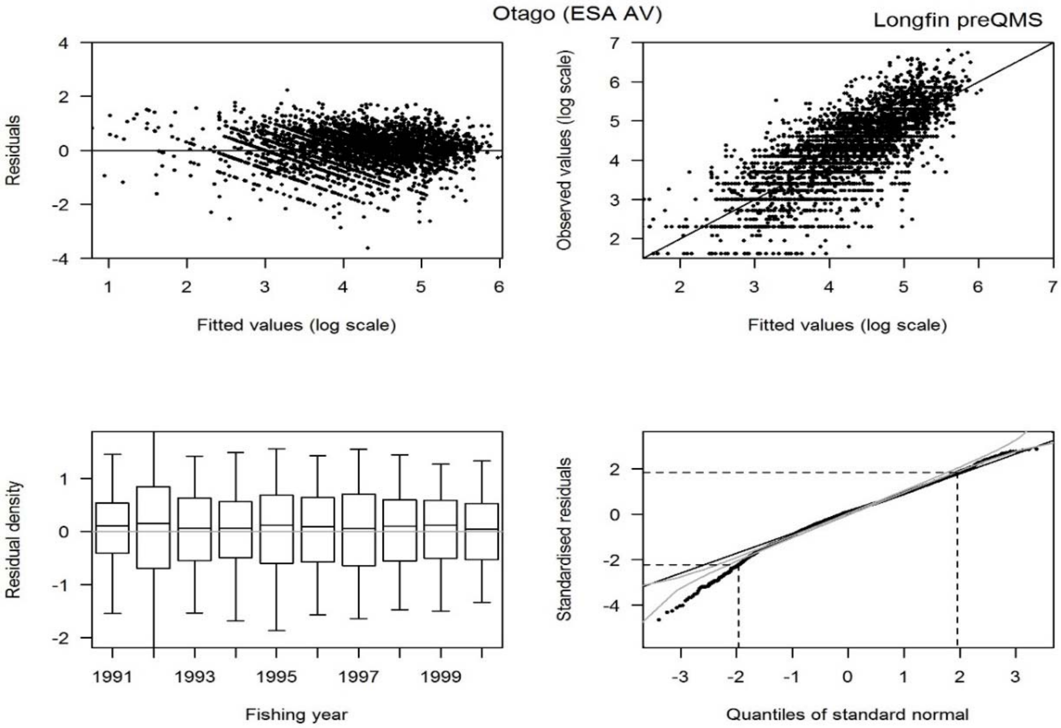



**Figure G22: Residual diagnostic plots for the longfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution (Otago (ESA AV)).**

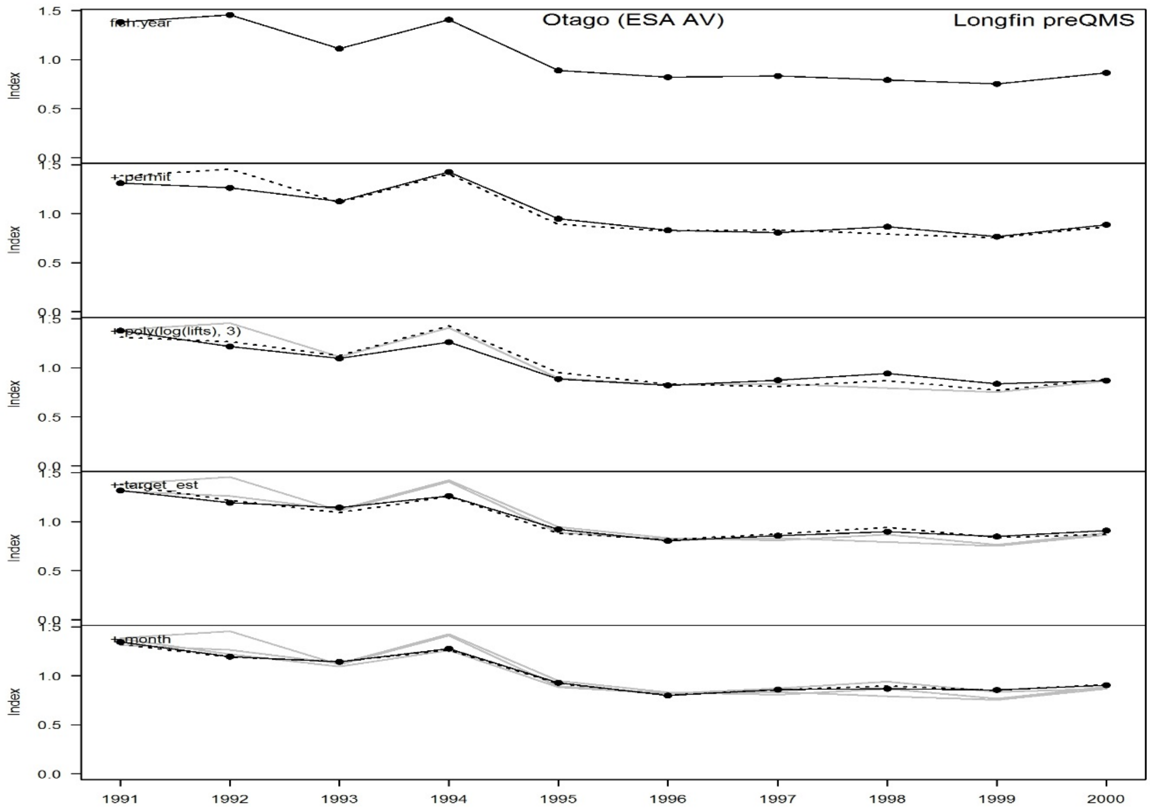



**Figure G23: Step plot for the longfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that (Otago (ESA AV)).**

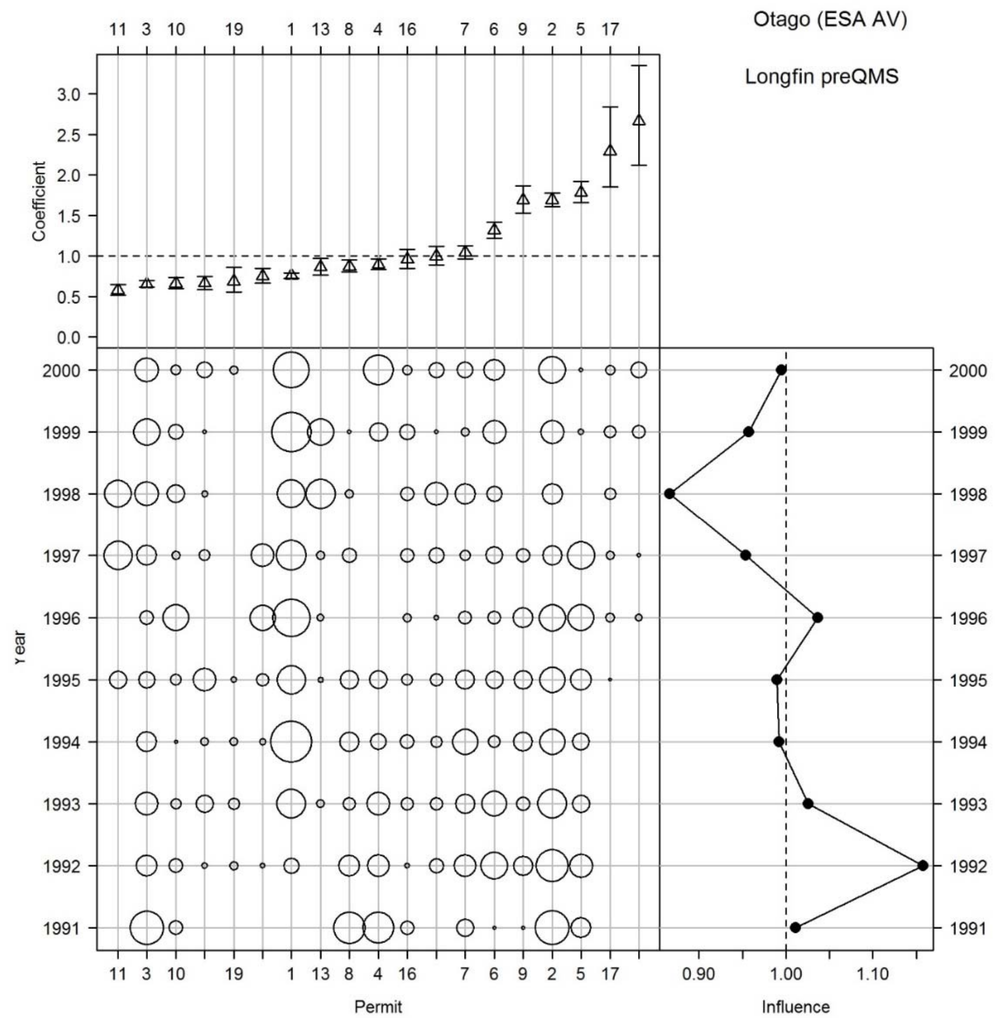



**Figure G24: Influence of permit for the longfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Otago (ESA AV)).**

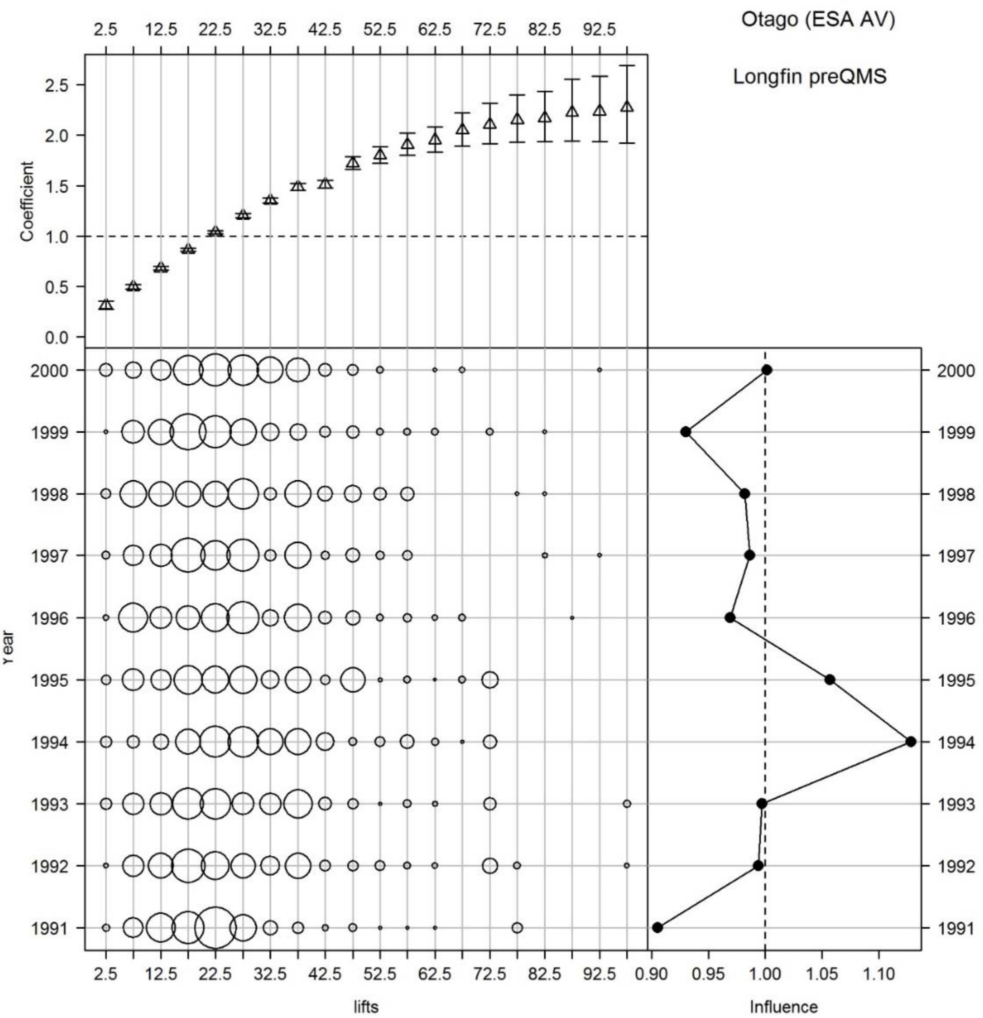



**Figure G25: Influence of lifts for the longfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (Otago (ESA AV)).**

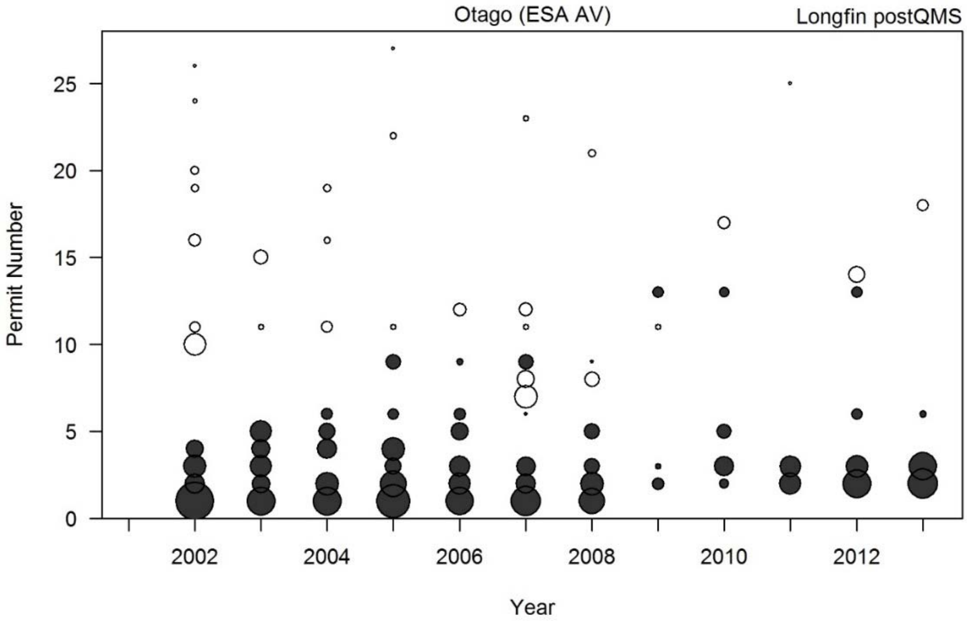



**Figure G26: Relative longfin catch from all fishers (all circles) for the years 2001–02 to 2012–13 (post-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

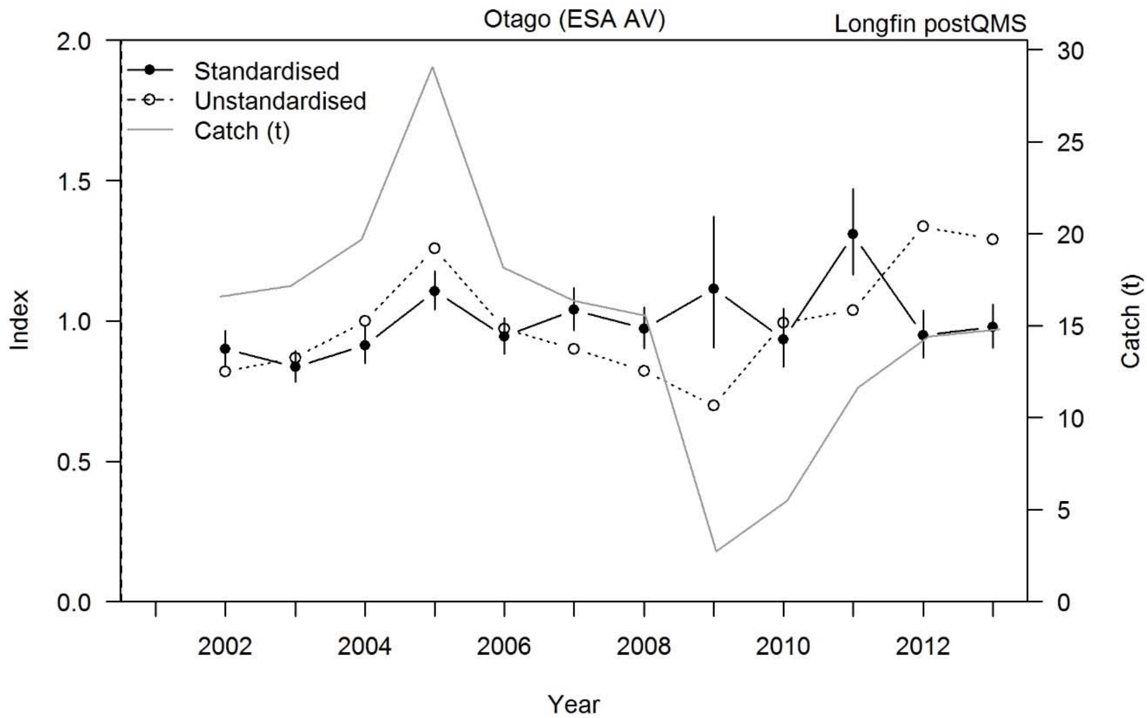



**Figure G27: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) post-QMS for the years 2001–02 to 2012–13. The catch by core fishers is also plotted. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

