Ministry for Primary Industries
Manatū Ahu Matua

# Catch-per-unit-effort (CPUE) analyses for FMA2 red gurnard (GUR 2)

New Zealand Fisheries Assessment Report 2018/10

M. I. Schofield
A. D. Langley
D. A. J. Middleton

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The fisheries taking gurnard in Quota Management Area (QMA) GUR 2 are described from 1989–90 to 2015–16 based on compulsory reported commercial catch and effort data held by the Ministry for Primary Industries (MPI). GUR 2 comprises the eastern North Island from Cape Runaway around to Mana Island on the west coast. Gurnard is a ubiquitous species caught as by-catch throughout GUR 2, however, the majority of the GUR 2 catch (82%) is captured by the mixed species (gurnard, snapper and trevally) bottom trawl fishery within Hawke Bay and Poverty Bay. The GUR 2 catch has been stable over the period examined, usually between 500 and 600 tonnes compared to the 725 t TACC, although the 2015/16 landings were 748 tonnes.

A Generalised Linear Modelling (GLM) approach was applied to model the magnitude of positive gurnard catches. The dependent variable of the catch magnitude CPUE model was the natural logarithm of catch. For the positive catch CPUE model, a Weibull error structure was adopted following an evaluation of alternative distributions. The mixed species CPUE index is the accepted index for monitoring abundance in GUR 2. The CPUE index has gradually declined from 1989–90 to 2011–12 and then increased rapidly over the last four years. This increase is corroborated by the tow based TCER series.

# 1. INTRODUCTION

Red gurnard (*Chelidonichthys kumu*) are ubiquitous in New Zealand inshore trawl fisheries and support a target fishery in Fisheries Management Area 2 (FMA 2, often referred to as Area 2) (Ministry for Primary Industries 2016). Gurnard is captured in a high proportion of FMA 2 inshore trawls as both a target species and by-catch.

The Area 2 trawl fleet operates between Cape Runnaway and Porangahau and is centered in the inshore waters of Hawke Bay. Previous characterisations of GUR 2 (Kendrick & Walker 2004, Kendrick & Bentley 2014) have identified three distinct GUR 2 fisheries: a bottom trawl fishery which targets gurnard, snapper and trevally; a flatfish target bottom trawl fishery; and a tarakihi target bottom trawl fishery. CPUE indices were previously derived for each fishery using a GLM approach (Kendrick & Walker 2004, Kendrick & Bentley 2014).

The Ministry for Primary Industries' Northern Inshore (Science) Working Group considered that the CPUE indices from the mixed-target bottom trawl (BT.MIX) fishery provided the most reliable index of stock abundance for GUR 2. These indices were adopted by the NINS WG as the primary index for the stock. Mean CPUE from the period 1990–91 to 2009–10 is used as a BMSY-compatible proxy for GUR 2 (Ministry for Primary Industries 2016). The most recent CPUE analysis reported in the MPI plenary included data to 2012–13 (Ministry for Primary Industries 2016), although an update of the analyses to 2014–15 was carried out in 2016 (Schofield et al. 2016). This report updates the fisheries characterisation and CPUE indices to 2015–16. This project was funded by Fisheries Inshore New Zealand and conducted by Trident Systems.

Throughout this report fishing years are referred to as the later year; thus the 1989/90 fishing year (1 October 1989 to 30 September 1990) is referred to as 1990.

# 2. METHODS

Statutory catch, effort and landings data for GUR 2 from the beginning of the 1990 fishing year (1 October 1989), to the end of the 2016 fishing year (30 September 2016) were sourced from the Ministry for Primary Industries' `warehou` database. The dataset captured all fishing effort in FMA 2 that had potential to capture gurnard (inshore trawls in Statistical Areas 011 to 016) regardless of whether gurnard was captured.

## 2.1 Data Grooming

Data were groomed within Trident's `kahawai` database which implements grooming methods described by Starr (2007) using code adapted from the Groomer package (Bentley 2012). The grooming process implements error checks on both the landings and effort datasets.

Missing values in 29 effort records were corrected using values from records on the corresponding forms, matched on the DCF (form) key. DCF correction was used for Catch Effort Landing Return (CELR) forms for the fields: primary method, target species and Statistical Area.

Grooming of effort data then used the logic described by Starr (2007) to correct likely erroneous or missing values in the reported target species, Statistical Area, primary method, date, time, position and units of effort. Effort records removed due to changes from the data grooming process are summarised in Table 1, further records were removed due to missing values.

**Table 1: Fishing effort grooming resulting in dropped effort records.**

| Code | Description | Frequency |
|---|---|---|
| FELLS | Coordinate outside of Statistical Area | 4 043 |
| FETSW | Target species invalid | 170 |

Grooming of landings also followed logic described by Starr (2007) to correct likely erroneous or missing values in the reported date, destination type, state code, conversion factor, and to remove duplicate landings. The majority of the landings removed during grooming were removed by rule LADTH that identifies landing records where the catch was not landed (destination types of P (Holding receptacle in the water), Q (Holding receptacle on land), or R (Retained on board)). Earlier in the timeseries some data were removed by the check LADUP which identifies duplicate landings (Figure 1).

There is a good correspondence between reported landings and the QMR/MHR returns (Figure 2).

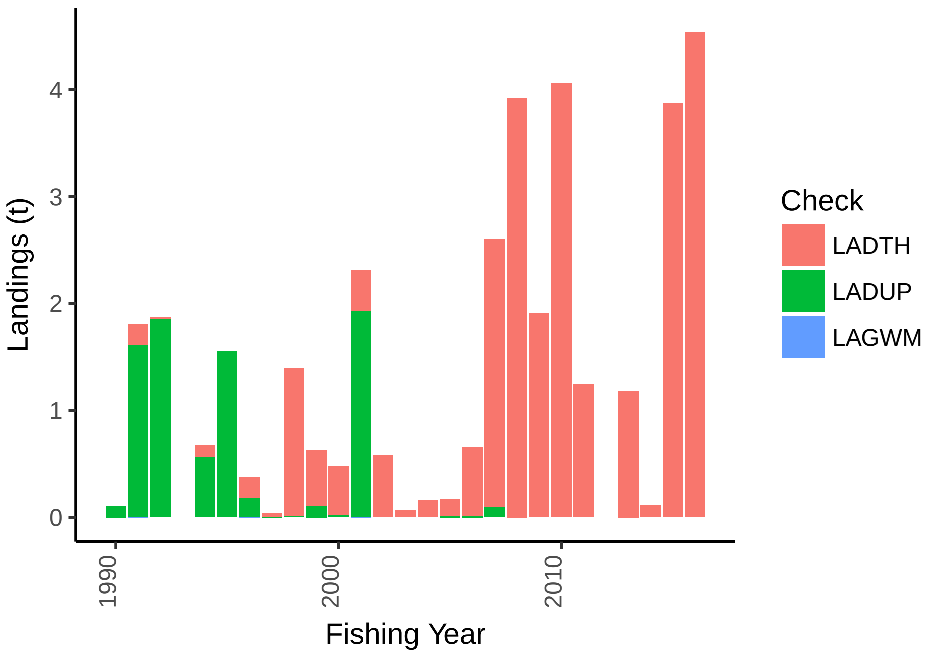


**Figure 1: The gurnard landings data removed from the GUR 2 CPUE analysis dataset, the bar colour indicates the grooming checks contributing to the removals.**

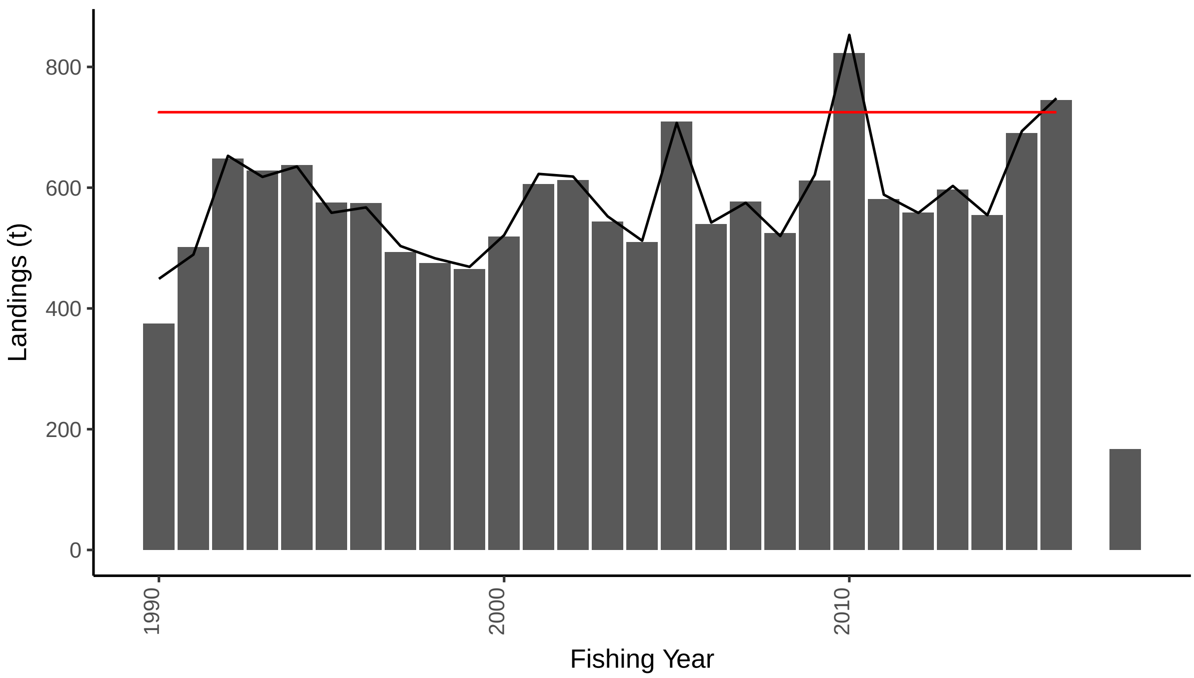


**Figure 2: A comparison between the groomed GUR 2 annual landed catch (bars), Quota Management Returns (QMR, 1990–2001) and Month Harvest Returns (MHR, 2002–2015) (black line) and Total Allowable Commercial Catch (TACC, red line).**

## 2.2 Analysis data sets

The data were configured to generate three separate data sets for the fishery characterisation and CPUE analyses. The fishery characterisation was conducted using the individual effort records for all fishing methods. Landed catches of the species of interest were allocated to the fishing event records following the methodology of Starr (2007); i.e. landed catches were predominantly allocated in proportion to the estimated catches associated with the fishing effort records.

For the bottom trawl fishing method, catch and effort data were generally recorded using CELR forms prior to 2008 and the TCER form in subsequent years (Figure 3). Two separate CPUE data sets were configured based on the two main data formats: an aggregated data set configured to approximate the format of the CELR data which includes data from 1990 to 2016, and a trawl event based data set that retains the detail of the TCER data format from 2008 – 2016. For the event based data set, the landed catch from each fishing trip was allocated amongst the trawl records from the respective fishing trips in proportion to the estimated catches of the species (following Starr 2007).

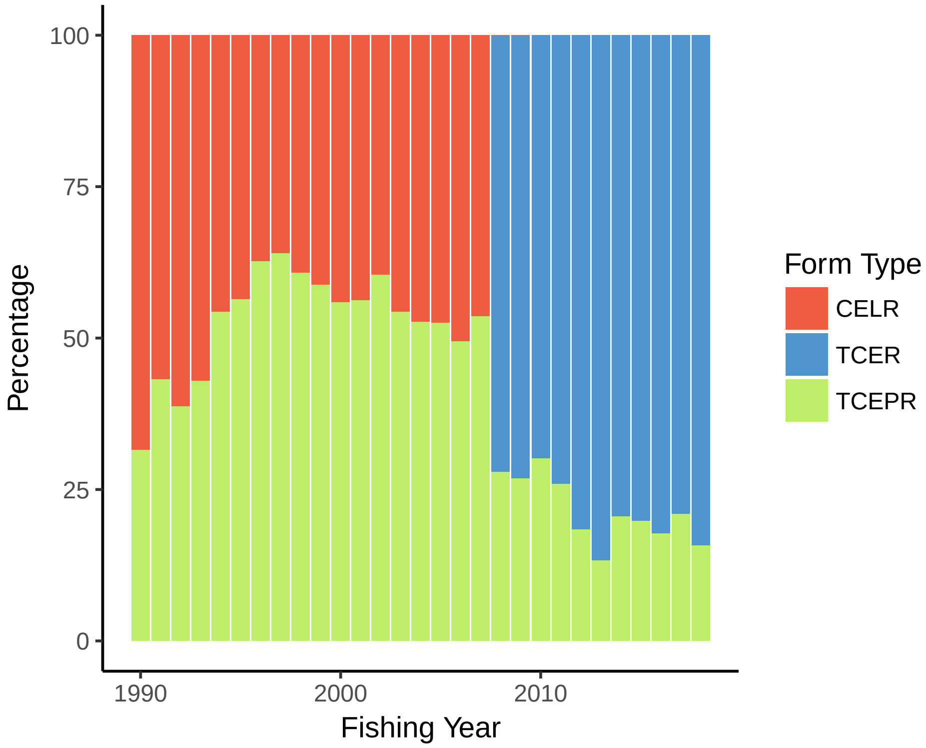


**Figure 3: The reporting form types for events that landed GUR 2 from the 1990 to the 2016 fishing year, TCER forms were introduced for vessels > 6m in the 2008 fishing year.**

The configuration of the aggregated CPUE data set summarised effort records for each vessel fishing day followed the approach of Langley (2014). For each fishing day, the following variables were derived: the number of trawls, total fishing duration (hours), the predominant target species and the predominant Statistical Area where fishing occurred. The estimated catches of all species were also determined for each fishing day. For comparability with the CELR data format, only the estimated catch of the five main species (by catch magnitude) were retained in the final aggregated data set. In the first instance, the landed catches of the species of interest from individual trips were allocated amongst the associated aggregated event records in proportion to the (daily aggregated) estimated catch of the species. In the absence of the species being included within the daily aggregated estimated catch, the landed catch was allocated in proportion to the fishing effort (number of trawls) within the fishing trip.

## 2.3 CPUE methods

### 2.3.1 Data filtering for CPUE analyses

When carrying out CPUE analyses, records were dropped if the fishing duration was less than 1 hour or if the daily aggregated effort was greater than 18 hours. For the tow resolution data set records were dropped if the duration exceeded 8 hours. Landings were excluded if they exceeded the 99th percentile and the estimated catch differed significantly from the reported landings.

### 2.3.2 CPUE models

A Generalised Linear Model (GLM) approach was used to model the occurrence (presence/absence) of positive gurnard catch and the magnitude of positive gurnard catches. The dependent variable of the catch magnitude CPUE models was the natural logarithm of catch. For the positive catch CPUE models, a Weibull error structure was adopted following an evaluation of alternative distributions (Log logistic, lognormal, Gamma). The presence/absence of gurnard catch was modelled based on a binomial distribution. 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).

The model terms offered to vessel-day models are evident in Table 2 and the model terms offered to the tow resolution models in Table 3. Fishing year (fyear) was forced into all CPUE models. Models were selected by forward stepwise selection of additional model terms was based on Akaike's Information Criterion (AIC) with predictors retained if they increased the deviance explained by at least 1%.

The influence of predictors in the various CPUE models was investigated using methods provided in the R package `influ` (Bentley et al. 2011).

**Table 2: The variables offered to the Binomial and Weibull vessel-day resolution GUR 2 CPUE model for model selection.**

| Variable | Definition | Data type | Range |
|---|---|---|---|
| Fishing Year | Fishing year | Categorical (27) | 1990–2016 |
| Vessel | Fishing vessel | Categorical (47) | |
| Month | Month | Categorical (12) | Jan-Dec |
| Area | Statistical Area | Categorical (6) | 011–016 |
| Area * Month | Area and month combination | Categorical (72) | |
| Duration | Natural logarithm of trawl duration (hours) | Continuous | ln(1–24) |
| Effort | Number of trawls in the vessel-day | Continuous | 1–6 |
| Target Species | Most frequent target species for the vessel-day | Categorical (3) | GUR, SNA, TRE |

**Table 3: The variables offered to the Binomial and Weibull TCER resolution GUR 2 CPUE model for model selection.**

| Variable | Definition | Data type | Range |
|---|---|---|---|
| Fishing Year | Fishing year | Categorical (9) | 2008–2016 |
| Vessel | Fishing vessel | Categorical (24) | |
| Month | Month | Categorical (12) | Jan-Dec |
| Area | Statistical Area | Categorical (6) | 011–016 |
| Area * Month | Area month combination | Categorical (72) | |
| Duration | Duration of fishing effort for the day (hours) | Continuous | ln(1–6) |
| Effort | Number of trawls in the day | Continuous | 1–6 |
| Target Species | Most frequent target species for the vessel-day | Categorical (3) | GUR, SNA, TRE |
| Latitude | Absolute start latitude for the trawl | Continuous | 37.45–40.915 |
| Longitude | Reported start longitude for the trawl | Continuous | 176.2–178.73 |
| Speed | Speed of the trawl (knots) | Continuous | 1.9–4 |
| Distance | Distance trawled (N. miles) | Continuous | 2–14 |
| Trawl width | Wingspread of the trawl gear (m) | Continuous | 5–40 |
| Trawl height | Headline height of trawl gear (m) | Continuous | 0.5–15 |
| Depth | Depth of the bottom (m) | Continuous | 1–100 |

## 3. CHARACTERISATION OF THE GUR 2 FISHERY

The GUR 2 fishery is primarily a bottom trawl fishery (Figure 4). Set netting and bottom longline fisheries consistently take a small catch of GUR 2, with Danish seine taking slightly larger catches but less consistently (Figure 4). The GUR 2 characterisation therefore focuses on the bottom trawl fishery.

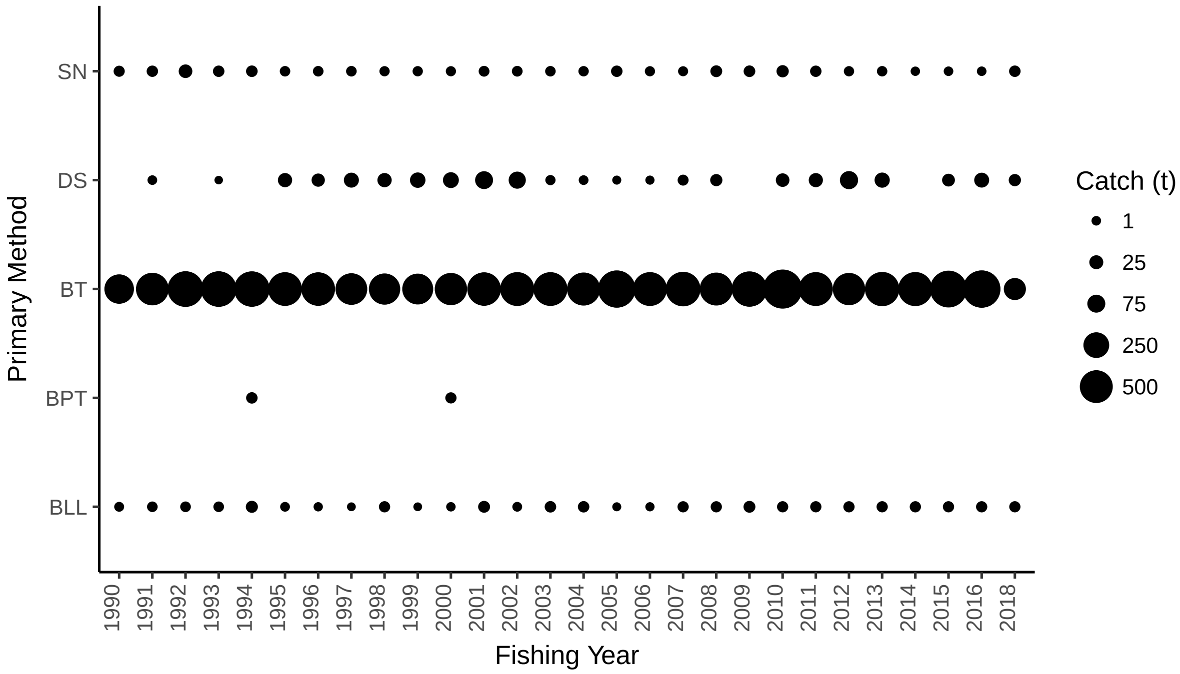


**Figure 4: GUR 2 catch by primary method from the 1990 to the 2016 fishing year.**

GUR 2 trawl catches are primarily from effort targeting gurnard, tarakihi, flatfish, snapper and trevally (Figure 5). With the exception of the flatfish target fishery, which has contracted, the amount of GUR 2 catch from effort targeted at each species has remained consistent throughout the time series (Figure 5).

The target bottom trawl fisheries can be grouped into thre categories based on fishing depth (Figure 6). A fishery targeting flatfish operates from 0–30 m. Between 5–80 m there is targeting of snapper, gurnard and trevally, and a tarakihi target fishery fishes depths of 30–120m (Figure 6).

The distribution of the GUR 2 catch between these three target fisheries is illustrated in Figure 7. Catches by the BT-MIX fishery have remained relatively stable through the time series, catches by the BT-FLA fishery have declined since 2000, whereas catches in the BT-TAR fishery have increased since 2006 (Figure 7). Overall, the BT-MIX fishery has taken 67% of the GUR 2 catch, compared to 22.5% and 7.3% from the BT-TAR and BT-FLA fisheries respectively.

