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Fishery characterisation and Catch-Per-Unit-Effort indices for tarakihi in TAR 1, TAR 2 and TAR 3

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For TAR 1, TAR 2 and TAR 3, the tarakihi catch is predominantly taken by the inshore trawl fleet, although a regionally significant target set net fishery also operates within TAR 3. Recent trends in the main tarakihi fisheries are described based on the analysis of catch and fishing effort data from the commercial fleet. The TAR 1 fishstock is partitioned into three distinct fishery areas: Bay of Plenty (BPLE), East Northland (ENLD) and west coast North Island (WCNI). These three areas are geographically distinct and the operation of the tarakihi fishery differs amongst them.

Standardized CPUE analyses were conducted for each of the main tarakihi fisheries within TAR 1, TAR 2 and TAR 3, updating and refining previous CPUE analyses to include data from the 1989/90–2015/16 fishing years. The fishery-specific standardised CPUE series are the primary indices of relative abundance for TAR 3 (trawl and set net fisheries), TAR 2 (trawl) and the three fishery areas that constitute TAR 1 (trawl). The six sets of CPUE indices were derived from the following catch and effort data sets:

TAR 3 trawl	multiple target species (TAR, RCO, BAR, WAR, GUR), daily aggregated data, 1989/90–2015/16.
TAR 3 set net	target fishery (TAR), daily aggregated data, 1989/90–2015/16.
TAR 2 trawl	multiple target species (TAR, SNA, BAR, WAR, GUR, SKI), daily aggregated data, 1989/90–2015/16.
BPLE trawl	multiple target species (TAR, SNA, BAR, TRE, JDO, GUR, SKI), daily aggregated data, 1989/90–2015/16.
ENLD trawl	target fishery (TAR), trawl event data, 1993/94–2015/16.
WCNI trawl	multiple target species (TAR, SNA, TRE), trawl event data, 1993/94–2015/16.

For the trawl fisheries, CPUE was modelled as two components: 1) the magnitude of the positive tarakihi catch (assuming either a lognormal or Weibull error distribution) and 2) the presence/absence of tarakihi in the catch (binomial model). Combined annual CPUE indices were derived from the year effects determined from the two models. For the TAR 3 set net fishery, the CPUE indices were derived from the lognormal CPUE model of positive tarakihi catch.

Both the BPLE and TAR 2 CPUE indices reached a peak during 2000/01–2004/05. There were corresponding peaks in the CPUE indices from the ENLD and TAR 3 set net fisheries at about the same time. The increase in the CPUE indices was preceded by a peak in the TAR3 trawl CPUE indices during 1999/2000–2001/02. More recently, the CPUE indices from the TAR 3 trawl fishery increased during 2009/10–2015/16, while the TAR 2 trawl CPUE indices also increased slightly during the last five years. This is contrasted by a sharp decline in the CPUE indices from BPLE and ENLD during 2009/10–2015/16. The CPUE indices from the northern WCNI trawl fishery generally declined between 1998/99–2003/04 and 2013/14–2015/16.

The results of the current study will be incorporated in the stock assessment of tarakihi along the east coast of the North and South Islands which is scheduled for completion in 2018. The CPUE indices will provide fishery-specific abundance indices, while the fishery characterizations provide additional information that determine the appropriate structure of the assessment model(s). Comparisons of the trends in the various CPUE indices may provide some indication of the degree of interconnectedness of the tarakihi stock (or stock units) amongst the various fishery areas (TAR 3, TAR 2, Bay of Plenty and East Northland). A more thorough appraisal of the trends in the different sets of CPUE indices will be

conducted within the framework of an integrated, age structured population model, incorporating the fishery catch and age composition data sets.

1 INTRODUCTION

Tarakihi (*Nemadactylus macropterus*) supports important inshore fisheries around the New Zealand coast. In the 2015/16 fishing year, the fisheries along the east coast of the South Island (TAR 3 TACC 1403 t), off the central east coast of the North Island (TAR 2 TACC 1796 t) and around the northern North Island (TAR 1 TACC 1447 t) yielded a cumulative commercial catch of 4311 t of tarakihi (Ministry for Primary Industries 2016).

Previous studies have characterised the main tarakihi fisheries based on catch and fishing effort data from the commercial fishing fleet (Kendrick 2009, Starr & Kendrick 2014). The tarakihi catch is predominantly taken by the inshore trawl fleet, although a regionally significant target set net fishery also operates within TAR 3. The previous studies have partitioned the TAR 1 fishstock into three distinct fishery areas: Bay of Plenty (BPLE), East Northland (ENLD) and west coast North Island (WCNI) (Figure 1). These three areas are geographically distinct and the operation of the tarakihi fishery differs amongst the three areas (Starr & Kendrick 2014).

The previous studies also derived standardized CPUE indices for each of the main tarakihi fisheries within TAR 1, TAR 2 and TAR 3 (Kendrick 2009, Starr & Kendrick 2014). The CPUE indices represent the primary index of tarakihi abundance in TAR 3 and TAR 2 and the three fishery areas that constitute TAR 1 (Ministry for Primary Industries 2016). For TAR 3, tarakihi abundance is also monitored by the time-series of *Kaharoa* east coast South Island inshore trawl surveys (Beentjes et al. 2015, Beentjes et al. 2016).

The current study updates the previous characterisations of the TAR 1, TAR 2 and TAR 3 fisheries, based on catch and effort data from the 1989/90–2015/16 fishing years. The CPUE analyses for TAR 3 (trawl and set net methods) and TAR 2 (trawl) and the three fishery areas that constitute TAR 1 (trawl) are also updated to the 2015/16 fishing year.

The study was funded by Ministry for Primary Industries under Research Contract TAR2016-01 entitled “Stock assessment of east coast tarakihi”. The results of the current study will be incorporated in the tarakihi stock assessment which is scheduled for completion in 2018.

2 DATA SETS

Commercial catch and effort data from the tarakihi fishery were sourced from the Ministry for Primary Industries (MPI) database *warehou*. The scope of the study encompassed the TAR 1, TAR 2 and TAR 3 fishstock areas and the data extract included the catch and effort data from any fishing trip that recorded a catch of tarakihi from any of these three fishstocks (Figure 1). The extract was supplemented by data from any additional fishing trips that conducted fishing within the Statistical Areas that comprise the three fishstock areas (Statistical Areas 001–024, 026 and 041–048) and targeted the range of inshore species (TAR, SNA, TRE, RCO, BAR, SKI, WAR, GUR, and JDO) that are caught in association with tarakihi.

In addition, a trawl fishery for tarakihi operates in the eastern area of Statistical Area 017 (Figure 1). While the fishery is within the TAR 7 fishstock, the proximity of the fishery to the tarakihi fisheries along the Wairarapa and Kaikoura coasts means that it is appropriate to consider the fishery within the scope of the stock assessment of tarakihi in the wider east coast area. Thus, the data extract included data from fishing trips that caught tarakihi within Statistical Area 017, including landed catches from TAR 7.

For the qualifying trips, all effort data records were sourced, regardless of whether or not tarakihi was landed. The estimated catches and landed catch records of all finfish species were sourced for the qualifying fishing trips. Data were complete to the end of the 2015/16 fishing year.

From 1989/90, most inshore fishing vessels reported catch and effort data via the Catch Effort Landing Return (CELR) which records aggregated fishing effort and the estimated catch of the top five species. Fishing effort and catch was required to be recorded for each target species and statistical area fished during each day, although typically catch and effort data were aggregated by fishing day (Langley

2014). The verified landed green weight that is obtained at the end of the trip was recorded on the Landings section of the CELR form.

From 1994/95, many of the inshore trawlers operating in TAR 1 reported fishing effort and catch data for individual trawls via the Trawl, Catch, Effort and Processing Return (TCEPR). In 2007/08, the Trawl, Catch and Effort Return (TCER) was introduced specifically for the inshore trawl fisheries and was adopted by most of the inshore trawl vessels within the tarakihi fishery, including the TAR 1 inshore trawl fleet. The TCER form records detailed fishing activity, including trawl start location and depth, and associated catches from individual trawls. Landed catches associated with trips reported on TCEPR and TCER forms is reported at the end of a trip on the Catch Landing Return (CLR).

New method specific reporting forms were also introduced for the set net fishery (Netting Catch Effort Landing Return) and longline fishery (Lining Trip Catch Effort Return) in 2006/07 and 2007/08, respectively.

The Quota Management System (QMS) totals are collected from fishing permit holders on a monthly basis (Monthly Harvest Return, MHR) and are subjected to a different regime of storage and checking.

2.1 Data processing

2.1.1 Fishery characterisation data set

The fishery characterisation data set included all fishing trips that landed tarakihi (TAR 1, TAR 2, TAR 3, TAR 7 and/or TAR 8) associated with fishing effort from within the Statistical Areas that defined the study area (Statistical Areas 001–024, 026 and 041–048) (Figure 1). The landed catch from TAR 7 and TAR 8 represented a relatively small proportion (7.9% and 3.3%) of the total tarakihi catch included in the characterisation data set.

The initial set of tarakihi landed catch records was screened to retain the records that represented the final destination of the tarakihi catch (destination codes L, A, C, E, and O). This resulted in a small reduction in the total tarakihi landed catch included in the characterisation data set, primarily due to the exclusion of TAR 3 landed catches transferred between vessels (destination code T) (Table 1).

Table 1: Total tarakihi landed catch included in the fishery characterisation data set at each step of the catch grooming process.

Criterion	Landed catch (t)	Percent of total landed catch
All landing records	126 228.6	100.0%
Destination codes (L, A, C, E, O)	123 956.4	98.2%
Exclude landed catch outliers	123 195.9	97.6%
Associated effort records	121 442.1	96.2%

Potential landed catch outliers were examined by comparing the corresponding landed catches and aggregated estimated catches from individual fishing trips. In most cases, the ratio of the trip landed catch to the estimated catch approximated 1.0 indicating a good correspondence between the landed catch and estimated catch (Figure 2). Potentially erroneous landed catch records were identified based on the ratio of the trip landed catch to the aggregated estimated catch; i.e. where the ratio exceeded a factor of 5.0, landed catches exceeded 250 kg and estimated catches exceeded 100 kg. A total of 251 trips (of a total of 222 814 trips) met these criteria and the landed catches for these trips were further examined by comparing the landed catch with the corresponding processed catch weight multiplied by the conversion factor of the associated state code. A subset of those trips had catch values derived from the processed catch data that were considerably lower than the landed catch. For these trips, the landed catches were corrected using the green weight equivalent of the processed catches. This resulted in a small reduction in the total tarakihi catch included in the data set (Table 1).

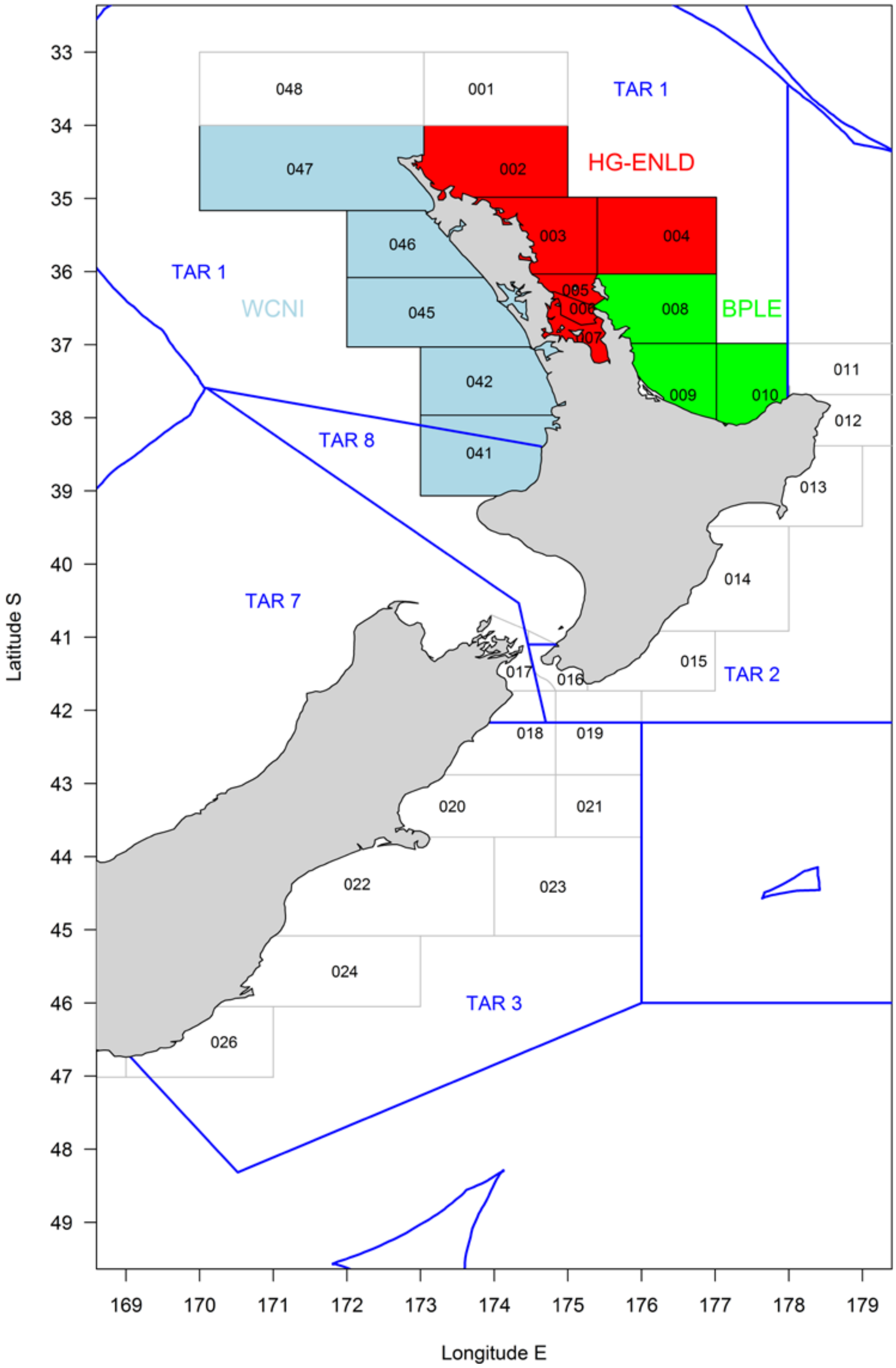

Figure 1: Map of tarakihi fishery areas defined based on Statistical Areas.

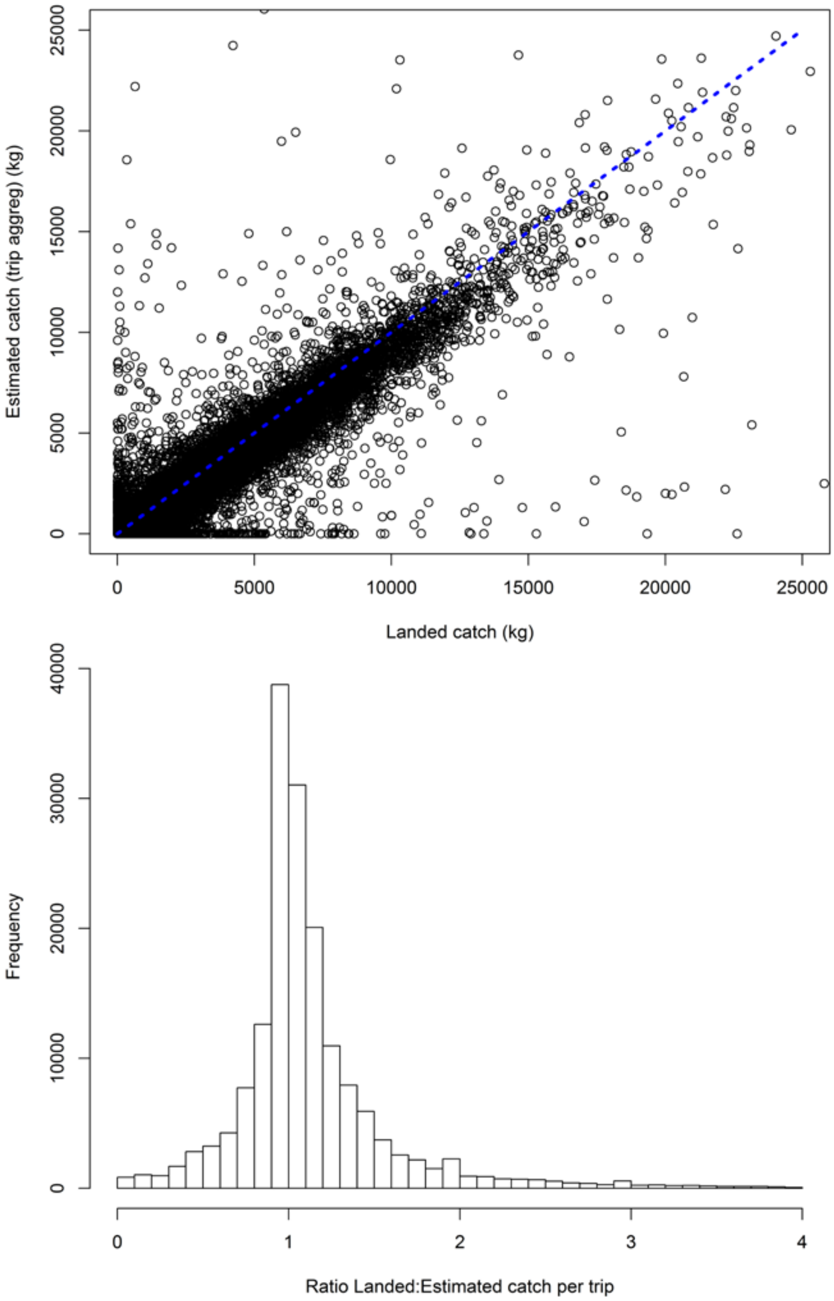

Figure 2: Ratio of the tarakihi landed catch and the sum of tarakihi estimated catches from individual fishing trips.

During 1989/90–1993/94, most (87–94%) of the tarakihi landed catch was associated with fishing effort recorded in the Catch Effort Landing Return (CELR) format (Figure 3). From 1994/95, many of the larger inshore trawl vessels operating in the snapper (SNA 1) fishery were required to complete the more detailed Trawl Catch Effort Processing Return (TCEPR) and, consequently, approximately 30–47% of the tarakihi landed catch was reported via the associated Catch Landing Return (CLR) during 1995/96–2006/07 (Figure 3). In 2007/08, the Trawl Catch Effort Return (TCER) was introduced to facilitate the collection of the fishing event based catch and effort data from the inshore trawl fleet. Since 2007/08, 60–70% of the tarakihi landed catch has been reported by vessels completing the TCER form, while 20–30% of the catch has continued to be reported in TCEPR format. The remainder of the tarakihi catch has been reported from the set net fishery (NCER format) and the longline fishery (LTCER format), while a small proportion of the catch continues to be reported in the CELR format (2–4% of landed catch).

For the main characterisation data set, catch and effort data from the qualifying fishing trips were aggregated in a manner that approximates the daily aggregate format of the CELR following the approach of Langley (2014). The approach aggregates method (gear type) specific fishing effort for each fishing vessel and fishing day. The resulting records are assigned a statistical area and target species based on the predominant statistical area and declared target species from the day of fishing. The estimated species catches are also aggregated by the vessel, gear, fishing day and the aggregate catches are ranked based on species catch weight. The five species with the largest estimated catches are retained, replicating the recording of the top five species estimated catches from the CELR. The estimated catches of the remainder of the species (non top five) are not included in the subsequent analysis.

This aggregation approach reduces the potential for the catch and effort data set to be influenced by the changes in reporting formats (e.g. from CELR to TCEPR and then TCER). Given the high proportion of the landed catch reported in the CELR format prior to 2001/02 it was considered important to maintain a consistent reporting format in the subsequent years.

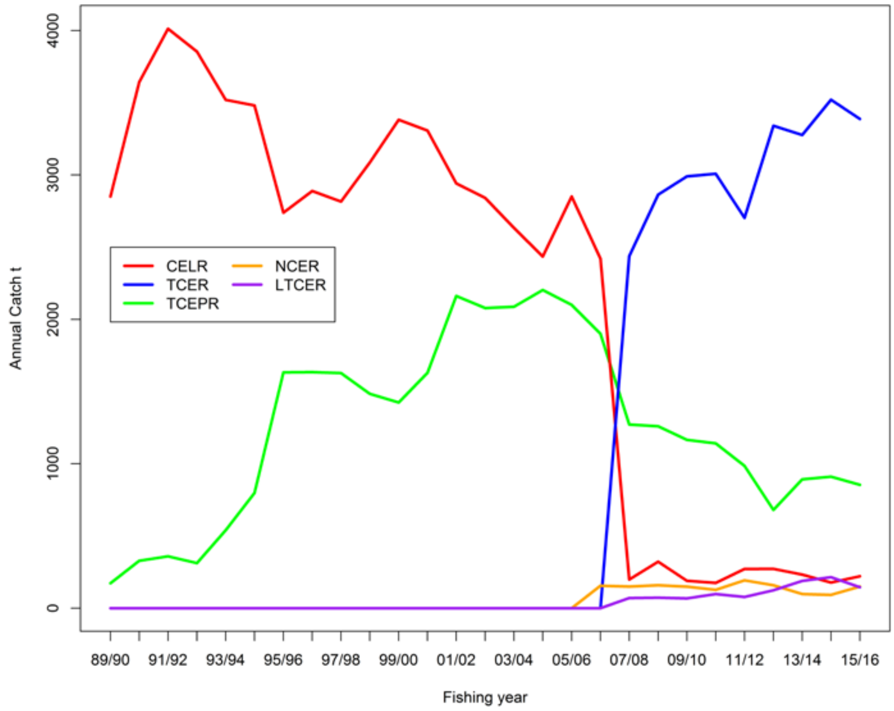

Figure 3: Total annual tarakihi landed catch associated with the statutory catch and effort reporting forms.

Most of the trips with a landed catch of tarakihi were successfully linked to the aggregated fishing effort records. However, the number of trips was reduced by the exclusion of effort records for fishing methods that would not be expected to catch tarakihi (e.g. surface longline and troll) and/or target species that are unlikely to be associated with tarakihi (e.g. ORH, SSO, and BOE) (213 812 trips retained). There were also fishing effort records that were missing the data fields required to generate the aggregated effort records. The reduction in the number of fishing trips included in the final data set resulted in a small reduction in the overall quantity of tarakihi landed catch (Table 1).

For 1989/90–2015/16, the TAR 1, 2, and 3 landed catches included in the characterisation data set approximated the annual TAR 1, 2, and 3 catches reported in MPI (2016) (Figure 4, Figure 5, Figure 6). The estimated catches of tarakihi from TAR 1, 2 and 3 generally represented 85–95% of the annual landed catch from each fishstock.

The landed catches of tarakihi from each fishing trip were apportioned to the aggregate fishing effort records following the approach developed by Starr (2007). For fishing trips that recorded at least one top five estimated catch of tarakihi, the tarakihi landed catch was allocated to the individual fishing effort records in proportion to the individual estimated catches (representing 98.0% of total landed catch and 68.7% of the effort records with allocated tarakihi catch). For fishing trips with no associated top five estimated catch of tarakihi, the landed catches were assigned to the daily fishing records in proportion to the number of trawls per day (representing 2.0% of total landed catch and 31.3% of the effort records with an allocated tarakihi catch).

The characterisation data set was subdivided following the spatial stratification of previous analyses: West coast North Island (WCNI), Statistical Areas 040–048; Hauraki Gulf and east Northland (HG-ENLD), Statistical Areas 002–007; Bay of Plenty (BPLE), Statistical Areas 008–010; TAR 2 East Coast North Island, Statistical Areas 011–016; East Coast South Island, Statistical Areas 017–024 and 026 (Figure 1).

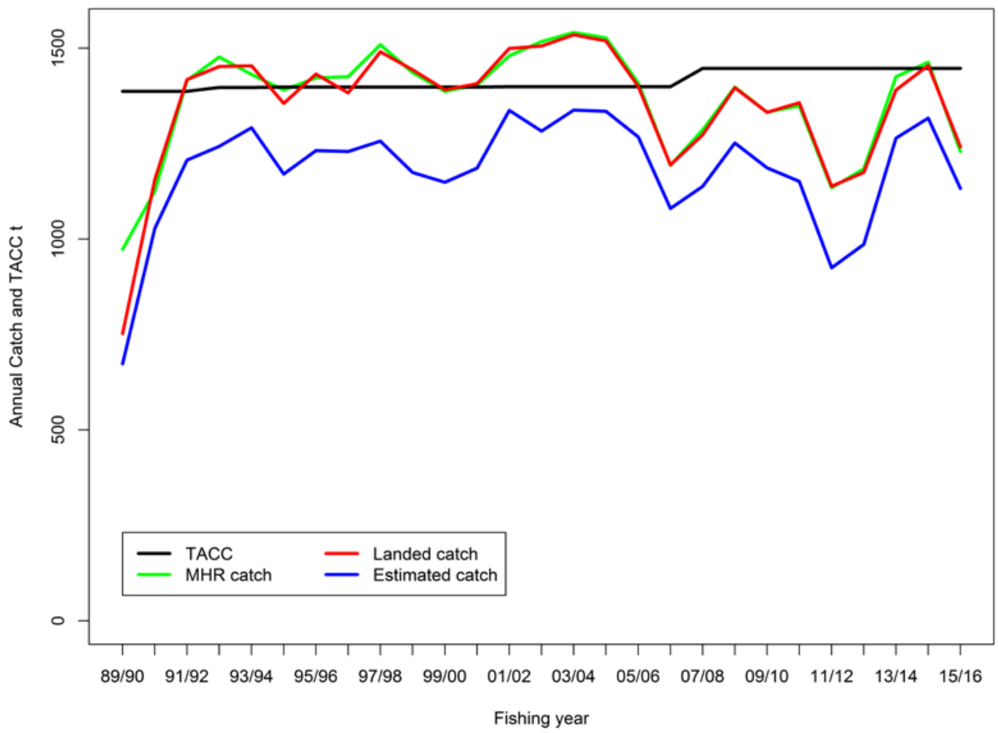

Figure 4: Comparison of total annual TAR 1 estimated and landed catches (t) by fishing year from vessel trip landing returns and the total reported landings (t) to the QMS (MHR).

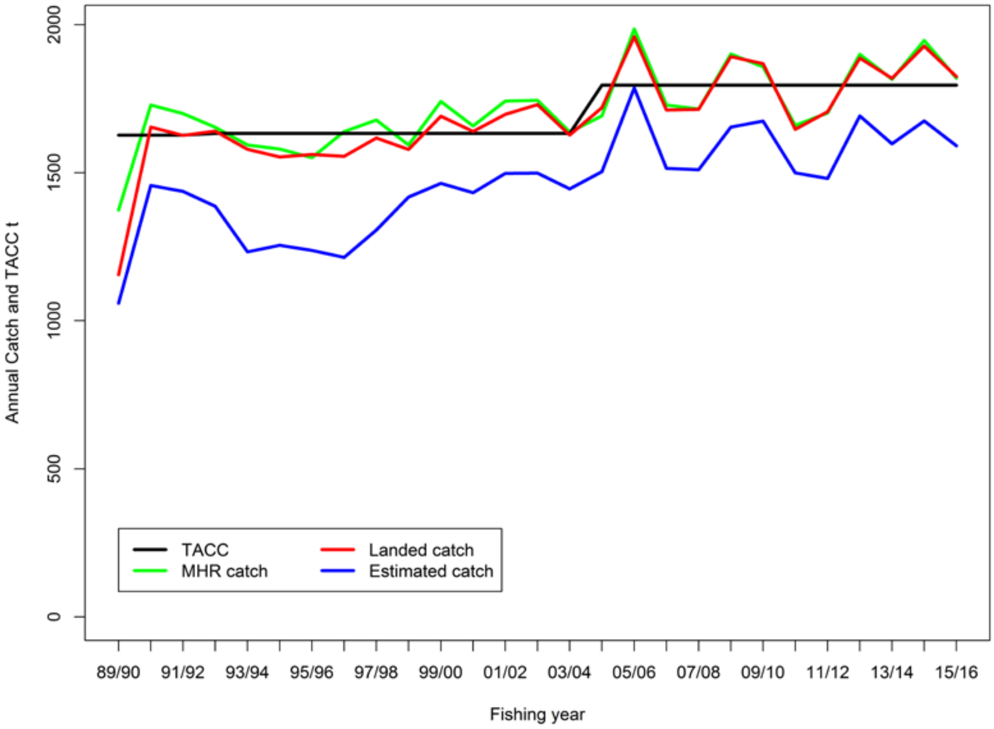

Figure 5: Comparison of total annual TAR 2 estimated and landed catches (t) by fishing year from vessel trip landing returns and the total reported landings (t) to the QMS (MHR).

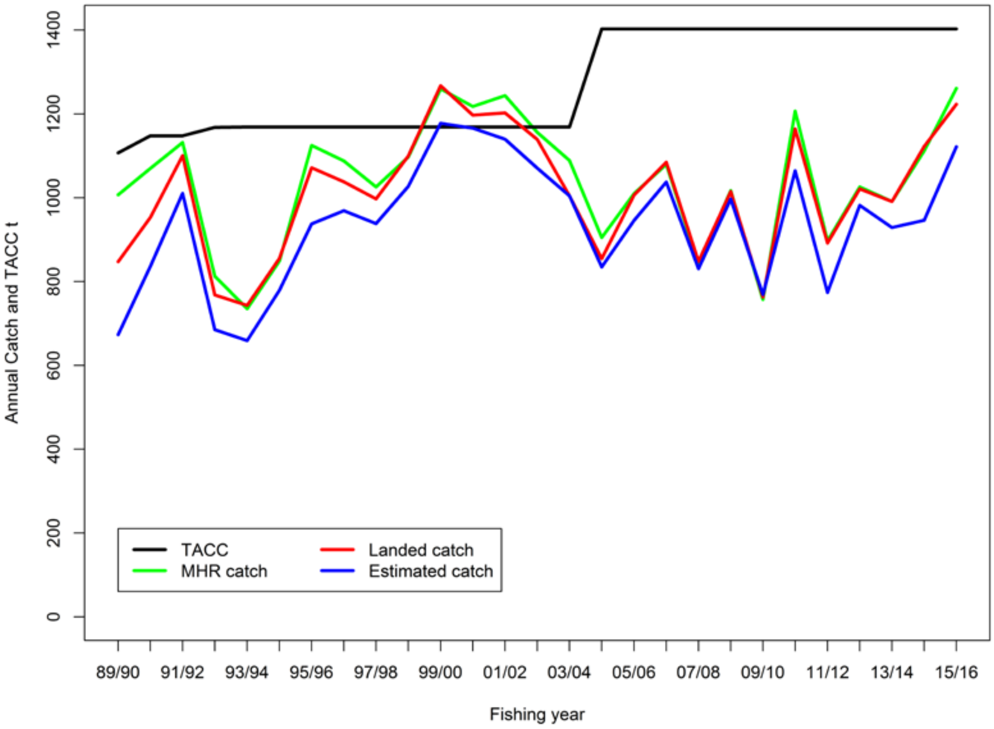

Figure 6: Comparison of total annual TAR 3 estimated and landed catches (t) by fishing year from vessel trip landing returns and the total reported landings (t) to the QMS (MHR).

2.1.2 Individual trawl data set

From 1995/96, fishing event based catch and effort data are available from the northern inshore trawl fleet, accounting for a substantial proportion of the total TAR 1 catch (Figure 3). Detailed fishing event based catch and effort data were collected in TCEPR format from 1994/95 and in both TCEPR and TCER formats from 2007/08 (Figure 3). The TCER form was introduced to the TAR 2 and TAR 3 trawl fleets in 2007/08.

The TCER records the details of individual trawls including start and end time, target species, trawl speed, and the location and bottom depth at the start of a trawl. This represents a comparable subset of the fishing event data recorded using the TCEPR format. A notable difference between the two formats is that the TCER form has the facility to record the estimated catch of the eight main species caught from the trawl, while only the trawl catch of the five main species can be recorded in the TCEPR format. This difference has the potential to result in a change in the reporting of the catch of the minor species, potentially increasing the number of small catches reported in the TCER format and, thereby, reducing the proportion of zero catch records. In turn, this has the potential to influence the allocation of the landed catches amongst fishing events from a fishing trip as this is usually based on the corresponding estimated catches from individual trawls.

For the composite TCEPR/TCER data set, estimated catches of tarakihi were associated with the individual trawl records and the ranking of tarakihi amongst the estimated species catches from the individual trawl was determined based on the reported estimated catch weight. For comparability with the TCEPR trawl records, tarakihi estimated catches from TCER records that were ranked lower than the 5th largest catch (i.e. the 6–8th ranked species) were reassigned an estimated catch of zero (0 kg). For each fishing trip, the aggregated top 5 estimated catch of tarakihi was determined. The landed catch of tarakihi from each fishing trip (from Section 2.1.1) was then allocated amongst the trawl records from the respective fishing trips in proportion to the estimated catches of tarakihi (top 5 species only). Virtually all of the qualifying fishing trips included at least one trawl with an estimated tarakihi catch enabling all landed catches to be allocated in this manner.

The tow based catch and effort data set was utilised to augment the fishery characterisations by providing information of the spatial distribution of the trawl catch of tarakihi for each of the main fisheries. The data set was also used to configure the area specific trawl CPUE data sets for each fishery area.

3 FISHERY CHARACTERISATION

For each of the three fishstocks (TAR 1, TAR 2 and TAR 3) the daily CELR format data set was summarised to identify the main tarakihi fisheries (by gear and target species) and characterize the spatial and seasonal distribution of the tarakihi catch from 1989/90–2015/16. For TAR 1 the analysis was conducted for the three constituent fishery areas (BPLE, ENLD and WCNI).

The TCER trawl event records from 2007/08–2015/16 were summarised to characterise the spatial distribution of tarakihi trawl catches (Figure 7) and nominal catch rates (Figure 8) within TAR 1, TAR 2 and TAR 3. Trawl records from 2007/08–2015/16 were aggregated by 0.1 degree of latitude and longitude.

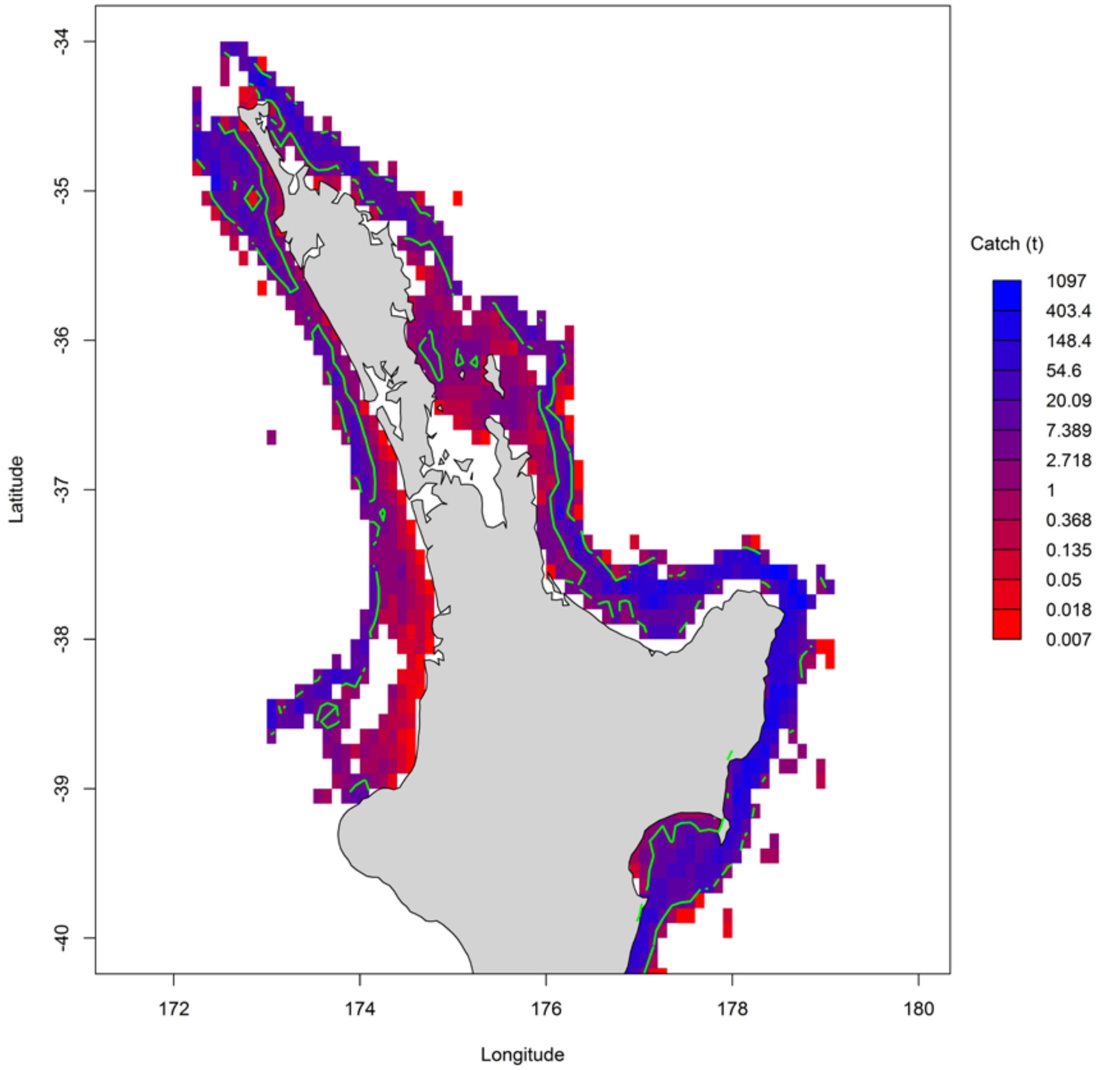

Figure 7a: Distribution of aggregated tarakihi catch from the bottom trawl fishery during 2007/08–2015/16. Catches are aggregated by 0.1 degree of latitude and longitude. Catches are plotted on a natural logarithmic scale. The green contour line represents a catch of 5 t.

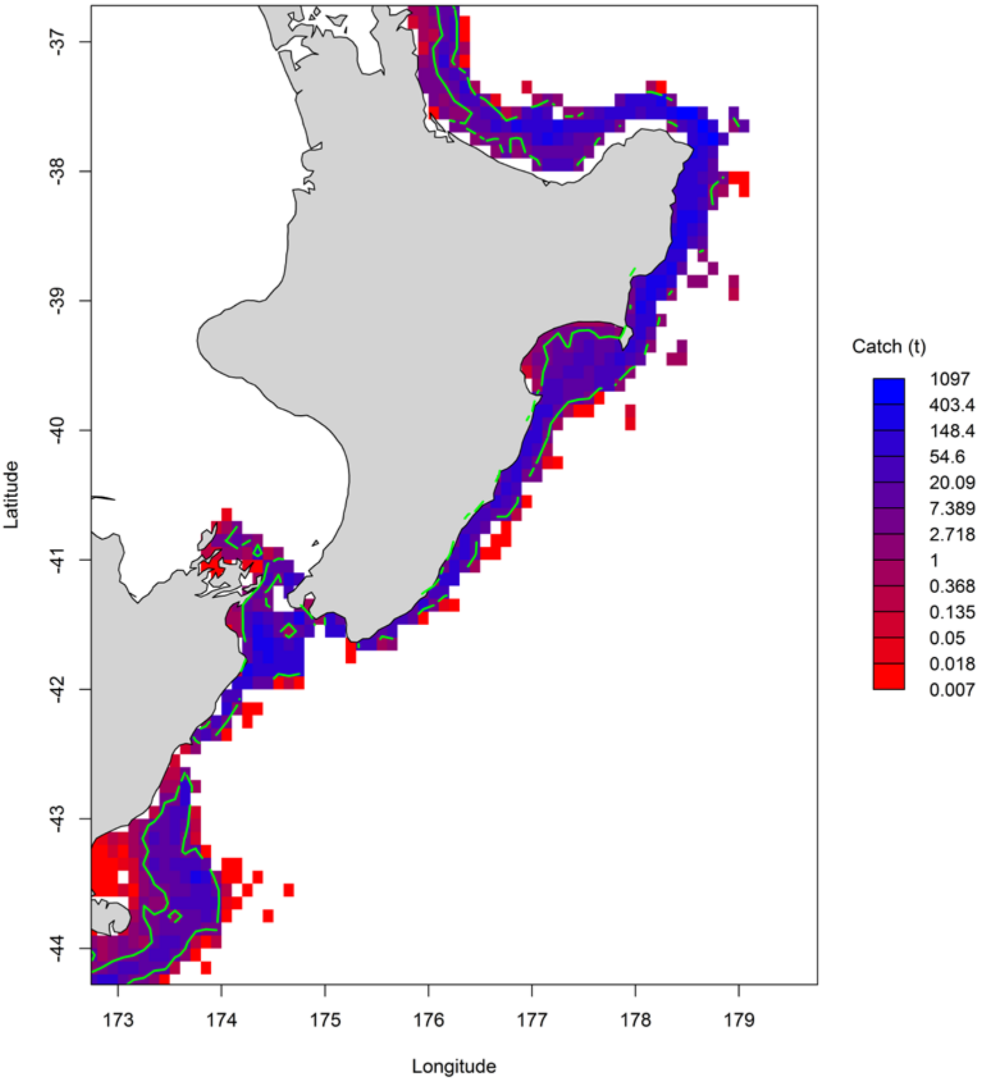

Figure 7b: Distribution of aggregated tarakihi catch from the bottom trawl fishery during 2007/08–2015/16. Catches are aggregated by 0.1 degree of latitude and longitude. Catches are plotted on a natural logarithmic scale. The green contour line represents a catch of 5 t.

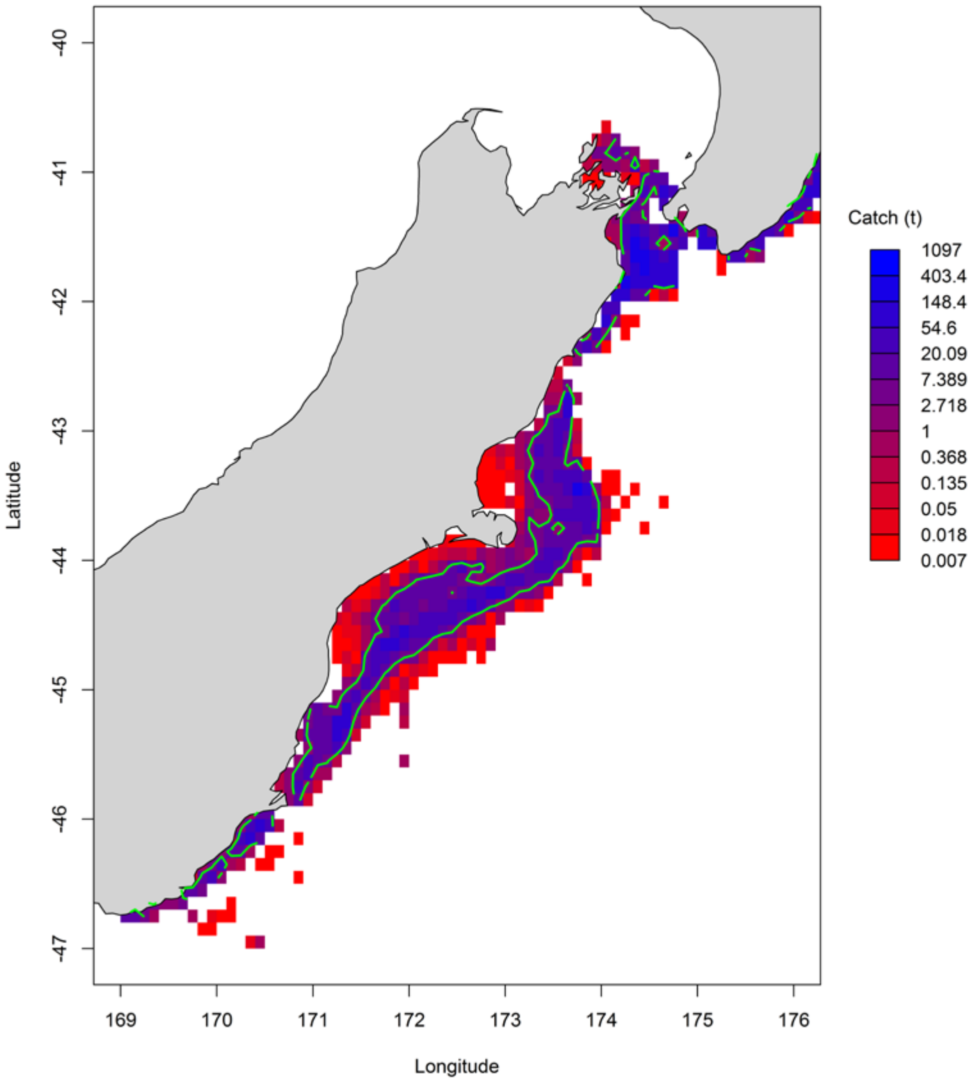

Figure 7c: Distribution of aggregated tarakihi catch from the bottom trawl fishery during 2007/08–2015/16. Catches are aggregated by 0.1 degree of latitude and longitude. Catches are plotted on a natural logarithmic scale. The green contour line represents a catch of 5 t.

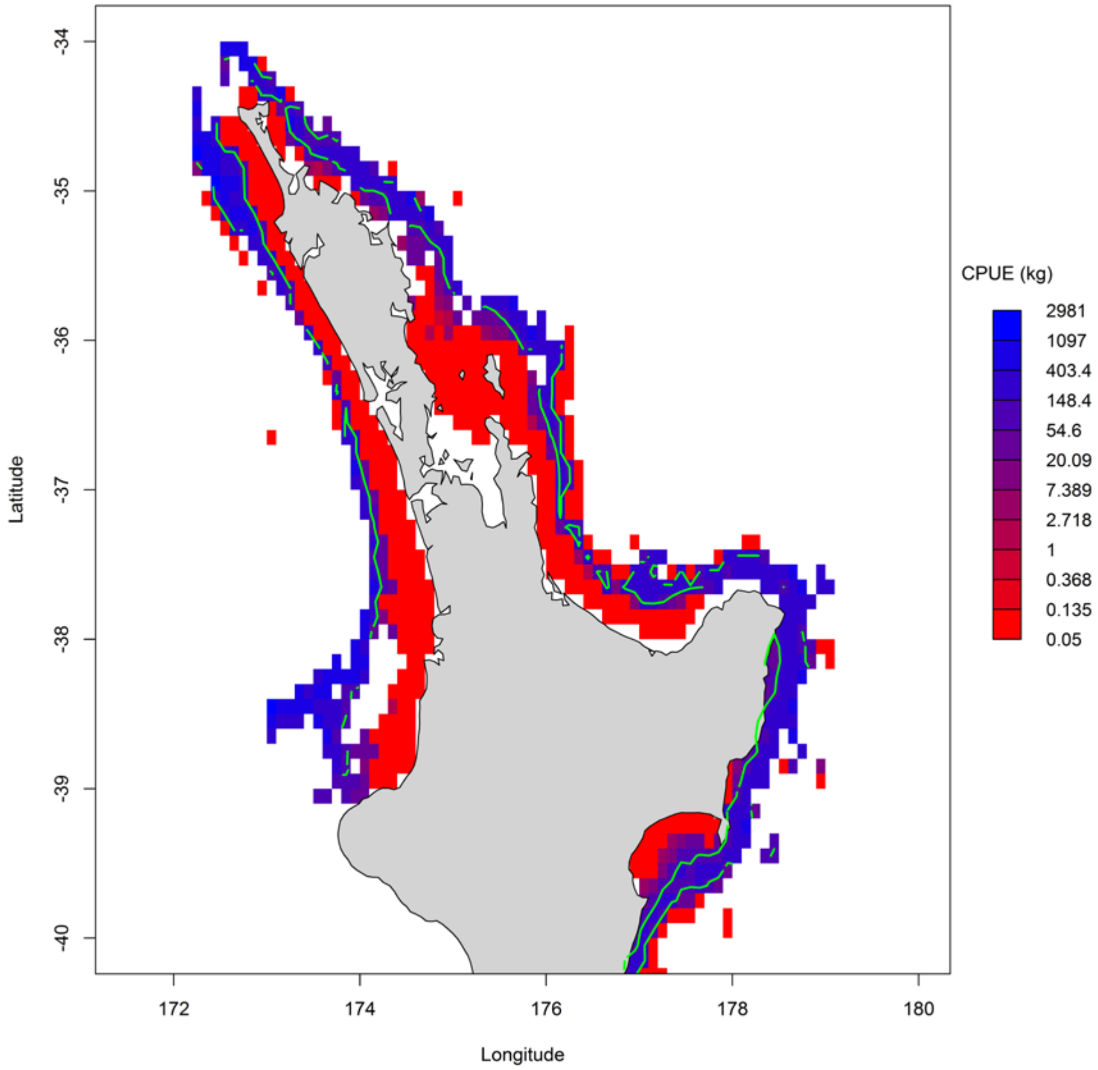

Figure 8a: Tarakihi catch rates (median catch per trawl) from the bottom trawl fishery during 2007/08–2015/16 by 0.1 degree of latitude and longitude. Catch rates are plotted on a natural logarithmic scale. The green contour line represents a catch rate of 100 kg per trawl.

