Fishery characterisations and catch-per-unit-effort indices for three sub-stocks of red gurnard in GUR 1, 1989–90 to 2008–09

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EXECUTIVE SUMMARY

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This study was contracted as MFish project GUR 2009–01 with the general objective: To characterise the red gurnard (*Chelidonichthys kumu*) fishery and undertake a CPUE analysis in GUR 1.

The annual landed greenweight of GUR 1, allocated to effort strata within each fishing trip, is described by fishing method for three substock areas; the west coast (FMA 9), and FMA 1 divided at the Coromandel Peninsula into east coast and Bay of Plenty. The main fishing methods in each substock are further described by fishing year for target species, statistical area, and month.

Red gurnard is taken on the west coast mainly by bottom trawl, although in recent years TACC pressure on snapper in SNA 8 has resulted in some contraction of the inshore trawl fishery and Danish seine has become increasingly important. On the east coast, gurnard is taken mainly by bottom longline, with most of the balance taken almost equally by bottom trawl and Danish seine, and from the Bay of Plenty almost equally by the three fishing methods. Target fishing accounts for a considerable proportion of catch in all substocks and in each of the important fishing methods, but may not represent true target fishing. Red gurnard is ubiquitous in the shallower inshore fisheries and is an almost unavoidable part of the catch when those fishing methods are targeted at snapper, trevally, or John dory. Within gear type, effort directed at those species seems to be effectively the same fishery with respect to red gurnard.

The northern inshore trawl fisheries are characterised by a systematic shift in reporting from the daily Catch Effort Landing Return (CELR) to the tow-by-tow Trawl Catch Effort Processing Return (TCEPR) in the mid 1990s. This may have affected the reporting of the target species field and could bias CPUE if it was monitored in a narrowly defined fishery, for example, target fishing. It is anticipated that this problem will be encountered in other trawl fisheries as CELRs are replaced by the new Trawl Catch Effort (TCE) form introduced in 2008. Possible solutions include producing separate series based on each format, or expand the fishery definition so that the fisher-nominated target species is not a critical delineator of relevant effort. Both approaches are taken in this study.

GUR 1 is monitored in the inshore bottom trawl fisheries and the shortened time series (available from 1995–96) that is based on catch effort data in tow-by-tow format is extended by four years. The analyses are based on landed greenweight allocated to effort in its original resolution (not amalgamated to trip-stratum) and the fishery definition used previously (tows targeted at gurnard, trevally, snapper or John dory) is expanded to include tows targeted at tarakihi to ensure representative coverage of the spatial distribution of red gurnard. This trend towards using broader fishery definitions by which to monitor the abundance of New Zealand inshore species reflects an increasing confidence in the models to account for operational differences between these fisheries as the datasets increase in size.

Ancillary series based on daily resolution data (from the CELR form) are also presented to extend the time series back to 1989–90. In each substock, there is good agreement between the series derived from the daily and tow-by-tow form types, for the overlapping period.

The series for each substock all show highly variable trends which cycle over a 4–9 year phase. Since the previous standardised series were calculated, the west coast series has declined to a low point that is similar to lows in the 1990s. The east coast series has also declined from its peak in the mid 2000s and is currently at around the mean for the series. The Bay of Plenty series has stayed relatively stable at a level above the mean for the last nine years and shows an upturn in the most recent year.

The Inshore Stock Assessment Working Group considered that these series were consistent with what one would expect from a short lived species with variable recruitment, and appeared to resemble equivalent series estimated for other GUR Fishstocks as well as biomass trends for gurnard from the two South Island trawl surveys.

1. INTRODUCTION

1.1 The fishery

Red gurnard is an important component of the inshore mixed species bottom trawl fishery throughout GUR 1 and is also taken by setnet off the west coast (QMA 9), and by Danish seine and bottom longline fishing off the east coast (QMA 1). Catches have ranged between 927 and 1629 t over the last decade and the TACC has never been reached (Figure 1), most likely because fishing effort is constrained in most years by TACCs of associated species, particularly snapper, trevally, and tarakihi. Since the mid 1990s most of the GUR 1 total has been taken from FMA 9, mainly as a bycatch of the snapper and trevally inshore trawl fisheries. The remaining 40% has been taken from FMA 1 as a bycatch of a number of fisheries, including inshore trawl fisheries for snapper, John dory, and tarakihi. Red gurnard is also an important recreational species with the annual catch from GUR 1 estimated to be 188–256 t during the 1999–2000 survey.

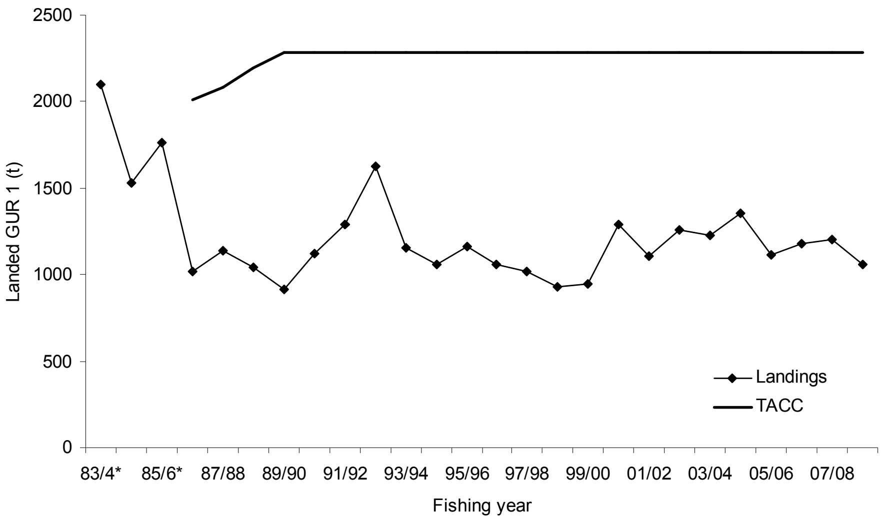

Figure 1: Reported landings of red gurnard (t) in GUR 1 from 1983–84 to 2008–09 and gazetted and actual TACCs (t) for 1986–87 to 2008–09. QMS data from Ministry of Fisheries 2009.

1.2 Previous work

GUR 1 was initially monitored using trawl surveys in the Hauraki Gulf, Bay of Plenty, and west coast of the North Island and the biomass estimates from those surveys are tabled in Appendix A. An attempt was made to assess the Fishstock in two substocks (GUR 1W and GUR 1E) using MIAEL estimation (Cordue 1998) that also included CPUE indices up to the 1996–97 fishing year (Stevenson 2000). The model performance indices were low and MCY estimates based on catch data were noted as subject to a great deal of uncertainty because of changes in the fishing patterns for the main target species. Since discontinuation of the trawl surveys in about 2000, standardised CPUE has been the accepted monitoring tool for GUR 1. Other red gurnard stocks that are currently monitored using standardised CPUE in defined inshore trawl fisheries are: GUR 2 which is monitored in a well defined target fishery, and separately for corroboration or contrast in flatfish tows and in tarakihi tows (Kendrick 2009a), and GUR 3 which is monitored in flatfish tows, and separately for corroboration or contrast in red cod tows (SeaFIC 2009).

The previous project GUR2005/01 identified seven independent fisheries for which there are potentially adequate time series of catch effort data (Kendrick 2009b). They included bottom trawl series targeted at snapper, red gurnard, trevally, or John dory, in each of the three substocks, as well as Danish seine and bottom longline targeted at either red gurnard or snapper in both the east coast and Bay of Plenty substocks. Lognormal models of positive catches were fitted to data from each fishery.

The bottom trawl (combined form types) for the west coast described a cyclical pattern that had returned to near its lowest level for the time series. Trends in trawl survey biomass indices were similar to those for standardised CPUE during the limited period in which trawl surveys were done.

The bottom trawl series (combined form types) for the east coast substock showed a steady four-fold increase from a low in the mid 1990s to 2004–05. The Danish seine series corroborated the bottom trawl trajectory although it was more optimistic. The bottom longline series was almost flat. Trawl survey indices are highly variable from year to year and do not seem to have been monitoring abundance of red gurnard.

The bottom trawl series (combined form types) in the Bay of Plenty also showed a low in the mid 1990s and a subsequent recovery. The Danish seine series was markedly more optimistic than that for bottom trawl, and the series for bottom longline showed a long steady decline over much of the analysis period, though it agreed on a steep increase in the two years to 2004–05. Trawl survey biomass indices were effectively flat.

Concerns about the utility of Danish seine and bottom longline fishery data for monitoring abundance led the Inshore Stock Assessment Working Group to focus on the three bottom trawl series as the most likely candidates in which to monitor abundance of GUR 1, although the large increases in those series were interpreted by the Working Group with caution due to the perceived potential for fishers to have improved their targeting of this species.

Because of the inclusion of bycatch, datasets were initially collated using the Starr (2007) methodology, based on landed greenweight and including data in both CELR and TCEPR formats. While this methodology was flagged in the project description and specified in the contract, it proved not entirely appropriate in this instance and additional analyses were requested. The potential for overly optimistic CPUE trajectories was identified in the systematic and almost total shift in reporting practice from CELR to TCEPR in the northern inshore trawl fishery. The Starr methodology includes an elegant procedure for combining data in the two formats, but does not solve the problems inherent in the shift in reporting practice.

Alternative (short) series based on positive estimated catches (regardless of target species) in bottom trawl tows reported on TCEPRs and analysed at original tow-by-tow resolution allayed these concerns somewhat, and did yield less optimistic series than the bottom trawl series (combined form types) for each substock area for the years in common. After discussion of the results, the additional analyses requested (TCEPR series 1989–90 to 2004–05) were the series preferred by the Inshore Stock Assessment Working Group for each substock area. It was noted, however, that they could nevertheless be done on landed rather than estimated catch using a variation of the Starr methodology that does not amalgamate the data.

It was recommended that the TCEPR bottom trawl series continue to be monitored in each of the three substocks, and that future work include CELR only series to cover the earlier years.

2. DATA SOURCES AND METHODS

The catch effort data extracted from the MFish database “warehou” defined qualifying trips as those that landed to GUR 1, or that had fishing events in a statistical area valid for GUR 1, and used bottom single or pair trawl, bottom longline or Danish seine method, and targeted any species excluding the following deepwater species (ORH, OEO, SOE, SOR, SSO, BOE, WOE, CDL, BYX, HOK, SCI, SQU, HAK, JMA).

For the trips thus defined we obtained all effort data whether or not red gurnard was landed, so that all and not just successful effort could be included in the calculation of CPUE. Landings and estimated catch data for any GUR Fishstock associated with those trips were also obtained.

The characterisations and CPUE analyses for this study were done on landed greenweight of GUR 1 as reported at the end of the fishing trip, either on the bottom part of the general Catch Effort Landing Returns (CELR) or, where fishing was reported on the more detailed Trawl Catch Effort and Processing Return (TCEPR/TCE), on the associated Catch Landing Return (CLR). The CELR form summarises the estimated catch and effort for a day or part day of fishing. It may therefore generalise the species targeted for the day. The TCEPR/TCE form reports in tow-by-tow resolution and includes more detail to describe fishing practice.

Two types of datasets were prepared for this study; the characterisation dataset collated landed greenweight of gurnard linked to effort strata (unique combinations of trip, method, target species and statistical area) using the method of Starr (2007). The CPUE datasets linked landed greenweight to individual tows and retained the data in their original resolution, but held separately by form type.

2.1 Methods used for grooming and collation of MFish catch and effort data

Commonly transposed effort fields (such as number of hooks and number of sets for longline) were corrected. Other outlier values in the effort data were identified from empirical distributions derived from the effort variable (duration or number tows) by identifying records where the values for these variables were in the extreme upper and lower tails of the distribution, and replacing them with the median value for the effort field for the affected vessel. Missing effort data were treated similarly. Missing values for statistical area, method, or target species within any trip were substituted with the predominant (most frequent) value for that field over all records for the trip. Trips with all fields missing for one of these descriptors were dropped entirely.

Outlier values in the landings data were identified by finding the trips with very high landings for red gurnard based on limit values supplied by the Ministry of Fisheries data unit. The effort data for these trips were then used to calculate the trip CPUE and the associated estimated catch. Trips which exceeded the upper 99 to 99.5% of the trip CPUE distribution for the entire dataset were dropped entirely, particularly if there was little estimated catch from the trip.

For the characterisation dataset the allocation of landed catch to effort is done by first summarising effort and estimated catch data for a fishing trip, for every unique combination of fishing method, statistical area, and target species (referred to as a "trip-stratum"). This reduces both CELR and TCEPR format records to lower resolution "amalgamated" data, giving fewer records per trip, but retains the original method, area, and target species recorded by the skipper.

The landed greenweight, declared at the end of the trip, is then allocated to the trip strata in proportion to the estimated catch. Where there are no estimated catches during the trip, the allocation is proportionate to the amount of effort. The allocated landed greenweight was then raised in the dataset to equal the QMR annual totals, and used to describe the GUR 1 fisheries in the characterisation part of this study.

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

Trips landing more than one fishstock of red gurnard from the straddling statistical area (041), or that used multiple fishing methods with incompatible measures of effort, were entirely dropped. This method of using allocated landings retained about 95% of landed GUR 1 for analysis in most years The estimated catch in the groomed dataset represented just under 90% of the allocated landings (Table 1, Figure 2). The allocated landed greenweights were then raised in the dataset to equal the QMR annual totals, and used to describe the GUR 1 fisheries in the characterisation part of this study.

For the CPUE datasets the landed greenweight, declared at the end of the trip, was allocated to individual tows in proportion to the estimated catch, or where there was none, to effort. This retained the data in their original resolution and the ancillary information describing each tow. For the CPUE standardisation part of this study, records for which any field had been corrected or replaced during grooming were dropped.

Table 1: Comparison of GUR 1 TACC and landed catch totals (t) from the MFish catch and effort forms by fishing year with the total reported landings (t) to the QMS. Also shown are the catch totals (t) which remain after the dataset has been prepared for analysis by dropping trips which reported to more than one red gurnard fishstock and fished in a straddling statistical area or that used multiple and incompatible gear types. The estimated catch total is the sum from all trips with matching landing data.

Fishing year	TACC (t)	QMR reported catches (t)	Bottom of form (some edits)	Landed catch for analysis (t)	Estimated catch in dataset (t)	% analysis catch of landed catch	% analysis catch of QMR	% estimated catch of analysis
89/90	2 283	916	741	712	633	96	78	89
90/91	2 284	1 123	1 069	1 034	939	90	88	91
91/92	2 284	1 294	1 279	1 239	1 129	95	96	91
92/93	2 284	1 629	1 595	1 524	1 353	91	95	89
93/94	2 284	1 153	1 199	1 154	1 030	85	85	89
94/95	2 287	1 054	1 037	993	943	74	87	95
95/96	2 287	1 163	1 137	1 107	971	93	98	88
96/97	2 287	1 055	1 043	999	873	88	83	87
97/98	2 287	1 015	1 032	976	860	85	81	88
98/99	2 287	927	946	904	767	97	98	85
99/00	2 287	944	989	959	812	98	98	85
00/01	2 287	1 294	1 320	1 254	1 103	95	99	88
01/02	2 287	1 109	1 111	1 045	907	95	99	87
02/03	2 287	1 256	1 276	1 224	1 074	99	104	88
03/04	2 287	1 225	1 234	1 174	985	99	100	84
04/05	2 287	1 354	1 372	1 294	1 126	99	98	87
05/06	2 287	1 113	1 150	1 066	939	100	101	88
06/07	2 287	1 180	1 194	1 125	1 017	96	99	90
07/08	2 287	1 199	1 230	1 112	1 051	98	96	95
08/09	2 287	1 060	1 077	989	907	99	93	92

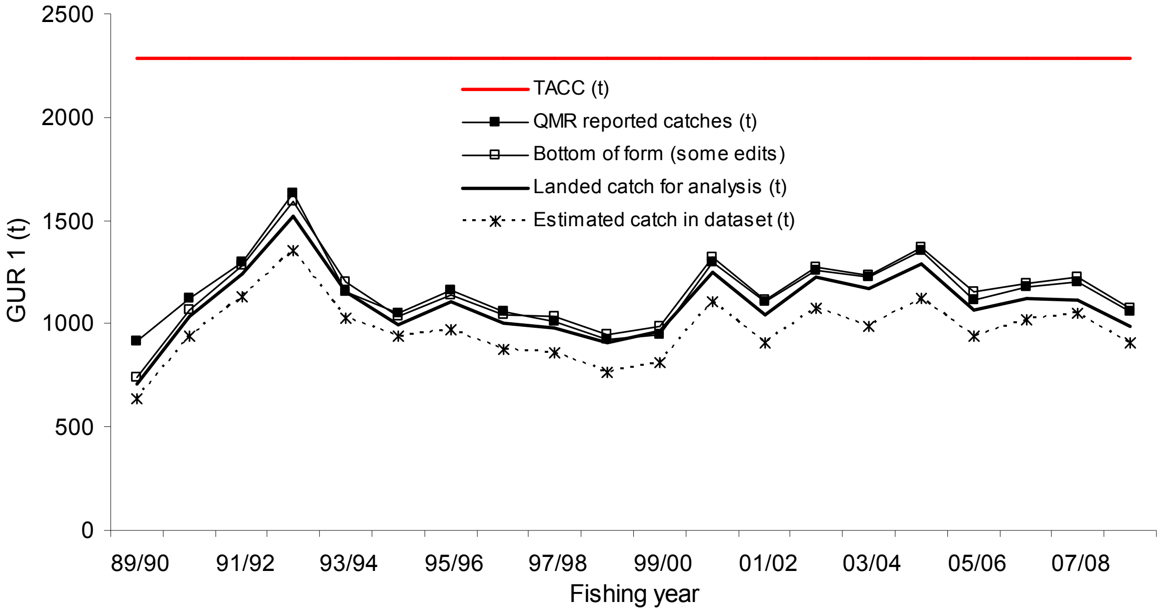

Figure 2: Plot of catch datasets presented in Table 1. The landings are totals reported on Catch Effort forms with some editing; the analysis dataset excludes all landings from trips that landed more than one gurnard fishstock and fished in a straddling statistical area or that used multiple incompatible fishing methods. The estimated catch total is the sum of all estimated catch in the analysis dataset.

2.2 Methods used for catch-per-unit-effort analysis

2.2.1 Defining fisheries

Fisheries are identified in the characterisation as likely candidates in which to monitor abundance of red gurnard based on a consideration of whether: 1) effort is effective with respect to red gurnard (accounts for a significant proportion of landed GUR 1), 2) the gear type is suitable for sampling, 3) the selected target fisheries are equally effective with respect to red gurnard (similar depth, catch rates, encounter rates, and – or other evidence of association), and 4) there has been reasonable stability in the operation of the fishery (based on examination of the areal and seasonal distribution of effort).

A clear definition of the fishery is also important if a meaningful analysis of success rate (probability of capture) is to be modelled separately to the catch rate in positive tows, because it defines how much unsuccessful effort is relevant and should be included in the analysis.

For GUR 1 the preferred series (Kendrick 2009b) monitors CPUE in TCEPR single bottom trawl tows targeted at a suite of closely associated species (snapper, trevally, gurnard and John dory) that are considered to be effectively the same fishery with respect to GUR 1. In this study, however, the definition was broadened to include deeper tows targeted at tarakihi to cover more completely the spatial distribution of gurnard. This represents a slightly different approach from that used previously because the tarakihi fishery is a demonstrably different fishery from the other target fisheries. This trend towards using a broader fishery definition reflects an increasing confidence in the models to account for operational differences between target fisheries as the datasets grow larger.

2.2.2 Landed greenweight versus estimated catch

The estimated catch of the top five species (top eight species in recent years) in the catch is reported (for a day's fishing) on Catch effort Landing Returns (CELRs), or for individual tows on Trawl Catch Effort and Processing Returns (TCEPRs). The estimated catch is often therefore an underestimate, and zero catches are as likely to mean the species was caught, but was not among the top five species, as that it wasn't caught at all. The shortfall was first acknowledged as a serious problem for monitoring bycatch species, but with the trend towards monitoring many species in mixed target fisheries, it is becoming acknowledged as a more general problem.

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

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

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

Another advantage to using landed, rather than estimated, catch is that the landings forms include QMS Fishstock information, and without it the catches from straddling statistical areas (statistical areas shared by more than one Fishstock) are unidentifiable and must generally be excluded from the dataset. With the benefit of Fishstock information, trips that fished in a straddling area but landed only to the Fishstock of interest can be retained.

2.2.3 Combining form types

Effort reported on the daily CELR form generally summarises a day's fishing in a single record, and therefore includes an unknown proportion of unsuccessful effort associated with each estimated catch. The amalgamation of TCEPR data to trip-stratum mimics that of the CELR format, by including qualifying effort whether successful or not, and allows data in both formats to be combined in a defensible manner.

There remains, however, concern about defining fisheries based on data in both formats in the northern inshore trawl fishery because of the almost total shift from CELR daily reporting to TCEPR tow-by-tow reporting that has resulted in a systematic improvement in the definition of target effort.

CELRs may report a mixture of fishing practices over a day's fishing, using a single target species. For example, Field & Hanchet (2001) in describing TAR 1 in this same inshore trawl fishery, reported that fishers were usually targeting a species mix, and that fishing strategies were aimed at maximising the catch of the quota mix rather than maximising the tarakihi catch. Therefore, on any particular day they may have tows targeting tarakihi, tows targeting a 50% tarakihi and 50% mix, and tows actively avoiding tarakihi. Unfortunately, this level of detail is not easily captured on CELRs, and was often combined into a daily record with a single reported target species.

The reporting behaviour on TCEPRs, however, is quite different, with a nominal target species recorded for each individual tow, and targeting potentially better defined.

In a study of TAR 1 in this same inshore trawl fishery, Kendrick (2009c) reported catch rates for targeted tarakihi to be lower on CELRs than on TCEPRs, presumably because CELRs include this other effort, and that, as the proportion of data reported on TCEPRs increased, so too did the annual simple catch rate. Additionally, there was a lower bycatch of tarakihi reported on TCEPRs in other target fisheries than was reported on the daily CELR, for the same reason. Thus, the systematic switch in form types potentially compromised both the target and bycatch series of CPUE.

To address this concern (which is peculiar to this northern inshore trawl fishery), a shorter series of CPUE based on TCEPR format data was collated for each trawl fishery. The current understanding of this problem (which will become relevant to many other fisheries as they switch from CELR to the new TCE form) is that it will have the greatest effect on time series based on a single target species, and is best allayed by monitoring abundance in fisheries that are defined across a wider range of target species.

2.2.4 Inclusion of zero catch information

Where a species is monitored in a well defined target fishery, zero catches are rare, and historically have been excluded. However, it is acknowledged that in many mixed species fisheries the reported target species can indicate: 1) the single species targeted, 2) the main of several species targeted, 3) the species for which the most quota is held (especially before the introduction of the current Actual Catch Entitlement (ACE) regime), 4) the main species actually caught (whether it was targeted or not), the species which legalises a subsequent bycatch trade, or 5) simply a logical species for that area and fishery (Paul & Bradford 2000), rather than any predetermined fishing behaviour. For this reason it would be spurious to consider only the target tows, or indeed to exclude them. This is a particular problem in CELR format data, as an entire day's fishing can be reported to a single target species.

Current practice in monitoring inshore species in New Zealand is to define a fishery that expends effective effort with respect to the species of interest, based on a single fishing method, a group of associated target species, and sometimes season or location. The fishery definition includes target species that are often caught together (associated), have a common depth range preference, and yield similar bycatch rates of the species of interest.

When a fishery is thus defined, it is logical that all qualifying effort, including unsuccessful effort, is included in the calculation of catch rate, but it is essential when using either CELR format catch-effort, or allocated landings, because the method for linking landed greenweight with effort amalgamates records to trip-stratum resolution and, therefore, incorporates zero-catches, i.e., effort for tows that were unsuccessful. CELR data are also amalgamated, being reported at the resolution of a fishing day, and they also include an unknown amount of unsuccessful effort: there is a potential for bias to be introduced through any systematic and undetectable change in success rate.

The most defensible way to standardise the measure of CPUE in non-target (or mixed target) fisheries is to include all qualifying effort, and to employ a model that can cope with zero catch information.

Currently this is done using a two-part model that combines indices from a lognormal model of catch rate in successful events and a binomial model of success rate (see Section 2.4). The reader is reminded, however, that for CELR, and for amalgamated TCEPR data, the zero catch information is not entirely captured in the binomial model; much of the zero catch information is already incorporated into the calculation of catch rates used in the lognormal part of the model.

2.2.5 Core fleet definitions

The data sets used for the standardised CPUE analyses were further restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables: the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery.

The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of gurnard. This selection process generally reduces the number of vessels in the dataset by about 70% while reducing the amount of landed gurnard catch by about 20%. Note that the vessels thus selected are not necessarily the top vessels with respect to catching gurnard.

2.2.6 Models

A lognormal linear model was fitted to successful catches of GUR 1, excluding zero catches, for each of the fisheries defined, and a binomial model which predicted success or failure of GUR 1 catch was fitted to the total dataset, including records that reported a zero catch of red gurnard. These two models were combined into a single set of indices using the method of Vignaux (1994).

Catches were standardised for variance in the explanatory variables using a stepwise multiple regression procedure, selecting until the improvement in model R2 was less than 0.01. The year effects were extracted as canonical coefficients (Francis 1999) so that confidence bounds could be calculated for each year.

The dependent variable for the lognormal models based on allocated landings was the log of landed weight of GUR 1 per record. The explanatory variables offered to the model were: fishing year (always forced as the first variable) and month (of landing), statistical area, target species, form type, and a unique vessel identifier. The logs of the total number of tows and of total duration of fishing were included as measures of effort to explain catch per trip-stratum.

For models based on TCEPR data in its original resolution, the dependent variable was the log of estimated catch per trawl tow, and bottom depth, tow speed, and the log of tow distance (calculated from speed and duration) were also offered as potential explanatory factors.

The dependent variable for the binomial model was a binary variable set to ‘1’ for records which had associated GUR 1 catch and set to ‘0’ for records with no catch. This model was offered the same explanatory variables as the lognormal model.

The two models were combined using;

$$C_i = \frac{L_i}{\left(1 - P_0\left[1 - \frac{1}{B_i}\right]\right)}$$

where Ci = combined index for year i
Li = lognormal index for year i
Bi = binomial index for year i
P0 = proportion zero for base year 0

It is relatively straightforward to calculate standard errors for the indices Li and Bi. However, this is not so for the combined index Ci because the standard errors of the two sets of indices are likely to be correlated as they come from the same dataset. Francis et al. (2001) suggested that a bootstrap procedure is the appropriate way to estimate the variability of the combined index, but this was not done for this paper.

2.2.7 Substock areas

Previous work has described GUR 1 as comprising two substocks (GUR 1W and GUR 1E), and MFish (2009) reported that there is no new information to suggest any changes to that structure. However, other species in this same northern inshore bottom trawl fishery are monitored in three substocks, with the eastern part being further divided by the Coromandel Peninsula. It seems appropriate to do the same for red gurnard, which is a fairly sedentary fish. In any case, whether or not red gurnard exists as separate biological substocks in the eastern part of GUR 1, the fisheries operate with some independence and for that reason are best described separately.

The three substocks for descriptive and CPUE analyses were defined on the basis of statistical area, as detailed in Table 2 with boundaries at Cape Reinga and Coromandel–Great Barrier Island. Offshore statistical areas were amalgamated with adjacent inshore areas.

Table 2: Statistical area definitions of GUR 1 substock areas used in the distribution tables and plots in this report.

Substock area	Statistical areas
West	041 042 043 044 045 046 047 048 101 102 103 104
East	001 002 003 004 005 006 007 105 106
Bay of Plenty	008 009 010 107

3. RESULTS

3.1 Characterisation of GUR 1

Catches from the east coast of Northland dominated the landings of GUR 1 before 1992–93. In that year catches peaked in all three substocks, but they more than doubled in west coast areas. West coast catches have accounted for more than half of GUR 1 since then with the balance coming almost equally from the eastern and Bay of Plenty substocks (Table 3, Figure 3).

In the mid 2000s the importance of the western substock declined briefly as trawl effort was diverted away from snapper (the SNA 8 TACC level was reduced on 1 October 2005 to ensure a faster rebuild of the stock) and catches of gurnard from both East Northland and the Bay of Plenty coincidentally peaked. Since then, catches from the west coast have again increased to exceed 600 t in 2008–09 (58% of GUR 1), with East Northland and Bay of Plenty landing 208 (20% of GUR 1) and 240 t (23 % of GUR 1) respectively.

Table 3: Distribution of landed red gurnard by substock area and fishing year, in tonnes and percent, from trips which landed GUR 1 for 1989–90 to 2004–05. Catches are scaled up to the annual QMR catch (Table 1). Percentages sum to 100 by year.

	Substock area (t)			Substock area (%)		
Fishing year	West Coast	East Coast	Bay of Plenty	West Coast	East Coast	Bay of Plenty
89–90	318	419	179	35	46	20
90–91	363	447	310	32	40	28
91–92	365	562	368	28	43	28
92–93	761	512	349	47	32	22
93–94	549	318	286	48	28	25
94–95	571	217	268	54	21	25
95–96	743	215	205	64	18	18
96–97	612	236	206	58	22	20
97–98	548	216	253	54	21	25
98–99	498	198	231	54	21	25
99–00	458	247	240	48	26	25
00–01	761	302	230	59	23	18
01–02	581	275	254	52	25	23
02–03	789	203	264	63	16	21
03–04	690	243	292	56	20	24
04–05	666	376	312	49	28	23
05–06	505	348	260	45	31	23
06–07	619	368	194	52	31	16
07–08	730	248	221	61	21	18
08–09	613	208	240	58	20	23

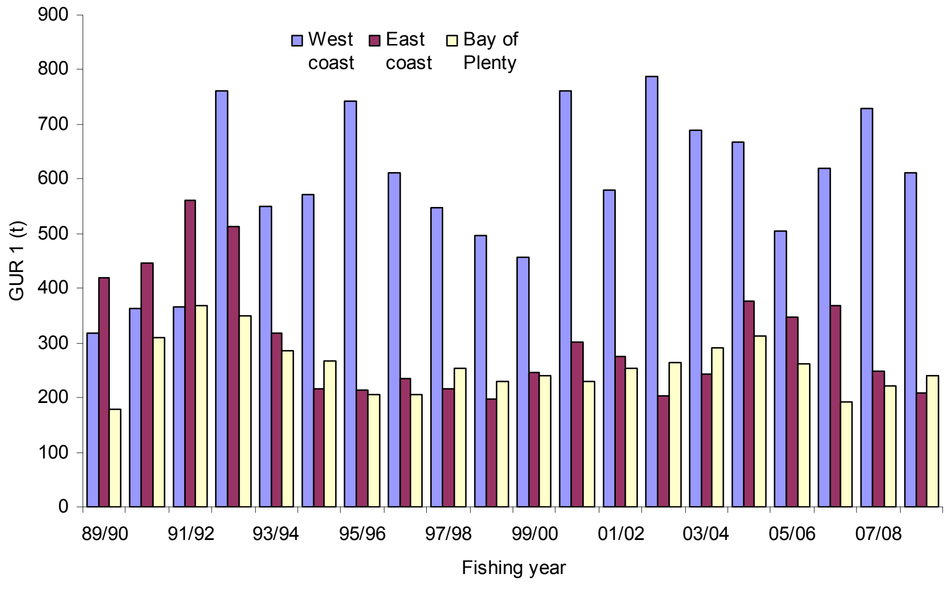

Figure 3: Landed catch of GUR 1 by substock area and fishing year.

3.2 Characterisation of the west coast GUR 1 fisheries

Historically, more than 70% of the catch of GUR 1 in the western substock was taken by bottom single trawl, with most of the balance taken by bottom pair trawl and small amounts by set net and Danish seine (Table 4). There has been a marked decline in the importance of bottom trawl since 2004–05, however, in response to the contraction of the snapper fishery, and in 2008–09, for the first time, bottom trawl accounted for less than half (40%) of the gurnard taken from the west coast substock of GUR 1. Set net has also declined and now takes less than 20 t per year.

Since 2006–07, a developing Danish seine fishery has accounted for an increasing amount of gurnard catch, expanding beyond its historical grounds in Area 047 into areas as far south as Area 042 (Figure 4), and in 2008–09 overtook bottom trawl as the main method. Danish seine is a method that is more selective for some species and may enable fishers to avoid snapper more effectively than when using bottom trawl. The Danish seine CPUE series is as yet too short to warrant an attempt at standardisation but may offer a useful time series in the future if it continues.

Table 4: Distribution of landed red gurnard by method and by fishing year for the west coast substock of GUR 1 in tonnes and in percent of substock annual landings. Catches are raised to the annual QMR catch (Table 1): 0, less than 0.5 t. Percentages sum to 100 by year. BT, bottom trawl; DS, Danish seine; BPT, bottom pair trawl; SN, setnet.