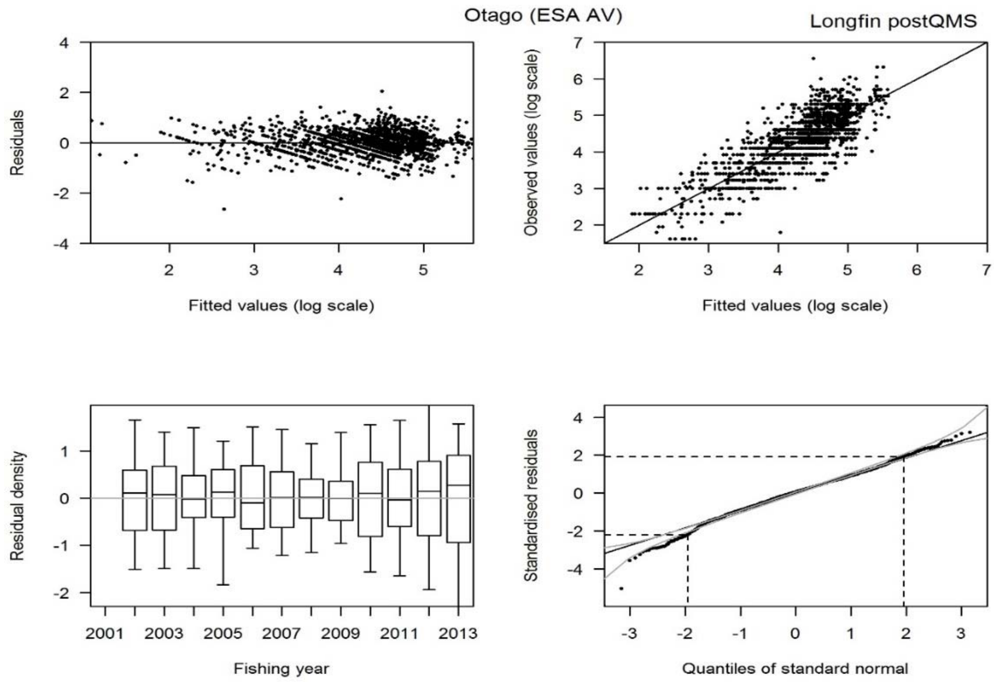



**Figure G28: Residual diagnostic plots for the longfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

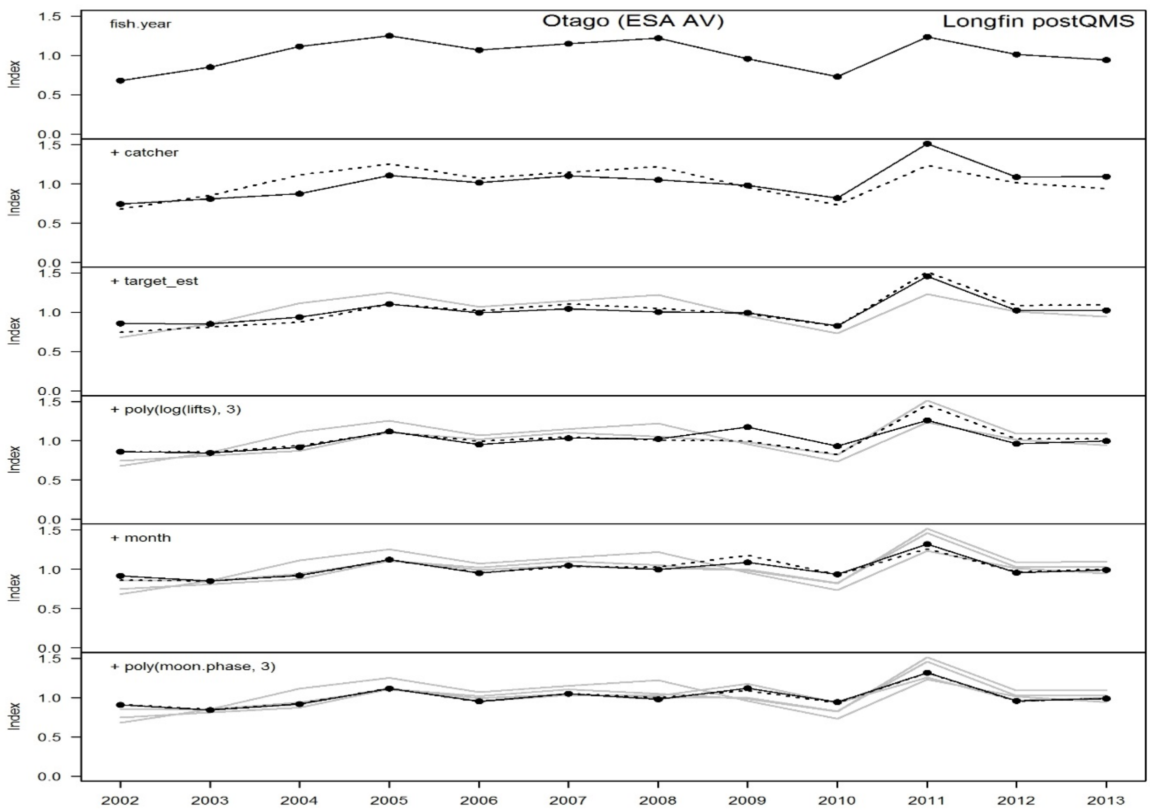



**Figure G29: Step plot for the longfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

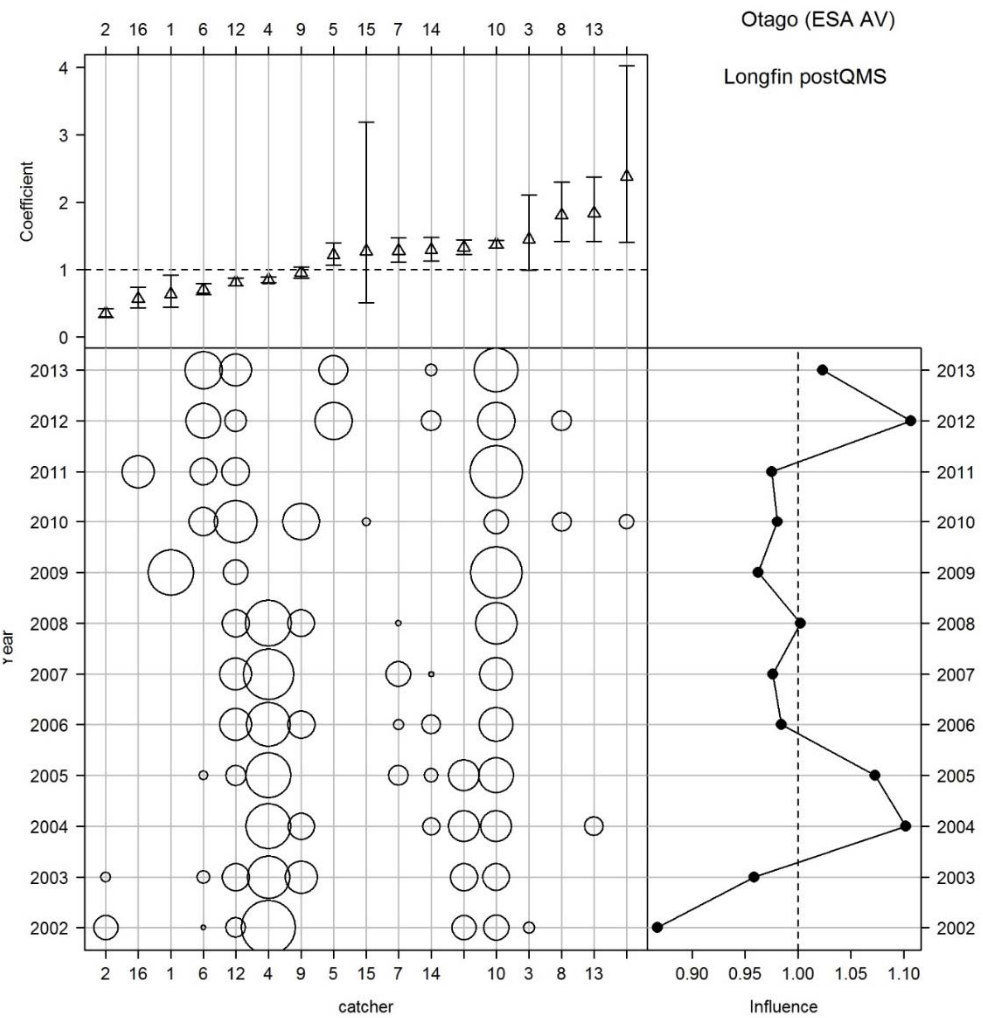



**Figure G30: Influence of catcher for the longfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

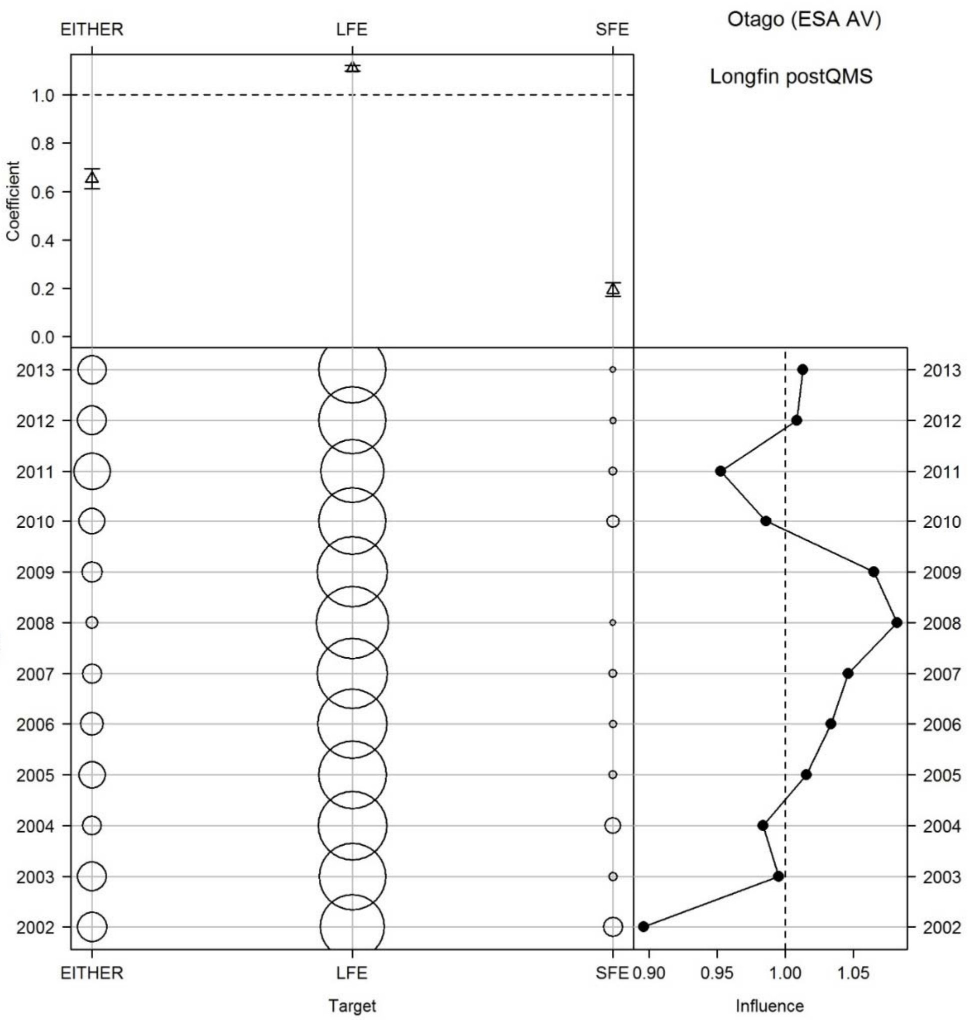



**Figure G31: Influence of target for the longfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (Otago (ESA AV)).**

**Appendix H: ESA 20 (AW)**

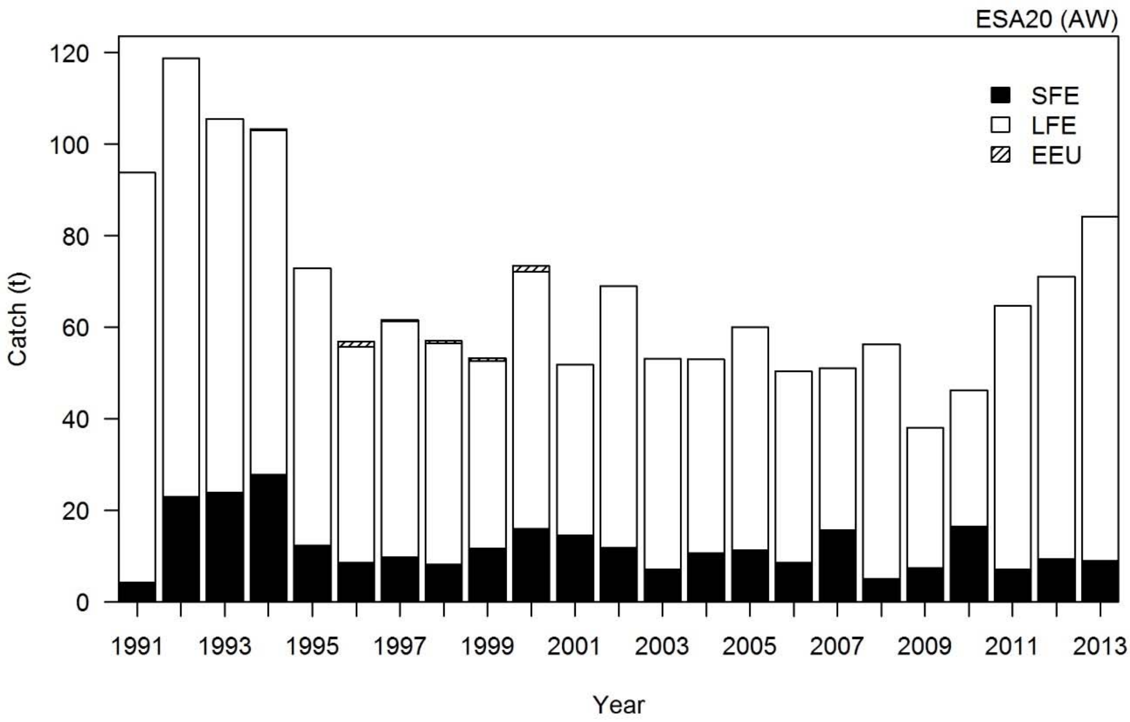



**Figure H1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (ESA20 (AW)).**

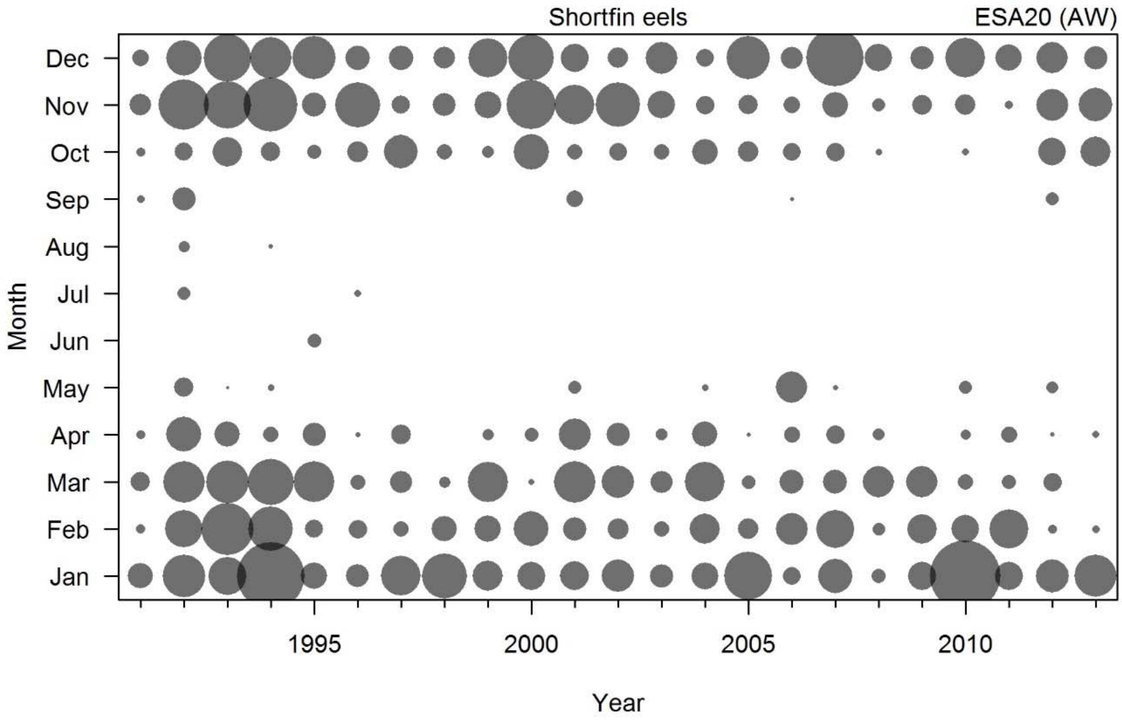



**Figure H2: Shortfin eel catch by month for the years 1990–91 to 2012–13 (ESA20 (AW)).**

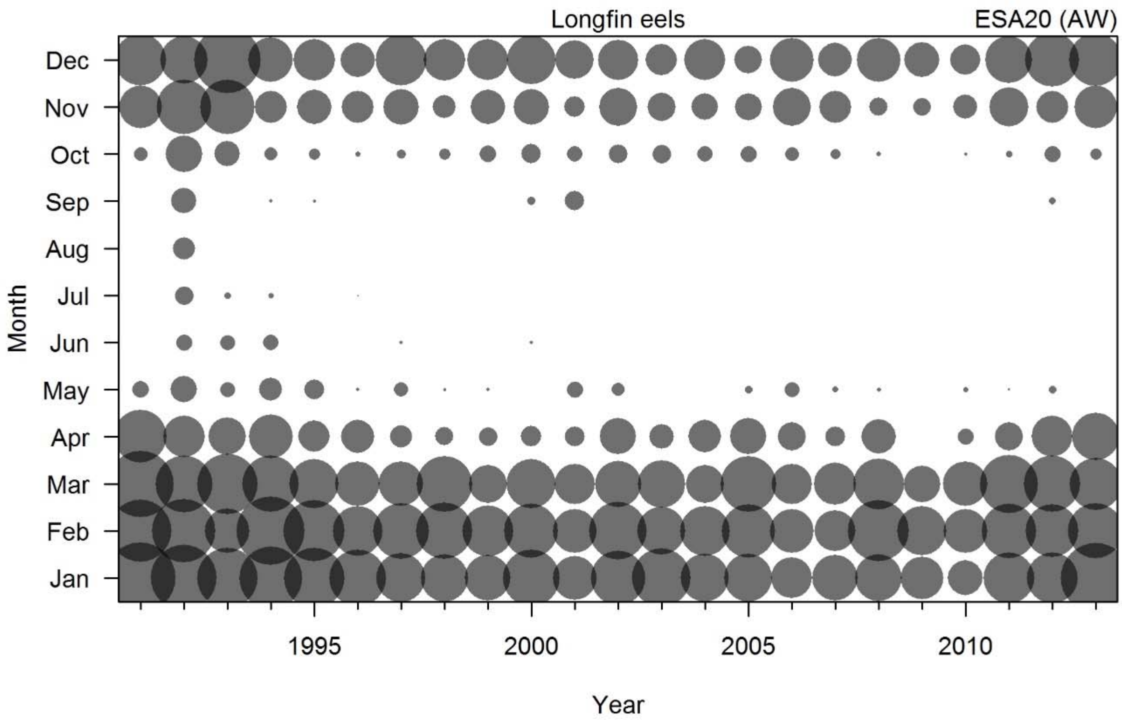



**Figure H3: Longfin eel catch by month for the years 1990–91 to 2012–13 (ESA20 (AW)).**

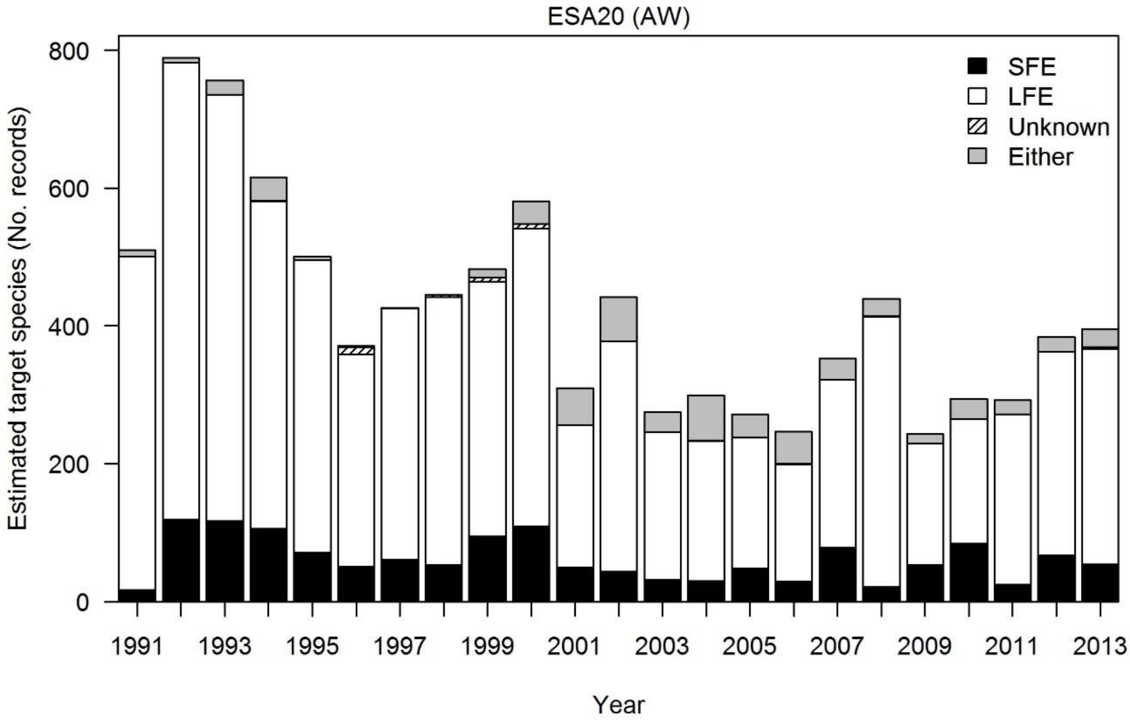



**Figure H4: Reconstructed target species for the years 1990–91 to 2012–13 (ESA20 (AW)).**

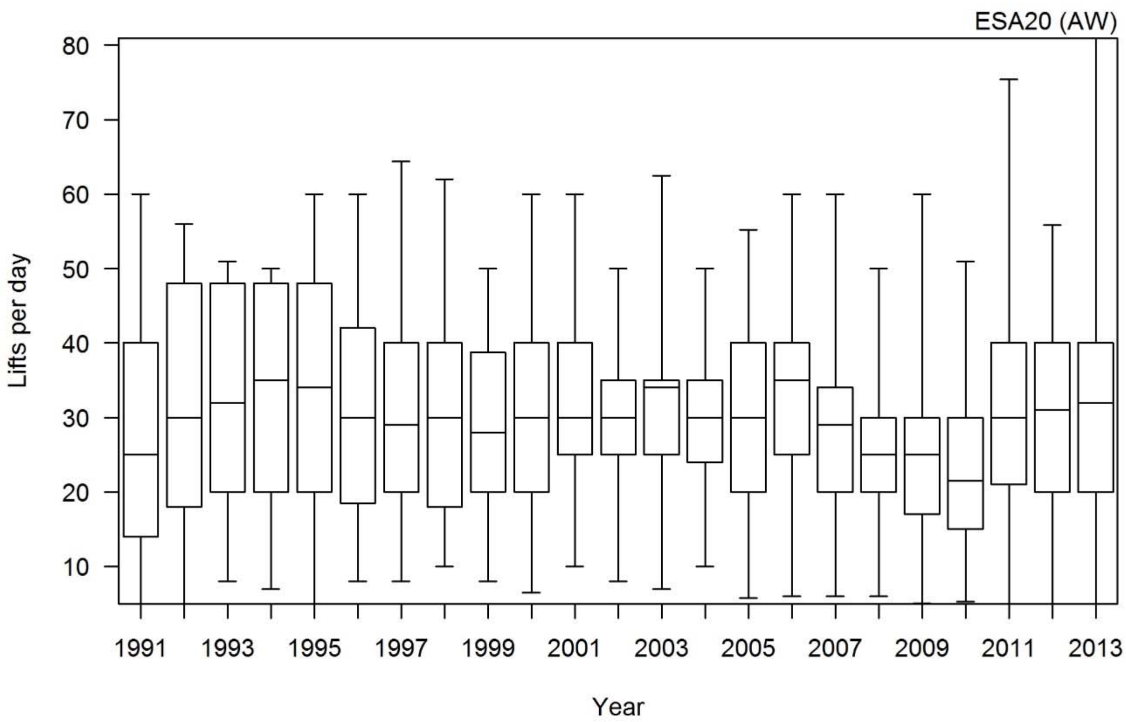



**Figure H5: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the median, the top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (ESA20 (AW)).**

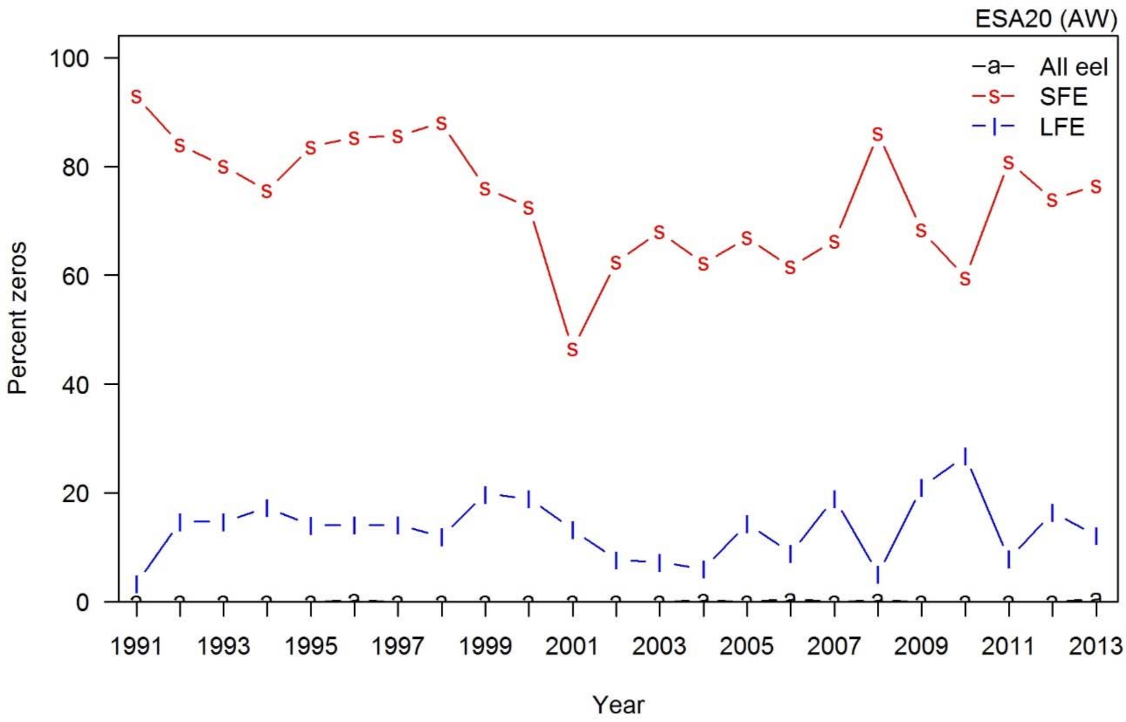



**Figure H6: Proportion of valid zero records for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13. Excludes zeros associated with reporting EEU (unclassified) (ESA20 (AW)).**

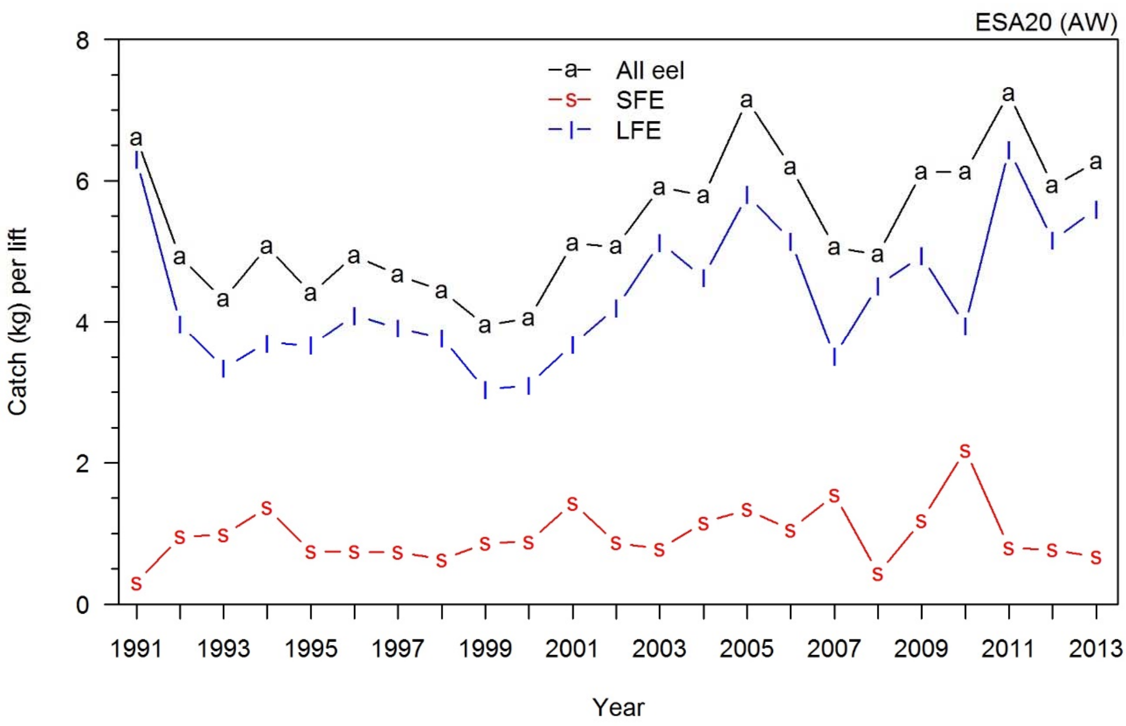



**Figure H7: Unstandardised catch per lift (total kg/total lifts) for all eels, shortfin (SFE), and longfin (LFE) for the years 1990–91 to 2012–13 (ESA20 (AW)).**

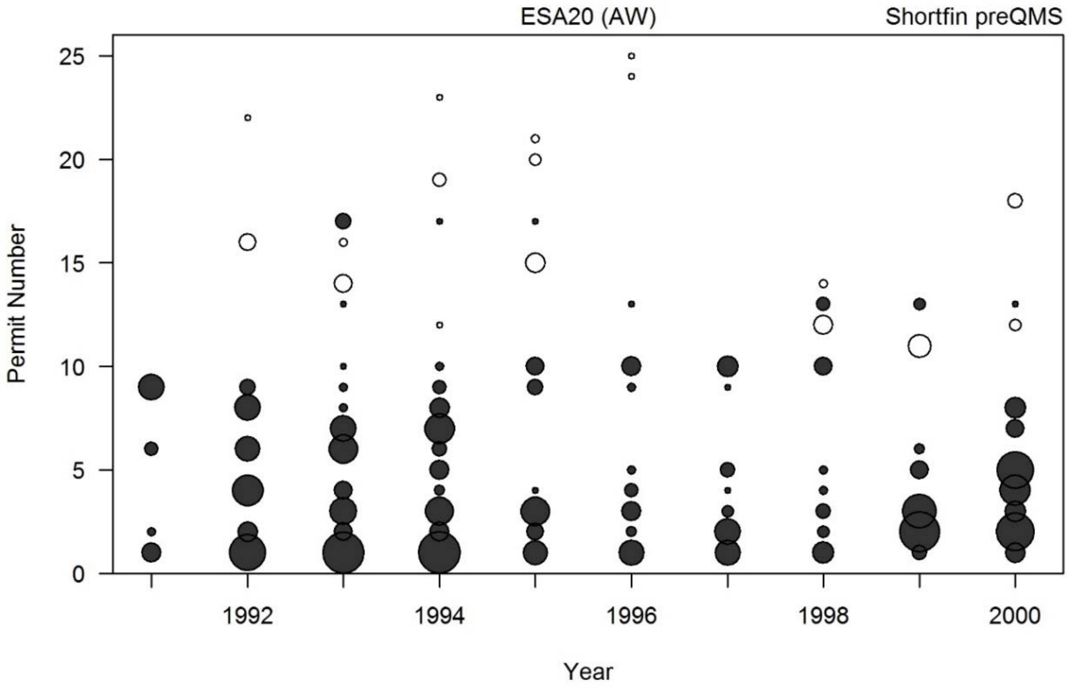



**Figure H8: Relative shortfin catch from all fishers (all circles) for the years 1990–91 to 1999–2000 (pre-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses (ESA20 (AW)).**

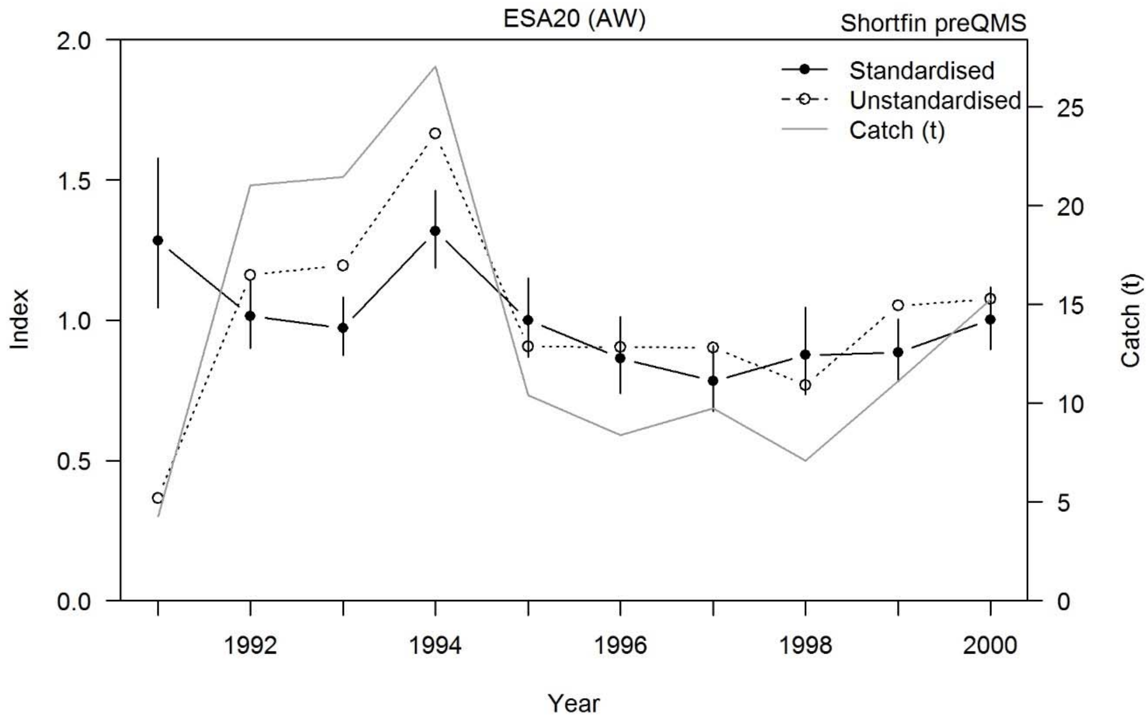



**Figure H9: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000. The catch by core fishers is also plotted (ESA20 (AW)).**

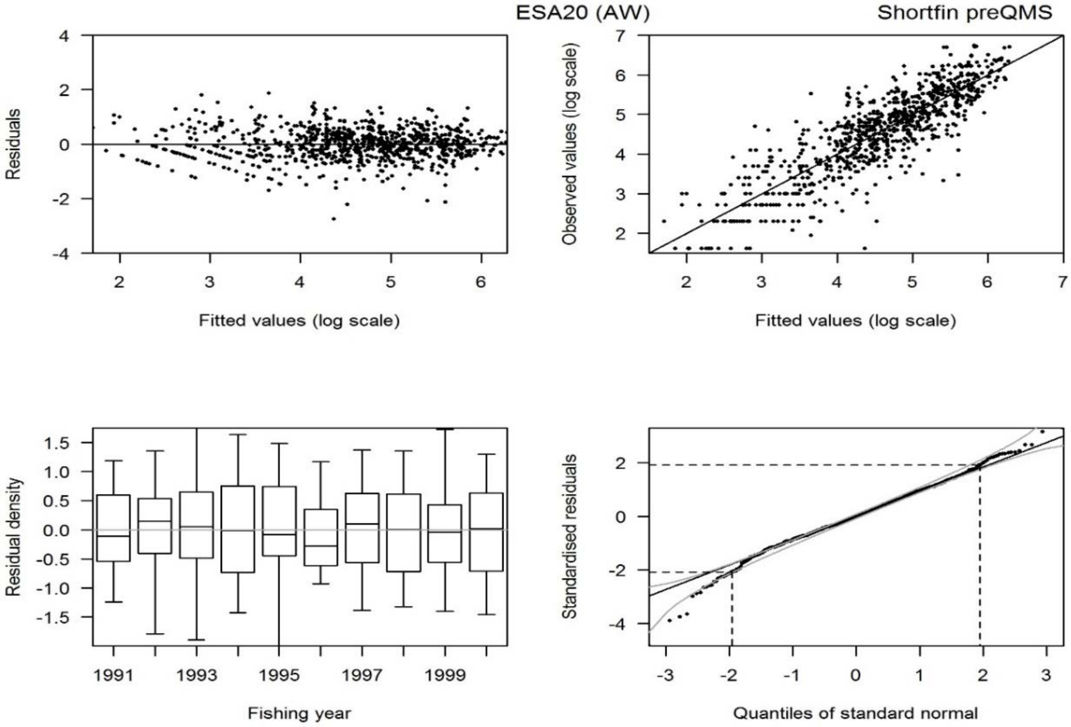



**Figure H10: Residual diagnostic plots for the shortfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution (ESA20 (AW)).**

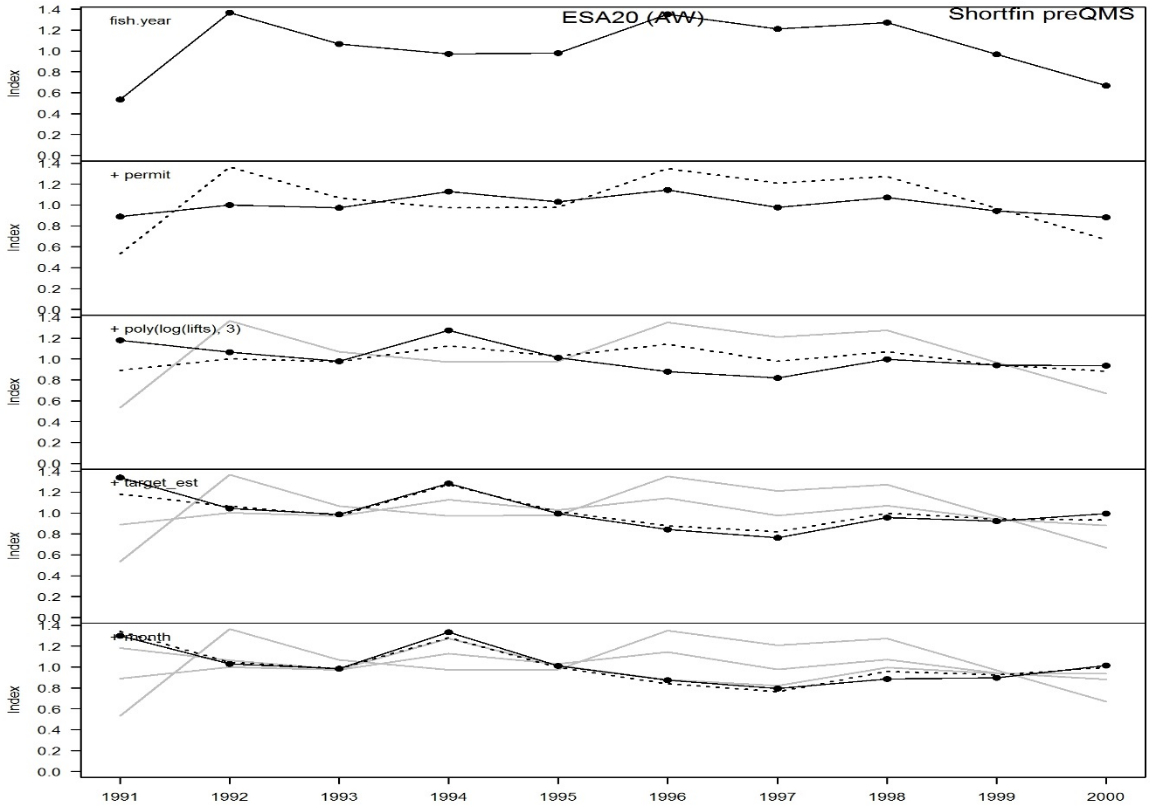



**Figure H11: Step plot for the shortfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that (ESA20 (AW)).**

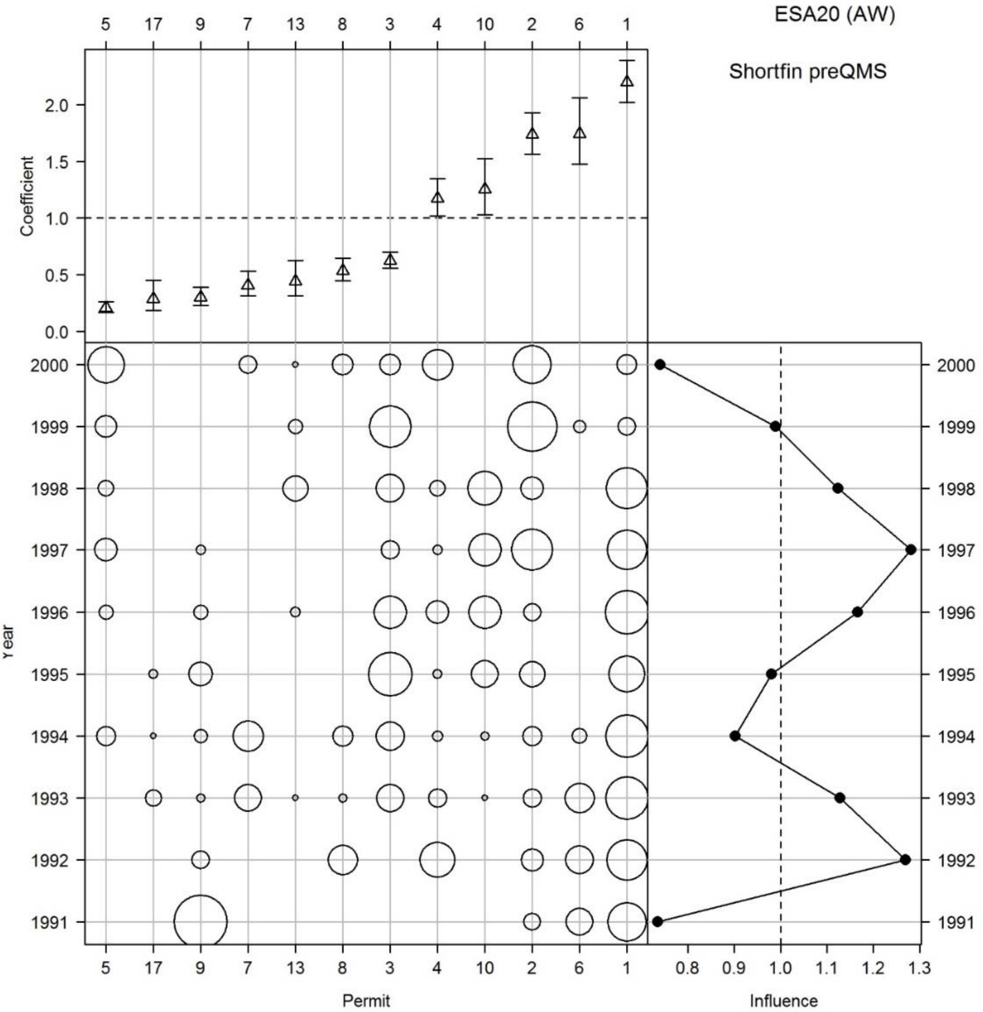



**Figure H12: Influence of permit for the shortfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (ESA20 (AW)).**

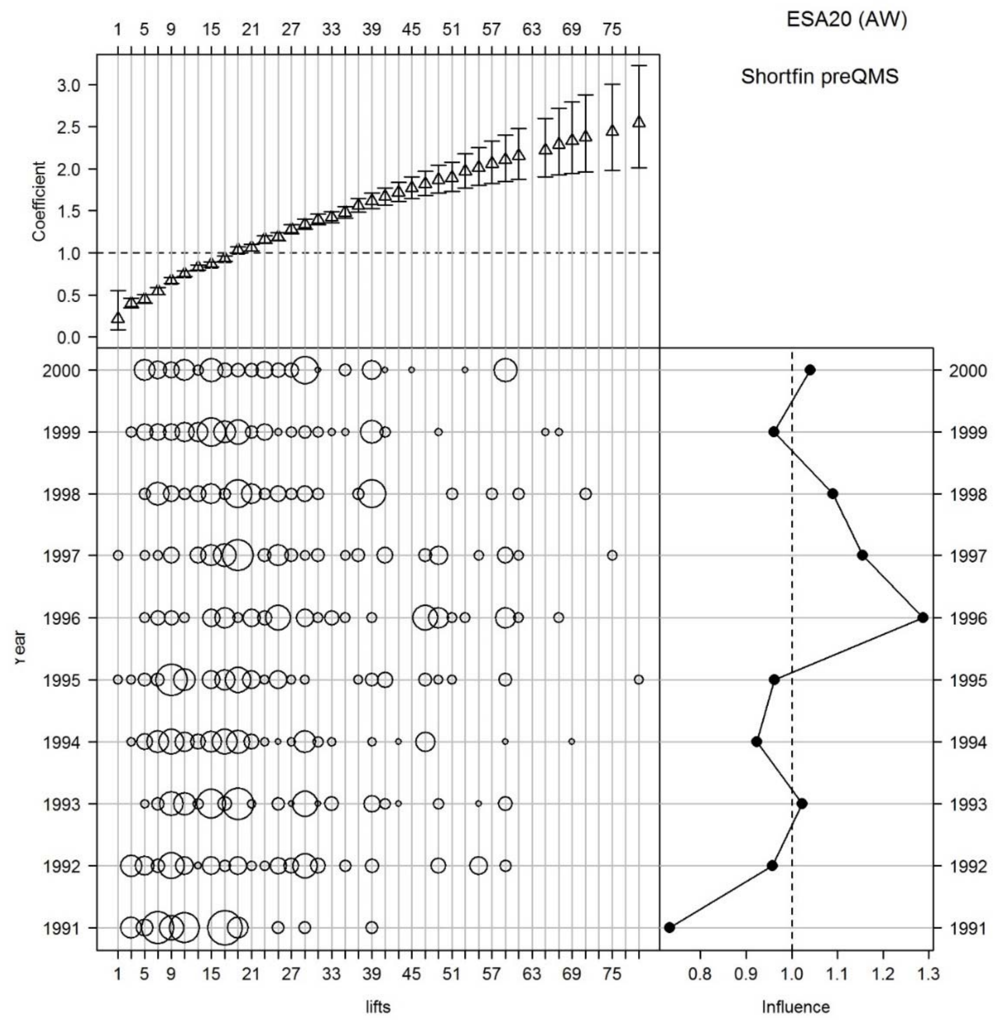



**Figure H13: Influence of lifts for the shortfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (ESA20 (AW)).**

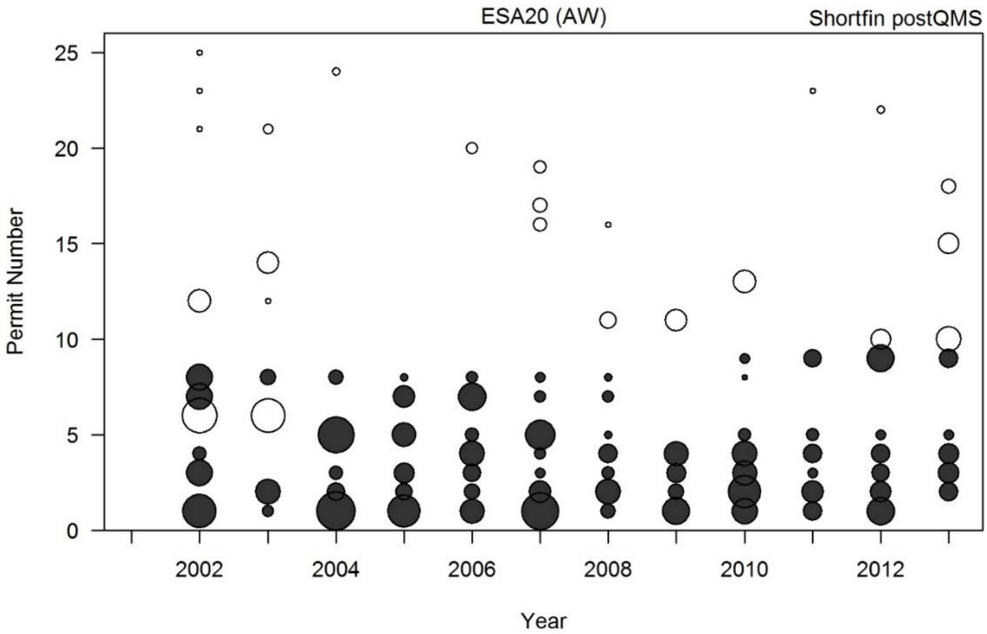



**Figure H14: Relative shortfin catch from all fishers (all circles) for the years 2001–02 to 2012–13 (post-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

