MINISTRY OF FISHERIES

Te Tautiaki i nga tini a Tangaroa

Abundance estimates for flatfish in FLA 1 from standardised catch per unit effort analysis of the set net fisheries, 1989–90 to 2003–04

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EXECUTIVE SUMMARY

This report presents the first standardised CPUE analyses for flatfish using estimated catch data from the FLA 1 set net fishery for 1989–90 to 2003–04. There are generally stable patterns of effort, fleet composition, and catches. Most catch was taken from the three main harbours of Manukau, Kaipara, and the Firth of Thames. Standardised CPUE for all flatfish species combined (mostly yellowbelly and sand flounder) declined in three west coast areas (Manukau, Kaipara, lower Waikato), and on the east coast in Firth of Thames, and in the east southern subarea. CPUE in the west coast areas of FLA 1 reflects abundance of yellowbelly flounder as the proportion of sand flounder in the west coast catch is very small. Important predictors of CPUE were vessel, target species, and day of year in all subareas. When the Firth of Thames was devolved by species, most of the decline was attributable to sand flounder, as the yellowbelly CPUE has remained stable since the mid 1990s. Additionally, we found that sand flounder catch rates were seasonal with a winter peak; yellowbelly catch rates peak in summer. These findings emphasises the value of carrying out CPUE analyses for individual flatfish species, where data are adequate, to determine which species are at most risk of overfishing. It also reinforces the value of reporting all flatfish estimated catch by individual species code rather than by the generic FLA code.

There are no other abundance indices for FLA 1 to validate whether the indexes determined from this study track abundance, but the decline in CPUE is consistent with perceptions of user groups that flatfish abundance has declined. We are not aware of any other major external changes that are likely to change the view generated from these data.

Sand flounder abundance appears to be related to sea surface temperature (SST) at the time of spawning. Catch rates are generally higher following cooler water temperatures two years before fish are caught, suggesting that SST may be affecting spawning success and/or survival of eggs and larvae. No relationship seems to exist for yellowbelly flounder abundance and SST.

1. INTRODUCTION

The flatfish commercial fishery comprises eight species: four flounders (black flounder, *Rhombosolea retiaria* (BFL); greenback flounder, *R. taparina* (GFL); sand flounder, *R. plebeian* (SFL); yellowbelly flounder, *R. leporine* (YBF)), two soles (lemon sole, *Pelotretus flavilatus* (LSO); New Zealand sole, *P. novaezeelandiae* (ESO)), brill, (*Colistium gunetheri* (BRI)), and turbot, (*Colistium nudipinnis* (TUR)) (Kirk 1989, Annala et al. 2004). The main species found in the north of New Zealand are sand flounder, often referred to as 'dabs' and yellowbelly flounder.

Flatfish are managed within the Quota Management System (QMS) essentially as a single species comprising four stocks under the generic species code FLA (FLA 1, FLA 2, FLA 3, and FLA 7). FLA 1 includes FMAs 1 and 9 (Figure 1). The codes for individual flatfish species (BRI, BFL, ESO, GFL, LSO, SFL, TUR, and YBF) are required to be used in the Catch-Effort section of the form. In practice, MFish accept either individual species codes or the generic FLA code because of the difficulties fishers find in complying with the reporting requirements. In FLA 1, between 1989–90 and 2001–02, 60% of the estimated catch was recorded under the code FLA, with 23% as YBF (yellowbelly flounder), 13% SFL (sand flounder), and negligible amounts of other species (Beentjes 2003).

Nearly all fishing on the west coast occurs within the harbours. The areas that provide the bulk of the flatfish catch are Thames, Kaipara Harbour, and Manukau Harbour. Commercial fishers report that the main flatfish species in the Kaipara and Manukau harbours is YBF, whereas historically SFL was equally abundant. YBF is larger and more valuable than SFL and is usually the target species of choice.

Annual flatfish catches for FLA 1 in recent years have been 600 to 800 t, but historically have varied two-fold with peaks in 1983–84 of 1215 t, and 1993–94 of 1136 t (Figure 2). FLA 1 has contributed, on average, 21% of the national total landings since introduction to the QMS in 1986–87. Although there does not appear to be a trend in total flatfish catch, SFL has been steadily declining since the peak in 1993–94 (Beentjes 2003).

The TACC for flatfish throughout all QMAs was set high to allow for the large fluctuations in annual catches resulting from highly variable recruitment (Figure 2). A high TACC allows fishers to take advantage of good years when flatfish are abundant, and the current FLA 1 TACC of 1187 t has never been caught. Indeed, on average, it has been 60% caught for the nine years from 1995–96 to 2003–04.

Ninety percent of FLA 1 landings are taken by set net, 5% by bottom trawl, and 4% by Danish seine. Set netting is used most commonly in Manukau Harbour, Kaipara Harbour, and Firth of Thames, trawling occurs on the open coast and the Firth of Thames, and Danish seine is used almost exclusively in Hauraki Gulf and Bay of Plenty.