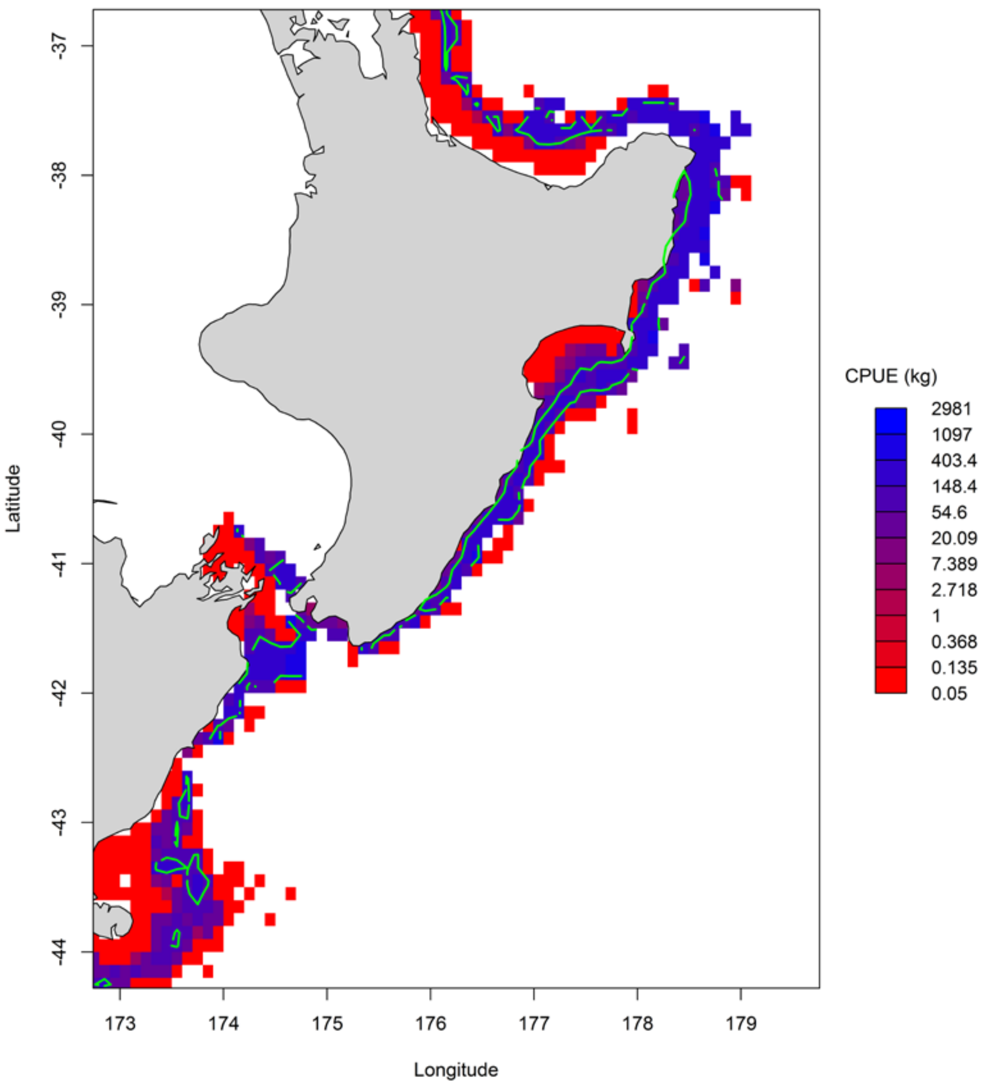

Figure 8b: Tarakihi catch rates (median catch per trawl) from the bottom trawl fishery during 2007/08–2015/16 by 0.1 degree of latitude and longitude. Catch rates are plotted on a natural logarithmic scale. The green contour line represents a catch rate of 100 kg per trawl.

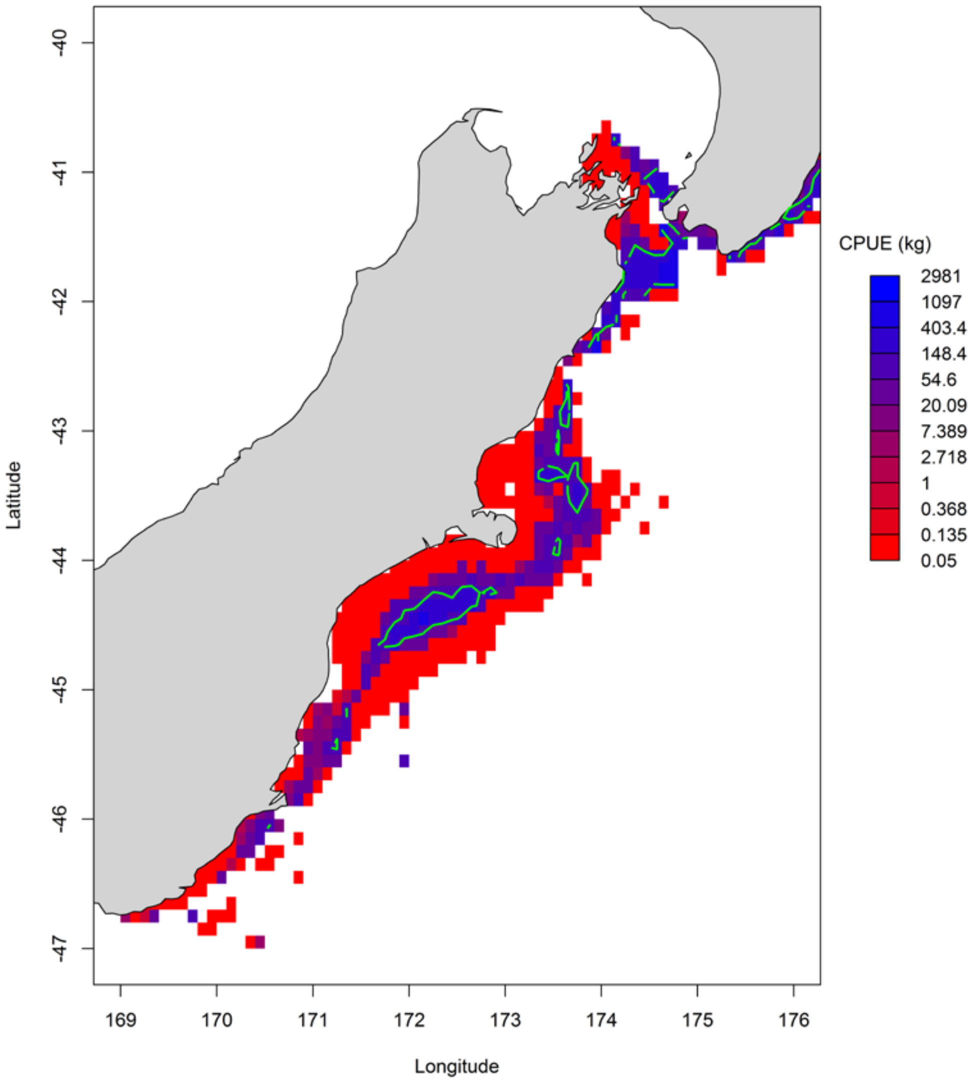

Figure 8c: Tarakihi catch rates (median catch per trawl) from the bottom trawl fishery during 2007/08–2015/16 by 0.1 degree of latitude and longitude. Catch rates are plotted on a natural logarithmic scale. The green contour line represents a catch rate of 100 kg per trawl.

3.1 TAR 1

During the early 1990s, annual catches of TAR 1 increased to about the level of the TACC and remained at that level during 1991/92–2005/06 (Figure 4). Annual catches fluctuated over the subsequent years with lower catches in 2006/07–2007/08 and 2011/12–2012/13 and 2015/16 and annual catches approaching the TACC level in 2008/09–2010/11 and 2013/14–2014/15 (Figure 4).

During 1989/90–2015/16, the Bay of Plenty fishery area accounted for 42.4% of the TAR 1 catch, although annual catches from the area were considerably more variable than for the HG-ENLD and WCNI areas (Figure 9, Appendix 1 Table A1). Catches from the Bay of Plenty fishery peaked in 1991/92–1994/95, 2001/02–2004/05 and 2008/10–2010/11. The annual catch from the BPLE area declined over the subsequent years and was relatively low during 2013/14–2015/16.

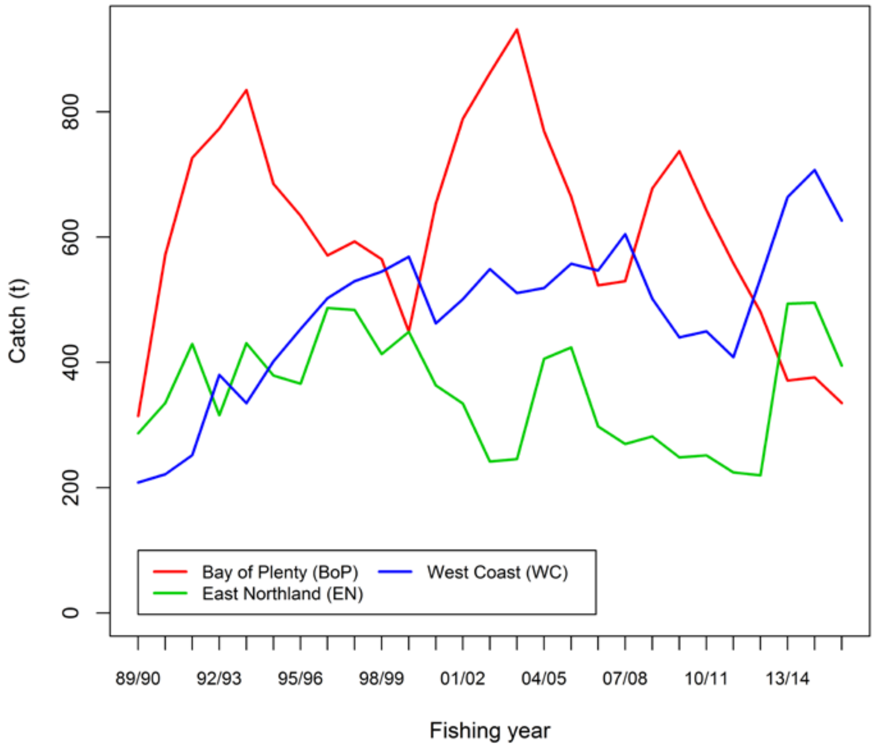

Figure 9: Annual catches of TAR 1 by fishery area.

Annual catches from HG-ENLD were relatively stable during the 1990s (Figure 9) and then fluctuated during subsequent years, with lower catches during 2002/03–2003/04 and 2006/07–2012/13.

Annual catches from WCNI increased during the 1990s and remained at the higher level during the 2000s (Figure 9). Catches were lower in 2009/10–2011/12 and then increased considerably in 2009/10–2013/14 and were maintained at the higher level in 2014/15–2015/16.

The following sub-sections present separate fishery characterisations for each of the three fishery areas of TAR 1.

3.1.1 Bay of Plenty (BPLE)

Within the BPLE area, tarakihi was predominantly caught by single bottom trawl throughout the 1990s and 2000s with the method accounting for 80–95% of the annual catches (Figure 10). Most of the bottom trawl catch was taken from the target trawl fishery. A small proportion of the tarakihi catch was also taken by the Danish seine (5.2% of the cumulative catch from 1989/90–2015/16), set net (3.4%) and bottom longline (2.3%).

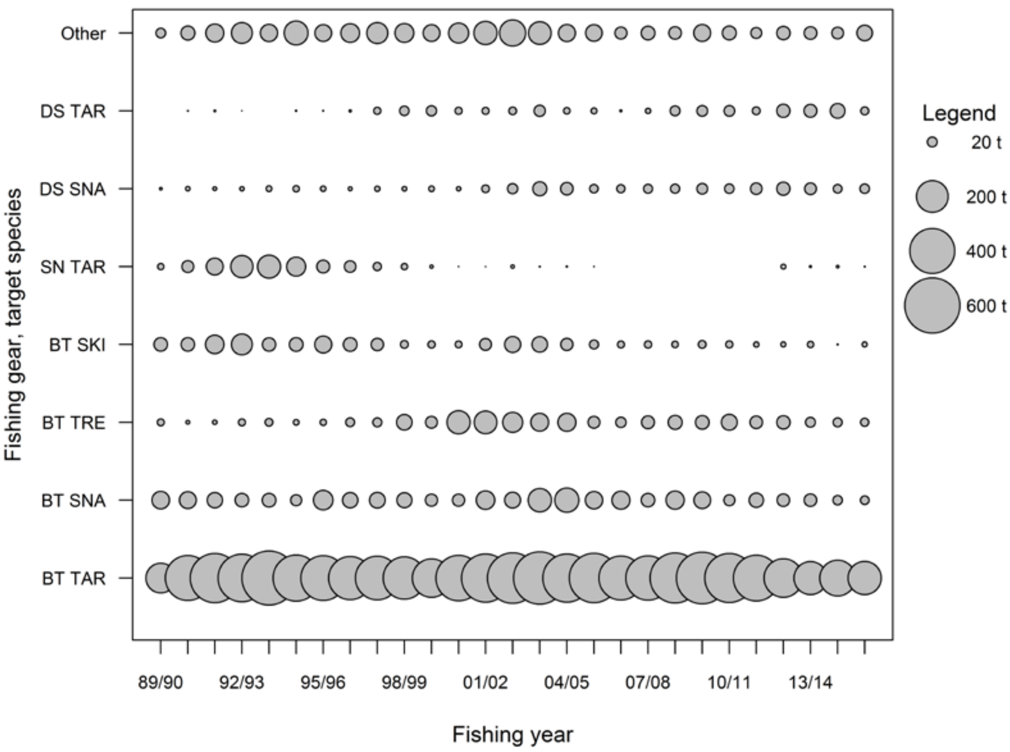

Figure 10: Landed catch of tarakihi from the Bay of Plenty fishery, by fishing method/target species and fishing year.

The data collected from TCER and TCEPR forms during 2007/08–2015/16 were used to characterize the depth distribution of the tarakihi bottom trawl catch from the BPLE single trawl fishery. Most of the catch was taken in the 80–230 m depth range by the target fishery (Figure 11). Minor catches were taken as a bycatch of the trawl fisheries operating in the 20–120 m depth range.

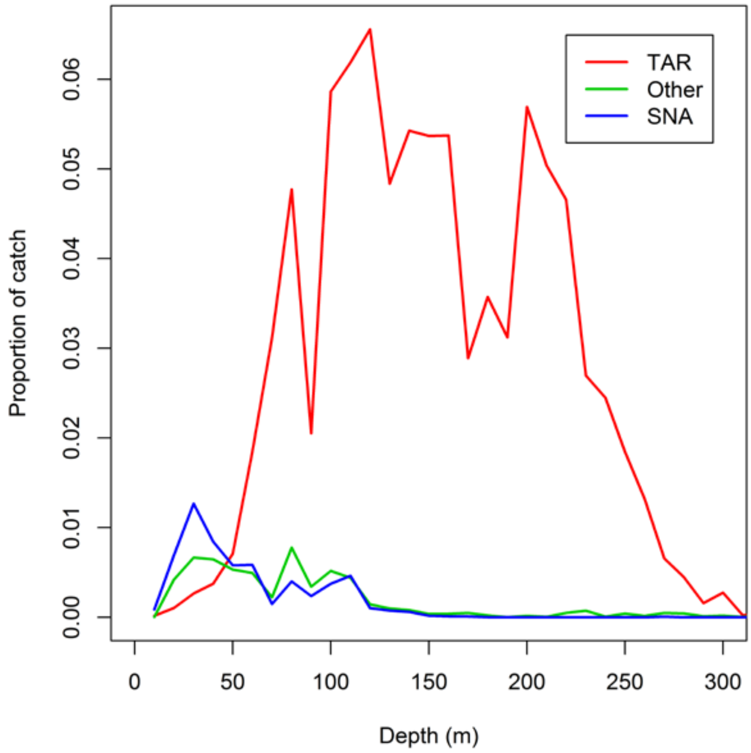

Figure 11: Proportional depth distribution of tarakihi single trawl catch from the BPLE fishery by bottom depth (10 metre depth intervals) and target species from 2007/08 to 2015/16 for the main bottom trawl target species (TCEPR or TCER records, all years combined).

While tarakihi is caught throughout the Bay of Plenty, most of the catch is taken from the central and eastern Bay of Plenty (Statistical Areas 009 and 010) (Figure 7a and Figure 12).

In the BPLE fishery, tarakihi is caught throughout the year although there is a seasonal peak in catch during March–May (Figure 13). The seasonal distribution in catch has become more pronounced in recent years; in 2013/14–2015/16 58.5% of the annual catch was taken during March–May.

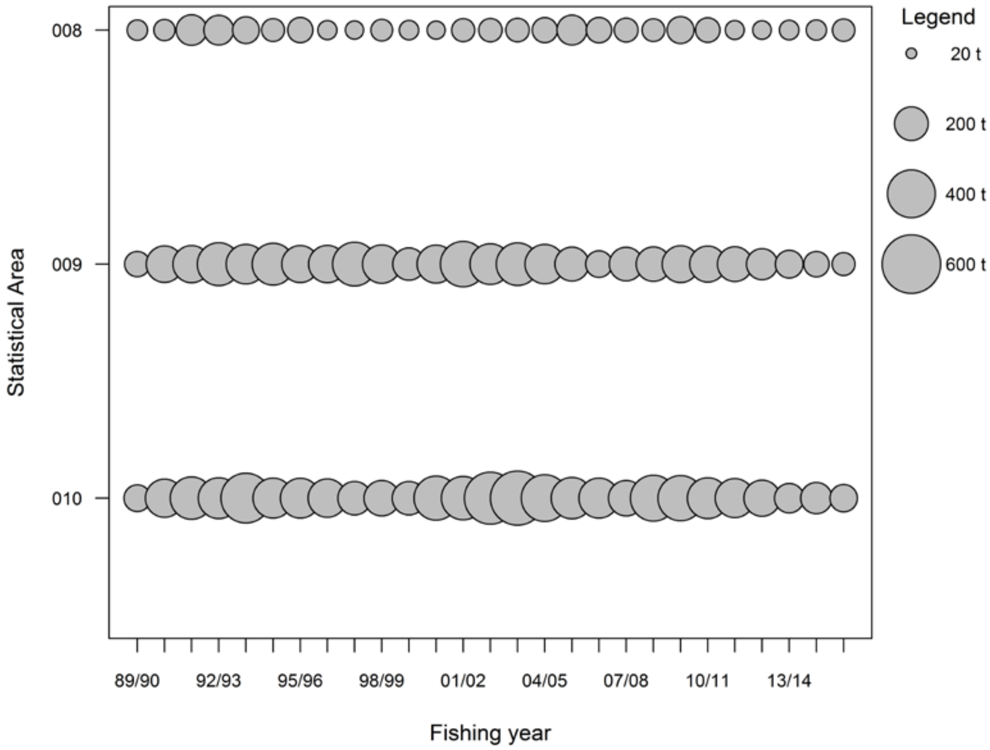

Figure 12: Annual distribution of tarakihi catch from BPLE by statistical area. The area of the circle is proportional to the catch.

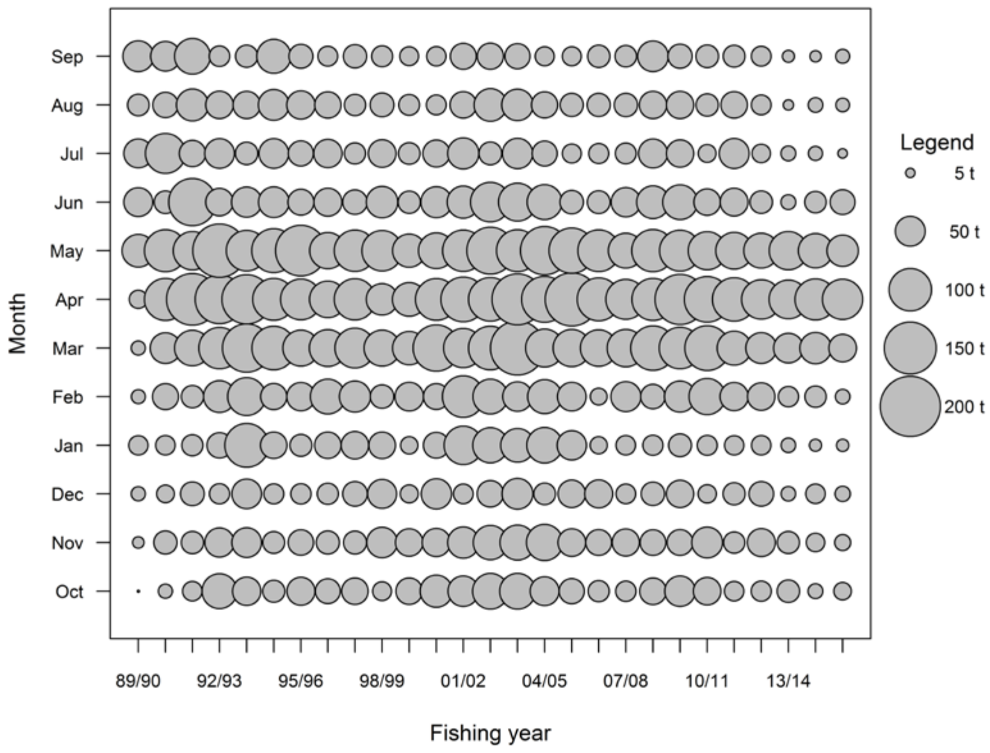

Figure 13: The monthly distribution of Tarakihi catches from BPLE by fishing year. Circle areas are proportional to the catch.

3.1.2 Hauraki Gulf and east Northland (HG-ENLD)

The catch from the HG-ENLD fishery was predominantly taken by the target single bottom trawl fishery (Figure 14). Tarakihi also represented a relatively small bycatch of the trawl fisheries targeting a range of other demersal species, including snapper, John dory and gemfish.

Tarakihi was also caught by the bottom longline (BLL) fishery, primarily as a bycatch of the snapper BLL fishery during the 1990s, although a target BLL fishery has developed in recent years.

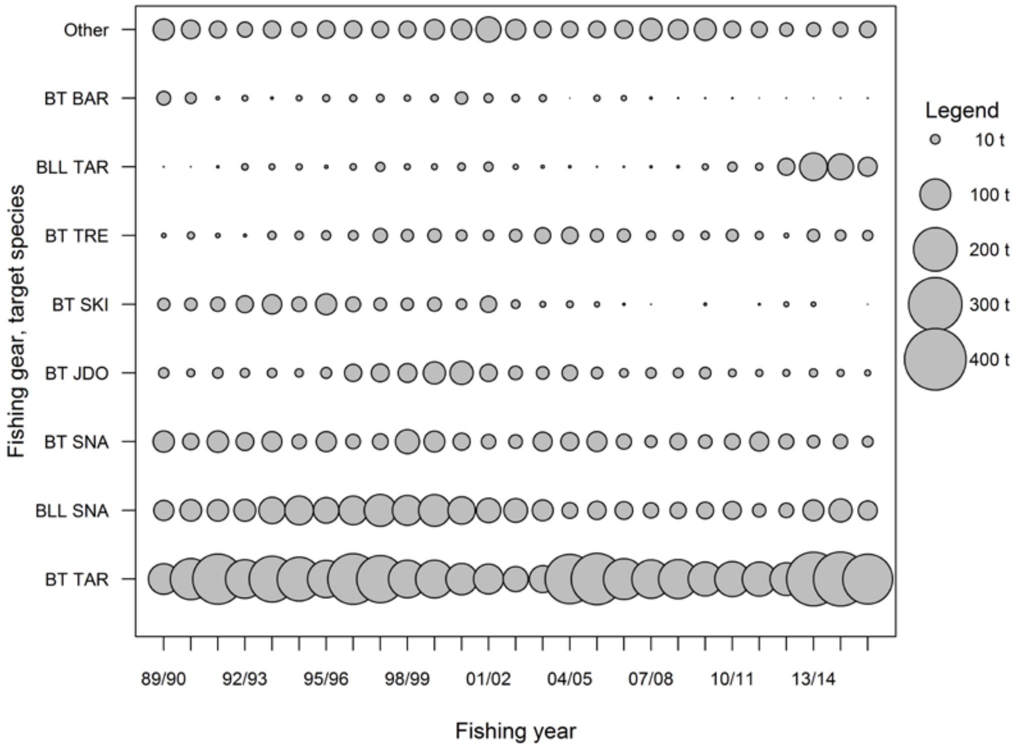

Figure 14: Landed catch of Tarakihi from the HG-ENLD fishery by fishing method/target species and fishing year.

Most of the tarakihi catch from HG-ENLD was taken from off the east Northland coast (Statistical Areas 002 and 003) with intermittent catches taken beyond the Hauraki Gulf, outside of Great Barrier Island (004) (Figure 7a and Figure 15). Minor catches of tarakihi were taken within the Hauraki Gulf (005, 006, 007). The catch from the target tarakihi BLL fishery was taken from off the northern east Northland coast (Statistical Area 002).

Most of the tarakihi trawl catch was taken in the 130–220 m depth range by the target fishery (Figure 16). The tarakihi bycatch from the inshore trawl fisheries was taken in the 30–140 m depth range.

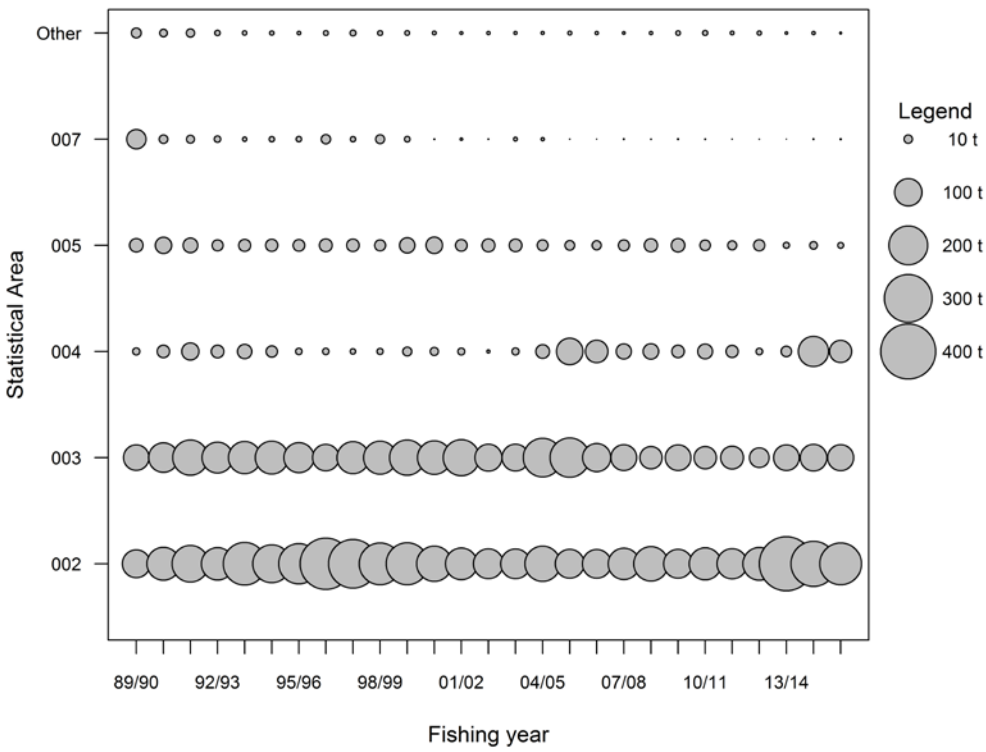

Figure 15: Annual distribution of tarakihi catch from HG-ENLD by statistical area. The area of the circle is proportional to the catch.

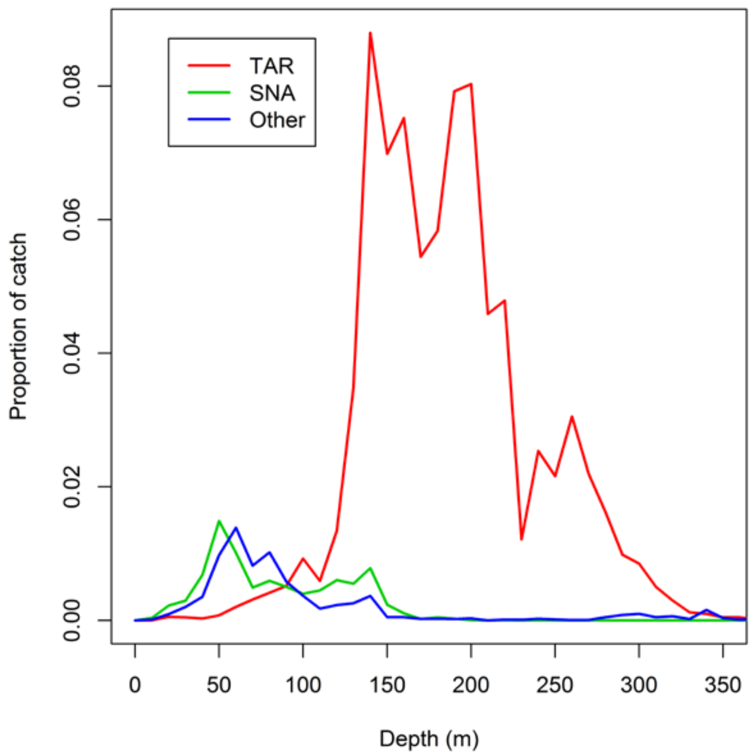

Figure 16: Proportional depth distribution of tarakihi single trawl catch from the HG-ENLD fishery by bottom depth (10 metre depth intervals) and target species from 2007/08 to 2015/16 for the main bottom trawl target species (TCEPR or TCER records, all years combined).

Monthly catches of tarakihi from the HG-ENLD fishery were generally higher during the second half of the fishing year (April–September) (Figure 17), although the monthly distribution of catch varied amongst years. In 2014/15–2015/16, a considerable proportion of the catch was also taken during October–November.

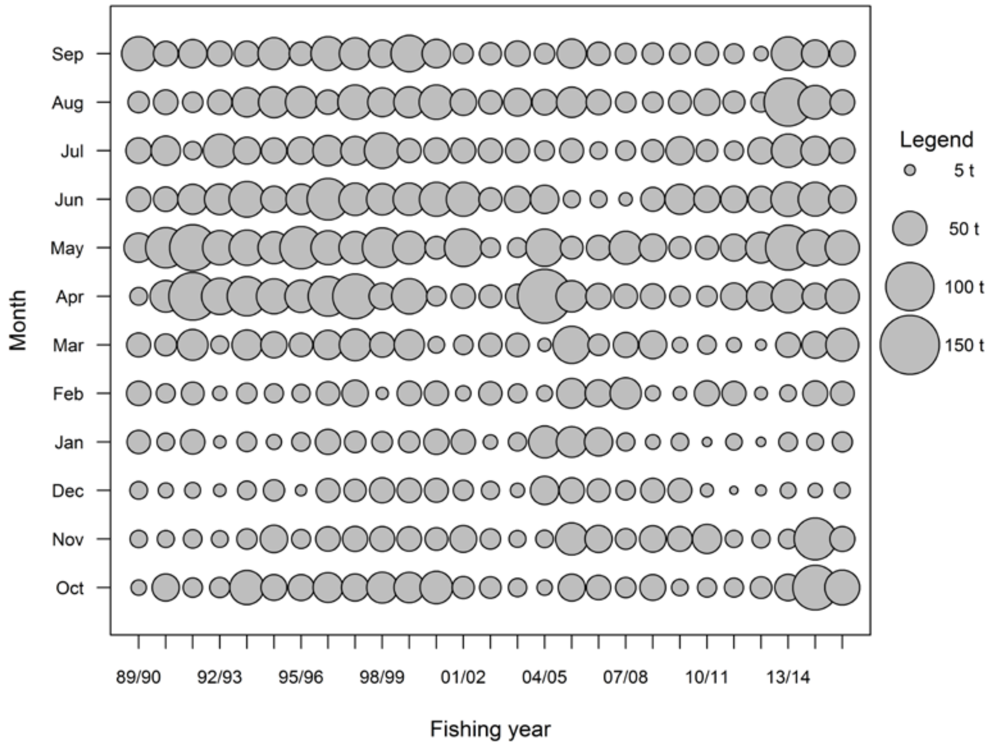

Figure 17: The monthly distribution of tarakihi catches from the HG-ENLD fishery by fishing year. Circle areas are proportional to the catch.

3.1.3 West coast North Island (WCNI)

Most (89.8%) of the catch from the WCNI tarakihi fishery was taken by the single bottom trawl method with most of the remainder taken by bottom pair trawl (Figure 18). The single trawl catch was predominately taken by the target fishery (63.1%) and as a bycatch of trawls targeting trevally (12.5%), snapper (9.5%) and red gurnard (5.0%) (Figure 18).

The tarakihi catch from the trawl fishery is taken throughout the WCNI fishery area between Cape Reinga and Cape Egmont (Figure 7), although catches tend to be concentrated in the area off Ninety Mile Beach (Statistical Area 047) (Figure 19). Since the mid-1990s, significant catches of tarakihi have also been taken in the outer North Taranaki Bight (041).

Most of the tarakihi trawl catch was taken by target trawls in the 100–200 m depth range (Figure 20). A small proportion of the tarakihi catch was taken in shallower areas, principally from trawls targeting trevally and, to a lesser extent, snapper and red gurnard.

Most of the tarakihi catch was taken during February–May although in some years considerable catches were taken outside of this period (Figure 21). During 2013/14–2015/16, there was an increase in the proportion of the annual catch taken during October–January.

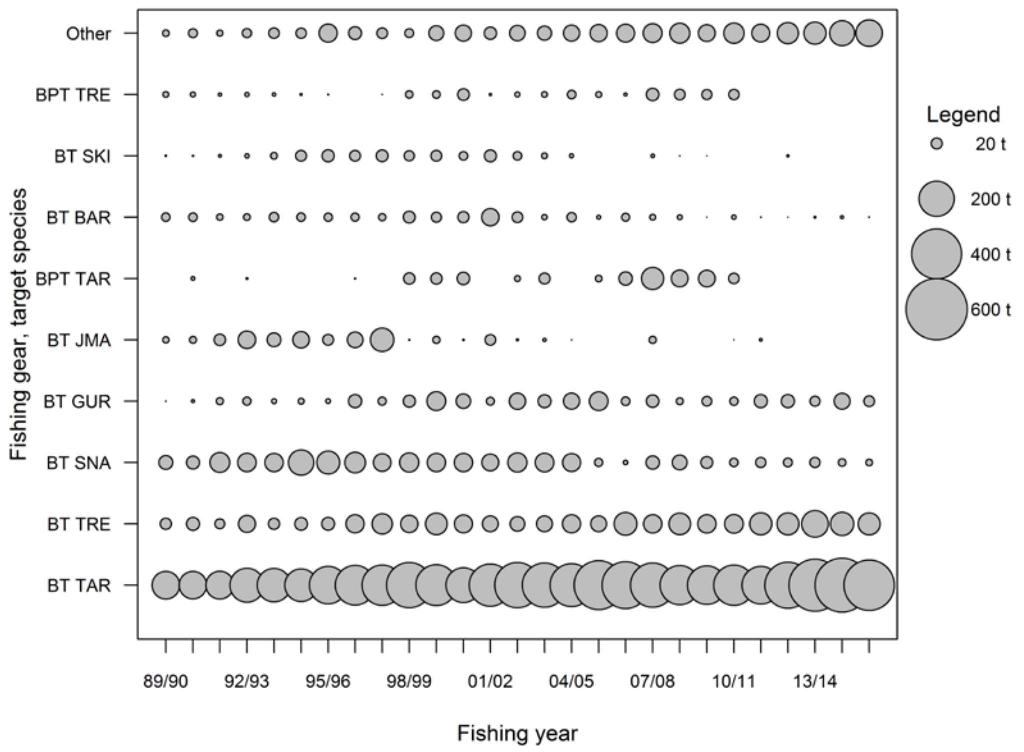

Figure 18: Landed catch of tarakihi from the WCNI fishery by fishing method/ target species and fishing year.

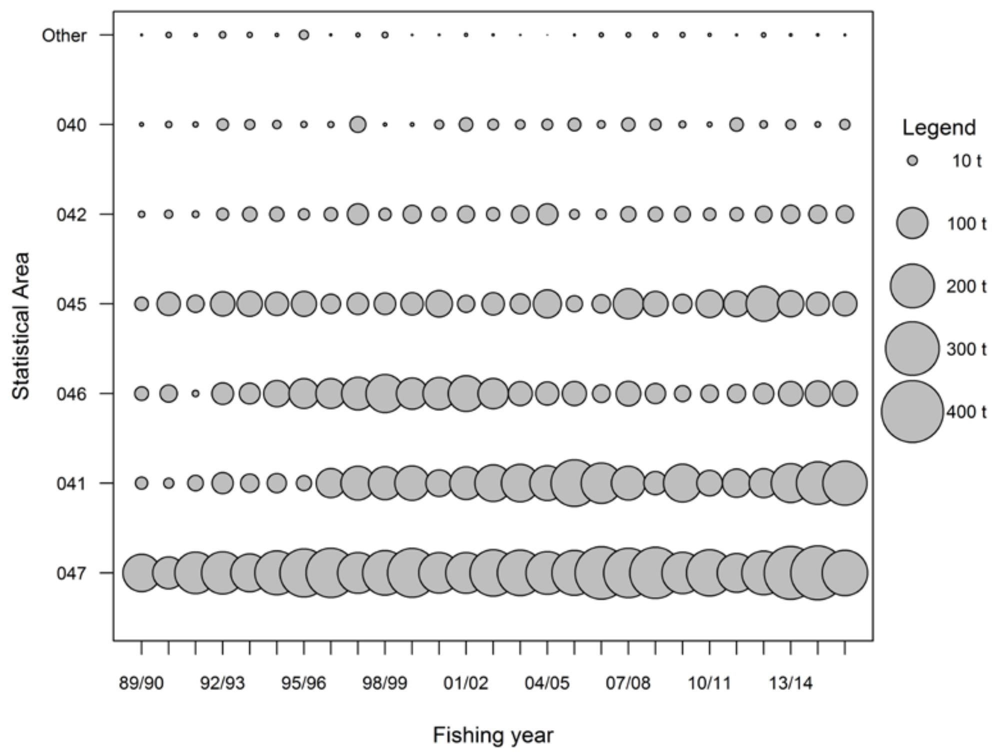

Figure 19: Annual distribution of tarakihi catch from the WCNI fishery by statistical area. The area of the circle is proportional to the catch.

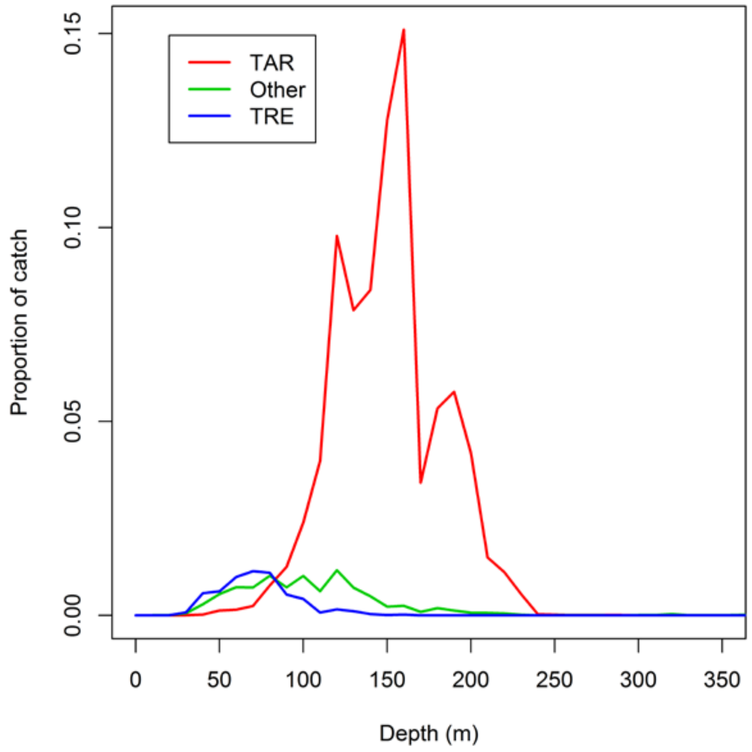

Figure 20: Proportional depth distribution of tarakihi single trawl catch from the WCNI fishery by bottom depth (10 metre depth intervals) and target species from 2007/08 to 2015/16 for the main bottom trawl target species (TCEPR or TCER records, all years combined).

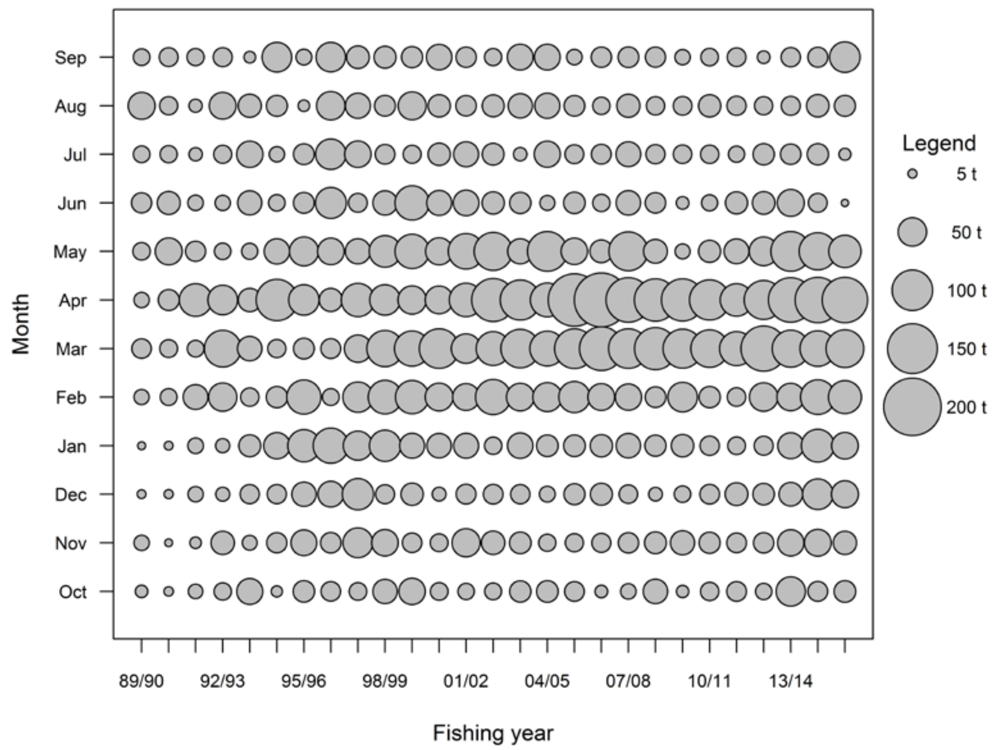

Figure 21: The monthly distribution of tarakihi catches from WCNI by fishing year. Circle areas are proportional to the catch.

3.2 TAR 2

Most (84.0%) of the catch from TAR 2 was taken by the target single bottom trawl fishery (Figure 22) with a small proportion of the catch taken as a bycatch of the red gurnard trawl fishery and the gemfish (SKI) target trawl fishery during the 1990s. The TAR 2 catch from the trawl fishery is taken throughout the fishstock area (Figure 7) although catches are largest from East Cape to Mahia Peninsula (Statistical Areas 011–013) (Figure 23).

Most of the target tarakihi trawl catch was taken in the 40–160 m depth range (Figure 24), while the relatively small proportion of the tarakihi catch taken by the red gurnard trawl fishery was predominantly taken in the 30–80 m depth range.

Tarakihi was caught throughout the year (Figure 25), although catches were generally higher during October–November due to higher catches from Statistical Area 013 during that period.

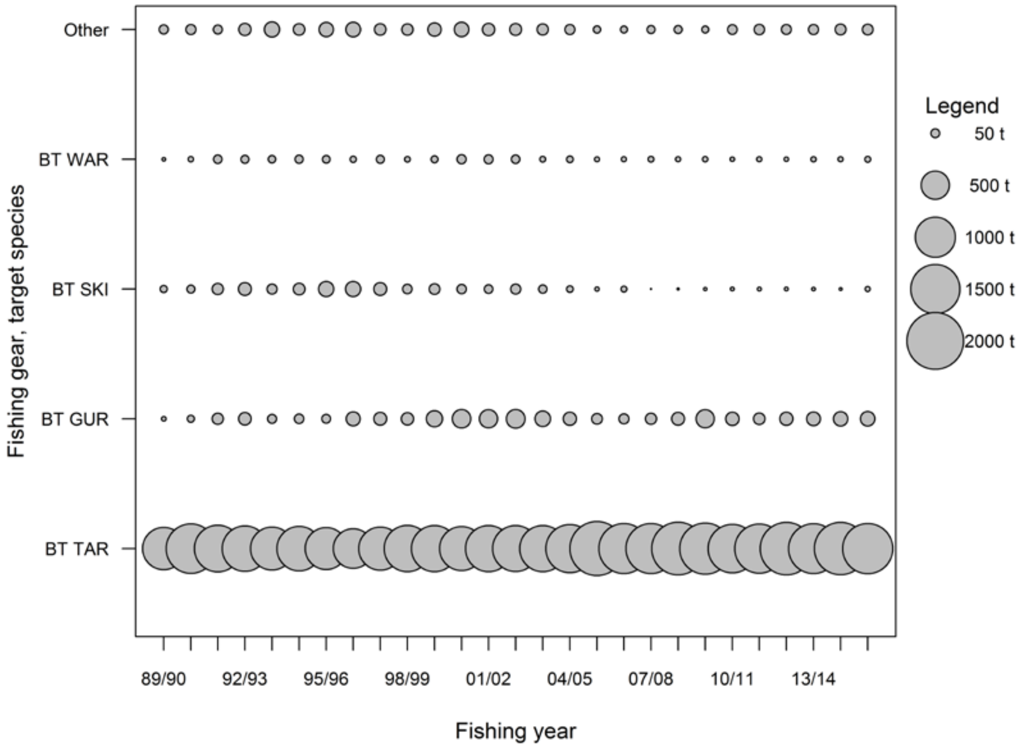

Figure 22: Landed catch of tarakihi from the central ECNI (TAR 2) fishery by fishing method/ target species and fishing year.