There is little seasonal variation in the gurnard catch from the bottom trawl fishery, and fishing is consistently distributed between Statistical Areas (Figure 8A) and target species (Figure 8B).

The majority of the GUR 2 catch is from gurnard target fishing in Statistical Areas 013 and 014 (Figure 9B) while catch from the tarakihi target fishery is spread across areas 011, 012, 013 and 014. Comparison with the distribution of target effort (Figure 9A) suggests that the catch rate of gurnard is higher for GUR and FLA target trawls than TAR target.

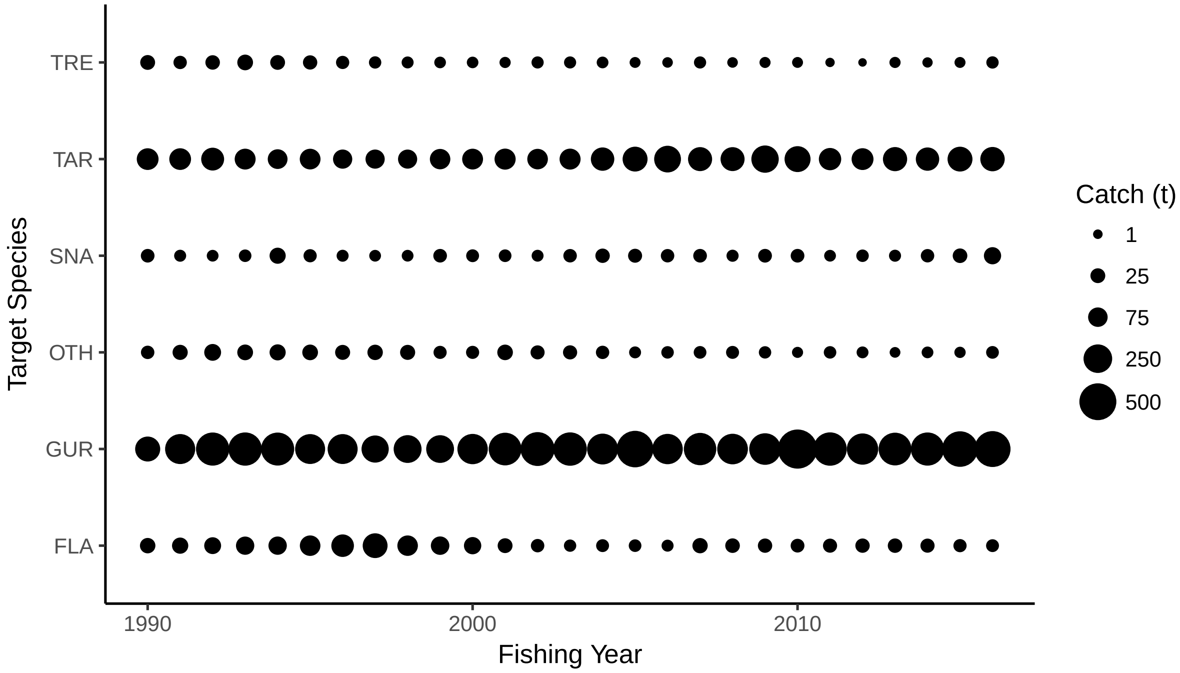


**Figure 5: GUR 2 bottom trawl catch by reported target species; all flatfish targets have been recorded as FLA.**

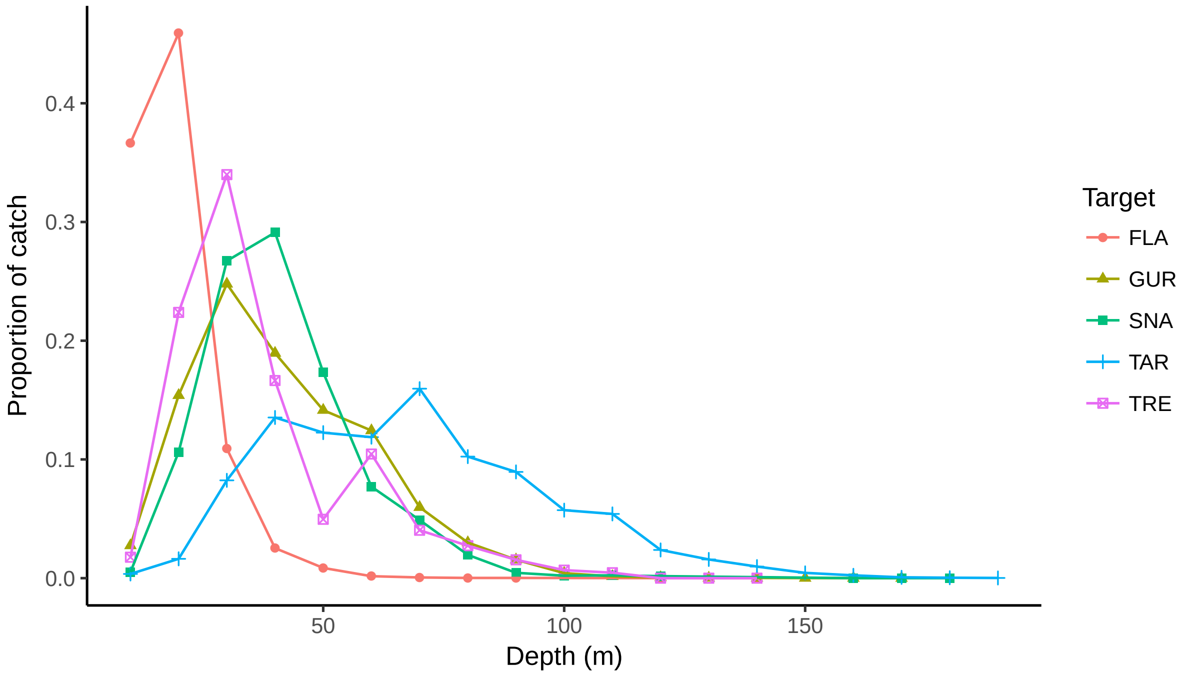


**Figure 6: Proportion of gurnard catch by depth for the main target species in the GUR 2 bottom trawl fisheries. Catches have been aggregated into 10 m bins. Only TCER data (between the 2008 – 2016 fishing years) were used.**

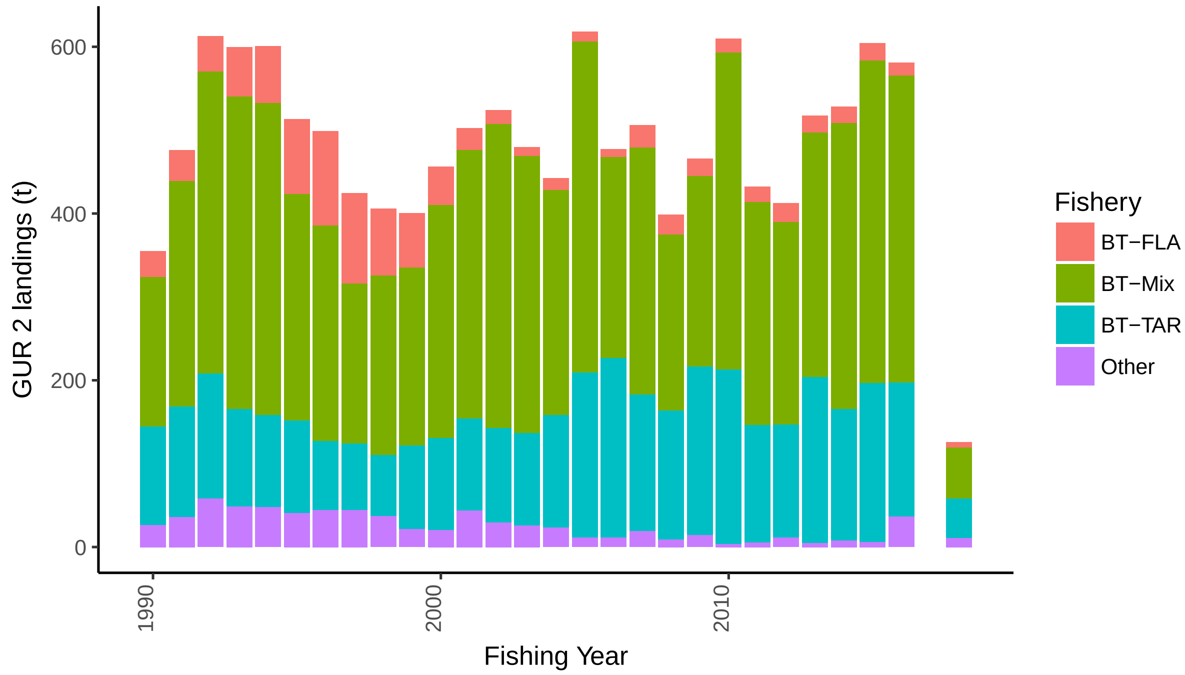


**Figure 7: Gurnard landings from the target trawl fisheries in GUR 2. Note that TCER forms were introduced in the 2008 fishing year.**

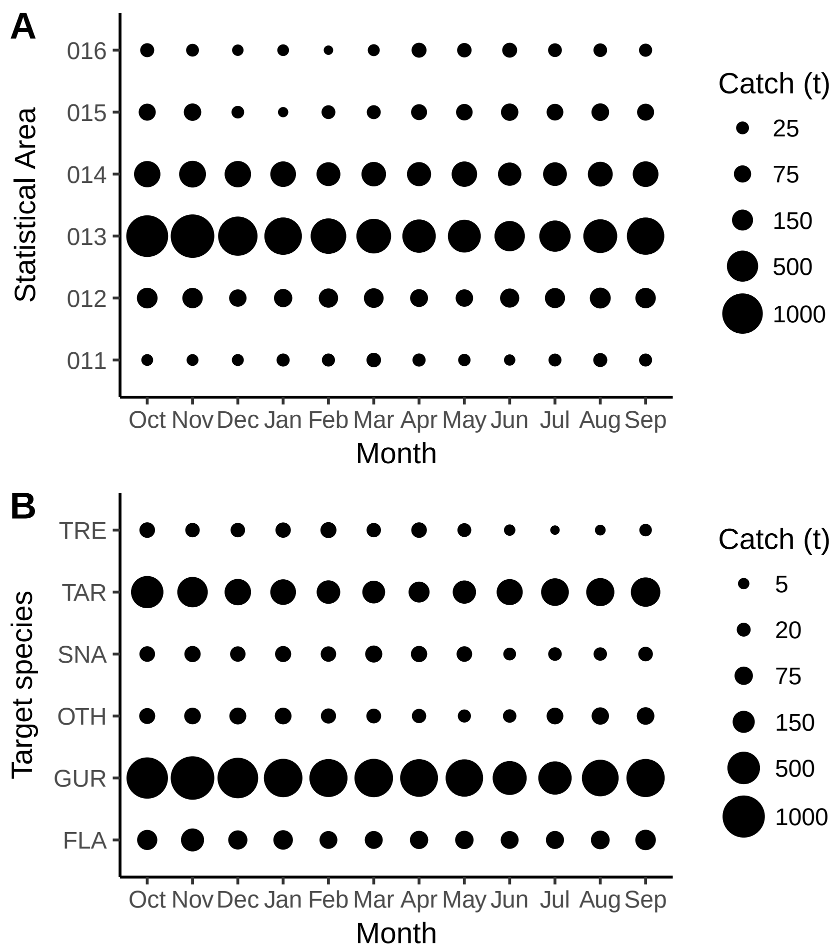


**Figure 8: Monthly GUR 2 bottom trawl catch by Statistical Area (A) and target species (B), aggregated from the 1990 to the 2016 fishing year.**

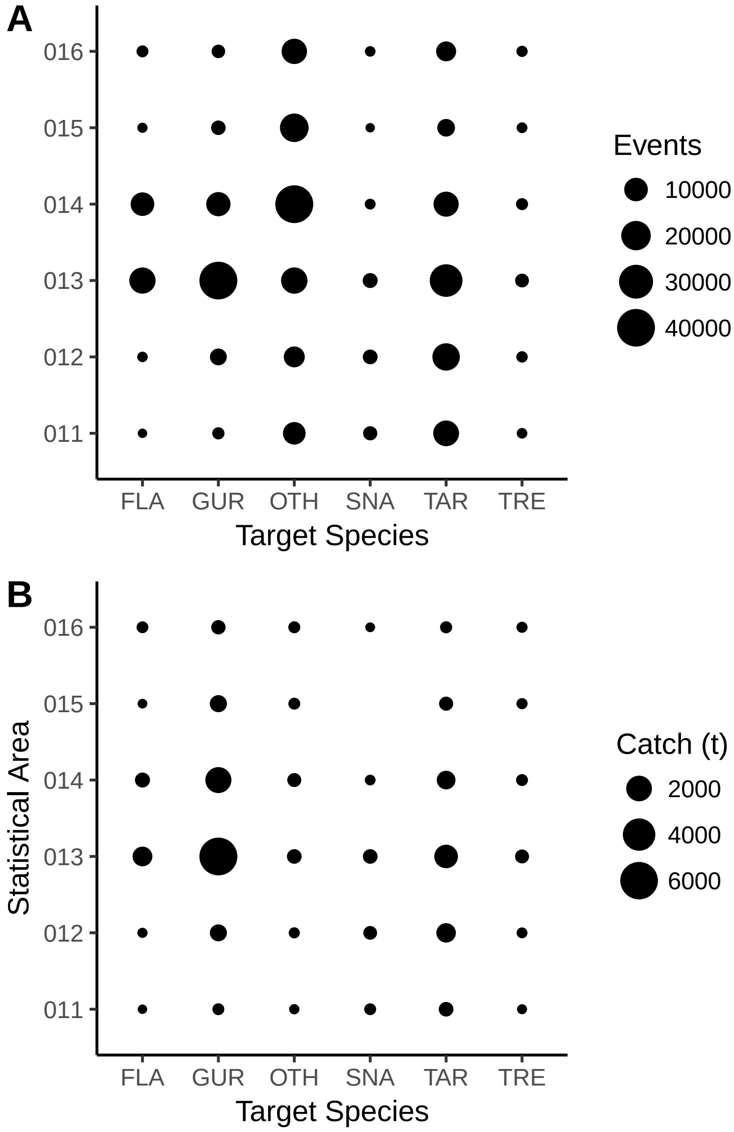


**Figure 9: The distribution of trawl effort (A) and gurnard catch (B) by target species and Statistical Area.**

Gurnard catch rates are greatest between 40 m and 60 m (Figure 10), the core depth distribution of the BT-MIX fishery (Figure 6).

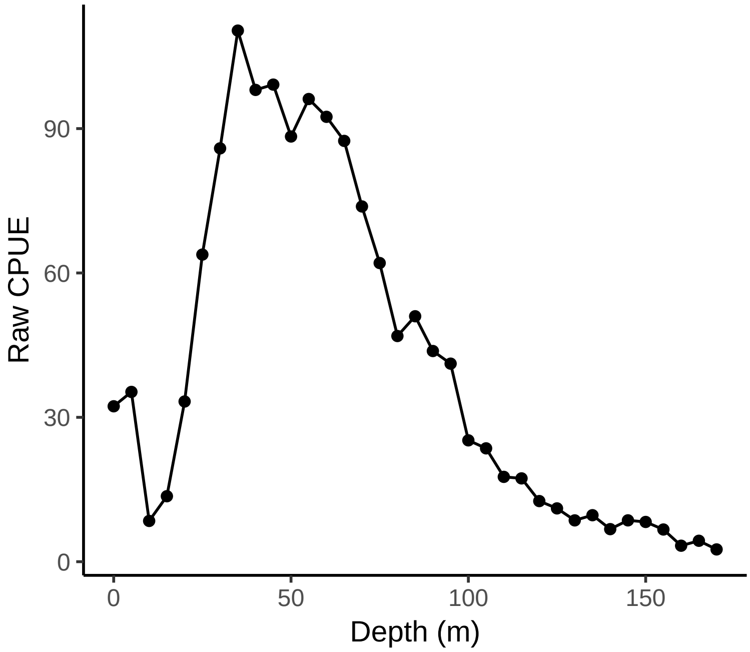


**Figure 10: Raw gurnard catch-per-unit-effort (allocated catch per trawl) by depth. Catches were aggregated in 5 m depth buns using TCER aggregated data from the 2008 to 2016 fishing years.**

The BT-MIX fishery operates in the inshore waters of Poverty Bay and Hawke Bay, while the BT-FLA fishery operates around the port of Napier and west of Mahia Peninsula (Figure 11). The BT-TAR fishery operates further offshore from Cape Runaway to Porangahau (Figure 11).

The majority of the GUR 2 catch is taken in Hawke Bay and Poverty Bay (Figure 11, Figure 12), while the catch-per-unit-effort is relatively homogenous through the inshore FMA 2 waters with a maximised CPUE in the centre of Hawke Bay (Figure 13).

There is a perception within the FMA 2 fishery that there has been an increase in the nummber of larg non-local vessels operating within Hawke Bay. These vessels are perceived to extract disproportional amounts of the FMA 2 catch. The contribution of larger vessels was investigated in Figure 14 and Figure 15, the average GUR 2 vessel size has remained constant through the series and the contribution of larger vessels peaked in 2005 and has declined since 2011.

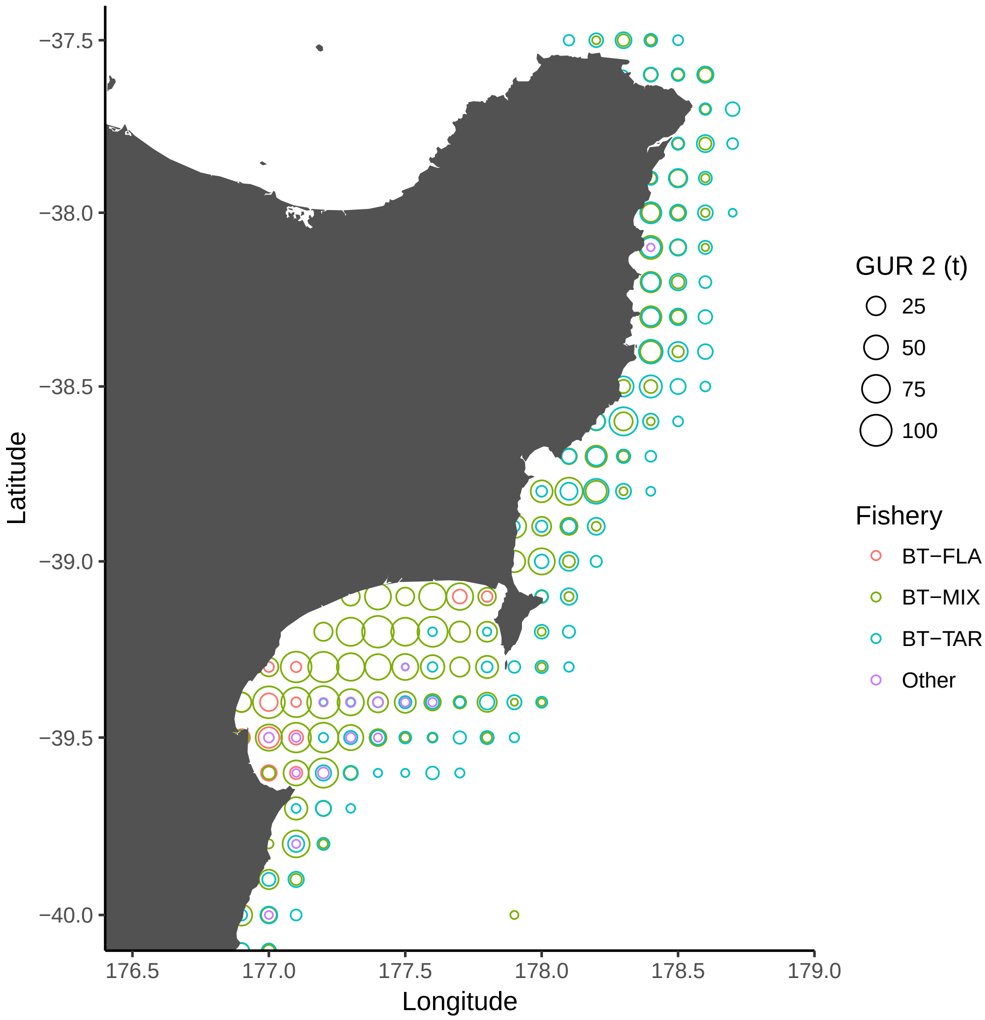


**Figure 11: The spatial distribution of catches by the three trawl fisheries within GUR 2, based on TCER data. Catches are aggregated to 0.1° ×0.1° cells, and only cells with at least 1 tonne of catch from the 2008 to the 2016 fishing year are displayed.**