										West coast
Fishing	Fishing method (t)					Fishing method (%)				
year	BT	DS	BPT	SN	Other	BT	DS	BPT	SN	Other
89/90	245		48	24	1	77	0	15	8	0
90/91	248		97	18	1	68	0	27	5	0
91/92	278		57	26	4	76	0	16	7	1
92/93	684	19	26	28	4	90	3	3	4	0
93/94	460	25	40	17	7	84	5	7	3	1
94/95	451	2	66	46	6	79	0	11	8	1
95/96	519	71	79	65	9	70	10	11	9	1
96/97	465	31	12	94	10	76	5	2	15	2
97/98	426	14	19	82	8	78	2	3	15	1
98/99	374	1	59	62	3	75	0	12	12	1
99/00	350	3	45	52	8	77	1	10	11	2
00/01	528	74	81	70	8	69	10	11	9	1
01/02	421	82	14	54	10	73	14	2	9	2
02/03	585	88	58	45	12	74	11	7	6	2
03/04	456	127	54	41	12	66	18	8	6	2
04/05	489	58	85	32	3	73	9	13	5	0
05/06	384	51	47	21	1	76	10	9	4	0
06/07	401	140	56	20	1	65	23	9	3	0
07/08	392	234	85	18	1	54	32	12	2	0
08/09	247	280	69	14	3	40	46	11	2	0

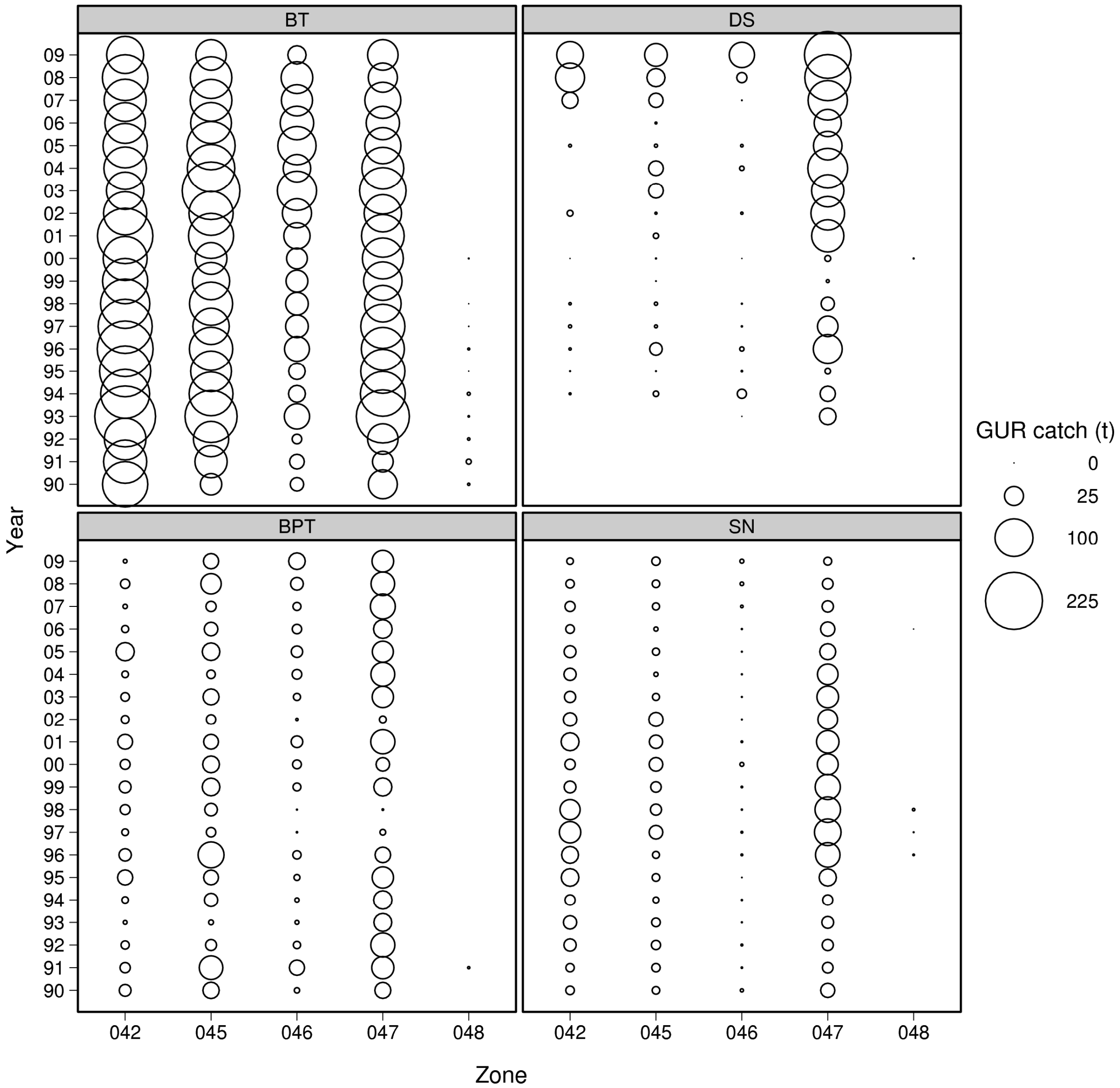

Figure 4: Spatial distribution of gurnard catches in the west coast substock for the four main methods and fishing year. Zones amalgamate offshore statistical areas with adjacent inshore areas.

3.2.1 West coast (single) bottom trawl

Before 2005–06, the bottom trawl catch of GUR 1 from the west coast substock was largely a bycatch of the snapper (25–61 % annually) and trevally fisheries (17–39 % annually), with most of the balance taken in targeted tows. It was more often reported as a bycatch of snapper tows during the first half of the time series and increasingly a targeted catch in the last half. The bycatch from tarakihi tows accounted for about 3% of the catch for the first half of the time series, but then declined to about half that level from 2000–01. A small proportion of red gurnard is also consistently taken in tows targeted at barracouta and John dory, but the total tonnage in each year is small.

Between 2004–05 and 2008–09 the catch of gurnard by bottom trawl in this substock dropped from 489 to 247 t with the decline occurring initially in snapper tows, but by 2008–09, the catch from gurnard target tows had also dropped. Only the trevally fishery has maintained historical levels of gurnard bycatch (Table 5, Figure 5), reflecting the quota mix that is held by the main operator.

Table 5: Distribution of bottom trawl caught red gurnard by target species (snapper, gurnard, trevally, John dory, tarakihi, and other) and by fishing year for the west substock of GUR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

West coast bottom trawl

Fishing	Target species (t)						Target species (%)					
year	SNA	GUR	TRE	JDO	TAR	Other	SNA	GUR	TRE	JDO	TAR	Other
89/90	113	66	53	0	11	2	46	27	22	0	5	1
90/91	98	71	59	0	12	9	39	29	24	0	5	4
91/92	144	69	48	0	9	8	52	25	17	0	3	3
92/93	360	125	153	0	19	27	53	18	22	0	3	4
93/94	264	73	97	0	16	10	58	16	21	0	3	2
94/95	275	57	96	0	11	12	61	13	21	0	3	3
95/96	297	50	146	4	10	11	57	10	28	1	2	2
96/97	176	129	143	2	11	5	38	28	31	0	2	1
97/98	182	57	166	3	12	5	43	13	39	1	3	1
98/99	144	81	130	0	13	6	38	22	35	0	3	2
99/00	91	143	99	1	11	5	26	41	28	0	3	1
00/01	206	195	113	3	7	5	39	37	21	0	1	1
01/02	171	124	112	2	7	4	41	30	27	1	2	1
02/03	186	234	154	1	7	4	32	40	26	0	1	1
03/04	191	125	130	1	8	1	42	27	29	0	2	0
04/05	122	206	153	0	6	2	25	42	31	0	1	1
05/06	76	196	100	0	5	7	20	51	26	0	1	2
06/07	43	107	243	0	6	2	11	27	61	0	1	0
07/08	53	128	200	0	9	3	13	33	51	0	2	1
08/09	48	59	128	0	8	3	19	24	52	0	3	1

The seasonality of the four most important target fisheries taking GUR 1 by bottom trawl is shown in Figure 5. Targeting of red gurnard occurred throughout the year in the first half of the time series but became more of a winter activity in the later half. The greatest catches from the snapper fishery are taken in spring and early summer and historically from the trevally fishery during the summer though that has shifted into spring as the bycatch from the snapper fishery has declined. There is little evidence of seasonality in the landings of gurnard from the other fisheries.

The spatial distribution of GUR 1 catch is similar among the main target fisheries (Figure 6), with all inshore statistical areas being important for red gurnard (Areas 043 and 044 are harbours that are protected from commercial trawling), but bycatch from snapper tows has declined in all areas while bycatch of red gurnard from trevally tows has increased to compensate. Target fisheries were developed in Areas 045 and 046 early in the 2000s, and also increased in the historically important target Areas 041, 042 and 047, coincident with the declining bycatch, but have since dropped away again as the trevally fishery has accounted for a greater proportion of the catch. Despite the shifts in target species used to describe the catch of red gurnard, catches have been maintained from the traditional areas and seasons.

Annual average catch rates (total catch per year/total tows per year) of gurnard in tows targeted at snapper, gurnard, or trevally are similar in magnitude and show similar trends. Catch rates varied between 65 kg per tow (for bycatch) and 200 kg per tow (for target fishing) in the late 1990s, increasing to between 120 and 300 kg per tow respectively in the mid 2000s except for an anomalous year in 2003–04 when catch rates were low. Catch rates in targeted tows are generally slightly higher than for bycatch, and in contrast, catch rates in tows targeted at tarakihi are much lower (less than 20 kg per tow). The encounter rates (of gurnard) also suggest similarities between target fisheries for trevally and snapper, with gurnard caught in 60–80 % of tows in the early part of the TCEPR/TCE time series increasing to 80–90% in the early 2000s when catch rates increased. In contrast, gurnard is reported in only 20–30% of tows targeted at tarakihi (Figure 7).

It is defensible to consider all bottom trawl targeted at snapper, trevally, or red gurnard in this substock area to be effectively the same fishery with respect to red gurnard, and the utility of target species as an explanatory variable to be doubtful. Successful tows (with respect to gurnard) in the three main target fisheries are also made in much the same depth range (at least for that subset reported on TCEPRS (Figure 8). Tow speeds are higher on average when targeting trevally than either snapper or gurnard, but as red gurnard is a relatively sedentary species it is unlikely that this would affect its catchability so long as the footrope was on the bottom.

Data are mainly reported on TCEPR after 1995–96 (Figure 9) and these data can be used in their original (tow-by-tow) resolution to standardise positive catches for bottom depth and tow speed, rather than for fisher-nominated target species. Distance towed can also be calculated and offered as a measure of effort in preference to duration towed. When a range of tow speeds is used in a mixed species fishery, duration may be a less meaningful measure of effort.

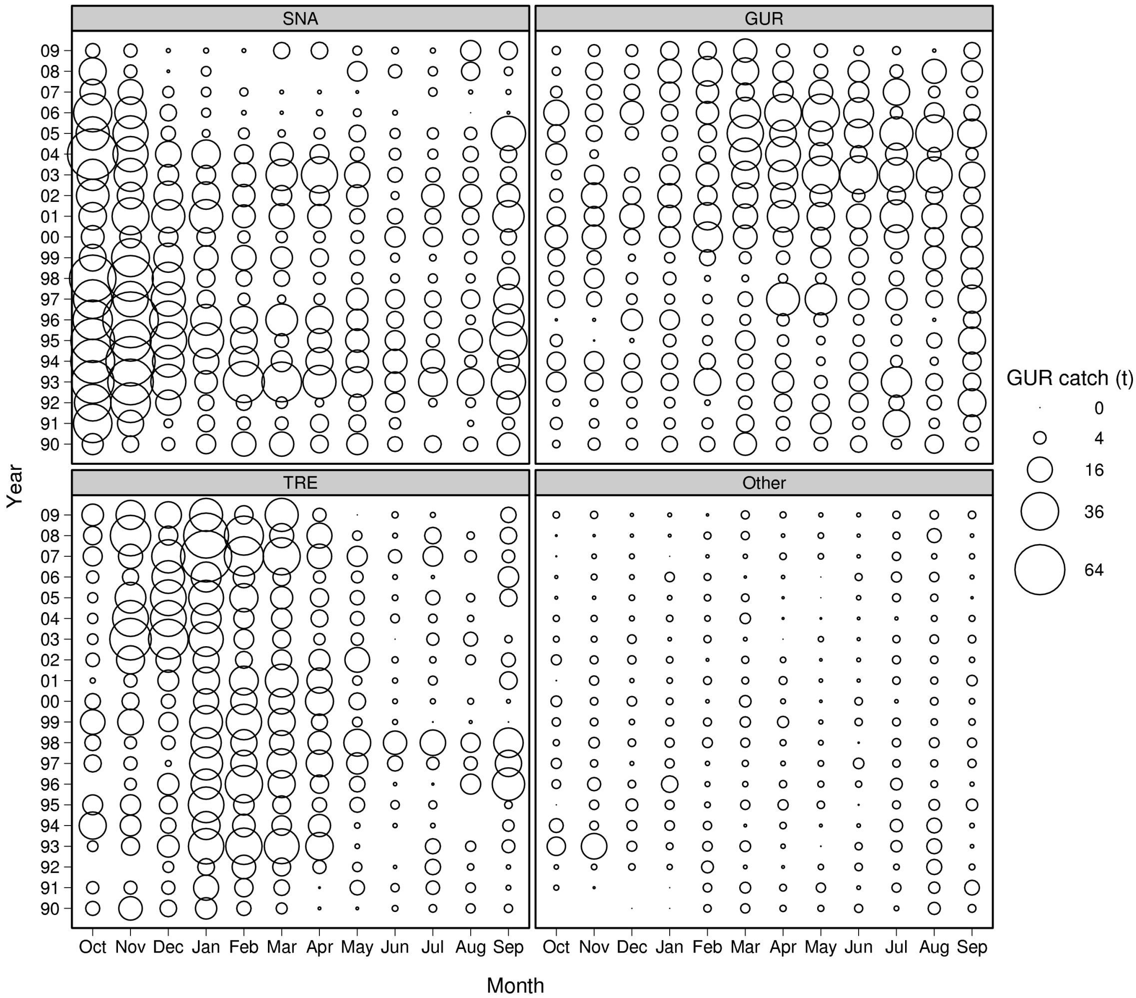

Figure 5: Comparison of the seasonal distribution of bottom trawl red gurnard catches for the three main target fisheries taking GUR 1 from the west coast substock area, by fishing year. Other includes tarakihi. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 5.

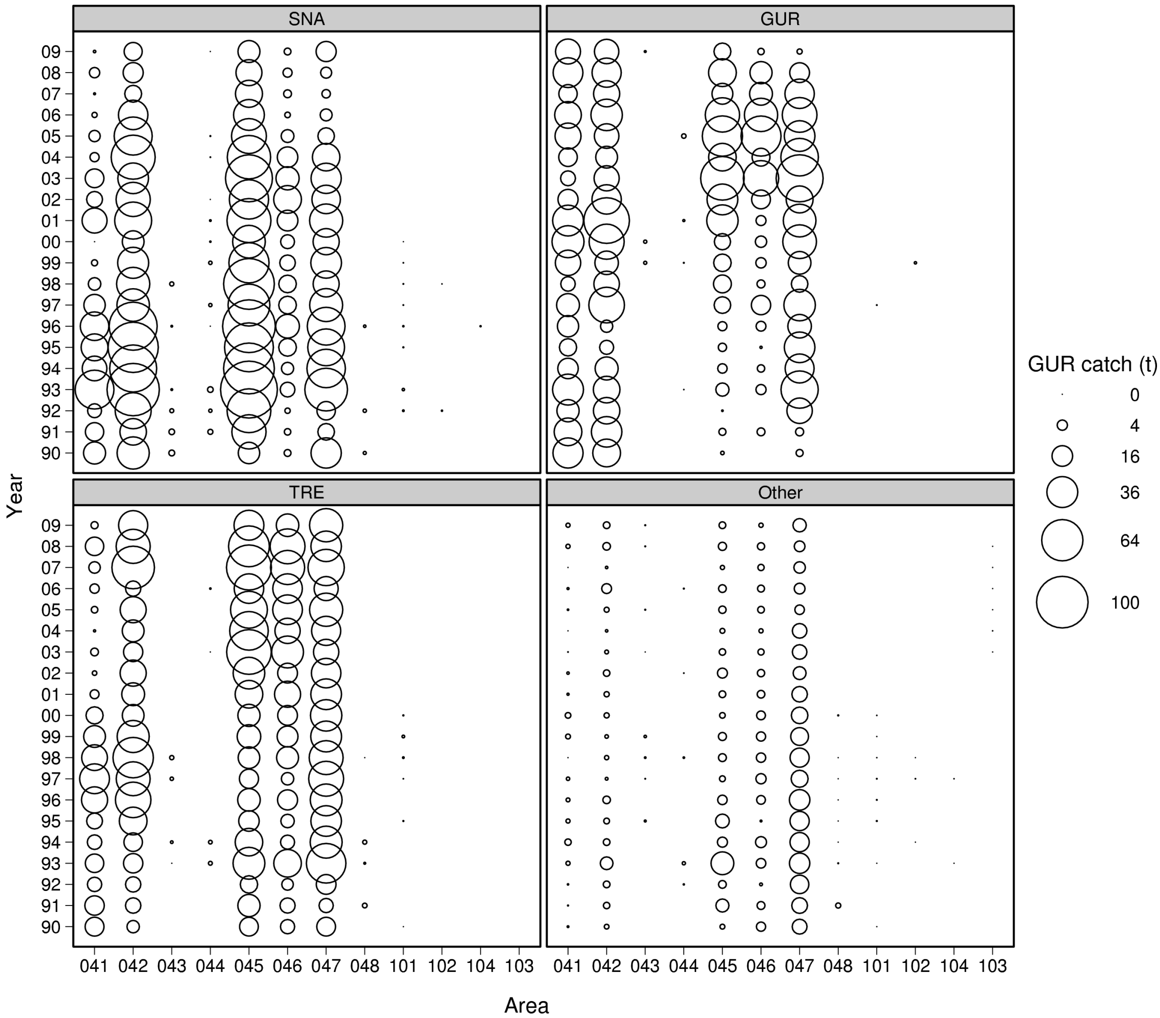

Figure 6: Comparison of the spatial distribution of bottom trawl red gurnard catches for the four main target fisheries taking GUR 1 from the west coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 5.

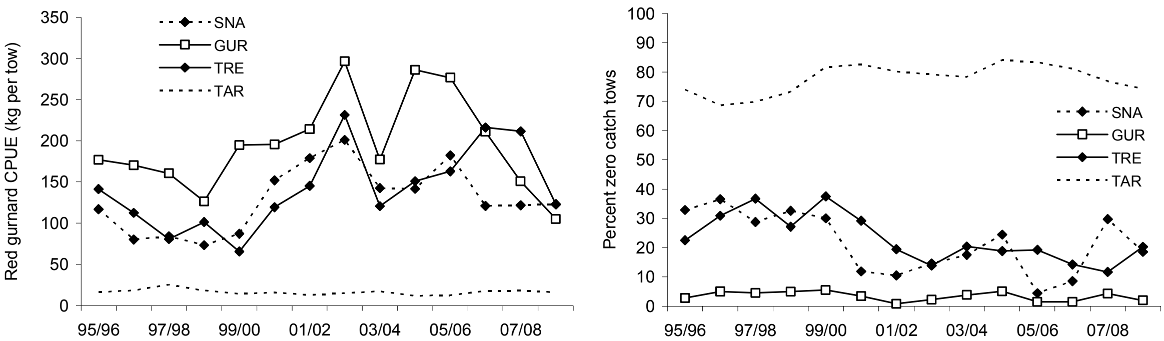

Figure 7: Unstandardised CPUE (kg/tow) and percent unsuccessful tows for red gurnard in the main target fisheries using single bottom trawl tows in the west coast substock of GUR 1 from TCEPR or TCE records since 1995–96.

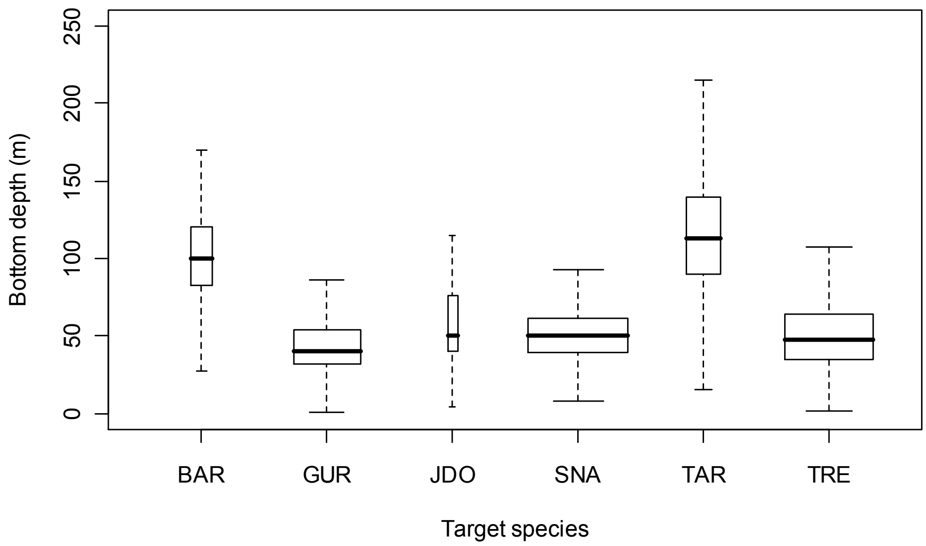

Figure 8: Box plot distributions (median and interquartiles) of bottom depth from TCEPR or TCE records of the single bottom trawl method for the main five target species where a catch of gurnard was reported (positive tows). All years and statistical areas for the western substock are combined. The width of the boxes is proportionate to the number of records.

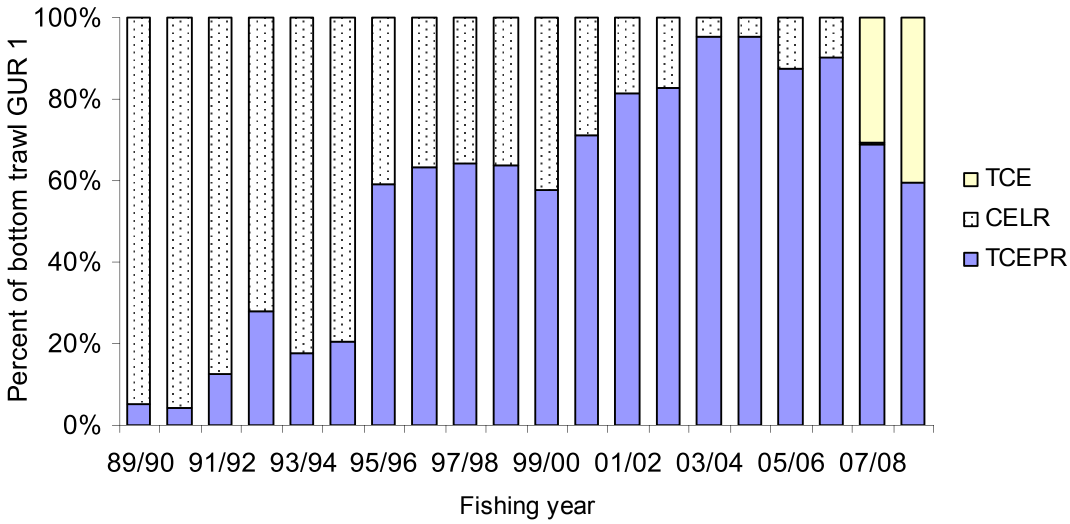

Figure 9: Change in reporting practice in the west coast trawl fishery. The percent of bottom trawl caught GUR 1 (by landed weight) reported on the tow-by-tow forms (TCEPR or TCE) and on the daily form (CELR) by fishing year.

3.2.2 West coast Danish seine

The Danish seine fishery is almost entirely targeted at red gurnard and has historically been mainly confined to Statistical Area 047. The recent expansion into the snapper grounds of Areas 046, 045, and 042 (Figure 10) has increased gurnard catches by about 250 t for an associated increase in snapper of less than 100 t of (Kendrick & Bentley 2010). There is little seasonal pattern to the landings of gurnard by this method (Figure 11).

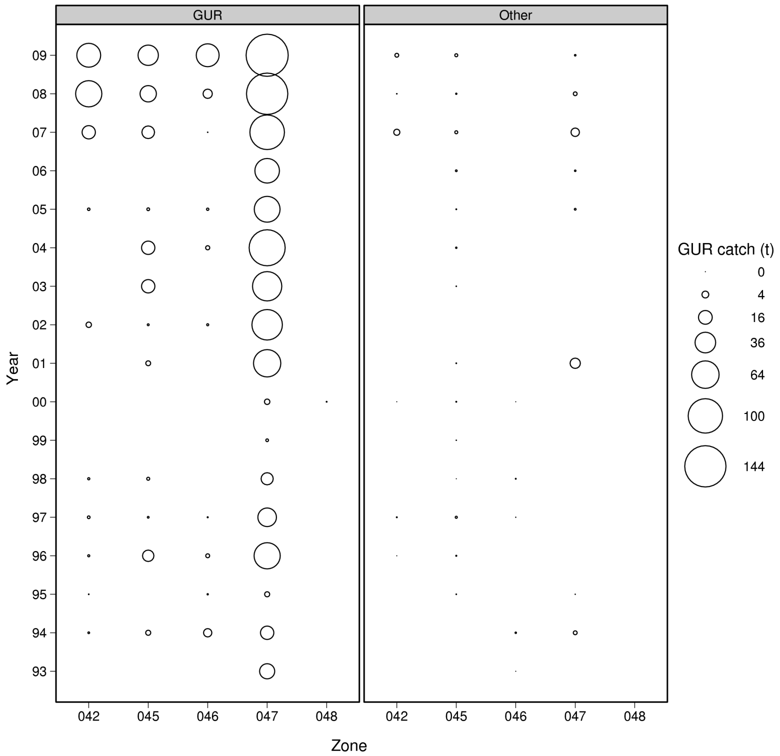

Figure 10: The distribution across statistical area, fishing year, and target species of catches of gurnard by Danish seine in the west coast substock.

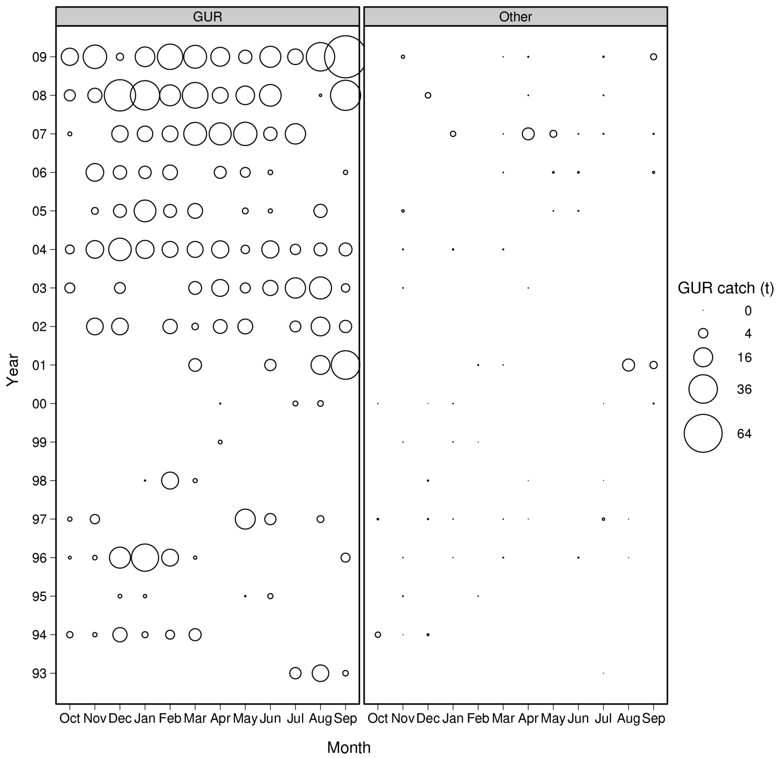

Figure 11: The seasonal distribution by fishing year and target species of catches of gurnard by Danish seine in the west coast substock.

3.3 Characterisation of the east coast GUR 1 fisheries

In the east coast areas GUR 1 has mainly been landed from bottom longline sets, which have accounted for 24–60 % of the landings of gurnard from this substock annually, followed in most years by bottom trawl (15– 44% annually), with most of the remainder taken by Danish seine. Small amounts (usually less than 5 t) have also been landed by bottom pair trawling and set net fisheries in each year (Table 6).

The trawl methods are largely confined to Areas 003 and 005, which are also fished by bottom longline. Bottom longline also takes considerable amounts of gurnard from Statistical Area 002, (Figure 12), and catches from that area have been relatively constant through the time series. Catches for all methods in the other important areas slumped during the 1990s, only increasing again in the mid 2000s. In the three most recent years (since 2006–07) catches have declined again by almost half in all three main methods, only being maintained in bottom longline in Area 002.

Table 6: Distribution of landed red gurnard by method and by fishing year for the east coast substock of GUR 1 in tonnes and in percent of substock annual landings. Catches are raised to the annual QMR catch (Table 1); 0, less than 0.5 t. Percentages sum to 100 by year. BT, bottom trawl; BPT, bottom pair trawl; BLL, bottom longline; SN, setnet; DS, Danish seine.

										East coast
Fishing	Fishing method (t)					Fishing method (%)				
year	BT	DS	BLL	BPT	Other	BT	DS	BLL	BPT	Other
89/90	155	54	130	49	31	37	13	31	12	7
90/91	172	111	107	45	13	38	25	24	10	3
91/92	221	132	190	9	10	39	24	34	2	2
92/93	149	114	219	18	12	29	22	43	4	2
93/94	66	77	155	14	6	21	24	49	4	2
94/95	42	35	123	8	9	20	16	57	4	4
95/96	43	44	109	4	14	20	20	51	2	7
96/97	33	68	123	1	12	14	29	52	0	5
97/98	48	32	130	0	6	22	15	60	0	3
98/99	60	25	100	2	11	30	13	50	1	5
99/00	72	52	110	2	10	29	21	45	1	4
00/01	90	77	116	3	16	30	26	38	1	5
01/02	117	49	100	8	2	42	18	36	3	1
02/03	80	25	84	10	5	39	12	41	5	2
03/04	100	32	100	8	3	41	13	41	3	1
04/05	173	63	125	13	3	46	17	33	3	1
05/06	132	91	116	6	4	38	26	33	2	1
06/07	133	111	112	7	5	36	30	30	2	1
07/08	89	87	60	8	4	36	35	24	3	2
08/09	70	62	67	6	3	34	30	32	3	1

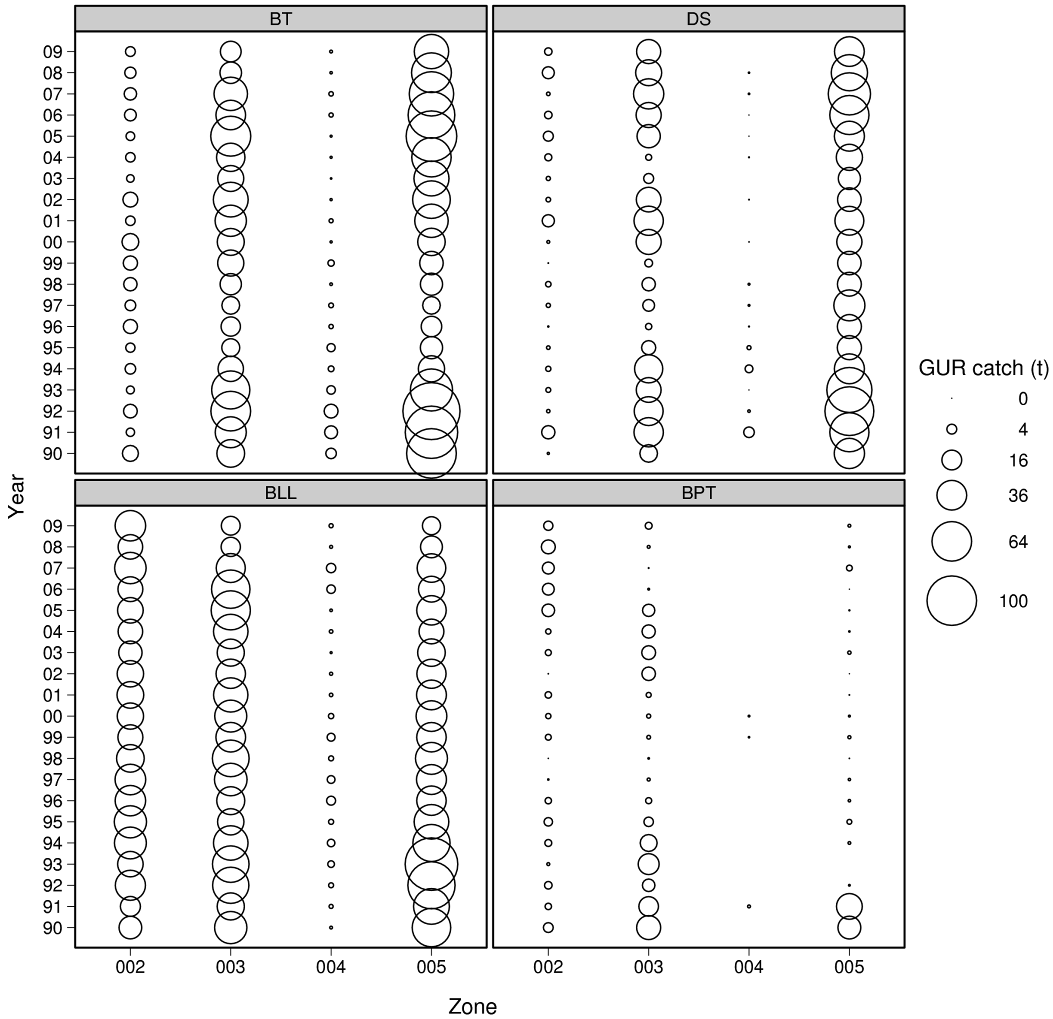

Figure 12: Spatial distribution of catches of gurnard by the four main methods in the east coast substock by fishing year. Zones amalgamate some offshore areas into adjacent inshore statistical areas.

3.3.1 East coast bottom trawl

The bottom trawl catch of GUR 1 in the east coast substock is largely a bycatch of snapper (59–21% annually) although this has decreased over time in favour of increased catch from John dory tows (11–52% annually), and from developing target fisheries (1–34 % annually). Trevally, tarakihi, and barracouta tows have also landed small amounts of red gurnard (typically less than 5 tonnes) in each year (Table 7). The target fishery almost disappeared the mid 1990s, and catches of red gurnard in other bottom trawl fisheries were also at their lowest during those years.

The transition from reporting trawl fishing on CELRs to reporting on TCEPRs is also marked for this substock with about 80% of the catch of gurnard reported in tow-by-tow resolution from 1997–98 (Figure 13).

