New Zealand Fisheries
Assessment Report
2009/64
December 2009
ISSN 1175-1584 (print)
ISSN 1179-5352 (online)

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New Zealand Fisheries Assessment Report 2009/64
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Published by Ministry of Fisheries
Wellington
2009

ISSN 1175-1584 (print)
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New Zealand Fisheries Assessment Report 2009/64. 56 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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This study was contracted as MFish project TAR2007/01 with the general objective: To characterise the TAR 1 fishery and update the standardised CPUE indices for TAR 1 using data up to the end of the 2006-07 fishing year.

The characterisation was performed on landed greenweight of TAR 1 and confirms that tarakihi is a well reported and mostly targeted species in TAR 1. Almost half of the catch is taken from the Bay of Plenty substock in most years with the balance coming almost equally from the west and east coast substocks. Single bottom trawl is the most important fishing method accounting for more than 85% of landed TAR 1 in the west coast and Bay of Plenty substocks, but bottom longline is also important in the east coast, accounting for about 20% of landed TAR 1 in most years. Trawl caught tarakihi is mainly targeted with most of the balance being a bycatch of snapper in each of the three substocks, but also importantly a bycatch of trevally tows in the west coast substock. The characterisation highlights shifts in the way the fishery in the east coast substock has operated since 2003–04 when the dominant operator changed the emphasis from the previous seasonal fishery to providing a year round supply of tarakihi to the domestic market via the Auckland Fish Market.

The Inshore Stock Assessment Working Group agreed in 2005 that CPUE analysis of tarakihi in TAR 1 should best be conducted using estimated catch based on TCEPR data only, analysed at original tow-by-tow resolution, for the years from 1995–96 after which most trawl catch effort data were reported on that form. Reasons for this include the systematic shift in reporting from the daily CELR form to the tow-by-tow TCEPR form and the ambiguity of the fisher-nominated target species especially as used on the CELR form.

This study updates those TCEPR series with an additional three years of data and also provides ancilliary series for each substock for the earlier years 1989–90 to 1995–96 based on CELR data.

The west coast TCEPR series shows a decline from 1995–96 to 2004–05, but a recovery in the last two years that puts the 2006–07 index at just above the average for the series. There was little effect of standardisation until recent years, when the model attempts to correct for changes in the participating fleet, particularly the loss of some of the poorer performing vessels.

The east coast TCEPR series is flat overall, but the effect of standardisation is marked due to changes in recent years to targeting tarakihi outside historical areas, months, and depths, as well as significant changes in the core fleet.

The Bay of Plenty series is also flat overall but shows increased abundance over five years at the start of this decade that appears to be over. There was little effect of standardisation, indicating some consistency in the way this fishery has operated.

1. INTRODUCTION

Tarakihi is a valued species in the New Zealand coastal trawl fishery with a long history of exploitation. The main fishing method is trawling, and most of the catch is taken in targeted tows, but smaller amounts are also taken as a bycatch of snapper, trevally, John dory, and gemfish tows. TAR 1 includes FMAs 9 and 1 (west and east Northland) and FMA 2 (Bay of Plenty).

TAR 1 entered the QMS in October 1986 with a TACC of 1210 t which increased in small increments to 1399 t by the 2006–07 fishing year (Figure 1). Catches have exceeded the TACC in most years and from 1 October 2007 the TAC for TAR 1 was increased to 2029 t and the TACC was increased from 1399 to 1447 t.

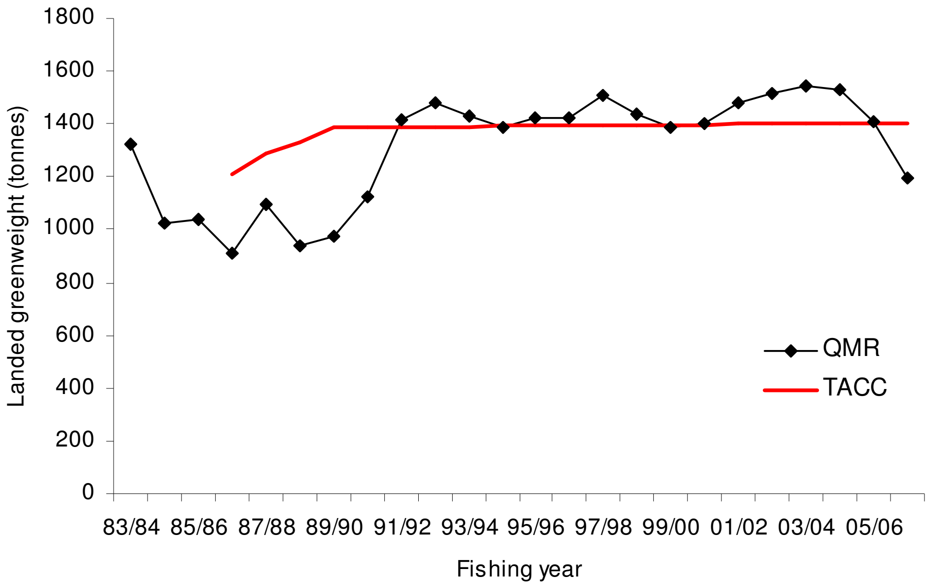


Figure 1: TACC and QMR landings (t) for TAR 1 (from MFish Plenary Report (2008)).

The estimates of relative abundance from the standardised CPUE analyses are currently the principal means of monitoring the state of the tarakihi fisheries. Given the extensive coverage of the fleet taking this species, CPUE should, in principle, be a reasonable indicator of the relative availability of this species over time if catch rate is affected by variations in tarakihi abundance.

Field & Hanchet (2001) provided standardised CPUE analyses for TAR 1 for 1989–90 to 1997–98, split into two areas, TAR 1 (west) and TAR 1 (east), at Cape Reinga. The indices were based on estimated catch from successful days only (with respect to tarakihi) in all single bottom trawl fisheries, including both target and bycatch data, with target species offered as a possible explanatory variable. They expressed concern that target species might not be consistently reported and should, to some degree, be ignored.

Kendrick (2006) provided standardised CPUE analyses for TAR 1 updated to 2003–04 and split into three substock areas; TAR 1 (east) being further divided into TAR 1 East, and Bay of Plenty. That study (MFish Project TAR2004-02), evaluated the utility of the Starr methodology (Starr 2007) for using landed rather than estimated catch to monitor tarakihi in a fishery that included both target and bycatch, but concluded that combining the data from the two catch effort form types, along with the amalgamation of data that the method requires, may introduce unnecessary bias into the analysis, particularly since the estimated catches tend to be very similar to the landed weights for this species.

The Starr methodology uses landed catch to offset genuine under-reporting that is a consequence of only being required to report the top five species as well as a tendency to visually underestimate catch. It does this by amalgamating records to the lowest level of aggregation valid for the CELR form type so that the two main formats (CELR and TCEPR) can be combined. The amalgamation of effort to trip-stratum is done on the basis of fisher-nominated *target species* as well as *fishing method* and *Statistical Area* within each trip.

The characterisation done for TAR2004-02 concluded that although there were well defined bottom trawl target fisheries for tarakihi in each of the three substock areas, a fundamental difference existed in the meaning of "target species" as recorded on the two form types, because fishers tend to lump all tows on a daily form into a single target species category while data collected on a tow-by-tow basis will possibly have more variation between target species. The systematic shift from the daily Catch Effort Landing Return (CELR) to the tow-by-tow Trawl Catch Effort Processing Return (TCEPR) over the study period appears to result in a biased CPUE trajectory.

One way of getting around this problem has been to use a wider range of fisher-nominated target species to identify relevant fishing activity. Several alternative fishery definitions were previously explored that included both target fishing for tarakihi as well as the bycatch of tarakihi when fishing for other species. These approaches resulted in different annual trends, which was attributed to the fisher's improved ability to specifically target species and which led the Working Group to view any increasing trajectories with caution.

Kendrick (2006) concluded that a (necessarily shorter) CPUE series based on TCEPR format data, and standardised for changes in bottom depth and tow distance (by incorporating tow speed information), was a defensible alternative to standardising for fisher-nominated field *target species*, and also allowed individual tows that encountered tarakihi to define effective effort with respect to tarakihi (rather than defining a fishery on the basis of *target species*). The TCEPR series did yield less optimistic trajectories, and were accepted by the Working Group.

This study updates the TCEPR series for each substock with an additional three years of data (1995–96 to 2006–07) based on positive estimated catches of tarakihi taken by single bottom trawl regardless of target species, and reported on TCEPRs. Anciliary series are also produced for each substock based on CELR data from the earlier years (1989–90 to 1999–2000).

2. DATA SOURCES AND METHODS

The characterisation for this study is done on landed greenweights of TAR 1 reported at the end of fishing trips on either 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), on the associated Catch Landing Return (CLR).

Landings were allocated to effort strata (that portion of a vessel-trip that uses a single fishing method within a single month and statistical area, targeted at just one species) proportionate to the estimated catch, or where there was none, to the number of fishing events. Landings were re-scaled in the dataset to equal the verified totals from Monthly Harvest Returns (MHR) or Quota Management Returns (QMR) before October 2001. The characterisation was done on an extract from the MFish catch effort database "*warehou*" that obtained all trip information associated with any landing of TAR 1.

The CPUE analyses are based on estimated catch from single bottom trawl events regardless of target species that reported a positive catch of tarakihi. The data are analysed in their original resolution, and separately for each form type.

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

Candidate trips were identified by searching for all landings to Fishstock TAR 1 or which fished using trawl gear in statistical areas valid for TAR 1 but did not land to TAR 1. Once trips that satisfied these criteria were identified, all effort and landing records associated with these trips were extracted.

Landings, estimated catch, and associated effort were all groomed separately before merging. Almost all TAR 1 were landed green (whole) to destination code L (landed to a licensed fish receiver in New Zealand). Outlier values in the landing data were identified by finding the trips with very high landings for tarakihi based on verified maximum 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 was also examined. 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.

Commonly transposed effort fields (such as number of hooks and number of sets for longline) were evaluated against each other and switched where the relation between them suggested they had been entered into the wrong field on the form. Other occasional outlier values (typos) in the effort data were identified by comparison with empirical distributions derived from the effort variable (duration or number tows), and where the values were in the extreme upper and lower tails of the distribution (a multiple of the 95th percentile value), they were replaced 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.

The allocation of landed catch to effort, performed for the characterisation section of the report, 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 were no estimated catches during the trip, the allocation was proportionate to the amount of effort, appropriate to the method used for the trip.

The data available for each trip included estimated and landed catch of tarakihi, 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 tarakihi from the straddling statistical area (041), or that used multiple fishing methods with incompatible measures of effort, were entirely dropped for the characterisation section of this report.

This method of using allocated landings retained more than 95% of landed TAR 1 for analysis in most years (the exceptions being 1989–90 and 2006–07). The estimated catch in the groomed dataset represented 84–94% of the allocated landings annually (Table 1, Figure 1). Total landed and estimated catch by trip are compared for each substock in Appendix A.

The allocated landed greenweights were then raised for each trip in the dataset to represent, when summed, the QMR annual totals used to describe the TAR 1 fisheries in the characterisation part of this study.

The CPUE analyses, however, were done on estimated catch and effort in original resolution.

Table 1: Comparison of TAR 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 tarakihi 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	Bottom of form (some edits)	Landed catch for analysis	Estimated catch in dataset	% analysis catch of QMR	% estimated catch of QMR	% estimated catch of analysis
89/90	1387	973	772.5	754.8	671.9	77.6	69.1	89.0
90/91	1387	1125	1155.7	1092.7	1026.9	97.1	91.3	94.0
91/92	1387	1415	1417.1	1363.8	1218.1	96.4	86.1	89.3
92/93	1397	1477	1451.5	1417.4	1251.8	96.0	84.8	88.3
93/94	1397	1431	1457.3	1424.1	1305.5	99.5	91.2	91.7
94/95	1398	1390	1375.8	1328.5	1202.1	95.6	86.5	90.5
95/96	1398	1422	1425.8	1353.2	1234.2	95.2	86.8	91.2
96/97	1398	1425	1376.3	1312.3	1241.9	92.1	87.1	94.6
97/98	1398	1509	1527.8	1415.8	1272.6	93.8	84.3	89.9
98/99	1398	1436	1435.0	1381.6	1182.9	96.2	82.4	85.6
99/00	1398	1387	1420.3	1356.1	1133.8	97.8	81.7	83.6
00/01	1398	1403	1407.0	1377.7	1187.5	98.2	84.6	86.2
01/02	1399	1480	1499.1	1451.8	1287.9	98.1	87.0	88.7
02/03	1399	1517	1505.4	1470.9	1253.7	97.0	82.6	85.2
03/04	1399	1541	1534.5	1494.2	1295.9	97.0	84.1	86.7
04/05	1399	1527	1525.3	1495.5	1322.1	97.9	86.6	88.4
05/06	1399	1409	1390.2	1330.8	1202.5	94.4	85.3	90.4
06/07	1399	1193	1181.4	1070.6	976.5	89.7	81.9	91.2

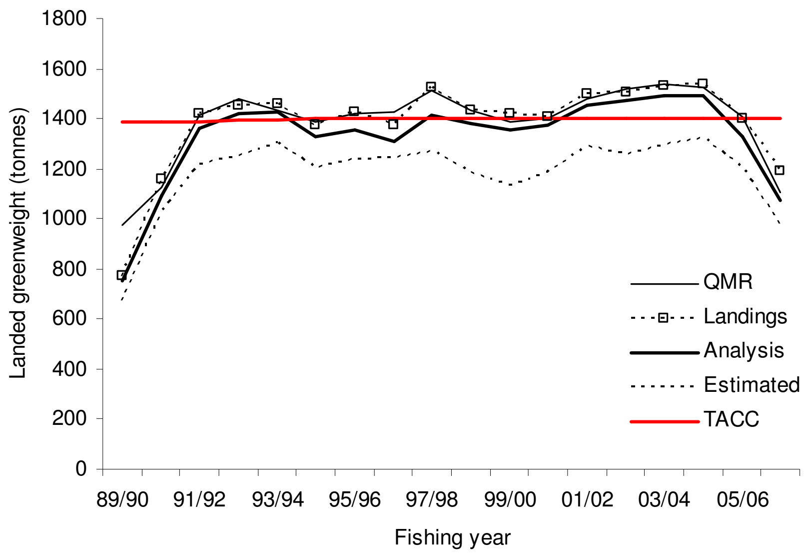


Figure 2: Plot of catch datasets presented in Table 1. The landings are totals reported on catch effort forms with some editing, the analysis dataset excludes all landings from trips that landed more than one tarakihi fishstock and fished in a straddling statistical area or that used multiple incompatible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

2.2. Substock areas

The three substocks used for descriptive and CPUE analysis, 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 TAR 1 substock areas used 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

2.3. Methods used for catch-per-unit-effort analysis

2.3.1. Landed greenweight versus estimated catch

The decision of whether to base the analysis of CPUE on estimated or landed catch is dependent primarily on whether CPUE is monitored in a target fishing or in a bycatch/mixed target fishery. The estimated catch of only the top five species in the catch is reported for a day's fishing on Catch Effort Landing Returns (CELRs), or for each individual tow 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. This means that species other than target species can not usually be reliably monitored using estimated catch.

Only the landings values, reported on the bottom part of the CELR, or on Catch Landing Returns (CLRs) respectively, represent total catches, but they are 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 (unique combinations of method/target/area) within that trip, using procedures that have become a standard approach where a species is monitored as a bycatch of other species or in a mixed target fishery that includes both target and bycatch (Starr 2007).

Generally it is advisable to use landed catch because even when a species is targeted or well reported, the estimated catch is likely to be biased towards a better representation of larger catches. However, the current methodology for using landed catch amalgamates effort to trip-strata resolution with a consequent loss of detail that must be evaluated in each case.

The previous study (Kendrick 2006) evaluated the Starr methodology for monitoring TAR 1, but reported increasing trends in the proportion of zero catches of tarakihi in each of the main bycatch fisheries (snapper and trevally tows) that contradicted increasing catch rates in the target fishery, and this was interpreted as evidence of improved targeting which could not adequately be accounted for in the standardised analysis given the level of detail available in CELR format data.

Subsequent investigation, however, suggests that the observed trends in encounter rate were probably an artefact of data amalgamation. The average number of tows included in a trip-stratum declined over the time series, partly as the result of better reporting practices, including the shift to TCEPR forms, but the trend is also inherent in the CELR format (Figure 3). This trend in the data roll-up can generate an apparent signal in the encounter rate because the smaller the number of events that are combined into one record, the greater the likelihood of the total catch being zero.

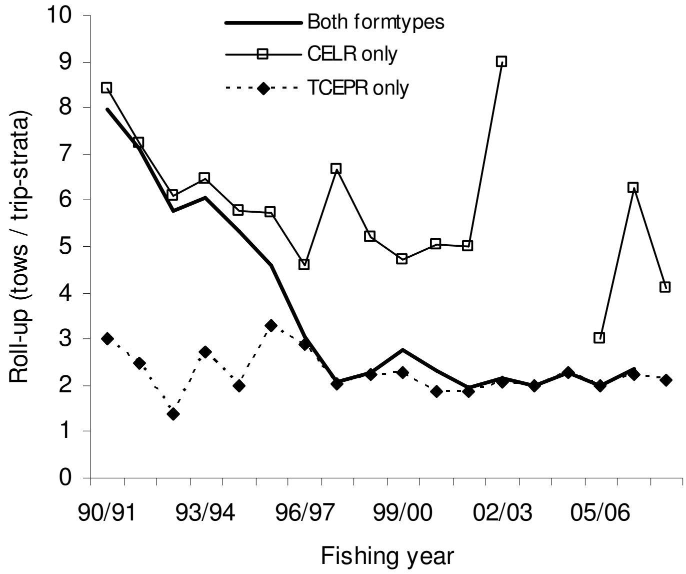


Figure 3: An example of trends in the amalgamation of data to trip-stratum using the Starr methodology for west coast target bottom trawl in TAR 1. The average number of tows per trip-stratum for each form type and for both form types combined.

Trends in data roll-up are not exclusively a function of the amalgamation procedures used in the Starr method (Starr 2007); they can also be inherent in CELR format data as is evident in the distribution of the underlying data for CELR models presented later in this report (see Appendix C). For other examples of a trend in the number of tows per record in CELR format data, the reader is referred to a CPUE analysis for TAR 3 (SeaFIC 2003).

The trends in data amalgamation may not be serious in themselves: they are not likely to affect catch rate estimates for example, but they are misleading in their effect on indicators such as success rate. The binomial models of success rate should be able to account for the effect of number of tows per record, unless it is seriously confounded with the year effect, as in this example.

The decision taken in 2005 to monitor TAR 1 in the more detailed TCEPR format data at original resolution eliminates much of the advantage of using the Starr methodology, and the TCEPR series updated here are based on estimated rather than landed catch.

Analysis of estimated catch (rather than allocated landings) is justified by the high reporting rate in this Fishstock (see Table 1), and by visual examination of plots of total estimated weight versus landed weights at trip resolution for each of the three substocks (Appendix A), in which there is no evidence of a trend in the underestimation of TAR 1. However, there is no reason why future work should not use a version of the Starr methodology to scale estimated catch up to landed greenweight without any amalgamation. The benefits would possibly not be great, but it would represent an attempt to address the potential bias in estimated catches in that they tend to be under-representative of smaller catches.

2.3.2. 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 (Starr 2007) 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 when analysing fisheries where there is a systematic shift in the data reporting format over time. In the northern inshore trawl fishery, there was such a shift from CELR daily reporting to TCEPR tow-by-tow reporting in the mid 1990s. This potentially causes a change in the depiction of effort explanatory variables (particularly "target species") which cannot be easily adjusted for using data amalgamation methods.

There is a tendency on CELRs to report mixed fishing practices in a single day of fishing, using a single target species. For example, Field & Hanchet (2001), when describing the TAR 1 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 tarakihi mix, and tows actively avoid tarakihi. Unfortunately, this level of detail is not always faithfully reported on the CELR form, being more often combined into a single daily record showing only one target species.

The reporting on TCEPRs is potentially better defined, with a nominal target species recorded for each individual tow.

In an earlier study of TAR 1, Kendrick (2006) reported catch rates for targeted tarakihi to be lower on CELRs than on TCEPRs, presumably because CELRs implicitly included non-TAR targeted effort, and, that as the proportion of data reported on TCEPRs increased, so too did the annual simple catch rate.

As an illustration, this simple analysis is repeated here using targeted bottom trawl in the west coast. A well defined target fishery can be expected to have very few genuine zero catches, and all specified effort should be considered to be effective. The unstandardised CPUE in this fishery expressed as total annual catch/total positive effort yields an optimistic trajectory that increases steadily from about 200 kg per tow in 1989–90 to nearer 800 kg per tow in 2006–07 (Figure 4).

Further breakdown of the CPUE in each year by form type, however, suggests that much of the apparent increase is the result of the systematic switch from daily reporting on CELR to reporting tow-by-tow on TCEPRs (Figure 5). Models that were offered form type did not give that variable significant explanatory power, probably because it was confounded with the year effect.