Between 203 t and 336 t of flatfish was estimated to be taken by recreational fishers in FLA 1 in 1999–2000 (R. Boyd & J. Reilly, KPMG, unpubl. results), which equates to about 33% of the catch in FLA 1 for that year. No quantitative data are available on Maori customary take, but flatfish are known to be an important and highly valued customary food source (Paul 2000).

A non-standardised CPUE analysis for the flatfish set net fishery in Kaipara Harbour for 1989–90 to 2000–01, showed that catch rates peaked in the 1990s, and then declined (Hartill 2002), indicating possible local depletion within the harbour. There are also concerns from both commercial and recreational groups regarding the sustainability of the flatfish fishery on the west coast, particularly in the Kaipara Harbour. The present study was commissioned by MFish as part of a Ministerial review of TACCs for FLA 1, SPO 1 and GMU 1.

1.1 Objectives

Overall objective

1. To review the TACCs for SPO 1, GMU 1 and FLA 1 using relative abundance indices and catch and effort information.

Specific objectives

1. To update the standardised CPUE indices for FLA 1 using data up to the end of 2003–2004.
2. To review the TACCs for FLA 1, GMU 1 and SPO 1 using available indices of abundance.
3. To recalculate MCY estimates using method 4 ($MCY = c*Yav$) of the 2004 Plenary Report and recent catch and data, and to evaluate these estimates in terms of the assumptions inherent to the method.

This report addresses specific objective 1.

2. METHODS

2.1 Definitions and abbreviations

All data were grouped by fishing year, i.e., 1 October to 30 September. Abbreviations were: MFish, Ministry of Fisheries; CELR, catch effort landing return; QMA, quota management area; FMA, fishery management area; FLA, generic flatfish; SFL, sand flounder; YBF, yellowbelly flounder; TACC, total allowable commercial catch; CPUE, catch per unit of effort; c.v., coefficient of variation; SST, sea surface temperature.

2.2 Data extraction

We extracted all CELR fishing records that targeted flatfish or reported flatfish among the top five species from 1 October 1988 to 30 September 2004 in FLA 1. The fishstock was determined for each record using the landed part of the CELR form. Flatfish includes fish codes BFL, BRI, ESO, FLA, FLO, GFL, LSO, SFL, SOL, TUR, and YBF.

Total estimated catch from FLA 1 for these data was 10 935 t. Records with missing or invalid vessel identification or date were discarded. Analysis was restricted to the set net fishing method (total estimated catch 9837 t), and then records were discarded from vessels for which the total flatfish catch was less than 1 t. The retained estimated catch associated with the groomed data set was 9728 t (88% of the original data). All reported analyses that follow are based on these data or some subset of them.

Each record of the resultant data reports a day or partial day of effort and may represent a single set of one net, or several sets of one or more nets. There are more than 170 000 records. Each record comprises vessel identification, date, statistical area, target species, total kilometre of net set, total hours fished, and total catch of flatfish. Table 1 shows the total annual landings from FLA 1 and the annual estimated catch from the study dataset. Typically estimated set net catch is about 80% of declared catch.

2.2.1 Data cleaning

Exploratory examination of the data showed few systematic errors. There were the usual typographical errors, but these tended to be random and caused few problems when in the predictor data as we binned these data and extreme values were merely assigned to the end bins (see Section 2.4.2). An exception was

for the net length field where instead of reporting metres of net, a fraction appeared to report number of nets. This was an important variable because it formed our CPUE index (kg/km) and it was not binned.

The net length field was edited as follows. We created a routine to work vessel by vessel, first ordering records by date then checking each reported net length by comparison with its neighbours. The 10 previous and 10 subsequent values in each case were examined and highlighted where the reported value was less than 1/7, or greater than 7 times the average value of adjacent records, or where the value was less than 20. In most cases a suitable edit was obvious, but where the recorded value was improbable and there was no obvious correction, we replaced the net length with a value that was consistent with its neighbouring values. A total of 1224 edits represented less than 1% of the data.

2.3   Descriptive analyses

2.3.1   Choice of subareas

We modelled seven separate subareas as follows.

Area	Statistical areas
Lower Waikato	041 and 042
Manukau Harbour	043
Kaipara Harbour	044
Northwest coast	045–047
East Northland	002 and 003
Firth of Thames	007
East southern	005, 006, 008–010

From knowledge of sand flounder and yellowbelly flounder movements in the Hauraki Gulf (Colman 1974), it is unlikely that flatfish mix freely over the whole of FLA 1 (Figure 1). An analysis of the whole area could be misleading about abundance trends if there had been serial exploitation within FLA 1, or even just large changes over time in the relative proportions of catch taken by the different regions. Fortunately, the large number of records meant sufficient data were available to allow trends within these subareas to be modelled separately

Catches from each statistical area in FLA 1 are shown in Table 2 and catches for the seven subareas in Table 3. The choice of which statistical areas to combine was based on catches and geographic proximity. The statistical areas 007, 043, and 044 had sufficient data for separate analyses, and the remaining statistical areas were grouped on geographic proximity.