Table 7: Distribution of bottom trawl caught red gurnard by target species (snapper, gurnard, trevally, John dory, tarakihi, and other) and by fishing year for the east substock of GUR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

Fishing	Target species (t)						Target species (%)					
year	SNA	GUR	TRE	JDO	TAR	Other	SNA	GUR	TRE	JDO	TAR	Other
89/90	89	18	2	31	11	4	57	12	1	20	7	3
90/91	94	36	7	20	13	3	55	21	4	12	7	2
91/92	128	52	2	23	10	4	58	24	1	11	5	2
92/93	78	42	2	19	4	3	53	29	1	13	3	2
93/94	38	4	1	18	3	1	58	6	2	28	5	2
94/95	21	1	2	15	4	1	49	2	5	35	9	2
95/96	13	0	6	20	3	1	31	1	13	46	7	2
96/97	9	3	2	16	2	1	28	9	5	50	6	3
97/98	17	3	5	18	3	1	36	7	11	37	7	2
98/99	17	8	6	25	3	1	29	14	10	41	4	2
99/00	21	14	5	25	4	3	28	20	7	35	6	4
00/01	19	17	2	47	4	1	21	19	2	52	4	1
01/02	34	30	4	40	4	5	29	25	3	35	3	4
02/03	23	17	2	34	4	1	28	21	2	42	4	2
03/04	31	28	3	35	2	1	31	28	3	35	2	1
04/05	60	55	3	51	3	1	35	32	2	29	2	1
05/06	49	47	3	29	3	1	37	35	2	22	2	1
06/07	49	29	6	47	2	0	37	22	5	36	1	0
07/08	29	17	7	35	1	0	32	19	8	39	1	0
08/09	25	6	7	30	2	0	35	8	10	43	3	0

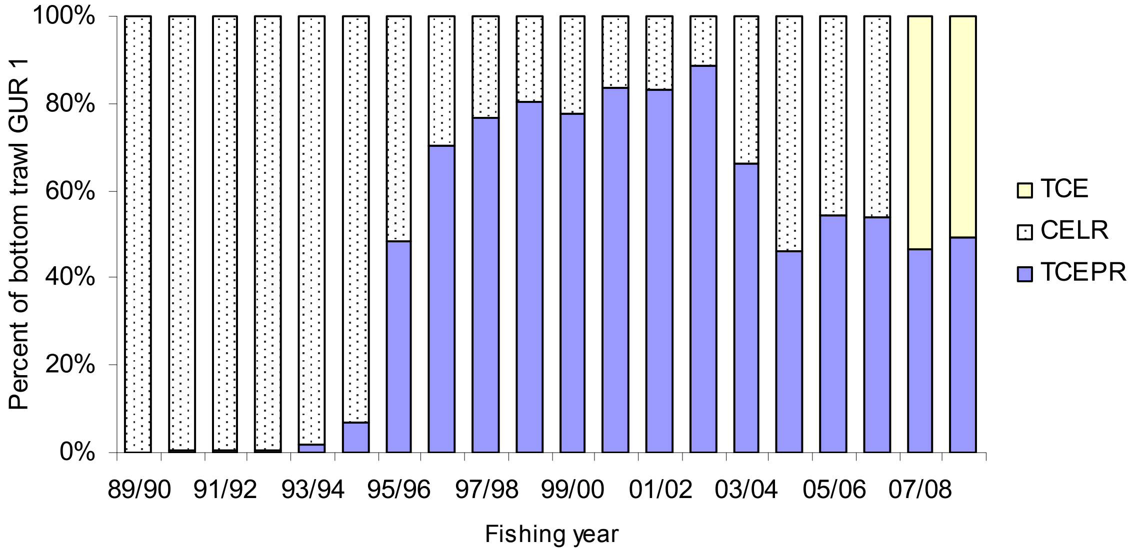

Figure 13: Change in reporting practice in the east coast trawl fishery. The percent of bottom trawl caught GUR 1 (by landed weight) reported on the tow-by-tow form (TCEPR) and the daily form (CELR) by fishing year.

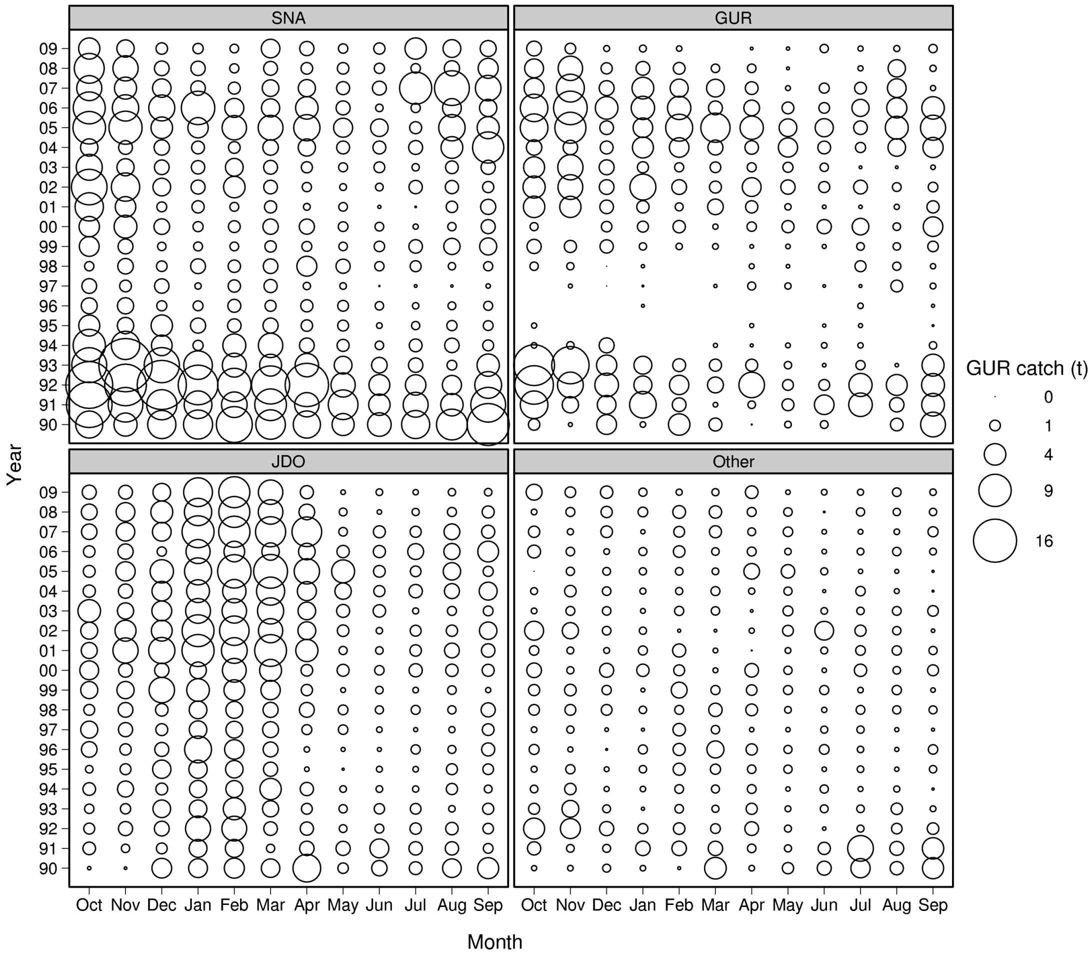

Figure 14: Comparison of the seasonal distribution of bottom trawl red gurnard catches for the three main target fisheries taking GUR 1 from the east coast substock area, by fishing year; snapper, gurnard and John dory. Other includes tarakihi and trevally. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 7.

Bycatch of gurnard from snapper and John dory tows is greater in the summer and autumn months as a function of the operation of those fisheries, but there is little evidence of seasonality in the target fishery, or in other tows which include tarakihi and trevally (Figure 14). There are also few differences in the spatial distribution of gurnard catches between target fisheries, with Statistical Areas 003, 005, and 006 being almost equally important (Figure 15). Catches from Area 001 may be an artefact of fishers wrongly recording the QMA as statistical area.

The patterns of CPUE in the three main target fisheries (SNA, JDO, and GUR) are similar, though target catch rates are considerably greater and more variable than bycatch rates. These series all suggest that availability was at its lowest in the mid to late 1990s, and then increased steadily almost three-fold to a peak in the mid 2000s from where it has since declined (Figure 16). Annual average catch rates in snapper and John dory tows have varied from less than 10 kg per tow in the mid 1990s to around 30 kg per tow in the mid 2000s, while annual average catch rates in target tows have ranged between 35 and 105 kg per tow respectively, quite a lot less than for the west coast. The pattern of unstandardised CPUE in tarakihi target tows is lower (usually less than 10 kg per tow) and shows a downturn during the years that catch rates increased in the other three target fisheries.

There are corroborative patterns to the encounter rates in each target fishery, with a higher incidence of unsuccessful tows in the first half of the time series, when catch rates were lower, compared to the later half, and considerably more zero catches in tarakihi tows than in snapper, John dory, or red gurnard tows (Figure 16). Catches of gurnard have been reported in an increasing proportion (from 30 to 70%) of snapper, trevally, and John dory tows, but in a flat trend in tarakihi tows at about 35% in most years.

A series of CPUE indices from bottom trawl across all effort in the three main target fisheries should be useful for monitoring abundance of red gurnard. The similarity in tow depth for successful tows in the three main fisheries (Figure 17) also supports the concept of them being effectively one fishery with respect to red gurnard, with unusually large catches of gurnard being described as target tows.

Initial exploratory series excluded tows set for tarakihi because that effort is typically deeper (Figure 17) and much of it is irrelevant to red gurnard (see the higher and increasing proportion of zero catches). The advice of the NINSWG, however, was to include tarakihi bottom trawl in the defined fishery to better cover the full spatial distribution of gurnard.

As for the west coast trawl fishery, data are mainly reported on TCEPR after 1995–96 and these data can be used in their original (tow-by-tow) resolution to standardise positive catches for bottom depth and tow speed, rather than for fisher-nominated target species. Distance towed can also be calculated and offered as a measure of effort in preference to duration towed.

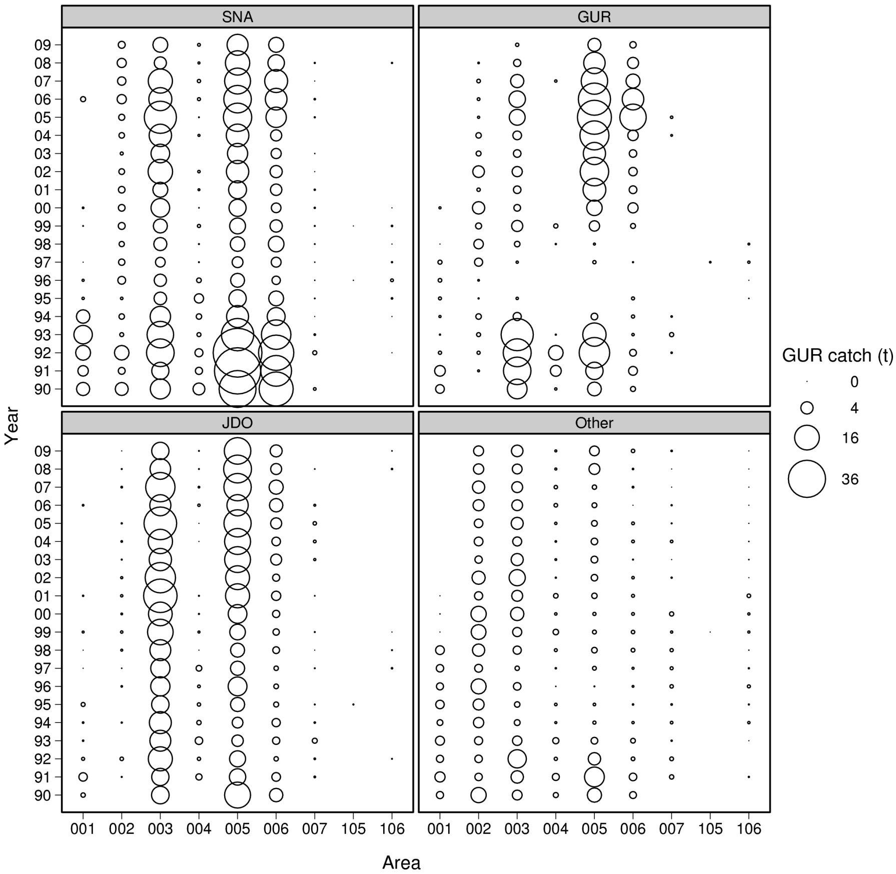

Figure 15: Comparison of the areal distribution of bottom trawl red gurnard catches for the three main target fisheries taking GUR 1 from the east coast substock by fishing year; snapper, gurnard, and John dory. Other included trevally and tarakihi. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 7.

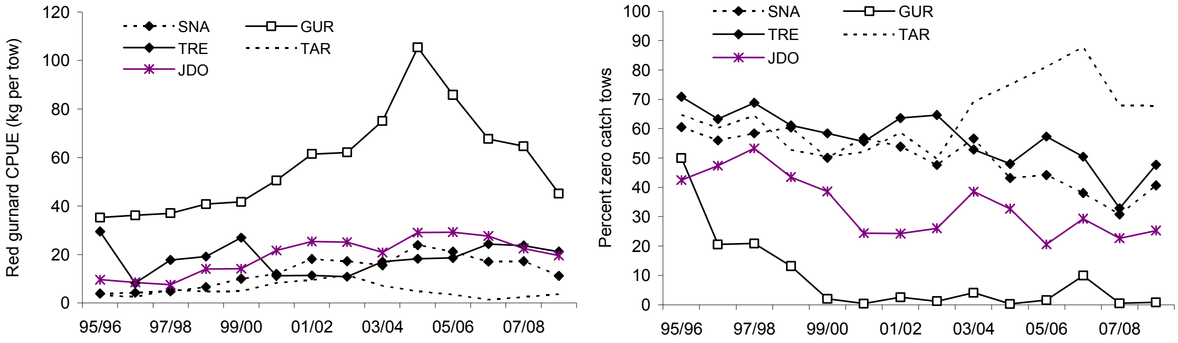

Figure 16: Unstandardised CPUE (kg/tow) and percent unsuccessful tows for red gurnard in the main target fisheries using single bottom trawl tows in the east coast substock of GUR 1 from TCEPR or TCE records since 1995–96.

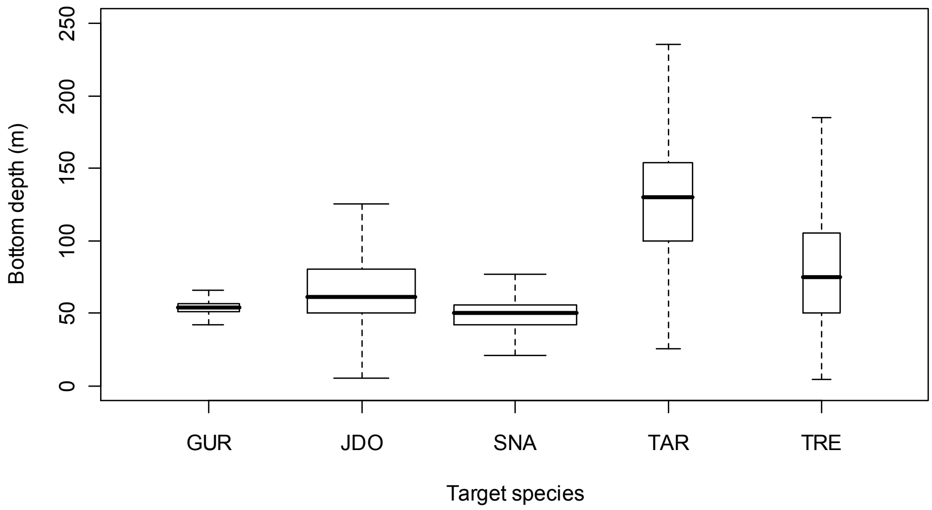

Figure 17: Box plot distributions (median and interquartiles) of bottom depth from TCEPR or TCE records of the single bottom trawl method for the main five target species where a catch of gurnard was reported (positive tows). All years and statistical areas for the eastern substock combined. The width of the boxes is proportionate to the number of records.

3.3.2 East coast Danish seine

Danish seine is the third most important gear type taking red gurnard in the eastern substock. In the first half of the time series, most of the catch was from target fishing or as a bycatch of sets made on snapper. During the mid 1990s the main target fishery taking red gurnard was more often John dory. In the late 2000s, catches in all three target fisheries peaked, but by 2008–09 had dropped away quite markedly in the snapper and John dory fisheries (Table 8).

There is little evidence of seasonality in red gurnard catches in any of the main target fisheries (Figure 18), but there has been a shift in the target fishery towards most catches occurring in the summer months. The areal distribution among target fisheries is also similar, coming mainly from Areas 003, 005, and 006 (Figure 19), Catches from Area 001 may be an artefact of fishers wrongly recording the QMA as the statistical area.

Danish seine is not normally considered a useful gear type for sampling for relative abundance as it is a highly targeted style of fishing. A CPUE series based on this fishery was presented in

Kendrick (2009b) but was not accepted by the working group. Nothing has fundamentally changed that would make it worthy of reconsideration in this study.

Danish seine is almost entirely reported on CELRs, and the declared target species on this form is often an approximation used to describe a whole day's fishing. The previous project (Kendrick 2009b) described similar bycatch rates of red gurnard between the two main bycatch fisheries (SNA and JDO), though the patterns with year seemed more complementary than corroborative, with higher rates reported in target sets that seemed too variable from year to year to be monitoring abundance, but may have merely been recording unusually high catches of red gurnard.

Red gurnard is part of most day's catch in these fisheries (present in more than 96% of records in each year). Without any ancilliary information about targeting behaviour it seems that the three main target fisheries may or may not describe real differences in fishing.

Table 8: Distribution of Danish seine caught red gurnard by target species (snapper, red gurnard, John dory, or other) and by fishing year for the eastern substock of GUR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

Fishing	Target species (t)				Target species (%)			
year	SNA	GUR	JDO	Other	SNA	GUR	JDO	Other
89/90	49	4	1	0	92	7	2	0
90/91	57	52	2	1	51	47	1	1
91/92	74	54	4	0	56	41	3	0
92/93	28	77	6	3	25	67	5	3
93/94	10	51	10	7	13	66	13	9
94/95	5	15	14	1	15	42	40	3
95/96	13	19	12	0	29	43	27	0
96/97	14	29	25	0	21	43	36	0
97/98	7	7	19	0	21	20	59	0
98/99	4	5	16	0	16	19	65	0
99/00	6	12	34	0	11	24	65	0
00/01	6	56	15	0	8	73	19	0
01/02	15	29	5	0	30	59	11	0
02/03	12	6	7	0	47	25	28	0
03/04	13	6	11	1	40	20	36	5
04/05	27	25	10	0	44	40	16	0
05/06	39	25	27	0	43	28	29	0
06/07	43	38	30	0	39	34	27	0
07/08	43	28	14	1	50	32	16	2
08/09	27	25	8	3	43	40	12	5

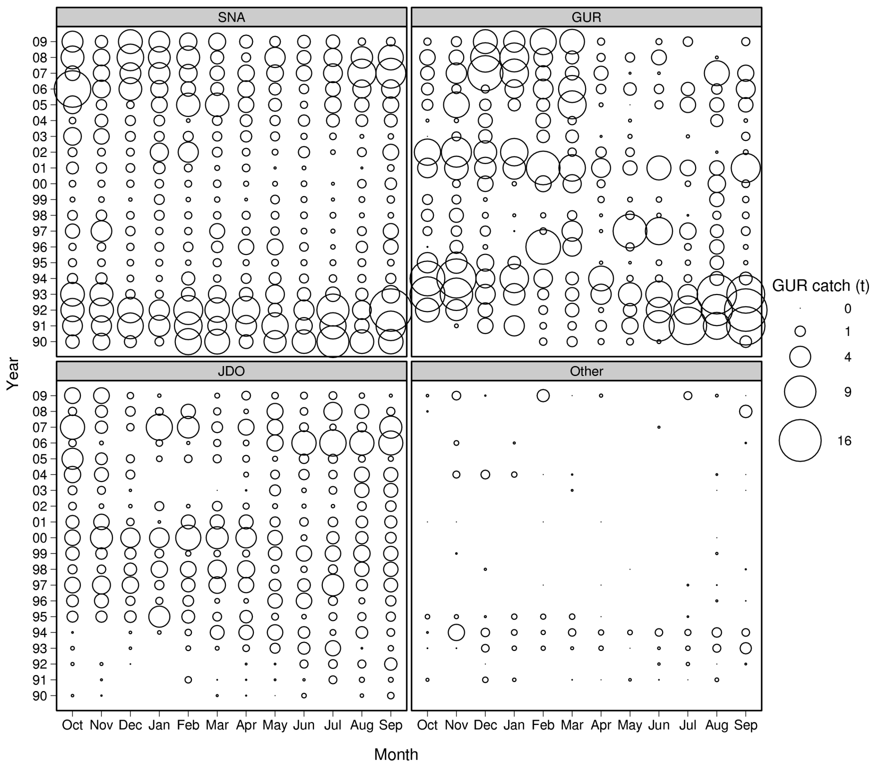

Figure 18: Comparison of the seasonal distribution of red gurnard catches for the three main target fisheries taking GUR 1 by Danish seine from the east coast substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 8.

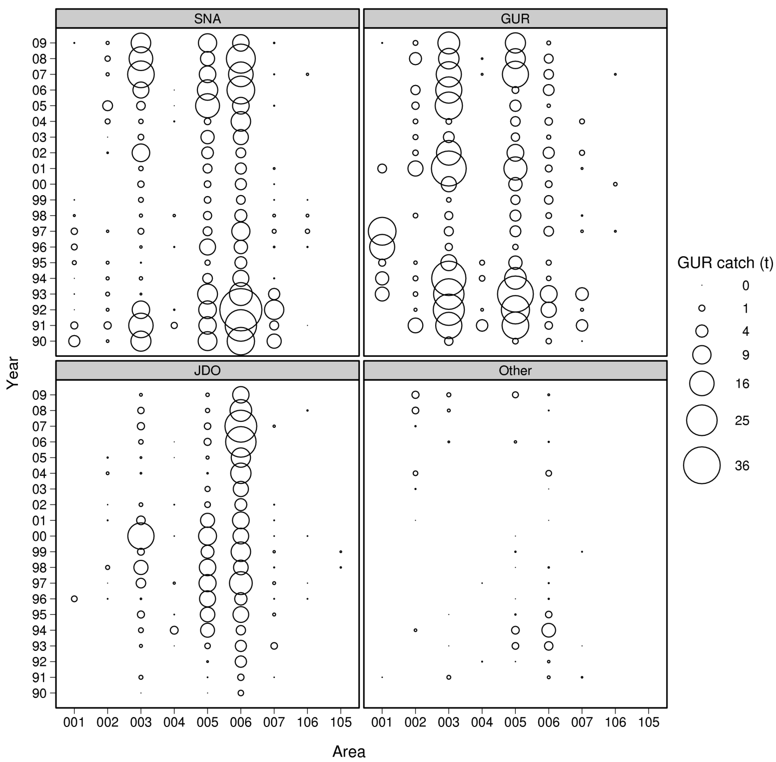

Figure 19: Comparison of the areal distribution of Danish seine red gurnard catches for the three main target fisheries taking GUR 1 from the east coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 8.

3.3.3 East coast bottom longline

There is a consistent history of landings of red gurnard from longline fisheries in the east coast areas of GUR 1. Most are a bycatch of effort directed at snapper (69–98% annually), but up to 30% of red gurnard landings by this method in the first half of the time series were from targeted fishing; this dropped to almost nothing in the late 1990s and increased again in the 2000s to peak at about 23% in 2004–05. In 2008–09 almost all (98%) longline caught red gurnard in this substock was again a bycatch of sets targeting snapper (Table 9).

Catches tend to be higher during the summer months in both target fisheries (Figure 20), and the areal distribution is also similar between them, although red gurnard caught in Area 002 is almost entirely a bycatch of snapper fishing and there is almost no targeting of red gurnard in that area (Figure 21). The longline method is reported on CELRs and so there is no information on depth fished with which to compare target fisheries, but the method is not very selective, lines are set on clear bottom, and we might expect red gurnard to be ubiquitous in longline fishing for snapper as it is in bottom trawls.

Red gurnard is part of the catch for almost every day's fishing (more than 97% in each year) whether targeted at red gurnard or at snapper. Bottom longline is a useful method for sampling the abundance of some species, and it is the main method catching red gurnard in this substock; however, a CPUE series based on this fishery presented by Kendrick (2009b) showed contradictory trends to other methods that suggested there had been a change in the way the fishery had operated (possibly towards more extensive and less targeted fishing) and the series was not accepted by the working group. Nothing has fundamentally changed that would make it worthwhile reconsidering this study.

Table 9: Distribution of longline caught red gurnard by target species (snapper, red gurnard, or other) and by fishing year for the eastern substock of GUR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

Fishing	Target species (t)			Target species (%)		
year	SNA	GUR	Other	SNA	GUR	Other
89/90	113	18	0	86	14	0
90/91	86	21	0	80	19	0
91/92	146	44	1	77	23	0
92/93	152	65	2	69	30	1
93/94	124	29	1	80	19	1
94/95	105	16	1	86	13	1
95/96	98	10	1	90	9	1
96/97	119	3	1	97	3	1
97/98	122	6	2	94	5	1
98/99	97	1	1	98	1	1
99/00	107	3	1	97	2	1
00/01	107	8	2	92	7	1
01/02	93	6	0	94	6	0
02/03	73	11	0	87	13	0
03/04	83	17	1	83	17	1
04/05	96	29	0	77	23	0
05/06	102	14	0	88	12	0
06/07	106	6	0	95	5	0
07/08	55	4	0	93	6	1
08/09	65	1	0	98	1	0

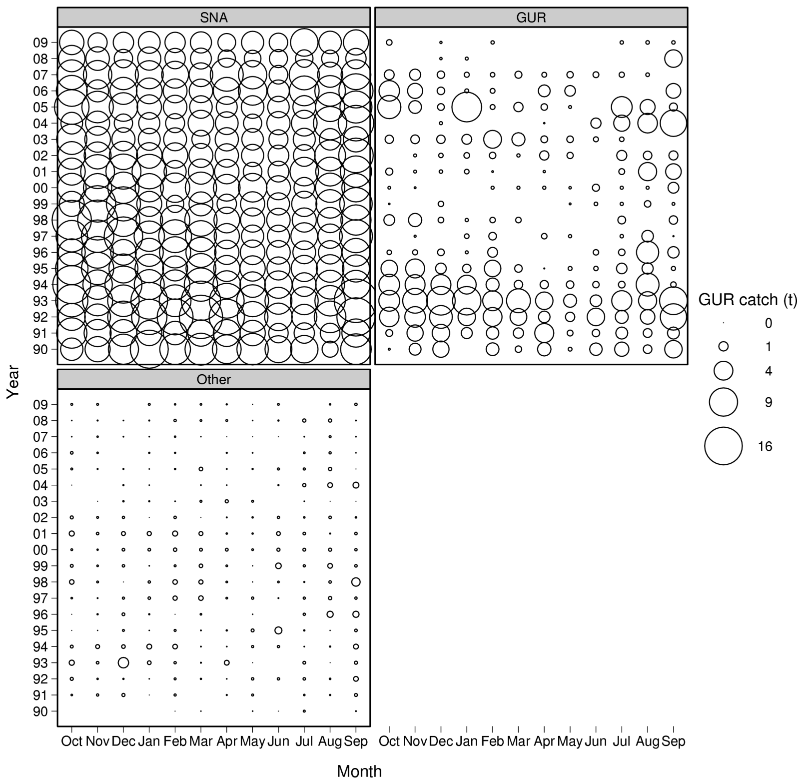

Figure 20: Comparison of the seasonal distribution of longline-caught red gurnard for the two main target fisheries taking GUR 1 from the east coast substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 9.

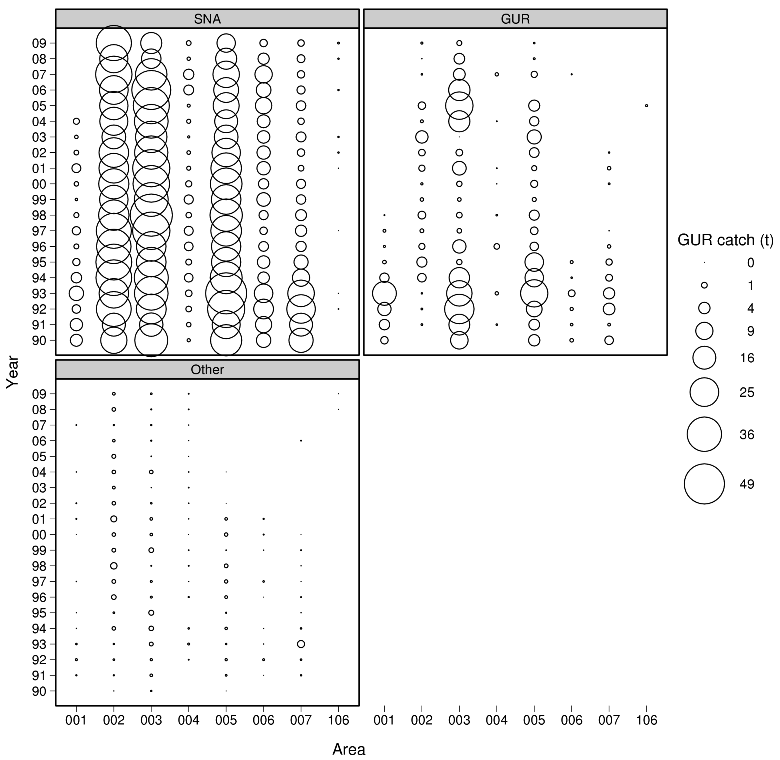

Figure 21: Comparison of the areal distribution of longline red gurnard catches for the two main target fisheries taking GUR 1 from the east coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 9.

3.4 Characterisation of the Bay of Plenty GUR 1 fisheries

GUR 1 has been landed in the Bay of Plenty almost equally from bottom trawl, Danish seine, and bottom longline fisheries over the period for which we have reliable catch effort data, though the relative importance of longline has declined, and that of Danish seine has increased over the times series in all three Statistical Areas (008 to 010). Bottom pair trawling and setnet were both more important in the early part of the time series than currently, but each has generally landed less than 30 t in any year (Table 10, Figure 22).

Table 10: Distribution of landed red gurnard by method and by fishing year for the Bay of Plenty substock of GUR 1 in tonnes and in percent of substock annual landings. Catches are raised to the annual QMR catch (Table 1) 0, less than 0.5 t. Percentages sum to 100 by year. BT, bottom trawl; BPT, bottom pair trawl; BLL, bottom longline; SN, setnet; DS, Danish seine.

Fishing	Fishing method (t)					Fishing method (%)				
year	BT	DS	BLL	BPT	Other	BT	DS	BLL	BPT	Other
89/90	82	27	45	18	7	46	15	25	10	4
90/91	94	51	119	26	19	30	17	38	8	6
91/92	114	85	131	26	12	31	23	36	7	3
92/93	102	78	141	10	17	29	22	40	3	5
93/94	78	94	93	5	16	27	33	32	2	6
94/95	56	104	70	20	17	21	39	26	7	6
95/96	53	64	60	3	26	26	31	29	1	12
96/97	56	63	56	1	30	27	30	27	0	15
97/98	64	112	54	1	23	25	44	21	0	9
98/99	71	98	44		18	31	42	19	0	8
99/00	68	96	31	1	44	29	40	13	0	18
00/01	106	56	42	0	25	46	24	18	0	11
01/02	113	101	34	2	5	44	40	13	1	2
02/03	118	115	23	2	6	45	44	9	1	2
03/04	113	128	31	14	6	39	44	11	5	2
04/05	127	131	38	11	4	41	42	12	4	1
05/06	109	110	33	2	7	42	42	13	1	3
06/07	71	82	31	1	8	37	43	16	0	4
07/08	86	98	27	1	9	39	45	12	0	4
08/09	93	114	23	1	9	39	47	9	0	4

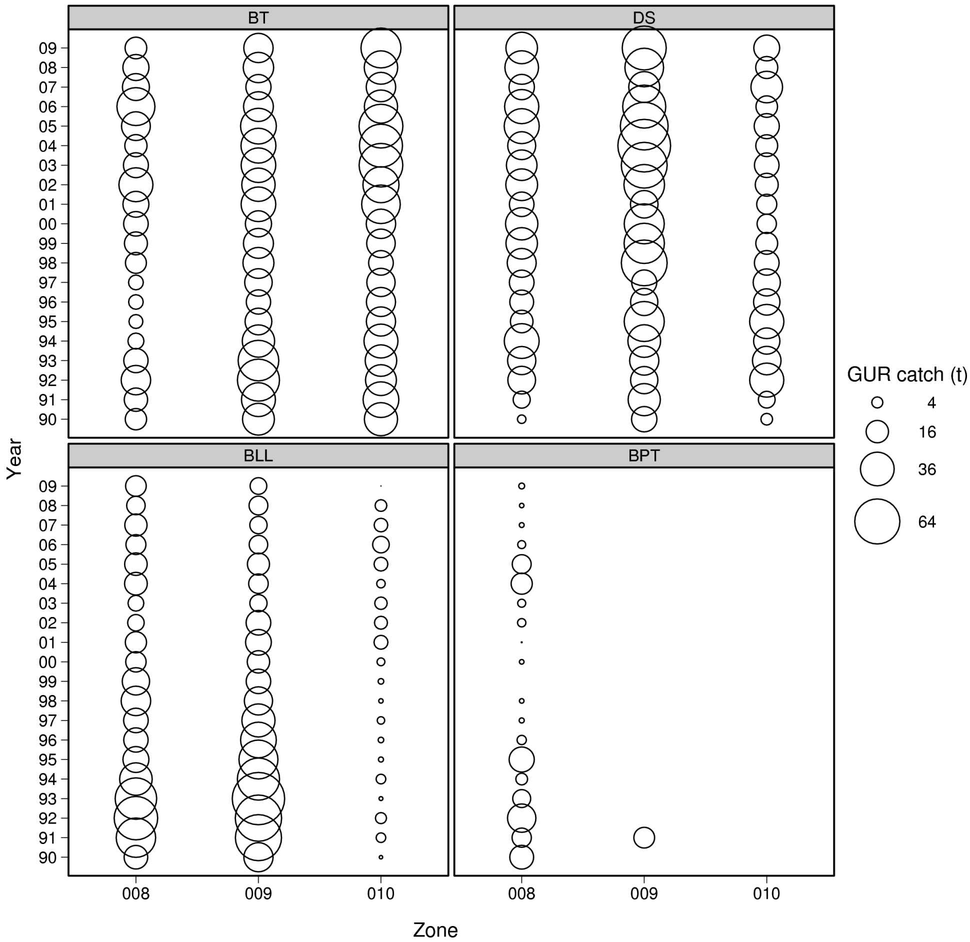

Figure 22: Spatial distribution of red gurnard catches by the four main methods in the Bay of Plenty substock by fishing year. Zones amalgamate some adjacent statistical areas.

3.4.1 Bay of Plenty bottom trawl

The bottom trawl fisheries in the Bay of Plenty differ from the other two substocks in the relatively greater importance of tarakihi tows, which account for almost as much of the bycatch of red gurnard as snapper tows in this substock. Fisheries targeted at John dory and trevally reported greater red gurnard catches in the last half of the time series, and targeted tows have been only sporadically important (Table 11).

The transition from reporting of trawl fishing on CELRs to reporting on TCEPRs is also marked for this substock and the greater detail in which tows are described on the TCEPR form may have had some effect on the apparent distribution of catch with target species (Figure 23).

There is no evidence of strong seasonality in landings of red gurnard from any of the main target fisheries (Figure 24), although the bycatch from tarakihi tows has shifted from year-round to more of a summer/autumn fishery, and there are few areal differences between target fisheries, except that John dory tows are focused on Area 008, whereas most other target fisheries are concentrated in Areas 009 and 010. Snapper tows are more evenly distributed in most years among the three statistical areas (Figure 25).