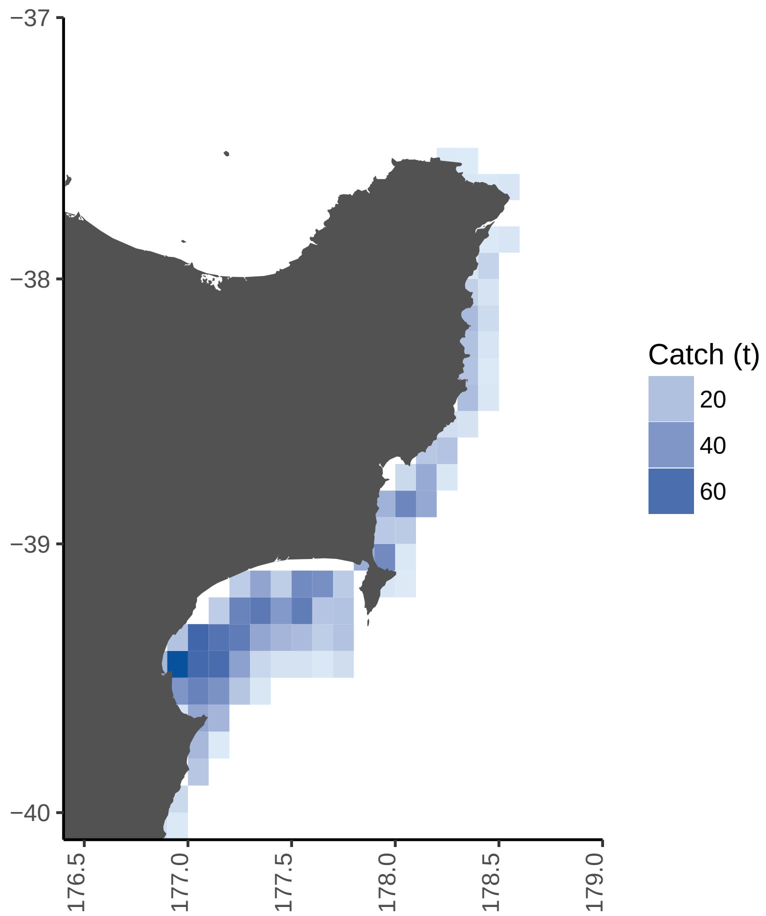


**Figure 12: The spatial distribution of catch within GUR 2, based on TCER data. Catches are aggregated to 0.1° ×0.1° cells, and only cells with at least 20 records from the 2008 to the 2016 fishing year are displayed.**

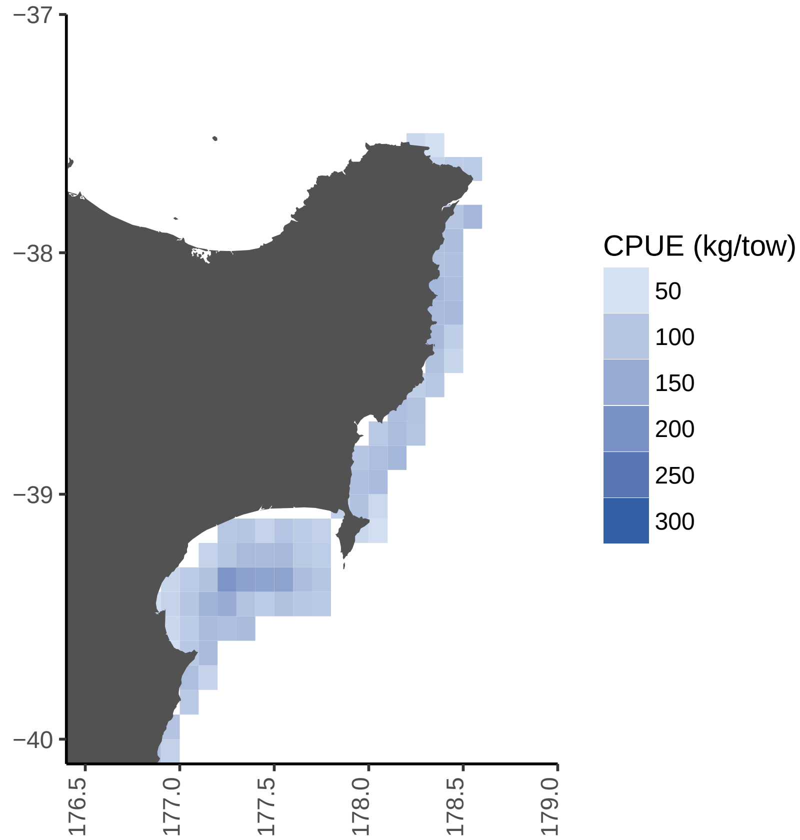


**Figure 13: The spatial distribution of CPUE within GUR 2, based on TCER data. Catches are aggregated to 0.1° ×0.1° cells, and only cells with at least 20 records from the 2008 to the 2016 fishing year are displayed.**

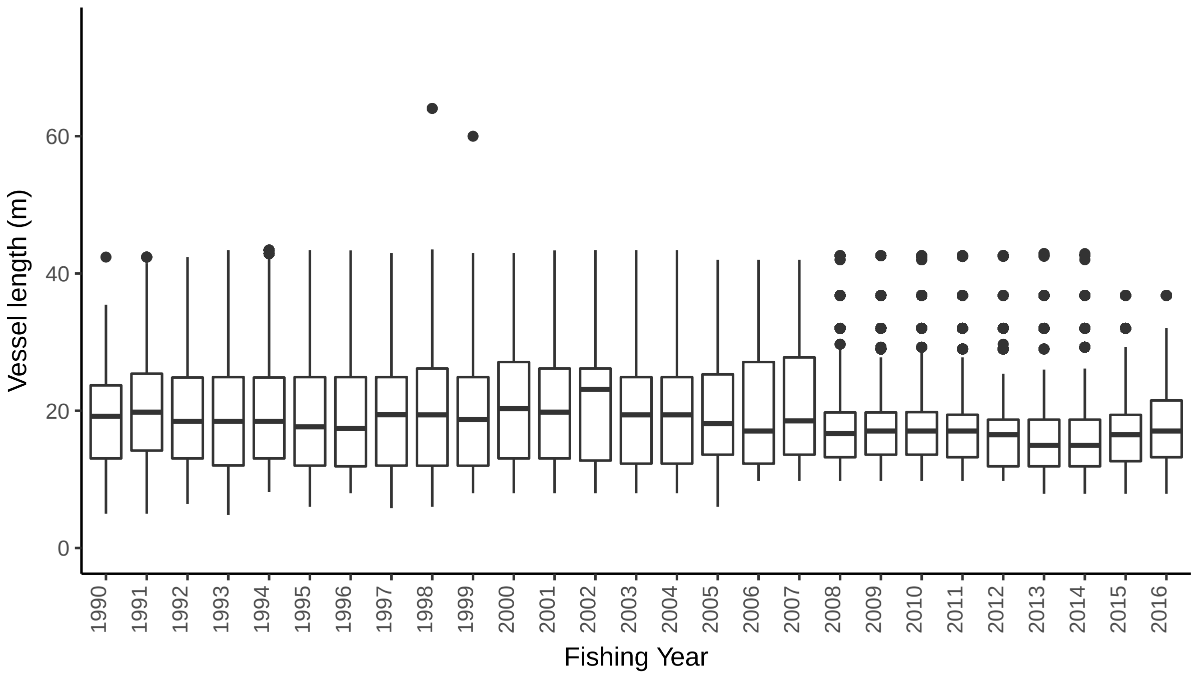


**Figure 14: Examination of the change in vessel size within the GUR 2 fleet fishing within Statistical Areas 013 and 014 from the 1990 to the 2016 fishing year.**

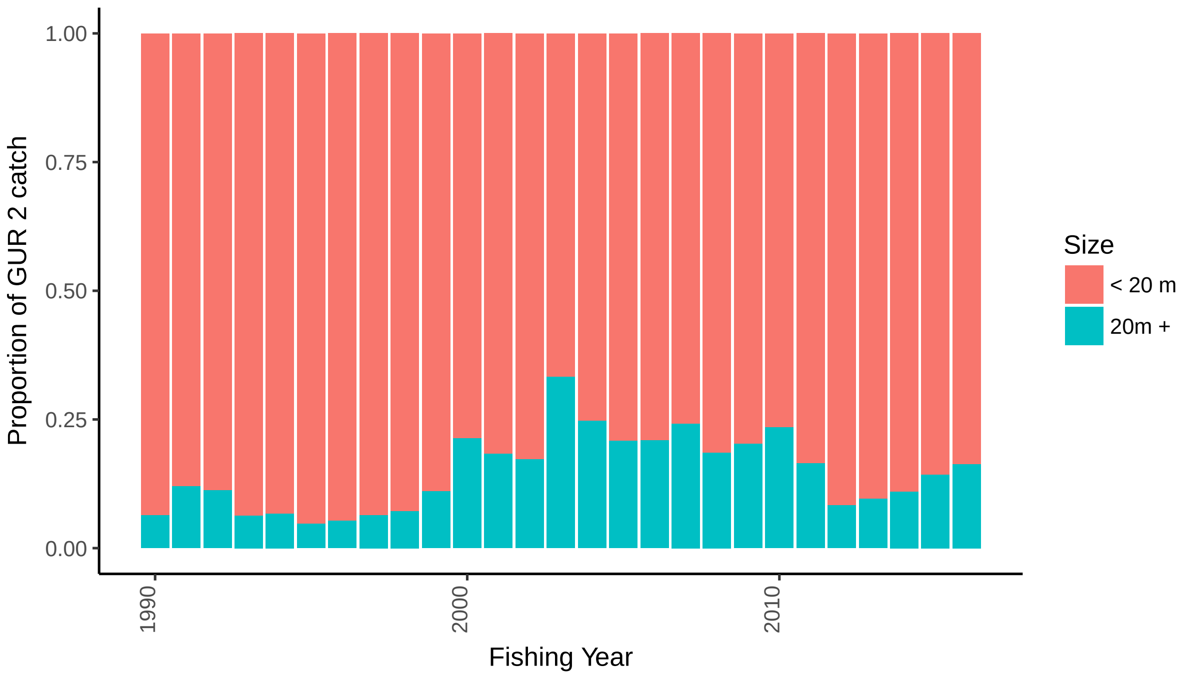


**Figure 15: Examination of the proportion of GUR 2 catch extracted by large (20 m +) and small vessels (less than 20 m) of the GUR 2 fleet fishing within Statistical Areas 013 and 014 from the 1990 to the 2016 fishing year.**

## 4. BT-MIX AGGREGATED DATA CPUE ANALYSIS

The BT-MIX aggregated data set extends from 1990 to 2016.

### 4.1 Aggregation

The number of fishing events within each stratum for alternative "roll ups" of the data is illustrated in Figure 16B. Most approaches aggregate the data to two fishing events per stratum. The percentage of events, trips and strata with positive catch is about 97% (Figure 16A).

The vessel-date aggregation, as used in the previous analysis (Kendrick & Bentley 2014) and recommended by Langley (2014) is used to provide a data set from 1990 to 2016.

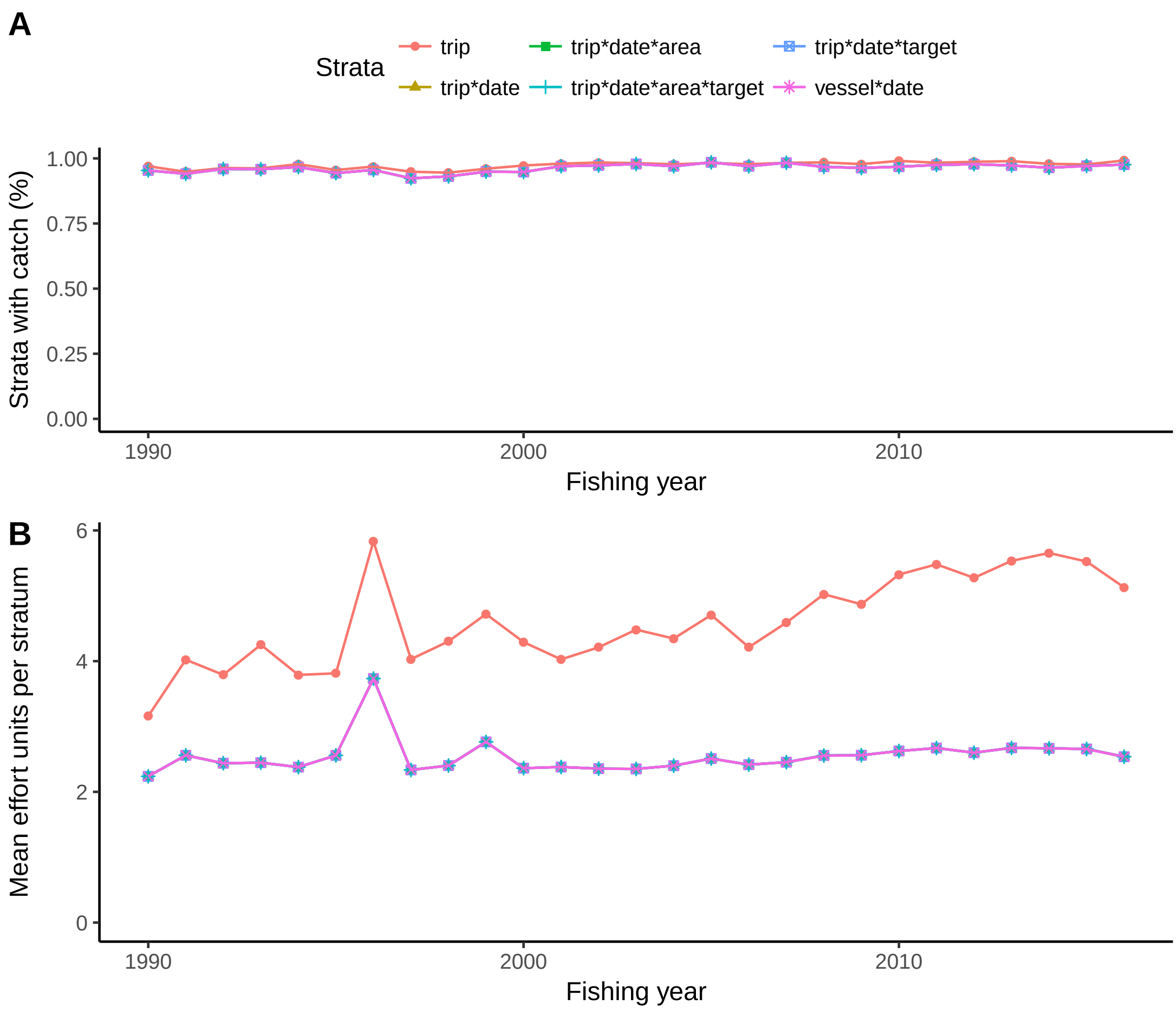


**Figure 16: Impact of alternate data aggregations. (A) the percentage of strata with positive catch; (B) the mean number of effort units (i.e tows) per stratum.**

## 4.2 Fishery definition

The BT-MIX fishery is defined as follows:

- Form type in (CEL, TCP, TCE)
- Primary method: bottom trawl (BT)
- Target species either gurnard, trevally or snapper (GUR, TRE, SNA)
- Fishing effort conducted within Statistical Areas 011, 012, 013, 014, 015 or 016
- Fishing effort conducted between 1 Oct 1989 and 30 Sept 2016

The BT-MIX fishery fleet size has reduced since 1994, with about 30 vessels operating since 2008, while the percentage of trips that caught gurnard has remained relatively constant at about 97% (Table 4).

Landings exceeding 1381 kg (99.5th percentile) were checked for accuracy and 12 records were removed due to large differences between estimated catch and landed catch.

**Table 4: Summary of the GUR 2 vessel-day aggregated data set. Records represent a row in the effort dataset while effort numbers indicate the number of tows. Trips caught and days caught are the percentage of trips and days respectively in the BT-MIX data set with GUR catches.**

| Fishing Year | Vessels | Trips | Records | Effort (num) | Effort (hrs) | Catch (t) | Trips caught | Days caught |
|---|---|---|---|---|---|---|---|---|
| 1990 | 46 | 597 | 845 | 1 886 | 6 659 | 209.4 | 97.0 | 95.4 |
| 1991 | 48 | 698 | 1 151 | 2 807 | 9 522 | 308.3 | 94.8 | 94.1 |
| 1992 | 62 | 1 033 | 1 735 | 3 915 | 14 834 | 404.5 | 96.3 | 96.0 |
| 1993 | 60 | 941 | 1 730 | 4 000 | 15 914 | 421.2 | 96.2 | 95.8 |
| 1994 | 60 | 1 187 | 2 107 | 4 498 | 17 340 | 429.9 | 97.8 | 96.7 |
| 1995 | 56 | 1 006 | 1 719 | 3 836 | 13 314 | 314.1 | 95.5 | 94.4 |
| 1996 | 51 | 797 | 1 582 | 4 648 | 12 318 | 300.3 | 96.9 | 95.6 |
| 1997 | 46 | 644 | 1 356 | 2 595 | 10 101 | 227.8 | 94.9 | 92.3 |
| 1998 | 47 | 694 | 1 460 | 2 986 | 11 090 | 243.2 | 94.7 | 93.2 |
| 1999 | 52 | 882 | 1 758 | 4 163 | 13 878 | 248.3 | 96.2 | 95.0 |
| 2000 | 41 | 952 | 1 935 | 4 085 | 16 071 | 312.2 | 97.3 | 94.8 |
| 2001 | 42 | 1 045 | 2 071 | 4 208 | 15 694 | 368.8 | 98.1 | 97.1 |
| 2002 | 44 | 1 134 | 2 325 | 4 776 | 17 992 | 402.2 | 98.5 | 97.3 |
| 2003 | 38 | 1 001 | 2 229 | 4 486 | 17 322 | 396.9 | 98.3 | 97.9 |
| 2004 | 36 | 839 | 1 792 | 3 646 | 14 038 | 331.3 | 97.7 | 97.0 |
| 2005 | 37 | 915 | 2 068 | 4 306 | 16 522 | 501.9 | 98.4 | 98.5 |
| 2006 | 38 | 851 | 1 653 | 3 585 | 13 328 | 306.7 | 97.9 | 97.0 |
| 2007 | 33 | 831 | 1 817 | 3 813 | 13 929 | 367.5 | 98.4 | 98.5 |
| 2008 | 34 | 645 | 3 239 | 3 240 | 11 567 | 296.6 | 98.6 | 96.8 |
| 2009 | 35 | 685 | 3 336 | 3 336 | 12 140 | 338.6 | 98.0 | 96.4 |
| 2010 | 36 | 851 | 4 531 | 4 531 | 16 619 | 580.3 | 99.1 | 96.9 |
| 2011 | 32 | 715 | 3 919 | 3 919 | 14 221 | 373.0 | 98.3 | 97.6 |
| 2012 | 32 | 616 | 3 249 | 3 249 | 11 890 | 319.1 | 98.7 | 97.8 |
| 2013 | 30 | 566 | 3 132 | 3 132 | 11 482 | 356.7 | 98.9 | 97.3 |
| 2014 | 31 | 620 | 3 506 | 3 506 | 12 927 | 376.4 | 97.9 | 96.4 |
| 2015 | 34 | 567 | 3 132 | 3 132 | 11 570 | 461.1 | 97.7 | 97.0 |
| 2016 | 29 | 619 | 3 174 | 3 174 | 11 895 | 498.5 | 99.3 | 97.7 |

## 4.3 Core vessel selection

Selecting vessels operating in the BT-MIX fishery for a minimum of 7 years and conducting 5 trips in each of these years (Figure 17) resulted in a core fleet of 47 vessels which accounted for 70.44% of the BT-MIX catch.

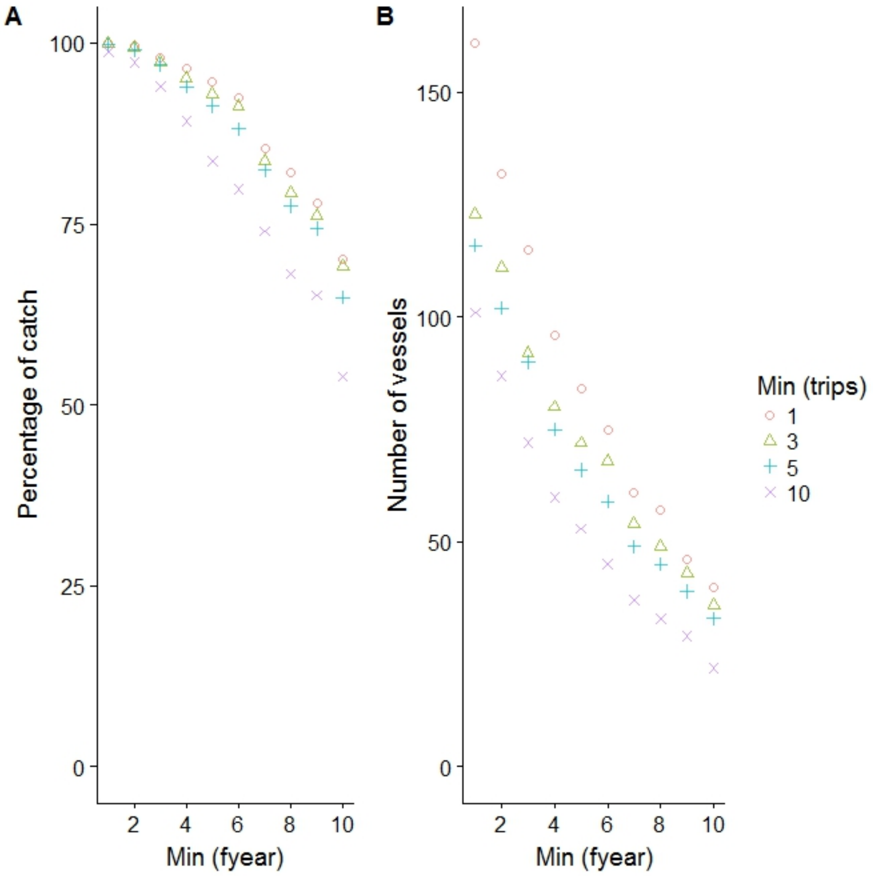


**Figure 17: Percentage of catch (left panel) and number of vessels (right panel) in the GUR 2 vessel-day aggregated dataset with alternative criteria for core fleet selection.**

There has been a turnover in the BT-MIX fleet from 1990 to 2016, with only eight vessels operating in the fishery throughout the series (Figure 18).

