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EXECUTIVE SUMMARY

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This study is contracted as MFish project TAR2004-02 with the specific objective: To update the standardised CPUE indices for TAR 1 using data up to the end of 2003/2004.

The previous indices (Project TAR1999/01) provided standardised CPUE analyses for TAR 1, 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.

On the basis of updated knowledge on the biology and stock identity of tarakihi (*Nemadactylus macropterus*), it was considered desirable for TAR 1 East to be further divided into Bay of Plenty, and TAR 1 East, so that three separate biological substocks are monitored. Other improvements to the standardised CPUE analysis include the use of landed greenweight rather than estimated catch, and a combined lognormal/binomial model to incorporate zero catch information from associated bycatch fisheries. Both these measures have become widely accepted for inshore species that are monitored in mixed target fisheries; i.e., where the nominal target species reported by the fisher is not relied on to delineate the effective effort, but rather all effort in a more broadly defined fishery is included. This is relevant to TAR 1 because of the concerns expressed by Field & Hanchet (2001) that target species might not be consistently reported and should, to some degree, be ignored.

The distribution of the fishery (landed catch) is described separately for the three substocks by fishing method, and in further detail for the bottom single trawls, by target species, location, and season. There is evidence in each of the three substock areas of well defined targeting of tarakihi in the autumn months of March to May, possibly focused on spawning or migratory fish. Tarakihi are available throughout the year, however, and catches outside the target fishery are often reported as a bycatch of snapper, trevally, and John dory tows. A more generalised index, calculated using both bycatch and target fishing, is considered desirable, and was also recommended by Field & Hanchet (2001).

Two alternative fisheries are defined for standardised CPUE analysis for each of the three substocks; a defined mixed target fishery (MIX) in which CPUE is calculated using catch over all effort, including unsuccessful effort, and a target fishery (TARG) based on the largely positive catches from fishing events targeted on tarakihi. In each case the series is recalculated using allocated landed catch and estimated catch at the same resolution, i.e., a trip-stratum, as was recommended by an MFish workshop, in May 2005, on Monitoring Inshore Species.

The Field & Hanchet (2001) series cannot be exactly replicated when using landed greenweight, because data, including all qualifying effort, are amalgamated at trip-strata resolution (a unique combination of trip, method, statistical area, and target species) and individual tows that report a positive catch of tarakihi cannot be isolated. In this study, the Field & Hanchet (2001) series are most closely replicated by the TARG series.

For each substock, the TARG series gives a flatter and/or a more optimistic picture, while the MIX series shows more contrast. In the Bay of Plenty substock, the target series increases 30% over the time series, while the MIX series declines slightly, but both agree on the major feature, a peak in 2001–02. In the Eastern substock, the TARG series is essentially flat and featureless, while the

MIX series shows a pronounced 7–8 year cyclical pattern that in 2003–04 was 45% below the 1989–90 index. In the Western substock, the target series increases overall by about 70% while the MIX series declines by a similar margin over the time series.

Most of the contradiction in the Western substock is in the first half of the time series, between 1989–90 and 1995–96, when target catch rates of tarakihi increased, and zero tarakihi catches in snapper and trevally tows also increased, driving bycatch rates down. The contradiction suggests improved targeting or reporting behaviour that compromises both target and bycatch CPUE for monitoring abundance, and coincides with the complete shift from reporting on daily Catch Effort Landing Returns (CELR) to tow-by-tow reporting on Trawl Catch Effort and Processing Returns (TCEPR's).

Introduction of GPS plotters and other technology has likely improved targeting and catchability of key species, allowing fishers to land the species mix required for management and marketing purposes. The systematic and total switch from reporting on daily Catch Effort Landing Returns (CELR) to tow-by-tow reporting on Trawl Catch Effort and Processing Returns (TCEPRs) has certainly improved the reporting of target species, and makes interpretation of long time series of CPUE difficult, particularly in the Western substock.

The Inshore Working Group suggested a truncated CPUE series that starts in 1995–96 (the first year in which most records are in TCEPR format), based on TCEPR data in their original format (using estimated rather than landed catch), using a successful catch of tarakihi to define effective effort, and standardising the resultant catch rates by variables such as bottom depth and distance towed, rather than the reported target species. The resultant datasets therefore include all tarakihi catch and no zero catch events. A truncated TCEPR series is presented for each substock.

For the Bay of Plenty and Eastern substocks, the TCEPR series confirms the patterns in the MIX and TARG trajectories over the subset of years that they coincide, suggesting an increase in the Bay of Plenty, and no overall change in the Eastern substock. For the Western substock the TCEPR series shows quite a well determined decline. The trajectory is similar to, but declines more steeply than, an extension of the previous series, and is a marked improvement over both TARG and MIX, which both show high interannual variability in the corresponding years

Future work should continue to develop the TCEPR series for each of the three substocks, providing that a high proportion of the catch continues to be reported in that format. Longer time series for the eastern and Bay of Plenty substocks, based on a broader definition of effective effort, may also be useful as ancillary series, as they appear able to show more contrast than a CPUE series based only on successful effort.

Reference: Field, K.; Hanchet, S.M. (2001). Catch-per-unit-effort analysis for tarakihi (*Nemadactylus macropterus*) in TAR 1, 2, 3, and 7. *New Zealand Fisheries Assessment Report 2001/60.* 73 p.

1 INTRODUCTION

Tarakihi (*Nemadactylus macropterus*) is a valued species in the New Zealand coastal trawl fishery with a long history of exploitation. Like the snapper fishery, this fishery has one of the longest and best reported catch histories in New Zealand (Annala 1988). The main fishing method in TAR 1 is trawling, and most of the catch is taken in targeted tows, but smaller amounts are also taken as a bycatch of trevally, snapper, John dory, and gemfish tows. 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.

Project TAR1999/01 provided standardised CPUE analyses for TAR 1, 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 (Field & Hanchet 2001).

The CPUE indices calculated for TAR 1W appeared to have increased between 1989–90 and 1995–96, followed by a slight decline. There was a similar slight (16%) decline in tarakihi abundance between two trawl surveys carried out in 1997 and 2000. The authors concluded that the CPUE was probably monitoring tarakihi abundance in the area. There have been no subsequent trawl surveys on the west coast of the North Island optimised for tarakihi.

For TAR 1E, CPUE appeared to have been relatively stable between 1989–90 and 1998–99, and there were no fishery-independent measures of abundance available for validation, but Field & Hanchet (2001) noted some consistency with trends in adjacent fishstocks TAR 1W and TAR 2 that gave some indirect support for the belief that CPUE indices may be monitoring abundance in TAR 1E.

This study is contracted as MFish project TAR2004-02 with the specific objective: To update the standardised CPUE indices for TAR 1 using data up to the end of 2003/2004. On the basis of updated knowledge on the biology and stock identity of tarakihi, it was considered desirable for TAR 1 East to be further divided into Bay of Plenty, and TAR 1 East, so that three separate biological substocks are monitored.

A Ministry of Fisheries workshop, Monitoring Inshore Species, held in May 2005 recommended that, for all inshore species CPUE series should be calculated using both landed wholeweight and estimated catch, both collated at the trip-strata resolution, and this study includes the results of CPUE standardisations done using those methods.

The Field & Hanchet (2001) series can not be exactly replicated when using landed greenweight, however, because the data are amalgamated at trip-strata resolution (a unique combination of trip, method, statistical area, and target species) including all qualifying effort, and individual tows that report a positive catch of tarakihi cannot be isolated. Several alternatives are presented.

2 METHODS

2.1 Landed greenweight versus estimated catch

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

Studies prepared for the MFish Adaptive Management Programme (AMP) have highlighted potentially serious biases from using estimated catch for even well reported species, such as tarakihi and gurnard.

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

The landings values, reported on the bottom part of the CELR, or on Catch Landing Returns (CLRs) respectively, represent total catches, are trip-based (available only at the end of the fishing trip), and are not directly linkable to individual fishing events or even to a single day's fishing.

The linkage can be simulated by apportioning the landed catch at the end of each trip to effort strata within the corresponding trip using procedures that have been developed for monitoring bycatch species in the AMP, and were comprehensively described by Manning et al. (2004).

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

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

A disadvantage of using allocated landings is that the consequence of data grooming can be severe, because individual fishing events cannot be excluded from the dataset without all records for the trip being identified and excluded. The emphasis of the error checking and data grooming procedures is therefore on correction rather than exclusion of errors. There can also be considerable data loss from excluding trips that used multiple fishing methods (where the measures of effort are incompatible), or that fished straddling statistical areas and landed to multiple Fishstocks.

2.2 Inclusion of zero catch information

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

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

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

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

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

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

Candidate trips were identified by searching for all effort records using the bottom trawl method in statistical areas that are valid for TAR 1. Once a list of trips that satisfied these criteria was identified, all effort and landing records associated with these trips were extracted.

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

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

The allocation of landed catch to effort is done by first summarising effort and estimated catch data for a fishing trip, for every unique combination of fishing method, statistical area, month, and target species (referred to as a "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 is proportionate to the amount of effort.

The data available for each trip included estimated and landed catch of tarakihi, total hours fished, total number of tows, 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 any species from one of the straddling statistical areas, or that used a multiple fishing methods with incompatible measures of effort, were entirely dropped.

This method of using allocated landings retained for analysis over 90% of landed TAR 1 in most years (the exception being 1989–90), the percentage was lowest during the middle of the time series. The estimated catch in the groomed dataset represented about 90% of the allocated landings for the first half of the time series and then dropped to fluctuate about 86% in the last seven years (Table 1, Figure 1). This represents a slightly decline in the reporting rate.

Table 1: Comparison of TAR 1 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 TAR fishstock and fished in a straddling statistical area. The estimated catch total is the sum from all trips with matching landing data.

Fishing year	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	973	772.5	754.8	671.9	77.6	69.1	89.0
90/91	1 125	1 155.7	1 092.7	1 026.9	97.1	91.3	94.0
91/92	1 415	1 417.1	1 363.8	1 218.1	96.4	86.1	89.3
92/93	1 477	1 451.5	1 417.4	1 251.8	96.0	84.8	88.3
93/94	1 431	1 457.3	1 424.1	1 305.5	99.5	91.2	91.7
94/95	1 390	1 375.8	1 328.5	1 202.1	95.6	86.5	90.5
95/96	1 422	1 425.8	1 353.2	1 234.2	95.2	86.8	91.2
96/97	1 425	1 376.3	1 312.3	1 241.9	92.1	87.1	94.6
97/98	1 509	1 527.8	1 415.8	1 272.6	93.8	84.3	89.9
98/99	1 436	1 435.0	1 381.6	1 182.9	96.2	82.4	85.6
99/00	1 387	1 420.3	1 356.1	1 133.8	97.8	81.7	83.6
00/01	1 403	1 407.0	1 377.7	1 187.5	98.2	84.6	86.2
01/02	1 480	1 499.1	1 451.8	1 287.9	98.1	87.0	88.7
02/03	1 517	1 505.4	1 470.9	1 253.7	97.0	82.6	85.2
03/04	1 541	1 534.5	1 494.2	1 295.9	97.0	84.1	86.7

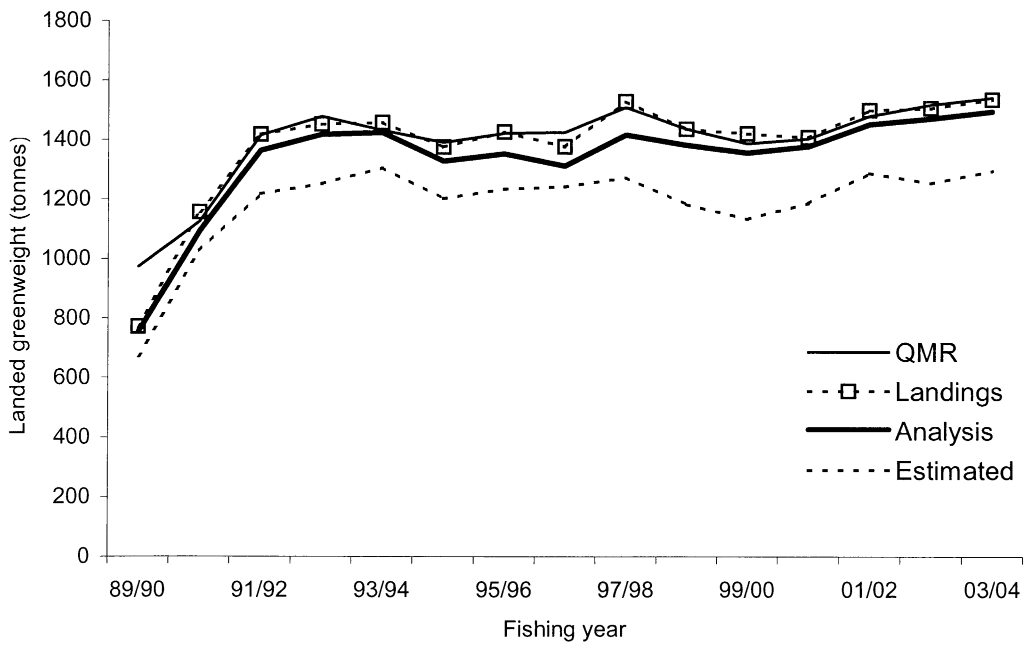

Figure 1: Plot of catch datasets presented in Table 1. The landings are totals reported on Catch Effort forms with some editing, the analysis dataset excludes all landings from trips that landed more than one tarakihi fishstock and fished in a straddling statistical area or that used multiple incompatible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

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

Two standardised CPUE analyses were performed on the mixed target species (MIX) datasets. A lognormal linear model was fitted to successful catches of TAR 1, excluding zero catches, and a binomial model which predicted success or failure of TAR 1 catch was fitted to the total dataset, including records that reported a zero catch of tarakihi. These two models were combined into a single set of indices using the method of Vignaux (1994).

The target (TARG) datasets contain very few zero catch records, and those are largely a product of the merge process that assigns landed catch on the basis of estimated catch. A zero record in this dataset is as likely to indicate that tarakihi was not among the top five species caught as a genuine null catch. Zero catches in those datasets were therefore excluded and a lognormal linear model fitted to the remaining catches.

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 model was the log of landed weight of TAR 1 per record (where a record is a trip/statistical area/target species stratum). The explanatory variables offered to the model were: fishing year (always forced as the first variable), and month (of landing), statistical area, target species, along with a unique vessel identifier. The total number of tows and total duration of fishing were included as measures of effort to explain catch per trip. For models based on data in its original resolution, bottom depth, tow speed, and tow length (calculated from speed and duration) were also offered.

The dependent variable for the binomial model was a binary variable set to '1' for records which had associated TAR 1 catch and set to '0' for records with no catch. This model was offered the same explanatory variables as the lognormal model.
The two models were combined using;

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

where C_i = combined index for year i
L_i = lognormal index for year i
B_i = binomial index for year i
P_0 = proportion zero for base year 0

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

2.5 Sub-stock areas

The three substocks 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 the distribution tables and plots in this report.

Substock area	Statistical areas
West	41 42 43 44 45 46 47 48 101 102 103 104
East	1 2 3 4 5 6 7 105 106
Bay of Plenty	8 9 10 107

3 RESULTS

About 50% of TAR 1 has consistently been landed from the Bay of Plenty, with the balance coming almost equally in most years from the Western and Eastern substocks. In the most recent five years, however, there has been a trend of increasing catch taken in the Bay of Plenty, accompanied by a sharp drop in removals from the Eastern areas. There has been less change, but also a slight drop in catches from the Western areas in the most recent year (Table 3).

There has been a complete shift from reporting on the daily CELR form to tow-by-tow reporting on TCEPRs in the Western substock. The transition year was 1994–95, and by 1995–96 almost 90% of tarakihi was reported on TCEPRs, and by 2000–01 it was almost 100%. There has been a similar though not as complete a shift in the other two substocks (Table 4).

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 2003–04. 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	232	879	27	15	58
03/04	344	229	968	22	15	63

Table 4: Percent landed TAR 1 by form type, for substock and fishing year.

Fishing	% TCEPR		
Year	West	East	Bay of Plenty
89/90	6	4	1
90/91	1	1	0
91/92	2	1	1
92/93	7	2	0
93/94	9	18	15
94/95	38	25	27
95/96	89	80	72
96/97	97	78	61
97/98	95	79	75
98/99	78	83	63
99/00	85	73	48
00/01	99	88	74
01/02	100	94	79
02/03	100	93	78
03/04	100	84	83

3.1 Characterisation of the West Coast trawl fisheries

Generally more than 90% of the catch from TAR 1 from the western areas is taken by single bottom trawl, with small amounts in each year taken by pair trawl, bottom longline, setnet and Danish Seine (Table 5).

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 (5–10%). Bycatch of trevally 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 (Table 6, Figure 2). Hoki was significant only in recent years.

The seasonality of the four most important target fisheries taking TAR 1 by bottom trawl is shown in Figure 3. Targeting of tarakihi occurs throughout the year, but the greatest catches are taken between February and May. Although snapper tows used to land tarakihi consistently through the year (during the early 1990s), bycatch from this fishery since 1996–97 has largely been outside of the main tarakihi target season. The bycatch from trevally tows comes mainly in the first half of the fishing year, and the bycatch from barracouta tows almost entirely in the last half of the fishing year.

The spatial distribution of the same four target fisheries is similar (Figure 4), with most of the tarakihi caught in area 047, followed by areas 45 and 46. Targeted catches of tarakihi have increased in area 46, varied from year to year in area 45, but have also increased over time in area 41 (which has only part of its area in TAR 1) and area 42. Areas 43 and 44 are harbours that are protected from commercial trawling. When snapper bycatch was more significant, it came largely from areas 47 and 45.

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 series. There is a definite seasonal peak from February to May, during which little bycatch is reported, and catches of tarakihi out of other fisheries have quite different seasonal and in some case spatial distributions.

Table 5: 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 scaled up 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.

												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	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	3	0	0	98	1	1	1	0	0
97/98	379	2	2	4	0	0	98	0	0	1	0	0
98/99	395	39	3	3	0	0	90	9	1	1	0	0
99/00	392	37	8	2	0	0	89	8	2	0	0	0
00/01	297	57	18	6	2	0	78	15	5	1	1	0
01/02	350	2	8	1	9	0	95	1	2	0	2	0
02/03	372	16	12	2	6	0	92	4	3	0	1	0
03/04	294	27	5	2	13	3	85	8	2	1	4	1

Table 6: Distribution of bottom trawl caught tarakihi by target species (tarakihi, snapper, trevally, barracouta, jemfish, john dory, hoki, gurnard or other) and by fishing year for the West 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.

																		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

In considering what effort is effective for tarakihi, and should therefore be included in the calculation of CPUE, we are restricted, by the inclusion of CELR format data, to using target species as a proxy for bottom depth, tow speed, and factors that would be more useful. It is clear that trawls that target snapper and trevally are overlapping the habitat of tarakihi to some extent, and even though snapper is known to have a quite different depth and habitat preference to tarakihi, the apparent shift in targeting behaviour of fishers on these two species means that it is probably important to include all effort directed at either. The contribution from trevally tows has been fairly consistent over the time series, and should also be included, but it would be inappropriate to include effort directed at other trawl caught species such as hoki, gemfish, etc., which have accounted for significant amounts of tarakihi for only a part of the time series.

The unstandardised CPUE of tarakihi in nominally targeted tows was reported at between 200 and 300 kg per tow in the early years (before 1994–95). It then increased sharply over two years to about 500 kg per tow, increasing again in 2001–02 and 2002–03 to 600 to 700 kg per tow. The pattern in tows targeted at snapper and at trevally is quite the opposite, dropping from annual averages that fluctuated around 40 kg per tow in the first half of the series to more stable levels at about half that rate in the last half of the series.

The relative unstandardised CPUE of tarakihi in successful trip-strata in each of these target fisheries is shown in Figure 5. The percentage of zero catches for each of the two bycatch fisheries is also shown in Figure 5 and is presumably indicative of the trend in proportion of zero catches at tow level i.e., that have been incorporated into the catch rate estimates, helping to explain the declining catch rates in those two fisheries. The contrast between CPUE trends indicates either improved targeting behaviour by fishers (higher target catch rates accompanied by less bycatch), or some change in reporting of target species. Although contradictory, it would appear they each tell part of the story, and need to be accounted for.

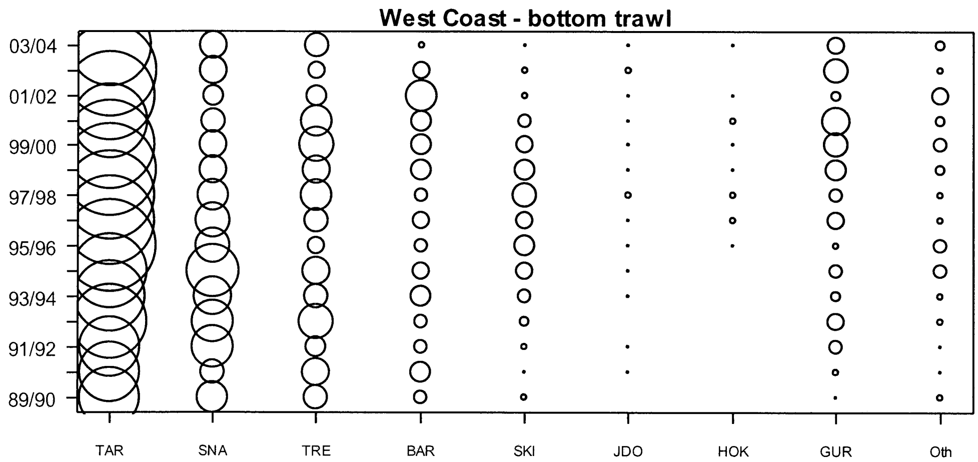

Figure 2: Distribution of bottom trawl caught tarakihi, for the West Coast substock area, by target species and fishing year. Circle areas are proportional to the catch totals by area, with the circle values given in Table 6.

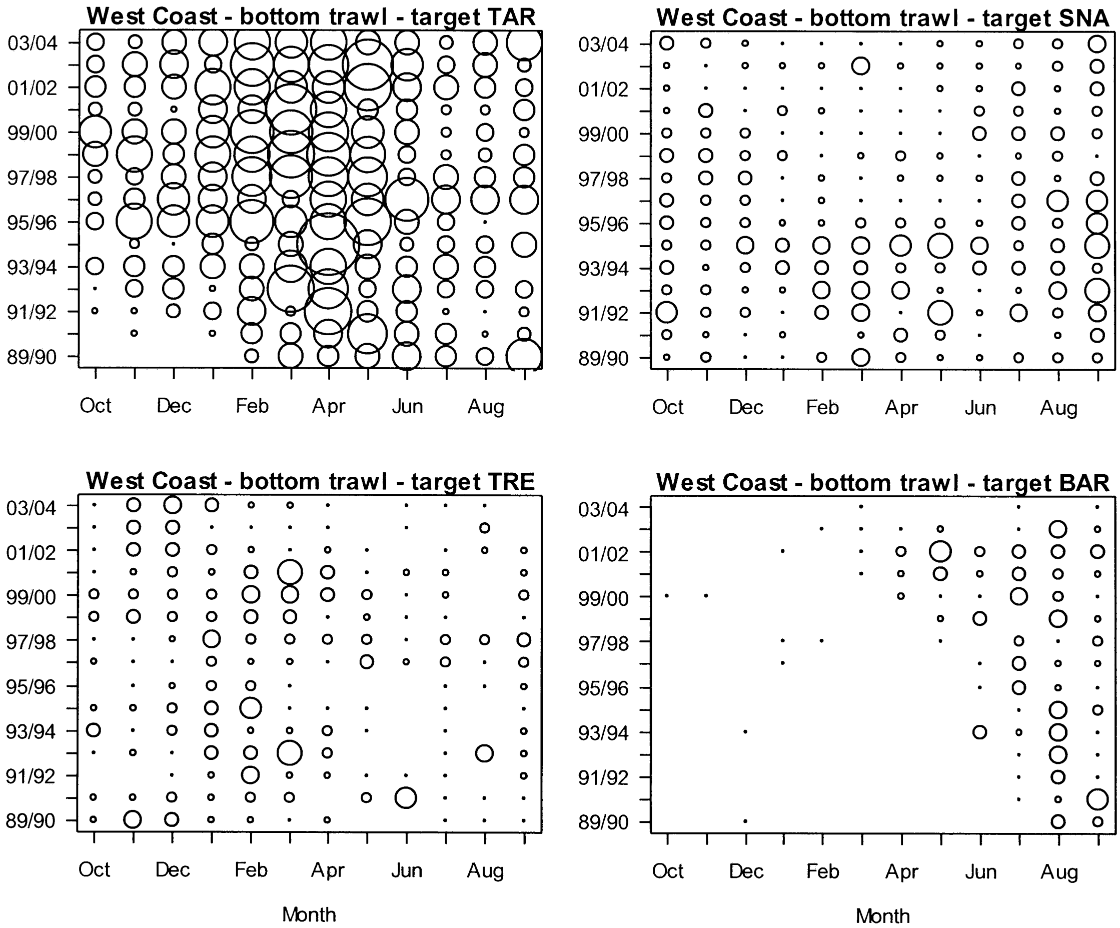

Figure 3: Comparison of the seasonal distribution of bottom trawl tarakihi catches for the four main target fisheries taking TAR 1 from the West Coast substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 6.