2.3.2   Fleet composition

We first examined the fleet composition on the basis of overall years in FLA 1. Second, for each subarea we examined the partitioning of the data by vessel and fishing year using a vessel-year cross table that details the extent to which vessels maintained a presence over time.

Year and vessel were key variables in the regression. Year because we wished to determine a year effect as an index of abundance; vessel because vessel typically explained most of the variance in the models. The year effect can be usefully informed only by data from vessels that were involved in more than a single year. To take an extreme case, if no vessel fished for more than a single year there is no information to separate year effects from vessel effects and the year effects would be unknowable. A more realistic case would be if the fleet had changed entirely at a given year. This would effectively divide the data into two series. We could determine year effects for each series but never establish their relativity. Even if

there are some vessels in both the before and after series there may be weakness in the year effect. Hence an impression of the persistence of vessels over time is useful in assessing the suitability of the data for our purpose. One way of examining this is to table the number of records by vessel and year. However, for these analyses, because of the large number of vessels, the tables are rather large (and there are seven to consider). Because the useful focus is on the way in which vessels persist or 'link' over years, another approach is to table the number of vessels that link each pair of years. We call this a vessel-year cross table. A link could be said to exist if the vessel has at least one record in each of the pair years, but we think it is more useful to apply some threshold to the link, say at least n records, to represent a meaningful link. We chose a threshold of 10 records. Examination of the vessel-year cross table allows us to detect weak linking between years or abrupt changes in the fleet. Mean linkage values (the average of linkage values from a given year to each other year in the dataset) can identify a year that is poorly linked (at least in a relative sense). Abrupt changes appear as blocks of zeros off the diagonal in the table.

2.3.3 Fleet movement

We examined the movement of vessels between subareas to establish whether there had been a trend in the participation of vessels over multiple subareas. Two statistics were examined. The first examined the proportion of those vessels with at least 50 records in a year that reported effort in more than a single subarea. The second (using the same vessels) examined the rate of subarea switching reported. A switch, as we defined it, occurs each time reported effort moved from one subarea to another. The switch rate is the ratio of number of switches to number of records.

2.3.4 Other descriptive analyses

Additional unstandardised analyses were completed included tabling raw catch and effort information by year for the whole of FLA 1, plotting annual catch by subarea, and plotting the pattern of fishing effort over the annual and lunar cycles for each subarea.

2.4 Standardised CPUE analyses

A log-linear regression model that has kilograms per kilometre of set net as the predicted variable was used to standardise CPUE (see Vignaux 1994). Year effects and a measure of their variation were derived. We used kilograms per kilometre of set net as our index of abundance, but other possible choices were kilograms per record of effort or kilograms per hour reported effort. The choice was based on a discussion with NIWA staff with experience of set net fisheries and standardised CPUE. In brief, it was considered that catches depend on the length of net used, but not necessarily on soak time, as the most effective fishing period was thought to occur over the turning of the tide.

The standardising models were built up step-wise where predictor terms were added one at a time to a base model until R^2 (the fraction of variance explained by the model), expressed as a percentage, failed to increase by more than one unit. The initial base model has only the year term and is the minimum model required from which we can extract a year effect (termed the null model). The year indices of the null model are the geometric means of the CPUE data for each year. As terms were added to the model, the year effect was progressively standardised, the index dropping in some years but raising in others.

2.4.1 Positive catches only

Apart from a four year period (1995–96 to 1998–99), there were very few reports of nil catches (see Table 4). It is not known why these four years are anomalous. A log-linear regression model cannot use zero catches, and either zero catches are ignored or a special treatment must be used for them (commonly a

small nominal catch is assumed). Because there is little overall trend in the fraction of zero catches, and doubt over the veracity of the zero catch information in the 4 year period, we excluded all zero catch records from the standardised analyses.

2.4.2 Predictor variables

Five categorical predictors were used (Table 5): vessel had a category for each vessel having at least 50 records in the regression; vessels with less than 50 records were lumped into an aggregate category; target species had categories for FLA, and YBF, and all other target species were lumped into an aggregate category; subarea had a category for each subarea (Figure 1). Two other predictors were initially continuous, (i.e., day and moon phase) but were converted to categorical by splitting the data into 10 evenly filled bins (the breakpoints between bins were chosen so that the bins had a similar number of records). Ten bins were chosen as sufficient to model any dependencies in the data without prejudice to the shape of any dependency, while ensuring that the resultant models were not over-parameterised.

We examined records where flatfish catches were reported by species. Only yellowbelly and sand flounder were ever reported in nontrivial amounts. We identified subareas where important amounts of both SFL and YBF were reported and conducted standardised CPUE analyses by species for those where sufficient data were available.

2.4.3 Extracting year and other effects

Year effects were extracted from the model using the method described by Coburn et al. (2003). The same method was used to extract the non-year effects. For example, the effect for target species X is the mean predicted value of the regression when the input data is altered, such that the target predictor takes the value X in every row. The exponential of this mean was taken to convert back to the original scale of the CPUE data and it is these values that are reported.