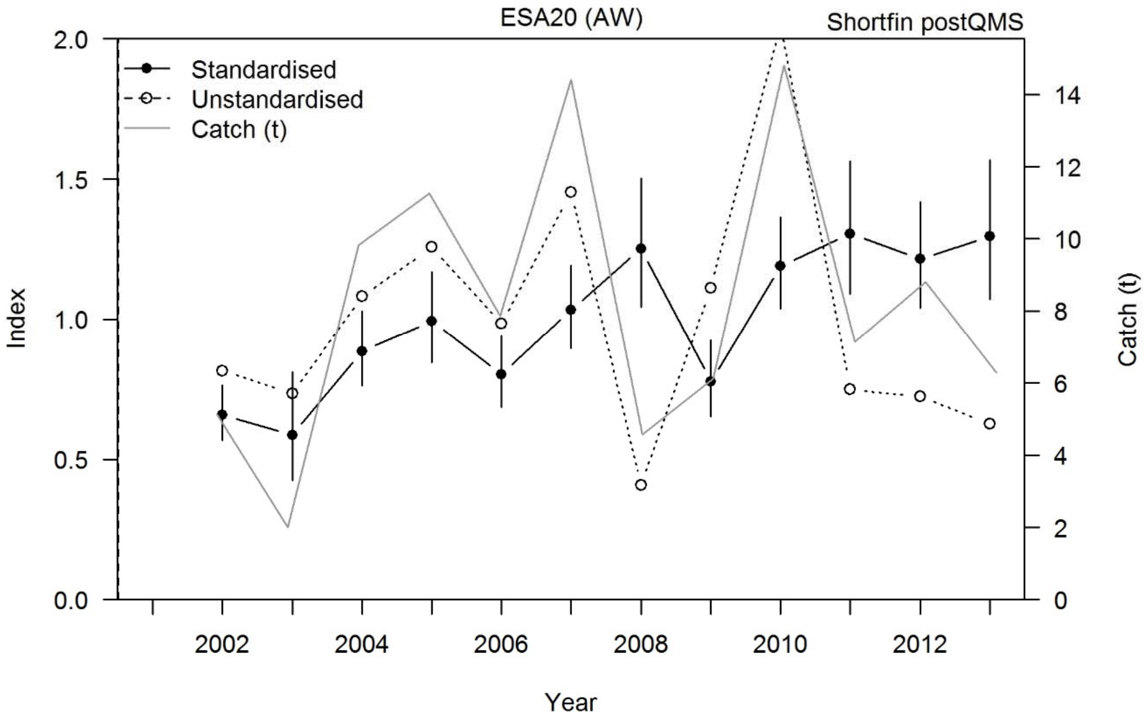



**Figure H15: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for shortfin (core fishers) post-QMS for the years 2001–02 to 2012–13. The catch by core fishers is also plotted. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

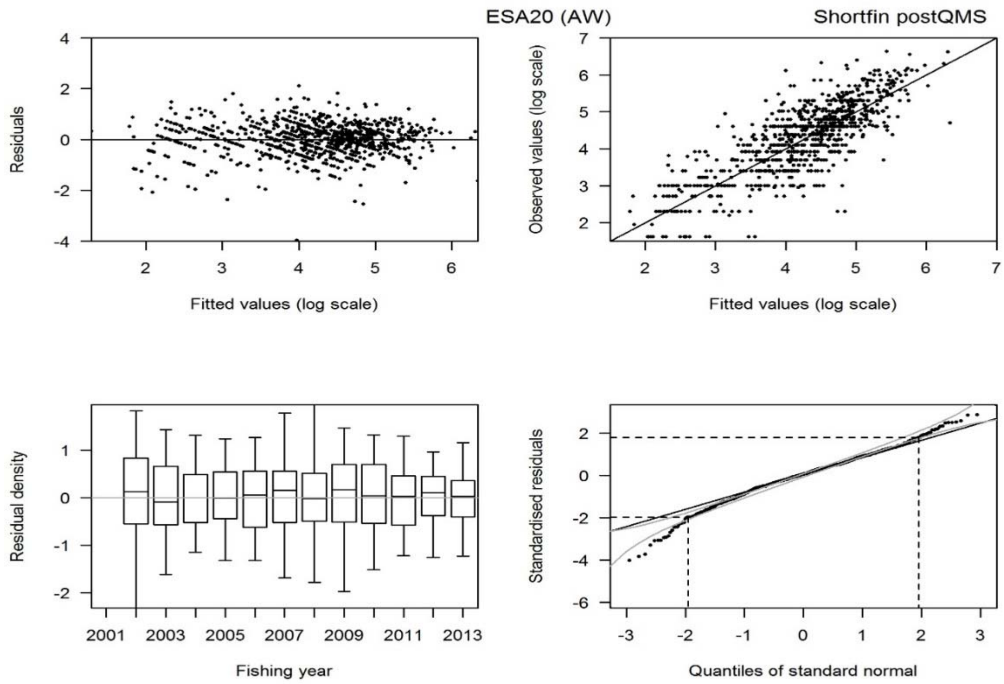



**Figure H16: Residual diagnostic plots for the shortfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

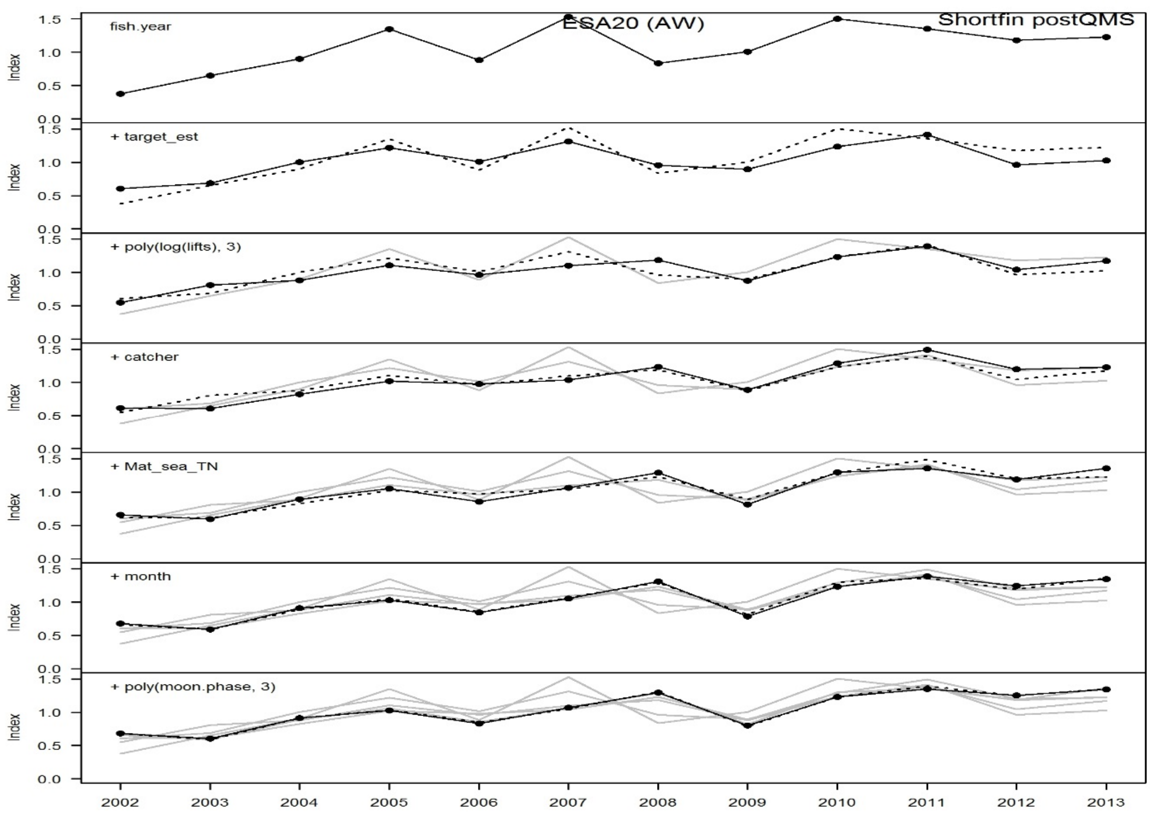



**Figure H17: Step plot for the shortfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

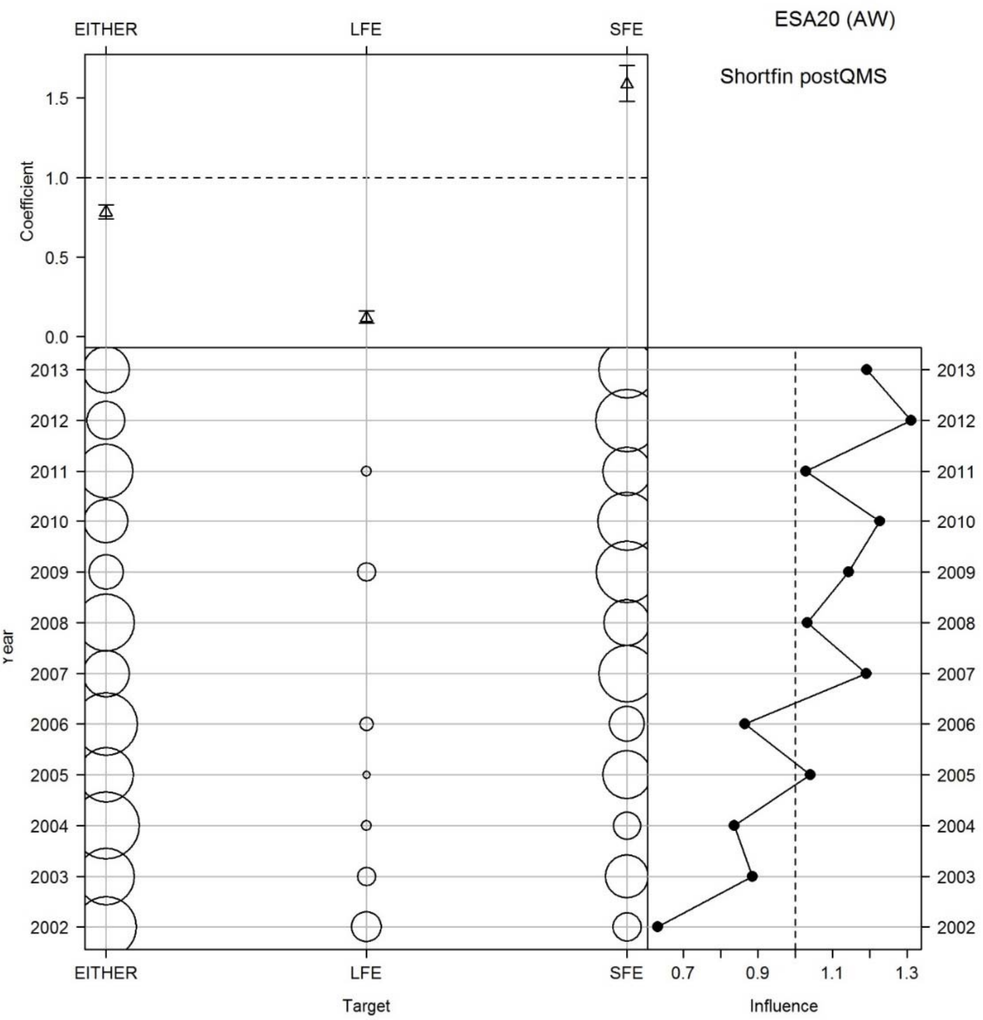



**Figure H18: Influence of catcher for the shortfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

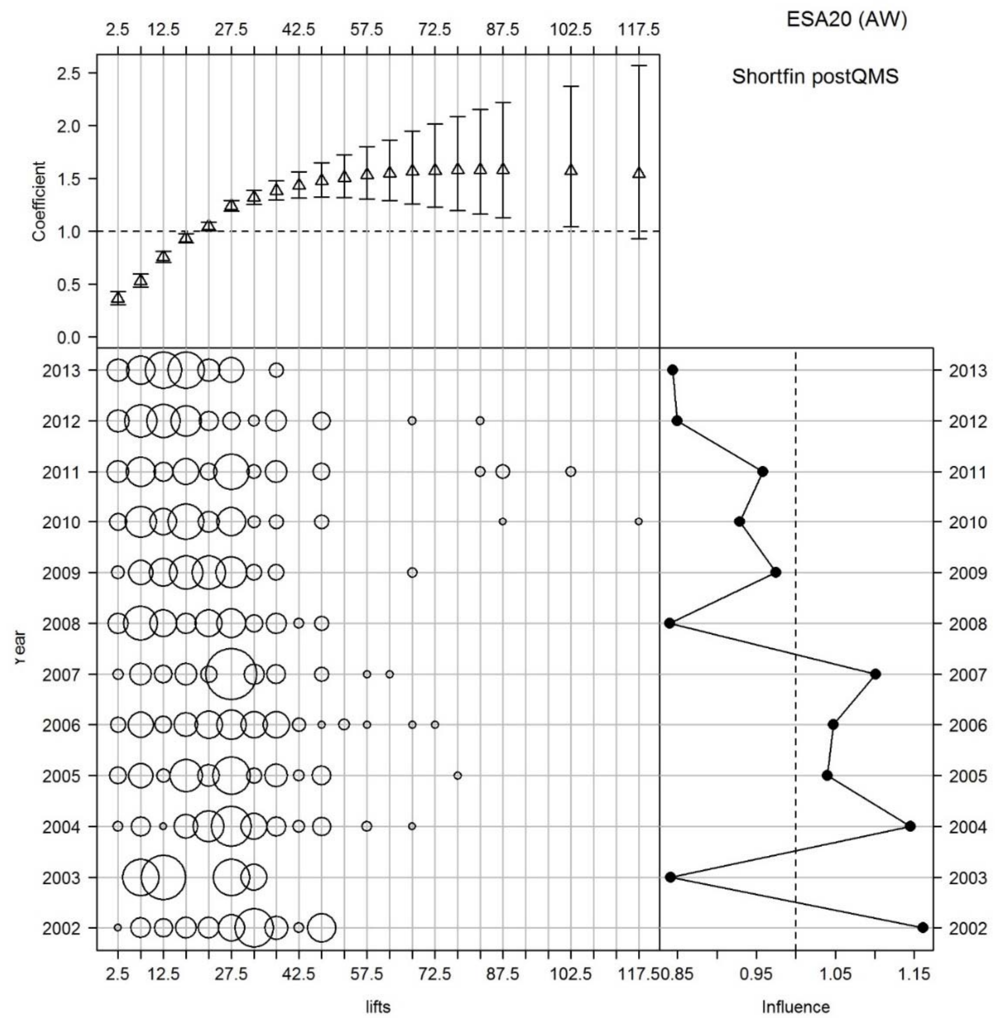



**Figure H19: Influence of target species for the shortfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

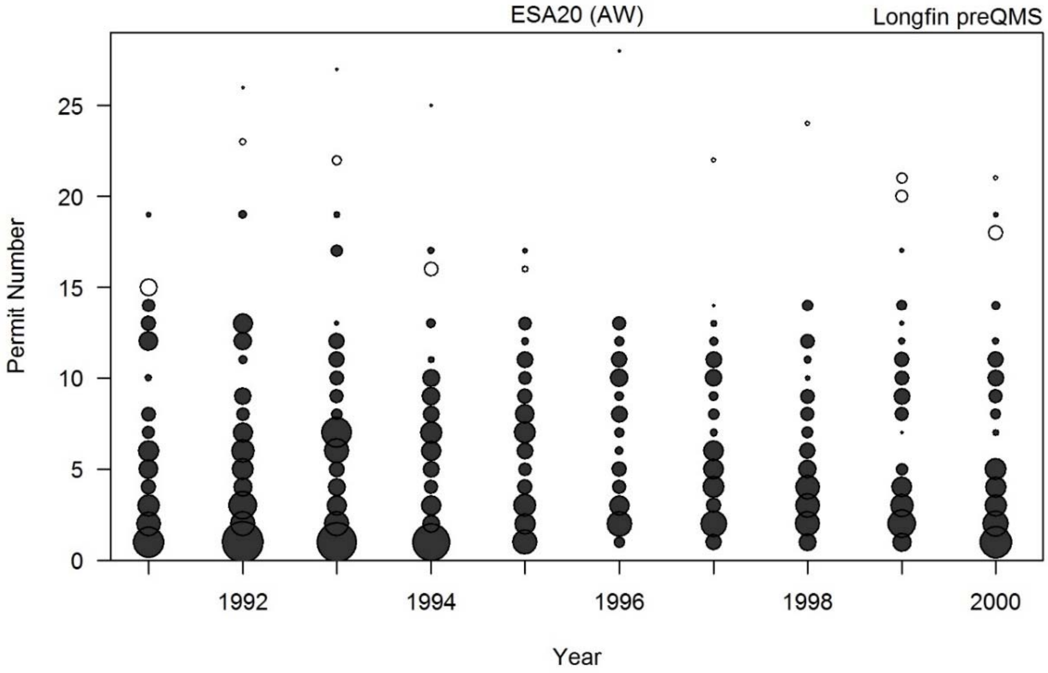



**Figure H20: Relative longfin catch from all fishers (all circles) for the years 1990–91 to 1999–2000 (pre-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses (ESA20 (AW)).**

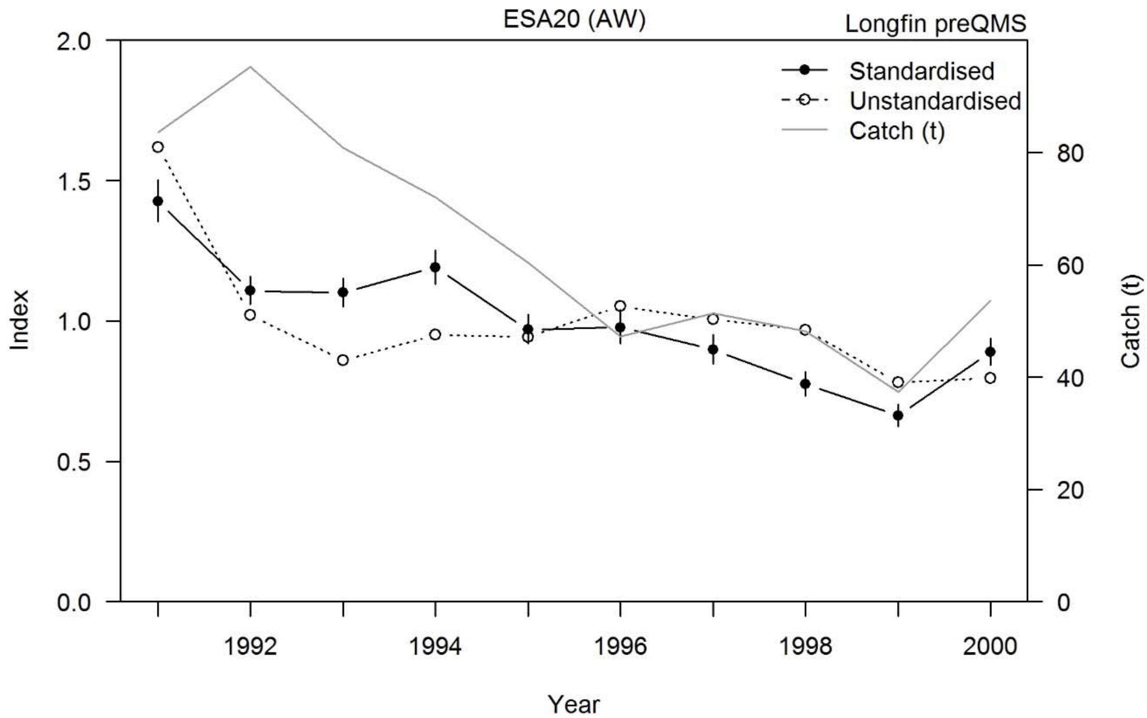



**Figure H21: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) pre-QMS for the years 1990–91 to 1999–2000. The catch by core fishers is also plotted (ESA20 (AW)).**

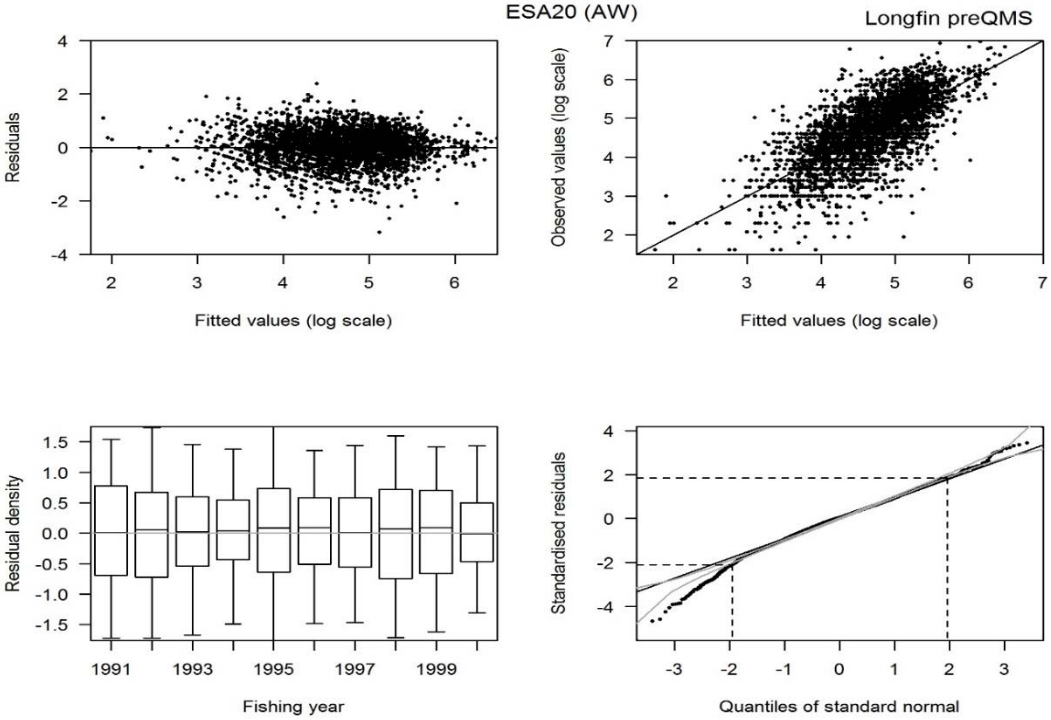



**Figure H22: Residual diagnostic plots for the longfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution (ESA20 (AW)).**

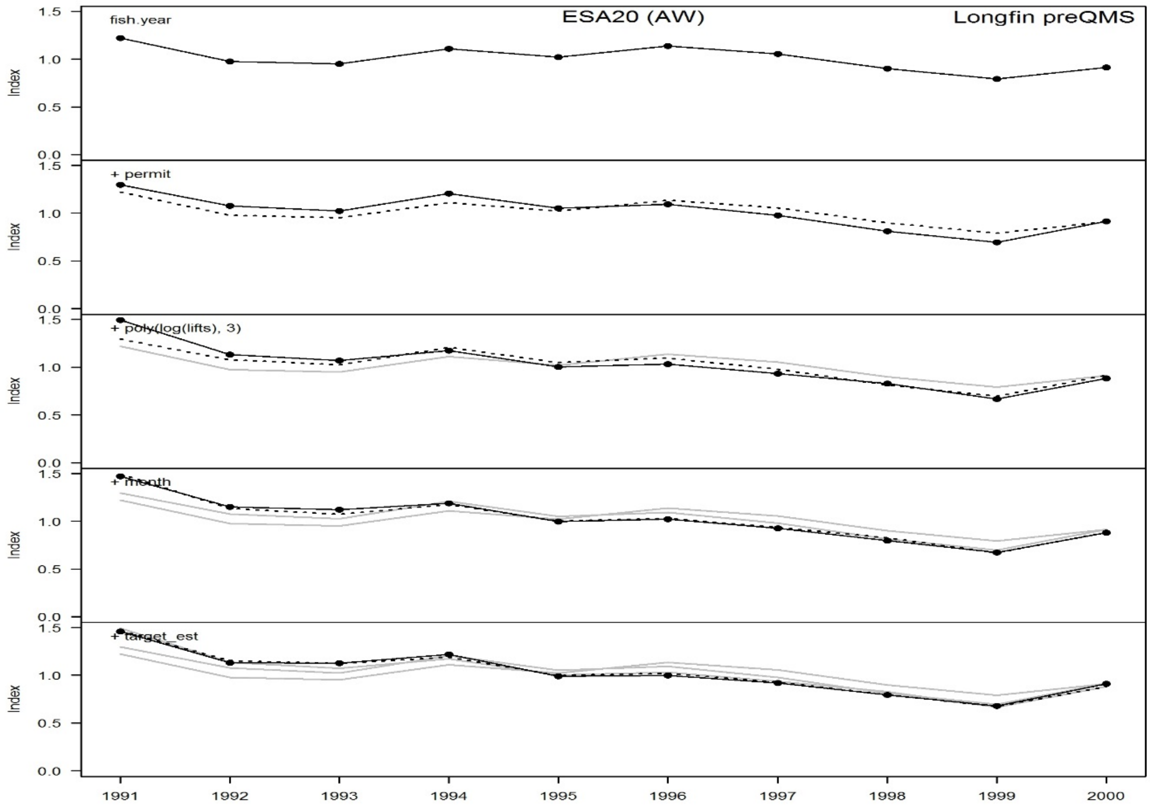



**Figure H23: Step plot for the longfin eel CPUE model for the years 1990–91 to 1999–2000 (pre-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that (ESA20 (AW)).**