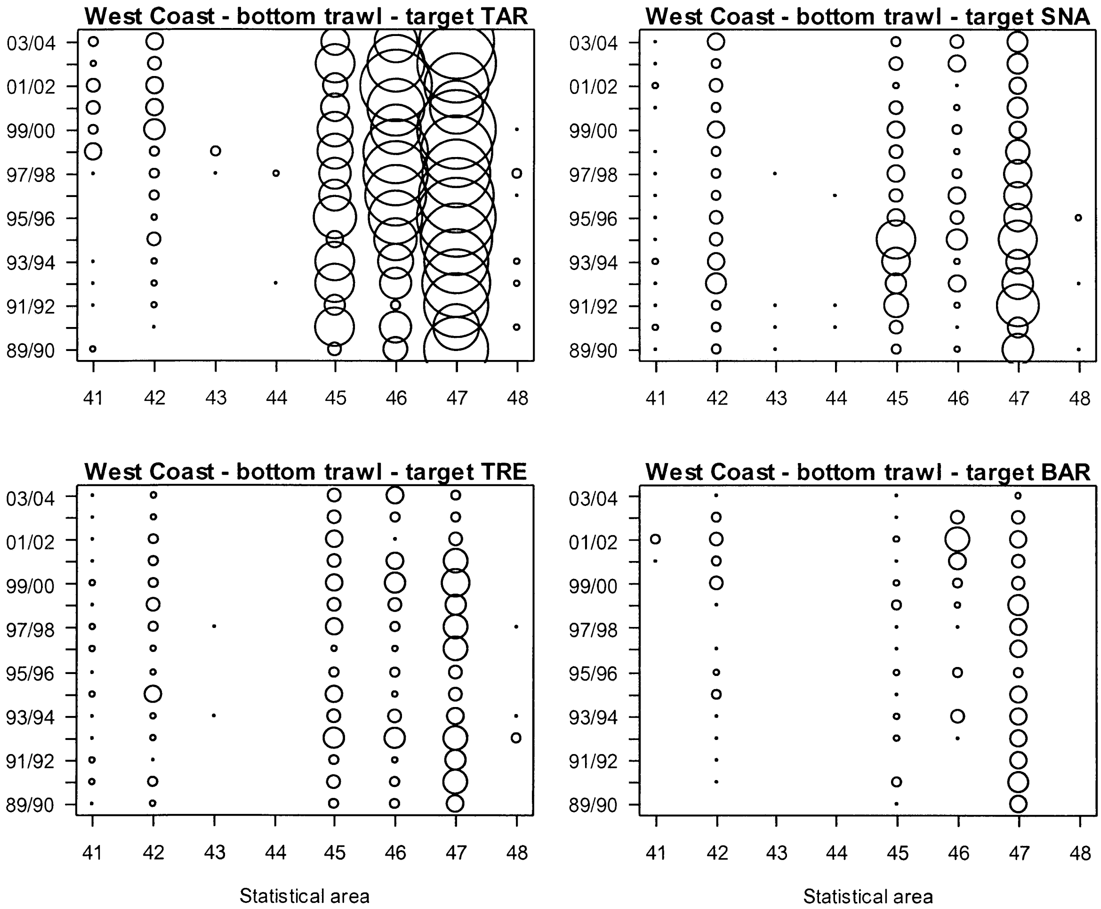

Figure 4: Comparison of the areal distribution of bottom trawl tarakihi catches among statistical areas for the four main target fisheries taking TAR 1 from the West Coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 6.

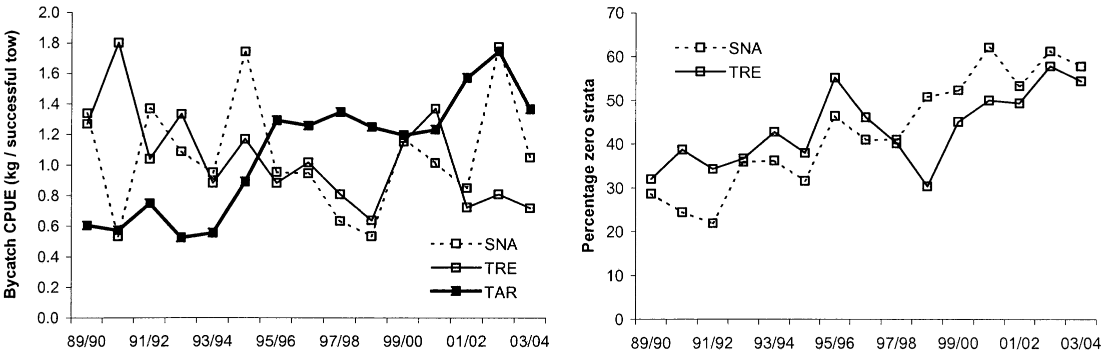

Figure 5: Unstandardised CPUE in successful trip-strata (relative to the geometric mean of each series) for West coast bottom trawl tarakihi in the three main target fisheries; tarakihi, snapper and trevally, and the percentage of zero catch strata in the by-catch fisheries; snapper and trevally, by fishing year.

3.2 The effect of form type in TAR 1 West

The contradictions in indicators of tarakihi abundance in the Western area consist of 1) an increasing catch rate in the target fishery and 2) an increasing proportion of zero catches of tarakihi in the bycatch fisheries for snapper and trevally.

These indicators are especially contradictory in the first half of the time series (1989–90 to 1995–96) and coincide with a systematic (and almost 100%) shift from reporting on CELRs (the daily form) to tow-by-tow reporting on TCEPRs (Figure 6).

The shift between forms has resulted in a systematic improvement in the definition of target effort that partly explains the contradictory indicators, though it is difficult to demonstrate because of the confounding of the year and the form type effects.

CELRs may report a mixture of fishing practices over a days fishing, using a single target species. Field & Hanchet (2001) reported, on the basis of interviews with operators, that although most tarakihi is reported as targeted, fishers were in fact usually targeting a species mix of which tarakihi was the dominant species, and that fishing strategies were aimed at maximising the catch of the quota mix rather than maximising the tarakihi catch. Therefore, on any particular day they may have tows targeting tarakihi, tows targeting a 50% tarakihi and 50% mix, and tows actively avoiding tarakihi. Unfortunately, this level of detail cannot be captured on the CELRs, and is often combined into a daily record for which the reported target species may be the single species targeted, the main of several species targeted, the species for which the most quota is held, the man species actually caught (whether it was targeted or not), the species which legalises a subsequent bycatch trade, or simply just a logical species for that area and fishery (Paul & Bradford 2000).

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

Catch rates for targeted tarakihi are consequently lower on CELRs than they are on TCEPRs, presumably because they include this other effort, and so, as the proportion of data reported on TCEPRS increases, so too does the annual simple catch rate. The increasing catch rates in the target fishery are not entirely a function of the shift from CELR to TCEPR form type however, as an increasing trend is also apparent in the TCEPR series (Figure 6).

In contrast, a high proportion of effort directed at snapper or trevally and reported on TCEPRs is shown to result in a zero catch of tarakihi, whereas that is much less common for a days fishing reported on a CELR. As the proportion of data reported on TCEPRs increases, so too does the proportion of zero tarakihi catches in the MIX fishery (Figure 7). Again, the proportion of zero catches is not entirely caused by the shift between form types, as the trend is also apparent in the TCEPR series from the snapper fishery (Figure 8).

Thus, the systematic switch in form types potentially compromises both the target series by exaggerating the contradictory trends, but is not the underlying cause, as the trends are also seen in the TCEPR data.

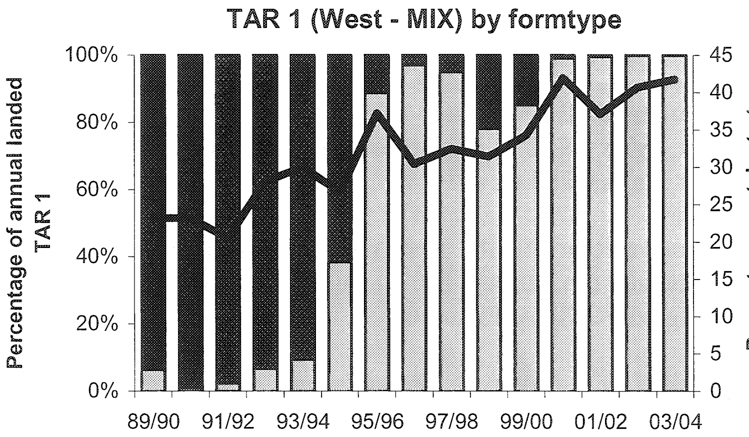

Figure 6: The proportion of targeted tarakihi landed from TAR 1W, and unstandardised CPUE, by form type and fishing year.

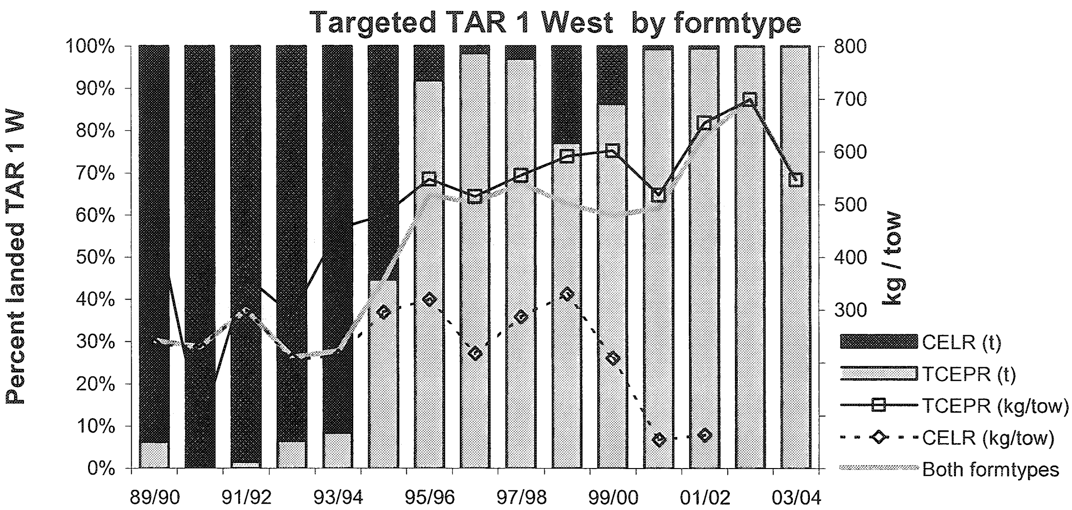

Figure 7: The percent of tarakihi landed from TAR 1W MIX (tows targeted at tarakihi, snapper, or trevally), by formtype and fishing year, the proportion of zero tarakihi catches (at trip-strata level).

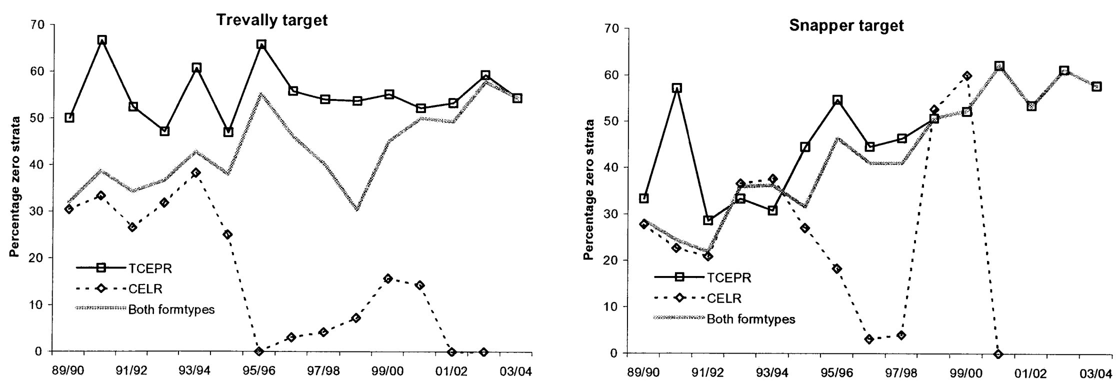

Figure 8: The percentage of zero tarakihi catches in the trevally and snapper bycatch fisheries of TAR 1W, by formtype and fishing year. The bold line for both formtypes combined, is the proportion zero catches in the MIX dataset.

3.3 Characterisation of the east coast trawl fisheries

Most of the catch of TAR 1 (56 – 83 % annually), from the eastern sub-stock is taken by single bottom trawl, with the balance largely taken by bottom longline fisheries. Small and variable amounts have also been taken in each year taken by pair trawl, set net and Danish Seine (Table 7). The bottom trawl catch is largely (50–72% annually) targeted, with the most consistently important proportion of bycatch coming from snapper tows. There have also been variable landings (2–20 %) of tarakihi as a bycatch of the gemfish fishery, and, in recent years from John dory tows. Trevally is not as important on this coast as in the Western areas, accounting for less than 8% of tarakihi landings in each year (Table 8, Figure 9).

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 scaled up to the annual QMR catch (Table 1). 0= less than 0.5 tonne. Percentages sum to 100 by year. BT=bottom trawl, BPT = bottom pair trawl, BLL= bottom longline, SN= setnet, DS=Danish seine.

East Coast

Fishing	Fishing method (t)						Fishing method (%)					
year	BT	BPT	BLL	SN	DS	Other	BT	BPT	BLL	SN	DS	Other
89/90	215	20	60	10	2	1	69	7	19	3	1	0
90/91	222	11	58	4	2	1	71	3	19	1	1	0
91/92	335	4	57	2	1	0	83	1	14	1	0	0
92/93	233	2	66	3	2	1	75	1	21	1	1	0
93/94	211	6	87	9	5	0	66	2	27	3	2	0
94/95	234	3	100	9	1	1	67	1	29	2	0	0
95/96	283	2	75	6	1	1	77	1	20	2	0	0
96/97	322	1	103	4	2	1	74	0	24	1	0	0
97/98	339	0	126	12	2	0	71	0	26	2	0	0
98/99	281	3	105	1	2	0	71	1	27	0	0	0
99/00	309	12	119	3	3	0	69	3	27	1	1	0
00/01	234	6	100	3	10	0	66	2	28	1	3	0
01/02	224	1	76	1	3	0	73	0	25	0	1	0
02/03	131	30	68	1	2	0	56	13	29	0	1	0
03/04	159	10	53	1	5	1	69	5	23	1	2	0

Table 8: Distribution of bottom trawl caught tarakihi by target species and by fishing year for the East Coast substock of TAR 1 in tonnes and percent. Catches are scaled up to the annual QMR catch (Table 1). 0.0= less than 0.5 tonne. Percentages sum to 100 by year. See Table 6 for explanation of target species codes.

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	108	66	4	2	17	15	-	2	1	50	31	2	1	8	7	-	1	0
90/91	155	27	5	1	17	7	0	2	7	70	12	2	0	8	3	0	1	3
91/92	241	47	4	1	23	11	2	1	4	72	14	1	0	7	3	0	0	1
92/93	159	33	0	4	25	8	0	2	2	68	14	0	2	11	4	0	1	1
93/94	118	39	7	2	35	9	0	0	1	56	18	4	1	17	4	0	0	0
94/95	170	18	8	3	26	8	0	1	1	72	8	3	1	11	3	0	1	0
95/96	165	36	9	4	56	13	0	0	1	58	13	3	1	20	5	0	0	0
96/97	219	21	9	1	28	34	4	3	3	68	6	3	0	9	10	1	1	1
97/98	223	23	24	5	17	36	5	3	2	66	7	7	2	5	11	1	1	1
98/99	155	51	10	1	17	36	0	2	9	55	18	3	0	6	13	0	1	3
99/00	165	45	14	4	19	48	1	9	3	53	14	5	1	6	16	0	3	1
00/01	115	23	7	10	12	58	-	4	5	49	10	3	4	5	25	-	2	2
01/02	113	17	8	7	21	31	-	4	23	50	8	4	3	10	14	-	2	10
02/03	71	16	9	1	10	19	-	3	2	54	12	7	1	8	14	-	2	2
03/04	88	34	13	2	3	14	0	3	3	55	22	8	1	2	9	0	2	2

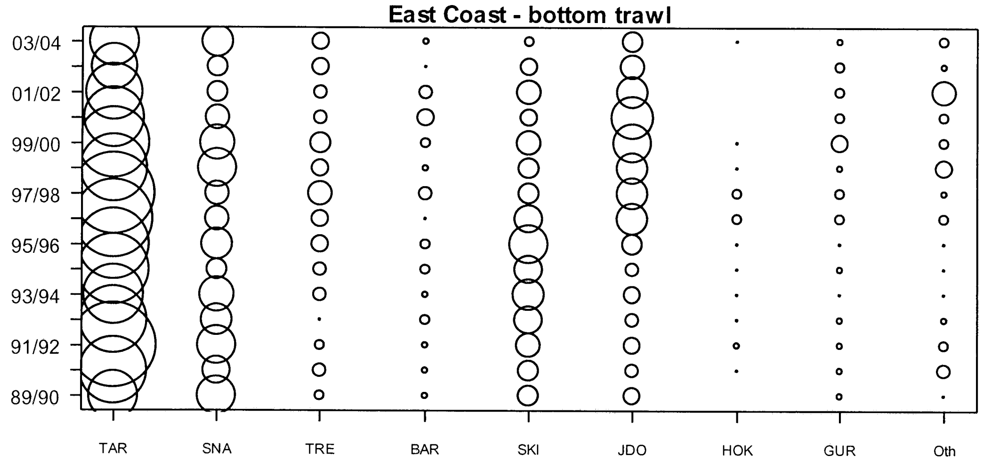

Figure 9: Distribution of bottom trawl caught tarakihi, for the East Coast substock area, by target species and fishing year. Circle areas are proportional to the catch totals by area, with the circle values given in Table 8.

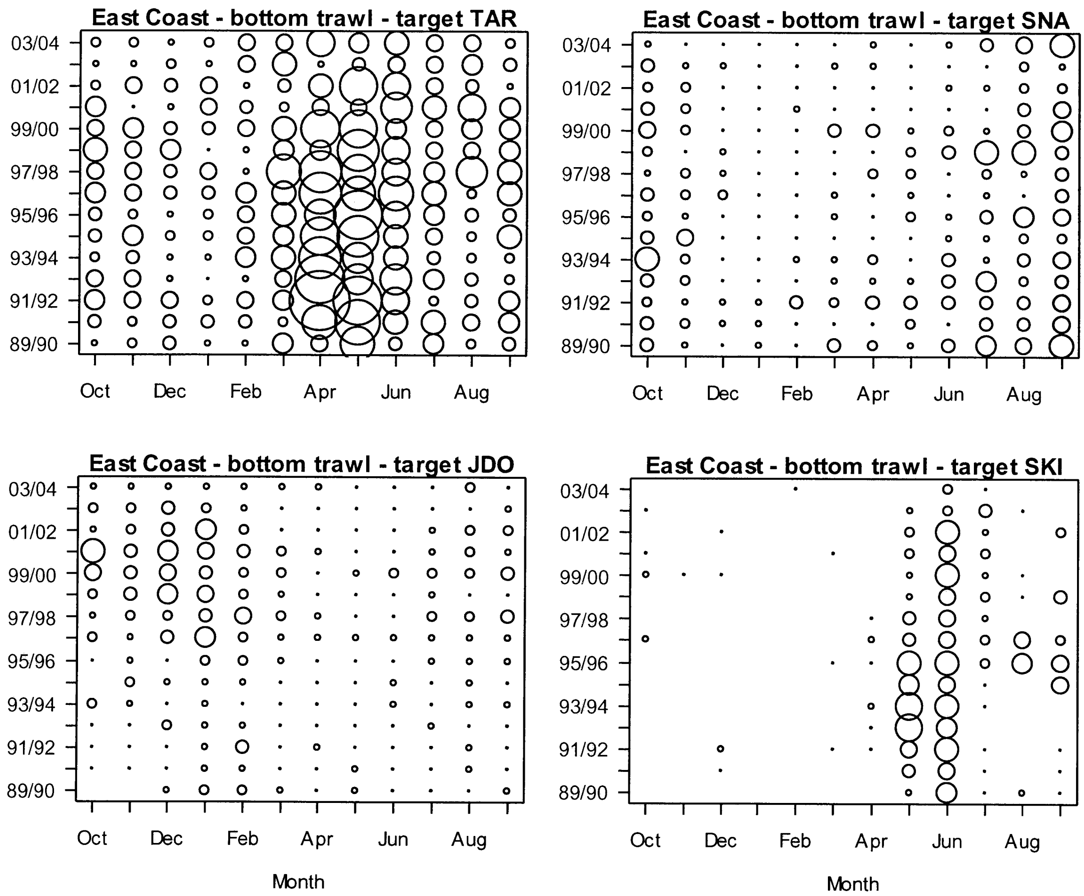

Figure 10: Comparison of seasonal distribution of bottom trawl tarakihi catches, for the four main target fisheries taking TAR 1 from the East Coast substock area, by fishing year. Circle areas are proportional to the catch totals by month, and target species, summing to the annual totals given in Table 8.

The seasonality of the four most important target fisheries taking TAR 1 by bottom trawl is shown in Figure 10. Targeting of tarakihi occurs throughout the year, but the greatest catches are taken between March and June, with a prominent peak in April and May. Bycatch from the gemfish fishery also occurs during those peak months.

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

The same four target fisheries also show quite different spatial distributions (Figure 11), with most of the targeted tarakihi caught in area 002, followed by area 003. The bycatch of tarakihi from snapper tows is more evenly distributed across valid areas, but is greatest from area 003, while bycatch from John dory fishing is almost entirely out of 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.

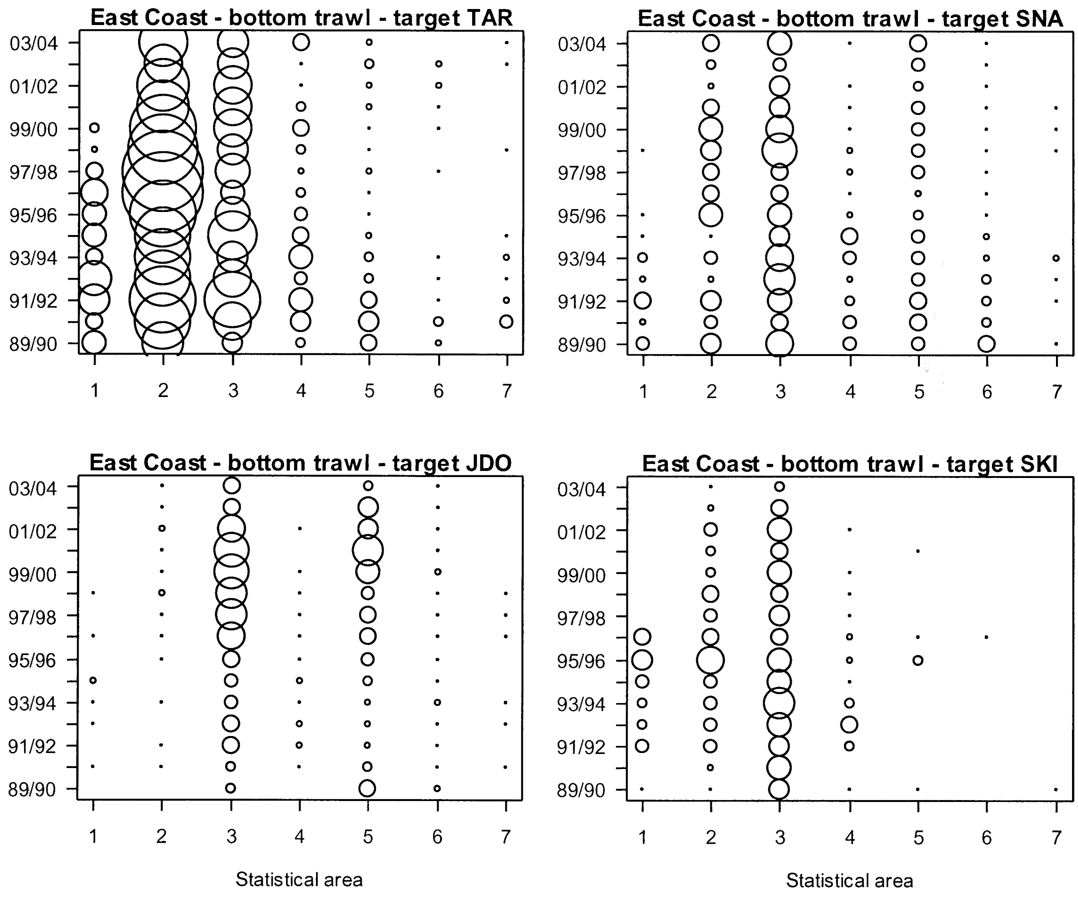

Figure 11: Comparison of the aerial distribution of bottom trawl tarakihi catches among statistical areas for the four main target fisheries taking TAR 1 from the East coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 8.