To address this concern (which is particular to the northern inshore trawl fishery), a shorter series of CPUE based on TCEPR format data was analysed for each trawl fishery, and the CELR data are analysed separately to provide an independent CPUE time series which is mainly applicable to the earlier years.

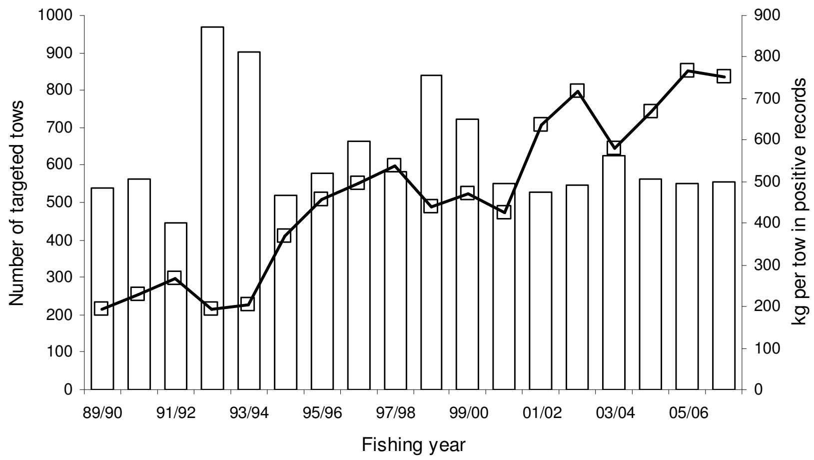


Figure 4: The number of positive tows (bars) and annual simple CPUE (kg/tow) of tarakihi caught in targeted bottom trawl tows in the west coast substock of TAR 1. Data in both TCEPR and CELR formats included.

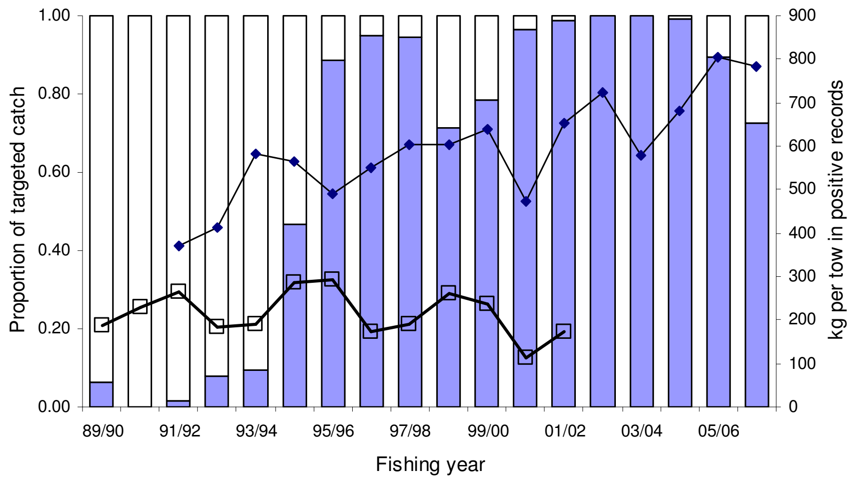


Figure 5: The simple ratios of total catch/total effort by form type for tarakihi caught in targeted bottom trawl tows in the west substock of TAR 1 and the proportion of the catch reported in each form type in each fishing year (light bars, CELR; dark bars, TCEPR) and in each fishing year.

2.3.3. Inclusion of zero catch information

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, include all the qualifying effort in the analysis dataset, and 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 from a binomial model of success rate.

Previous attempts (Kendrick 2006) to model success rate were not convincing, and one of the reasons is that, when using data derived from the CELR form, or data based on the TCEPR form that has been amalgamated, the zero catch information is not entirely captured in the binomial model because much of the zero catch information is already incorporated into the calculation of catch rates used in the lognormal part of the model. This is because amalgamated totals of catch and of effort include qualified but unsuccessful tows. The utility of the binomial model is further compromised if there is any trend in the data roll-up that confounds the year effect.

Following the decision to base the analyses on tow-by tow (TCEPR) data, the Working Group asked to see binomial models revisited in this study. This work was done but is not reported here. The definition of the fishery is tricky because it can include a lot of irrelevant (zero catch) effort, such as bottom trawl targeted at hoki, for example. For each substock, the binomial indices of the success rate of tows in trips that landed TAR 1 confirmed and exaggerated the pattern of indices from the associated TCEPR models of catch rate in successful tows. It was not considered defensible to combine them.

2.3.4. Defining fisheries

The fisheries in which TAR 1 is monitored are defined as positive (estimated catch of tarakihi) days (for CELR) or tows (for TCEPR) from bottom trawl trips in valid statistical areas, regardless of the target species recorded by the fisher on the effort part of the form. Data from trips that fished in the straddling statistical area (041) and only landed to TAR 1 were also included.

2.3.5. Core fleet definitions

The data sets used for the standardised CPUE analyses (summarised in Appendix F) were further restricted to those vessels that participated consistently 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 effect of these two variables on the amount of landed tarakihi retained in the dataset and on the number of core vessels is depicted for each dataset in Appendix G.

The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of tarakihi. This selection process generally reduced the number of vessels in the dataset by about 70% while reducing the amount of landed tarakihi catch by about 20%. Note that the vessels thus selected are not necessarily the top vessels with respect to catching tarakihi. The number of trips in each fishing year for the selected vessels and the distribution of the length of participation for the core vessels in each fishery are provided in Appendix H.

2.3.6. Models

A lognormal linear model was fitted to successful catches of TAR 1. Catches were standardised against variation in the explanatory variables using a stepwise multiple regression procedure, selecting until the improvement in model R^2 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 was the log of landed weight of TAR 1 per record (for the CELR series that meant for a successful day and for the TCEPR series that meant for a successful tow). The explanatory variables offered to the model included the categorical variables *fishing year* (always forced as the first variable), *month* (of landing), *statistical area*, *target species*, and a unique *vessel* identifier.

Continuous variables that were offered as third order polynomials included the total *number of tows* (CELR only) and total *duration* of fishing as alternative measures of effort to explain catch per trip. For models based on TCEPR data, *bottom depth*, tow *speed*, and *tow length* (calculated from *speed* and *duration*) were also offered.

3. RESULTS

On average, the Bay of Plenty has accounted for about 50% of landed TAR 1, with the balance coming almost equally in most years from the western and eastern substocks. However, landings from the Bay of Plenty have varied cyclically more than from the other two areas, with peaks in the early 1990s and early 2000s of almost twice that of the low years of (1989–90, 1990–00, and 2006–07), during which years landings from the three substock areas were almost equal (Table 3, Figure 6).

Table 3: Distribution of landed tarakihi by substock area and fishing year, in tonnes and percent, from trips which landed TAR 1 for 1989–90 to 2006–07. 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	245	312	417	25	32	43
90/91	208	314	603	19	28	54
91/92	232	405	778	16	29	55
92/93	329	311	837	22	21	57
93/94	290	320	821	20	22	57
94/95	358	348	684	26	25	49
95/96	388	368	665	27	26	47
96/97	392	433	601	27	30	42
97/98	386	479	644	26	32	43
98/99	440	393	603	31	27	42
99/00	440	446	501	32	32	36
00/01	380	353	670	27	25	48
01/02	369	306	805	25	21	54
02/03	406	234	877	27	15	58
03/04	344	241	956	22	16	62
04/05	408	374	747	27	24	49
05/06	308	423	679	22	30	48
06/07	351	243	509	32	22	46

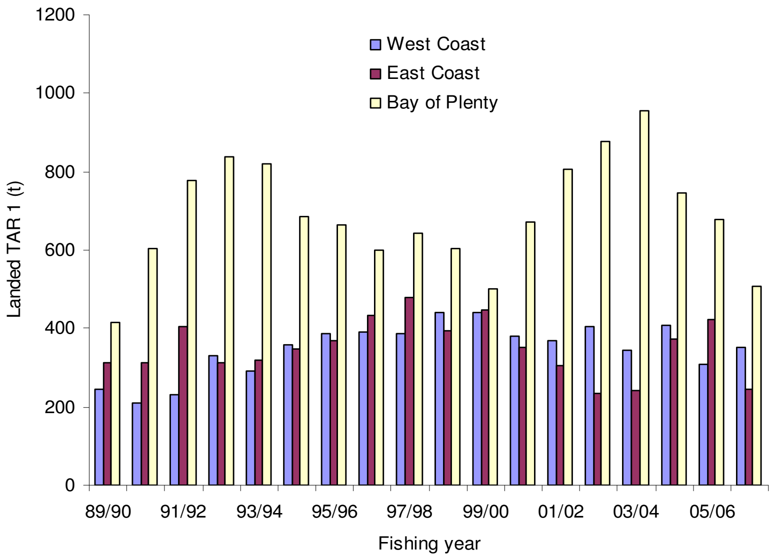


Figure 6: Landed catch of TAR 1 by substock area and fishing year.

3.1. Characterisation of the west coast TAR 1 fisheries

Generally more than 90% of the catch from the western areas in TAR 1 is taken by single bottom trawl, with most of the balance taken by pair trawl and small amounts in each year by bottom longline, setnet, and Danish seine (Table 4).

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

												West Coast
Fishing	Fishing method (t)						Fishing method (%)					
year	BT	BPT	BLL	SN	DS	Other	BT	BPT	BLL	SN	DS	Other
89/90	229	14	0	-	0	1	94	6	0	-	0	0
90/91	187	18	-	-	0	3	90	9	-	-	0	1
91/92	224	5	1	-	0	1	97	2	1	-	0	0
92/93	314	9	5	0	0	1	95	3	1	0	0	0
93/94	271	14	3	0	0	2	94	5	1	0	0	1
94/95	347	7	4	0	0	0	97	2	1	0	0	0
95/96	371	9	6	1	1	0	96	2	2	0	0	0
96/97	383	3	2	0	3	0	98	1	1	0	1	0
97/98	379	2	2	0	4	0	98	0	0	0	1	0
98/99	395	39	3	0	3	0	90	9	1	0	1	0
99/00	392	37	8	0	2	0	89	8	2	0	0	0
00/01	297	57	18	2	6	0	78	15	5	1	1	0
01/02	350	2	8	9	1	0	95	1	2	2	0	0
02/03	372	16	12	6	2	0	92	4	3	1	0	0
03/04	294	27	5	13	2	3	85	8	2	4	1	1
04/05	363	34	5	5	1	0	89	8	1	1	0	0
05/06	271	8	11	11	2	4	88	3	4	4	1	1
06/07	285	42	13	4	2	6	81	12	4	1	1	2

3.1.1. West coast bottom trawl

The bottom trawl catch is mostly targeted, but was reported more often (10–30%) as a bycatch of snapper tows during the first half of the time series than it was after about 1996–97 (5–12%). Bycatch from trevally targeted tows has fluctuated between 3 and 15% of annual tarakihi catch, and small amounts have also been taken as a bycatch of barracouta and gurnard fisheries in most years. A gemfish fishery landed about 10–20 t of TAR 1 annually between 1994–95 and 1999–2000, but had largely disappeared by 2003–04 with the drop in the SKI 1 TACC (Table 5, **Figure 7**).

The seasonality of the four most important target fisheries taking TAR 1 by bottom trawl is shown in Figure 8. Targeting of tarakihi occurs throughout the year, but the largest catches are taken between February and May. Although snapper targeted tows used to land tarakihi consistently throughout the year (during the early 1990s), bycatch from this fishery since 1996–97 has been outside the main tarakihi target season. The bycatch from trevally targeted tows comes mainly from the first half of the fishing year, and the bycatch from barracouta targeted tows are almost entirely from the last half of the fishing year.

The spatial distribution of the four main target fisheries is similar (Figure 9), with most tarakihi caught in Area 047, followed by Areas 046 and 045. Targeted catches of tarakihi increased in Area 046 up to 2001–02 but then declined, and have varied from year to year in Area 045. Areas 043 and 044 are harbours that are protected from commercial trawling and are not included. When snapper bycatch was higher (in the early 1990s), it came largely from Areas 047 and 045. Bycatch from trevally and barracouta target fishing is more evenly distributed, though Area 047 still dominates.

While there is almost certainly some blurring of the definition of target species, as evidenced by the shift away from tarakihi being reported as a bycatch of snapper, these distributional plots do suggest a well defined target fishery for tarakihi in this area, especially in the last half of the time series. There is a definite seasonal peak from February to May, during which little bycatch is reported, and catches of tarakihi from other fisheries have quite different seasonal, and in some cases, spatial distributions. The depth distribution of tows nominally targeted at tarakihi in this substock is centred closely around 130–140 metres (Figure 10) and suggests consistent targeting behaviour with respect to depth.

There has been a complete shift from reporting on the daily CELR form to tow-by-tow reporting on TCEPRs in the western substock. In 1989–90 most (90%) of TAR 1 was reported on CELRs, while by 1995–96 almost 90% of tarakihi was reported on TCEPRs, and by 2003–04 it was almost 100% (Table 6). Some recent changes in the fleet have seen a reversal of that trend with 33% of tarakihi catch reported on CELRs trend in 2006–07 (Table 6).

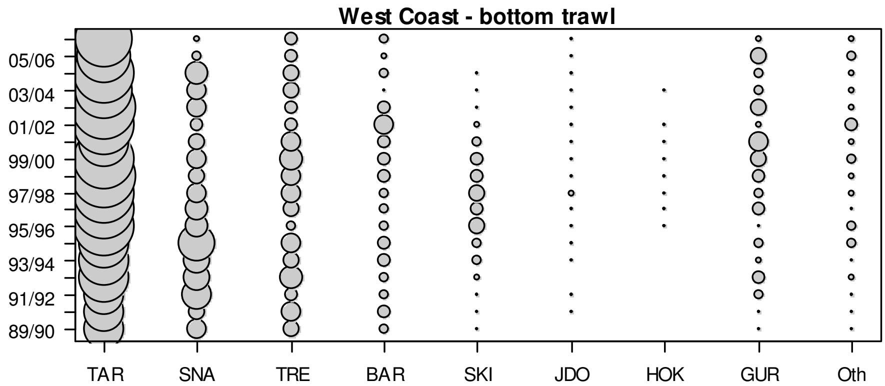


Figure 7: Distribution of bottom trawl caught tarakihi for the west coast substock area by target species and fishing year. Circle areas are proportional to the catch totals by area, with the circle values given in Table 5.

Table 5: Distribution of bottom trawl caught tarakihi by target species (tarakihi, snapper, trevally, barracouta, tarakihi, John dory, and other) and by fishing year for the west coast substock of TAR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0, less than 0.5 tonne. – none reported. Percentages sum to 100 by year.

																		West coast bottom trawl
Fishing	Target species (t)									Target species (%)								
year	TAR	SNA	TRE	BAR	SKI	JDO	HOK	GUR	Other	TAR	SNA	TRE	BAR	SKI	JDO	HOK	GUR	Other
89/90	152	40	23	10	1	-	-	0	2	66	17	10	4	1	-	-	0	1
90/91	124	21	28	13	1	0	-	1	0	66	11	15	7	0	0	-	1	0
91/92	127	65	15	7	2	0	-	8	0	56	29	7	3	1	0	-	4	0
92/93	187	58	44	8	3	0	-	11	2	60	18	14	3	1	0	-	4	1
93/94	173	50	20	15	8	0	-	3	1	64	18	7	6	3	0	-	1	1
94/95	187	100	26	12	10	0	-	6	6	54	29	7	3	3	0	-	2	2
95/96	286	42	10	8	18	1	0	1	6	77	11	3	2	5	0	0	0	2
96/97	282	41	22	10	13	0	1	12	1	74	11	6	3	3	0	0	3	0
97/98	268	35	35	9	19	2	1	7	2	71	9	9	2	5	1	0	2	1
98/99	292	25	26	17	14	0	0	17	4	74	6	7	4	4	0	0	4	1
99/00	270	27	44	14	11	0	1	19	6	69	7	11	4	3	0	0	5	2
00/01	191	19	33	16	7	1	1	26	3	64	7	11	5	2	0	0	9	1
01/02	268	16	15	33	2	1	0	3	12	77	5	4	9	1	0	0	1	3
02/03	291	27	12	12	2	2	0	23	2	78	7	3	3	0	0	0	6	1
03/04	231	28	19	1	0	1	0	9	5	79	9	6	0	0	0	0	3	2
04/05	277	43	21	10	0	1	-	10	2	76	12	6	3	0	0	-	3	1
05/06	221	7	12	3	-	1	0	22	6	81	3	4	1	-	0	0	8	2
06/07	249	3	16	7	-	0	-	5	4	87	1	6	3	-	0	-	2	1

Table 6: Change in reporting practice in the west coast bottom trawl fishery. The percent of bottom trawl-caught TAR 1 (by landed weight) and percent of effort (tows) reported on the daily form (CELR) and on the tow-by-tow form (TCEPR) by fishing year.

Fishing	Greenweight (%)		Effort (%)	
Year	CELR	TCEPR	CELR	TCEPR
89/90	90	10	93	7
90/91	97	3	95	5
91/92	98	2	88	12
92/93	94	6	80	20
93/94	90	10	84	16
94/95	63	37	64	36
95/96	13	87	23	77
96/97	5	95	11	89
97/98	7	93	17	83
98/99	26	74	28	72
99/00	18	82	27	73
00/01	8	92	17	83
01/02	1	99	12	88
02/03	3	97	11	89
03/04	0	100	2	98
04/05	1	99	3	97
05/06	6	94	13	87
06/07	33	67	10	90

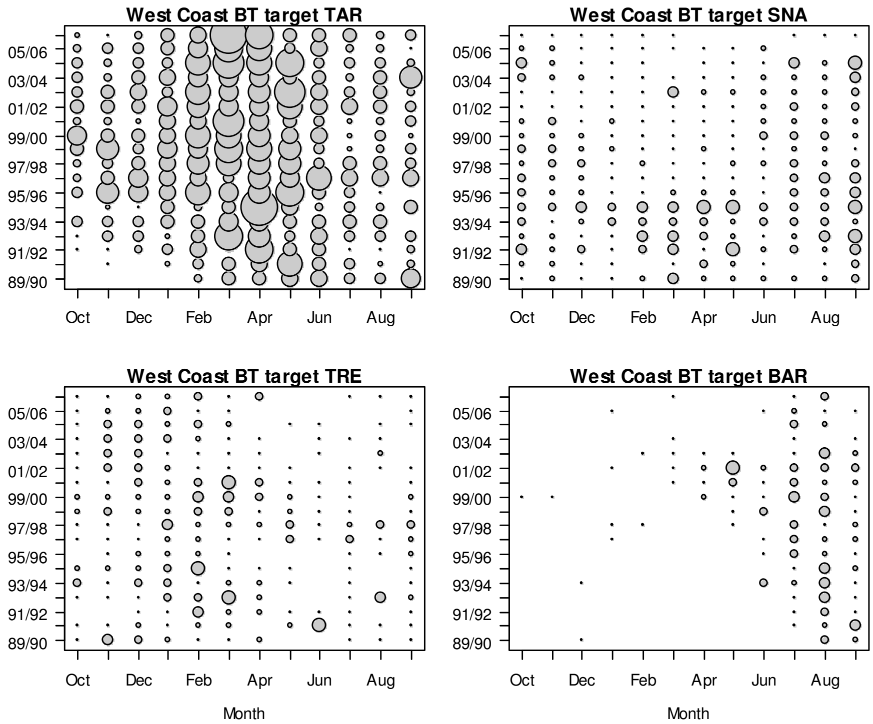


Figure 8: Comparison of the seasonal distribution of bottom trawl tarakihi catches for the four main target fisheries taking TAR 1 from the west coast substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 5.

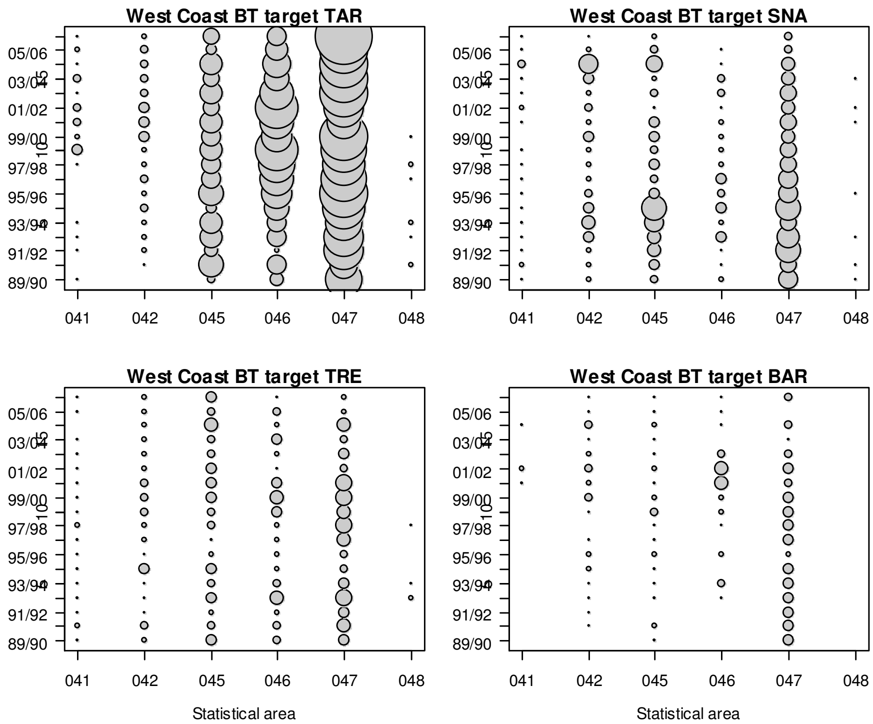


Figure 9: Comparison of the areal distribution of bottom trawl tarakihi catches for the four main target fisheries taking TAR 1 from the west coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 5.

