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Catch per unit effort (CPUE) analyses and characterisation of the North Island commercial freshwater eel fishery, 1990–91 to 2014–15

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This report presents the updated fishery characterisations and standardised CPUE analyses for the North Island commercial freshwater eel fishery from 1991 to 2015 (i.e., fishing years 1990–91 to 2014–15), extending the time series by three years. Analyses were carried out for shortfin and longfin eels individually for all 12 North Island eel statistical areas (ESAs AA–AM). Reconstructed target species and water quality variables were included as predictor variables for the first time for North Island analyses. Binomial CPUE analyses were attempted for the first time for New Zealand eels, but were rejected by the Eel Working Group on the basis that target species could not be included as a predictor variable and hence the resulting indices were likely to be biased. Similarly, the CPUE analyses using processor size grade landings were rejected because a substantial proportion of the data could not be effectively linked with the catch effort data.

CPUE and fishery characterisation analyses were based on groomed estimated catch, which was 89% of the landed catch over the 25-year time series. Virtually all instances when estimated catch was lower than landed catch for each species occurred before 2002, largely due to a significant portion of the catch being reported as unidentified eel (EEU), as well as the removal of suspect records recorded on Catch Effort Landing Returns (CELRs). From 2002 onward, when Eel Catch Effort Returns (ECER) replaced CELRs, there was a good match between estimated and landed catch. Catch and effort associated with EEU records were not used in the CPUE analysis.

Throughout the 25-year North Island time series, shortfin estimated groomed catches accounted for nearly three-quarters (73%) of the combined shortfin and longfin eel catch. Over the last eight years this has increased as longfin catch has decreased, and in 2015 it was 86%. Shortfin is the dominant species with respect to catch proportions in all ESAs except Wellington (AM) and Taranaki (AJ), which have yielded more longfin, whereas proportions in Rangitikei-Whanganui (AH) are close to parity. When EEU was a valid species code before 2002 it accounted for 36% of the estimated North Island eel catch. The largest proportion of the shortfin catch (22%) comes from Northland (AA), with two-thirds (64%) from just four ESAs (Northland AA, Auckland AB, Waikato AD, and Hawke’s Bay AG). Seventy percent of the longfin catch is from five ESAs (Northland, AA, Waikato AD, Rangitikei-Whanganui AH, Taranaki AJ, and Hawke’s Bay AG).

Unstandardised (geometric mean of catch per lift) CPUE analyses were carried out separately for longfin and shortfin species, and for each ESA, using estimated groomed catches for all data, and for core fishers. Standardised CPUE analyses were carried out separately for each species and ESA for core fishers using a Generalised Linear Model (GLM), where the response variable was daily non-zero catch. The three variables, target species, permit and lifts were included in all models. Target species often explained the most variance in the non-zero catch GLM, especially for longfin, for which the trends in CPUE changed more than shortfin compared to previous analyses when target was not offered to the model.

Shortfin CPUE summary

Shortfin standardised CPUE analyses were acceptable for all ESA analyses, except Wellington (ESA AM) where no analyses were attempted due to insufficient data. In general, CPUE for North Island shortfin either initially declined or there were no trends, followed by strong increases, beginning from around 2002 (except Northland (ESA AA) where CPUE steadily increased throughout the time series). Subsequent shortfin reductions in the TACC in 2007–08 are likely to have contributed to the improved CPUE at this time. The non-reporting of legal-sized shortfin returned alive to the water in the last five years, and the regulatory increase in escape tube size from 25 mm to 31 mm in 2013–14, suggest that the shortfin CPUE estimates are conservative since about 2007.

Longfin CPUE summary

Longfin standardised CPUE analyses based on robust data sets were completed for: Northland (ESA AA), Auckland (AB), Hauraki (AC) and Waikato (AD). No analyses were attempted for Wellington (ESA AM). There were fewer data for longfin analyses than for shortfin for most areas, and indices were often more variable or associated with wider confidence intervals. In general, CPUE for North Island longfin initially declined, followed by increases or no trend beginning from around 2002 (except Northland (ESA AA) where CPUE declined slightly throughout the time series). The addition of reconstructed target species as an explanatory variable had a much greater impact on longfin CPUE indices than shortfin indices, tending to reduce the steepness of the initial decline and increase CPUE in recent years. The trends for longfin have therefore changed since the last analyses up to 2011–12. The longfin fishery appears to be showing indications of a halt and in some cases a reversal in the declines in CPUE that were observed over the first 10 years of the time series. Subsequent reductions in the longfin TACC in 2007–08 are likely to have contributed to the improved CPUE at this time. The non-reporting of legal-sized eels returned alive to the water, the introduction of the 4 kg maximum size for longfins in 2007, and the regulatory increase in escape tube size from 25 mm to 31 mm in 2013–14, suggest that the longfin CPUE estimates are conservative since about 2007.

1. INTRODUCTION

This report presents the results of a catch per unit effort (CPUE) analysis for the commercial freshwater eel fishery for all North Island eel statistical areas (ESA) for the fishing years 1990–91 to 2014–15, and updates previous similar analyses (Beentjes & Bull 2002, Beentjes & Dunn 2003a, 2003b, 2010, 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) (Ministry for Primary Industries 2016). Catches then progressively declined, but since 2004–05 they have fluctuated around 600 to 700 t with no trend.

Historical catches

North Island catches have contributed between 51 and 72% of the New Zealand total eel catch, and over the last 10 years the average has been 57%.

Shortfin has consistently been the dominant species in the North Island, representing, on average, about 71% of the landed catch, increasing to 82% over the last 10 years, and in 2014–15 it was the highest on record at 88% of the catch (Figure 1). Despite the dominance of shortfin, longfin is caught throughout the North Island, and approaches 50% or more of the catch in Rangitikei-Whanganui (AH), Taranaki (AJ), and in catchments of Waikato (AD) that drain westward to the coast (Beentjes 2005, 2008a, 2008b, 2013) (Figure 2).

Shortfin catches declined overall from 1995–96 until 2008–09 in the North Island, and then fluctuated around 300 t with no trend (Figure 1). Similarly, longfin catches declined from 1990–91 to 2008–09 and have since fluctuated between about 40 and 80 t with no trend.

In the South Island there was little difference between longfin and shortfin catches until about 2002–03, after which shortfin landings significantly exceeded those of longfin with the exception of three years from 2011–12 to 2013–14. Both South Island shortfin and longfin catches declined after about 1993–94, although the decline was most marked for longfin. Over the past 13 years, shortfin catch has been remarkably stable compared to longfin catch, which has varied more than three-fold (Figure 1).

The trends of declining catches preceded the introduction of eels into the Quota Management System (QMS) in both the North (2004–05) and South Islands (2000–01).

Quota Management System (QMS)

The New Zealand eel fishery was introduced into the Quota Management System (QMS) in stages, beginning with the South Island in 2000–01, with five Quota Management Areas and Total Allowable Commercial Catches (TACC) set for shortfin and longfin species combined (Figure 3). 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 2016). In 2016–17, separate TACCs were set for South Island shortfin and longfin with four QMAs allocated a nominal TACC for longfin of 1 t for each of LFE 11, 12, 13 and 14, essentially closing these areas to commercial fishing and leaving LFE 15 and 16 to provide the commercial longfin catch. These two South Island QMAs have provided about 80% of the longfin catch since introduction to the QMS.

The Chatham Island eel fishery was introduced into the QMS in 2004 as a single QMA with TACCs for each species. Lastly, the North Island eel fishery was introduced into the QMS in 2004–05 with four separate QMAs, each with shortfin and longfin TACCs (Figure 3). The TACCs were subsequently reduced for all North Island stocks in 2007–08, by 58% for longfin and 26% for shortfin (all stocks combined). The only fishing year that TACCs were fully caught for all North Island shortfin and longfin stocks was 2011–12 (Ministry for Primary Industries 2016) (Figure 1).

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).

Statistical areas for reporting catch effort data were changed from numeric codes (1–23) to alpha codes (AA–AZ) in July 2000 (see Figure 2, Table 1). In this report ESAs are referred to by the current alpha codes, although some previous analyses used the numeric codes. Table 1 shows the relationship between ESAs (numeric and alpha), QMAs and area names.

1.3 Specific objective

To analyse CPUE trends in the North Island commercial eel fisheries (LFE 20, LFE 21, LFE 22, LFE 23, SFE 20, SFE 21, SFE 22, SFE 23) using data up to the end of the fishing year 2014–15.

2. METHODS

2.1 Catch effort data extraction and grooming

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 comprised each daily record from fishing years (1 October to 30 September) 1990–91 to 2014–15 for all North 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 (subsequently referred to as 'lifts')
- 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 2014–15)

- 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 (= catcher). 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 for North Island analyses. Identity of the catcher 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., JBLOG, 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 296 to 105 after grooming and recoding. There is no guarantee that the assignment was correct in all cases.

In the current analyses, all ECER data for the years 2001–02 to 2014–15 (13 years) for all North Island ESAs were extracted, groomed for errors or missing data, and appended to the existing groomed data sets from CELR data, creating a time series for each ESA from 1990–91 to 2014–15 (25 years) (Table 2). The CELR data were not re-extracted 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 2003a). The transition between CELR and ECER in 2001–02 is considered to have had no effect on the continuity of the way in which estimated catches and effort data are recorded, as both forms provided estimated catch of shortfin and longfin eels, the number of nets set per night, and the statistical area where eels were caught. The only real difference is that EEU was not recorded on ECER forms so all data can be used in the species-specific analyses.

Inspection of the unencrypted data during the analyses up to 2006–07 revealed a number of South Island fishers that had been recorded as fishing in the North Island (Beentjes & Dunn 2010). After contacting some of these individuals and speaking with MPI at this time, it was clear that this was implausible and more likely an error in reporting of statistical area or data punching. This resulted in data from 10 South Island permit holders being excluded from the analysis in 2001–02 and 2002–03, accounting for 76 t of catch (0.7% of the total data in the data set). The bulk of this misreporting was from ESAs AA (70%), AB (18%), and AM (10%). These data errors had not been corrected in the MPI database at the time of the current analyses, and these permits were again excluded.

Apart from the South Island fishers, there were no deletions and all ECER records were retained in the current characterisation analyses, including those from set net catch. In previous analyses set net catch data were excluded before the characterisation, and if the variable 'number of net lifts' was missing the case was also removed from the data set. This time we imputed the number of lifts as the median from the fishing year it was missing; there were very few records with missing lifts per ESA so this was trivial, but this procedure retained all the catch. The CPUE analyses were carried out only on catch where method was recorded as fyke net (FN).

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 important rivers from or near each ESA were obtained from regional councils and the NIWA hydrological database (NIWA Water Resources and Climate Archive) (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 North Island 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 North 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 15ºC 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 the preceding or following four months. When water quality data 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 factor to account for possible 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).

2.3 Linking permits

The previous North Island CPUE analyses up to 2006–07 showed that some of the new entrants were not new to the fishery, post introduction of North Island eel stocks into the QMS in 2004–05, i.e., they had fished for existing permit holders during the permit moratorium and following introduction of eels into the QMS began fishing under their own permit entity (Beentjes & Dunn 2010). These fishers were all new entrants that had fished for someone else pre-QMS and if they were the only fisher that had landed catch under a pre-QMS *Client_name*, and that client did not land catch pre- and post-QMS, they were linked in the analyses, i.e., new entrant *Client_key* was changed to the existing *Client_key* of the previous employer. In all, there were 16 linkages made where existing permit entities were combined with permit entities that first appeared in 2004–05 (Beentjes & Dunn 2010). These linkages were retained in the current analyses.

2.4 Reconstructed target species

Target species is recorded in CELR forms but not in ECER forms and was not used as a predictor variable in previous analyses. In the current analyses target species was reconstructed for all records, including those from CELR data, from 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. A ‘common sense’ default minimum value of 80% was used in some cases because higher values tended to assign too many records to the category ‘either’, when kappa was above 80%.

2.5 Dealing with the time series

South Island CPUE analyses are split between pre- and post-QMS data sets because of the discontinuity of fishers following the introduction of South Island eels into the QMS in 2000 (Beentjes & Dunn 2015).

Unlike the North Island, 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.

Despite linking permits in the North Island, following the introduction into the QMS in 2004–05, there was still a clear drop in both the numbers of existing fishers and the appearance of new entrants. To determine whether models spanning the entire period for each statistical area were able to reliably estimate fisher coefficients over the transition, Beentjes & Dunn (2015) carried out separate pre- and post-QMS CPUE analyses and compared these to continuous time series CPUE analyses for the period 1991–2012. For all ESAs, the continuous versus pre- and post-QMS CPUE trends showed no marked differences and the continuous time series were accepted as valid. In the current analyses, CPUE analyses were carried out only for the continuous time series (1991–2015).

2.6 Analysis of CPUE data

2.6.1 Unstandardised CPUE analyses

Unstandardised CPUE analyses were carried out for each North Island ESA data set for shortfin, longfin, and all eels (all eels include those recorded as EEU). It is presented as the geometric mean of catch (>zero)/total lifts per year for all raw data, and also for core fishers. The core fishers unstandardised CPUE indices are plotted alongside the standardised CPUE indices.

2.6.2 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 data set restricting data analysis to core fishers (identified by permit number). Shortfin core fishers were defined as those that 1) caught shortfin eels in at least three years in each of which fishing took place on 10 days or more, and 2) caught more than 1000 kg over all years. Longfin core fishers were defined in the same way as shortfin but using only longfin catch data.

The GLM model (non-zero catch)

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 number of net lifts per day as a possible predictor allows the model to consider non-linear relationships between catch and effort.

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, number of lifts, month (season), river flow (for selected rivers within each ESA analysis), 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. The variable ‘catcher’ was only recorded from 2002 onward so could not be used in the GLM model.

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 giving 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.

2.6.3 Binomial and combined model

In previous analyses, zeros were not included in the CPUE analyses. In the current analyses the valid zeros (categories 1 and 2 below) were modelled using a binomial model that estimates the probability of a non-zero catch, with a binomial response and logit link function. The GLM and binomial models were then combined giving a combined CPUE index.

Records with a catch of zero for either species occur in the following ways:

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. The legitimacy of these zeros cannot be determined, so by default they are treated as valid 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, and were therefore not included in the CPUE analyses.

2.7 CPUE analyses from landed catch data

In addition to the routine standardised CPUE analyses carried out for North Island eels using estimated catch from ECERs, the Eel Working Group (EELWG-2012-39) recommended that analyses be carried out to link the landings data collected from the MPI project ‘Monitoring commercial eel fisheries’ (EEL201502) with the catch effort data to model standardised 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 2016). A similar analysis was carried out for the South Island in 2015 (Beentjes & Dunn 2015).

Landings data

North Island eel species-specific size grade landings data by ESA and sub-area were available from 2003–04 to 2014–15. For both longfin and shortfin, the largest size grade in the North Island is over 1000 g. A landing can include one or more 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), and were the same data 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

Standardised CPUE analyses were carried out for SFE and LFE separately for the catch of the large size grade using the groomed and merged data sets. No core fisher restriction was applied. Estimates of year effects and associated standard errors were then obtained using a forward stepwise Generalised Linear Model (GLM) (McCullagh & Nelder 1989), with landed catch modelled as the response variables (see Section 2.6.2 on the GLM). The predictor variables selected by the GLM were permit, month, number of lifts, sub-area, catcher and target. The standardised CPUE from the total landed catch (all size grades combined) was compared with that from the estimated catch over the same period to test for consistency in trends.

2.8 Reporting legal-sized eels that were released

The weight of all eels of legal size (220–4000 g) caught and released by commercial fishers are required to be included as part of the estimated catch recorded on ECERs, and separately on ECLRs under the destination code ‘X’. It was revealed at the Eel Working Group Meeting in April 2017 (EELWG 2017-06) that some fishers are incorrectly recording only their retained legal-sized eels on the ECERs. The confusion by eel fishers around this rule relates to the lack of destination ‘X’ as a legitimate code on ECLRs until about 2007–08, when MPI sent out an information pamphlet explaining how to correctly report eel catch on statutory forms. The use of destination ‘X’ code has increased in the last few years as quota cuts have resulted in some fishers having insufficient Annual Catch Entitlement (ACE) to cover their catch. Further, specific longfin size grades have become less marketable and fishers have been requested by processors not to land these eels.

The way in which individual fishers report discarded legal catch was investigated to: 1) gauge the level and types of misreporting, and 2) determine if a correction could be applied to the catch data by the application of a suite of rules. This was carried out by comparing trip data recorded in ECERs and ECLRs for five core North Island fishers. The legal requirement is that all fish reported on the ECLR should correspond to fish reported on the ECER.

2.9 Fyke net specifications

There are no known published specification plans or descriptions of the fishing gear used in the North Island commercial eel fishery. Eel fishers in the North Island were interviewed as part of MPI project EEL201401 in 2015, which aimed to quantify the areas fished for longfin by commercial eel fishers. During interviews in Masterton two eel fishers based in the central North Island were asked about the gear they use for catching eels and the procedures used. Photos were taken of one fisher’s fyke nets.

3. RESULTS

3.1 Descriptive analyses

3.1.1 Groomed data used in the CPUE analyses

A comparison of total groomed estimated catch for the North Island extracted from CELRs/ECERs with the reported landed weights is shown in Figure 4. The groomed total estimated eel catch, including unclassified (EEU), was less than the landed catch before 2002 in some years by as much as 20%, after which they were virtually identical. Overall, total groomed estimated eel catch used in the CPUE analyses was 89% of the total reported landed catch for the North Island over the 25-year time series.

Grooming of estimated catch data from throughout the country before 2002 resulted in the deletion of between 2 and 12% of records (Beentjes & Dunn 2003a) and a lower total estimated catch over this period than was caught. From 2002, with the introduction of the ECER form, the quality of the eel fishery catch effort data improved significantly and deletions to the extracted catch effort data sets have been negligible. Despite the loss of data from the early years through grooming, the total estimated and landed catch have the same temporal trend.

When plotted by species the estimated catch as a proportion of the landed catch is much less than for total catch because EEU is not included (Figure 4). Before 2002, however, the data on landed catch by species is not of a high standard and is only estimated (Ministry for Primary Industries 2016). For both shortfin and longfin, the match from 2002 onward is close.

A small proportion (1.8%) of the shortfin catch over the last 25 years was caught using fine mesh set nets in estuaries where they are set across channels capturing eels on the receding tide (Figure 5). Of the set net catch, 56% was from ESA AC and 44% from AD. There was no longfin catch recorded by set net.

3.1.2 Spatial and temporal distribution of species catch

The relative amounts of groomed estimated catch reported as SFE, LFE or EEU in each ESA for all years combined are shown in Table 3 and Figure 6, and by year in Figure 7. Overall, the total recorded North Island catch from 1990–91 to 2014–15 was 57% shortfin, 22% longfin, and 21% EEU. When EEU was a valid species code (i.e., pre-2002) it accounted for over one-third (36%) of the estimated North Island eels catch (Figure 7). Some proportion of annual catch was recorded as EEU in all North Island ESAs and this ranged from less than 0.05% (Poverty Bay, AF) to 45% (Waikato, AD). EEU was not recorded in any ESA after 2001 with all catches reported by species (LFE or SFE). This coincides with the introduction of the ECER in 2002 when EEU was no longer accepted as a valid reporting species code (Figure 7). The proportion of the shortfin catch in individual ESAs was two to six times greater than longfin in all ESAs except Rangitikei-Whanganui (AH), Taranaki (AJ) and Wellington (AM), where longfin was dominant (Table 3, Figure 6). Nearly half of the North Island total eel catch over the last 24 years was taken from just the two ESAs: Waikato (AD) and Northland (AA), which contributed 27% and 20%, respectively.

By far the largest proportion of the shortfin catch (22%) comes from Northland (AA), with two-thirds (64%) from just four ESAs (Northland AA, Auckland AB, Waikato AD and Hawke’s Bay AG) (Table 3, Figure 6). Almost three-quarters (70%) of the longfin catch is from five ESAs (Northland AA, Waikato AD, Rangitikei-Whanganui AH, Taranaki AJ and Hawke’s Bay AG). Waikato (AD) and Northland (AA) contributed the bulk of the EEU reported catch (72%).

Because there were a significant number of data before 2002 deleted during the grooming process it is not valid to consider trends in the groomed estimated catch before 2002. From 2002 to 2009, however, there is a trend of declining estimated catch of all eels, after which annual estimated catch is comparatively stable or increasing (Figure 7).

3.2 Reporting legal-sized eels that have been released

By understanding how fishers report discarded legal catch it was hoped that a correction could be applied to the catch data by the application of a suite of rules. In simple terms, if a fisher catches 100 kg of legal-sized eels (220–4000g) and chooses to release 10 kg to the water, he must record 100 kg on his ECER (estimated catch), and then 100 kg in his ECLR, split between 90 kg under destination ‘L’ (estimated catch landed), and 10 kg under destination ‘X’ (estimated catch released), of which the latter does not count against the fisher’s ACE. In this way, the sum of ECLR destination ‘L’ and destination ‘X’ must equal the sum of ECER estimated catch.