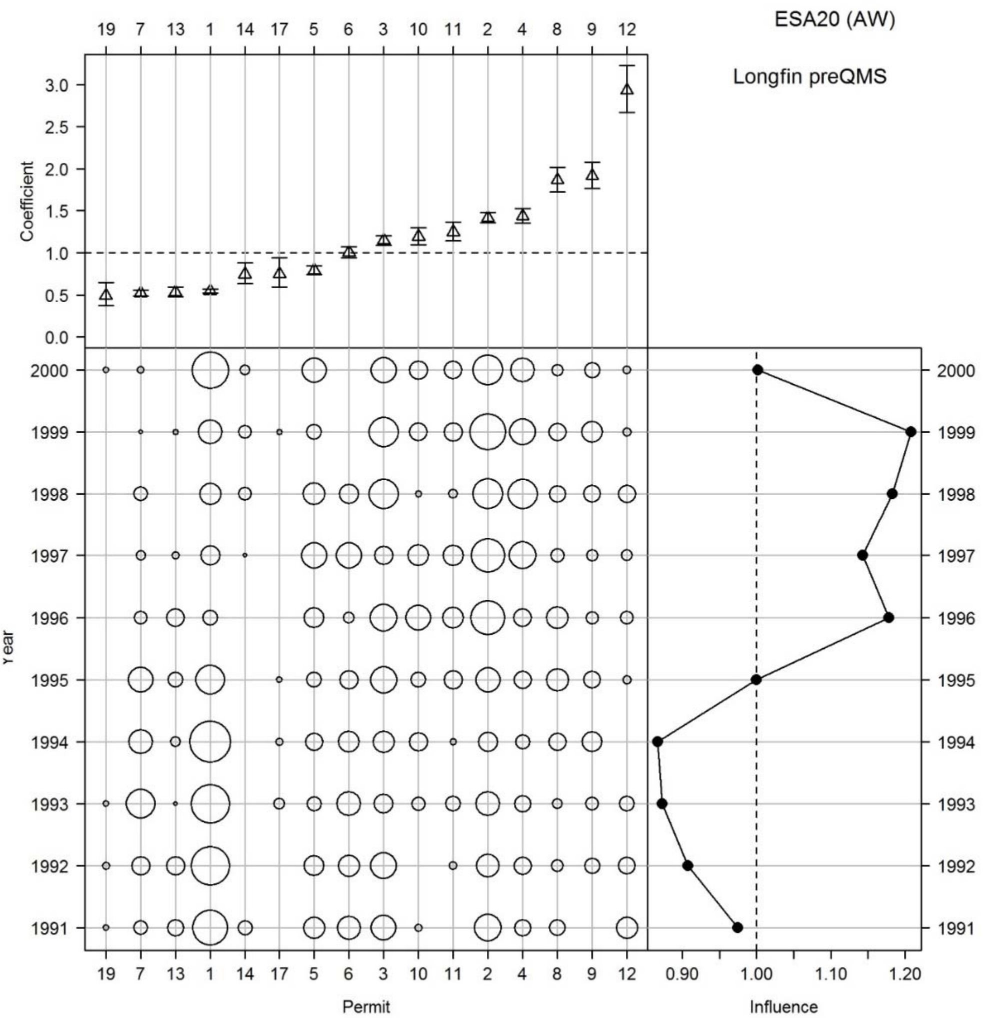



**Figure H24: Influence of permit for the longfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (ESA20 (AW)).**

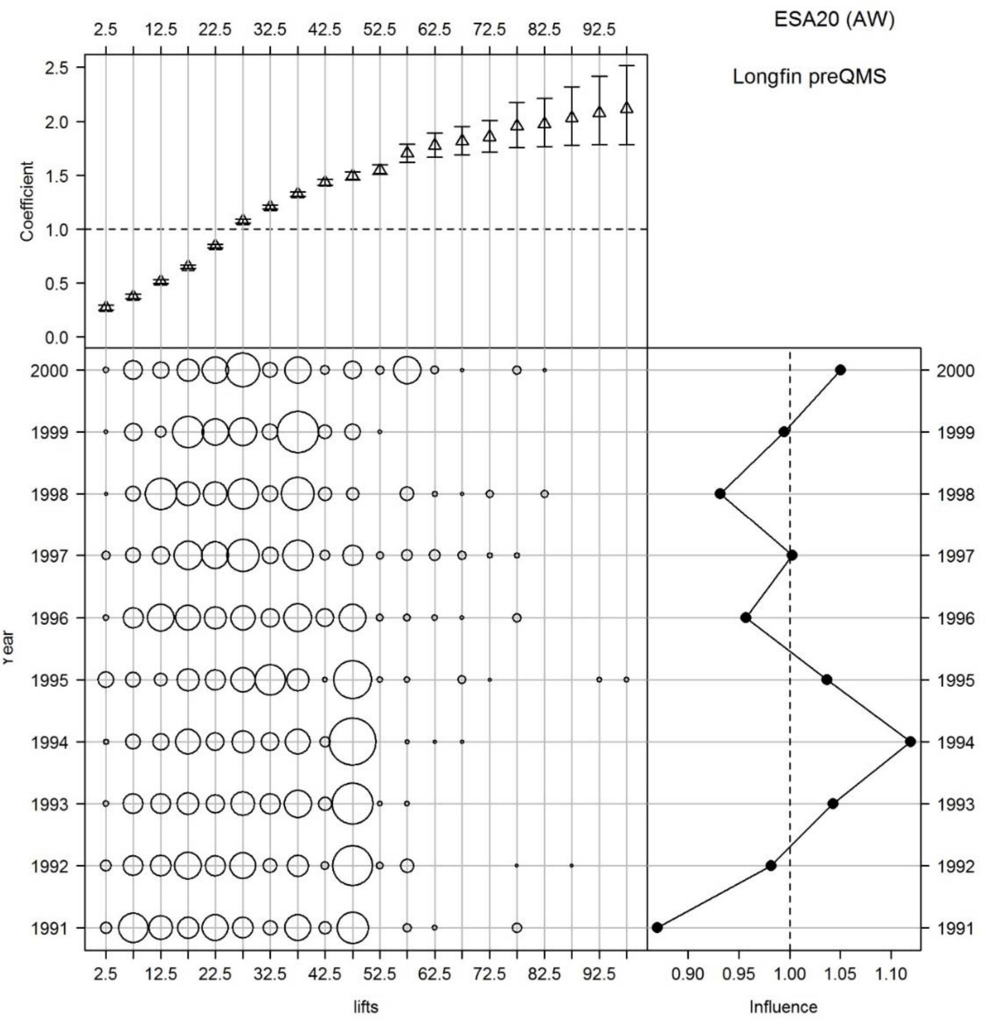



**Figure H25: Influence of lifts for the longfin CPUE model for the years 1990–91 to 1999–2000 (pre-QMS) (ESA20 (AW)).**

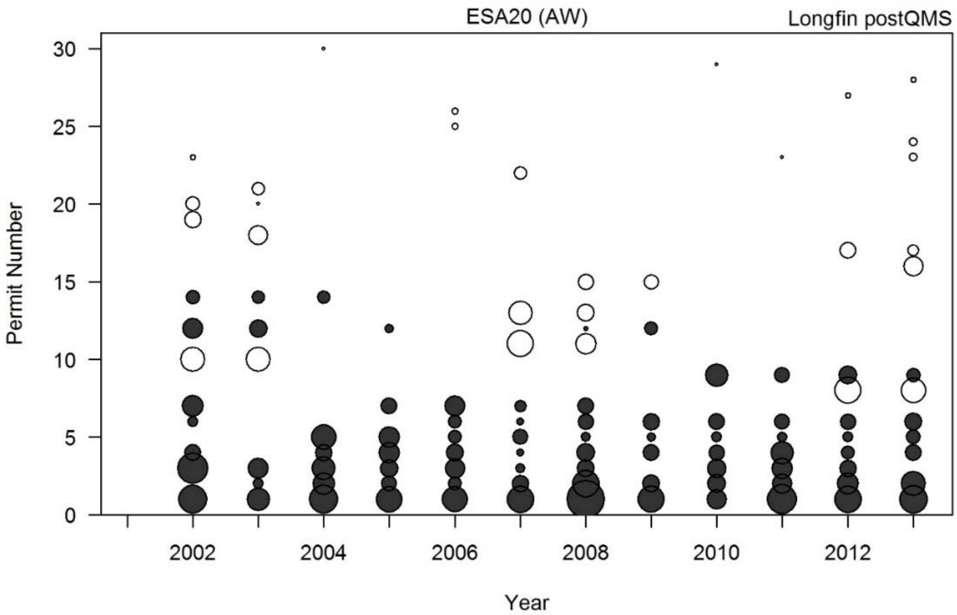



**Figure H26: Relative longfin catch from all fishers (all circles) for the years 2001–02 to 2012–13 (post-QMS), and for core fishers (dark shaded circles) included in the catch per unit effort analyses. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

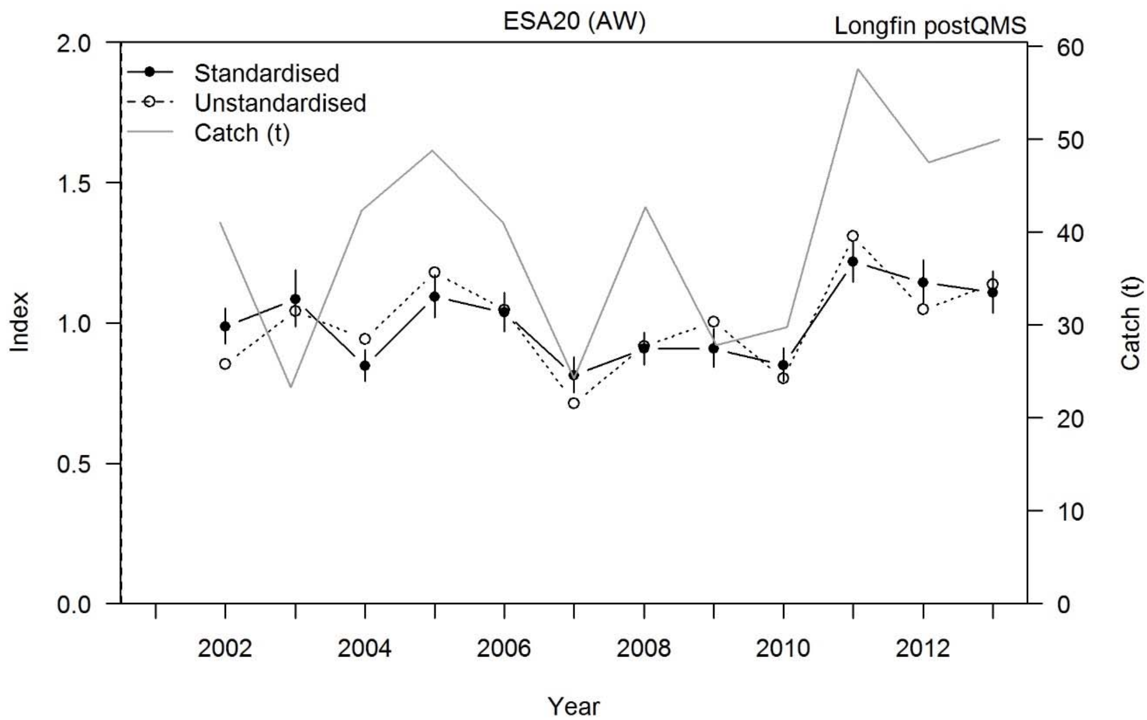



**Figure H27: Indices of unstandardised (catch per lift for all fishers) and standardised CPUE for longfin (core fishers) post-QMS for the years 2001–02 to 2012–13. The catch by core fishers is also plotted. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

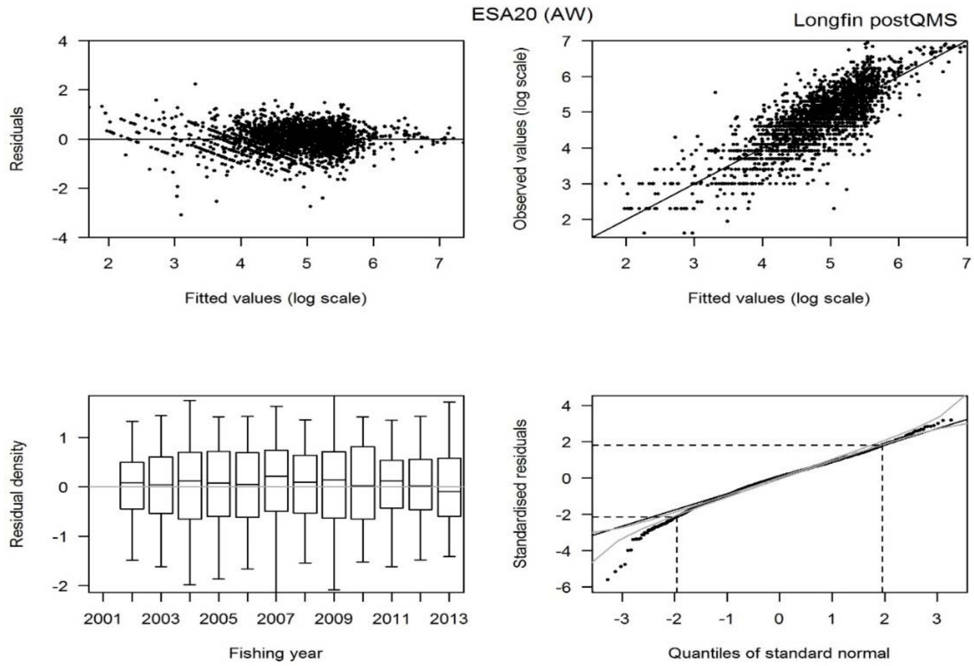



**Figure H28: Residual diagnostic plots for the longfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). The grey lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

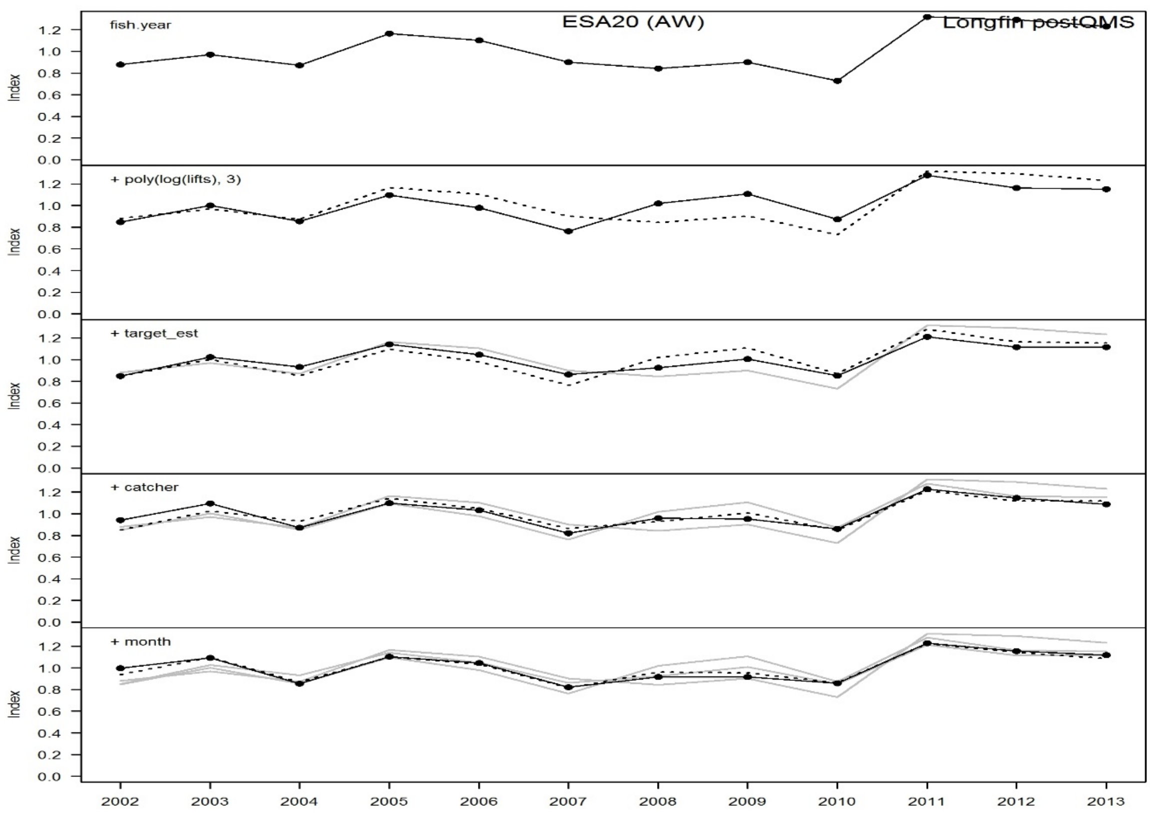



**Figure H29: Step plot for the longfin eel CPUE model for the years 2001–02 to 2012–13 (post-QMS). Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index shown by the dotted line and the grey lines for steps before that. 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

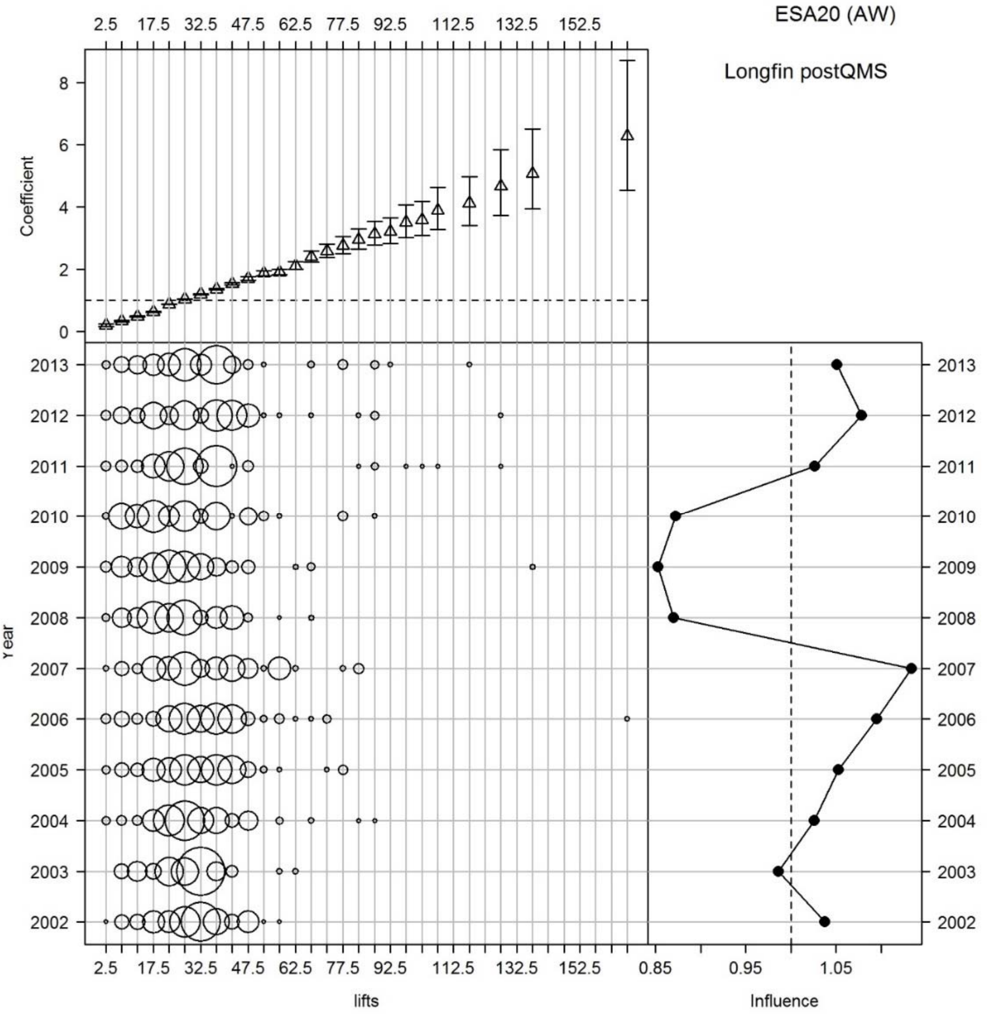



**Figure H30: Influence of catcher for the longfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

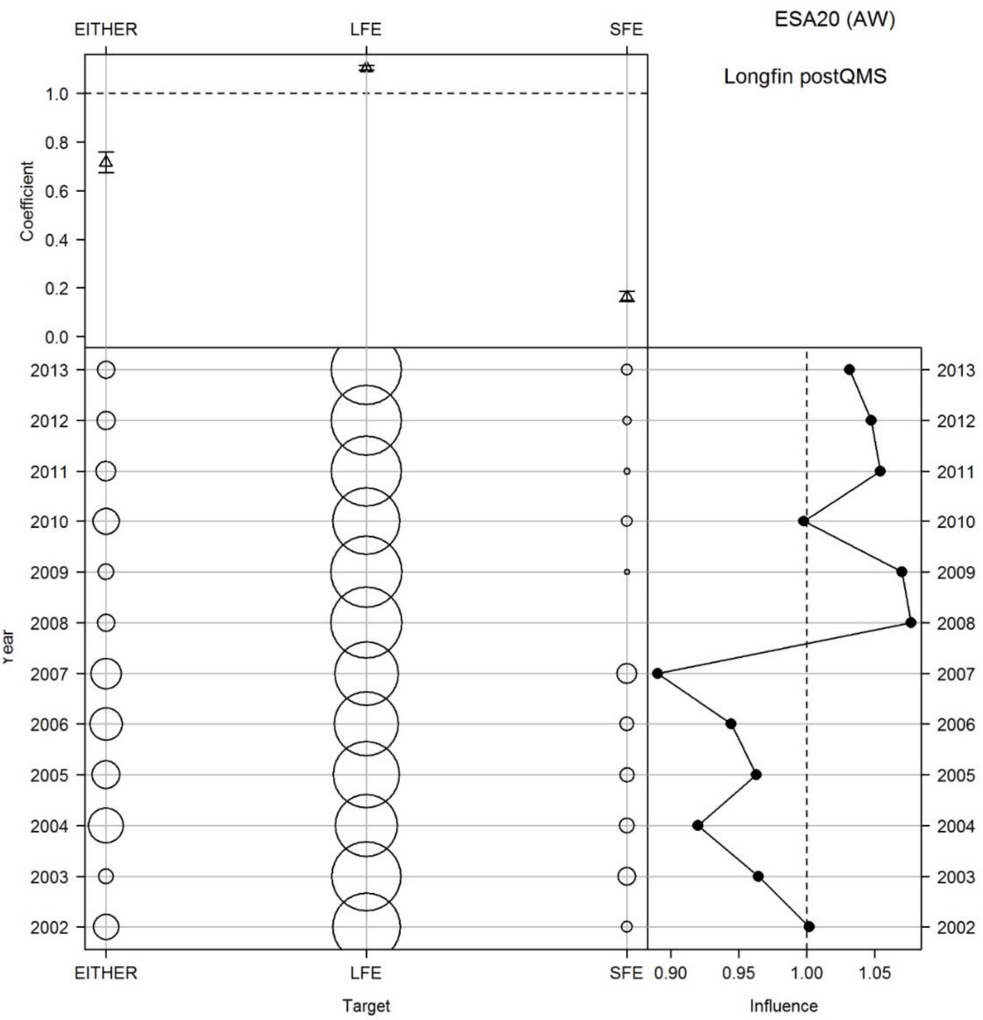



**Figure H31: Influence of target for the longfin CPUE model for the years 2001–02 to 2012–13 (post-QMS). 2000–01 not included in the model as the predictor variable 'catcher' only exists from 2001–02 onward (ESA20 (AW)).**

## Appendix I: ESA AS1

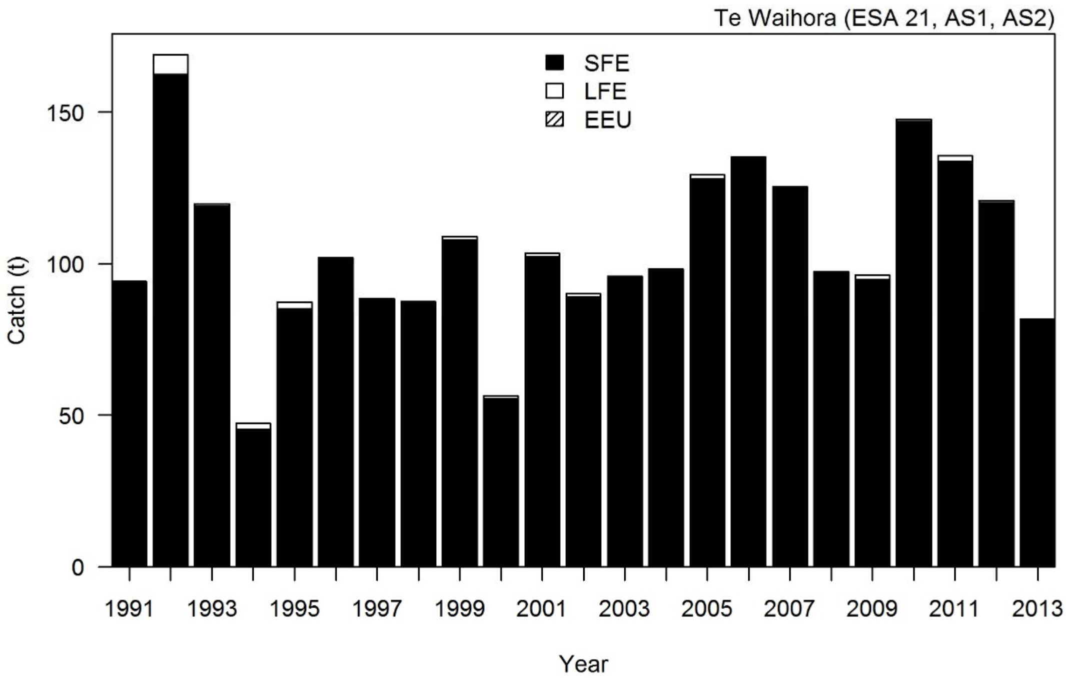



**Figure I1: Total estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2012–13 (Te Waihora (ESA 21, AS1, AS2)).**

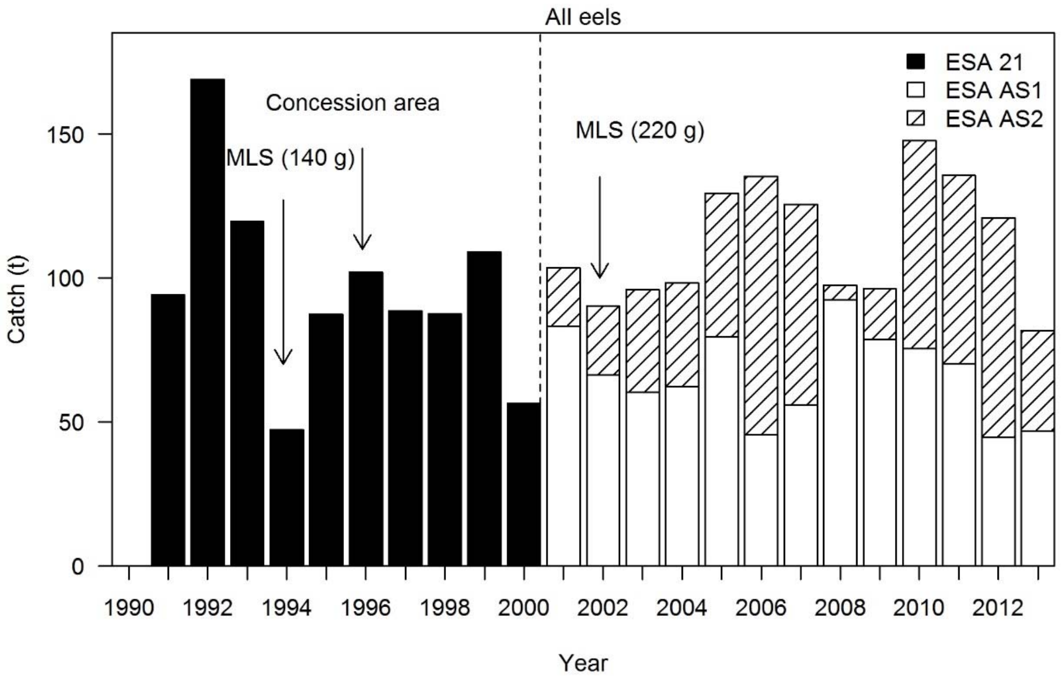



**Figure I2: Total estimated commercial catch of all eels (shortfin and longfin combined) by eel statistical area for the years 1990–91 to 2012–13. Minimum legal size (MLS) introduced in 1996 increasing by 10 g per year until it reached 220 g in 2001. The concession area was introduced in 1996, but ESA AS codes were not valid until 2001 (Te Waihora (ESA 21, AS1, AS2)).**

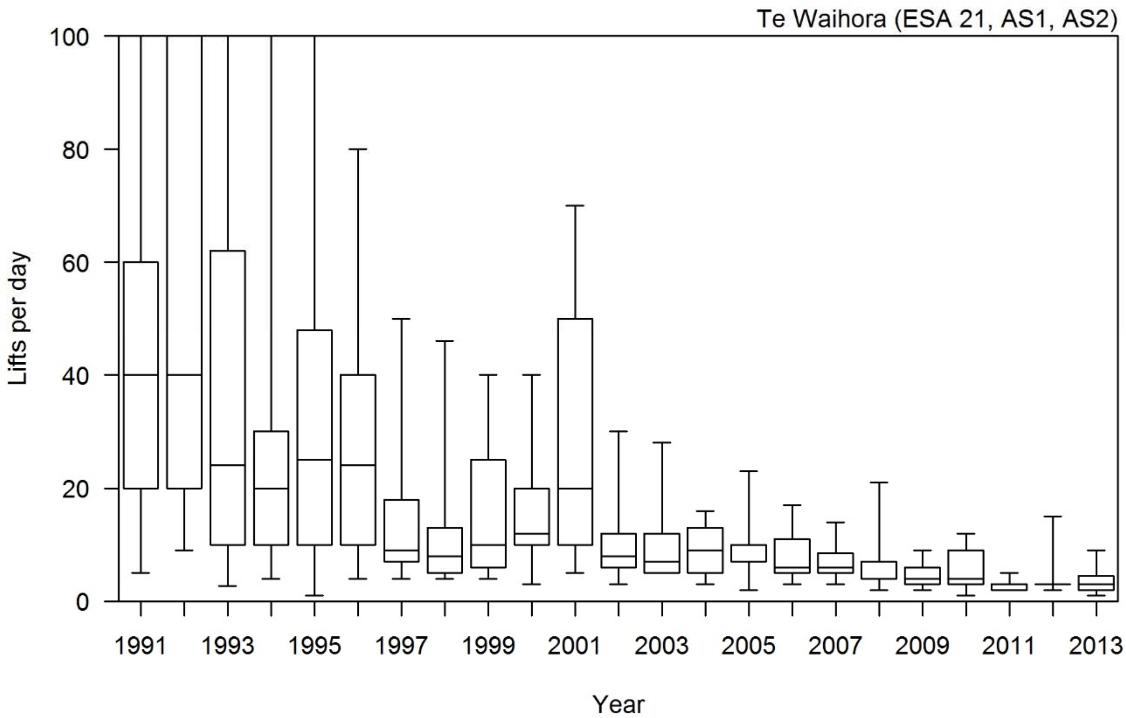



**Figure I3: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the** median, **the top and** bottom **of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (Te Waihora (ESA 21, AS1, AS2)).**