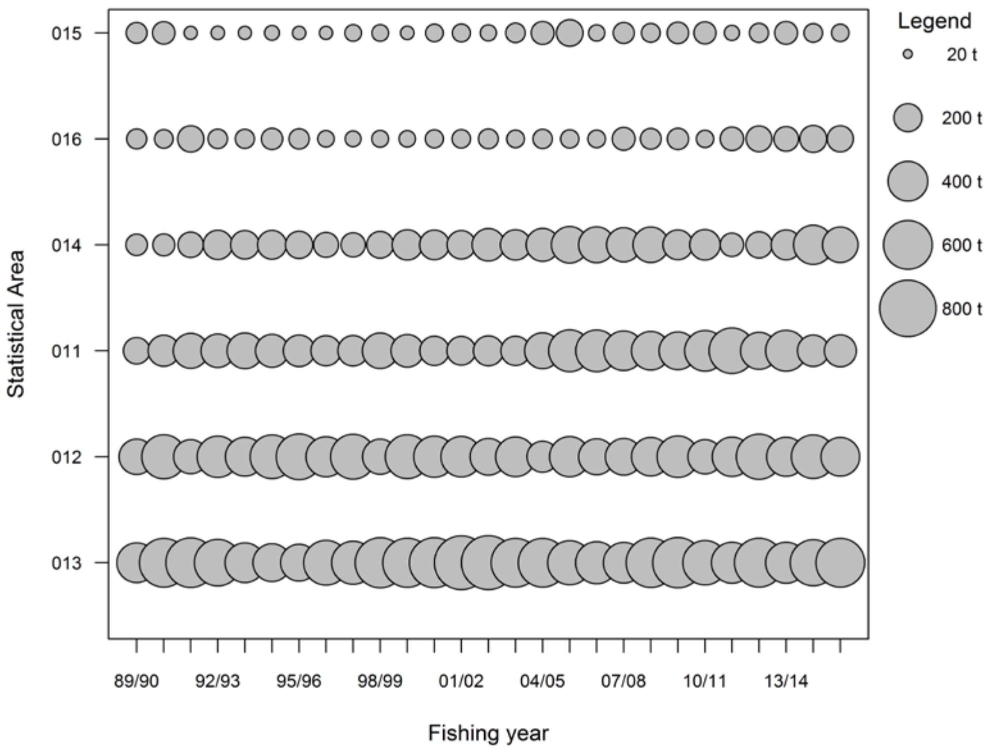

Figure 23: Annual distribution of tarakihi catch from the central ECNI (TAR 2) fishery by statistical area. The area of the circle is proportional to the catch.

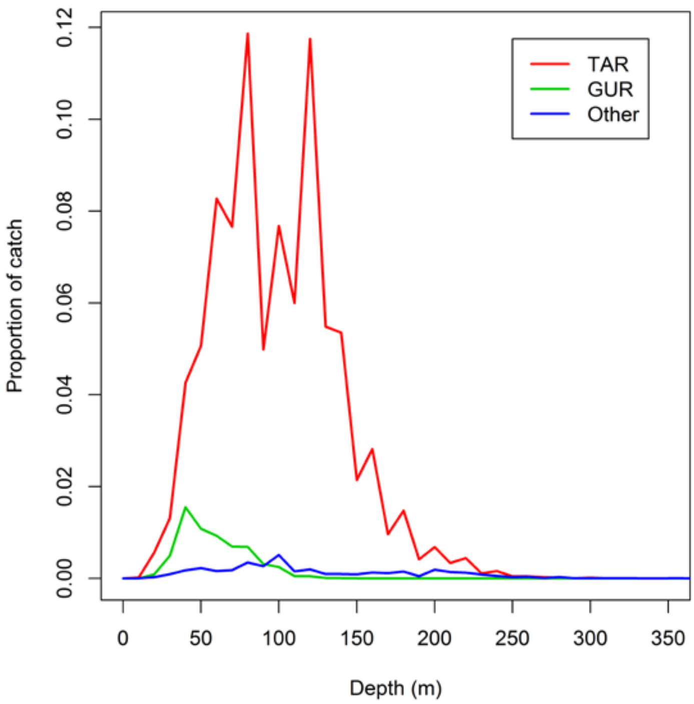

Figure 24: Proportional depth distribution of tarakihi single trawl catch from the central ECNI (TAR 2) fishery by bottom depth (10 metre depth intervals) and target species from 2007/08 to 2015/16 for the main bottom trawl target species (TCEPR or TCER records, all years combined).

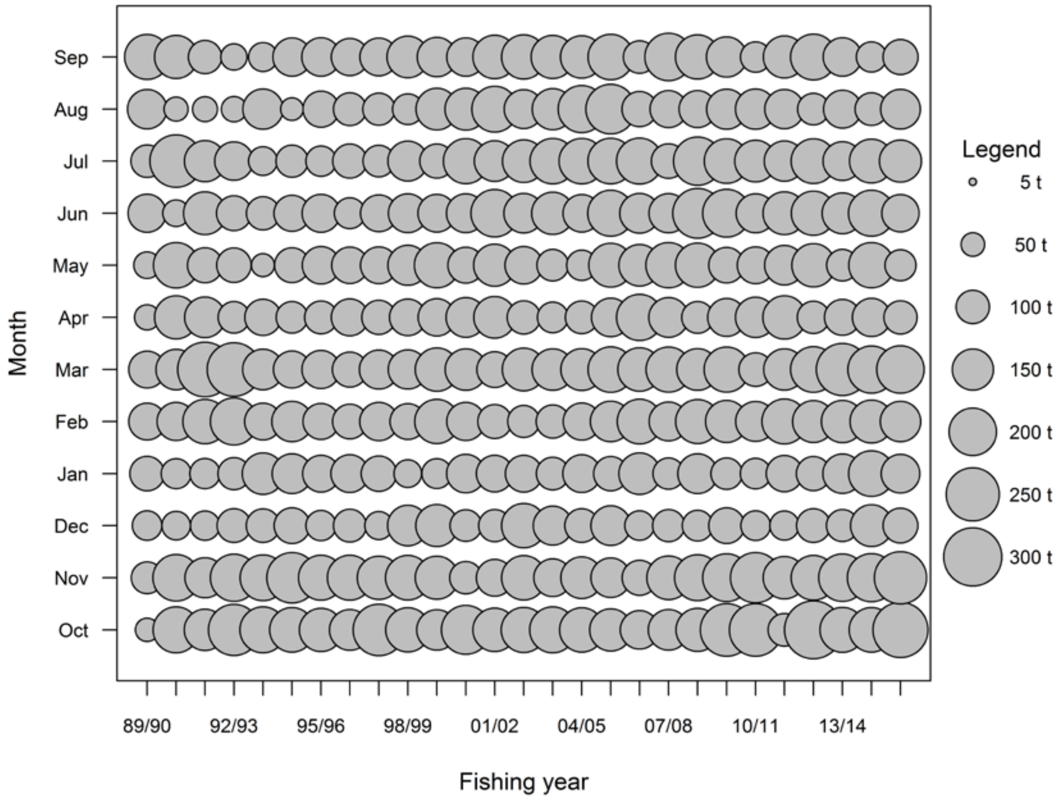

Figure 25: The monthly distribution of tarakihi catches from central ECNI (TAR 2) by fishing year. Circle areas are proportional to the catch.

3.3 TAR 3

Tarakihi are caught in a range of fisheries in TAR 3. During 1989/90–2015/16, most of the catch was taken by the trawl method either targeting tarakihi (36.3% of total catch) or as a bycatch from the main inshore trawl fisheries, principally red cod (17.7%) and barracouta (11.4%) (Figure 26). The tarakihi target set net fishery accounted for 18.4% of the total TAR 3 catch. In addition, Danish seine vessels have targeted tarakihi since 2006/07.

During the 1990s, the target trawl fishery accounted for approximately 20–25% of the total TAR 3 catch. During the early 2000s, the total BAR 1 and RCO 3 catches declined considerably and there was a corresponding decline in the tarakihi bycatch from these trawl fisheries. There was a corresponding increase in the proportion of the TAR 3 catch taken by the target trawl fishery and the fishery has accounted for about 55% of the TAR 3 catch from 2004/05–2015/16. The catch from the target set net fishery was also lower from 2004/05 (Figure 26).

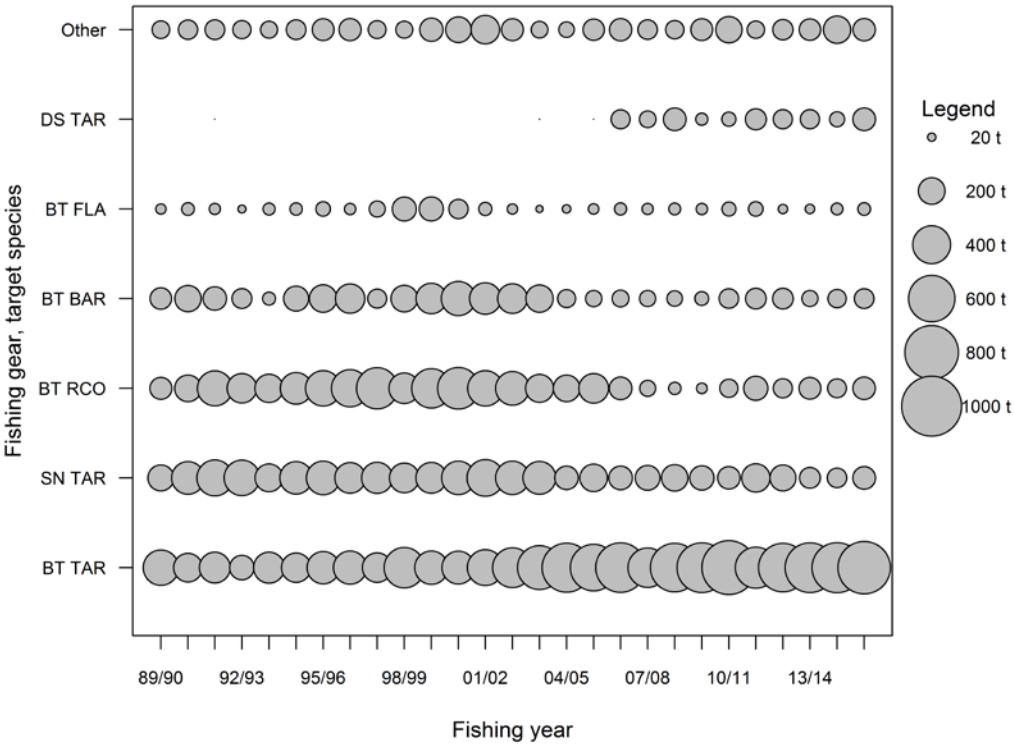

Figure 26: Landed catch of tarakihi from the east coast South Island (TAR 3) fishery by fishing method/ target species and fishing year.

Tarakihi are caught by bottom trawl throughout the Canterbury Bight (Statistical Area 022), Pegasus Bay (020), off Cape Campbell (018) and in the southwestern approaches to Cook Strait (Statistical Area 017, primarily within TAR 7) (Figure 7). The TAR 3 target set net fishery operates off the Kaikoura coast within Statistical Area 018. The proportion of the tarakihi catch from Statistical Area 018 taken by set net declined from approximately 60% during the 1990s to 36% in 2013/14–2015/16.

During the last decade, Statistical Areas 018 and 022 each accounted for approximately 30% of the annual tarakihi catch, with approximately 20% of the annual catch taken from Statistical Area 020 (Figure 27).

Most of the tarakihi trawl catch was taken in the 50–140 m depth range, predominantly from the target fishery (Figure 28). The red cod and barracouta trawl fisheries caught tarakihi over a similar depth range to the target trawl fishery.

The TAR 3 catch from the trawl fishery was taken throughout the year although there was generally a higher proportion of the catch taken during January–May (Figure 29). The tarakihi catch from the set net fishery was predominantly taken during December–February and April–May and catches were negligible during July–October (Figure 30).

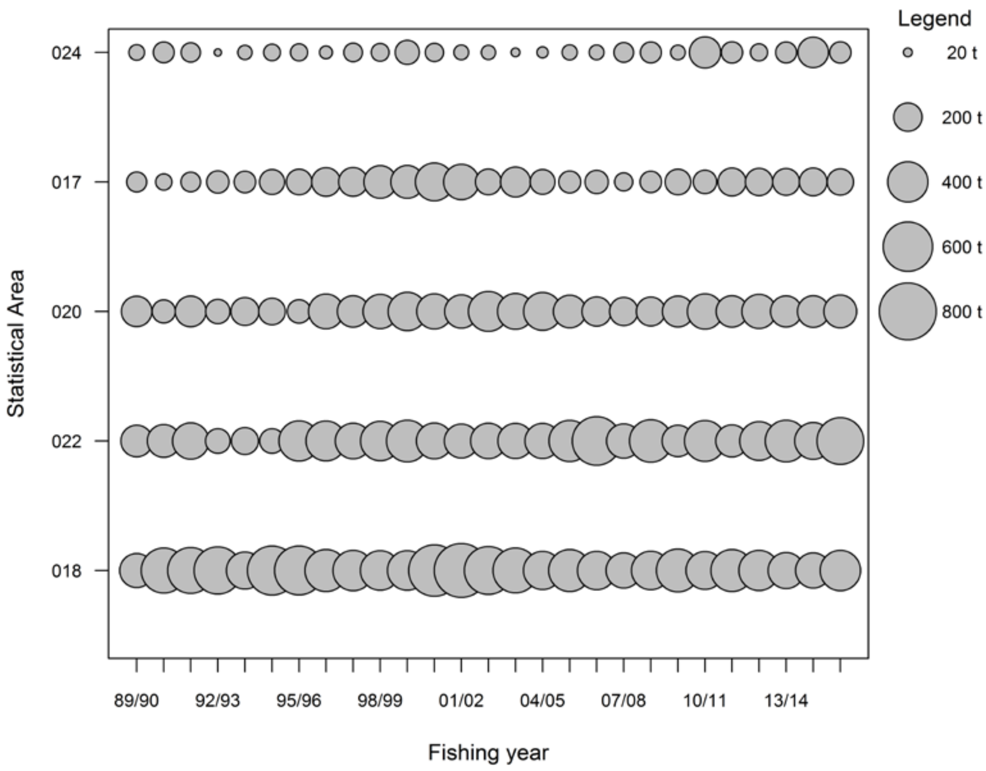

Figure 27: Annual distribution of tarakihi catch from the east coast South Island (TAR 3) fishery by statistical area. The area of the circle is proportional to the catch.

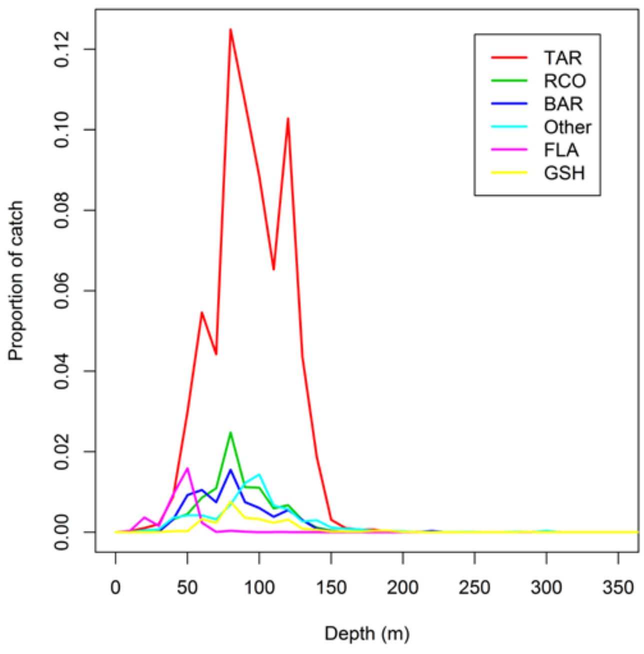

Figure 28: Proportional depth distribution of tarakihi single trawl catch from the east coast South Island (TAR 3) fishery by bottom depth (10 metre depth intervals) and target species from 2007/08 to 2015/16 for the main bottom trawl target species (TCEPR or TCER records, all years combined).

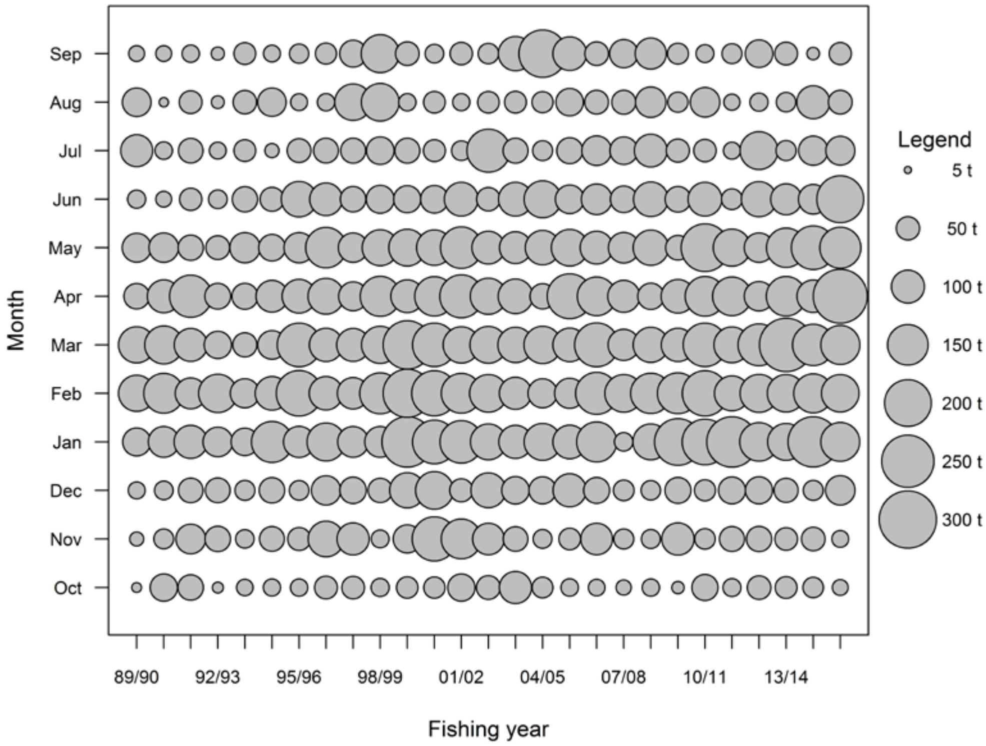

Figure 29: The monthly distribution of tarakihi catches from east coast South Island (TAR 3) bottom trawl fishery by fishing year. Circle areas are proportional to the catch.

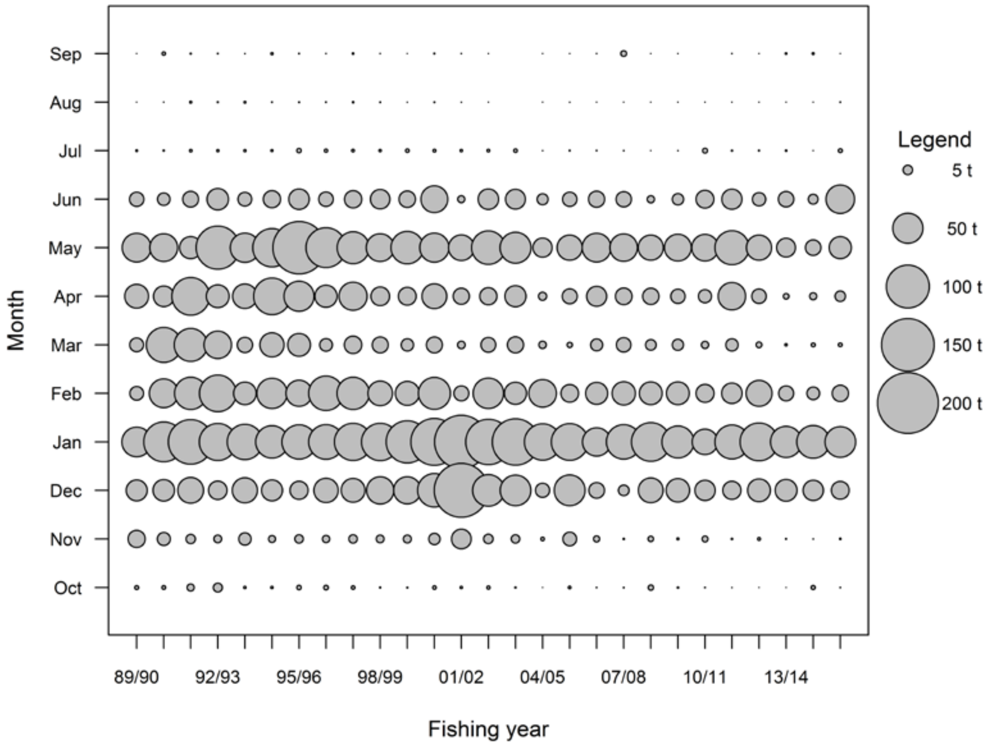

Figure 30: The monthly distribution of tarakihi catches from east coast South Island (TAR 3) set net fishery by fishing year. Circle areas are proportional to the catch.

4 CPUE Analyses

CPUE analyses were conducted for the trawl fisheries operated in each of the main fishery areas and the target set net fishery operating in TAR 3. Initially, the individual CPUE analyses were based on the specifications of the analyses conducted by Starr & Kendrick (2014). For some analyses, a review of the initial model diagnostics resulted in refinements to the specification of the respective CPUE data sets.

4.1 Methodology

The CPUE analyses were based either on the daily (CELR) format or the trawl event based data sets configured in Section 2.1. The individual data sets were defined based on the gear method, Statistical Area fished, and the target species (see Table 4). Each CPUE data set was further limited to a set of (core) vessels based on fishery specific criteria that are detailed in the specific sections.

A Generalised Linear Modelling (GLM) approach was used to model separately the occurrence of tarakihi catches (presence/absence) and the magnitude of positive tarakihi catches. The dependent variable of the catch magnitude CPUE models was the natural logarithm of catch. For the positive catch CPUE models, a lognormal error structure was initially adopted, although alternative distributions (Weibull, Gamma) were investigated for those model residuals that deviated considerably from the distributional assumptions. The presence/absence of tarakihi catch was modelled based on a binomial distribution.

For the trawl fisheries, CPUE modelling was initially conducted using both data formats. The potential explanatory variables available for inclusion in the daily CPUE models are defined in Table 2, while the trawl event based variables are presented in Table 3. The two sets of CPUE indices were compared and further analyses were conducted to reconcile any significant differences between the daily and event based indices.

Limited variables were available for inclusion in the TAR 3 set net CPUE analysis. These variables are described in Section 4.7.1.

Table 2: The variables included in the daily CELR format trawl catch and effort data sets.

Variable	Definition	Data type
Vessel	Fishing vessel category	Categoric
FishingYear	Fishing year	Categoric
Month	Month	Categoric
StatArea	Statistical area for day of fishing	Categoric
TargetSpecies	Target species for day of fishing.	Categoric
NumTrawl	Natural logarithm of the number of trawls conducted.	
Duration	Natural logarithm of total trawl duration (hours)	Continuous
Speed	Trawl speed (knots)	Continuous
GearWidth	Wingspread of trawl gear (m)	Continuous
GearHeight	Headline height of trawl gear (m)	Continuous
TARcatch	TAR trawl catch (kg).	Continuous
TARbin	Presence (1) or absence (0) of TAR catch in trawl.	Categoric

Table 3: The variables included in the trawl event based CPUE data sets.

Variable	Definition	Data type
Vessel	Fishing vessel category	Categoric
FishingYear	Fishing year	Categoric
Month	Month	Categoric (12)
Latitude	Latitude at the start location of trawl.	Continuous
Longitude	Longitude at the start location of trawl.	Continuous
Loc2	Start location of trawl categorised by 0.2 degree latitude/longitude cell.	Categoric
Latitude1	Start location of trawl categorised by 0.1 degree latitude.	Categoric
TargetSpecies	Declared target species for trawl.	Categoric
Duration	Natural logarithm of trawl duration (hours)	Continuous
Depth	Fishing depth (m)	Continuous
StartTime	Hour at the start of trawl.	Continuous
Speed	Trawl speed (knots)	Continuous
GearWidth	Wingspread of trawl gear (m)	Continuous
GearHeight	Headline height of trawl gear (m)	Continuous
TARcatch	Scaled estimated TAR trawl catch (kg).	Continuous
TARbin	Presence (1) or absence (0) of TAR catch in trawl.	Categoric

A step-wise fitting procedure was implemented to configure each of the CPUE models. The fitting procedure initially considered the range of potential explanatory variables (Table 3) with the continuous variables typically parameterised as a third order polynomial function. The categoric variable *FishingYear* was included in the initial model and subsequent variables were included in the model based on the improvement in the AIC. Additional variables were included in the model until the improvement in the Nagelkerke pseudo-R^2 was less than 0.5%.

The influence of each of the main variables in the CPUE models were examined following the approach of Bentley et al. (2011). Annual trends in the residuals of each model were examined with respect to target species and Statistical Area.

The final (combined) indices were determined from the product of the positive catch CPUE indices and the binomial indices following the approach of Stefansson (1996). A recent local study highlighted the importance of incorporating both components in the derivation of the final indices, particularly for bycatch fisheries where the reporting of smaller catches may be variable (particularly over time) (Langley 2015). The confidence intervals associated with the combined indices were determined using a bootstrapping approach.

Table 4: Definitions of the data sets included in each of the final CPUE analyses.

Index	Method	Statistical Areas	Target species	Data format	First year
WCNI_BT_MIX	BT	045–047	TAR, SNA, TRE	Event	1993/94
ENLD_BT_TAR	BT	002, 003	TAR	Event	1993/94
BPLE_BT_MIX	BT	008–010	TAR, SNA, TRE, BAR, JDO, GUR, SKI	Day	1989/90
TAR2_BT_MIX	BT	011–015	TAR, SNA, BAR, WAR, GUR, SKI	Day	1989/90
TAR3_BT_MIX	BT	017, 018, 022, 024, 026	TAR, RCO, BAR, WAR, GUR	Day	1989/90
TAR3_SN_TAR	SN	018	TAR	Day	1989/90

4.2 TAR 1 Bay of Plenty single trawl CPUE *BPLE_BT_MIX*

The BPLE trawl CPUE analysis was based on the daily catch and effort data for the inshore bottom trawl fishery targeting the suite of inshore species within Statistical Areas 008–010 (Table 4). Preliminary CPUE modelling of the Bay of Plenty single trawl replicated the CPUE indices derived by Starr & Kendrick (2014). For the Bay of Plenty fishery area, event based fishing effort records were available from 1993/94. Comparative CPUE models formulated from the two data formats (event based and daily) yielded very similar annual CPUE indices for the corresponding period. The final CPUE model was based on the daily data set, which included an additional four years (1989/90–1992/93).

4.2.1 Data set

The definition of the BPLE_BT_Mix data set is specified in Table 4. The core fleet, defined based on continuity criteria of a minimum annual catch of 1000 kg in at least six years, accounted for 95% of the total tarakihi catch included in the CELR format data set. The criteria resulted in the selection of 42 unique vessels including eight vessels that operated in the fishery for at least 20 years (Figure 31). Approximately half of the tarakihi catch included in the data set was taken by seven vessels.

Almost all of the tarakihi catch was allocated to the daily aggregated fishing effort records based on the distribution of the estimated catch within individual fishing trips (Figure 32). A relatively small proportion (10–20%) of the positive catch records were allocated based on the distribution of fishing events amongst trips (i.e. those trips with no estimated catches of tarakihi). The tarakihi catches allocated based on effort distribution were generally small (median 10 kg). Over the study period, there was a relatively constant proportion of records (generally 25–30%) with no allocated catch of tarakihi (Figure 32, Appendix 2 Table A3).

The number of trawls conducted per fishing day and the total duration of trawling remained relatively stable throughout the study period (Figure 33). There was no appreciable change in either of the main fishing effort metrics associated with the introduction of the TCER reporting form in 2007/08. The daily catch of tarakihi fluctuated over the study period and declined considerably during 2009/10–2015/16 (Figure 33).

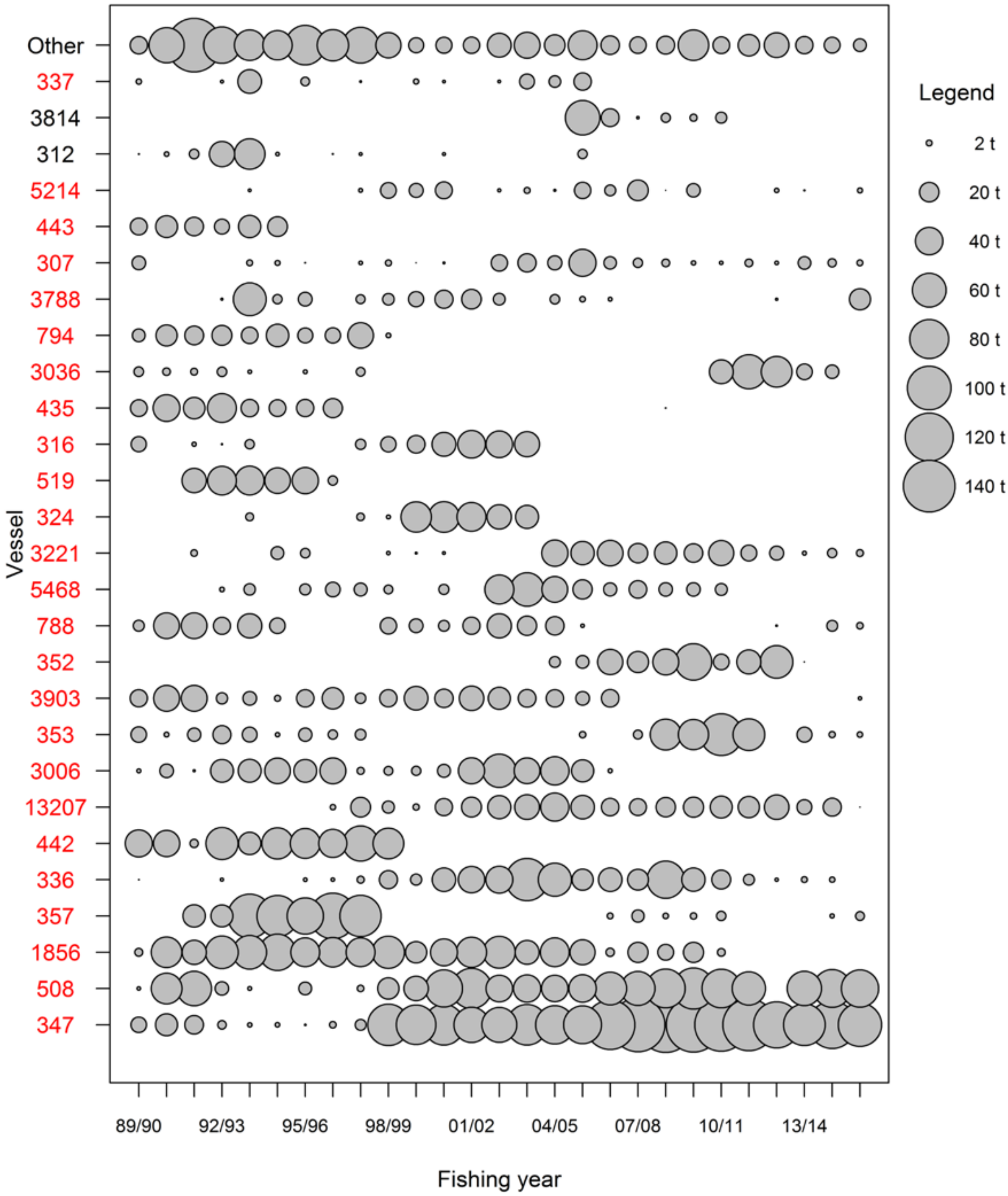

Figure 31: Distribution of tarakihi BPLE trawl catch by year and fishing vessel. The core fleet included in the final CPUE data set are highlighted in red.

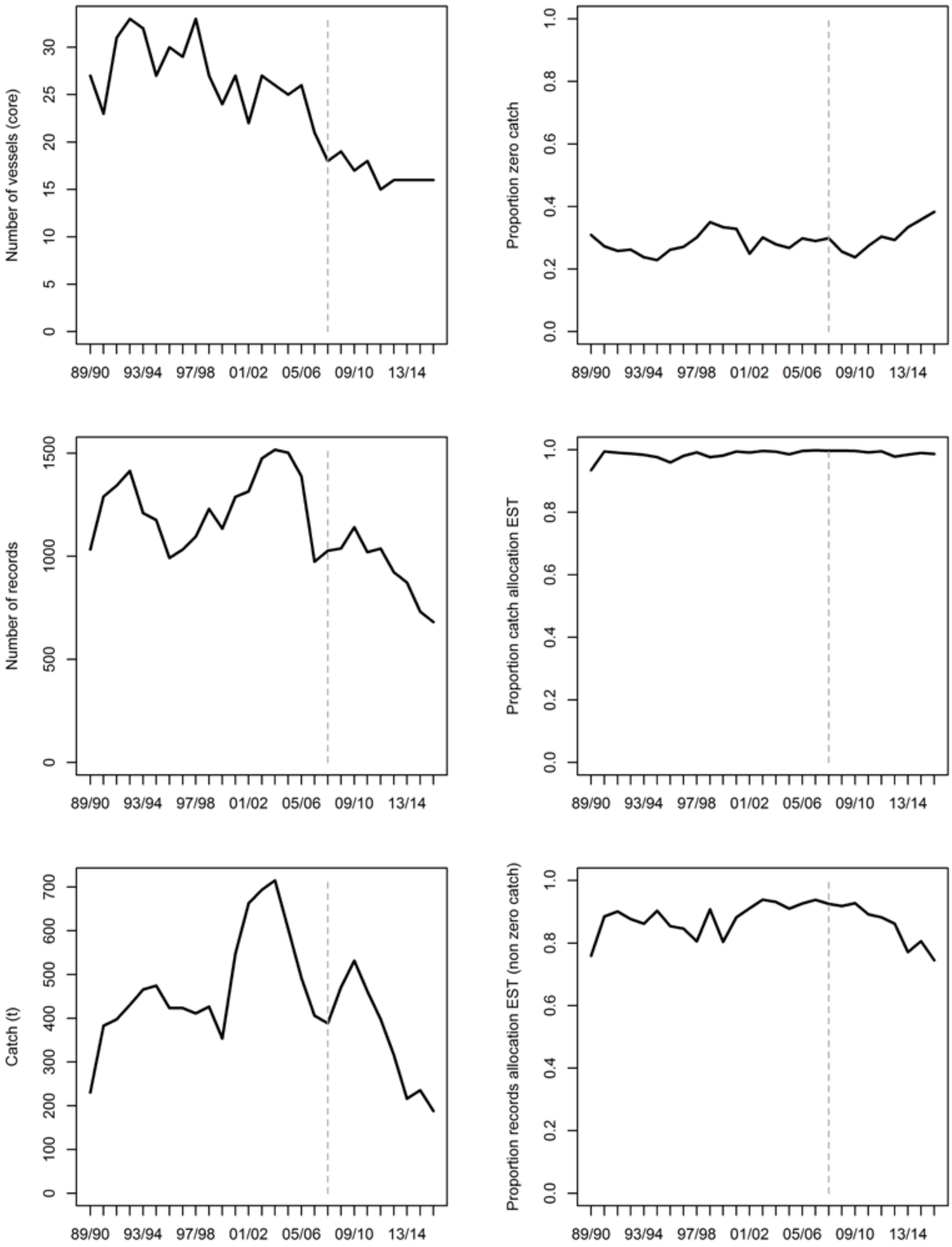

Figure 32: A summary of the data included in the BPLE core vessel data set by fishing year, including the proportion of the catch and effort records with tarakihi catches allocated based on the distribution of estimated tarakihi catch (rather than fishing effort). The dashed vertical line represents the year the TCER reporting form was introduced.

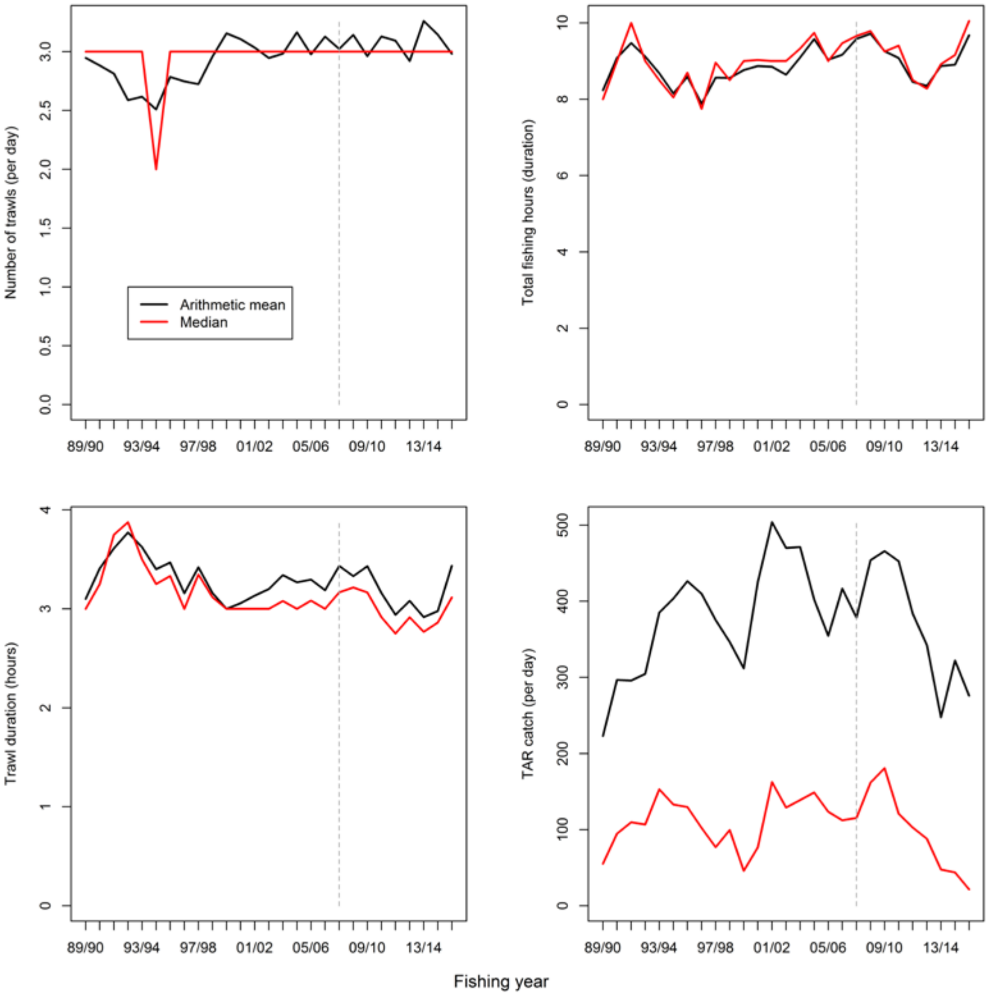

Figure 33: Annual trends in the main fishing effort and tarakihi catch rates (average and median) for the BPLE core vessel data set. The dashed vertical line represents the year the TCER reporting form was introduced.

The fishing event records are dominated by trawls targeting tarakihi, snapper and trevally (from 1998/99) (Figure 34). During the early 1990s, there was a considerable decline in trawls targeting gemfish (SKI) and the associated fishing effort remained low in subsequent years. From 2009/10, there was a steady decline in the proportion of trawls targeting tarakihi (Figure 34).

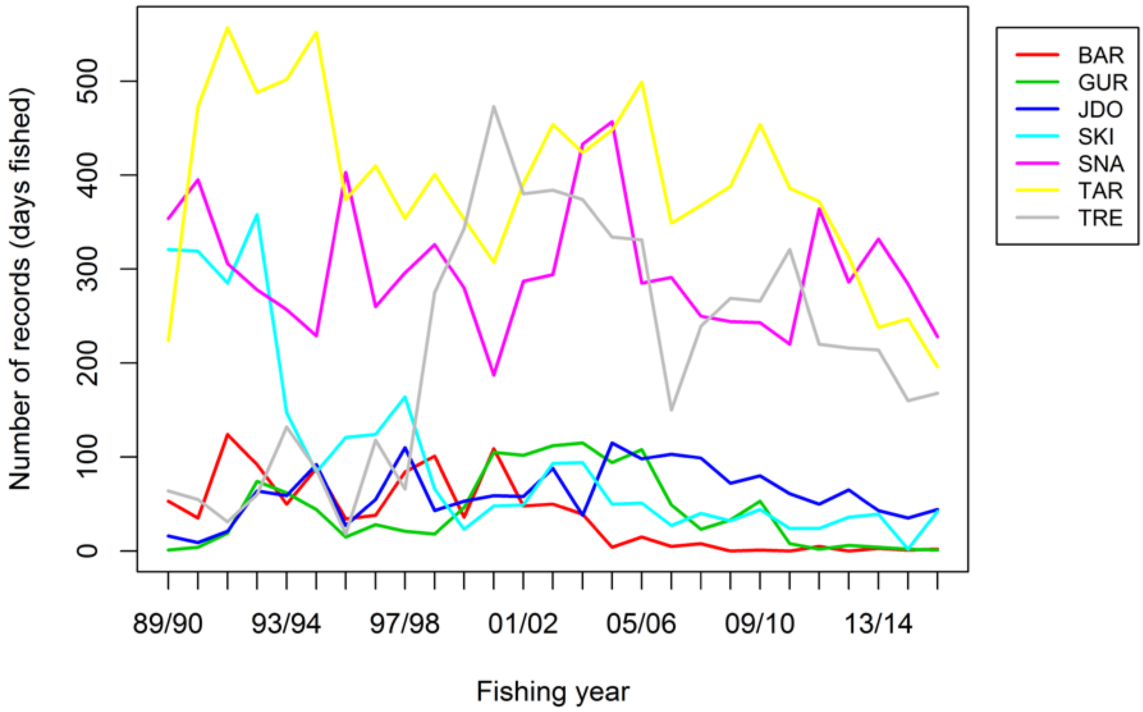

Figure 34: Annual distribution of daily fishing records by target species for the BPLE core vessel CPUE data set.

4.2.2 CPUE models

The positive catch CPUE model assumed a Weibull error structure following Starr & Kendrick (2014). The dependant variable was natural logarithm of daily catch and model included the predictor variables *FishingYear*, *TargetSpecies*, *Vessel*, natural logarithm of *Duration*, *Month* and *StatArea* (Table 5). Overall, the model explained 40.1% of the variation in the positive catch of tarakihi (Nagelkerke pseudo-R^2), while the *FishingYear* variable accounted for a small proportion of the variation (1.8%). The distribution of the CPUE model residuals is generally consistent with the assumption of normality (Figure 35).

Table 5: Summary of stepwise selection of variables in the BPLE positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	26	-157 947	315 950.1	0.018 *
TargetSpecies	6	-155 192	310 451.1	0.235 *
Vessel	41	-154 029	308 207.3	0.312 *
Duration	3	-153 090	306 335.5	0.368 *
Month	11	-152 822	305 821.5	0.384 *
StatArea	2	-152 496	305 173.7	0.401 *
NumTrawl	3	-152 436	305 060.0	0.405
Month:StatArea	22	-152 380	304 992.1	0.408

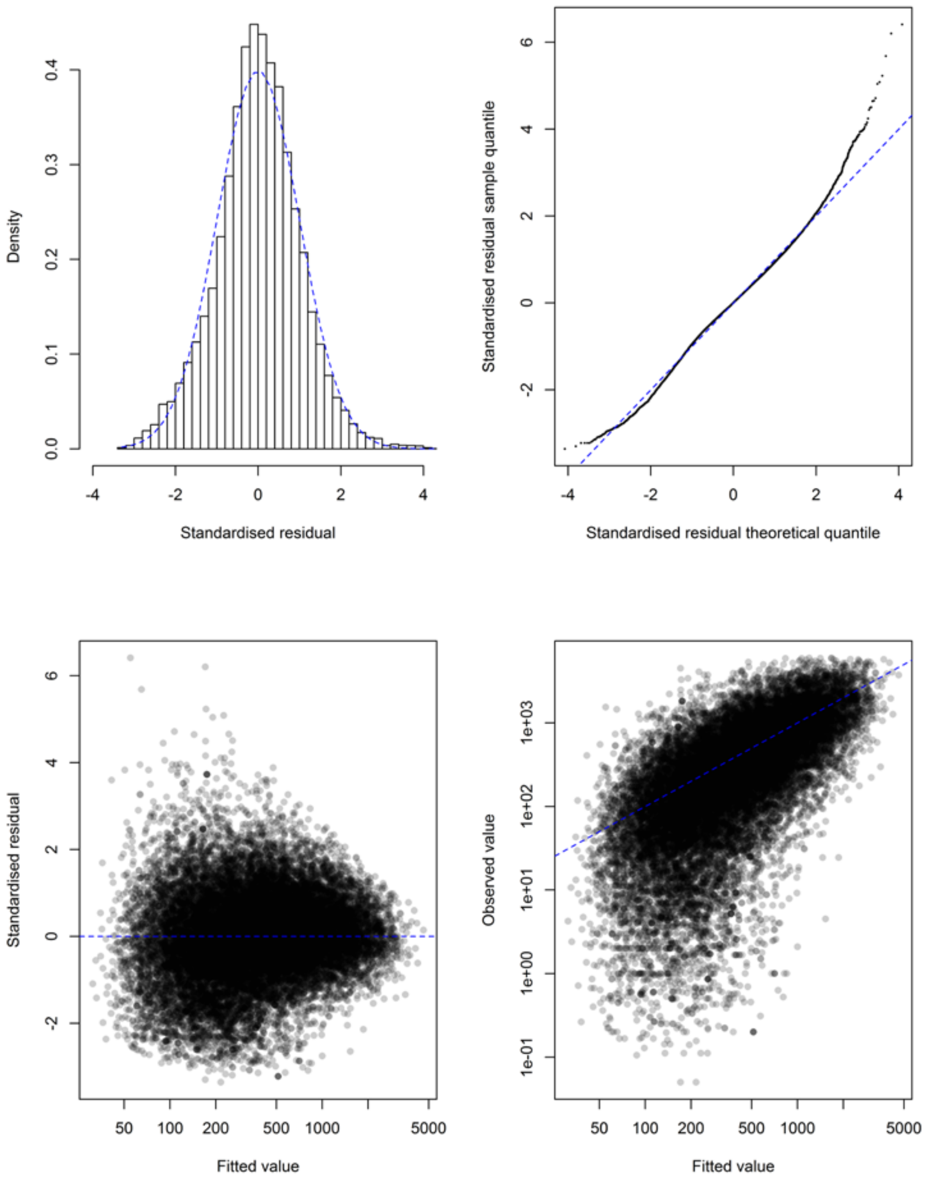

Figure 35: Residual diagnostics for the positive catch CPUE model for the BPLE trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

The annual indices derived from the positive catch CPUE model increased during 1991/92–1996/97, declined in 1999/2000 and then increased to reach a peak during 2001/02–2003/04 (Figure 36). The indices declined rapidly in 2004/05–2005/06 and continued to decline at a lower rate during the subsequent years.

The *TargetSpecies* and *Vessel* variables were the most influential variables included in the CPUE model. The increased targeting of trevally during the early 2000s contributed to the increase in the standardised CPUE indices during that period (Figure 37, Appendix 4 Figure A1). The increased dominance of the more efficient vessels in the fleet in the subsequent years influenced the extent of the decline in the CPUE indices relative to the unstandardized catch rates (Figure 37, Appendix 4 Figure A2). An examination of the residuals from the CPUE model revealed that the CPUE trends are comparable among individual Target Species and Statistical Areas (Appendix 4 Figures A3 and A4).