There appears to be a very well defined target fishery in this substock area, with a tight seasonal peak in April and May mostly directed at area 002, and to a lesser extent area 003. While there is some overlap with the gemfish fishery in the same months, that is mainly from area 003. Otherwise, most of the bycatch tarakihi comes out of other months and other areas. Outside this target fishery, which is likely aimed at a spawning migration, tarakihi are present throughout the substock area, throughout the rest of the year, and are then also taken in tows directed at snapper and John dory. In order to monitor tarakihi in a more broadly defined fishery than the target fishery, it seems most appropriate to include tows targeted at snapper and John dory throughout the year and throughout all areas valid for TAR 1E.

The unstandardised CPUE of tarakihi in nominally targeted tows has varied between 200 and 300 kg per tow with too much interannual variation to allow the overall increase to be described as a trend. Catch rates in the two main bycatch fisheries have also varied from year to year between 10 and 30 kg per tow, with generally greater values in the later half of the series than in the earlier years.

The relative unstandardised CPUE for tarakihi in each of these target fisheries is shown along with the percentage of zero catches for each of the bycatch fisheries in Figure 12. There is no overall trend in the percentage zero catches of tarakihi in snapper or John dory tows.

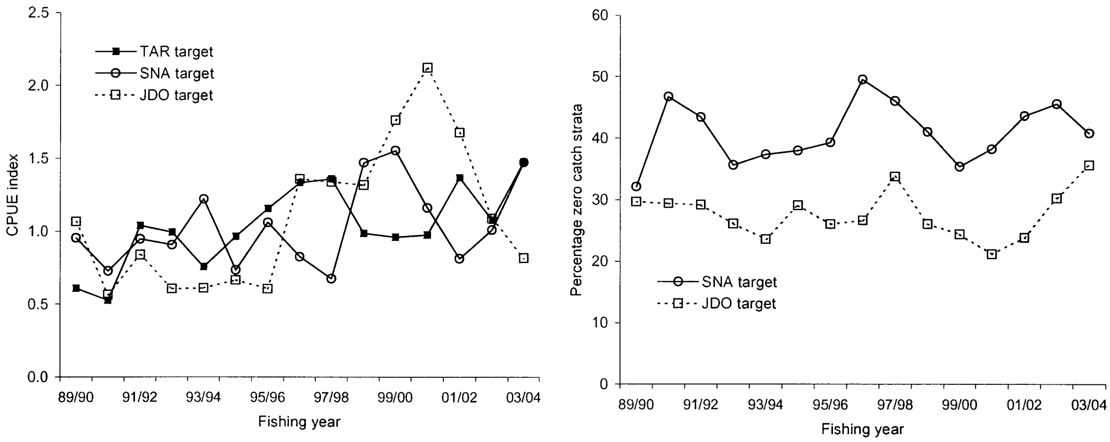

Figure 12: Unstandardised CPUE in successful trip-strata (relative to the geometric mean of each series) for East Coast bottom trawl tarakihi in the three main target fisheries; tarakihi, snapper, and John dory, and the percentage of zero catch strata in the bycatch fisheries, snapper and John dory, by fishing year.

3.4 Characterisation of the Bay of Plenty trawl fisheries

Bottom single trawl has generally accounted for more than 90% of TAR 1 from the Bay of Plenty, with the exception of a few years in the mid 1990s when set netting, 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 longlining, accounting for 1–4% of annual landings, and an increasing catch taken by Danish seine in recent years, peaking at 71 t (7%) in 2003–04 (Table 9).

The bottom trawl catch is mostly targeted (more than 70% in most years), with snapper and trevally 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 subsequently declined in importance. Other fisheries landing between 1 to 5% of the tarakihi catch annually include barracouta, John dory, hoki, and gurnard (Table 10, Figure 13).

The seasonality of the four most important target fisheries taking TAR 1 by bottom trawl is examined in Figure 14. Targeting of tarakihi occurs throughout the year, with the greatest catches during March, April, and May. Bycatch from the snapper fishery also occurs throughout the year, but mainly outside the main tarakihi target season. The bycatch from trevally tows is taken consistently through the year, with no evidence of a seasonal peak, but has become considerably more important in the last six years. The bycatch from the gemfish fishery was almost entirely during May and June in each fishing year (Figure 14).

The spatial distribution of the same four target fisheries is more similar (Figure 15), with most of the tarakihi caught in area 010, followed by areas 009 and 008.

Table 9: Distribution by of landed tarakihi by fishing method 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). 0.0 = less than 0.5 tonne. Percentages sum to 100 by year.

												Bay of Plenty
Fishing	Fishing method (t)						Fishing method (%)					
year	BT	BPT	BLL	SN	DS	Other	BT	BPT	BLL	SN	DS	Other
89/90	389	2	9	13	2	2	93	1	2	3	1	1
90/91	541	3	20	34	5	0	90	0	3	6	1	0
91/92	678	2	24	66	7	1	87	0	3	9	1	0
92/93	682	1	30	118	6	1	81	0	4	14	1	0
93/94	667	1	27	116	9	1	81	0	3	14	1	0
94/95	562	3	23	81	14	0	82	0	3	12	2	0
95/96	594	1	17	45	8	1	89	0	3	7	1	0
96/97	530	0	19	43	8	0	88	0	3	7	1	0
97/98	580	0	15	16	31	1	90	0	2	3	5	0
98/99	543	-	12	10	37	0	90	-	2	2	6	0
99/00	443	1	19	3	35	1	89	0	4	1	7	0
00/01	626	0	21	1	22	0	93	0	3	0	3	0
01/02	753	1	12	1	37	0	94	0	2	0	5	0
02/03	820	3	10	3	42	0	93	0	1	0	5	0
03/04	881	4	11	0	71	0	91	0	1	0	7	0

Table 10: Distribution of bottom trawl caught tarakihi by target species 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). 0.0 = less than 0.5 tonne. Percentages sum to 100 by year.

																		Bay of Plenty 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	233	86	11	7	46	1	2	0	1	60	22	3	2	12	0	1	0	0
90/91	418	63	3	11	37	1	0	1	6	77	12	1	2	7	0	0	0	1
91/92	509	53	4	19	71	6	7	6	3	75	8	1	3	11	1	1	1	0
92/93	477	42	12	12	100	9	14	10	5	70	6	2	2	15	1	2	1	1
93/94	557	45	11	5	26	4	6	9	4	84	7	2	1	4	1	1	1	1
94/95	433	32	7	23	34	11	17	1	5	77	6	1	4	6	2	3	0	1
95/96	460	58	4	6	41	5	12	3	6	77	10	1	1	7	1	2	0	1
96/97	420	26	10	5	27	3	26	8	5	79	5	2	1	5	1	5	1	1
97/98	413	34	9	10	24	15	54	9	12	71	6	2	2	4	3	9	2	2
98/99	406	29	37	22	7	5	32	1	4	75	5	7	4	1	1	6	0	1
99/00	342	18	24	7	10	8	18	11	5	77	4	5	1	2	2	4	2	1
00/01	436	24	95	21	8	9	5	10	19	70	4	15	3	1	1	1	2	3
01/02	531	51	73	23	25	17	4	11	18	71	7	10	3	3	2	0	1	2
02/03	591	51	54	27	26	10	13	39	12	72	6	7	3	3	1	2	5	1
03/04	654	75	27	29	10	8	24	40	15	74	9	3	3	1	1	3	5	2

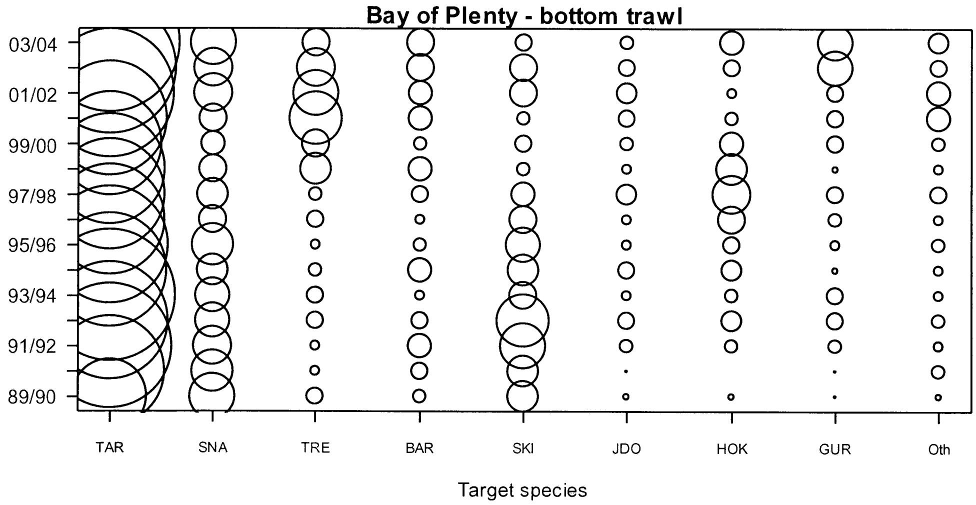

Figure 13: Distribution of bottom trawl caught tarakihi for the Bay of Plenty substock area, by target species and fishing year. Circle areas are proportional to the catch totals by area, with the circle values given in Table 10.

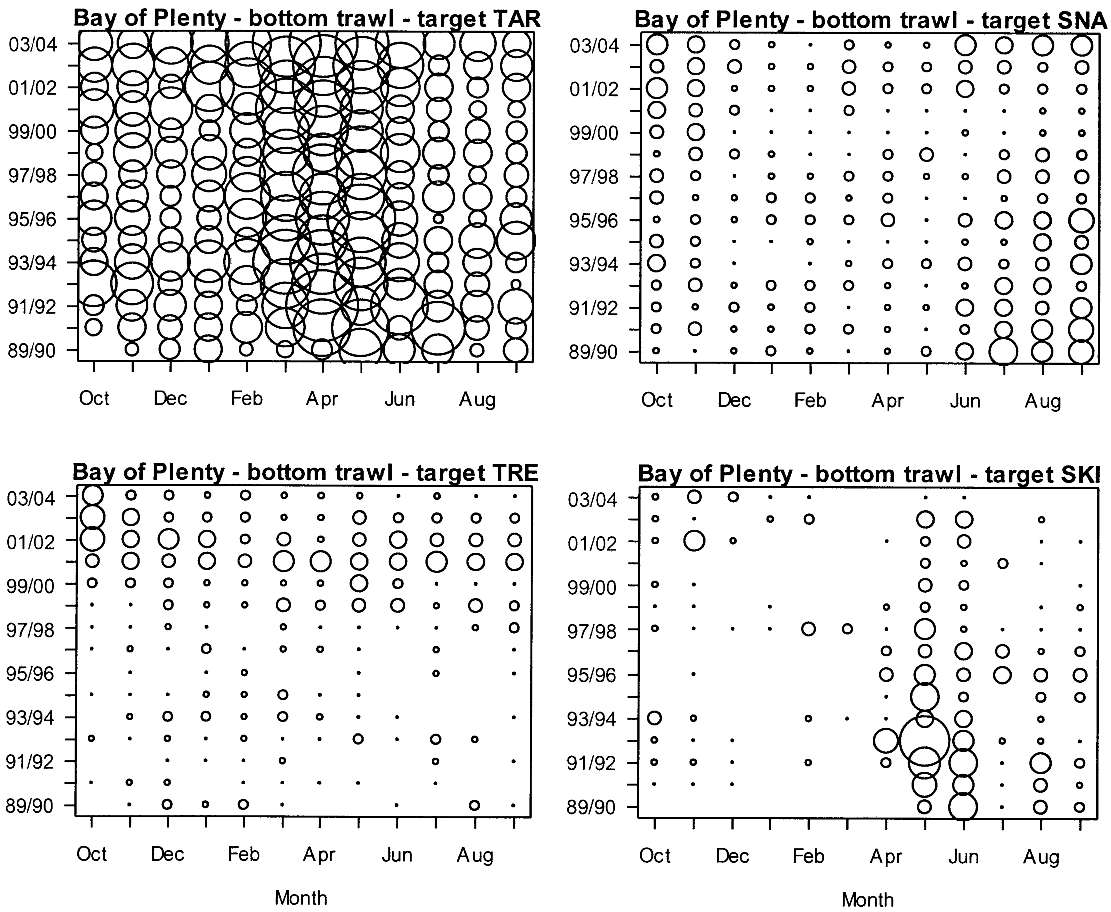

Figure 14: Comparison of seasonal distribution of bottom trawl tarakihi catches for the four main target fisheries taking TAR 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by month, and target species, summing to the annual totals given in Table 10.

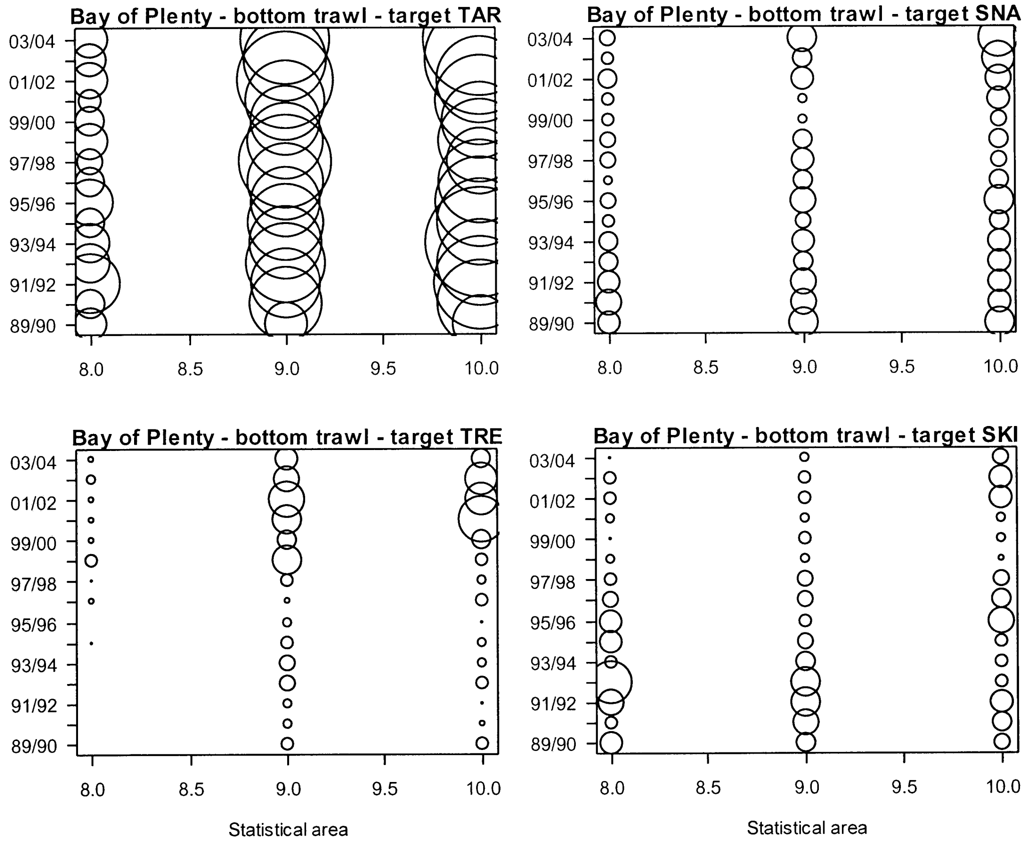

Figure 15: Comparison of the areal distribution of bottom trawl tarakihi catches among statistical areas for the four main target fisheries taking TAR 1 from the Bay of Plenty substock area by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 10.

The unstandardised CPUE of tarakihi in nominally targeted tows, while an order of magnitude greater than in snapper or trevally tows, nevertheless has followed a very similar pattern over time to those bycatch series. They each show (in agreement) considerable variation from year to year for most of the series, dropping to a low in 1999–2000 and peaking in the subsequent two years (Figure 16). The proportion of zero catches in the two main bycatch fisheries also agree closely with each other in their pattern (no overall trend) of variation over time (Figure 16).

While there is clearly a target fishery for tarakihi in the Bay of Plenty that is focused on March, April, and May (possibly a spawning migration), target fishing also occurs throughout the year. Tarakihi is also taken in considerable amounts in tows directed at snapper, and trevally outside the peak season. In order to monitor tarakihi in a more broadly defined fishery (than that nominated by the fisher as target fishing), it seems most appropriate to include tows targeted at snapper and trevally throughout the year and throughout all areas valid for TAR 1 Bay of Plenty.

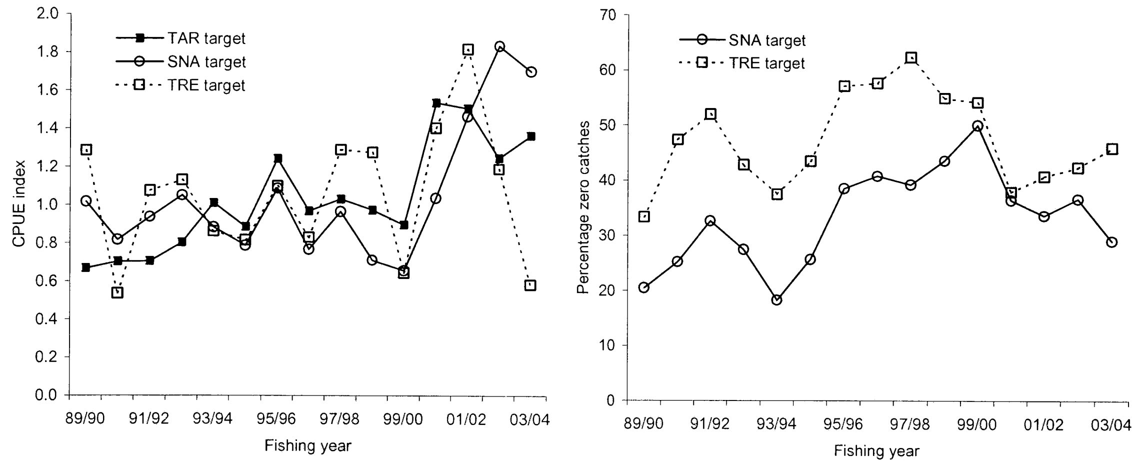

Figure 16: Unstandardised CPUE in successful trip-strata (relative to the geometric mean of each series) for Bay of Plenty bottom trawl tarakihi in the three main target fisheries, tarakihi, snapper, and trevally, and the percentage of zero catch strata in the by-catch fisheries; snapper and trevally, by fishing year.

3.5 Fishery definitions for standardised CPUE analysis

Field & Hanchet (2001) carried out standardised CPUE analysis using all successful vessel-days (estimated catch of tarakihi more than zero) from the bottom trawl fishery regardless of the reported target species, noting that interviews with fishers had led them to believe that target species was recorded inconsistently and was probably not a reliable delimiter of the fishery.

Their definition of effective effort is very close to successful effort (perhaps including some unsuccessful tows in days that reported a catch), but it should be noted that it does not monitor tarakihi in the snapper, trevally, and other trawl fisheries as such, i.e., it does not go all the way to saying that the reported target species is meaningless, else it would include all the bottom trawl effort. What it does do is provide an alternative, and defensible, definition of the target fishery.

When allocated landings are used, the datasets defined by Field & Hanchet (2001) cannot be exactly duplicated because successful days cannot be isolated. They are amalgamated with all effort in a trip/method/target/area stratum, and much of that effort may be unsuccessful with respect to tarakihi. The Field & Hanchet (2001) series is best approximated, when using allocated landings, by target strata.

The logical extension of their approach, however, is to more broadly define the fishing effort that is relevant, giving less weight to the reported target species, and calculate CPUE over all the defined effort rather than just the successful effort. This fits in well with the current practice for monitoring stocks in mixed species fisheries, which is to define a fishery that expends effective effort with respect to the species of interest, on the basis of a single fishing method, a group of associated target species, and sometimes season or location.

When a mixed species fishery is thus defined, it is logical that all effort, including unsuccessful effort, is included in the calculation of catch rate, but it is also essential for internal consistency, because both CELR format catch-effort, and allocated landings, use amalgamated data (daily, or trip-strata resolution respectively), and already incorporate an unknown amount of zero-catch information from tows that were unsuccessful. There is, therefore, the potential for bias to be introduced through any systematic and undetectable changes in success rate.

The most defensible way to standardise the measure of CPUE is to include all qualifying effort, and to employ a model that can cope with zero catch information.

In contrast, when a species is monitored in a well defined target fishery, zero catches are rare, and historically have been excluded. Using only positive catches is a way of defining a target fishery, and avoids the difficulty of modelling zero catches, but interpretation must take into account the usual caveats concerning hyper stability when monitoring aggregated or schooling species in target (or successful) effort only.

Both approaches are used in this study: target fishing, because there are well-defined target fisheries for tarakihi, and because monitoring the target fishery most closely extends the previous series; and a more broadly defined mixed species fishery, that calculates CPUE over all defined effort rather than only successful effort, because the concerns that Field & Hanchet (2001) expressed about the reported target species are no doubt well founded, and because tarakihi is a schooling species that might potentially demonstrate hyperstability, e.g., when schools are encountered, the reported catch rates might remain as high as ever, even as the abundance of schools declines.

For each of the three substock areas, two alternative approaches are used to define fisheries and therefore datasets for standardised CPUE analysis: MIX and TARG (note that TARG is in each case a subset of MIX).

3.5.1 TCEPR series

Bottom trawl fishing events in each of the three TAR 1 substock areas has largely been reported in TCEPR format in the most recent 10 years. This gives the opportunity to calculate alternative (albeit truncated) CPUE series using tow-by-tow data that have the following advantages; 1) allows an alternative definition of effective effort by selecting all (and only) those tows that reported a positive catch of tarakihi, 2) allows the distance towed to be calculated from tow duration and tow speed, and used as the measure of effort (tow duration being a poor proxy in a mixed species fishery where various tow speeds are used), and 3) allows bottom depth and tow speed to be included in the potential explanatory variables offered to the models as possibly better proxies for targeting behaviour than the fisher-nominated target species.

For each of the three substock areas, this third approach was taken using only TCEPR format data to yield truncated series of CPUE indices for the most recent 9–10 years. The TCEPR series uses estimated catch in the original tow-by-tow format, positive catches to define the fishery (making no use of fisher nominated target species), and includes only positive catches in the standardisation.

The target species factor was removed from the base model. Fishers are asked to record in their logbooks the species being targeted for each individual set and this information was used in the MIX and TARG models to help differentiate the various types of sets. However, it is likely that the corresponding target factor is correlated with bottom depth and different gear settings also included in the model. Furthermore, ideally the target species information should be filled just after the set is deployed, but if in fact this information is provided after the catch is hauled, and is consequently correlated with what was actually caught, then this factor is no longer serving the purpose for which is was designed (it will be highly correlated with the resulting CPUE but not be explanatory).

3.5.2 Fisheries defined in the West Coast substock

MIX: All single bottom-trawl fishing events targeted at tarakihi, snapper, or trevally, in any statistical area valid for the West Coast substock of TAR 1, from trips that reported a landing of TAR 1. This definition allowed the use of total effort and not just successful effort in the analysis of catch rates.
TARG: All single bottom-trawl fishing events targeted at tarakihi in any statistical area valid for the West Coast substock of TAR 1, from trips that reported a landing of TAR 1. The small proportion of zero catch records resulting from the merge were dropped, so only successful catches were included.
TCEPR: Individual single bottom-trawl tows, using all target species, reported on TCEPRs, that caught tarakihi in any statistical area valid for the West Coast substock of TAR 1. Only successful catches were included.

3.5.3 Fisheries defined in the East Coast substock

MIX: All single bottom-trawl fishing events targeted at tarakihi, snapper, or John dory, in any statistical area valid for the East Coast substock of TAR 1, from trips that reported a landing of TAR 1. This definition allowed the use of total effort and not just successful effort in the analysis of catch rates.
TARG: All single bottom-trawl fishing events targeted at tarakihi in any statistical area valid for the East Coast substock of TAR 1, from trips that reported a landing of TAR 1. The small proportion of zero catch records resulting from the merge were dropped, so only successful catches were included
TCEPR: Individual single bottom-trawl tows, using all target species, reported on TCEPRs, that caught tarakihi in any statistical area valid for the East Coast substock of TAR 1. Only successful catches were included.