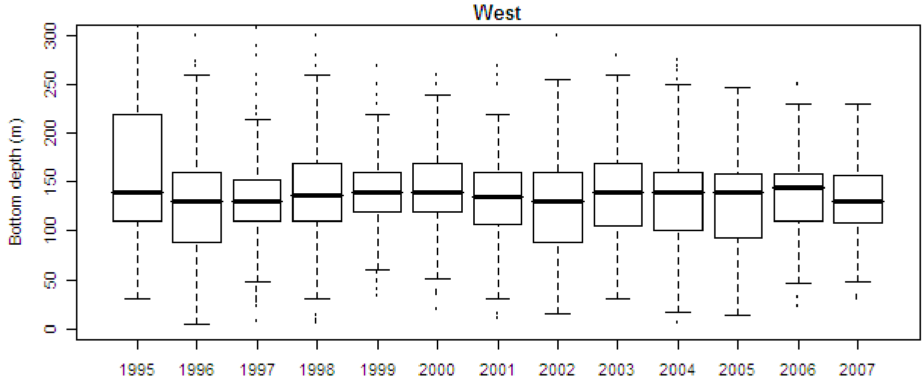


Figure 10: Distribution of bottom depths reported on TCEPRs for tarakihi target tows in the west substock area of TAR 1, by fishing year.

3.2. Characterisation of the east coast TAR 1 fisheries

Most of the catch of tarakihi (57–87% annually) from the eastern substock of TAR 1 is taken by single bottom trawl, with the balance mostly taken by bottom longline fishing. Small and variable amounts have also been taken in each year by pair trawl, set net, and Danish seine (Table 7).

Table 7: Distribution of landed tarakihi by method and by fishing year for the east coast substock of TAR 1 in tonnes and in percent of substock annual landings. Catches are raised to the annual QMR catch (Table 1.) Percentages sum to 100 by year. 0, less than 0.5 t; 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	BLL	BPT	SN	DS	Other	BT	BLL	BPT	SN	DS	Other
89/90	215	60	20	10	2	1	69	19	7	3	1	0
90/91	222	58	11	4	2	1	71	19	3	1	1	0
91/92	335	57	4	2	1	0	83	14	1	1	0	0
92/93	233	66	2	3	2	1	75	21	1	1	1	0
93/94	211	87	6	9	5	0	66	27	2	3	2	0
94/95	234	100	3	9	1	1	67	29	1	2	0	0
95/96	283	75	2	6	1	1	77	20	1	2	0	0
96/97	322	103	1	4	2	1	74	24	0	1	0	0
97/98	339	126	0	12	2	0	71	26	0	2	0	0
98/99	281	105	3	1	2	0	71	27	1	0	0	0
99/00	309	119	12	3	3	0	69	27	3	1	1	0
00/01	234	100	6	3	10	0	66	28	2	1	3	0
01/02	224	76	1	1	3	0	73	25	0	0	1	0
02/03	132	69	30	1	2	0	57	29	13	0	1	0
03/04	170	54	10	1	5	1	71	22	4	0	2	0
04/05	322	35	7	1	8	0	86	9	2	0	2	0
05/06	367	44	4	1	6	0	87	10	1	0	1	0
06/07	179	41	12	4	6	1	74	17	5	2	2	0

3.2.1. East coast bottom trawl

The bottom trawl catch of tarakihi in the eastern substock is largely (50–72% annually) from tows targeted at tarakihi, with the most important bycatch coming from snapper targeted tows. There were also variable landings (2–20%) of tarakihi as a bycatch of the gemfish fishery before 2004–05, and, in recent years, from John dory tows. Trevally is not as important on this coast as in the western substock, and accounts for less than 8% of tarakihi landings in each year (Table 8, Figure 11).

There was also a marked shift from reporting on the daily CELR form to tow-by-tow reporting on TCEPRs in the eastern substock. In 1989–90 most (97%) of TAR 1 was reported on CELRs, but by 1995–96 almost 68% of tarakihi was reported on TCEPRs, and by 2000–01 that statistic was about 90% (Table 9). Some changes in the fleet have seen a subsequent reversal of the trend with 51% of tarakihi catch reported on CELRs in 2006–07 (Table 9).

The seasonality of the four most important target fisheries taking TAR 1 by bottom trawl is shown in Figure 12. Targeting of tarakihi occurs throughout the year, but the highest catches are taken between March and June, with a prominent peak in April and May. There has been a marked shift in targeting behaviour in the most recent three years towards year-round fishing and this coincides with the opening of the Auckland Fish Market and domestic marketing initiatives for tarakihi (Andrew Bond, Sanfords, pers.comm.) Bycatch from the gemfish fishery also occurred during the peak months of May and June, but that fishery had almost disappeared by 2005–06.

The bycatch from snapper targeted tows comes mainly from the winter months, July to October, and the bycatch from John dory targeted tows mostly comes from the first half of the fishing year, October to February.

The four main target fisheries also show quite different spatial distributions (Figure 13), with most of the targeted tarakihi historically caught in Area 002, but this has shifted in the most recent three years, so that Areas 003 and 004 are equally important. The observations for Area 001 may be erroneous as fishers have in the past recorded QMA instead of statistical area. The bycatch of tarakihi from snapper targeted tows is distributed evenly through the time series between Areas 002 and 003, but some catches also consistently come from Area 005, while the bycatch from John dory targeted fishing is almost entirely from Areas 003 and 005. The catches landed from the gemfish fishery initially came out of Areas 001 to 004, but have been maintained consistently only from Area 003.

There appears to have been a very well defined target fishery in this substock area, with a tight seasonal peak in April and May, mostly occurring in Area 002, and to a lesser extent Area 003. Outside this target fishery, tarakihi are present throughout the year and throughout the substock area, and have historically been taken in tows directed at snapper and John dory. In recent years tarakihi have been actively targeted outside the historical target fishery period by extending effort into other areas, months, and into deeper water (Figure 14).

Table 8: Distribution of bottom trawl caught tarakihi by target species (tarakihi, snapper, trevally, barracouta, scampi, John dory, hoki, red gurnard and other) and by fishing year for the east substock of TAR 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.

East Coast bottom trawl

Fishing	Target species (t)									Target species (%)								
year	TAR	SNA	TRE	BAR	SKI	JDO	HOK	GUR	Other	TAR	SNA	TRE	BAR	SKI	JDO	HOK	GUR	Other
89/90	107	68	4	2	17	14	-	2	1	50	32	2	1	8	7	-	1	0
90/91	151	29	5	1	15	7	0	3	11	68	13	2	0	7	3	0	1	5
91/92	238	47	4	1	24	11	1	4	4	71	14	1	0	7	3	0	1	1
92/93	152	33	1	3	31	9	1	2	2	65	14	0	1	13	4	0	1	1
93/94	119	39	7	2	34	8	0	0	1	57	18	3	1	16	4	0	0	0
94/95	166	23	7	3	25	8	0	1	1	71	10	3	1	11	3	0	1	0
95/96	164	36	10	4	55	13	0	0	2	58	13	4	1	19	4	0	0	1
96/97	218	21	9	1	29	34	4	3	3	68	6	3	0	9	10	1	1	1
97/98	221	23	24	5	17	36	6	3	3	65	7	7	2	5	11	2	1	1
98/99	155	51	10	1	17	36	1	2	9	55	18	3	0	6	13	0	1	3
99/00	166	43	14	4	18	47	1	9	6	54	14	5	1	6	15	0	3	2
00/01	114	23	7	10	11	55	0	4	9	49	10	3	4	5	24	0	2	4
01/02	110	17	8	6	21	30	0	4	27	49	8	3	3	10	14	0	2	12
02/03	71	16	9	1	10	19	-	3	4	54	12	7	1	7	14	-	2	3
03/04	97	34	13	3	3	14	0	3	3	57	20	7	2	2	8	0	2	2
04/05	244	28	15	0	5	25	0	3	0	76	9	5	0	2	8	0	1	0
05/06	312	28	8	2	1	8	1	3	3	85	8	2	1	0	2	0	1	1
06/07	139	20	7	1	0	8	0	1	3	78	11	4	0	0	5	0	1	2

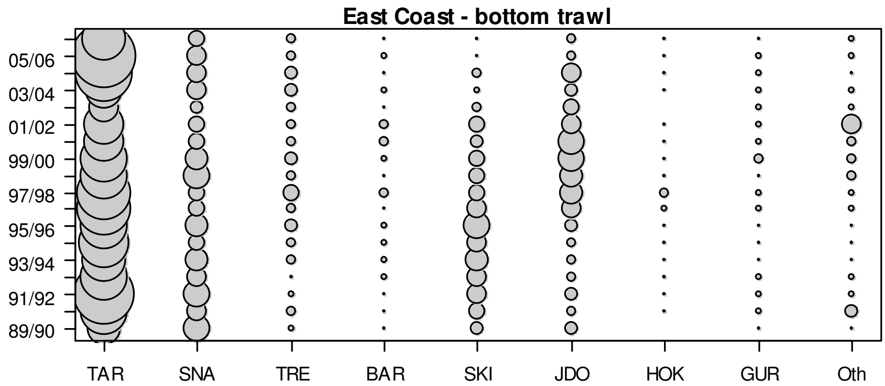


Figure 11: Distribution of bottom trawl caught tarakihi, for the east coast substock area, by target species and fishing year. Circle areas are proportional to the catch totals by area, with the circle values and species codes given in Table 8.

Table 9: Change in reporting practice in the east coast bottom trawl fishery. The percent of bottom trawl caught TAR 1 (by landed weight) and percent of effort (tows) reported on the daily form (CELR) and on the tow-by-tow form (TCEPR) by fishing year.

Fishing	Greenweight (%)		Effort (%)	
Year	CELR	TCEPR	CELR	TCEPR
89/90	92	8	97	3
90/91	95	5	96	4
91/92	96	4	97	3
92/93	91	9	94	6
93/94	70	30	89	11
94/95	72	28	82	18
95/96	22	78	32	68
96/97	25	75	26	74
97/98	24	76	17	83
98/99	18	82	17	83
99/00	27	73	21	79
00/01	12	88	10	90
01/02	16	84	17	83
02/03	7	93	18	82
03/04	13	87	34	66
04/05	32	68	60	40
05/06	26	74	50	50
06/07	37	63	51	49

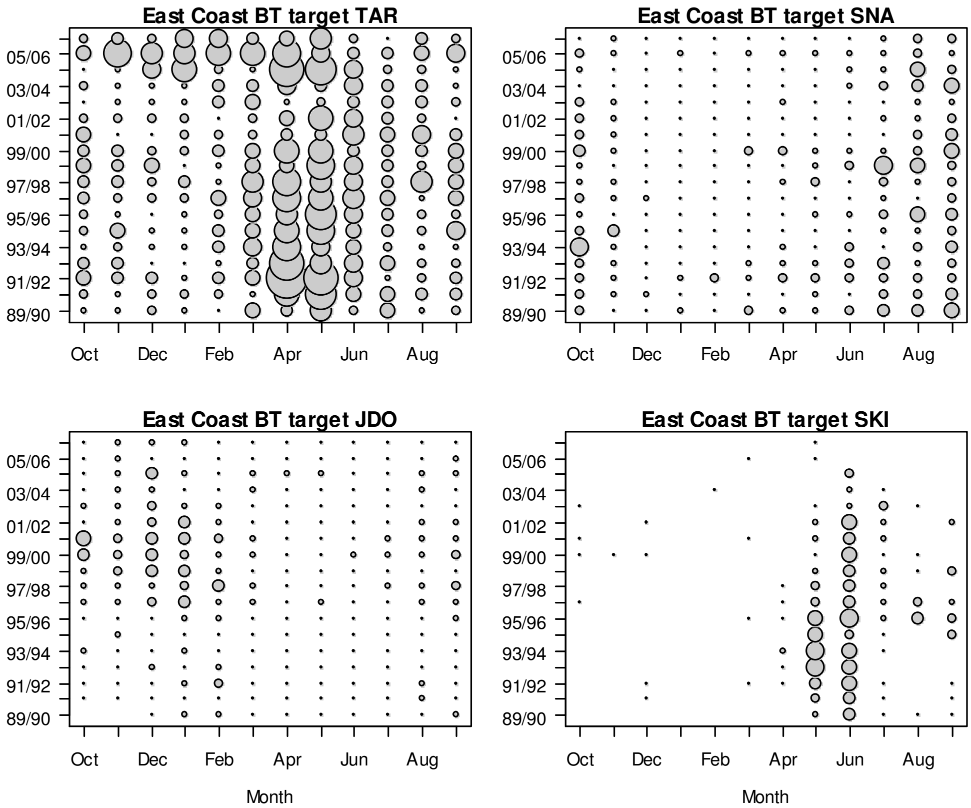


Figure 12: Comparison of the seasonal distribution of bottom trawl tarakihi catches for the four main target fisheries taking TAR 1 from the east coast substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 8.

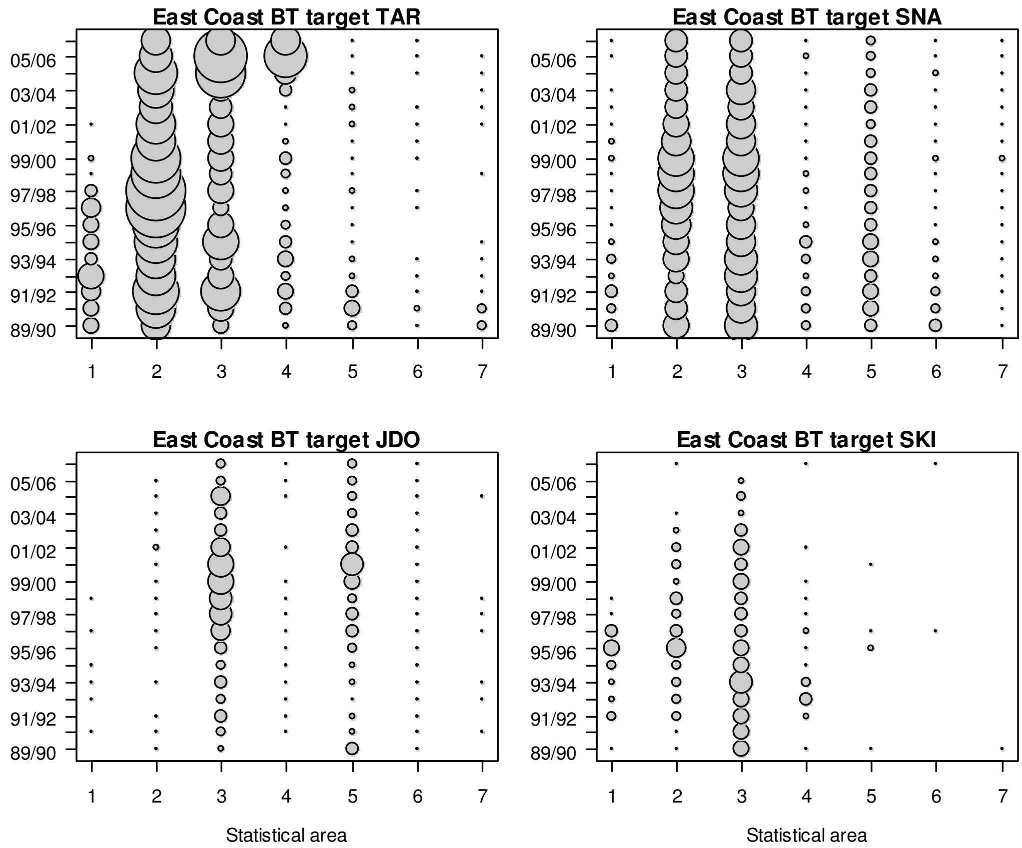


Figure 13: Comparison of the areal distribution of bottom trawl tarakihi catches for the four main target fisheries taking TAR 1 from the east coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 8.

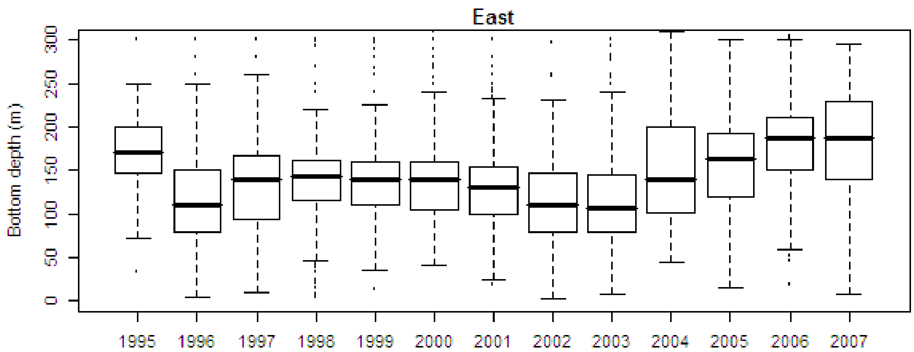


Figure 14: Distribution of bottom depths reported on TCEPRs for tarakihi target tows in the east substock area of TAR 1, by fishing year.

3.3. Characterisation of the Bay of Plenty TAR 1 fisheries

Bottom single trawl has generally accounted for more than 90% of tarakihi landed from the Bay of Plenty substock of TAR 1, with the exception of a few years in the mid 1990s when set net, at its peak, landed over 100 t of tarakihi annually (almost 15% of the Bay of Plenty tarakihi catch). That fishery had largely disappeared by 1999–2000. There has been a small but consistent catch of tarakihi from bottom longline, accounting for 1–4% of annual landings, and in the last half of the time series 3–7% of the catch has been taken by Danish seine, peaking at 71 t (7%) in 2003–04 (Table 10).

Table 10: Distribution of landed tarakihi by method and by fishing year for the Bay of Plenty substock of TAR 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)						Bay of Plenty Fishing method (%)					
year	BT	SN	DS	BLL	BPT	Other	BT	SN	DS	BLL	BPT	Other
89/90	389	13	2	9	2	2	93	3	1	2	1	1
90/91	541	34	5	20	3	0	90	6	1	3	0	0
91/92	678	66	7	24	2	1	87	9	1	3	0	0
92/93	682	118	6	30	1	1	81	14	1	4	0	0
93/94	667	116	9	27	1	1	81	14	1	3	0	0
94/95	562	81	14	23	3	0	82	12	2	3	0	0
95/96	594	45	8	17	1	1	89	7	1	3	0	0
96/97	530	43	8	19	0	0	88	7	1	3	0	0
97/98	580	16	31	15	0	1	90	3	5	2	0	0
98/99	543	10	37	12		0	90	2	6	2		0
99/00	443	3	35	19	1	1	89	1	7	4	0	0
00/01	626	1	22	21	0	0	93	0	3	3	0	0
01/02	753	1	37	12	1	0	94	0	5	2	0	0
02/03	819	3	42	10	3	0	93	0	5	1	0	0
03/04	870	0	71	10	4	0	91	0	7	1	0	0
04/05	693	1	42	7	3	0	93	0	6	1	0	0
05/06	637	1	31	9	0	1	94	0	5	1	0	0
06/07	486	0	17	6	0	0	95	0	3	1	0	0

3.3.1. Bay of Plenty bottom trawl

The bottom trawl catch is mostly targeted at tarakihi (more than 70% in most years), with snapper and trevally targeted tows accounting for most of the balance, especially in recent years. A fishery for gemfish took 7–15% of the Bay of Plenty tarakihi catch in the early 1990s but has subsequently declined in importance with the reduction in the SKI 1 TACC. Other target fisheries landing between 1 and 5% of the tarakihi catch annually include barracouta, John dory, hoki, and red gurnard (Table 11, Figure 15).

There was also a marked shift from reporting on the daily CELR form to tow-by-tow reporting on TCEPRs in the Bay of Plenty substock. In 1989–90 most (93%) of TAR 1 was reported on CELRs, but by 1996–97 almost 89% was reported on TCEPRs, and this proportion has remained high, being 98% in 2003–04 and about 90% in 2006–07 (Table 12).