The extent of destination ‘X’ reporting by fishers increased from less than 0.01% of the total landed North Island eel catch in 2007–08 when it was first used, to 3.1% in 2014–15, and was used more often for longfin eels (Figure 8). Comparison of individual trip data from ECER and ECLR forms showed that of five core fishers and multiple trips examined, there was no consistency either within or between fishers in the methods of reporting. Some fishers filled in the forms correctly for some trips and not for others, and dates and catches could not always be reconciled between ECER and ECLRs. There was no simple rule or suite of rules that could be applied to the ECER data to correct for any under-reporting of released eels and any attempt to do so is likely to result in more errors in the data. There are also likely to be some fishers who release legal-sized eels and don't report these on either the ECER or the ECLR as destination 'X'.

3.3 Fyke net specifications

In the South Island, shortfin fyke nets are unbaited and have very long leaders, whereas longfin nets are smaller overall, have short leaders and are always baited (Beentjes & Dunn 2015). South Island shortfin fyke nets are commonly used in ponds, lagoons and receding flood waters, and capture little longfin, even if present. The long leader on shortfin nets 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. Longfin fyke nets are commonly used in streams, rivers and lakes, and catch few shortfin, even if present.

In contrast, in the North Island the same type of fyke net is routinely used for both shortfin and longfin and these nets are baited, regardless of target species (Figure 9). Bait is placed either at the leader or in the codend. A longer leader, however, may sometimes be used when targeting shortfin. Nets are generally about 2.5 m in length, have two valves and a D ring about 600 mm high and 600 mm wide. Smaller versions of these fyke nets are sometime used in small creeks.

3.4 Fishery characterisation and CPUE analyses by ESA

The number of records (including those with zero catch), number of fishers, and groomed estimated catch of shortfin, longfin and unidentified eels are presented in Table 2. Results are presented standalone for each ESA beginning with the characterisation of the fishery, followed by the continuous time series CPUE analyses and diagnostics for shortfin and longfin, in that order. No CPUE analyses were carried out for ESA AM (Wellington) because of insufficient data. In the fishery characterisations, before about 2002 when EEU was used as a valid reporting species code, species catch data (SFE and LFE) may not be representative of the fisheries, i.e., for example, fishers using the species codes in favour of the generic EEU code, may have targeted and landed more of one species than the other, biasing the catch data.

3.4.1 Northland (ESA AA)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AA have been variable, but declined sharply in 2005 and have continued to decline with the lowest landings recorded in 2015 (Appendix A1). A high proportion of the total eel catch (19%) has been reported as unidentified (EEU) and before 2002 it was about one-third (37%) of the catch (Table 3, Appendix A1). Over the 25-year time series, Northland has contributed 20% of the total North Island eel catch and shortfin have been the dominant species in the catch (SFE 63%, LFE 18%, EEU 19%) (Table 3, Appendix A1).

Season – The Northland shortfin and longfin fisheries operate all year round (Appendices A2, A3).

Target species – Shortfin was the dominant target species (reconstructed) in all years, with a marked decline in longfin targeting in recent years to the extent that longfin was not a target species in 2015 for any fishing event (Appendix A4).

Lifts – The median number of lifts per day has declined in the last 15 years from about 25 to 20 (Appendix A5).

Zeros – There were very few zero records for total catch (15 records), where eels of either species were not caught (Appendix A6). Apart from the spike in zero shortfin catch records in 1999, there were no trends for either species. The proportion of zero catch records in the last 15 years is less than 5% for shortfin and around 50% for longfin.

Catch per day – The median annual shortfin non-zero catch has fluctuated between about 50 and 100 kg per day with indications of higher daily catch in the most recent years (Appendix A7). The median annual longfin non-zero catch fluctuated between about 20 and 70 kg per day with indications of lower daily catch since about 2002 (Appendix A8).

Shortfin CPUE analyses (ESA AA)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data show a clear increasing trend, steepest after 2007 with the highest catch rate recorded in 2015 (about 5 kg per lift) (Appendix A9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix A10. The shortfin core data used in the CPUE analyses retain 93% of the catch, but lose about two-thirds of the original fishers (Appendix 2). There are 26 shortfin core fishers: 20 pre-QMS and 18 post-QMS fishers (11 existing and 6 new entrants) (Appendices 2 and A11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers with a progressive increase over time (Appendix A12). The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables target, permit and lifts were included in the model in that order and explained 50% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix A12). Shortfin catch for core fishers has declined steadily since 2003, when catch was recorded by species.

Residual diagnostics are shown in Appendix A13, influence step plots in Appendix A14, and CDI plots for each of the model predictor variables in Appendices A15–A17. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AA)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show a slight downward trend until 2006, after which it is stable with catch rates around 1 kg per lift (Appendix A9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix A18. The longfin core data used in the CPUE analyses retain 93% of the catch, but lose about two-thirds of the original fishers (Appendix 2). There are 20 longfin core fishers: 14 pre-QMS and 11 post-QMS fishers (7 existing and 6 new entrants) (Appendices 2 and A19).

Standardised CPUE – The standardised CPUE for longfin catch followed the same general pattern as unstandardised catch rates for core fishers with an overall slight decline until 2009, after which it shows a gradually increasing trend (Appendix A20). The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables target, permit, lifts and month were included in the model in that order and explained 63% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix A20). Longfin catch for core fishers has declined steeply after 2002, when catch was recorded by species, but was stable since 2010.

Residual diagnostics are shown in Appendix A21, influence step plots in Appendix A22, and CDI plots for each of the model predictor variables in Appendices A23–A26. Target species has a large influence on the indices, lowering the indices in the first nine years when longfin was the main target species, and raising the indices after that time when shortfin replaced longfin as the main target species. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.2 Auckland (ESA AB)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AB have been variable, between and among years, with highest sustained catches recorded in the second half of the 1990s followed by catches that were generally about half that of the 1990s (Appendix B1). A high proportion of the total eel catch (15%) has been reported as unidentified (EEU), and before 2002 it was about one-quarter (24%) of the catch (Table 3, Appendix B1). Over the 25-year time series, Auckland has contributed 10% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 65%, LFE 19%, EEU 15%) (Table 3, Appendix B1).

Season – The Auckland shortfin and longfin fisheries operate all year round but catches are generally lower over the winter months (Appendices B2, B3).

Target species – Shortfin was the dominant target species (reconstructed) in all years, with a marked decline in longfin targeting in recent years to the extent that it was negligible from 2008 onward, and not used in 2015 for any fishing event (Appendix B4).

Lifts – The median number of lifts per day has been stable, ranging from about 20 to 25 nets per day (Appendix B5).

Zeros – There were very few zero records for total catch (8 records), where eels of either species were not caught (Appendix B6). The proportion of zero shortfin catch records before 2002 ranged from about 10 to 25%, after which it was always less than 5%. The proportion of zero longfin catch records has fluctuated over time with no clear trends, and in the last 10 years has been about 40%.

Catch per day – The median annual shortfin non-zero catch has fluctuated between about 50 and 140 kg per day with indications of higher daily catch in the most recent years averaging about 100 kg per day since 2005 (Appendix B7). The median annual longfin non-zero catch fluctuated between about 20 and 80 kg per day with lower daily catch since 2008 when it averaged about 25 kg per day (Appendix B8).

Shortfin CPUE analyses (ESA AB)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data show a clear increasing trend since 2002 with the highest catch rate recorded in 2015 (about 5 kg per lift) (Appendix B9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix B10. The shortfin core data used in the CPUE analyses retain 91% of the catch, but lose about two-thirds of the original fishers (Appendix 2). There are 16 shortfin core fishers: 12 pre-QMS and 9 post-QMS fishers (5 existing and 4 new entrants) (Appendices 2 and B11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers with a progressive increase over time since 2003 (Appendix B12). The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables permit, target and lifts were included in the model in that order and explained 64% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix B12). Shortfin catch for core fishers after 2002, when catch was recorded by species, fluctuated with no trend.

Residual diagnostics are shown in Appendix B13, influence step plots in Appendix B14, and CDI plots for each of the model predictor variables in Appendices B15–B17. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AB)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show a downward trend until 2006, after which it is stable with catch rates around 1 kg per lift (Appendix B9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix B18. The longfin core data used in the CPUE analyses retain 83% of the catch, but lose about two-thirds of the original fishers (Appendix 2). There are 15 core longfin fishers: 10 pre-QMS and 8 post-QMS fishers (3 existing and 5 new entrants) (Appendices 2 and B19).

Standardised CPUE – The standardised CPUE for longfin catch followed the same general pattern as unstandardised catch rates for core fishers with an overall slight decline until 2006, after which it is stable (Appendix B20). The generally narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables target, permit and lifts were included in the model in that order and explained 68% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix B20). Longfin catch for core fishers after 2002, when catch was recorded by species, fluctuated without trend.

Residual diagnostics are shown in Appendix B21, influence step plots in Appendix B22, and CDI plots for each of the model predictor variables in Appendices B23–B25. Target species has a large influence on the indices, lowering the indices in the first 10 years when longfin was the main target species, and raising the indices after that time when shortfin replaced longfin as the main target species. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.3 Hauraki (ESA AC)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AC have been variable, between and among years, and, notwithstanding the lowest catches in 2009 and 2010, there is no trend (Appendix C1). A low proportion of the total eel catch (8%) was reported as unidentified (EEU), and before 2002 this was 16% of the catch (Table 3, Appendix C1). Over the 25-year time series, Hauraki has contributed 6% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 79%, LFE 13%, EEU 8%) (Table 3, Appendix C1).

Season – The Hauraki shortfin and longfin fisheries operate all year round but catches are generally lower over the winter months (Appendices C2, C3).

Target species – Shortfin was the dominant target species (reconstructed) in all years, with longfin targeting negligible in most years, or non-existent (Appendix C4).

Lifts – The median number of lifts per day has been variable, ranging from about 15 to 25 nets per day with no trend (Appendix C5).

Zeros – There were no zero records for total catch where eels of either species were not caught (Appendix C6). The proportion of zero shortfin catch records was less than 5% (and sometimes 0%) in most years. The proportion of zero longfin catch records has fluctuated over time with no clear trends, and in the last 10 years has averaged about 60%.

Catch per day – The median annual shortfin non-zero catch fluctuated between about 60 and 100 kg per day with no trend (Appendix C7). The median annual longfin non-zero catch ranged between about 5 and 50 kg per day. Longfin catch was initially around 50 kg per day in the first three years and after that dropped to around 20 kg per day (Appendix C8).

Shortfin CPUE analyses (ESA AC)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data ranged from about 3 to 4 kg per lift with no trend (Appendix C9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix C10. The shortfin core data used in the CPUE analyses retain 96% of the catch, but lose about two-thirds of the original fishers (Appendix 2). There are 14 shortfin core fishers: 8 pre-QMS and 8 post-QMS fishers (2 existing and 6 new entrants) (Appendices 2 and C11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers with no trend until a steep and sustained increase after 2010 (Appendix C12). The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables permit, target, lifts, month and Waihou River flow were included in the model in that order and explained 40% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix C12). Shortfin catch for core fishers after 2002, when catch was recorded by species, fluctuated with no trend.

Residual diagnostics are shown in Appendix C13, influence step plots in Appendix C14, and CDI plots for each of the model predictor variables in Appendices C15–C18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AC)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show a sharp decline in the first few years followed by a very gradual decline, with 2015 the lowest catch rate in the time series (Appendix C9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix C19. The longfin core data used in the CPUE analyses retain 93% of the catch, but lose about two-thirds of the original fishers (Appendix 2). There are 9 longfin core fishers: 8 pre-QMS and 5 post-QMS fishers (2 existing and 3 new entrants) (Appendices 2 and C20).

Standardised CPUE – The standardised CPUE for longfin catch followed the same general pattern as unstandardised catch rates for core fishers with a steep decline until 2001, after which it was variable with no trend (Appendix C21). The generally narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables target, lifts and permit were included in the model in that order and explained 58% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix C21). Longfin catch for core fishers after 2002, when catch was recorded by species, fluctuated but generally declined.

Residual diagnostics are shown in Appendix C22, influence step plots in Appendix C23, and CDI plots for each of the model predictor variables in Appendices C24–C26. Target species has a large influence on the indices, lowering the indices in the first three years when longfin was targeted more often than shortfin. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.4 Waikato (ESA AD)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AD are characterised by a peak in the mid-1990s followed by a steady decline until 2003, after which catches have been reasonably stable (Appendix D1). A high proportion of the total eel catch (42%) has been reported as unidentified (EEU) and before 2002 it was nearly three-quarters (71%) of the catch (Table 3, Appendix D1). Over the 25-year time series, Waikato has contributed 27% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 42%, LFE 15%, EEU 42%) (Table 3, Appendix D1).

Season – The Waikato shortfin and longfin fisheries operate all year round, but catches are generally lower over the winter months, especially for longfin (Appendices D2, D3).

Target species – Shortfin was the dominant target species (reconstructed) in all years, with a marked decline in longfin targeting in the last six years to the extent that longfin was a negligible target species in 2015 (Appendix D4).

Lifts – The median number of lifts per day has ranged from 20 to 30 nets with no clear trend (Appendix D5).

Zeros – There were 285 zero records for total catch, but the incidence was very low until 2012 to 2014 when, for about 5% of records, neither species was caught (Appendix D6). There was a gradual declining trend in zero shortfin catch records over the time series, and it has been about 10% for the last 10 years. Longfin zero catch records have fluctuated with no trend and averaged about 50%.

Catch per day – The median annual shortfin non-zero catch has fluctuated between about 25 and 75 kg per day with indications of higher daily catch in the last 10 years (Appendix D7). The median annual longfin non-zero catch fluctuated between about 10 and 70 kg per day with indications of a gradual decline, with 2015 the lowest in the time series (Appendix D8).

Shortfin CPUE analyses (ESA AD)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data show a slight decline until 2003, followed by a gradual increase, with the highest catch rate recorded in 2011 (about 3 kg per lift) (Appendix D9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix D10. The shortfin core data used in the CPUE analyses retain 98% of the catch, but lose about half of the original fishers (Appendix 2). There are 27 shortfin core fishers: 21 pre-QMS and 15 post-QMS fishers (9 existing and 6 new entrants) (Appendices 2 and D11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers with gradual increases and decreases over time, but no overall long-term trend (Appendix D12). The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables permit, target, lifts, month, and Waipa River flow were included in the model in that order and explained 51% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix D12). Shortfin catch for core fishers has fluctuated with no trend since 2002, when catch was recorded by species.

Residual diagnostics are shown in Appendix D13, influence step plots in Appendix D14, and CDI plots for each of the model predictor variables in Appendices D15–D18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AD)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show a steep downward trend until 2008, after which there is a gradual decline to 2015 where catch rates were less than 0.5 kg per lift (Appendix D9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix D19. The longfin core data used in the CPUE analyses retain 96% of the catch, but lose about half of the original fishers (Appendix 2). There are 25 longfin core fishers: 20 pre-QMS and 14 post-QMS fishers (9 existing and 5 new entrants) (Appendices 2 and D20).

Standardised CPUE – The standardised CPUE for longfin catch does not follow the same pattern as unstandardised catch rates for core fishers. The unstandardised indices decline over the time series whereas the standardised indices show no long-term trend (Appendix D21). The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables target, permit, lifts and month were included in the model in that order and explained 66% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 a large proportion of the catch was reported as EEU (Appendix D21). Longfin catch for core fishers declined steeply after 2002, when catch was recorded by species.

Residual diagnostics are shown in Appendix D22, influence step plots in Appendix D23, and CDI plots for each of the model predictor variables in Appendices D24–D27. Target species has a large influence on the indices, lowering the indices in the first seven years when longfin was the main target species, and raising the indices after that time when shortfin replaced longfin as the main target species. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.5 Bay of Plenty (ESA AE)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AE peaked in 1995 and fluctuated without trend thereafter (Appendix E1). A low proportion of the total eel catch (7%) has been reported as unidentified (EEU) and before 2000 it was 13% of the catch (Table 3, Appendix D1). Over the 25-year time series, Bay of Plenty has contributed 3.5% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 66%, LFE 27%, EEU 7%) (Table 3, Appendix E1).

Season – The Bay of Plenty shortfin and longfin fisheries operate all year round, but catches are generally lower or non-existent over the winter months, especially in recent years and for longfin (Appendices E2, E3).

Target species – Shortfin was the dominant target species (reconstructed) in all years, with a marked decline in longfin targeting in the last 10 years to the extent that longfin has become a negligible or non-existent target species (Appendix E4).

Lifts – The median number of lifts per day has fluctuated greatly and ranged from about 20 to 40 nets with indication of an increase in the last 10 years (Appendix E5).

Zeros – There were no zero records for total catch (Appendix E6). Shortfin zero catch records peaked in 1999 and 2000 at about 55% and then, apart from a few spikes, declined generally to levels of below about 5%. Longfin zero catch records fluctuated from about 20 to 70% with no trend.

Catch per day – The median annual shortfin non-zero catch has fluctuated greatly between about 25 and 200 kg per day with higher daily catches in the last 10 years (Appendix E7). The median annual longfin non-zero catch fluctuated greatly between about 20 and 125 kg per day with no trend (Appendix E8).

Shortfin CPUE analyses (ESA AE)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data show a slight decline until 2002, followed by a steep increase with the highest catch rate recorded in 2010 (about 6 kg per lift) (Appendix E9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix E10. The shortfin core data used in the CPUE analyses retain 85% of the catch, but lose 60% of the original fishers (Appendix 2). There are 8 shortfin core fishers: 5 pre-QMS and 4 post-QMS fishers (1 existing and 3 new entrants) (Appendices 2 and E11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers with a gradual decline until about 2002, after which CPUE has steeply increased to well above the series average (Appendix E12). The narrow confidence intervals around the indices before 2005 indicate that there were adequate fishers and catch in these analyses, but after 2005 confidence intervals are much larger, reflecting the decline in catches. The variables lifts, target, permit and month were included in the model in that order and explained 62% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2000, 13% of the catch was reported as EEU (Appendix E12). Shortfin catch for core fishers has fluctuated with no trend since 2000, when catch was recorded by species.

Residual diagnostics are shown in Appendix E13, influence step plots in Appendix E14, and CDI plots for each of the model predictor variables in Appendices E15–E18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AE)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data has fluctuated, with a particularly strong peak in 1999, but there is no long-term trend with catch rates ranging from about 1 to 3 kg per lift over the last 10 years (Appendix E9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix E19. The longfin core data used in the CPUE analyses retain 87% of the catch, but lose 58% of the original fishers (Appendix 2). There are 8 longfin core fishers: 5 pre-QMS and 3 post-QMS fishers (0 existing and 3 new entrants) (Appendices 2 and E20).

Standardised CPUE – The standardised CPUE for longfin catch generally follows the same pattern as unstandardised catch rates for core fishers (Appendix E21). Standardised CPUE declines until 1997, after which it fluctuates without trend. There were insufficient core fisher data to produce an index for 2015. The wide confidence intervals around the indices reflect the low number of fishing events available for this analysis. The variables target, permit, lifts and month were included in the model in that order and explained 66% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2000, 13% of the catch was reported as EEU (Appendix E21). Longfin catch for core fishers declined after 2002, when catch was recorded by species.

Residual diagnostics are shown in Appendix E22, influence step plots in Appendix E23, and CDI plots for each of the model predictor variables in Appendices E24–E27. Target species has a large influence on the indices, generally lowering the indices from 1996 to 2000 when longfin was the main target species, and raising the indices after that time when shortfin replaced longfin as the main target species. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.6 Poverty Bay (ESA AF)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AF peaked in 1995 and fluctuated greatly with no trend since that time with several years when there was negligible or zero catch of eels (Appendix F1). Since 2007 the longfin catch has been negligible or zero. A very low proportion of the total eel catch (0.4%) has been reported as unidentified (EEU) and this was confined to 1991 (Table 3, Appendix F1). Over the 25-year time series, Poverty Bay has contributed 1.6% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 76%, LFE 23%, EEU 1.6%) (Table 3, Appendix F1).

Season – The Poverty Bay shortfin and longfin fisheries operate all year round, but catches are lower or non-existent over the winter months, especially for longfin (Appendices F2, F3).

Target species – Shortfin or a mix of species (= either) were the dominant target species (reconstructed) in all years, with negligible or no longfin targeting after 2002 (Appendix F4).

Lifts – The median number of lifts per day has fluctuated greatly and ranged from about 20 to 80 nets (Appendix F5).

Zeros – There was only one zero record for total catch (Appendix F6). Shortfin zero catch records declined until 1990, after which, apart from a few spikes, were zero or close to it. Longfin zero catch records fluctuated greatly because there were several years with no longfin catch.

Catch per day – The median annual shortfin non-zero catch has fluctuated greatly between about 100 and 800 kg per day, but daily catches were most variable in the last 12 years (Appendix F7). The median annual longfin non-zero catch fluctuated greatly between about 10 and 120 kg per day with no trend (Appendix F8).

Shortfin CPUE analyses (ESA AF)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data are highly variable, but excluding the years when there was no catch (2009 and 2011) there was no trend until the last few years when catch rates increased dramatically (Appendix F9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix F10. The shortfin core data used in the CPUE analyses retain 79% of the catch, but lose about two-thirds of the original fishers (Appendix 2). There are 5 shortfin core fishers: 4 pre-QMS and 2 post-QMS fishers (1 existing and 1 new entrant) (Appendices 2 and F11).