3.5.4 Fisheries defined in the Bay of Plenty substock

MIX: All single bottom-trawl fishing events targeted at tarakihi, snapper, or trevally, in any statistical area valid for the Bay of Plenty substock of TAR 1, from trips that reported a landing of TAR 1. This definition allowed the use of total effort and not just successful effort in the analysis of catch rates.
TARG:All single bottom-trawl fishing events targeted at tarakihi in any statistical area valid for the Bay of Plenty substock of TAR 1, from trips that reported a landing of TAR 1. The small proportion of zero catch records resulting from the merge were dropped, so only successful catches were included.
TCEPR: Individual single bottom-trawl tows, using all target species, reported on TCEPRs, that caught tarakihi in any statistical area valid for the Bay of Plenty substock of TAR 1. Only successful catches were included.

3.6 Core fleet definitions

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

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%. 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 G. Data sets for the final core vessels are summarised in Appendix E.

3.7 Models applied

Two standardised CPUE analyses were performed on each of the MIX datasets. A lognormal linear model was fitted to successful catches of TAR 1, excluding zero catches, and a binomial model which predicted success or failure of TAR 1 catch was fitted to the total dataset, including records that reported a zero catch of tarakihi. These two models were combined into a single set of indices using the method of Vignaux (1994).

The target fisheries contain very few zero catch records, and those are largely a product of the merge process that assigns landed catch on the basis of estimated catch. A zero record in this dataset is therefore more likely to indicate that tarakihi was not among the top five species caught than a genuine null catch. Zero catches in this dataset were therefore excluded and a lognormal linear model fitted to the remaining catches. Each of the models detailed above was also re-run using estimated catch rather than allocated landings at the same trip-strata resolution. The TCEPR datasets include only positive catches, and were also fitted using a lognormal linear model only. A summary of the models applied is shown in Table 11.

Table 11: Summary of CPUE model runs done for the TAR 1 FAR. TS, model performed using trip-stratum level; DS, model performed at the original (daily stratum or tow-by-tow) level; –, model not applicable or not done.

		Landed catch				Estimated catch		
Area	Model	Lognormal	Binomial	Combined	Arithmetic	Lognormal	Binomial	Combined
West	TARG	TS	–	–	TS	TS	–	–
coast	MIX	TS	TS	TS	TS	TS	TS	TS
	TCEPR	–	–	–	–	DS	–	–
	Field-Hanchet	–	–	–	–	DS	–	–
East	TARG	TS	–	–	TS	TS	–	–
coast	MIX	TS	TS	TS	TS	TS	TS	TS
	TCEPR	–	–	–	–	DS	–	–
Bay of	TARG	TS	–	–	TS	TS	–	–
Plenty	MIX	TS	TS	TS	TS	TS	TS	TS
	TCEPR	–	–	–	–	DS	–	–

4 MODEL RESULTS

4.1 Model selection

The final models selected are described in Tables 12 to 14. The lognormal models explained between 41% (Bay of Plenty TCEPR) and 65% (Eastern MIX) of the variance in log tarakihi catches, and the binomial models explained around 30% of variance in success rate for each substock area. The reader is reminded not to make direct comparisons of the performance of the various models based on the R^2 values, as they are based in each case on different datasets.

Fishing year was forced as the first variable in each case to facilitate the extraction of canonical year effects, but it explained very little (less than 5%) of the variance in each case. Target species was the most important factor in the Western and Bay of Plenty MIX models; statistical area was the most important in the Eastern MIX model. In each TARG fishery, the measure of effort was the most significant factor. In most cases tow duration was selected rather than number of tows as the better measure of effort. In the TCEPR series the tow speed was used to calculate the more informative measure; tow length, and number of tows and duration were not offered. The categorical variable, vessel ID, was offered as a proxy for the suite of vessel performance measures used by Field & Hanchet (2001), and, although accepted into each model, it entered rather lower in the order of acceptance than is often the case in these analyses.

Month entered most models (the exceptions being the Eastern Binomial, and the Bay of Plenty MIX lognormal model), confirming the seasonal peak seen in the characterisations. For the Eastern MIX lognormal model, a month*target interaction was required to prevent the seasonal effect being subsumed into the highly correlated target species effect, but it made no discernible difference to the indices. A significant month*area interaction effect in the Western MIX lognormal model also had no discernible effect on the year effects and so was dropped. If there is a coastal migration then the month, and/or statistical area resolution of the data is too coarse to describe it.

For each MIX dataset, alternative lognormal models that dropped target species, or that were applied to just the target fishery window of area and month, either did not alter, or did not improve, the CPUE series. In alternative models, form type was offered as a potential explanatory variable but was not accepted into any model, presumably because it is so highly correlated with, and subsumed into, the year effect.

Bottom depth was accepted into all three TCEPR models, yielding only slightly different indices to alternative models that offered target species. Tow speed was also offered to each of the TCEPR models, but did not enter as a significant explanatory.

Diagnostic residual plots are presented for each model in Appendix A. In each substock, there is a good fit to most of the data to the lognormal assumption, with some departure in the extreme tails of the distribution and some patterns in the residuals that are not adequately modelled. This is most marked in the TARG models, and least evident in the TCEPR models.

Expected log catch rates for each significant predictor variable in each model are presented in Appendix B. In the MIX fisheries, catches are predicted to be several-fold greater in tows that report tarakihi to be the target species than in other tows. This difference is much greater in the West substock than in the East or the Bay of Plenty. There is a better defined month effect in the TARG models than in the MIX, and this is reproduced in the coefficients from the TCEPR models. There is good agreement between models on the area effects for each substock, and the TCEPR models across all substocks, agree that the greatest catches are predicted in the 200–250m bottom depth range. There are linear relationships between catch and the unit of effort over the range in which most of the data occur. The distributions of the underlying data are shown in Appendix C.

Table 12: Order of acceptance of variables into the lognormal and binomial models of TAR 1 in the West Coast MIX bottom trawl fishery, and into the lognormal models of the West Coast TARG and TCEPR fisheries, for core vessels, with the amount of explained deviance for each variable. Fishing year was forced as the first variable.

West Coast MIX (TAR, SNA, TRE)

Lognormal model		R^2
1	Fishing year	0.031
2	Target species	0.351
3	Statistical area	0.487
4	Total tow duration	0.555
5	Vessel	0.587
6	Month	0.604

Binomial model		R^2
1	Fishing year	0.016
2	Target species	0.176
3	Vessel	0.254
4	Number of tows	0.308
5	Month	0.322

West Coast TARG (TAR)

Lognormal model		R^2
1	Fishing year	0.020
2	Total tow duration	0.321
3	Statistical area	0.405
4	Month	0.463
5	Vessel	0.523

West Coast TCEPR

Lognormal model		R^2
1	Fishing year	0.011
2	Bottom depth	0.282
3	Vessel ID	0.428
4	Statistical area	0.489
5	Total Tow length	0.520
6	Month	0.536

Table 13: Order of acceptance of variables into the lognormal and binomial models of TAR 1 in the East Coast MIX bottom trawl fishery, and into the lognormal model of the East Coast TARG and TCEPR fisheries, for core vessels, with the amount of explained deviance for each variable. Fishing year was forced as the first variable.

East Coast MIX (TAR, SNA, JDO)

Lognormal model		R^2
1	Fishing year	0.013
2	Statistical area	0.339
3	Vessel	0.432
4	Total tow duration	0.517
5	Target species	0.578
6	Month	0.613
7	Month*target	0.657

Binomial model		R^2
1	Fishing year	0.006
2	Statistical area	0.172
3	Total tow duration	0.263
4	Target species	0.300
5	Vessel	0.320

East Coast TARG (TAR)

Lognormal model		R^2
1	Fishing year	0.019
2	Total tow duration	0.312
3	Vessel	0.464
4	Month	0.499
5	Statistical area	0.520

East Coast TCEPR

Lognormal model		R^2
1	Fishing year	0.017
2	Vessel ID	0.362
3	Statistical area	0.444
4	Bottom depth	0.485
5	Month	0.502
6	Towlength	0.520

Table 14: Order of acceptance of variables into the lognormal and binomial models of TAR 1 in the Bay of Plenty MIX bottom trawl fishery, and into the lognormal model of the Bay of Plenty TARGET and TCEPR fisheries, for core vessels, with the amount of explained deviance for each variable. Fishing year was forced as the first variable.

Bay of Plenty MIX (TAR, SNA, TRE)

Lognormal model		R^2
1	Fishing year	0.012
2	Target species	0.300
3	Total tow duration	0.438
4	Vessel	0.502
5	Statistical area	0.518

Binomial model		R^2
1	Fishing year	0.018
2	Target species	0.239
3	Number of tows	0.289
4	Month	0.311
5	Vessel	0.323

Bay of Plenty TARG (TAR)

Lognormal model		R^2
1	Fishing year	0.022
2	Number of tows	0.325
3	Vessel	0.415
4	Month	0.456
5	Total tow duration	0.477
6	Statistical area	0.498

Bay of Plenty TCEPR

Lognormal model		R^2
1	Fishing year	0.028
2	Bottom depth	0.262
3	Vessel ID	0.357
4	Statistical area	0.384
5	Month	0.412
6	Towlength	0.428

4.2 Trends in model year effects

Canonical year effects were extracted from each of the final fitted models and are compared in Figures 17, 19, and 21. The annual indices from each model fit, along with 95% confidence intervals, are given in Appendix D.

4.2.1 West Coast substock

In the western substock, target fishing showed a steady two-fold increase in CPUE between 1989–90 and 1995–96. Over the following eight years, the series fluctuates around that level without any trend either up or down, but the interannual variation is comparatively great. In the more broadly defined MIX fishery, CPUE declined by about 50% between 1989–90 and 1997–98, although the first few points are not well determined, and then also fluctuated through a magnitude that is not likely to be explainable biologically. The effect of standardisation is greatest in the MIX lognormal model, as the model attempts to account for contradictory trends between the main target fisheries included in the dataset. The increasing trend in zero catches that is modelled in the binomial part of the combined model further emphasises the generally downward trajectory for the MIX fishery. Alternative series for TARG and MIX based on estimated catches at the same trip-strata resolution are both flatter than the series based on landed catches, perhaps indicating the loss of contrast from using data that is only recorded for the top five species (Figure 17).

The final series from the MIX and TARG fisheries contradict each other in the first half of the series, and both series exhibit high interannual variation in the second half of the series. The contradiction is driven by increasing catch rates in target fishing, coincident with an increasing proportion of zero catches of tarakihi in tows targeted at snapper (Section 3.2), and suggests that improved targeting, improved reporting of target species, or other commercial behaviour is compromising the consistency of any fishery defined on the basis of reported target species, and therefore its utility for monitoring abundance of tarakihi. In this situation it is likely that the series based on targeted tows is overly optimistic, and that although the MIX model is an attempt to balance out the signals from catch rates and encounter rates, it is a rather arbitrary solution.

The truncated TCEPR series (which takes no account of the fisher-nominated target species, but uses bottom depth and a positive catch of tarakihi to define effective effort) shows a reasonably steady and well determined decline in the nine years since 1995–96, over the period that both the MIX and TARG models demonstrate large interannual variation.

The Field & Hanchet series is replicated (using estimated catch, but at daily resolution), and extended by confronting the same model with the additional five years of data, and it falls between the TARG and the MIX series (Figure 18). The extended Field & Hanchet series is compared with the TCEPR series in the right hand panel of Figure 18 and the two agree very closely for the years that they coincide, despite the first being standardised for target species, and the second standardised for bottom depth. The TCEPR and the Field & Hanchet (2001) series are both based on positive catches of tarakihi so that they might be considered to represent alternative (and broader) definitions of target fishing, with all the usual caveats and concerns regarding hyperstability.

It is conceivable that the earlier indices, which are almost entirely based on CELR format data, are not directly comparable with the later half of the series, which is almost totally reported on TCEPRs (Section 3.2). Effort reported on CELRs is amalgamated, usually over a day, and would have included an unknown proportion of unsuccessful tows, and may account for the lower indices in the first half of the time series. For this reason, both the Field & Hanchet (2001), and the TARG lognormal series must be rejected.

The MIX series should be less affected by the switch between form types, and is a defensible attempt to describe a longer time series of CPUE abundance indices, but it must be acknowledged that the selection of unsuccessful effort that is incorporated in that series is nevertheless arbitrary, and is based on the fisher-definition of target species, which appears to have improved over time regardless of the form type on which it is reported.

It is recommended that the truncated TCEPR-only series continue to be monitored for this substock.

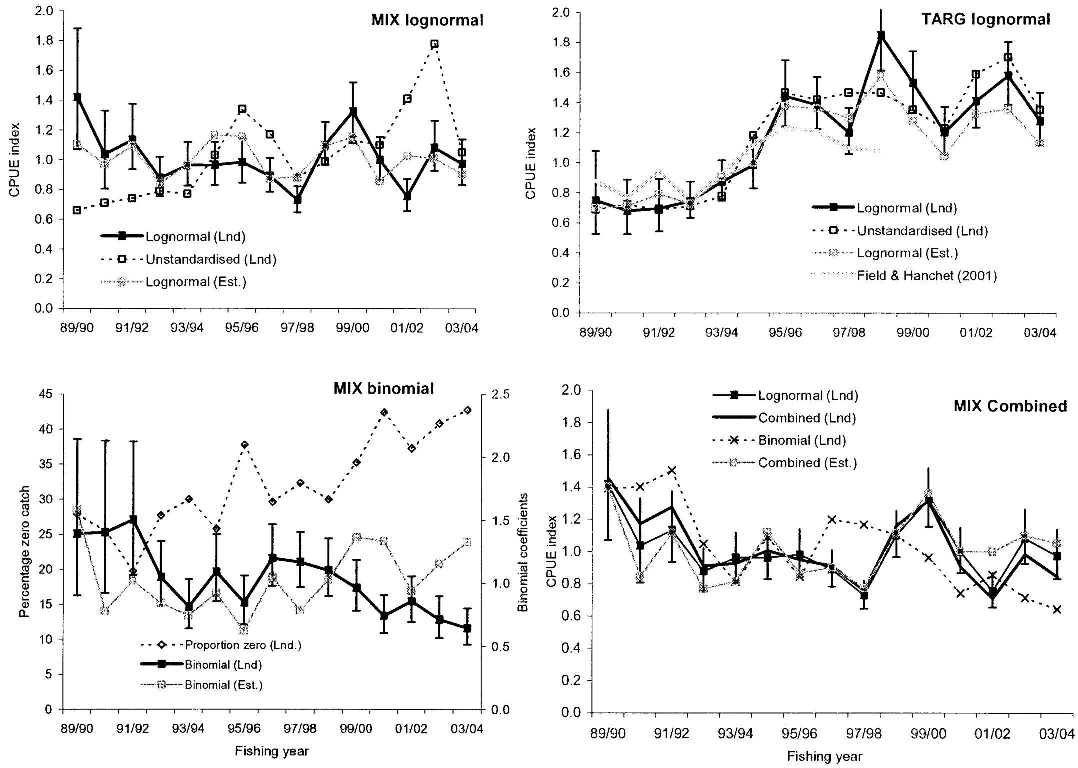

Figure 17: Comparison of models for the West Coast substock of TAR 1: MIX lognormal model of successful landed catches in bottom trawl targeted on tarakihi, snapper, or trevally; MIX binomial model predicting success or failure of TAR 1 landed catch in the MIX fishery; MIX combined model incorporating the lognormal and binomial indices for the MIX fishery, and TARG lognormal model of successful landed catches in target fishing only. Also shown are equivalent series calculated using estimated catch at the same trip-strata resolution, and the indices from the previous study where comparable.

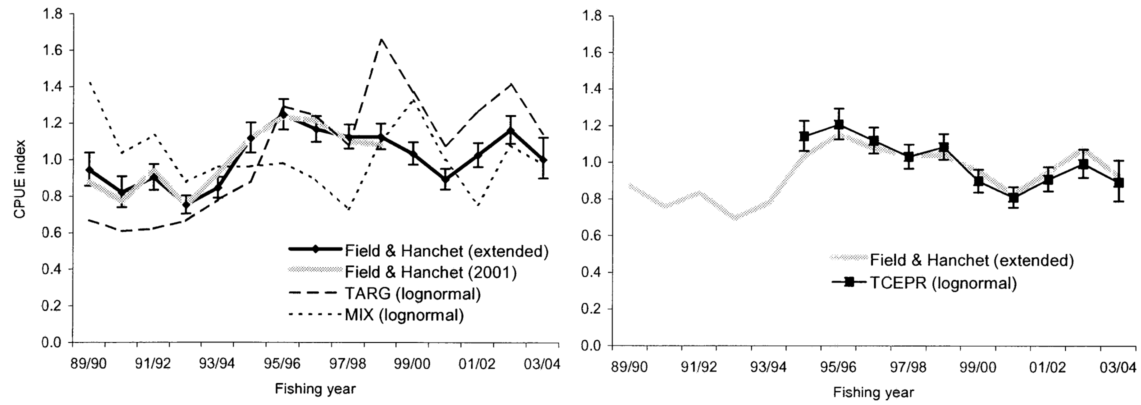

Figure 18: Relative indices from the previous study based on all positive estimated catches of tarakihi (Field & Hanchet 2001), and the year effects from confronting the same model with the additional five years of data at daily resolution (Field & Hanchet extended), compared with the series for MIX and TARG [[left panel], the extended series from the left panel compared with the TCEPR series for TAR 1 West [right panel], rescaled relative to the mean of the years in common.

4.2.2 East Coast substock

In the Eastern substock, the CPUE series calculated from target fishing is essentially flat, showing some interannual variation especially in the early half of the series, but no overall trend. The MIX model, which includes effort directed at snapper and John dory, shows a more cyclical pattern with the lowest points in the mid 1990s, and peaking in 1999–2000, declining again slightly since then. The indices from the binomial model of success rate broadly agree and when combined, serve to emphasise those features. The 2002–03 combined index is 45% lower than the 1989–90 index, but this difference appears to represent the magnitude of the cyclical pattern rather than a sustained decline (Figure 19). A cyclical pattern of abundance has also been described for tarakihi in TAR 3 (Sullivan 1981, SeaFIC 2003).

The previous indices from Field & Hanchet (2001) are overlaid on the TARG series for comparison, but they were calculated from all East Coast areas (including Bay of Plenty), so are not directly comparable. They were essentially flat with considerably less interannual variation than the TARG indices for the same period.

The effect of standardisation is considerable in the MIX models (both lognormal and binomial) which both largely standardise for an area effect. There is a clear target fishery in this substock that is focused on area 002 during April and May, although a considerable amount of tarakihi is caught outside this target fishery, and the MIX model attempts to provide a more generalised index of relative abundance for the substock by standardising for the high catches expected during that month/area window.

Alternative series based on estimated catch at the same trip-strata resolution are flatter in the MIX lognormal model, perhaps indicating the loss of contrast in data that is reported only when tarakihi are among the top five species, but show more contrast in the binomial model. Overall, in the final Combined model, the series based on estimated catch is flatter, but not very different from the series based on landed weight (Figure 19).

The truncated TCEPR series (which takes no account of the fisher-nominated target species, but uses bottom depth and a positive catch of tarakihi to define effective effort) essentially takes a middle line between the MIX and TARG series. It shows a peak in 2000–01, and a slight decline over the three years since then, giving a similar humped trajectory to that seen in the later half of the MIX series (Figure 20).

In this Eastern substock there is reasonably good agreement between indicators (catch rates and success rates) in each of the main target fisheries (Section 3.3), suggesting that it might be defensible to combine them. The TCEPR series, which is based on successful catches across all target fishing, seems to corroborate the humped trajectory of the MIX series, giving some confidence that it succeeds in giving a more generalised index of abundance of tarakihi in this substock than does the target series.

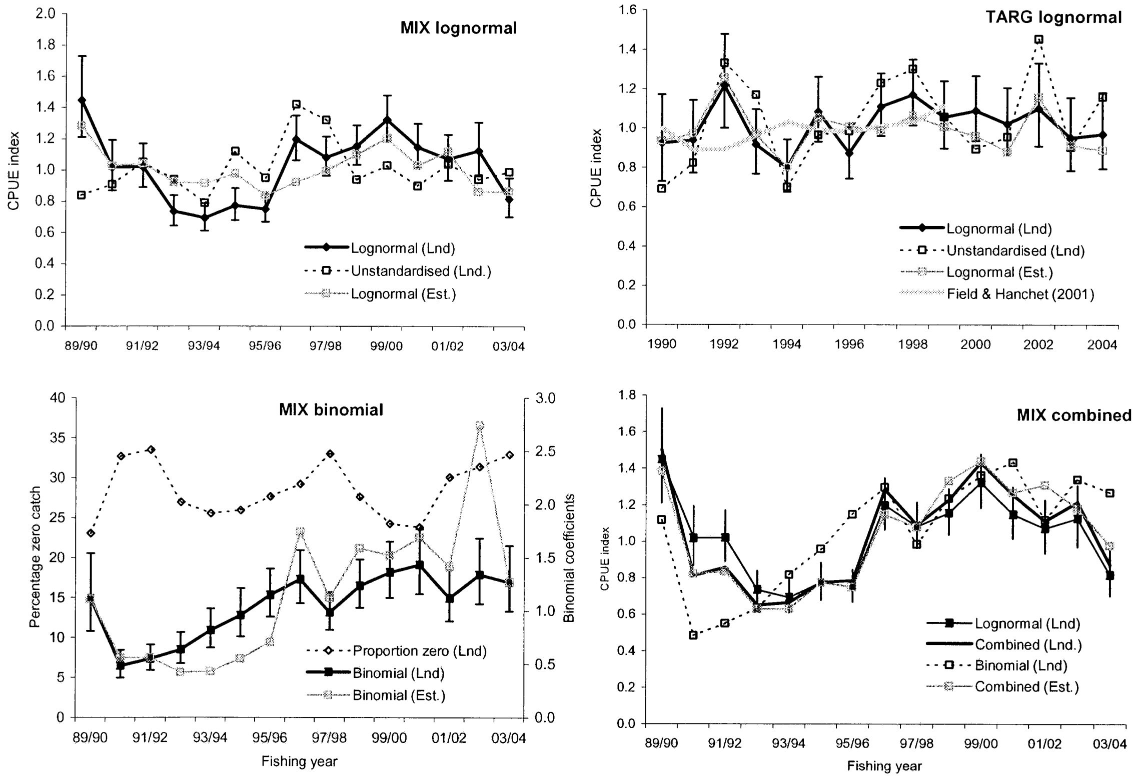

Figure 19: Comparison of models for the East Coast substock of TAR 1: MIX lognormal model of successful landed catches in bottom trawl targeted on tarakihi, snapper or John dory; MIX binomial model predicting success or failure of TAR 1 landed catch in the MIX fishery; MIX combined model incorporating the lognormal and binomial indices for the MIX fishery, and TARG lognormal model of successful landed catches in target fishing only (each series relative to the mean of the years in common). Also shown are equivalent series calculated using estimated catch at the same trip-strata resolution, and the indices from the previous study.

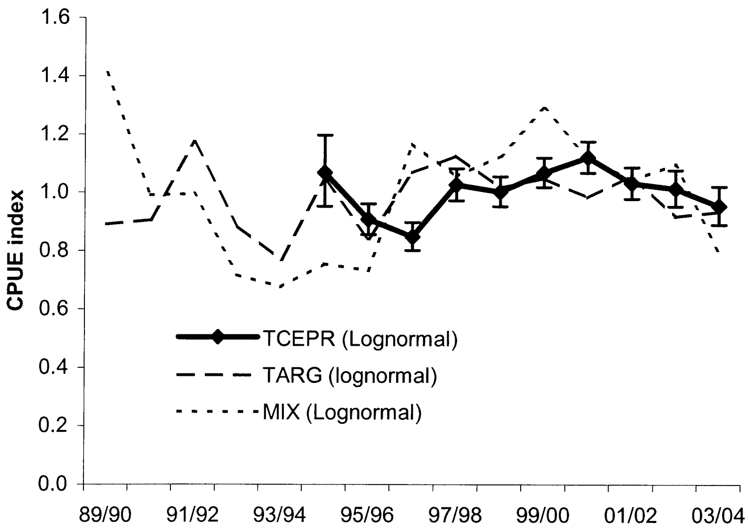

Figure 20: Relative indices from the lognormal models of successful bottom trawl catches reported by core vessels in TCEPR format for TAR 1 East, compared with the series for MIX and TARG (Figure 19), each series relative to the mean of the years in common.