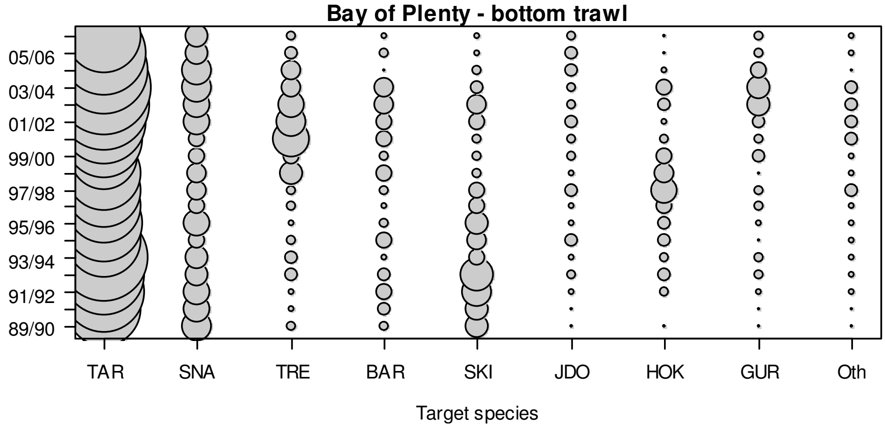


Figure 15: Distribution of bottom trawl caught tarakihi, for the Bay of Plenty substock area, by target species and fishing year. Circle areas are proportional to the catch totals by area, with the circle values and species codes given in Table 11.

Table 11: Distribution of bottom trawl caught tarakihi by target species (tarakihi, snapper, trevally, barracouta, scampi, John dory, hoki, red gurnard or other) and by fishing year for the Bay of Plenty substock of TAR 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	TAR	SNA	TRE	BAR	SKI	JDO	HOK	GUR	Other	TAR	SNA	TRE	BAR	SKI	JDO	HOK	GUR	Other
89/90	235	82	12	8	47	1	2	0	2	61	21	3	2	12	0	1	0	0
90/91	425	61	3	11	39	0	0	0	1	78	11	1	2	7	0	0	0	0
91/92	513	51	4	20	72	5	8	3	2	76	8	1	3	11	1	1	1	0
92/93	485	41	12	12	95	8	14	10	5	71	6	2	2	14	1	2	2	1
93/94	563	42	12	5	23	4	6	9	4	84	6	2	1	3	1	1	1	1
94/95	438	26	7	24	34	11	17	1	5	78	5	1	4	6	2	3	0	1
95/96	463	57	3	6	41	5	12	3	5	78	10	0	1	7	1	2	0	1
96/97	422	26	10	5	26	2	26	8	5	80	5	2	1	5	0	5	2	1
97/98	416	33	9	10	24	15	53	9	12	72	6	2	2	4	3	9	2	2
98/99	407	29	37	22	7	5	32	1	3	75	5	7	4	1	1	6	0	1
99/00	344	18	24	7	10	8	18	11	3	78	4	5	2	2	2	4	2	1
00/01	439	24	96	21	8	9	5	10	15	70	4	15	3	1	1	1	2	2
01/02	535	51	74	23	24	17	4	11	14	71	7	10	3	3	2	0	1	2
02/03	590	51	54	27	26	10	13	39	11	72	6	7	3	3	1	2	5	1
03/04	644	75	27	28	10	8	24	40	15	74	9	3	3	1	1	3	5	2
04/05	557	64	27	2	5	11	4	22	1	80	9	4	0	1	2	1	3	0
05/06	546	38	16	7	2	13	1	10	3	86	6	3	1	0	2	0	2	0
06/07	418	36	7	2	2	8	1	6	5	86	8	1	0	1	2	0	1	1

The seasonality of the four most important target fisheries taking Bay of Plenty TAR 1 by bottom trawl is examined in Figure 16. Targeting of tarakihi occurs throughout the year, with the greatest catches during March, April, and May. Bycatch from the snapper targeted fishery also occurs throughout the year, but mostly outside the main tarakihi target season. The bycatch from trevally target tows is taken consistently through the year, with no evidence of a seasonal peak, but was considerably more important between 1999–2000 and 2003–04 than in the three years since then. The bycatch from the gemfish target fishery occurred almost entirely during May and June in each fishing year, coincident with the gemfish spawning migration (Fu et al. 2008).

The spatial distribution of each of these four target fisheries is similar (Figure 17), with most of the tarakihi taken in Area 010, followed by Areas 009 and 008.

Table 12: Change in reporting practice in the east coast bottom trawl fishery. The percent of bottom trawl caught TAR 1 (by landed weight) and percent of effort (tows) reported on the daily form (CELR) and on the tow-by-tow form (TCEPR) by fishing year.

Fishing	Greenweight (%)		Effort (%)	
Year	CELR	TCEPR	CELR	TCEPR
89/90	90	10	93	7
90/91	97	3	95	5
91/92	98	2	88	12
92/93	94	6	80	20
93/94	90	10	84	16
94/95	63	37	64	36
95/96	13	87	23	77
96/97	5	95	11	89
97/98	7	93	17	83
98/99	26	74	28	72
99/00	18	82	27	73
00/01	8	92	17	83
01/02	1	99	12	88
02/03	3	97	11	89
03/04	0	100	2	98
04/05	1	99	3	97
05/06	6	94	13	87
06/07	33	67	10	90

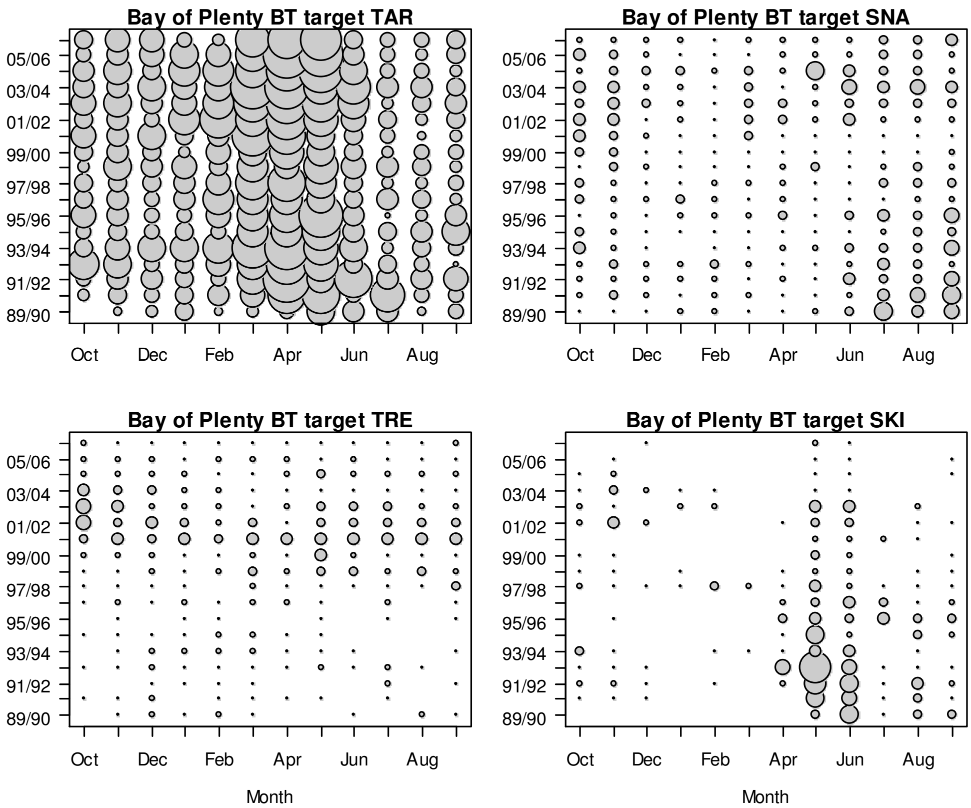


Figure 16: Comparison of the seasonal distribution of bottom trawl tarakihi catches for the four main target fisheries taking TAR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 11.

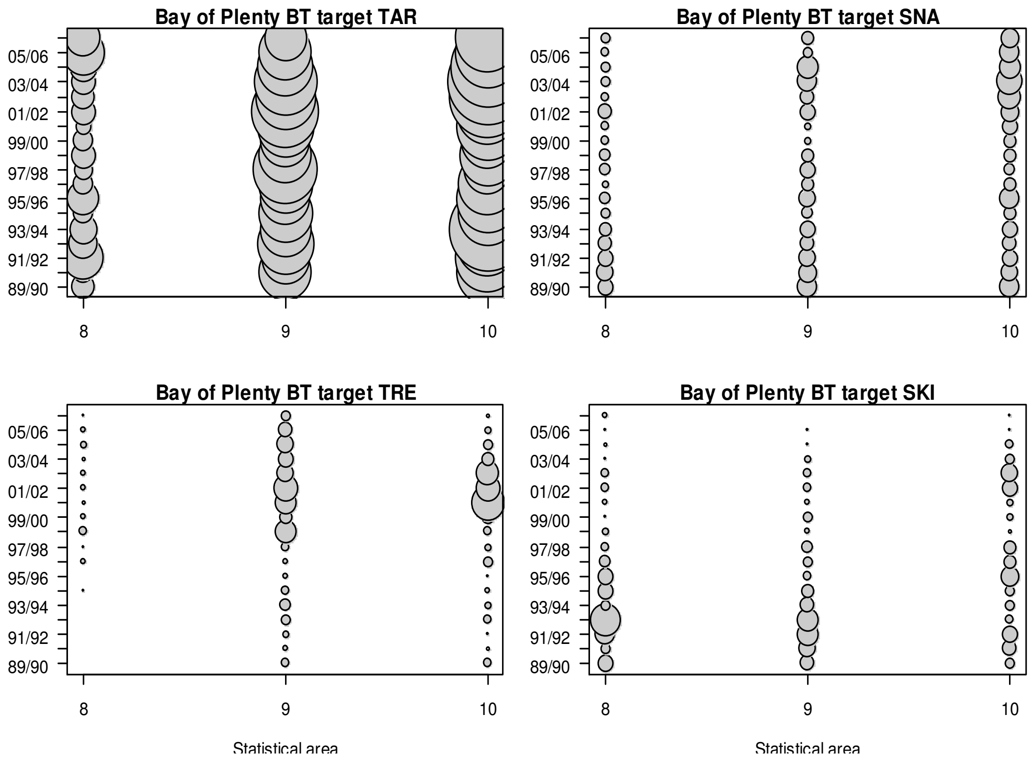


Figure 17: Comparison of the areal distribution of bottom trawl tarakihi catches among statistical areas for the four main target fisheries taking TAR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 11.

While there is clearly a target fishery for tarakihi in the Bay of Plenty that is focused on March, April, and May, target fishing also occurs throughout the year. A considerable amount of tarakihi is also taken in tows directed at snapper and trevally outside the peak season. The depth at which tarakihi is targeted in this substock area varies more within years than it does in the other two substocks, but shows no significant trend up or down over time (Figure 18).

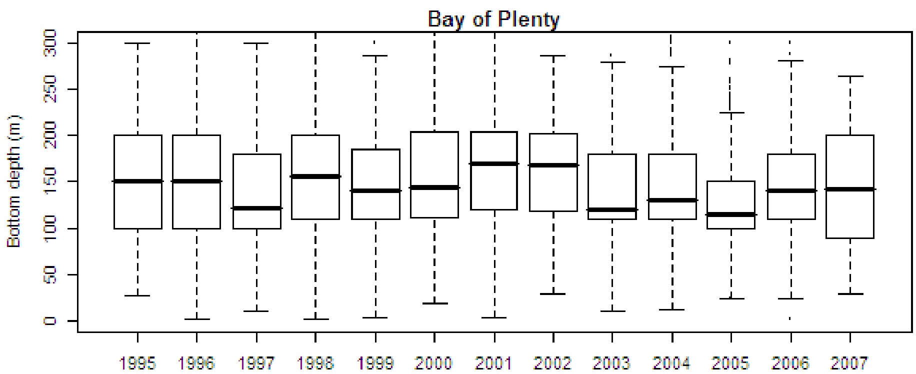


Figure 18: Distribution of bottom depths reported on TCEPRs for tarakihi target tows in the Bay of Plenty substock area of TAR 1, by fishing year.

3.4. Fishery definitions for standardised CPUE analysis

While it may seem obvious to analyse target fishing in the inshore bottom trawl fisheries because it accounts for most of the landed tarakihi, there is evidence of improved reporting of target species inherent in the shift in reporting from CELRs to TCEPRs that cannot be reliably standardised because it is confounded with year effect. This effect should be mitigated by doing separate analyses by form type. However, concerns about the misuse of the *target species* field because of factors such as availability of quota, the requirement before 2001–02 to hold quota before target fishing toward a species, as well as evidence of a marked change in targeting behaviour in recent years in the eastern substock support a decision to define effective effort on the basis of the presence of catch and other related explanatory variables, rather than on the fisher-nominated target species.

Bottom trawl fishing events in each of the three TAR 1 substock areas have been mostly reported in the TCEPR format in the most recent 10 years. This gives the opportunity to calculate shortened CPUE series based on tow-by-tow data that have the following advantages;

1) allows an alternative definition of effective effort by selecting only those tows that reported an estimated catch of tarakihi,
2) allows the distance towed to be calculated from tow duration and tow speed fields and used as the measure of effort (higher tow speeds are used for targetting trevally than other species, and tow duration may not be an equivalent measure of effort across target fisheries) 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.

For each substock area, a second series, that covers the early years of available data is based on data provided in the CELR format, using records with positive estimated catches reported on the daily section of the effort part of the form. These are not directly comparable with the TCEPR series because each record (a positive day) will include an unknown number of unsuccessful tows.

For each of the three TAR 1 substock areas, two fisheries are defined for monitoring tarakihi.

1. TCEPR series

Records with positive estimated catches of tarakihi from single bottom trawl fishing (regardless of fisher-nominated target species), reported using the TCEPR form, and using the original tow-by-tow resolution. This series begins in 1995–96, the year when most of the available data are provided using the TCEPR formtype.

2. CELR series

Records with positive estimated catches of tarakihi from single bottom trawl fishing (regardless of fisher-nominated target species), reported using the CELR formtype and used in the original daily resolution. The time series end in 1999–2000 when there are insufficient data to continue the series.

3.5. Model selection

The CELR-based and TCEPR-based lognormal models for each of the three substock areas explained between 42 and 58% of the variance in catch and their parameterisations were quite similar (Table 13 to 15). For the TCEPR-based models, *Fishing year* was forced as the first variable but explained little of the variance in catch. *Bottom depth* entered as the most important variable in the west and Bay of Plenty substocks, followed by *vessel* ID. This order was reversed for the east coast substock. *Statistical Area* and *month* had significant explanatory power within each substock area, and the log of the *distance towed* entered each model as an additional measure of effort to explain catch per tow. Alternative models (not shown), which offered *target species* as an explanatory variable in lieu of depth, had similar explanatory power as the model which used bottom depth and the two sets of resultant annual indices were almost indiscernible. This supports the observation that target species is relatively well reported on TCEPRs (in contrast to CELRs) (See also Appendix Figure B1 for the distribution of bottom depth with target species). Tow speed was not accepted into any of the three TCEPR models.

Without the advantage of depth information, the CELR-based models were offered fisher-nominated *target species* as a potential explanatory variable, and that was the most important variable for each substock entering with the greatest explanatory power after *fishing year* (forced). *Vessel* ID was the next most important for both the west and the east coast substocks, and was also accepted into the Bay of Plenty model. The log of the *number of tows* was selected in preference to total *tow duration* by each of the models but had the most explanatory power in the Bay of Plenty model. There was also a significant *Statistical Area* effect for each substock and a significant *month* effect for the west coast and Bay of Plenty. *Month* was not accepted into the east coast (CELR, lognormal model, even though it was accepted into the east coast (TCEPR) model, presumably because target species is an effective proxy for season in the CELR series while the TCEPR series includes better seasonal data in recent years as the fishery has expanded outside its historical March–June season.

Month*area interactions were also attempted to help describe any coastal migration of tarakihi, but where they were accepted they had no discernible effect on the year effects and so were dropped.

Table 13: Order of acceptance of variables into the lognormal models of TAR 1 catch by core vessels in the two defined west coast fisheries (Section 2.4), with the amount of explained deviance (R^2) for each variable at final selection. Variables accepted into the model are marked with an *. Final model R^2 is in bold. Fishing year was forced as the first variable.

WEST_CELR	R^2	WEST_TCEPR	R^2
*Fishing year**	0.013	*Fishing year**	0.008
*Target species**	0.209	*Bottom depth**	0.239
*Vessel**	0.308	*Vessel**	0.358
*Month**	0.396	*Statistical area**	0.428
*Log(Number tows)**	0.442	*Month**	0.463
*Statistical area**	**0.459**	*Log(Tow distance)**	**0.490**
Log(Duration)	0.464	*Speed*	0.496

Table 14: Order of acceptance of variables into the models of TAR 1 catch by core vessels in the two defined east coast fisheries (Section 2.4), with the amount of explained deviance (R^2) for each variable at each step of the selection procedure. Variables accepted into the model are marked with an *. Final model R^2 is in bold. Fishing year was forced as the first variable.

EAST_CELR	R^2	EAST_TCEPR	R^2
*Fishing year**	0.015	*Fishing year**	0.054
*Target species**	0.412	*Vessel**	0.341
*Vessel**	0.527	*Bottom depth**	0.444
*Log(Number of tows)**	0.573	*Statistical area**	0.490
*Statistical area**	**0.586**	*Log(Tow distance)**	0.515
Month	0.593	*Month**	**0.531**
Log(Duration)	0.592	*Speed*	0.534

Table 15: Order of acceptance of variables into the models of TAR 1 catch by core vessels in the two defined Bay of Plenty fisheries (Section 2.4), with the amount of explained deviance (R^2) for each variable at each step of the selection procedure. Variables accepted into the model are marked with an *. Final model R^2 is in bold. Fishing year was forced as the first variable.

BOP_CELR	R^2	BOP_TCEPR	R^2
*Fishing year**	0.024	*Fishing year**	0.009
*Target species**	0.250	*Bottom depth**	0.264
*Log(Number of tows)**	0.375	*Vessel**	0.344
*Vessel**	0.447	*Month**	0.373
*Month**	0.471	*Statistical area**	0.395
*Statistical area**	**0.481**	*Log(Tow distance)**	**0.416**
Log(Duration)	0.488	*Speed*	0.417

3.6. Model fits

Diagnostic residual plots are presented for each model in Appendix B. They show good fits of the data to the lognormal assumption over most of the data with some departure at the extremes. The annual indices are well determined with small error bars around the point estimates, except for some transition years when data for one or both form types are sparse.

Expected log catch rates for each significant predictor variable in each model are presented alongside plots of the distribution of the underlying data in Appendix C.

For the west coast substock (Figures C1 and C2), there are linear relationships described between catch and effort over the range in which most of the data occur. The number of tows per record for the west coast CELR series declines over time, coincident with the decline in the number of vessels included in the later part of that time series, and in the TCEPR data set there are a few large catches in very short tows that look unusual but appear, on investigation, to be genuine. The vessel's coefficients show there are consistent differences of up to threefold in performance with respect to tarakihi catch among vessels, and a change in the CELR fleet after 1994–95 reflects the shift to reporting on TCEPRs. The west coast TCEPR series shows the loss of some of the poorer performing vessels in the most recent few years. Predicted catch rate peaks at about 200 m bottom depth, but most tows were shallower than that. Both CELR and TCEPR models agree closely in describing the seasonal and areal effects, with peak predicted catch rates between March and May (although those months seem to have been avoided in some years) and higher catches expected in the more northern statistical areas.

For the east coast substock (Figures C3 and C4) the CELR model is mainly driven by a shift in targeting from tarakihi to John dory between 1995–96 and 2000–01, and also by the loss of most of the participating vessels after 1994–95. The TCEPR model is also driven by a dramatic change in the participating fleet with the loss of many of the poorer performing vessels in the last three years (since 2003–04). Catch is predicted to be highest between 200 and 300 m bottom depth, and although most tows are made in less than 100 m there has clearly been a shift towards deeper tows and also into Statistical Area 004 in recent years. There is a clear seasonal peak of abundance in April and May, but generally a suggestion of avoidance of those months. There is a linear relationship between catch and effort and a trend towards longer tows in the most recent 4–5 years (since 2002–03).

For the Bay of Plenty substock (Figure C5 and C6) the distribution plots show a lot of consistency in how the fishery has operated, with no obvious trends or shifts that might confound the year effects. There is a linear relationship between catch and effort within the range that most of the data occur, consistent differences of three to fourfold in performance with respect to tarakihi catch between vessels, and some changes in fleet composition that largely account for the effect of standardisation. The seasonal peak in March to May is still evident but is not so pronounced as in the east coast substock, and the distribution plots suggest that in most years the fishery is focused on those months.

Catch is predicted to be highest at just over 200 m bottom depth but most tows are shallower than that, with no trend either up or down in depth fished over time. Catches are predicted to be greatest in Statistical Area 010, and lowest in Area 008, with very tight error bars around each coefficient. There has been a slight shift towards more records of catch coming from Area 010 in recent years.