An estimate of confidence intervals for the year effects was calculated using a jackknife method based on the estimated year effects from each of n models, where there are n vessel categories in the regression. Each of the n models was fitted to those data from all vessels except one in turn (see Doonan et al. (1995) for more mathematical detail).

2.4.4 Model assumptions and diagnostics

Residuals were examined for both normality and homoskedasticity. Normality was examined with a quantile-quantile plot (i.e., quantiles of the residuals are plotted against quantiles of a normal distribution, and if the residuals are normally distributed the points will lie along a straight line through the origin with a slope of one). Homoskedasticity (the assumption that all partitions of the data have residuals that are drawn from a common distribution) was examined using a simple two-sided randomisation test. The vessel category was used to provide partitions of the data and the standard deviation was used as the test statistic. The standard deviation of the residuals from each vessel category was compared to standard deviations from 1000 random samples (of size n, where there were n records by this vessel in the regression) taken from the set of all model residuals. The test is significant at the 1% level if $N <= 5$ or $N >= 995$ where N is the number of cases where the data standard deviation exceeds the sample standard deviation. We report the fraction of vessels for which the test is significant at the 1% level.

2.5 Sea surface temperature

Sea surface temperature (SST) from Leigh, lagged by two years, was plotted against standardised CPUE for sand flounder and yellowbelly for Firth of Thames. The two year lag was used because typically these species recruit at about age two (Colman 1994).

3. RESULTS

3.1 Descriptive analyses

3.1.1 Fleet composition and movement

Vessels' involvement in the fishery varied widely (Figure 3) from a single year (29 vessels) to all possible years (21 vessels). The most common period of involvement was 2 years, and over half of all vessels were involved for at least 4 years.

Examined by subareas (Appendix 1), there was a robust partition of the data over fishing years and vessel. In no case did any individual years emerge as being particularly poorly linked, and in no case is there series splitting. Mean linkage values range from 5.1 to 8.1 in lower Waikato; 10.6 to 17.2 in Manukau; 14.8 to 24.4 in Kaipara; 3.2 to 6.1 in north west; 5.6 to 9.7 in east Northland; 19.2 to 34.4 in Firth of Thames, and 2.1 to 5.6 in east southern.

There was no trend in the fraction of vessels fishing in more than a single subarea over the period of the study (Figure 4); similarly, there was no trend in the rate of subarea switching (Figure 5).

3.1.2 Unstandardised catch and effort data

Catch and effort data for all of FLA 1 are generally stable (see Table 4). Apart from 1988–89, which appears to be only partially reported, catches ranged from 474 (1995–96) to 860 t (1992–93), and effort ranged from 7500 (1989–90) to 13 900 records (2000–01). Median net length and median hours showed no trend, but median catch per record declined. In each of the first five full years (1989–90 to 1993–94) median catch per record exceeded 40 kg but in the last five years it did not. Note that the anomalous zero fraction catch years are excluded in this comparison.

Annual catches by subarea (Figure 6) were fairly stable, except in the Firth of Thames where high catches occurred in the early 1990s. Subareas with the largest catches were Firth of Thames, Kaipara Harbour, and Manukau Harbour.

The typical seasonal pattern of effort was for least effort to occur in winter, with a peak in summer (except a brief dip over the New Year) (Figure 7). However, there were subareas differences. Firth of Thames was strongly seasonal but some subareas had little or no seasonal change, e.g., lower Waikato, east southern.

In the west coast subareas, effort was least on spring tides (full and new moons) and maximum on neap tides (first quarter and last quarter moons) (Figure 8). The effect was minimal or non-existent in the east coast subareas.

3.2 Standardised CPUE

Important predictor variables were vessel, target species, and day. These were consistent over the subareas (Tables 6–12). Total R^2 (explained variance) for the selected models ranged from 37.1% for east

Northland, to 64.7% for north west. Probably more importantly for this type of analysis is the R^2 that can be attributed to non-year predictors. This is the difference between R^2 of the final model and R^2 of the null model. This has the following values: Lower Waikato, 59.5; Manukau, 38.2; Kaipara, 34.7; north west, 59.4; east Northland, 35.1; Firth of Thames, 52.3; and east southern, 41.2.

Standardised FLA CPUE trends downward in the west coast subareas, Manukau, Kaipara, and to a lesser extent in the lower Waikato. On the east coast, CPUE declined in Firth of Thames and east southern subareas (Figure 9), but showed no trend in the other subareas. The values are given in Appendix 2.

3.2.1 Vessel effects

Vessel effects from the three major subareas (Firth of Thames, Kaipara, and Manukau) were examined and found to be log normally distributed (Figure 10), i.e., there are as many vessels that have double the typical fishing effectiveness as there are that have half.

For vessels that fished in more than one subarea, we found fishing effectiveness was correlated, i.e., vessels that were effective in one area tended to be effective in others (Figure 11).