The catch probability has been stable through the time series at around 95% while raw CPUE has fluctuated around 80 kg per tow, although there was an increase since 2012 (Figure 19).

The filtered data set for the core fleet is summarised in Table 5.

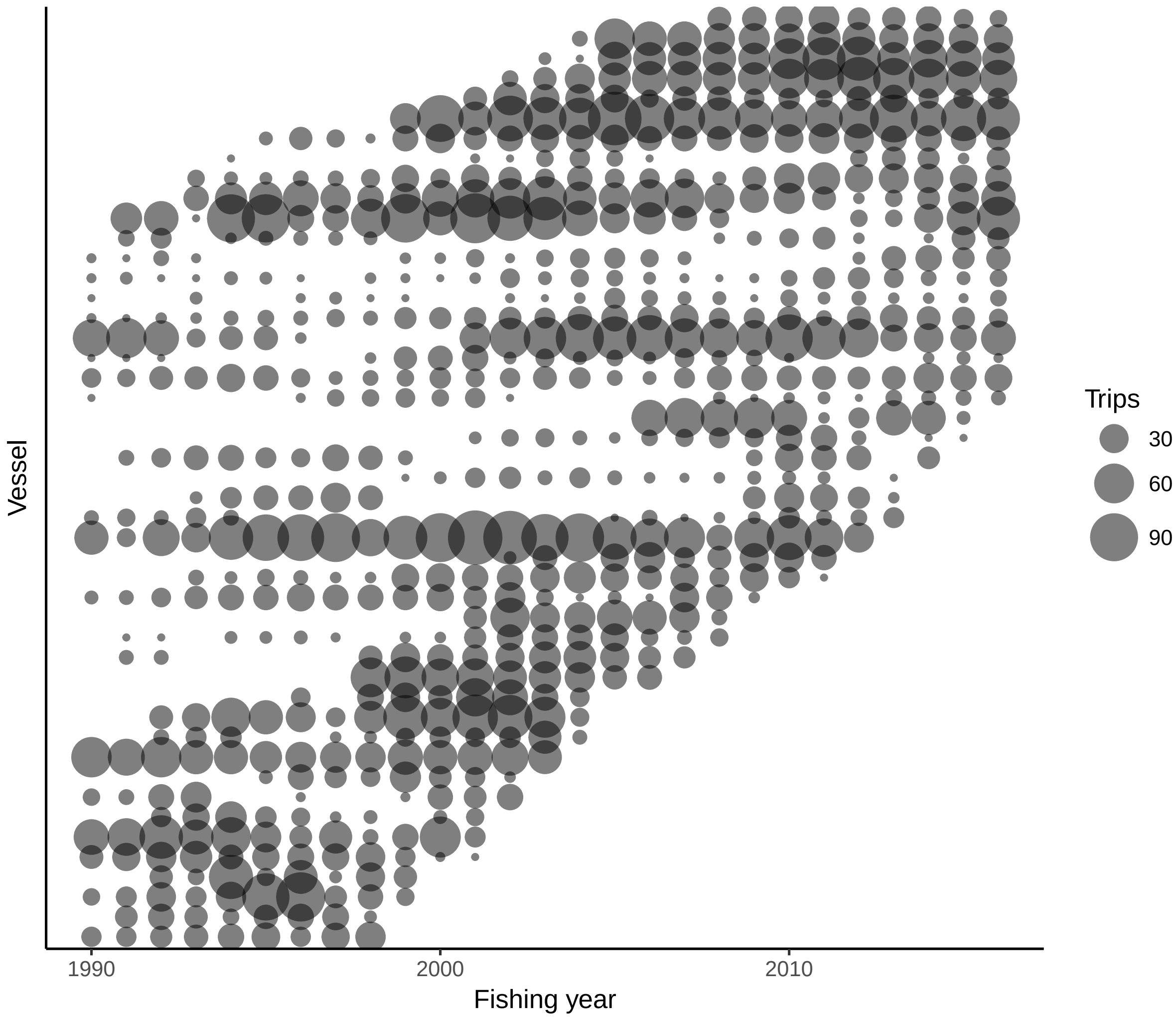


**Figure 18: Number of trips by fishing year for core GUR 2 vessel-day vessels. The area of circles is proportional to the number of trips.**

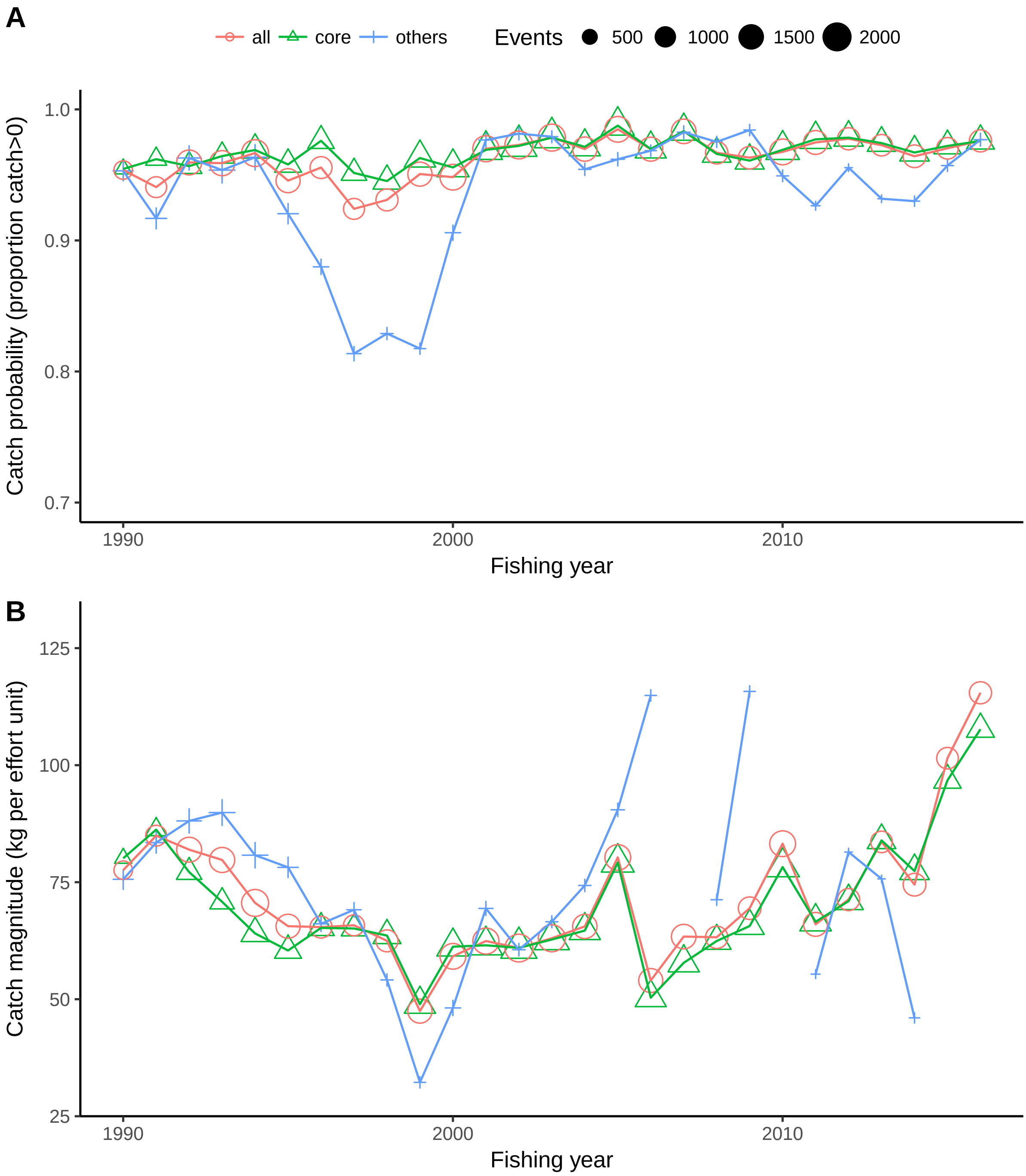


**Figure 19: The proportion of strata with positive catch (A) and the raw CPUE (geometric mean of catch divided by effort where catch was positive (B) for all GUR 2 vessel-day vessels, core vessels and non-core vessels. Point size is proportional to the number of fishing events.**

**Table 5: Summary of GUR 2 vessel-day data subset by fishing year after the data was restricted to the core fleet and outliers were removed. Events represent a row in the effort dataset, trips caught represents the number of trips which reported catching GUR and events caught represents the percentage of days with positive catch. Fishing years are labelled by the later calendar year e.g. 1990 = 1989/1990.**

| Fishing Year | Vessels | Trips | Records | Effort (num) | Effort (hrs) | Catch (t) | Trips caught | Days caught |
|---|---|---|---|---|---|---|---|---|
| 1990 | 17 | 290 | 374 | 838 | 2 941 | 98.4 | 98.6 | 95.5 |
| 1991 | 21 | 361 | 606 | 1 466 | 5 073 | 168.1 | 96.1 | 96.2 |
| 1992 | 26 | 562 | 961 | 2 160 | 8 092 | 204.0 | 96.6 | 95.7 |
| 1993 | 27 | 469 | 863 | 2 072 | 7 762 | 186.7 | 96.6 | 96.4 |
| 1994 | 26 | 734 | 1 236 | 2 648 | 9 493 | 237.6 | 98.0 | 96.9 |
| 1995 | 26 | 684 | 1 155 | 2 843 | 8 786 | 214.2 | 96.8 | 95.9 |
| 1996 | 30 | 625 | 1 193 | 3 712 | 9 827 | 233.8 | 98.2 | 97.6 |
| 1997 | 27 | 505 | 1 068 | 2 147 | 8 364 | 192.0 | 98.0 | 95.2 |
| 1998 | 30 | 594 | 1 203 | 2 603 | 9 815 | 211.0 | 96.3 | 94.5 |
| 1999 | 30 | 784 | 1 562 | 3 819 | 12 785 | 232.9 | 97.8 | 96.4 |
| 2000 | 27 | 783 | 1 571 | 3 506 | 13 935 | 275.3 | 97.7 | 95.6 |
| 2001 | 32 | 929 | 1 773 | 3 711 | 13 802 | 324.0 | 98.0 | 97.0 |
| 2002 | 32 | 1 015 | 2 110 | 4 397 | 16 613 | 361.2 | 98.6 | 97.3 |
| 2003 | 30 | 929 | 2 055 | 4 144 | 15 927 | 361.2 | 98.3 | 97.8 |
| 2004 | 29 | 765 | 1 620 | 3 272 | 12 490 | 290.3 | 97.9 | 97.2 |
| 2005 | 28 | 831 | 1 760 | 3 816 | 14 663 | 434.1 | 98.3 | 98.8 |
| 2006 | 29 | 779 | 1 449 | 3 248 | 12 056 | 241.3 | 98.2 | 97.0 |
| 2007 | 27 | 735 | 1 517 | 3 379 | 12 319 | 287.6 | 98.4 | 98.5 |
| 2008 | 28 | 580 | 2 902 | 2 903 | 10 392 | 264.1 | 98.8 | 96.7 |
| 2009 | 27 | 623 | 2 977 | 2 977 | 10 799 | 282.2 | 97.9 | 96.2 |
| 2010 | 26 | 784 | 4 108 | 4 108 | 15 072 | 473.9 | 99.6 | 97.1 |
| 2011 | 25 | 672 | 3 743 | 3 743 | 13 639 | 358.3 | 98.7 | 97.9 |
| 2012 | 26 | 593 | 3 127 | 3 127 | 11 450 | 305.8 | 99.0 | 97.8 |
| 2013 | 22 | 543 | 3 012 | 3 012 | 11 064 | 345.6 | 99.3 | 97.5 |
| 2014 | 23 | 543 | 3 226 | 3 226 | 12 049 | 356.7 | 98.7 | 96.7 |
| 2015 | 23 | 489 | 2 748 | 2 748 | 10 184 | 377.2 | 98.6 | 97.2 |
| 2016 | 20 | 542 | 2 739 | 2 739 | 10 127 | 388.9 | 99.5 | 97.6 |

## 4.4 Occurrence of catch

Occurrence of positive catch was modelled using a binomial generalised linear model (GLM) with a logistic link function. The full set of terms offered to the stepwise selection algorithm was:
$\sim fyear + vessel + poly(log(duration), 3) + target + area * month + area + month + poly(width, 3) + poly(height, 3)$

The final model after stepwise selection (Table 6) was:
$\sim fyear + vessel + target + poly(log(duration), 3) + area$

**Table 6: Summary of stepwise selection for GUR 2 vessel-day occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Predictor | Df | AIC | % deviance | add % deviance | Included |
|---|---|---|---|---|---|
| fyear | 25 | 10816.0 | 0.9 | 0.9 | * |
| + vessel | 48 | 10051.0 | 8.9 | 7.9 | * |
| + target | 2 | 9733.0 | 11.8 | 3.0 | * |
| + poly(log(duration), 3) | 3 | 9568.0 | 13.4 | 1.6 | * |
| + area | 5 | 9544.0 | 13.7 | 0.3 | |

Most of the records in the BT-MIX aggregated data have positive catch (Figure 20). The NINS WG has accepted the BT-MIX CPUE index with indices derived from the positive catch component only (Ministry for Primary Industries 2016).

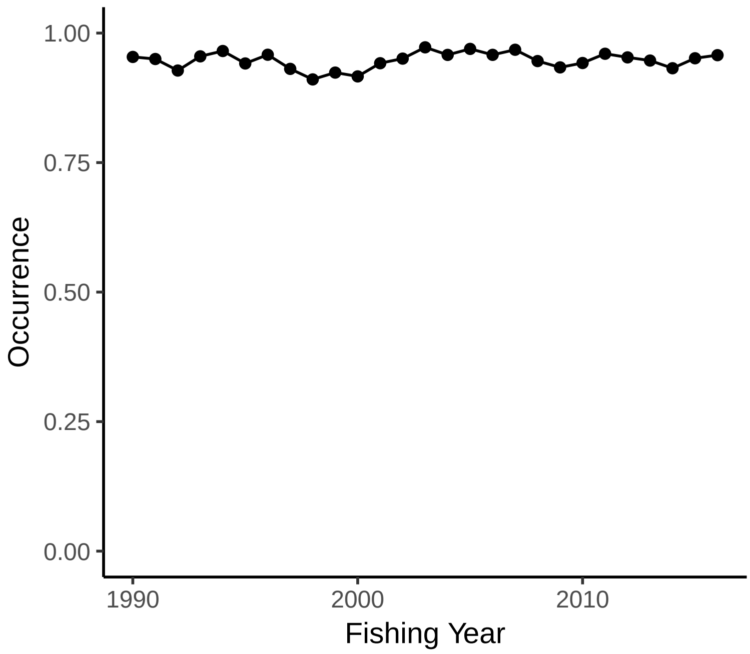


**Figure 20: The occurrence of positive catch indices for the BT-MIX fishery.**

### 4.5 Magnitude of positive catches

The natural logarithm of positive catch was modelled using a Weibull GLM. The full set of model terms offered to the stepwise selection algorithm was:
$\sim fyear + vessel + poly(log(duration), 3) + target + area * month + area + month + poly(width, 3) + poly(height, 3)$

The final model after stepwise selection (Table 7) was:
$\sim fyear + poly(log(duration), 3) + vessel + target + area * month$

**Table 7: Summary of stepwise selection for GUR 2 vessel-day magnitude of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Predictor | Df | AIC | % deviance | add % deviance | Included |
|---|---|---|---|---|---|
| fyear | 25 | 455854.0 | 2.2 | 2.2 | * |
| + poly(log(duration), 3) | 3 | 443481.0 | 28.2 | 26.0 | * |
| + vessel | 48 | 433023.0 | 45.2 | 17.0 | * |
| + target | 2 | 432331.0 | 46.1 | 1.0 | * |
| + area_month | 71 | 431697.0 | 47.2 | 1.1 | * |

### 4.5.1 Model diagnostics

The model residuals indicate small GUR 2 catches are poorly predicted by the model (Figure 21), but deviations from the expected distribution are largely restricted to the tails of the distribution.

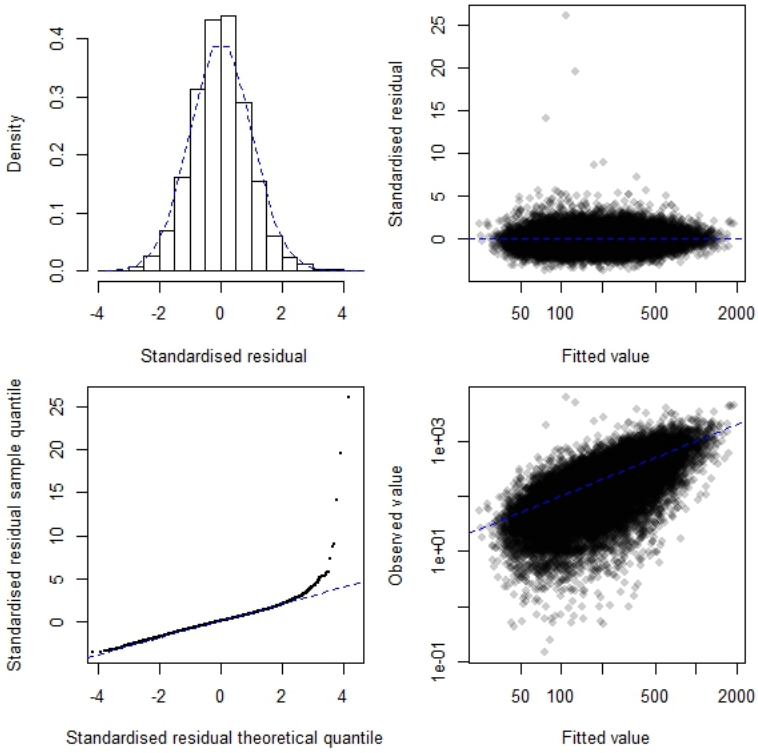


**Figure 21: The Weibull diagnostic plots for the GUR 2 vessel-day model. top left: Standardised residuals from the accepted generalised linear model fit; top right: The standardised residuals versus the fitted values; bottom left: Quantile-quantile plot of observed response versus likelihood of the distribution of these values; bottom right: Observed values vs fitted values.**

### 4.5.2 Influence of predictors on CPUE indices

The standardised and unstandardised CPUE indices for the BT-MIX fishery are relatively similar (Figure 22). Figure 23 shows the change in the indices as each term is sequentially added to the model. The addition of both duration and vessel moderate the recent increase in unstandardised CPUE, whereas the addition of further predictors had negligible impact on the indices.