3.7. Trends in model year effects

Canonical year effects were extracted from each of the final fitted models and are compared for each substock in Figures 19, 21 and 23. The annual indices from each model fit, along with 95% confidence intervals, are given in Appendix E.

3.7.1. West coast substock

The standardised CPUE indices from the TCEPR model of the west coast substock decline by about 40% from 1995–96 to 2004–05, extending the decline described previously (Kendrick 2006) by a further year before a marked recovery in the following two years (2005–06 and 2006–07). The effect of standardisation is not great; the increase in nominal CPUE in 2005–06 is lessened, and the increase in 2006–07 is steepened as the model attempts to correct for the departure from the fleet of some of the key vessels in recent years (Figure C1), but the overall trajectory is almost unchanged. The similarity between unstandardised and standardised CPUE indicates a fishery that has operated in a consistent manner over the time series.

The CELR series for the earlier years appears to increase overall but has large error bars around the last five points, which are the years of overlap with the TCEPR series (Figure 19). The three series are overlaid in Figure 20, and show good agreement with the previous analysis for the years in common, and a suggestion that the current index (2006–07) lies close to the average for the time series overall.

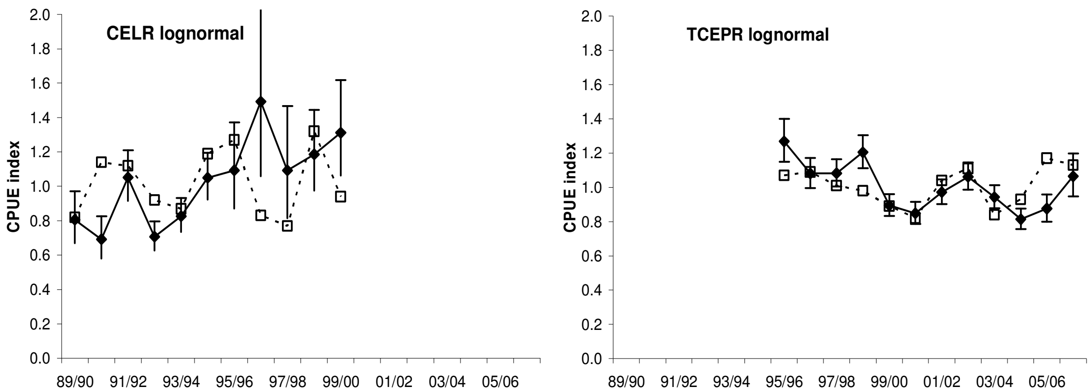


Figure 19: Effect of standardisation for lognormal models of successful estimated catches of tarakihi (regardless of target) in west coast bottom trawl reported on CELR before 1999–2000 [left], and on TCEPR after 1995–96 [right]. Broken lines are arithmetic catch rates (kg/tow for CELR and kg/n.m for TCEPR) relative to the geometric mean of the series. Solid lines are the standardised CPUE canonical indices with ± 2 * SE error bars.

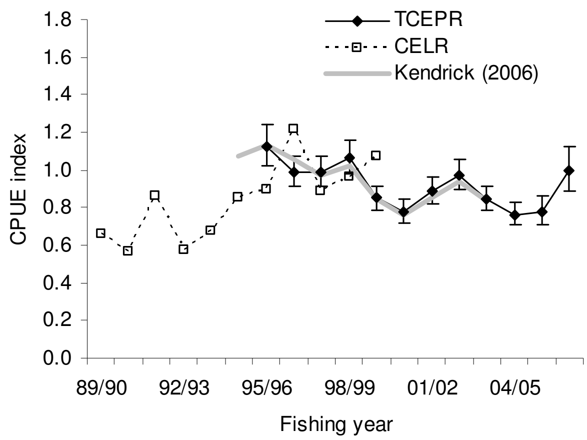


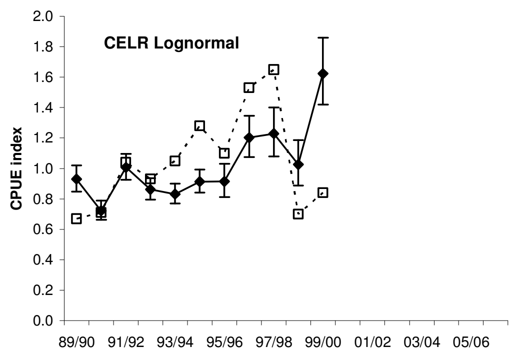
Figure 20: Comparison of indices of abundance for the west coast substock of TAR 1. The previous TCEPR series (Kendrick 2006) are overlaid for comparison. All series have been rescaled relative to the years they have in common.

3.7.2. East coast substock

The standardised CPUE indices from the TCEPR model of the east coast substock are flat overall, having recovered in 1997–98 after two low years and then plateaued at the new level for about eight years before declining in the two most recent years back to the levels as low as those last seen in 1995–96 and 1996–97. The indices are well determined with small error bars and little interannual variance.

There is little net effect of standardisation because both unstandardised and standardised series are flat overall, but the differences between the two series within the time series describe a fishery in which fishers are able to manipulate catch rates markedly. The CELR series for the earlier years appear to increase overall but with large error bars around the last five points, which are the years of overlap with the TCEPR series (Figure 21).

The three series are plotted together in Figure 22, and show good agreement with the previous analysis for the years in common and a suggestion that the index currently lies slightly below the average for the time series overall.



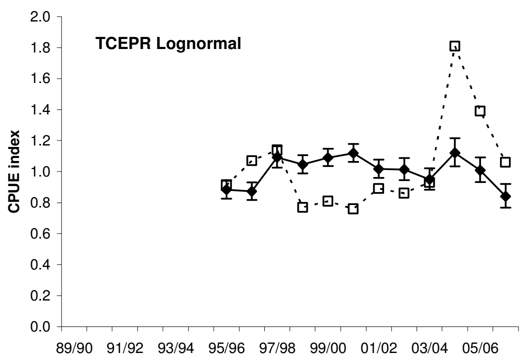


Figure 21: Effect of standardisation for lognormal models of successful estimated catches of tarakihi (regardless of target species) in east coast bottom trawl reported on CELR before 1999-00 [left], and on TCEPR after 1995-96 [right]. Broken lines are arithmetic catch rates (kg / tow and kg / n.m..) relative to the geometric mean of the series. Solid lines are the standardised CPUE canonical indices with ± 2 * SE error bars

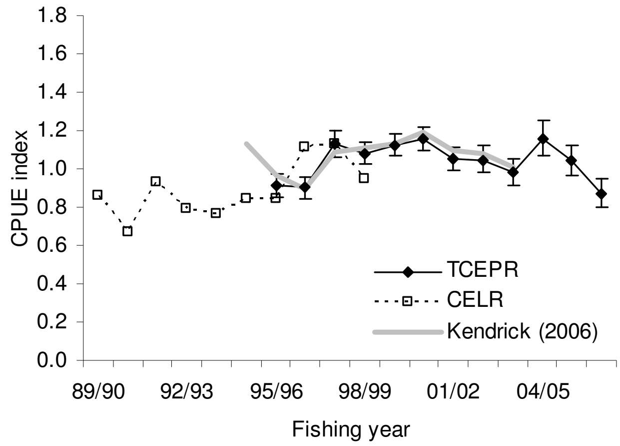


Figure 22: Comparison of CPUE indices of abundance for the east coast substock of TAR 1. The previous TCEPR series (Kendrick 2006) is included for comparison. All series have been rescaled relative to the years they have in common.

3.7.3. Bay of Plenty substock

The standardised CPUE indices from the TCEPR model of the Bay of Plenty substock are flat overall, with a hump of higher abundance that was sustained over about five years in the first half of the 2000s. The indices are well determined with small error bars and little interannual variance. The effect of standardisation is neglible, indicating a fishery that has operated in a consistent manner over the time series.

The effect of standardisation of the CELR series for the earlier years is greater, even discounting the last five points which have large error bars around them, and flattens the steep nominal increase (Figure 23). The increase in the nominal CPUE coincided with small increases of effort in Statistical Area 010 and in earlier months of the year, trends that were reversed in subsequent years. The three series are plotted together in Figure 24, and show good agreement with the previous analysis for the years in common and a suggestion that the index currently lies at or very near the average for the time series overall.

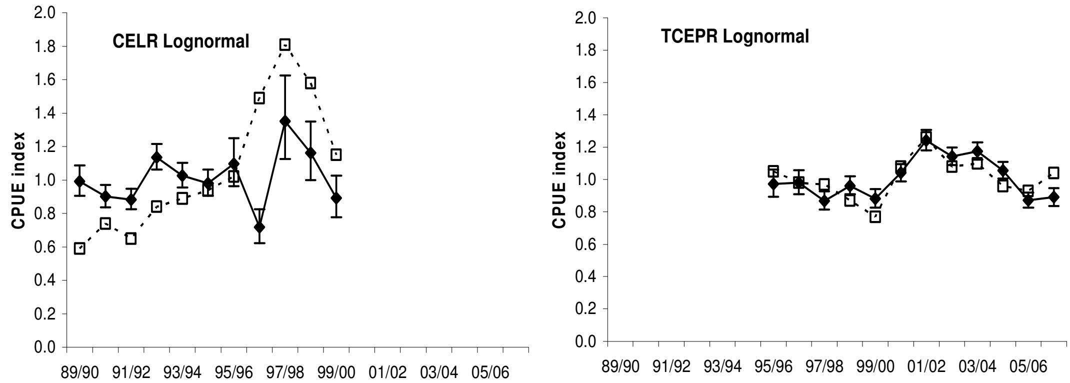


Figure 23: Effect of standardisation for lognormal models of successful estimated catches of tarakihi (regardless of target species) in Bay of Plenty bottom trawl reported on CELR before 1999–2000 [left], and on TCEPR after 1995–96 [right]. Broken lines are arithmetic catch rates (kg/tow for CELR and kg/n.m for TCEPR) relative to the geometric mean of the series. Solid lines are the standardised CPUE canonical indices with ± 2 * SE error bars

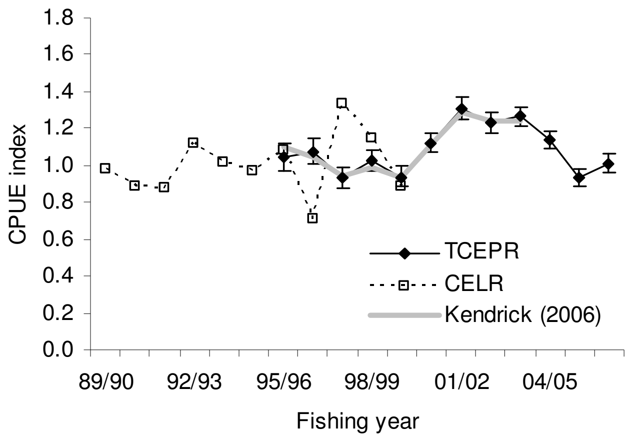


Figure 24: Comparison of abundance indices available for the Bay of Plenty substock of TAR 1. The previous TCEPR series (Kendrick 2006) are included for comparison. All series have been rescaled relative to the years they have in common.

4. CONCLUSIONS

There is little advantage in basing CPUE analysis of TAR 1 on landed rather than estimated catch because tarakihi in TAR 1 is a well reported species, and a large proportion of the catch comes from target fishing for tarakihi. The currently accepted CPUE index of abundance for each of the three substocks of TAR 1 was initially based on estimated catch because the Starr method for using landed catch combines data from the two main form types (CELR and TCEPR) and amalgamates data to trip-stratum resolution, both of which were shown in previous work (repeated in this report) to cause biases in the analysis of the catch and effort data for this Fishstock.

However, there is no reason why future work should not use a version of the Starr methodology to scale estimated catch up to landed greenweight without any amalgamation. The benefits would possibly not be great, but it would represent an attempt to address potential bias which may exist in estimated catches, in that they tend to be under-representative of smaller catches.

There is concern about combining data from the two main form types because of a systematic shift from reporting on CELRs to TCEPRs. Catch rates of TAR 1 in targeted fishing are on average lower when reported on CELRs than when reported on TCEPRs, and, as the proportion of data reported on TCEPRs increases, so too does the nominal CPUE. This is a function of the fisher-nominated target species being better specified at tow-by-tow resolution than at daily resolution, while CELR data includes other less that relevant effort.

Additionally, there are concerns about relying on fisher-nominated target species to define a fishery that has been operated consistently enough to monitor abundance of TAR 1. Although there are well determined historical target fisheries for tarakihi in each of the three substock areas, targeting of tarakihi in the east coast substock has expanded in the last three years beyond the historical season into other areas and depths to provide fish year round to the Auckland Fish Market. Models based on TCEPR data may be able to account for these shifts, but models based on amalgamated and/or CELR data, would almost certainly not.

Tarakihi in TAR 1 are caught by trawl in association with target fishing for snapper and trevally. Catches of these three species have long been constrained by the availability of quota. Before introduction of ACE, fishers could not target any species for which they did not have adequate quota, and this also will most probably have influenced what was recorded as the target species in many instances.

The approach chosen by the Working Group in 2005 to avoid reliance on fisher-nominated target species was to base the analyses on TCEPR data, used in their original tow-by-tow resolution and to allow the model to account for targeting behaviour using the finer detail data such as depth and tow speed. Consideration of alternative TCEPR models in this study (not shown), that included target species (either as well as, or instead of, depth) suggests that its inclusion results in little difference in the annual indices, indicating that target species is well reported on TCEPRs.

Target species is probably less well reported on CELRs and there are no suitable proxies for it in that daily format, so two independent series are produced; CELR for the earlier years, and TCEPR for the recent years

Using TCEPR data in original resolution has the additional advantage that effective effort can be defined as tows that encountered tarakihi; this is not possible for CELR data, or for TCEPR data that have been amalgamated with CELR data.

The inclusion of zero catch information has been explored but it is noted that trends in the amalgamation of TCEPR and CELR data to a common resolution (trip-stratum) as in the Starr method compromise the nominal indicator (proportion of zeros), and the binomial model is unable to correct for the number of tows per record when there is a trend that is confounded with the year effect. Also, it should be noted that for CELR data, or for TCEPR data that has been amalgamated with CELR data, much of the zero catch information is included in catch rate because the totals of catch and effort include any qualifying but unsuccessful tows.

When the fishery to be monitored is defined by positive trawl tows, as is currently accepted practice for TAR 1, success rate can be calculated only from a differently defined fishery and it would certainly not be defensible to combine resultant indices with the lognormal model indices.

The CELR series for each of the three substocks all suggest some increase from levels of abundance in 1989–90, but are characterised by wide error bars in the years of overlap with the TCEPR series (1995–96 to 1999–2000). In the east coast and Bay of Plenty substocks, large nominal increases are effectively flattened by standardisation, but there was less effect on nominal CPUE in the west coast substock area.

The west coast TCEPR series shows a decline from 1995–96 to 2004–05, but a recovery in the last two years that puts the 2006–07 index at just above the average for the series. There was little effect of standardisation until recent years, when the model attempts to correct for changes in the participating fleet, particularly the loss of some of the poorer performing vessels.

The east coast TCEPR series is flat overall, but the effect of standardisation is marked due to changes in the fishery in recent years to targeting tarakihi outside historical areas, months, and depths, as well as to significant changes in the core fleet.

The Bay of Plenty series is also flat overall but shows a "hump" of increased abundance over five years at the start of this decade that appears to have returned to the original levels. There was little effect of standardisation, indicating some consistency in the way this fishery has operated.

5. ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries as project TAR2007-01. Thanks to members of the Inshore Fishery Assessment Working Group, particularly Paul Starr, for methodology and helpful suggestions.

6. REFERENCES

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APPENDIX A: ESTIMATED AND LANDED CATCH OF TARAKIHI

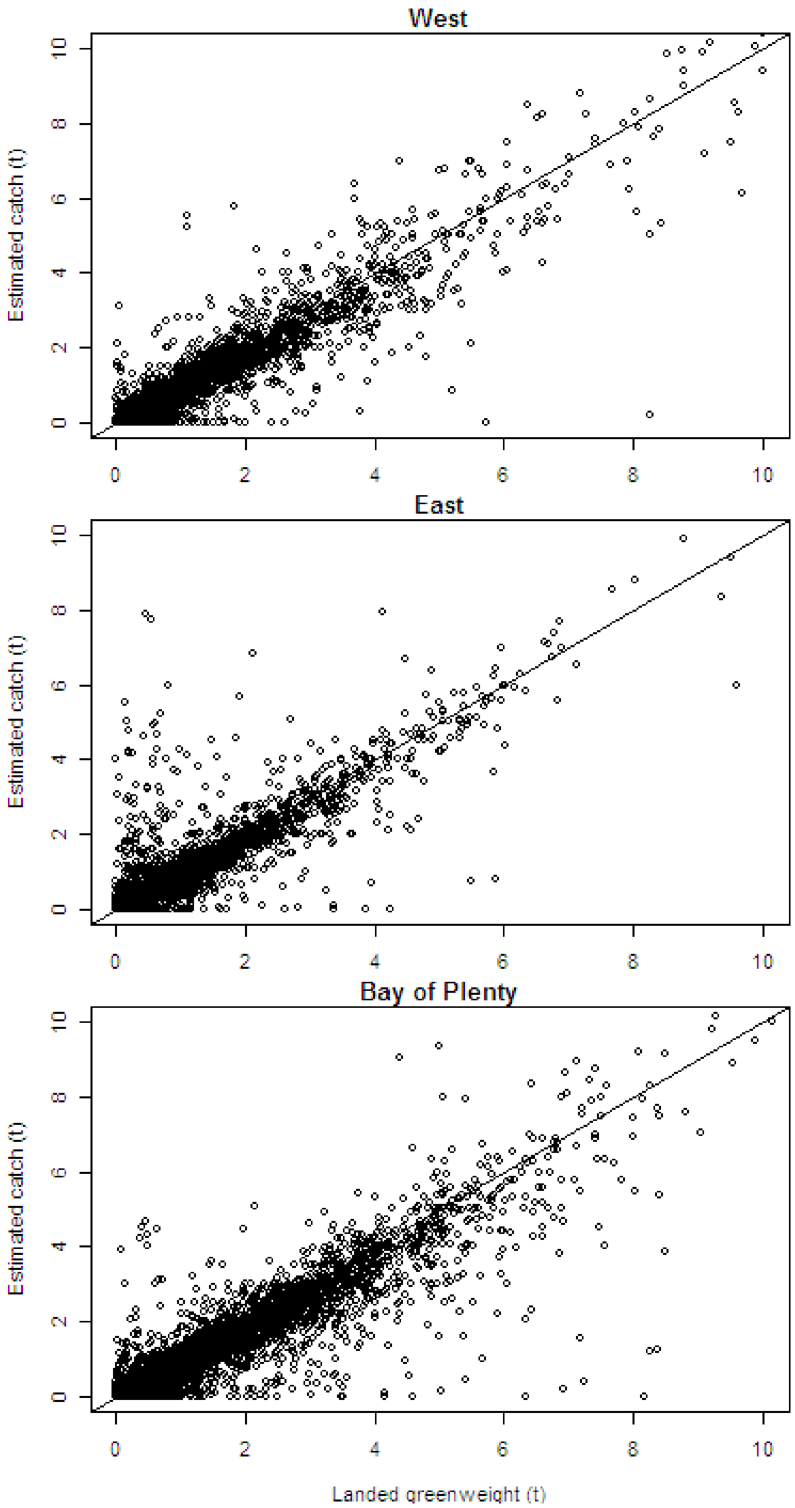


Figure A1: **Scatter plots of the total estimated catch compared to the landed greenweight of TAR 1 for all positive bottom trawl trips in each for the three substocks. The landed catch is the total greenweight landed and weighed at the end of the trip, and the estimates are made by the skipper for the top five species in the catch. If perfectly reported, the points would lie along the 1:1 line.**

APPENDIX B: DISTRIBUTION OF BOTTOM DEPTH (TCEPR) BY TARGET SPECIES

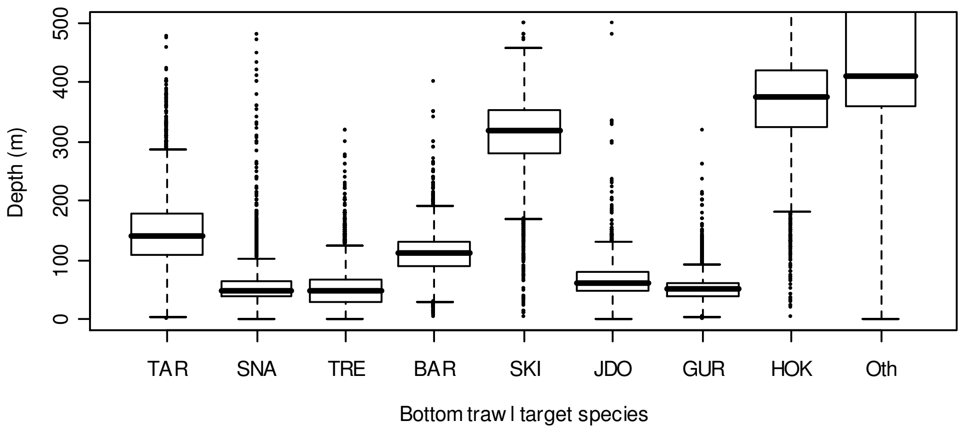


Figure B1: Distribution of bottom depths reported on TCEPRs by target species, all areas and years combined.