Standardised CPUE – The standardised CPUE for shortfin catch has insufficient core fisher data to provide meaningful indices (Appendix F12). Accordingly, no diagnostics are presented. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AF)

Unstandardised catch rates – There are insufficient data to comment on the geometric mean of catch per lift for longfin raw data (Appendix F9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix F13. The longfin core data used in the CPUE analyses retain 70% of the catch, but lose 63% of the original fishers (Appendix 2). There are 3 longfin core fishers: 3 pre-QMS and 1 post-QMS fishers (1 existing and 0 new entrants) (Appendices 2 and F14).

Standardised CPUE – The standardised CPUE for longfin catch has insufficient core fisher data to provide meaningful indices (Appendix F15). Accordingly, no diagnostics are presented. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.7 Hawke’s Bay (ESA AG)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AG are characterised by a peak in the early 1990s followed by fluctuating catches with no trend (Appendix G1). A low proportion of the total eel catch (1.7%) has been reported as unidentified (EEU) and before 2002 it was 4% of the catch (Table 3, Appendix G1). Over the 25-year time series, Hawke’s Bay has contributed 9% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 76%, LFE 22%, EEU 2%) (Table 3, Appendix G1).

Season – The Hawke’s Bay shortfin and longfin fisheries operated all year round historically, with less catch in winter, but since 2007 there have been virtually no catches in the winter months (Appendices G2, G3).

Target species – Shortfin was the dominant target species (reconstructed) in all years, with a marked decline in longfin targeting in the last eight years to the extent that longfin was not a target species in three of these years (Appendix G4).

Lifts – The median number of lifts per day has ranged from 20 to 60 nets with no clear trend (Appendix G5).

Zeros – There were 46 zero records for total catch, all in 1997 when neither species was caught (Appendix G6). There was a gradual declining trend in zero shortfin catch records over the time series, and it has been zero or close to zero for the last eight years. Longfin zero catch records have fluctuated from about 30 to 80% with no trend.

Catch per day – The median annual shortfin non-zero catch has fluctuated greatly between about 50 and 300 kg per day with a sustained period of low daily catches from 2005 to 2008 (Appendix G7). The median annual longfin non-zero catch fluctuated greatly between about 10 and 200 kg per day with a steep decline until 1997 after which there was no trend (Appendix G8).

Shortfin CPUE analyses (ESA AG)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data show a steep decline until 1998, followed by a gradual increase with the highest catch rate recorded in 2014 (about 7 kg per lift) (Appendix G9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix G10. The shortfin core data used in the CPUE analyses retain 98% of the catch, but lose more than two-thirds of the original fishers (Appendix 2). There are 11 shortfin core fishers: 9 pre-QMS and 3 post-QMS fishers (1 existing and 2 new entrants) (Appendices 2 and G11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers after 2000. Standardised CPUE shows a steady decline until 2002, followed by a steep increase to well above the series mean (Appendix G12). The generally narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables permit, lifts, target and month were included in the model in that order and explained 76% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2001, 4% of the catch was reported as EEU (Appendix G12). Shortfin catch for core fishers has fluctuated with no trend since 2001, when catch was recorded by species.

Residual diagnostics are shown in Appendix G13, influence step plots in Appendix G14, and CDI plots for each of the model predictor variables in Appendices G15–G18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4. Permit has a large influence on the indices, raising the indices in the late 1990s when there were several core fishers with low coefficients (= low catch rates), and lowering the indices after that time when there were more core fishers with higher coefficients.

Longfin CPUE analyses (ESA AG)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show a steep downward trend until 1997, after which it has fluctuated with no clear trend (Appendix G9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix G19. The longfin core data used in the CPUE analyses retain 70% of the catch, but lose 80% of the original fishers (Appendix 2). There are 6 longfin core fishers: 4 pre-QMS and 3 post-QMS fishers (1 existing and 2 new entrants) (Appendices 2 and G20).

Standardised CPUE – The standardised CPUE for longfin catch follows the same pattern as unstandardised catch rates for core fishers, but only in the middle of the time series. There were insufficient core fisher data to produce standardised indices for 2009, 2010 and 2011. Despite this, the standardised indices show a general decline in CPUE until about 2001, after which there is an increasing trend to levels similar to those at the beginning of the series (Appendix G21). The variable widths of confidence intervals around the indices reflect the number of fishers and catch in these analyses. The variables target, permit, lifts and month were included in the model in that order and explained 65% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002, 4% of the catch was reported as EEU (Appendix G21). Longfin catch for core fishers fluctuated but declined steeply after 2002, when catch was recorded by species.

Residual diagnostics are shown in Appendix G22, influence step plots in Appendix G23, and CDI plots for each of the model predictor variables in Appendices G24–G27. Target species has a large influence on the indices, lowering the indices in the first six years when longfin was the main target species, and raising the indices in the last eight years when shortfin replaced longfin as the main target species. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.8 Rangitikei-Whanganui (ESA AH)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AH have been variable, but have generally declined over time, although they have been stable over the last eight years (Appendix H1). A low proportion of the total eel catch (5%) has been reported as unidentified (EEU) and before 2001 it was 7% of the catch (Table 3, Appendix H1). Over the 25-year time series, Rangitikei-Whanganui has contributed 7.5% of the total North Island eel catch, and shortfin and longfin have been landed in similar quantities (LFE 48%, SFE 47%, EEU 5%), although the proportion of longfin catch has dropped away over the last eight years (Table 3, Appendix H1).

Season – The Rangitikei-Whanganui shortfin and longfin fisheries have operated throughout the year historically, with little catch in the winter months (Appendices H2, H3).

Target species – Longfin was the dominant target species (reconstructed) up until 2006, after which there was a marked decline in longfin targeting to the extent that longfin was a negligible or non-existent target in two of the last eight years (Appendix H4).

Lifts – The median number of lifts per day has ranged from 20 to 40 nets with indications of a slight increasing trend (Appendix H5).

Zeros – There were 3 zero records for total catch all in 1997, when neither species was caught (Appendix H6). There was a gradual declining trend in zero shortfin catch records over the time series, and it has been zero or close to zero for the last four years. Longfin zero catch records have fluctuated, with indications of an increase in the last 10 years.

Catch per day – The median annual shortfin non-zero catch has fluctuated greatly between about 50 and 280 kg per day with a sustained period of low daily catches up to 2005, followed by a steep increase (Appendix H7). The median annual longfin non-zero catch fluctuated greatly between about 10 and 160 kg per day with an overall declining trend (Appendix H8).

Shortfin CPUE analyses (ESA AH)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data were generally stable until 2005, followed by a steep increase which levelled off around 2009 at about 7 kg per lift (Appendix H9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix H10. The shortfin core data used in the CPUE analyses retain 69% of the catch, but lose more than two-thirds of the original fishers (Appendix 2). There are 11 shortfin core fishers: 11 pre-QMS and 5 post-QMS fishers (5 existing and 0 new entrants) (Appendices 2 and H11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers. Standardised CPUE shows a steady decline until 2004, followed by a steep increase, dropping off in the last three years (Appendix H12). The generally narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses in pre-QMS years, but confidence intervals are much wider after this. The variables target, lifts, permit, and month were included in the model in that order and explained 67% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2002 7% of the catch was reported as EEU (Appendix H12). Shortfin catch for core fishers has fluctuated with no trend since 2002, when catch was recorded by species.

Residual diagnostics are shown in Appendix H13, influence step plots in Appendix H14, and CDI plots for each of the model predictor variables in Appendices H15–H18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4. Target species has a large influence, lifting the indices in the first five years when longfin was the main target species, and lowering the indices in the last nine years when shortfin replaced longfin as the main target species.

Longfin CPUE analyses (ESA AH)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show a downward trend since 1995, with the lowest catch rates in 2015 (less than 1 kg per lift) (Appendix H9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix H19. The longfin core data used in the CPUE analyses retain 84% of the catch, but lose more than two-thirds of the original fishers (Appendix 2). There are 10 longfin core fishers: 10 pre-QMS and 4 post-QMS fishers (4 existing and 0 new entrants) (Appendices 2 and H20).

Standardised CPUE – The standardised CPUE for longfin catch follows the same pattern as unstandardised catch rates for core fishers. There were insufficient core fisher data to produce standardised indices after 2007. Despite this, the standardised indices show a general decline in CPUE until 2004, after which there is an increasing trend (Appendix H21). The variable widths of confidence intervals around the indices reflect the number of fishers and catch in these analyses. The variables permit, target, lifts and month were included in the model in that order and explained 55% of the variation in CPUE (Appendix 3). The longfin catch by core fishers generally follows the same trend as the CPUE indices, although before 2001, 7% of the catch was reported as EEU (Appendix H21).

Residual diagnostics are shown in Appendix H22, influence step plots in Appendix H23, and CDI plots for each of the model predictor variables in Appendices H24–H27. Permit and target species have a large influence on the indices. Permit raises the indices in the first seven years when there were several core fishers with low coefficients (= low catch rates), and lowers the indices towards the end of the time series when there were more core fishers with higher coefficients. Target has the opposite effect, lowering the indices in the first seven years when longfin was the main target species. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.9 Taranaki (ESA AJ)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AJ have been variable, but are considerably smaller over the last 10 years with the notable exception of 2006 (Appendix J1). Nine percent of the total eel catch has been reported as unidentified (EEU) and before 2001 it was 16% of the catch (Table 3, Appendix J1). Over the 25-year time series, Taranaki has contributed 4% of the total North Island eel catch and longfin have been the dominant species in the catch (LFE 57%, SFE 33%, EEU 9%) although the proportion of longfin catch has dropped away over the last six years (Table 3, Appendix J1).

Season – The Taranaki shortfin and longfin fisheries have operated throughout the year historically, with little or no catch in the winter months (Appendices J2, J3).

Target species – Longfin was almost the only target species (reconstructed) in the first few years, but over time shortfin has gradually overtaken longfin as the main target (Appendix J4).

Lifts – The median number of lifts per day has been very stable at about 20 nets (Appendix J5).

Zeros – There were 57 zero records for total catch, mostly in 1997 when neither species was caught (Appendix J6). There was a gradual declining trend in zero shortfin catch records over the time series, and it has been around 20% for the last six years. Longfin zero catch records have fluctuated, with indications of an increase over time, with the exception of the last two years.

Catch per day – The median annual shortfin non-zero catch has fluctuated greatly between about 20 and 140 kg per day with indications of an increase after 2007 (Appendix J7). The median annual longfin non-zero catch fluctuated greatly between about 20 and 120 kg per day with no trend (Appendix J8).

Shortfin CPUE analyses (ESA AJ)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data showed an initial decline followed by a stable period until about 2007, after which catch rates increased steeply and then levelled out at about 4 kg per lift (Appendix J9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix J10. The shortfin core data used in the CPUE analyses retain 73% of the catch, but lose more than two-thirds of the original fishers (Appendix 2). There are 6 shortfin core fishers: 6 pre-QMS and 3 post-QMS fishers (3 existing and 0 new entrants) (Appendices 2 and J11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers, with the exception of 2011 and 2012. Standardised CPUE indices fluctuate between some years but overall show a decline until about 2004, and since then have fluctuated without trend (Appendix J12). The variable widths of confidence intervals around the indices reflect the number of fishers and catch in these analyses. The variables target, permit, lifts and month were included in the model in that order and explained 64% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2001, 16% of the catch was reported as EEU (Appendix J12). Shortfin catch for core fishers dropped substantially from 2002 to 2005 and has since been stable.

Residual diagnostics are shown in Appendix J13, influence step plots in Appendix J14, and CDI plots for each of the model predictor variables in Appendices J15–J18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4. Target species has a large influence, lifting the indices in the first seven years when longfin was the main target species, and lowering the indices in the latter years when shortfin replaced longfin as the main target species.

Longfin CPUE analyses (ESA AJ)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show a downward trend until 2003, followed by increasing catch rates (Appendix J9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix J19. The longfin core data used in the CPUE analyses retain 88% of the catch, but lose 60% of the original fishers (Appendix 2). There are 8 longfin core fishers: 8 pre-QMS and 4 post-QMS fishers (4 existing and 0 new entrants) (Appendices 2 and J20).

Standardised CPUE – The standardised CPUE for longfin catch follows the same pattern as unstandardised catch rates for core fishers until about 2008 (Appendix J21). There were insufficient core fisher data to produce standardised indices for 2009 and post-QMS indices are based on catches mostly from only one to two fishers (see Appendix J20). Despite this, the standardised indices show a general decline in CPUE until 2003, after which there is an increasing trend until 2012 before dropping again

(Appendix J21). The wide confidence intervals around the indices post-QMS, reflect the low numbers of fishers and catch in these analyses. The variables permit, target, lifts and month were included in the model in that order and explained 70% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2001, 16% of the catch was reported as EEU (Appendix J21). Longfin catch for core fishers dropped steeply from 2003 to 2005 and then continued to decline until 2015.

Residual diagnostics are shown in Appendix J22, influence step plots in Appendix J23, and CDI plots for each of the model predictor variables in Appendices J24–J27. Permit and target species have a large influence on the indices. Permit raises the indices initially because there were several core fishers with low coefficients (= low catch rates), and lowers the indices towards the end of the time series when there were more core fishers with higher coefficients. Target has the opposite effect, lowering the indices initially when longfin was the main target species and then raising them in the latter period when shortfin became the main target species. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.10 Manawatu (ESA AK)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AK have been variable, with five of the largest catches taken before 2001 (Appendix K1). Thirty percent of the total eel catch has been reported as unidentified (EEU) and before 2001 it was 61% of the catch (Table 3, Appendix K1). Over the 25-year time series, Manawatu has contributed 7% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 58%, LFE 12%, EEU 30%) with species proportions remaining stable over time (Table 3, Appendix K1).

Season – The Manawatu shortfin and longfin fisheries have operated throughout all seasons in some years, but generally little or no catch is taken in the winter months (Appendices K2, K3).

Target species – Shortfin has been the dominant target species throughout and in the last seven years there has been almost no targeting of longfin (Appendix K4).

Lifts – The median number of lifts per day has been variable, but averaged about 30 nets (Appendix K5).

Zeros – There were 2 zero records for total catch when neither species was caught (Appendix K6). There was a gradual declining trend in zero shortfin catch records over the time series, and it has been close to 0% for the last seven years. Longfin zero catch records have fluctuated, with no trend.

Catch per day – The median annual shortfin non-zero catch has fluctuated greatly between about 40 and 300 kg per day, with consistently low daily catches between 1994 and 2003 (Appendix K7). The median annual longfin non-zero catch fluctuated greatly between about 20 and 200 kg per day with no clear trend (Appendix K8).

Shortfin CPUE analyses (ESA AK)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data showed an initial decline followed by a sustained period of low catch rates, with the exception of 1999, increasing in 2004 after which catch rates have remained relatively high and stable at about 7 kg per lift (Appendix K9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix K10. The shortfin core data used in the CPUE analyses retain 83% of the catch, but lose more than two-thirds of the original fishers (Appendix 2). There are 11 shortfin core fishers: 9 pre-QMS and 7 post-QMS fishers (5 existing and 2 new entrants) (Appendices 2 and K11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers. Standardised CPUE indices show an initial steep decline until about 2003, followed by an increase in 2004, after which it is relatively high and stable with no trend (Appendix K12). The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses. The variables target, lifts, permit and month were included in the model in that order and explained 58% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2001, 61% of the catch was reported as EEU (Appendix K12). Shortfin catch for core fishers has fluctuated more than seven-fold since 2001 with no trend.

Residual diagnostics are shown in Appendix K13, influence step plots in Appendix K14, and CDI plots for each of the model predictor variables in Appendices K15–K18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AK)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show an initial steep downward trend until 1995, and apart from a rise between 1999 and 2001, have been stable at about 2 kg per lift (Appendix K9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix K19. The longfin core data used in the CPUE analyses retain 56% of the catch, but lose 70% of the original fishers (Appendix 2). There are 10 longfin core fishers: 7 pre-QMS and 7 post-QMS fishers (4 existing and 3 new entrants) (Appendices 2 and K20).

Standardised CPUE – The standardised CPUE for longfin catch follows the same general pattern as unstandardised catch rates for core fishers, but is more stable (Appendix K21). There were insufficient core fisher data to produce standardised indices for 1991, 1992, 1997 and 1999. Despite this, the standardised indices show a steep decline in CPUE until 2003, a two-fold increase in 2004 and stable with no trend thereafter (Appendix K21). The wide confidence intervals around the indices post-QMS reflect the low numbers of fishers and catch in these analyses. The variables target, permit, lifts, month and moon were included in the model in that order and explained 57% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2001, 61% of the catch was reported as EEU (Appendix K21). Longfin catch for core fishers since 2001 has fluctuated four-fold without trend.

Residual diagnostics are shown in Appendix K22, influence step plots in Appendix K23, and CDI plots for each of the model predictor variables in Appendices K24–K27. Target species and permit have a large influence on the indices. Target lowers the indices initially when longfin was the main target species, raising them in the latter period when shortfin became the main target species. Permit raises the indices initially because there were several core fishers with low coefficients (= low catch rates). Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.11 Wairarapa (ESA AL)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AL have been variable, but tend to be lower after 2003, with negligible catch in 2003 (Appendix L1). Thirteen percent of the total eel catch has been reported as unidentified (EEU), and before 2001 it was 27% of the catch (Table 3, Appendix L1). Over the 25-year time series, Wairarapa has contributed 5% of the total North Island eel catch, and shortfin have been the dominant species in the catch (SFE 54%, LFE 33%, EEU 13%), with the proportion of longfin declining over the last 10 years (Table 3, Appendix L1).

Season – The Wairarapa shortfin and longfin fisheries have operated throughout all seasons in some years, but in recent years generally little or no catch is taken in the winter months (Appendices L2 and L3).

Target species – Shortfin was marginally the main target species before 2005, after which it has become the dominant target species, with negligible targeting of longfin in 2011 (Appendix L4).

Lifts – The median number of lifts per day has been variable, but averaged about 30 nets (Appendix L5). *Zeros* – There were two zero records for total catch in 2009, when neither species was caught (Appendix L6). There was a gradual declining trend in zero shortfin catch records over the time series, and it has been close to 0% for the last 10 years. Longfin zero catch records have fluctuated, with no trend.

Catch per day – The median annual shortfin non-zero catch has fluctuated between about 50 and 200 kg per day, with no trend (Appendix L7). The median annual longfin non-zero catch fluctuated between about 25 and 220 kg per day, with no clear trend (Appendix L8).

Shortfin CPUE analyses (ESA AL)

Unstandardised catch rates – Geometric mean of catch per lift from the shortfin raw data showed an initial steep decline continuing until 2004, followed by a sharp increase in 2005 and thereafter catch rates were stable at about 5 kg per lift (Appendix L9).

Core fishers – The relationship between shortfin catch and years of participation in the fishery is shown in Appendix L10. The shortfin core data used in the CPUE analyses retain 87% of the catch, but lose more than two-thirds of the original fishers (Appendix 2). There are 10 shortfin core fishers: 6 pre-QMS and 5 post-QMS fishers (1 existing and 4 new entrants) (Appendices 2 and L11).

Standardised CPUE – The standardised CPUE for shortfin catch followed the same general pattern as unstandardised catch rates for core fishers. Standardised CPUE indices were generated from 1993 onward showing an initial increase followed by a steady decline from 1995 to 2003. CPUE increased sharply in 2005 and was stable with no trend thereafter, but higher than the pre-QMS indices (Appendix L12). The wide confidence intervals around the indices post-QMS reflect the low numbers of fishers and catch in these analyses. The variables target, lifts, permit and month were included in the model in that order and explained 70% of the variation in CPUE (Appendix 3). The shortfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2001, 27% of the catch was reported as EEU (Appendix L12). Shortfin catch for core fishers has fluctuated more than five-fold since 2001 with no trend.

Residual diagnostics are shown in Appendix L13, influence step plots in Appendix L14, and CDI plots for each of the model predictor variables in Appendices L15–L18. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

Longfin CPUE analyses (ESA AL)

Unstandardised catch rates – Geometric mean of catch per lift for longfin raw data show an initial steep downward trend, followed by a steady decline until 2005, and then a trend of gradually increasing catch rates thereafter. In the last few years catch rates have been about 2.5 kg per lift (Appendix L9).

Core fishers – The relationship between longfin catch and years of participation in the fishery is shown in Appendix L19. The longfin core data used in the CPUE analyses retain 88% of the catch, but lose two-thirds of the original fishers (Appendix 2). There are 9 longfin core fishers: 5 pre-QMS and 5 post-QMS fishers (1 existing and 4 new entrants) (Appendices 2 and L20).