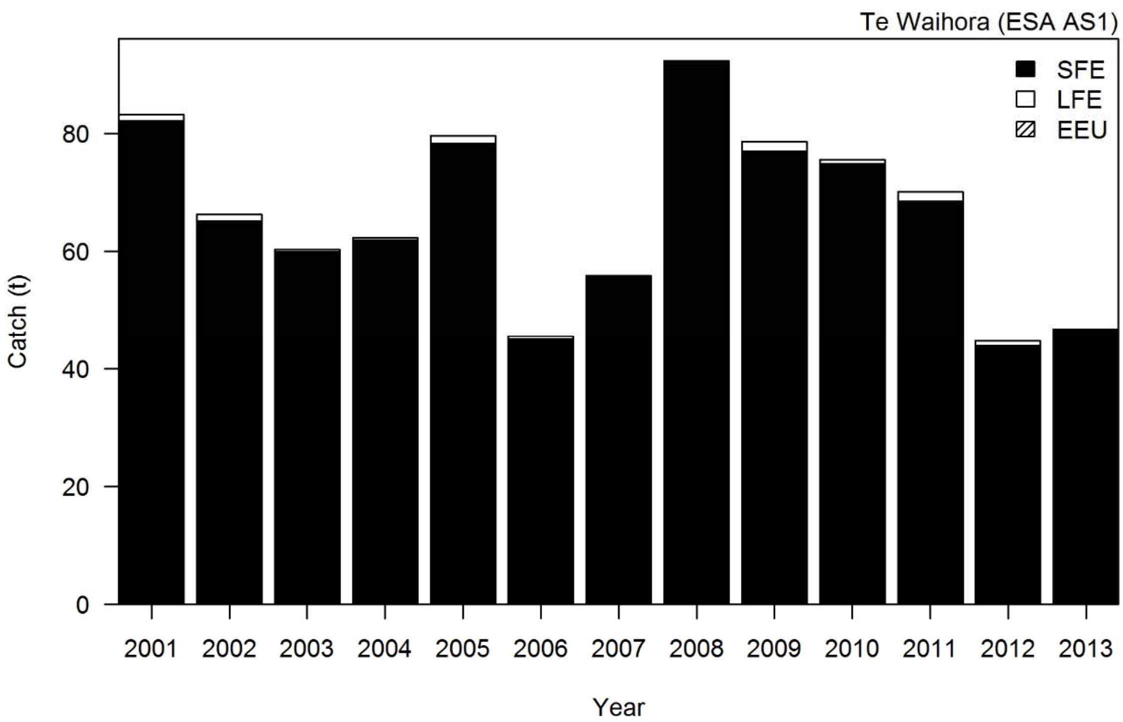



**Figure I4: Total estimated commercial catch of shortfin (SFE) and longfin (LFE) from AS1 (lake)** for **the years 2000–01 to 2012–13 (Te Waihora (ESA AS1)).**

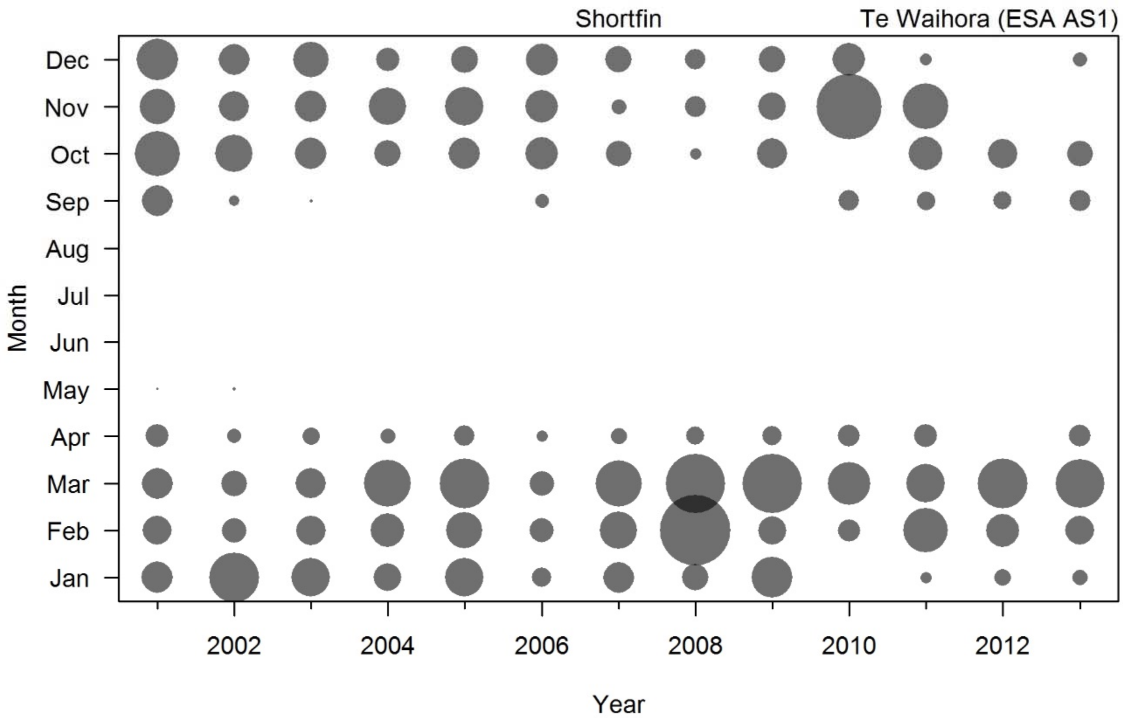



**Figure I5: Shortfin eel catch by month for the years 1990–91 to 2012–13 (Te Waihora (ESA AS1)).**

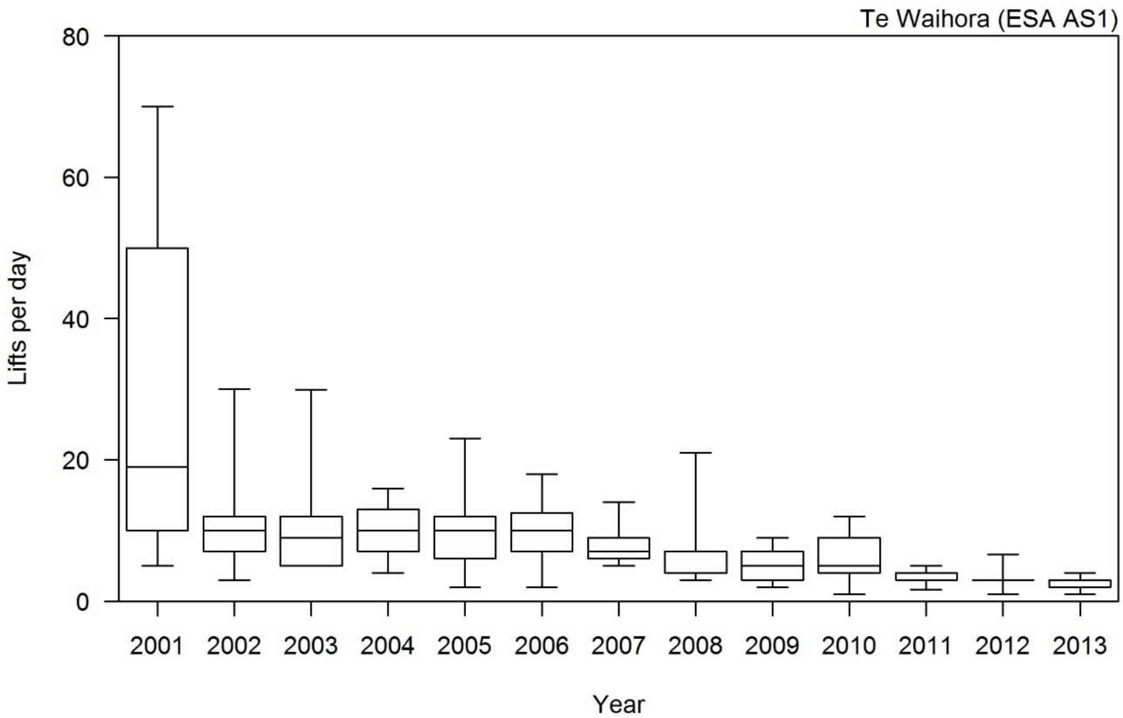



**Figure I6: Total lifts per day for the years 1990–91 to 2012–13. The horizontal line is the** median, the **top and bottom of the box are the interquartiles (25th and 75th), and error bars are the 95th percentile range (Te Waihora (ESA AS1)).**

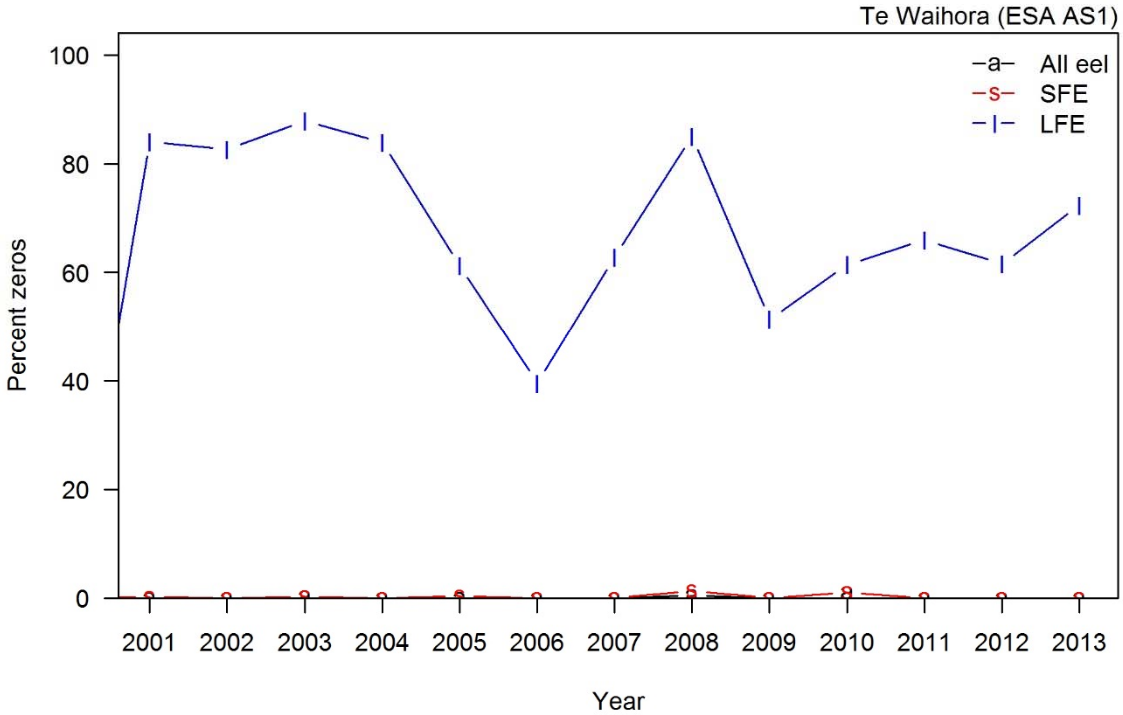



**Figure I7: Proportion of zero records for all eel, shortfin (SFE),** and **longfin (LFE) catch for the years** 2000–**01 to 2012–13 (Te Waihora (ESA AS1)).**

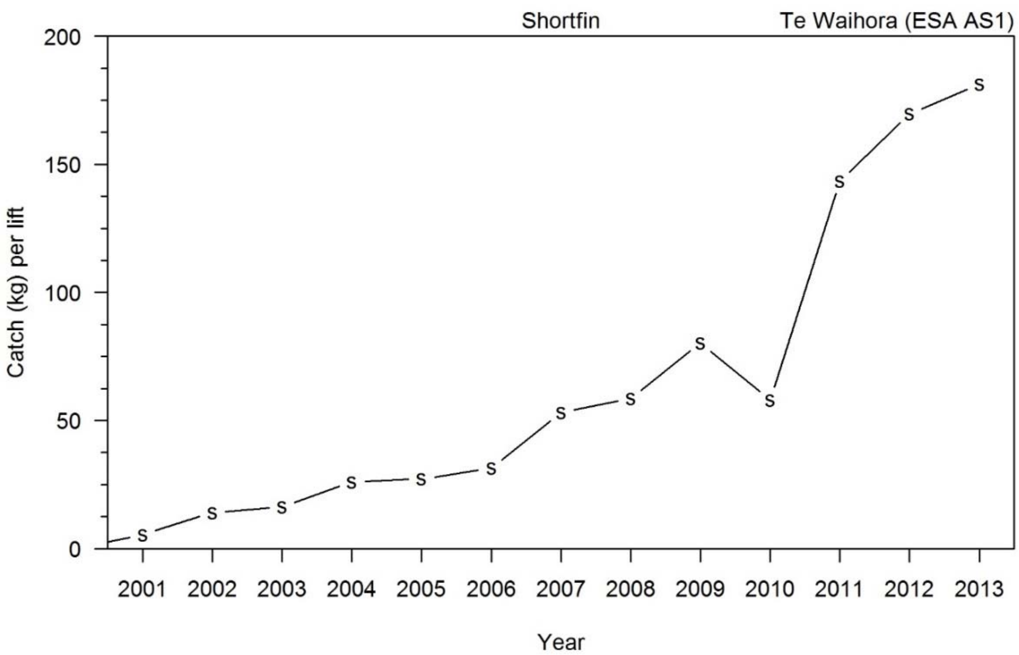



**Figure I8: Unstandardised catch per lift for shortfin eels for the years 2000–01 to 2012–13** (Te Waihora **(ESA AS1)).**

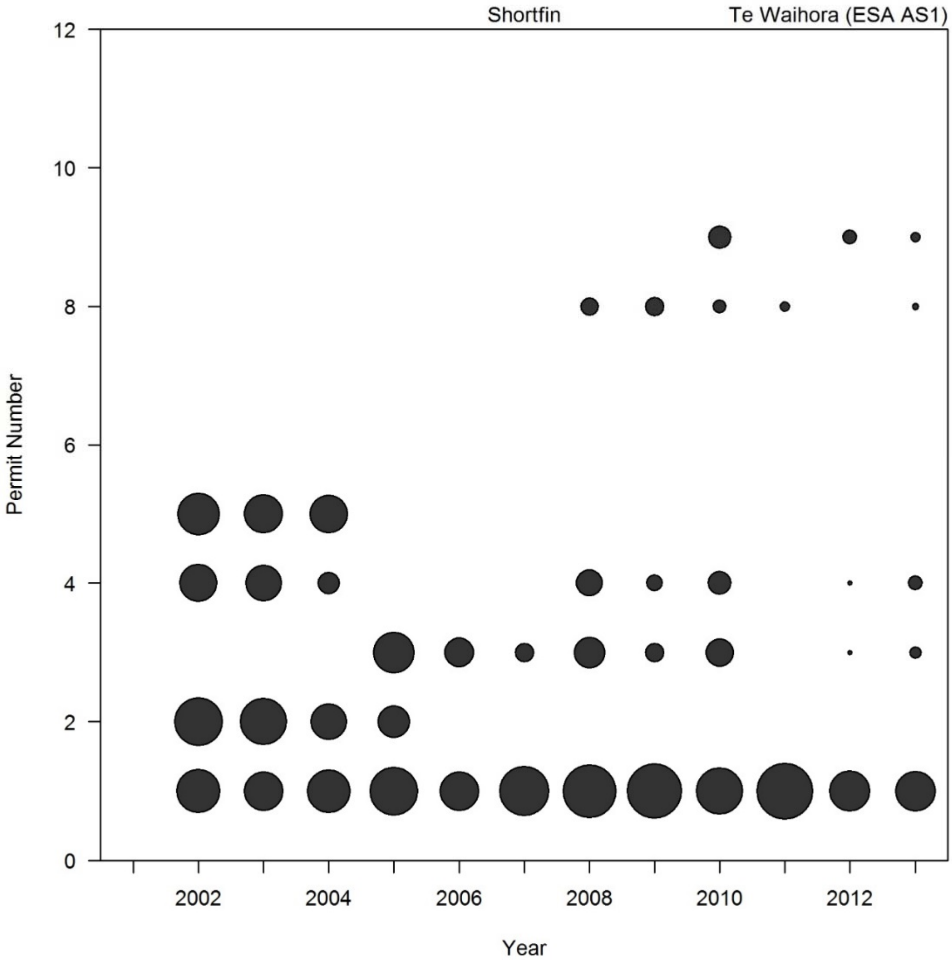



**Figure I9: Relative catch of shortfin from all fishers (all circles) from** AS1 **(lake) for the years 2000–01 to 2012–13,** and **for core fishers (dark shaded circles) included in the catch per unit effort analyses (Te Waihora (ESA AS1)).**

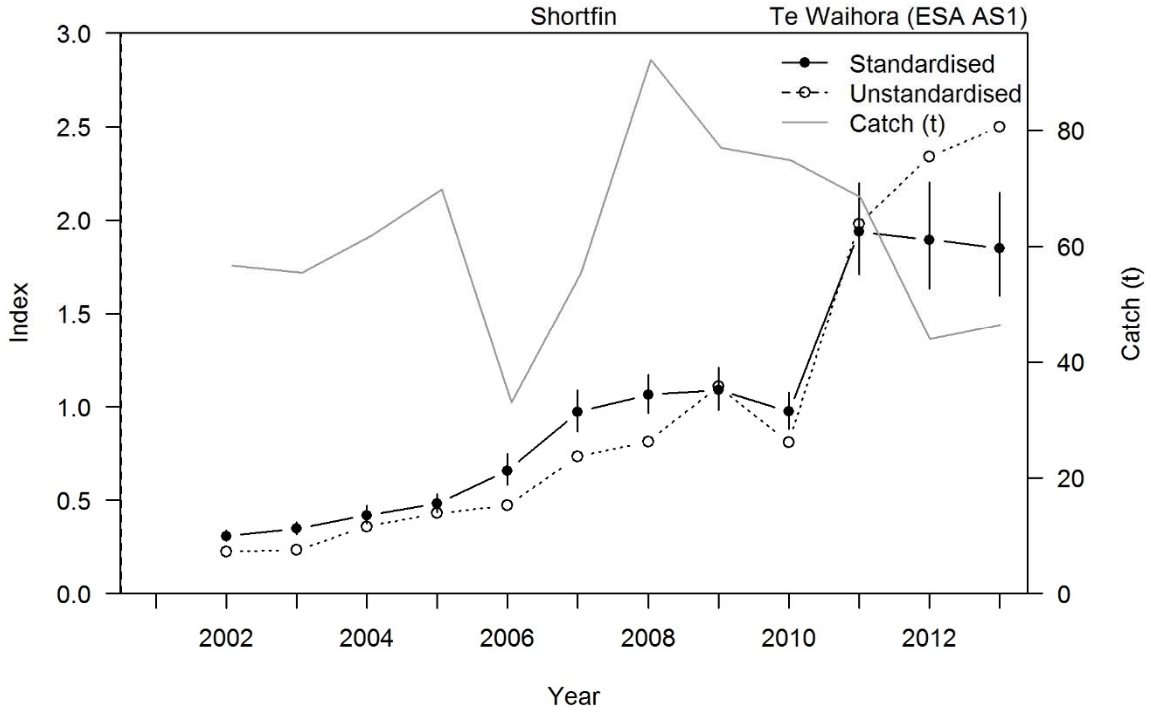



**Figure I10: Indices of unstandardised catch per lift and standardised CPUE from AS1 (lake) for the core fishers shortfin CPUE model for the years 2000–01 to 2012–13. The catch by core fishers is also plotted (Te Waihora (ESA AS1)).**

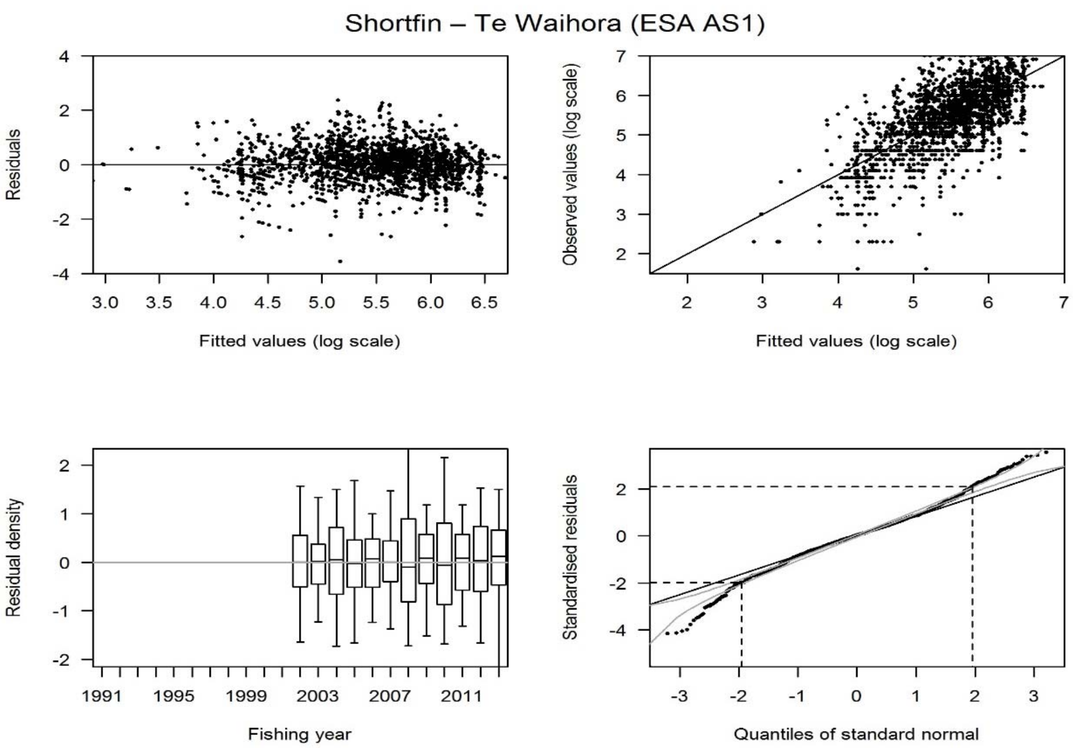



**Figure I11: Residual diagnostic plots for the shortfin CPUE model from AS1 (lake) for the years 2000–01 to 2012–13. The** grey **lines on the quantile-quantile plot represent the 95% confidence envelopes of a standard normal distribution (Te Waihora (ESA AS1)).**

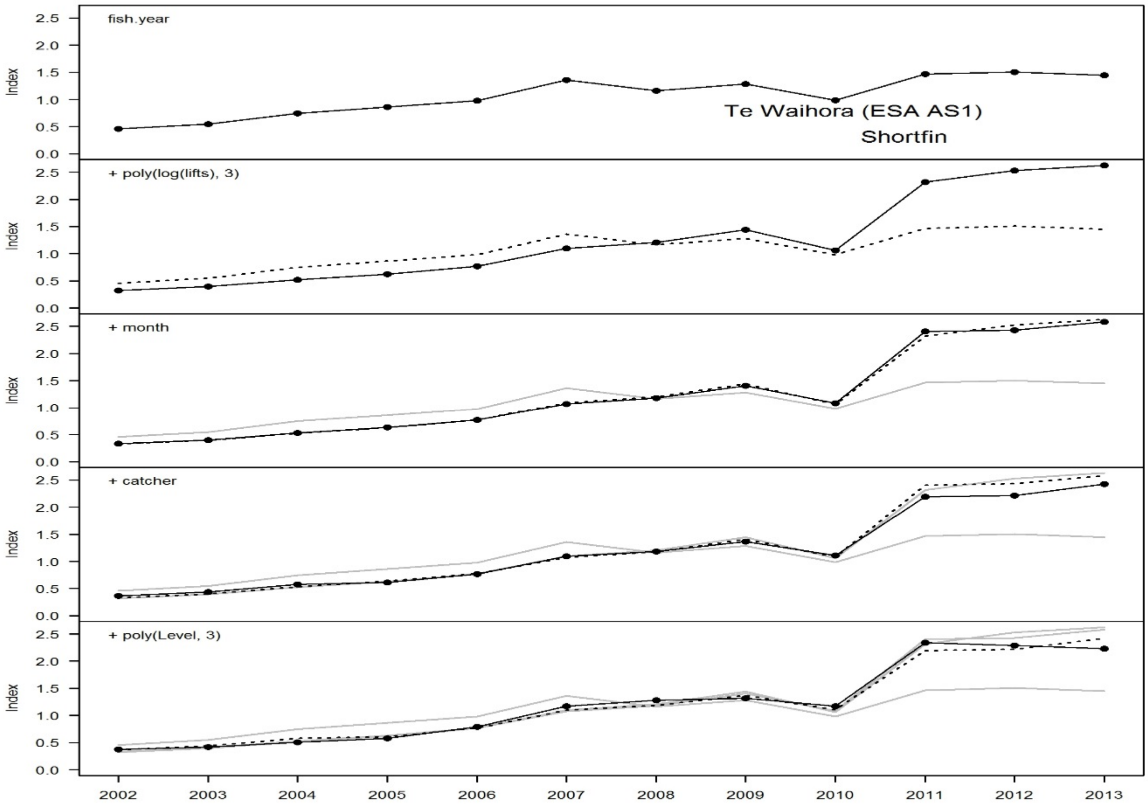



**Figure I12: Step plot for the shortfin eel CPUE model from** AS1 (**lake) for the years 2000–01 to 2012–13. Each panel shows the standardised CPUE index as each explanatory variable is added to the model with the previous index** shown **by the dotted** line **and the grey lines for steps before that (Te Waihora (ESA AS1)).**

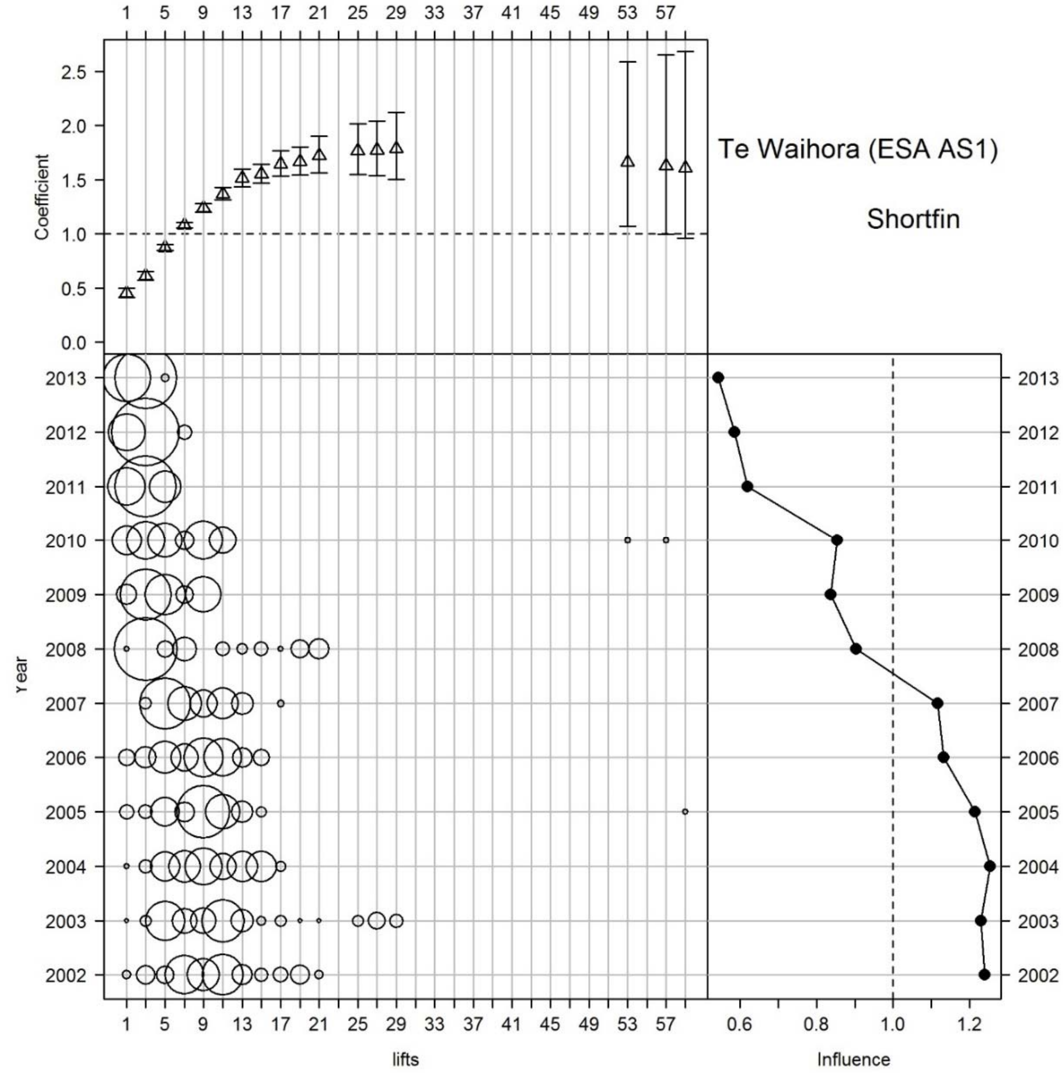



**Figure I13: Influence of lifts for the shortfin CPUE model from AS1 (lake) for the years 2000–01 to 2012–13 (Te Waihora (ESA AS1)).**

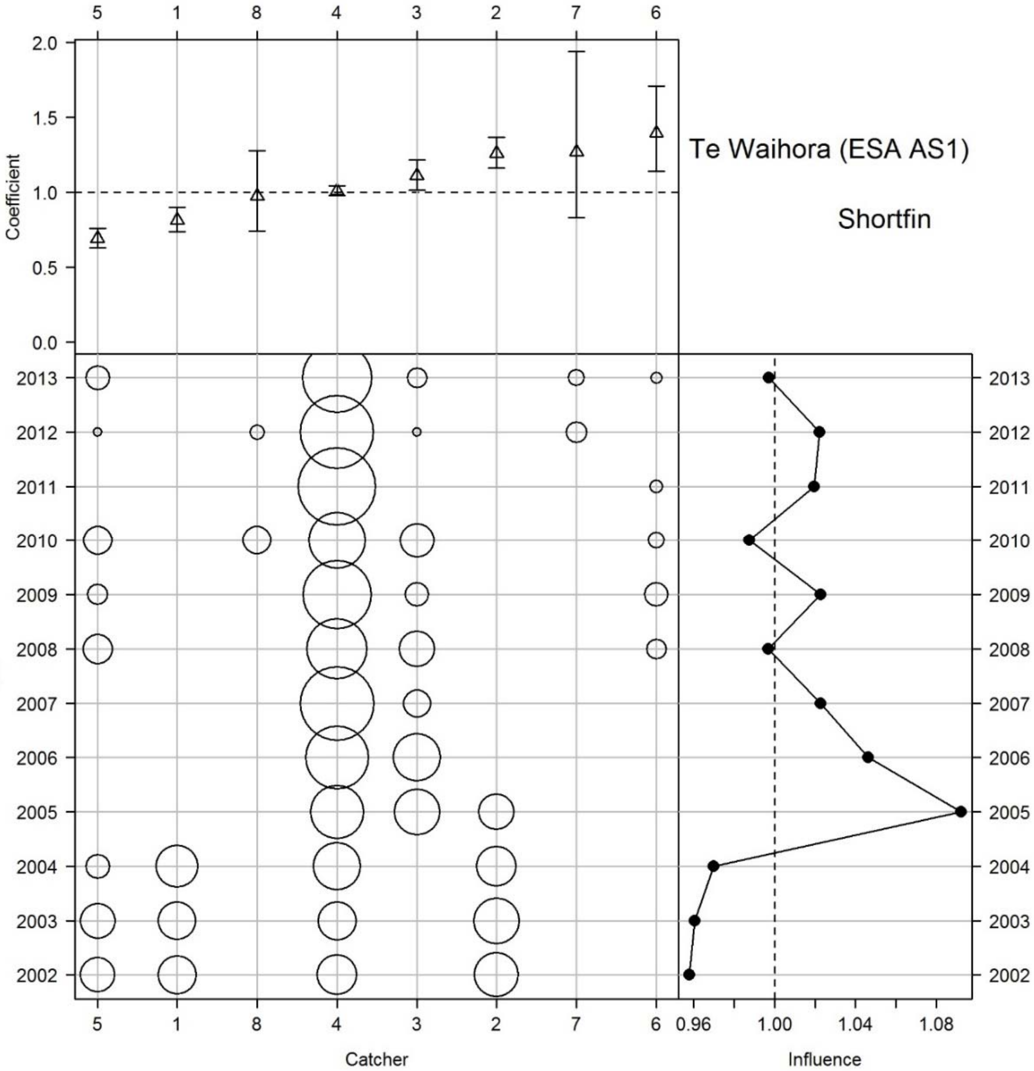



**Figure I14: Influence of permit number for the shortfin** CPUE **model** from **AS1 (**lake) **for the years 2000–01 to 2012–13 (Te Waihora (ESA AS1)).**