4.2.3 Bay of Plenty substock

In the Bay of Plenty substock, the CPUE series calculated from target fishing is essentially flat between 1989–90 and 1999–2000 except for two slightly lower years in 1991–92 and 1999–00. The main feature of the series is a sharp increase (two-fold over two years) to a peak in 2001–02, finishing in 2003–04 at a level that is still about 30% above the mean. Standardisation flattens the slightly increasing trend in the unstandardised CPUE (Figure 21).

The MIX model, which includes effort directed at snapper and trevally, has a high initial index, and a lower peak in 2001–02 with additional smaller peaks in 1989–90, 1993–94, and 1997–98 that give the series more of an appearance of 3–4 year cycles of abundance, a feature that has been described in other tarakihi stocks (Sullivan 1981, SeaFIC 2003). Overall, the series decreases slightly. The indices from the binomial model of success rate broadly agree, and when combined, serve to emphasise those features (Figure 21).

The previous indices from Field & Hanchet (2001) are overlaid on the TARG series for comparison, but they were calculated from all East Coast areas, so are not directly comparable. They were essentially flat with less interannual variation than the TARG indices for the same period.

The effect of standardisation is considerable in the MIX models (both lognormal and binomial) which both largely standardise for a target species effect There is a clear target fishery in this substock during April and May, although a considerable amount of tarakihi is caught outside this target fishery, and the MIX model attempts to provide a more generalised index of relative abundance for the substock by standardising for the high catches expected in the target fishery.

Alternative series based on estimated catch at the same trip-strata resolution are flatter in the MIX lognormal model of catch rate, perhaps indicating the loss of contrast in data that are reported only when tarakihi are among the top five species, but show more contrast in the binomial model of successful versus unsuccessful catches. Overall, in the final Combined model, the series based on estimated catch is not very different from the series based on landed weight.

The truncated TCEPR series (which takes no account of the fisher-nominated target species, but uses bottom depth and a positive catch of tarakihi to define effective effort) confirms the features seen in both the MIX and TARG model; a low in 1999–2000 and a peak in 2001–02, but with less emphasis, so that overall it is flatter (Figure 22).

In this Bay of Plenty substock there is reasonably good agreement between indicators (catch rates and success rates) in each of the main target fisheries (Section 3.4), suggesting that it might be defensible to combine them. The TCEPR series, which is based on successful catches across all target fishing, corroborates the recent increase seen in both the MIX and the TARG series, but not the cyclical appearance of the MIX series.

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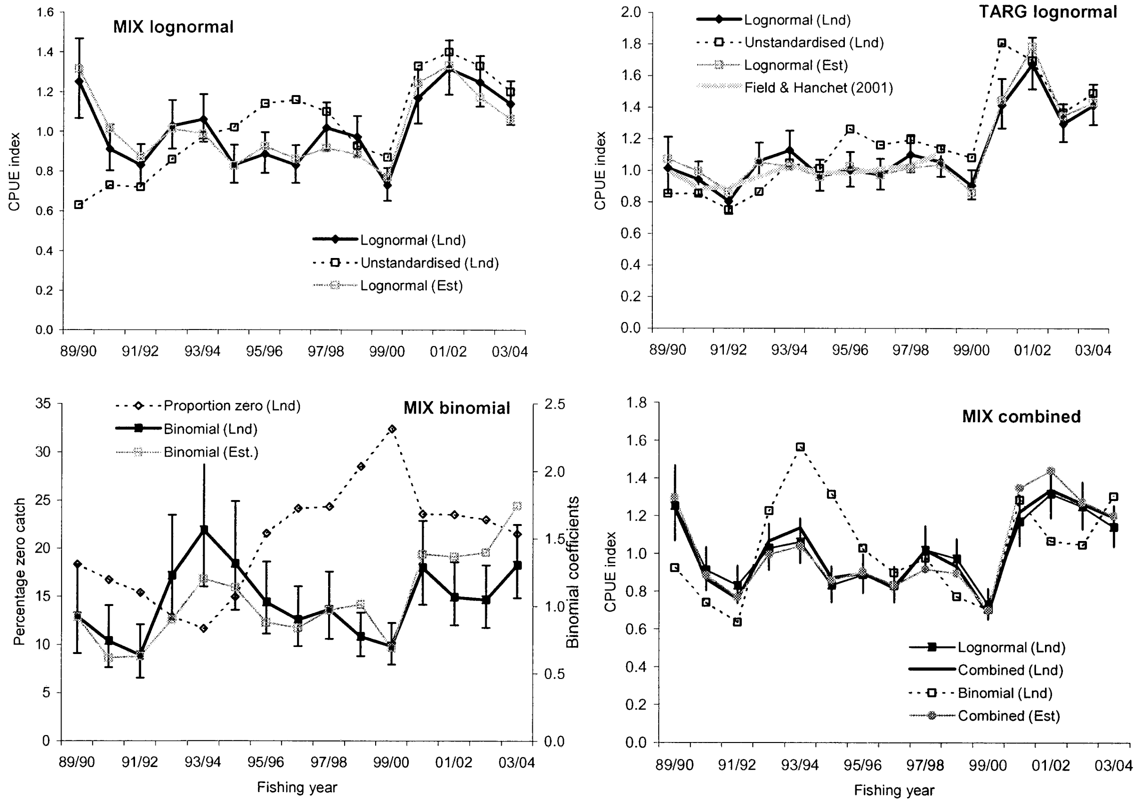

Figure 21: Comparison of models for the Bay of Plenty substock of TAR 1: MIX lognormal model of successful landed catches in bottom trawl targeted on tarakihi, snapper, or John dory; MIX binomial model predicting success or failure of TAR 1 landed catch in the MIX fishery; MIX combined model incorporating the lognormal and binomial indices for the MIX fishery, and TARG lognormal model of successful landed catches in target fishing only. Also shown are equivalent series calculated using estimated catch at the same trip-strata resolution.

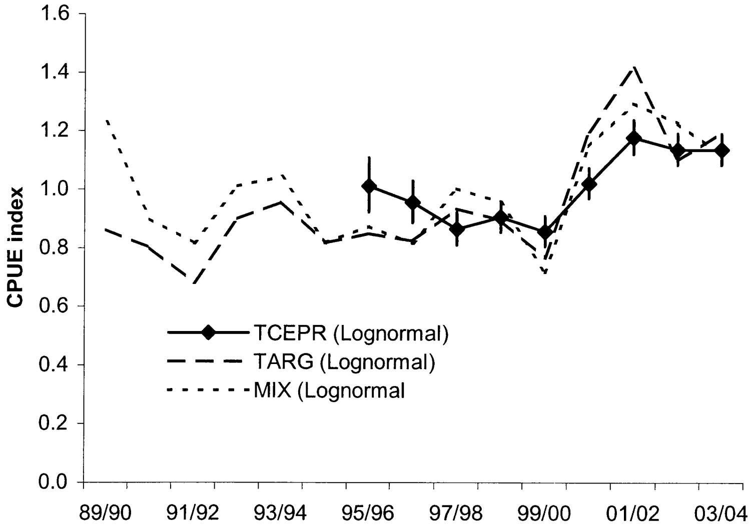

Figure 22: Relative indices from the lognormal model of successful bottom trawl catches reported by core vessels in TCEPR format for TAR 1 Bay of Plenty, compared with series for MIX and TARG, each series relative to the mean for the years in common.

5 CONCLUSIONS

Tarakihi in TAR 1 is a well reported and largely targeted species, and it is not clear that the use of landed (rather than estimated) catch markedly improves the standardised CPUE for this Fishstock. It is done here so that bycatch can best be included in the calculation of CPUE. There is a strong argument for monitoring TAR 1 in a wider fishery than that nominated by the fisher as target fishing for the following reasons.

Target fishing is focused on March to April and may be directed at spawning migrations, as is known to be the case for this species in other areas, notably area 018, off Kaikoura in TAR 3. CPUE indices based on such aggregations are unlikely to be sensitive to any changes in the abundance of the underlying population, or to be representative of the overall stock. Industry notes that the opening of the Auckland fish market in May 2004 is encouraging fishers to take tarakihi all year round rather than mostly in the historical peak months of autumn. This affects only the final index of the series presented here, and is standardised for, with the inclusion of the month effect in all models for TAR 1 West and East, but the implication that there have been changes in fishing practices in order to achieve the required species mix needs to be kept in mind in future work.

The recorded target species has various implications, and, especially on the daily CELR forms, may not consistently delineate the target fishery.

There is evidence of improved targeting of tarakihi in the Western substock that yields overly optimistic CPUE trajectories when based on nominated target fishing events. There is also an improved definition of target effort as the result of a systematic and total shift from reporting on CELRs to TCEPRs in the Western substock that exacerbates that bias.

However, the approach used in this study still uses fisher-nominated target species to define the effective effort, with all the inconsistencies associated with that field, and the high interannual variance in the Western indices suggests that the inclusion of unsuccessful effort is not being done appropriately.

The alternative TCEPR series uses estimated catch in original resolution so that catch can be standardised for bottom depth rather than target species. It also allows the isolation of just those tows that reported a catch of tarakihi. The better determined trend, and the better model fits, suggest that despite the shortfall associated with using estimated catch, the TCEPR dataset is better representing the fishery for tarakihi, particularly in the Western substock, whereas, there is broad agreement between the alternative approaches for the Eastern and Bay of Plenty substocks.

It is recommended that TAR 1 be monitored in each substock using catches reported on TCEPRs, standardised for factors other than target species, but that the development of indices based on a broader fishery definition should be pursued, particularly in the Eastern and Bay of Plenty substocks where there appears to be some contrast that is not captured in an analysis based on successful catches only.

6 ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries as project TAR 2004-02. Thanks to members of the Inshore Stock Assessment Working Group, particularly Paul Starr and Jeremy McKenzie, for methodology and helpful suggestions.

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APPENDIX A: RESIDUAL PLOTS

West Coast substock - MIX lognormal model

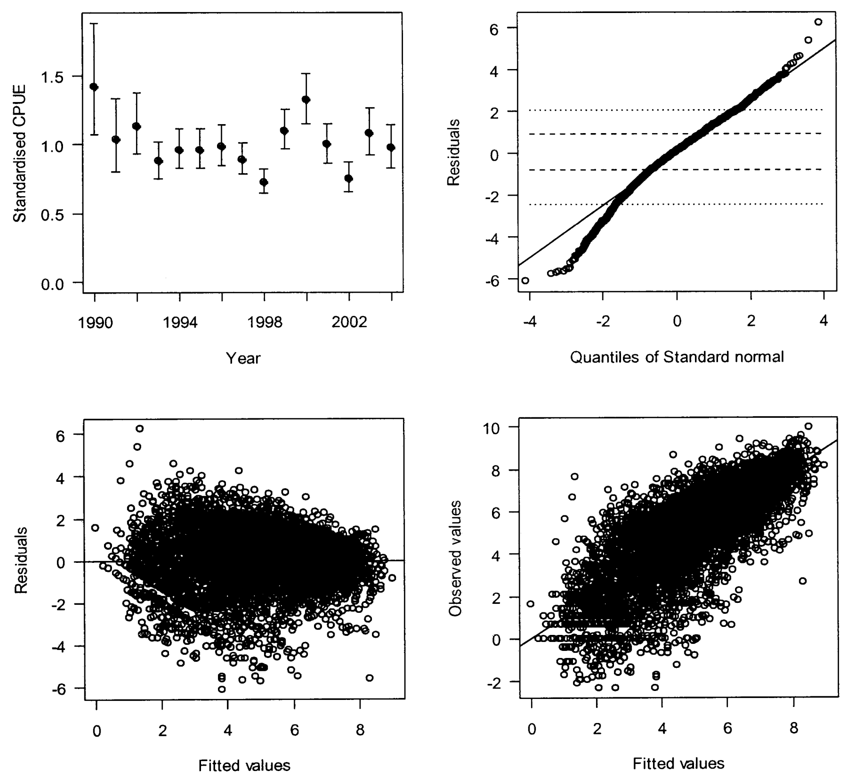

Figure A1: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the West Coast MIX bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

West Coast substock - TARG lognormal model

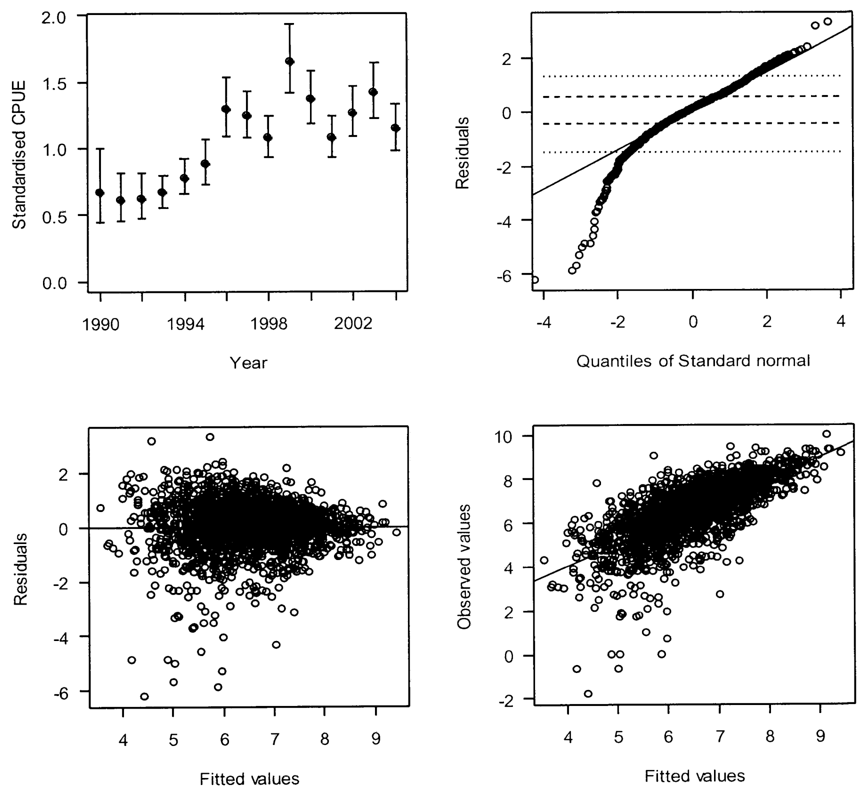

Figure A2: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the West Coast TARG bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

West Coast substock - TCEPR Lognormal model

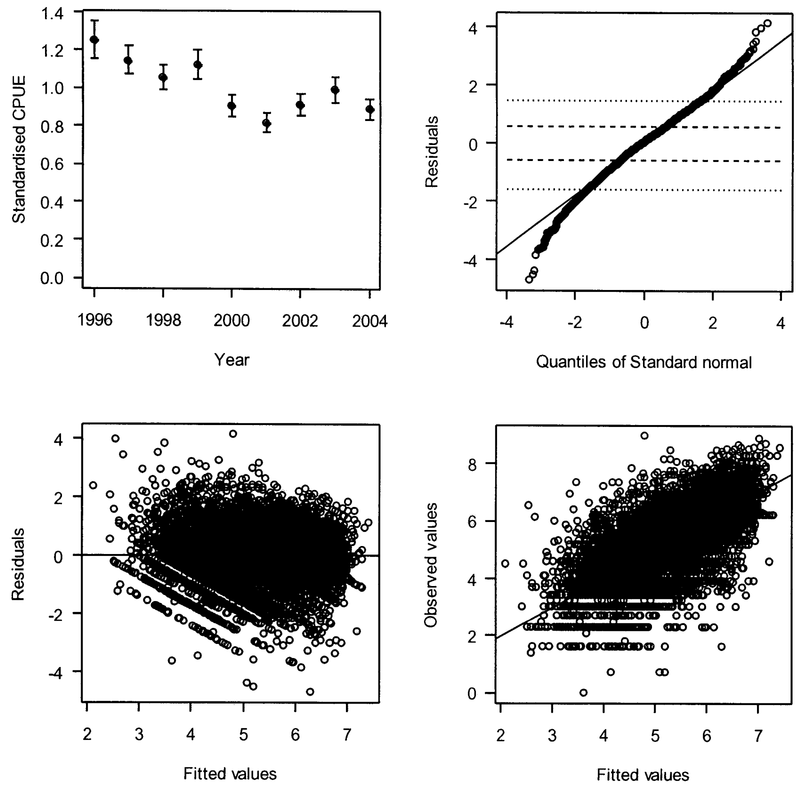

Figure A3: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the West Coast TCEPR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

East Coast substock - MIX lognormal model

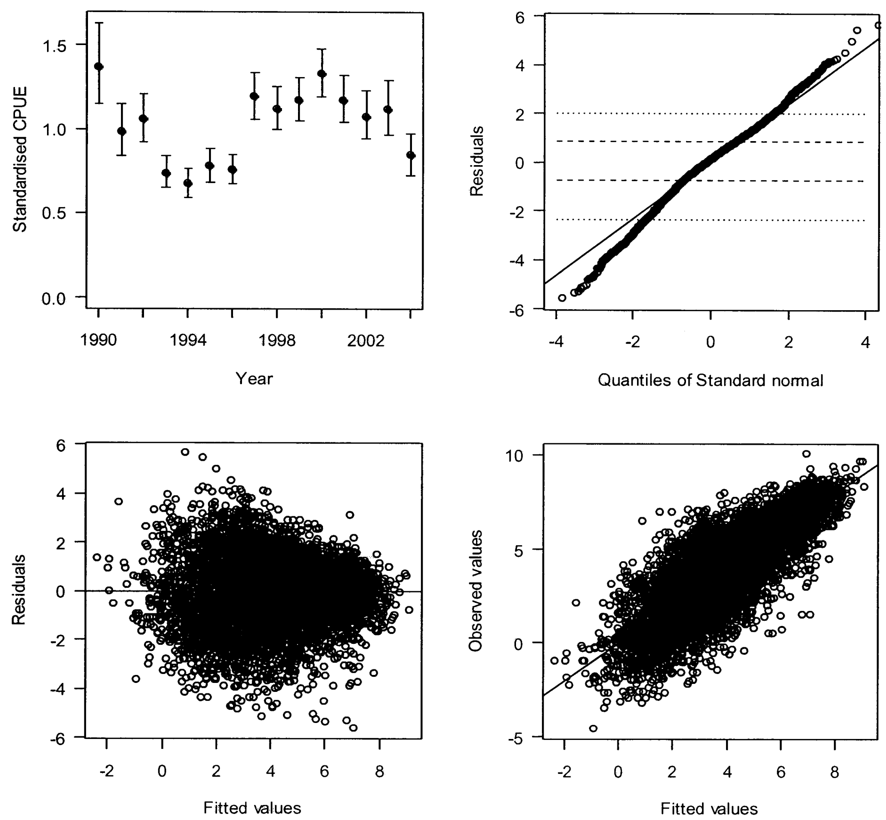

Figure A4: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the East Coast MIX bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

East Coast substock - TARG lognormal model

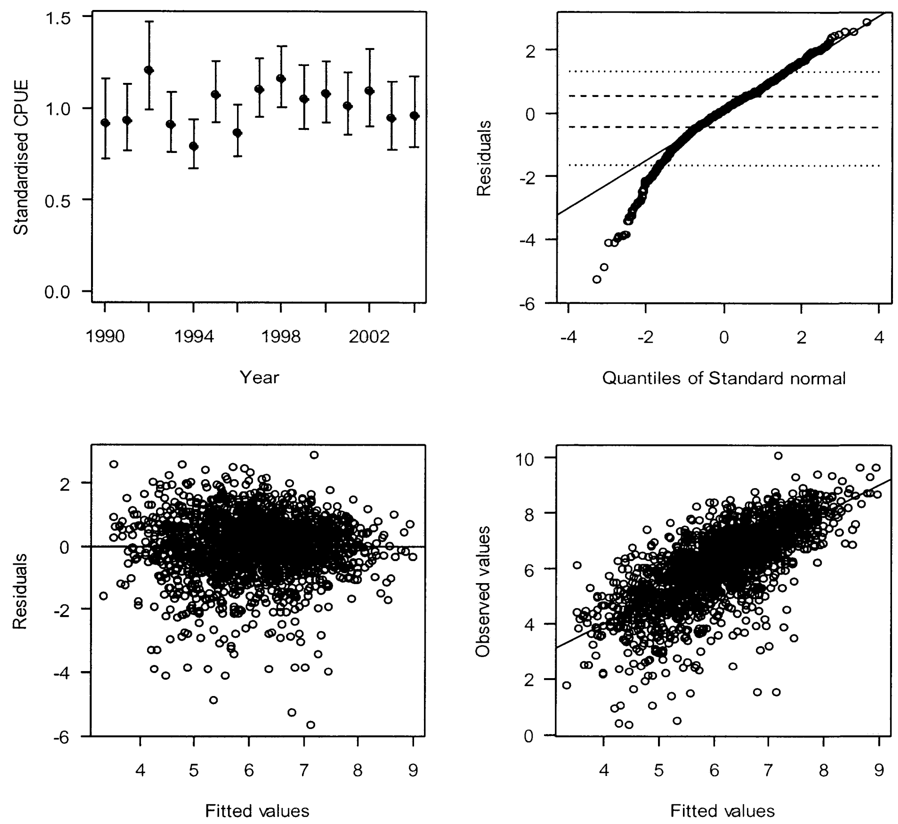

Figure A5: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the East Coast TARG bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

East Coast substock - TCEPR lognormal model

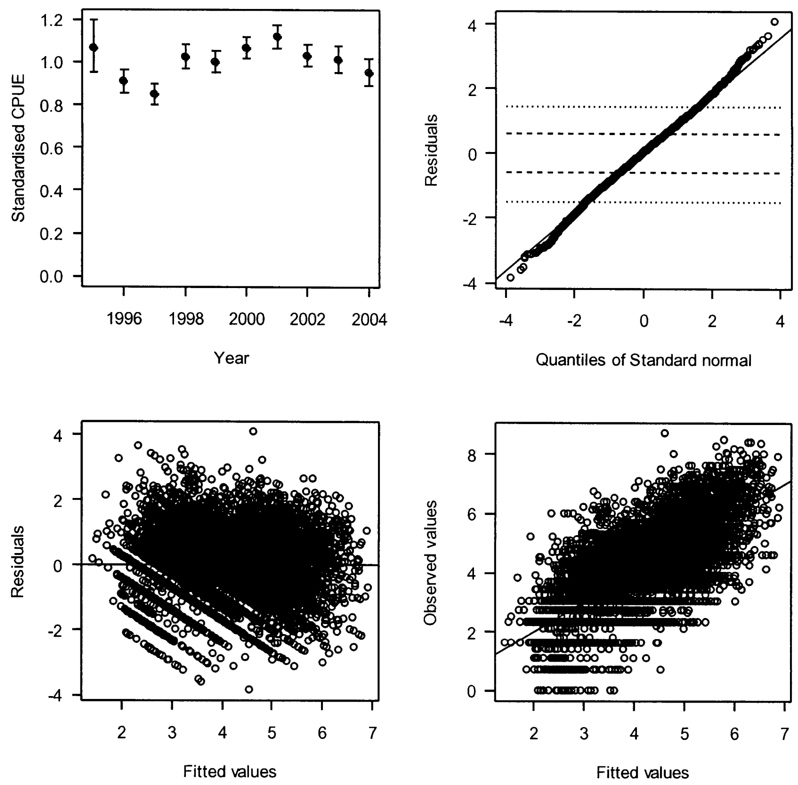

Figure A6: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the East Coast TCEPR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

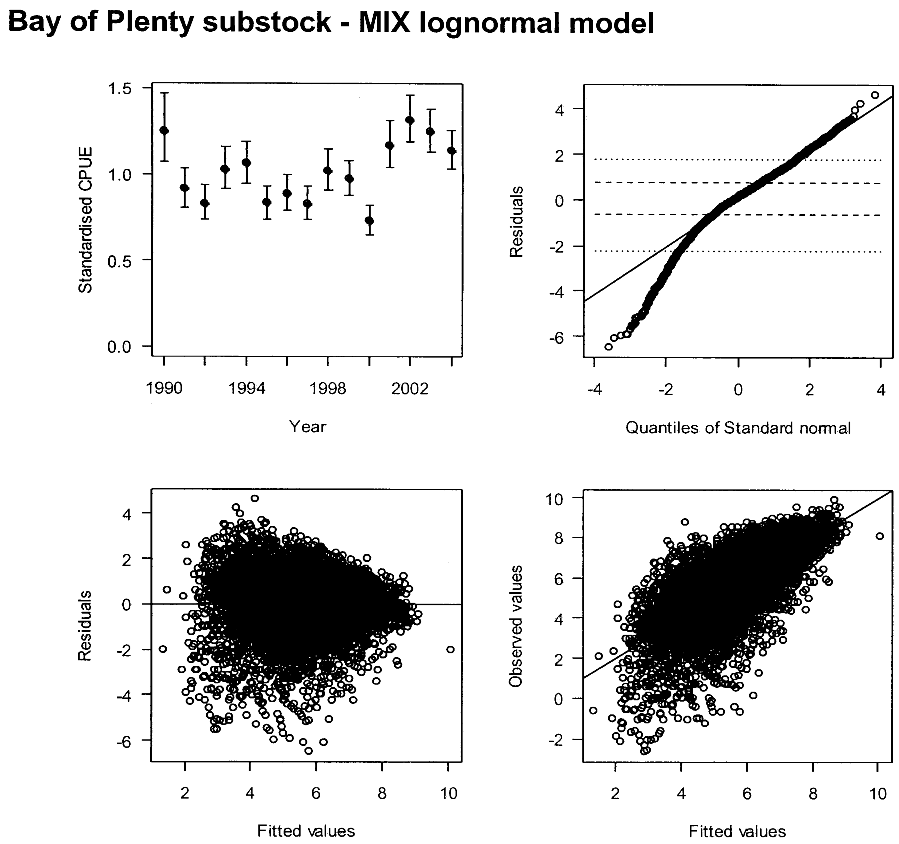

Figure A7: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the Bay of Plenty MIX bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