Standardised CPUE – The standardised CPUE for longfin catch follows the same general pattern as unstandardised catch rates for core fishers, but is more stable (Appendix L21). There were insufficient core fisher data to produce standardised indices for 1992. The standardised indices show a gradual decline in CPUE until 2004 followed by a fluctuating but generally increasing trend (Appendix L21). The wide confidence intervals around the indices post-QMS, reflect the low numbers of fishers and catch in these analyses. The variables target, lifts, permit and month were included in the model in that order and explained 67% of the variation in CPUE (Appendix 3). The longfin catch by core fishers does not follow the same trend as the CPUE indices, although before 2001, 27% of the catch was reported as EEU (Appendix L21). Longfin catch by core fishers declined massively after 2003 and has fluctuated since then at lower levels without trend.

Residual diagnostics are shown in Appendix L22, influence step plots in Appendix L23, and CDI plots for each of the model predictor variables in Appendices L24–L27. Target species and lifts have a large influence on the indices. Target lowers the indices initially when longfin was the main target species, raising them in the latter period when shortfin became the main target species. Lifts lowers the indices initially because there were several core fishers with high coefficients (= low catch rates), and raises them after 2002 when the opposite occurred. Standardised indices and 95% confidence intervals are tabulated in Appendix 4.

3.4.12 Wellington (ESA AM)

Fishery characteristics 1991–2015

Catch – Reported annual eel catches in ESA AM have been highly variable with catches landed from only eight of the 25-year time series, and not since 2008 (Appendix M1). Two percent of the total eel catch has been reported as unidentified (EEU), although this was all in 1991, 1992 and 1993 (Table 3, Appendix M1). Over the 25-year time series Wellington has contributed only 0.1% of the total North Island eel catch and longfin have been the dominant species in the catch (LFE 55%, SFE 43%, EEE 1%) (Table 3, Appendix M1). There are too few data to present sensible plots on lifts or catch per day, zero catch, seasonal catch, or catch rates, and no CPUE analyses were carried out for Wellington.

3.5 Binomial CPUE analyses

Reconstructed target species could not be offered to the binomial model because, by definition, a target of longfin or shortfin cannot result in zero catch in the models. Without target species, the binomial was unable to adjust for the systematic targeting known to have occurred in recent years and hence was unable to provide a reliable index of abundance. The results of binomial analyses were presented to the MPI Eel Working Group (EELWG 2017-06) and the Stock Assessment Plenary in May 2017 where it was rejected on this basis. For this reason, the results of the binomial are not shown in this report.

3.6 CPUE analyses from landed catch data

There was a poor match between permit identities in the size grade data and the catch effort data, i.e., permits in the size grade data were not always found in the catch effort data, and vice versa. Further, the matching of the catch between these data sets was also poor and most commonly only about half the catch qualified as a good match. Because a substantial proportion of the data could not be effectively linked, the MPI Eel Working Group (EELWG 2017-06) rejected these indices of abundance and they are not presented in this report.

4. DISCUSSION

4.1 General

This report presents the updated fishery characterisations and standardised CPUE analyses (GLM) for the North Island commercial freshwater eel fishery from 1991 to 2015, extending the time series by three years. Analyses were carried out at the level of eel statistical area for individual species (shortfin and longfin). Reconstructed target species was included as a predictor variable for the first time for North Island analyses, as were water quality variables. Binomial CPUE analyses were attempted for the first time for New Zealand eels, but were by rejected by the Eel Working Group on the basis that target species could not be included as a predictor variable (because it was derived from catch composition) and hence the resulting indices were likely to be biased. Similarly, the CPUE analyses using the size grade landings were rejected because a substantial proportion of the data could not be effectively linked with the catch effort data.

4.2 Catch and species distribution

Throughout the 25-year North Island time series, ignoring catch from unidentified eel (EEU), shortfin estimated groomed catches accounted for nearly three-quarters (73%) of the total eel catch. Over the last eight years this has increased as longfin catch has decreased, and in 2015 it was 86% (see Figure 7). The species catch composition from groomed estimated catch in the last five years is similar to that recorded for the landed catch (Beentjes 2016). Shortfin is the dominant species with respect to catch proportions in all ESAs except Wellington (AM) and Taranaki (AJ), which have yielded more longfin, whereas proportions in Rangitikei-Whanganui (AH) are close to parity (see Table 3, Figure 6). Hauraki (AC) yielded the highest proportion of shortfin in the catch at nearly 80%.

The relative proportions of the North Island eel catch contributed by each ESA from 1990–91 to 2014–15 have remained largely unchanged since the 1980s (Jellyman 1994). The largest contributors of longfin since 1991 have been, in descending order, Waikato (AD), Northland (AA), Rangitikei-Whanganui (AH) and Taranaki (AJ), which together represent 61% of the total longfin catch (see Table 3). Similarly, for shortfin, the key areas have been Northland (AA), Waikato (AD), Hawke's Bay (AG) and Auckland (AB), which together represent 64% of the total shortfin catch (see Table 3).

Historic reporting of catches as unidentified (EEU) has presented problems in the catch effort analyses for individual eel species. The extent to which EEU rather than LFE or SFE was recorded by fishers varied between regions. It was used extensively in Waikato (71% of catch before 2002) and Northland (37% of catch before 2001), and resulted in considerable data loss in the individual species CPUE analyses, although this was offset to some extent by the large data sets for both these areas. Replacement of the CELR form with the ECER and ECLR on 1 October 2001 did not give the option of recording EEU and there have been no records of EEU in the catch effort data since 2000–01.

4.3 Factors affecting CPUE indices

Catch effort reporting forms

In the freshwater eel fishery, catch of each species is estimated by observation of catches in fyke nets or in holding bags, rather than from standard fish bins containing separated species as in marine fisheries. There is the possibility, therefore, that in catches dominated by one species, the minor catch may be overlooked or underestimated. Only two species (SFE and LFE) are caught in any abundance in fyke nets and these will always have been included in the catch-effort section of CELRs, which only allows reporting of the top five species, whereas the current ECER form (introduced 2001–02) has dedicated fields for SFE and LFE catch.

Loss of data from grooming and use of EEU code

Overall, total groomed estimated eel catch used in the CPUE analyses was missing up to 12% of records before 2001 because of errors in reporting on CELRs (Beentjes & Dunn 2003a) (see Figure 4). With the introduction of the ECER form in 2001–02, very few records were removed from the analyses during grooming. The trends in estimated and landed total eel catch are similar, however, indicating that estimated catch is likely to be proportional to total landed catch, and hence can be legitimately used for CPUE analysis. The estimated eel species-specific catch as a proportion of the landed catch is even less because 36% of the catch before 2002 was reported as EEU, and consequently is not included in the individual species analyses (see Figure 4).

Non-reporting of legal-sized eels on catch effort forms

A further issue affecting CPUE is the non-reporting or incorrect reporting of the estimated catch for legal-sized eels returned alive to the water. Fishers are legally entitled to return eels of legal size (220–4000 g) to the water, but are still required by law to complete the catch effort section of the ECER including estimates of released legal-sized eels, and to report the released estimated catch under destination 'X' in the ECLR destination field. Comparison of individual trip data from 2015 ECER and ECLR forms showed that there was no consistency either within or between fishers in the methods of reporting, with some fishers filling in the forms correctly for some trips and not for others. At the Eel Working Group meeting in April 2017 (EELWG 2017-06), it was apparent that, of the fishers present, there was no clear understanding of the legal requirement to record all released legal-sized eel on the ECER. The implication of under-reporting the catch of released eels in ECERs is that it will bias both the estimated catch and subsequent CPUE indices downward. Fortunately, the amount of catch reported under destination 'X' appears to have been small (see Figure 8), notwithstanding the catch from fishers who may have released legal-sized eels and not reported this in either ECER or ECLRs. Releasing eels of legal size is a consequence of fishers having insufficient ACE to cover their catch, and volatile markets for specific grades. Longfin eels are usually more affected because of the larger TACC cuts for this species, and it is also the less marketable species. This has been more of a problem in LFE 23 (ESAs AH, Rangitikei-Whanganui; AJ, Taranaki) since 2007–08 when the longfin TACC was reduced from 41 to 9 t and fishers often had no option but to either target shortfin by fishing in areas where longfin are not commonly caught, or to release any legal-sized longfin caught. Further, 'quota shelving' has occurred in LFE 23 and SFE 23 and since 2008 where only 50% of the longfin and 40% of the shortfin ACE was available for lease (Dale Walters, NZ Eel Processors, pers. comm.).

The best approach to deal with this issue is to educate fishers on the correct methods for reporting their catch on statutory forms. This could be augmented by more explicit explanatory notes on reporting forms, and implementing error checking business rules when returns are entered into the MPI catch effort database by FishServe. The introduction of the Integrated Electronic Monitoring and Reporting System (IEMRS) for the commercial eel fishery in April 2018 is likely to improve reporting through data auto-checking routines built into the reporting software.

Release of over 4 kg longfins and migratory eels

Missing from the estimated catch are longfin eels over 4 kg, which must legally be returned to the water on capture (in fishing regulations from April 2007), but are not required to be reported on ECERs or ECLRs because they are not of legal size limit. While the extent of these over 4 kg longfin eel releases is unknown, it is reported anecdotally by fishers to be increasing. Data from one key fisher in the Waikato area recorded catch and releases of 4 kg longfins in 2013–14 at 44, 2014–15 at 54, 2015–16 at 75, and for the first six month of 2016–17 at 127, showing an increasing trend over time (Tom Hollings, pers. comm.). The effect will be to underestimate CPUE indices for longfin eels after April 2007. In the South Island, eel fishers reported in voluntary log books that over 1400 longfins heavier than 4 kg were caught and released in 2013–14 (Bill Chisolm, pers. comm.), some of which were as large as 16 kg. This equated conservatively to about 6 t of longfin eels corresponding to about 4% of the 2012–13 South Island longfin landed catch (Beentjes & Dunn 2015). The planned introduction of the IEMRS for the eel fishery in April 2018 should record the release of longfin eels over 4 kg, as well as other information such as finer-scale catch location details.

There is also a voluntary code of practice to release eels that are in a migratory condition when caught, many of which could be of legal size for both species. The extent of this practice, and whether these releases are correctly entered on ECER and ECLR forms, is unknown.

Escape tube modifications

The legal escape tube size in the North Island eel fishery until recently was 25 mm and was designed to allow eels smaller than 220 g (minimum legal size, MLS) to escape from the fyke nets if captured, although in practice eels below the MLS are often caught. A voluntary code of practice has been in place in the North Island since 2010–11 to use 31 mm tubes, although the level of compliance by fishers is unknown. This became a legal requirement on 1 October 2013, consistent with the South Island where 31 mm has been the legal escape tube size since 1996–97. A 31 mm escape tube can be expected to retain eels larger than about 300 g, hence the North Island CPUE for both species may be conservative since 2010–11, as eels that would previously have been retained are able to escape. Further, processors agreed not to process eels less than 300 g since about 2009–10 and for one processor as far back as 2006–07 for longfin eels. Most of these small eels (220–300 g) if caught by fishers are released at the point of capture, and any that are landed into processors are graded out and returned to local rivers without being weighed (Dale Walters, NZ Eel Processors, pers. comm.). It is not known if these small released eels of legal size (220–300g) are correctly recorded on ECERs and ECLRs; if not, this will result in a conservative estimate of CPUE for the years concerned.

Some fishers are also using 35 mm escape tubes voluntarily to reduce catch of small eels, mainly in the south of the North Island.

4.4 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 analyses of 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 or Port Waikato for targeting freshwater eels. Fyke net method was recorded on nearly all North Island ECERs. The fyke net fishing gear described in Section 3.3, as far we know and have been informed by the eel industry, has remained unchanged over the time series of CPUE. If there are changes to these net specifications in the future it will be important to have this documented.

4.5 Standardised CPUE analyses (GLM)

4.5.1 Core fishers

The restriction of CPUE analyses to core fishers ensured that only committed and experienced fishers (having had at least three years in the fishery) were included in the analyses, hence reducing the overall variability in catch rates. This resulted in very little loss of data, but often considerable loss of fishers from the analyses (see Appendix 2). This was not a problem before the introduction of North Island eel stocks into the QMS in 2004–05 because the fishery was in effect closed to new entrants and few fishers exited the fishery. To be eligible to convert provisional catch history to quota shares, fishers needed to have held a fishing permit at the date of the gazette notice of the Minister's decision to introduce North Island eel stocks into the QMS (D. Allen, Ministry for Primary Industries, pers. comm.).

Following the introduction of the fishery into the QMS, quota shares were allocated and harvesting rights were transferable. TAC/TACCs were set substantially below historic catches, and many long-term fishers left the fishery and were replaced by fewer new entrants. Our exploration of the permit identities from unencrypted data provided by Ministry for Primary Industries Research Data Management (RDM) during a previous North Island CPUE analysis (Beentjes & Dunn 2010), revealed that in reality many of the post-QMS entrants were experienced eel fishers by virtue of having previously fished on behalf of other permit holders under FOTFAV (fishing-other-than-from-a-vessel) agreements; many of these fishers subsequently fished ACE. Indeed, in many cases civil agreements were in place for the transfer of harvesting rights from the original permit holder to their agents once eels had entered the QMS. Linking these fishers with the earlier permit holder to a large extent improved the continuity of the time series for all areas. Regardless, comparison of CPUE indices between pre-QMS and post-QMS, and examination of continuous time series, showed that despite the loss of existing fishers and arrival of new entrants post-QMS, the continuous time series remained unaffected.

4.5.2 Predictor variables

The standardised CPUE analyses allow for effects that explanatory variables may have on the catch rates. These variables included lifts, target species, fisher (permit), season (month), moon phase, river flow and water quality (see Appendix 3). The three variables, target, permit and lifts were included in all models. Target species often explained the most variance in the non-zero catch GLM, especially for longfin, for which the trends in CPUE changed more than shortfin when compared to previous analyses where target was not offered to the model (see Appendix 3). This is not surprising since targeting of shortfin has become more common in the last 10 years because, for longfin, the TACC has been reduced more than shortfin, ACE was less available, and markets were less favourable. For longfin, particularly, the effect on the unstandardised CPUE indices (geometric mean of catch rates including year effect) was to lower the indices initially when longfin was the main target species, and raise them in later years when shortfin became the main target species (see Appendix D21). The finding that month was an important variable affecting catch rates is understandable since water temperature varies seasonally and eel catch rates have been found to decline markedly in winter (Jellyman 1991, 1997). Further, apart from the northern ESAs, fishing is mainly seasonal in the North Island with little fishing and processing of eels in the winter months. The inclusion of permit indicates the importance of fisher experience and/or ability on catch rates. Lifts was always included as it is the key indicator of relative effort. River flow entered the model for shortfin in two areas and only one area for longfin. Moon phase entered the model only once, for longfin. Water quality variables were not included in any model. The step and influence plots were useful for explaining how the different variables entering the model altered the annual CPUE coefficients, particularly target and permit.

4.5.3 Shortfin CPUE summary

Shortfin standardised CPUE analyses were carried out for all North Island ESAs, except ESA AM, from 1991 to 2015 and were acceptable for all ESA analyses. The standardised CPUE indices and confidence intervals are shown in Figure 10 for each ESA. The trends in shortfin standardised CPUE are summarised as follows:

1. Northland (ESA AA): Increasing trend in CPUE since early 1990s, but relatively stable over the most recent six years. The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
2. Auckland (ESA AB): No trend in CPUE until 2003, after which it increases consistently. The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
3. Hauraki (ESA AC): No trend in CPUE until 2010, after which it has increased. The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
4. Waikato (ESA AD): No long-term trend in CPUE until 2003, after which it increased. The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
5. Bay of Plenty (ESA AE): No trend in CPUE until 2002, after which it increased steeply to a peak in 2012. The narrow confidence intervals around the indices before 2005 indicate that there were adequate fishers and catch in these analyses, but after that the confidence intervals are much larger reflecting the loss of fishers and data.
6. Poverty Bay (ESA AF): There were insufficient data to model CPUE in 11 of the 25 years, including all years after 2009. Given this and the wide confidence intervals around the indices in the later years, no trend can be inferred from the time series.
7. Hawke’s Bay (ESA AG): CPUE declined until 2002, followed by a steep increase to well above all former levels. The narrow confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
8. Rangitikei-Whanganui (ESA AH): CPUE declined gradually until 2004, and then increased steeply to above the series mean. The wider confidence intervals around the indices after 2005 reflect the loss of fishers and data in the analyses.
9. Taranaki (ESA AJ): CPUE has fluctuated without trend throughout the series. There were insufficient data to model CPUE in 2009. The wider confidence intervals around the indices before 1994 and after 2005 reflect the low numbers of fishers and data in the analyses.
10. Manawatu (ESA AK): CPUE dropped markedly from 1992 to 1994, was stable until an increase in 2004, and has fluctuated without trend since then. There were insufficient data to model CPUE in 1991, 1992 and 2004. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
11. Wairarapa (ESA AL): CPUE declined from 1995 to 2003, increased until 2008 and has fluctuated without trend, above the series mean, since then. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses for most years.
12. Wellington (ESA AM): No CPUE analyses carried out because of insufficient data.

In general, CPUE for North Island shortfin, except Northland (ESA AA) where CPUE steadily increased throughout the time series, either initially declined or there were no trends, followed by strong increases, beginning from around 2002, a few years before the introduction of North Island eel stocks into the

QMS in 2005 (Figure 10). Subsequent shortfin reductions in catch through a 26% TACC reduction in 2007–08 are likely to have contributed to the improved CPUE for North Island shortfin at this time. As discussed, the non-reporting of legal-sized shortfin returned alive to the water in the last five years, and the regulatory increase in escape tube size from 25 mm to 31 mm in 2013–14, suggest that the shortfin CPUE estimates are conservative since about 2007.

4.5.4 Longfin CPUE summary

Longfin standardised CPUE analyses were carried out for all North Island ESAs from 1991 to 2015, except ESA AM. The most robust longfin data sets were for Northland (AA), Auckland (AB), Hauraki (AC) and Waikato (AD). The standardised CPUE indices are shown in Figure 10.

For each ESA the trends in standardised CPUE were as follows:

1. Northland (ESA AA): Slight downward trend in CPUE over the time series. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
2. Auckland (ESA AB): A slight decline in CPUE to 2005, but stable thereafter. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
3. Hauraki (ESA AC): Steep decline in CPUE to 2001, and then without trend/stable until a decline in 2014–15. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
4. Waikato (ESA AD): A moderate decline in CPUE to 1998, and then a gradual increase to just below the level of the former peak by 2015. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
5. Bay of Plenty (ESA AE): A steep decline in CPUE to 2000, and then a gradual increase to a peak in 2013. There were insufficient data to model CPUE in 2015. The wide confidence intervals around the indices in some years are a consequence of few fishers and little catch in these analyses.
6. Poverty Bay (ESA AF): There were insufficient data to model CPUE in 16 of the 25 years, including all years after 2007. No trend can be inferred from the time series.
7. Hawke’s Bay (ESA AG): CPUE declined until 1997, fluctuated without trend until 2008 and then increased to above the level at the beginning of the series. There were insufficient data to model CPUE in 2009, 2001 and 2011. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses for most years.
8. Rangitikei-Whanganui (ESA AH): Steep decline in CPUE to 2004, and then increasing until 2006. There were insufficient data to model CPUE after 2007. Confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses.
9. Taranaki (ESA AJ): CPUE declined until 2003, followed by a gradual increase until 2012, and a decline since then. There were insufficient data to model CPUE in 2009. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses until 2007.
10. Manawatu (ESA AK): CPUE declined steeply until 2003, increased in 2004 and has fluctuated without trend since then. There were insufficient data to model CPUE in 1991, 1992, 1997 and 1999. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses for most years.
11. Wairarapa (ESA AL): CPUE declined until 2003, increased in 2004 and since then has been fluctuating with indications of a slight increasing trend. The confidence intervals around the indices indicate that there were adequate fishers and catch in these analyses for most years.
12. Wellington (ESA AM): No CPUE analyses carried out because of insufficient data.

There were fewer data for longfin analyses than for shortfin for most areas, and indices were often more variable or associated with wider confidence intervals. In general, CPUE for North Island longfin initially declined, followed by increases or were stable without trend (except Northland (ESA AA) where CPUE declined slightly throughout the time series) beginning from around 2002, a few years before the introduction of North Island eel stocks into the QMS in 2005 (Figure 10). The addition of reconstructed target species as an explanatory variable had a much greater impact on longfin CPUE indices than shortfin indices, tending to reduce the steepness of the initial decline and increase CPUE in recent years. The trends for longfin have therefore changed since the last analyses up to 2011–12 (Beentjes & Dunn 2013).

For longfin, there appears to be a halt, and in some cases a reversal, in the declines in CPUE that were observed in the first 10 years of the time series. The North Island longfin TACC for all QMAs combined was reduced by 58% in 2007–08, conceivably contributing to the higher CPUE indices. The non-reporting of legal-sized eels returned alive to the water, the introduction of the 4 kg maximum size for longfins in 2007, and the regulatory increase in escape tube size from 25 mm to 31 mm in 2013–14, suggest that the longfin CPUE estimates are biased low since about 2007.

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7. TABLES AND FIGURES

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 ESA up to October 2001.

	QMA		ESA		
Area	LFE	SFE	Alpha (from 1 Oct 2001)		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-Whanganui	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, fishers (= permits), 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 2015 for method fyke net. ESA, eel statistical area.