Table 11: Distribution of bottom trawl caught red gurnard by target species (snapper, gurnard, trevally, John dory, tarakihi, or other) and by fishing year for the Bay of Plenty substock of GUR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

Bay of Plenty bottom trawl

Fishing	Target species (t)						Target species (%)					
year	SNA	GUR	TRE	JDO	TAR	Other	SNA	GUR	TRE	JDO	TAR	Other
89/90	50	3	5	2	15	7	61	3	6	3	18	8
90/91	53	6	6	1	23	6	56	6	6	1	25	6
91/92	48	13	3	6	26	17	43	11	3	5	23	15
92/93	27	19	10	8	28	10	27	18	10	8	28	10
93/94	21	10	11	5	26	5	26	13	14	7	34	7
94/95	16	4	7	6	18	5	28	8	13	12	32	8
95/96	30	3	2	3	9	5	58	5	4	6	18	10
96/97	18	9	8	4	11	5	32	16	15	8	20	10
97/98	25	7	5	8	12	7	38	11	8	13	19	10
98/99	23	4	18	10	12	5	32	5	25	13	17	7
99/00	20	10	16	6	10	6	28	15	24	9	15	9
00/01	22	16	43	8	12	5	21	15	41	8	11	5
01/02	34	12	26	21	17	3	30	11	23	19	15	2
02/03	34	21	21	11	27	3	29	18	18	10	23	2
03/04	35	14	32	6	25	2	31	12	28	5	22	2
04/05	48	17	23	11	27	1	38	13	18	9	22	1
05/06	30	37	17	5	17	2	28	34	16	4	16	2
06/07	31	4	13	10	11	2	44	6	18	14	15	3
07/08	33	4	18	12	17	2	38	5	21	14	19	3
08/09	31	13	22	7	20	0	33	14	23	8	22	0

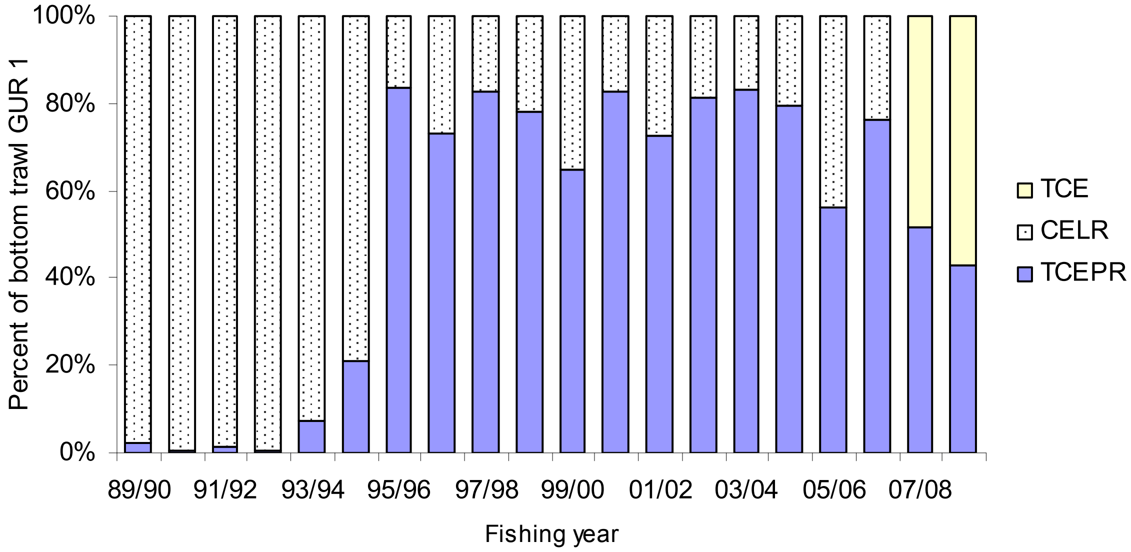

Figure 23: Change in reporting practice in the Bay of Plenty trawl fisheries. The percent of bottom trawl caught GUR 1 (by landed green-weight) reported on the tow-by-tow form (TCEPR) and the daily form (CELR) by fishing year.

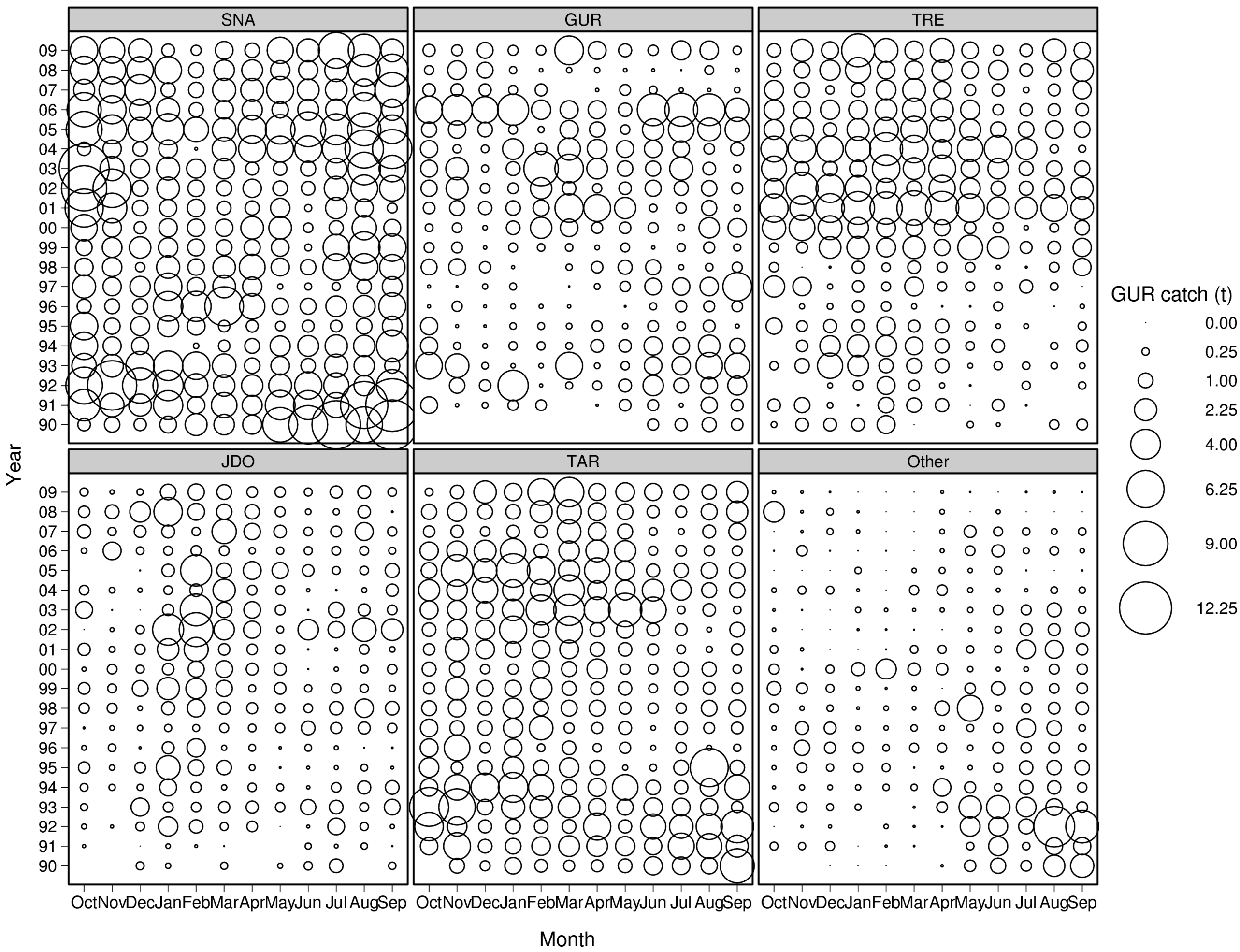

Figure 24: Comparison of the seasonal distribution of bottom trawl red gurnard catches for the five main target fisheries taking GUR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 11.

Annual average catch rates of gurnard as bycatch of snapper and trevally bottom trawls are similar to those in the east coast substock but the catch rates in targeted tows are smaller, with the annual average varying between 20 and 70 kg per tow (Figure 26). The patterns of CPUE in the four main bottom trawl target fisheries (TAR, SNA, TRE, and JDO) resemble each other, though catch rates are lower in the tarakihi tows than in tows targeted at species more closely associated with red gurnard (SNA, TRE, and JDO) and catch rates in targeted tows are somewhat higher than bycatch rates, but with greater interannual variation. These series all suggest that availability was at its lowest in the mid to late 1990s, and has increased steadily by between two to four-fold since then, with a marked increase in the two most recent years in target tows. As seen in the east coast substock, catch rates of gurnard in tows targeting John dory tend to be higher than tows targeting snapper or trevally.

There are corroborative patterns to the encounter rates in each target fishery, with a higher incidence of unsuccessful tows in the first half of the time series, when catch rates were lower, compared to the later half, and considerably more zero catches in tarakihi tows (50–70%) than in snapper, John dory, or gurnard tows. Catches of gurnard were reported in an increasing proportion (from 50 to 70%) of snapper and trevally tows, and also in an increasing proportion of John dory tows over the time series. Gurnard was reported in about 35% of tarakihi tows in most years, with a flat trend (Figure 26).

As for the west and east coast trawl fisheries, there is some question about the utility of the target species field for delineating a fishery in which to monitor gurnard. There have been considerable shifts over time in the relative importance of target species and they may reflect changes in reporting rather than in fishing practices. The greater detail available in TCEPR/TCE format data in later years may allow models to better account for such shifts using bottom depth and tow speed rather than fisher-nominated target species. Distance towed can also be calculated and offered as a measure of effort in preference to duration to account for the different tow speeds employed.

Initial exploratory series excluded tows for tarakihi because that effort is typically deeper (Figure 27) and much of it is irrelevant to red gurnard (see the higher and increasing proportion of zero catches). The advice of the NINSWG, however, was to include tarakihi bottom trawl in the defined fishery to better cover the full spatial distribution of gurnard.

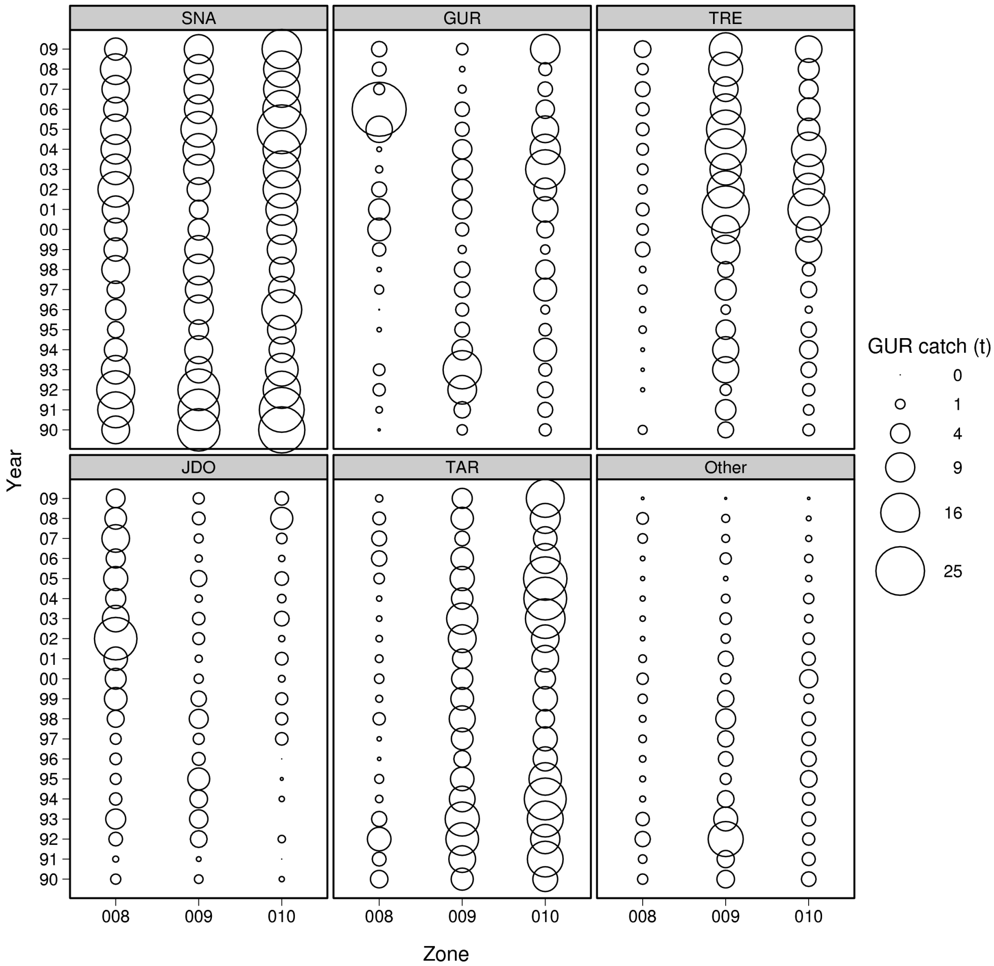

Figure 25: Comparison of the areal distribution of bottom trawl red gurnard catches among statistical areas for the five main target fisheries taking GUR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 11.

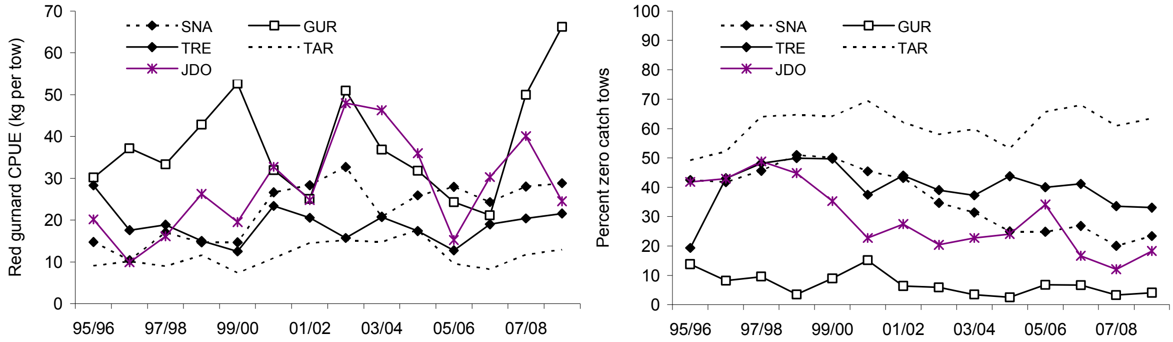

Figure 26: Unstandardised CPUE (kg/tow) and percent unsuccessful tows for red gurnard in the main target fisheries using single bottom trawl tows in the Bay of Plenty substock of GUR 1 from TCEPR or TCE records since 1995–96.

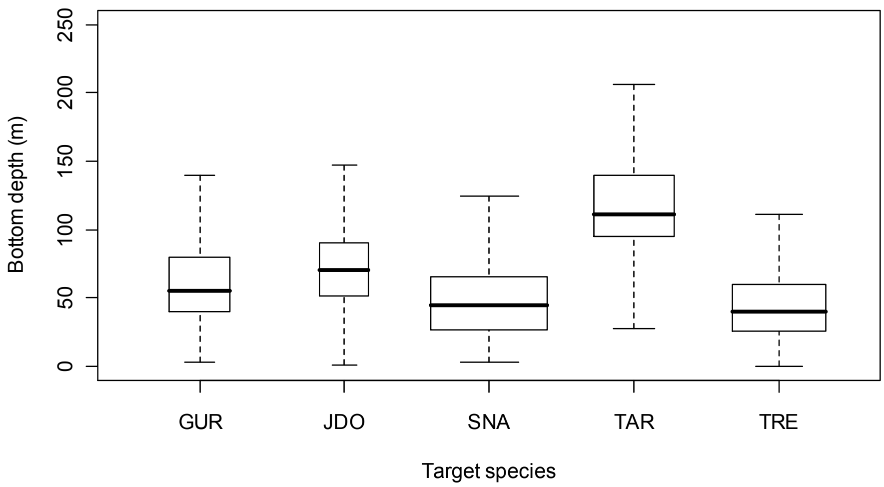

Figure 27: Box plot distributions (median and interquartiles) of bottom depth from TCEPR or TCE records of the single bottom trawl method for the main five target species where a catch of gurnard was reported (positive tows). All years and statistical areas for the Bay of Plenty substock combined. The width of the boxes is proportionate to the number of records.

3.4.2 Bay of Plenty Danish seine

Danish seine is an increasingly important gear type taking red gurnard in the Bay of Plenty; catch is almost entirely from sets made on either snapper or red gurnard, but with most of the recent increase coming from sets made on snapper. The relative importance of the two main target species has varied in a reciprocal pattern over the time series. In the first half of the time series, most of the catch was from snapper sets, after 1995–96 the opposite was true, and in the most recent two years, sets made on snapper once again accounted for most red gurnard caught by Danish seine (Table 12). A small amount (usually less than 5 t) is landed each year from sets made on John dory and on other species.

Gurnard is taken throughout the year but there have been some large shifts over time in the patterns of catch with season. In the 1990s most gurnard, whether bycatch or targeted, was landed in the last half of the fishing year (May to September), but a summer fishery has developed in both fisheries during the late 2000s, and most targeted gurnard is now landed during the first half of the year (October to April) (Figure 28). The spatial distribution of the two target fisheries is similar, with the largest catches coming from Area 009 and smaller but more consistent catches from Areas 008 and 010. (Figure 29).

Danish seine is not normally considered a useful gear type for sampling for relative abundance as it is a highly targeted style of fishing. CPUE series based on this fishery was presented by Kendrick (2009b) but was not accepted by the working group. Nothing has fundamentally changed that would make it worthwhile reconsidering this study.

Danish seine is almost entirely reported on CELRs, meaning that the declared target species on this form is often an approximation used to describe a whole day's fishing. Without any ancillary information about targeting behaviour it seems that the two main target fisheries may or may not describe real differences in fishing behaviour, and possibly describe different aspects of what is effectively the same fishery with respect to red gurnard. Red gurnard is part of the catch for almost every day's fishing (more than 95% in each year) whether targeted at red gurnard or at snapper and the previous project (Kendrick 2009b) noted that patterns of CPUE indices for the two main target fisheries agreed with each other and that the proportion of zero catches provided little additional information. Catch rates in target sets were somewhat greater than bycatch rates but showed more inter-annual variation.

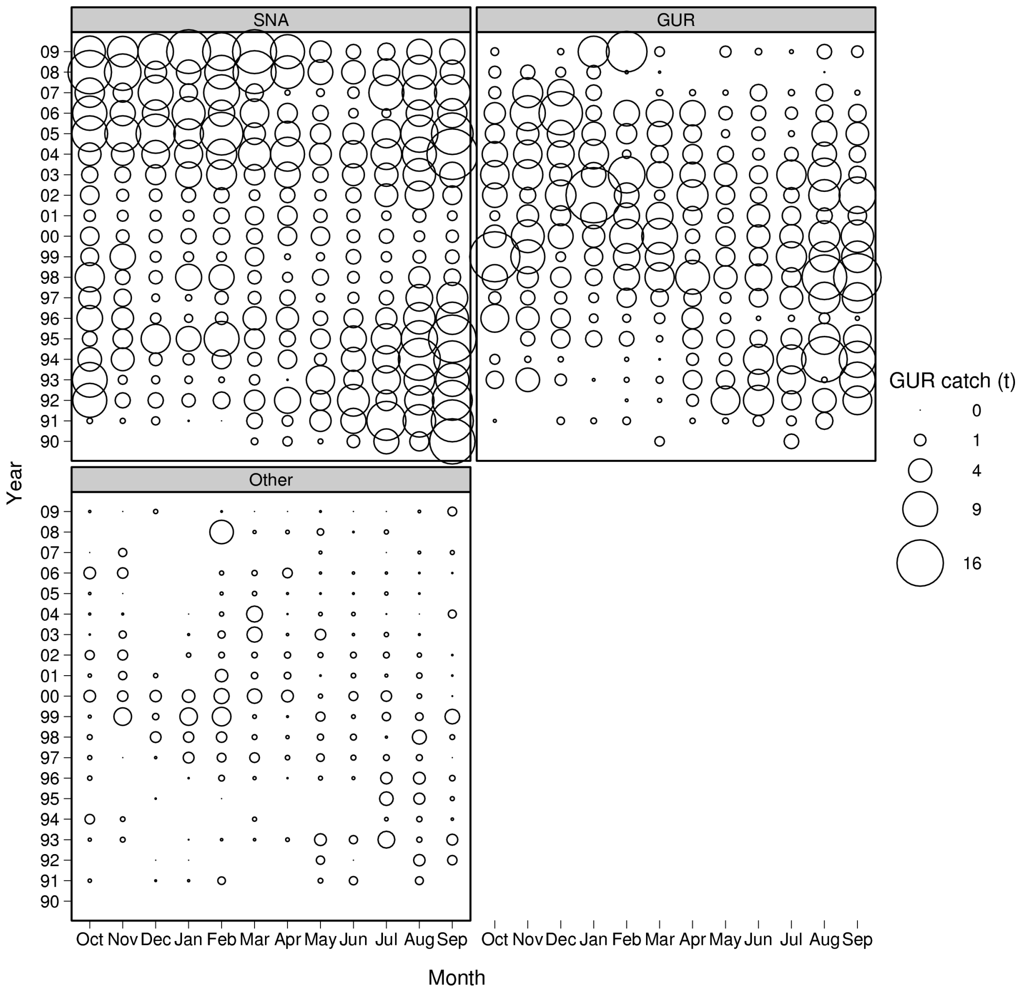

Figure 28: Comparison of the seasonal distribution of Danish seine red gurnard catches for the two main target fisheries taking GUR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 12.

Table 12: Distribution of Danish seine caught red gurnard by target species (snapper, red gurnard, trevally, John dory, tarakihi, or other) and by fishing year for the Bay of Plenty substock of GUR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

Fishing year	Target species (t)						Target species (%)					
	SNA	GUR	TRE	JDO	TAR	Other	SNA	GUR	TRE	JDO	TAR	Other
89/90	25	2				0	92	8	0	0	0	0
90/91	44	5	0	0	0	1	86	11	1	1	1	1
91/92	56	27		0	1	1	65	32	0	0	2	1
92/93	41	32	0	3		2	53	41	0	4	0	2
93/94	51	42	0	0		1	54	44	0	0	0	1
94/95	70	31		0	0	2	68	30	0	0	0	2
95/96	41	20	0	1	0	1	64	31	0	2	0	2
96/97	26	33	1	2	0	1	42	52	1	3	0	1
97/98	30	76	0	2	2	2	27	68	0	2	2	1
98/99	18	69	2	6	2	1	18	71	2	6	3	1
99/00	20	65	6	1	3	0	21	68	6	1	3	0
00/01	16	37	1	0	1	0	28	66	2	0	3	0
01/02	26	72	1	0	1	0	25	71	1	0	1	0
02/03	48	63	1	2	1	0	42	55	1	2	1	0
03/04	86	39	0	0	2	0	67	30	0	0	2	0
04/05	94	36			0	0	72	28	0	0	0	0
05/06	55	52	1	2	0	0	50	47	1	1	0	0
06/07	61	20	0	0	0	0	75	25	0	0	1	0
07/08	89	5	0	4	0	0	90	5	0	5	0	0
08/09	88	25			1	0	77	22	0	0	1	0

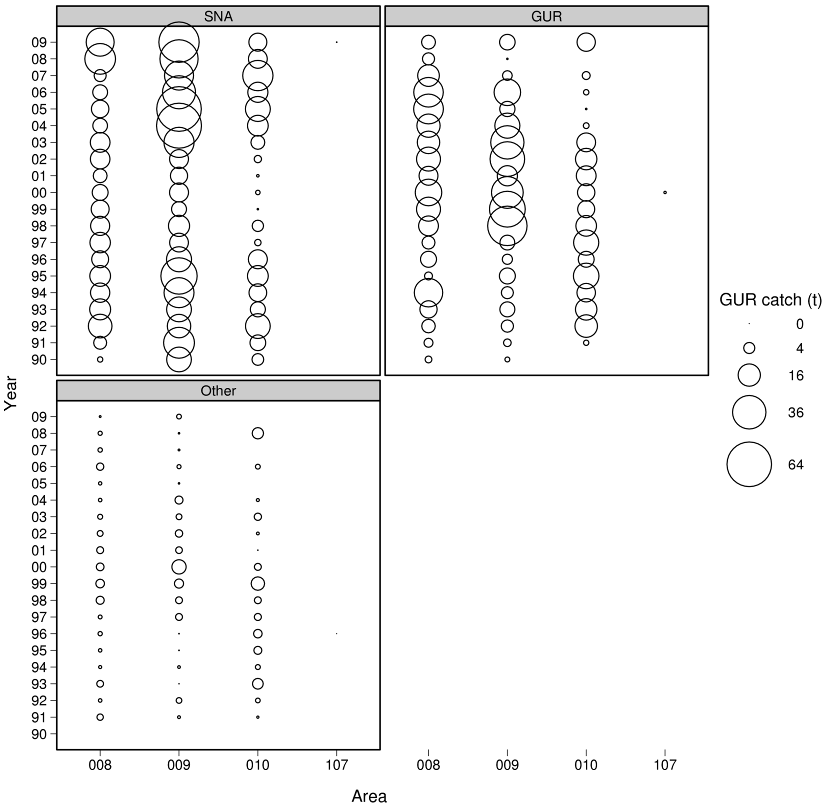

Figure 29: Comparison of the areal distribution of Danish seine red gurnard catches among statistical areas for the two main target fisheries taking GUR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 12.

3.4.3 Bay of Plenty bottom longline

Bottom longlining has accounted for a declining proportion of the red gurnard catch in the Bay of Plenty, mostly as a function of decreased target fishing. The bycatch from the snapper fishery has also declined, but not so markedly (Table 13). Red gurnard are caught throughout the year in both fisheries (Figure 30), and although it was largely landed in winter from the snapper fishery in the early half of the time series, that is no longer the case. Catches from the snapper fishery have declined in Aeas 008 and 009 and increased in Area 010 in the last half of the time period. The largest targeted catches of gurnard came from Area 009 in the early 1990s but have declined since then in all areas (Figure 31).

The longline method is reported on CELRs and so there is no information on depth fished with which to compare target fisheries, but the method is not very selective, lines are set on clear bottom, and we might expect red gurnard to as be ubiquitous in longline fishing for snapper as it is in bottom trawls set on that species.

Bottom longline is a useful method for sampling the abundance of some species, and it is an important method catching red gurnard in this substock; however, the fishery has declined markedly and has also moved away from targeting gurnard. A CPUE series based on this fishery presented by Kendrick (2009b) declined steadily in contrast to CPUE series for other methods, and was not accepted by the working group. Nothing has fundamentally changed that would make it worthwhile reconsidering this study.

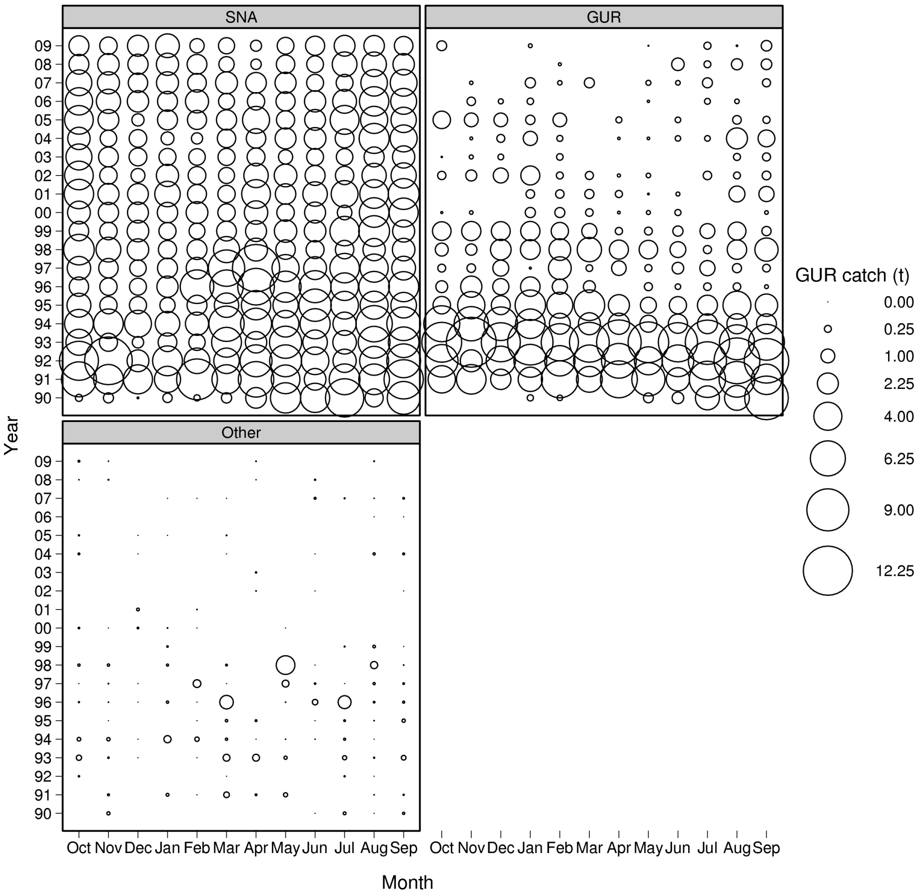

Figure 30: Comparison of the seasonal distribution of longline red gurnard catches for the two main target fisheries taking GUR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 13.

Table 13: Distribution of longline caught red gurnard by target species (red gurnard, snapper, or other) and by fishing year for the Bay of Plenty substock of GUR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

Fishing	Target species (t)						Target species (%)					
year	SNA	GUR	TRE	JDO	TAR	Other	SNA	GUR	TRE	JDO	TAR	Other
89/90	28	17				0	61	38	0	0	0	0
90/91	62	57			0	0	52	48	0	0	0	0
91/92	60	71	0		0	0	46	54	0	0	0	0
92/93	37	103	0		0	1	26	73	0	0	0	0
93/94	53	39	0	0	0	0	57	42	0	0	0	0
94/95	36	34			0	0	52	48	0	0	0	0
95/96	49	9	0		0	2	81	16	0	0	0	3
96/97	46	9	0	0	0	1	83	16	0	0	0	1
97/98	31	21			0	2	57	39	0	0	0	4
98/99	30	14			0	0	67	33	0	0	0	0
99/00	30	2			0	0	94	6	0	0	0	0
00/01	38	4				0	90	10	0	0	0	0
01/02	28	6				0	83	17	0	0	0	0
02/03	21	1				0	95	5	0	0	0	0
03/04	25	6				0	82	18	0	0	0	0
04/05	32	6			0	0	84	16	0	0	0	0
05/06	32	1				0	97	3	0	0	0	0
06/07	29	2				0	92	7	0	0	0	0
07/08	24	2				0	91	9	0	0	0	0
08/09	21	1			0	0	94	6	0	0	0	0

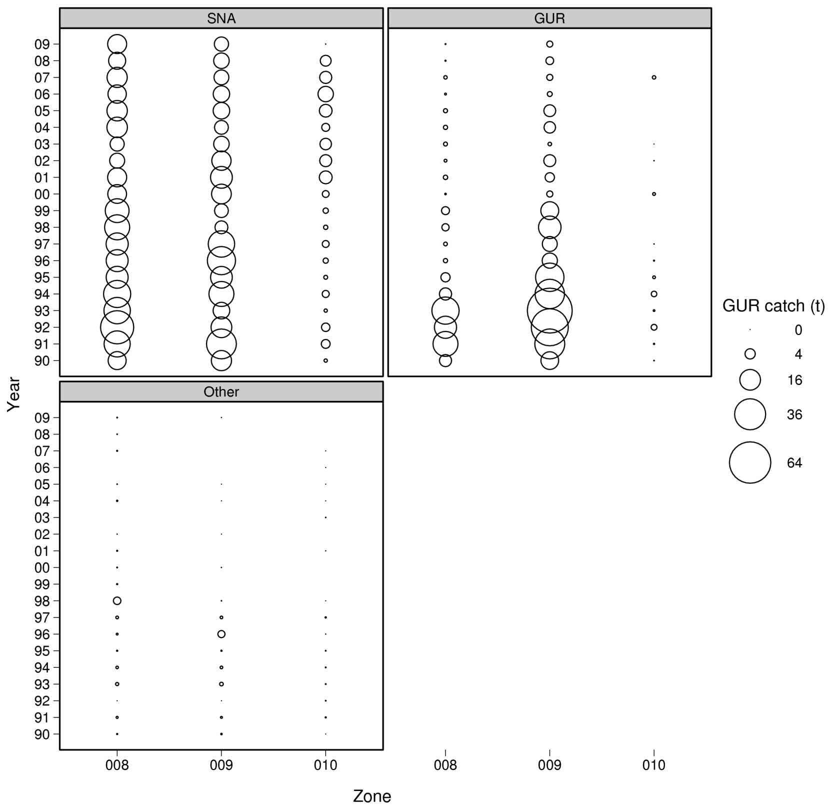

Figure 31: Comparison of the areal distribution of longline red gurnard catches for the two main target fisheries taking GUR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 13.

3.5 Standardised CPUE analysis

3.5.1 Fishery definitions

GUR 1 is monitored using standardised CPUE series for the inshore bottom trawl fisheries operating in each substock. The fishery definitions have been expanded to include tows targeted at tarakihi. Bottom trawl fishing events in each of the three GUR 1 substock areas have largely been reported in TCEPR format over the last 10 years. This enables the calculation of 10-year CPUE series using tow-by-tow data that have the following advantages: 1) allow individual tows that reported a positive catch of red gurnard to be selected; 2) allows the distance towed to be calculated from tow duration and tow speed (tow duration being a poor proxy for effort in a mixed species fishery where various tow speeds are used); and 3) allows bottom depth and tow speed to be included as potential explanatory variables offering possibly better proxies for targeting behaviour than the fisher-nominated target species. The TCEPR series are augmented by series estimated from the earlier years based on the daily CELR form.

Each defined fishery and associated analyses are described by the substock and formtype. Six fisheries were defined;

West Coast - Trips that landed GUR 1, events that;
Used bottom (single) trawl method
Fished in Statistical Areas 042–048 (including adjacent offshore areas)
Including target species GUR, TRE, TAR, or SNA

1. **W_TCE**
    * Reported on TCEPR or TCE tow-by-tow forms
    * 1995–96 to 2008–09
2. **W_CEL (ancillary series presented without detailed diagnostics)**
    * Reported on CELR daily form
    * 1989–90 to 2000–01

East Coast - Trips that landed GUR 1, events that;
Used bottom (single) trawl method
Fished in Statistical Areas 001–007 (including adjacent offshore areas)
Including target species GUR, TRE, JDO, TAR or SNA

3. **E_TCE**
    * Reported on TCEPR or TCE tow-by-tow forms
    * 1995–96 to 2008–09
4. **E_CEL (ancillary series presented without detailed diagnostics)**
    * Reported on CELR daily form
    * 1989–90 to 2000–01

Bay of Plenty - Trips that landed GUR 1, events that;
Used bottom (single) trawl method
Fished in Statistical Areas 008–010 (including adjacent offshore areas)
Including target species GUR, TRE, JDO, TAR or SNA

5. **BoP_TCE**
    * Reported on TCEPR or TCE tow-by-tow forms
    * 1995–96 to 2008–09
6. **BoP_CEL (ancillary series presented without detailed diagnostics)**
    * Reported on CELR daily form
    * 1989–90 to 2000–01

The selection and participation of the core vessels in each fishery is described in Appendix B. Data for the years of overlap between the CEL and the TCE datasets (1995–96 to 2000–01) are sparse but there is adequate overlap of vessels across each time series. The final datasets for each model and substock after selection of core vessels are summarised in Appendix C.