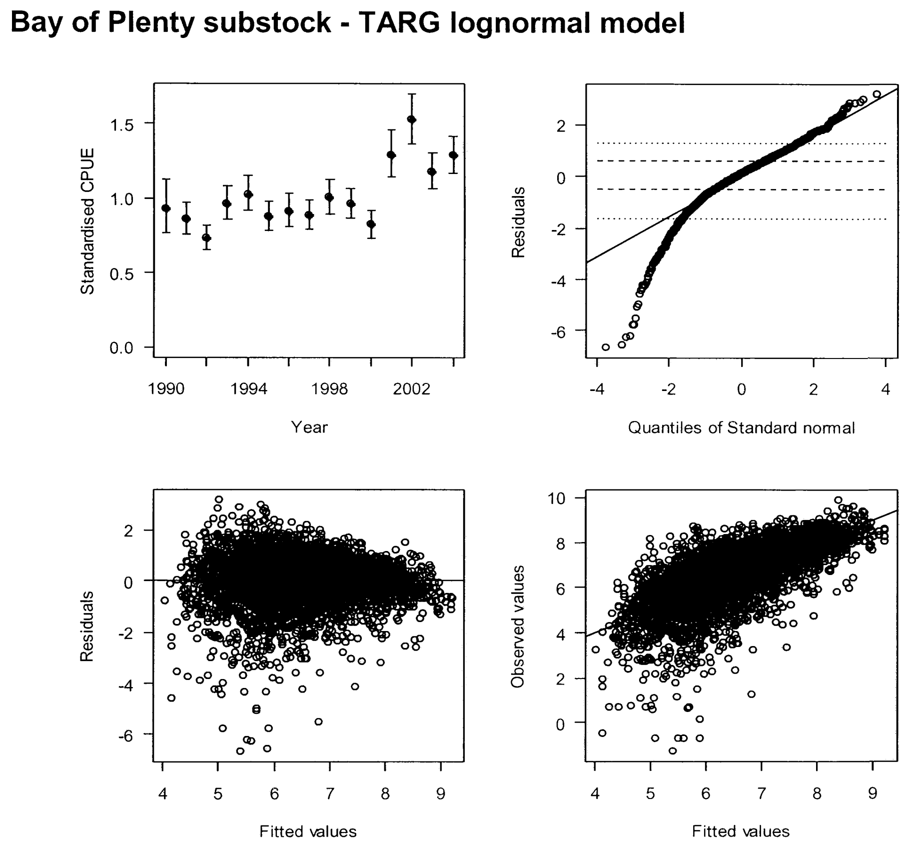

Figure A8: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the Bay of Plenty TARG bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against 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

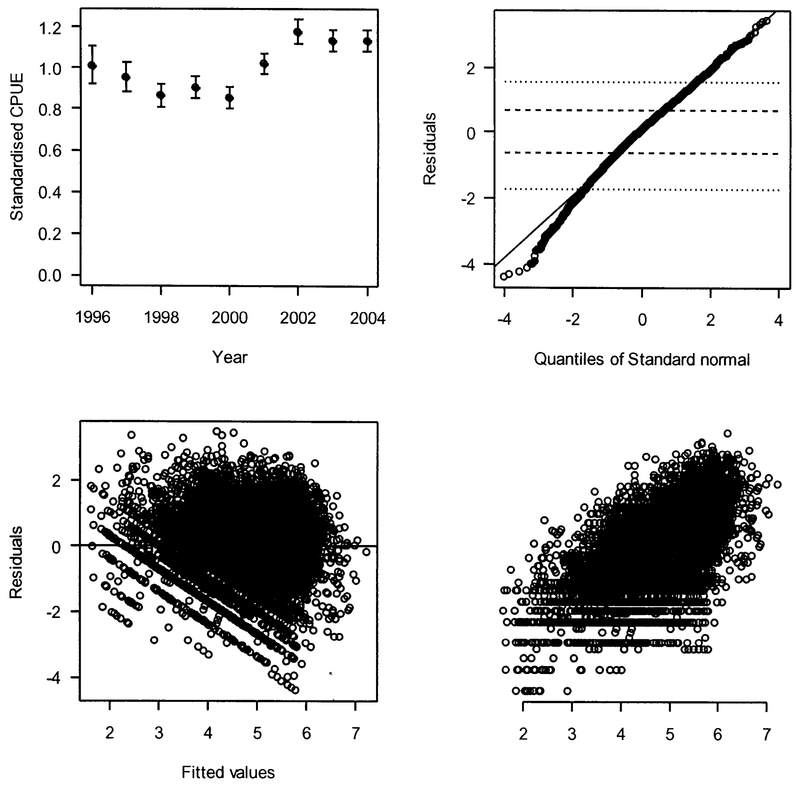

Figure A9: Plots of the fit of the standardised CPUE model to successful catches of TAR 1 in the Bay of Plenty TCEPR bottom trawl fishery. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

APPENDIX B: MODEL COEFFICIENTS

West Coast MIX model terms

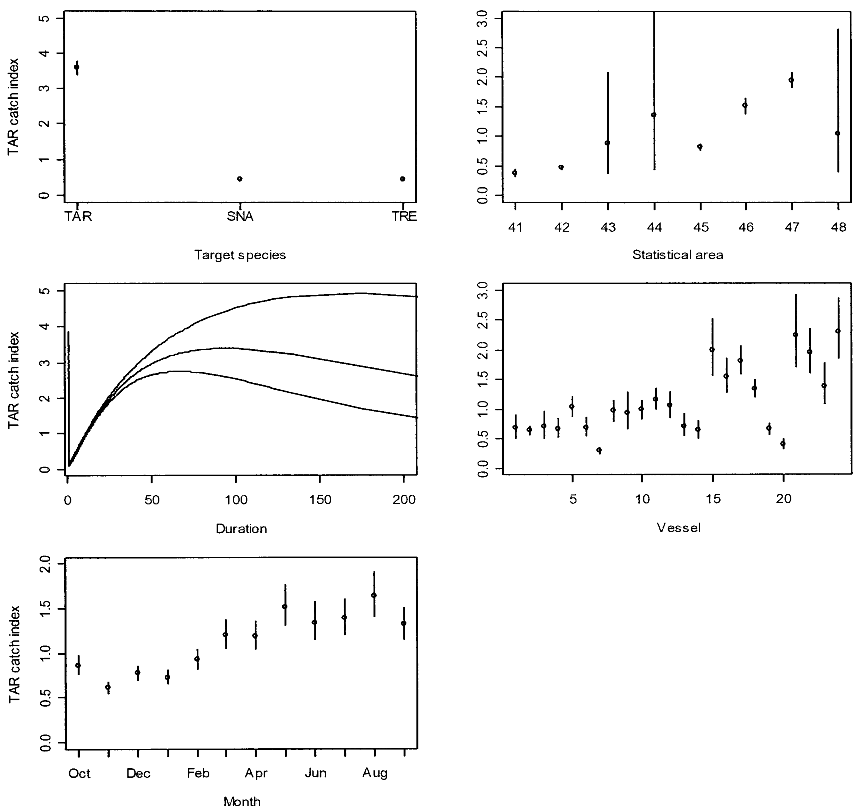

Figure B1: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the West Coast MIX fishery with 95% confidence intervals.

West Coast TARG model terms

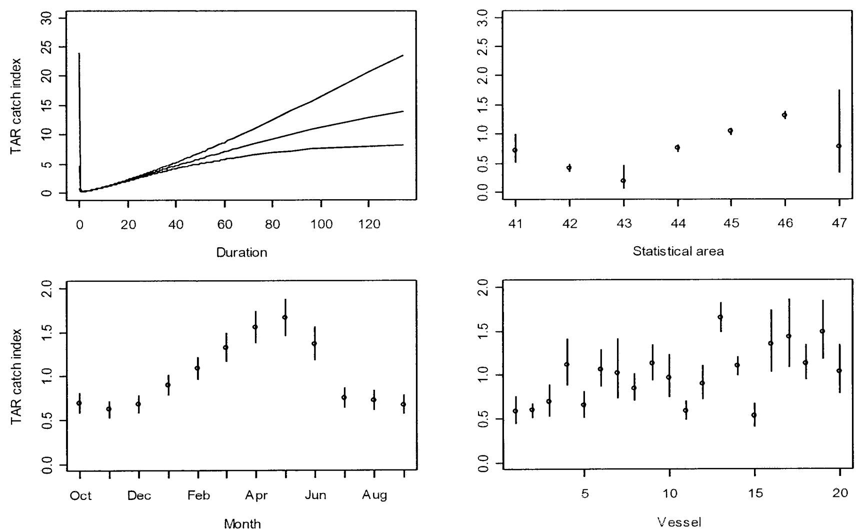

Figure B2: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the West Coast TARG fishery with 95% confidence intervals.

West Coast TCEPR model terms

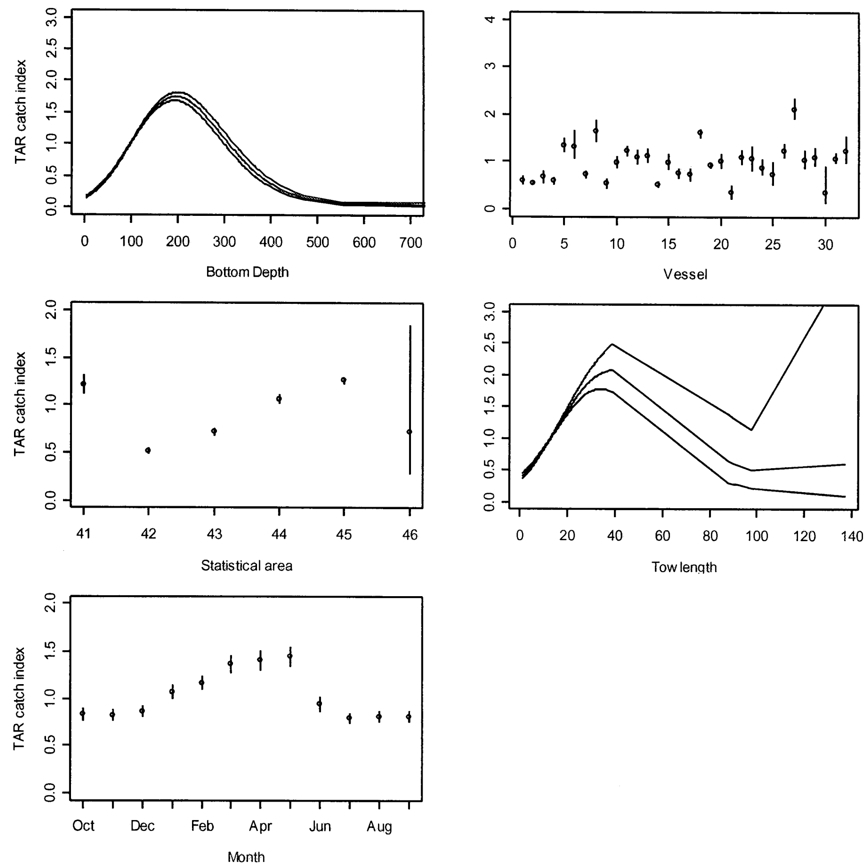

Figure B3: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the West Coast TCEPR fishery with 95% confidence intervals.

East Coast MIX model terms

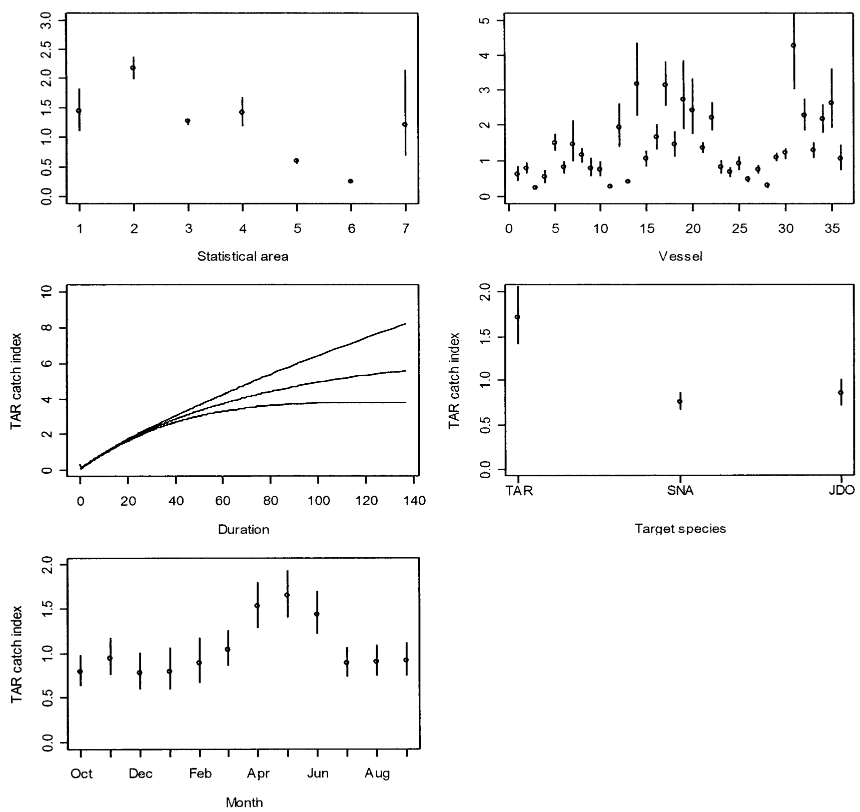

Figure B4: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the East Coast MIX fishery with 95% confidence intervals.

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East Coast TARG model terms

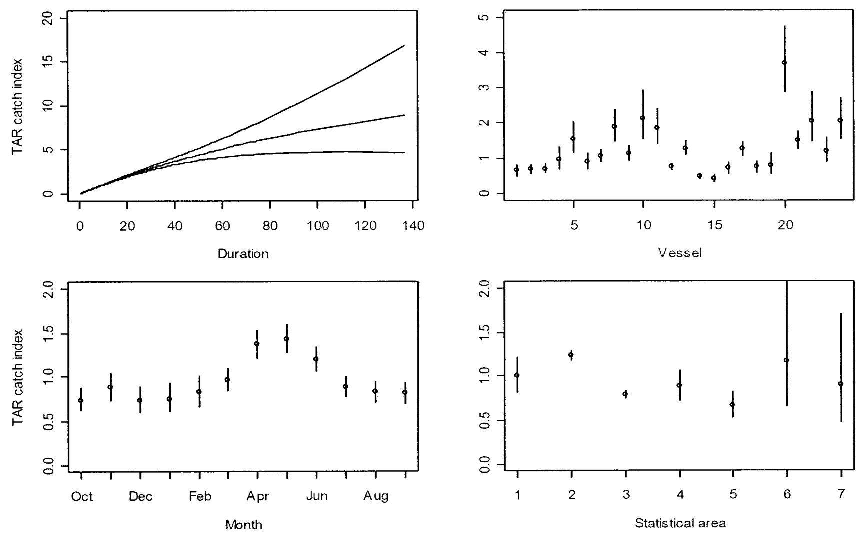


Figure B5: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the East Coast TARG fishery with 95% confidence intervals.

East Coast TCEPR model terms

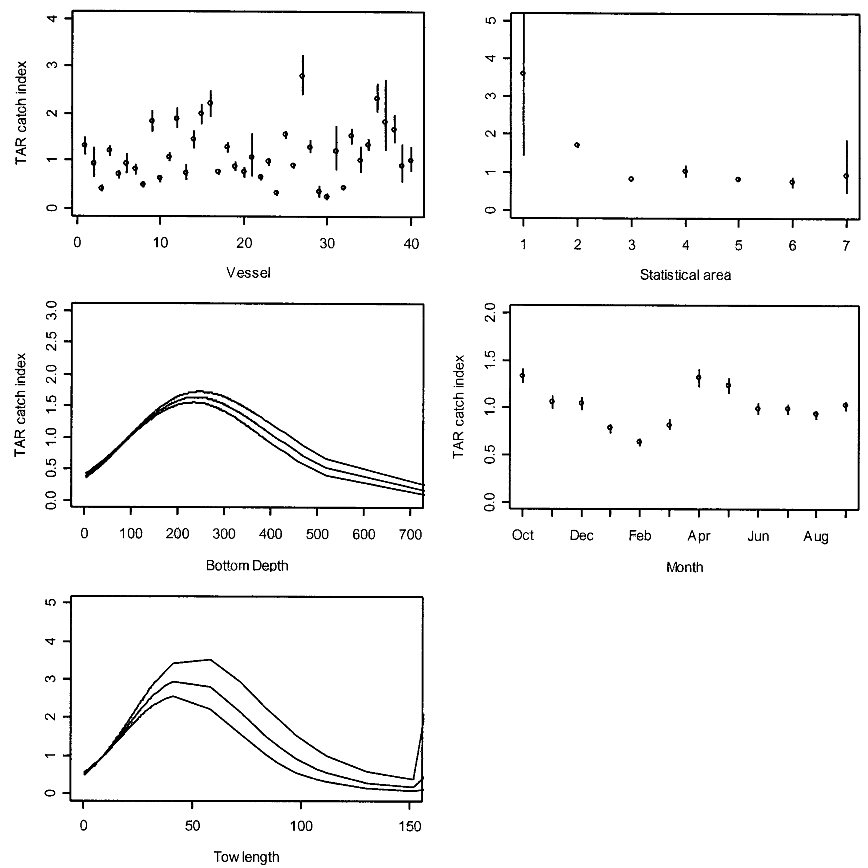
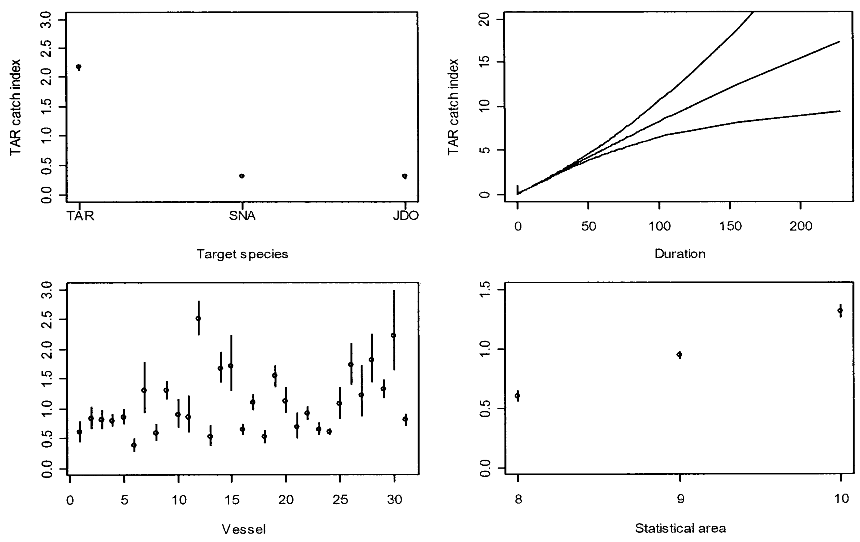


Figure B6: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the East Coast TCEPR fishery with 95% confidence intervals.

Bay of Plenty MIX model terms



Bay of Plenty TARG model terms

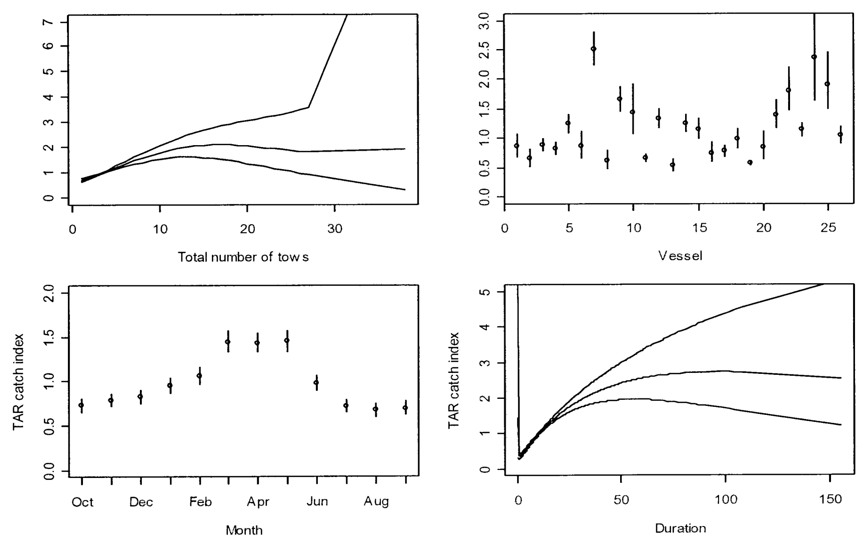


Figure B7: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the Bay of Plenty MIX fishery with 95% confidence intervals.

Figure B8: 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 TARG fishery with 95% confidence intervals.

Bay of Plenty TCEPR model terms

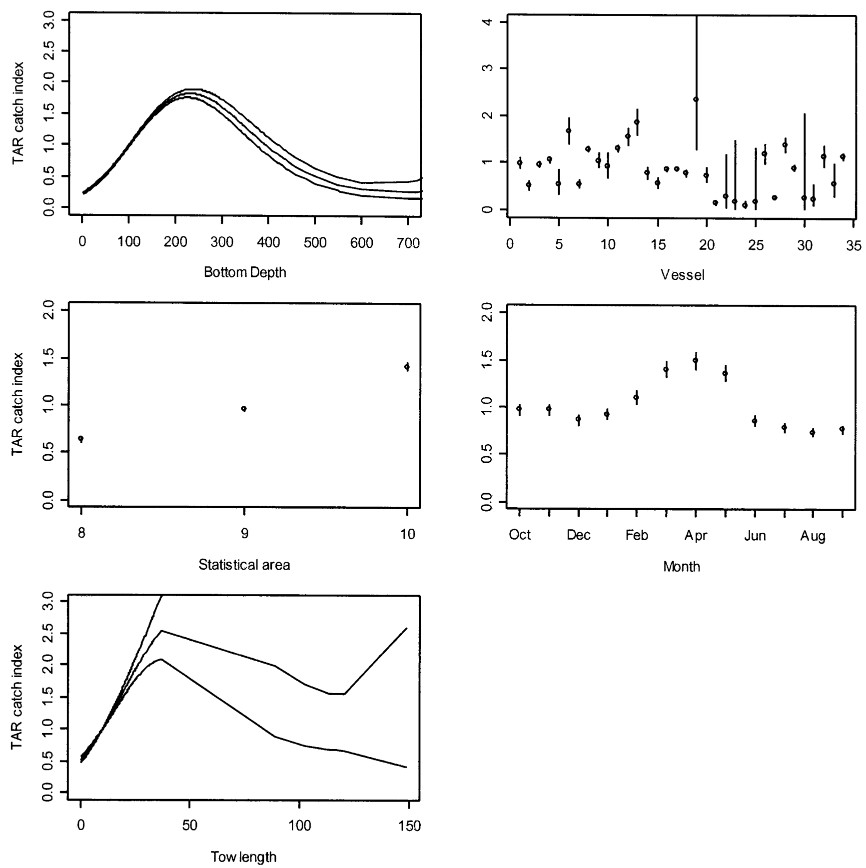


Figure B9: Plots of predicted relative catch per trip for the categorical and continuous variables included in the lognormal model of TAR 1 catches in the Bay of Plenty TCEPR fishery with 95% confidence intervals.