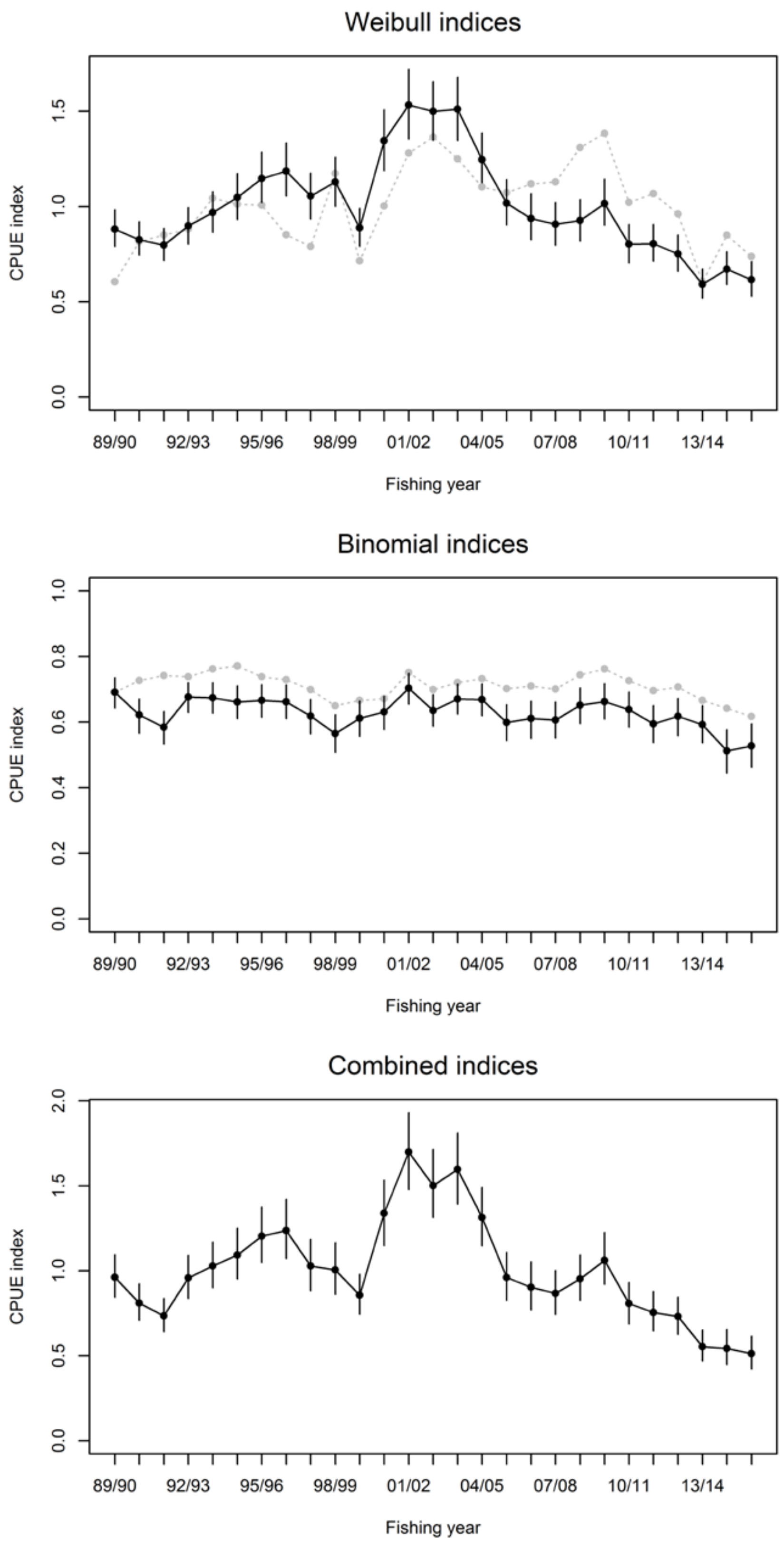

Figure 36: A comparison of the BPLE trawl standardised CPUE indices and the geometric mean of the annual catch per day (grey line) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records (grey line) in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A19 (Appendix 3).

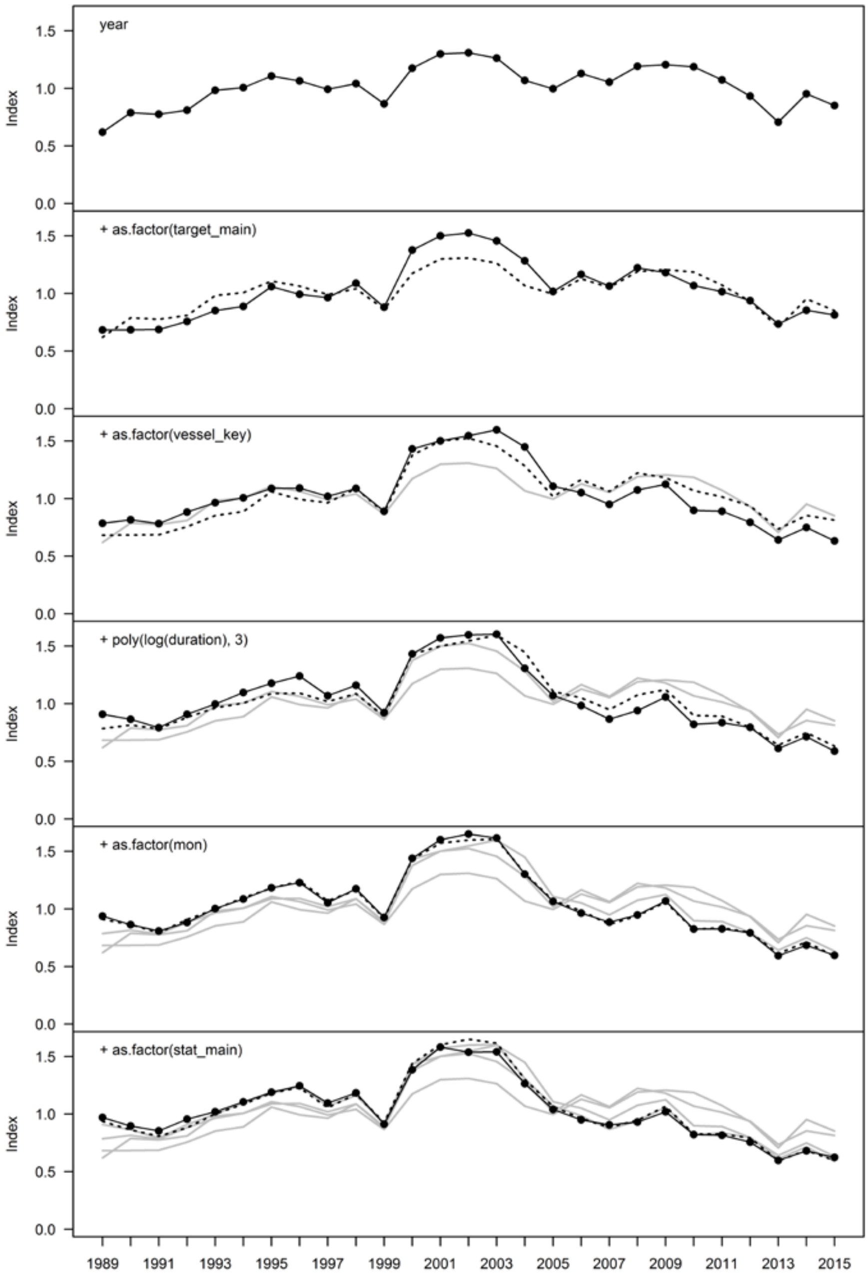

Figure 37: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the positive catch CPUE model for the BPLE trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1989 denotes the 1989/90 fishing year).

The occurrence of tarakihi in daily BPLE trawl catches was predicted by the binomial model including the explanatory variables *FishingYear*, *TargetSpecies*, *Duration*, *Vessel* and *Month* (Table 6). The resulting annual indices derived from the binomial model were generally comparable to the annual proportion of positive catch records. The binomial indices were relatively stable prior to 2009/10, and then declined during the more recent years (Figure 36).

The annual trend in the combined BPLE trawl CPUE indices was comparable to the indices from the positive catch CPUE model, although the decline in the indices from 2004/05 was more pronounced. The combined CPUE indices for 2013/14–2015/16 are the lowest for the entire time-series. (Figure 36, Appendix 3 Table A9).

Table 6: Summary of stepwise selection of variables in the BPLE tarakihi catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	26	-18 418	36 889.8	0.009 *
TargetSpecies	6	-14 974	30 014.6	0.293 *
Duration	3	-14 521	29 113.7	0.326 *
Vessel	41	-14 284	28 722.3	0.343 *
Month	11	-14 193	28 561.5	0.349 *
NumTrawl	3	-14 162	28 506.7	0.352
StatArea	2	-14 156	28 498.3	0.352
Month:StatArea	22	-14 129	28 488.9	0.354

4.3 TAR 1 East Northland single trawl CPUE *ENLD_BT_TAR*

Initially, CPUE modelling of the East Northland single trawl fishery followed the analysis of Starr & Kendrick (2014), incorporating data from a range of trawl fisheries operating within Statistical Areas 002–007. This data set was numerically dominated by records from the target snapper and John dory trawl fisheries operating within the relatively shallow areas (40–100 m) of Statistical Areas 003 and 005. The preliminary CPUE indices were therefore dominated by the trends in tarakihi CPUE from the data from the snapper and John dory trawl fisheries. An examination of the residuals from the CPUE models indicated that the CPUE trend for the target tarakihi fishery differed considerably from the base CPUE indices.

The East Northland tarakihi target trawl fishery operates primarily within Statistical Areas 002 and 003 in the 130–220 m depth range and accounts for most of the tarakihi catch from the fishery area. An examination of the event based catch and effort data revealed considerable spatial variability in the catch rate of tarakihi at the minimum resolution of the trawl data set (approximately 0.1 degree of latitude and longitude). There was also an indication that tarakihi target trawls had become more concentrated in the areas of higher tarakihi catch rate from 2003/04 onwards. This may relate to a change in the declaration of target species in response to the change in the catch balancing provisions in 2001 (ACE provisions of the Fisheries Amendment Act 2001).

It was considered that the trends in CPUE from the target tarakihi trawl fishery were more likely to provide an index of abundance of recruited tarakihi within the East Northland fishery area (than the tarakihi bycatch from the snapper and John dory trawl fisheries). Changes in the spatial operation of the target trawl fishery meant that it was necessary to conduct the CPUE modelling using the event based data only.

4.3.1 Data set

The definition of the EN_BT_TAR data set is specified in Table 4. The target tarakihi trawl fishery generally accounted for 50–75% of the annual tarakihi trawl catch from the Hauraki Gulf–East Northland area.

The core fleet, defined based on continuity criteria of a minimum annual catch of 1000 kg in at least six years, accounted for 87.6% of the total tarakihi catch included in the target CPUE data set. The criteria resulted in the selection of 28 unique vessels including four vessels that operated in the fishery for at least 14 years (of the 23 years) (Figure 38). Approximately half of the tarakihi catch included in the data set was taken by seven vessels.

Limited catch and effort data are included in the first two years of the time-series (1993/94 and 1994/95) due to the small number of vessels completing the trawl event based fishing return (TCEPR) prior to 1995/96 (Figure 39). During 1995/96–2001/02, the core fleet encompassed 15–18 vessels although the fleet reduced in the following years and during 2007/08–2012/13 8–10 vessels participated in the fishery. There was an increase in vessel activity in the more recent years, with a relatively high level of fishing effort and catch occurring in 2013/14 (Figure 39).

All of the tarakihi catch was allocated to the individual fishing event records based on the distribution of the estimated catch within individual fishing trips; i.e. all trips targeting tarakihi recorded at least one estimated catch of tarakihi. Over the study period, there was a relatively small proportion (generally 2–8%) of fishing event records with no allocated catch of tarakihi (Figure 39, Appendix 2 Table A4).

There was a general increase in trawl duration during 1994/95–2007/08, while tarakihi catches remained relatively stable over the entire study period (Figure 40). During the late 1990s, most of the target trawls occurred in the northern area of the fishery (north of the Bay of Islands), although in the subsequent years fishing effort was more evenly distributed throughout the area. Fishing effort generally occurred in deeper water from 2005/06 onwards. Over the last decade, fishing effort was also increasingly concentrated during early morning and evening with limited fishing during the day (Figure 40).

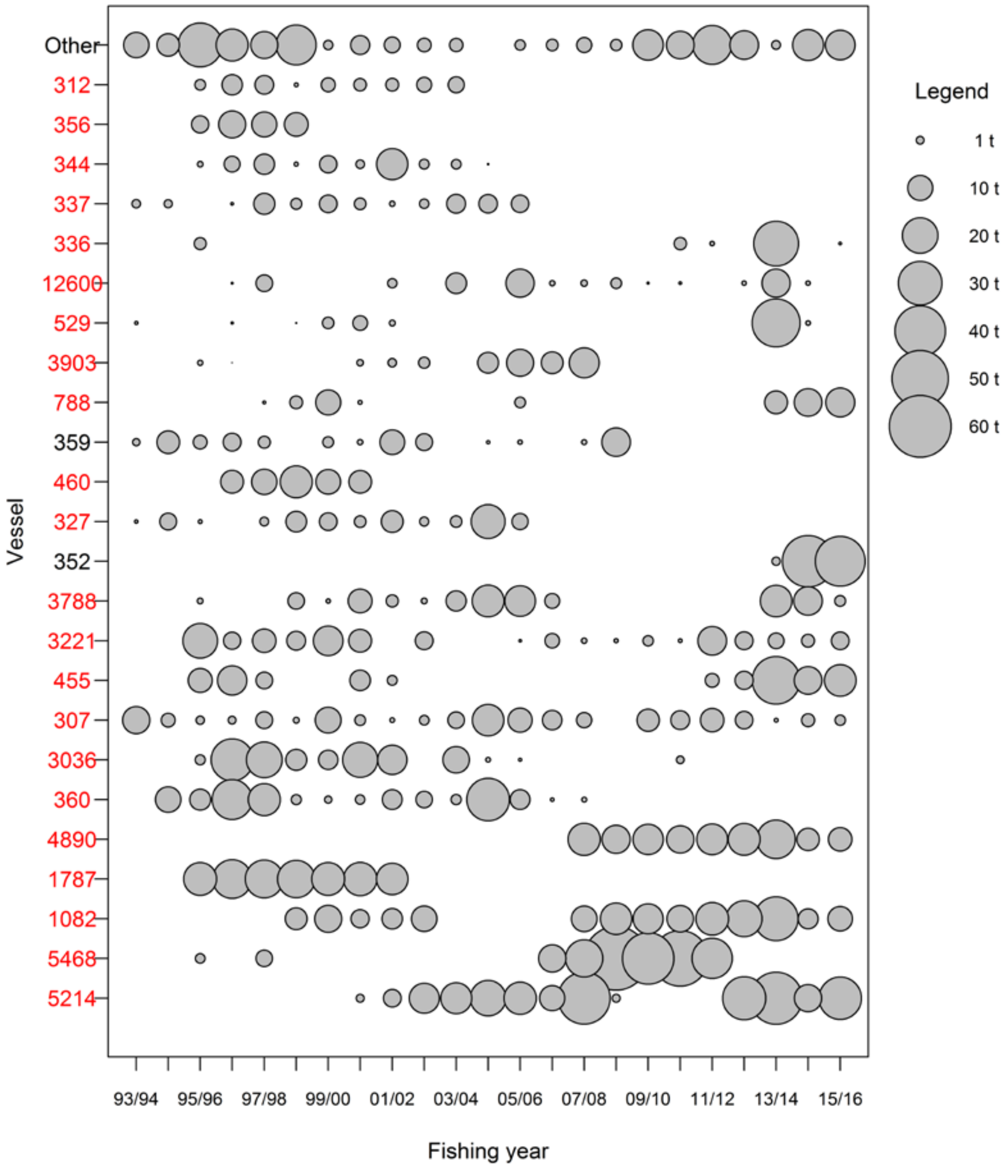

Figure 38: Distribution of tarakihi East Northland trawl catch by year and fishing vessel (event based data). The core fleet included in the final CPUE data set are highlighted in red.

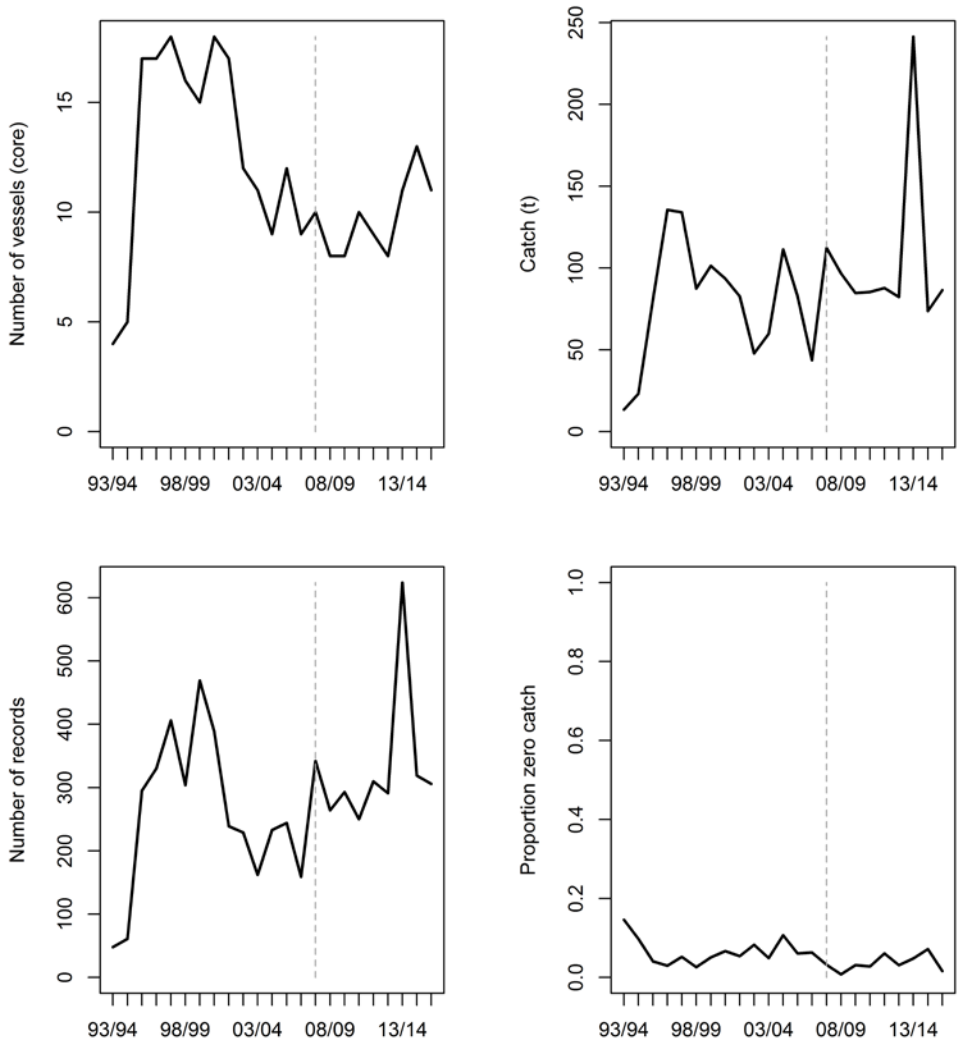

Figure 39: A summary of the data included in the ENLD core vessel data set by fishing year. The dashed vertical line represents the year the TCER reporting form was introduced.

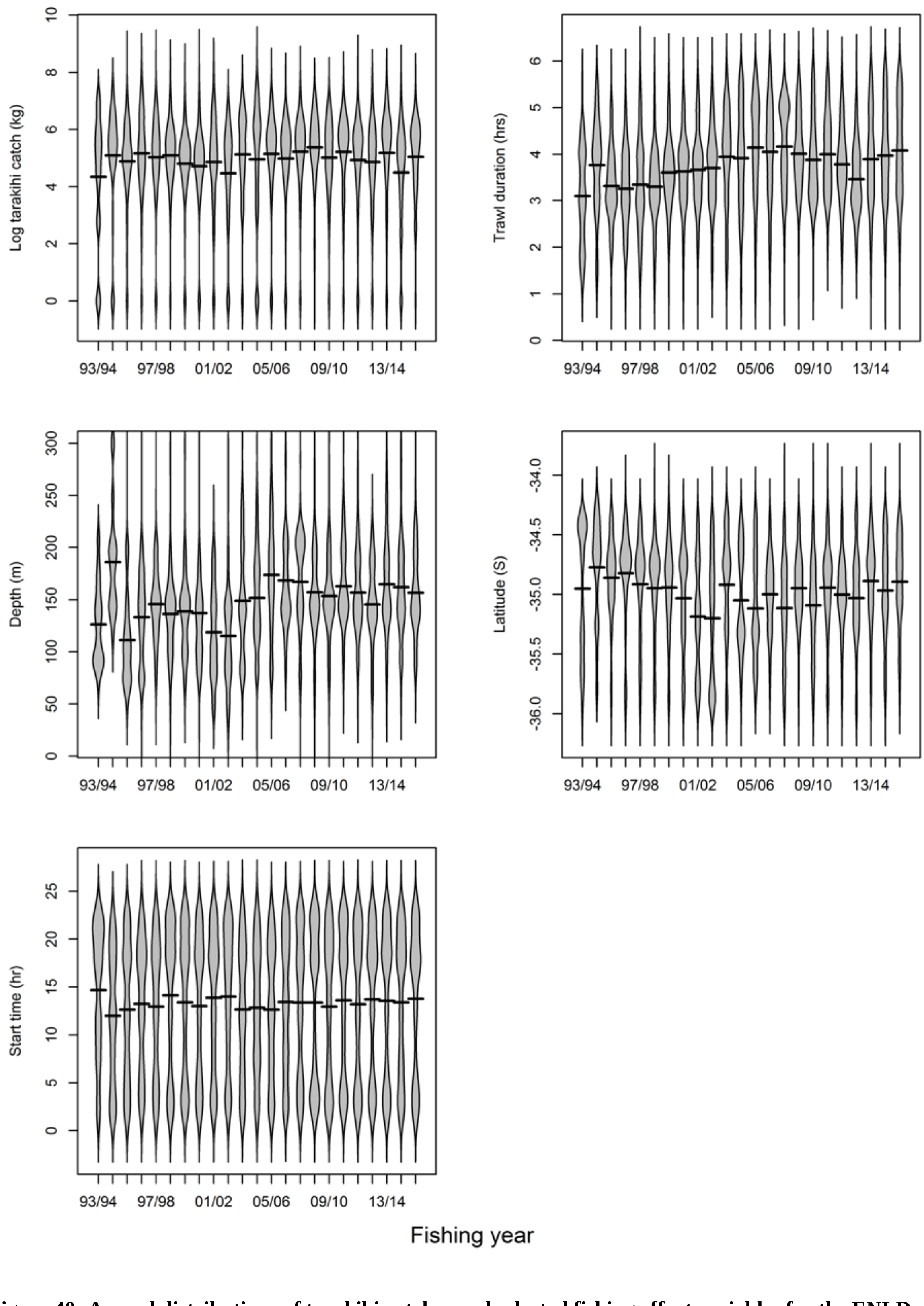

Figure 40: Annual distributions of tarakihi catches and selected fishing effort variables for the ENLD core vessel data set. The horizontal lines represent the average annual value.

4.3.2 CPUE models

For the positive catch CPUE model, preliminary modelling revealed that a Weibull distribution was most consistent with the error structure of the fitted data. The final positive catch CPUE model included most of the potential predictor variables, explaining 49.1% of the variation in the positive catch of tarakihi (Nagelkerke pseudo-R^2) (Table 7). The variables *Latitude1*, *Vessel* and *Depth* accounted for most of the explained variation, while the *FishingYear* variable accounted for 4.2% of the variation. The distribution of the CPUE model residuals is consistent with the assumption of normality (Figure 41).

Table 7: Summary of stepwise selection of variables in the ENLD positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	22	-41 977	84 001.3	0.042 *
Latitude1	20	-41 041	82 170.2	0.292 *
Vessel	27	-40 539	81 219.2	0.398 *
Depth	3	-40 312	80 772.1	0.440 *
Duration	3	-40 173	80 500.6	0.465 *
Month	11	-40 063	80 302.5	0.483 *
StartTime	3	-40 016	80 214.4	0.491 *
Distance	3	-39 997	80 182.5	0.494
Speed	3	-39 996	80 186.5	0.494

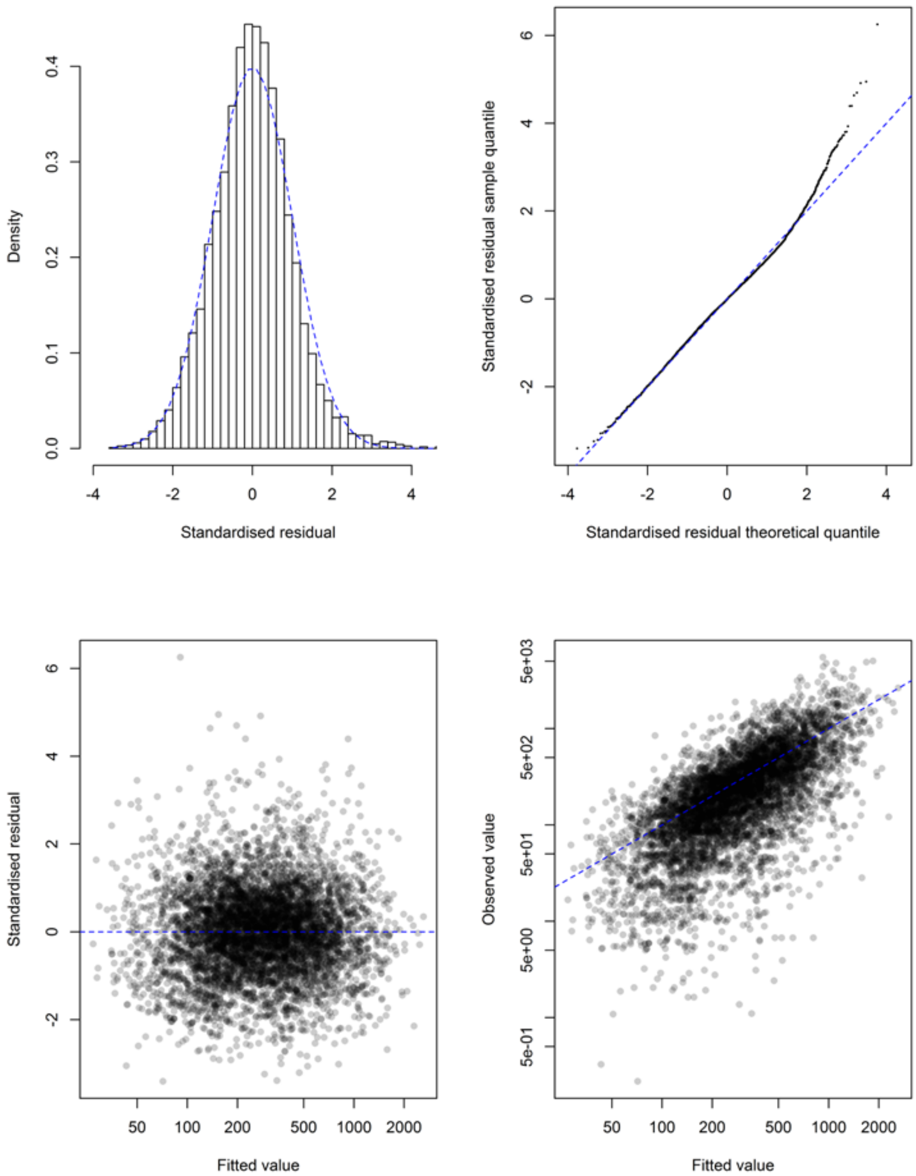

Figure 41: Residual diagnostics for the positive catch CPUE model for the ENLD trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

The annual indices derived from the positive catch CPUE model fluctuated during 1993/94–2005/06 and then stabilised during 2006/07–2013/14 (Figure 42). The indices declined markedly in 2014/15 and remained at the lower level in 2015/16. The trend in the CPUE indices was generally comparable to the annual trend in the unstandardized catch rates (Figure 42). The influence of the main variables included in the CPUE model tend to counteract the influence of other key variables. For example, the inclusion of the *Vessel* variable moderates the decline in the unstandardized CPUE indices during 2004/05–2015/16, although this effect was counteracted by the inclusion of the *Latitude1* location variable and the *Depth* variable which accounted for a shift to deeper trawls in more productive locations during the same period (Figure 43, Appendix 4 Figures A5–7).

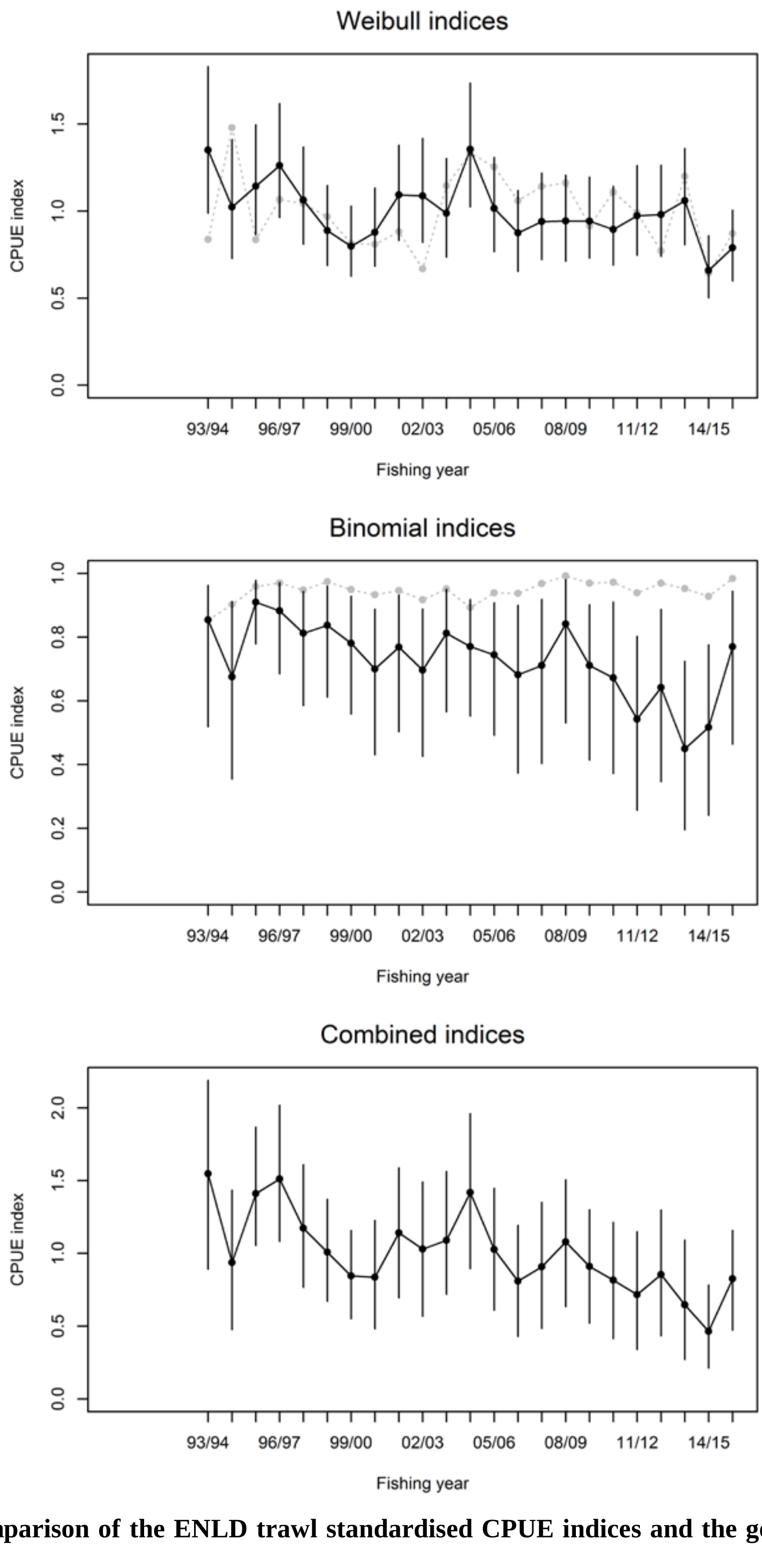

Figure 42: A comparison of the ENLD trawl standardised CPUE indices and the geometric mean of the annual catch per day (grey line) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records (grey line) in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A10 (Appendix 3).

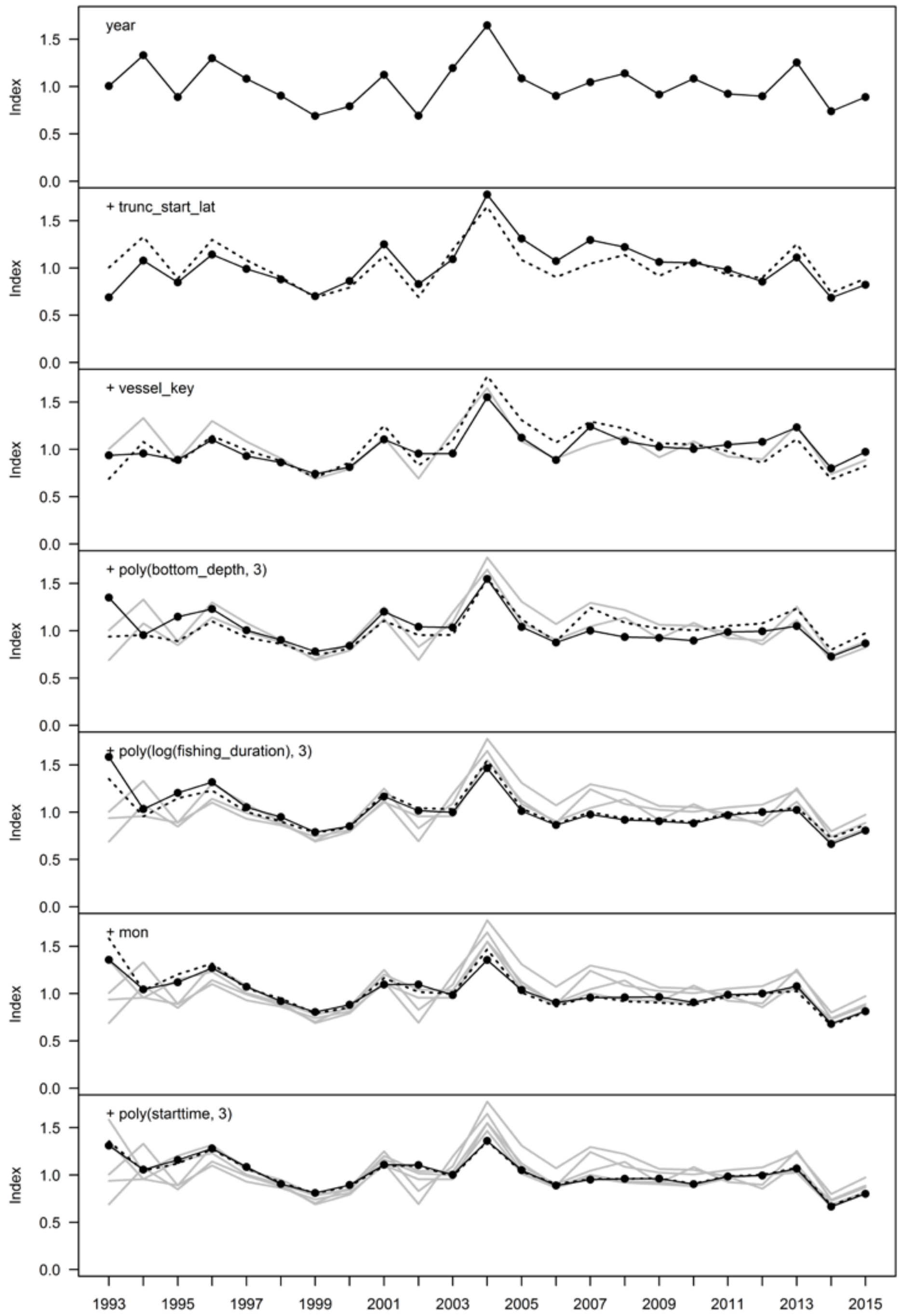

Figure 43: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the positive catch CPUE model for the ENLD trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1993 denotes the 1993/94 fishing year).

The occurrence of tarakihi in the ENLD trawl catch was predicted by the binomial model including the explanatory variables *FishingYear*, *StartTime*, *Vessel*, *Depth*, *Duration* and *Speed* (Table 8). The *StartTime* variable had the highest explanatory power in the model and the model estimated that there was a considerably higher probability of catching tarakihi during the morning and evening compared to during the day.

The annual indices derived from the binomial model declined considerably during 1995/96–2013/14, in contrast to the annual proportion of non zero catch records which remained relatively stable throughout the period (Figure 42). The decline in the binomial indices was primarily attributable to the inclusion of the *Vessel* and *Depth* variables in the model (Figure 44). The model estimated that there is a higher probability of catching tarakihi with increasing fishing depth (to a maximum depth of approximately 200 m). The influence of the *Vessel* variable was attributable to two of the main vessels operating in the fishery in recent years. These vessels both had a lower proportion of trawls catching tarakihi during 2011/12–2014/15. The proportion of records with a catch of tarakihi increased in 2015/16 and, correspondingly, the binomial indices increased.

The combined ENLD trawl CPUE indices are strongly influenced by the binomial indices, particularly during 2005/06–2015/16 (Figure 42, Appendix 3 Table A10). The combined indices decline during this period and the most recent indices are considerably lower than the indices from the initial years (1993/94–1996/97). However, the combined indices are relatively poorly determined, largely reflecting the low precision of the binomial indices.

The sensitivity of the CPUE indices was investigated by repeating the CPUE analysis with the two key vessels excluded from the CPUE data set. The binomial indices were sensitive to the exclusion of these vessels. This yielded combined indices that were more optimistic during 2011/12–2014/15, although the overall trend in the indices was similar to the combined CPUE indices from the base analysis.

Table 8: Summary of stepwise selection of variables in the ENLD tarakihi catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	22	-1 223	2 492.1	0.037 *
StartTime	3	-1 110	2 272.0	0.142 *
Vessel	27	-1 023	2 152.3	0.220 *
Depth	3	-972	2 056.0	0.265 *
Duration	3	-953	2 024.2	0.281 *
Speed	3	-946	2 016.4	0.287 *
Month	11	-934	2 013.6	0.298
Latitude	17	-917	2 014.8	0.312
Distance	3	-917	2 019.4	0.313

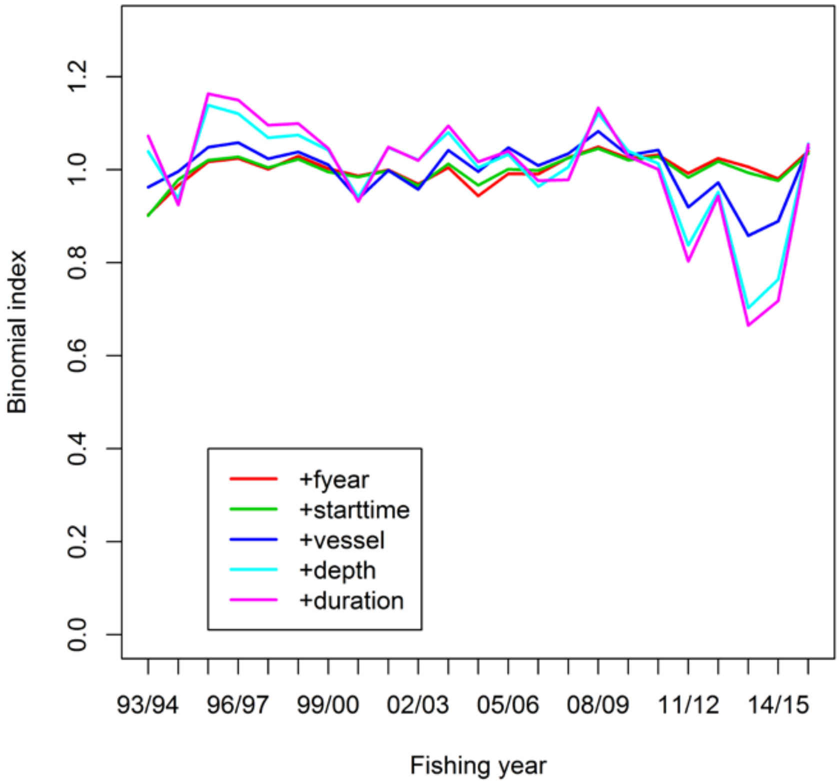

Figure 44: The influence of the step-wise inclusion of the main explanatory variables in the ENLD binomial CPUE model. The initial model included the *FishingYear* variable (+fyear) and additional variables were added sequentially.

4.4 TAR 1 northern West Coast single trawl CPUE *WCNI_BT_MIX*

Initially, CPUE modelling of the East Northland single trawl fishery followed the analysis of Starr & Kendrick (2014), incorporating CELR format data from the tarakihi, snapper and trevally target trawl fisheries operating within Statistical Areas 041, 042, 045–047. However, an analysis of the model residuals revealed that there were significantly different CPUE trends between the southern (041 and 042) and northern (045–047) areas of the fishery. In general, the WCNI tarakihi fishery has been dominated by catch (and fishing effort) in the northern area of the fishery, primarily within Statistical Area 047. On that basis, it was decided to restrict the analysis to the northern fishery area (Statistical Areas 045–047).

For the northern WCNI fishery area, initial CPUE modelling compared CPUE indices derived from daily CELR format data with CPUE indices derived from the event (trawl) based records. There was a marked difference in the CPUE indices derived from the two data sets from 2009/10 onwards. This was attributed to a change in fishing depth, with a concentration of target tarakihi trawls in the depth range yielding higher tarakihi catch rates. The event based CPUE analysis was able to take account of this change in fishing depth, whilst the daily aggregate CELR format data does not include information regarding fishing depth.

The final analysis was conducted using the event based data set from the tarakihi, snapper and trevally target trawl fisheries operating within Statistical Areas 045–047. The final CPUE indices are considered to be indicative of trends in abundance for the northern WCNI area only (rather than the entire WCNI tarakihi fishery).

4.4.1 Data set

The definition of the WC_BT_MIX data set is specified in Table 4. Since 1999/2000, the northern trawl fishery generally accounted for approximately 70% of the annual tarakihi trawl catch from the WCNI area.

The core fleet, defined based on continuity criteria of a minimum of 10 fishing trips in at least three years, accounted for 89.0% of the total tarakihi catch included in the CPUE data set. The criteria resulted in the selection of 27 unique vessels including two vessels that operated in the fishery for at least 15 years (of the 23 years) (Figure 45). Approximately half of the tarakihi catch included in the data set was taken by five vessels.

Limited catch and effort data are included in the first two years of the time-series (1993/94 and 1994/95) due to the small number of vessels completing the trawl event based fishing return (TCEPR) prior to 1995/96 (Figure 46). During 1995/96/97–2002/03, the core fleet was comprised of 14–17 vessels. A number of vessels ceased to operate in the fishery during the mid–late 2000s and in the most recent years the core fleet was comprised of 7–10 vessels. Nonetheless, there was a general increase in the catch of tarakihi over the last decade (Figure 46).

Virtually all of the tarakihi catch was allocated to the individual fishing event records based on the distribution of the estimated catch within individual fishing trips; i.e. virtually all trips targeting tarakihi recorded at least one estimated catch of tarakihi. Over the study period, there was a relatively high proportion (generally 60–70%) of fishing event records with no allocated catch of tarakihi (Figure 46, Appendix 2 Table A7). These records were predominantly from trawls targeting snapper or trevally.

Since the mid 2000s, fishing effort was increasingly concentrated in an area off northern Ninety Mile Beach with a corresponding increase in fishing depth (Figure 47).

Figure 45: Distribution of tarakihi northern WCNI trawl catch by year and fishing vessel (event based data). The core fleet included in the final CPUE data set are highlighted in red.

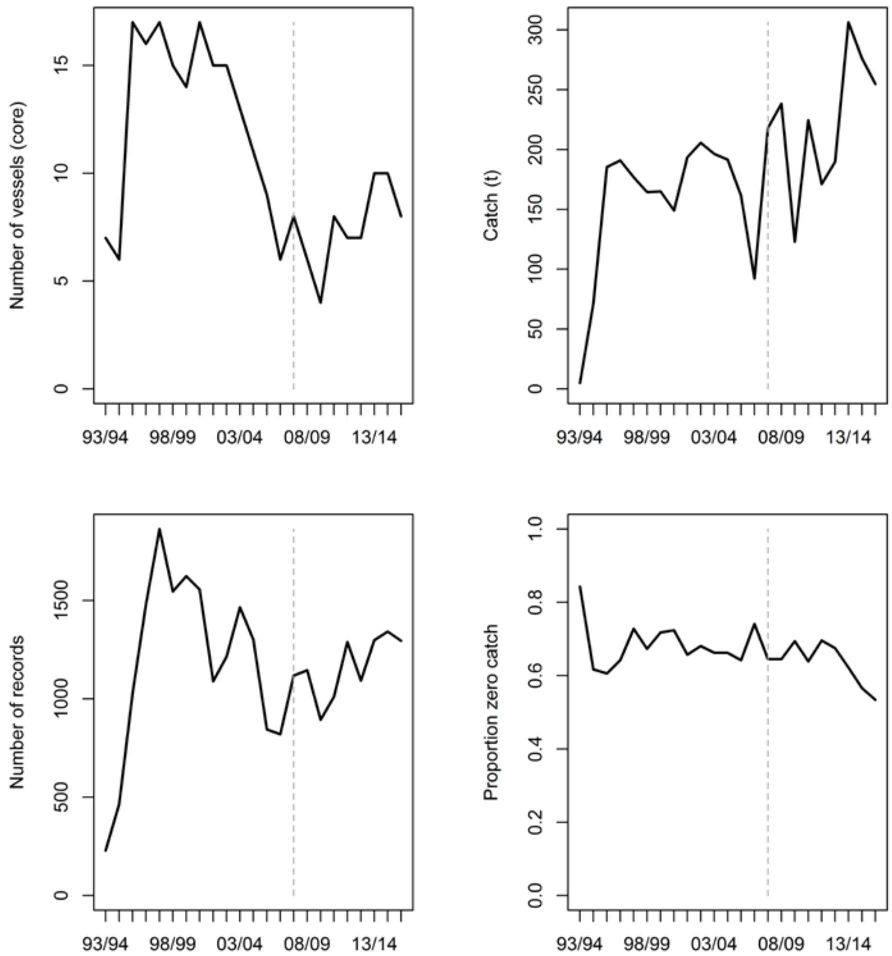

Figure 46: A summary of the data included in the northern WCNI core vessel data set by fishing year. The dashed vertical line represents the year the TCER reporting form was introduced.

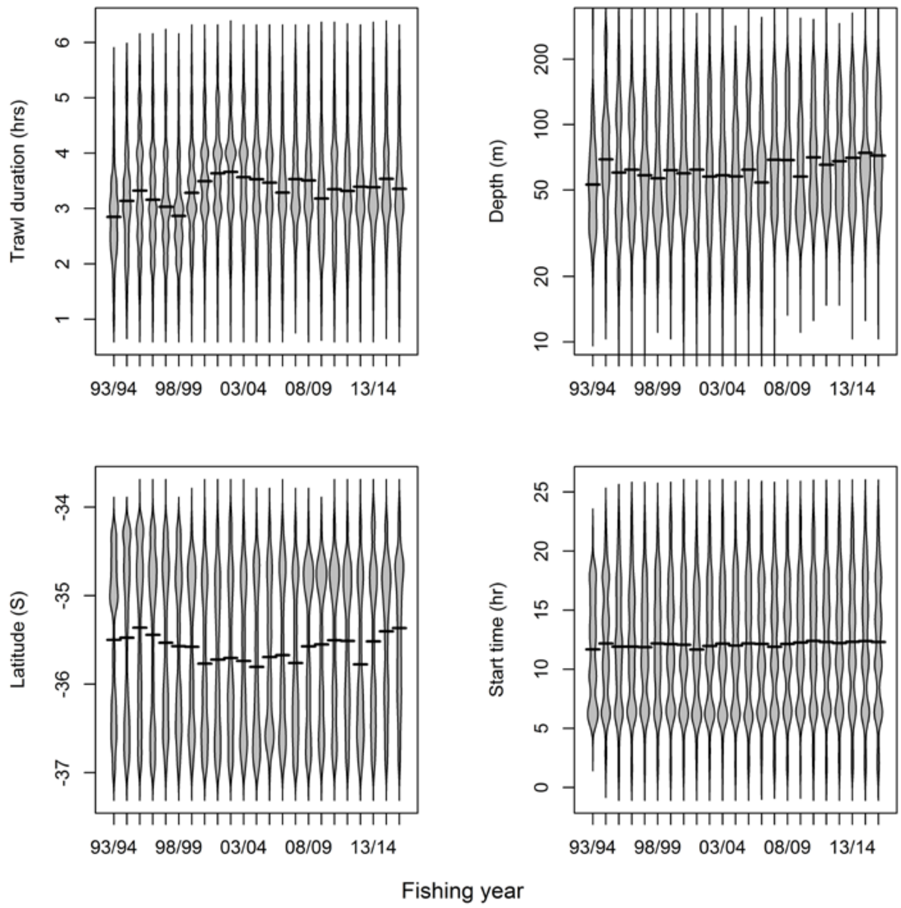

Figure 47: Annual distributions of tarakihi catches and selected fishing effort variables for the northern WCNI core vessel data set. The horizontal lines represent the average annual value.

4.4.2 CPUE models

The positive catch CPUE model assumed a Lognormal error structure. The CPUE model included most of the potential predictor variables, explaining 51.6% of the variation in the positive catch of tarakihi (Nagelkerke pseudo-R^2) (Table 9). The variables *TargetSpecies*, *Vessel* and *Depth* accounted for most of the explained variation, while the *FishingYear* variable accounted for 1.8% of the variation. The distribution of the CPUE model residuals is consistent with the assumption of normality (Figure 48).