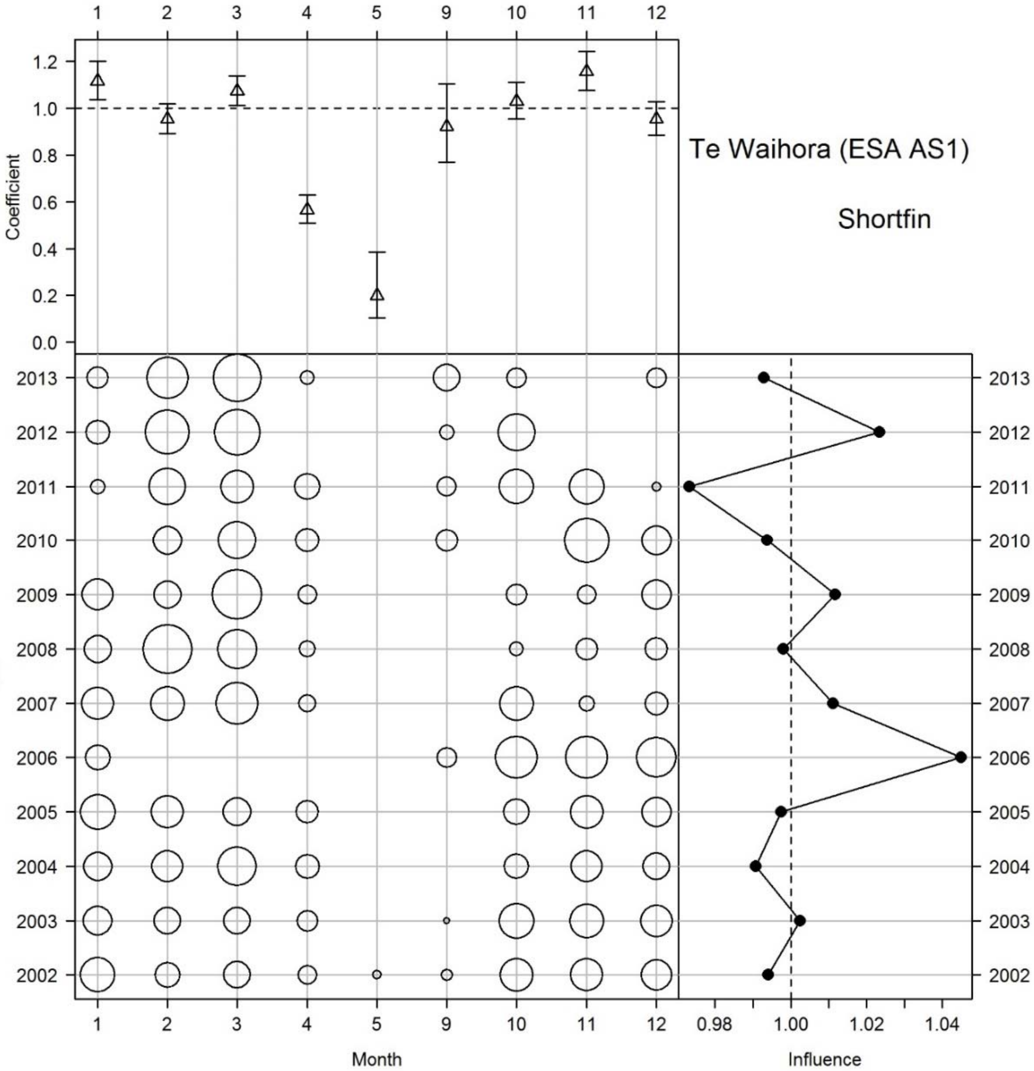



**Figure I15: Influence of month for the shortfin CPUE model from AS1 (lake) for the years 2000–01 to 2012–13 (Te Waihora (ESA AS1)).**

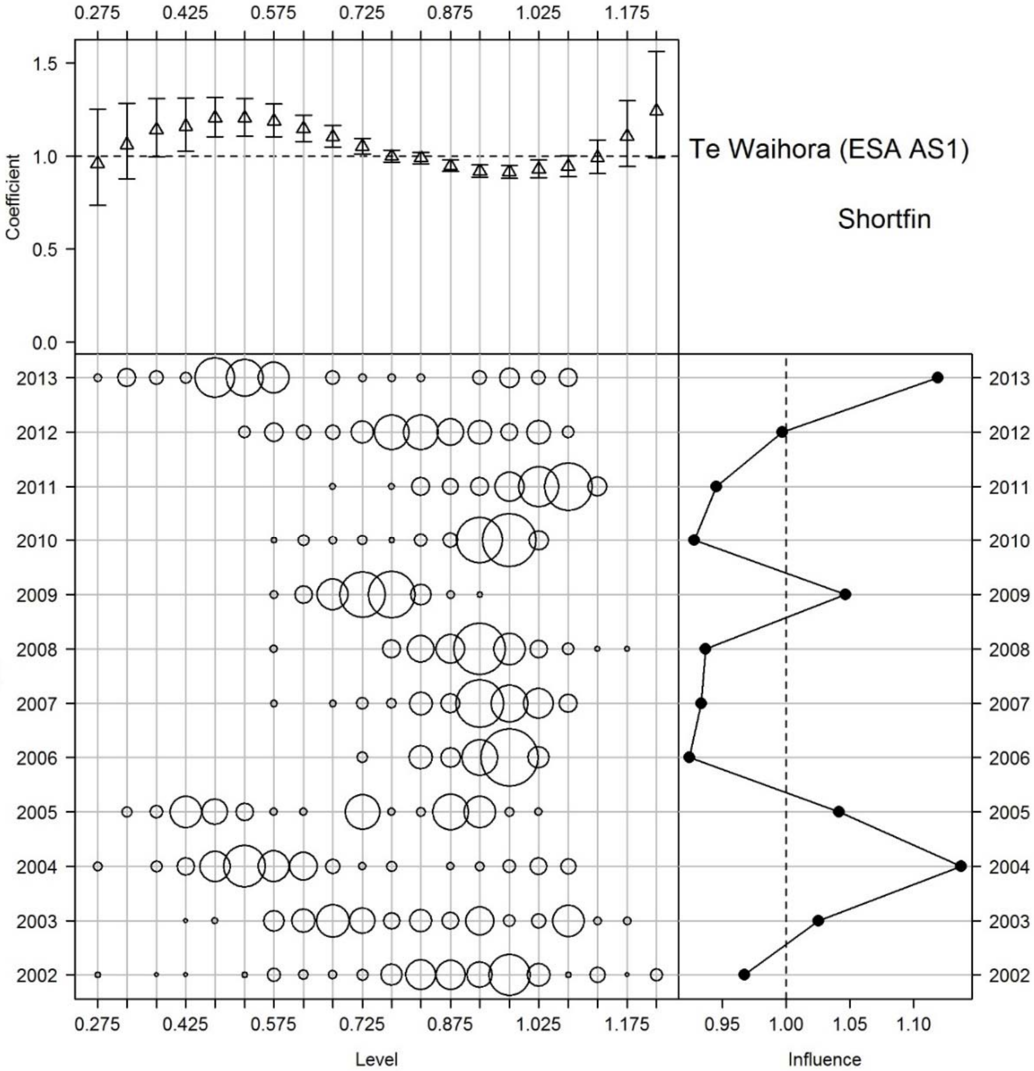



**Figure I16: Influence of** lake level **for the shortfin CPUE model from AS1** **(lake)** for **the years 2000–01 to 2012–13 (Te Waihora (ESA AS1)).**

**Appendices J to M: Plots of trial CPUE analyses from landed catch linked with effort from catch-effort forms (ECER) for data rich ESAs (AX, AV, AW and AS1).**

**Appendix J: ESA AX**

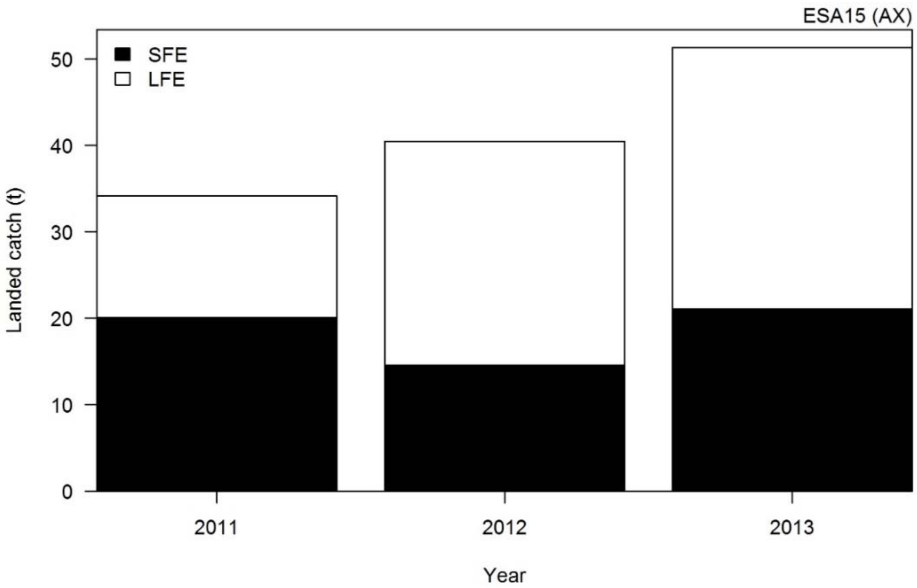



**Figure J1: Total landed catch of shortfin (SFE) and longfin (LFE) for the years 2010–11 to 2012–13 as provided by processors (Westland (ESA AX)).**

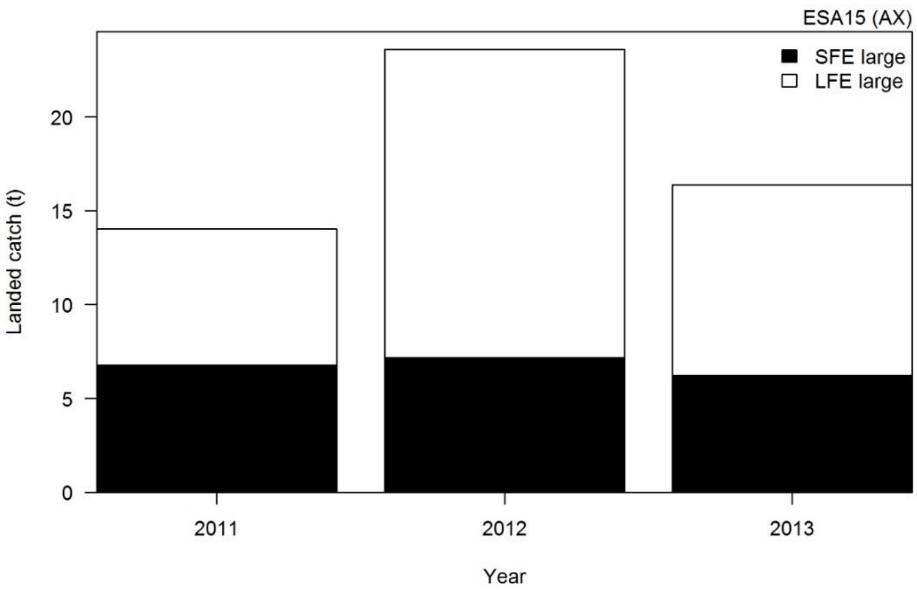



**Figure J2: Total landed catch of shortfin (SFE) and longfin (LFE) in the large size grades for the years 2010–11 to 2012–13 as provided by processors (Westland (ESA AX)).**

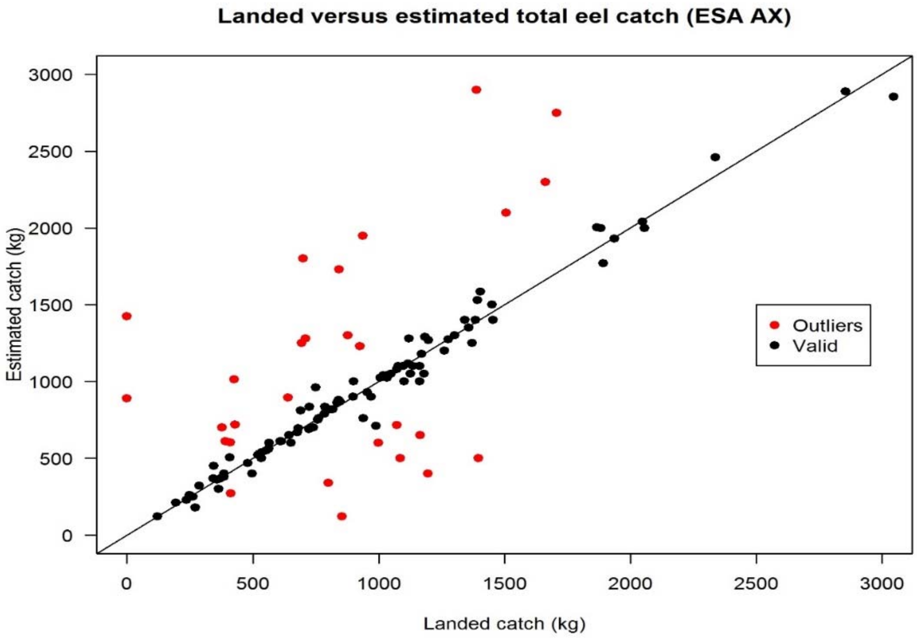



**Figure J3: Landed versus estimated catch eel catch (all eels) for the years 2010–11 to 2012–13. Red dots represent outliers excluded from the CPUE analyses (Westland (ESA AX)).**

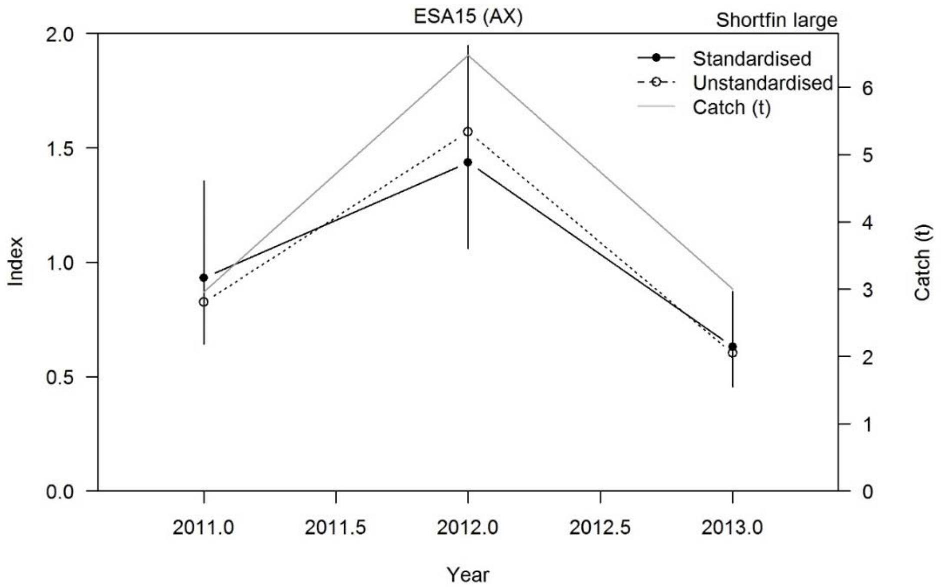



**Figure J4: Indices of unstandardised (catch per lift) and standardised CPUE for shortfin for the large size grade (over 800 g) for the years 2010–11 to 2012–13. The catch is also plotted (Westland (ESA AX)).**

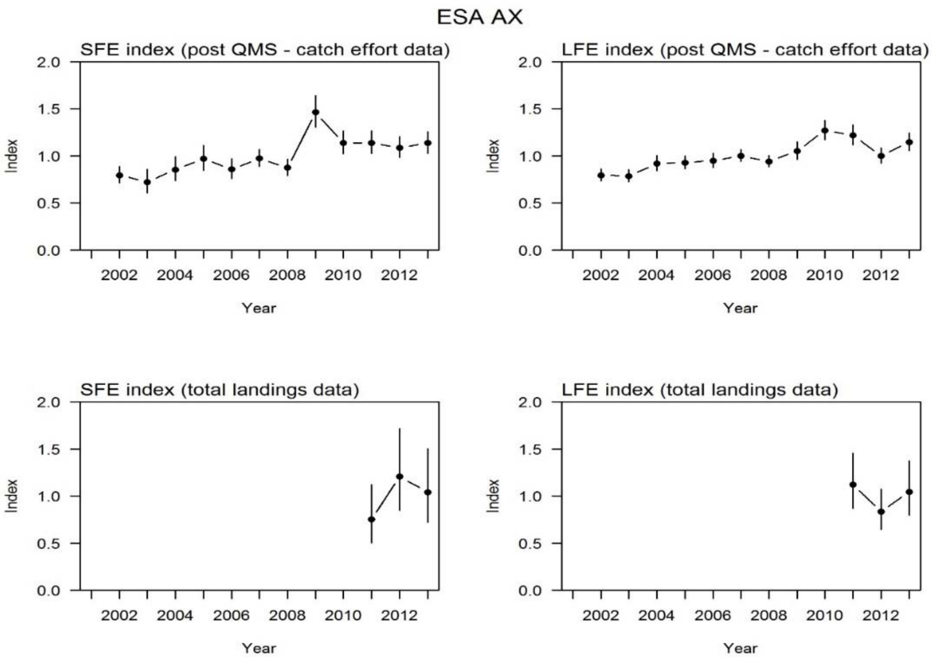



**Figure J5: Indices of standardised CPUE for shortfin and longfin for total estimated catch (top) and landed catch (bottom) (Westland (ESA AX)).**

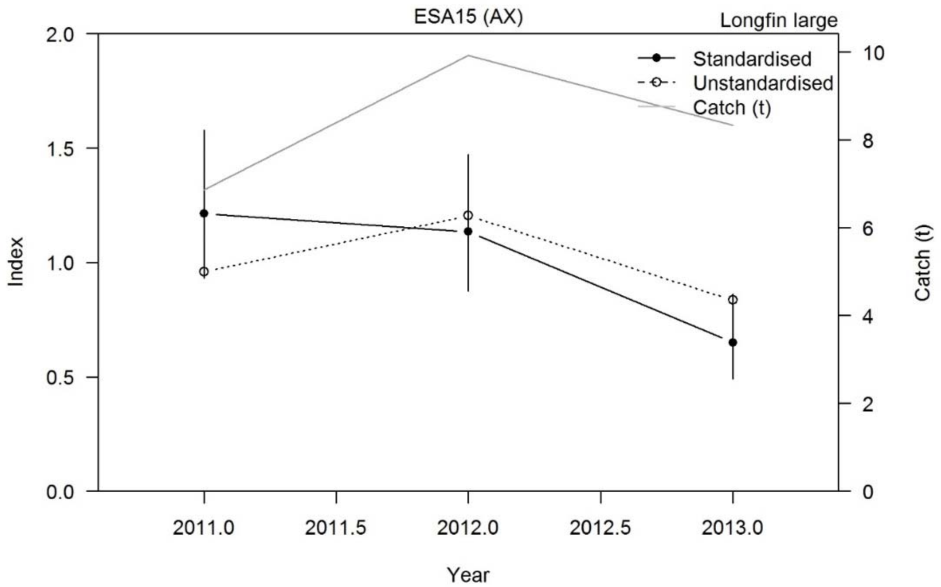



**Figure J6: Indices of unstandardised (catch per lift) and standardised CPUE for longfin for the large size grade (over 1000 g) for the years 2010–11 to 2012–13. The catch is also plotted (Westland (ESA AX)).**

## Appendix K: ESA AV

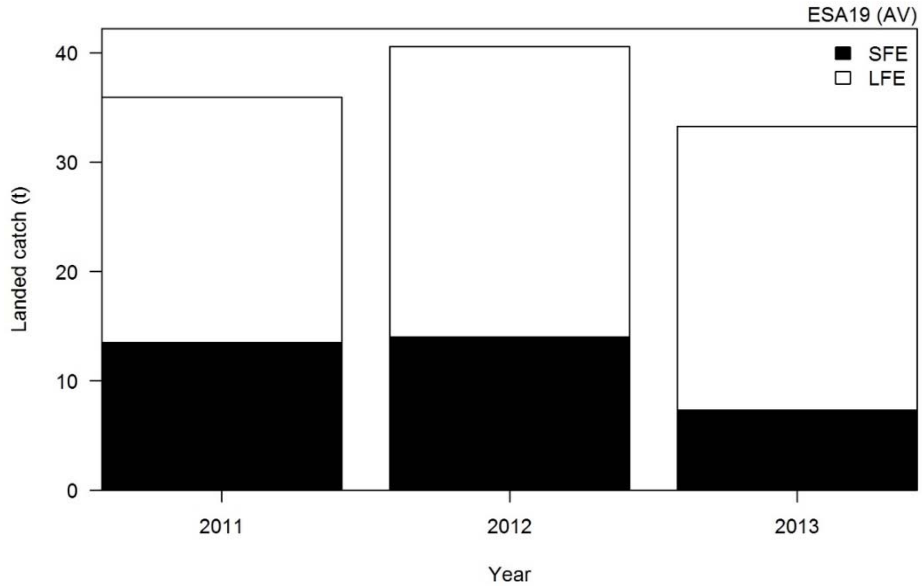



**Figure K1: Total landed catch of shortfin (SFE) and longfin (LFE) for the years 2010–11 to 2012–13 as provided by processors (Otago (ESA AV)).**

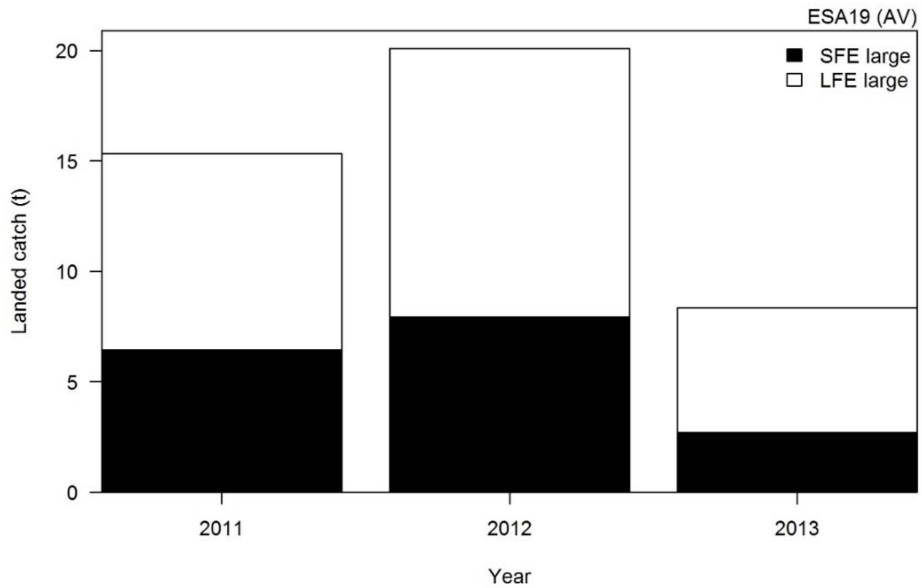



**Figure K2: Total landed catch of shortfin (SFE) and longfin (LFE) in the large size grades for the years 2010–11 to 2012–13 as provided by processors (Otago (ESA AV)).**

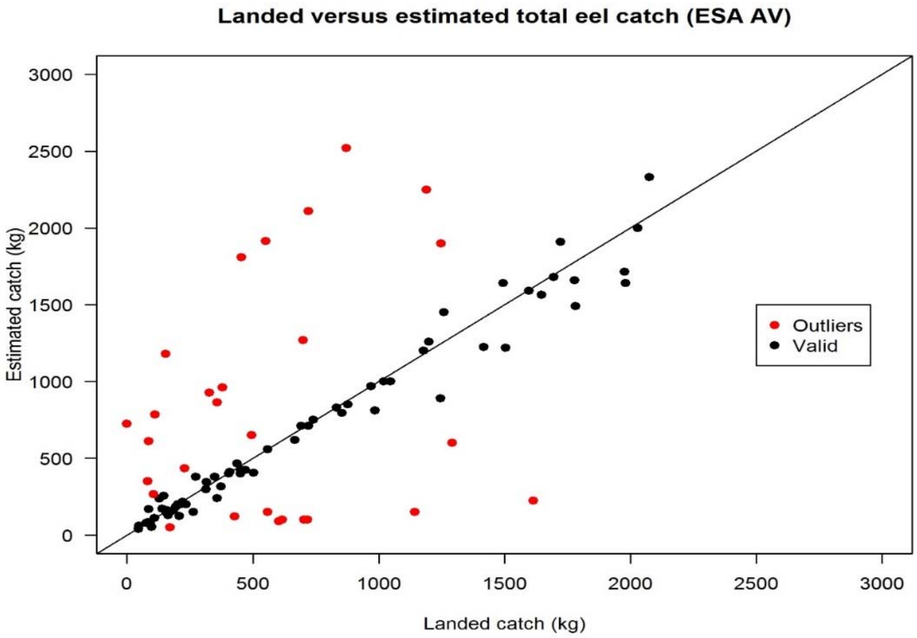



**Figure K3: Landed versus estimated catch eel catch (all eels) for the years 2010–11 to 2012–13. Red dots represent outliers excluded from the CPUE analyses (Otago (ESA AV)).**

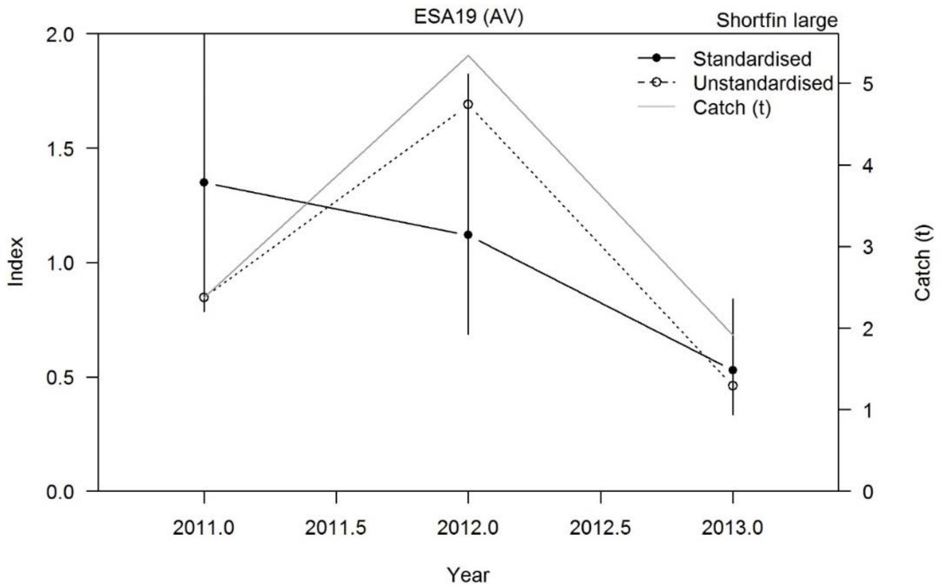



**Figure K4: Indices of unstandardised (catch per lift) and standardised CPUE for shortfin for the large size grade (over 800 g) for the years 2010–11 to 2012–13. The catch is also plotted (Otago (ESA AV)).**

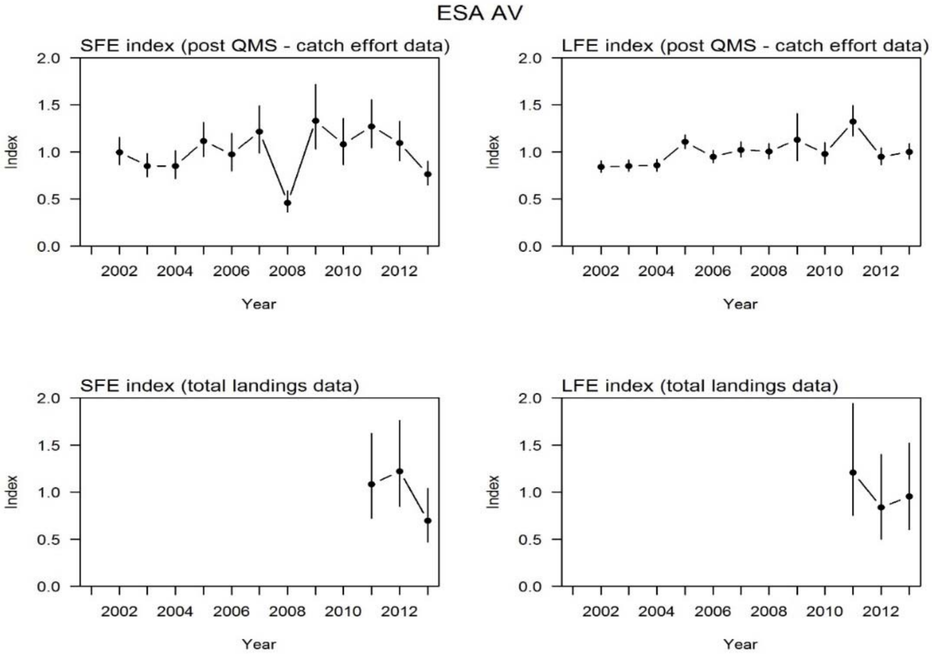



**Figure K5: Indices of standardised CPUE for shortfin and longfin for total estimated catch (top) and landed catch (bottom) (Otago (ESA AV)).**

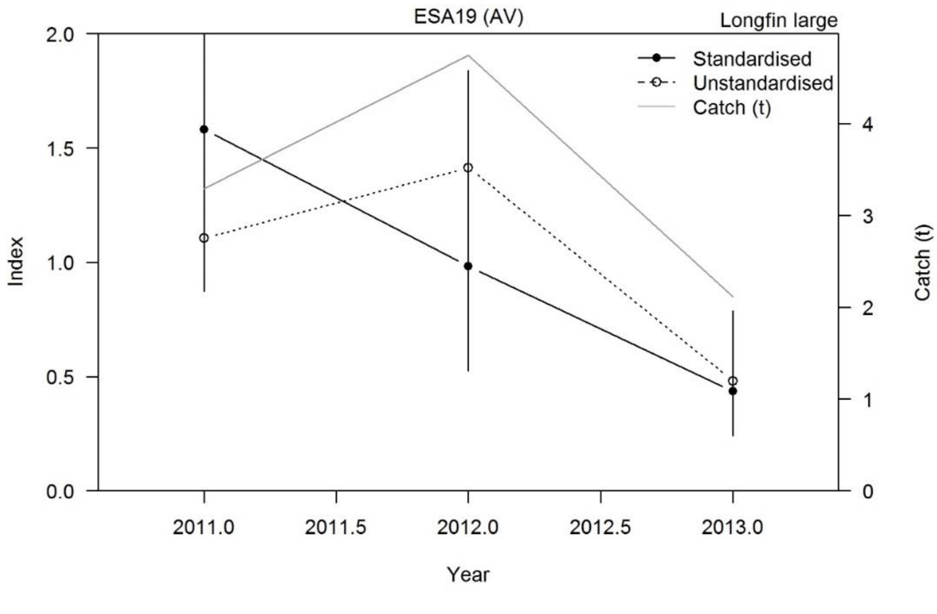



**Figure K6: Indices of unstandardised (catch per lift) and standardised CPUE for longfin for the large size grade (over 1000 g) for the years 2010–11 to 2012–13. The catch is also plotted (Otago (ESA AV)).**