3.2.2 Model assumptions

Regression residuals for the above models deviate somewhat from normality (Figure 12).

The randomisation test of the null hypothesis, 'that residuals from vessel partitions of the data was from the same distribution as the overall regression', was rejected at the 1% level for about half the vessels in each analyses (Table 13). These analyses are therefore heteroskedastic with respect to vessel.

3.3 Species analyses

Sand flounder estimated catches were negligible in the west coast subareas (Table 14) and only significant in the Firth of Thames and east southern subareas (Tables 14 and 15). Because east southern is a small fishery (the catch of any one species never exceeded 20 t annually), standardised CPUE by species was conducted only for the Firth of Thames. For the Firth of Thames, typically more than half of estimated flatfish catches were reported by species (Figure 13). For the standardised analysis we used 1990–91 as the first year because that was the first year in which a non-trivial catch was reported by species.

Important predictors were vessel, target, and day (Tables 16 and 17). For YBF, day was more important than target. The Models explained 36.2% (SFL) and 39.9% (YBF) of the variance, respectively.

SFL CPUE increased in the early 1990s to peak in 1993–94 and fell subsequently. CPUE for YBF declined in the early 1990s, but has been stable since the mid 1990s (Figure 14; see also Appendix 3 for actual values).

Non-year effects for these models are shown in Figures 15 and 16. Of note are the counter-cyclic day effects; sand flounder catch rates peak in winter, yellowbelly catch rates in summer.

3.3.1 Sea surface temperature and catch rates

Sea surface temperature, lagged by two years, plotted against sand flounder CPUE in the Firth of Thames indicates that a relationship may exist (Figure 17). Catch rates are generally higher following cooler water temperatures two years before fish are caught. There seems to be no such relationship for yellowbelly flounder.

4. DISCUSSION

This report presents the first standardised CPUE analyses for flatfish using estimated catch data from the FLA 1 set net fishery for 1989–90 to 2003–04.

4.1 Descriptive analyses

The patterns of effort, fleet composition, and catches were generally stable for the flatfish fisheries in FLA 1. Most catch was taken from the three main harbours of Manukau, Kaipara, and the Firth of Thames. Sand flounder catches were small, relative to yellowbelly on the west coast, but were significant in the Firth of Thames and east southern subareas. Sand flounder estimated catch (as reported) from Firth of Thames has declined since 1992–93, although this trend may be confounded by the use of the reporting code FLA.

4.2 Standardised CPUE

The decision to split the analyses into seven subareas and the choice of kilogram per kilometre of set net as the index of abundance was important in shaping this analysis. Standardised CPUE for all flatfish species combined (mostly yellowbelly and sand flounder) declined in three west coast areas (Manukau, Kaipara, lower Waikato), on the east coast in Firth of Thames, and in the east southern subarea (Figure 9). FLA 1 CPUE in the west coast areas reflects abundance of yellowbelly flounder as the proportion of sand flounder in the west coast catch is very small (see Tables 14 and 15). When the Firth of Thames was devolved by species, most of the decline was attributable to sand flounder, as the yellowbelly CPUE has remained stable since the mid 1990s (Figure 14). This trend is consistent with the concerns of commercial and recreational fishers who maintain that sand flounder was historically more abundant in west coast harbours, but has progressively declined relative to yellowbelly flounder. This emphasises the need to carry out CPUE analyses for individual flatfish species, where data are adequate, to determine which species are at most risk of overfishing. It also reinforces the need to report all flatfish estimated catch by individual species code rather than by the generic FLA code.

The trend in standardised CPUE in the Kaipara was similar to that for the unstandardised CPUE analysis for the years 1989–90 to 2000–01(Hartill 2002), with both analyses indicating declining abundance.

Although standardised CPUE shows a decline in the key fisheries, this is not reflected in the overall catch of FLA 1, which although fluctuating, shows no indication of decreasing over time (see Figure 2). Similarly, effort shows no compelling increase (see Table 4). These trends together show the importance of conducting standardised CPUE analyses before drawing inference about abundance trends.

Important predictors of CPUE were vessel, target species, and day of year in all subareas. For the Firth of Thames, yellowbelly flounder catch rates peaked during the warmest months (as they do in the

other areas) when effort was greatest, and sand flounder catch rates peaked in winter (Figures 15 and 16).

4.2.1 Does standardised CPUE index abundance?

There are no other abundance indices for FLA 1 to validate whether the indices determined from this study track abundance (Dunn et al. 2000). However, there are many aspects that make these analyses favourable candidates for successful CPUE. There is a generally stable pattern of fishing effort and catches over time; in particular, the fishing vessels change gradually over time. We were able to conduct the study at a spatial resolution (the subareas) that is probably consistent with the adult movements of flatfish. Tagging studies of yellowbelly flounder and sand flounder in the Hauraki Gulf and Canterbury Bight have shown that movements are localised and restricted to offshore migration to spawn in winter and spring, followed by inshore migration to feed in summer (Colman 1974). All recovered tagged yellowbelly and all but one sand flounder had not moved outside their tagging location in the Firth of Thames (Colman 1974). At least for the main harbours, the long history of fishing and the enclosed nature of these areas make it very likely that they have been fully explored.