Table 9: Summary of stepwise selection of variables in the northern WCNI positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	22	-15 380	30 808	0.018 *
TargetSpecies	2	-13 609	27 269	0.345 *
Vessel	26	-13 113	26 331	0.416 *
Depth	3	-12 861	25 832	0.450 *
Latitude	5	-12 601	25 323	0.482 *
Duration	3	-12 453	25 032	0.500 *
Month	11	-12 307	24 762	0.516 *
StartTime	3	-12 257	24 667	0.522
Distance	3	-12 254	24 667	0.523

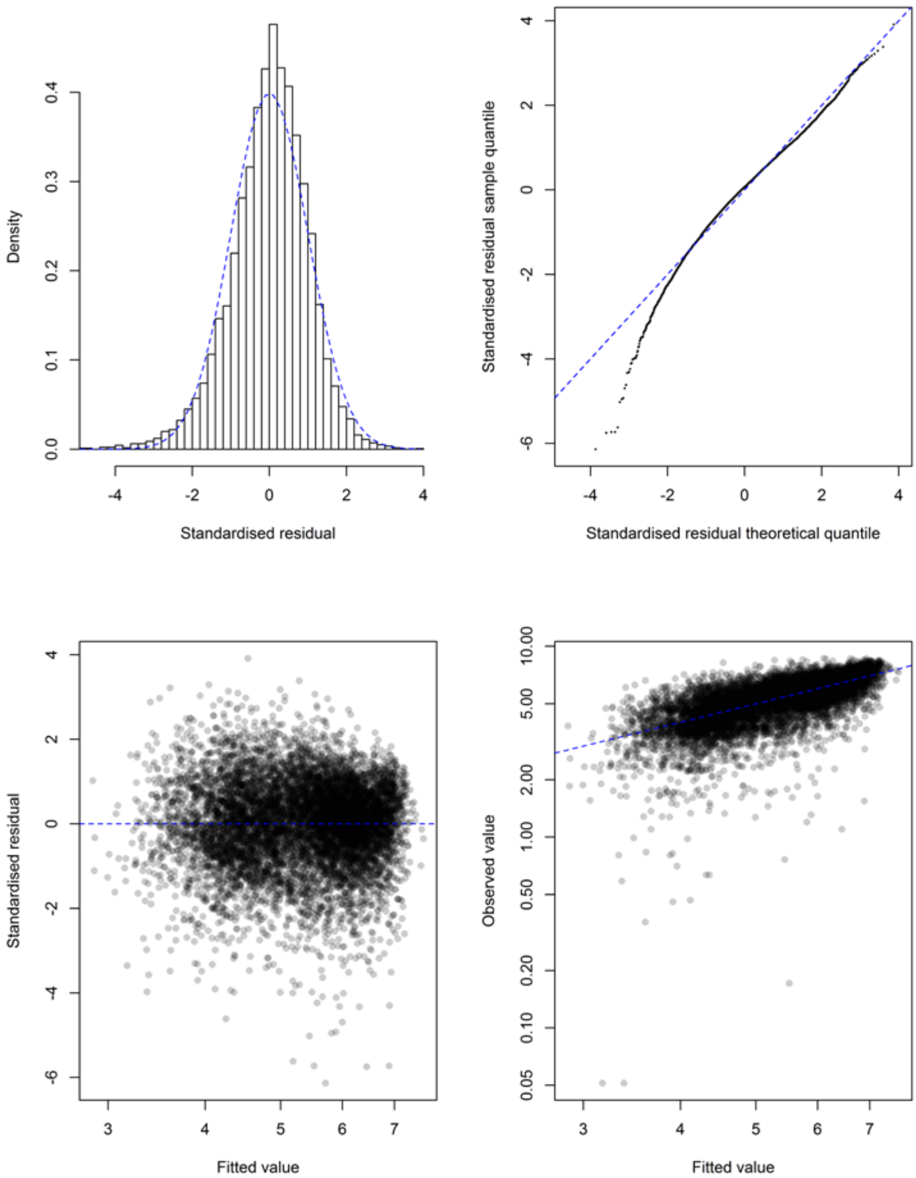

Figure 48: Residual diagnostics for the positive catch CPUE model for the northern WCNI trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

The annual indices derived from the positive catch CPUE model generally decline from 1994/95–1995/96 to 2008/09 and stabilize at the lower level for the remainder of the period (Figure 49). The trend in the CPUE indices countered the annual trend in the unstandardized catch rates which were generally higher during 2005/06–2013/14 (Figure 49). The main variables influencing the CPUE indices are *TargetSpecies*, *Vessel* and *Depth* (Figure 50, Appendix 4 Figures A8–10).

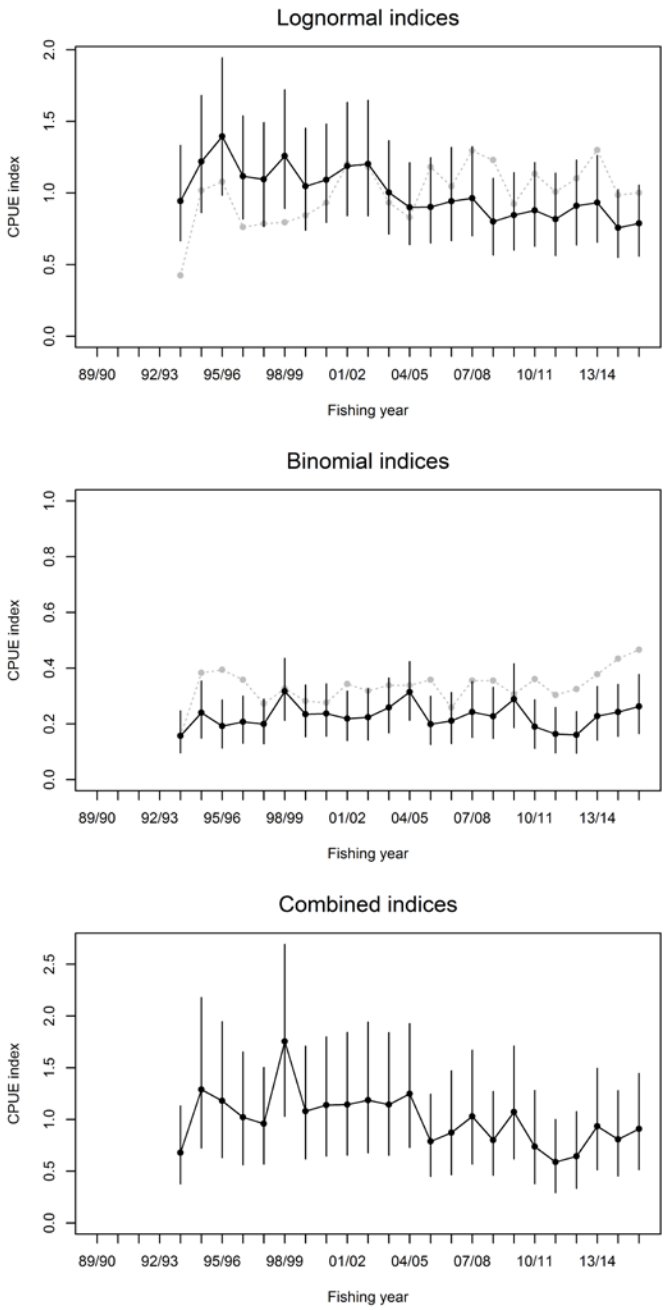

Figure 49: A comparison of the northern WCNI trawl standardised CPUE indices and the geometric mean of the annual catch per day (grey line) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records (grey line) in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A11 (Appendix 3).

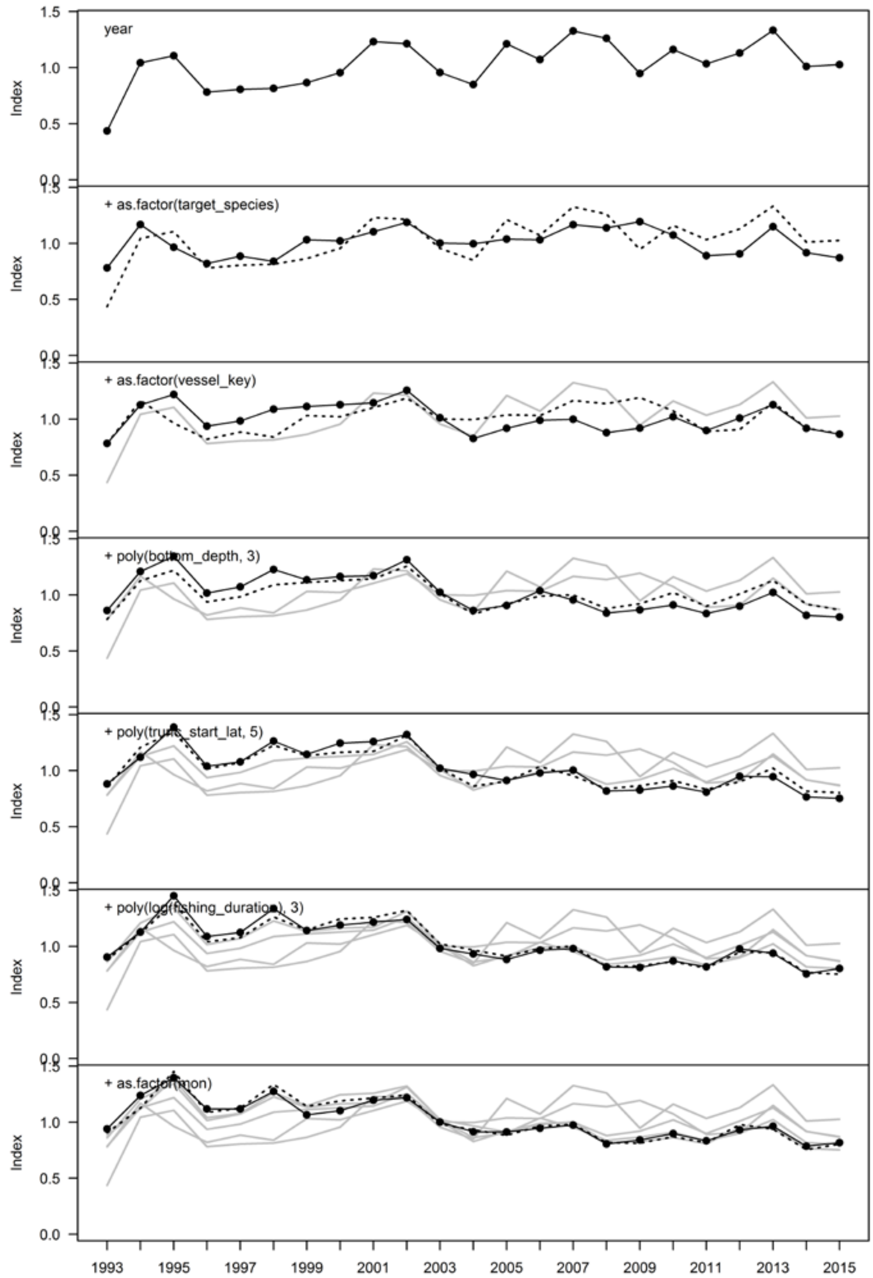

Figure 50: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the positive catch CPUE model for the northern WCNI trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1993 denotes the 1993/94 fishing year).

The occurrence of tarakihi in the northern WCNI trawl catch is predominantly explained by *TargetSpecies* and *Depth* (Table 10). The annual indices derived from the binomial model are relatively constant over the study period (Figure 49). Consequently, the binomial indices only have a minor influence on the combined CPUE indices which are dominated by the CPUE indices from the lognormal model. The lognormal indices have a relatively high standard error which contributes to the relatively high uncertainty associated with the northern WCNI indices (Figure 49, Appendix 3 Table A11).

Table 10: Summary of stepwise selection of variables in the northern WCNI tarakihi catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	22	-17 102	34 250	0.018 *
TargetSpecies	2	-10 854	21 758	0.524 *
Depth	3	-9 893	19 843	0.583 *
Vessel	26	-9 506	19 120	0.606 *
Latitude	5	-9 246	18 611	0.621 *
Month	11	-8 932	18 003	0.639 *
StartTime	3	-8 826	17 798	0.644 *
Duration	3	-8 778	17 709	0.647
Speed	3	-8 765	17 687	0.648

4.5 TAR 2 single trawl CPUE *TAR2_BT_MIX*

The TAR 2 trawl CPUE analysis was based on the CELR format (i.e. daily aggregated) catch and effort data for the inshore bottom trawl fishery targeting the suite of inshore species within Statistical Areas 011–016 (Figure 1). Preliminary CPUE modelling of the TAR 2 single trawl replicated the CPUE indices derived by Starr & Kendrick (2014), although CPUE trends from Statistical Area 016 differed considerably from the other constituent Statistical Areas. Fishing effort and tarakihi catch were relatively limited for Statistical Area 016 (Figure 23) and, consequently, it was decided to exclude the area from the final CPUE data set.

For TAR 2, event based fishing effort records (TCER) were available from 2007/08. Comparative CPUE models formulated from the two data formats (event based and CELR) yielded similar annual CPUE indices for the corresponding period (2007/08–2015/16). The final CPUE model was based on the CELR format data set from 1989/90–2015/16.

4.5.1 Data set

The definition of the TAR2_BT_MIX data set is specified in Table 4. The core fleet, defined based on continuity criteria of a minimum annual catch of 1000 kg in at least six years, accounted for 93% of the total tarakihi catch included in the CELR format (i.e. daily aggregated) data set. The criteria resulted in the selection of 65 unique vessels including 13 vessels that operated in the fishery for at least 20 years (Figure 51). Approximately half of the tarakihi catch included in the data set was taken by ten vessels.

The number of vessels included in the core fleet declined from the late 1990s, while the annual catch of tarakihi remained relatively stable (Figure 52). There was a decline in the number of daily fishing records included in the core vessel data set from 2009/10 to 2015/16 (Figure 52) and a corresponding decline in the total number of trawls per annum (Appendix 2 Table A6).

Almost all of the tarakihi catch was allocated to the daily aggregated fishing effort records based on the distribution of the estimated catch within individual fishing trips (Figure 52). A relatively small proportion (7–15%) of the positive catch records were allocated based on the distribution of fishing events amongst trips (i.e. those trips with no estimated catches of tarakihi). The tarakihi catches allocated based on effort distribution were generally small (median 4 kg). Over the study period, there was a relatively constant proportion of records (generally 15–20%) with no allocated catch of tarakihi (Figure 52, Appendix 2 Table A6).

The average number of trawls conducted per fishing day increased during the early–mid 2000s, with a corresponding increase in the duration of fishing (Figure 53). The total fishing duration remained relatively stable during the subsequent years. There was no appreciable change in the main fishing effort metrics associated with the introduction of the TCER reporting form in 2007/08 (Figure 53). The average daily catch of tarakihi increased gradually during 1989/90–2012/13 and then increased sharply in 2013/14 and was maintained at the higher level over the two most recent years (Figure 53).

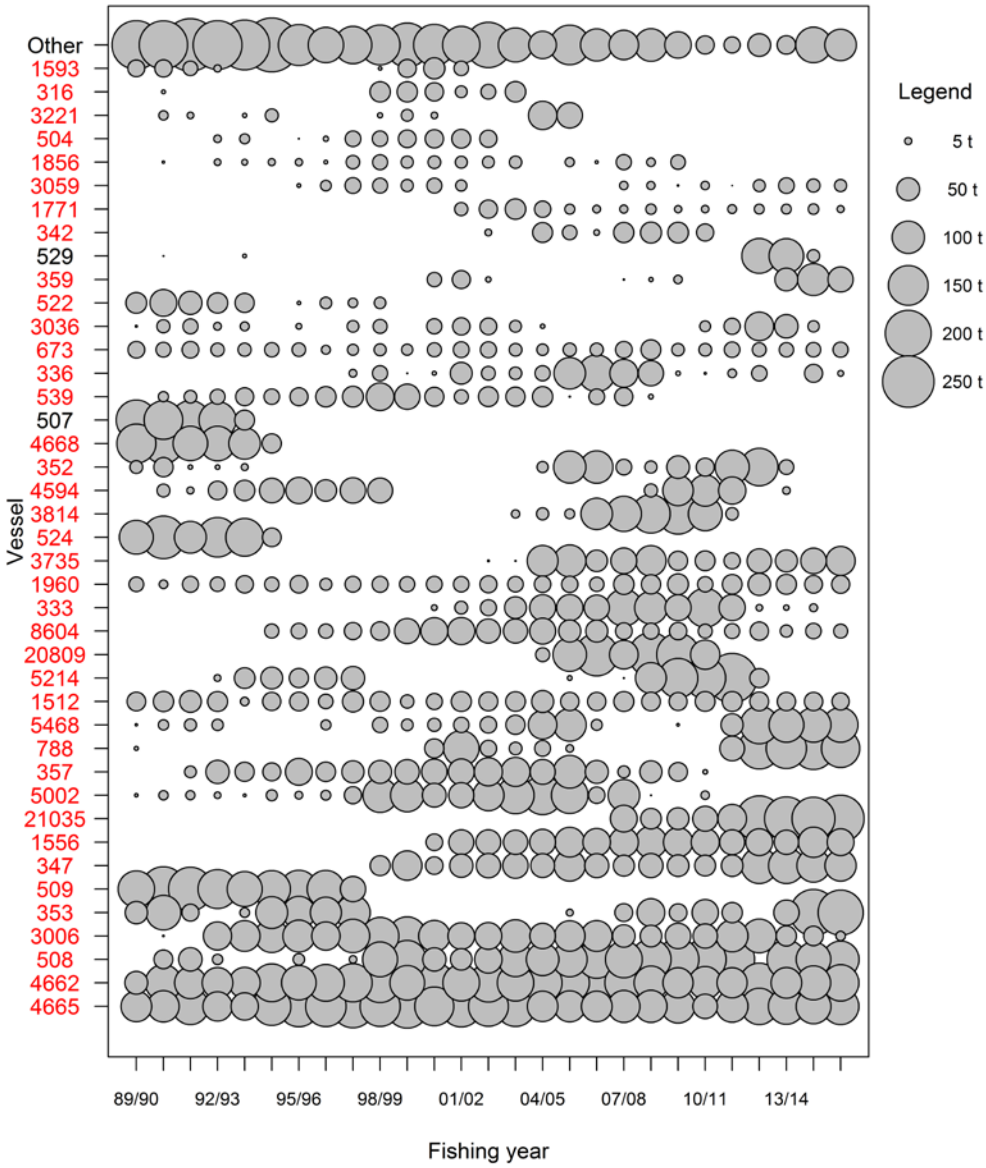

Figure 51: Distribution of tarakihi TAR 2 trawl catch by year and fishing vessel. The core fleet included in the final CPUE data set are highlighted in red.

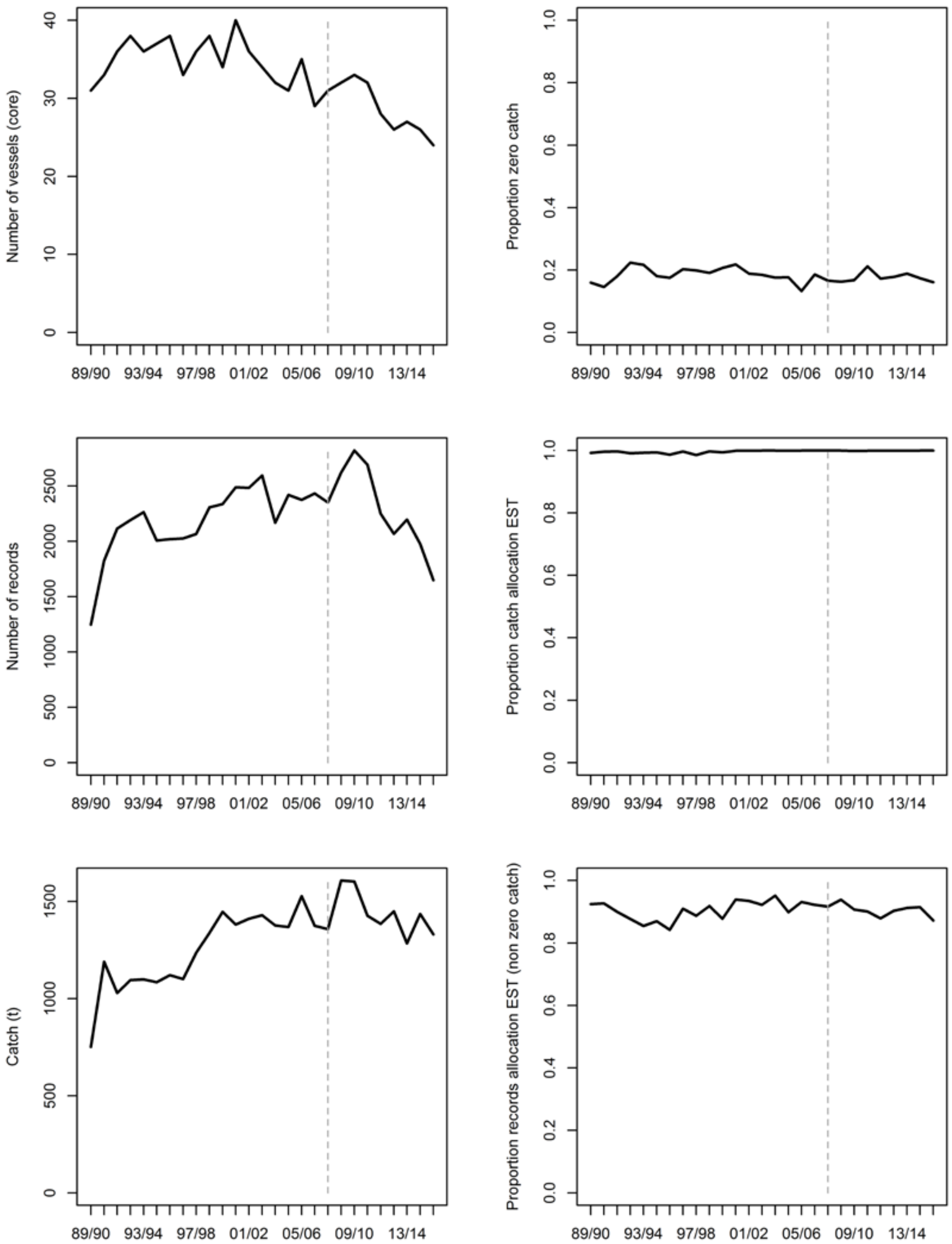

Figure 52: A summary of the data included in the TAR 2 core vessel data set by fishing year, including the proportion of the catch and effort records with tarakihi catches allocated based on the distribution of estimated tarakihi catch (rather than fishing effort). The dashed vertical line represents the year the TCER reporting form was introduced.

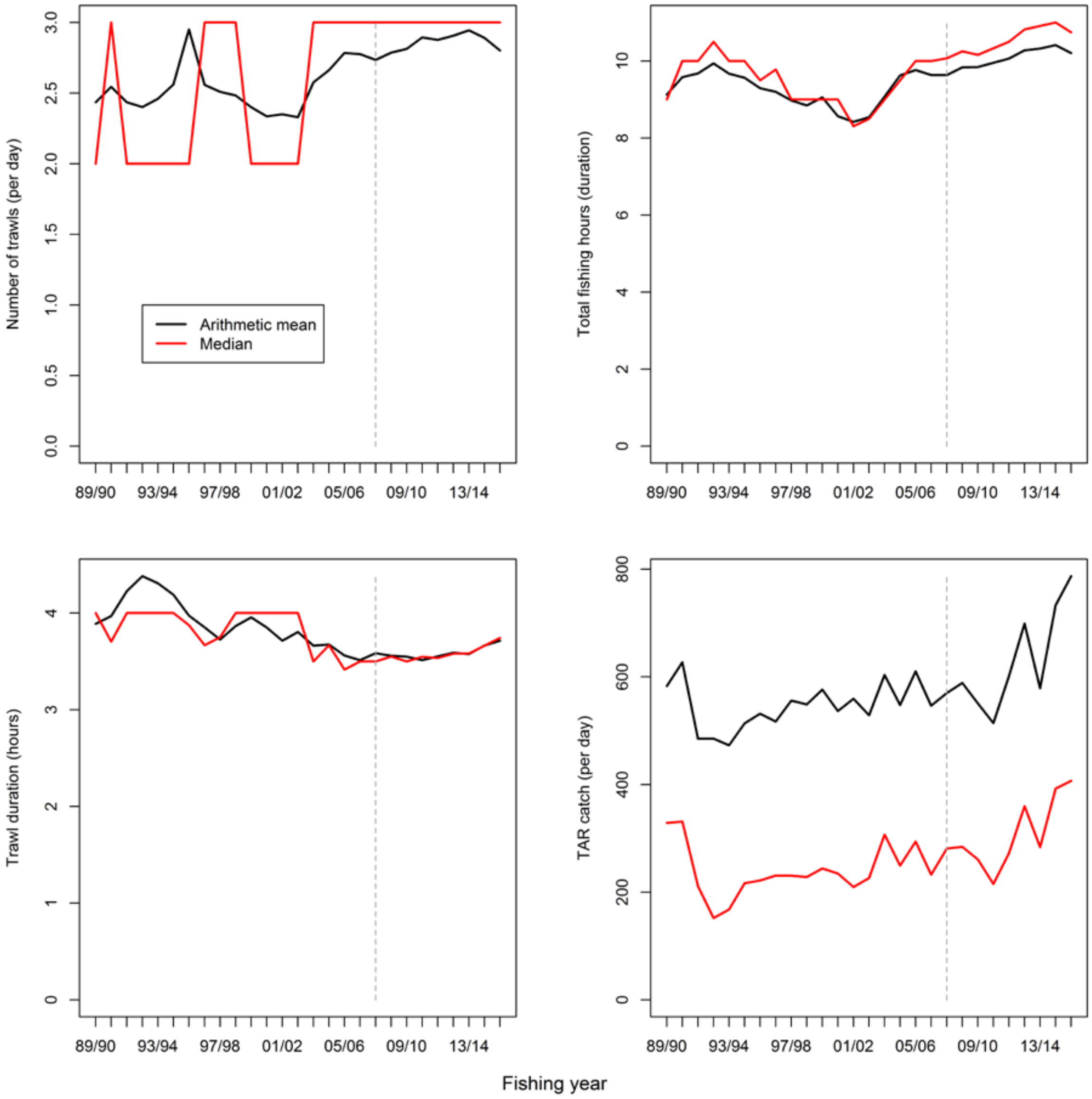

Figure 53: Annual trends in the main fishing effort metrics and tarakihi catch rates (average and median) for the TAR 2 core vessel data set. The dashed vertical line represents the year the TCER reporting form was introduced.

The fishing event records are dominated by trawls targeting tarakihi and red gurnard (Figure 54). During the 1990s, there was a considerable decline in trawls targeting gemfish (SKI) and the associated fishing effort remained low in subsequent years (Figure 54).

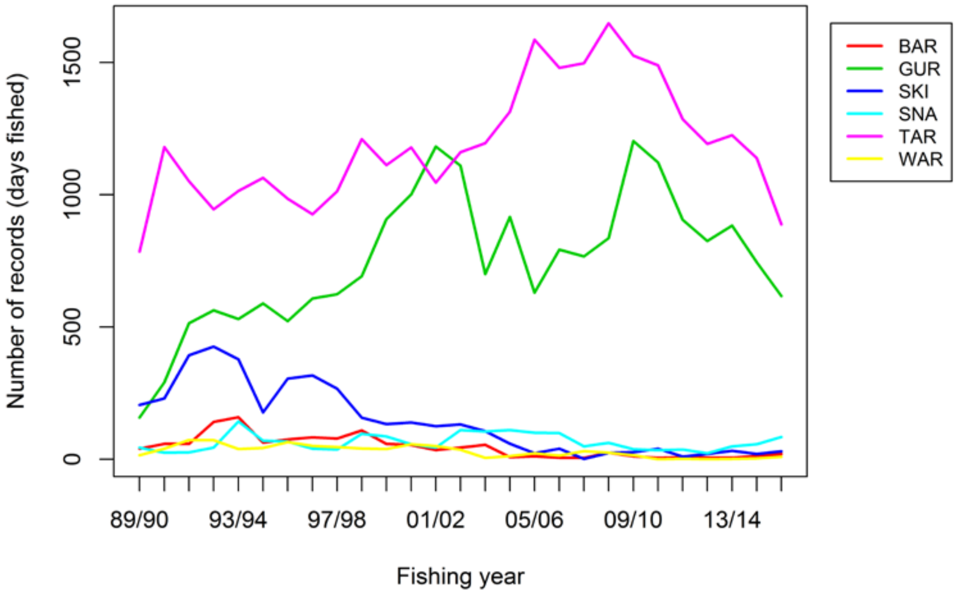

Figure 54: Annual distribution of daily fishing records by target species for the TAR 2 core vessel CPUE data set.

4.5.2 CPUE models

The positive catch CPUE model assumed a lognormal error structure following Starr & Kendrick (2014). The model included the predictor variables *FishingYear*, *TargetSpecies*, *Vessel*, natural logarithm of *Duration* and *StatArea* (Table 11). Overall, the model explained 54.6% of the variation in the positive catch of tarakihi (Nagelkerke pseudo-R^2), while the *FishingYear* variable accounted for a small proportion of the variation (0.5%). The distribution of the CPUE model residuals is generally consistent with the assumption of normality (Figure 55), although the mode of the distribution is slightly positively skewed, countering the tail of negative residuals (corresponding to observations with small catches, less than 2 kg).

Table 11: Summary of stepwise selection of variables in the TAR 2 positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	26	-110 412	220 880.8	0.005 *
TargetSpecies	5	-99 334	198 733.7	0.345 *
Vessel	65	-93 888	187 972.9	0.468 *
Duration	3	-90 332	180 865.3	0.535 *
StatArea	5	-89 709	179 629.5	0.546 *
NumTrawls	3	-89 494	179 205.9	0.550
Month	11	-89 320	178 879.6	0.553

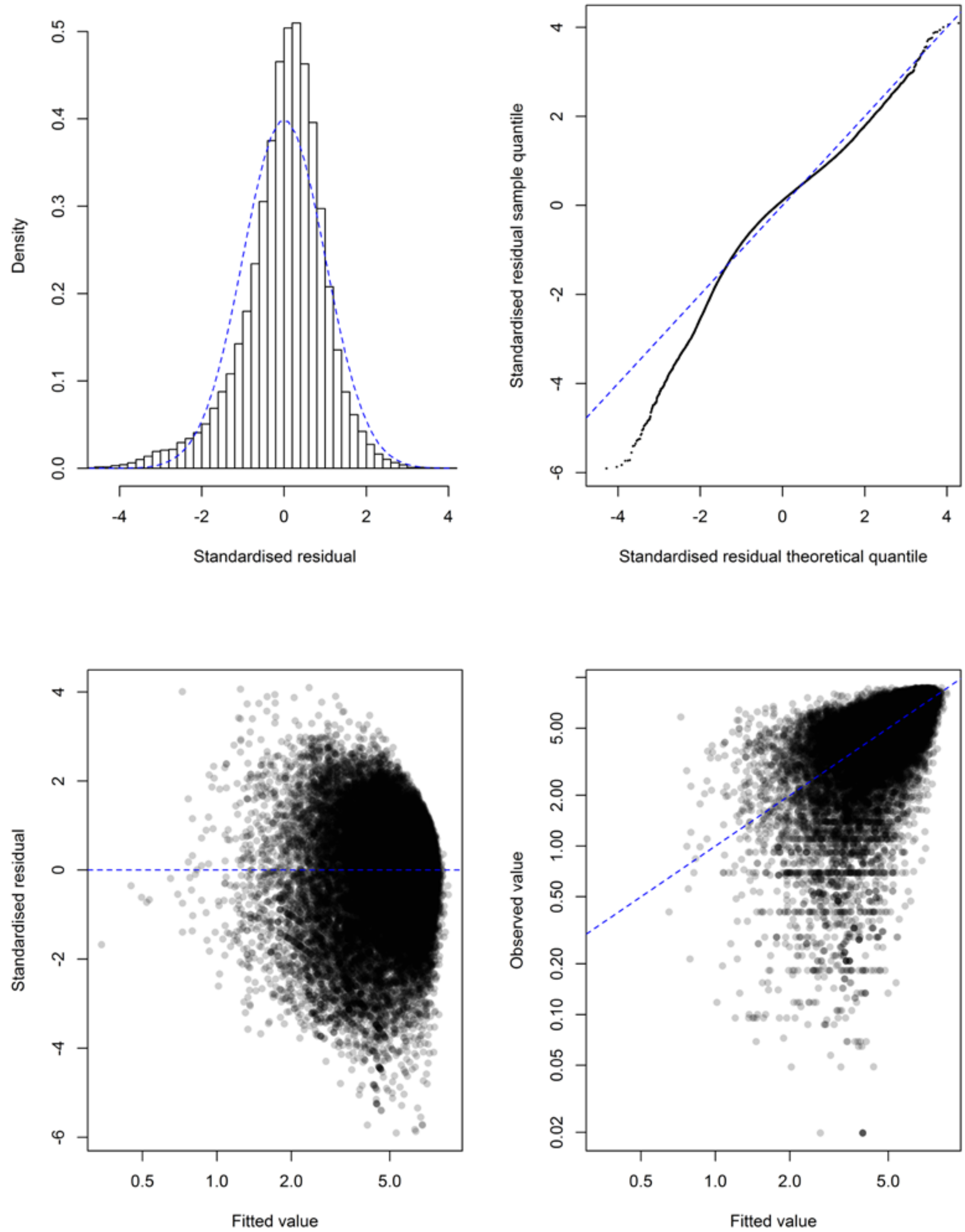

Figure 55: Residual diagnostics for the positive catch CPUE model for the TAR 2 trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

The annual indices derived from the positive catch CPUE model increased sharply during 1995/96–2001/02 and remaining at the higher level until 2003/04 (Figure 56). The index declined sharply in 2004/05 and continued to decline at a lower rate during 2004/05–2006/07. The indices fluctuated over the subsequent years and were at a relatively low level in 2010/11–2011/12 before increasing slightly over the four most recent years (Figure 56).

The *TargetSpecies*, *Vessel* and *Duration* variables were the most influential variables included in the CPUE model. The inclusion of all three factors resulted in considerable deviation in the standardised CPUE indices from the nominal CPUE, especially during 1998/99–2002/03 (Figure 56 and Figure 57). The increased targeting of red gurnard during the early 2000s contributed to the increase in the standardised CPUE indices during that period (Figure 57, Appendix 4 Figure A11). Similarly, there was an apparent shift towards more efficient vessels during 1998/99–2002/03 and a concurrent reduction in daily fishing duration that contributed to the increase in the standardized CPUE indices (Figure 57, Appendix 4 Figures A12 and A13). An examination of the residuals from the CPUE model revealed that the CPUE trends are generally comparable among individual Target Species and Statistical Areas (Appendix 4 Figures A14 and A15).

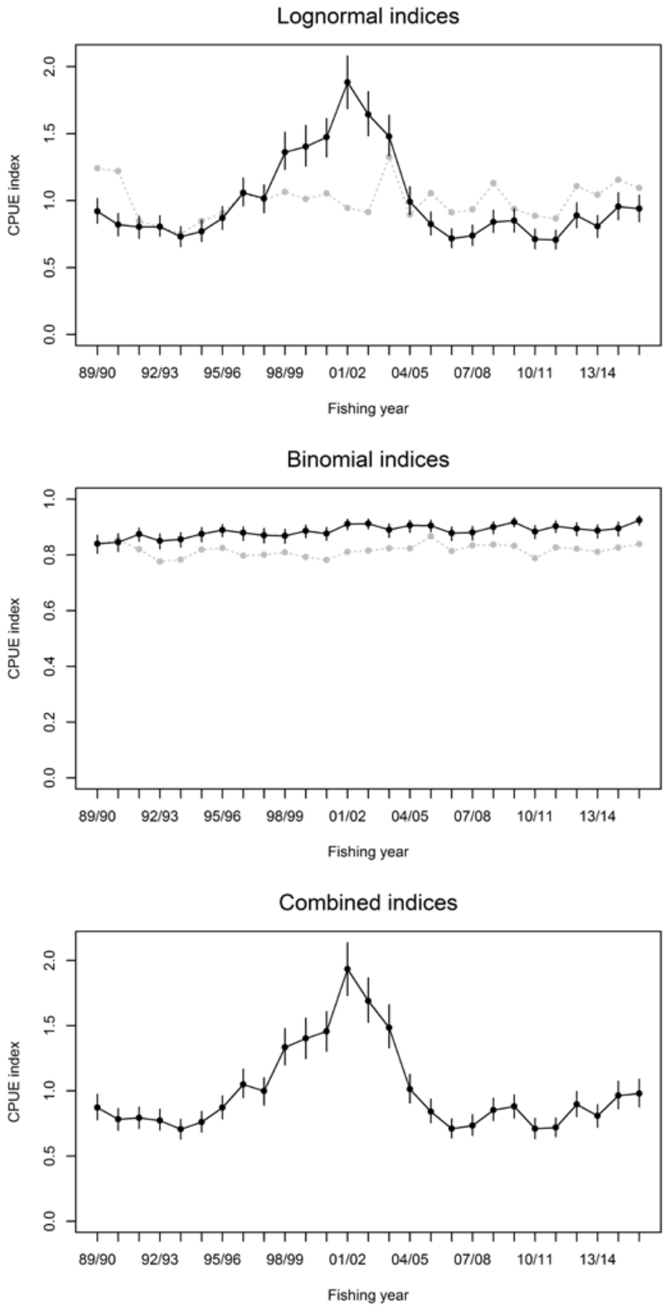

Figure 56: A comparison of the TAR 2 trawl standardised CPUE indices and the geometric mean of the annual catch per day (grey line) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records (grey line) in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A12 (Appendix 3).

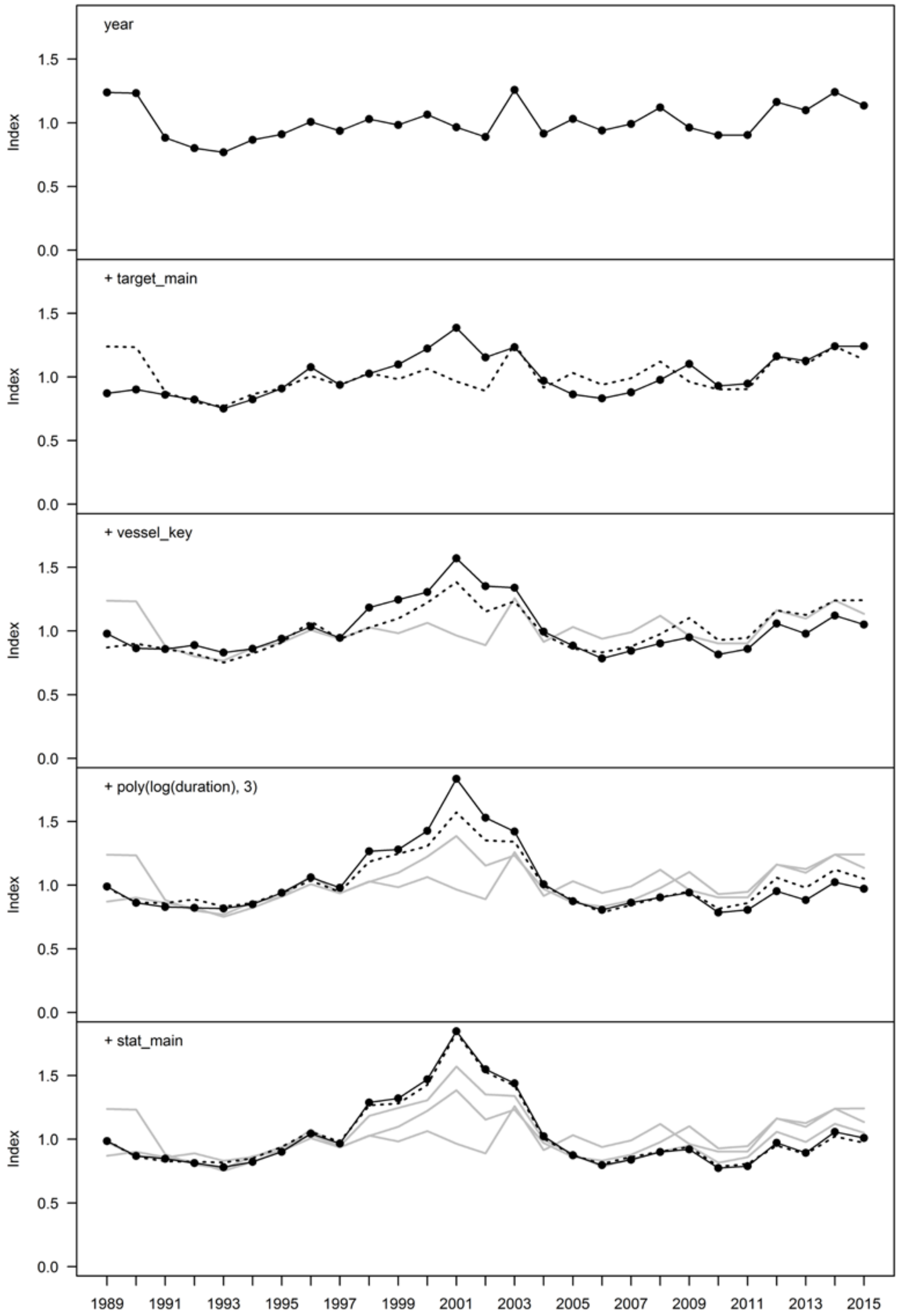

Figure 57: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the positive catch CPUE model for the TAR 2 trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1989 denotes the 1989/90 fishing year).

The occurrence of tarakihi in the TAR 2 trawl catch was predicted by the binomial model including the explanatory variables *FishingYear*, *TargetSpecies*, *Vessel*, *NumTrawls*, *StatArea* and *Month* (Table 12). The resulting annual indices derived from the binomial model are relatively constant throughout the time-series and are generally comparable to the annual proportion of positive catch records (Figure 56). Consequently, the trend in the combined CPUE indices is very similar to the positive catch CPUE indices (Figure 56, Appendix 3 Table A12).

Table 12: Summary of stepwise selection of variables in the TAR 2 tarakihi catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	26	-30 299	60 651.6	0.005 *
TargetSpecies	5	-22 933	45 930.1	0.337 *
Vessel	65	-22 055	44 304.3	0.372 *
NumTrawls	3	-21 714	43 627.1	0.385 *
StatArea	5	-21 583	43 375.1	0.390 *
Month	11	-21 473	43 177.2	0.395 *
Duration	3	-21 441	43 120.3	0.396

4.6 TAR 3 single trawl CPUE *TAR3_BT_MIX*

The TAR 3 trawl CPUE analysis was based on the CELR format (i.e. daily aggregated) catch and effort data for the inshore bottom trawl fishery targeting the suite of inshore species within Statistical Areas 017, 018, 020, 022, 024 and 026 (Figure 1). Preliminary CPUE modelling of the TAR 3 single trawl data set replicated the CPUE indices derived by Starr & Kendrick (2014).

For TAR 3, event based fishing effort records (TCER) were available from 2007/08. Comparative CPUE models formulated from the two data formats (event based and CELR) yielded similar annual CPUE indices for the corresponding period (2007/08–2015/16). The final CPUE model was based on the CELR format data set from 1989/90–2015/16.

4.6.1 Data set

The definition of the TAR3_BT_MIX data set is specified in Table 4. The core fleet, defined based on continuity criteria of a minimum annual catch of 1000 kg in at least six years, accounted for 88% of the total tarakihi catch included in the CELR format data set. The criteria resulted in the selection of 74 unique vessels including 23 vessels that operated in the fishery for at least 20 years (Figure 58). Approximately half of the tarakihi catch included in the core vessels data set was taken by 15 vessels.

The number of vessels included in the core fleet reached a peak in the mid-1990s and steadily declined during the late 1990s and early 2000s with a corresponding trend in the number of fishing days (records) (Figure 59). The number of vessels operating in the trawl fishery and the associated fishing effort remained relatively stable over the last decade. The annual catch of tarakihi by the core fleet increased during the 1990s and fluctuated over the subsequent years (Figure 59, Appendix 2 Table A7).

Almost all of the tarakihi catch was allocated to the daily aggregated fishing effort records based on the distribution of the estimated catch within individual fishing trips (Figure 59). Prior to 2004/05, a relatively high proportion (40–50%) of the positive catch records were allocated based on the distribution of fishing events amongst trips (i.e. those trips with a landed catch of tarakihi but no estimated catches of tarakihi), rather than based on estimated catch. The proportion of trips that caught tarakihi without recording an estimated catch declined in subsequent years corresponding to the increase in targeting of tarakihi. The tarakihi catches allocated based on effort distribution were generally small (median 8 kg). Over the study period, there was a relatively constant proportion of records (generally 17–23%) with no allocated catch of tarakihi; i.e. fishing days with no estimated catch of tarakihi or fishing days from trips with no landed catch of tarakihi (Figure 59, Appendix 2 Table A7).

The number of trawls conducted per fishing day remained relatively stable throughout the study period (Figure 60). The average trawl duration and the total fishing duration increased during the late 1990s–early 2000s and subsequently declined during the last decade. There was no appreciable change in the main fishing effort metrics associated with the introduction of the TCER reporting form in 2007/08 (Figure 60). The average daily catch of tarakihi increased steadily during 1989/90–2010/11 and increased again in 2015/16 (Figure 60).

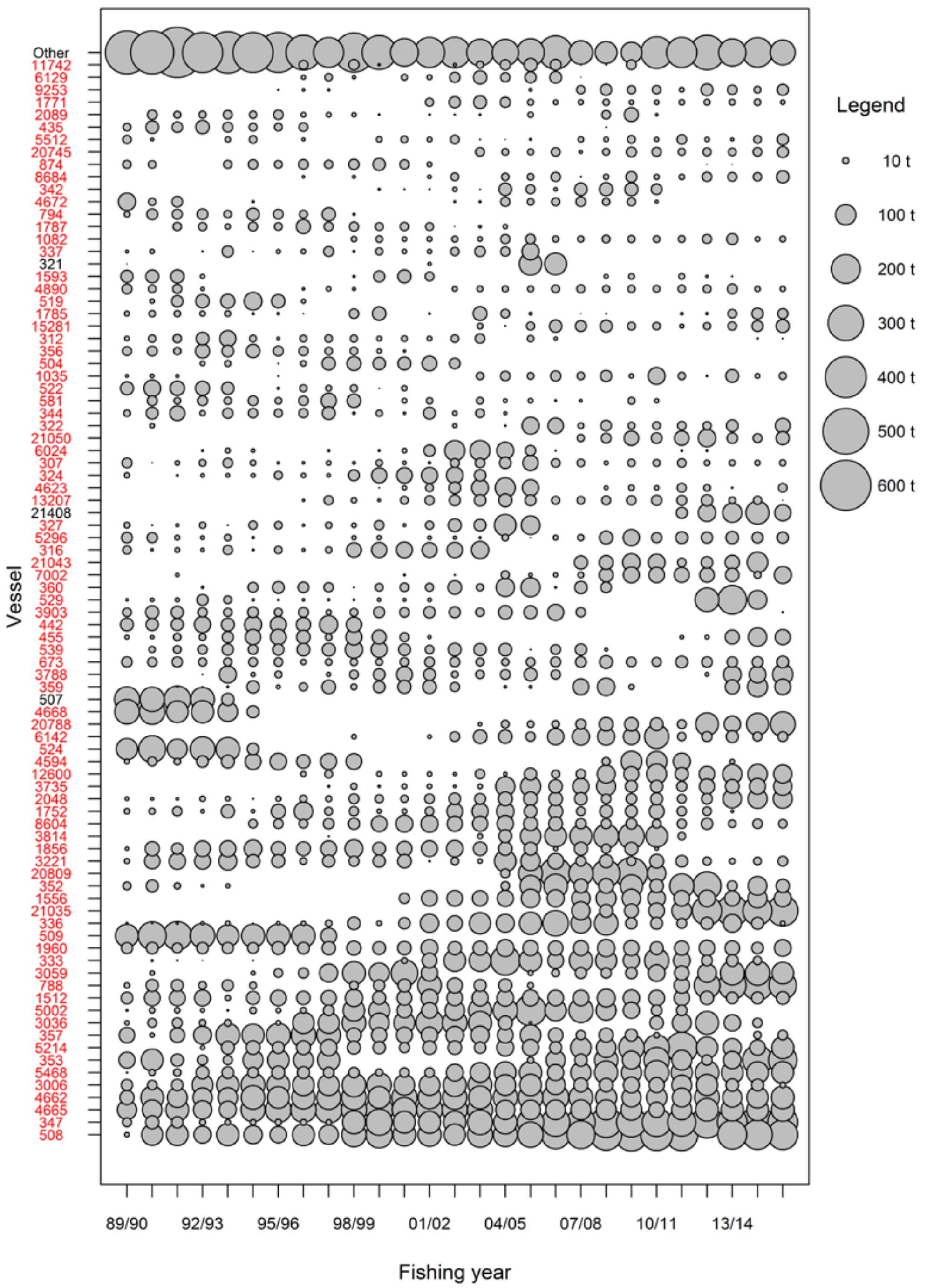

Figure 58: Distribution of tarakihi TAR 3 trawl catch by year and fishing vessel. The core fleet included in the final CPUE data set are highlighted in red.