## Appendix L: ESA AW

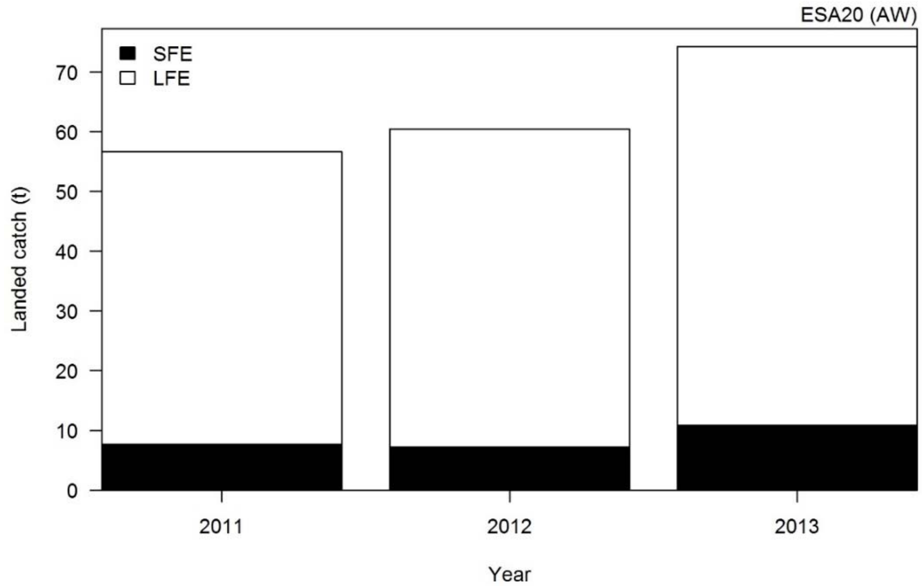



**Figure L1: Total landed catch of shortfin (SFE) and longfin (LFE) for the years 2010–11 to 2012–13 as provided by processors (ESA20 (AW)).**

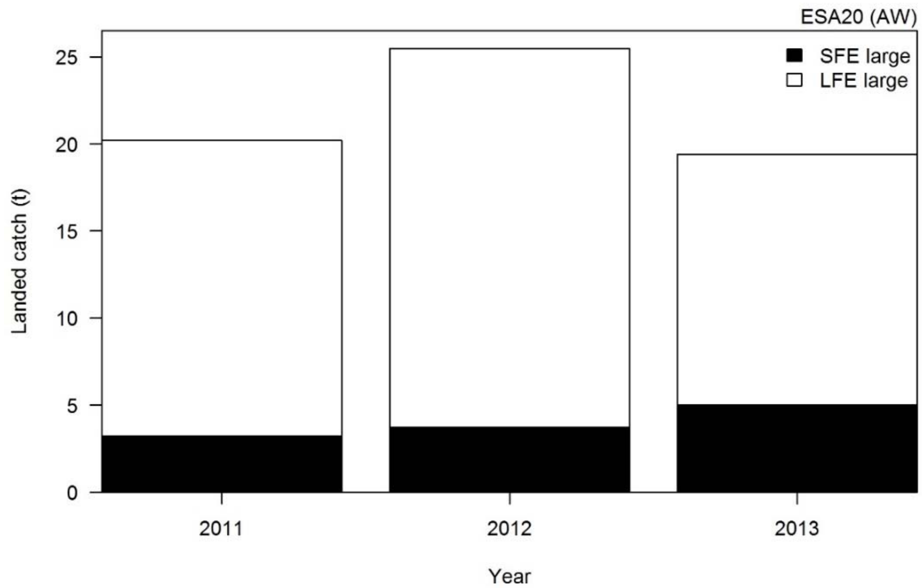



**Figure L2: Total landed catch of shortfin (SFE) and longfin (LFE) in the large size grades for the years 2010–11 to 2012–13 as provided by processors (ESA20 (AW)).**

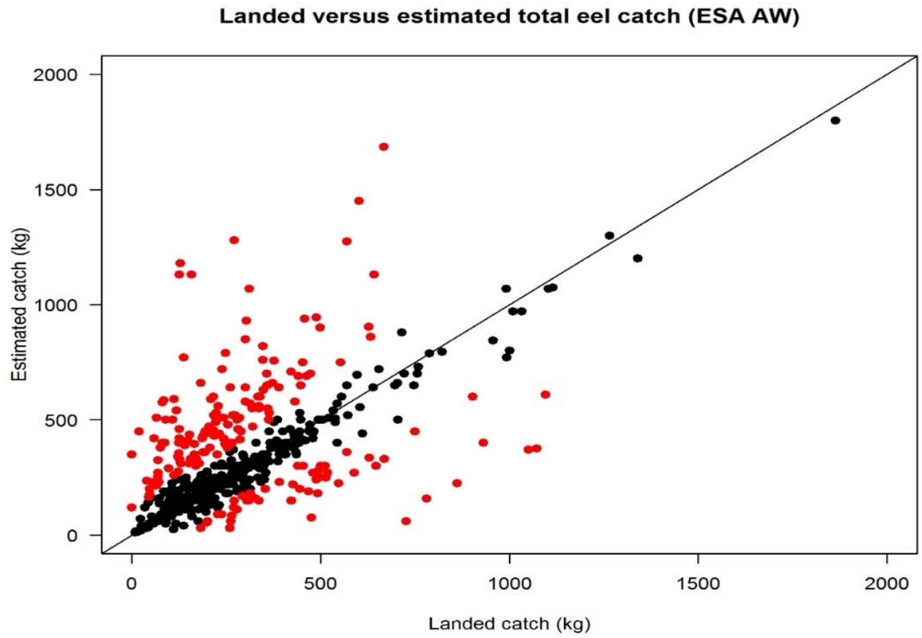



**Figure L3: Landed versus estimated catch eel catch (all eels) for the years 2010–11 to 2012–13. Red dots represent outliers excluded from the CPUE analyses (ESA20 (AW)).**

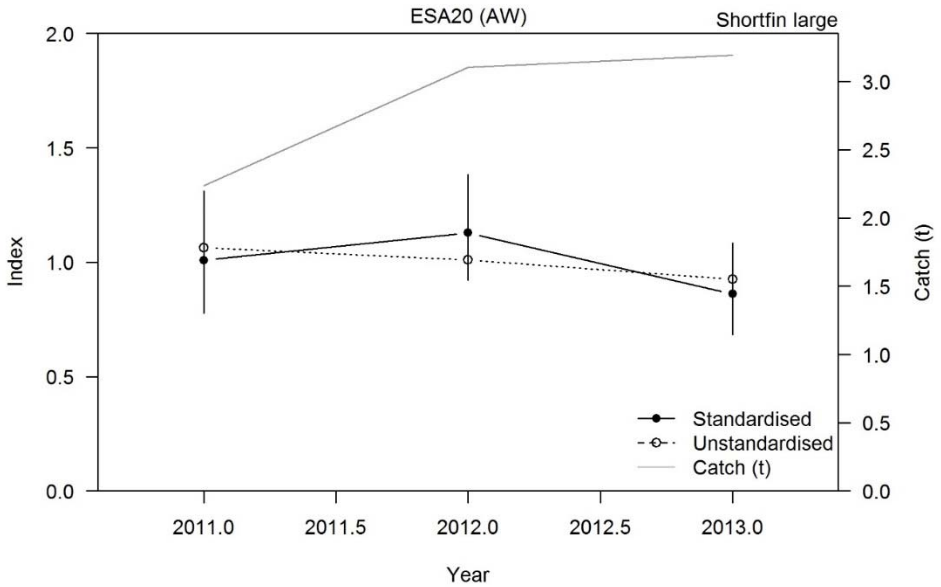



**Figure L4**: **Indices of unstandardised (catch per lift) and standardised CPUE for shortfin for the large size grade (over 800 g) for the years 2010–11 to 2012–13. The catch is also plotted (ESA20 (AW)).**

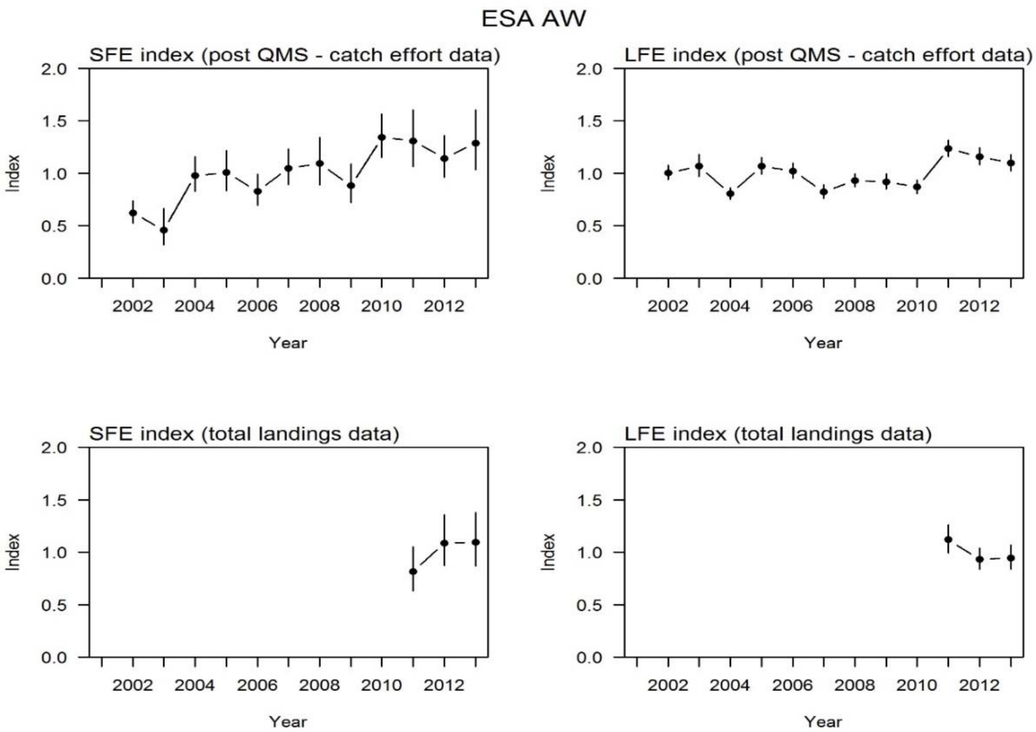



**Figure L5: Indices of standardised CPUE for shortfin and longfin for total estimated catch (top) and landed catch (bottom) (ESA20 (AW)).**

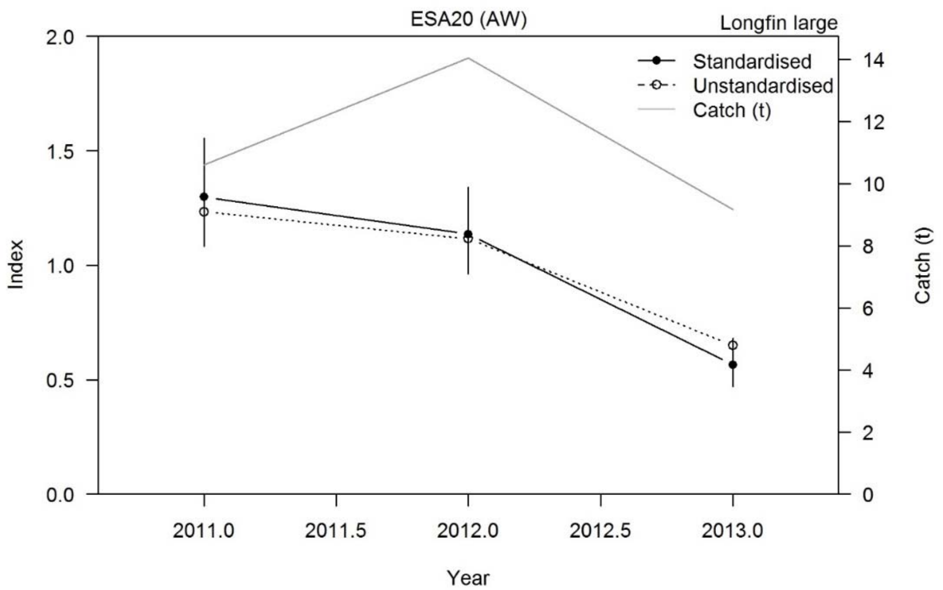



**Figure L6: Indices of unstandardised (catch per lift) and standardised CPUE for longfin for the large size grade (over 1000 g) for the years 2010–11 to 2012–13. The catch is also plotted (ESA20 (AW)).**

**Appendix M: ESA AS1**

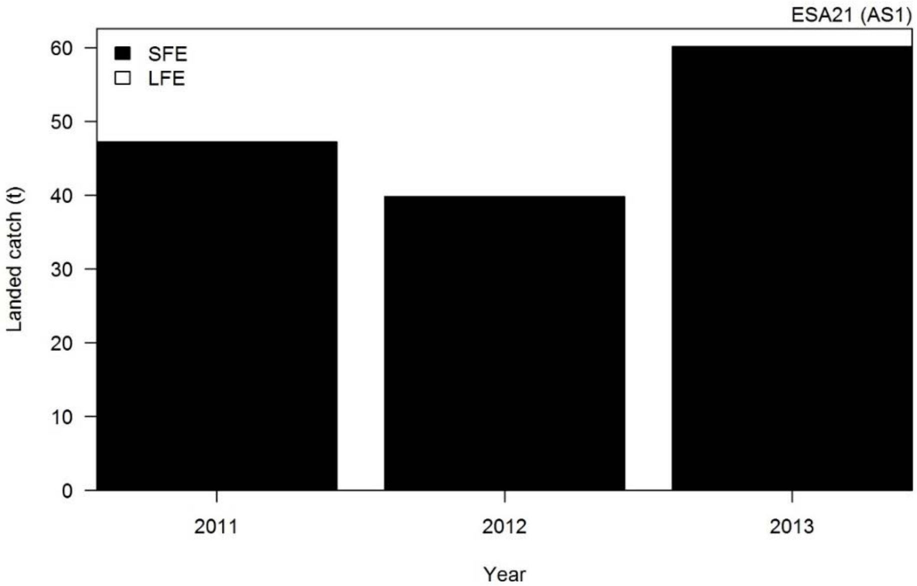



**Figure M1: Total landed catch of shortfin (SFE) and longfin (LFE) for the years 2010–11 to 2012–13 as provided by processors (Te Waihora (ESA 21, AS1, AS2)).**

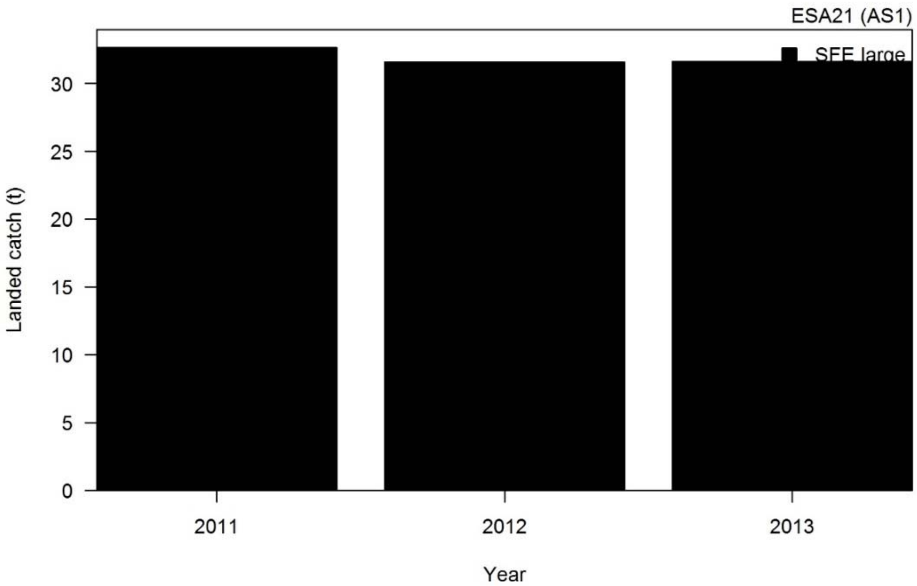



**Figure M2: Total landed catch of shortfin (SFE) and longfin (LFE) in the large size grades for the years 2010–11 to 2012–13 as provided by processors (Te Waihora (ESA 21, AS1, AS2)).**

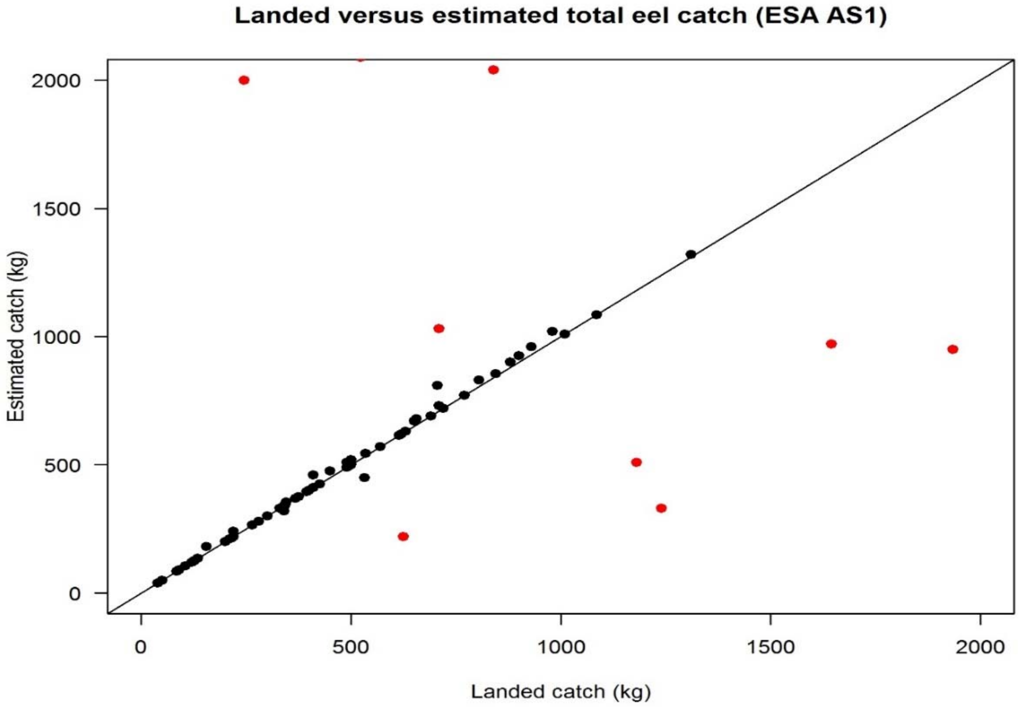



**Figure M3: Landed versus estimated catch eel catch (all eels) for the years 2010–11 to 2012–13. Red dots represent outliers excluded from the CPUE analyses (Te Waihora (ESA 21, AS1, AS2)).**

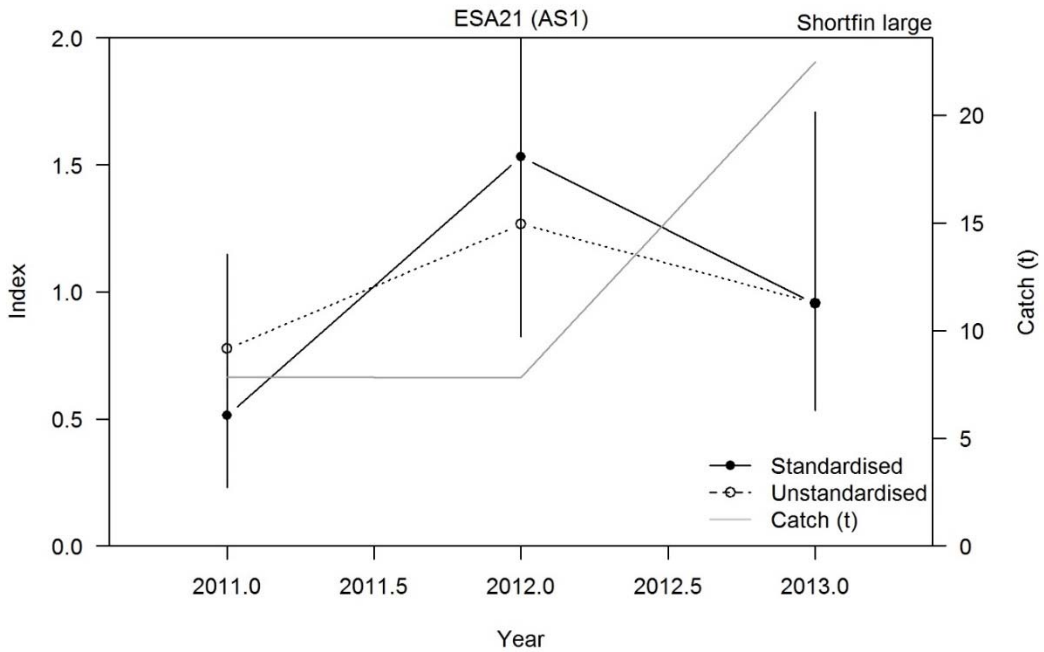



**Figure M4**: **Indices of unstandardised (catch per lift) and standardised CPUE for shortfin for the large size grade (over 800 g) for the years 2010–11 to 2012–13. The catch is also plotted (Te Waihora (ESA** 21, **AS1, AS2)).**

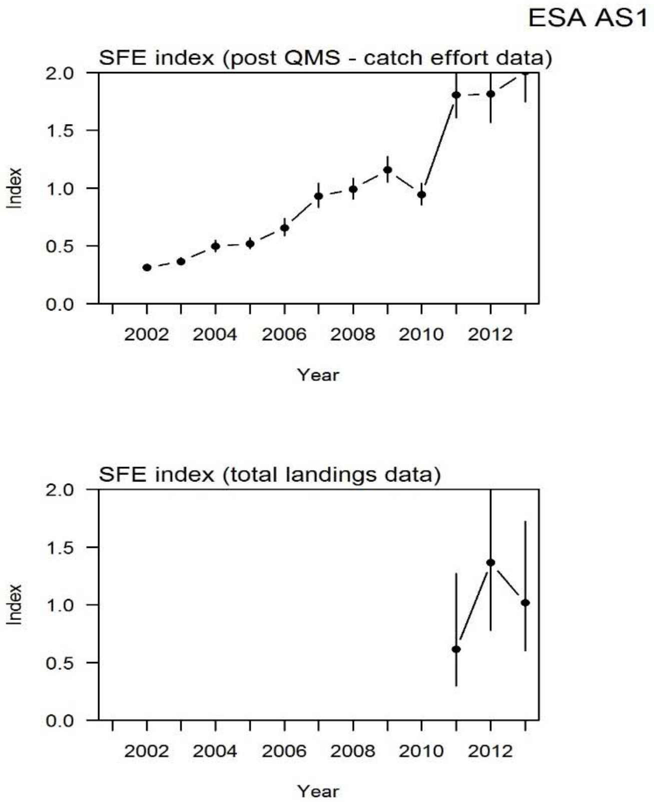



**Figure M5: Indices of standardised CPUE for shortfin and longfin for total estimated catch (top) and landed catch (bottom) (Te Waihora (ESA 21, AS1, AS2)).**

**Appendix 1: Daily mean river flow and water quality data used in the standardised CPUE analyses. Availability of water quality at all sites is indicated. * New sites included in current analyses up to 2012–13. **Te Waihora level and if lake was open or closed to the ocean.**

| Region | ESA | River/lake | Site location | Water quality data | Source |
|---|---|---|---|---|---|
| Nelson | 13 (AN) | Wairau River | Site 60109 Wairau at Barnetts Bank | Yes (close by site) | NIWA |
| | | Buller River | Site 93203 Buller at Te Kuha | Yes | NIWA |
| Marlborough | 14 (AP–AQ) | Wairau River | Site 60109 Wairau at Barnetts Bank | Yes (close by site) | NIWA |
| Westland | 15 (AX) | Buller River | Site 93203 Buller at Te Kuha | Yes | NIWA |
| | | Grey River | Site 91401 Grey at Dobson* | Yes | NIWA |
| | | Hokitika River | Site 90612 Hokitika at Gorge* | No | NIWA |
| Nth Canty | 16 (AR) | Wairau River | Site 60109 Wairau at Barnetts Bank | Yes (close by site) | NIWA |
| | | Rakaia River | Site 68526 Rakaia at Fighting Hill | | NIWA |
| Sth Canty | 17 (AT) | Waitaki River | Site 71104 Waitaki at Kurow | Yes | Environment Canterbury |
| | | Rakaia River | Site 68526 Rakaia at Fighting Hill | No | NIWA |
| Waitaki | 18 (AU) | Waitaki River | Site 71104 Waitaki at Kurow | Yes | Environment Canterbury |
| Otago | 19 (AV) | Clutha River | Site 75207 Clutha at Balclutha | Yes | NIWA |
| | | Taieri River | Site 74308 Taieri at Outram* | Yes | Otago Regional Council |
| | | Waipori River | Site 74321 Waipori at Berrick* | No | Otago Regional Council |
| Southland | 20 (AW) | Mataura River | Site 77505, Parawa | Yes | Environment Southland |
| | | Mataura River | Site 77519 Seaward Downs* | Yes | Environment Southland |
| | | Aparima | Site 78901 Aparima at Thornbury* | No | Environment Southland |
| | | Oreti River | Site 78601 Oreti at Wallacetown* | Yes | Environment Southland |
| | | Waiau River | Site 79701 Waiau at Tuatapere* | Yes | NIWA/Meridian |
| Te Waihora | AS | Selwyn River | Site 68001 Selwyn at Whitecliffs* | No | NIWA |
| | | Te Waihora** | Site 68302 Te Waihora at Taumutu* | No | Environment Canterbury |

**Appendix 2: Number of records, fishers (catches over zero), and catch in all and core shortfin, and all and core longfin, pre- and post QMS used in the CPUE analyses. Records do not include those with zero catch. SFE, shortfin; LFE, longfin; QMS, quota management system; ESA, eel statistical area. – not applicable.**

| | | Pre-QMS | | | Post-QMS | | |
|---|---|---|---|---|---|---|---|
| Area | Dataset | Records | Fishers | Catch (kg) | Records | Fishers | Catch (kg) |
| ESA 13 (AN) | All SFE | 270 | 6 | 17 399 | – | – | – |
| | Core SFE | 246 | 1 | 14 651 | – | – | – |
| | All LFE | 899 | 6 | 98 692 | – | – | – |
| | Core LFE | 773 | 4 | 87 496 | – | – | – |
| ESA 14 (AP_AQ) | All SFE | 779 | 6 | 72 324 | – | – | – |
| | Core SFE | 771 | 3 | 72 014 | – | – | – |
| | All LFE | 694 | 7 | 53 480 | – | – | – |
| | Core LFE | 659 | 3 | 50 112 | – | – | – |
| ESA 15 (AX) | All SFE | 1 031 | 15 | 123 459 | 1271 | 12 | 189 624 |
| | Core SFE | 952 | 6 | 118 713 | 1230 | 7 | 186 739 |
| | All LFE | 4 683 | 16 | 434 499 | 2482 | 16 | 260 459 |
| | Core LFE | 4 561 | 11 | 409 067 | 2325 | 8 | 241 101 |
| ESA 16 (AR) | All SFE | 1 737 | 17 | 213 679 | – | – | – |
| | Core SFE | 1 663 | 9 | 202 534 | – | – | – |
| | All LFE | 1 270 | 22 | 132 914 | – | – | – |
| | Core LFE | 1 146 | 8 | 126 191 | – | – | – |
| ESA 17 (AT) | All SFE | 1 389 | 11 | 112 109 | – | – | – |
| | Core SFE | 1 360 | 9 | 109 494 | – | – | – |
| | All LFE | 1 431 | 17 | 109 044 | – | – | – |
| | Core LFE | 1 376 | 8 | 100 824 | – | – | – |
| ESA 18 (AU) | All SFE | 390 | 13 | 39 653 | – | – | – |
| | Core SFE | 357 | 7 | 36 201 | – | – | – |
| | All LFE | 729 | 17 | 79 025 | – | – | – |
| | Core LFE | 682 | 9 | 75 604 | – | – | – |
| ESA 19 (AV) | All SFE | 2 105 | 22 | 131 162 | 1033 | 21 | 93 018 |
| | Core SFE | 2 038 | 17 | 128 687 | 836 | 8 | 73 370 |
| | All LFE | 4 236 | 26 | 425 538 | 2 197 | 27 | 205 758 |
| | Core LFE | 4 159 | 19 | 420 895 | 1 878 | 8 | 181 692 |

**Appendix 2 – *continued***

| Area | Dataset | Pre-QMS Records | Pre-QMS Fishers | Pre-QMS Catch (kg) | Post-QMS Records | Post-QMS Fishers | Post-QMS Catch (kg) |
|---|---|---|---|---|---|---|---|
| ESA 20 (AW) | All SFE | 984 | 25 | 145 257 | 1 177 | 25 | 118 932 |
| | Core SFE | 901 | 12 | 135 826 | 939 | 8 | 98 190 |
| | All LFE | 4 661 | 28 | 646 876 | 3 449 | 30 | 577 971 |
| | Core LFE | 4 527 | 16 | 629 689 | 2 752 | 10 | 476 122 |
| ESA 21 (AS1) | All SFE | – | – | – | 2 477 | 11 | 768 519 |
| | Core SFE | – | – | – | 2 243 | 7 | 735 100 |

**Appendix 3: Predictor variables and $R^2$ values from GLM stepwise regression analysis for pre- and post- QMS CPUE analyses. Variables are shown in order of acceptance by the model with associated cumulative $R^2$ value. Only variables entered into the model are shown. LFE, longfin; SFE, shortfin; – NA.**

| Region | Species | Variable | $R^2$ Pre-QMS | Variable | $R^2$ Post-QMS |
|---|---|---|---|---|---|
| ESA AN | SFE | Fishing year | 0.05 | – | – |
| | | target | 0.40 | – | – |
| | | month | 0.44 | – | – |
| | | Lifts | 0.46 | – | – |
| | | Buller flow | 0.47 | – | – |
| | | Moon | 0.48 | – | – |
| | | Buller clarity | 0.48 | – | – |
| | | Wairau flow | 0.49 | – | – |
| | LFE | Fishing year | 0.16 | – | – |
| | | Lifts | 0.27 | – | – |
| | | Permit | 0.35 | – | – |
| | | Target | 0.39 | – | – |
| | | Month | 0.42 | – | – |
| | | Bull phosphate | 0.43 | – | – |
| | | Buller flow | 0.44 | – | – |
| | | Buller pH | 0.44 | – | – |
| ESA AP/AQ | SFE | Fishing year | 0.50 | – | – |
| | | Target | 0.57 | – | – |
| | | Lifts | 0.64 | – | – |
| | | Month | 0.67 | – | – |
| | | Permit | 0.69 | – | – |
| | | Wairau River flow | 0.70 | – | – |
| | LFE | Fishing year | 0.23 | – | – |
| | | Target | 0.38 | – | – |
| | | Lifts | 0.45 | – | – |
| | | Permit | 0.50 | – | – |
| | | Month | 0.54 | – | – |
| ESA AR | SFE | Fishing year | 0.06 | – | – |
| | | Permit | 0.46 | – | – |
| | | Lifts | 0.57 | – | – |
| | | Target | 0.60 | – | – |
| | | Month | 0.61 | – | – |
| | LFE | Fishing year | 0.15 | – | – |
| | | Permit | 0.39 | – | – |
| | | Target | 0.46 | – | – |
| | | Lifts | 0.52 | – | – |
| | | Month | 0.55 | – | – |
| ESA AT | SFE | Fishing year | 0.09 | – | – |
| | | Permit | 0.38 | – | – |
| | | Lifts | 0.45 | – | – |
| | | Target | 0.53 | – | – |
| | | Month | 0.54 | – | – |
| | | Waitaki River pH | 0.55 | – | – |