Flatfish are not thought to be a schooling fish, and set netting is a relatively passive method, so some major reservations of using CPUE as an index of abundance are avoided. Finally, the decline in CPUE is also consistent with perceptions of user groups that flatfish abundance has declined.

4.3 Other factors

Fishers target flatfish and indeed a flatfish-specific net is used. Reported mean and median mesh sizes from most of the subareas have increased by about 5 mm over the period studied. This includes each of the major harbour fisheries of Manukau, Kaipara, and Thames (Appendix 4). Other things being equal, these increases might be expected to decrease catch rates. However, anecdotal reports suggest that changes in net type (mono, multimono, rag) are also occurring and that the effects of this change on catch rates may be equal to or greater than any effect of mesh size changes (see Appendix 4). No information on net type is formally collected, so this is unavailable to the regression analyses. Mesh size was not used as an explanatory variable in the regressions because it was thought that it is sporadically reported. Only yearly medians and trimmed means were thought to be useful.

We are not aware of any other major external changes that are likely to change the view generated from these data. It seems likely that overall external changes would act to improve catch rates relative to abundance over time rather than the opposite.

Sand flounder abundance appears to be related to SST at the time of spawning (Figure 17). Catch rates are generally higher following cooler water temperatures two years before fish are caught, suggesting that SST may be affecting spawning success and/or survival of eggs and larvae for sand flounder. A similar relationship between abundance and SST has been described for red cod (Beentjes & Renwick 2001), a species which is also fast growing with high mortality, and supports a fishery which is strongly recruitment driven. No such relationship is apparent for yellowbelly flounder abundance and SST. It is possible that the decline in sand flounder abundance is partially a result of a sustained period of unfavourable environmental conditions for spawning and/or survival.

4.4 Conclusion

The main harbour fisheries of Kaipara and Manukau on the west coast and the Firth of Thames on the east coast emerge as areas of steadily declining CPUE which is unlikely to be related to factors other than abundance. The declines in overall flatfish abundance appear to be mainly of sand flounder in the

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Firth of Thames, whereas in west coast harbours where sand flounder is less common, the decline may be more related to yellowbelly flounder abundance.

5. ACKNOWLEDGMENTS

6. REFERENCES

Annala, J.H.; Sullivan, K.J.; Smith, N.W.McL.; Griffiths, M.H.; Todd, P.R.; Mace, P.M.; Connell, A.M. (comps.) (2004). Report from the Fishery Assessment Plenary, April 2004: stock assessments and yield estimates. 690 p. (Unpublished report held in NIWA library, Wellington.)

Beentjes, M. P. (2003). Review of flatfish catch data and species composition. *New Zealand Fisheries Assessment Report 17*. 22 p.

Beentjes, M. P.; Renwick, J. A. (2001). The relationship between red cod, *Pseudophycis bachus*, recruitment and environmental variables in New Zealand. *Environmental Biology of Fishes 61*: 315–328.

Coburn, R.P.; Doonan, I.J.; McMillan, P.J. (2003). Stock assessment of smooth oreo in the Southland fishery (OEO 1 and 3A) for 2003. *New Zealand Fisheries Assessment Report 2003/62*. 32 p.

Colman, J. A. (1974). Movements of flounders in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research 8:* 79–93.

Colman, J. A. (1994). New Zealand flatfish. *Seafood New Zealand 2:* 34–36.

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C; Cordue, P.L. (1995). Assessment of smooth oreo for 1995. New Zealand Fisheries Assessment Research Document 95/12. 31 p. (Unpublished report held in NIWA library, Wellington.)

Dunn, A.; Harley, S.J.; Doonan, I.J.; Bull, B. (2000). Calculation and interpretation of catch-per-unit-effort (CPUE) indices. *New Zealand Fisheries Assessment Report 2000/1*. 44 p.

Hartill, B. (2002). Characterisation of the commercial FLA, GMU and SPO fisheries in the Kaipara Harbour. Final Research Report for Ministry of Fisheries Research Project MOF2002/03C Objective 1. 23 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Kirk, P.D. (1989). Flatfish fishery assessment 1989. New Zealand Fisheries Assessment Research Document 89/8. 24 p. (Unpublished report held in NIWA library, Wellington.)

Paul, L.J. (2000). New Zealand fishes. Identification, natural history and fisheries. Reed Books, Auckland. 253 p.

Sullivan, K.J.; Mace, P.M.; Smith, N.W.McL.; Griffiths, M.H.; Todd, P.R.; Livingston, M.E.; Harley, S.J.; Key, J.M.; Connell, A.M. (comps) (2005). Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792 p. (Unpublished report held in NIWA library, Wellington.)

Vignaux, M. (1994). Catch per unit effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. New Zealand Fisheries Assessment Research Document 94/11. 29 p. (Unpublished report held in NIWA library, Wellington.)