APPENDIX C: UNDERLYING DATA DISTRIBUTIONS

West Coast substock MIX model

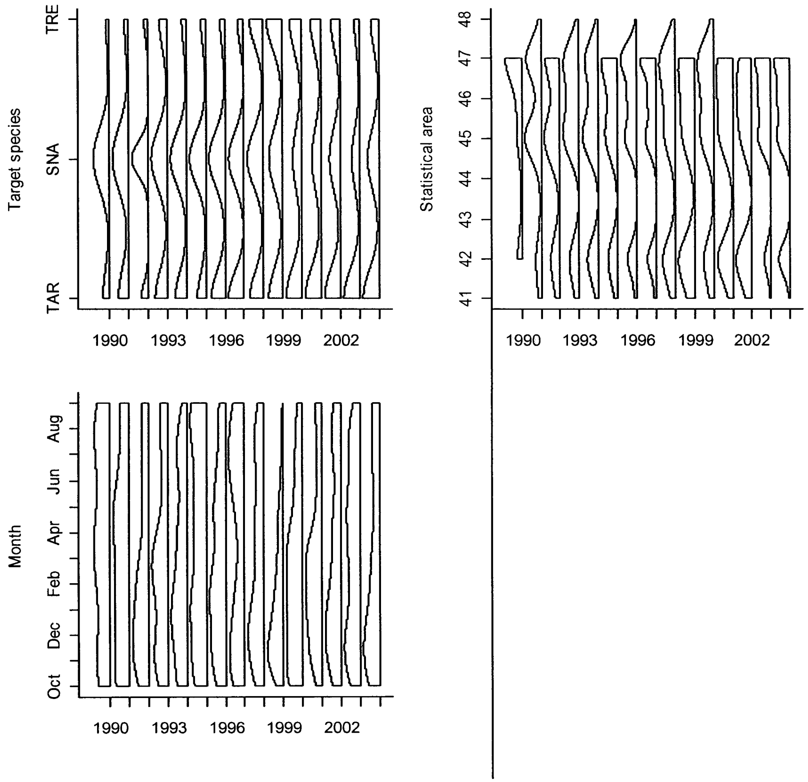


Figure C1: Distribution of the selected explanatory variables included in the standardised CPUE model of TAR 1 catches in the West Coast MIX fishery. Fishing years are coded using the last year of the pair.

West Coast substock TARG model

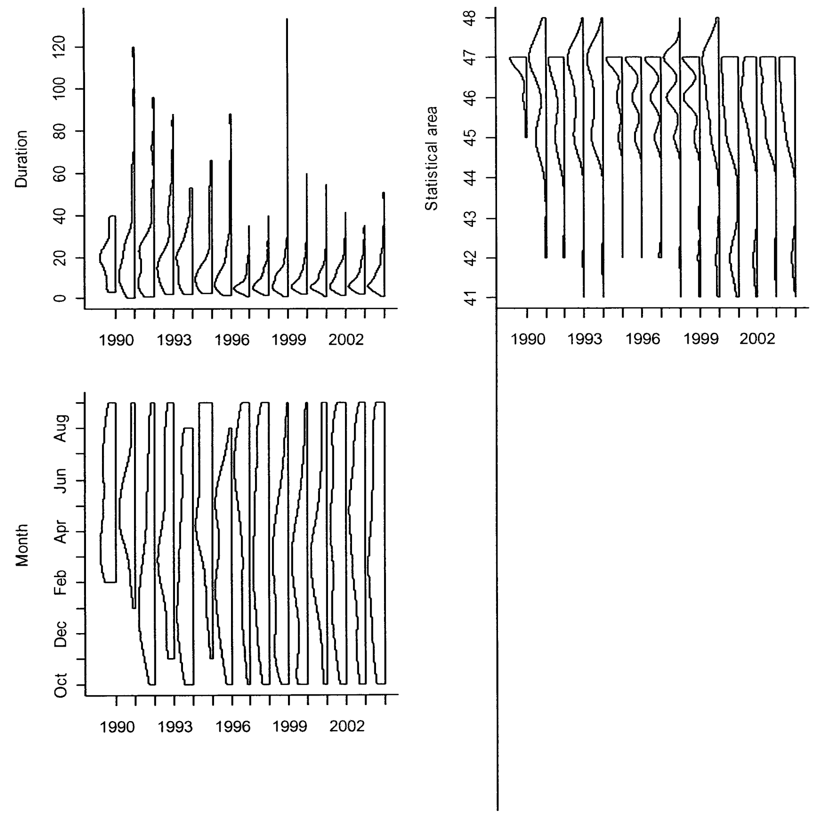


Figure C2: Distribution of the selected explanatory variables included in the standardised CPUE model of TAR 1 catches in the West Coast TARG fishery. Fishing years are coded using the last year of the pair.

East Coast substock MIX model

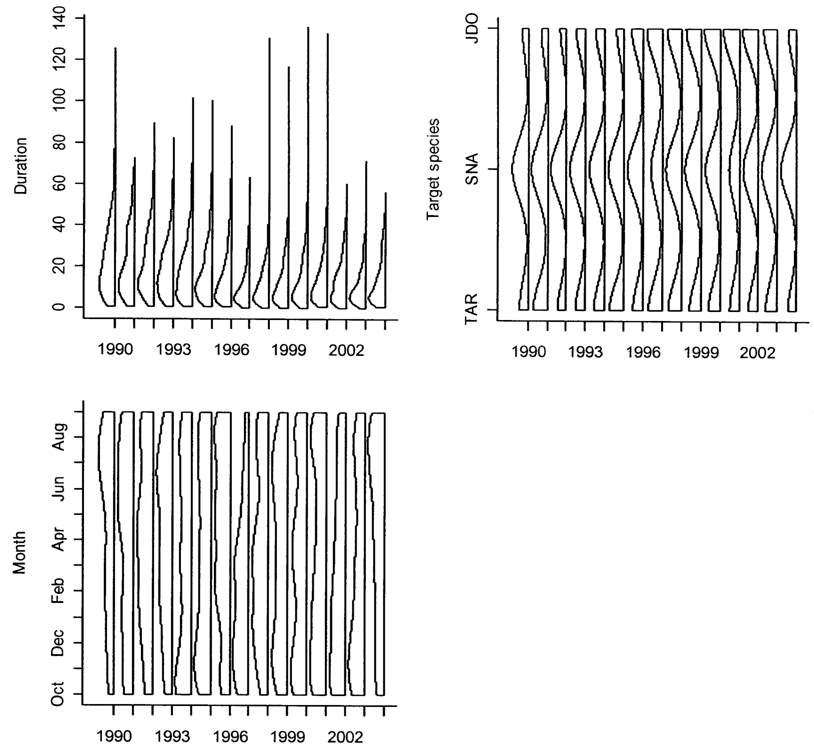


Figure C3: Distribution of the selected explanatory variables included in the standardised CPUE model of TAR 1 catches in the East Coast MIX fishery. Fishing years are coded using the last year of the pair.

East Coast substock TARG model

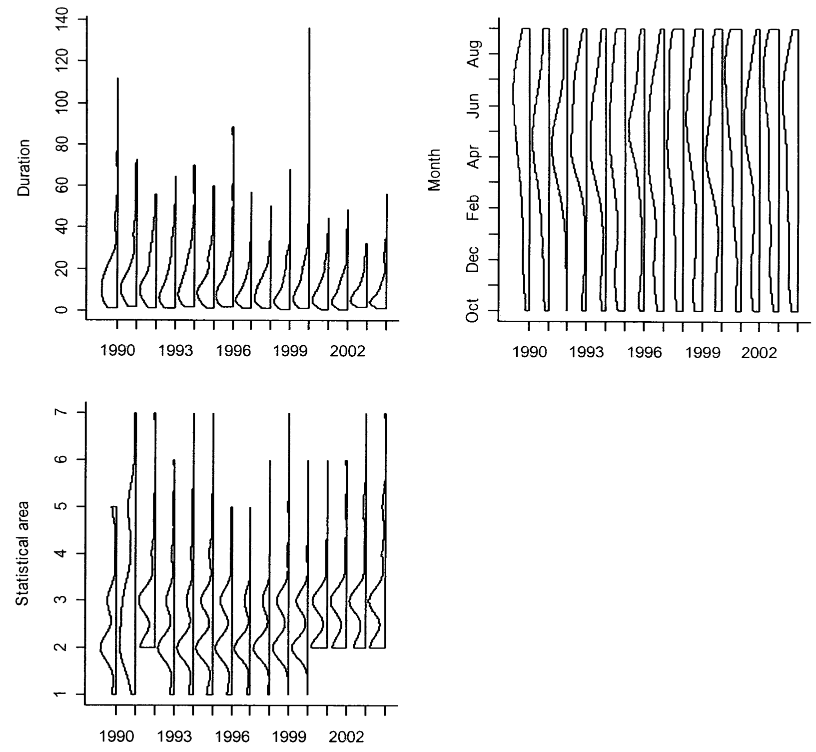


Figure C4: Distribution of the selected explanatory variables included in the standardised CPUE model of TAR 1 catches in the East Coast TARG fishery. Fishing years are coded using the last year of the pair.

Bay of Plenty substock MIX model

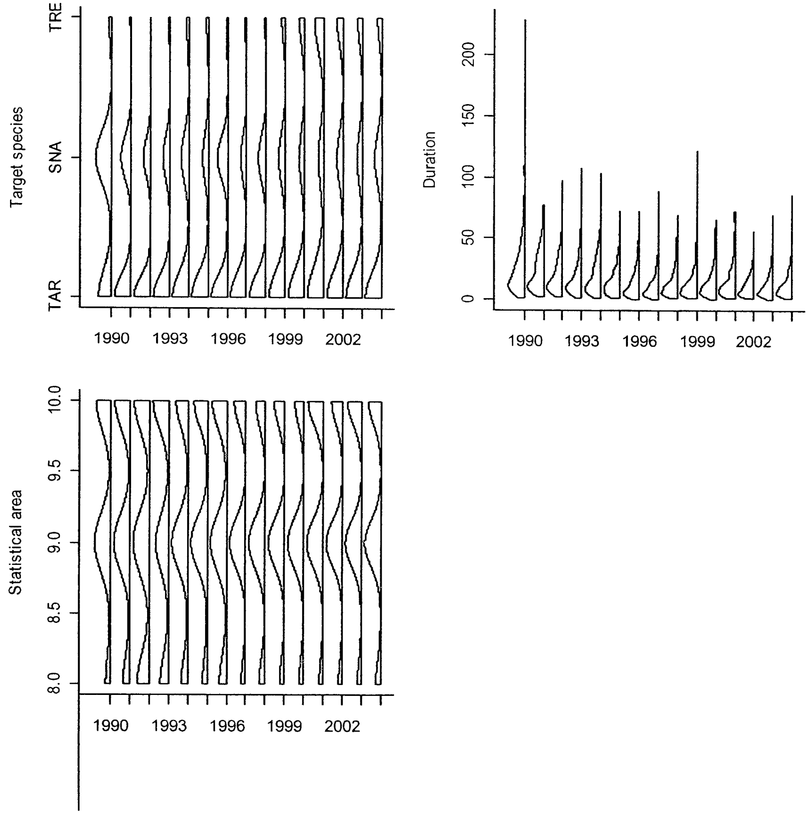


Figure C5: Distribution of the selected explanatory variables included in the standardised CPUE model of TAR 1 catches in the Bay of Plenty MIX fishery. Fishing years are coded using the last year of the pair.

Bay of Plenty substock TARG model

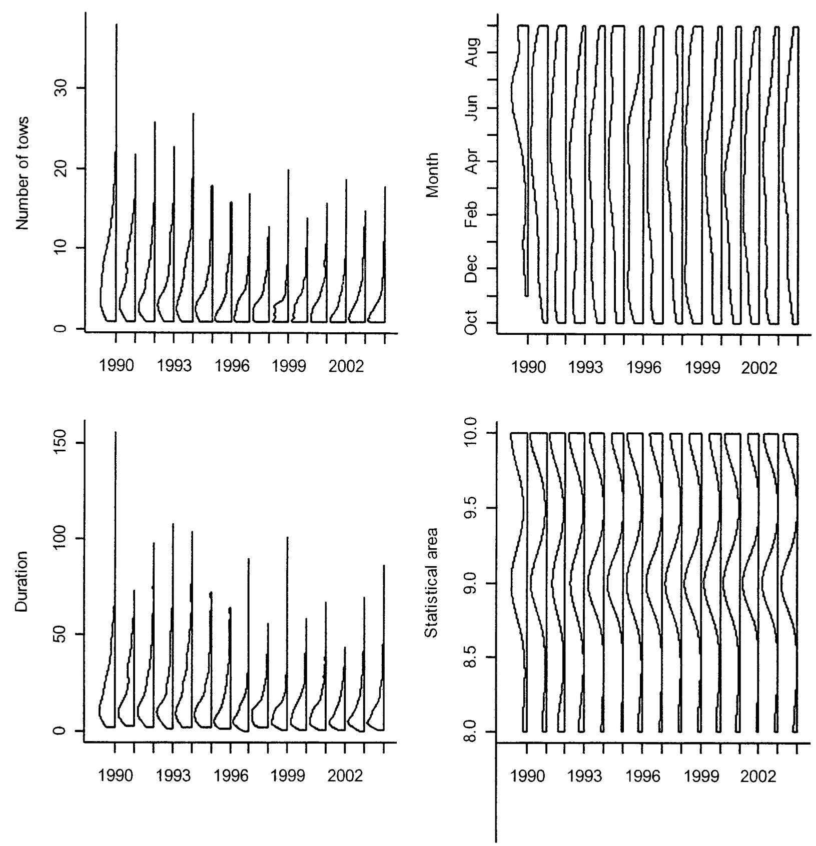


Figure C6: Distribution of the selected explanatory variables included in the standardised CPUE model of TAR 1 catches in the Bay of Plenty TARG fishery. Fishing years are coded using the last year of the pair.

APPENDIX D: CPUE INDICES

Table D1: Relative year effects and 95% confidence intervals (in parentheses) for all CPUE lognormal models fitted.

Fishing year	Western substock		
	MIX	TARG	TCEPR
89/90	1.420 (1.071 - 1.881)	0.669 (0.449 - 0.999)	
90/91	1.036 (0.807 - 1.331)	0.609 (0.454 - 0.817)	
91/92	1.134 (0.935 - 1.375)	0.622 (0.472 - 0.819)	
92/93	0.878 (0.755 - 1.020)	0.665 (0.555 - 0.798)	
93/94	0.961 (0.826 - 1.119)	0.780 (0.658 - 0.926)	
94/95	0.963 (0.829 - 1.118)	0.880 (0.728 - 1.065)	1.142 (1.028 - 1.268)
95/96	0.982 (0.845 - 1.141)	1.292 (1.092 - 1.530)	1.206 (1.117 - 1.303)
96/97	0.890 (0.784 - 1.010)	1.241 (1.079 - 1.427)	1.117 (1.047 - 1.193)
97/98	0.729 (0.647 - 0.821)	1.076 (0.933 - 1.240)	1.030 (0.967 - 1.098)
98/99	1.101 (0.966 - 1.254)	1.656 (1.421 - 1.930)	1.083 (1.010 - 1.162)
99/00	1.324 (1.154 - 1.520)	1.371 (1.188 - 1.581)	0.898 (0.841 - 0.958)
00/01	1.000 (0.868 - 1.152)	1.078 (0.932 - 1.246)	0.809 (0.758 - 0.863)
01/02	0.755 (0.655 - 0.870)	1.263 (1.088 - 1.467)	0.907 (0.850 - 0.967)
02/03	1.082 (0.926 - 1.264)	1.415 (1.222 - 1.638)	0.992 (0.928 - 1.060)
03/04	0.974 (0.832 - 1.139)	1.144 (0.981 - 1.335)	0.891 (0.836 - 0.950)

Fishing year	Eastern substock		
	MIX	TARG	TCEPR
89/90	1.448 (1.212 - 1.729)	0.917 (0.722 - 1.164)	
90/91	1.018 (0.869 - 1.193)	0.932 (0.766 - 1.134)	
91/92	1.021 (0.891 - 1.171)	1.207 (0.992 - 1.468)	
92/93	0.736 (0.645 - 0.839)	0.910 (0.761 - 1.088)	
93/94	0.694 (0.611 - 0.788)	0.792 (0.671 - 0.936)	
94/95	0.775 (0.679 - 0.884)	1.075 (0.923 - 1.253)	1.067 (0.952 - 1.196)
95/96	0.751 (0.668 - 0.846)	0.866 (0.736 - 1.019)	0.906 (0.855 - 0.961)
96/97	1.198 (1.064 - 1.348)	1.100 (0.952 - 1.270)	0.847 (0.801 - 0.896)
97/98	1.083 (0.965 - 1.215)	1.160 (1.005 - 1.340)	1.025 (0.972 - 1.082)
98/99	1.155 (1.036 - 1.289)	1.047 (0.889 - 1.232)	1.002 (0.952 - 1.054)
99/00	1.323 (1.183 - 1.478)	1.080 (0.927 - 1.258)	1.067 (1.018 - 1.119)
00/01	1.148 (1.016 - 1.297)	1.012 (0.856 - 1.198)	1.120 (1.067 - 1.175)
01/02	1.071 (0.934 - 1.227)	1.091 (0.900 - 1.322)	1.031 (0.978 - 1.086)
02/03	1.125 (0.970 - 1.306)	0.944 (0.777 - 1.147)	1.012 (0.952 - 1.077)
03/04	0.816 (0.701 - 0.950)	0.961 (0.788 - 1.174)	0.953 (0.889 - 1.021)

Fishing year	Bay of Plenty substock		
	MIX	TARG	TCEPR
89/90	1.251 (1.067 - 1.467)	0.927 (0.765 - 1.124)	
90/91	0.912 (0.805 - 1.034)	0.861 (0.761 - 0.974)	
91/92	0.830 (0.736 - 0.936)	0.734 (0.654 - 0.822)	
92/93	1.028 (0.913 - 1.157)	0.968 (0.865 - 1.084)	
93/94	1.060 (0.948 - 1.186)	1.029 (0.918 - 1.153)	
94/95	0.832 (0.741 - 0.933)	0.880 (0.787 - 0.984)	
95/96	0.887 (0.790 - 0.996)	0.915 (0.811 - 1.031)	1.011 (1.108 - 0.922)
96/97	0.830 (0.741 - 0.930)	0.887 (0.795 - 0.990)	0.955 (1.029 - 0.886)
97/98	1.019 (0.906 - 1.145)	1.004 (0.893 - 1.129)	0.864 (0.922 - 0.810)
98/99	0.973 (0.877 - 1.078)	0.963 (0.869 - 1.068)	0.905 (0.959 - 0.853)
99/00	0.730 (0.652 - 0.816)	0.826 (0.739 - 0.924)	0.856 (0.910 - 0.805)
00/01	1.168 (1.041 - 1.311)	1.292 (1.145 - 1.458)	1.020 (1.074 - 0.969)
01/02	1.316 (1.187 - 1.459)	1.526 (1.371 - 1.698)	1.178 (1.237 - 1.121)
02/03	1.247 (1.127 - 1.380)	1.183 (1.070 - 1.308)	1.136 (1.191 - 1.084)
03/04	1.140 (1.035 - 1.255)	1.288 (1.167 - 1.422)	1.135 (1.190 - 1.083)

Table D2: Relative year effects and 95% confidence intervals (in parentheses) for the constituent parts (See section 2.4) of the Combined CPUE models fitted.

Fishing year	Western substock MIX											
	Lognormal						Binomial					Combined
89/90	1.420	(1.071	-	1.881)		1.392	(0.905	-	2.142)			1.457
90/91	1.036	(0.807	-	1.331)		1.403	(0.923	-	2.133)			1.173
91/92	1.134	(0.935	-	1.375)		1.504	(1.065	-	2.125)			1.277
92/93	0.878	(0.755	-	1.020)		1.047	(0.822	-	1.335)			0.911
93/94	0.961	(0.826	-	1.119)		0.812	(0.640	-	1.031)			0.928
94/95	0.963	(0.829	-	1.118)		1.090	(0.856	-	1.388)			1.006
95/96	0.982	(0.845	-	1.141)		0.845	(0.673	-	1.060)			0.951
96/97	0.890	(0.784	-	1.010)		1.199	(0.979	-	1.468)			0.911
97/98	0.729	(0.647	-	0.821)		1.168	(0.971	-	1.406)			0.760
98/99	1.101	(0.966	-	1.254)		1.103	(0.898	-	1.354)			1.160
99/00	1.324	(1.154	-	1.520)		0.963	(0.781	-	1.186)			1.316
00/01	1.000	(0.868	-	1.152)		0.742	(0.608	-	0.906)			0.908
01/02	0.755	(0.655	-	0.870)		0.857	(0.694	-	1.057)			0.710
02/03	1.082	(0.926	-	1.264)		0.714	(0.566	-	0.900)			0.984
03/04	0.974	(0.832	-	1.139)		0.643	(0.517	-	0.801)			0.845

Fishing year	Eastern substock MIX											
	Lognormal						Binomial					Combined
89/90	1.448	(1.212	-	1.729)		1.118	(0.810	-	1.543)			1.503
90/91	1.018	(0.869	-	1.193)		0.484	(0.370	-	0.634)			0.812
91/92	1.021	(0.891	-	1.171)		0.551	(0.444	-	0.685)			0.857
92/93	0.736	(0.645	-	0.839)		0.636	(0.507	-	0.798)			0.650
93/94	0.694	(0.611	-	0.788)		0.817	(0.655	-	1.020)			0.664
94/95	0.775	(0.679	-	0.884)		0.960	(0.759	-	1.213)			0.775
95/96	0.751	(0.668	-	0.846)		1.149	(0.946	-	1.395)			0.785
96/97	1.198	(1.064	-	1.348)		1.297	(1.070	-	1.571)			1.284
97/98	1.083	(0.965	-	1.215)		0.984	(0.823	-	1.177)			1.090
98/99	1.155	(1.036	-	1.289)		1.236	(1.030	-	1.484)			1.227
99/00	1.323	(1.183	-	1.478)		1.361	(1.123	-	1.651)			1.433
00/01	1.148	(1.016	-	1.297)		1.433	(1.160	-	1.770)			1.256
01/02	1.071	(0.934	-	1.227)		1.119	(0.903	-	1.387)			1.112
02/03	1.125	(0.970	-	1.306)		1.340	(1.067	-	1.682)			1.215
03/04	0.816	(0.701	-	0.950)		1.267	(0.996	-	1.612)			0.871

Fishing year	Bay of Plenty substock MIX											
	Lognormal						Binomial					Combined
89/90	1.251	(1.067	-	1.467)		0.923	(0.650	-	1.310)			1.239
90/91	0.912	(0.805	-	1.034)		0.741	(0.546	-	1.006)			0.865
91/92	0.830	(0.736	-	0.936)		0.635	(0.468	-	0.863)			0.759
92/93	1.028	(0.913	-	1.157)		1.226	(0.898	-	1.675)			1.066
93/94	1.060	(0.948	-	1.186)		1.563	(1.144	-	2.136)			1.136
94/95	0.832	(0.741	-	0.933)		1.313	(0.970	-	1.777)			0.871
95/96	0.887	(0.790	-	0.996)		1.028	(0.796	-	1.328)			0.895
96/97	0.830	(0.741	-	0.930)		0.897	(0.703	-	1.145)			0.818
97/98	1.019	(0.906	-	1.145)		0.975	(0.757	-	1.256)			1.019
98/99	0.973	(0.877	-	1.078)		0.774	(0.629	-	0.951)			0.930
99/00	0.730	(0.652	-	0.816)		0.704	(0.567	-	0.874)			0.684
00/01	1.168	(1.041	-	1.311)		1.284	(1.010	-	1.632)			1.220
01/02	1.316	(1.187	-	1.459)		1.066	(0.857	-	1.326)			1.336
02/03	1.247	(1.127	-	1.380)		1.047	(0.841	-	1.302)			1.263
03/04	1.140	(1.035	-	1.255)		1.303	(1.059	-	1.603)			1.193

APPENDIX E: DATA SUMMARIES

Table E1: Data summaries for the two West Coast fisheries defined for standardised CPUE analysis for core vessels; MIX (core vessels based on a minimum of 10 trips per year for at least 6 years), TARGET (core vessels based on a minimum of 5 trips per year for at least 4 years), and TCEPR (core vessels based on a minimum of 10 tows per year for at least 3 years); Number of trips, percentage of strata that recorded a zero catch of tarakihi, number of core vessels, total number of tows, landed weight of TAR 1 (tonnes), and the simple catch rate of TAR 1 across all tows(kg/tow).