**Appendix 3 –*continued***

| Region | Species | Variable | $R^2$ Pre-QMS | Variable | $R^2$ Post-QMS |
|---|---|---|---|---|---|
| ESA AT | LFE | Fishing year | 0.18 | – | – |
| | | Target | 0.37 | – | – |
| | | Permit | 0.45 | – | – |
| | | Lifts | 0.50 | – | – |
| | | Month | 0.52 | – | – |
| ESA AU | SFE | Fishing year | 0.17 | – | – |
| | | Permit | 0.52 | – | – |
| | | Target | 0.61 | – | – |
| | | Lifts | 0.70 | – | – |
| | | Month | 0.71 | – | – |
| | | Waitaki River temp | 0.73 | – | – |
| | LFE | Fishing year | 0.21 | – | – |
| | | Lifts | 0.41 | – | – |
| | | Permit | 0.46 | – | – |
| | | Month | 0.50 | – | – |
| | | Target | 0.52 | – | – |
| | | Waitaki River pH | 0.54 | – | – |
| | | Moon | 0.54 | – | – |
| ESA AX | SFE | Fishing year | 0.13 | Fishing year | 0.23 |
| | | Permit | 0.64 | Catcher | 0.67 |
| | | Target | 0.73 | Target | 0.73 |
| | | Lifts | 0.77 | Lifts | 0.78 |
| | | Month | 0.78 | Grey River flow | 0.79 |
| | | Buller River nitrogen | 0.79 | | |
| | LFE | Fishing year | 0.06 | Fishing year | 0.11 |
| | | Permit | 0.51 | Catcher | 0.50 |
| | | Lifts | 0.59 | Lifts | 0.60 |
| | | Target | 0.63 | Target | 0.70 |
| | | Month | 0.64 | | |
| ESA AV | SFE | Fishing year | 0.07 | Fishing year | 0.11 |
| | | Permit | 0.38 | Catcher | 0.63 |
| | | Lifts | 0.51 | Target | 0.71 |
| | | Month | 0.54 | Lifts | 0.75 |
| | | Moon | 0.54 | Month | 0.76 |
| | | | | Taieri River flow | 0.77 |
| | LFE | Fishing year | 0.06 | Fishing year | 0.07 |
| | | Permit | 0.37 | Catcher | 0.41 |
| | | Lifts | 0.50 | Target | 0.59 |
| | | Target | 0.60 | Lifts | 0.66 |
| | | Month | 0.61 | Month | 0.67 |
| | | | | Moon | 0.68 |
| ESA AW | SFE | Fishing year | 0.05 | Fishing year | 0.16 |
| | | Permit | 0.34 | Target | 0.43 |
| | | Lifts | 0.56 | Lifts | 0.57 |
| | | Month | 0.59 | Catcher | 0.64 |
| | | Waiau River flow | 0.60 | Mataura nitrogen | 0.64 |
| | | | | Month | 0.65 |
| | | | | Moon | 0.66 |

**Appendix 3 –*continued***

| Region | Species | Variable | $R^2$ Pre-QMS | Variable | $R^2$ Post-QMS |
|---|---|---|---|---|---|
| ESA AW | LFE | Fishing year | 0.02 | Fishing year | 0.05 |
| | | Permit | 0.25 | Lifts | 0.46 |
| | | Lifts | 0.46 | Target | 0.59 |
| | | Month | 0.49 | Catcher | 0.65 |
| | | Target | 0.50 | Month | 0.67 |
| ESA AS1 | SFE | – | – | Fishing year | 0.22 |
| | | – | – | Lifts | 0.37 |
| | | – | – | Month | 0.42 |
| | | | | Catcher | 0.45 |
| | | | | Lake level | 0.46 |

**Appendix 4: CPUE indices by ESA for shortfin and longfin, pre- and post QMS. CI, 95% confidence intervals; s.e., standard error; CV, coefficient of variation; –, insufficient data or not done. 1991 represents 1990–91 fishing year.**

## ESA AN

Shortfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | – | – | – | – | – | 2001 | – | – | – | – | – |
| 1992 | – | – | – | – | – | 2002 | – | – | – | – | – |
| 1993 | 1.24 | 0.59 | 2.63 | 0.38 | 0.39 | 2003 | – | – | – | – | – |
| 1994 | 1.16 | 0.65 | 2.05 | 0.29 | 0.29 | 2004 | – | – | – | – | – |
| 1995 | – | – | – | – | – | 2005 | – | – | – | – | – |
| 1996 | 0.89 | 0.72 | 1.11 | 0.11 | 0.11 | 2006 | – | – | – | – | – |
| 1997 | 0.41 | 0.26 | 0.66 | 0.23 | 0.24 | 2007 | – | – | – | – | – |
| 1998 | 0.97 | 0.76 | 1.23 | 0.12 | 0.12 | 2008 | – | – | – | – | – |
| 1999 | 1.37 | 1.05 | 1.78 | 0.13 | 0.13 | 2009 | – | – | – | – | – |
| 2000 | 1.43 | 1.08 | 1.89 | 0.14 | 0.14 | 2010 | – | – | – | – | – |

Longfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 2.29 | 1.84 | 2.86 | 0.11 | 0.11 | 2001 | – | – | – | – | – |
| 1992 | 1.15 | 1.00 | 1.33 | 0.07 | 0.07 | 2002 | – | – | – | – | – |
| 1993 | 0.80 | 0.71 | 0.90 | 0.06 | 0.06 | 2003 | – | – | – | – | – |
| 1994 | 1.06 | 0.88 | 1.29 | 0.09 | 0.09 | 2004 | – | – | – | – | – |
| 1995 | 0.85 | 0.75 | 0.97 | 0.06 | 0.06 | 2005 | – | – | – | – | – |
| 1996 | 0.81 | 0.73 | 0.90 | 0.05 | 0.05 | 2006 | – | – | – | – | – |
| 1997 | 0.66 | 0.54 | 0.83 | 0.11 | 0.11 | 2007 | – | – | – | – | – |
| 1998 | 0.72 | 0.62 | 0.83 | 0.07 | 0.07 | 2008 | – | – | – | – | – |
| 1999 | 1.10 | 0.93 | 1.29 | 0.08 | 0.08 | 2009 | – | – | – | – | – |
| 2000 | 1.23 | 1.04 | 1.46 | 0.09 | 0.09 | 2010 | – | – | – | – | – |

## ESA AP-AQ

Shortfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 2.36 | 2.06 | 2.71 | 0.07 | 0.07 | 2001 | – | – | – | – | – |
| 1992 | 1.94 | 1.66 | 2.27 | 0.08 | 0.08 | 2002 | – | – | – | – | – |
| 1993 | 1.59 | 1.37 | 1.86 | 0.08 | 0.08 | 2003 | – | – | – | – | – |
| 1994 | 1.34 | 1.20 | 1.51 | 0.06 | 0.06 | 2004 | – | – | – | – | – |
| 1995 | 1.14 | 1.03 | 1.27 | 0.05 | 0.05 | 2005 | – | – | – | – | – |
| 1996 | 0.65 | 0.59 | 0.71 | 0.05 | 0.05 | 2006 | – | – | – | – | – |
| 1997 | 0.55 | 0.48 | 0.63 | 0.07 | 0.07 | 2007 | – | – | – | – | – |
| 1998 | 0.38 | 0.33 | 0.43 | 0.06 | 0.06 | 2008 | – | – | – | – | – |
| 1999 | 0.73 | 0.65 | 0.82 | 0.06 | 0.06 | 2009 | – | – | – | – | – |
| 2000 | 0.91 | 0.79 | 1.04 | 0.07 | 0.07 | 2010 | – | – | – | – | – |

Longfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.72 | 1.44 | 2.05 | 0.09 | 0.09 | 2001 | – | – | – | – | – |
| 1992 | 1.18 | 0.90 | 1.55 | 0.14 | 0.14 | 2002 | – | – | – | – | – |
| 1993 | 1.21 | 0.60 | 2.43 | 0.35 | 0.36 | 2003 | – | – | – | – | – |
| 1994 | 1.43 | 1.18 | 1.73 | 0.10 | 0.10 | 2004 | – | – | – | – | – |
| 1995 | 1.17 | 0.99 | 1.39 | 0.08 | 0.08 | 2005 | – | – | – | – | – |
| 1996 | 1.19 | 1.03 | 1.39 | 0.08 | 0.08 | 2006 | – | – | – | – | – |
| 1997 | 0.68 | 0.58 | 0.80 | 0.08 | 0.08 | 2007 | – | – | – | – | – |
| 1998 | 0.77 | 0.66 | 0.89 | 0.07 | 0.07 | 2008 | – | – | – | – | – |
| 1999 | 0.83 | 0.72 | 0.95 | 0.07 | 0.07 | 2009 | – | – | – | – | – |
| 2000 | 0.47 | 0.40 | 0.55 | 0.08 | 0.08 | 2010 | – | – | – | – | – |

## ESA AR

Shortfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.13 | 0.99 | 1.28 | 0.07 | 0.07 | 2001 | – | – | – | – | – |
| 1992 | 1.09 | 1.00 | 1.19 | 0.04 | 0.04 | 2002 | – | – | – | – | – |
| 1993 | 0.94 | 0.84 | 1.06 | 0.06 | 0.06 | 2003 | – | – | – | – | – |
| 1994 | 1.01 | 0.94 | 1.08 | 0.04 | 0.04 | 2004 | – | – | – | – | – |
| 1995 | 0.81 | 0.75 | 0.87 | 0.04 | 0.04 | 2005 | – | – | – | – | – |
| 1996 | 0.98 | 0.90 | 1.06 | 0.04 | 0.04 | 2006 | – | – | – | – | – |
| 1997 | 0.97 | 0.89 | 1.05 | 0.04 | 0.04 | 2007 | – | – | – | – | – |
| 1998 | 1.00 | 0.91 | 1.10 | 0.05 | 0.05 | 2008 | – | – | – | – | – |
| 1999 | 1.13 | 0.99 | 1.27 | 0.06 | 0.06 | 2009 | – | – | – | – | – |
| 2000 | 0.99 | 0.73 | 1.34 | 0.15 | 0.15 | 2010 | – | – | – | – | – |

Longfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.29 | 1.11 | 1.51 | 0.08 | 0.08 | 2001 | – | – | – | – | – |
| 1992 | 0.87 | 0.77 | 0.99 | 0.06 | 0.06 | 2002 | – | – | – | – | – |
| 1993 | 1.00 | 0.85 | 1.19 | 0.08 | 0.08 | 2003 | – | – | – | – | – |
| 1994 | 1.06 | 0.94 | 1.18 | 0.06 | 0.06 | 2004 | – | – | – | – | – |
| 1995 | 0.75 | 0.67 | 0.83 | 0.05 | 0.05 | 2005 | – | – | – | – | – |
| 1996 | 1.21 | 1.08 | 1.36 | 0.06 | 0.06 | 2006 | – | – | – | – | – |
| 1997 | 1.09 | 0.97 | 1.23 | 0.06 | 0.06 | 2007 | – | – | – | – | – |
| 1998 | 0.75 | 0.65 | 0.87 | 0.07 | 0.07 | 2008 | – | – | – | – | – |
| 1999 | 1.02 | 0.88 | 1.17 | 0.07 | 0.07 | 2009 | – | – | – | – | – |
| 2000 | 1.10 | 0.92 | 1.32 | 0.09 | 0.09 | 2010 | – | – | – | – | – |

## ESA AT

Shortfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 2.09 | 1.79 | 2.45 | 0.08 | 0.08 | 2001 | – | – | – | – | – |
| 1992 | 1.07 | 0.97 | 1.18 | 0.05 | 0.05 | 2002 | – | – | – | – | – |
| 1993 | 0.84 | 0.77 | 0.93 | 0.05 | 0.05 | 2003 | – | – | – | – | – |
| 1994 | 1.01 | 0.91 | 1.12 | 0.05 | 0.05 | 2004 | – | – | – | – | – |
| 1995 | 0.79 | 0.72 | 0.87 | 0.05 | 0.05 | 2005 | – | – | – | – | – |
| 1996 | 0.97 | 0.87 | 1.08 | 0.05 | 0.05 | 2006 | – | – | – | – | – |
| 1997 | 0.85 | 0.77 | 0.95 | 0.05 | 0.05 | 2007 | – | – | – | – | – |
| 1998 | 1.07 | 0.93 | 1.23 | 0.07 | 0.07 | 2008 | – | – | – | – | – |
| 1999 | 0.67 | 0.56 | 0.80 | 0.09 | 0.09 | 2009 | – | – | – | – | – |
| 2000 | 1.13 | 1.00 | 1.28 | 0.06 | 0.06 | 2010 | – | – | – | – | – |

Longfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.89 | 1.63 | 2.20 | 0.07 | 0.07 | 2001 | – | – | – | – | – |
| 1992 | 0.74 | 0.67 | 0.81 | 0.05 | 0.05 | 2002 | – | – | – | – | – |
| 1993 | 0.78 | 0.70 | 0.87 | 0.06 | 0.06 | 2003 | – | – | – | – | – |
| 1994 | 1.05 | 0.95 | 1.16 | 0.05 | 0.05 | 2004 | – | – | – | – | – |
| 1995 | 0.88 | 0.79 | 0.97 | 0.05 | 0.05 | 2005 | – | – | – | – | – |
| 1996 | 0.78 | 0.70 | 0.87 | 0.05 | 0.05 | 2006 | – | – | – | – | – |
| 1997 | 0.96 | 0.85 | 1.09 | 0.06 | 0.06 | 2007 | – | – | – | – | – |
| 1998 | 0.99 | 0.84 | 1.17 | 0.08 | 0.08 | 2008 | – | – | – | – | – |
| 1999 | 0.85 | 0.68 | 1.05 | 0.11 | 0.11 | 2009 | – | – | – | – | – |
| 2000 | 1.59 | 1.39 | 1.83 | 0.07 | 0.07 | 2010 | – | – | – | – | – |

## ESA AU

| Shortfin | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre-QMS | | | | | | Post-QMS | | | | | |
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.70 | 1.09 | 2.65 | 0.22 | 0.23 | 2001 | – | – | – | – | – |
| 1992 | 1.46 | 1.01 | 2.13 | 0.19 | 0.19 | 2002 | – | – | – | – | – |
| 1993 | 0.69 | 0.57 | 0.84 | 0.10 | 0.10 | 2003 | – | – | – | – | – |
| 1994 | 1.06 | 0.73 | 1.54 | 0.19 | 0.19 | 2004 | – | – | – | – | – |
| 1995 | 0.84 | 0.68 | 1.04 | 0.11 | 0.11 | 2005 | – | – | – | – | – |
| 1996 | 1.31 | 1.04 | 1.64 | 0.11 | 0.11 | 2006 | – | – | – | – | – |
| 1997 | 0.85 | 0.68 | 1.06 | 0.11 | 0.11 | 2007 | – | – | – | – | – |
| 1998 | 1.10 | 0.85 | 1.42 | 0.13 | 0.13 | 2008 | – | – | – | – | – |
| 1999 | 0.61 | 0.46 | 0.80 | 0.14 | 0.14 | 2009 | – | – | – | – | – |
| 2000 | 0.88 | 0.68 | 1.13 | 0.13 | 0.13 | 2010 | – | – | – | – | – |

| Longfin | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre-QMS | | | | | | Post-QMS | | | | | |
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.19 | 0.96 | 1.49 | 0.11 | 0.11 | 2001 | – | – | – | – | – |
| 1992 | 0.95 | 0.73 | 1.25 | 0.13 | 0.13 | 2002 | – | – | – | – | – |
| 1993 | 0.82 | 0.69 | 0.97 | 0.08 | 0.08 | 2003 | – | – | – | – | – |
| 1994 | 0.78 | 0.65 | 0.95 | 0.09 | 0.09 | 2004 | – | – | – | – | – |
| 1995 | 0.69 | 0.61 | 0.79 | 0.07 | 0.07 | 2005 | – | – | – | – | – |
| 1996 | 1.22 | 0.95 | 1.55 | 0.12 | 0.12 | 2006 | – | – | – | – | – |
| 1997 | 1.11 | 0.94 | 1.30 | 0.08 | 0.08 | 2007 | – | – | – | – | – |
| 1998 | 0.97 | 0.81 | 1.15 | 0.09 | 0.09 | 2008 | – | – | – | – | – |
| 1999 | 1.34 | 1.10 | 1.62 | 0.10 | 0.10 | 2009 | – | – | – | – | – |
| 2000 | 1.14 | 0.89 | 1.46 | 0.12 | 0.13 | 2010 | – | – | – | – | – |

## ESA AX

Shortfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 0.96 | 0.86 | 1.08 | 0.06 | 0.06 | 2001 | – | – | – | – | – |
| 1992 | 0.61 | 0.48 | 0.77 | 0.12 | 0.12 | 2002 | 0.81 | 0.72 | 0.90 | 0.06 | 0.06 |
| 1993 | 1.07 | 0.95 | 1.20 | 0.06 | 0.06 | 2003 | 0.73 | 0.62 | 0.88 | 0.09 | 0.09 |
| 1994 | 0.95 | 0.86 | 1.04 | 0.05 | 0.05 | 2004 | 0.87 | 0.75 | 1.01 | 0.07 | 0.07 |
| 1995 | 0.90 | 0.80 | 1.01 | 0.06 | 0.06 | 2005 | 0.99 | 0.86 | 1.13 | 0.07 | 0.07 |
| 1996 | 0.85 | 0.74 | 0.98 | 0.07 | 0.07 | 2006 | 0.87 | 0.77 | 0.99 | 0.06 | 0.06 |
| 1997 | 0.75 | 0.65 | 0.86 | 0.07 | 0.07 | 2007 | 0.99 | 0.90 | 1.09 | 0.05 | 0.05 |
| 1998 | 1.31 | 1.13 | 1.53 | 0.08 | 0.08 | 2008 | 0.89 | 0.80 | 0.98 | 0.05 | 0.05 |
| 1999 | 1.52 | 1.35 | 1.73 | 0.06 | 0.06 | 2009 | 1.49 | 1.33 | 1.67 | 0.06 | 0.06 |
| 2000 | 1.48 | 1.27 | 1.73 | 0.08 | 0.08 | 2010 | 1.16 | 1.04 | 1.29 | 0.05 | 0.05 |
| | | | | | | 2011 | 1.16 | 1.04 | 1.29 | 0.05 | 0.05 |
| | | | | | | 2012 | 1.11 | 1.00 | 1.23 | 0.05 | 0.05 |
| | | | | | | 2013 | 1.16 | 1.04 | 1.28 | 0.05 | 0.05 |

Longfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.09 | 1.02 | 1.16 | 0.03 | 0.03 | 2001 | – | – | – | – | – |
| 1992 | 0.95 | 0.89 | 1.02 | 0.03 | 0.03 | 2002 | 0.80 | 0.74 | 0.87 | 0.04 | 0.04 |
| 1993 | 0.76 | 0.71 | 0.81 | 0.03 | 0.03 | 2003 | 0.79 | 0.73 | 0.86 | 0.04 | 0.04 |
| 1994 | 0.89 | 0.84 | 0.95 | 0.03 | 0.03 | 2004 | 0.93 | 0.85 | 1.02 | 0.05 | 0.05 |
| 1995 | 1.10 | 1.03 | 1.18 | 0.03 | 0.03 | 2005 | 0.94 | 0.87 | 1.01 | 0.04 | 0.04 |
| 1996 | 0.99 | 0.92 | 1.06 | 0.03 | 0.03 | 2006 | 0.96 | 0.88 | 1.04 | 0.04 | 0.04 |
| 1997 | 0.94 | 0.88 | 1.01 | 0.03 | 0.03 | 2007 | 1.01 | 0.95 | 1.08 | 0.03 | 0.03 |
| 1998 | 0.97 | 0.89 | 1.05 | 0.04 | 0.04 | 2008 | 0.95 | 0.89 | 1.01 | 0.03 | 0.03 |
| 1999 | 1.11 | 1.03 | 1.19 | 0.03 | 0.03 | 2009 | 1.06 | 0.97 | 1.16 | 0.05 | 0.05 |
| 2000 | 1.29 | 1.19 | 1.41 | 0.04 | 0.04 | 2010 | 1.28 | 1.18 | 1.39 | 0.04 | 0.04 |
| | | | | | | 2011 | 1.23 | 1.13 | 1.34 | 0.04 | 0.04 |
| | | | | | | 2012 | 1.01 | 0.93 | 1.09 | 0.04 | 0.04 |
| | | | | | | 2013 | 1.16 | 1.06 | 1.26 | 0.04 | 0.04 |

## ESA AV

Shortfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.51 | 1.28 | 1.79 | 0.08 | 0.08 | 2001 | | | | | |
| 1992 | 1.20 | 1.05 | 1.37 | 0.07 | 0.07 | 2002 | 0.86 | 0.76 | 0.99 | 0.07 | 0.07 |
| 1993 | 1.05 | 0.96 | 1.15 | 0.05 | 0.05 | 2003 | 0.86 | 0.75 | 0.98 | 0.07 | 0.07 |
| 1994 | 1.03 | 0.94 | 1.12 | 0.04 | 0.04 | 2004 | 0.76 | 0.65 | 0.89 | 0.08 | 0.08 |
| 1995 | 0.92 | 0.84 | 1.01 | 0.05 | 0.05 | 2005 | 1.05 | 0.91 | 1.22 | 0.07 | 0.07 |
| 1996 | 0.87 | 0.79 | 0.95 | 0.05 | 0.05 | 2006 | 0.89 | 0.74 | 1.07 | 0.09 | 0.09 |
| 1997 | 0.90 | 0.81 | 0.99 | 0.05 | 0.05 | 2007 | 1.21 | 1.00 | 1.46 | 0.09 | 0.09 |
| 1998 | 0.84 | 0.75 | 0.94 | 0.06 | 0.06 | 2008 | 0.80 | 0.64 | 1.01 | 0.12 | 0.12 |
| 1999 | 0.83 | 0.75 | 0.92 | 0.05 | 0.05 | 2009 | 1.26 | 0.99 | 1.59 | 0.12 | 0.12 |
| 2000 | 1.02 | 0.94 | 1.12 | 0.04 | 0.04 | 2010 | 1.27 | 1.04 | 1.57 | 0.10 | 0.10 |
| | | | | | | 2011 | 1.34 | 1.12 | 1.61 | 0.09 | 0.09 |
| | | | | | | 2012 | 1.12 | 0.94 | 1.34 | 0.09 | 0.09 |
| | | | | | | 2013 | 0.81 | 0.70 | 0.94 | 0.07 | 0.07 |

Longfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.35 | 1.26 | 1.43 | 0.03 | 0.03 | 2001 | | | | | |
| 1992 | 1.20 | 1.13 | 1.27 | 0.03 | 0.03 | 2002 | 0.91 | 0.84 | 0.97 | 0.04 | 0.04 |
| 1993 | 1.14 | 1.08 | 1.21 | 0.03 | 0.03 | 2003 | 0.84 | 0.79 | 0.90 | 0.03 | 0.03 |
| 1994 | 1.27 | 1.21 | 1.35 | 0.03 | 0.03 | 2004 | 0.92 | 0.86 | 0.99 | 0.04 | 0.04 |
| 1995 | 0.93 | 0.88 | 0.98 | 0.03 | 0.03 | 2005 | 1.11 | 1.05 | 1.19 | 0.03 | 0.03 |
| 1996 | 0.80 | 0.75 | 0.85 | 0.03 | 0.03 | 2006 | 0.95 | 0.89 | 1.02 | 0.03 | 0.03 |
| 1997 | 0.86 | 0.80 | 0.92 | 0.03 | 0.03 | 2007 | 1.05 | 0.97 | 1.13 | 0.04 | 0.04 |
| 1998 | 0.87 | 0.81 | 0.93 | 0.03 | 0.03 | 2008 | 0.98 | 0.91 | 1.06 | 0.04 | 0.04 |
| 1999 | 0.85 | 0.80 | 0.91 | 0.03 | 0.03 | 2009 | 1.12 | 0.91 | 1.38 | 0.10 | 0.10 |
| 2000 | 0.91 | 0.85 | 0.97 | 0.03 | 0.03 | 2010 | 0.94 | 0.84 | 1.05 | 0.06 | 0.06 |
| | | | | | | 2011 | 1.32 | 1.17 | 1.48 | 0.06 | 0.06 |
| | | | | | | 2012 | 0.96 | 0.87 | 1.05 | 0.04 | 0.04 |
| | | | | | | 2013 | 0.99 | 0.91 | 1.07 | 0.04 | 0.04 |

## ESA AW

Shortfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.30 | 1.06 | 1.60 | 0.10 | 0.10 | 2001 | | | | | |
| 1992 | 1.03 | 0.91 | 1.16 | 0.06 | 0.06 | 2002 | 0.68 | 0.59 | 0.79 | 0.07 | 0.07 |
| 1993 | 0.99 | 0.89 | 1.10 | 0.05 | 0.05 | 2003 | 0.61 | 0.44 | 0.84 | 0.16 | 0.16 |
| 1994 | 1.33 | 1.20 | 1.48 | 0.05 | 0.05 | 2004 | 0.91 | 0.79 | 1.06 | 0.08 | 0.08 |
| 1995 | 1.01 | 0.88 | 1.17 | 0.07 | 0.07 | 2005 | 1.03 | 0.87 | 1.21 | 0.08 | 0.08 |
| 1996 | 0.88 | 0.75 | 1.03 | 0.08 | 0.08 | 2006 | 0.83 | 0.71 | 0.97 | 0.08 | 0.08 |
| 1997 | 0.79 | 0.68 | 0.92 | 0.07 | 0.07 | 2007 | 1.07 | 0.93 | 1.23 | 0.07 | 0.07 |
| 1998 | 0.89 | 0.74 | 1.06 | 0.09 | 0.09 | 2008 | 1.29 | 1.08 | 1.55 | 0.09 | 0.09 |
| 1999 | 0.90 | 0.79 | 1.02 | 0.06 | 0.06 | 2009 | 0.80 | 0.67 | 0.96 | 0.09 | 0.09 |
| 2000 | 1.01 | 0.91 | 1.13 | 0.06 | 0.06 | 2010 | 1.23 | 1.07 | 1.41 | 0.07 | 0.07 |
| | | | | | | 2011 | 1.35 | 1.13 | 1.62 | 0.09 | 0.09 |
| | | | | | | 2012 | 1.26 | 1.07 | 1.47 | 0.08 | 0.08 |
| | | | | | | 2013 | 1.34 | 1.11 | 1.62 | 0.10 | 0.10 |

Longfin

| Pre-QMS | | | | | | Post-QMS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | 1.46 | 1.38 | 1.54 | 0.03 | 0.03 | 2001 | | | | | |
| 1992 | 1.13 | 1.08 | 1.18 | 0.02 | 0.02 | 2002 | 1.00 | 0.93 | 1.06 | 0.03 | 0.03 |
| 1993 | 1.13 | 1.07 | 1.18 | 0.02 | 0.02 | 2003 | 1.09 | 1.00 | 1.20 | 0.05 | 0.05 |
| 1994 | 1.22 | 1.16 | 1.28 | 0.03 | 0.03 | 2004 | 0.85 | 0.80 | 0.91 | 0.03 | 0.03 |
| 1995 | 0.99 | 0.94 | 1.05 | 0.03 | 0.03 | 2005 | 1.10 | 1.03 | 1.18 | 0.03 | 0.03 |
| 1996 | 1.00 | 0.94 | 1.06 | 0.03 | 0.03 | 2006 | 1.05 | 0.98 | 1.12 | 0.03 | 0.03 |
| 1997 | 0.92 | 0.87 | 0.97 | 0.03 | 0.03 | 2007 | 0.82 | 0.76 | 0.89 | 0.04 | 0.04 |
| 1998 | 0.79 | 0.75 | 0.84 | 0.03 | 0.03 | 2008 | 0.92 | 0.86 | 0.97 | 0.03 | 0.03 |
| 1999 | 0.68 | 0.64 | 0.72 | 0.03 | 0.03 | 2009 | 0.92 | 0.85 | 0.99 | 0.04 | 0.04 |
| 2000 | 0.91 | 0.86 | 0.96 | 0.03 | 0.03 | 2010 | 0.86 | 0.80 | 0.92 | 0.03 | 0.03 |
| | | | | | | 2011 | 1.23 | 1.16 | 1.30 | 0.03 | 0.03 |
| | | | | | | 2012 | 1.15 | 1.08 | 1.23 | 0.03 | 0.03 |
| | | | | | | 2013 | 1.12 | 1.05 | 1.19 | 0.03 | 0.03 |

## ESA AS1

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Shortfin |
| | | | | | Pre-QMS | | | | | | Post-QMS |
| | | Confidence intervals | | | | | | Confidence intervals | | | |
| Year | Index | Lower | Upper | s.e. | CV | Year | Index | Lower | Upper | s.e. | CV |
| 1991 | – | – | – | – | – | 2001 | | | | | |
| 1992 | – | – | – | – | – | 2002 | 0.37 | 0.34 | 0.41 | 0.05 | 0.05 |
| 1993 | – | – | – | – | – | 2003 | 0.42 | 0.38 | 0.46 | 0.05 | 0.05 |
| 1994 | – | – | – | – | – | 2004 | 0.51 | 0.45 | 0.57 | 0.06 | 0.06 |
| 1995 | – | – | – | – | – | 2005 | 0.58 | 0.52 | 0.64 | 0.05 | 0.05 |
| 1996 | – | – | – | – | – | 2006 | 0.79 | 0.70 | 0.90 | 0.06 | 0.06 |
| 1997 | – | – | – | – | – | 2007 | 1.17 | 1.04 | 1.32 | 0.06 | 0.06 |
| 1998 | – | – | – | – | – | 2008 | 1.28 | 1.17 | 1.41 | 0.05 | 0.05 |
| 1999 | – | – | – | – | – | 2009 | 1.31 | 1.18 | 1.46 | 0.05 | 0.05 |
| 2000 | – | – | – | – | – | 2010 | 1.17 | 1.06 | 1.30 | 0.05 | 0.05 |
| | | | | | | 2011 | 2.34 | 2.06 | 2.65 | 0.06 | 0.06 |
| | | | | | | 2012 | 2.29 | 1.97 | 2.65 | 0.07 | 0.08 |
| | | | | | | 2013 | 2.23 | 1.92 | 2.59 | 0.07 | 0.07 |