							Estimated catch (t)
ESA	Region	Fishers	Records	Unidentified	Shortfin	Longfin	Total
AA	Northland	85	26 139	502 888	1 671 283	494 140	2 668 311
AB	Auckland	61	9 228	196 311	843 222	250 846	1 290 379
AC	Hauraki	43	8 949	67 068	694 023	114 761	875 852
AD	Waikato	62	44 190	1 528 776	1 520 287	549 308	3 598 371
AE	Bay of Plenty	27	3 708	35 090	315 846	127 445	478 381
AF	Poverty Bay	15	939	10	164 924	50 505	215 439
AG	Hawke’s Bay	23	5 602	21 125	921 907	272 641	1 215 673
AH	Rangitikei-Whanganui	38	4 456	46 282	487 553	470 527	1 004 362
AJ	Taranaki	29	3 799	44 043	161 712	280 916	486 671
AK	Manawatu	38	4 527	275 947	520 795	109 240	905 982
AL	Wairarapa	34	3 689	93 485	387 454	232 358	713 297
AM	Wellington	10	103	210	6 151	7 904	14 265
Totals			115 329	2 811 235	7 695 157	2 960 591	13 466 983

Table 3: Percent of groomed estimated catch by species within and among ESAs from combined years 1991 to 2015 for method fyke net. ESA, eel statistical area; LFE, longfin; SFE, shortfin; EEU, unclassified.

		Percent species catch within ESA				Percent species catch among ESAs			
ESA	Region	SFE	LFE	EEU	Total	Total	SFE	LFE	EEU
AA	Northland	62.6	18.5	18.8	100	19.81	21.72	16.69	17.89
AB	Auckland	65.3	19.4	15.2	100	9.58	10.96	8.47	6.98
AC	Hauraki	79.2	13.1	7.7	100	6.50	9.02	3.88	2.39
AD	Waikato	42.2	15.3	42.5	100	26.72	19.76	18.55	54.38
AE	Bay of Plenty	66.0	26.6	7.3	100	3.55	4.10	4.30	1.25
AF	Poverty Bay	76.6	23.4	0.0	100	1.60	2.14	1.71	0.00
AG	Hawke’s Bay	75.8	22.4	1.7	100	9.03	11.98	9.21	0.75
AH	Rangitikei-Whanganui	48.5	46.8	4.6	100	7.46	6.34	15.89	1.65
AJ	Taranaki	33.2	57.7	9.0	100	3.61	2.10	9.49	1.57
AK	Manawatu	57.5	12.1	30.5	100	6.73	6.77	3.69	9.82
AL	Wairarapa	54.3	32.6	13.1	100	5.30	5.04	7.85	3.33
AM	Wellington	43.1	55.4	1.5	100	0.11	0.08	0.27	0.01
Overall		57.1	22.0	20.9	100	100	100	100	100

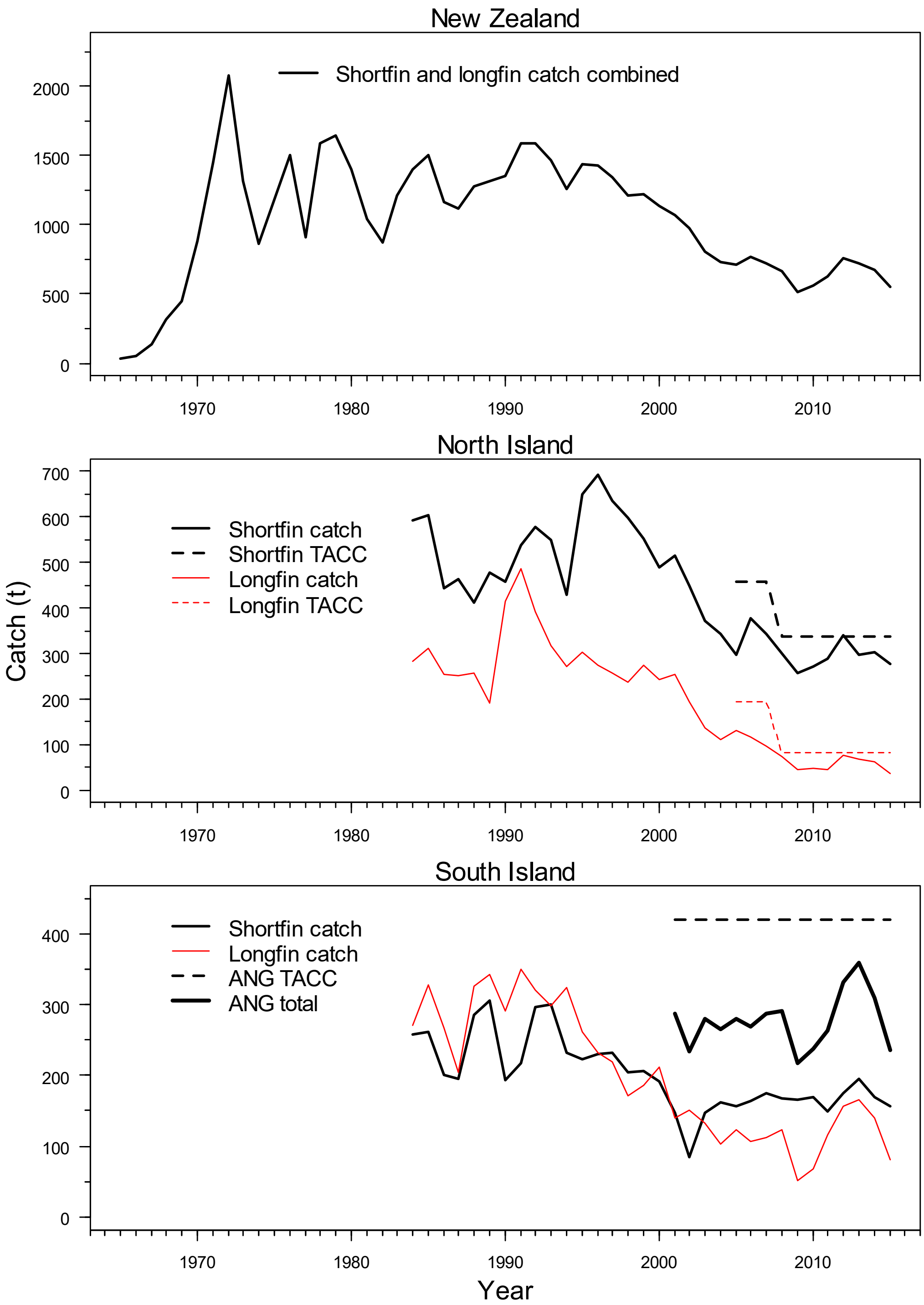


Figure 1: Landed catches of shortfin and longfin eels, and Total Allowable Commercial Catch (TACC) for each species up to 2014–15. Data are shown by calendar year up until 1988 and by fishing year from 1988–99 onward (Data from Ministry for Primary Industries 2016). These catches are based on MAF Fisheries Statistics Unit (FSU), Licensed Fish Receiver Returns (LFRR), Quota Management Reports (QMR), and Monthly Harvest Returns (MHR).

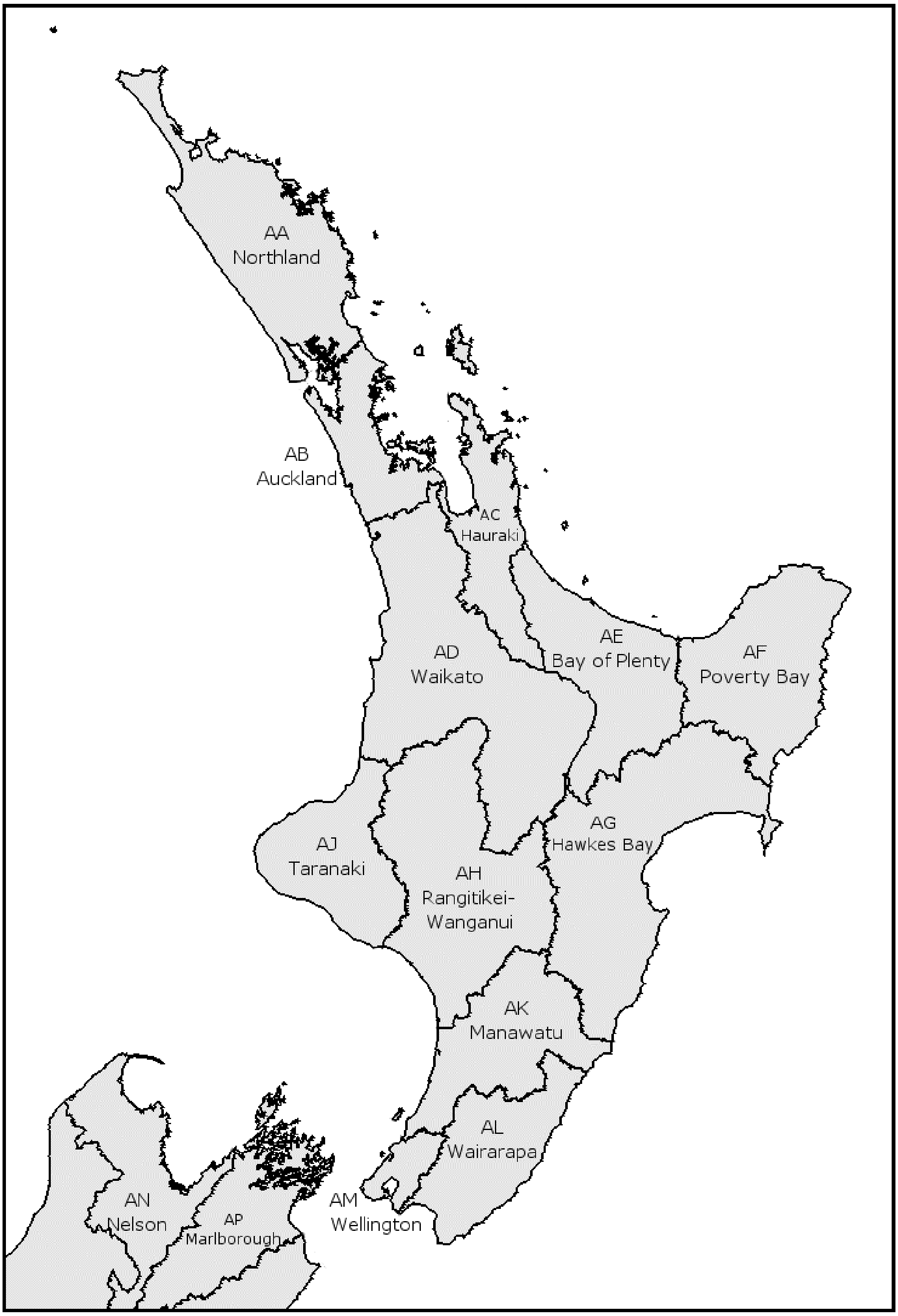


Figure 2: North Island eel statistical areas (ESAs). See Table 1 for old ESA numeric codes 13 to 23.

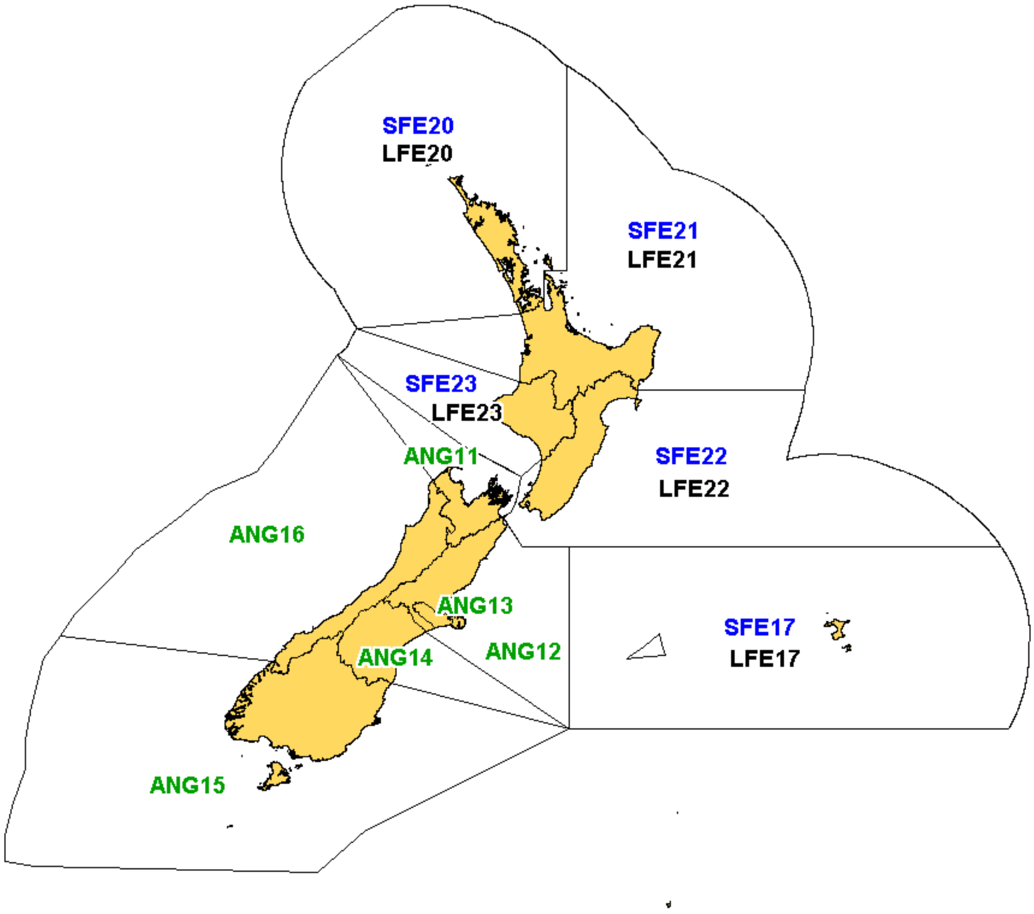


Figure 3: Quota Management Areas for the New Zealand eel fishery (see Table 1 for breakdown by eel statistical areas). Shortfin stocks are denoted by the prefix SFE, and longfin by LFE. ANG comprises both shortfin and longfin combined. (Figure from Ministry for Primary Industries 2016). In 2016–17, separate TACCs were set for South Island shortfin and longfin (SFE 11–16; LFE 11–16).

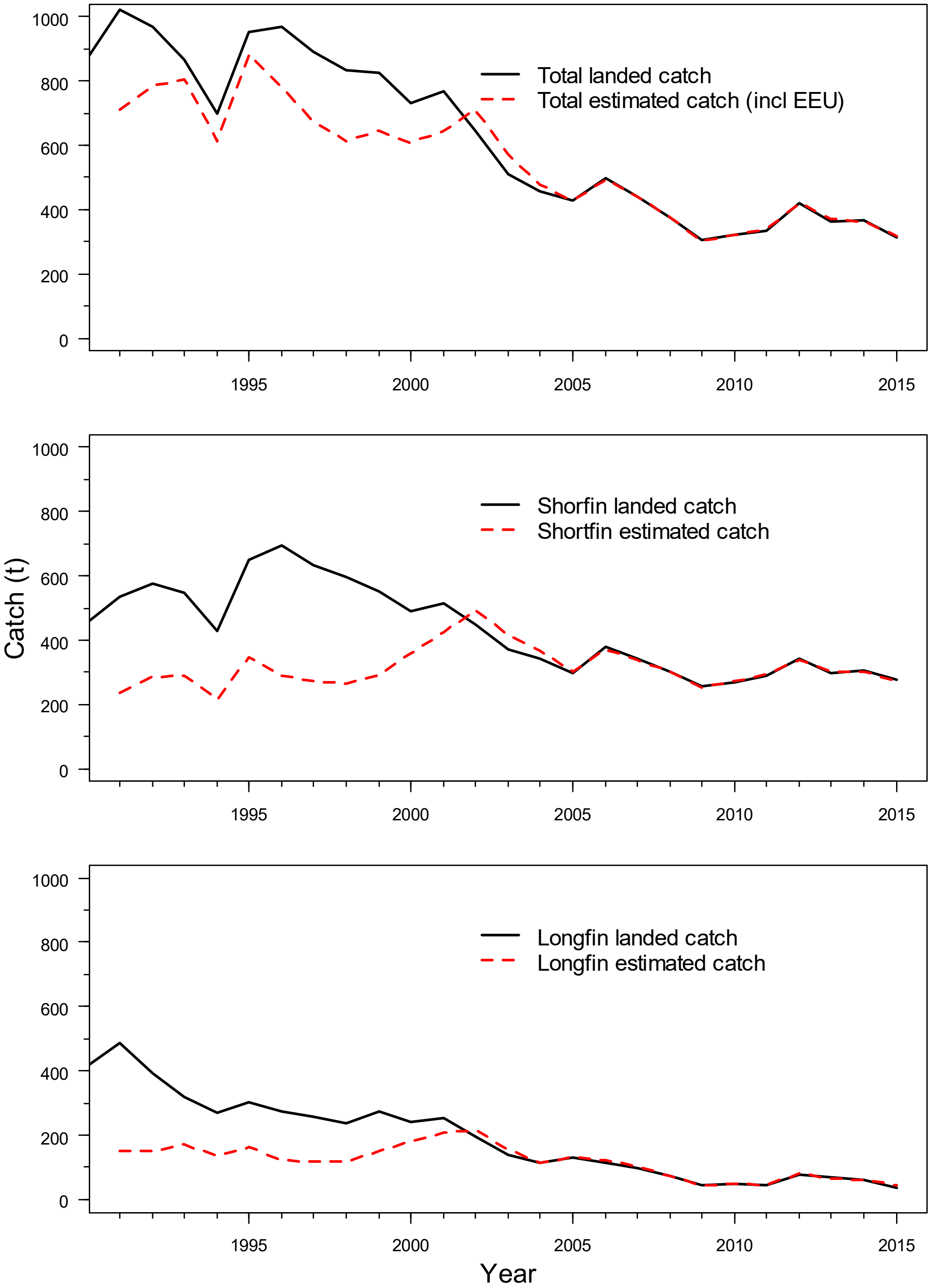


Figure 4: North Island groomed estimated commercial catch of all eels (top), shortfin (middle), and longfin (bottom) from 1991 to 2015, and landed catch from 1990 to 2015. Estimated catches are from CELR and ECER (after 2001) and include methods fyke net and set net. The landed catches are from processors (1992–2000) and LFRR/QMR (2001–15) (Ministry for Primary Industries 2016). Dates shown represent the end of the fishing year i.e., 1991 = 1990–91 fishing year. EEU, unclassified eel catch.

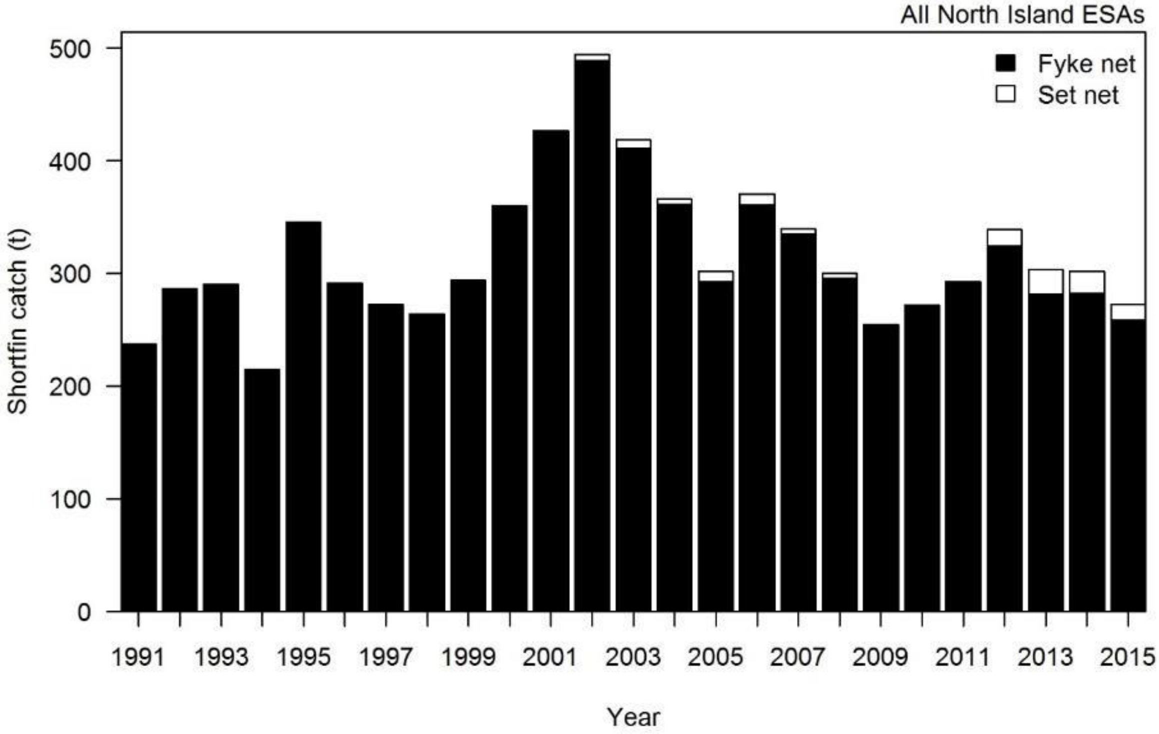


Figure 5: North Island groomed estimated commercial catch of shortfin by method for the years 1990–91 to 2014–15. All set net catch was from ESAs AC (56%) and AD (44%). There was no longfin catch by method set net. Dates shown represent the end of the fishing year i.e., 1991 = 1990–91 fishing year.