Table 1: FLA 1 landed and estimated catch from set net. Landed catches taken from the 2005 Plenary Report (after Sullivan et al. 2005).

Fishing year	Landed catch (t)	Est. catch. (t)
1988-89	787	32
1989-90	791	534
1990-91	849	745
1991-92	940	795
1992-93	1106	860
1993-94	1136	844
1994-95	964	784
1995-96	628	474
1996-97	741	509
1997-98	728	490
1998-99	690	530
1999-00	751	632
2000-01	792	699
2001-02	596	511
2002-03	686	581
2003-04	784	649

Table 2: Estimated setnet FLA 1 catch (t) for each stat area by fishing year. Data includes only those edited records used in the standardised analyses.

Fishing year	1	2	3	4	5	6	7	8	9	10	37	39	40	41	42	43	44	45	46	47	48
1988-89	0	1	1	0	0	0	7	0	1	0	0	0	0	1	2	4	11	2	1	0	0
1989-90	12	5	19	0	1	2	186	0	18	4	0	0	0	4	8	65	188	14	7	0	0
1990-91	29	2	23	0	1	3	350	1	25	12	0	0	0	7	6	82	177	14	11	0	0
1991-92	11	7	28	1	1	11	383	1	15	11	0	0	0	9	5	87	187	17	18	1	0
1992-93	7	12	34	1	2	10	402	0	20	21	0	0	0	11	7	117	181	19	10	4	0
1993-94	8	11	30	1	0	18	418	0	15	17	0	0	0	7	6	128	151	14	14	6	0
1994-95	1	13	29	1	1	5	312	1	14	18	0	0	0	10	8	116	199	33	14	8	0
1995-96	3	10	26	2	0	4	114	9	12	16	0	0	0	10	8	72	149	23	8	8	0
1996-97	1	10	25	6	0	3	129	2	13	21	0	0	0	16	12	79	161	16	6	8	0
1997-98	2	6	17	6	0	0	121	4	12	16	0	0	0	16	8	101	154	11	7	8	0
1998-99	0	9	20	6	0	0	143	0	14	20	0	0	0	16	11	93	156	21	19	1	0
1999-00	6	10	26	4	0	0	158	0	11	8	0	0	0	15	11	113	248	3	14	5	0
2000-01	0	7	30	3	0	0	191	1	6	2	0	0	0	15	14	117	280	4	24	6	0
2001-02	3	13	36	1	0	0	107	0	8	1	0	0	0	14	10	84	207	2	22	3	0
2002-03	4	19	32	0	0	0	222	0	11	6	0	0	0	15	9	59	187	0	15	1	0
2003-04	4	26	34	1	0	0	232	1	10	4	0	0	0	13	13	72	210	0	29	1	0

Table 3: Estimated set net FLA 1 catches grouped by the subareas chosen for the standardised analyses. Includes only those edited records used in the standardised analyses.

Fishing year	Lower Waikato	Manukau	Kaipara	North west	East Northland	Firth of Thames	East southern	Others
1988-89	3	4	11	2	2	7	2	0
1989-90	12	65	188	21	24	186	25	12
1990-91	13	82	177	26	25	350	41	30
1991-92	14	87	187	37	36	383	39	12
1992-93	17	117	181	34	46	402	53	9
1993-94	14	128	151	33	41	418	50	9
1994-95	18	116	199	56	42	312	38	3
1995-96	18	72	149	38	36	114	41	6
1996-97	28	79	161	31	36	129	40	7
1997-98	25	101	154	25	23	121	32	9
1998-99	28	93	156	41	28	143	34	7
1999-00	26	113	248	22	36	158	19	10
2000-01	29	117	280	34	37	191	9	3
2001-02	24	84	207	27	49	107	9	4
2002-03	24	59	187	16	51	222	18	4
2003-04	25	72	210	30	59	232	15	4

Table 4: Estimated set net FLA 1 catch and effort from edited records used in the standardised analyses. Includes stat areas: 1–10, 37, 39, and 40–48.

Fishing year	Number	Catch (t)	Median net length (m)	Median hrs	Median catch per record (kg)	% zero
1988-89	816	32	700	7.2	30	0.2
1989-90	7 524	534	700	6.0	47	0.5
1990-91	11 123	745	800	6.0	43	0.5
1991-92	11 584	795	800	6.0	42	0.4
1992-93	12 269	860	800	6.0	45	0.7
1993-94	11 849	844	800	6.0	42	0.4
1994-95	11 116	784	800	6.0	50	0.5
1995-96	9 453	474	800	6.0	31	11.0
1996-97	10 443	509	800	6.0	30	17.3
1997-98	11 002	490	800	6.0	30	17.7
1998-99	11 566	530	800	6.0	30	10.6
1999-00	12 957	632	800	6.0	35	2.7
2000-01	13 874	699	800	6.0	40	1.0
2001-02	11 472	511	800	6.0	30	0.7
2002-03	12 407	581	800	7.2	35	0.9
2003-04	12 516	649	800	6.0	40	0.6

Table 5: Summary of non-year variables that could be selected in the regression models. All were categorical variables. df is the number of parameters to be estimated for that variable; –, not available: it depends on the dataset.