APPENDIX C: RESIDUAL PLOTS

West coast substock - CELR lognormal model

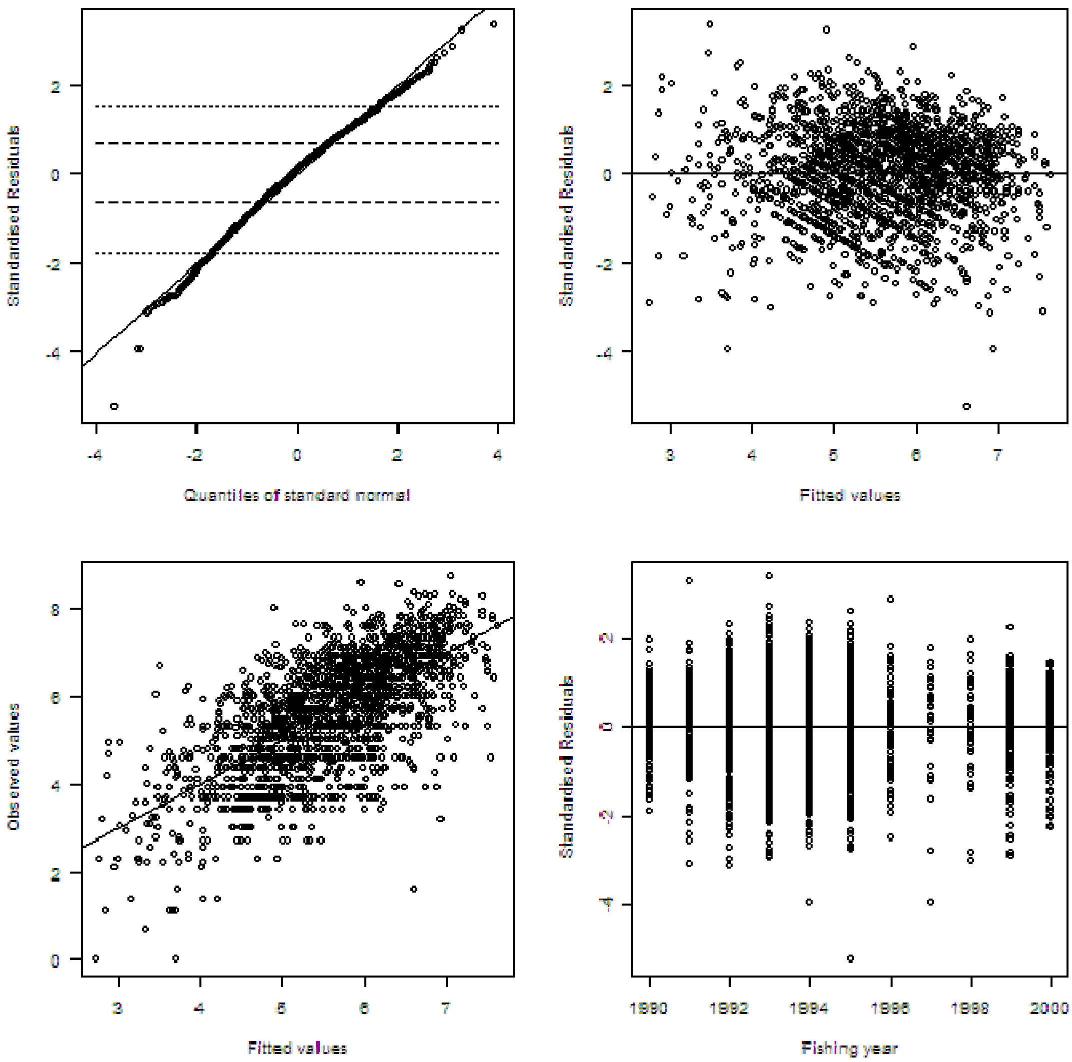


Figure C1: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the west coast CELR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

West coast substock - TCEPR lognormal model

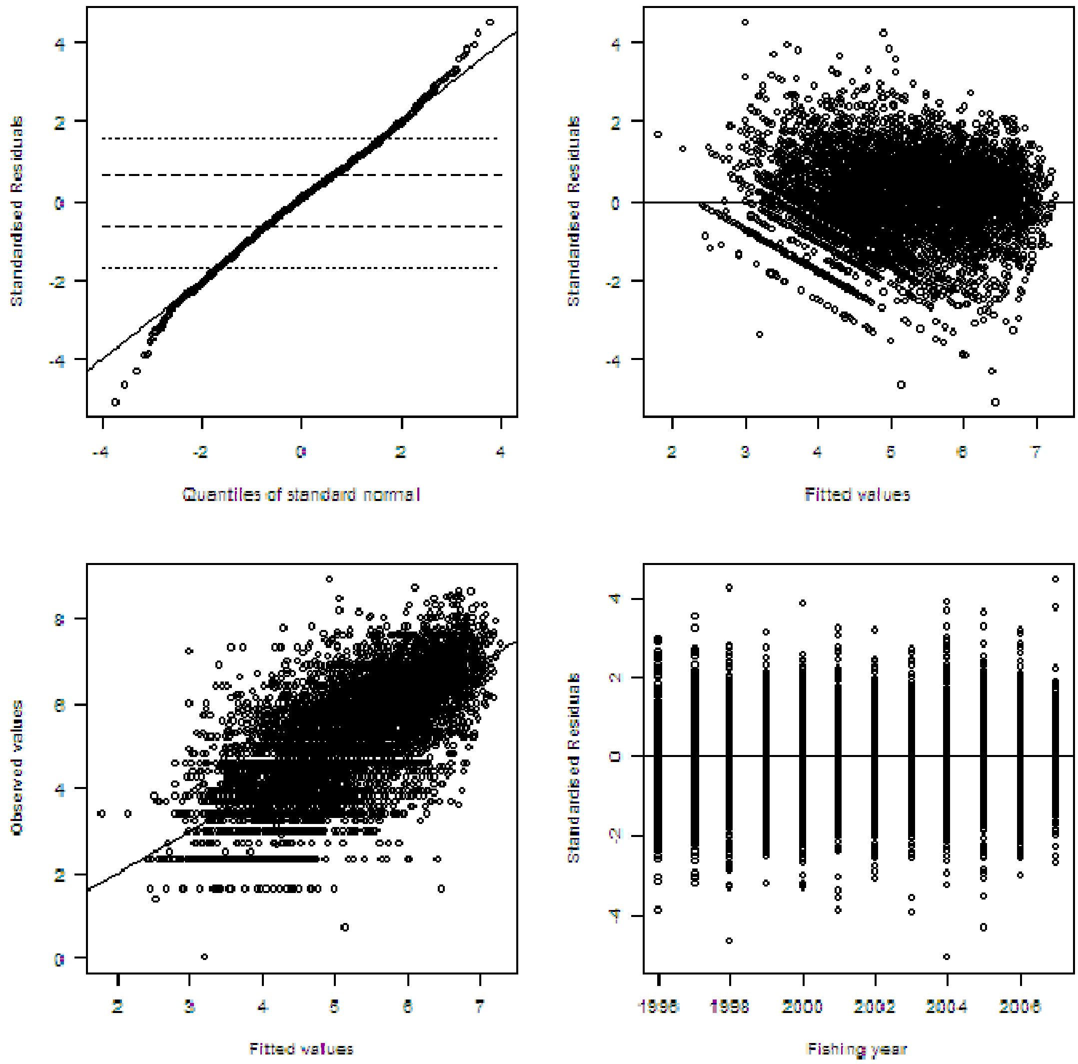


Figure C2: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the west coast TCEPR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

East coast substock - CELR lognormal model

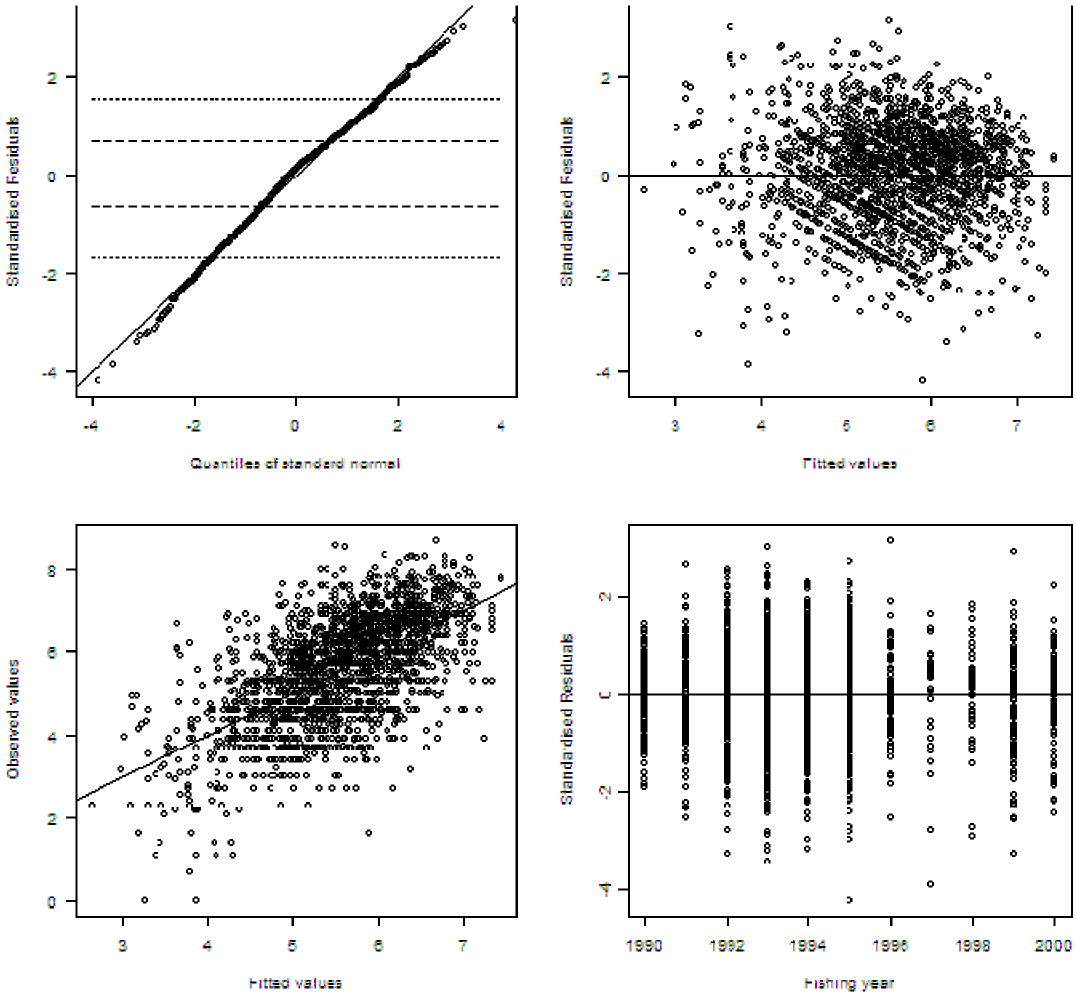


Figure C3: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the east coast CELR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

East coast substock - TCEPR lognormal model

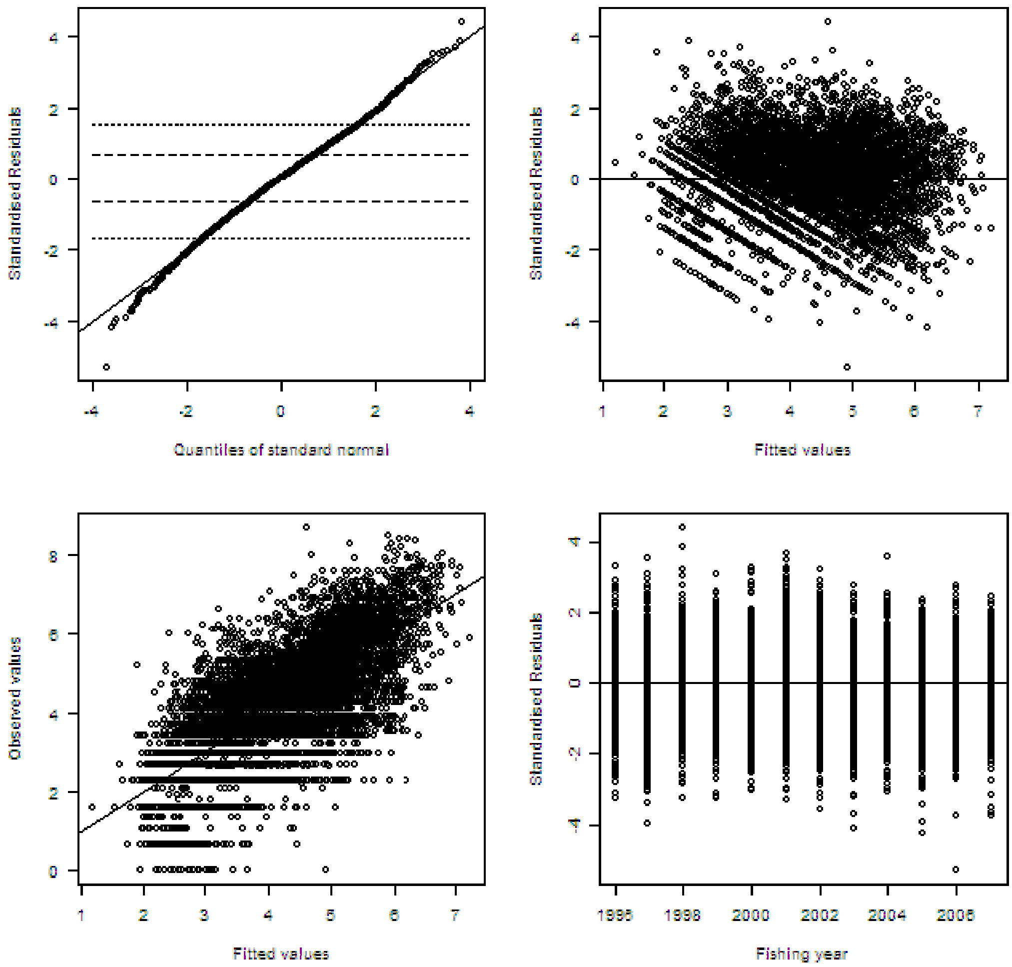


Figure C4: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the east coast TCEPR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

Bay of Plenty substock - CELR lognormal model

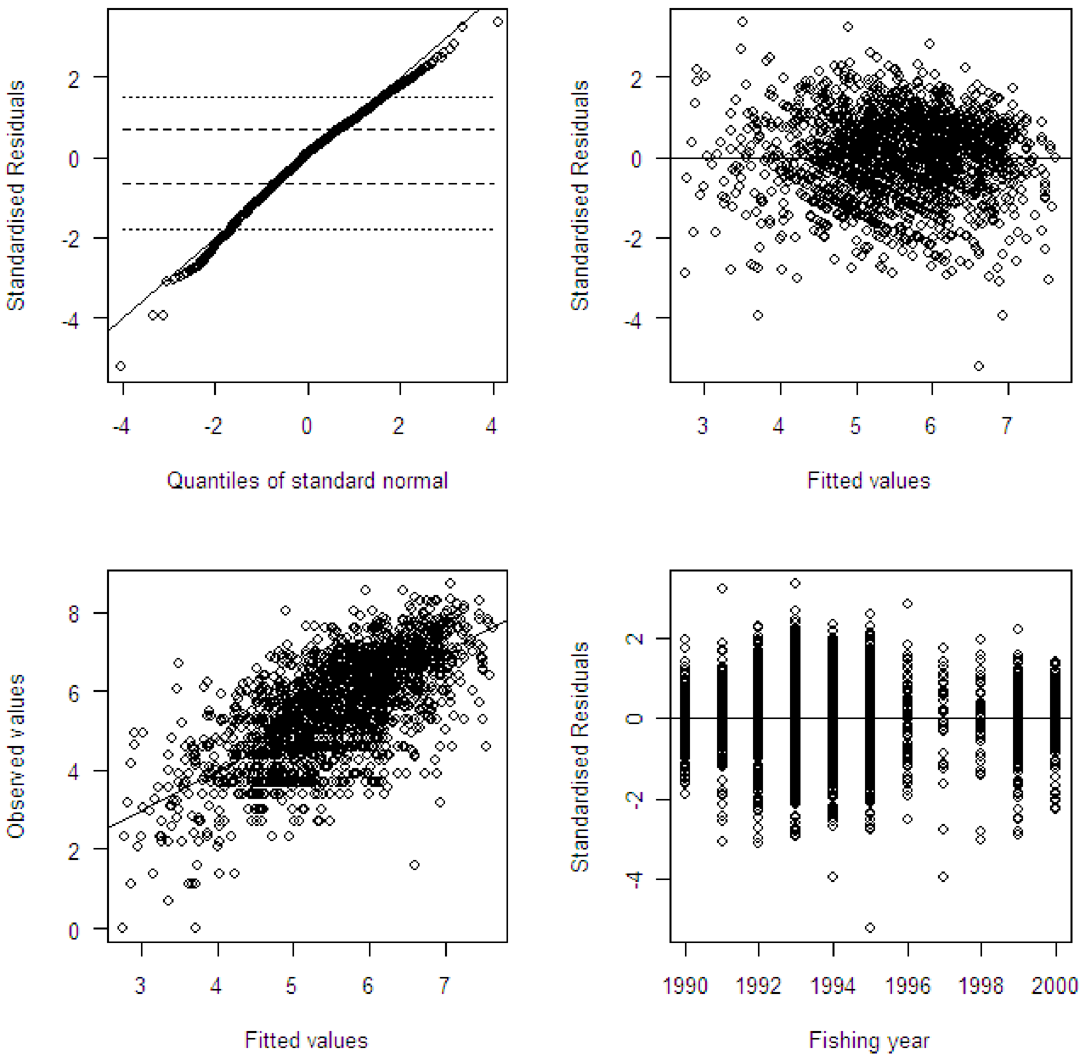


Figure C5: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the Bay of Plenty CELR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

Bay of Plenty substock - TCEPR lognormal model

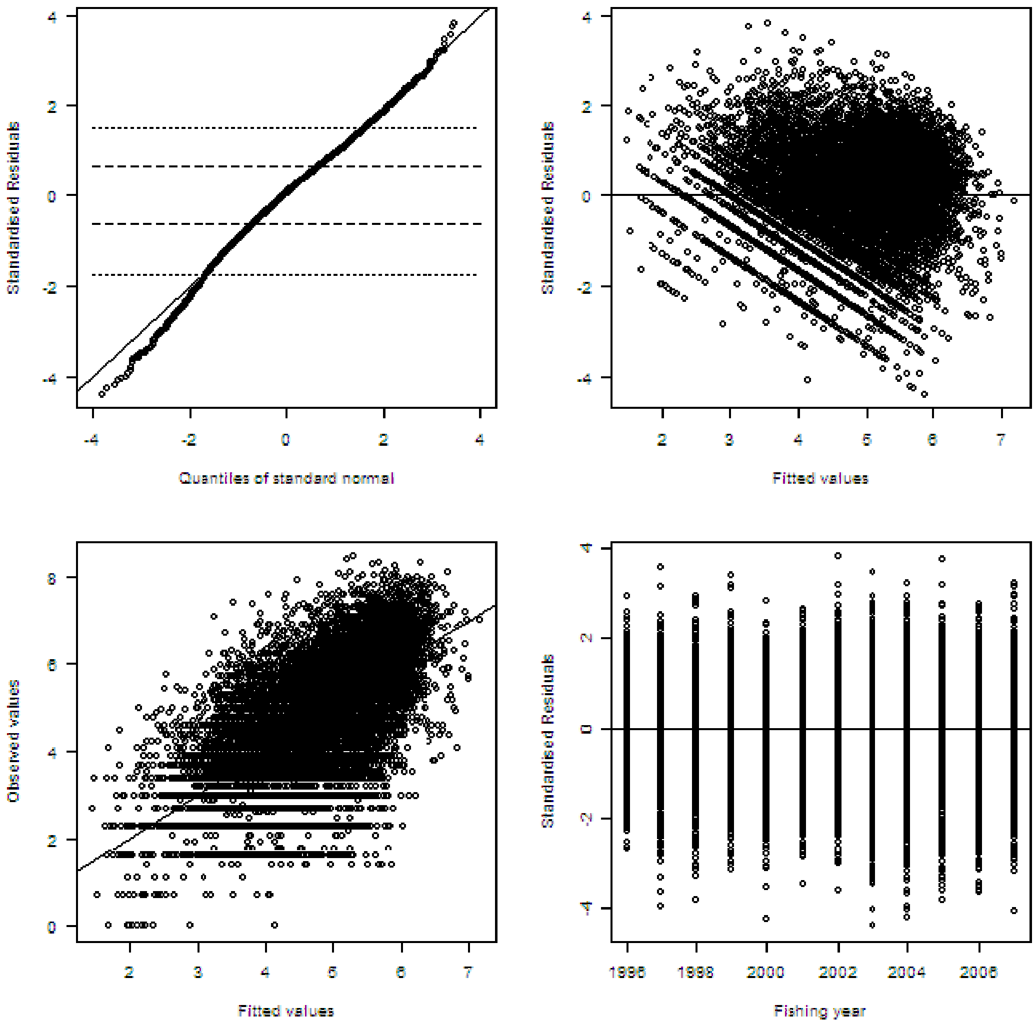


Figure C6: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the Bay of Plenty TCEPR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