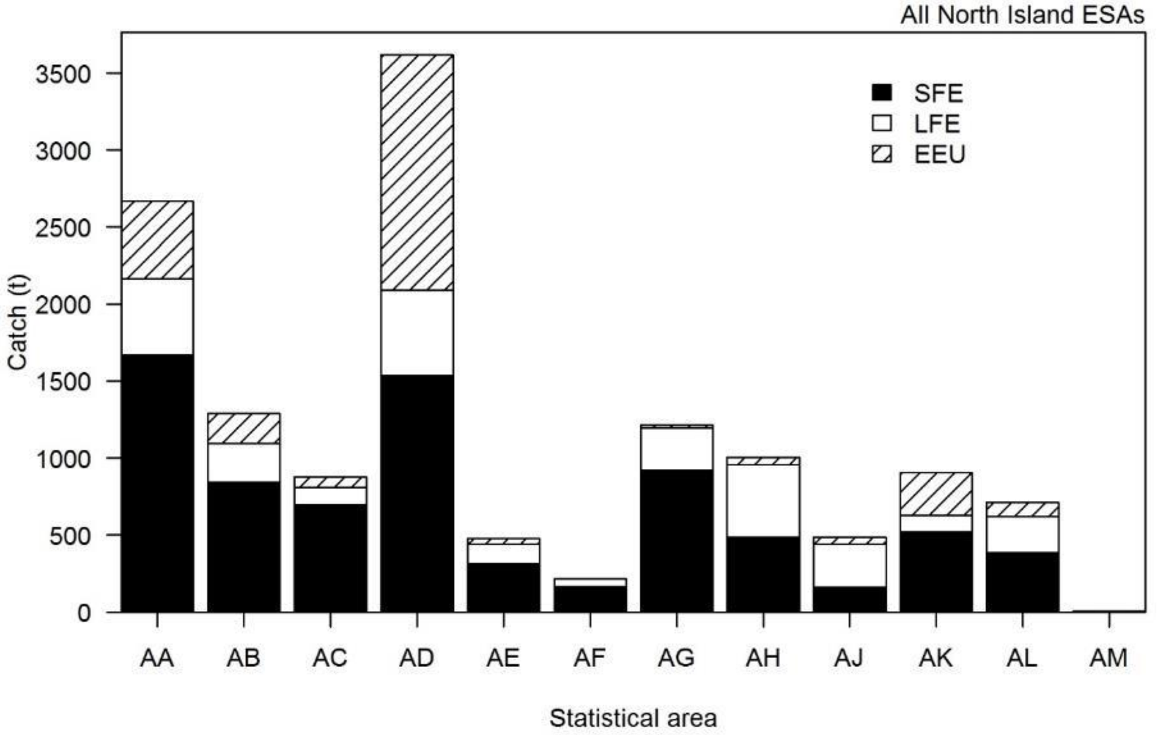


Figure 6: North Island groomed estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) by statistical area for the combined years 1990–91 to 2014–15 for method fyke net.

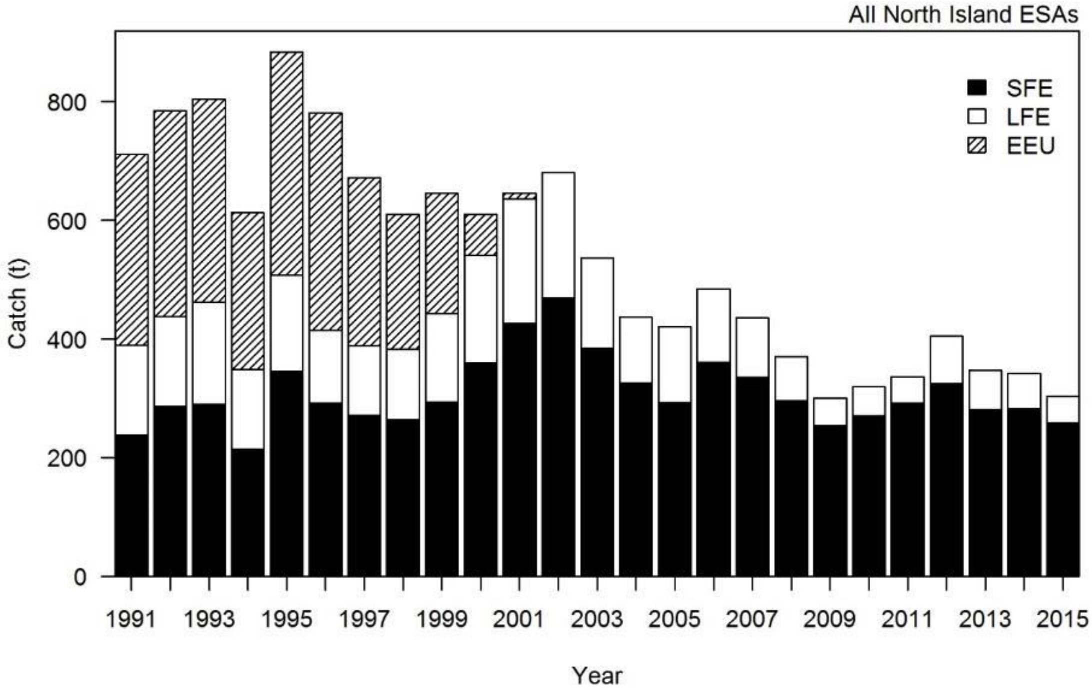


Figure 7: North Island groomed estimated commercial catch of shortfin (SFE), longfin (LFE), and unclassified eel catch (EEU) for the years 1990–91 to 2014–15 for method fyke net. Dates shown represent the end of the fishing year i.e., 1991 = 1990–91 fishing year.

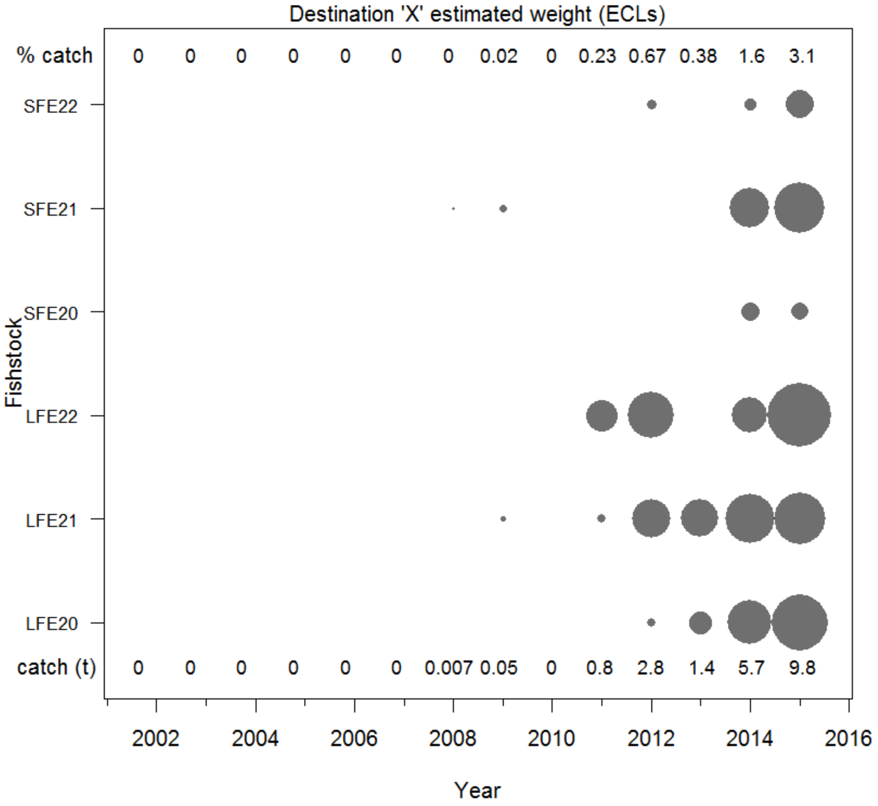
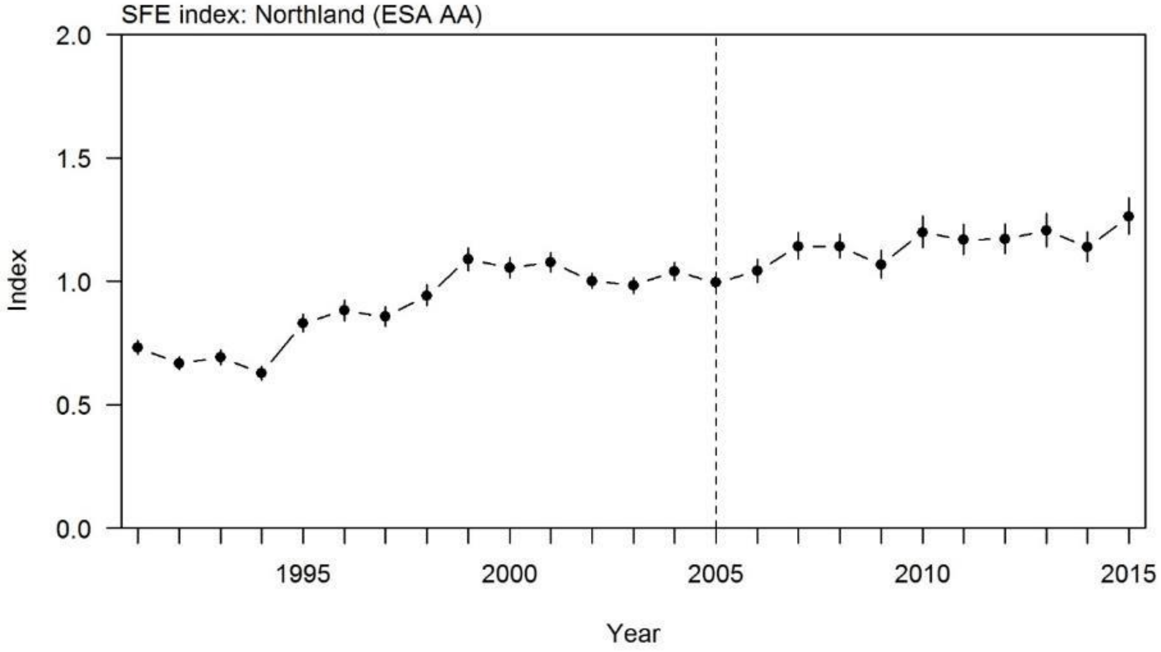


Figure 8: North Island commercial catch of shortfin by longfin by fishstock for the years 2001–15 recorded in ECLRs under destination 'X'. The top numbers are the percent of total landed catch each year recorded as destination 'X', and the bottom number represents the weight of the catch recorded as destination 'X'. Dates shown represent the end of the fishing year i.e., 1991 = 1990–91 fishing year.

Figure 9: Typical fyke net used in North Island commercial fishing operations when targeting either shortfin or longfin eels. Nets are routinely baited for both target species. Photo by Mike Beentjes (NIWA).



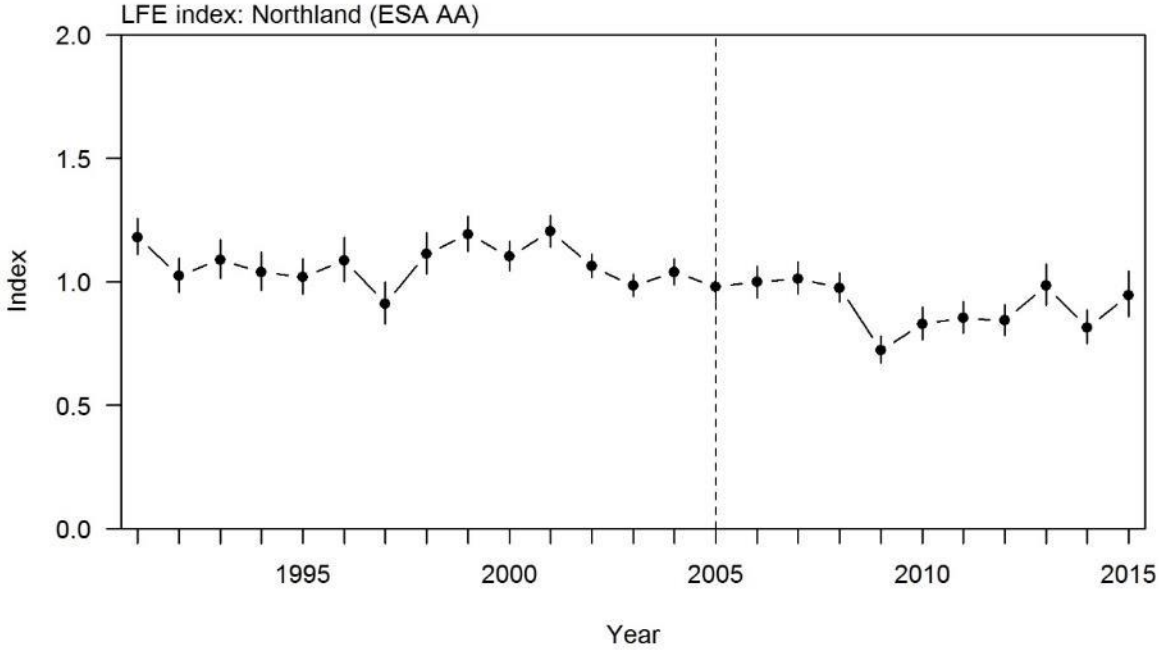
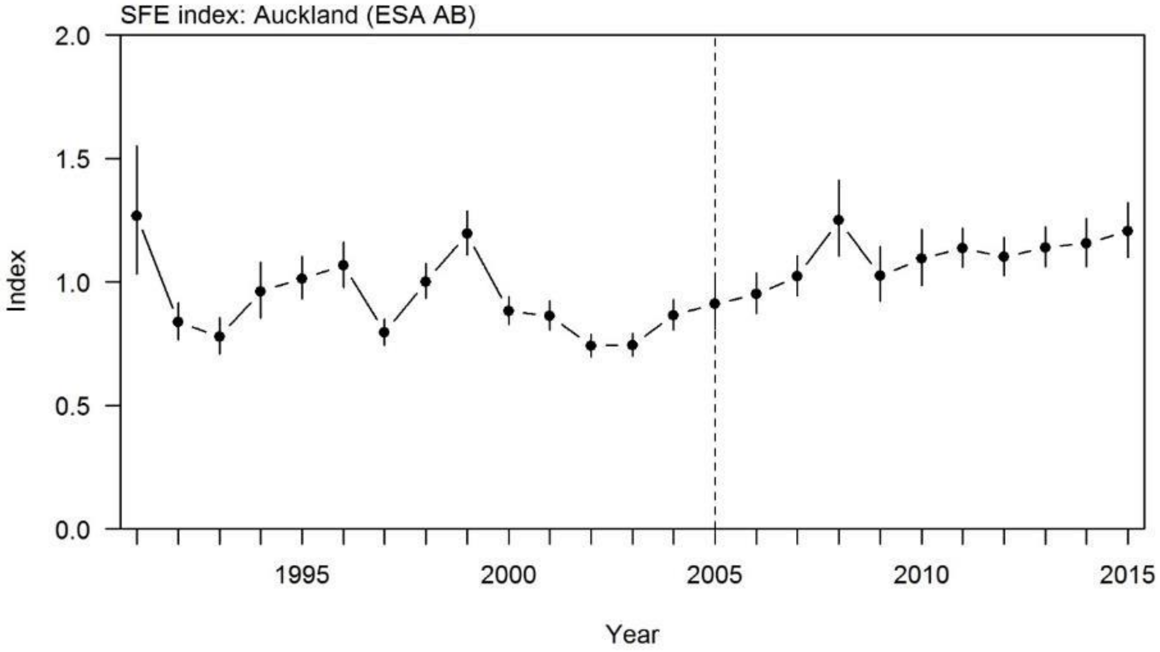
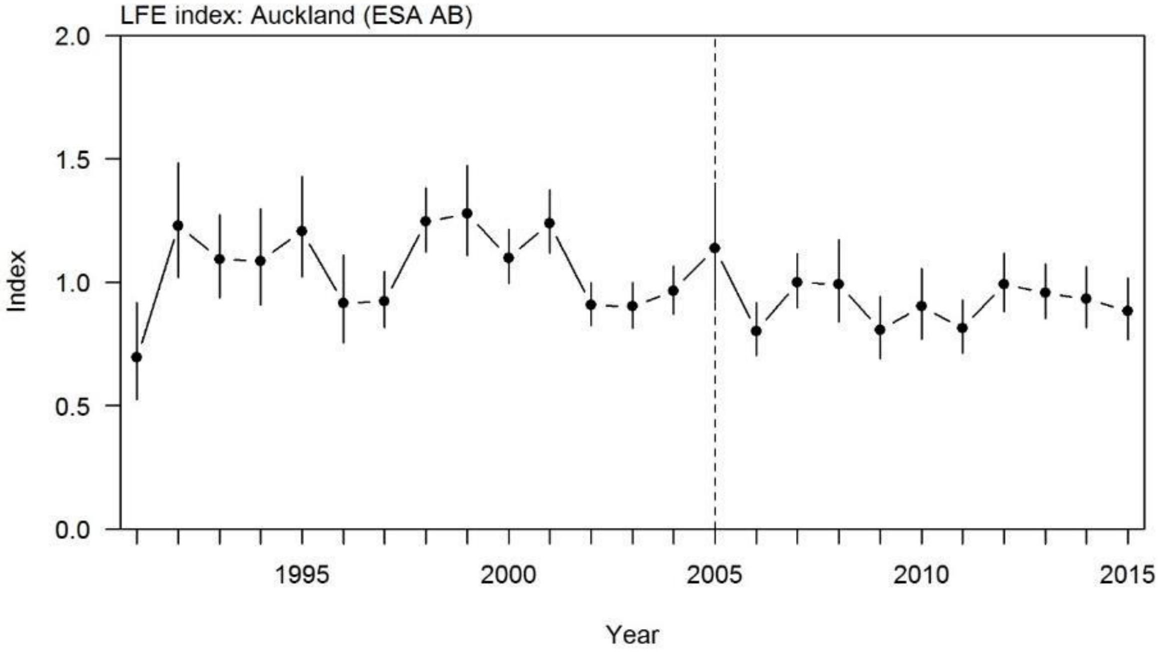


Figure 10: Standardised CPUE indices for shortfin and longfin eels for the years 1991–2015 for each North Island ESA, except AM, where there was insufficient data. The vertical dashed line indicates introduction of the QMS in 2004–05. Dates shown represent the end of the fishing year i.e., 1991 = 1990–91 fishing year. [Continued on next pages]





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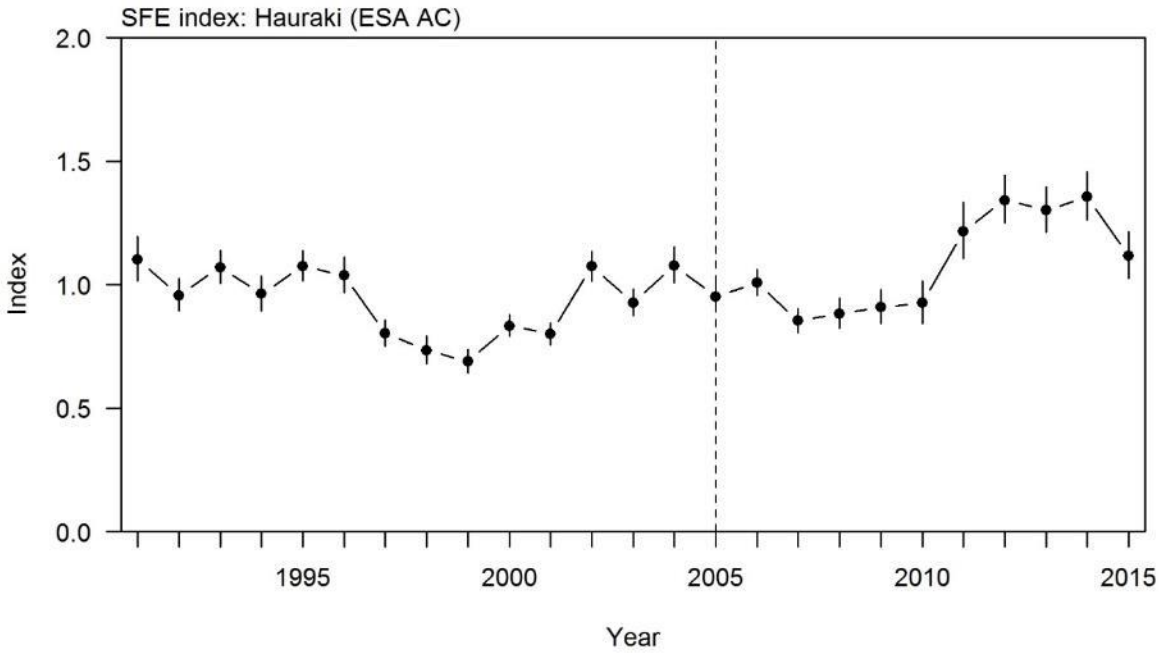