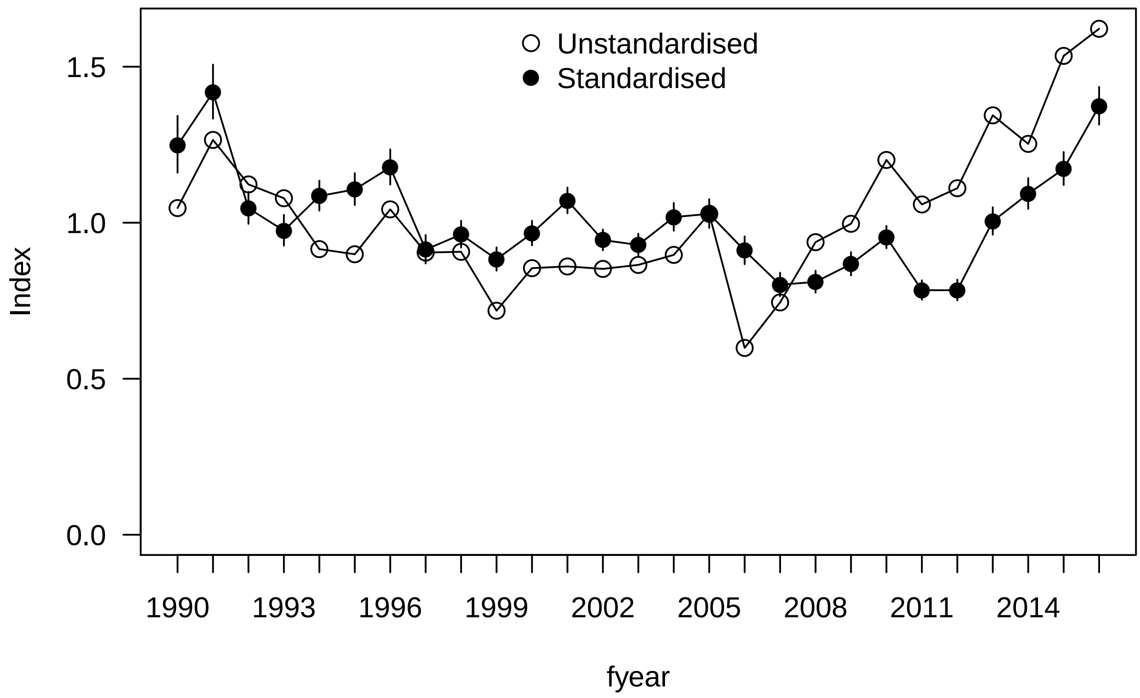


**Figure 22: A comparison of the standardised and unstandardised CPUE indices for the GUR 2 vessel-day model. The unstandardised index is the geometric mean of the catch per strata and is not adjusted for effort.**

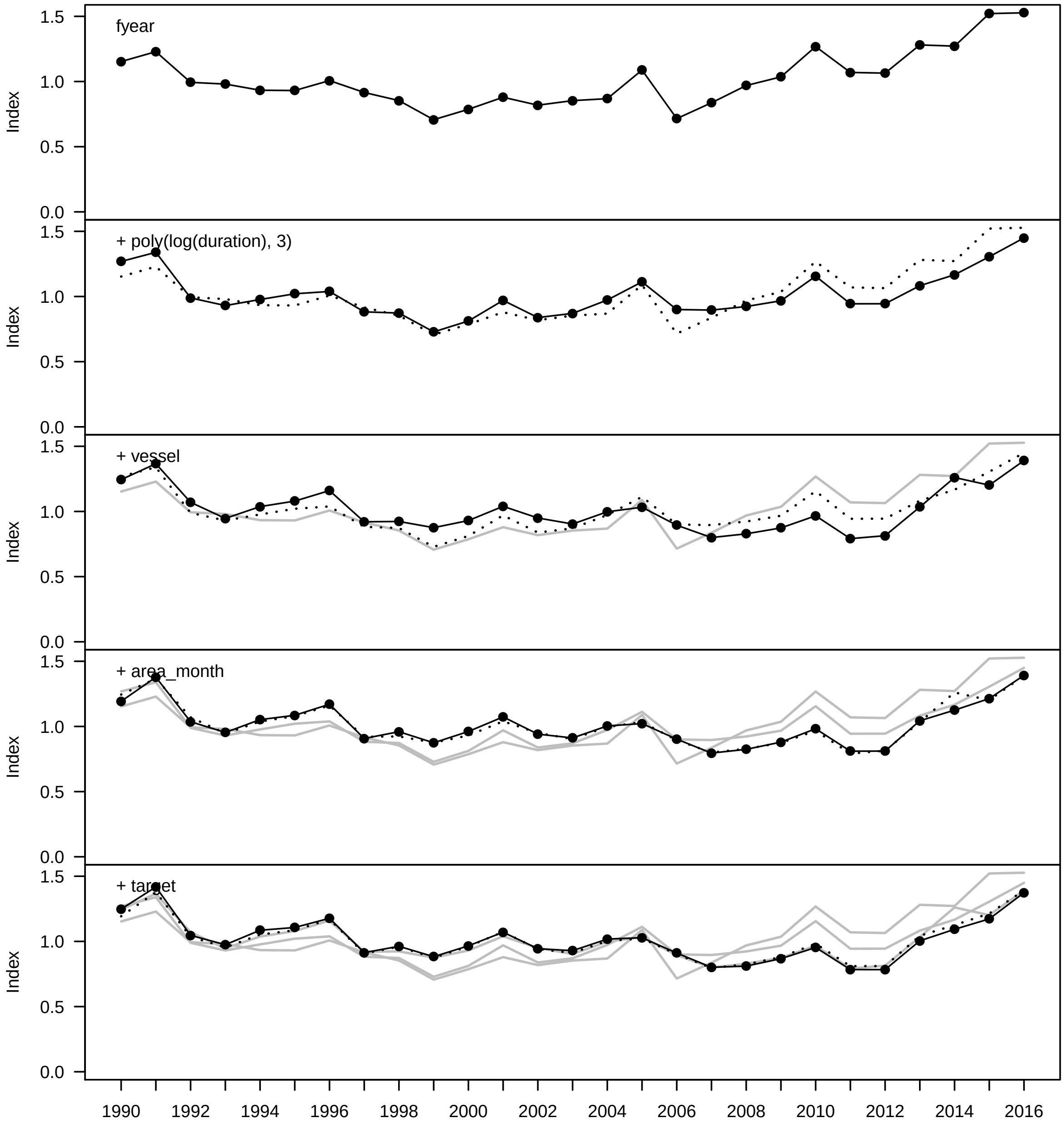


**Figure 23: Changes in GUR 2 vessel-day annual CPUE indices as each term is successively added to the model. The indices are normalised to a geometric mean of 1.**

The introduction of TCER forms in 2008 appears have influenced the reporting of fishing duration (Figure 24) with the aggregated totals from the TCER forms being more smoothly distributed around the rounded numbers in the CELR data. There is a general increase in fishing duration since 2007 (Figure 24).

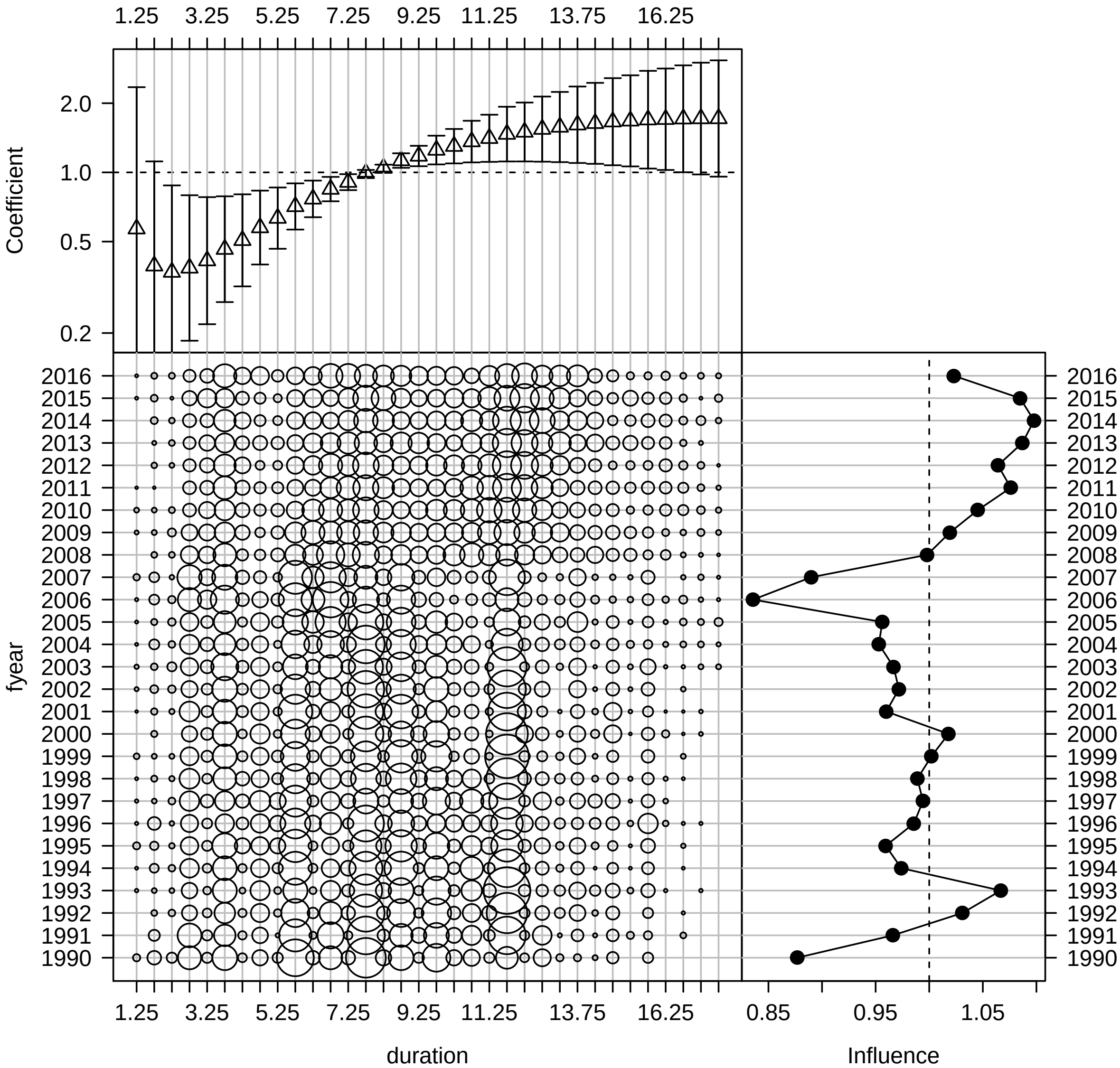


**Figure 24: Coefficient-distribution-influence plot for fishing duration in the GUR 2 vessel-day positive catch model.**

Since early 2000 the change in fleet composition has been towards a fleet comprised of vessels with higher catch rates (Figure 25).

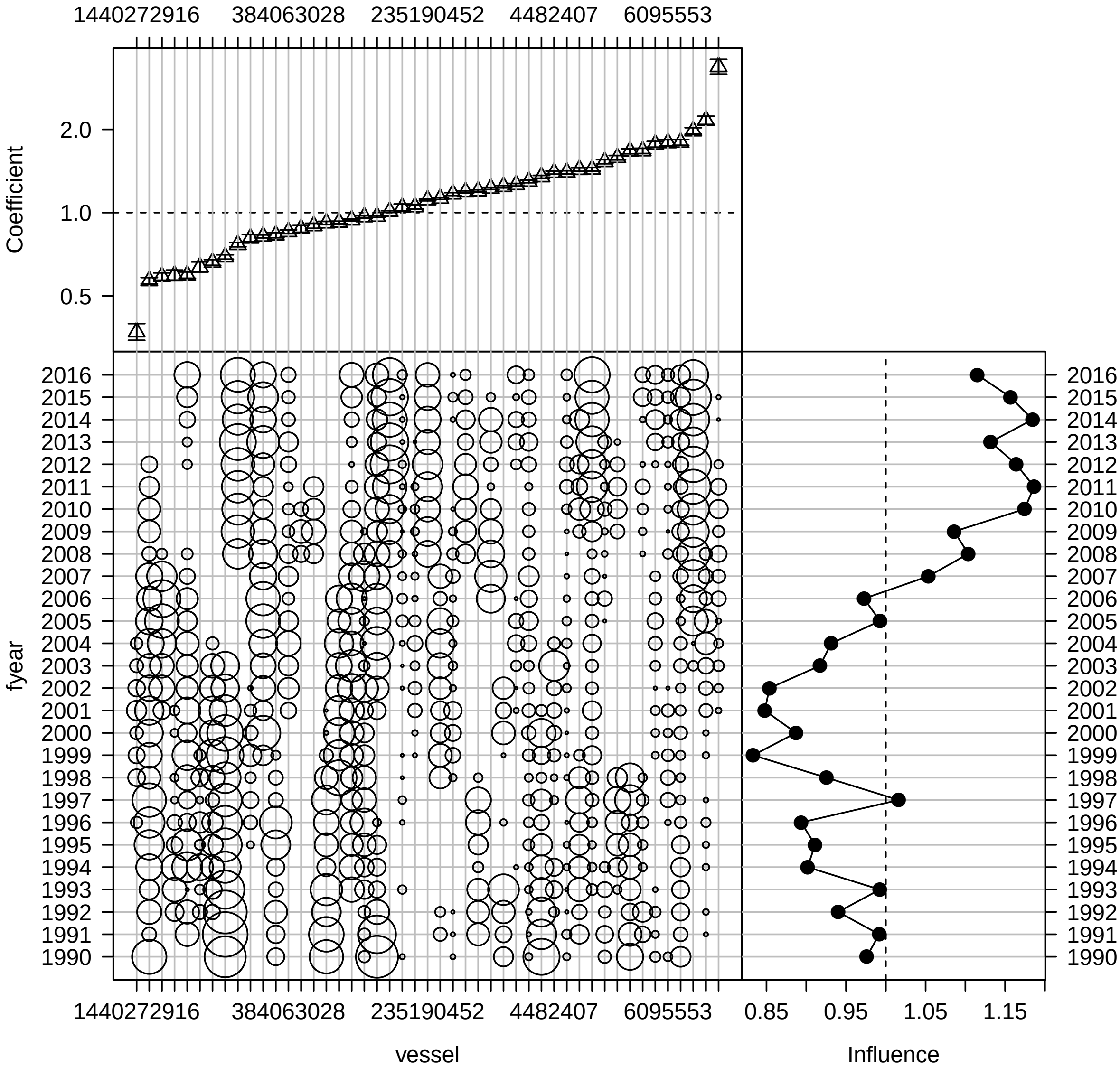


**Figure 25: GUR 2 vessel-day coefficient-distribution-influence plot for vessel.**

Coefficients for the core fishing areas (012, 013 and 014) are positive. Area 014 is relatively stable with the exception of a December peak, 013 has lower coefficients in January to May then increases from June to November and Area 012 coefficients trough from April to July (Figure 26). In contrast Statistical Areas 011, 015 and 016 show more variation; Area 011 coefficients fluctuate without trend through the fishing year (Figure 26). Area 015 coefficients gradually increase to peak in May then decline till September.

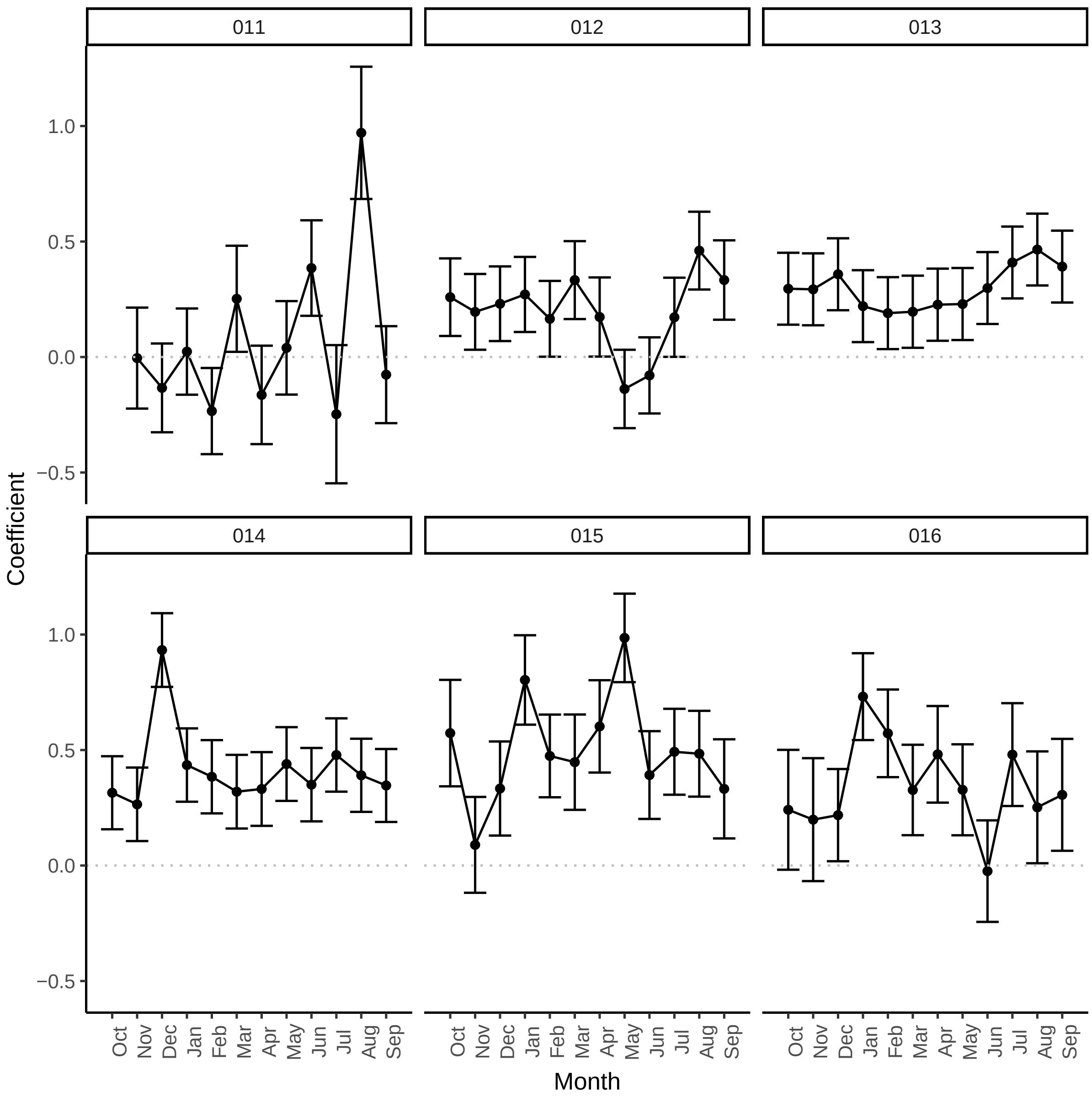


**Figure 26: Coefficients for the area * month interaction from the GUR 2 vessel-day model, coefficients are plotted with 1 standard error intervals.**

Gurnard is the dominant target species in the BT MIX fishery, snapper is targeted sporadically and trevally targeting has declined through the series (Figure 27).

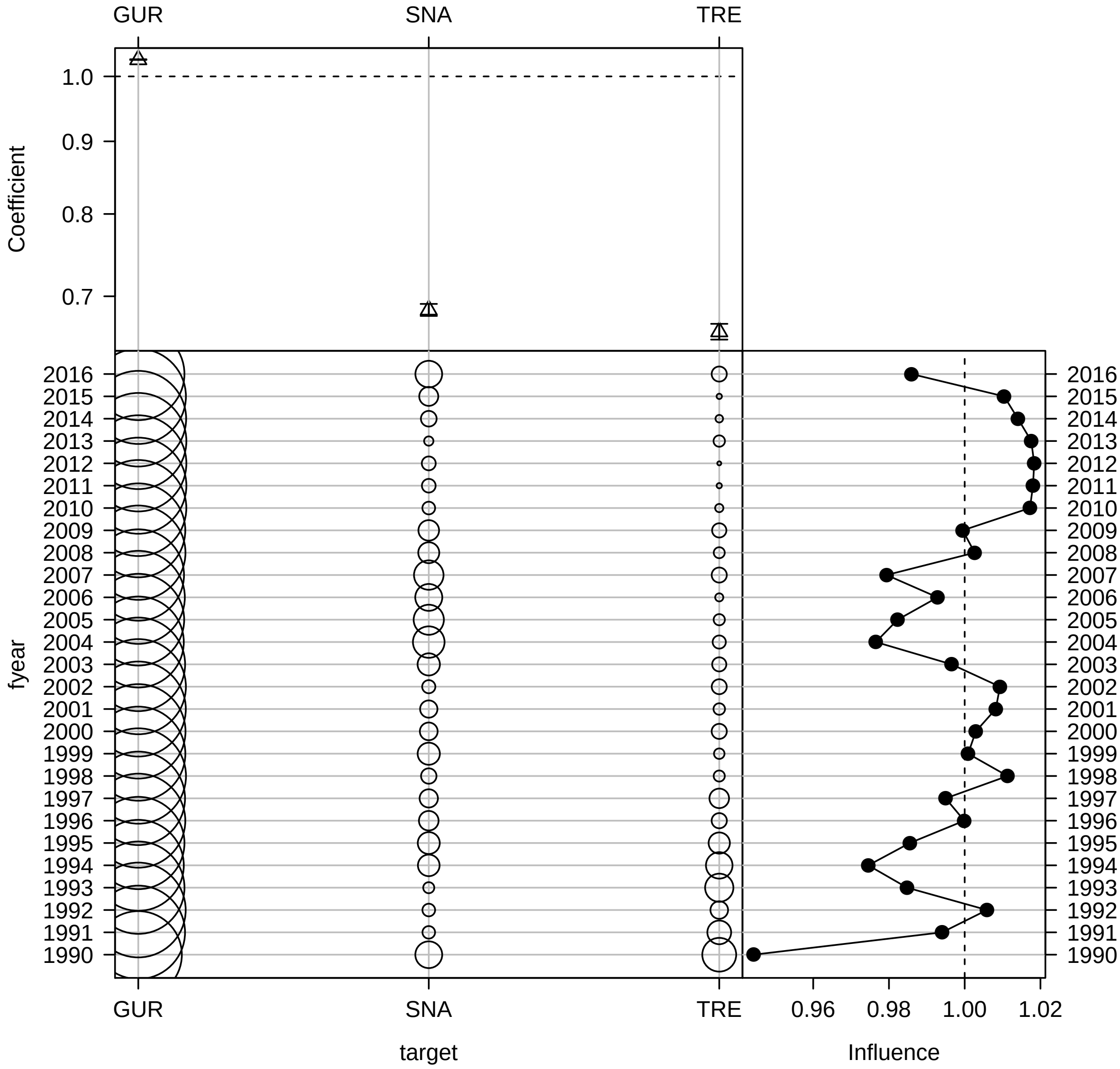


**Figure 27: GUR 2 vessel-day coefficient-distribution-influence plot for target species.**

### 4.5.3 Residual implied coefficients

Implied indexes for target species by year demonstrate that catches are higher when GUR was targeted than when SNA or TRE were targeted (Figure 28). GUR was the dominant target species in terms of records and consequently, the overall CPUE index closely follows the implied GUR target index (Figure 28). The CPUE trends from the SNA and TRE target fishing are more variable than GUR target although the general trends from these two fisheries are broadly consistent with the overall CPUE indices (Figure 28).