3.5.2 Models fitted

Three models (lognormal, binomial, and combined) were fitted to each of the six fisheries defined above; only the lognormal models representing the magnitude of catch were accepted by the Working Group as monitoring abundance. The binomial models that represent the probability of capture are included for completeness and may give corroborative evidence of any gross trends in abundance. The combined models indicate the effect of combining indices from the lognormal and binomial models and give some perspective to the relative importance of the trends in annual indices from each model. It should be remembered that catch effort in CELR format is effectively amalgamated data, and much of the zero catch information is already incorporated into the catch per day so that the binomial and combined models might be expected to be less informative for the CELR datasets than for the TCEPR datasets.

3.5.3 Model selection and model fits

The final lognormal and binomial models selected for each substock and based on TCEPR/TCE format data are described in Tables 14 to 16. The fit of the models to the lognormal assumption was examined by plotting the residuals (Appendix D Figures D1 to D3). The fit of the data to the lognormal assumption is reasonable for most models, though the standardised residuals display slight skewing and departure in the extreme ends of the distribution. The final models selected for the ancillary CEL series are described in Appendix E.

The lognormal models explained 36% (WC), 47% (EC), and 20% (BP) of the variance in log catch. Fishing year was forced as the first variable in each case to facilitate the extraction of canonical year effects, and explained 6–7% of the variance in log catch in the west coast and Bay of Plenty substocks, and 18% of the variance in the east coast substock. Vessel ID was included as the factor with greatest explanatory power in the east coast and Bay of Plenty models and second most important in the west coast, after bottom depth. Bottom depth was accepted into all three models, although models for the west coast and east coast fisheries also included target species. Duration of fishing was the most informative of the offered measures of effort in all three fisheries, although it was not significant in the BoP model. Month also entered models for the west coast and Bay of Plenty. Statistical area was not important in any of these fisheries, although bottom depth and target species were probably effective proxies, accounting for any variance among areas.

Interestingly, neither distance towed nor tow speed had significant explanatory power in any of these three models, and although bottom depth was important, alternative models that were not offered bottom depth, but that selected target species, yielded very similar year effects. This suggests that target species is well reported and informative on TCEPR/TCEs and that bottom depth is providing little additional information.

The cumulative effect as each variable was added to the lognormal model is shown in Figures 32 to 34. These plots emphasise the importance of vessel in moving the standardised series away from the unstandardised series even when it is not the first factor accepted. For example, in the W_TCE model bottom depth enters the model with the most explanatory power, increasing the explained variance by about 11%, but does not markedly change the annual indices from their annual geometric means. Vessel enters the model after bottom depth, and explains a further 11% of variance, dramatically dropping the annual indices in the first seven years and in the mid 2000s. As other factors are included they effect very little additional change to the annual indices. Similarly, most of the movement of the standardised series away from the unstandardised for the E_TCE and BP_TCE models, is the result of vessel entering the model with other significant factors having little additional effect.

The influence of each variable accepted into the TCEPR/TCE lognormal models is described by influence plots (Jiang & Bentley 2008) in Appendix F. They illustrate the combined effect of (a) the expected log catch for each level of the variable (model coefficients) and (b) the distribution of the levels of the variable in each year, and therefore describe the influence that the variable has on the unstandardised CPUE and which is accounted for by the standardisation. Note: Influence plots for the CEL models are not included.

In the W_TCE fishery, a shift towards deeper tows in the last two years of the series and towards more winter fishing are predicted to have had a negative influence on observed CPUE for gurnard, but these were overwhelmed by changes in the core fleet (poorer performing vessels dropping out), as well as a shift towards longer tow durations and increased targeting of trevally which have all had a positive effect on observed CPUE and have had to be accounted for by the model. There is a very similar picture for the east coast fishery where the loss of some poorer performing vessels has been responsible for much of the increase in observed CPUE in the last half of the time series, but a shift away from targeting snapper towards increased targeting of John dory and gurnard in the mid 2000s and an accompanying shift in bottom depth away from very shallow fishing to tows centred on 50 m depth in the last half of the time series has also contributed to the increase.

Changes in the core fleet of the BP_TCE fishery that have positively influenced observed CPUE are very marked. Shifts in the depth fished in this substock have trended towards deeper tows, with an associated positive influence on CPUE, although the effect of depth on predicted catch of gurnard is not great in this substock. Likewise, the small shifts in season have had little influence on observed CPUE from year to year so that their influence overall has been neutral.

It could be said that tow speed is being offered twice to these models because it is offered as a main effect and is also used in the calculation of distance towed (speed x duration). That was done here to check whether distance is a more informative measure of effort than duration in a mixed species fishery where tow speed varies with species being targeted. Tow speed is offered as a main effect as a potentially more informative descriptor of targeting behaviour than the fisher-nominated target species. Tow speed has been shown to vary, on average, with target species, in particular tows tend to be faster when targeted at trevally, which is a pelagic species, than when targeted at snapper or gurnard. However, the differences are non-significant in that they fall within the variance of tows speeds used for any single species, and tow speed was not accepted into any of these models in either form.

The binomial models explained 28% (WC), 12% (EC), and 13% (BP) of the variance in the probability of capture and included vessel and target species in all substocks, and also bottom depth in the case of the west coast and Bay of Plenty models. No binomial model accepted any measure of effort and that is understandable because unsuccessful tows with respect to gurnard are mainly those targeted at tarakihi so that target species, or a proxy thereof, can be expected to explain most of the variance in encountering gurnard.

West coast substock

Table 14: Summary of final lognormal and binomial models for the W_TCE fishery based on the vessel selection criteria of at least three trips per year in at least three or more fishing years. Independent variables are listed in the order of acceptance to the model. AIC, Akaike Information Criterion; R2, proportion of deviance explained at each step and in the final model (bold); Final, Whether or not variable was included in final model; Fishing year was forced as the first variable.

Lognormal terms	DF	Deviance	AIC	R2	Final
None	0	26 798	69 187	0.000	
fyear	14	24 903	67 512	0.071	*
poly(bottom 3)	17	21 563	64 177	0.195	*
vessel	42	18 434	60 589	0.312	*
poly(log(duration) 3)	45	17 875	59 881	0.333	*
target	48	17 570	59 488	0.344	*
month	59	17 292	59 141	**0.355**	*
poly(log(distance) 3)	62	17 251	59 091	0.356	
area	71	17 236	59 088	0.357	
poly(speed 3)	74	17 231	59 087	0.357	

Binomial terms	DF	Deviance	AIC	R2	Final
None	0	40 636	40 638	0.000	
fyear	14	40 011	40 039	0.015	*
poly(bottom 3)	17	31 797	31 831	0.218	*
vessel	42	30 285	30 369	0.255	*
target	45	29 475	29 565	**0.275**	*
poly(log(duration) 3)	48	29 156	29 252	0.283	
month	59	29 071	29 189	0.285	
area	68	29 032	29 168	0.286	

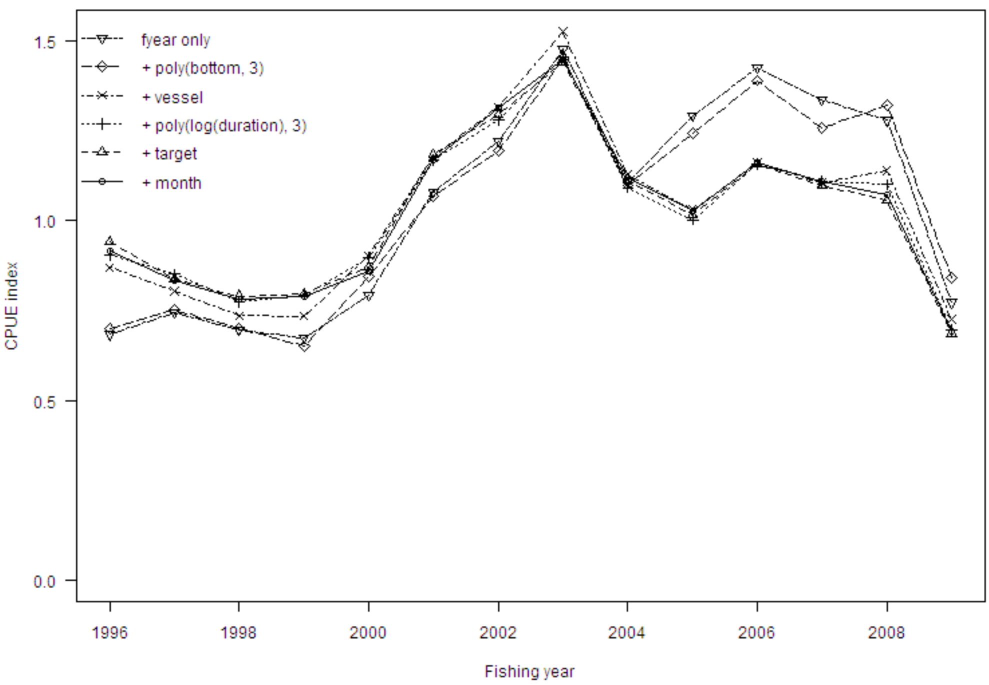

Figure 32: Annual indices from the W_TCE lognormal model at each step in the variable selection process.

East coast substock

Table 15: Summary of final lognormal and binomial models for the E_TCE fishery based on the vessel selection criteria of at least 5 trips per year in at least five or more fishing years. See caption to Table 14 for details.

Lognormal terms	DF	Deviance	AIC	R2	Final
None	0	60 123	83 808	0.000	
fyear	14	49 256	79 501	0.181	*
vessel	39	36 990	73 325	0.385	*
target	43	33 670	71 289	0.440	*
poly(log(duration) 3)	46	32 545	70 556	0.459	*
poly(bottom 3)	49	31 730	70 011	**0.472**	*
month	60	31 188	69 658	0.481	
zone	64	31 001	69 536	0.484	
poly(speed 3)	67	30 913	69 480	0.486	
poly(log(distance) 3)	70	30 897	69 475	0.486	

Binomial terms	DF	Deviance	AIC	R2	Final
None	0	55 134	55 136	0.000	
fyear	14	54 356	54 384	0.014	*
target	18	49 994	50 030	0.093	*
vessel	43	48 663	48 749	**0.117**	*
poly(bottom 3)	46	48 352	48 444	0.123	
month	57	48 210	48 324	0.126	
zone	61	48 140	48 262	0.127	
poly(log(duration) 3)	64	48 101	48 229	0.128	

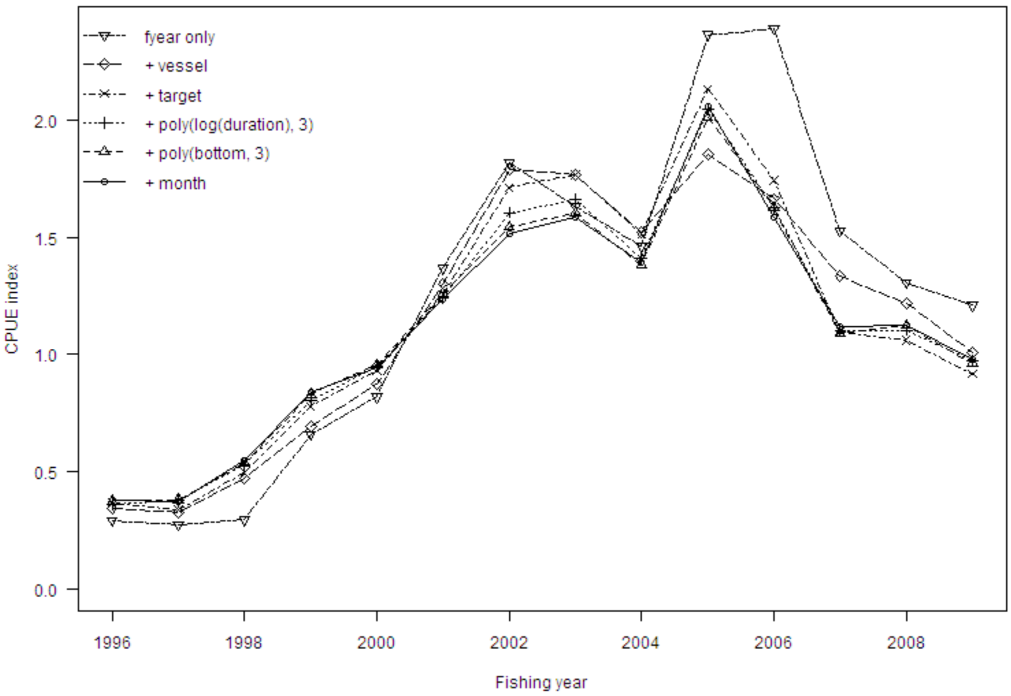

Figure 33:Annual indices from the E_TCE lognormal model at each step in the variable selection process.

Bay of Plenty substock

Table 16: Summary of final lognormal and binomial models for the BoP_TCE fishery based on the vessel selection criteria of at least 5 trips per year in at least five or more fishing years. See caption to Table 14 for details.

Lognormal terms	DF	Deviance	AIC	R2	Final
None	0	28 589	67 007	0.000	
fyear	14	26 892	65 721	0.059	*
vessel	35	23 933	63 265	0.163	*
poly(bottom 3)	38	23 161	62 568	0.190	*
month	49	22 783	62 238	**0.203**	*
zone	51	22 529	62 001	0.212	
poly(log(duration) 3)	54	22 351	61 837	0.218	
target	58	22 216	61 715	0.223	
poly(speed 3)	61	22 199	61 704	0.224	
poly(log(distance) 3)	64	22 190	61 702	0.224	

Binomial terms	DF	Deviance	AIC	R2	Final
None	0	51 977	51 979	0.000	
fyear	14	51 580	51 608	0.008	*
target	18	47 767	47 803	0.081	*
poly(bottom 3)	21	46 239	46 281	0.110	*
vessel	42	44 990	45 074	**0.134**	*
zone	44	44 658	44 746	0.141	
poly(log(distance) 3)	47	44 573	44 667	0.142	
month	58	44 490	44 606	0.144	
poly(speed 3)	61	44 483	44 605	0.144	
poly(log(duration) 3)	64	44 476	44 604	0.144	

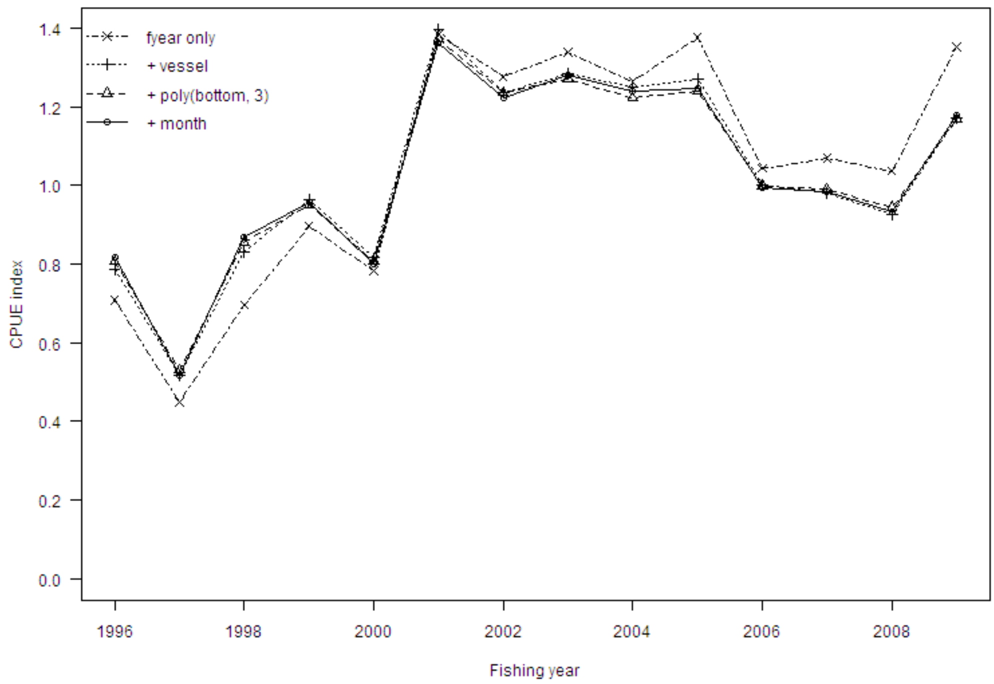

Figure 34: Annual indices from the BP_TCE lognormal model at each step in the variable selection process.

3.5.4 Trends in model year effects and comparisons with other models

The year effects from each model are described for each fishery in Figures 35, 37, and 39. They show the effect of standardisation of a) the probability of capture, b) catch rate in successful tows, and the effect of combining the two indices. The two shortened time series (CEL and TCE) of standardised CPUE produced from lognormal models in each substock are compared in Figures 36, 38, and 40 rescaled to the years they have in common. There is good agreement between the two series over the years of overlap, but rescaling may have caused some visual distortion to the magnitude of the trends and the actual unstandardised and standardised CPUE indices with 95% confidence intervals are tabled in Appendix G.

For each fishery, annual CPUE indices are well determined with small confidence intervals around each point and changes in direction that are sustained over several consecutive years rather than manifesting as interannual variance. The effect of standardising the probability of capture (binomial model) was not great in any fishery, whether based on CEL or TCEPR/TCE format data, and the effect of combining lognormal and binomial indices was likewise slight.

In each fishery, the series of standardised CPUE from the lognormal models (both CELR and TCE) show a less optimistic trend than the unstandardised series and moves the predicted CPUE in recent years downwards as the models accounted for improved performance in the core fleets and shifts away from targeting snapper that have resulted in increased catches of gurnard. The trajectories nevertheless describe large increases in availability during the early to mid 2000s, and, in each substock, a subsequent decline from those peaks.

In the west coast substock the series had been stable for five years at a level that was above the mean for the TCE series until a sharp decline in 2008–09 to the lowest level since 1989–90. In the east coast substock the series has been in decline since 2004–05 and the 2008–09 index was at about the mean for the TCE series, and in the Bay of Plenty the series has been flat for nine years at a level above the mean and has increased in the most recent year.

A comparison with the indices from the previous project is given in Appendix H. In those plots all series have been rescaled relative to the years they have in common, and the differences will be due to the use of landed catch rather than estimated catch, and the different fishery definitions used this study. There is good agreement with the previous series for the west coast, but for the other two substocks the magnitude of the trends is greater in this study than was reported by Kendrick (2009b).

West coast substock

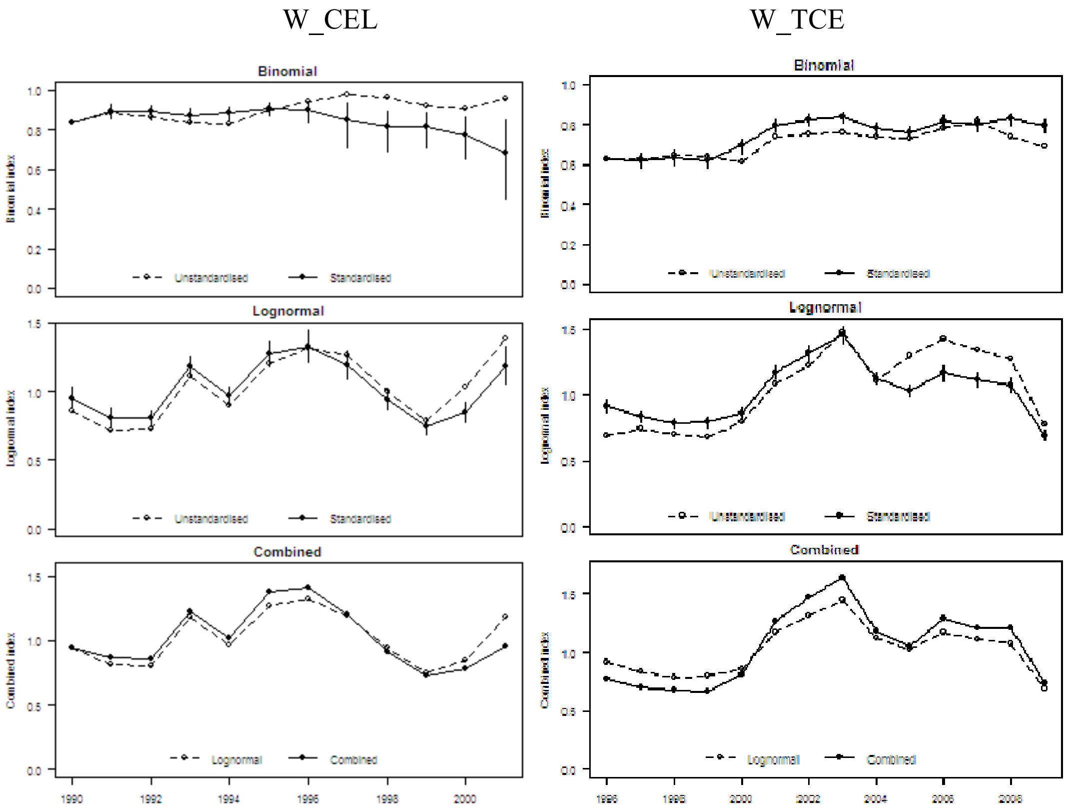

Figure 35: Different standardised annual CPUE indices for the W_CEL fishery 1989–90 to 2000–01 [left], and the W_TCE fishery 1995–96 to 2008–09[right]. Top: Binomial index representing probability of capture. Middle: Lognormal index representing magnitude of catch. Bottom: Combined index representing expected catch.

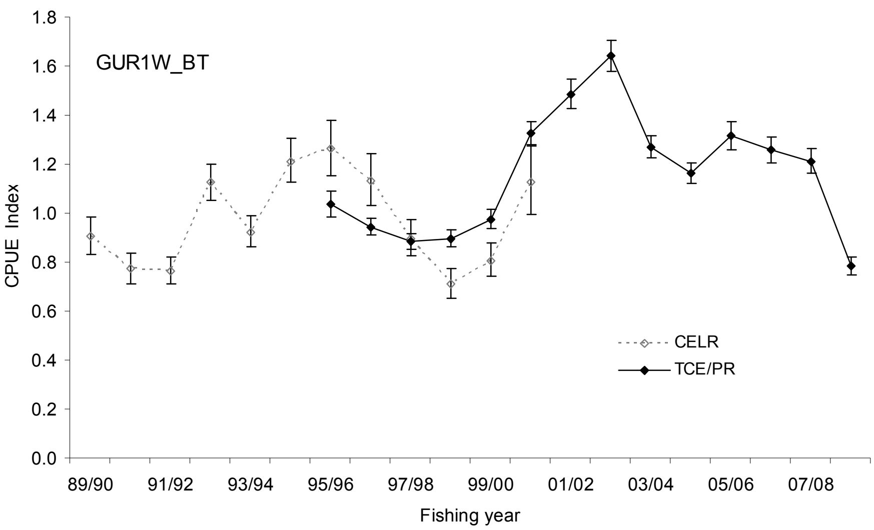

Figure 36: Comparison of the lognormal series (±2 SE) for W_CEL and W_TCE rescaled relative to the geometric means over the years in common.

East coast substock

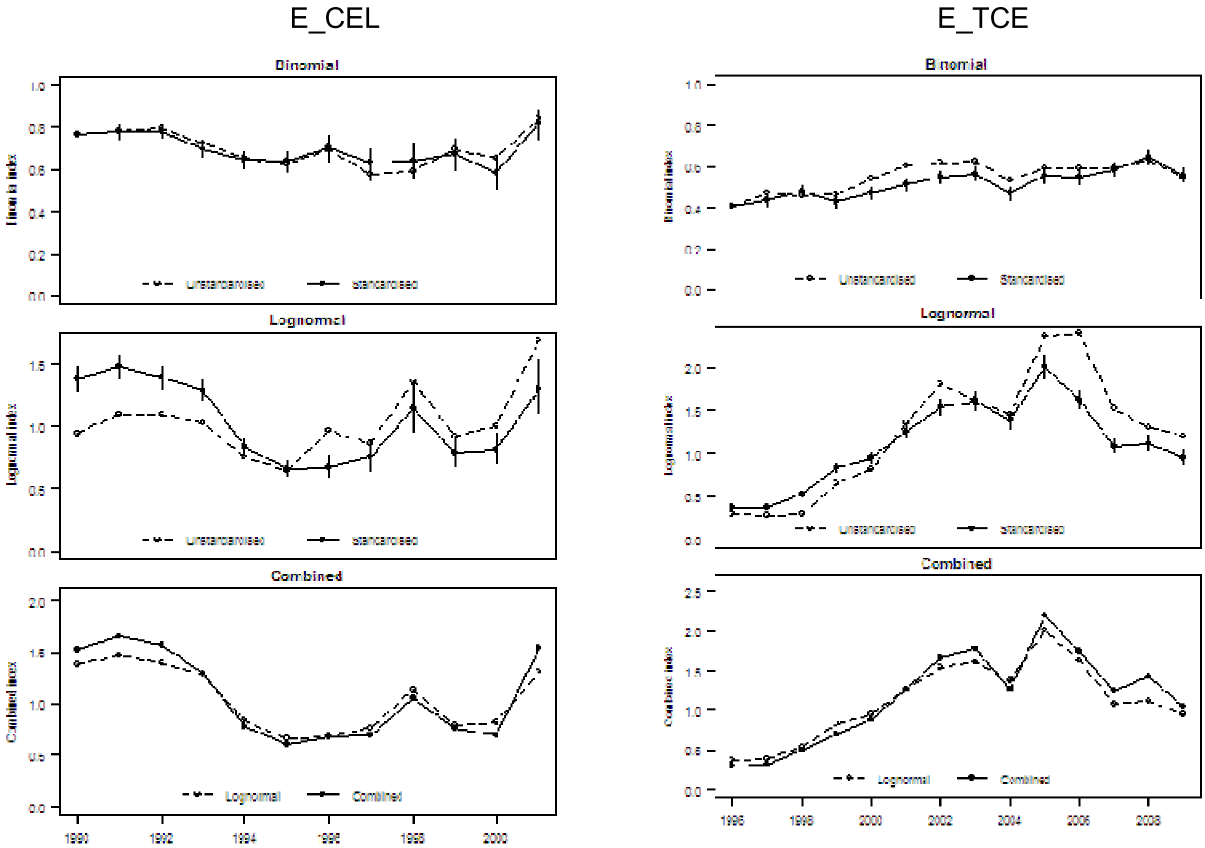

Figure 37: Different standardised annual CPUE indices for E_CEL 1989–90 to 2000–01 [left], and E_TCE 1995–96 to 2008–09[right]. Top: Binomial index representing probability of capture. Middle: Lognormal index representing magnitude of catch. Bottom: Combined index representing expected catch.

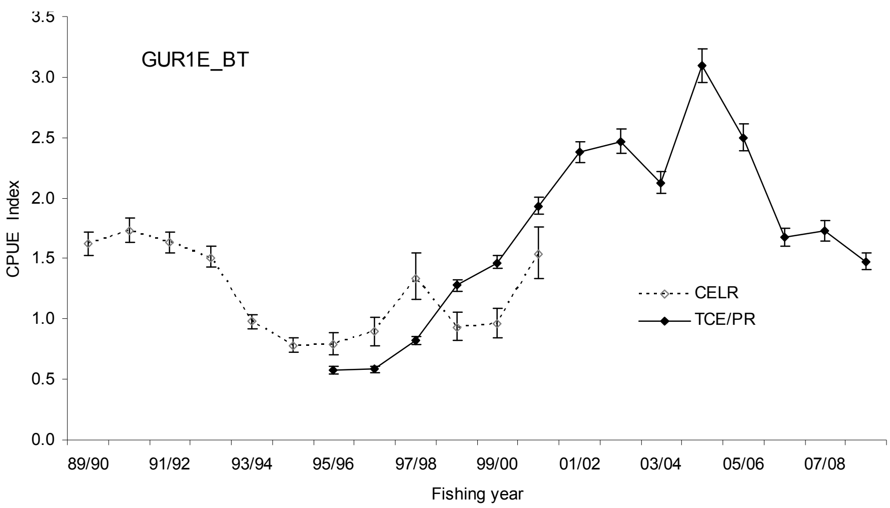

Figure 38: Comparison of the lognormal series (±2 SE) for E_CEL and E_TCE rescaled relative to the geometric means over the years in common.

Bay of Plenty substock

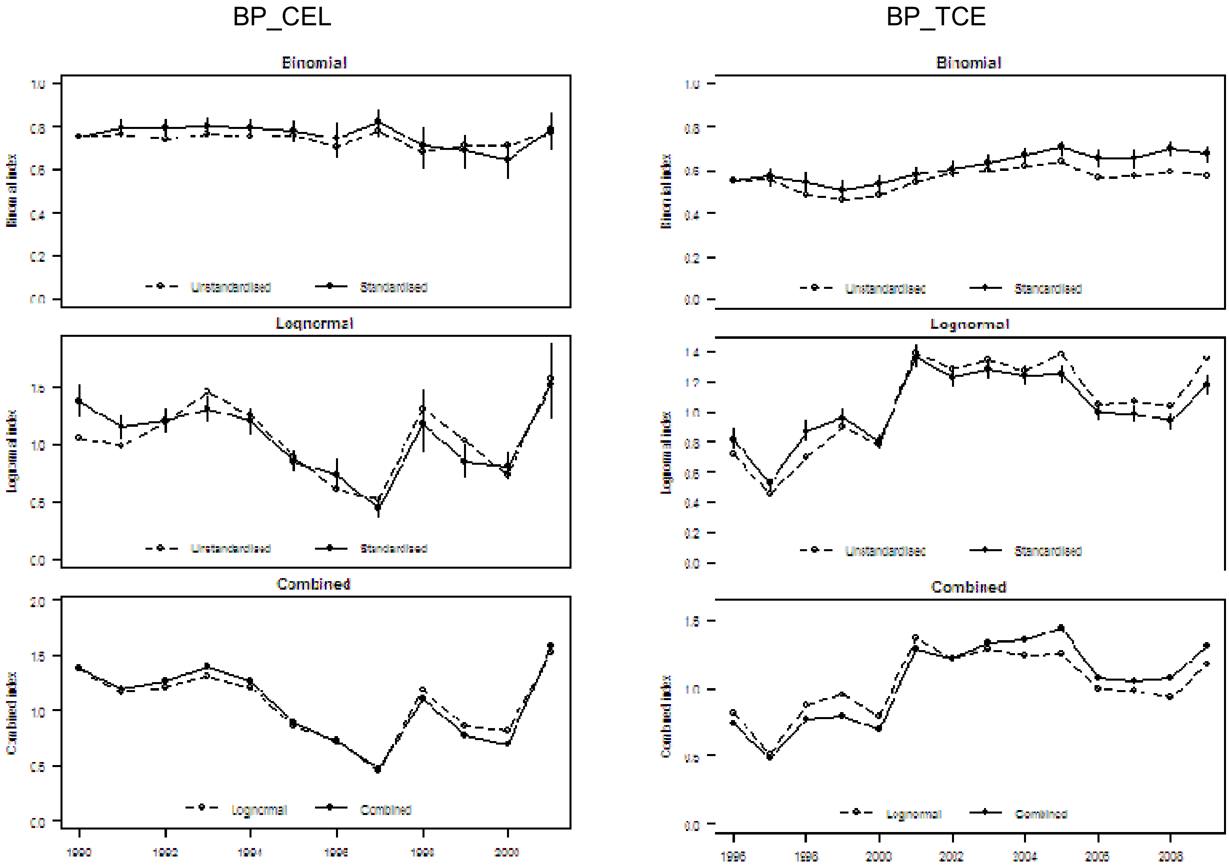

Figure 39: Different standardised annual CPUE indices for BP_CEL 1989–90 to 2000–01 [left], and BP_TCE 1995–96 to 2008–09[right]. Top: Binomial index representing probability of capture. Middle: Lognormal index representing magnitude of catch. Bottom: Combined index representing expected catch.

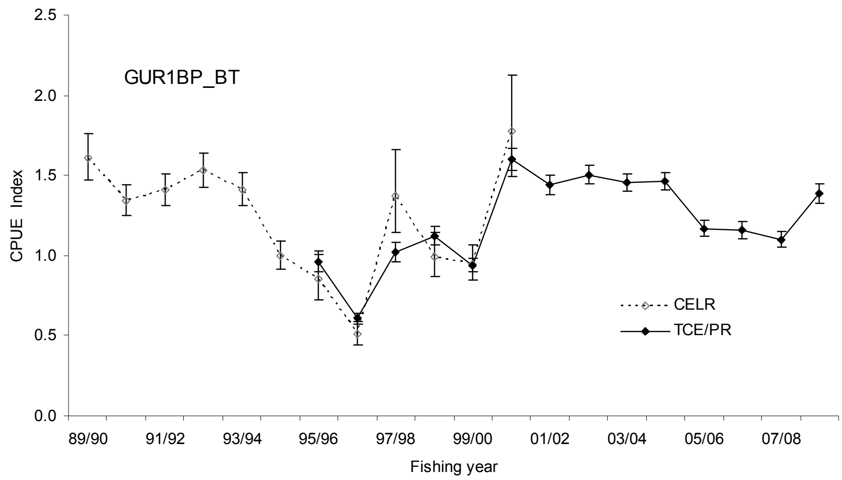

Figure 40: Comparison of the lognormal series (±2 SE) for BP_CEL and BP_TCE rescaled relative to the geometric means over the years in common.

4. CONCLUSIONS

Highly variable trends which cycle over a 4–8 year phase were estimated by the log normal CPUE indices. The NINSWG considered that these series were consistent with what one would expect from a short-lived species with variable recruitment and appeared to resemble equivalent series estimated for other GUR Fishstocks (e.g., GUR 3). They also resembled the biomass trends estimated for gurnard from the two South Island trawl surveys.

The northern inshore trawl fisheries for red gurnard are characterised by two important aspects: 1) there are not clear and consistent target fisheries for this species, despite much of the catch being described as targeted, and it is necessary to monitor abundance across mixed target fisheries (including both bycatch and target effort); 2) the dominant operator in this northern inshore trawl shifted its fleet to the tow-by-tow reporting on TCEPRs in the mid 1990s. The Starr (2007) methodology includes an elegant procedure for combining data in the two formats, but does not solve the problems inherent in such a total and systematic shift in reporting practice.

This study concludes that fisher-nominated target is not a reliable delineator of effective effort. A suite of similar fisheries targeted at snapper, trevally, and John dory, as well as at red gurnard, is more likely to represent effort that is representative with respect to red gurnard than just those tows nominally targeted, and this means monitoring bycatch in a mixed target fishery.

Some of the anticipated benefits of doing the standardisations on TCEPR data only were not realised as neither tow speed nor distance were accepted into any model, and although bottom depth was important in each substock, target species was often also included. Annual indices from alternative models (not shown) that weren't offered bottom depth (and which consequently accepted target species) were not dissimilar. This is not surprising as target species is a much more informative factor in tow-by-tow (TCE) data than for daily (CEL) data because it is better defined. With the wider definition of fisheries used in this study, the potential bias from the different way in which target species is used across forms is less likely to be a problem, and series that combined data across formtypes using the Starr methodology gave very similar results (not shown). With the mandatory switch to the new TCE form in trawl fisheries, future work should continue to explore CPUE series based on the more detailed catch effort data in tow-by-tow resolution. The CELR series presented here can probably be re-presented (without re-working) alongside updated TCE series in the future.