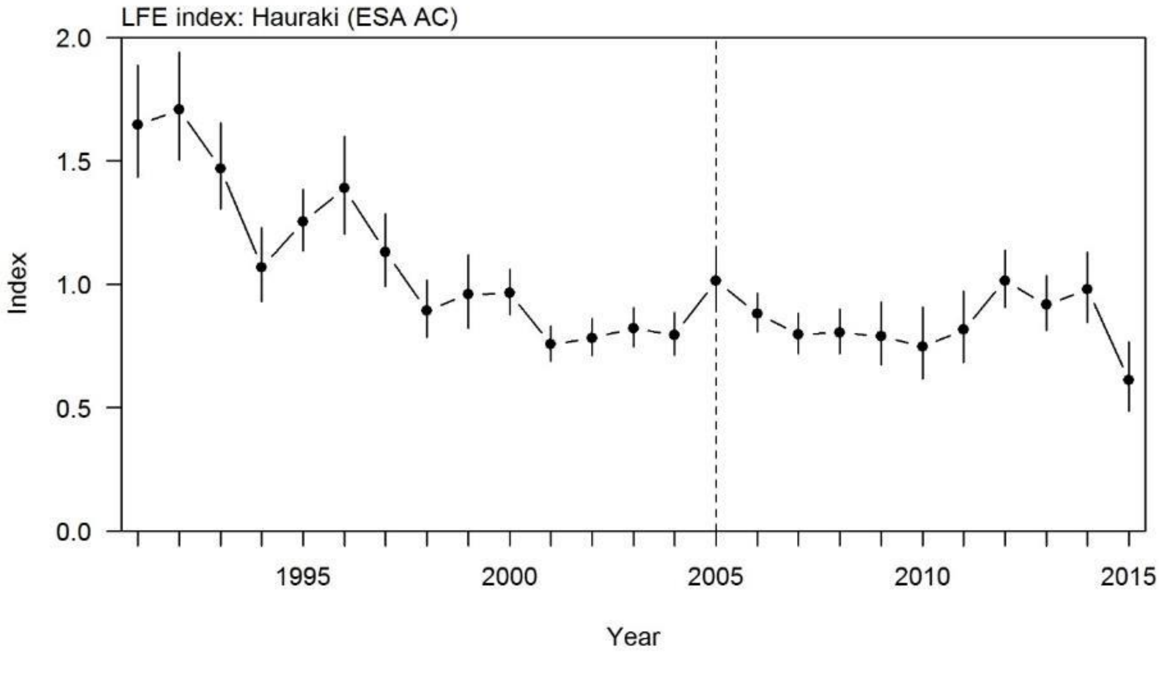

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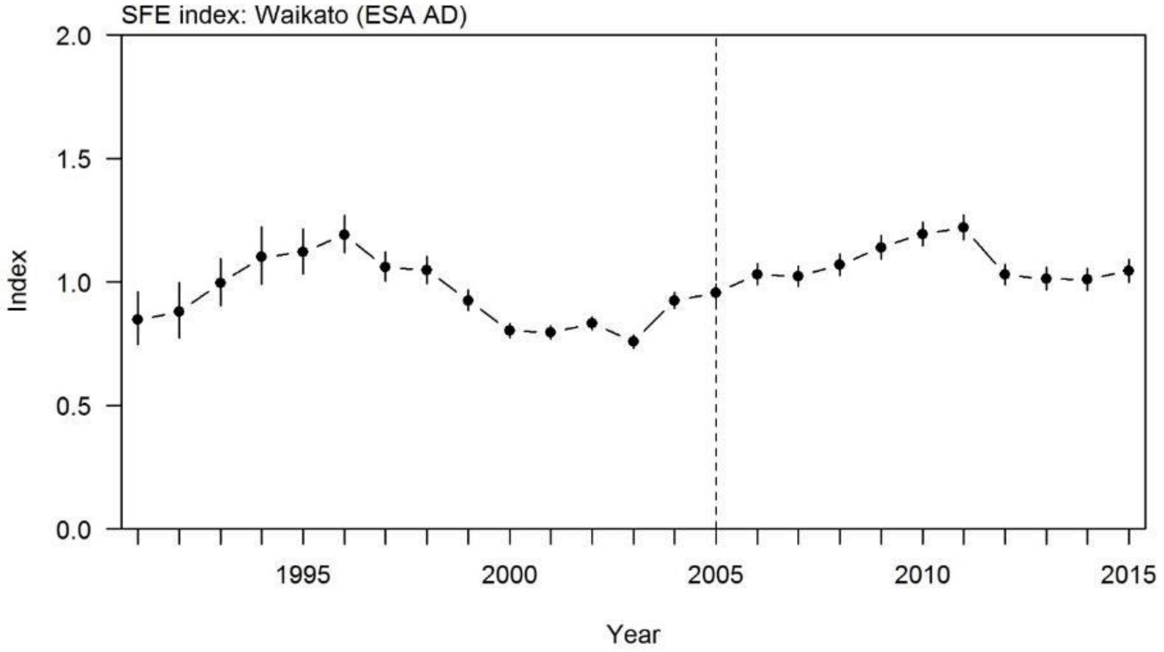

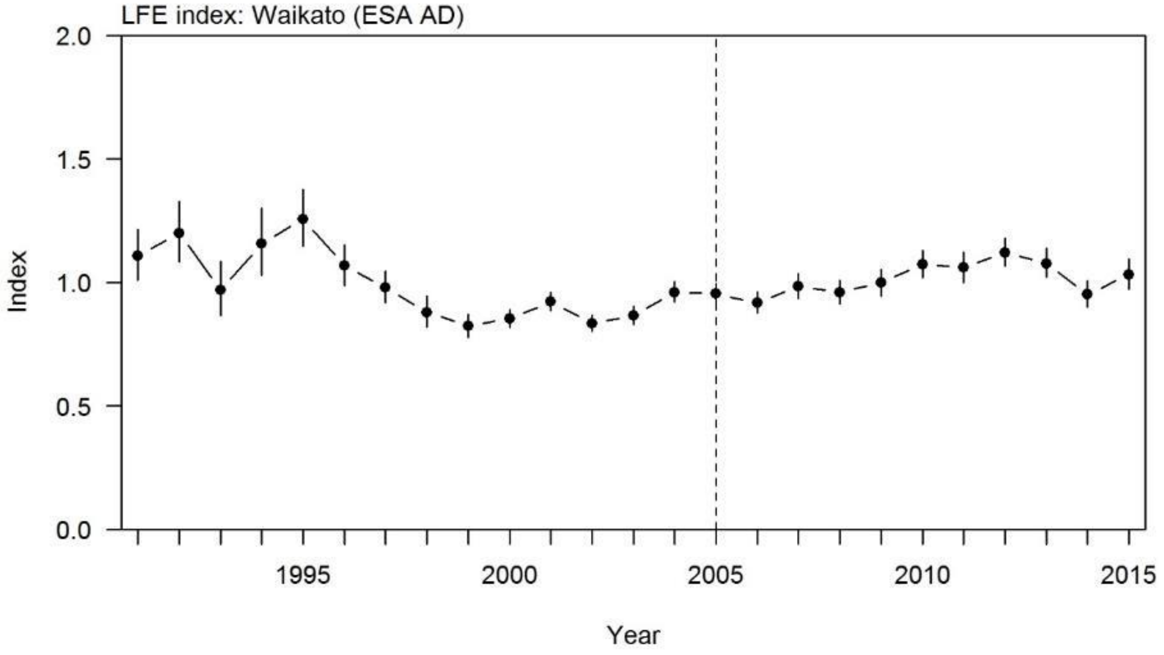

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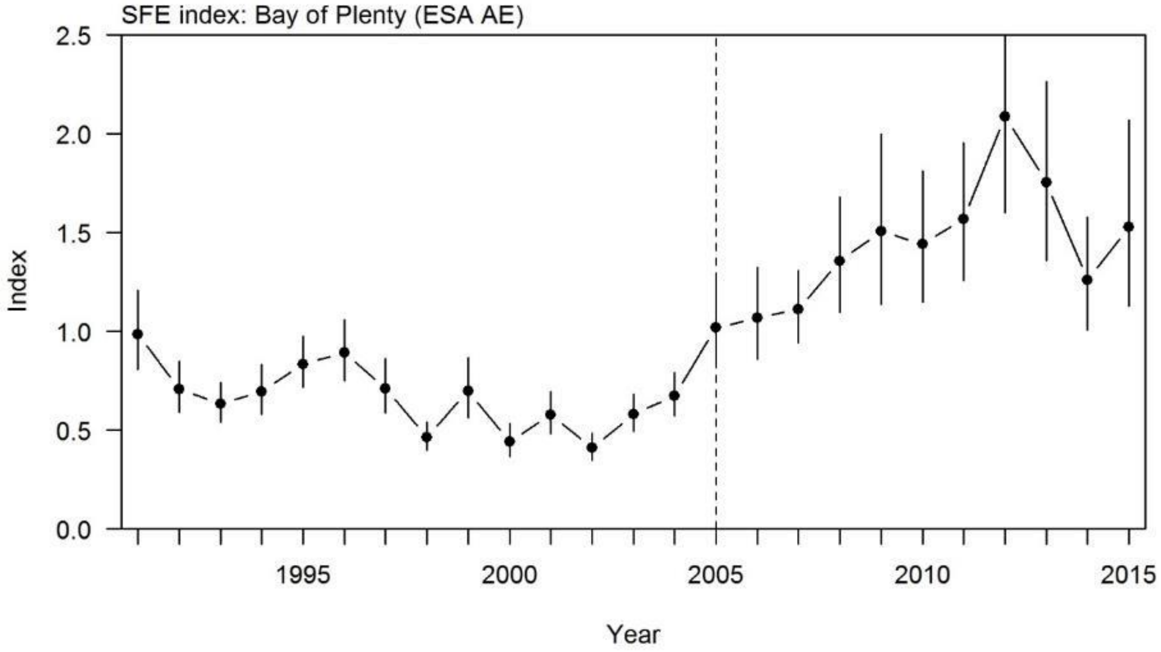

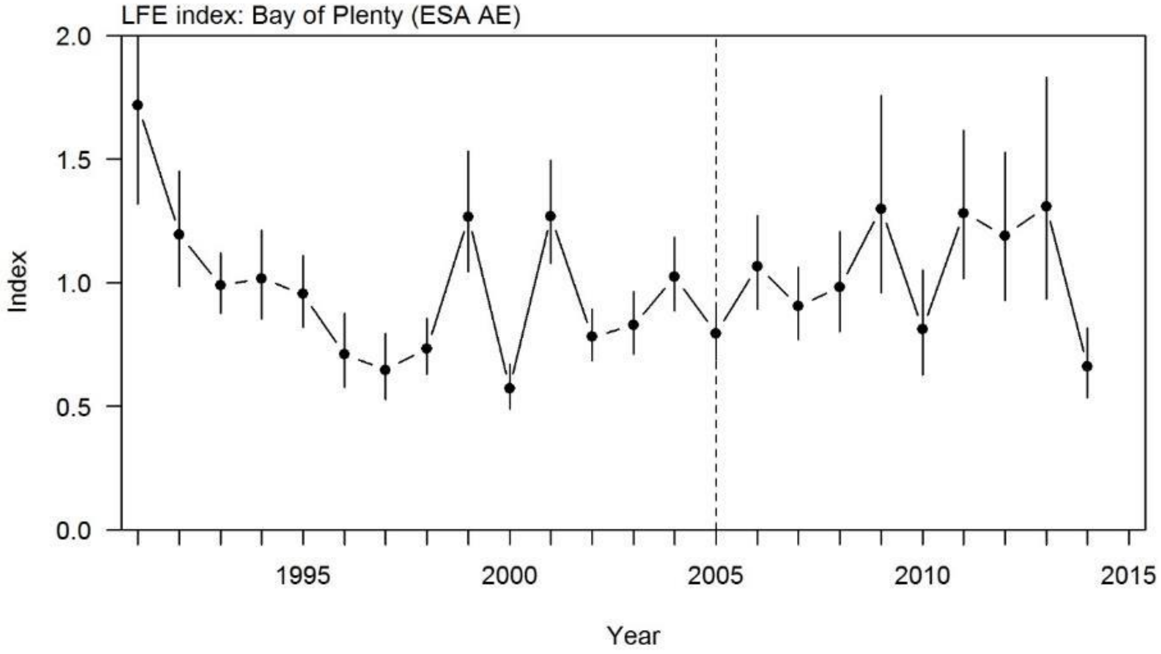

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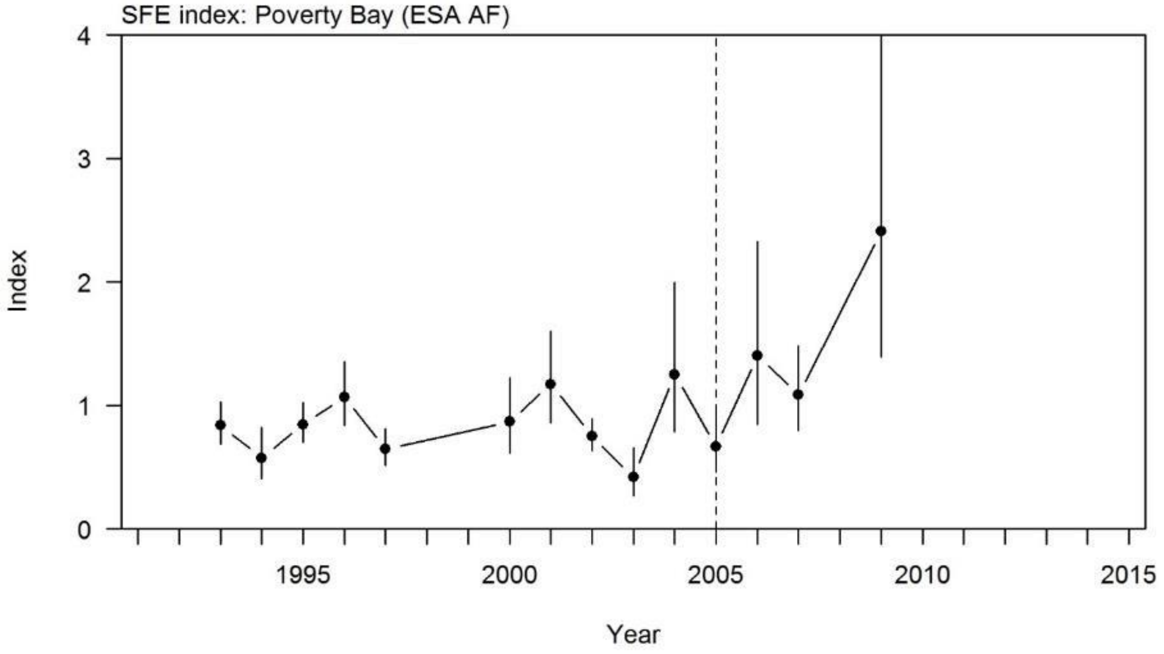

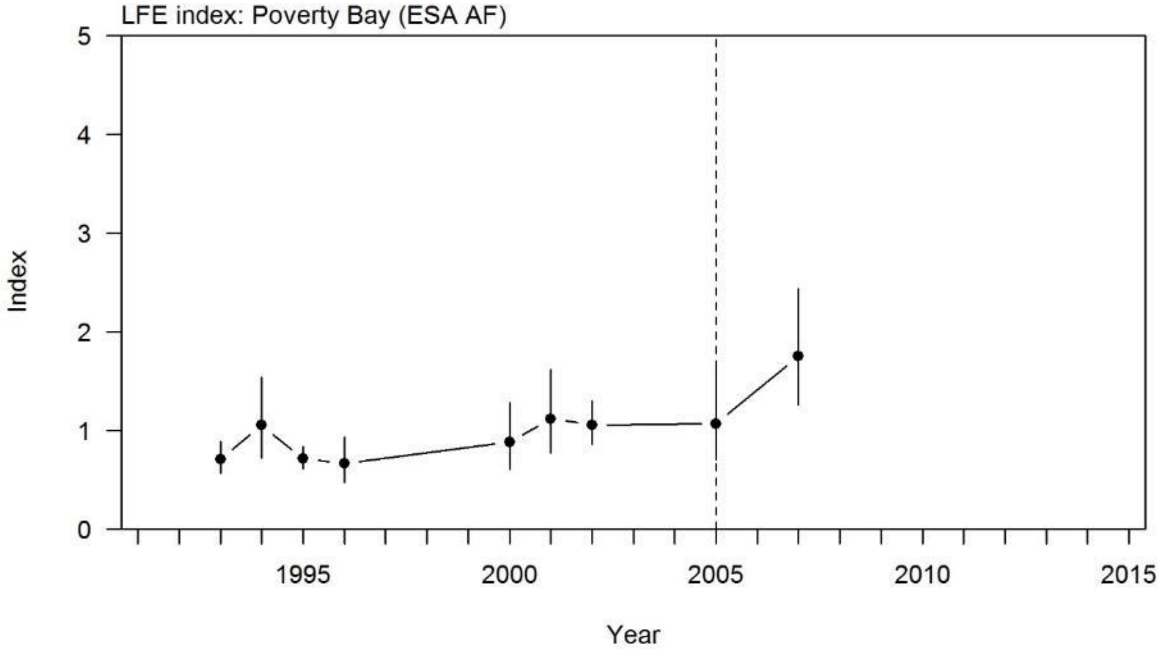

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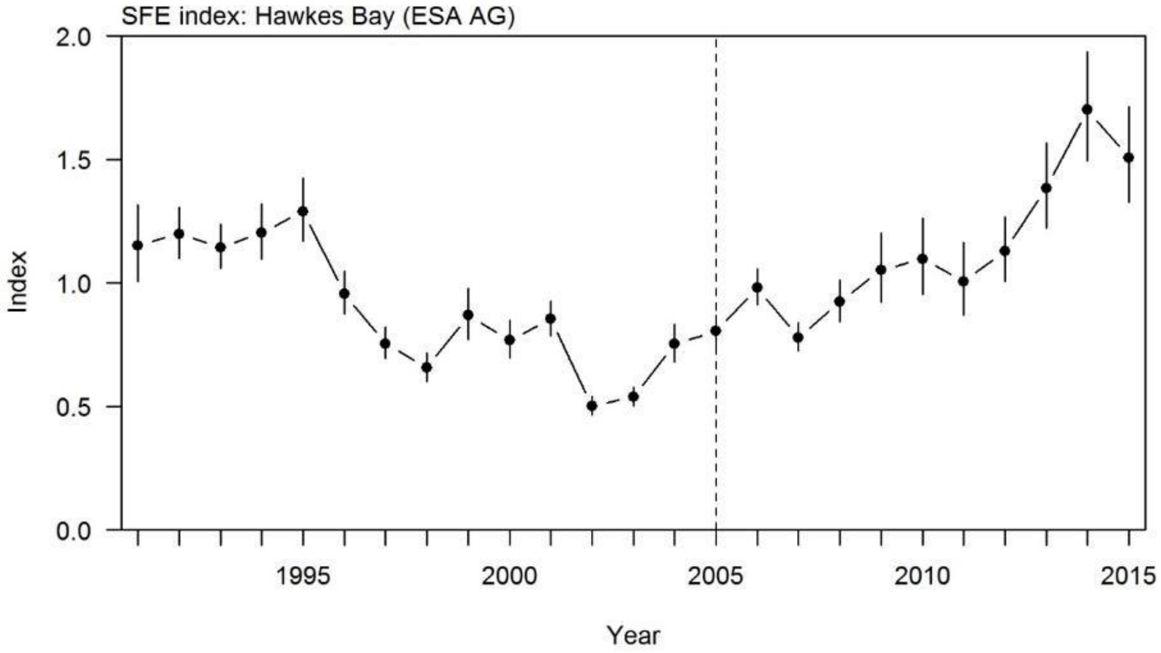