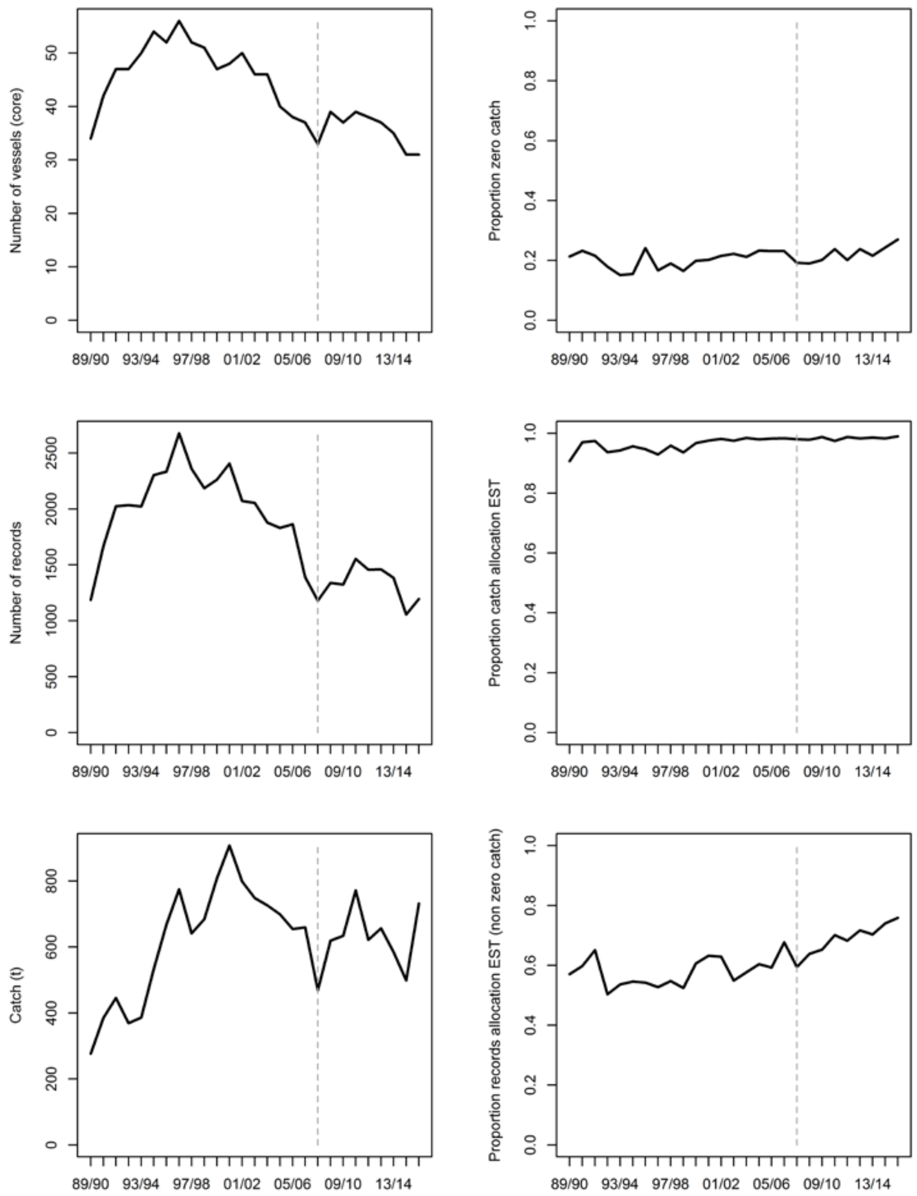

Figure 59: A summary of the data included in the TAR 3 core vessel data set by fishing year, including the proportion of the catch and effort records with tarakihi catches allocated based on the distribution of estimated tarakihi catch (rather than fishing effort). The dashed vertical line represents the year the TCER reporting form was introduced.

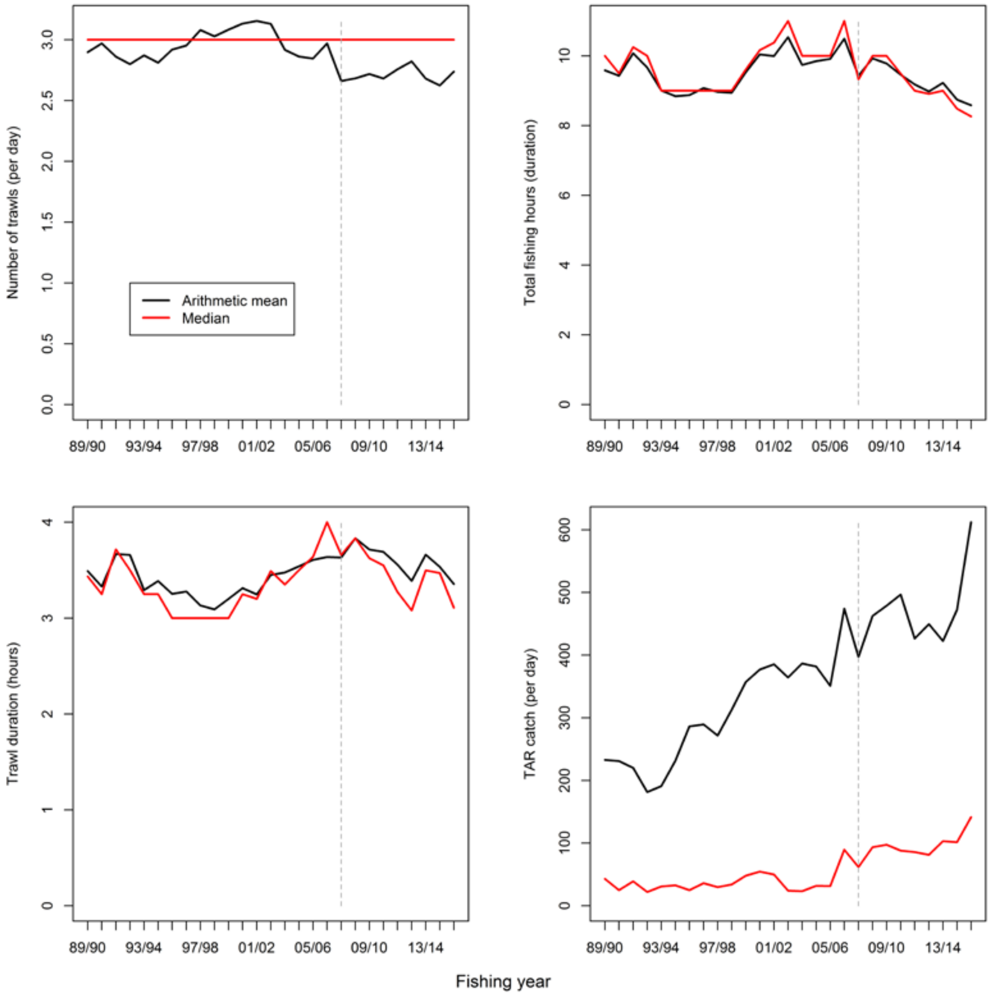

Figure 60: Annual trends in the main fishing effort metrics and tarakihi catch rates (average and median) for the TAR 3 core vessel data set. The dashed vertical line represents the year the TCER reporting form was introduced.

The fishing event records are dominated by trawls targeting red cod, barracouta and tarakihi (Figure 61). During the 1990s and early 2000s, fishing effort was dominated by the red cod target fishery and, to a lesser extent, the barracouta fishery. Fishing effort in both fisheries declined considerably during the late 1990s and early 2000s. From the early 2000s, there was an increase in the level of fishing effort targeting tarakihi and the fishery accounted for approximately 40% of the annual effort from 2008/09 (Figure 61).

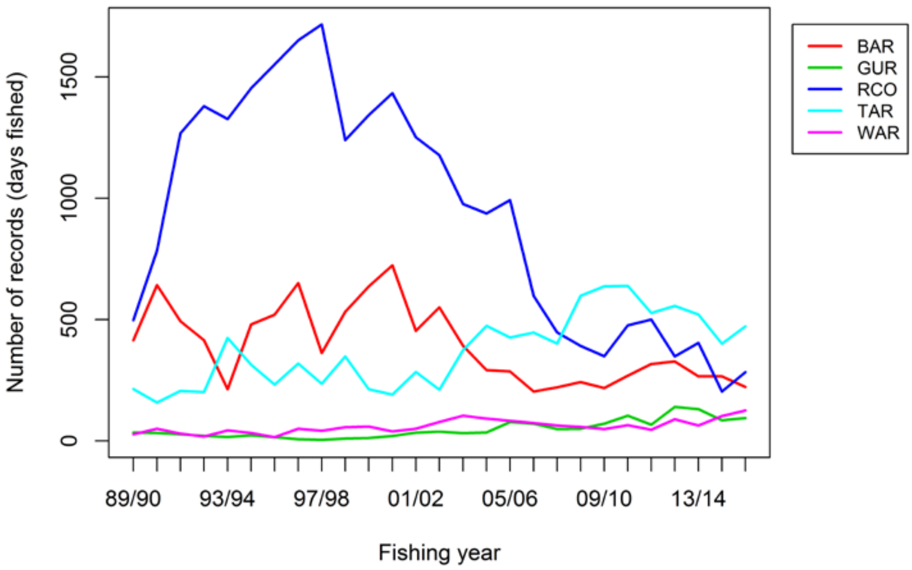

Figure 61: Annual distribution of daily fishing records by target species for the TAR 3 core vessel trawl CPUE data set.

4.6.2 CPUE models

The positive catch CPUE model assumed a lognormal error structure following Starr & Kendrick (2014). The model included the predictor variables *FishingYear*, *TargetSpecies*, *Vessel*, natural logarithm of *Duration*, *Month* and *StatArea* and the interaction between *Month* and *StatArea* (Table 13). Overall, the model explained 37.3% of the variation in the positive catch of tarakihi (Nagelkerke pseudo-R^2), while the *FishingYear* variable accounted for a small proportion of the variation (2.9%). The distribution of the CPUE model residuals is consistent with the assumption of normality (Figure 62).

Table 13: Summary of stepwise selection of variables in the TAR 3 positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (% Improvement)
FishingYear	26	-87 774	175 604.2	0.029 *
TargetSpecies	4	-84 183	168 430.0	0.196 *
Vessel	73	-82 008	164 226.1	0.283 *
Duration	3	-80 919	162 054.6	0.323 *
Month	11	-80 385	161 008.8	0.341 *
StatArea	4	-79 919	160 084.9	0.357 *
Month:StatArea	44	-79 466	159 271.0	0.373 *
NumTrawls	3	-79 915	160 081.4	0.357

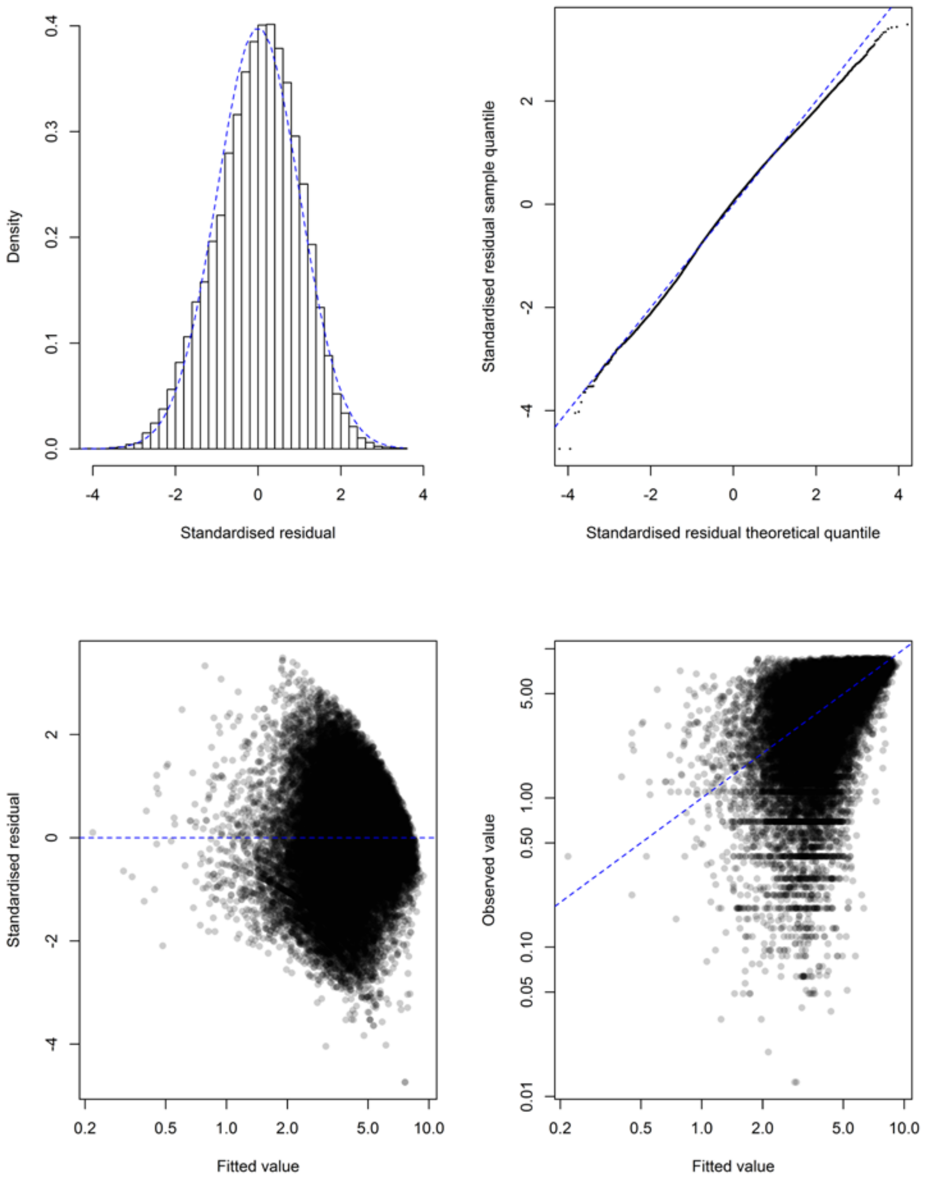

Figure 62: Residual diagnostics for the positive catch CPUE model for the TAR 3 trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

The annual indices derived from the positive catch CPUE model fluctuated over the study period with periods of higher CPUE occurring at approximately 4–5 year intervals, specifically in 1990/91–1991/92, 1995/96–1997/98, 1999/2000–2001/02, 2006/07, 2010/11 and 2013/14–2015/16 (Figure 63).

The *TargetSpecies, Vessel* and *Duration* variables were the most influential variables included in the CPUE model. The inclusion of all three factors resulted in considerable deviation in the standardised CPUE indices from the nominal CPUE from 2002/03 onwards (Figure 63 and Figure 64). The increased targeting of tarakihi during the 2000s moderated the standardised CPUE indices during that period (Figure 64, Appendix 4 Figure A16). Similarly, there was an apparent shift towards more efficient vessels during the early 2000s and a small increase in daily fishing duration at that time (Figure 64, Appendix 4 Figures A17 and A18). Collectively, the inclusion of these three variables in the CPUE model accounted for most of the large increase in nominal CPUE from the early 2000s.

An examination of the residuals from the CPUE model revealed that the CPUE trends are generally comparable among three main target fisheries (tarakihi, barracouta and red cod) (Appendix 4 Figure A19), while CPUE indices are more variable for the red gurnard and blue warehou fisheries. Limited data are available from these two fisheries and, hence, the trends in the residuals are not considered to be indicative of trends in tarakihi abundance.

A high (45%) proportion of the core vessel effort records are from Statistical Area 022 and the overall CPUE indices are comparable to the trends in CPUE from that Statistical Area (Appendix 4 Figure A20). In general, the CPUE trends from Statistical Areas 017, 018 and 020 are also comparable with the overall indices, although there is some variability in the periods of higher CPUE (generally ± 1 year) (Appendix 4 Figure A20).

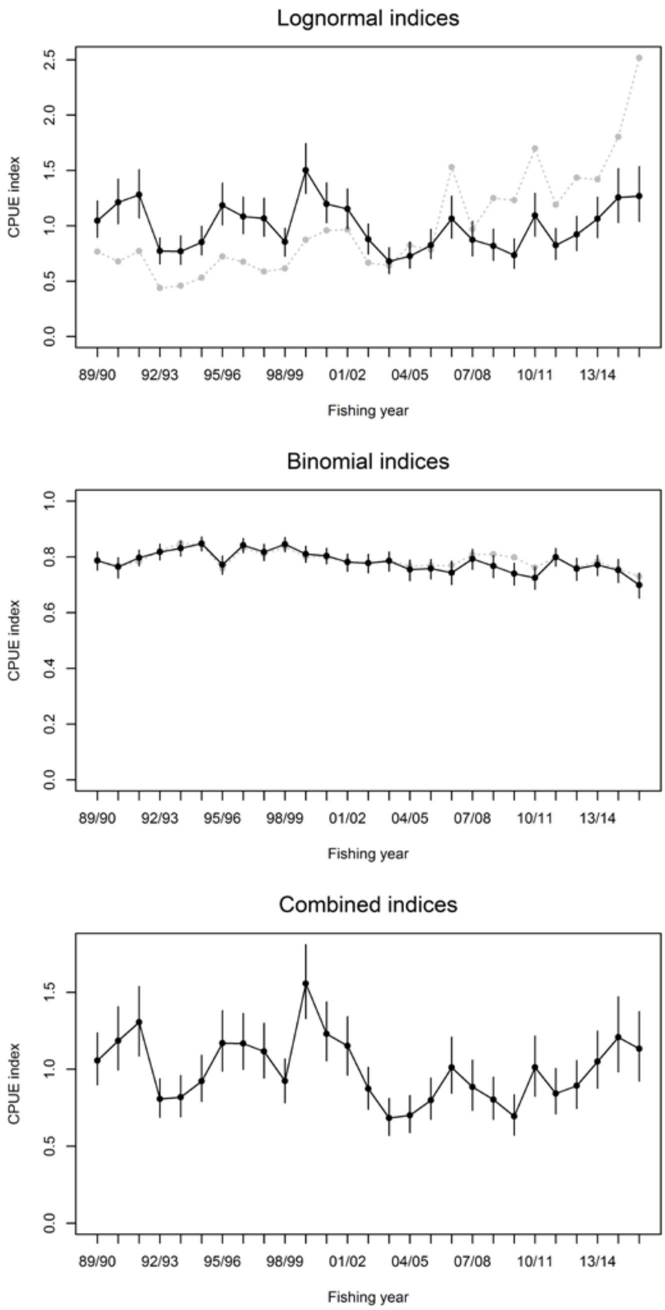

Figure 63: A comparison of the TAR 3 trawl standardised CPUE indices and the geometric mean of the annual catch per day (grey line) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records (grey line) in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A13 (Appendix 3).

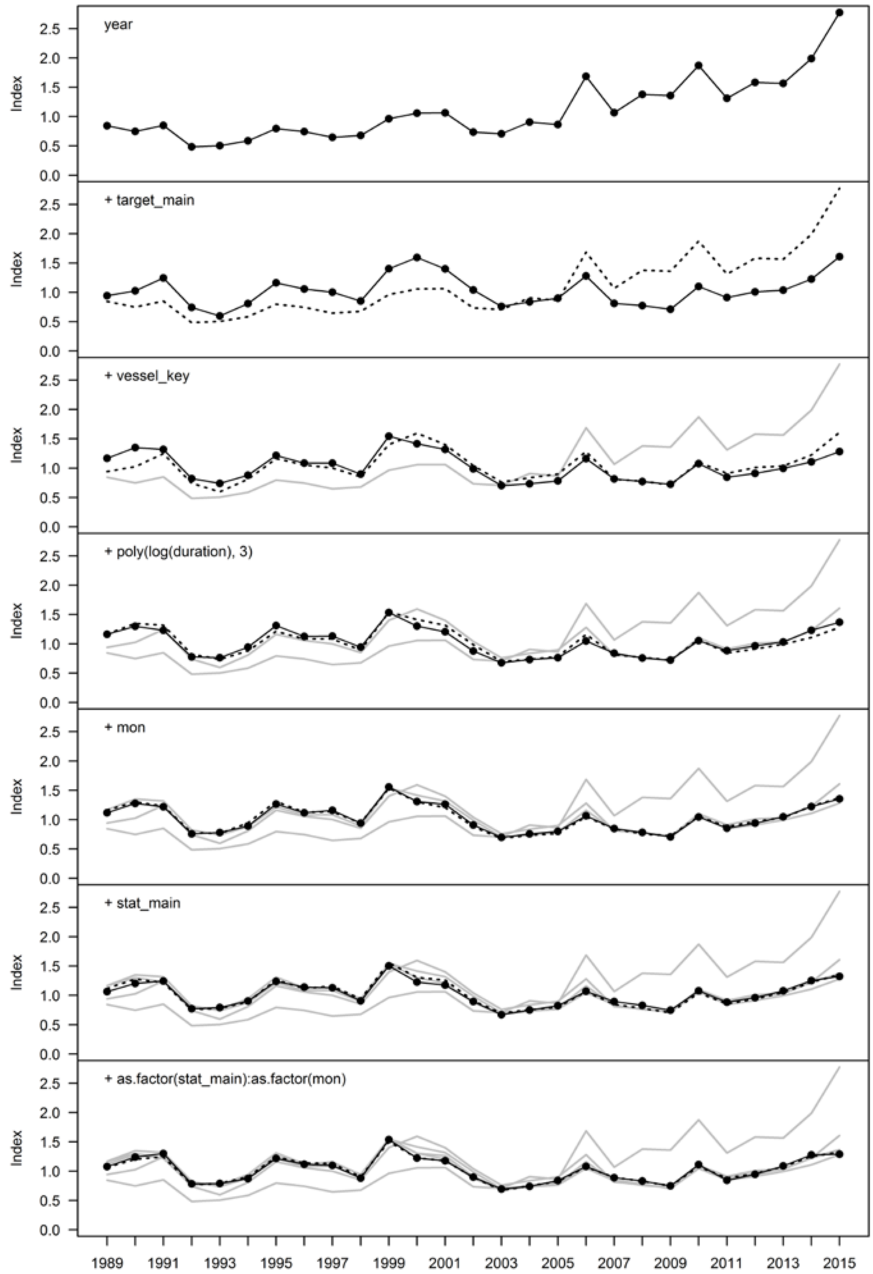

Figure 64: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the positive catch CPUE model for the TAR 3 trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1989 denotes the 1989/90 fishing year).

The occurrence of tarakihi in the TAR 3 trawl catch was predicted by the binomial model including the explanatory variables *FishingYear*, *TargetSpecies*, *Vessel*, *Duration*, and *Month,StatArea* interaction (Table 14). The resulting annual indices derived from the binomial model are relatively constant throughout the time-series and are generally comparable to the annual proportion of positive catch records (Figure 63). Consequently, the trend in the combined CPUE indices is very similar to the positive catch CPUE indices (Appendix 3 Table A13).

Table 14: Summary of stepwise selection of variables in the TAR 3 tarakihi catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	**DF**	**Log likelihood**	**AIC**	**Nagelkerke pseudo-R^2 (% Improvement)**
FishingYear	26	-24 515	49 083.5	0.008 *
TargetSpecies	4	-23 243	46 548.4	0.088 *
Vessel	73	-22 413	45 034.2	0.138 *
Duration	3	-22 285	44 784.3	0.145 *
StatArea	4	-22 238	44 697.4	0.148 *
Month:StatArea	44	-22 132	44 595.1	0.154 *
Month	11	-22 195	44 633.5	0.150

4.7 TAR 3 set net CPUE *TAR3_SN_TAR*

The TAR 3 set net CPUE analysis was based on the CELR format catch and effort data for the target set net fishery within Statistical Area 018 (Figure 1). Preliminary CPUE modelling of the TAR 3 set net fishery replicated the CPUE indices derived by Starr & Kendrick (2014).

For TAR 3 set net, event based fishing effort records (NCER) were available from 2006/07. For this fishery, the NCER form provided limited additional information compared to the CELR format data and, hence, no additional CPUE analysis was conducted using the event based data.

4.7.1 Data set

The definition of the TAR3_SN_TAR data set is specified in Table 4. The core fleet, defined based on continuity criteria of a minimum annual catch of 1000 kg in at least six years, accounted for 91% of the total tarakihi catch included in the CELR format data set. The criteria resulted in the selection of 10 unique vessels including five vessels that operated in the fishery for at least 15 years (Figure 65). Approximately half of the tarakihi catch included in the core vessels data set was taken by four vessels.

A relatively small number of core vessels operated in the fishery each year (Figure 66). Since 2006/07, two vessels retired from the fishery and there were only 3–4 vessels operating in the fishery in the last few years. There was a corresponding decline in the number of days fished (effort records) and a general decline in the annual catch of tarakihi from the fishery (Figure 66, Appendix 2 Table A8).

Almost all fishing days recorded an associated estimated catch of tarakihi and, hence, there was a negligible number of zero catch records and landed catches were allocated almost exclusively based on the associated estimated catches from the trip (Figure 66).

The fishing operation typically sets 3–7 nets in the morning and recovers the nets the following day. Each net is about 150–300 m in length, representing a total of 1500–2000 m of net set per day (Figure 67). There was an increase in fishing duration (soak time) that occurred at about the time the NCER forms were introduced (2006/07) which may indicate a change in the reporting of this variable (Figure 67). Consequently, fishing duration was not included in the range of potential explanatory variables in the CPUE model. Tarakihi catch rates (catch per day) fluctuated over the study period with higher catch rates occurring in 1990/91–1991/92, 2001/02–2002/03 and 2011/12 (Figure 67).

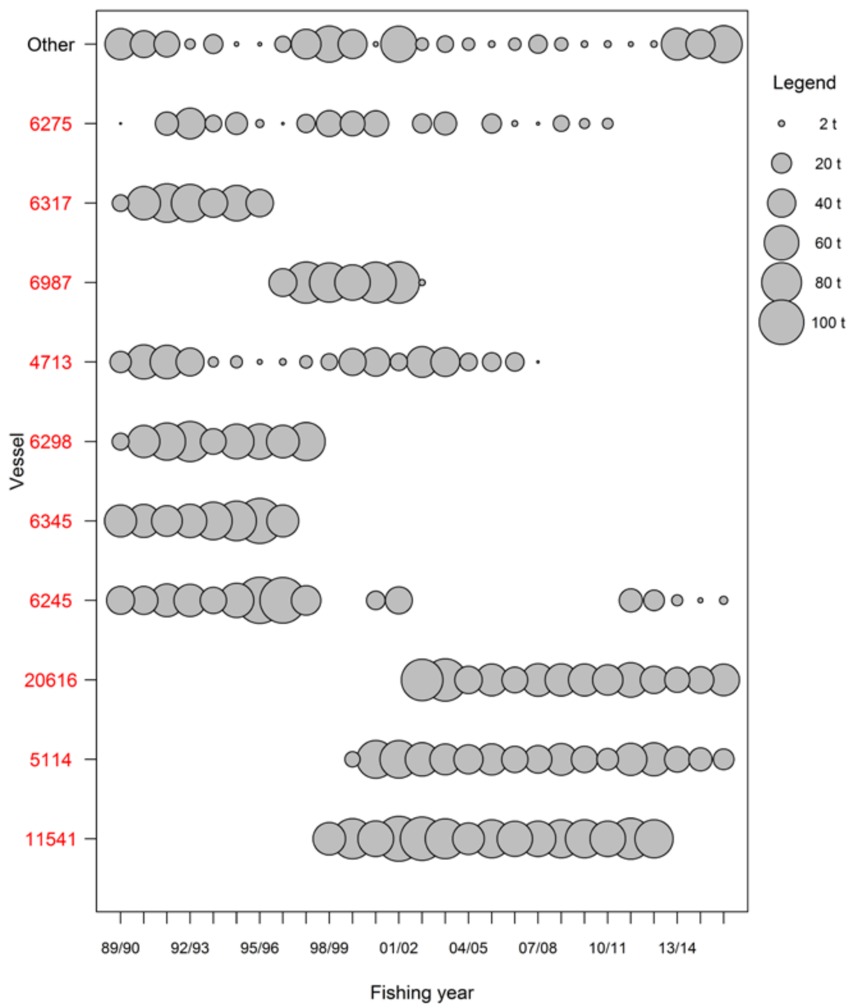

Figure 65: Distribution of tarakihi TAR 3 set net catch by year and fishing vessel. The core fleet included in the final CPUE data set are highlighted in red.

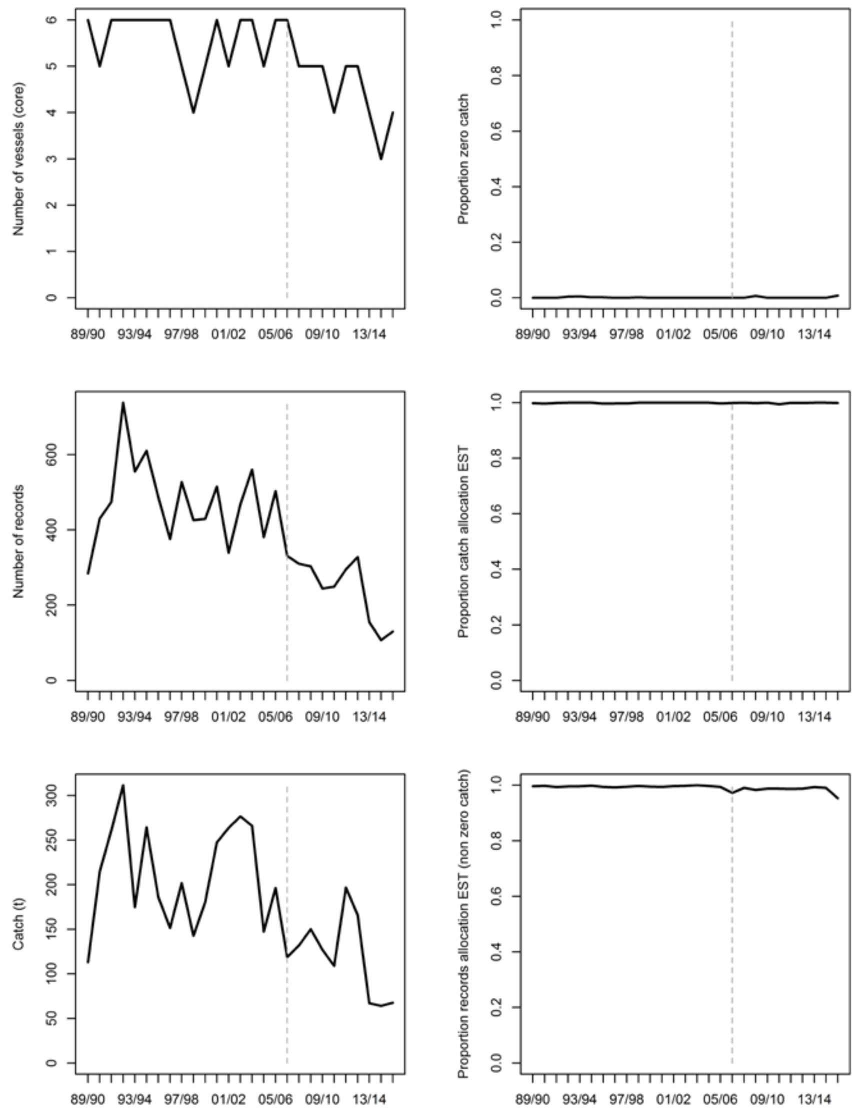

Figure 66: A summary of the data included in the TAR 3 set net core vessel data set by fishing year, including the proportion of the catch and effort records with tarakihi catches allocated based on the distribution of estimated tarakihi catch (rather than fishing effort). The dashed vertical line represents the year the NCER reporting form was introduced.

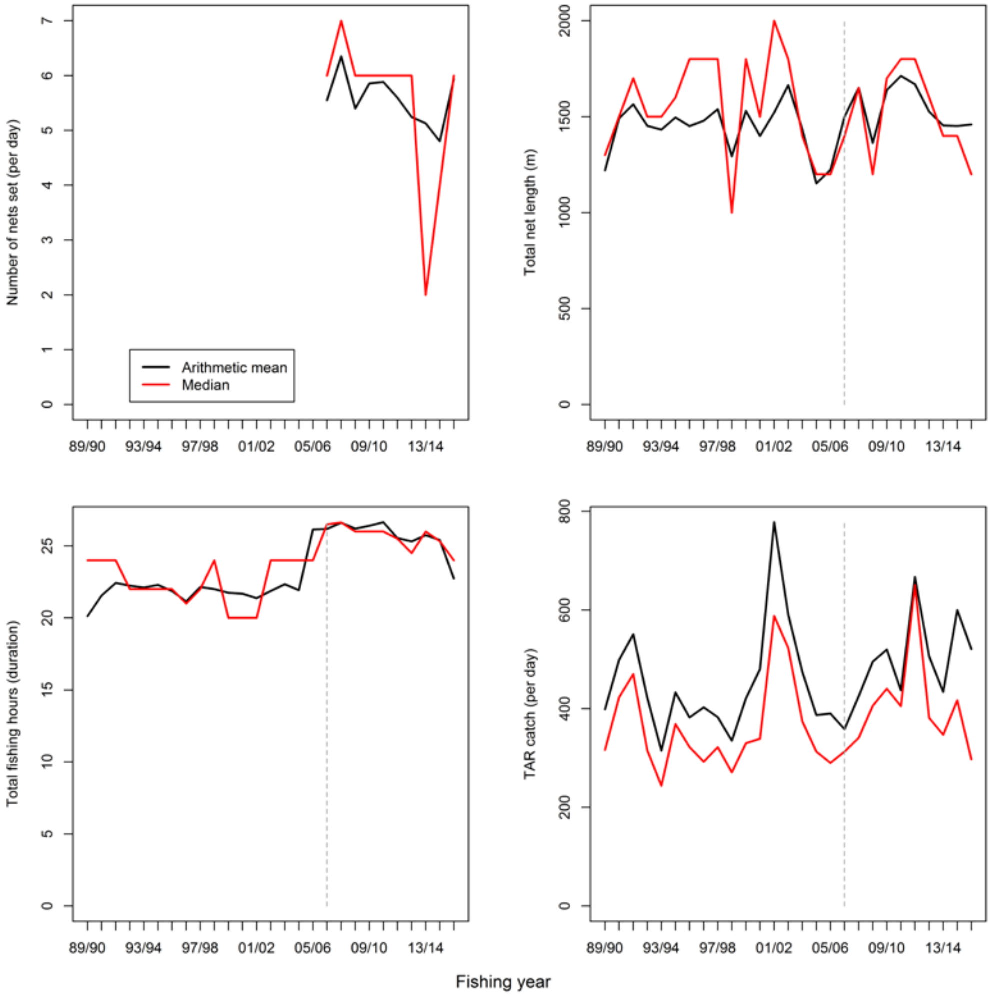

Figure 67: Annual trends in the main fishing effort metrics and tarakihi catch rates (average and median) for the TAR 3 set net core vessel data set. The dashed vertical line represents the year the NCER reporting form was introduced.

4.7.2 CPUE model

Given the negligible number of zero catch records, CPUE modelling was limited to the positive catch component only. The CPUE model assumed a lognormal error structure following Starr & Kendrick (2014). The model included all four potential predictor variables: *FishingYear*, *Vessel*, *Month* and the natural logarithm of *NetLength* (Table 15). Overall, the model explained 37.5% of the variation in the positive catch of tarakihi (Nagelkerke pseudo-R^2), while the *FishingYear* variable accounted for a small proportion of the variation (3.7%). The distribution of the CPUE model residuals is generally consistent with the assumption of normality (Figure 68) although the distribution is skewed by the long tail of negative residuals that correspond to small catch (< 10 kg) observations .

Table 15: Summary of stepwise selection of variables in the TAR 3 set net positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2 (%	
FishingYear	26	-16 414	32 884.4	0.037	*
Vessel	10	-15 770	31 615.3	0.153	*
Month	10	-15 005	30 107.0	0.273	*
NetLength	3	-14 262	28 626.3	0.375	*

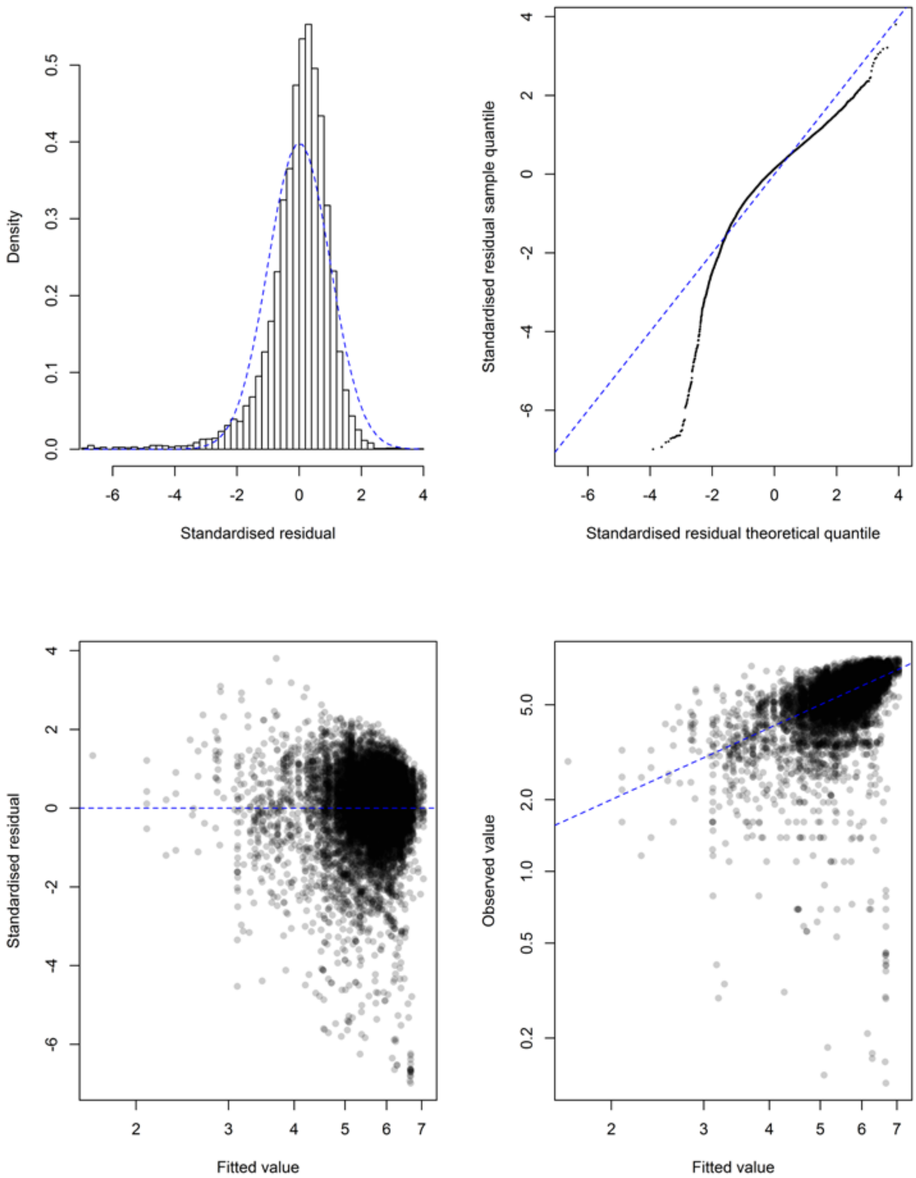

Figure 68: Residual diagnostics for the positive catch CPUE model for the TAR 3 set net fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

The annual indices derived from the positive catch CPUE model generally declined over the study, although the decline is moderated by short periods of higher CPUE (in 1989/90–1991/92, 2000/2001–2001/02, and 2011/12) (Figure 69).

The *Vessel* and *Month* variables were the most influential variables included in the CPUE model (Figure 70). The model estimates that the fleet has become increasingly dominated by the more efficient vessels (Appendix 4 Figure A21), while fishing has become more concentrated during the peak fishing seasons (January and May) (Appendix 4 Figure A22). The inclusion of these two variables in the CPUE model resulted in a declining trend in the CPUE indices relative to the nominal catch rate from the fishery (Figure 69).

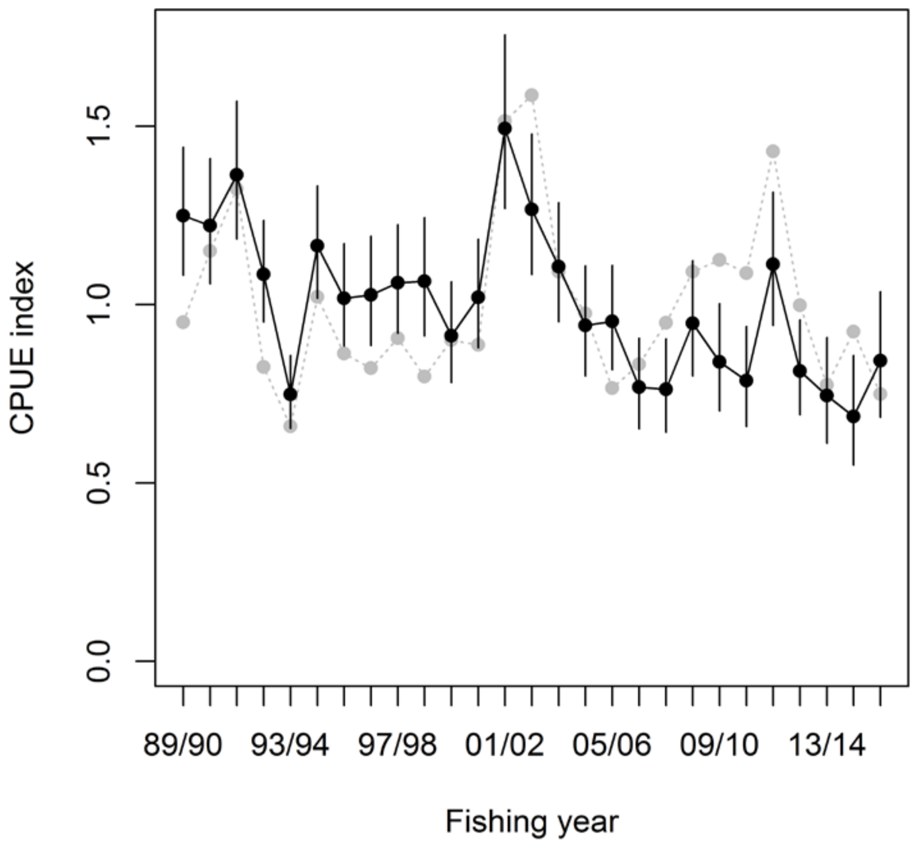

Figure 69: A comparison of the TAR 3 set net standardised CPUE indices and the geometric mean of the annual catch per day (grey line). The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A14 (Appendix 3).

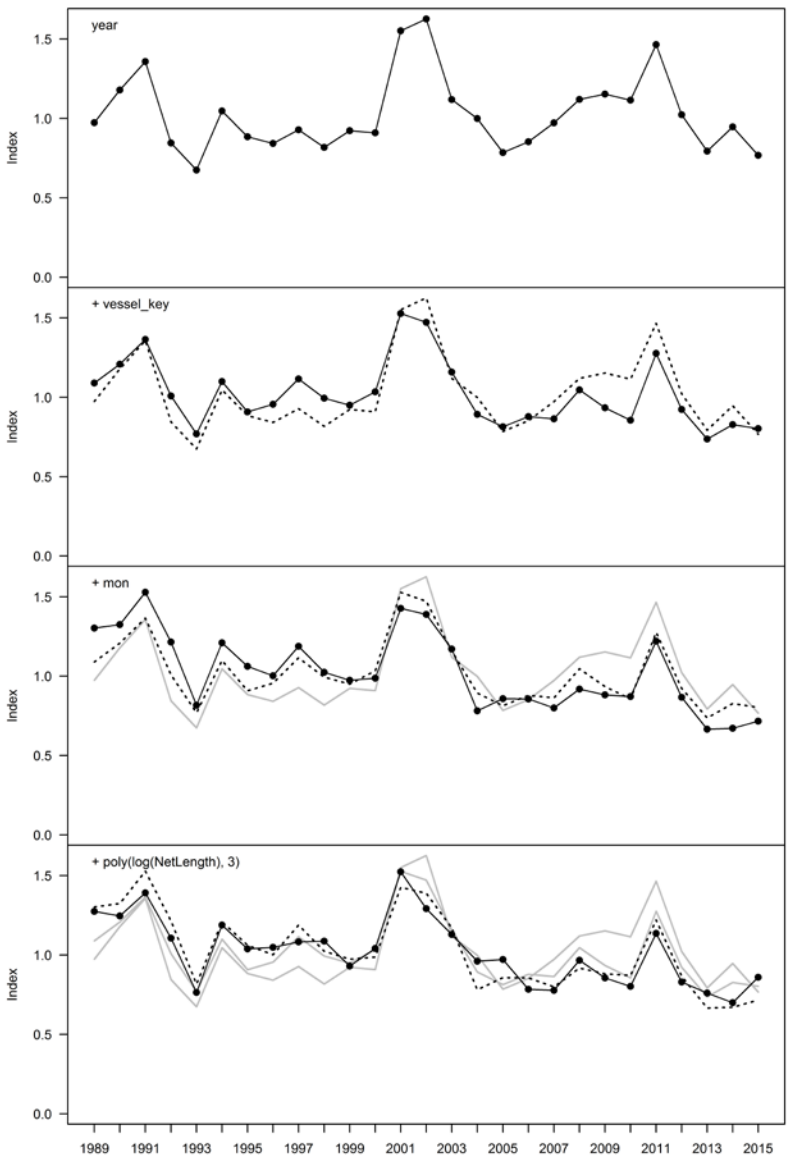

Figure 70: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the positive catch CPUE model for the TAR 3 set net fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1989 denotes the 1989/90 fishing year).

4.8 Comparative CPUE trends

The BPLE_BT_MIX and TAR2_BT_MIX CPUE indices both reveal a strong peak in the annual CPUE indices during 2000/01–2004/05 (Figure 71). There is a short lag between the two sets of indices during this period; the increase in TAR2_BT_MIX CPUE indices precedes the BPLE_BT_MIX by one year, while the higher level of CPUE indices from BPLE_BT_MIX was maintained for a further year.

For some of the other sets of CPUE indices, there are periods of higher CPUE that generally coincide with the peak in the BPLE_BT_MIX and TAR2_BT_MIX CPUE indices, although the magnitude of the increase is less pronounced. For the ENLD_BT_TAR CPUE indices, there is a period of higher CPUE during 2001/02–2005/06 that lags the BPLE_BT_MIX peak by one year (Figure 71), while there is a peak in the TAR3_SN_TAR CPUE indices during 2001/02–2003/04. There is a preceding peak in the TAR3_BT_MIX CPUE indices during 1999/2000–2001/02. There was no indication of a corresponding peak in the WCNI_BT_MIX CPUE indices.

There are other similarities between the BPLE_BT_MIX and ENLD_BT_TAR CPUE indices. Both sets of indices reveal a peak during 1995/96–1997/98, although the peak is more pronounced in the ENLD_BT_TAR series. Further, the two sets of indices declined by a similar magnitude during 2005/06–2014/15 (Figure 71). These two trends were not apparent in the time-series of TAR2_BT_MIX CPUE indices. In contrast, there is a slight increase in the most recent TAR2_BT_MIX CPUE indices (during 2011/12–2015/16). This increase has followed an increase in the TAR3_BT_MIX CPUE indices during 2009/2010–2015/16 (Figure 71).