The use of a TCEPR/TCE only series was first promoted by Davies et al. (2006) for snapper in this same inshore trawl fishery. They proposed that the shortened series yielded more realistic (less overly optimistic) trajectories because they were able to use tow distance rather than tow duration in the standardisation. Kendrick (2009c) proposed that the overly optimistic CPUE trajectories were an artefact of combining data across formtypes and that the systematic shift in reporting in this fishery from the daily to the tow-by-tow forms, with their inherently different uses of the target species field, led to the bias. This problem was, at that time, confined to the northern inshore trawl fishery but it is likely to be encountered more widely as a result of the mandatory introduction of the new TCE form. Experience so far suggests that the problem is mitigated by widening the fishery definition to include more target species and indeed, in this study, alternative series that combined data across both formtypes using the Starr methodology yielded very similar annual indices to those presented here. In this study, there was little advantage gained from the more detailed descriptive data that are ancillary to catch and effort when reported tow-by-tow. However, it is assumed that greater use will be made in the future of the finer resolution spatial information in these data, and that the new series will become more informative. It is recommended that the TCEPR/TCE series should continue to be developed in future analyses.

The main factor standardised for in these models is vessel, and in each substock there have been changes in the core fleet that has seen the loss of many of the poorer performing vessels that has helped to increase the observed CPUE. Other shifts that have been influential include shifts away from targeting snapper and towards trevally, gurnard, and John dory, with the accompanying shifts in bottom depth towards more tows in the preferred depth range of gurnard, and, in the west coast substock, towards longer tow durations that have also had a positive influence on observed CPUE, although the models appear to have done a reasonable job of accounting for them.

5. ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries as project GUR2009–01. Thanks to members of the Inshore Fishery Assessment Working Group, particularly Paul Starr and Malcolm Francis, for methodology and helpful suggestions.

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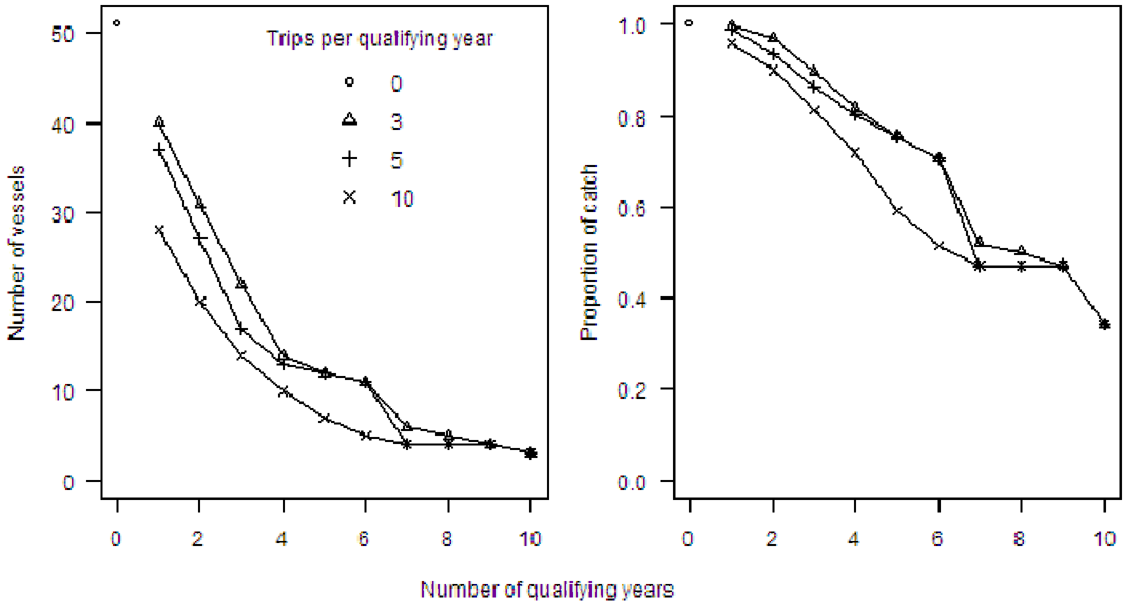
APPENDIX A: BIOMASS ESTIMATES FROM DISCONTINUED TRAWL SURVEY SERIES

Table A2: Estimates of red gurnard biomass (t) from *Kaharoa* trawl surveys.

Year	Trip Code	Biomass	c.v. (%)
Hauraki Gulf			
1984	KAH8421	595	15
1985	KAH8517	49	44
1986	KAH8613	426	36
1987	KAH8716	255	15
1988	KAH8810	749	19
1989	KAH8917	105	29
1990	KAH9016	141	16
1992	KAH9212	330	9
1993	KAH9311	177	17
1994	KAH9411	247	19
1997	KAH9720	242	14
2000	KAH0012	24	46
Bay of Plenty			
1983	KAH8303	380	23
1985	KAH8506	57	17
1987	KAH8711	410	28
1990	KAH9004	432	12
1992	KAH9202	290	9
1996	KAH9601	332	14
1999	KAH9902	364	14
North Island west coast (QMA 9)			
1986	KAH8612	1 763	16
1987	KAH8715	2 022	24
1989	KAH8918	1 013	12
1991	KAH9111	1 846	23
1994	KAH9410	2 498	30
1996	KAH9615	1 820	1

Appendix B. CORE VESSEL SELECTION



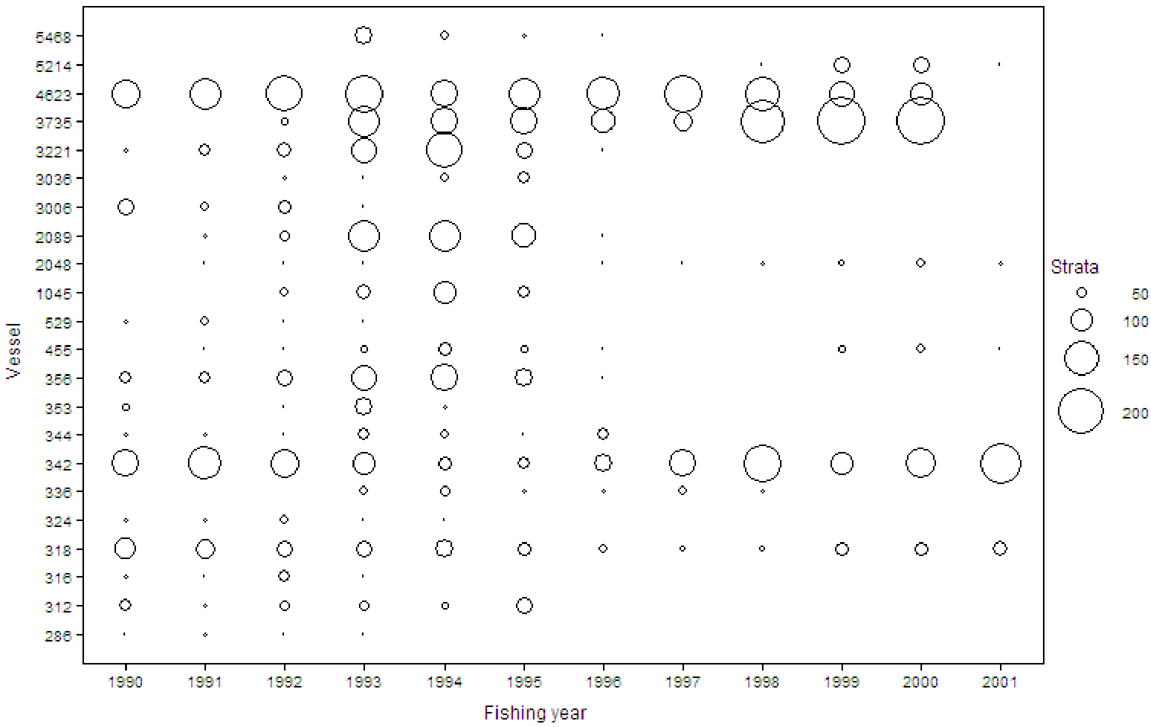


Figure B.1: The number of vessels [top left] and the proportion of landed GUR 1 [top right] retained in the W_CEL dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 3 trips per year in at least five years), number of records for each vessel in each fishing year [bottom].

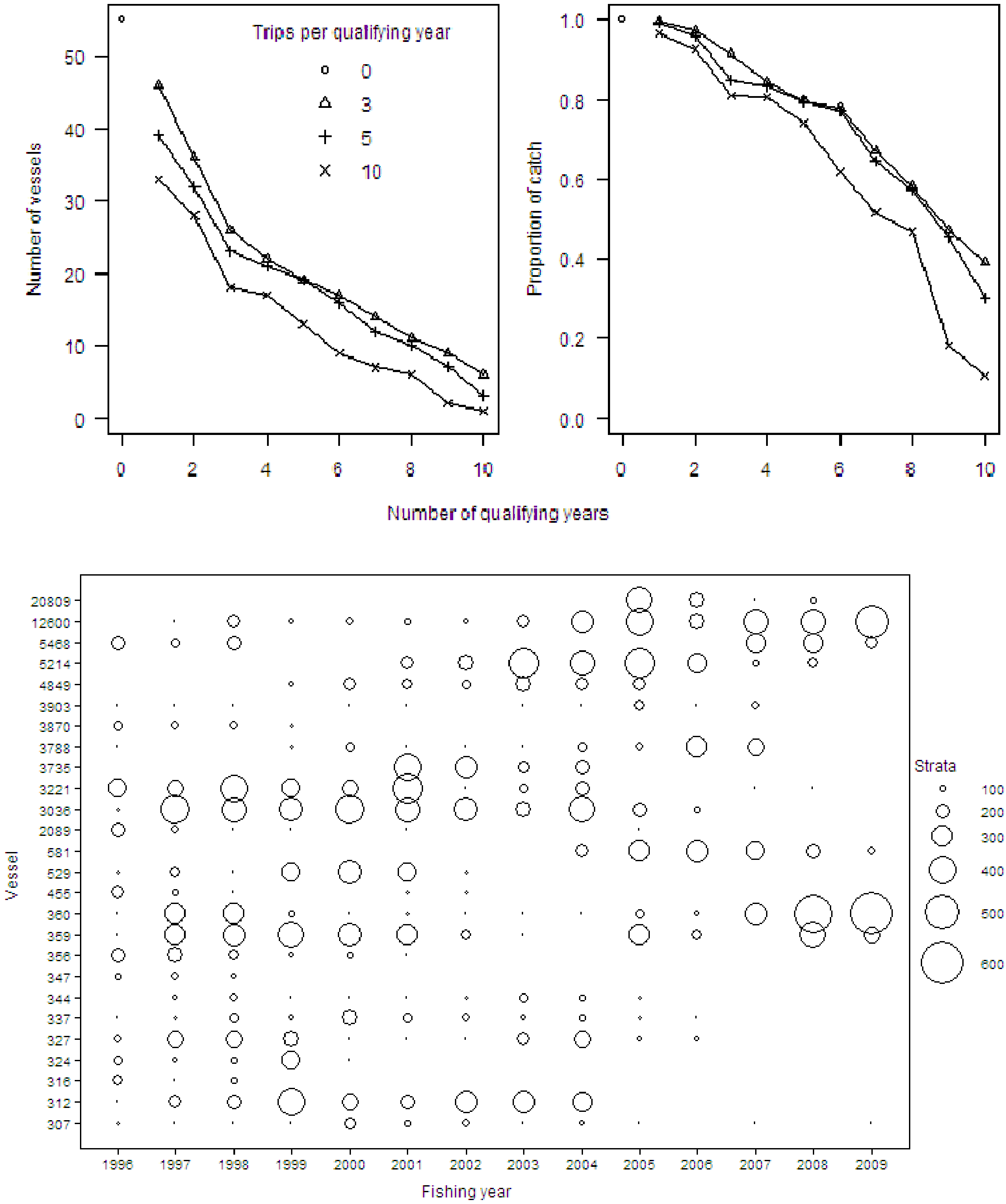


Figure B.2: The number of vessels [top left] and the proportion of landed GUR 1 [top right] retained in the W_TCE dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 3 trips per year in at least three years), number of records for each vessel in each fishing year [bottom].

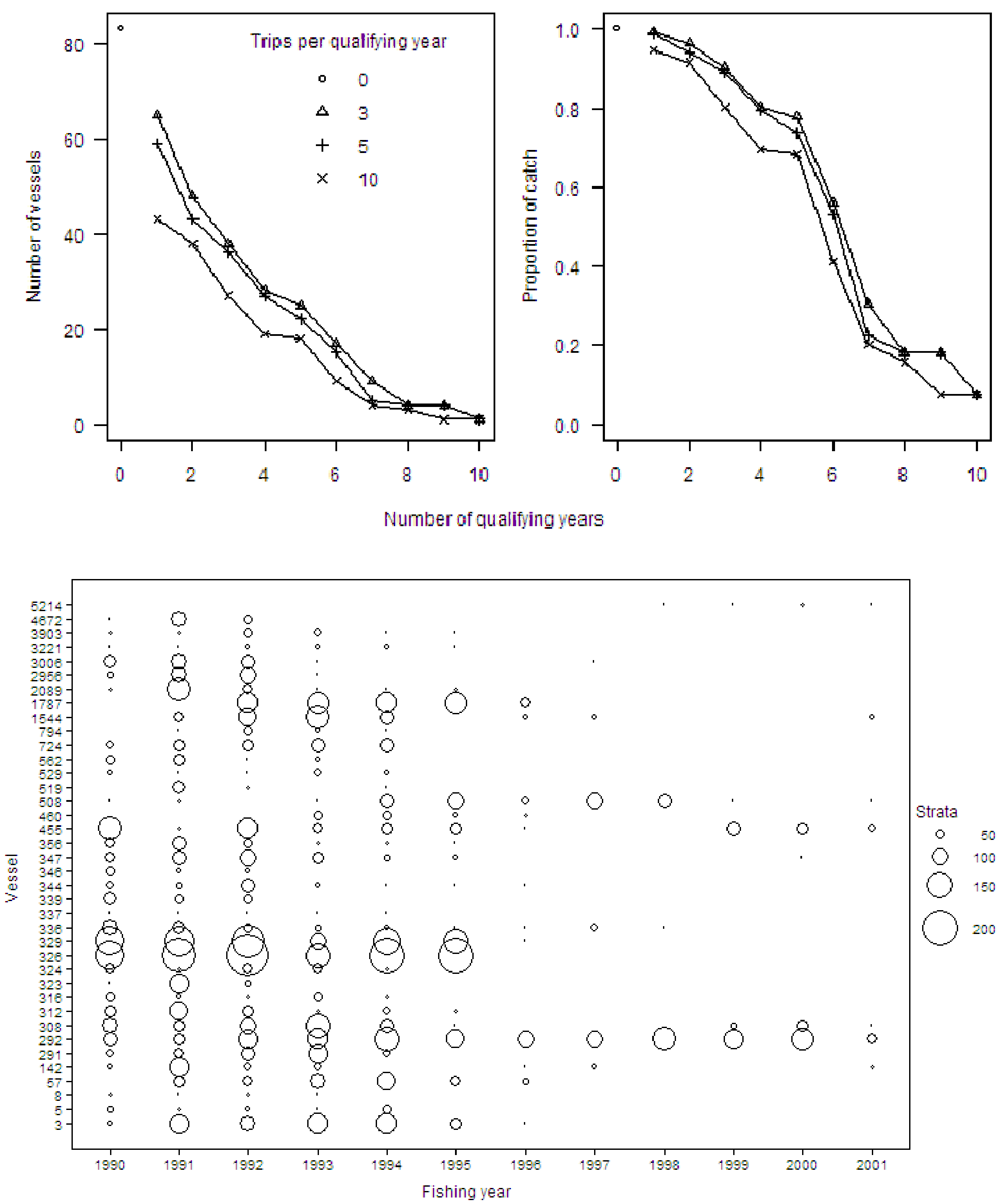
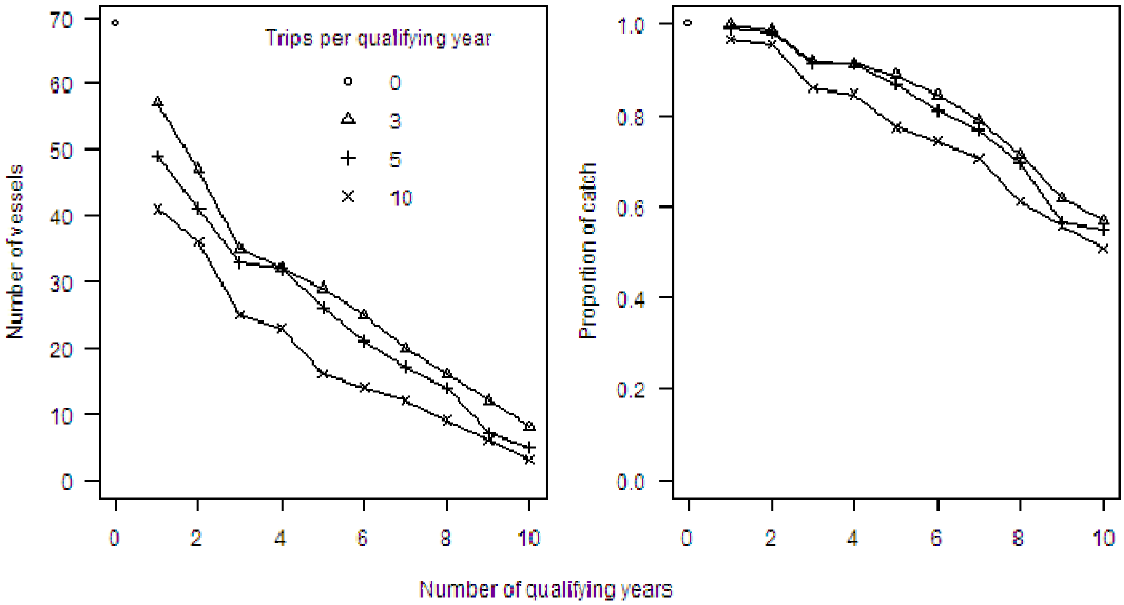


Figure B.3: The number of vessels [top left] and the proportion of landed GUR 1 [top right] retained in the E_CEL dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 3 trips per year in at least three years), number of records for each vessel in each fishing year [bottom].



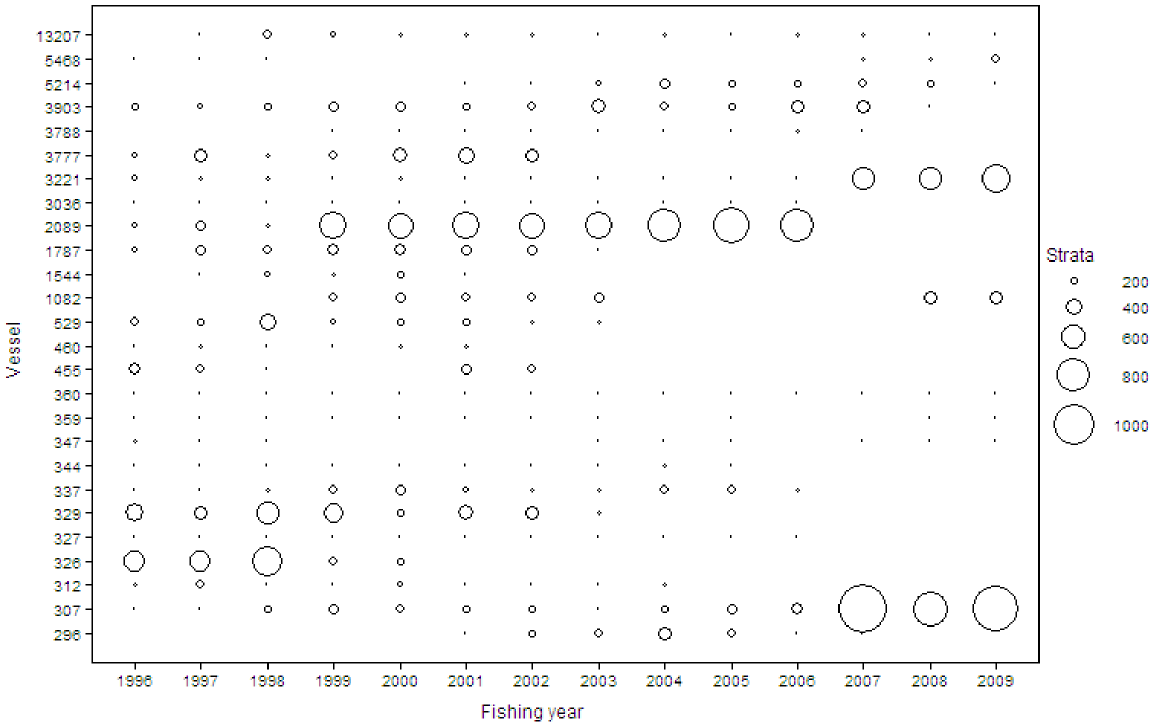


Figure B.4: The number of vessels [top left] and the proportion of landed GUR 1 [top right] retained in the E_TCE dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 5 trips per year in at least five years), number of records for each vessel in each fishing year [bottom].

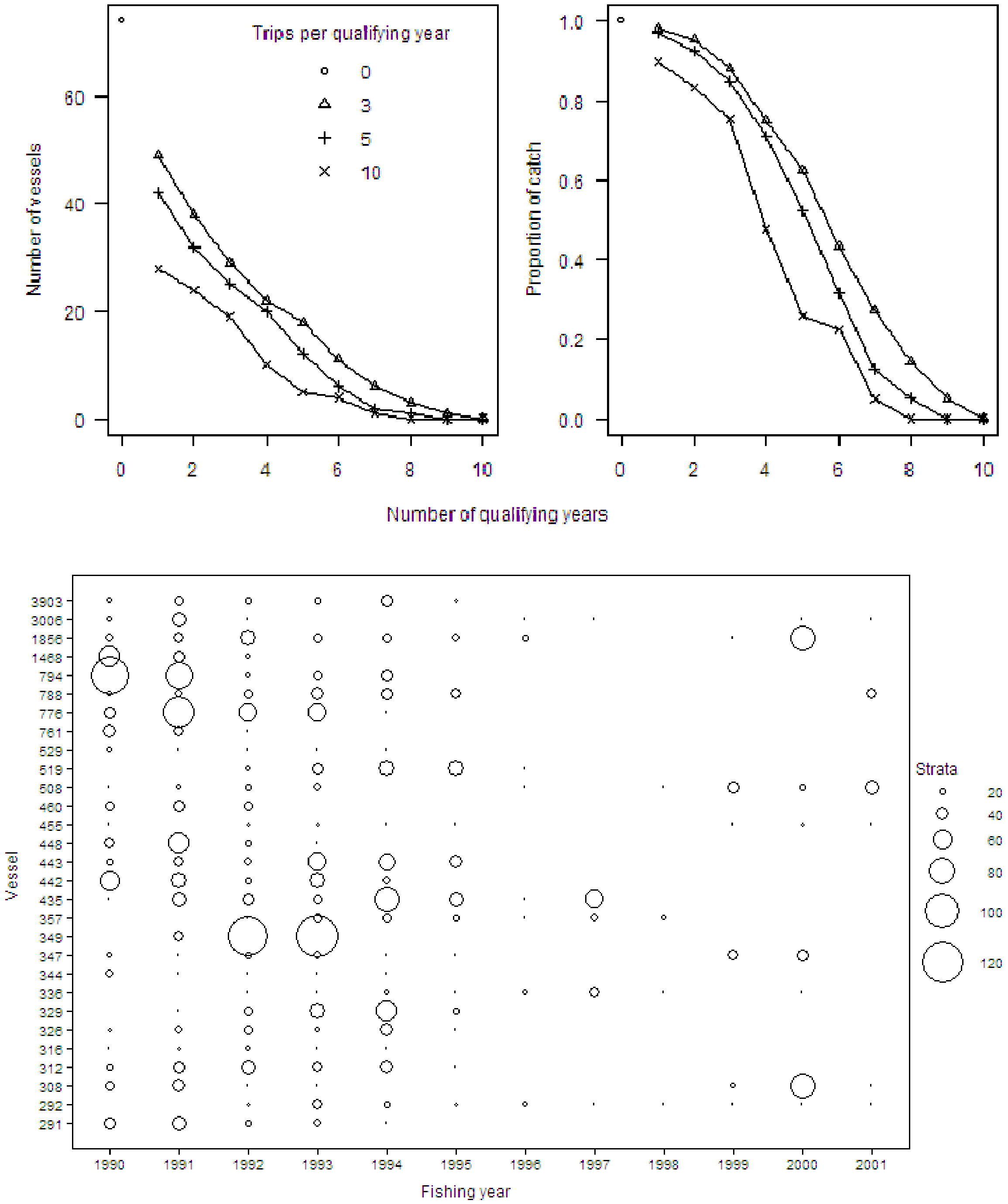


Figure B.5: The number of vessels [top left] and the proportion of landed GUR 1 [top right] retained in the BoP_CEL dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 3 trips per year in at least three years), number of records for each vessel in each fishing year [bottom].

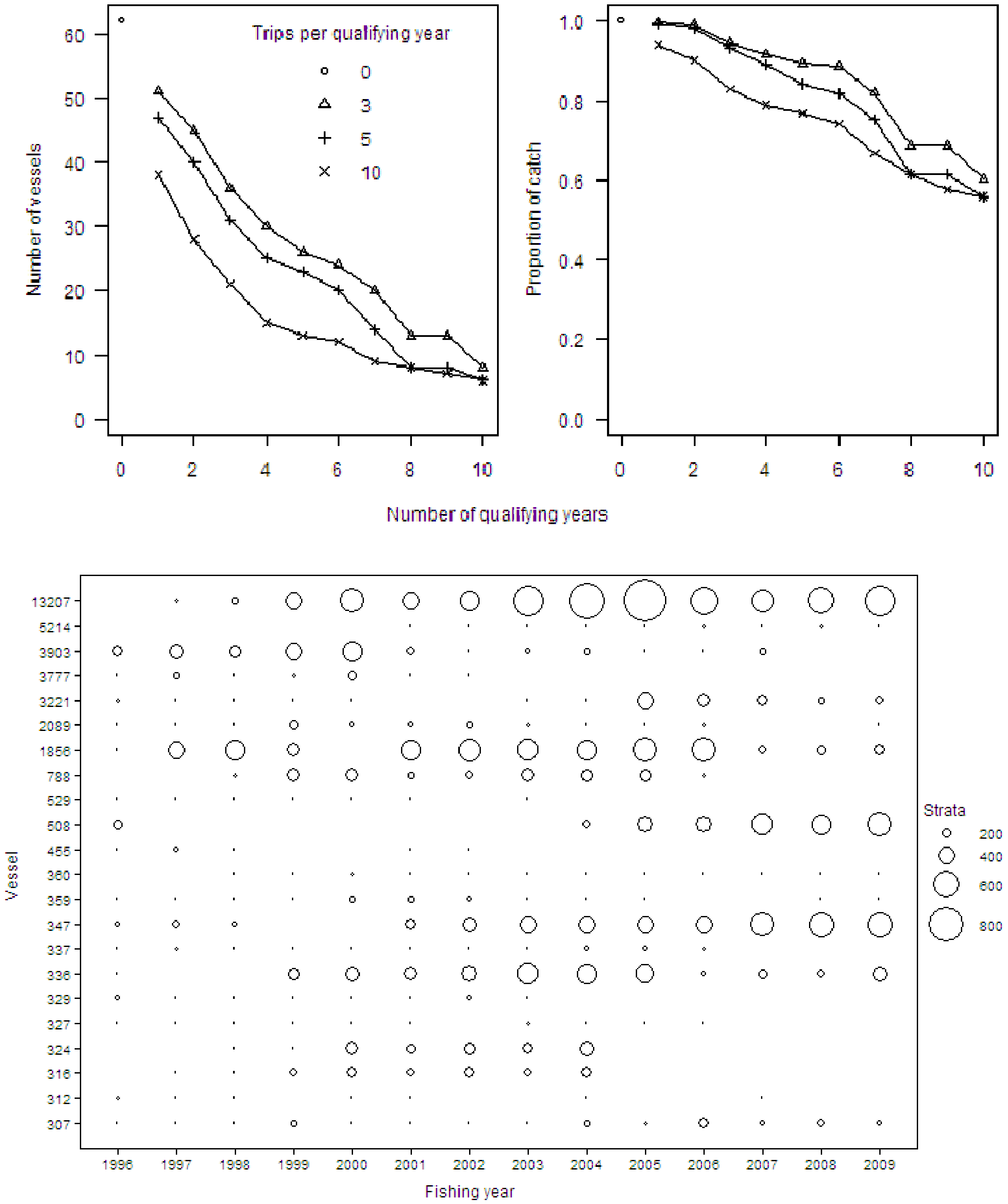


Figure B.6: The number of vessels [top left] and the proportion of landed GUR 1 [top right] retained in the BoP_TCE dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 5 trips per year in at least five years), number of records for each vessel in each fishing year [bottom].

Appendix C. DATA SUMMARIES

Table C.1: Data summary for the W_CEL bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 3 tows per year for at least 5 years); Number of trips, percentage of strata that recorded a zero catch of gurnard, number of core vessels, total number of tows, landed weight of GUR 1 (tonnes), and the simple catch rate of GUR 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero strata	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1989/90	392	16	13	2 021	130	64
1990/91	430	12	15	2 103	118	56
1991/92	506	14	19	2 843	188	66
1992/93	650	16	21	4 610	409	89
1993/94	580	17	16	4 279	327	76
1994/95	495	10	14	3 082	309	100
1995/96	401	6	12	1 534	165	108
1996/97	400	2	6	1 239	142	115
1997/98	504	4	7	1 664	134	81
1998/99	434	8	7	1 773	123	69
1999/00	372	9	7	1 754	135	77
2000/01	169	4	5	803	85	106

Table C.2: Data summary for the W_TCE bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 3 tows per year for at least 3 years); Number of trips, percentage of tows that recorded a zero catch of gurnard, number of core vessels, total number of tows, landed weight of GUR 1 (tonnes), and the simple catch rate of GUR 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero tows	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1995/96	205	38	19	2 003	188	94
1996/97	309	38	20	2 964	247	83
1997/98	304	36	20	3 157	241	76
1998/99	219	36	17	2 726	191	70
1999/00	230	39	16	2 621	201	77
2000/01	314	26	19	2 825	359	127
2001/02	291	25	16	2 104	301	143
2002/03	205	24	15	2 136	417	195
2003/04	228	26	15	2 815	357	127
2004/05	222	27	15	2 807	443	158
2005/06	166	22	11	1 802	315	175
2006/07	141	18	10	1 708	288	169
2007/08	156	26	8	1 998	317	159
2008/09	116	31	6	1 642	163	99

Table C.3: Data summary for the E_CEL bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 3 tows per year for at least 3 years); Number of trips, percentage of strata that recorded a zero catch of gurnard, number of core vessels, total number of tows, landed weight of GUR 1 (tonnes), and the simple catch rate of GUR 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero strata	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1989/90	522	23	31	6 049	92	15
1990/91	693	22	35	8 083	127	16
1991/92	767	21	35	8 832	166	19
1992/93	646	28	32	6 782	118	17
1993/94	577	34	28	5 609	60	11
1994/95	363	38	18	3 652	31	9
1995/96	107	30	12	952	13	14
1996/97	97	42	6	864	8	9
1997/98	71	41	4	692	9	13
1998/99	93	31	5	824	9	11
1999/00	110	34	5	912	13	15
2000/01	71	16	7	534	12	22

Table C.4: Data summary for the E_TCE bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 5 tows per year for at least 5 years); Number of trips, percentage of tows that recorded a zero catch of gurnard, number of core vessels, total number of tows, landed weight of GUR 1 (tonnes), and the simple catch rate of GUR 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero tows	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1995/96	281	59	20	2 634	15	6
1996/97	358	53	22	3 110	18	6
1997/98	411	55	22	3 695	24	6
1998/99	363	53	21	3 580	35	10
1999/00	371	46	21	3 638	49	13
2000/01	375	39	23	3 537	69	19
2001/02	362	38	21	3 296	83	25
2002/03	284	37	20	2 409	58	24
2003/04	270	47	15	2 466	59	24
2004/05	203	41	15	2 192	73	33
2005/06	213	41	12	2 145	64	30
2006/07	264	41	10	2 710	63	23
2007/08	226	36	10	2 227	45	20
2008/09	195	45	9	2 541	38	15

Table C.5: Data summary for the BoP_CEL bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 3 tows per year for at least 3 years); Number of trips, percentage of strata that recorded a zero catch of gurnard, number of core vessels, total number of tows, landed weight of GUR 1 (tonnes), and the simple catch rate of GUR 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero strata	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1989/90	303	24	28	2 963	48	16
1990/91	512	23	26	4 128	76	18
1991/92	488	26	31	3 678	83	22
1992/93	479	24	29	3 426	76	22
1993/94	443	25	27	3 085	59	19
1994/95	311	24	18	1 758	32	18
1995/96	60	30	9	425	5	12
1996/97	121	22	6	624	10	15
1997/98	68	32	8	360	7	19
1998/99	147	29	8	865	13	16
1999/00	150	29	10	1 270	20	15
2000/01	53	22	6	490	15	30

Table C.6: Data summary for the BoP_TCE bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 5 tows per year for at least 5 years); Number of trips, percentage of tows that recorded a zero catch of gurnard, number of core vessels, total number of tows, landed weight of GUR 1 (tonnes), and the simple catch rate of GUR 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero tows	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1995/96	142	45	16	1 171	17	15
1996/97	189	45	16	1 670	19	12
1997/98	203	52	19	1 690	27	16
1998/99	295	54	17	2 723	39	14
1999/00	286	51	17	2 936	41	14
2000/01	316	46	20	2 801	61	22
2001/02	347	42	17	2 902	63	22
2002/03	369	40	18	3 357	83	25
2003/04	401	38	18	3 821	84	22
2004/05	353	36	15	3 861	91	24
2005/06	328	43	14	3 111	50	16
2006/07	252	43	11	2 507	39	16
2007/08	268	41	10	2 580	47	18
2008/09	274	43	11	2 839	60	21

Appendix D. MODEL SELECTION FOR CELR SERIES

Table D.1: Summary of final lognormal and binomial models for the W_CEL fishery based on the vessel selection criteria of at least 3 trips per year in at least five or more fishing years. Independent variables are listed in the order of acceptance to the model. AIC: Akaike Information Criterion, R2: Proportion of deviance explained, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.