MIX fishery

Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
89/90	81	28	14	1285	53	41
90/91	101	25	13	1299	81	63
91/92	173	20	14	1428	134	94
92/93	267	28	20	2366	245	104
93/94	284	30	20	2021	218	108
94/95	269	26	20	1895	290	153
95/96	271	38	21	1315	305	232
96/97	345	30	22	1384	282	204
97/98	415	32	23	1722	280	163
98/99	357	30	21	1841	274	149
99/00	294	35	19	1768	292	165
00/01	258	42	17	1238	228	184
01/02	267	37	16	1019	290	284
02/03	194	41	14	1044	313	300
03/04	193	43	13	1471	237	161

TARGET fishery

Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
89/90	19	0	5	488	23	48
90/91	35	3	7	523	61	116
91/92	38	2	7	406	56	137
92/93	82	1	13	853	145	170
93/94	103	5	14	775	156	201
94/95	77	2	14	499	172	345
95/96	100	3	13	525	241	458
96/97	154	3	16	516	197	381
97/98	136	2	17	466	221	474
98/99	123	1	13	560	237	423
99/00	143	4	17	550	253	459
00/01	128	2	16	379	185	487
01/02	129	1	15	417	257	617
02/03	119	3	14	404	277	685
03/04	112	3	13	410	207	506

TCEPR fishery

Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
94/95	77	0	12	325	112	346
95/96	177	0	22	737	277	375
96/97	273	0	23	947	363	383
97/98	258	0	24	930	350	377
98/99	198	0	22	778	299	384
99/00	224	0	18	887	327	369
00/01	259	0	22	892	284	319
01/02	255	0	18	928	378	407
02/03	228	0	17	872	424	487
03/04	234	0	18	973	383	393

Note: While the TARGET fishery is a true subset of the MIX fishery, the TCEPR fishery, although comprising a subset in terms of formtype, is not selected on the basis of target species (as are both MIX and TARGET fisheries), and therefore is often the larger dataset, especially in later years when the TCEPR formtype prevails.

Table E2: Data summaries for the two East Coast fisheries defined for standardised CPUE analysis for core vessels; MIX (core vessels based on a minimum of 5 trips per year for at least 5 years), and TARGET (core vessels based on a minimum of 5 trips per year for at least 3 years), and TCEPR (core vessels based on a minimum of 10 tows per year for at least 3 years). Number of trips, percentage of strata that recorded a zero catch of tarakihi, number of core vessels, total number of tows, landed weight of TAR 1 (tonnes), and the simple catch rate of TAR 1 across all tows (kg/tow).

MIX fishery

Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
89/90	231	23	23	3859	116	30
90/91	319	33	25	4063	148	36
91/92	410	33	28	4202	225	53
92/93	415	27	30	3309	184	56
93/94	423	26	28	3310	164	50
94/95	378	26	28	2975	199	67
95/96	427	28	30	3385	182	54
96/97	438	29	29	3144	248	79
97/98	485	33	30	3727	246	66
98/99	474	28	29	3857	218	56
99/00	458	24	30	3693	241	65
00/01	382	24	25	3065	176	57
01/02	327	30	23	2435	144	59
02/03	272	31	20	2001	93	47
03/04	307	33	16	2292	118	51

TARGET fishery

Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
89/90	61	2	12	624	63	101
90/91	107	3	13	1353	121	90
91/92	84	0	17	1042	158	151
92/93	98	2	17	699	134	192
93/94	109	1	15	771	109	141
94/95	128	1	18	778	161	206
95/96	117	2	20	612	127	208
96/97	146	1	18	668	199	298
97/98	144	4	19	680	194	285
98/99	115	0	18	677	119	176
99/00	128	3	19	767	149	194
00/01	116	4	18	523	102	195
01/02	84	3	17	357	104	290
02/03	83	3	13	282	67	238
03/04	76	1	14	280	78	280

TCEPR fishery

Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
94/95	64	0	14	257	60	235
95/96	252	0	30	1105	161	146
96/97	287	0	30	1153	192	167
97/98	324	0	35	1281	209	163
98/99	279	0	28	1403	159	113
99/00	300	0	28	1704	206	121
00/01	318	0	30	1555	177	114
01/02	275	0	25	1321	176	133
02/03	254	0	21	1025	128	124
03/04	190	0	20	765	128	168

Table E3: Data summaries for the two Bay of Plenty fisheries defined for standardised CPUE analysis for core vessels; MIX (core vessels based on a minimum of 5 trips per year for at least 5 years), and TARGET (core vessels based on a minimum of 5 trips per year for at least 4 years), and TCEPR (core vessels based on a minimum of 10 tows per year for at least 5 years). Number of trips, percentage of strata that recorded a zero catch of tarakihi, number of core vessels, total number of tows, landed weight of TAR 1 (tonnes), and the simple catch rate of TAR 1 across all tows (kg/tow).

MIX fishery

Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
89/90	199	18	25	2708	205	76
90/91	344	17	21	3864	371	96
91/92	375	15	26	3648	373	102
92/93	389	13	28	3030	423	140
93/94	403	12	29	3232	566	175
94/95	349	15	26	2477	412	166
95/96	330	22	26	2531	404	160
96/97	372	24	24	2373	355	149
97/98	306	24	27	2225	371	167
98/99	372	29	23	2904	395	136
99/00	332	32	21	2626	349	133
00/01	333	24	21	2805	504	180
01/02	409	24	18	2837	621	219
02/03	425	23	21	3087	634	205
03/04	440	21	19	3559	679	191

TARGET fishery

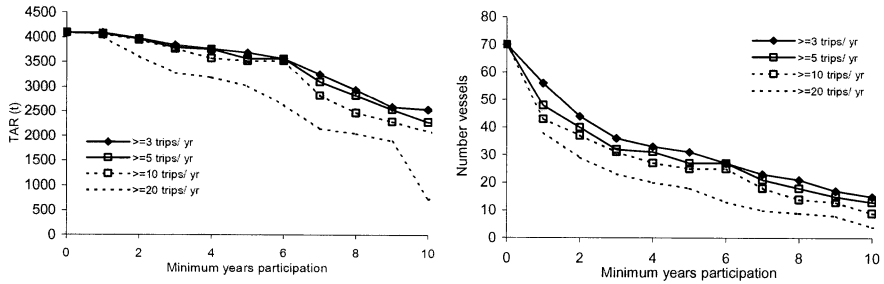
Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
89/90	91	1	17	857	156	182
90/91	236	0	13	1806	343	190
91/92	265	0	17	2166	349	161
92/93	274	0	22	1808	404	223
93/94	234	2	21	1714	485	283
94/95	245	2	18	1471	367	249
95/96	191	2	19	1121	327	291
96/97	244	3	16	1277	325	255
97/98	199	3	22	1204	335	279
98/99	246	1	18	1278	355	278
99/00	227	2	16	1176	320	272
00/01	205	2	18	889	416	468
01/02	273	2	13	1111	506	455
02/03	297	1	17	1477	539	365
03/04	325	1	15	1473	588	399

TCEPR fishery

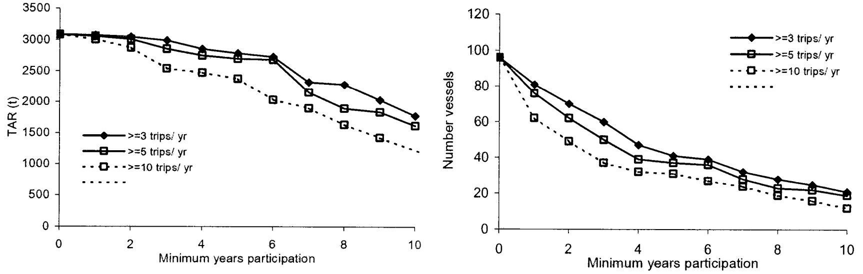
Fishing year	No. Trips	% zero	No. vessels	No. tows	TAR (t)	CPUE kg/tow
95/96	120	0	22	479	96	201
96/97	172	0	26	699	121	173
97/98	196	0	25	883	175	198
98/99	278	0	23	1125	185	164
99/00	246	0	21	1071	171	160
00/01	313	0	28	1508	363	241
01/02	388	0	22	1717	503	293
02/03	382	0	25	1925	528	274
03/04	392	0	20	2038	581	285

APPENDIX F: CORE VESSEL SELECTIONS

West Coast MIX fishery (min. 6 years at min. 10 trips per yr)



East Coast MIX fishery (min. 5 years at min. 5 trips per yr)



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

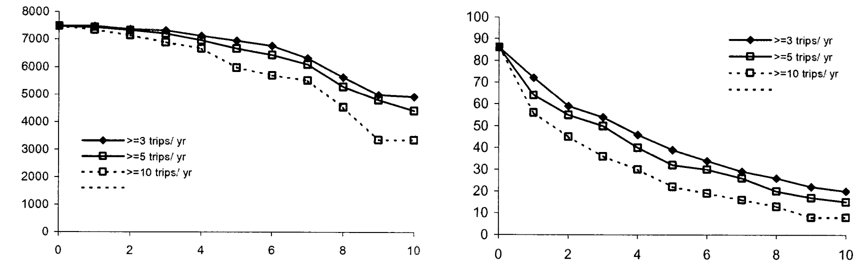
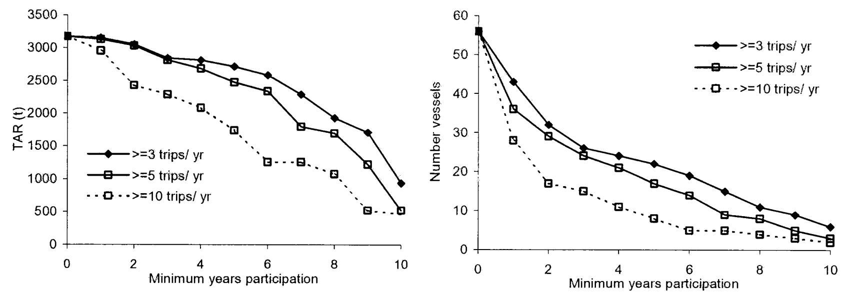
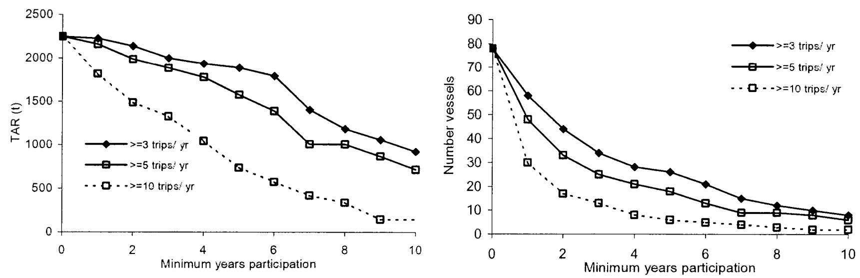


Figure F1: The total landed TAR 1 [left panel] and the number of vessels [right panel] retained in the MIX fishery datasets for the three substocks, depending on the minimum number of qualifying years used to define core vessels. Alternative definitions of a qualifying year (minimum number of trips per year) are indicated in the legends.

West Coast Target fishery (min. 4 years at min. 5 trips per yr)



East Coast Target fishery (min. 3 years at min. 5 trips per yr)



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

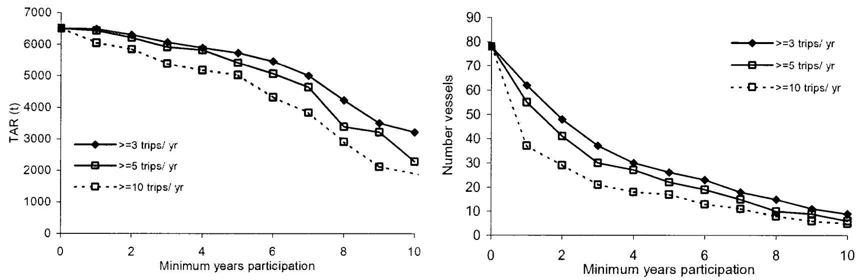
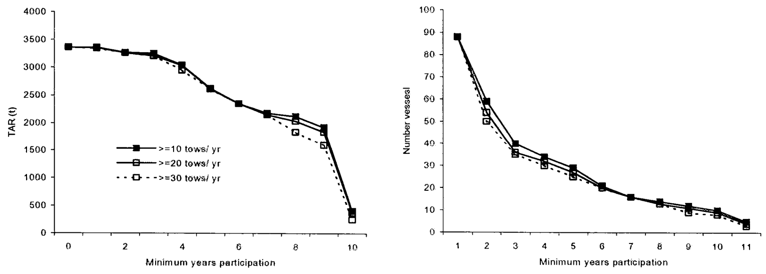
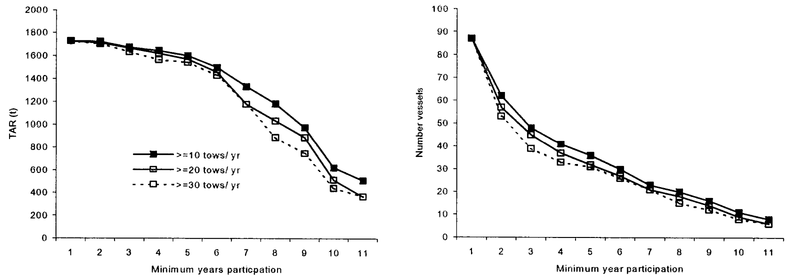


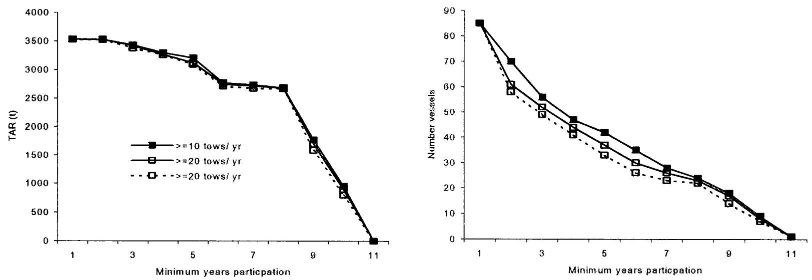
Figure F2: The total landed TAR 1 [left panel] and the number of vessels [right panel] retained in the Target fishery datasets for the three substocks depending on the minimum number of qualifying years used to define core vessels. Alternative definitions of a qualifying year (minimum number of trips per year) are indicated in the legend.

West Coast TCEPR fishery (min. 3 years at min. 10 tows per yr)





East Coast TCEPR fishery (min. 3 years at min. 10 tows per yr)

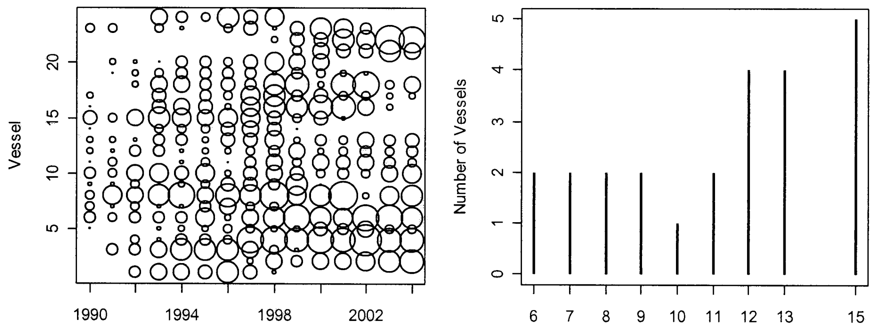


Bay of Plenty TCEPR fishery (min. 5 years at min. 10 tows per yr)

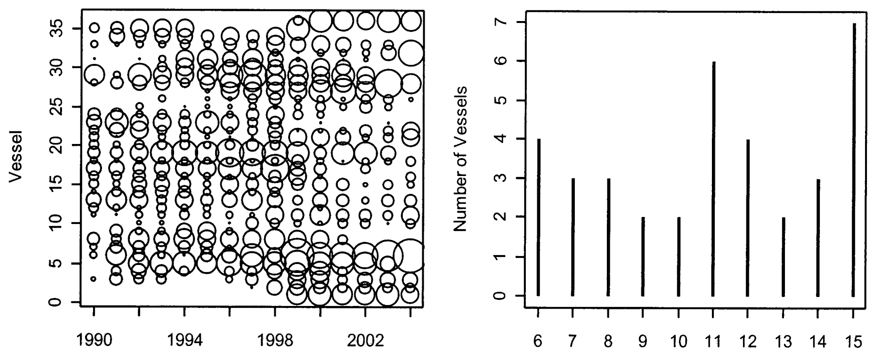
Figure F3: The total landed TAR 1 [left panel] and the number of vessels [right panel] retained in the TCEPR fishery datasets for the three substocks, depending on the minimum number of qualifying years used to define core vessels. Alternative definitions of a qualifying year (minimum number of trips per year) are indicated in the legends.

APPENDIX G: CORE VESSEL PARTICIPATION

Participation of selected core vessels in the West Coast MIX fishery



Participation of selected core vessels in the East Coast MIX fishery



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

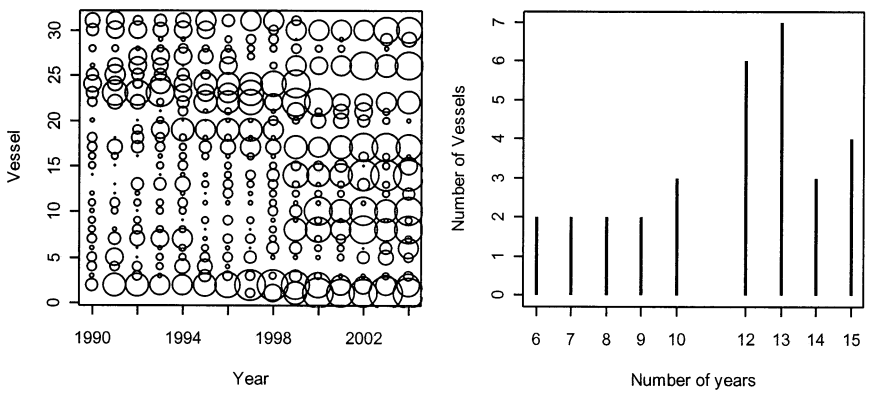
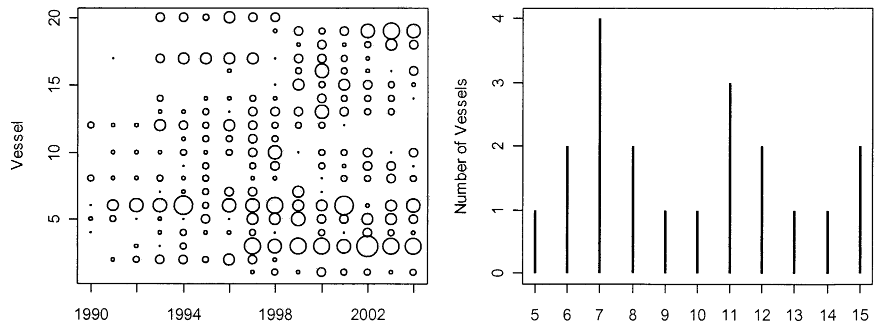
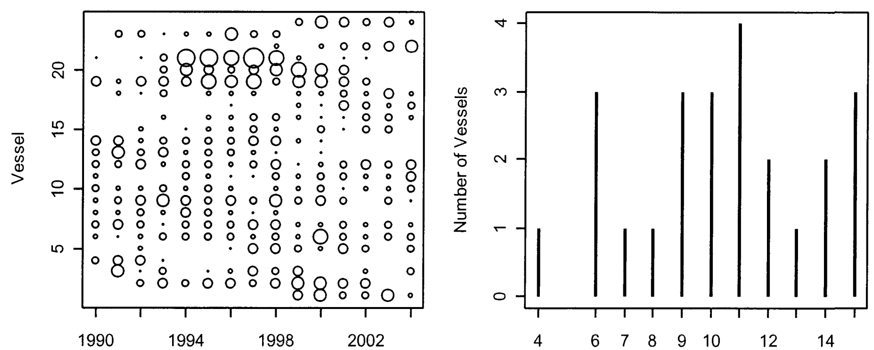


Figure G1: The participation of core vessels in the MIX bottom trawl fisheries; number of records for each vessel in each fishing year and distribution of length of participation.

Participation of selected core vessels in the West Coast Target fishery



Participation of selected core vessels in the East Coast Target fishery



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

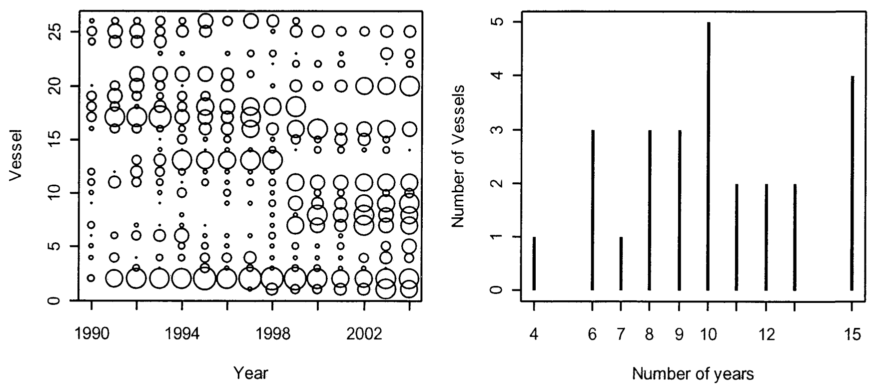


Figure G2: The participation of core vessels in the TARG bottom trawl fisheries; number of records for each vessel in each fishing year and distribution of length of participation.

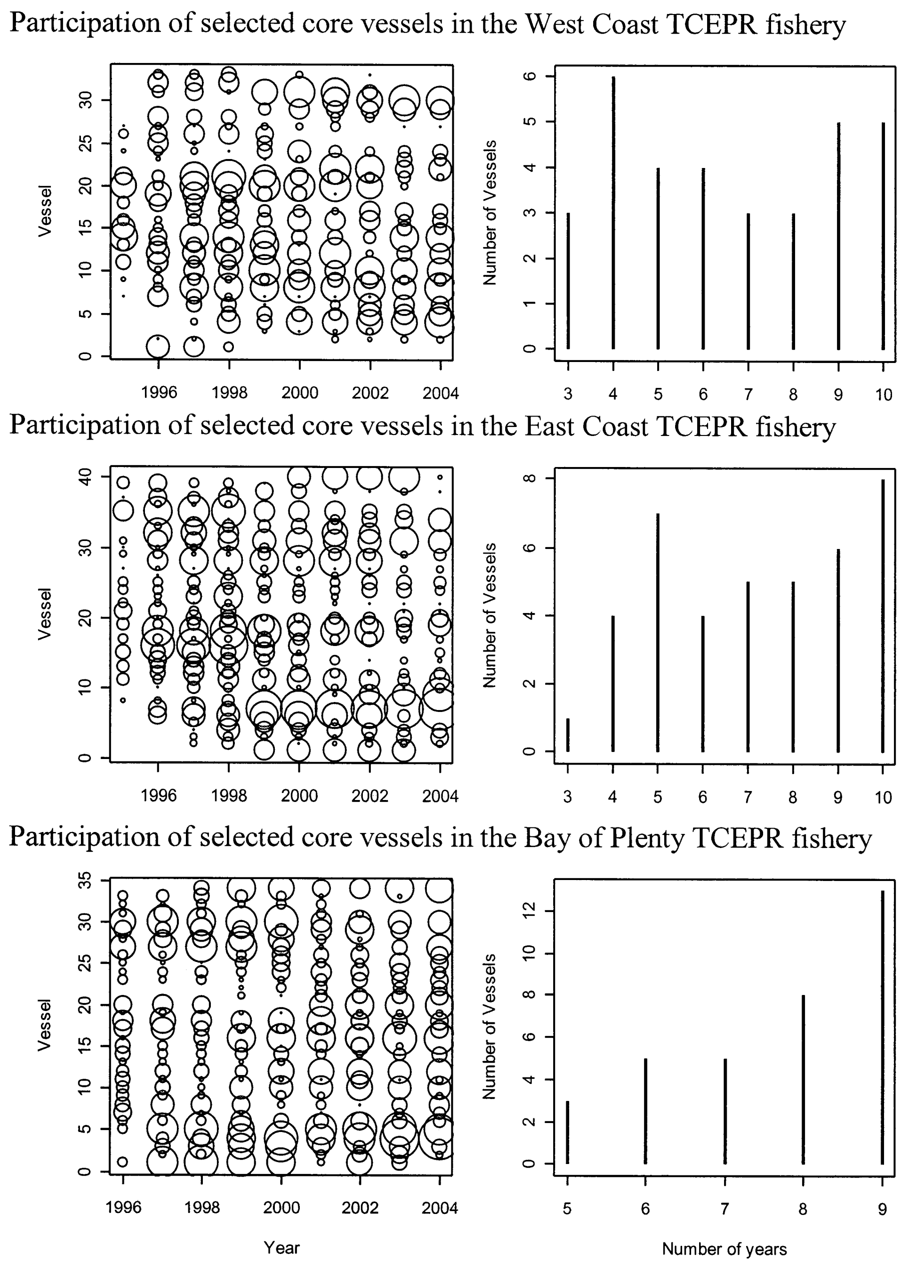


Figure G3: The participation of core vessels in the TCEPR bottom trawl fisheries; number of records for each vessel in each fishing year and distribution of length of participation.