Correlation coefficients were derived amongst the six sets of CPUE indices lagged by annual intervals of up to five years. The lag period that yielded the highest positive correlation between two sets of CPUE indices was selected (Table 16). All selected correlations were significant (at 5% threshold), although none of the correlations are considered to be strong (i.e. corr. coef. exceeding 0.70) and, hence, limited conclusions can be drawn from these results.

Nonetheless, it is worth noting that the best correlation between the TAR3_BT_MIX CPUE indices and the CPUE indices from the other fisheries occurred when the indices were lagged between 2–5 years (Table 16 and Figure 71). The highest correlations between the BPLE_BT_MIX and TAR2_BT_MIX and between the BPLE_BT_MIX and ENLD_BT_TAR CPUE indices were evident when there was no lag between the individual sets of CPUE indices.

The best correlation between TAR2_BT_MIX and ENLD_BT_TAR CPUE occurred when the latter series was lagged by 5 years (Table 16). This result appears to be somewhat spurious and is due to the higher CPUE indices earlier in the ENLD_BT_MIX time series being correlated with the large peak in the TAR2_BT_MIX indices (during 2000/01–2004/05). Similarly, the 5 year lag between the ENLD_BT_TAR and WCNI_BT_MIX CPUE indices appears to be strongly influenced by the high 1998/99 CPUE index from the WCNI_BT_MIX time series (Table 16 and Figure 71).

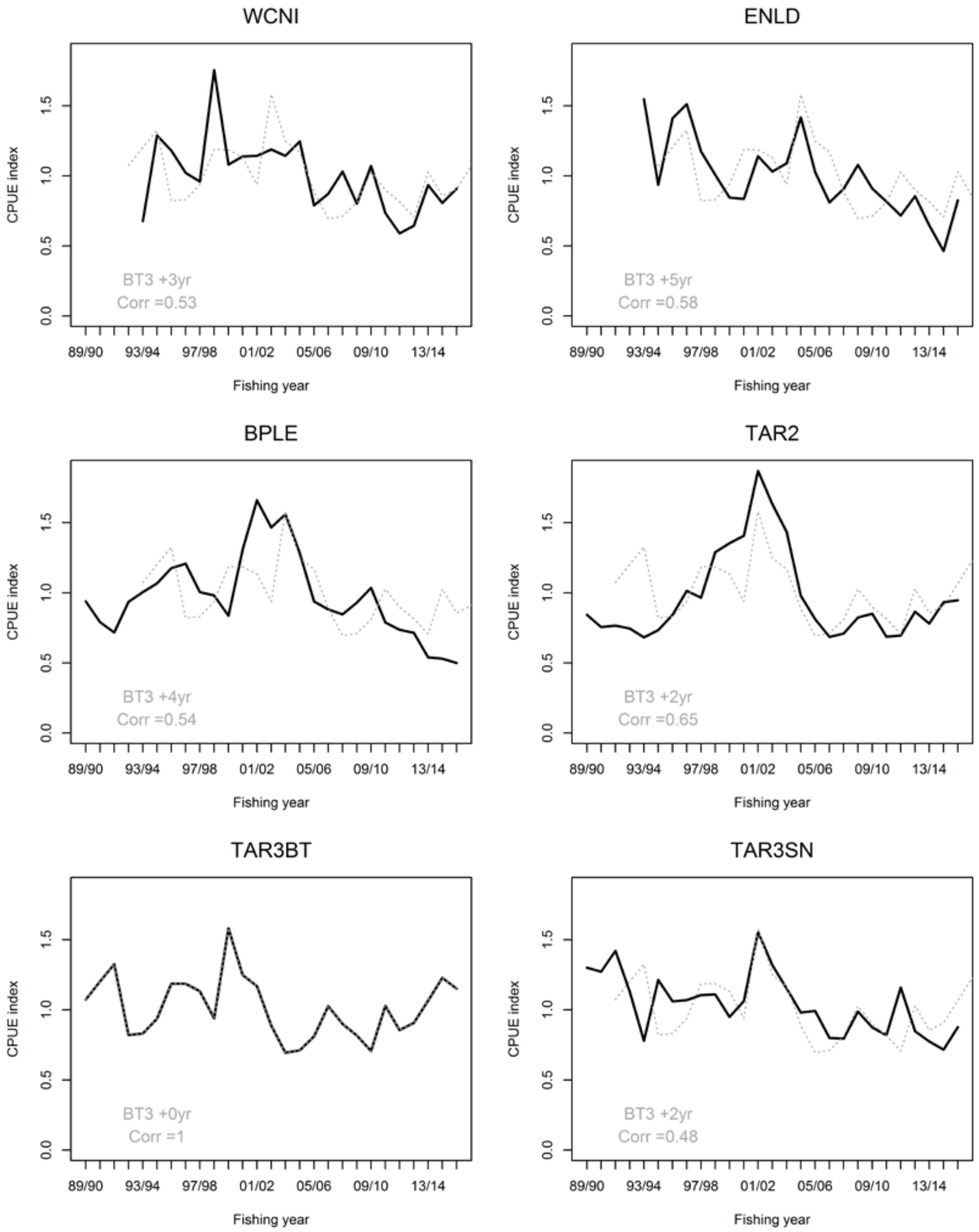

Figure 71: A comparison of the CPUE indices derived for each fishery (combined indices, except for TAR3SN). The CPUE indices from each fishery are contrasted with the TAR3-BT-MIX CPUE indices (TAR3BT) which are lagged by the interval (in years) that provided the highest positive correlation between the two sets of indices. The interval and the correlation coefficient is presented for each panel.

Table 16: Correlation coefficients among the individual sets of CPUE indices (top right) and the associated lag interval (in years). The lag represents the shift in the indices in the rows relative to the indices in the columns. For example, the highest correlation between the TAR3BT and TAR2 CPUE indices occurs with a 2 year lag on the TAR3BT CPUE indices. All correlations are significant at the 5% level.

Index						Index
	BPLE	ENLD	WCNI	TAR2	TAR3BT	TAR3SN
BPLE		0.59	0.59	0.69	0.54	0.53
ENLD	0		0.64	0.52	0.58	0.50
WCNI	3	-5		0.51	0.53	0.56
TAR2	0	-5	0		0.65	0.47
TAR3BT	4	5	3	2		0.48
TAR3SN	0	1	-4	0	-2	

4.9 Seasonal CPUE trends

An additional CPUE model was configured to investigate seasonal trends in tarakihi catch rates amongst the Statistical Areas that support the tarakihi fishery along the eastern coasts of the North and South Islands. The purpose of the analysis was to highlight seasonal patterns in CPUE that may be indicative of spatio-temporal changes in the availability of tarakihi associated with spawning behaviour or other important biological processes.

The analysis was limited to TCER bottom trawl fishing event records from 2007/08–2015/16 within specified Statistical Areas (002–005, 008–018, 020 and 022) and was limited to trawls within the depth range that was likely to catch tarakihi (30–250 m). There was no constraint on the declared target species of the individual trawls, although the data set was limited to trawls that caught tarakihi.

A simple GLM was configured to predict the natural logarithm of tarakihi trawl catch (in kilograms) as a function of the interaction between *Month* and *StatArea* variables and the additional explanatory variables *Duration* and *Depth*. For each *StatArea*, the *Month* terms were extracted and normalised to define the seasonal trend in tarakihi catch rate in the individual Statistical Area.

The seasonal trends in tarakihi CPUE differed considerably amongst Statistical Areas (Figure 72). The spawning period for tarakihi is generally defined as occurring in March–May (Ministry for Primary Industries 2016). Peaks in tarakihi CPUE during March–May occurred in Statistical Areas 002, 003, and 008–010, while CPUE was low (or below average) during March–May in Statistical Areas 004, 005, and 013. There is no strong seasonal trend in CPUE in the area of the main tarakihi fishery around East Cape–Mahia (Figure 72), although spawning is known to occur in that area.

In the areas off the east coast of the South Island (Statistical Areas 017, 018, 020 and 022), tarakihi CPUE was highest during December–March and lowest during July–October (Figure 72). Off the Wairarapa coast (Statistical Areas 015, 014 and 013), tarakihi CPUE increased during May–June from a lower level in December–March. These CPUE trends could be explained by a seasonal movement of tarakihi northwards from the South Island east coast during March–May with the northward migration of fish continuing along the Wairarapa coast during April–June.

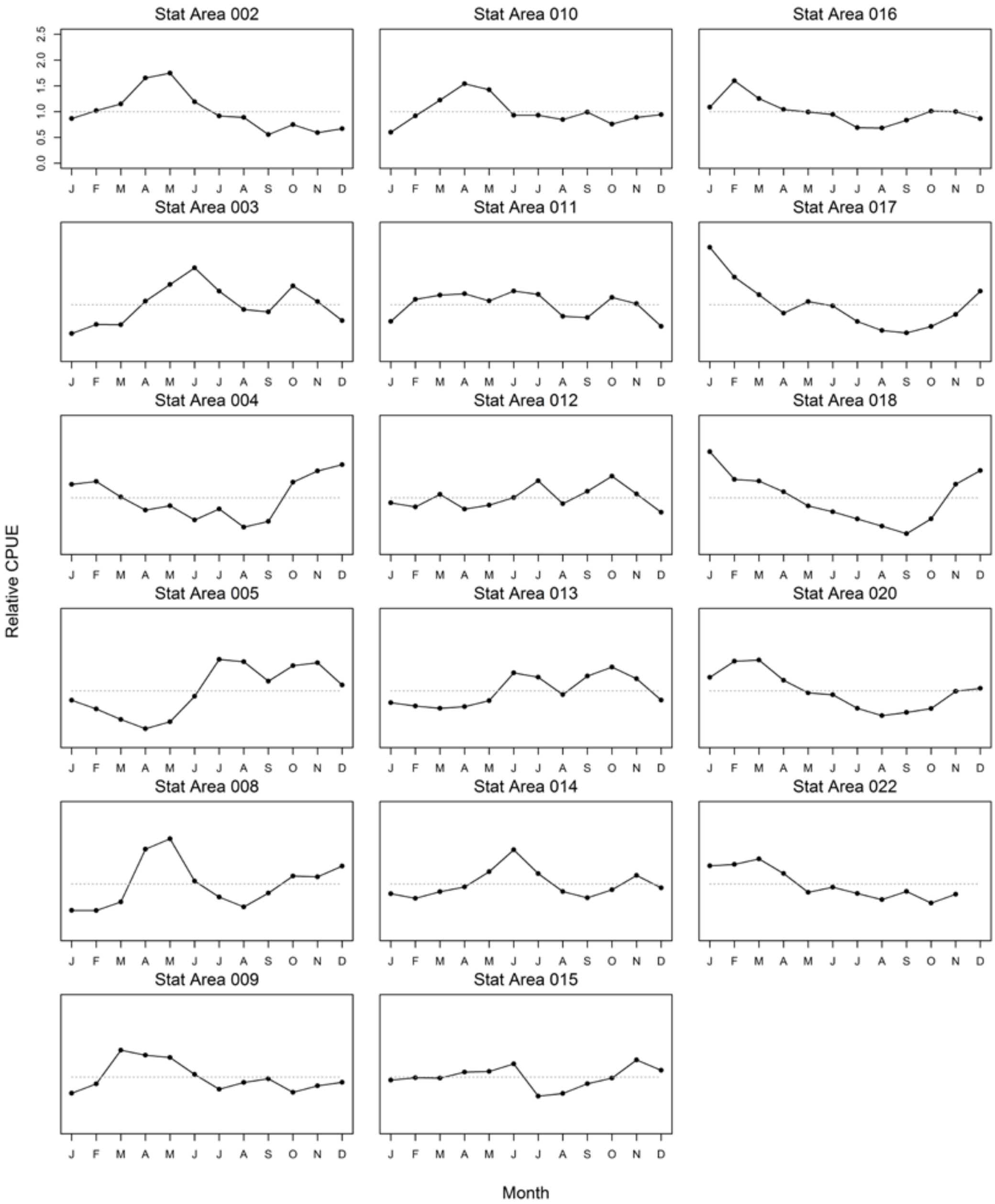

Figure 72: Monthly CPUE coefficients for tarakihi derived for each of the main Statistical Areas of the east coast fishery. The coefficient were derived from a simple GLM based on TCER bottom trawl event records and incorporated a Month:StatArea interaction term. Coefficients were normalised to the average of the series from each Statistical Area. The horizontal line represents the average of the series.

5 DISCUSSION

The analyses presented in this report have been undertaken as part of a larger project to conduct a stock assessment of tarakihi off the east coast of the North and South Islands. These analyses contribute to the stock assessment in a number of ways. The fishery characterisations provide information to define the main tarakihi fisheries (by fishing method, area and season) to be included within the modelling framework and collate of annual catches for each fishery.

The CPUE indices are intended to provide a fishery specific time-series of relative abundance indices for the tarakihi, either for the entire stock or at the appropriate regional scale corresponding to the fishery. Further, the comparison of the annual CPUE indices may also provide an indication of the degree of interconnectedness of the tarakihi stock (or stock units) amongst the various fishery areas (TAR 3, TAR

2, Bay of Plenty and East Northland). There are similarities and differences amongst the various time series of CPUE indices. Catch sampling has revealed that the individual fisheries catch different sizes and ages of fish indicating that there are differences in selectivity and/or differences in the age-specific availability of tarakihi amongst the fisheries (e.g. McKenzie et al. 2017). There may also be regional scale differences in the level of exploitation of the tarakihi populations that may contribute to differences in the relative abundance of tarakihi amongst fishery areas.

A more thorough appraisal of the trends in the different sets of CPUE indices needs to be conducted within the framework of an integrated, age structured population model, incorporating the fishery catch and age composition data sets. Such an analysis will be conducted during the development phase of the east coast tarakihi stock assessment modelling.

The stock assessment modelling will be strongly reliant on the assumption that the individual CPUE indices are proportional to tarakihi abundance. For most fishery areas, there is limited information available to directly corroborate this assumption. A reasonable time series (n = 10) of fishery independent estimates of tarakihi abundance is available from the *Kaharoa* winter east coast South Island inshore trawl surveys. There is weak negative correlation (corr. coef = -0.36) between the TAR3_BT_MIX CPUE indices and the corresponding tarakihi trawl survey biomass estimates. The difference in the trends between the two sets of abundance indices may be attributable to differences in the selectivity of the trawl survey and the selectivity of the commercial fishery CPUE. These processes will be investigated and evaluated in the framework of the stock assessment model.

Recent age composition data from the fisheries and trawl surveys also indicates that annual recruitment of tarakihi varies considerably. The correspondence between the trends in fishery CPUE, especially the short-term fluctuations in the CPUE indices, and the variability in the strength of recruiting year classes may provide some additional information to corroborate the individual sets of CPUE indices.

6 MANAGEMENT IMPLICATIONS

The Inshore Working Group accepted the six sets of CPUE indices as potential abundance indices for tarakihi in the respective fishery areas. The CPUE indices, with the exception of the WCNI_BT_MIX CPUE indices, will be included in the stock assessment of east coast tarakihi that will be completed in 2018. The structure of the stock assessment model(s) will also be informed by the fishery characterisations and CPUE analyses.

The stock relationships of tarakihi off the west coast of the North Island are unclear. There is no assessment scheduled for the area that is comprised of the western portion of TAR 1 (TAR 1W) and TAR 8. The WCNI_BT_MIX CPUE index encompasses the fishery in the northern area of TAR 1W which has historically accounted for most of the TAR 1W catch. However, considerable tarakihi catches are also taken in other areas of TAR 1W, especially in the outer area of the North Taranaki Bight. The CPUE trends for this area are not consistent with the time-series of WCNI_BT_MIX indices and, consequently, the CPUE indices are not considered representative of the entire TAR 1W area or the wider area of the west coast North Island (including TAR 8). Nonetheless, there has been a considerable decline in the WCNI_BT_MIX CPUE indices and further research is required to evaluate the status of tarakihi off the west coast of the North Island.

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APPENDIX 1. SUMMARY OF ANNUAL CATCHES BY AREA AND METHOD

Table A1: Annual catches (tonnes) of tarakihi from the TAR 1 by fishery area.

Fishing year			Fishery area	Total
	Bay of Plenty	East Northland	West coast	
1989/90	314	287	196	798
1990/91	572	335	207	1 114
1991/92	726	429	218	1 373
1992/93	773	316	325	1 414
1993/94	835	431	268	1 533
1994/95	685	379	358	1 422
1995/96	634	366	428	1 427
1996/97	571	487	416	1 474
1997/98	593	484	414	1 490
1998/99	565	413	443	1 421
1999/2000	449	449	452	1 349
2000/01	654	363	383	1 400
2001/02	789	334	378	1 501
2002/03	862	242	406	1 509
2003/04	931	246	355	1 532
2004/05	769	406	384	1 559
2005/06	664	424	311	1 400
2006/07	523	298	353	1 174
2007/08	530	270	473	1 273
2008/09	678	282	426	1 385
2009/10	737	248	291	1 277
2010/11	643	252	361	1 255
2011/12	558	224	297	1 080
2012/13	481	220	432	1 132
2013/14	371	494	532	1 397
2014/15	376	495	586	1 457
2015/16	335	395	488	1 218

Table A2: Annual catches (tonnes) of tarakihi from TAR 2 and TAR 3 by fishing method. Annual catches for TAR 3 include additional catch from Statistical Areas 017 and 018 from TAR 7.

Fishing year	TAR 2	TAR3			
		Fishing method			Total
		SN	BT	Other	
1989/90	1 225	199	731	0	930
1990/91	1 679	311	767	0	1 078
1991/92	1 612	387	887	2	1 276
1992/93	1 627	373	616	0	989
1993/94	1 450	244	642	1	887
1994/95	1 505	338	809	3	1 150
1995/96	1 468	377	983	8	1 368
1996/97	1 415	302	1 077	3	1 383
1997/98	1 501	303	956	1	1 260
1998/99	1 590	252	1 157	1	1 409
1999/2000	1 714	273	1 320	2	1 595
2000/01	1 662	380	1 348	4	1 731
2001/02	1 728	403	1 270	1	1 674
2002/03	1 735	336	1 155	1	1 492
2003/04	1 627	314	1 047	5	1 366
2004/05	1 678	159	1 049	1	1 209
2005/06	1 947	214	1 093	4	1 311
2006/07	1 689	178	1 062	115	1 355
2007/08	1 698	185	706	89	980
2008/09	1 891	206	891	152	1 248
2009/10	1 898	179	934	45	1 159
2010/11	1 664	149	1 248	64	1 460
2011/12	1 688	241	879	133	1 252
2012/13	1 915	204	1 005	113	1 321
2013/14	1 756	127	1 041	114	1 282
2014/15	1 938	114	1 127	75	1 316
2015/16	1 816	163	1 176	157	1 496

APPENDIX 2. CPUE DATA SETS

Table A3: Summary of the catch and effort data from the Bay of Plenty (BPLE) single trawl CPUE data set (core vessels only).

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number trawls	Duration (hrs)	Percent zero catch
1989/90	1 033	27	270	230.5	3 045	8 505	30.9
1990/91	1 290	23	400	382.8	3 719	11 720	27.3
1991/92	1 343	31	471	397.4	3 779	12 721	25.8
1992/93	1 414	33	510	430.7	3 660	12 892	26.2
1993/94	1 209	32	439	465.6	3 164	10 494	23.8
1994/95	1 176	27	416	474.5	2 950	9 585	22.9
1995/96	992	30	389	423.1	2 764	8 520	26.2
1996/97	1 033	29	420	423.4	2 839	8 142	27.1
1997/98	1 095	33	396	411.0	2 983	9 381	30.1
1998/99	1 230	27	414	426.4	3 639	10 528	35
1999/2000	1 134	24	380	353.7	3 579	9 938	33.4
2000/01	1 288	27	445	547.7	4 003	11 428	32.9
2001/02	1 315	22	478	662.5	3 991	11 639	24.9
2002/03	1 475	27	554	693.5	4 346	12 749	30.1
2003/04	1 517	26	540	714.9	4 526	13 794	27.9
2004/05	1 502	25	505	604.1	4 755	14 381	26.8
2005/06	1 387	26	504	492.0	4 130	12 531	29.8
2006/07	974	21	348	405.9	3 047	8 930	29
2007/08	1 027	18	353	388.6	3 105	9 841	29.9
2008/09	1 038	19	367	471.2	3 262	10 085	25.6
2009/10	1 141	17	414	531.6	3 380	10 567	23.8
2010/11	1 020	18	357	461.6	3 192	9 262	27.4
2011/12	1 037	15	360	398.0	3 208	8 768	30.4
2012/13	922	16	340	315.8	2 693	7 701	29.3
2013/14	873	16	318	216.2	2 847	7 744	33.4
2014/15	731	16	277	235.5	2 299	6 510	35.8
2015/16	681	16	243	188.0	2 031	6 590	38.3

Table A4: Summary of the catch and effort data from the East Northland (ENLD) single trawl CPUE data set (core vessels only).

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number trawls	Duration (hrs)	Percent zero catch
1989/90							
1990/91							
1991/92							
1992/93							
1993/94	48	4	8	13.4	48	149	14.6
1994/95	61	5	13	23.1	61	229	9.8
1995/96	295	17	81	80.8	295	979	4.1
1996/97	330	17	105	135.6	330	1 075	3.0
1997/98	406	18	111	134.0	406	1 358	5.2
1998/99	304	16	88	87.4	304	1 004	2.6
1999/2000	469	15	99	101.3	469	1 690	5.1
2000/01	389	18	112	93.5	389	1 409	6.7
2001/02	239	17	78	82.7	239	874	5.4
2002/03	229	12	79	47.8	229	847	8.3
2003/04	162	11	58	59.8	162	639	4.9
2004/05	233	9	69	111.3	233	912	10.7
2005/06	244	12	86	82.7	244	1 011	6.1
2006/07	159	9	56	43.6	159	644	6.3
2007/08	342	10	78	112.2	342	1 424	3.2
2008/09	264	8	61	96.7	264	1 059	0.8
2009/10	293	8	69	84.7	293	1 137	3.1
2010/11	250	10	63	85.3	250	999	2.8
2011/12	310	9	68	87.8	310	1 171	6.1
2012/13	291	8	62	82.3	291	1 008	3.1
2013/14	624	11	123	241.4	624	2 429	4.8
2014/15	319	13	94	73.7	319	1 267	7.2
2015/16	306	11	83	86.5	306	1 248	1.6

Table A5: Summary of the catch and effort data from the northern west coast North Island (WCNI) single trawl CPUE data set (core vessels only).

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number trawls	Duration (hrs)	Percent zero catch
1989/90							
1990/91							
1991/92							
1992/93							
1993/94	229	7	24	4.9	229	652	84.3
1994/95	465	6	42	71.2	465	1 459	61.7
1995/96	1 027	17	143	185.5	1 027	3 414	60.6
1996/97	1 479	16	229	190.9	1 479	4 672	64.2
1997/98	1 863	17	217	176.9	1 863	5 649	72.8
1998/99	1 546	15	157	164.5	1 546	4 430	67.3
1999/2000	1 624	14	187	165	1 624	5 335	71.8
2000/01	1 556	17	185	149.1	1 556	5 438	72.4
2001/02	1 089	15	156	193.5	1 089	3 959	65.7
2002/03	1 215	15	166	205.7	1 215	4 449	68.1
2003/04	1 465	13	165	196.3	1 465	5 224	66.2
2004/05	1 301	11	141	191.6	1 301	4 591	66.2
2005/06	844	9	98	161.4	844	2 927	64.2
2006/07	820	6	91	92.2	820	2 697	74.1
2007/08	1 118	8	131	218.1	1 118	3 949	64.5
2008/09	1 145	6	114	238.3	1 145	4 017	64.5
2009/10	894	4	79	122.9	894	2 843	69.4
2010/11	1 011	8	116	224.6	1 011	3 385	63.9
2011/12	1 289	7	133	171.2	1 289	4 278	69.6
2012/13	1 093	7	140	189.7	1 093	3 711	67.5
2013/14	1 298	10	162	306.3	1 298	4 393	62.2
2014/15	1 342	10	156	276.1	1 342	4 746	56.6
2015/16	1 295	8	117	254.8	1 295	4 343	53.4

Table A6: Summary of the catch and effort data from the TAR 2 single trawl CPUE data set (core vessels only).

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number trawls	Duration (hrs)	Percent zero catch
1989/90	1 247	31	470	751.3	3 115	11 810	16.0
1990/91	1 824	33	650	1 189.3	4 698	17 865	14.6
1991/92	2 115	36	817	1 028.8	5 202	20 900	18.0
1992/93	2 191	38	817	1 094.7	5 325	22 367	22.4
1993/94	2 263	36	799	1 099.1	5 665	22 799	21.7
1994/95	2 006	37	732	1 084.3	5 308	20 283	18.1
1995/96	2 019	38	749	1 120.8	5 911	19 664	17.5
1996/97	2 025	33	718	1 100.2	5 227	19 290	20.3
1997/98	2 065	36	723	1 235.5	5 318	19 403	19.9
1998/99	2 305	38	805	1 337.4	5 805	20 996	19.1
1999/2000	2 336	34	750	1 446.5	5 669	21 939	20.7
2000/01	2 487	40	791	1 380.6	5 849	21 913	21.8
2001/02	2 482	36	825	1 410.5	5 875	21 357	18.9
2002/03	2 593	34	843	1 429.2	6 098	22 691	18.5
2003/04	2 166	32	740	1 376.7	5 680	20 387	17.6
2004/05	2 419	31	827	1 367.8	6 512	23 863	17.7
2005/06	2 373	35	808	1 527.4	6 808	24 207	13.3
2006/07	2 431	29	714	1 374.4	6 959	24 361	18.6
2007/08	2 350	31	678	1 357.6	6 609	23 472	16.6
2008/09	2 620	32	769	1 607.5	7 508	26 741	16.3
2009/10	2 820	33	848	1 602.2	8 109	28 565	16.8
2010/11	2 690	32	768	1 426.3	7 909	27 579	21.2
2011/12	2 248	28	680	1 384.3	6 644	23 450	17.3
2012/13	2 066	26	598	1 449.0	6 126	21 858	17.8
2013/14	2 196	27	646	1 283.9	6 626	23 365	18.9
2014/15	1 976	26	580	1 435.1	5 833	21 079	17.4
2015/16	1 648	24	517	1 330.2	4 697	17 287	16.1

Table A7: Summary of the catch and effort data from the TAR 3 single trawl CPUE data set (core vessels only).

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number trawls	Duration (hrs)	Percent zero catch
1989/90	1 187	34	623	276.5	3 440	11 377	21.3
1990/91	1 667	42	901	384.9	4 952	15 718	23.2
1991/92	2 024	47	1 092	445.4	5 791	20 393	21.6
1992/93	2 034	47	1 171	369.1	5 694	19 657	17.9
1993/94	2 022	50	1 235	386.1	5 807	18 212	15.1
1994/95	2 303	54	1 342	533.1	6 474	20 365	15.5
1995/96	2 333	52	1 153	667.8	6 810	20 701	24.1
1996/97	2 677	56	1 474	774.8	7 906	24 301	16.7
1997/98	2 359	52	1 316	640.9	7 265	21 155	19.0
1998/99	2 185	51	1 234	683.9	6 617	19 537	16.5
1999/2000	2 262	47	1 187	808.0	6 975	21 557	19.9
2000/01	2 406	48	1 195	907.3	7 539	24 156	20.2
2001/02	2 072	50	1 048	798.5	6 536	20 711	21.5
2002/03	2 054	46	984	748.0	6 431	21 648	22.2
2003/04	1 878	46	911	726.2	5 478	18 287	21.2
2004/05	1 830	40	886	698.9	5 238	18 023	23.3
2005/06	1 864	38	915	654.2	5 304	18 478	23.1
2006/07	1 391	37	684	659.4	4 132	14 597	23.1
2007/08	1 181	33	581	469.2	3 143	11 142	19.2
2008/09	1 339	39	676	619.2	3 592	13 292	19.0
2009/10	1 324	37	658	633.9	3 599	12 951	20.2
2010/11	1 553	39	740	771.3	4 165	14 695	23.8
2011/12	1 457	38	680	621.5	4 018	13 380	20.1
2012/13	1 460	37	646	656.4	4 120	13 107	23.8
2013/14	1 385	35	640	585.0	3 712	12 782	21.6
2014/15	1 056	31	533	498.8	2 772	9 234	24.3
2015/16	1 196	31	554	732.0	3 275	10 268	27.0

Table A8: Summary of the catch and effort data from the TAR 3 set net CPUE data set (core vessels only).

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number sets	Percent zero catch
1989/90	284	6	284	113.2	284	0.0
1990/91	430	5	424	214.6	430	0.0
1991/92	474	6	471	261.0	474	0.0
1992/93	738	6	729	311.5	738	0.4
1993/94	555	6	546	174.9	555	0.5
1994/95	610	6	538	264.2	610	0.2
1995/96	487	6	474	186.2	487	0.2
1996/97	376	6	373	151.5	376	0.0
1997/98	527	5	524	201.8	527	0.0
1998/99	426	4	425	142.7	426	0.2
1999/2000	429	5	421	180.6	429	0.0
2000/01	515	6	515	247.3	515	0.0
2001/02	339	5	338	263.7	339	0.0
2002/03	468	6	465	276.5	468	0.0
2003/04	560	6	556	266.0	560	0.0
2004/05	381	5	380	147.5	381	0.0
2005/06	503	6	503	196.2	503	0.0
2006/07	331	6	329	118.6	1 837	0.0
2007/08	310	5	308	131.9	1 969	0.0
2008/09	303	5	303	150.1	1 636	0.7
2009/10	244	5	244	126.9	1 429	0.0
2010/11	249	4	248	108.9	1 465	0.0
2011/12	295	5	293	196.7	1 651	0.0
2012/13	328	5	319	166.0	1 720	0.0
2013/14	155	4	142	67.2	795	0.0
2014/15	107	3	106	64.2	514	0.0
2015/16	130	4	128	67.7	772	0.8

APPENDIX 3. TABULATED CPUE INDICES

Table A9: Annual BPLE trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.

Fishing	Combined			Binomial			Weibull		
year	Index	LCI	UCI	Index	LCI	UCI	Index	LCI	UCI
89/90	0.693	0.608	0.788	0.691	0.644	0.735	1.000	0.898	1.116
90/91	0.583	0.511	0.665	0.622	0.566	0.670	0.938	0.848	1.046
91/92	0.529	0.463	0.603	0.585	0.533	0.632	0.905	0.815	1.005
92/93	0.690	0.604	0.786	0.676	0.630	0.720	1.021	0.912	1.130
93/94	0.741	0.649	0.842	0.674	0.627	0.720	1.100	0.982	1.224
94/95	0.787	0.686	0.901	0.661	0.611	0.711	1.190	1.060	1.332
95/96	0.867	0.756	0.991	0.666	0.616	0.714	1.302	1.160	1.461
96/97	0.891	0.773	1.023	0.662	0.611	0.713	1.347	1.200	1.515
97/98	0.741	0.636	0.854	0.618	0.565	0.669	1.199	1.062	1.334
98/99	0.724	0.621	0.840	0.565	0.508	0.622	1.282	1.138	1.429
99/00	0.617	0.537	0.706	0.611	0.557	0.664	1.009	0.900	1.125
00/01	0.964	0.828	1.105	0.631	0.578	0.679	1.528	1.349	1.712
01/02	1.224	1.066	1.391	0.703	0.655	0.749	1.740	1.539	1.955
02/03	1.081	0.947	1.235	0.635	0.588	0.684	1.703	1.531	1.879
03/04	1.151	1.004	1.305	0.670	0.625	0.716	1.716	1.530	1.907
04/05	0.946	0.826	1.074	0.669	0.619	0.716	1.415	1.278	1.574
05/06	0.692	0.595	0.799	0.599	0.544	0.653	1.156	1.026	1.296
06/07	0.650	0.555	0.759	0.611	0.550	0.664	1.064	0.939	1.213
07/08	0.624	0.536	0.722	0.606	0.552	0.661	1.030	0.906	1.161
08/09	0.686	0.595	0.787	0.652	0.596	0.705	1.053	0.931	1.177
09/10	0.764	0.665	0.883	0.663	0.610	0.717	1.154	1.025	1.299
10/11	0.582	0.496	0.671	0.639	0.585	0.692	0.911	0.800	1.029
11/12	0.543	0.466	0.633	0.595	0.538	0.650	0.914	0.811	1.028
12/13	0.527	0.452	0.609	0.618	0.559	0.672	0.853	0.750	0.966
13/14	0.398	0.339	0.470	0.592	0.537	0.651	0.673	0.591	0.764
14/15	0.391	0.324	0.472	0.512	0.445	0.576	0.762	0.672	0.867
15/16	0.369	0.304	0.443	0.528	0.463	0.595	0.699	0.603	0.807

Table A10: Annual ENLD trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.

Fishing	Combined			Binomial			Weibull		
year	Index	LCI	UCI	Index	LCI	UCI	Index	LCI	UCI
93/94	0.844	0.486	1.194	0.854	0.519	0.962	1.000	0.733	1.356
94/95	0.511	0.260	0.782	0.675	0.355	0.912	0.758	0.539	1.045
95/96	0.769	0.575	1.019	0.910	0.779	0.978	0.846	0.641	1.109
96/97	0.824	0.590	1.101	0.882	0.685	0.971	0.934	0.714	1.198
97/98	0.640	0.419	0.878	0.812	0.586	0.944	0.787	0.600	1.013
98/99	0.550	0.366	0.748	0.837	0.612	0.960	0.657	0.510	0.849
99/00	0.461	0.300	0.632	0.781	0.559	0.929	0.591	0.464	0.762
00/01	0.456	0.263	0.669	0.700	0.431	0.888	0.650	0.506	0.839
01/02	0.622	0.379	0.866	0.769	0.504	0.932	0.809	0.616	1.021
02/03	0.562	0.309	0.813	0.696	0.426	0.889	0.806	0.608	1.051
03/04	0.594	0.393	0.853	0.812	0.565	0.951	0.732	0.545	0.965
04/05	0.773	0.488	1.069	0.770	0.553	0.918	1.003	0.759	1.286
05/06	0.560	0.333	0.789	0.744	0.492	0.908	0.752	0.568	0.969
06/07	0.442	0.234	0.650	0.682	0.373	0.900	0.648	0.484	0.828
07/08	0.495	0.264	0.737	0.711	0.404	0.919	0.696	0.534	0.902
08/09	0.588	0.346	0.822	0.841	0.531	0.981	0.698	0.528	0.894
09/10	0.496	0.284	0.709	0.711	0.415	0.902	0.698	0.541	0.886
10/11	0.445	0.225	0.662	0.672	0.372	0.911	0.663	0.511	0.847
11/12	0.391	0.185	0.627	0.543	0.257	0.803	0.721	0.553	0.935
12/13	0.466	0.237	0.709	0.642	0.347	0.888	0.726	0.549	0.936
13/14	0.353	0.147	0.595	0.450	0.195	0.725	0.785	0.597	1.008
14/15	0.253	0.115	0.427	0.517	0.241	0.776	0.489	0.372	0.636
15/16	0.450	0.257	0.632	0.770	0.464	0.944	0.585	0.444	0.745

Table A11: Annual northern WCNI trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.

Fishing	Combined			Binomial			Lognormal		
year	Index	LCI	UCI	Index	LCI	UCI	Index	LCI	UCI
93/94	0.163	0.091	0.273	0.157	0.096	0.247	1.000	0.707	1.412
94/95	0.310	0.175	0.525	0.240	0.149	0.354	1.293	0.915	1.782
95/96	0.284	0.152	0.468	0.192	0.113	0.286	1.478	1.043	2.061
96/97	0.246	0.135	0.398	0.208	0.131	0.300	1.183	0.867	1.630
97/98	0.231	0.137	0.362	0.199	0.129	0.289	1.161	0.812	1.580
98/99	0.422	0.248	0.649	0.317	0.213	0.435	1.334	0.946	1.822
99/00	0.260	0.149	0.411	0.235	0.154	0.339	1.109	0.785	1.540
00/01	0.274	0.156	0.433	0.237	0.156	0.344	1.157	0.842	1.570
01/02	0.275	0.158	0.444	0.219	0.141	0.318	1.258	0.892	1.729
02/03	0.286	0.163	0.467	0.224	0.143	0.326	1.274	0.891	1.745
03/04	0.275	0.157	0.443	0.259	0.168	0.365	1.063	0.756	1.446
04/05	0.300	0.176	0.464	0.315	0.213	0.423	0.954	0.679	1.284
05/06	0.190	0.108	0.300	0.199	0.126	0.300	0.956	0.690	1.321
06/07	0.210	0.112	0.354	0.211	0.130	0.313	0.998	0.708	1.396
07/08	0.248	0.137	0.402	0.243	0.151	0.352	1.020	0.744	1.403
08/09	0.193	0.111	0.306	0.227	0.148	0.332	0.848	0.601	1.168
09/10	0.258	0.149	0.412	0.289	0.186	0.416	0.896	0.638	1.211
10/11	0.177	0.091	0.308	0.190	0.112	0.287	0.932	0.667	1.285
11/12	0.142	0.071	0.241	0.164	0.097	0.259	0.866	0.598	1.208
12/13	0.155	0.080	0.259	0.161	0.095	0.244	0.965	0.677	1.303
13/14	0.225	0.124	0.360	0.228	0.142	0.334	0.988	0.696	1.338
14/15	0.194	0.109	0.308	0.243	0.155	0.342	0.802	0.584	1.085
15/16	0.219	0.124	0.348	0.262	0.165	0.378	0.834	0.592	1.119

Table A12: Annual TAR2 trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.

Fishing	Combined			Binomial			Lognormal		
year	Index	LCI	UCI	Index	LCI	UCI	Index	LCI	UCI
89/90	0.840	0.750	0.939	0.840	0.806	0.871	1.000	0.903	1.105
90/91	0.753	0.673	0.832	0.845	0.812	0.876	0.891	0.800	0.982
91/92	0.764	0.684	0.843	0.875	0.849	0.897	0.873	0.781	0.961
92/93	0.743	0.673	0.828	0.850	0.822	0.876	0.874	0.799	0.963
93/94	0.680	0.608	0.754	0.856	0.829	0.880	0.795	0.715	0.878
94/95	0.732	0.659	0.812	0.875	0.847	0.898	0.837	0.755	0.929
95/96	0.840	0.756	0.927	0.889	0.866	0.909	0.945	0.853	1.040
96/97	1.011	0.913	1.124	0.879	0.852	0.900	1.150	1.043	1.270
97/98	0.962	0.859	1.060	0.871	0.843	0.895	1.104	0.989	1.215
98/99	1.285	1.155	1.424	0.869	0.842	0.892	1.480	1.340	1.642
99/00	1.350	1.201	1.501	0.886	0.862	0.907	1.524	1.367	1.697
00/01	1.403	1.256	1.549	0.877	0.853	0.899	1.600	1.440	1.751
01/02	1.863	1.667	2.059	0.911	0.891	0.928	2.046	1.833	2.261
02/03	1.627	1.469	1.798	0.912	0.894	0.929	1.784	1.613	1.971
03/04	1.430	1.281	1.600	0.890	0.864	0.912	1.606	1.451	1.780
04/05	0.976	0.875	1.085	0.906	0.882	0.924	1.077	0.973	1.200
05/06	0.810	0.727	0.902	0.905	0.883	0.925	0.895	0.808	0.996
06/07	0.683	0.616	0.757	0.878	0.852	0.901	0.778	0.705	0.858
07/08	0.707	0.634	0.787	0.881	0.853	0.903	0.802	0.723	0.889
08/09	0.821	0.744	0.910	0.900	0.876	0.919	0.913	0.828	1.009
09/10	0.848	0.763	0.934	0.918	0.901	0.934	0.924	0.833	1.020
10/11	0.684	0.610	0.761	0.884	0.859	0.906	0.774	0.695	0.856
11/12	0.693	0.625	0.762	0.903	0.881	0.922	0.767	0.694	0.846
12/13	0.863	0.774	0.959	0.894	0.869	0.916	0.965	0.866	1.070
13/14	0.778	0.696	0.863	0.887	0.861	0.908	0.878	0.788	0.967
14/15	0.929	0.832	1.034	0.895	0.868	0.918	1.038	0.932	1.152
15/16	0.944	0.845	1.051	0.924	0.907	0.940	1.021	0.916	1.131

Table A13: Annual TAR3 trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.

Fishing	Combined			Binomial			Lognormal		
year	Index	LCI	UCI	Index	LCI	UCI	Index	LCI	UCI
89/90	0.790	0.673	0.925	0.787	0.753	0.818	1.000	0.857	1.171
90/91	0.886	0.744	1.052	0.764	0.724	0.797	1.159	0.975	1.360
91/92	0.976	0.813	1.150	0.797	0.767	0.825	1.224	1.025	1.442
92/93	0.604	0.514	0.702	0.818	0.789	0.846	0.739	0.627	0.852
93/94	0.612	0.518	0.718	0.831	0.803	0.858	0.737	0.624	0.870
94/95	0.690	0.592	0.816	0.848	0.822	0.871	0.814	0.705	0.953
95/96	0.874	0.739	1.033	0.772	0.738	0.804	1.132	0.965	1.327
96/97	0.873	0.748	1.019	0.842	0.815	0.867	1.037	0.889	1.206
97/98	0.834	0.706	0.971	0.817	0.786	0.846	1.021	0.867	1.195
98/99	0.691	0.585	0.798	0.846	0.819	0.870	0.817	0.694	0.936
99/00	1.164	0.994	1.354	0.810	0.781	0.838	1.437	1.236	1.668
00/01	0.919	0.789	1.074	0.804	0.776	0.831	1.144	0.983	1.328
01/02	0.861	0.720	1.004	0.781	0.748	0.810	1.102	0.931	1.276
02/03	0.653	0.554	0.758	0.777	0.743	0.810	0.840	0.713	0.972
03/04	0.511	0.427	0.606	0.786	0.749	0.818	0.650	0.545	0.768
04/05	0.524	0.441	0.620	0.755	0.715	0.789	0.694	0.591	0.816
05/06	0.597	0.505	0.706	0.758	0.721	0.791	0.788	0.674	0.927
06/07	0.756	0.632	0.904	0.743	0.701	0.785	1.017	0.850	1.212
07/08	0.662	0.549	0.793	0.793	0.755	0.827	0.835	0.696	0.996
08/09	0.601	0.505	0.710	0.767	0.726	0.805	0.783	0.658	0.929
09/10	0.520	0.428	0.624	0.740	0.699	0.778	0.702	0.589	0.844
10/11	0.757	0.617	0.910	0.725	0.683	0.765	1.044	0.867	1.237
11/12	0.630	0.532	0.752	0.799	0.767	0.831	0.788	0.665	0.934
12/13	0.668	0.558	0.791	0.758	0.716	0.795	0.881	0.741	1.039
13/14	0.785	0.656	0.934	0.772	0.733	0.806	1.018	0.854	1.204
14/15	0.904	0.736	1.100	0.752	0.709	0.792	1.201	0.985	1.450
15/16	0.847	0.691	1.029	0.699	0.652	0.742	1.212	0.994	1.468

Table A14: Annual TAR3 set net CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.

Fishing	Lognormal		
year	Index	LCI	UCI
89/90	1.000	0.867	1.154
90/91	0.978	0.848	1.128
91/92	1.092	0.949	1.257
92/93	0.868	0.762	0.990
93/94	0.599	0.523	0.686
94/95	0.933	0.815	1.067
95/96	0.815	0.708	0.938
96/97	0.822	0.709	0.954
97/98	0.850	0.736	0.980
98/99	0.853	0.731	0.996
99/00	0.730	0.626	0.852
00/01	0.817	0.704	0.947
01/02	1.196	1.017	1.406
02/03	1.014	0.869	1.183
03/04	0.886	0.762	1.029
04/05	0.754	0.640	0.887
05/06	0.763	0.655	0.889
06/07	0.615	0.522	0.725
07/08	0.610	0.515	0.724
08/09	0.759	0.640	0.899
09/10	0.672	0.562	0.803
10/11	0.630	0.527	0.752
11/12	0.891	0.754	1.053
12/13	0.651	0.554	0.766
13/14	0.596	0.489	0.727
14/15	0.550	0.440	0.686
15/16	0.674	0.548	0.830

APPENDIX 4. CPUE MODEL DIAGNOSTICS

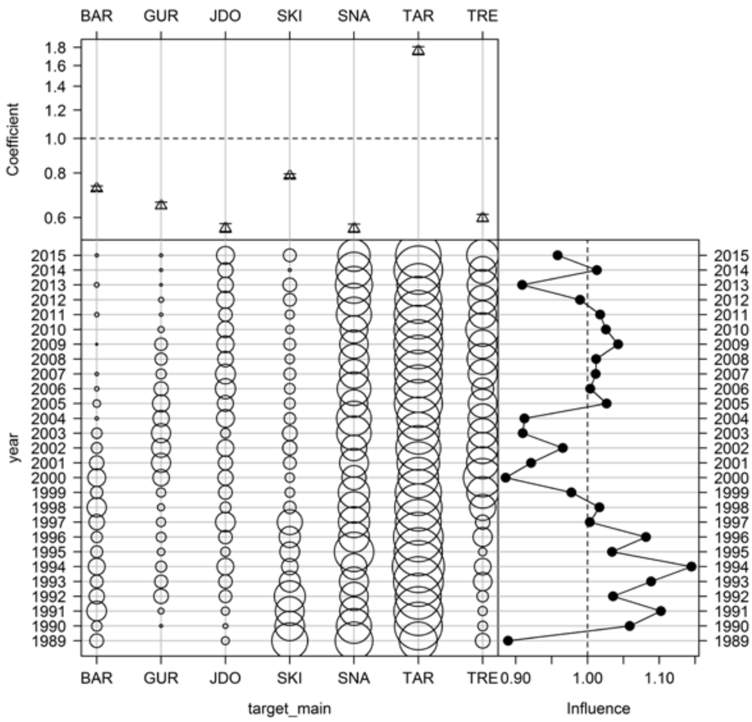

Figure A1: Influence plot of the *TargetSpecies* variable in the positive catch *BPLE_BT_Mix* CPUE model.

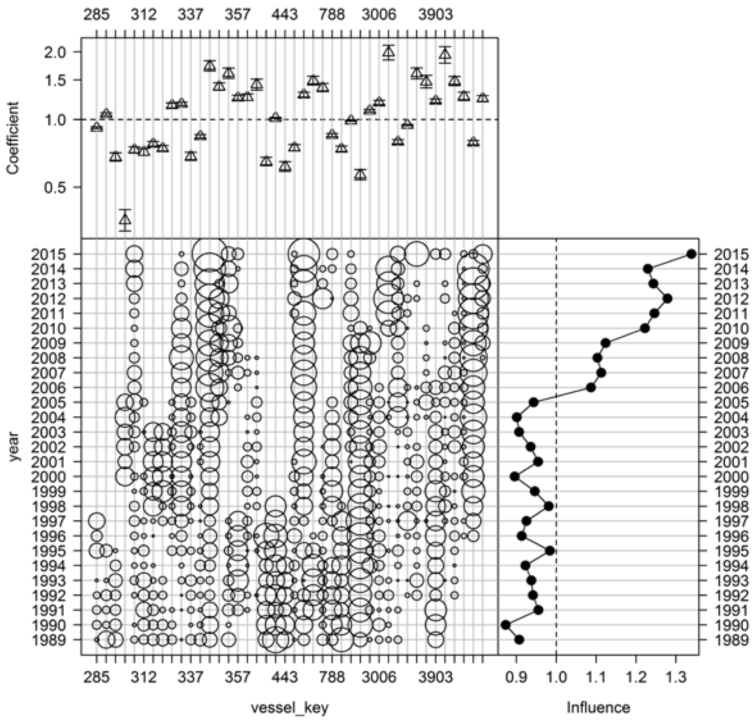

Figure A2: Influence plot of the *Vessel* variable in the positive catch *BPLE_BT_Mix* CPUE model.