Lognormal terms	DF	Deviance	AIC	R2	Final
None	0	9 679	23 689	0.000	
fyear	12	9 314	23 414	0.038	*
poly(log(num) 3)	15	8 073	22 314	0.166	*
target	18	7 558	21 810	0.219	*
vessel	39	7 113	21 383	0.265	*
poly(log(duration) 3)	42	6 989	21 253	**0.278**	*
month	53	6 920	21 198	0.285	
area	60	6 899	21 188	0.287	

Binomial terms	DF	Deviance	AIC	R2	Final
None	0	6 207	6 209	0.000	
fyear	12	5 976	6 000	0.037	*
vessel	33	4 591	4 657	0.260	*
target	36	4 168	4 240	**0.329**	*
poly(log(num) 3)	39	4 131	4 209	0.335	
area	46	4 100	4 192	0.340	
month	57	4 075	4 189	0.344	

Table D.2: Summary of final lognormal and binomial models for the E_CEL fishery based on the vessel selection criteria of at least 3 trips per year in at least three or more fishing years. See caption to Table D1 for details.

Lognormal terms	DF	Deviance	AIC	R2	Final
None	0	14 655	30 412	0.000	
fyear	12	14 271	30 189	0.026	*
vessel	49	12 186	28 809	0.169	*
poly(log(duration) 3)	52	11 217	28 053	0.235	*
target	56	10 467	27 423	0.286	*
month	67	10 044	27 066	0.315	*
poly(log(num) 3)	70	10 002	27 033	0.318	
zone	74	9 990	27 030	0.318	

Binomial terms	DF	Deviance	AIC	R2	Final
None	0	14 800	14 802	0.000	
fyear	12	14 523	14 547	0.019	*
vessel	49	13 591	13 689	0.082	*
target	53	13 219	13 325	0.107	*
zone	57	13 116	13 230	0.114	
poly(log(duration) 3)	60	13 023	13 143	0.120	
month	71	12 971	13 113	0.124	
poly(log(num) 3)	74	12 964	13 112	0.124	

Table D.3: Summary of final lognormal and binomial models for the BoP_CEL fishery based on the vessel selection criteria of at least 3 trips per year in at least three or more fishing years. See caption to Table D1 for details.

Lognormal terms	DF	Deviance	AIC	R2	Final
None	0	9 161	19 674	0.000	
fyear	12	8 794	19 449	0.040	*
vessel	46	8 094	19 016	0.116	*
poly(log(num) 3)	49	7 538	18 592	0.177	*
target	53	7 125	18 259	0.222	*
month	64	6 786	17 986	0.259	*
zone	66	6 656	17 873	0.273	*
poly(log(duration) 3)	69	6 622	17 848	0.277	

Binomial terms	DF	Deviance	AIC	R2	Final
None	0	9 063	9 065	0.000	
fyear	12	9 045	9 069	0.002	*
target	16	8 553	8 585	0.056	*
vessel	50	8 182	8 282	0.097	*
poly(log(num) 3)	53	8 156	8 262	0.100	
month	64	8 126	8 254	0.103	
poly(log(duration) 3)	67	8 118	8 252	0.104	

Appendix E. RESIDUAL PLOTS

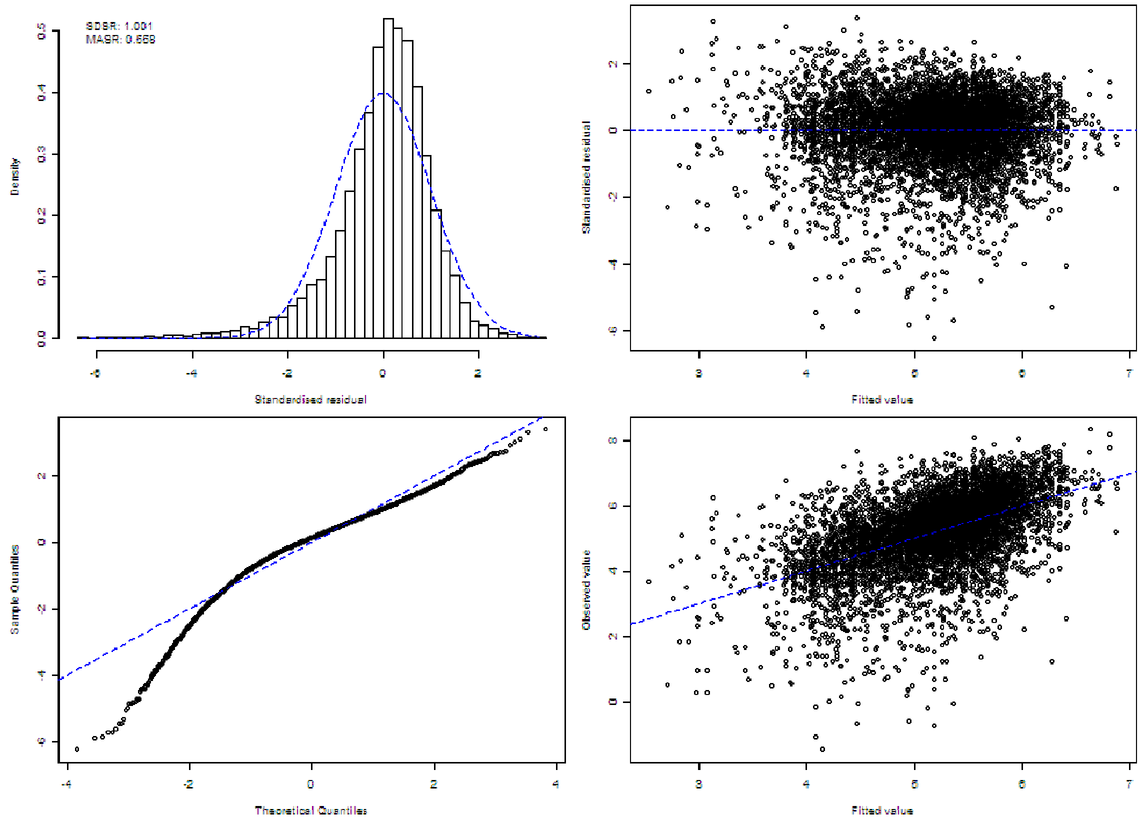


Figure E.1: Plots of the fit of the standardised CPUE model to successful catches of gurnard in the GUR 1 (W_CEL) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

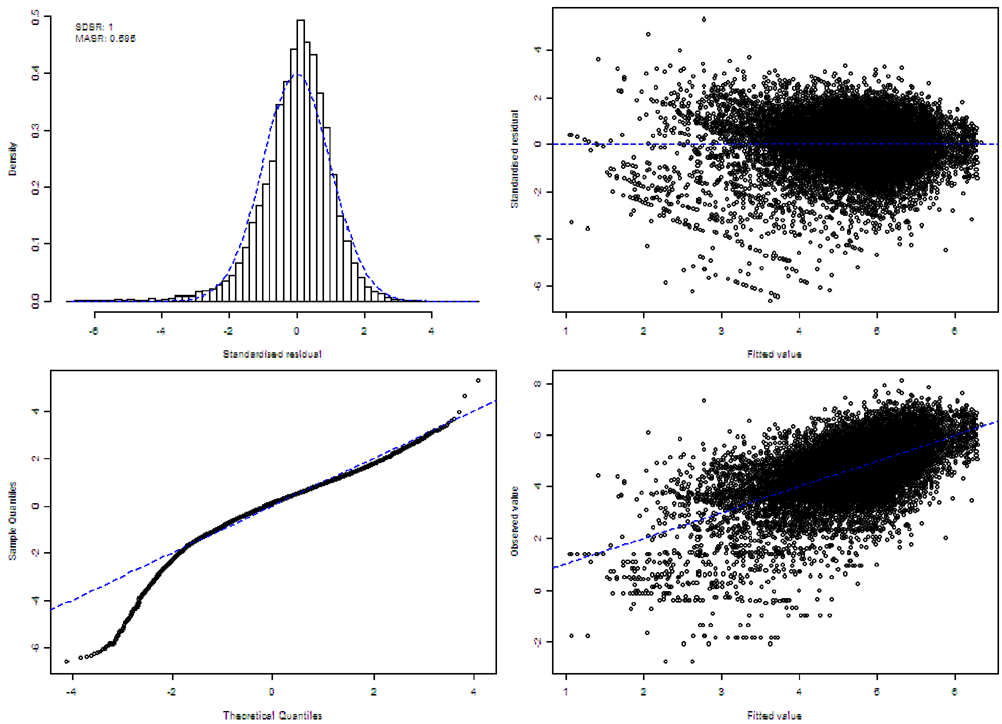


Figure E.2: Plots of the fit of the standardised CPUE model to successful catches of gurnard in the GUR 1 (W_TCE) fishery.

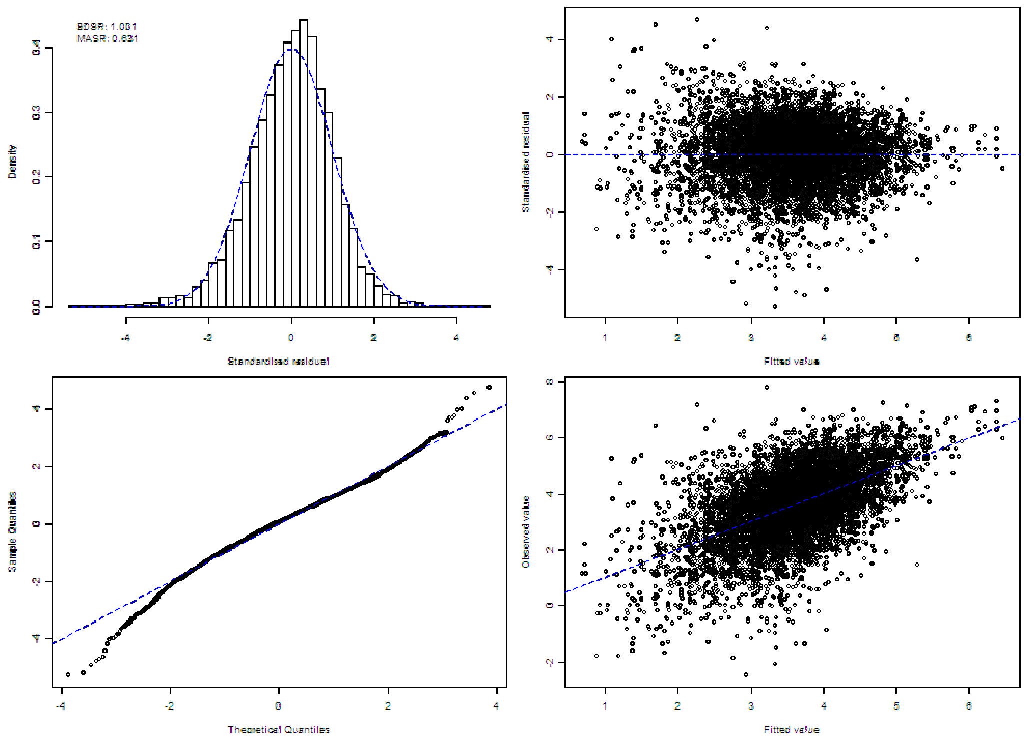


Figure E.3: Plots of the fit of the standardised CPUE model to successful catches of gurnard in the GUR 1 (E_CEL) fishery.

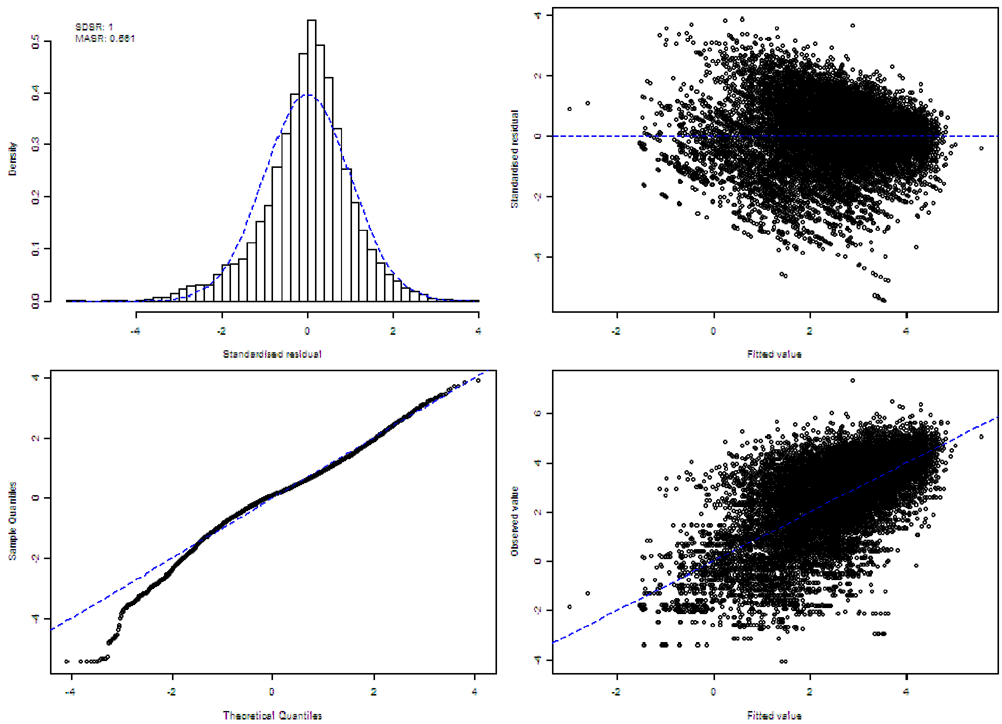


Figure E.4: Plots of the fit of the standardised CPUE model to successful catches of gurnard in the GUR 1 (E_TCE) fishery.

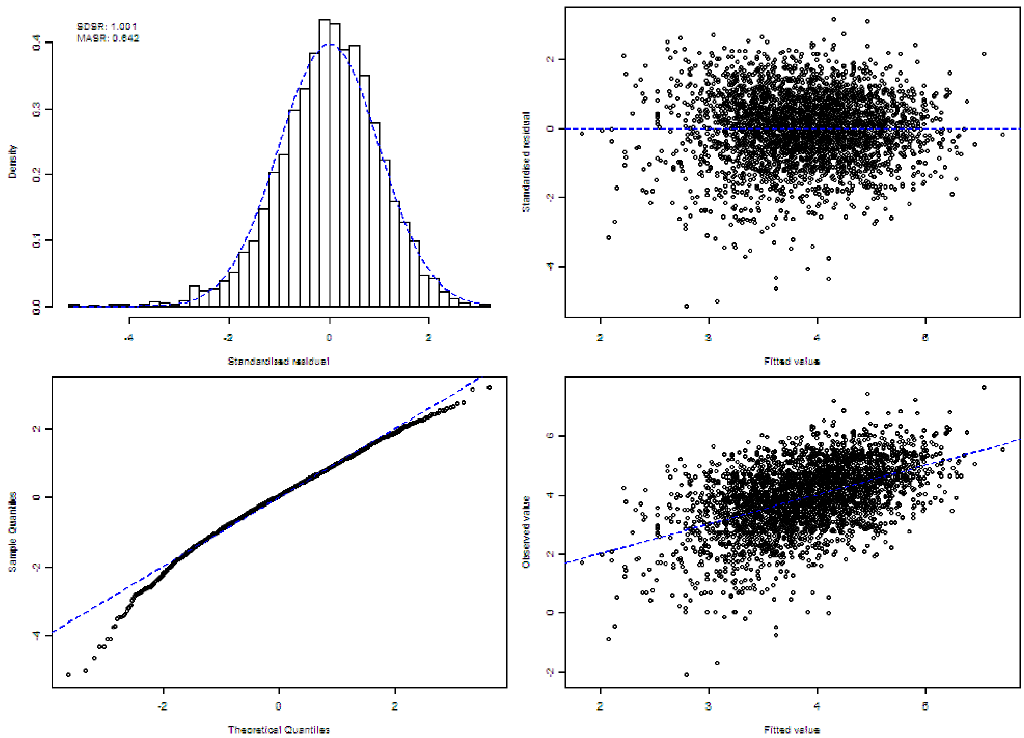


Figure E.5: Plots of the fit of the standardised CPUE model to successful catches of gurnard in the GUR 1 (BoP_CEL) fishery.

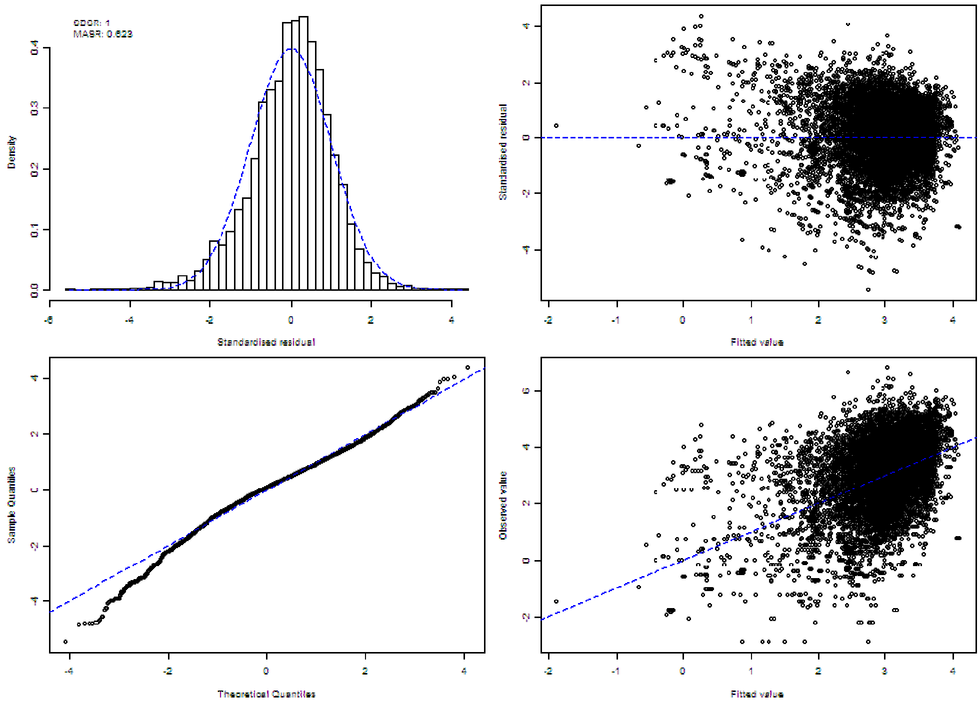


Figure E.6: Plots of the fit of the standardised CPUE model to successful catches of gurnard in the GUR 1 (BoP_TCE) fishery.

Appendix F. MODEL COEFFICIENT INFLUENCE PLOTS

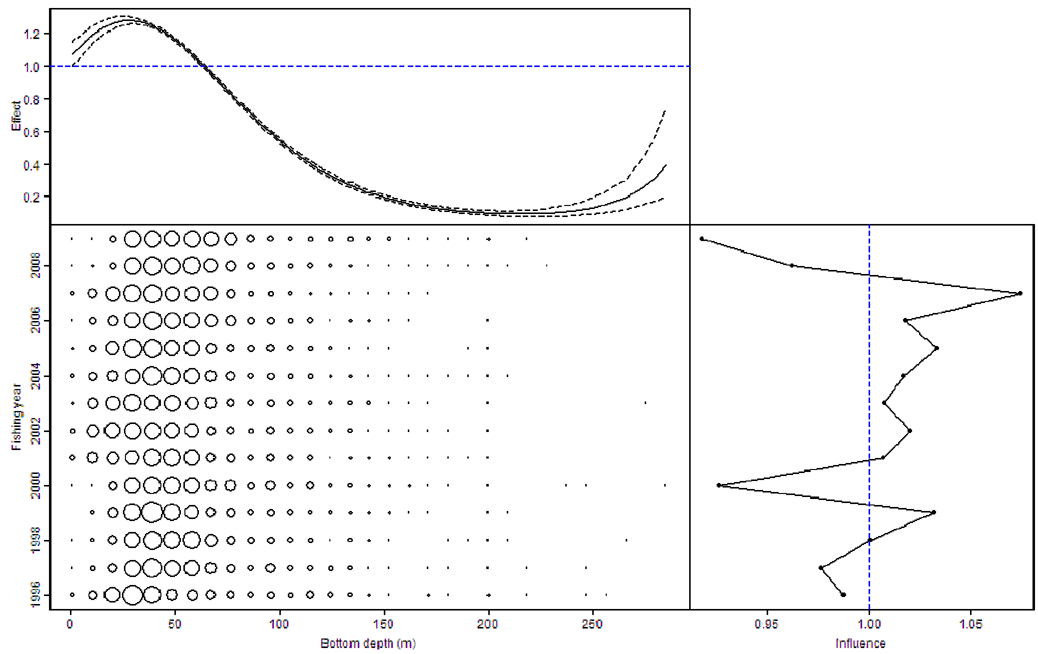


Figure F.1: Effect and influence of bottom depth in the W_TCP lognormal model. Top: relative effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

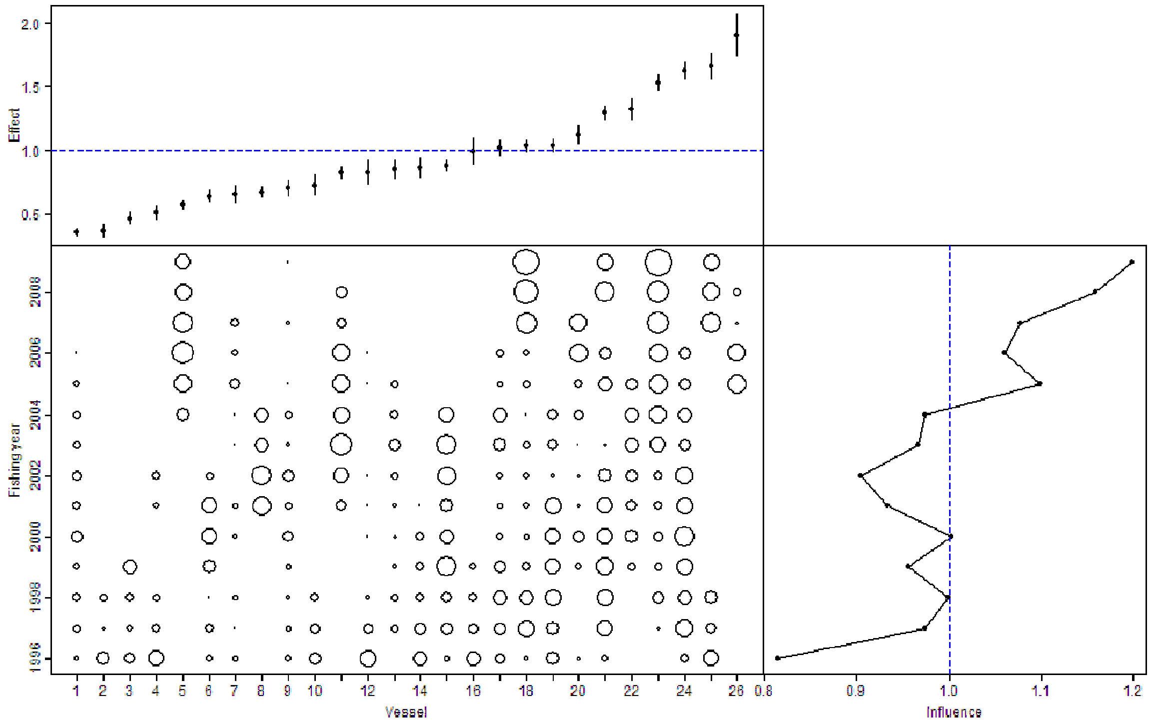


Figure F.2: Effect and influence of vessel in the W_TCP lognormal model. See caption of Figure F.1 for details.

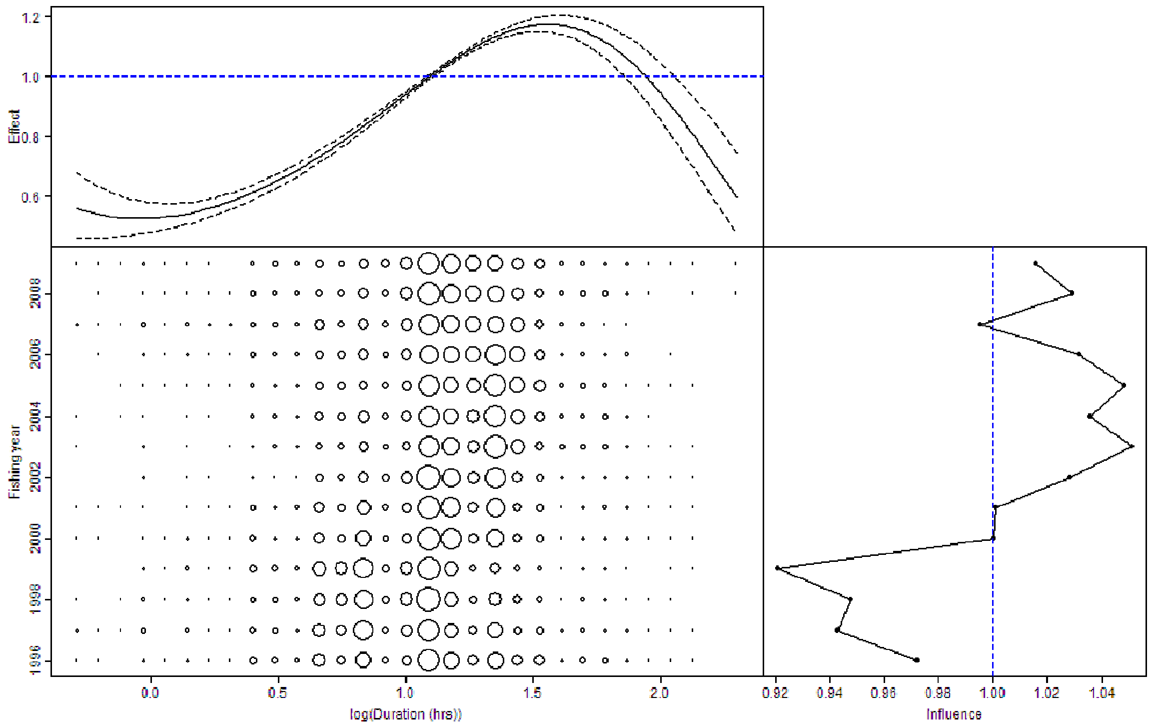


Figure F.3: Effect and influence of log of duration towed in the W_TCP lognormal model. See caption of Figure F.1 for details.

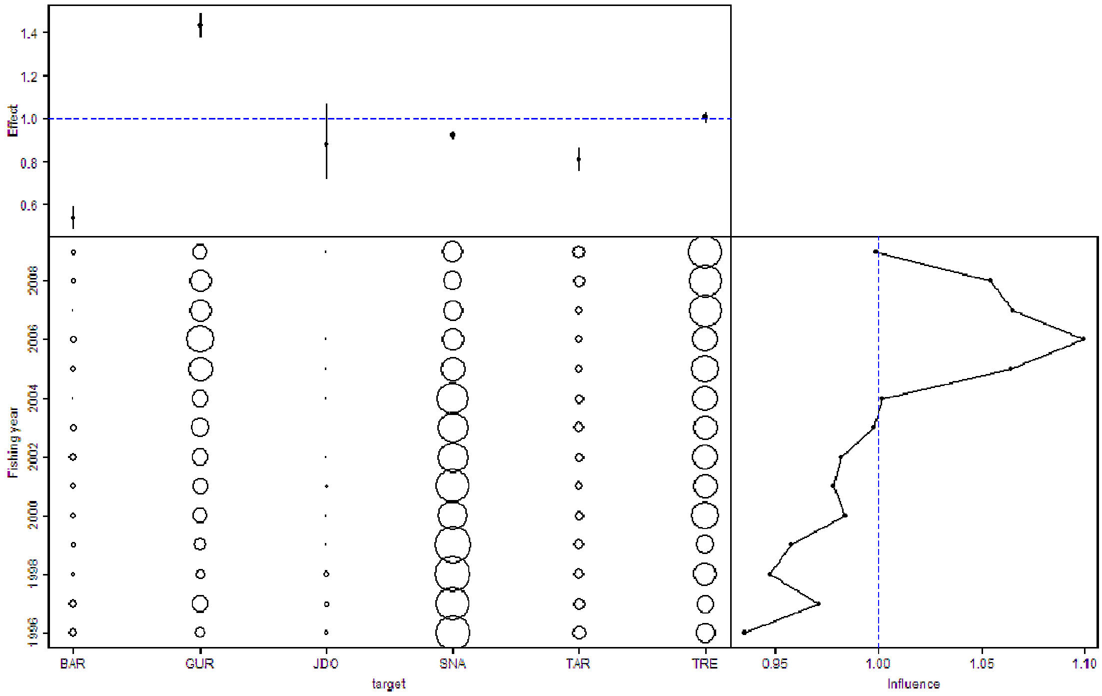


Figure F.4: Effect and influence of target species in the W_TCP lognormal model. See caption of Figure F.1 for details.

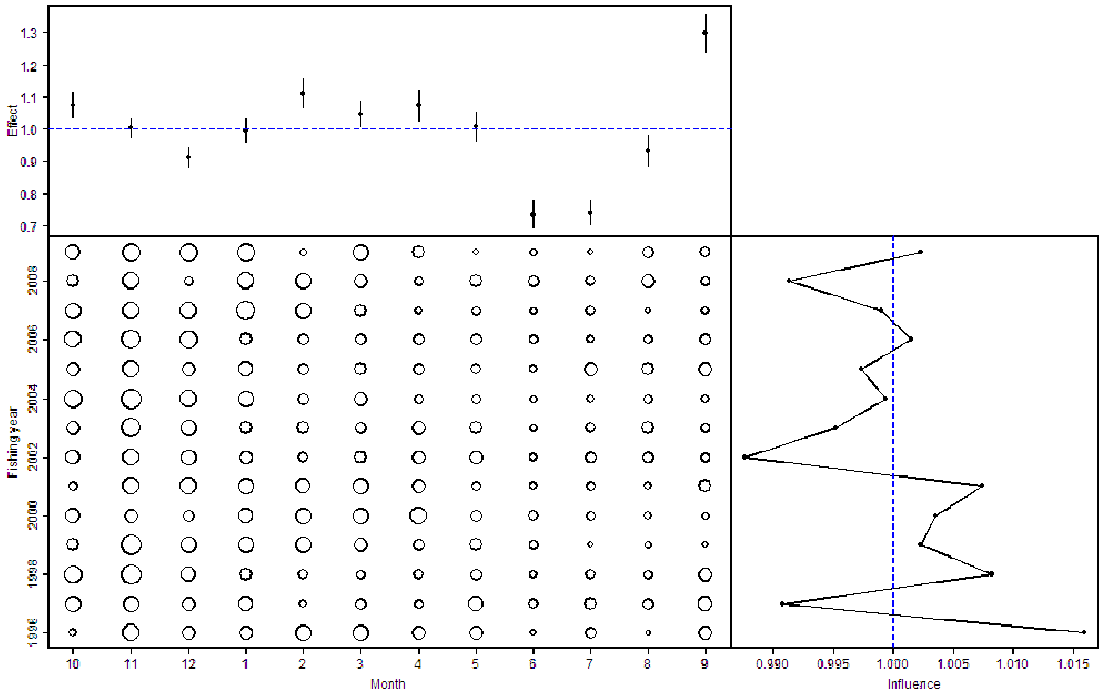


Figure F.5: Effect and influence of month in the W_TCP lognormal model. See caption of Figure F.1 for details.

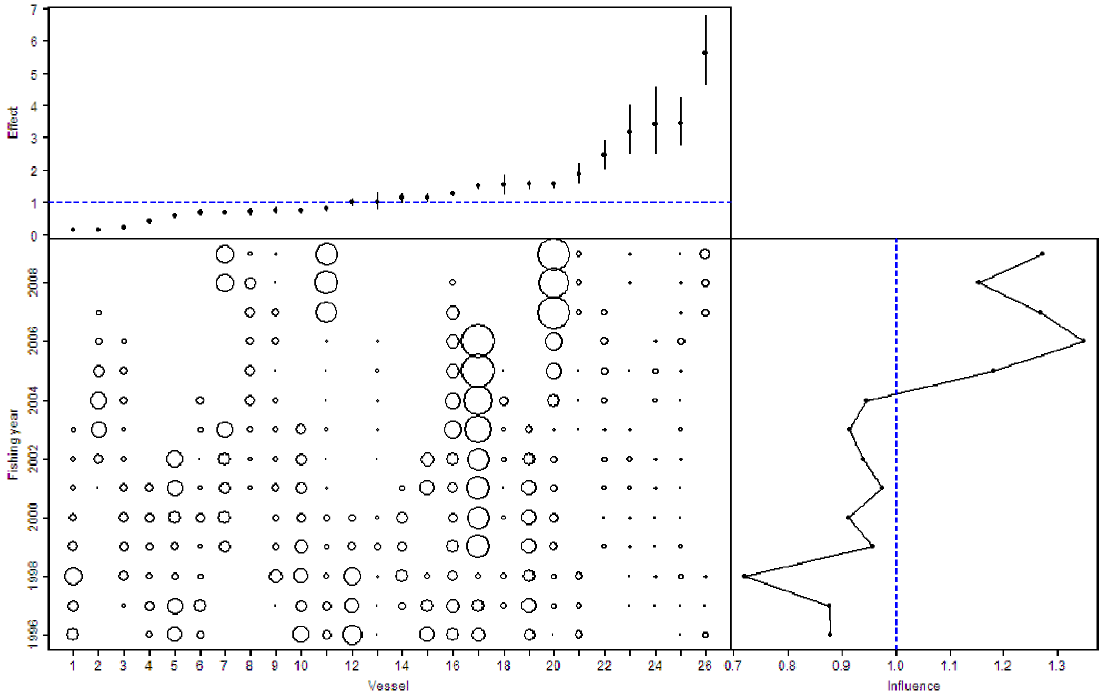


Figure F.6: Effect and influence of vessel in the E_TCP lognormal model. See caption of Figure F.1 for details.