APPENDIX D: MODEL COEFFICIENTS AND DISTRIBUTION OF UNDERLYING DATA

West coast CELR model

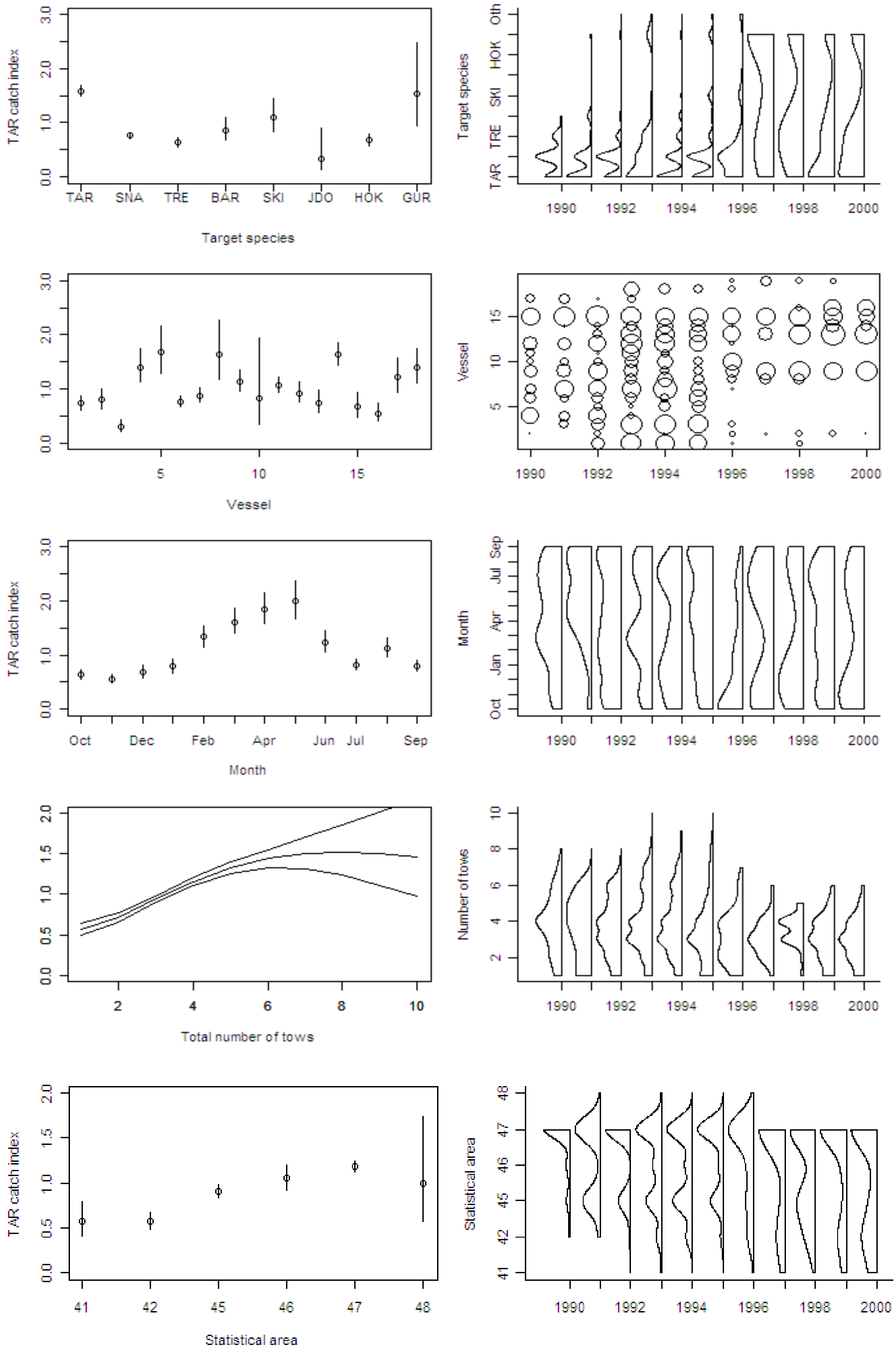


Figure D1: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the west coast bottom trawl fishery with 95% confidence intervals. Distribution of the underlying data. Fishing years are coded using the last year of the pair.

West Coast TCEPR model

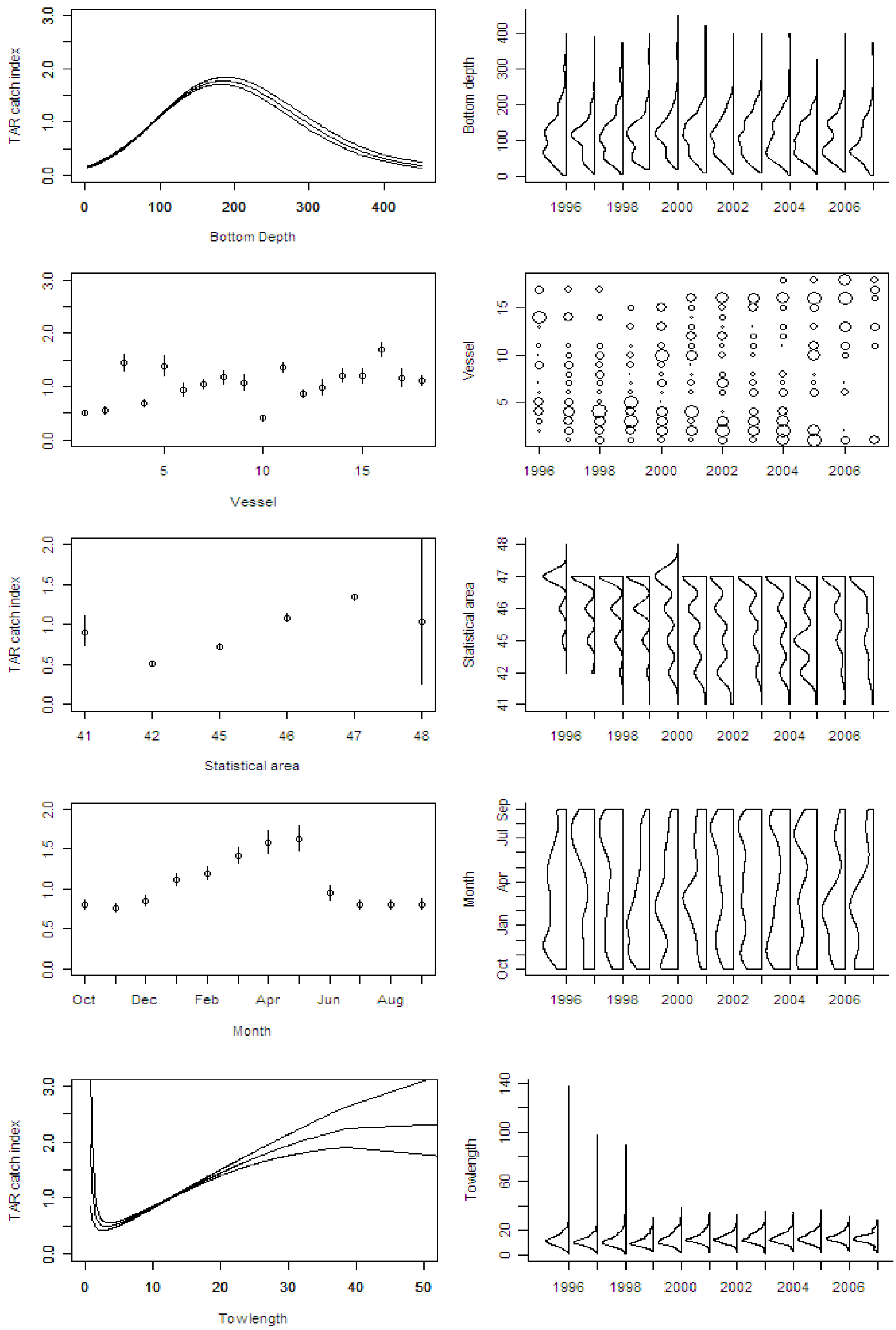


Figure D2: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the west coast TCEPR bottom trawl fishery with 95% confidence intervals. Distribution of the underlying data. Fishing years are coded using the last year of the pair.

East coast CELR model

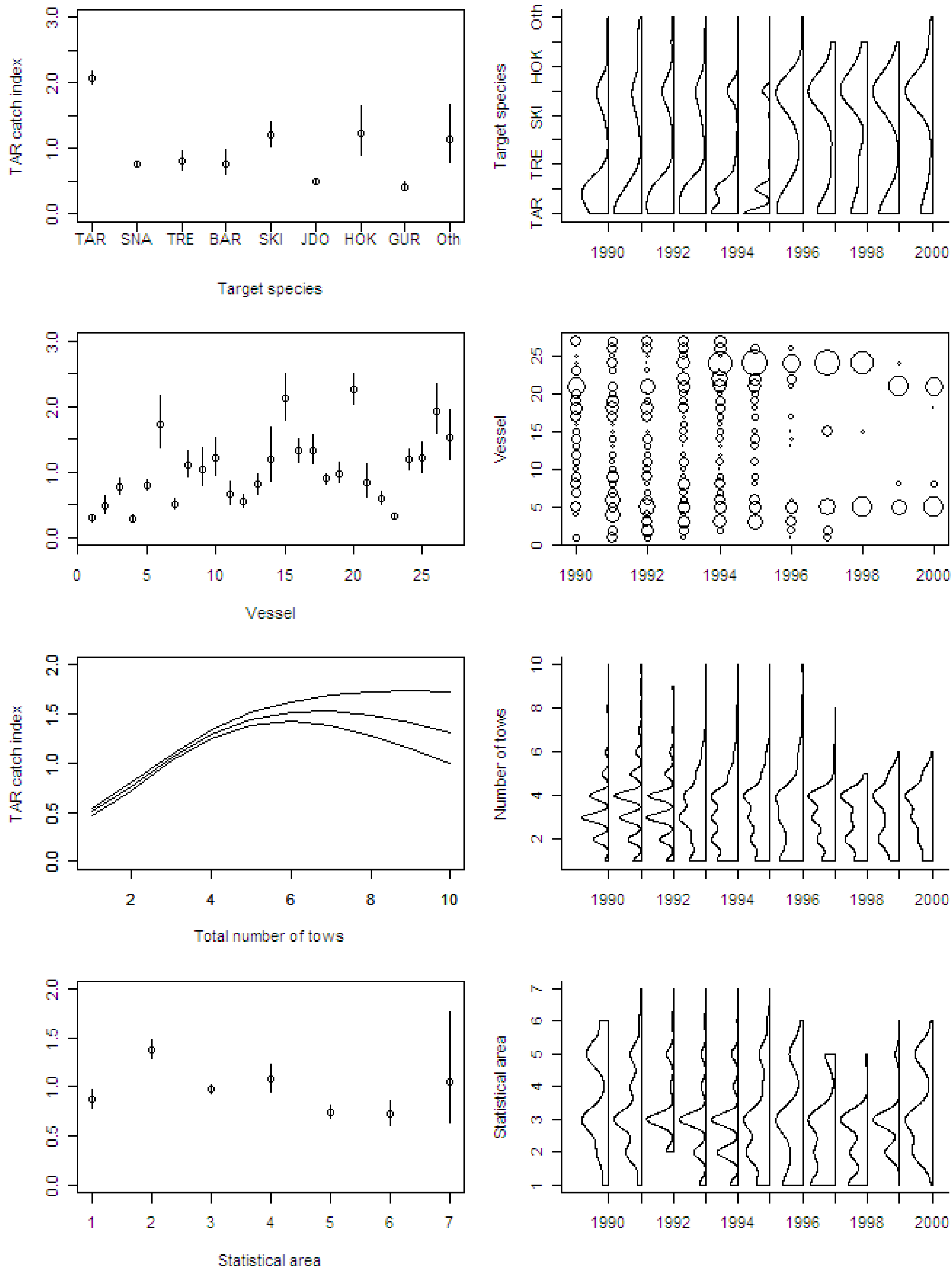


Figure D3: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the east coast bottom trawl fishery with 95% confidence intervals. . Distribution of the underlying data. Fishing years are coded using the last year of the pair.

East coast TCEPR model

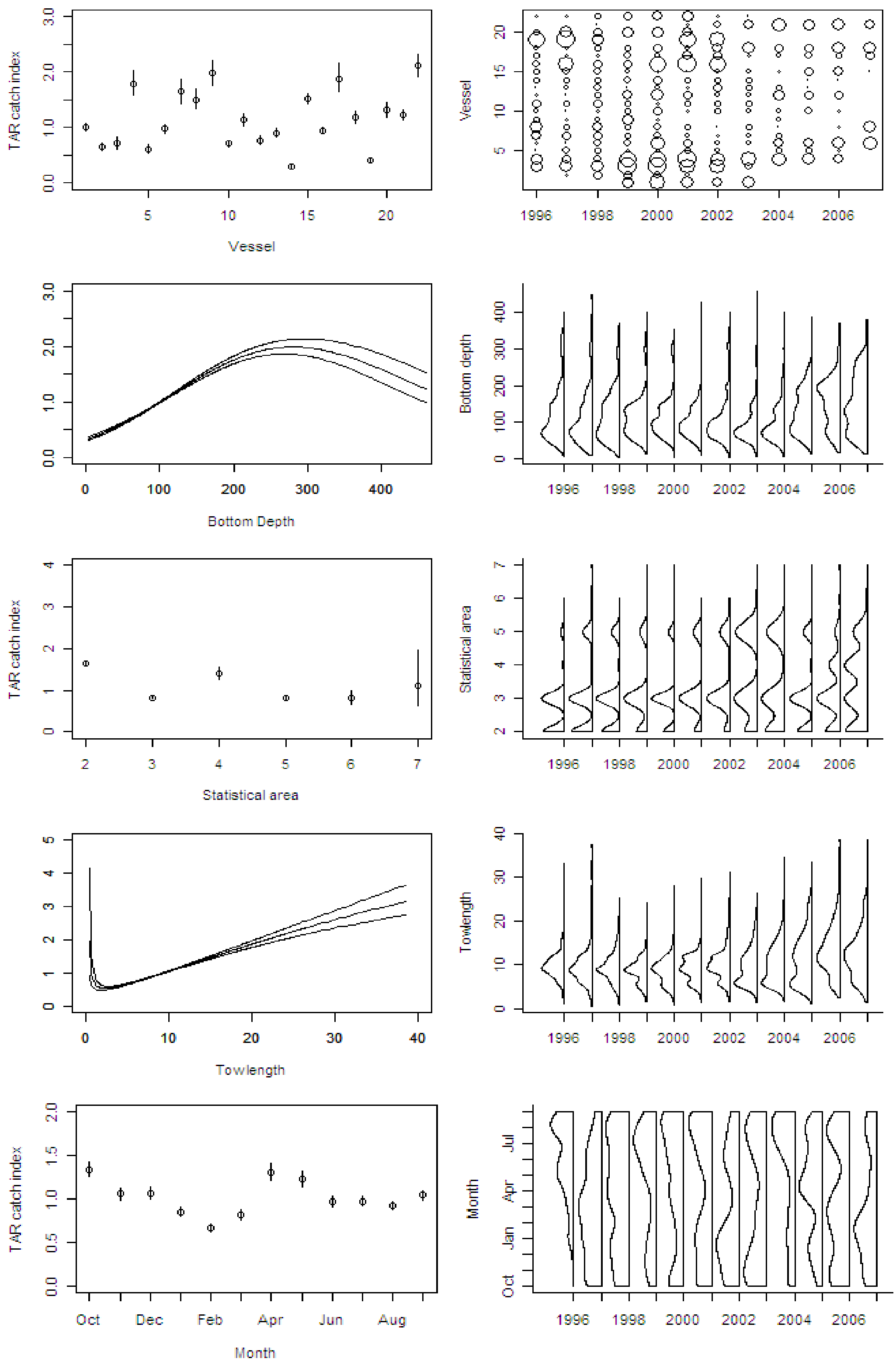


Figure D4: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the east coast TCEPR bottom trawl fishery with 95% confidence intervals. Distribution of the underlying data. Fishing years are coded using the last year of the pair.

Bay of Plenty CELR model

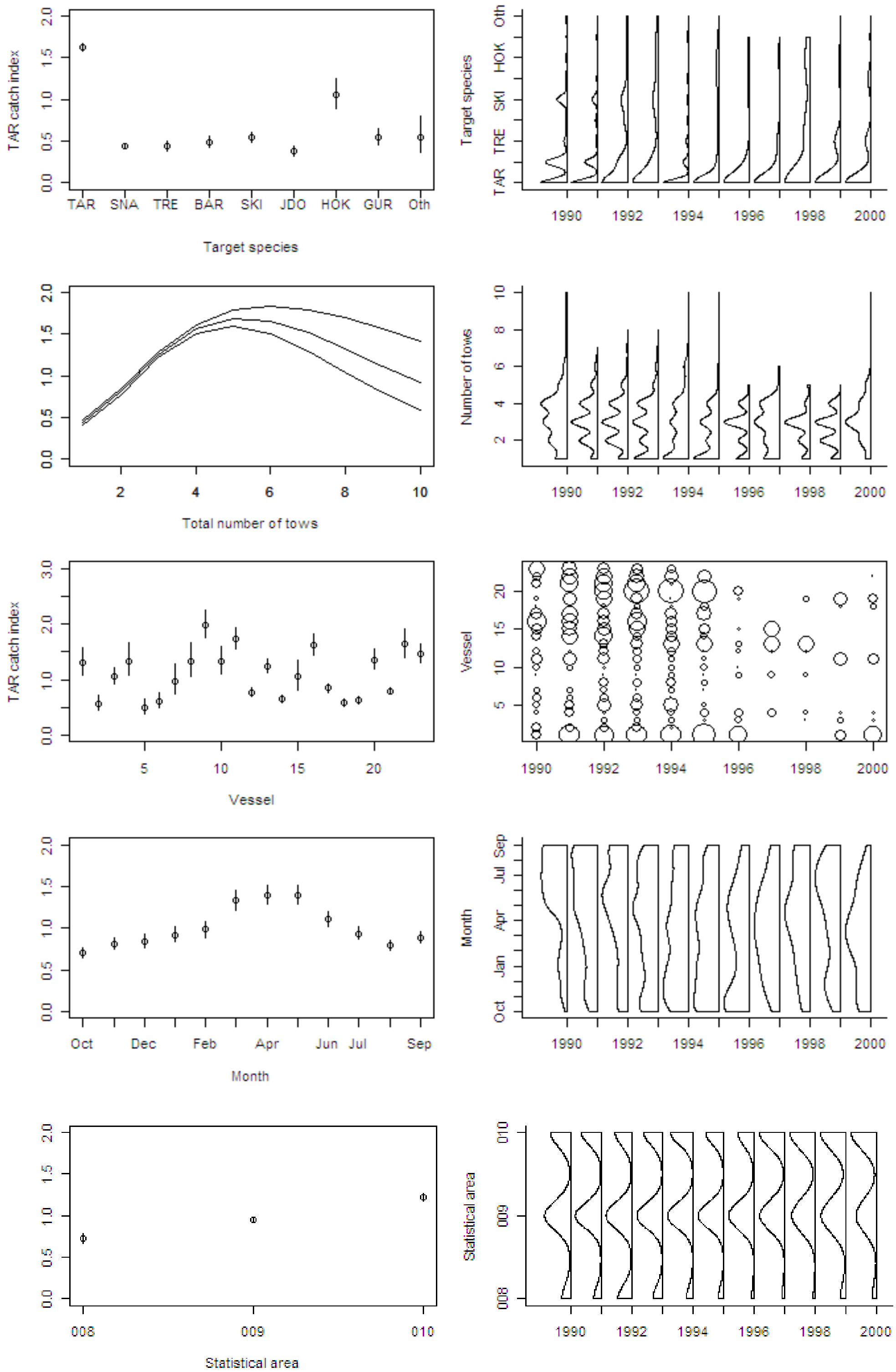


Figure D5: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the Bay of Plenty bottom trawl fishery with 95% confidence intervals . Distribution of the underlying data. Fishing years are coded using the last year of the pair.