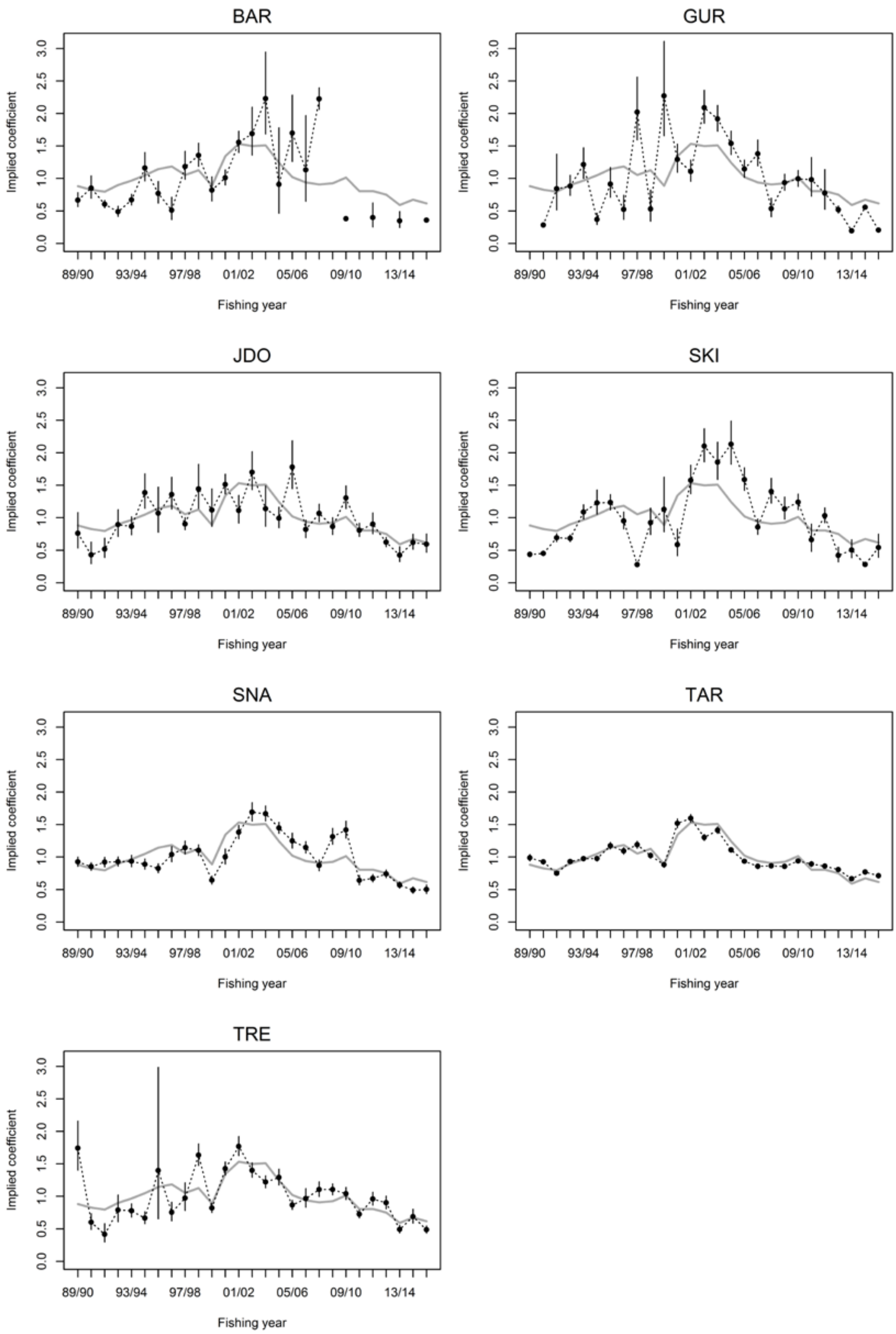

Figure A3: Annual implied coefficients (points) for the individual target species included in the positive catch *BPLE_BT_Mix* CPUE model. The grey line represents the annual CPUE indices derived from the positive catch CPUE model. The confidence intervals represent the standard error of the annual residuals.

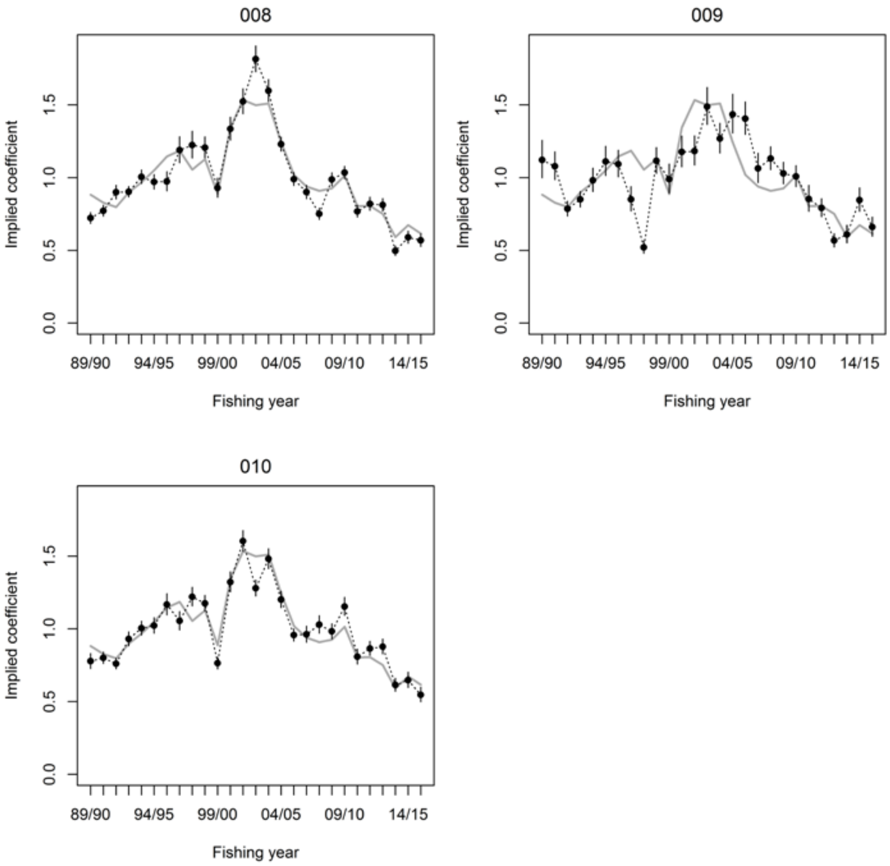

Figure A4: Annual implied coefficients (points) for the individual Statistical Areas included in the positive catch *BPLE_BT_Mix* CPUE model. The grey line represents the annual CPUE indices derived from the positive catch CPUE model. The confidence intervals represent the standard error of the annual residuals.

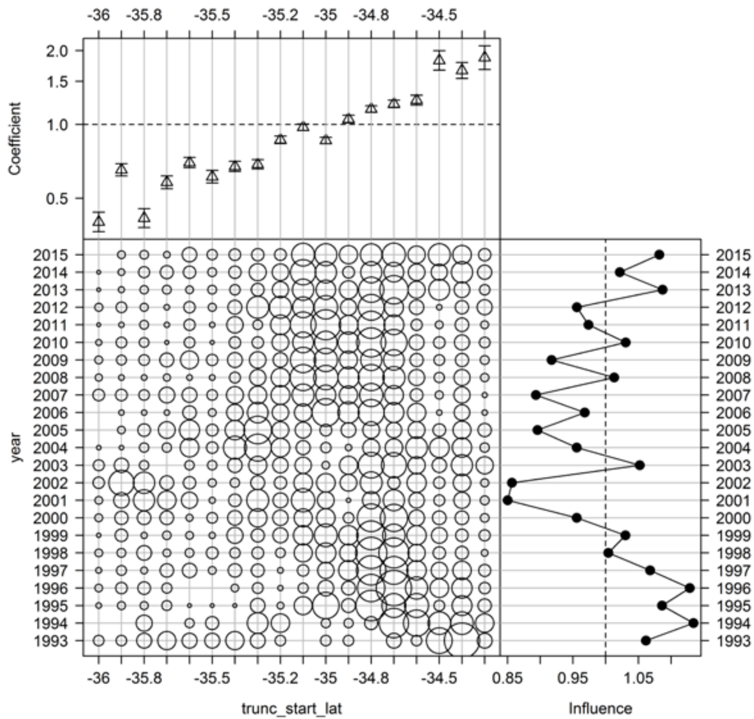

Figure A5: Influence plot of the *Latitude1* variable in the positive catch *EN_BT_TAR* CPUE model.

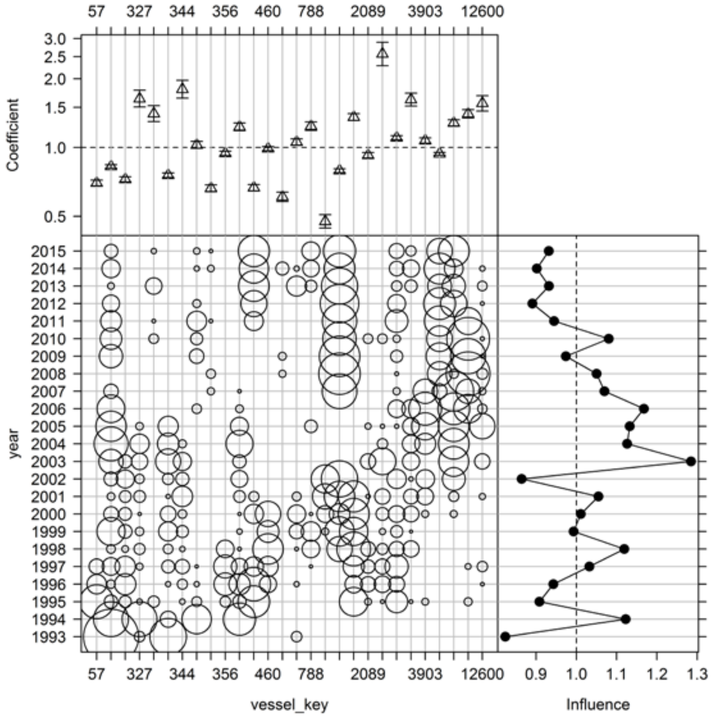

Figure A6: Influence plot of the *Vessel* variable in the positive catch *EN_BT_TAR* CPUE model.

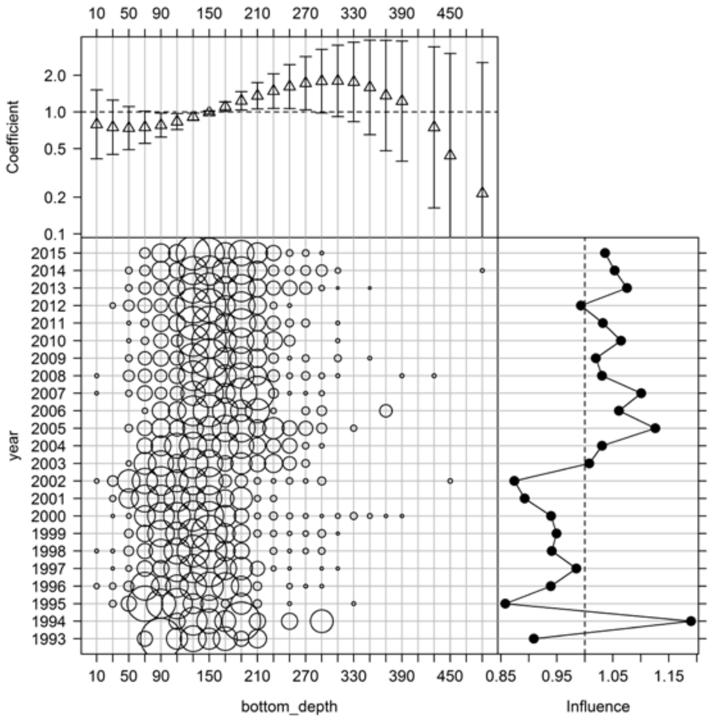

Figure A7: Influence plot of the *Depth* variable in the positive catch *EN_BT_TAR* CPUE model.

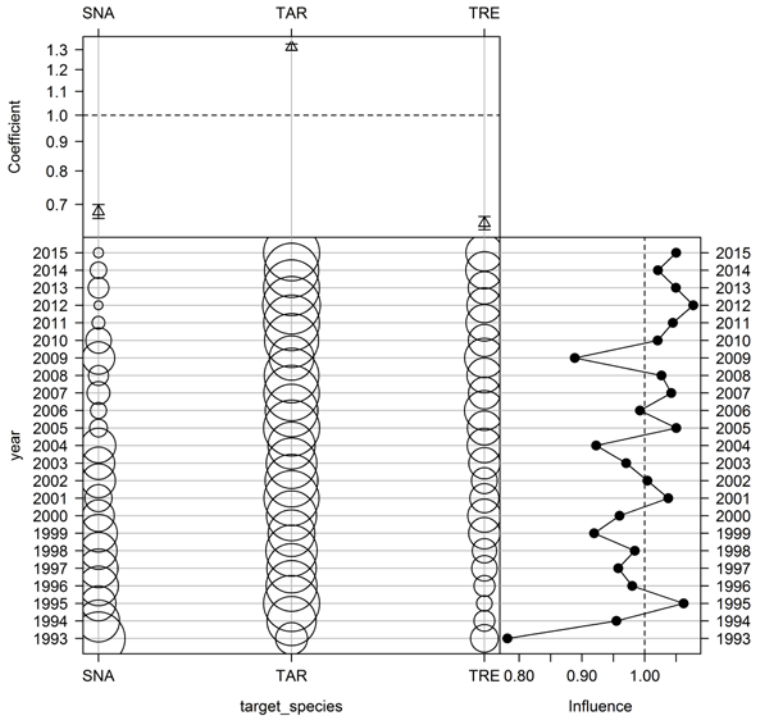

Figure A8: Influence plot of the *TargetSpecies* variable in the positive catch *WC_BT_TAR* CPUE model.

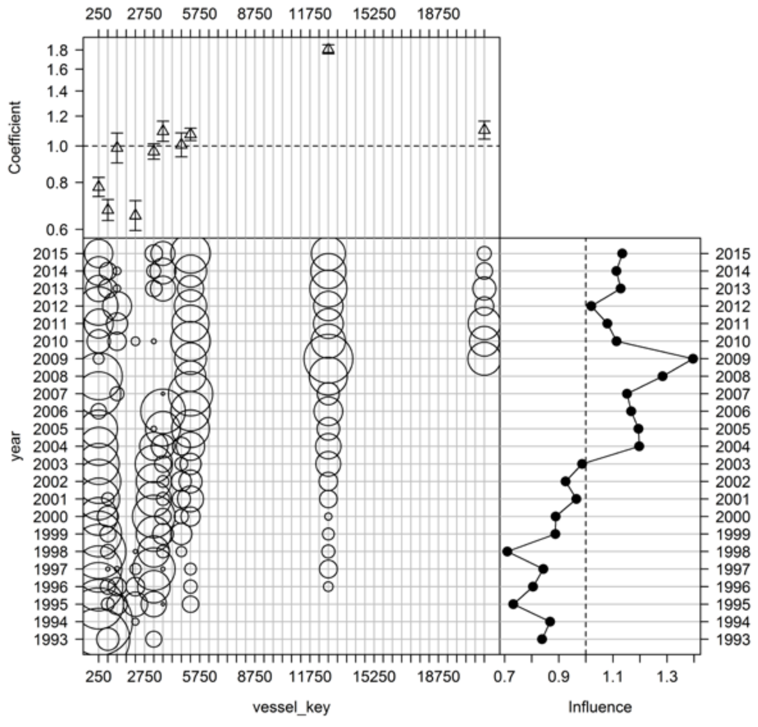

Figure A9: Influence plot of the *Vessel* variable in the positive catch *WC_BT_TAR* CPUE model.

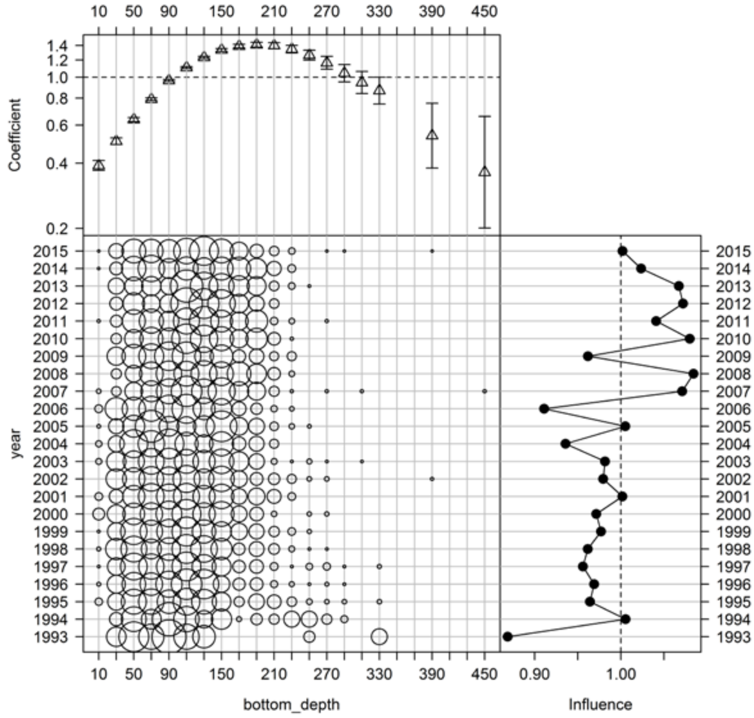

Figure A10: Influence plot of the *Depth* variable in the positive catch *WC_BT_TAR* CPUE model.

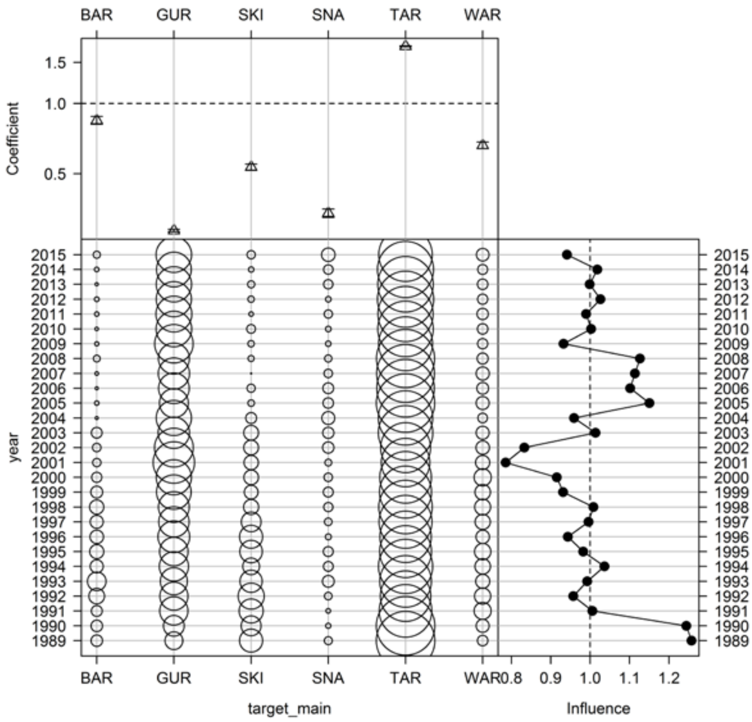

Figure A11: Influence plot of the *TargetSpecies* variable in the positive catch *TAR2_BT_MIX* CPUE model.

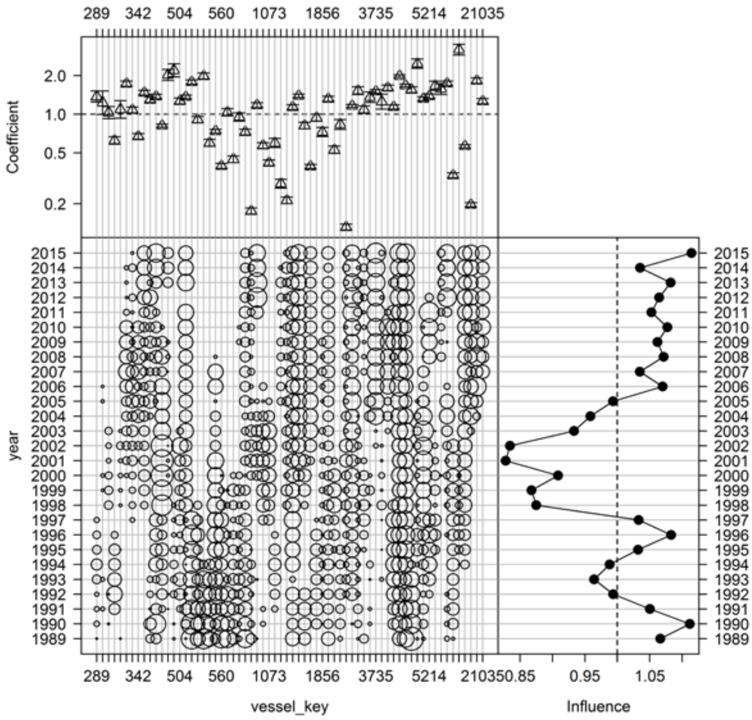

Figure A12: Influence plot of the *Vessel* variable in the positive catch *TAR2_BT_MIX* CPUE model.

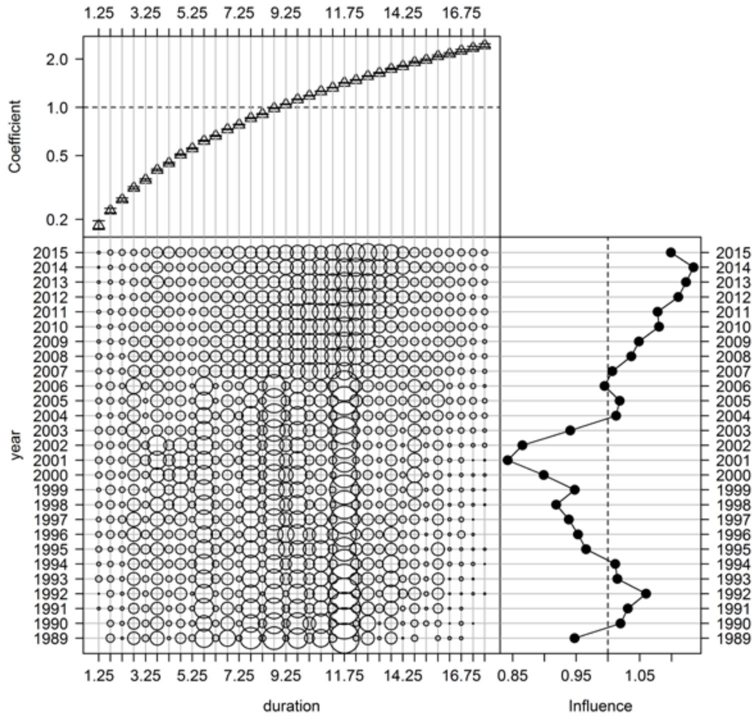

Figure A13: Influence plot of the *Duration* variable in the positive catch *TAR2_BT_MIX* CPUE model.

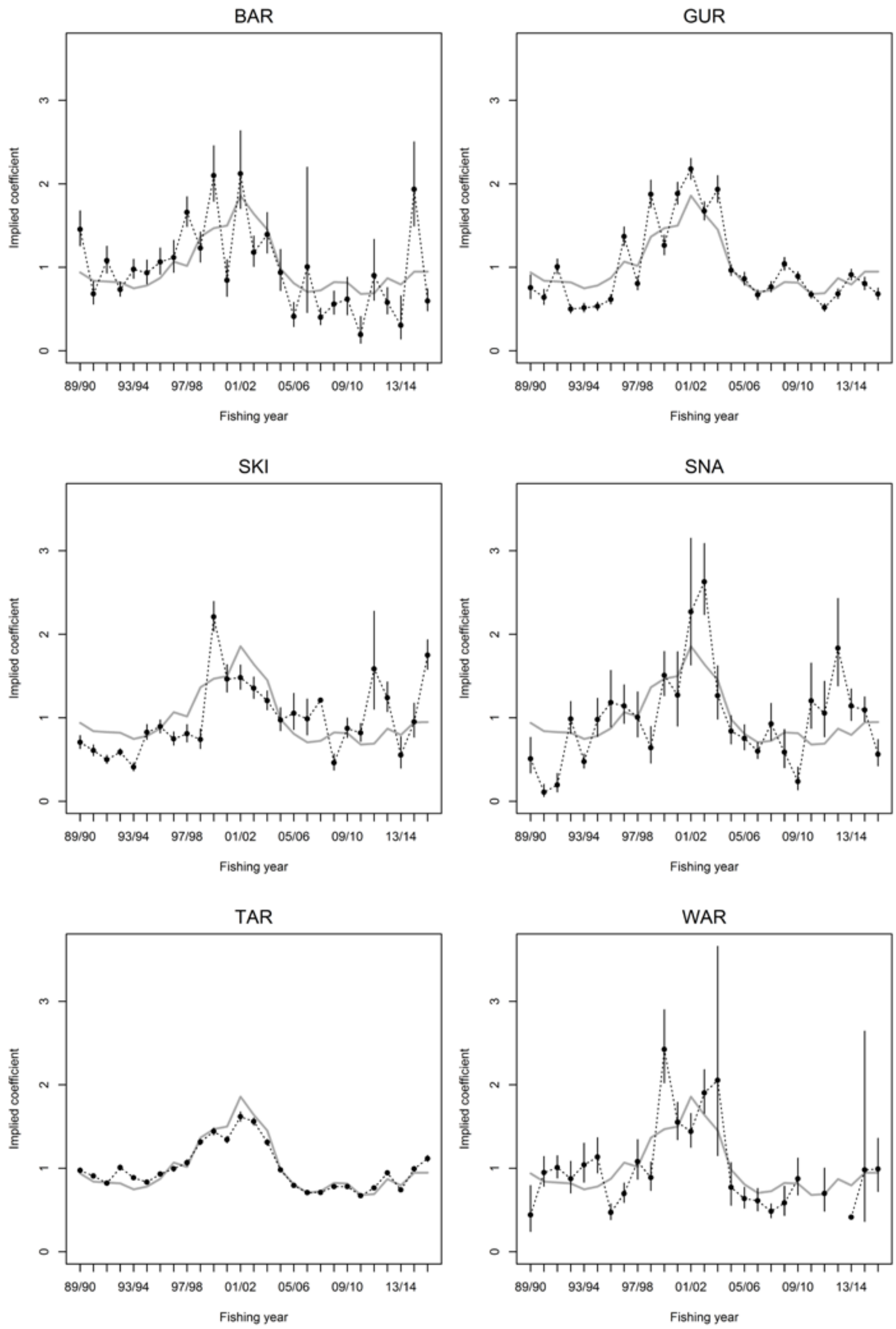

Figure A14: Annual implied coefficients (points) for the individual Target Species included in the positive catch *TAR2_BT_Mix* CPUE model. The grey line represents the annual CPUE indices derived from the positive catch CPUE model. The confidence intervals represent the standard error of the annual residuals.

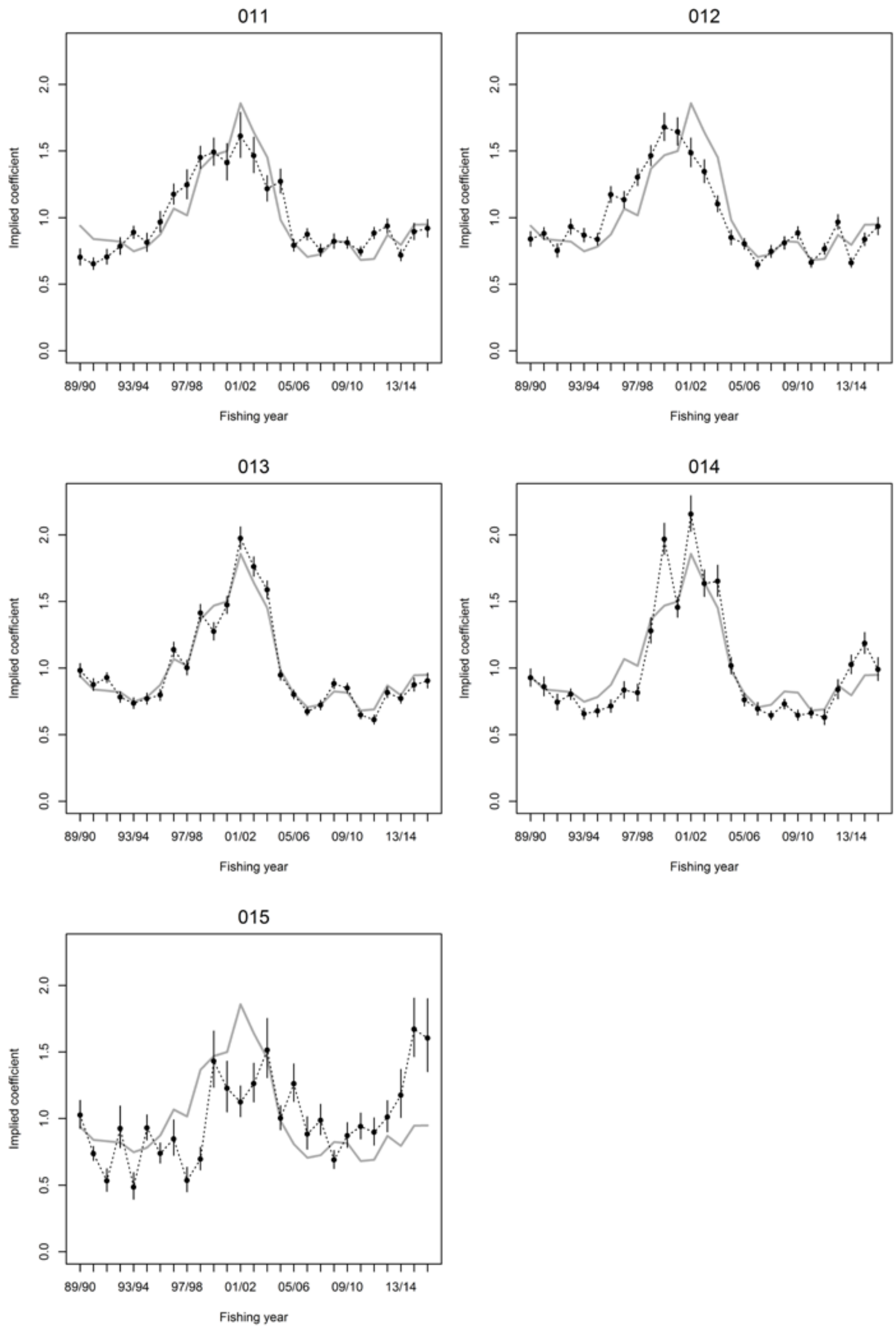

Figure A15: Annual implied coefficients (points) for the individual Statistical Areas included in the positive catch *TAR2_BT_Mix* CPUE model. The grey line represents the annual CPUE indices derived from the positive catch CPUE model. The confidence intervals represent the standard error of the annual residuals.

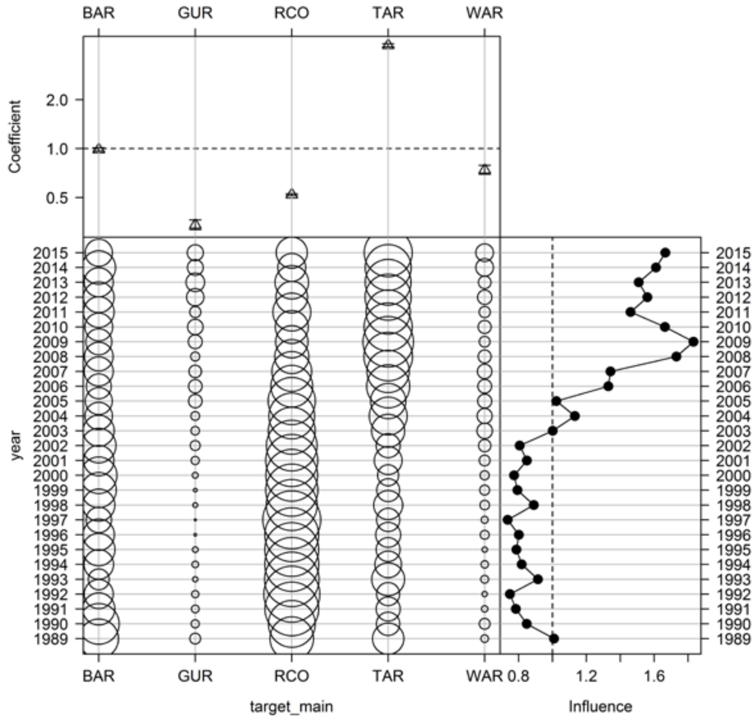

Figure A16: Influence plot of the *TargetSpecies* variable in the positive catch *TAR3_BT_MIX* CPUE model.

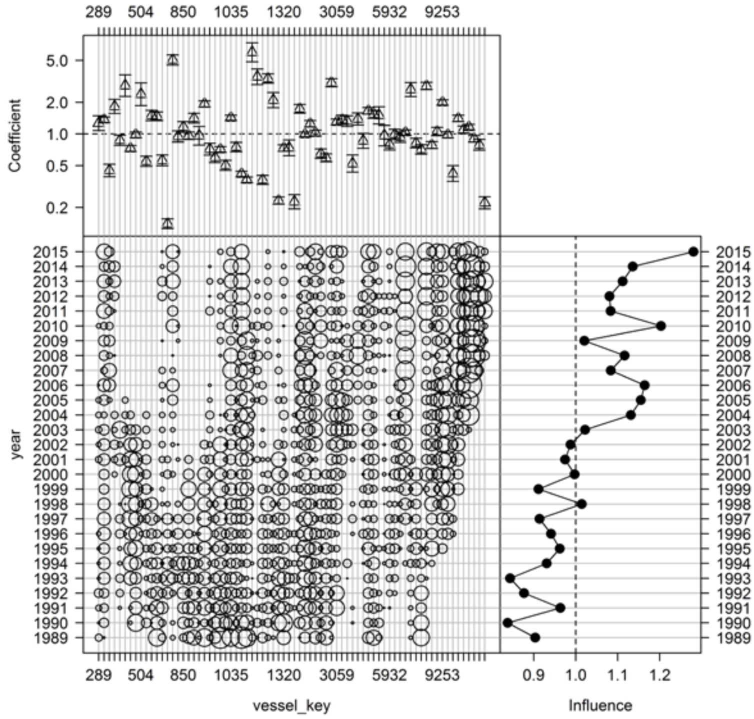

Figure A17: Influence plot of the *Vessel* variable in the positive catch *TAR3_BT_MIX* CPUE model.

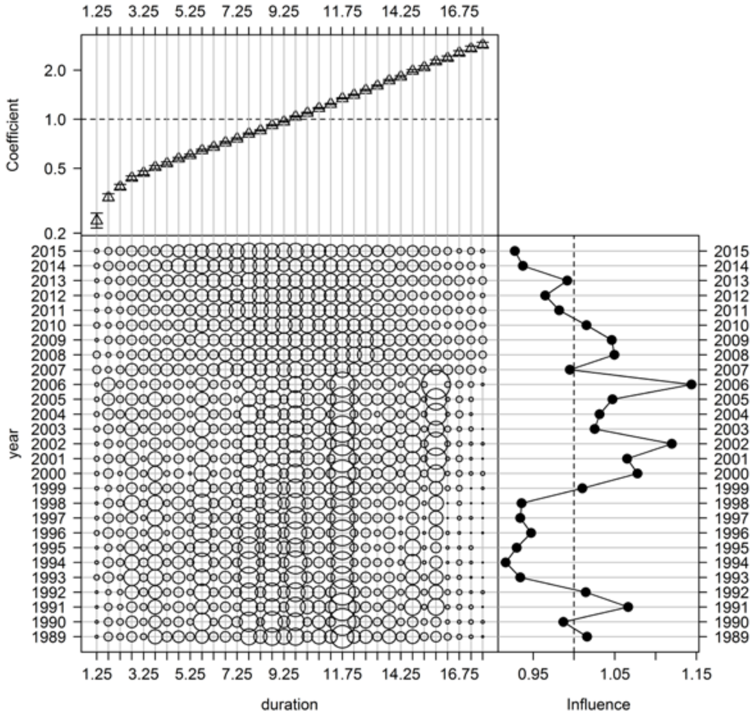

Figure A18: Influence plot of the *Duration* variable in the positive catch *TAR3_BT_MIX* CPUE model.

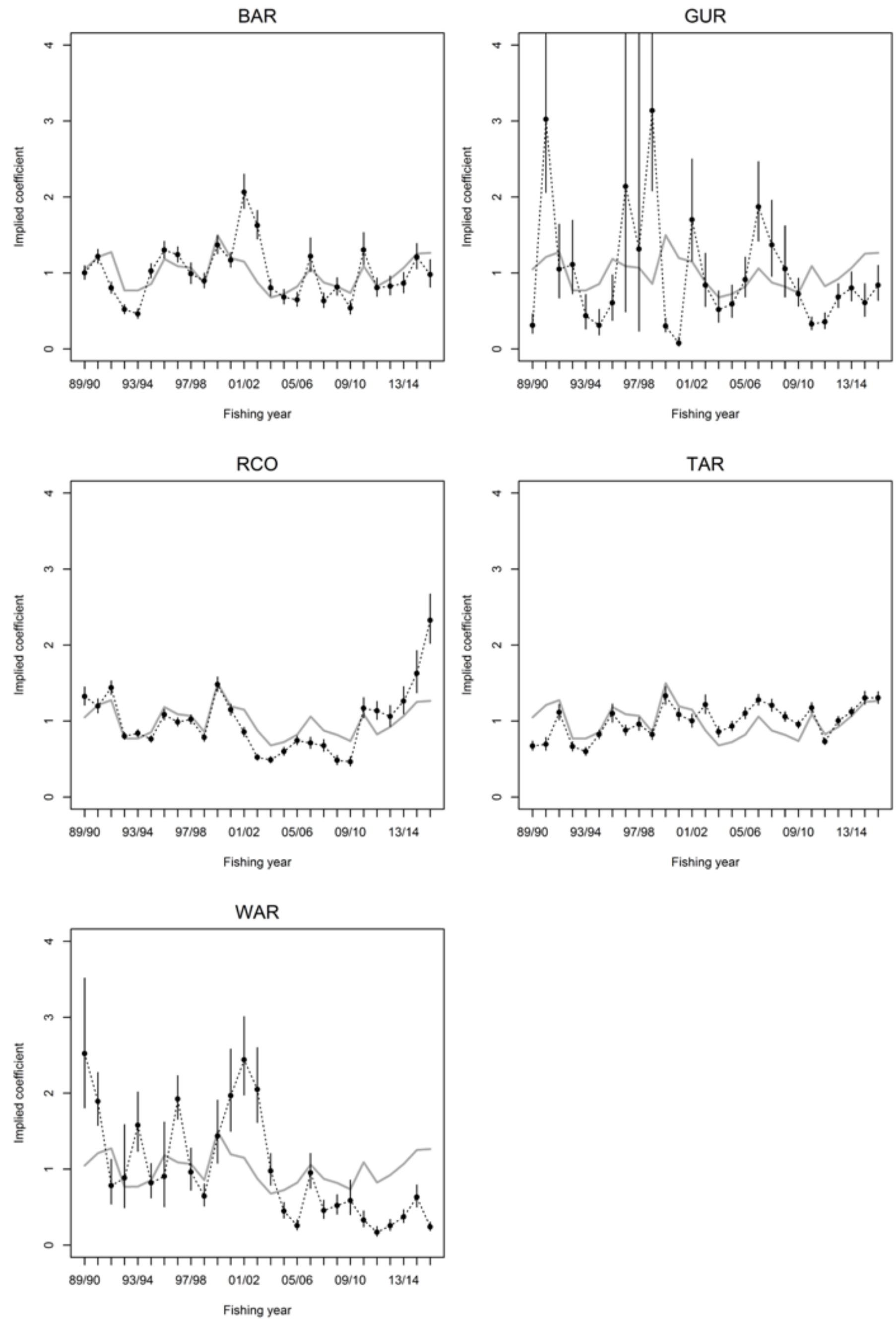

Figure A19: Annual implied coefficients (points) for the individual Target Species included in the positive catch *TAR3_BT_Mix* CPUE model. The grey line represents the annual CPUE indices derived from the positive catch CPUE model. The confidence intervals represent the standard error of the annual residuals.

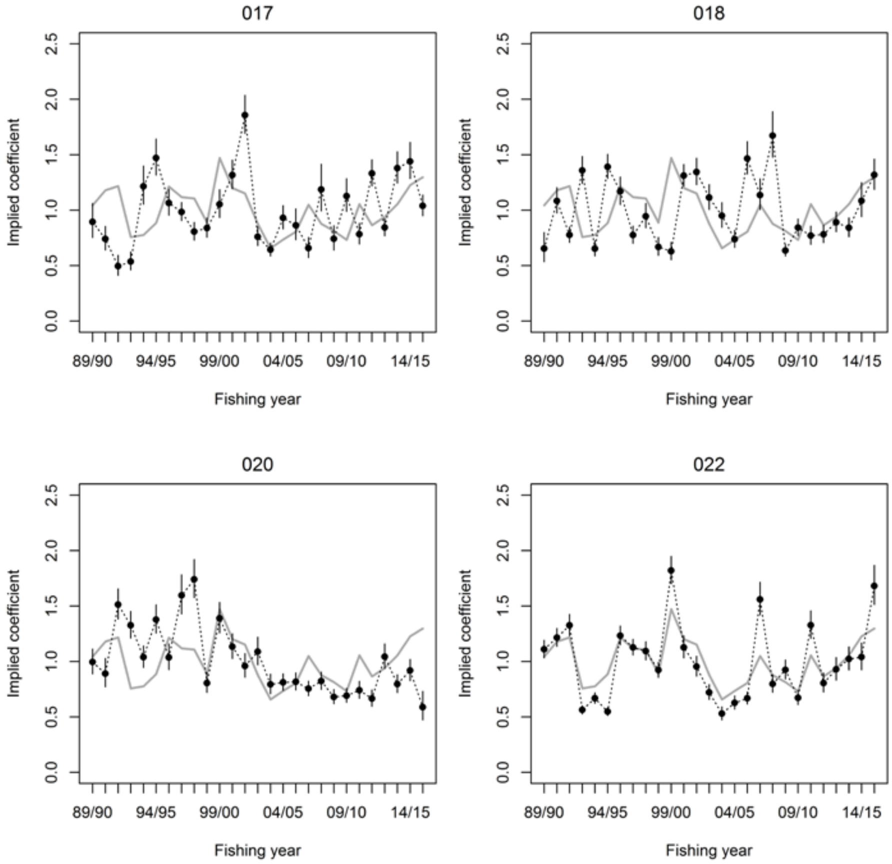

Figure A20: Annual implied coefficients (points) for the individual Statistical Area included in the positive catch *TAR3_BT_Mix* CPUE model (excluding the *Month:StatArea* interaction term). The grey line represents the annual CPUE indices derived from the positive catch CPUE model. The confidence intervals represent the standard error of the annual residuals.

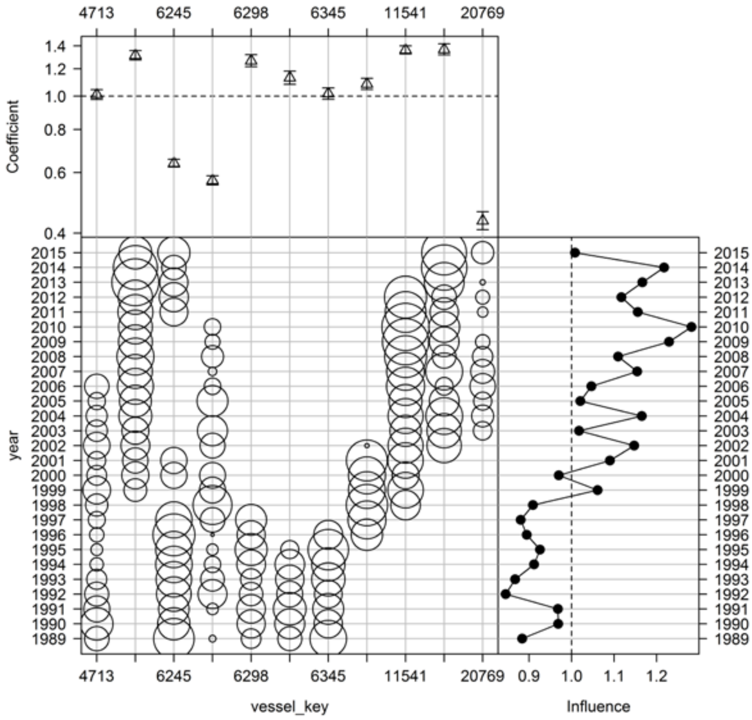

Figure A21: Influence plot of the *Vessel* variable in the positive catch *TAR3_SN_TAR* CPUE model.

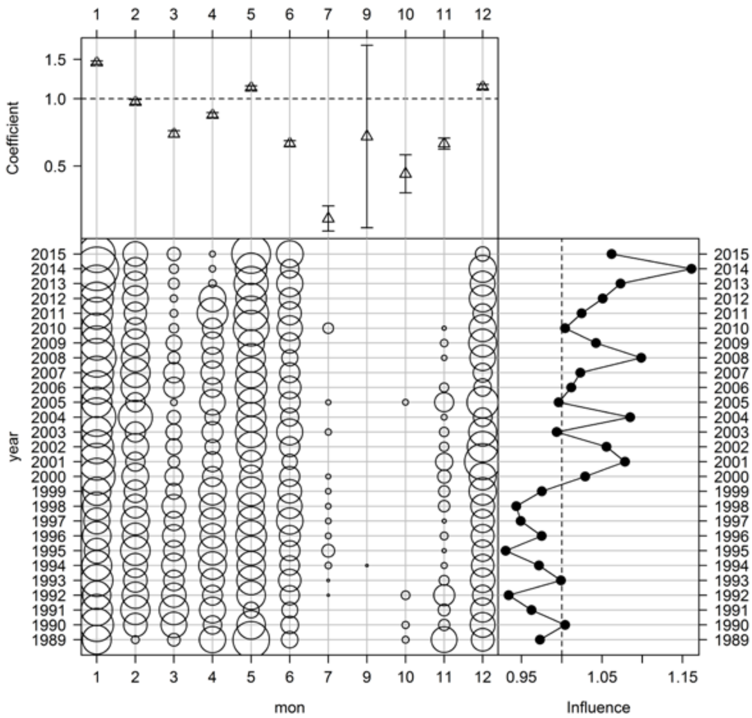

Figure A22: Influence plot of the *Month* variable in the positive catch *TAR3_SN_TAR* CPUE model.

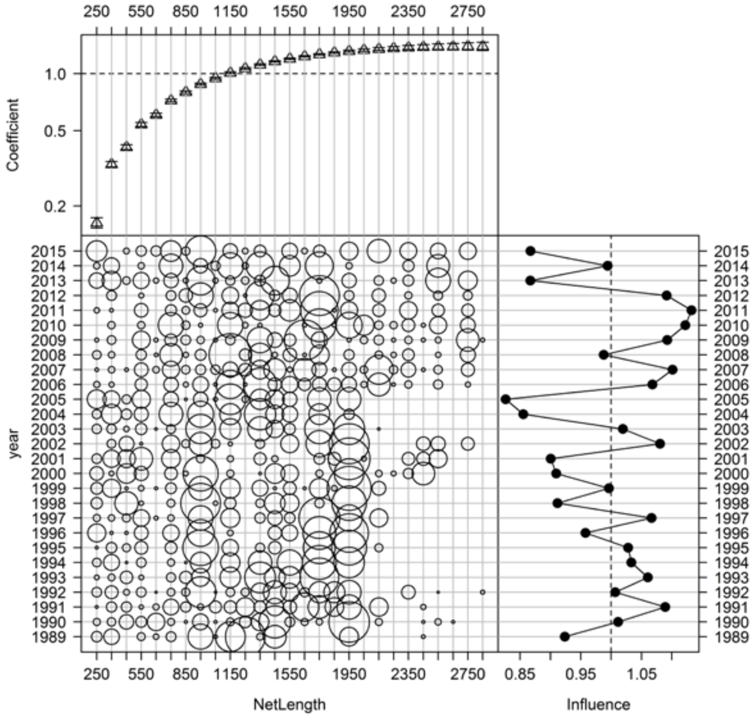

Figure A23: Influence plot of the *NetLength* variable in the positive catch *TAR3_SN_TAR* CPUE model.