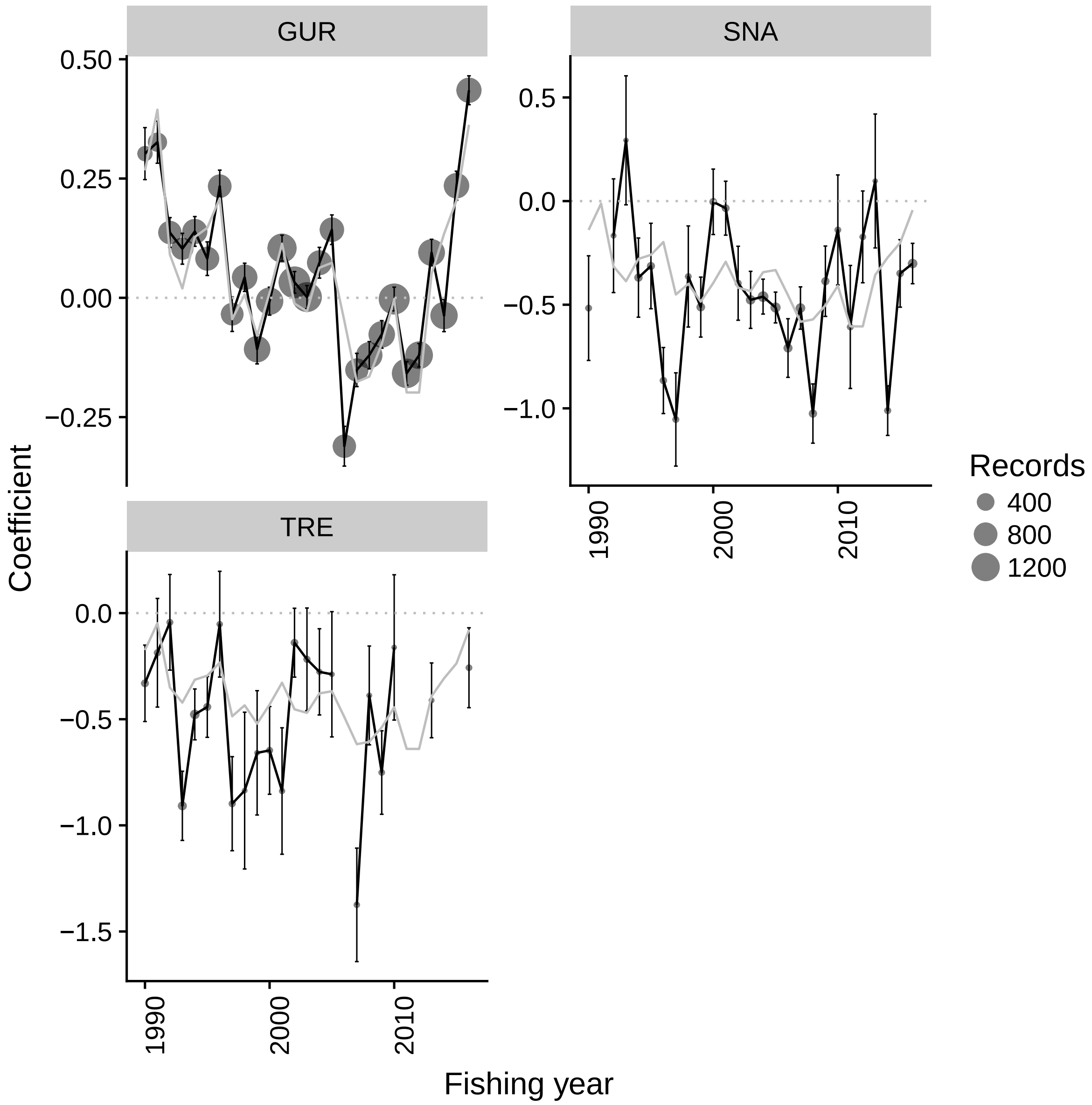


**Figure 28: Implied CPUE indices (in log space) for the different target species in the GUR 2 vessel-day fishery over time. Error bars indicate one standard error of the standardised residuals, and the grey line shows the overall BT-MIX index.**

## 5. BT-MIX TOW DATA CPUE ANALYSIS

### 5.1 Fishery definition

The fishery definition for the BT-MIX TCER fishery is:

- Form type (TCER)
- Primary method: bottom trawl (BT)
- Target species (GUR, SNA, TRE)
- Fishing effort conducted within Statistical Areas 011, 012, 013, 014, 015 and 016
- Fishing effort conducted between 1 Oct 2008 and 30 Sept 2016

The BT-MIX TCER fishery had consistent levels of fishing effort annually, with the exception of 2010 when effort (and catches) were higher (Table 8).

**Table 8: Summary of the TCER data subset by fishing year after the GUR 2 TCER fishery definition has been applied. Events represent a row in the effort dataset, trips caught represents the number of trips which reported catching GUR and events caught represents the percentage of days with positive catch. Fishing years are labelled by the later calendar year e.g. 1990 = 1989/1990.**

| Fishing Year | Vessels | Trips | Records | Effort (num) | Effort (hrs) | Catch (t) | Trips caught | Days caught |
|---|---|---|---|---|---|---|---|---|
| 1990 | 46 | 597 | 845 | 1 886 | 6 659 | 209.4 | 97.0 | 95.4 |
| 1991 | 48 | 698 | 1 151 | 2 807 | 9 522 | 308.3 | 94.8 | 94.1 |
| 1992 | 62 | 1 033 | 1 735 | 3 915 | 14 834 | 404.5 | 96.3 | 96.0 |
| 1993 | 60 | 941 | 1 730 | 4 000 | 15 914 | 421.2 | 96.2 | 95.8 |
| 1994 | 60 | 1 187 | 2 107 | 4 498 | 17 340 | 429.9 | 97.8 | 96.7 |
| 1995 | 56 | 1 006 | 1 719 | 3 836 | 13 314 | 314.1 | 95.5 | 94.4 |
| 1996 | 51 | 797 | 1 582 | 4 648 | 12 318 | 300.3 | 96.9 | 95.6 |
| 1997 | 46 | 644 | 1 356 | 2 595 | 10 101 | 227.8 | 94.9 | 92.3 |
| 1998 | 47 | 694 | 1 460 | 2 986 | 11 090 | 243.2 | 94.7 | 93.2 |
| 1999 | 52 | 882 | 1 758 | 4 163 | 13 878 | 248.3 | 96.2 | 95.0 |
| 2000 | 41 | 952 | 1 935 | 4 085 | 16 071 | 312.2 | 97.3 | 94.8 |
| 2001 | 42 | 1 045 | 2 071 | 4 208 | 15 694 | 368.8 | 98.1 | 97.1 |
| 2002 | 44 | 1 134 | 2 325 | 4 776 | 17 992 | 402.2 | 98.5 | 97.3 |
| 2003 | 38 | 1 001 | 2 229 | 4 486 | 17 322 | 396.9 | 98.3 | 97.9 |
| 2004 | 36 | 839 | 1 792 | 3 646 | 14 038 | 331.3 | 97.7 | 97.0 |
| 2005 | 37 | 915 | 2 068 | 4 306 | 16 522 | 501.9 | 98.4 | 98.5 |
| 2006 | 38 | 851 | 1 653 | 3 585 | 13 328 | 306.7 | 97.9 | 97.0 |
| 2007 | 33 | 831 | 1 817 | 3 813 | 13 929 | 367.5 | 98.4 | 98.5 |
| 2008 | 34 | 645 | 3 239 | 3 240 | 11 567 | 296.6 | 98.6 | 96.8 |
| 2009 | 35 | 685 | 3 336 | 3 336 | 12 140 | 338.6 | 98.0 | 96.4 |
| 2010 | 36 | 851 | 4 531 | 4 531 | 16 619 | 580.3 | 99.1 | 96.9 |
| 2011 | 32 | 715 | 3 919 | 3 919 | 14 221 | 373.0 | 98.3 | 97.6 |
| 2012 | 32 | 616 | 3 249 | 3 249 | 11 890 | 319.1 | 98.7 | 97.8 |
| 2013 | 30 | 566 | 3 132 | 3 132 | 11 482 | 356.7 | 98.9 | 97.3 |
| 2014 | 31 | 620 | 3 506 | 3 506 | 12 927 | 376.4 | 97.9 | 96.4 |
| 2015 | 34 | 567 | 3 132 | 3 132 | 11 570 | 461.1 | 97.7 | 97.0 |
| 2016 | 29 | 619 | 3 174 | 3 174 | 11 895 | 498.5 | 99.3 | 97.7 |

## 5.2 Data filtering

Records were dropped if fishing duration was less than 1 hour or greater than 5.5 hours (99.5th percentile). 208 landings exceeded 663.5 kg (99th percentile), 5 of these landings were removed because of a lack of internal corroboration between reported estimated catch and landed catch.

## 5.3 Core vessel selection

The BT-MIX TCER analysis applied a core fleet definition (Figure 29) of vessels operating in the fishery for 5 years and conducting at least 5 trips in each of these years. Applying this criteria resulted in a core fleet of 24 vessels who accounted for 83.13% of the GUR 2 catch.

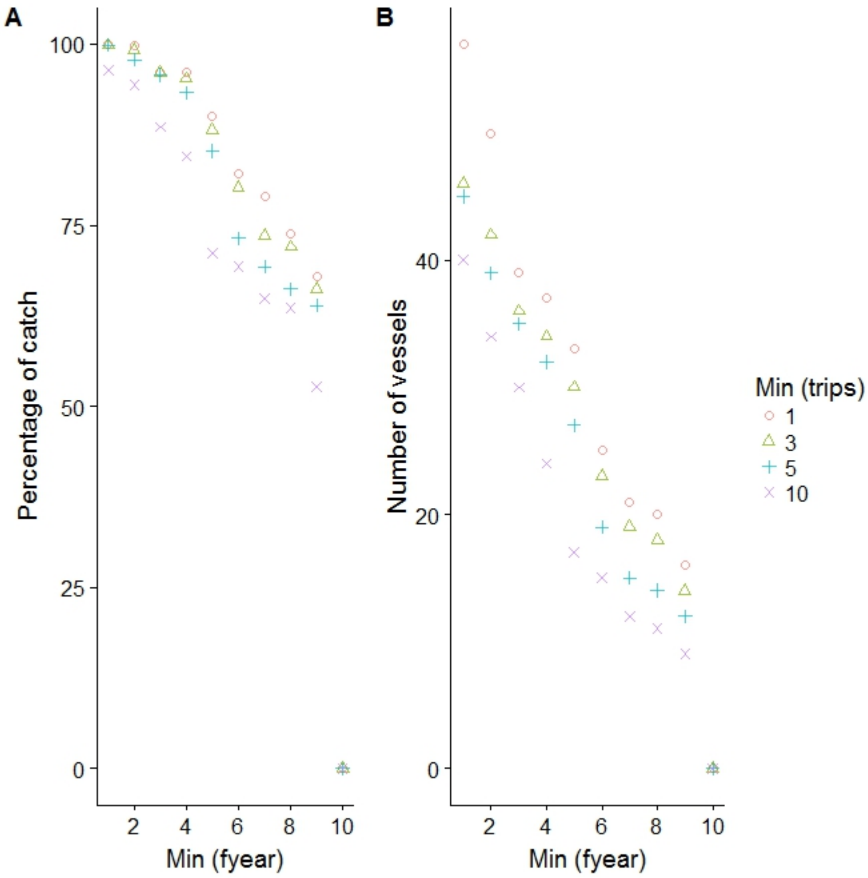


**Figure 29: Percentage of catch (left panel) and number of vessels (right panel) in the BT-MIX TCER dataset with alternative criteria for core fleet selection.**

The core fleet was stable, with the majority of vessels operating throughout the TCER time series (Figure 30).

The catch probability in the BT-MIX TCER data was about 98%, while the raw catch magnitude has increased through the TCER series from 70 to 110 kg per tow (Figure 31).

A summary of the data used for CPUE analysis after filtering and restriction to the core fleet is provided in Table 9.

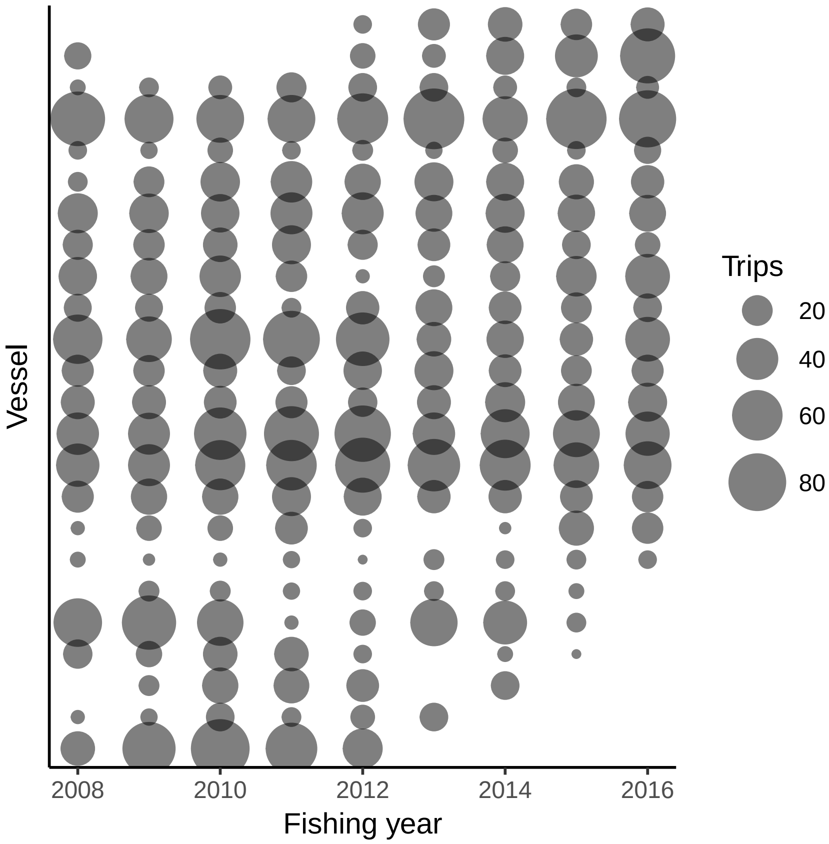


**Figure 30: Number of trips by fishing year for core BT-MIX TCER vessels. The area of circles is proportional to the number of trips for a vessel in a fishing year.**

**Table 9: Summary of data subset by fishing year after the data was restricted to the core fleet and outliers were removed. Events represent a row in the effort dataset, trips caught represents the number of trips which reported catching GUR and events caught represents the percentage of days with positive catch. Fishing years are labelled by the later calendar year e.g. 1990 = 1989/1990.**

| Fishing Year | Vessels | Trips | Records | Effort (num) | Effort (hrs) | Catch (t) | Trips caught | Days caught |
|---|---|---|---|---|---|---|---|---|
| 2008 | 21 | 536 | 2 434 | 2 435 | 8 661 | 235.5 | 98.3 | 96.4 |
| 2009 | 22 | 593 | 2 501 | 2 501 | 9 083 | 266.3 | 97.8 | 96.4 |
| 2010 | 22 | 754 | 3 616 | 3 616 | 13 231 | 460.3 | 99.5 | 97.4 |
| 2011 | 22 | 672 | 3 374 | 3 374 | 12 323 | 348.8 | 98.4 | 97.7 |
| 2012 | 24 | 634 | 3 005 | 3 005 | 11 037 | 314.4 | 98.6 | 97.6 |
| 2013 | 20 | 578 | 2 956 | 2 956 | 10 810 | 361.3 | 98.4 | 97.0 |
| 2014 | 22 | 586 | 3 077 | 3 077 | 11 466 | 349.0 | 98.6 | 96.3 |
| 2015 | 21 | 543 | 2 685 | 2 685 | 9 900 | 390.9 | 99.1 | 97.5 |
| 2016 | 19 | 589 | 2 635 | 2 635 | 9 724 | 395.2 | 98.3 | 97.0 |

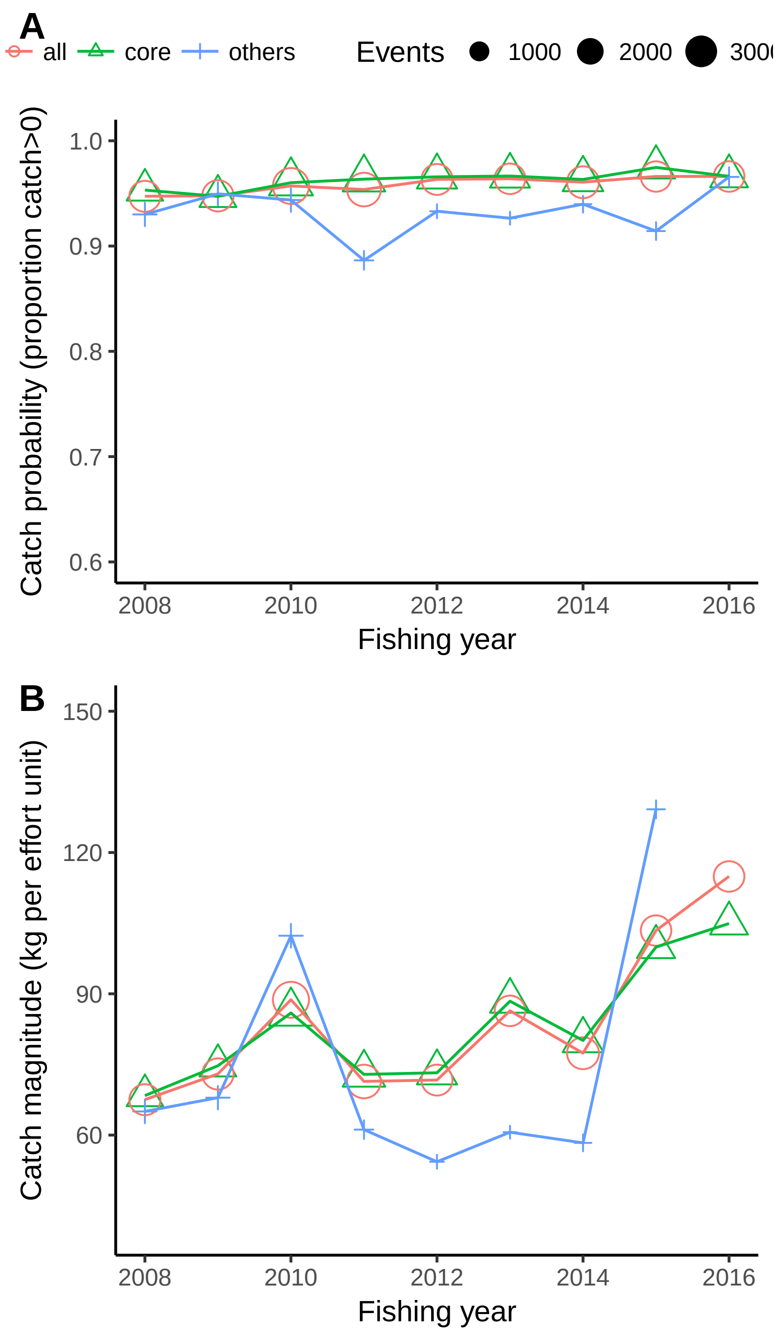


**Figure 31: Comparison of the proportion of strata with positive catch (upper) and the unstandardised CPUE (geometric mean of catch divided by effort where catch was positive; lower) for all GUR 2 TCER vessels, core vessels and other vessels (not in the core fleet). * point size is proportional to the number of fishing events.**

### 5.3.1 Occurrence of catch

Occurrence of positive catch was modelled using a binomial GLM with a logistic link function. The full set of terms offered to the stepwise selection algorithm was:
$\sim fyear + vessel + area + area * month + poly(log(duration), 3) + target + poly(bottom, 3) + month + poly(width, 3) + poly(height, 3) + poly(lon, 3) + poly(abs(lat), 3)$

The final model after stepwise selection (Table 10) was:
$\sim fyear + vessel + poly(bottom, 3) + month + area$

**Table 10: Summary of stepwise selection for GUR 2 TCER occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Predictor | Df | AIC | %dev.expl | add%dev.expl | Included |
|---|---|---|---|---|---|
| fyear | 7 | 5 525.0 | 1.4 | 1.4 | * |
| + vessel | 16 | 5 362.0 | 4.9 | 3.5 | * |
| + poly(bottom, 3) | 3 | 5 308.0 | 6.0 | 1.1 | * |
| + month | 11 | 5 276.0 | 7.0 | 1.0 | * |
| + poly(lon, 3) | 3 | 5 258.0 | 7.4 | 0.4 | |
| + area | 5 | 5 226.0 | 8.1 | 0.7 | * |
| + poly(abs(lat), 3) | 3 | 5 215.0 | 8.4 | 0.3 | |
| + poly(width, 3) | 3 | 5 212.0 | 8.6 | 0.2 | |
| + target | 2 | 5 211.0 | 8.7 | 0.1 | |

Almost all of the records in the BT-MIX TCER data captured gurnard (Figure 32). As a result a combined CPUE index is unnecessary and the index can be formed using positive catches only.