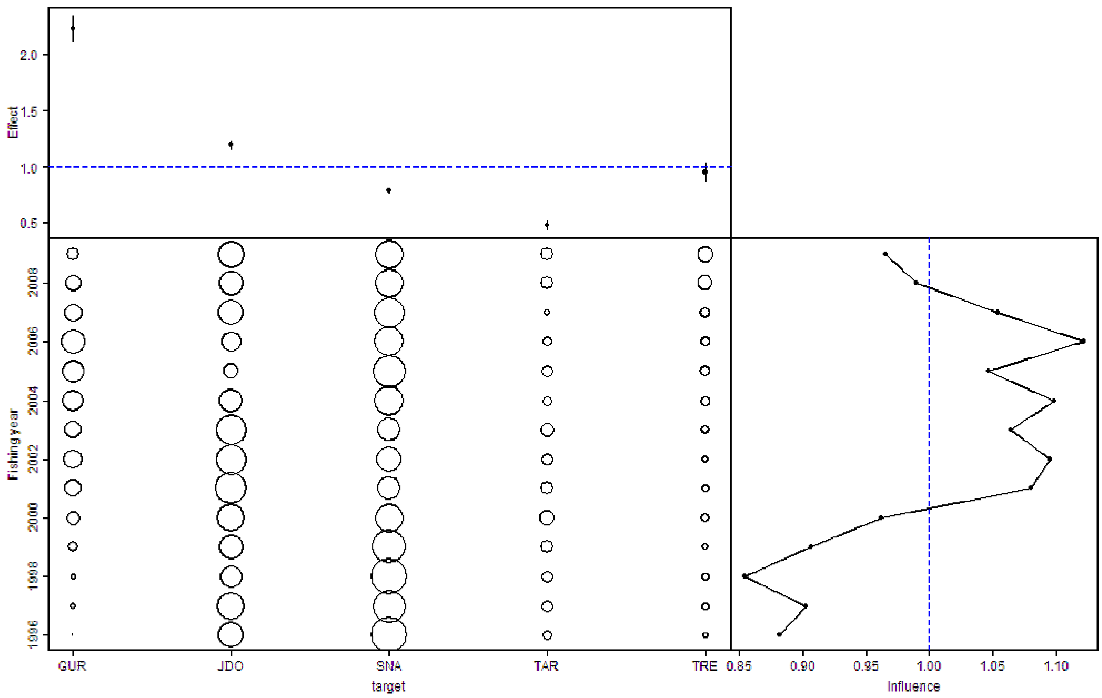


Figure F.7: Effect and influence of target species in the E_TCP lognormal model. See caption of Figure F.1 for details.

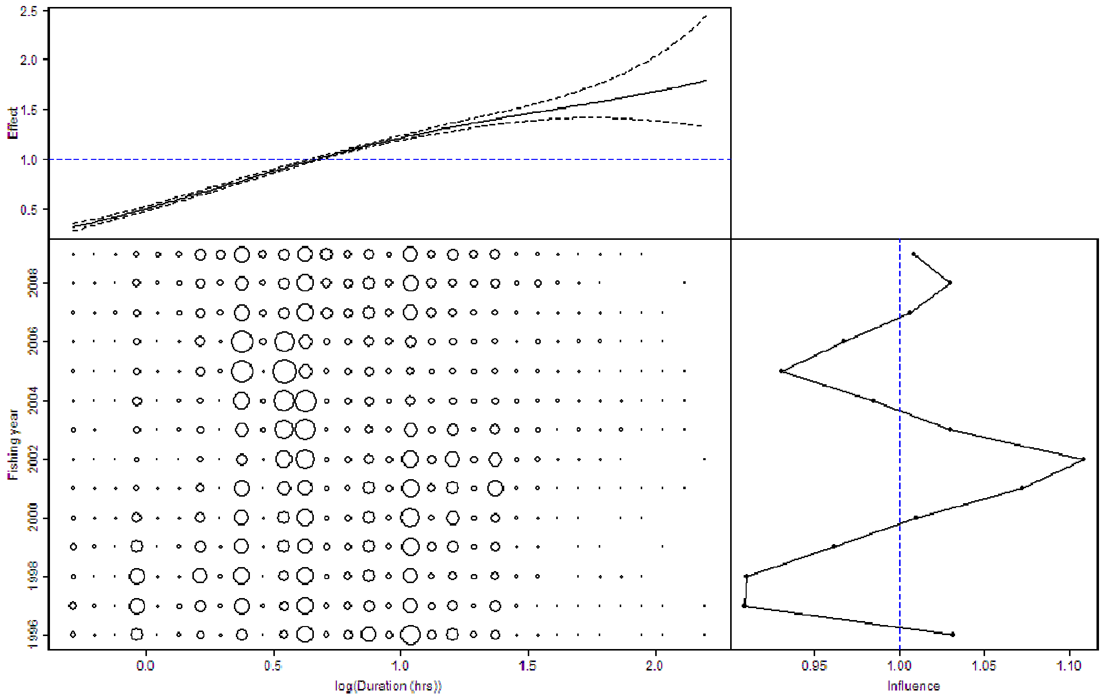


Figure F.8: Effect and influence of log of duration in the E_TCP lognormal model. See caption of Figure F.1 for details.

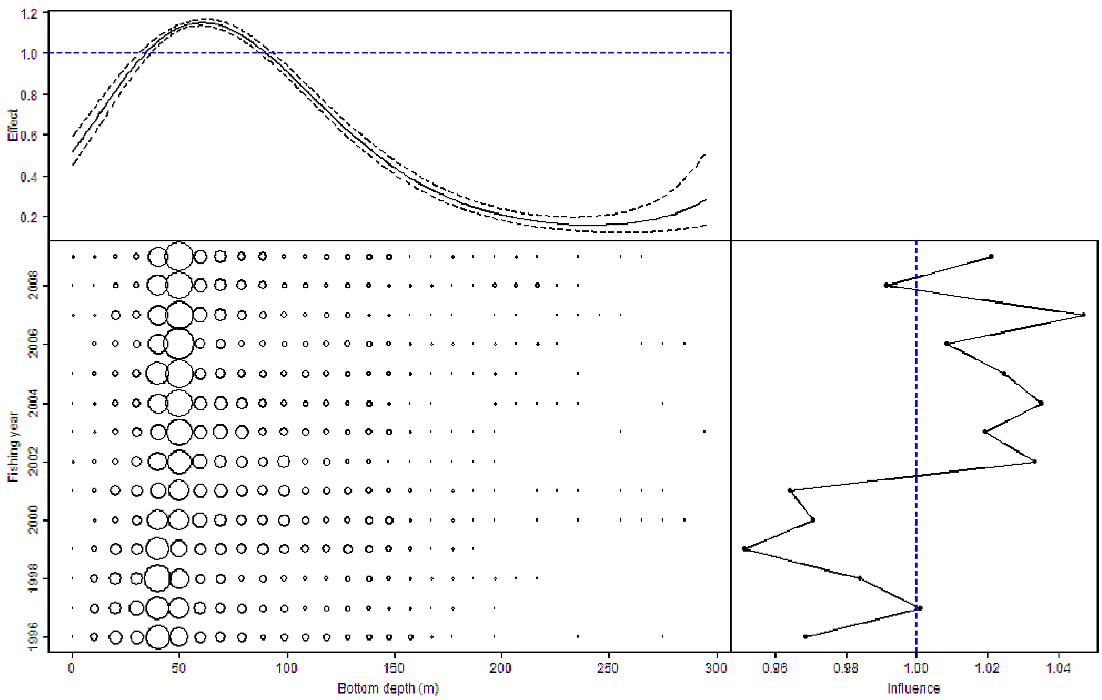


Figure F.9: Effect and influence of bottom depth in the E_TCP lognormal model. See caption of Figure F.1 for details.

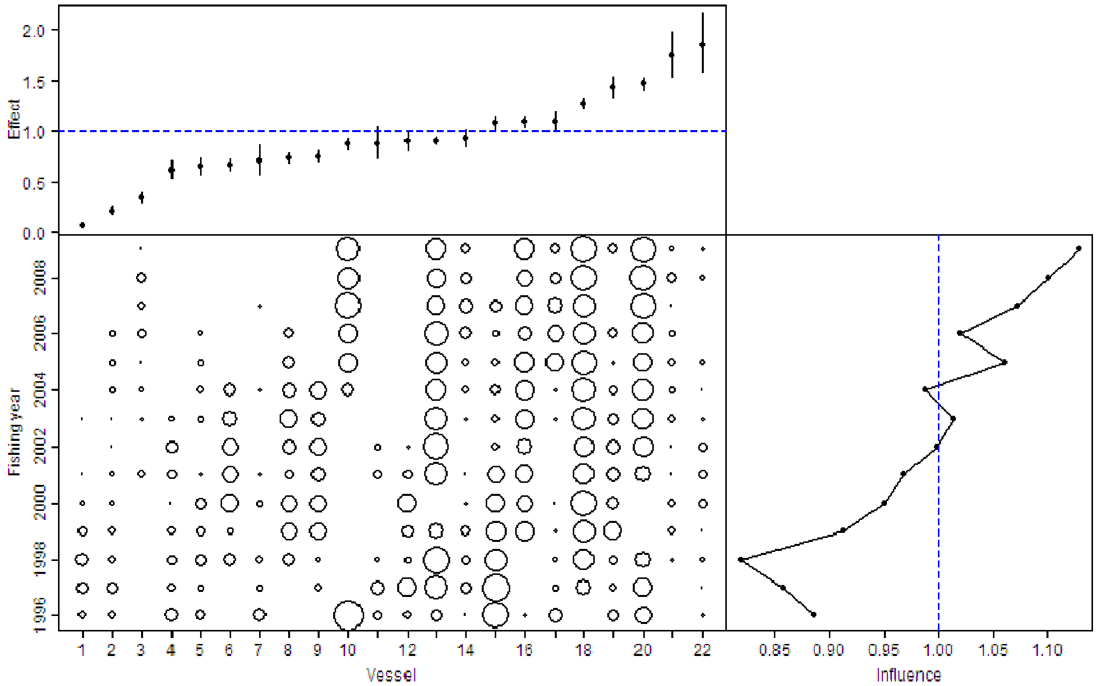


Figure F.10: Effect and influence of vessel in the BoP_TCP lognormal model. See caption of Figure F.1 for details.

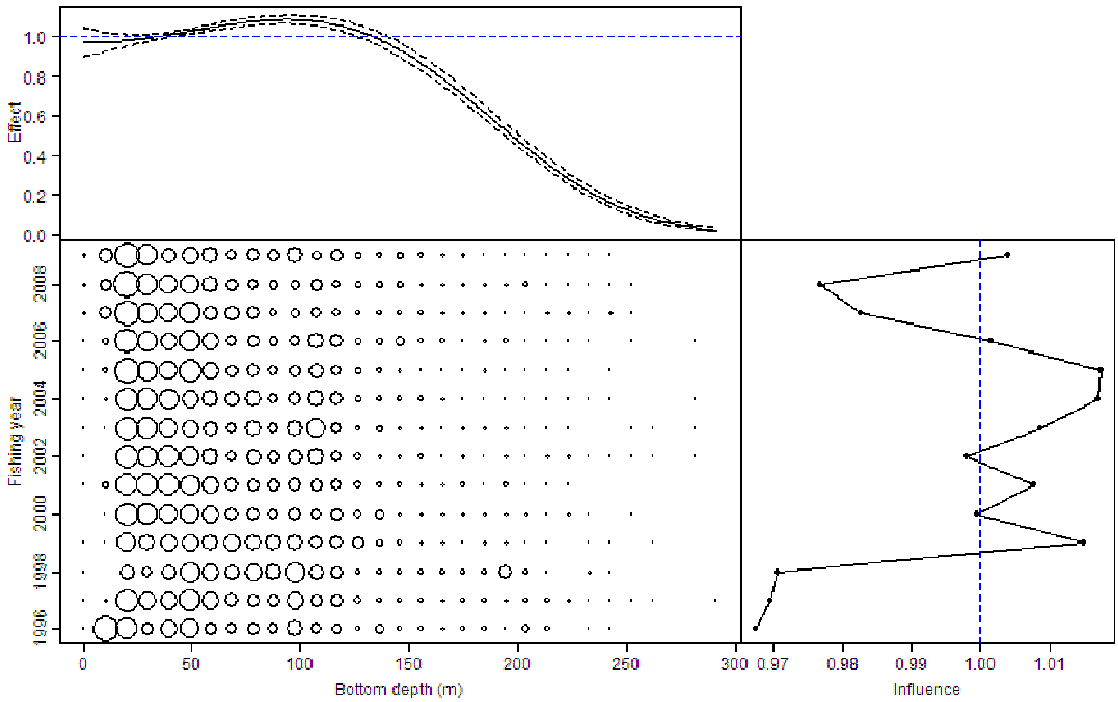


Figure F.11: Effect and influence of bottom depth in the BoP_TCP lognormal model. See caption of Figure F.1 for details.

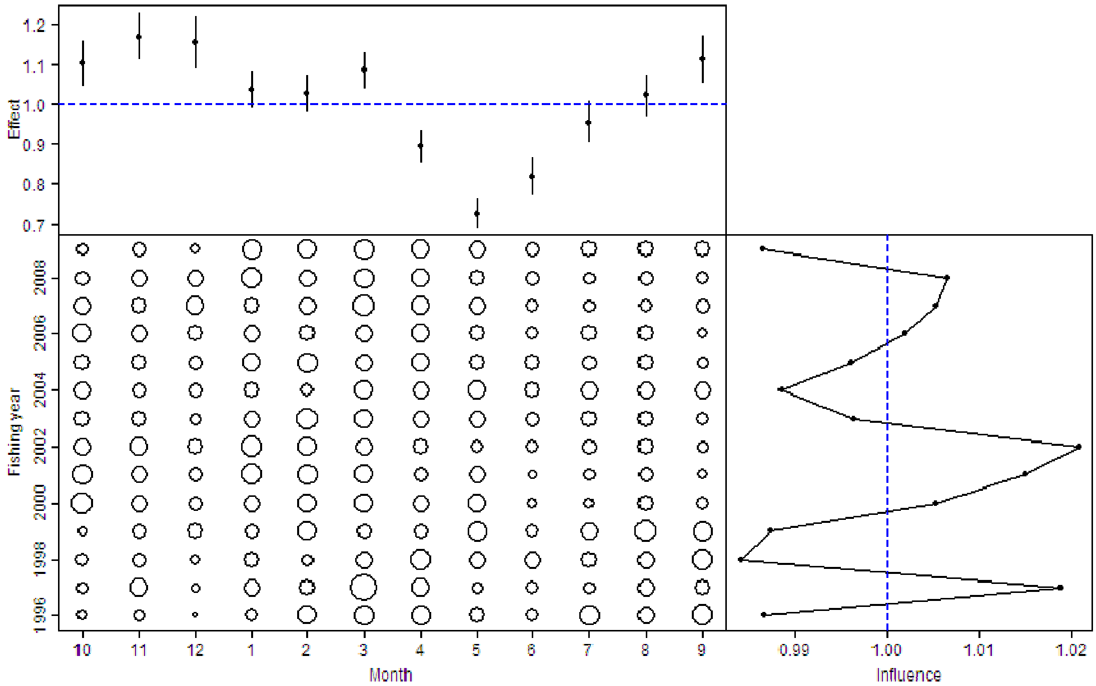


Figure F.12: Effect and influence of month in the BoP_TCP lognormal model. See caption of Figure F.1 for details.

Appendix G. CPUE INDICES

Table G.1: Measures of CPUE, and relative year effects and 95% confidence intervals for the CPUE models fitted to the (W_CEL) bottom trawl dataset for GUR 1. Core fleet only except where otherwise labelled.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation	Binomial standardisation	Combined standardisation
1989/90	0.836	0.847	0.855	0.949 (0.875-1.029)	0.836	0.943 (0.870-1.023)
1990/91	0.726	0.705	0.718	0.811 (0.750-0.877)	0.896 (0.854-0.926)	0.864 (0.799-0.934)
1991/92	0.818	0.834	0.723	0.804 (0.749-0.862)	0.892 (0.854-0.921)	0.852 (0.795-0.914)
1992/93	1.210	1.194	1.109	1.182 (1.112-1.257)	0.875 (0.833-0.907)	1.230 (1.157-1.307)
1993/94	1.022	1.017	0.904	0.970 (0.908-1.035)	0.885 (0.845-0.916)	1.020 (0.956-1.089)
1994/95	1.210	1.211	1.199	1.272 (1.186-1.365)	0.907 (0.870-0.935)	1.372 (1.279-1.472)
1995/96	1.247	1.245	1.312	1.325 (1.216-1.443)	0.897 (0.833-0.938)	1.412 (1.296-1.539)
1996/97	1.281	1.280	1.260	1.188 (1.088-1.298)	0.852 (0.706-0.933)	1.204 (1.102-1.315)
1997/98	0.914	0.913	1.004	0.941 (0.869-1.018)	0.813 (0.690-0.895)	0.910 (0.840-0.984)
1998/99	0.806	0.817	0.792	0.748 (0.689-0.812)	0.814 (0.707-0.888)	0.724 (0.667-0.786)
1999/00	0.934	0.948	1.029	0.848 (0.781-0.920)	0.775 (0.656-0.862)	0.781 (0.720-0.848)
2000/01	1.226	1.212	1.386	1.181 (1.049-1.329)	0.681 (0.450-0.848)	0.956 (0.850-1.076)

Table G.2: Measures of CPUE, and relative year effects and 95% confidence intervals for the CPUE models fitted to the (W_TCE) bottom trawl dataset for GUR 1. Core fleet only except where otherwise labelled.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation	Binomial standardisation	Combined standardisation
1995/96	1.002	0.894	0.685	0.916 (0.866-0.969)	0.624	0.773 (0.731-0.818)
1996/97	0.810	0.792	0.744	0.834 (0.800-0.870)	0.617 (0.581-0.651)	0.696 (0.668-0.726)
1997/98	0.718	0.702	0.699	0.782 (0.752-0.814)	0.634 (0.599-0.668)	0.671 (0.645-0.698)
1998/99	0.687	0.650	0.680	0.791 (0.757-0.826)	0.620 (0.582-0.656)	0.663 (0.635-0.693)
1999/00	0.740	0.741	0.791	0.861 (0.824-0.900)	0.692 (0.657-0.726)	0.807 (0.772-0.843)
2000/01	1.024	1.023	1.079	1.171 (1.125-1.218)	0.797 (0.769-0.823)	1.263 (1.214-1.314)
2001/02	1.125	1.131	1.220	1.313 (1.256-1.373)	0.825 (0.796-0.850)	1.466 (1.402-1.533)
2002/03	1.505	1.530	1.476	1.450 (1.387-1.515)	0.833 (0.805-0.858)	1.635 (1.564-1.708)
2003/04	0.977	1.023	1.106	1.122 (1.079-1.166)	0.778 (0.747-0.806)	1.181 (1.136-1.228)
2004/05	1.287	1.285	1.291	1.026 (0.985-1.069)	0.756 (0.722-0.788)	1.050 (1.008-1.095)
2005/06	1.337	1.335	1.426	1.163 (1.107-1.220)	0.816 (0.782-0.846)	1.284 (1.223-1.348)
2006/07	1.292	1.225	1.336	1.110 (1.057-1.165)	0.804 (0.768-0.835)	1.207 (1.150-1.267)
2007/08	1.128	1.275	1.278	1.072 (1.023-1.123)	0.826 (0.796-0.853)	1.198 (1.144-1.256)
2008/09	0.795	0.861	0.772	0.693 (0.657-0.730)	0.792 (0.756-0.823)	0.742 (0.703-0.782)

Table G.3: Measures of CPUE, and relative year effects and 95% confidence intervals for the CPUE models fitted to the (E_CEL) bottom trawl dataset for GUR 1. Core fleet only except where otherwise labelled.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation	Binomial standardisation	Combined standardisation
1989/90	1.071	1.014	0.939	1.380 (1.286-1.481)	0.769	1.533 (1.428-1.645)
1990/91	1.035	1.019	1.096	1.475 (1.379-1.577)	0.778 (0.748-0.805)	1.656 (1.549-1.771)
1991/92	1.235	1.211	1.097	1.391 (1.306-1.482)	0.779 (0.750-0.806)	1.566 (1.469-1.668)
1992/93	1.269	1.215	1.022	1.287 (1.203-1.377)	0.694 (0.657-0.729)	1.290 (1.206-1.380)
1993/94	0.805	0.816	0.759	0.835 (0.778-0.896)	0.646 (0.606-0.683)	0.778 (0.725-0.836)
1994/95	0.711	0.690	0.643	0.664 (0.610-0.724)	0.638 (0.593-0.680)	0.612 (0.561-0.667)
1995/96	0.997	1.008	0.973	0.673 (0.588-0.770)	0.701 (0.634-0.760)	0.681 (0.595-0.780)
1996/97	0.805	0.809	0.856	0.760 (0.652-0.886)	0.630 (0.556-0.699)	0.692 (0.593-0.807)
1997/98	1.117	1.128	1.360	1.142 (0.962-1.355)	0.643 (0.562-0.716)	1.060 (0.893-1.258)
1998/99	0.833	0.837	0.925	0.793 (0.681-0.924)	0.673 (0.596-0.742)	0.772 (0.663-0.899)
1999/00	0.991	1.125	1.003	0.817 (0.703-0.949)	0.583 (0.504-0.657)	0.687 (0.591-0.799)
2000/01	1.359	1.347	1.687	1.306 (1.112-1.534)	0.820 (0.746-0.876)	1.547 (1.317-1.816)

Table G.4: Measures of CPUE, and relative year effects and 95% confidence intervals for the CPUE models fitted to the (E_TCE) bottom trawl dataset for GUR 1. Core fleet only except where otherwise labelled.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation	Binomial standardisation	Combined standardisation
1995/96	0.489	0.476	0.290	0.375 (0.348-0.404)	0.411	0.301 (0.280-0.325)
1996/97	0.449	0.429	0.273	0.380 (0.356-0.405)	0.436 (0.409-0.464)	0.324 (0.304-0.346)
1997/98	0.516	0.487	0.293	0.534 (0.501-0.569)	0.477 (0.450-0.504)	0.499 (0.468-0.532)
1998/99	0.763	0.734	0.656	0.830 (0.782-0.881)	0.430 (0.403-0.458)	0.699 (0.658-0.742)
1999/00	0.825	0.858	0.812	0.954 (0.903-1.009)	0.469 (0.441-0.497)	0.876 (0.829-0.926)
2000/01	1.076	1.115	1.360	1.260 (1.193-1.330)	0.511 (0.482-0.539)	1.259 (1.193-1.330)
2001/02	1.419	1.418	1.819	1.546 (1.463-1.633)	0.549 (0.521-0.578)	1.664 (1.575-1.758)
2002/03	1.295	1.335	1.634	1.603 (1.506-1.707)	0.564 (0.532-0.595)	1.771 (1.663-1.886)
2003/04	1.572	1.548	1.462	1.383 (1.293-1.480)	0.469 (0.436-0.502)	1.270 (1.187-1.359)
2004/05	1.991	1.956	2.367	2.012 (1.880-2.154)	0.555 (0.521-0.588)	2.187 (2.043-2.342)
2005/06	1.783	1.748	2.394	1.626 (1.519-1.740)	0.548 (0.514-0.581)	1.744 (1.629-1.866)
2006/07	1.397	1.363	1.530	1.090 (1.018-1.168)	0.584 (0.553-0.616)	1.248 (1.165-1.337)
2007/08	1.056	1.109	1.306	1.124 (1.045-1.208)	0.647 (0.615-0.678)	1.424 (1.325-1.531)
2008/09	0.861	0.946	1.211	0.960 (0.892-1.034)	0.557 (0.524-0.590)	1.048 (0.973-1.128)

Table G.5: Measures of CPUE, and relative year effects and 95% confidence intervals for the CPUE models fitted to the (BoP_CEL) bottom trawl dataset for GUR 1. Core fleet only except where otherwise labelled.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation	Binomial standardisation	Combined standardisation
1989/90	0.904	0.861	1.056	1.376 (1.241-1.525)	0.755	1.372 (1.237-1.521)
1990/91	0.957	0.964	0.978	1.147 (1.054-1.249)	0.793 (0.754-0.826)	1.200 (1.103-1.307)
1991/92	1.172	1.224	1.186	1.203 (1.108-1.307)	0.791 (0.752-0.826)	1.257 (1.158-1.365)
1992/93	1.198	1.202	1.452	1.307 (1.205-1.417)	0.804 (0.765-0.838)	1.387 (1.279-1.504)
1993/94	1.028	1.040	1.262	1.206 (1.106-1.316)	0.793 (0.750-0.829)	1.262 (1.157-1.377)
1994/95	0.969	0.967	0.884	0.853 (0.769-0.946)	0.782 (0.731-0.825)	0.880 (0.794-0.976)
1995/96	0.665	0.677	0.616	0.729 (0.603-0.881)	0.745 (0.659-0.816)	0.717 (0.593-0.867)
1996/97	0.880	0.832	0.526	0.437 (0.371-0.515)	0.820 (0.753-0.872)	0.473 (0.401-0.558)
1997/98	1.182	1.159	1.313	1.176 (0.945-1.463)	0.709 (0.606-0.795)	1.101 (0.885-1.370)
1998/99	0.897	0.899	1.035	0.850 (0.723-1.000)	0.686 (0.602-0.759)	0.769 (0.654-0.905)
1999/00	0.869	0.876	0.727	0.809 (0.706-0.927)	0.646 (0.565-0.719)	0.690 (0.602-0.791)
2000/01	1.531	1.582	1.574	1.521 (1.236-1.871)	0.788 (0.694-0.859)	1.583 (1.287-1.947)

Table G.6: Measures of CPUE, and relative year effects and 95% confidence intervals for the CPUE models fitted to the (BoP_TCE) bottom trawl dataset for GUR 1. Core fleet only except where otherwise labelled.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation	Binomial standardisation	Combined standardisation
1995/96	0.795	0.834	0.709	0.817 (0.754-0.884)	0.551	0.741 (0.684-0.802)
1996/97	0.670	0.652	0.449	0.517 (0.483-0.553)	0.567 (0.526-0.607)	0.482 (0.450-0.516)
1997/98	0.950	1.034	0.694	0.868 (0.810-0.931)	0.544 (0.503-0.585)	0.778 (0.725-0.834)
1998/99	0.999	0.972	0.896	0.956 (0.903-1.013)	0.509 (0.471-0.547)	0.800 (0.756-0.848)
1999/00	0.880	0.888	0.783	0.800 (0.757-0.845)	0.531 (0.493-0.569)	0.698 (0.661-0.738)
2000/01	1.243	1.257	1.384	1.363 (1.293-1.436)	0.573 (0.535-0.611)	1.285 (1.220-1.354)
2001/02	1.198	1.166	1.277	1.224 (1.164-1.286)	0.605 (0.567-0.642)	1.219 (1.159-1.281)
2002/03	1.268	1.296	1.339	1.281 (1.223-1.342)	0.631 (0.595-0.666)	1.331 (1.271-1.394)
2003/04	1.052	1.115	1.264	1.241 (1.189-1.295)	0.664 (0.630-0.697)	1.356 (1.299-1.415)
2004/05	1.083	1.150	1.376	1.248 (1.196-1.302)	0.702 (0.669-0.732)	1.441 (1.381-1.503)
2005/06	0.884	0.895	1.044	0.994 (0.946-1.044)	0.654 (0.618-0.688)	1.069 (1.018-1.123)
2006/07	0.960	0.854	1.070	0.985 (0.933-1.040)	0.651 (0.614-0.686)	1.055 (0.999-1.114)
2007/08	1.069	0.959	1.037	0.934 (0.886-0.985)	0.699 (0.664-0.731)	1.074 (1.018-1.132)
2008/09	1.150	1.154	1.352	1.180 (1.121-1.241)	0.673 (0.638-0.706)	1.306 (1.241-1.374)

Appendix H. COMPARISON WITH PREVIOUS SERIES

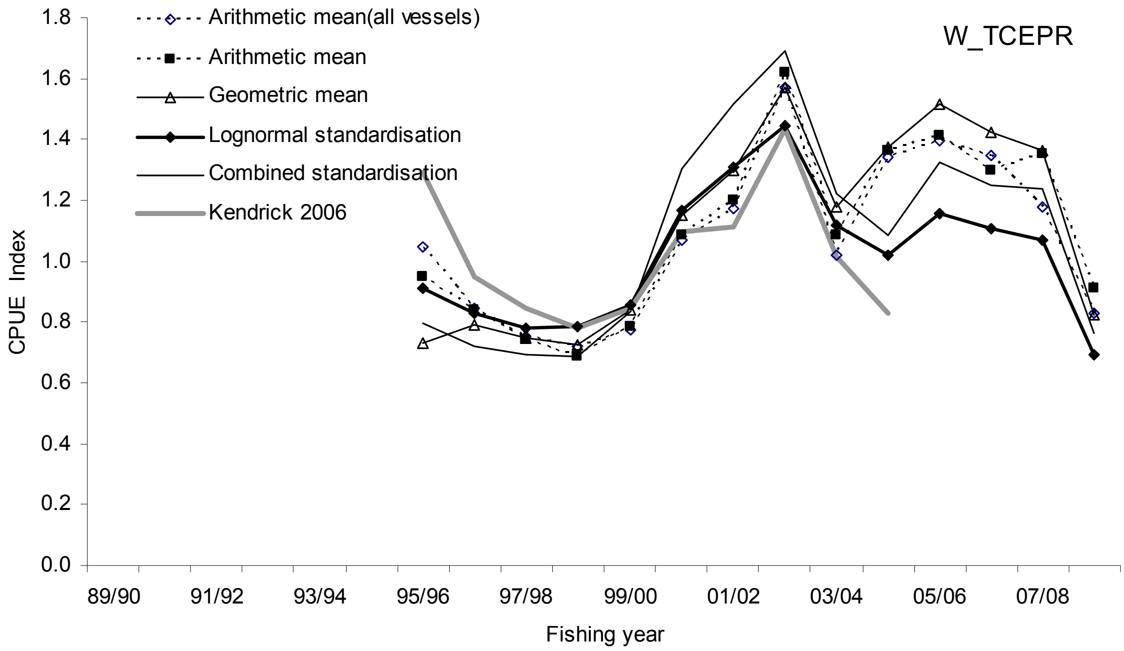


Figure H.1: Effect of core vessel selection, standardisation, and combining of annual lognormal and binomial annual indices for W_TCE. Unstandardised CPUE is based on kg/tow. Previous series from a similar model (Kendrick 2006) are overlaid for comparison. All series have been rescaled to the geometric mean of the years in common (1995–96 to 2004–05).

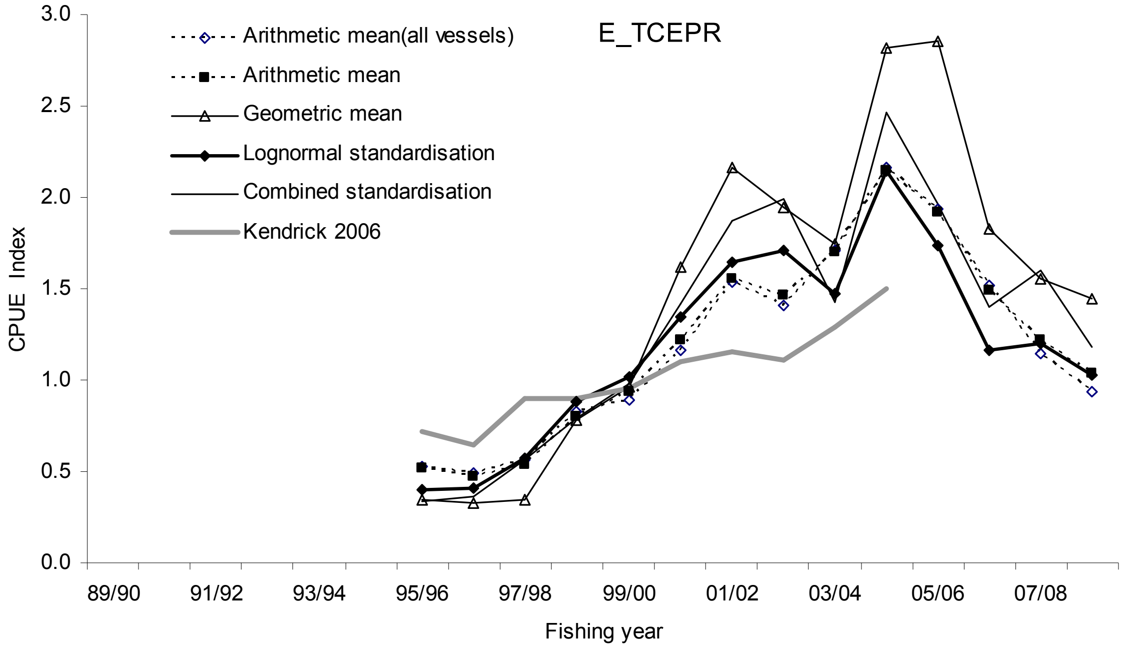


Figure H.2: Effect of core vessel selection, standardisation, and combining of annual lognormal and binomial annual indices for E_TCE. Unstandardised CPUE is based on kg/tow. Previous series from a similar model (Kendrick 2006) are overlaid for comparison. All series have been rescaled to the geometric mean of the years in common (1995–96 to 2004–05).

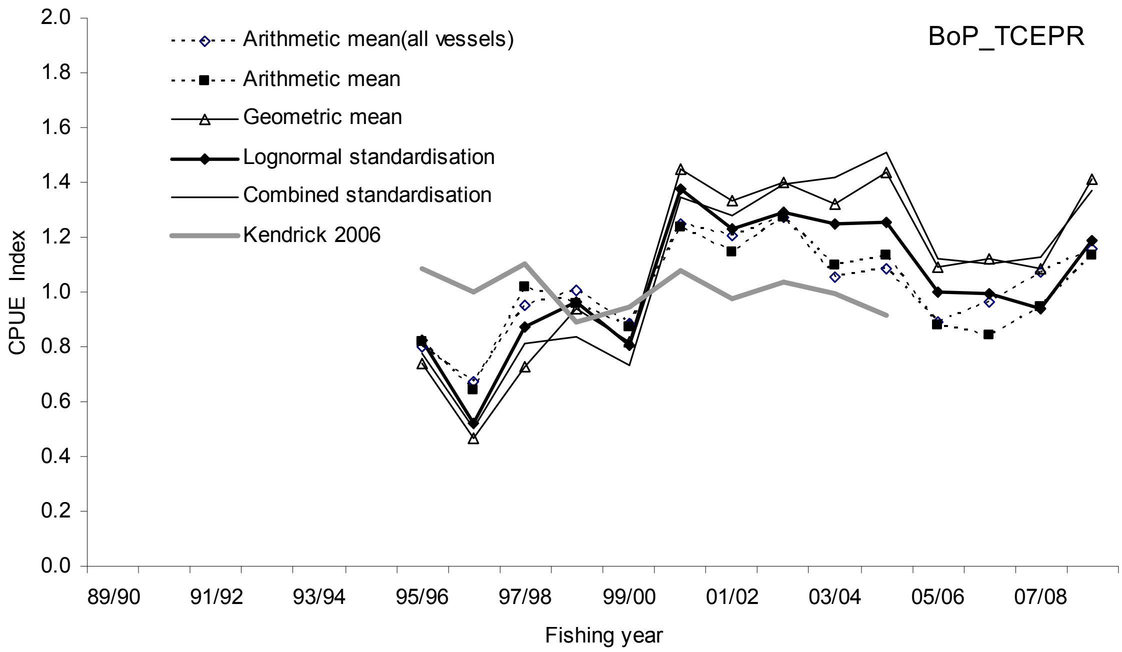


Figure H.3: Effect of core vessel selection, standardisation, and combining of annual lognormal and binomial annual indices for BP_TCE. Unstandardised CPUE is based on kg/tow. Previous series from a similar model (Kendrick 2006) are overlaid for comparison. All series have been rescaled to the geometric mean of the years in common (1995–96 to 2004–05)