Bay of Plenty TCEPR model

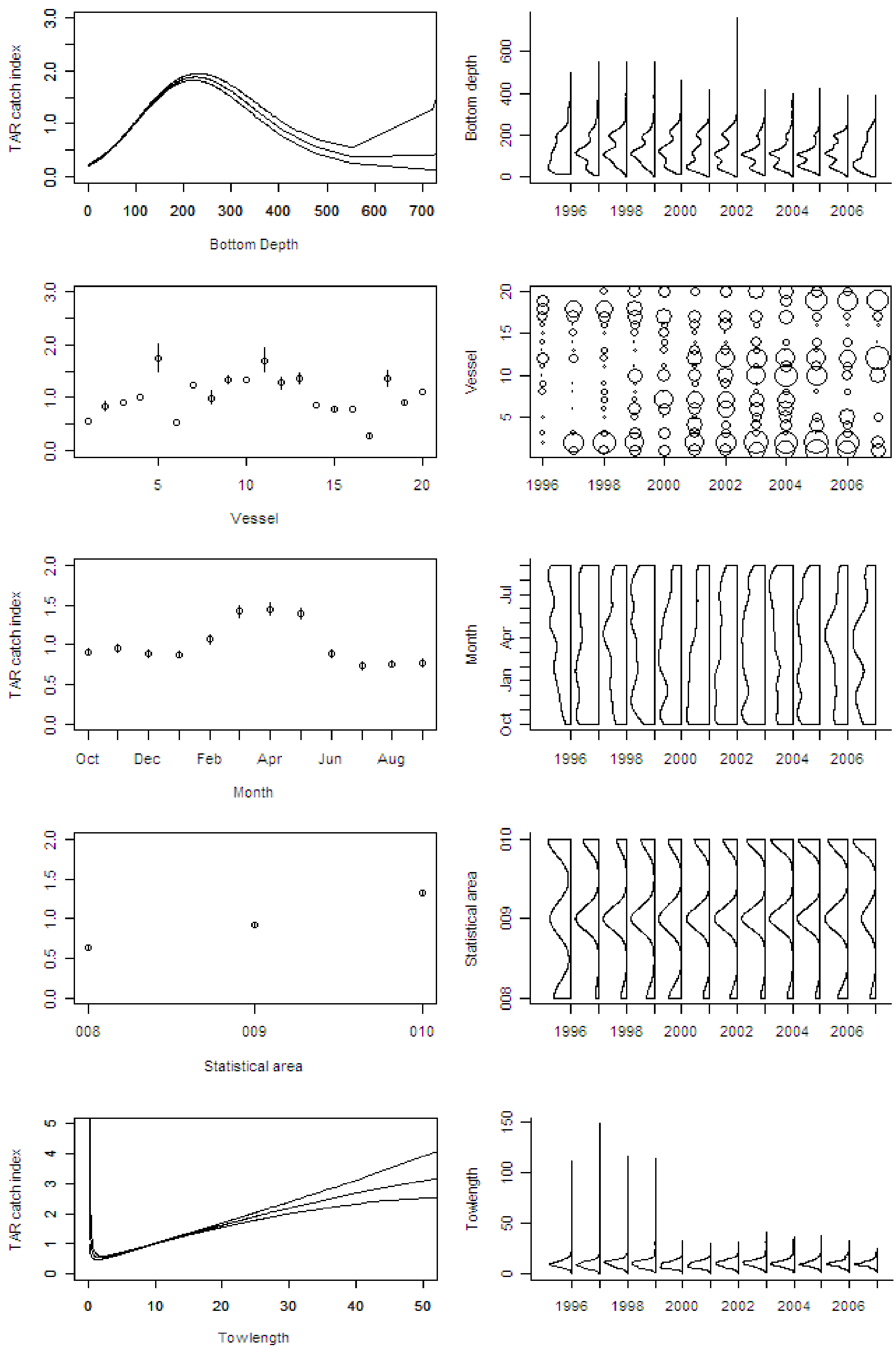


Figure D6: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the Bay of Plenty TCEPR bottom trawl fishery with 95% confidence intervals. Distribution of the underlying data. Fishing years are coded using the last year of the pair.

APPENDIX E: CPUE INDICES

Table E1: Relative year effects, standard error, and 95% confidence intervals for the CPUE models fitted to the west coast substock fisheries for TAR 1.

West coast Lognormals

Fishing				TCEPR				CELR
year	Index	SE	Upper	Lower	Index	SE	Upper	Lower
89/90					0.806	0.094	0.972	0.668
90/91					0.692	0.089	0.826	0.580
91/92					1.052	0.070	1.210	0.915
92/93					0.707	0.059	0.796	0.628
93/94					0.827	0.060	0.932	0.733
94/95					1.050	0.064	1.194	0.923
95/96	1.268	0.049	1.399	1.149	1.094	0.114	1.373	0.871
96/97	1.081	0.040	1.172	0.997	1.492	0.171	2.103	1.059
97/98	1.082	0.037	1.165	1.005	1.093	0.147	1.467	0.815
98/99	1.204	0.040	1.305	1.111	1.186	0.098	1.444	0.974
99/00	0.894	0.036	0.960	0.833	1.312	0.105	1.618	1.063
00/01	0.849	0.038	0.915	0.787				
01/02	0.971	0.037	1.046	0.902				
02/03	1.062	0.038	1.145	0.985				
03/04	0.943	0.035	1.011	0.879				
04/05	0.814	0.037	0.876	0.756				
05/06	0.876	0.046	0.959	0.800				
06/07	1.065	0.059	1.197	0.947				

Table E2: Relative year effects, standard error, and 95% confidence intervals for the CPUE models fitted to the east coast substock fisheries for TAR 1.

East coast Lognormals

Fishing				TCEPR				CELR
year	Index	SE	Upper	Lower	Index	SE	Upper	Lower
89/90					0.930	0.046	1.021	0.848
90/91					0.722	0.044	0.788	0.662
91/92					1.007	0.042	1.096	0.926
92/93					0.862	0.041	0.936	0.794
93/94					0.832	0.039	0.900	0.770
94/95					0.914	0.042	0.993	0.841
95/96	0.884	0.034	0.945	0.826	0.914	0.060	1.030	0.811
96/97	0.872	0.032	0.930	0.819	1.203	0.056	1.346	1.076
97/98	1.093	0.032	1.164	1.026	1.229	0.065	1.400	1.079
98/99	1.045	0.028	1.105	0.988	1.026	0.073	1.187	0.887
99/00	1.090	0.025	1.146	1.036				
00/01	1.119	0.026	1.179	1.063				
01/02	1.017	0.029	1.077	0.961				
02/03	1.014	0.035	1.087	0.946				
03/04	0.950	0.036	1.022	0.883				
04/05	1.120	0.040	1.214	1.034				
05/06	1.009	0.039	1.091	0.933				
06/07	0.841	0.045	0.920	0.769				

Table E3: Relative year effects, standard error, and 95% confidence intervals for the CPUE models fitted to the Bay of Plenty substock fisheries for TAR 1.

BoP Lognormals

Fishing				TCEPR				CELR
year	Index	SE	Upper	Lower	Index	SE	Upper	Lower
89/90					0.993	0.046	1.088	0.905
90/91					0.902	0.037	0.971	0.838
91/92					0.884	0.035	0.949	0.824
92/93					1.136	0.034	1.216	1.062
93/94					1.027	0.036	1.104	0.955
94/95					0.981	0.040	1.062	0.905
95/96	0.973	0.043	1.060	0.892	1.097	0.065	1.250	0.963
96/97	0.981	0.037	1.057	0.910	0.717	0.070	0.825	0.624
97/98	0.869	0.033	0.928	0.815	1.352	0.092	1.624	1.125
98/99	0.962	0.029	1.019	0.908	1.162	0.075	1.351	1.000
99/00	0.881	0.032	0.940	0.826	0.893	0.069	1.026	0.778
00/01	1.041	0.026	1.097	0.988				
01/02	1.242	0.025	1.306	1.181				
02/03	1.143	0.024	1.198	1.090				
03/04	1.175	0.023	1.230	1.123				
04/05	1.056	0.024	1.109	1.006				
05/06	0.871	0.027	0.919	0.826				
06/07	0.890	0.031	0.947	0.837				

APPENDIX F: DATA SUMMARIES

Table F1: Data summaries for core vessels in the two west coast fisheries defined for standardised CPUE analysis for CELR (core vessels based on a minimum of 5 trips per year in at least 3 years), and TCEPR (core vessels based on a minimum of 10 trips per year in at least 3 years); Number of trips, number of core vessels, number of tows (in positive days, CELR; or in positive tows, TCEPR), landed weight of TAR 1 (tonnes).

	CELR				TCEPR			
Fishing year	No. Trips	No. vessels	No. Tows	TAR 1 landed (t)	No. Trips	No. vessels	Positive Tows	TAR 1 landed (t)
89/90	72	7	598	70				
90/91	71	9	563	92				
91/92	137	13	1066	170				
92/93	192	16	1747	230				
93/94	199	15	1558	193				
94/95	145	12	1076	183				
95/96	45	13	261	47	97	12	453	178
96/97	20	4	114	14	183	13	582	211
97/98	26	7	159	17	201	13	687	239
98/99	68	5	441	83	154	13	628	201
99/00	72	5	365	49	179	13	751	254
00/01					203	15	664	221
01/02					192	14	696	283
02/03					172	13	650	293
03/04					190	13	767	257
04/05					167	11	744	281
05/06					124	9	516	247
06/07					87	6	280	123

Table F2: Data summaries for core vessels in the two east coast fisheries defined for standardised CPUE analysis for CELR (core vessels based on a minimum of 3 trips per year in at least 4 years), and TCEPR (core vessels based on a minimum of 5 trips per year in at least 5 years); Number of trips, number of core vessels, number of tows (in positive days CELR; or positive tows TCEPR), landed weight of TAR 1 (tonnes).

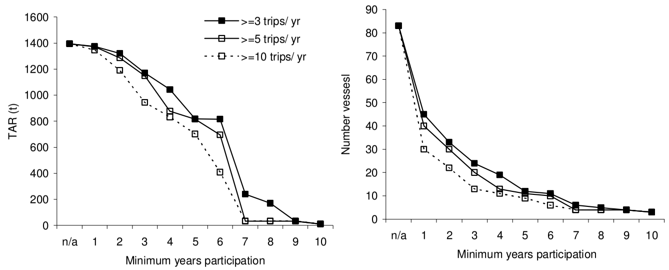
	CELR				TCEPR			
Fishing year	No. Trips	No. vessels	No. Tows	TAR 1 landed (t)	No. Trips	No. vessels	Positive Tows	TAR 1 landed (t)
89/90	199	22	1768	129				
90/91	252	25	2211	172				
91/92	273	25	1936	218				
92/93	283	27	1821	184				
93/94	291	25	1994	227				
94/95	250	18	1708	237				
95/96	96	13	714	85	178	19	848	131
96/97	111	5	872	145	225	20	953	165
97/98	73	3	623	112	227	21	872	163
98/99	67	4	518	39	244	20	1219	135
99/00	77	4	620	56	253	20	1529	178
00/01					279	21	1419	166
01/02					231	19	1112	166
02/03					178	16	704	98
03/04					140	13	658	107
04/05					118	11	529	188
05/06					142	11	617	189
06/07					114	6	477	102

Table F3: Data summaries for core vessels in the two Bay of Plenty fisheries defined for standardised CPUE analysis for; CELR (core vessels based on a minimum of 5 trips per year in at least 4 years), and TCEPR (core vessels based on a minimum of 5 trips per year in at least 3 years); Number of trips, number of core vessels, number of tows (in positive days CELR; or positive tows TCEPR), landed weight of TAR 1 (tonnes).

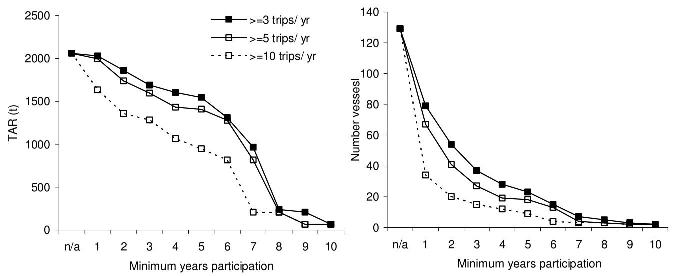
	CELR				TCEPR			
Fishing year	No. Trips	No. vessels	No. Tows	TAR 1 landed (t)	No. Trips	No. vessels	Positive Tows	TAR 1 landed (t)
89/90	201	19	1866	209				
90/91	383	17	2963	413				
91/92	452	23	3214	398				
92/93	479	23	2983	473				
93/94	380	23	2412	408				
94/95	307	17	1671	299				
95/96	94	10	589	113	121	15	521	134
96/97	123	5	580	164	162	13	742	158
97/98	57	6	306	105	196	16	972	231
98/99	78	6	472	141	281	17	1235	241
99/00	95	7	630	138	230	14	1024	168
00/01					317	18	1559	360
01/02					383	15	1673	502
02/03					397	17	1918	521
03/04					410	16	2127	585
04/05					318	15	1924	461
05/06					301	14	1528	354
06/07					190	9	1174	293

APPENDIX G: CORE VESSEL SELECTIONS

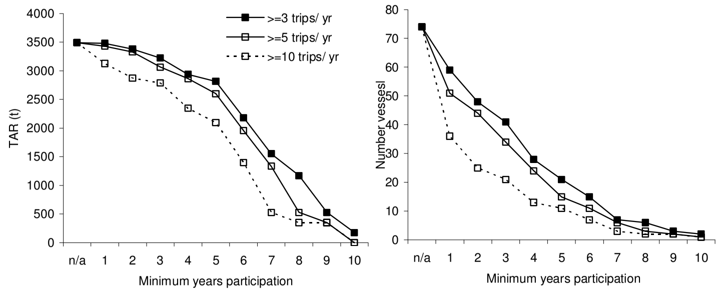
West coast CELR fishery (min. 3 years at min. 5 trips per yr)



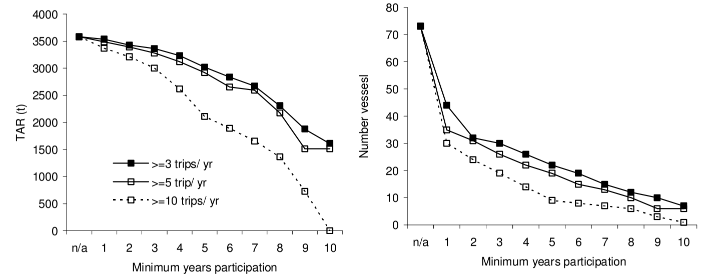
East coast CELR fishery (min. 4 years at min. 3 trips per yr)



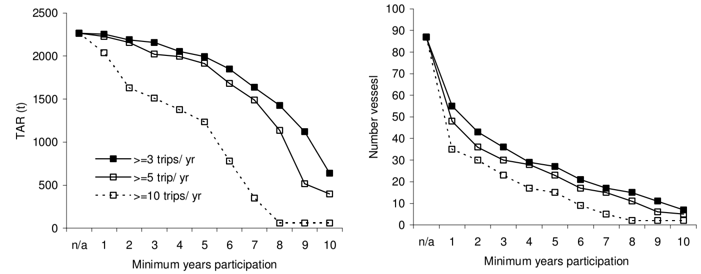
Bay of Plenty CELR fishery (min. 4 years at min. 5 trips per yr)



West coast TCEPR fishery (min. 3 years at min. 10 trips per yr)



East coast TCEPR fishery (min. 5 years at min. 5 trips per yr)



Bay of Plenty TCEPR fishery (min. 5 years at min. 5 trips per yr)

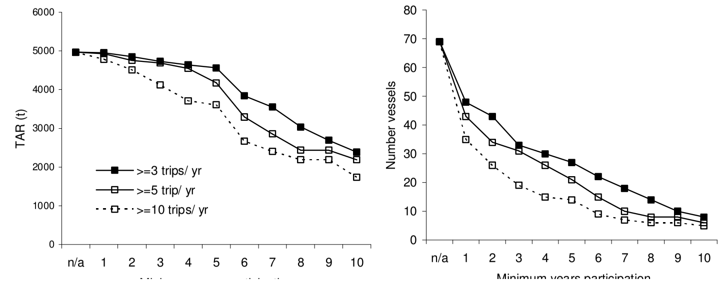
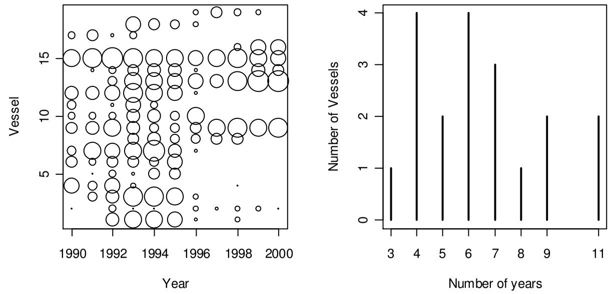


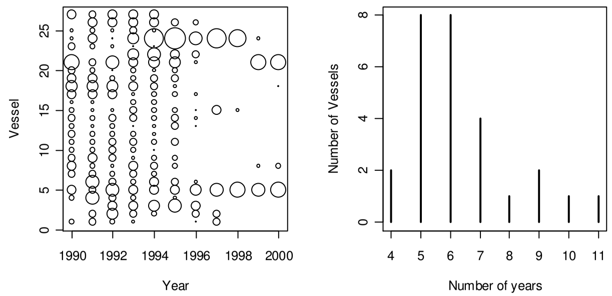
Figure G1: The total landed TAR 1 [left panel] and the number of vessels [right panel] retained in the CELR and TCEPR datasets for the three substocks depending on the minimum number of qualifying years used to define core vessels. Alternative definitions of a qualifying year (minimum number of trips per year) are indicated in the legend.

APPENDIX H: CORE VESSEL PARTICIPATION

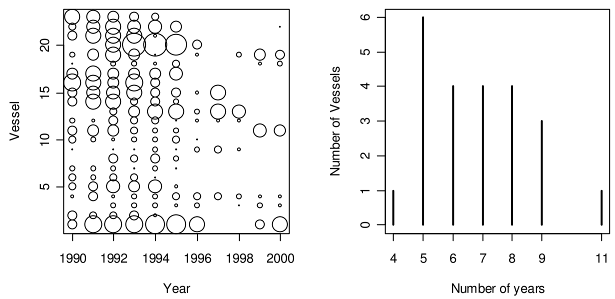
Participation of selected core vessels in the west coast CELR fishery



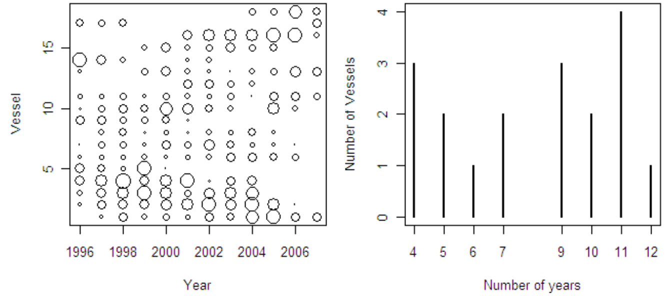
Participation of selected core vessels in the east coast CELR fishery



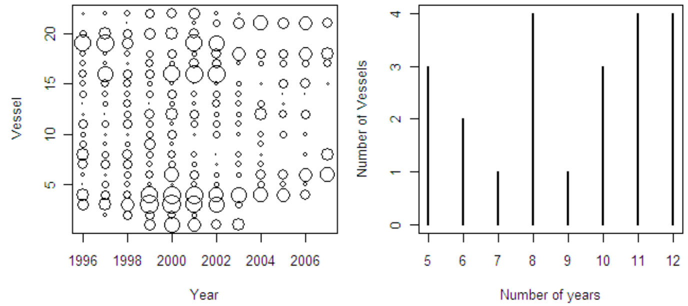
Participation of selected core vessels in the Bay of Plenty CELR fishery



Participation of selected core vessels in the west coast TCEPR fishery



Participation of selected core vessels in the east coast TCEPR fishery



Participation of selected core vessels in the Bay of Plenty TCEPR fishery

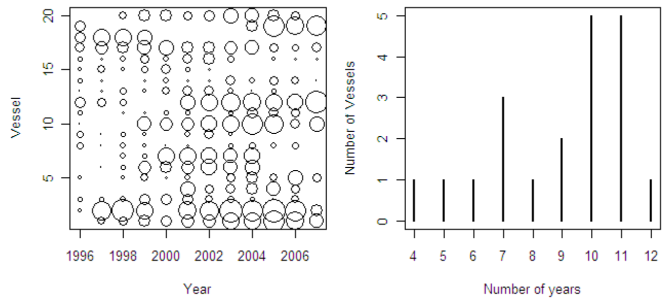


Figure H1: The participation of core vessels in the CELR and TCEPR bottom trawl fisheries; number of records for each vessel in each fishing year and distribution of length of participation.