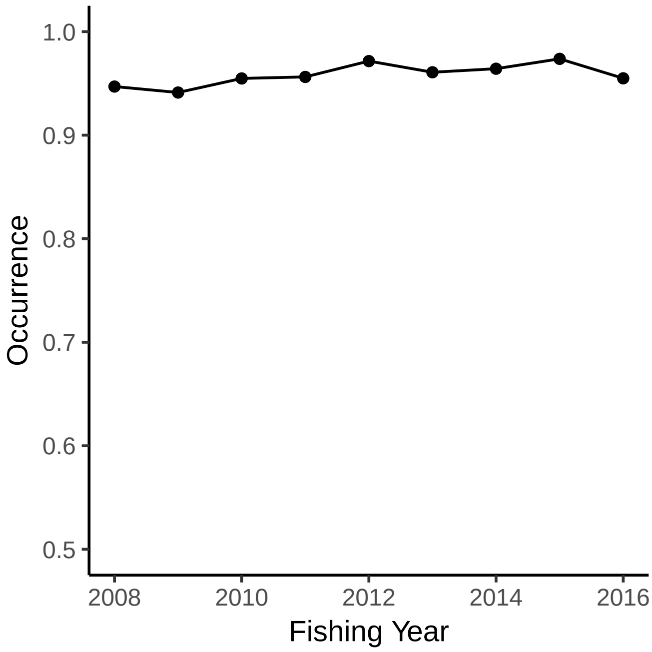


**Figure 32: The occurrence of positive catch indices for the BT-MIX TCER fishery.**

### 5.3.2 Magnitude of positive catch

The natural logarithm of positive catch were modelled using a GLM with a Weibul error distribution. The full set of model terms offered to the stepwise selection algorithm was
$fyear + vessel + area + area * month + target + poly(log(duration), 3) + poly(bottom, 3) + month + poly(width, 3) + poly(height, 3) + poly(lon, 3) + poly(abs(lat), 3)$
The final model formula after stepwise selection (Table 11) was:
$\sim fyear + vessel + poly(log(duration), 3) + area * month + poly(bottom, 3) + poly(abs(lat), 3) + poly(width, 3)$

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

| Predictor | Df | AIC | %dev.expl | add%dev.expl | Included |
|---|---|---|---|---|---|
| fyear | 7 | 185815.0 | 4.9 | 4.9 | * |
| + vessel | 16 | 183627.0 | 15.7 | 10.8 | * |
| + poly(log(duration), 3) | 3 | 182777.0 | 19.6 | 3.9 | * |
| + area_month | 71 | 182256.0 | 22.5 | 2.9 | * |
| + target | 2 | 181987.0 | 23.6 | 1.2 | * |
| + poly(bottom, 3) | 3 | 181813.0 | 24.4 | 0.8 | * |
| + poly(width, 3) | 3 | 181664.0 | 25.0 | 0.6 | * |
| + poly(lon, 3) | 3 | 181587.0 | 25.4 | 0.3 | |

## 5.4 Model diagnostics

Model residuals from the positive log(catch) model show a reasonable approximation to the Weibull distribution (Figure 33).

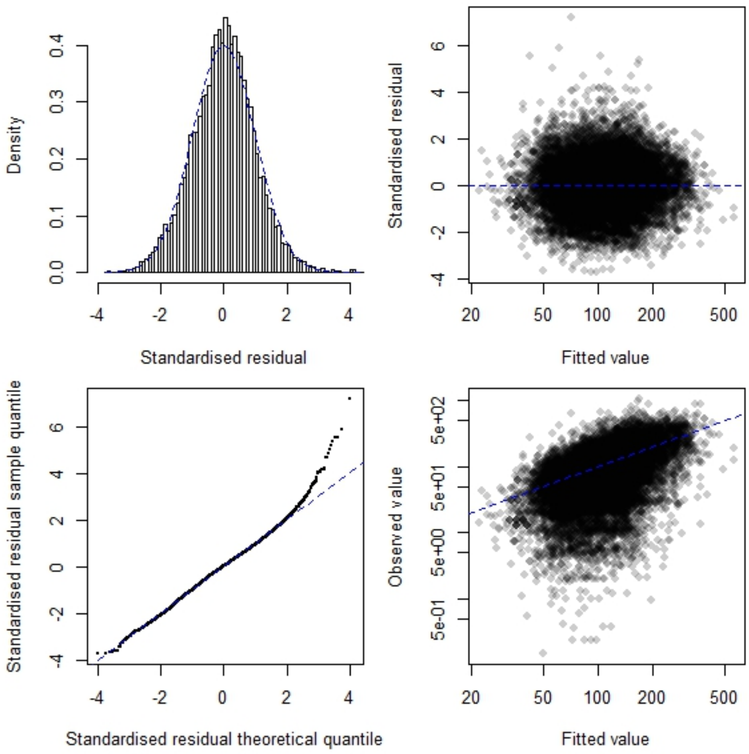


**Figure 33: The Weibull diagnostic plots for the GUR 2 TCER model. top left: Standardised residuals from the accepted generalised linear model fit; top right: The standardised residuals versus the fitted values; bottom left: Quantile-quantile plot of observed response versus likelihood of the distribution of these values; bottom right: Observed values vs fitted values.**

### 5.4.1 Influence of predictors on CPUE indices

The standardised and unstandardised CPUE indices for the BT-MIX TCER fishery are very similar (Figure 34). The standardisation has minimal impact on the CPUE indices, consequently none of the terms included in the model are influential on the indices (Figure 35).

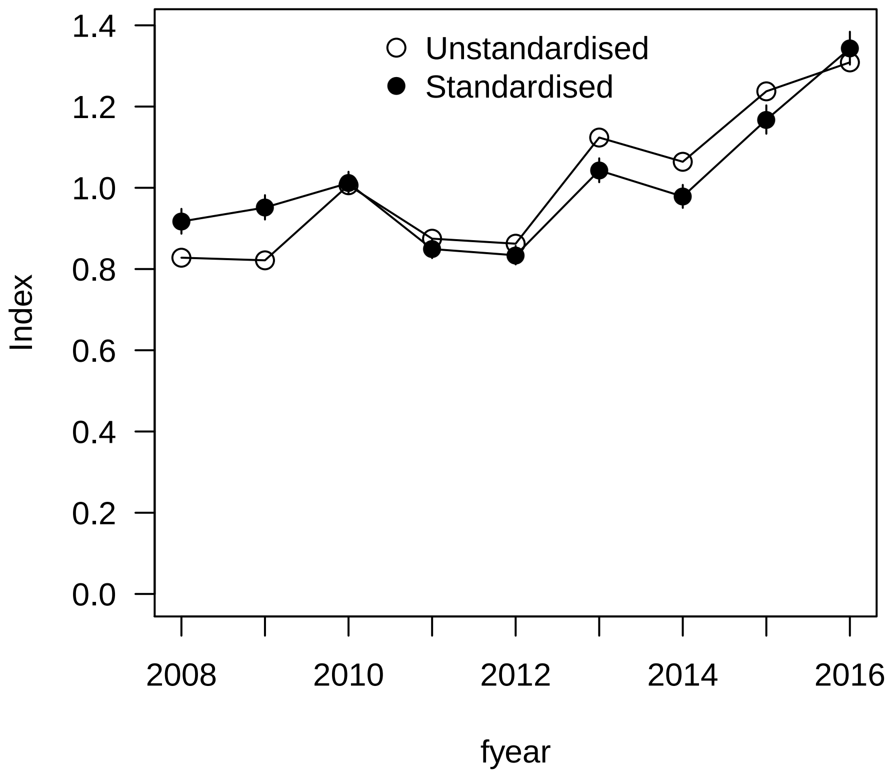


**Figure 34: A comparison of the standardised and unstandardised BT-MIX TCER indices. The unstandardised index is the geometric mean of the catch per tow and is not adjusted for effort.**

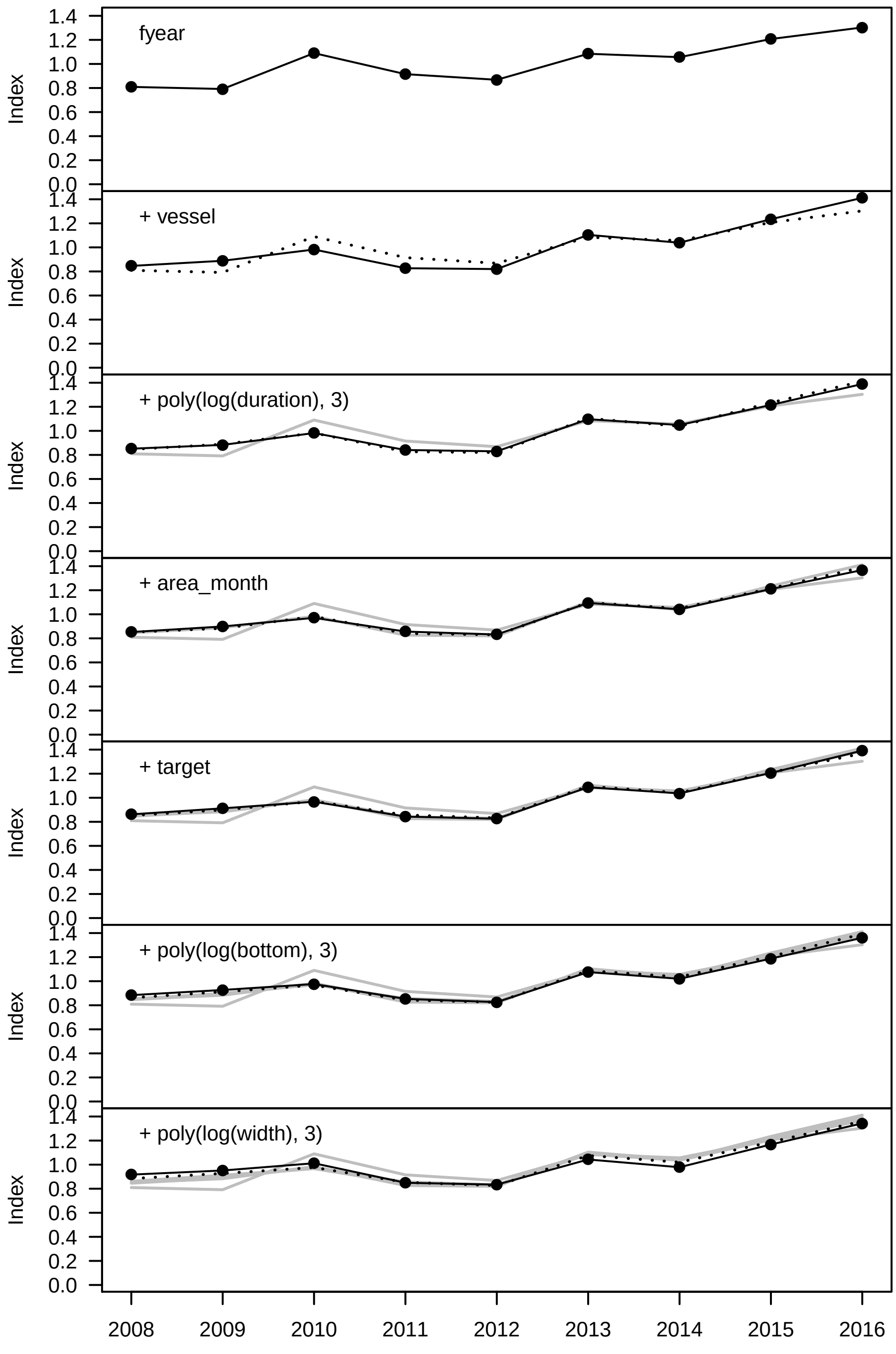


**Figure 35: Changes in BT-MIX TCER annual CPUE indices as each term is successively added to the model. The indices are normalised to a geometric mean of 1.**

The there are a range of vessel coefficients in the GUR 2 TCER series, however the composition of the GUR 2 fleet has been consistent through the TCER series (Figure 36).

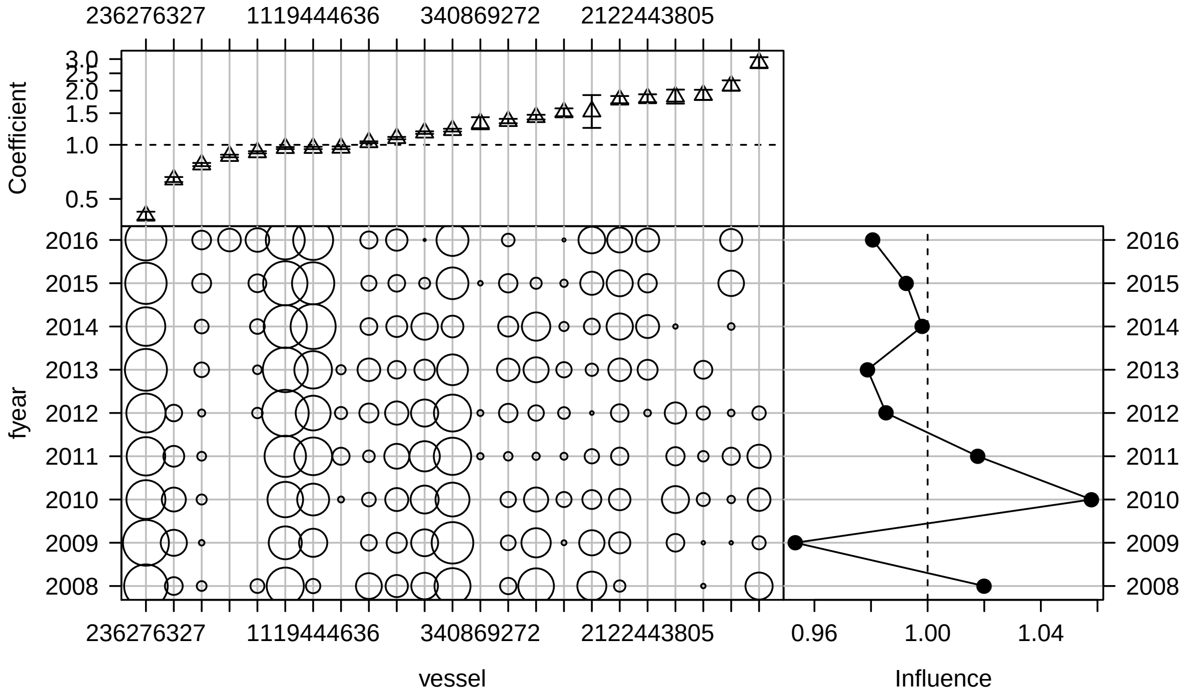


**Figure 36: BT-MIX 2 TCER coefficient-distribution-influence plot for vessel.**

The majority of tows are between 3 hours and 5 hours, and tow duration has been consistent through the TCER series (Figure 37).

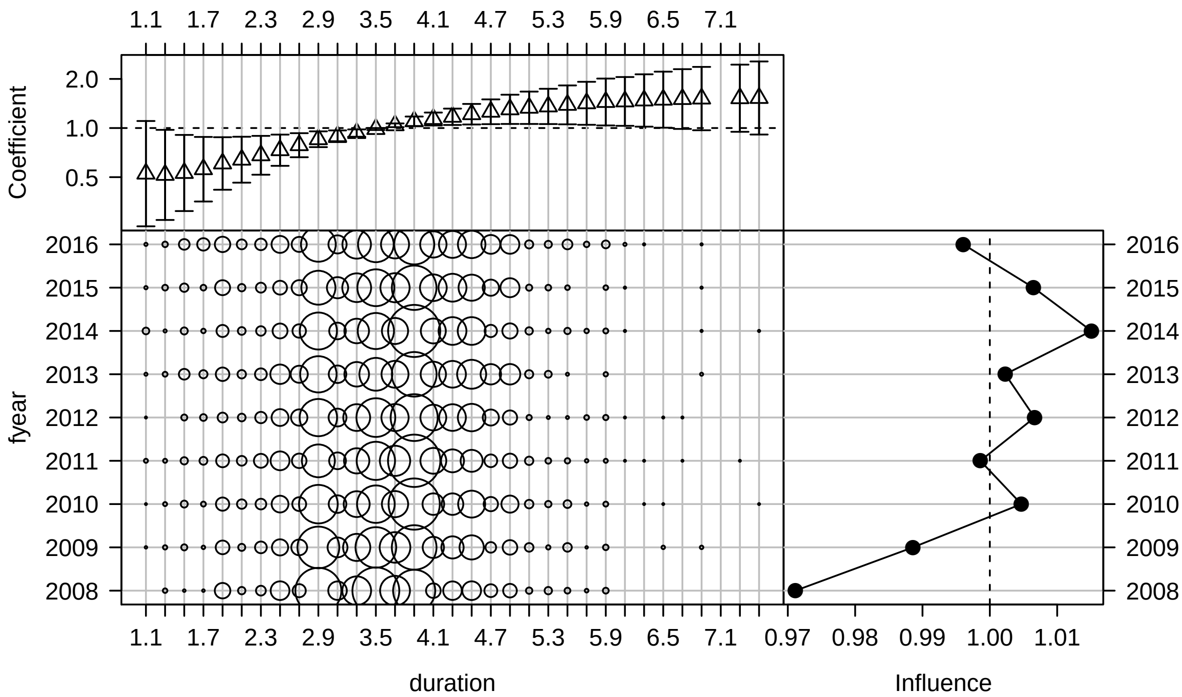


**Figure 37: BT-MIX 2 TCER coefficient-distribution-influence plot for fishing duration.**

There is a seasonal pattern evident in the core GUR 2 areas (012, 013, 014); area 012 has higher coefficients in spring and early summer compared to winter; areas 013 and 014 are opposite, area 013 has higher coefficients in spring and early summer whereas 014 has higher coefficients in winter (Figure 38). In area 011 coefficients declined from October to March then increased to September. Area 015 has a flat trajectory with a trough in December, whereas 016 coefficients are at a minima in October to December, then increased to peak February then declined to June then increased to September (Figure 38)

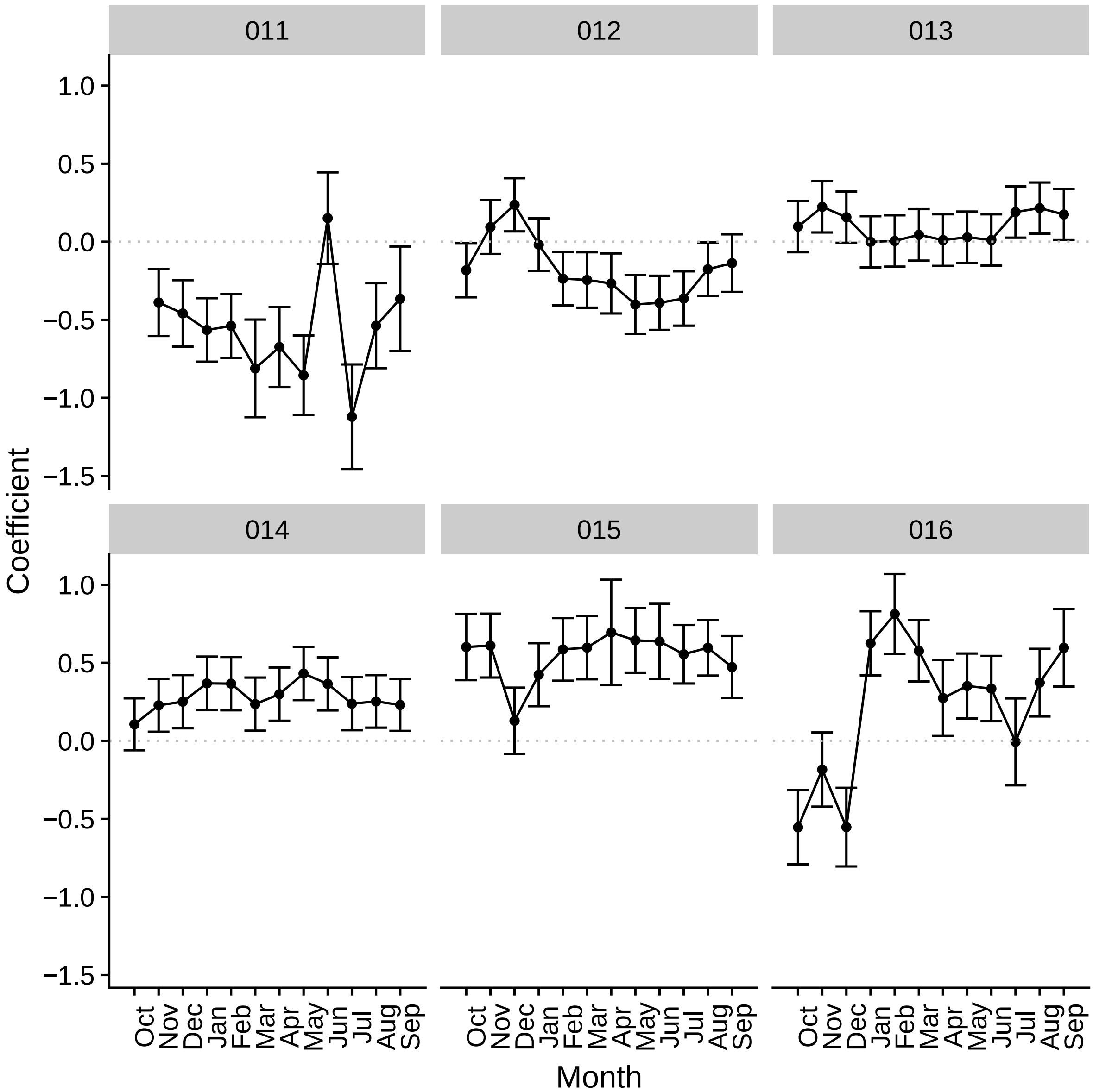


**Figure 38: Coefficients for the area * month interaction from the GUR 2 TCER model, coefficients are plotted with 1 standard error intervals.**

Gurnard is the dominant target species in the BT MIX fishery, snapper targeting has increased over the last three years, although there is little influence on the CPUE indices (Figure 39).