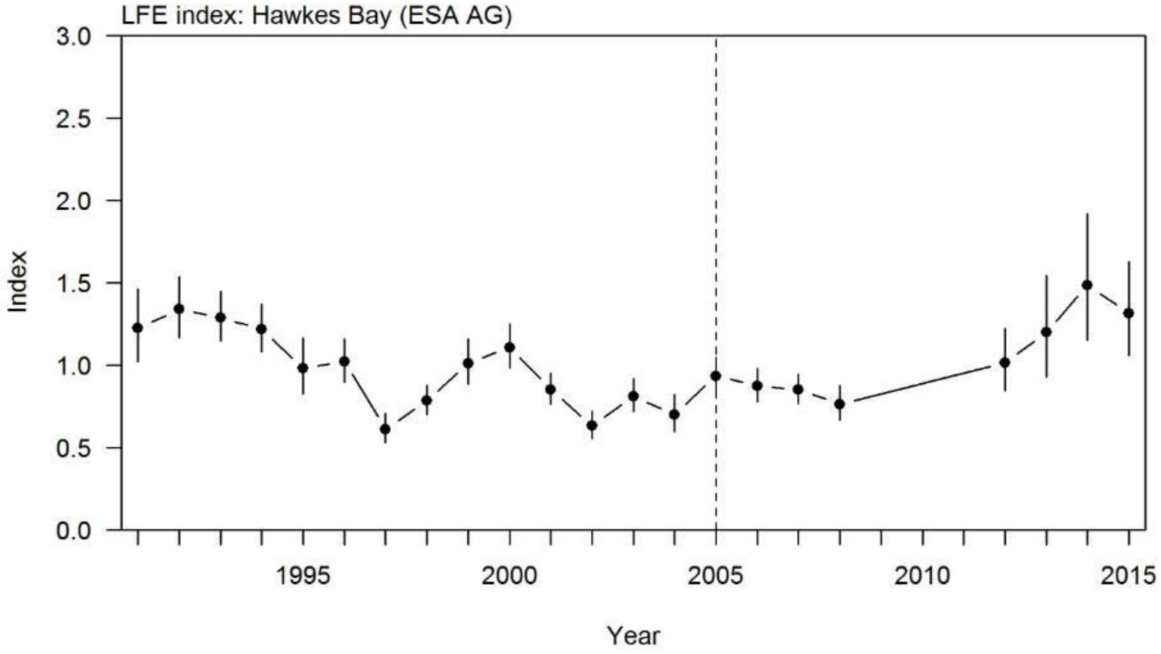

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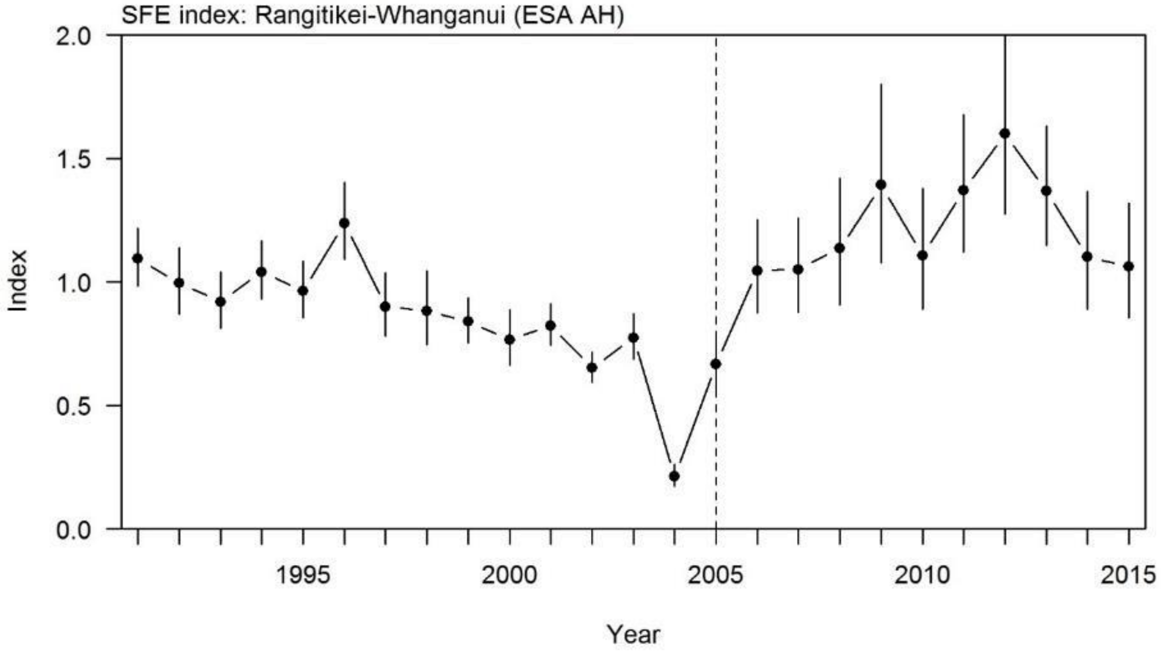

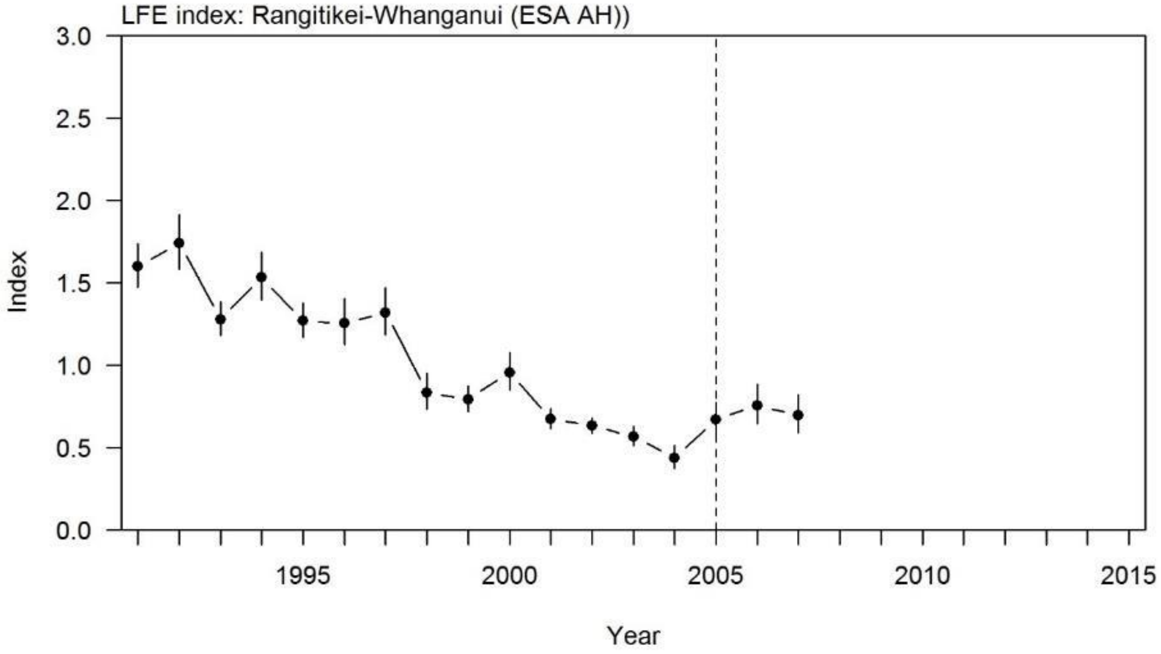

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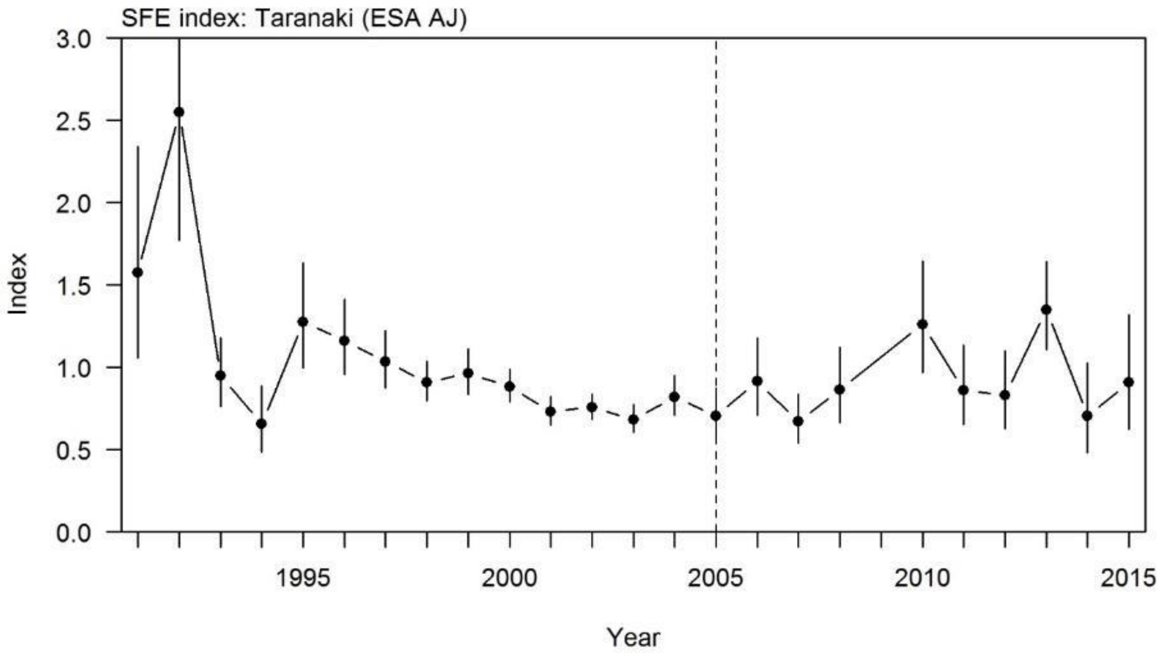

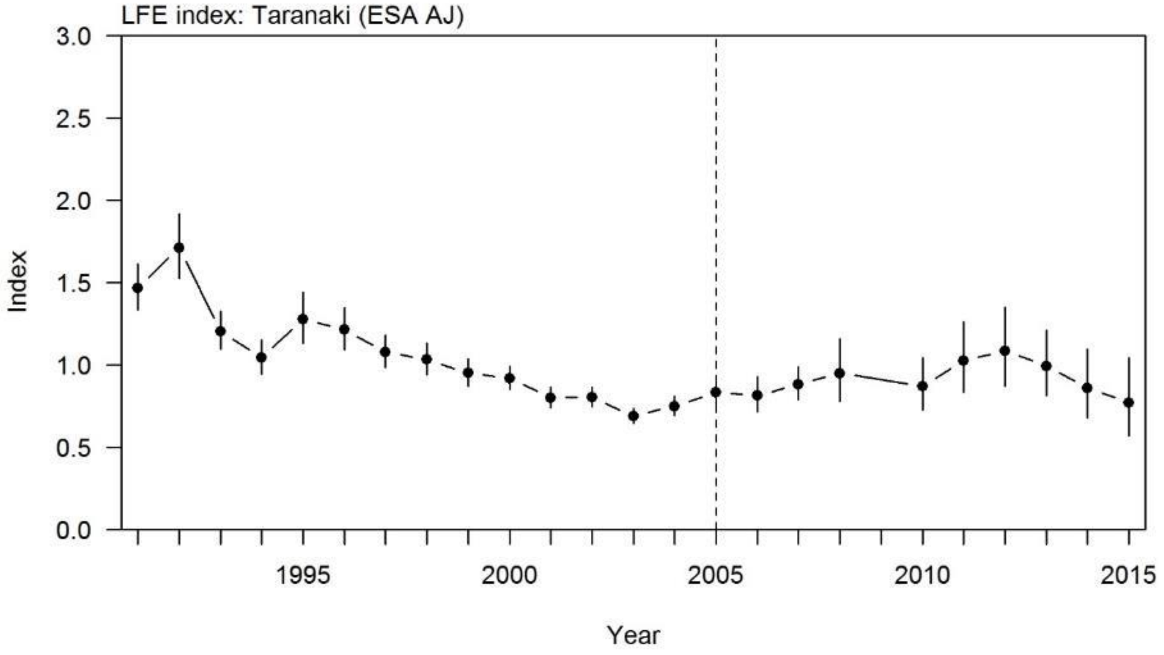

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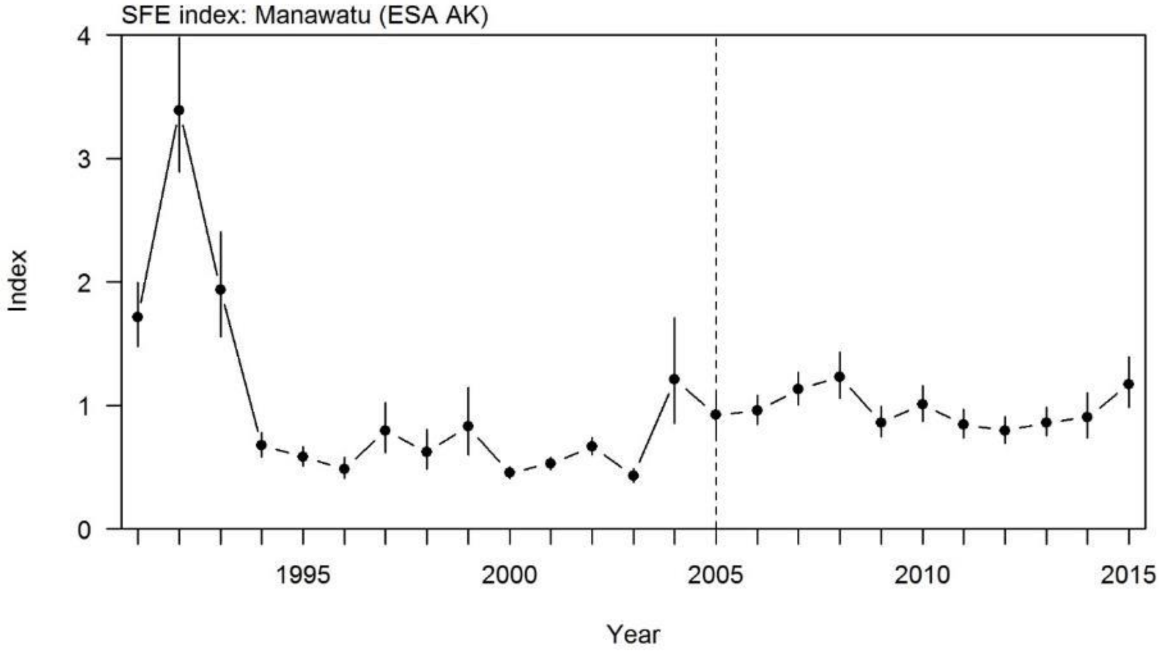

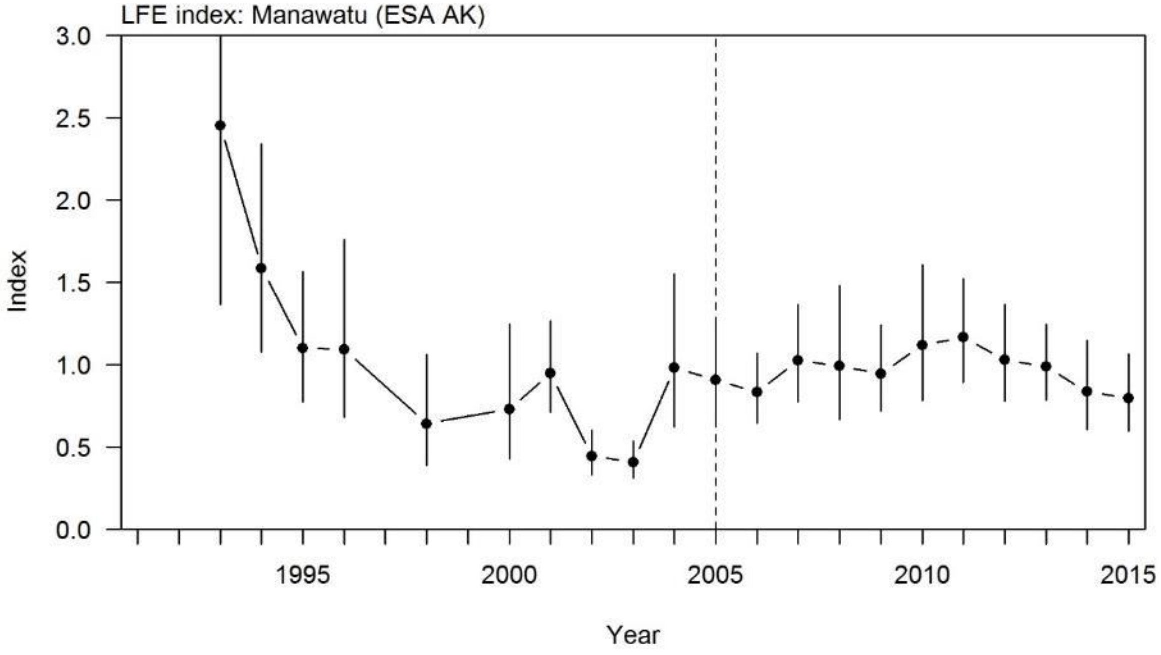

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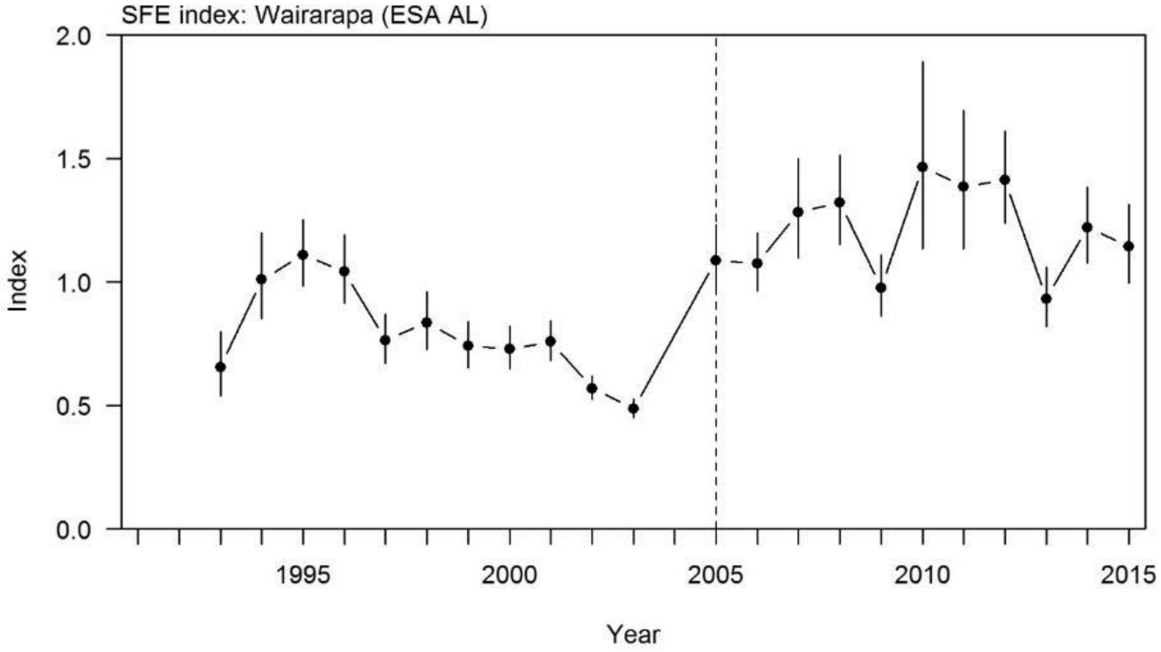

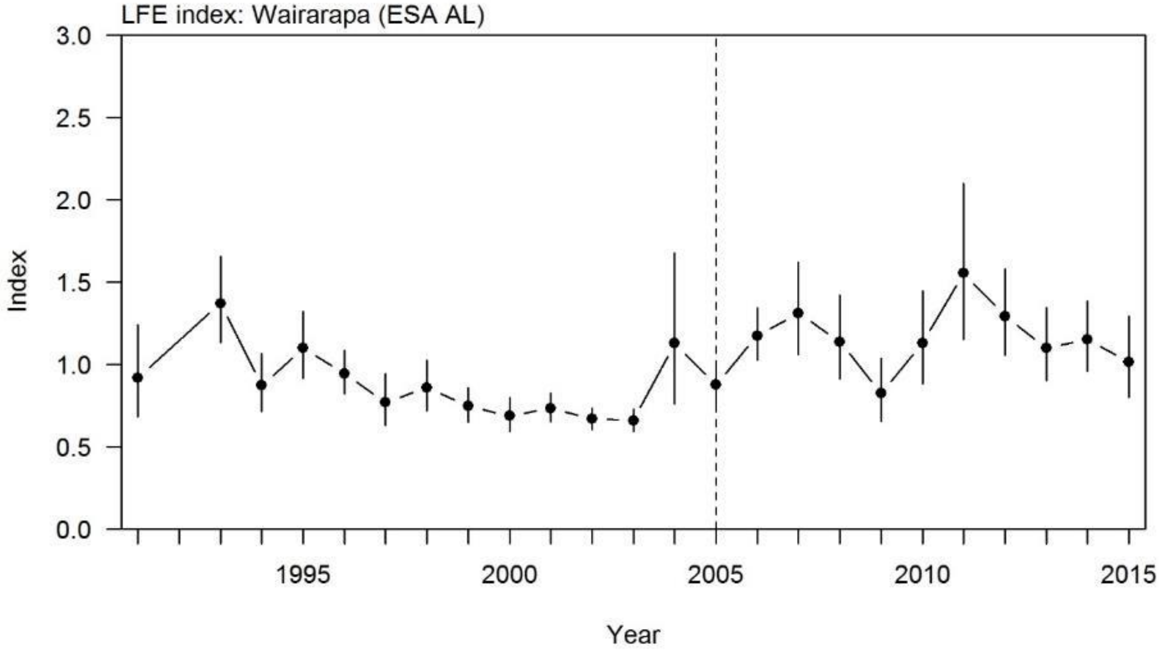

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