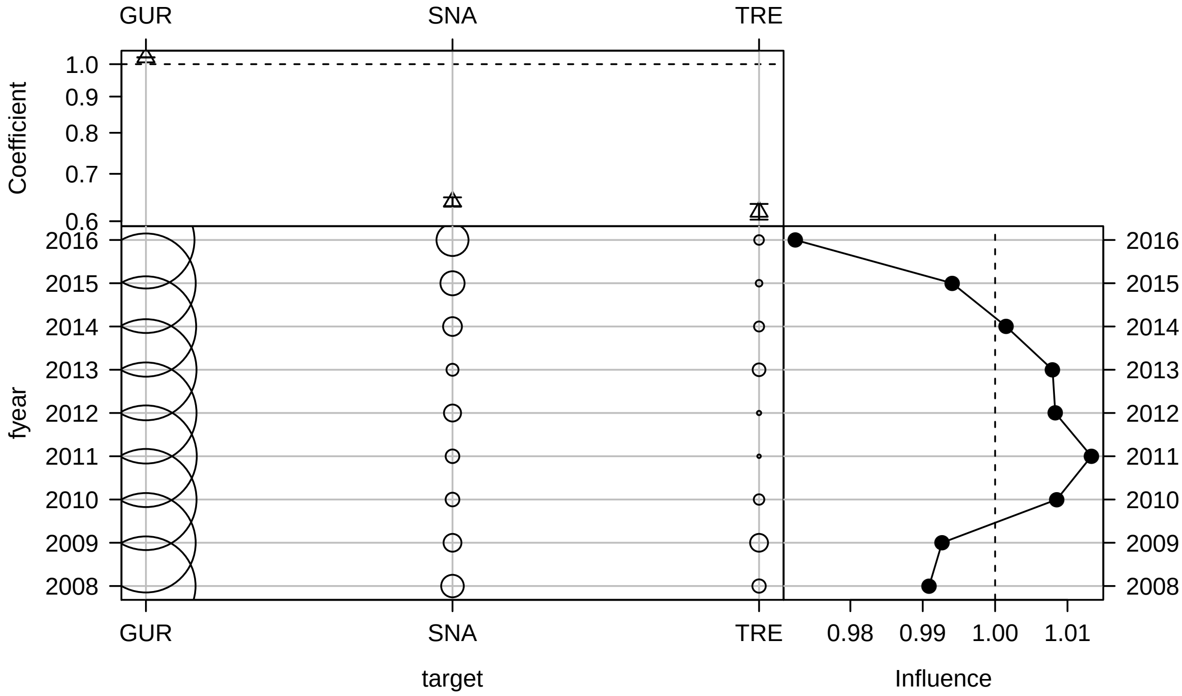


**Figure 39: BT-MIX TCER coefficient-distribution-influence plot for target species.**

For the predominant fishing depths between 20 and 70 m, the effect or fishing depth is fairly flat. There is evidence of an increase in fishing depths from 2008 to 2016 although the overall influence is negligible (Figure 40).

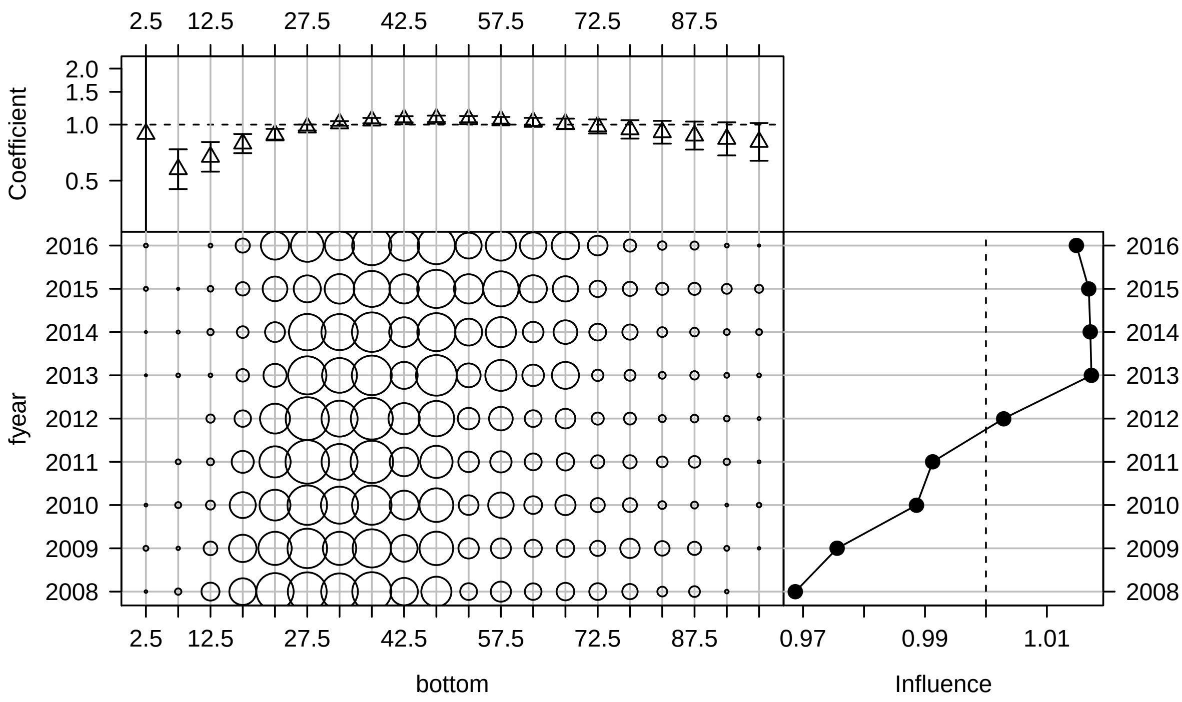


**Figure 40: BT-MIX TCER coefficient-distribution-influence plot for fishing depth.**

A range of trawl widths are used in the BT-MIX TCER fleet and, while wider trawls had higher coefficients, the overall effect and influence is minor (Figure 41).

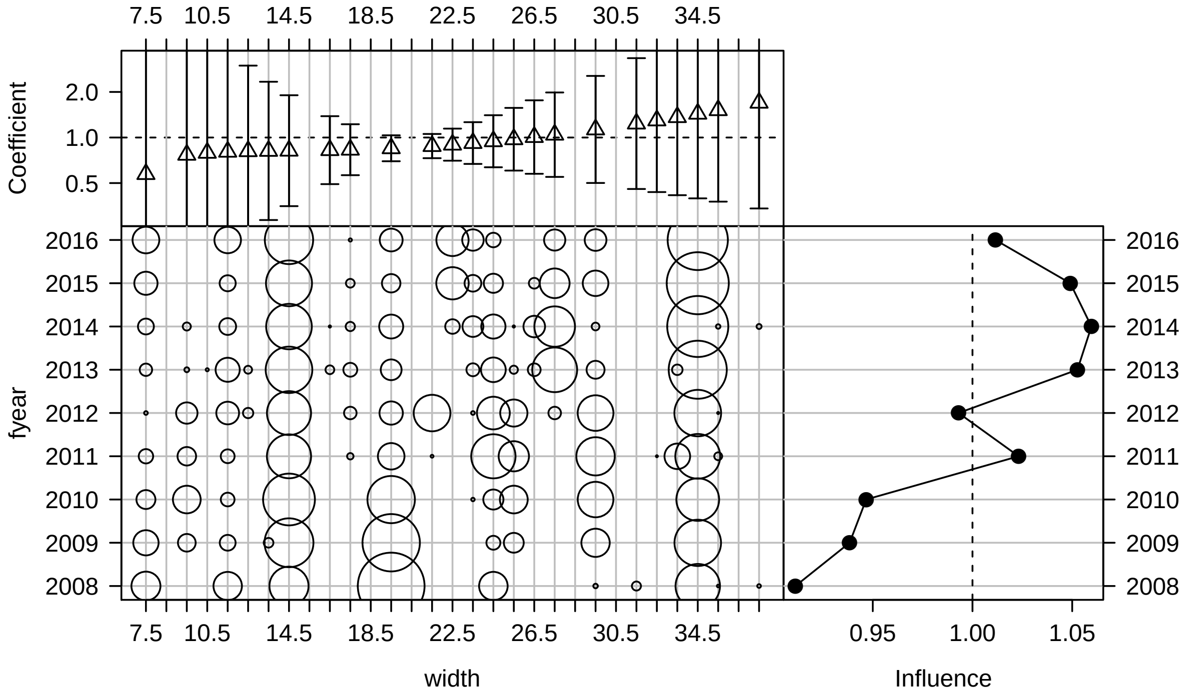


**Figure 41: GUR 2 TCER coefficient-distribution-influence plot for gear width.**

## 5.5 Spatial residuals

The introduction of the fine scale spatial reporting on the TCER form allows examination of spatial residuals.

Positive residuals in the centre of Hawke Bay were apparent in 2011–2013 (Figure 42, middle) and this pattern is stronger in 2014–2016 (Figure 42, bottom). During 2008 to 2016 there was a shift in the overall distribution of fishing effort in the BT-MIX fishery towards the centre of Hawke Bay and away from the Port of Napier.

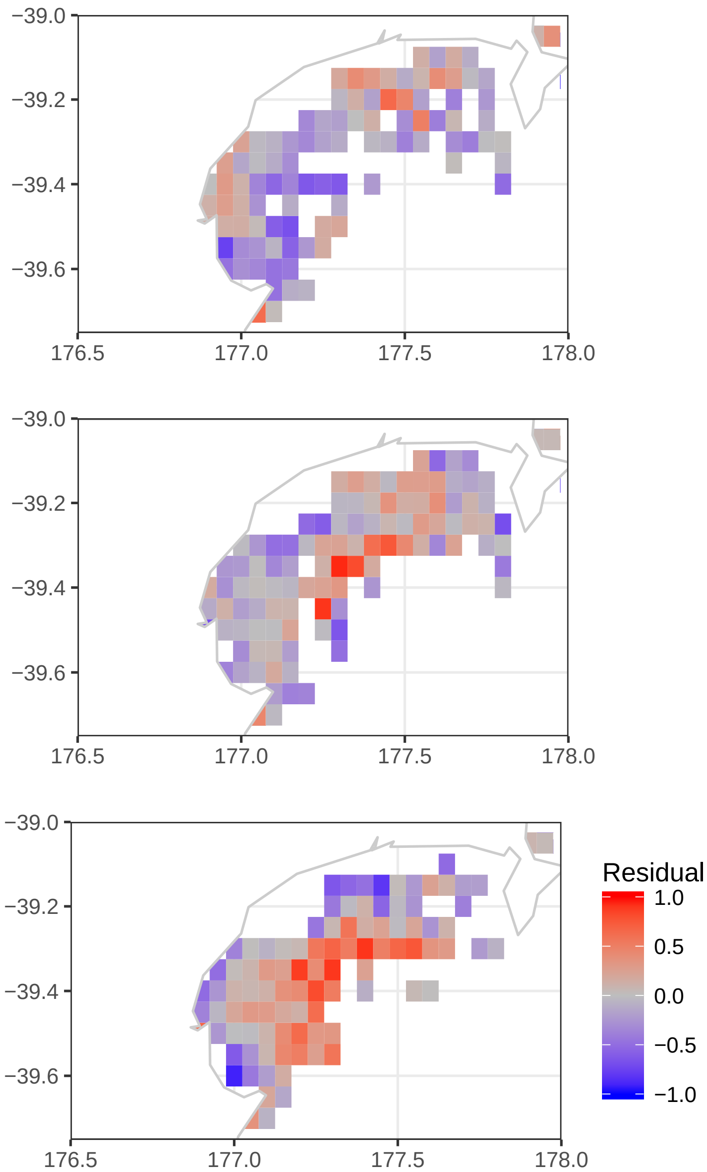


**Figure 42: The mean residuals from the abundance model for GUR 2, residuals are plotted with 0.1 degree lat long bins and a threshold of 30 tows before a bin was included. Top: 2008–2010, Middle: 2011–2013, Bottom: 2014–2016.**

## 6. DISCUSSION

The GUR 2 fishery is primarily a target bottom trawl fishery, focused in Hawke Bay. Gurnard target bottom trawling occurs within a mixed fishery with snapper and trevally as secondary targets. Gurnard is also a significant bycatch in the deeper tarakihi target trawl fishery.

The distribution of fishing effort relative to target species, month and area have remained relatively stable since last examined by Kendrick & Bentley (2014). As a result, the focus of CPUE analyses remains the mixed-target bottom trawl fishery (BT-MIX). Two sets of CPUE indices were derived from the fishery data: a long term series, with data aggregated to CELR resolution, and a shorter series with TCER (tow resolution) data.

In the longer aggregated BT-MIX CPUE series, there are indications of cyclical variations in abundance with a 4 – 5 year period (Figure 43). There was an overall decreasing trend in CPUE from 1990 – 2007, after which CPUE has trended upwards with an especially rapid increase from 2012 – 2016.

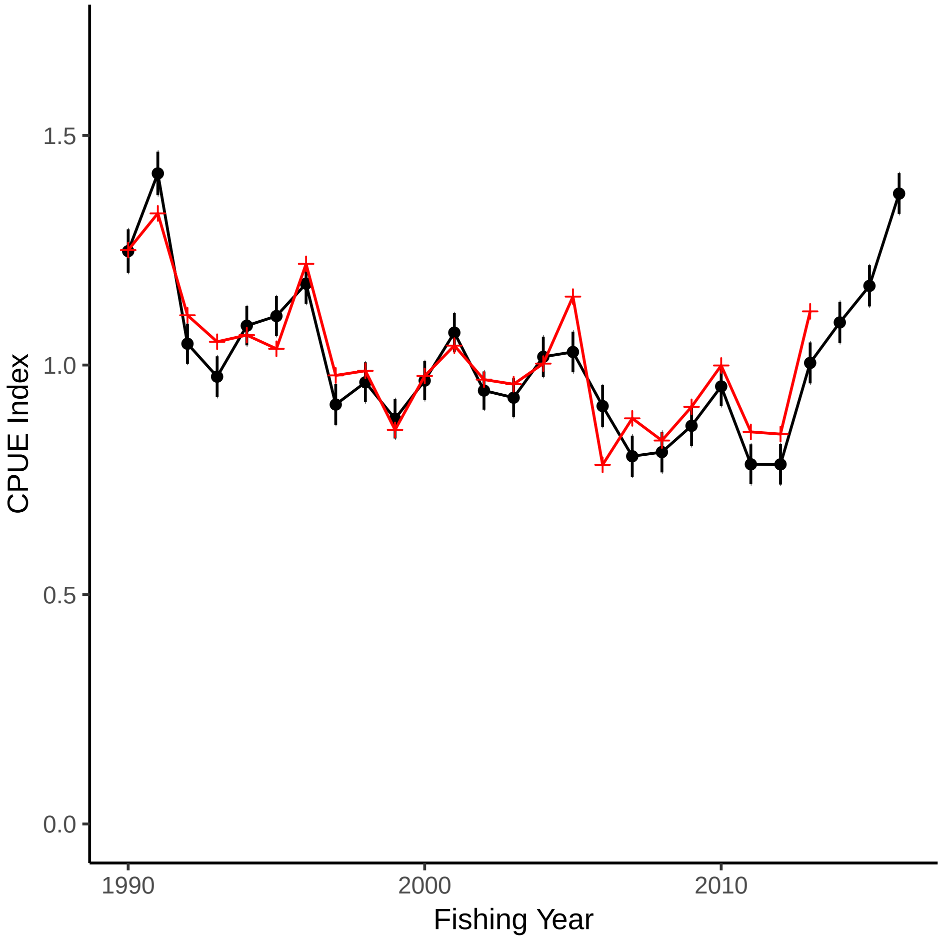


**Figure 43: The CPUE indices for the GUR 2 vessel-day fishery (black) and the last analysis of GUR 2 vessel-day (red), indices are plotted with 1 standard error intervals.**

The shorter TCER series also shows a strongly increasing trend from 2012 – 2016 (Figure 44).

Both BT-MIX series show a good correspondence with the previous analysis of CPUE in GUR 2 (Kendrick & Bentley 2014). The key feature of the updated analysis is the increasing trend in gurnard abundance since 2012, with abundance in 2016 comparable to levels in 1991.

The increase in abundance has also corresponded with an increase in the catch rates in the central areas of Hawke Bay.

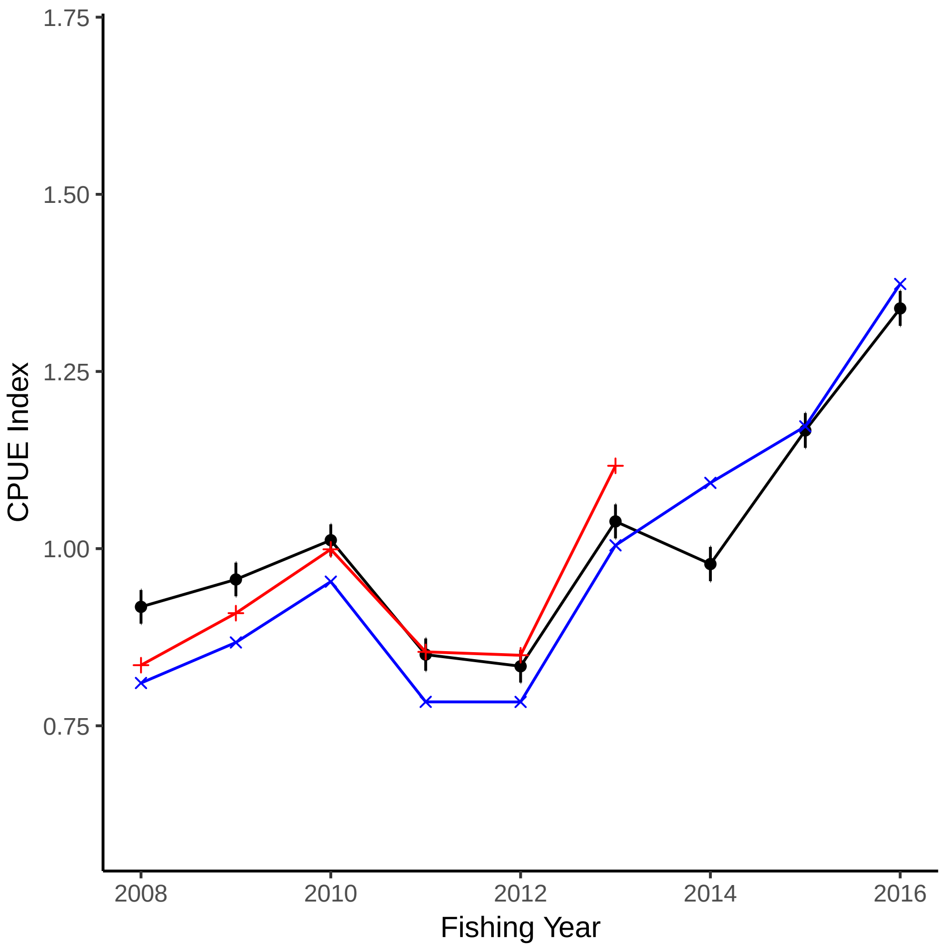


**Figure 44: The CPUE indices for the GUR 2 TCER fishery (black), the last analysis of GUR 2 vessel-day (red) and the GUR 2 vessel-day CPUE indices (this analysis, blue), indices are plotted with 1 standard error intervals.**

## 6.1 Management Implications

The NINS WG has accepted the BT-MIX CPUE index with indices derived from the positive catch component only (Ministry for Primary Industries 2016). The BMSY proxy is the mean of the CPUE indices from 1990–91 to 2009–10, since the last assessment CPUE indices started above the BMSY proxy and continued to rise with the 2016 index the highest in the GUR 2 series.

## 6.2 Acknowledgements

This study was funded by Fisheries Inshore New Zealand and the project was conducted by Trident Systems LP. Members of the Northern Inshore Fishery Assessment Working Group reviewed the analysis. Software developed by Nokome Bentley was utilised for the presentation of CPUE model diagnostics.

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# 8. APPENDICES

## 8.1 Appendix 1 Tabulated CPUE indices

**Table 12: Annual GUR 2 vessel day CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95 percent confidence intervals.**

| Fishing Year | Index | LCI | UCI |
|---|---|---|---|
| 1990 | 1.248 | 1.201 | 1.296 |
| 1991 | 1.417 | 1.370 | 1.465 |
| 1992 | 1.046 | 1.003 | 1.090 |
| 1993 | 0.975 | 0.930 | 1.019 |
| 1994 | 1.086 | 1.043 | 1.128 |
| 1995 | 1.107 | 1.063 | 1.150 |
| 1996 | 1.177 | 1.133 | 1.221 |
| 1997 | 0.914 | 0.870 | 0.958 |
| 1998 | 0.962 | 0.919 | 1.006 |
| 1999 | 0.883 | 0.840 | 0.926 |
| 2000 | 0.966 | 0.924 | 1.009 |
| 2001 | 1.071 | 1.028 | 1.113 |
| 2002 | 0.944 | 0.903 | 0.986 |
| 2003 | 0.929 | 0.887 | 0.971 |
| 2004 | 1.018 | 0.974 | 1.062 |
| 2005 | 1.028 | 0.984 | 1.073 |
| 2006 | 0.911 | 0.865 | 0.956 |
| 2007 | 0.801 | 0.756 | 0.846 |
| 2008 | 0.810 | 0.766 | 0.855 |
| 2009 | 0.868 | 0.823 | 0.912 |
| 2010 | 0.953 | 0.911 | 0.996 |
| 2011 | 0.784 | 0.740 | 0.827 |
| 2012 | 0.784 | 0.740 | 0.828 |
| 2013 | 1.005 | 0.960 | 1.049 |
| 2014 | 1.093 | 1.048 | 1.138 |
| 2015 | 1.173 | 1.128 | 1.217 |
| 2016 | 1.374 | 1.329 | 1.418 |

**Table 13: Annual GUR 2 TCER CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95 percent confidence intervals.**

| Fishing Year | Index | LCI | UCI |
|---|---|---|---|
| 1990 | 1.248 | 1.201 | 1.296 |
| 1991 | 1.417 | 1.370 | 1.465 |
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