Variable	Df	Description
Vessel	–	A parameter estimated for each vessel with at least 50 tows. Vessels with fewer than 50 tows were grouped together.
Target	3	Target species, FLA, YBF, or other.
Day of year	9	The fishing year divided into 10 periods.
Stat area	–	As many stat areas as in the subarea. This variable drops out of model for a single stat area
Moon phase	9	The moon phase divided into 10 periods

Table 6: R^2 values (%) during the stepwise selection of variables for the lower Waikato regression. New variables were added one at a time until R^2 (%) failed to increase by at least 1 unit. At each step the variable that increased R^2 the most was added to the model. Variables considered for the regression are given in Table 5. The final step shown has an improvement value of not more than 1 and it is the step after that which is the selected model. In this case the final model includes vessel and target and has an R^2 of 61.6. Improvement at each step is the difference between R^2 at this step and R^2 at the previous step or the null model R^2 for step 1.

	Step 1	Step 2	Step 3
Vessel	59.7	-	-
Target	34.1	61.6	-
Stat area	16.9	60.3	62.0
Day of year	2.5	59.9	61.8
Moon phase	2.2	59.8	61.6
Improvement	57.7	1.9	0.4

Table 7: R^2 values (%) during the stepwise selection of variables for the Manukau regression. See Table 6 for details.

	Step 1	Step 2	Step 3	Step 4
Vessel	34.0	-	-	-
Target	18.0	42.9	-	-
Day of year	9.5	36.0	44.0	-
Moon phase	6.0	34.2	43.0	44.0
Improvement	28.2	8.9	1.1	0.1

Table 8: R^2 values (%) during the stepwise selection of variables for the Kaipara regression. See Table 6 for details.

	Step 1	Step 2	Step 3
Vessel	25.0	-	-
Target	17.9	38.4	-
Day of year	5.7	26.6	39.2
Moon phase	4.0	25.1	38.5
Improvement	21.3	13.4	0.8

Table 9: R^2 values (%) during the stepwise selection of variables for the north west regression. See Table 6 for details.

	Step 1	Step 2	Step 3
Vessel	59.4	-	-
Target	51.0	64.7	-
Day of year	7.3	59.7	64.8
Moon phase	5.9	59.5	64.8
Stat area	33.7	59.5	64.7
Improvement	54.1	5.3	0.1

Table 10: R^2 values (%) during the stepwise selection of variables for the east Northland regression. See Table 6 for details.

	Step 1	Step 2	Step 3
Vessel	23.4	-	-
Target	20.4	37.1	-
Day of year	3.2	24.8	38.0
Moon phase	2.4	23.8	37.3
Stat area	4.4	23.5	37.1
Improvement	21.5	13.6	0.9

Table 11: R^2 values (%) during the stepwise selection of variables for the Firth of Thames regression. See Table 6 for details.

	Step 1	Step 2	Step 3	Step 4
Vessel	41.3	-	-	-
Target	37.5	52.5	-	-
Day of year	9.6	44.2	54.1	-
Moon phase	2.3	41.5	52.6	54.2
Improvement	39.5	11.2	1.6	0.1

Table 12: R^2 values (%) during the stepwise selection of variables for the east southern regression. See Table 6 for details.

	Step 1	Step 2	Step 3	Step 4
Vessel	40.0	-	-	-
Target	22.9	45.6	-	-
Day of year	8.4	40.9	46.8	-
Stat area	7.8	40.4	45.9	47.1
Moon phase	5.8	40.1	45.7	46.9
Improvement	34.4	5.6	1.2	0.3

Table 13: Number of vessel categories and the fraction of vessels significant at 1% level for the randomisation test of homoskedasticity.

	Lower Waikato	Manukau	Kaipara	North west	East Northland	Firth of Thames	East southern
No. of vessel categories	22	77	99	31	41	145	34
Fraction of significant vessels	0.50	0.43	0.48	0.52	0.68	0.48	0.47

Table 14: Sand flounder estimated catch (t) by fishing year and subarea.

Fishing year	Lower Waikato	Manukau	Kaipara	North west	East Northland	Firth of Thames	East southern	Other
1989-90	0	0	0	0	0	0	0	0
1990-91	0	0	0	0	0	48	9	5
1991-92	0	0	0	0	0	44	14	0
1992-93	0	0	2	0	0	60	10	0
1993-94	0	0	1	1	2	130	11	1
1994-95	0	0	0	3	2	80	18	0
1995-96	0	0	1	1	2	35	18	0
1996-97	0	0	1	1	8	28	7	1
1997-98	0	0	1	0	0	26	8	1
1998-99	0	0	3	0	1	28	8	0
1999-00	0	0	3	0	4	49	3	1
2000-01	0	0	2	1	6	34	1	0
2001-02	0	0	4	0	5	15	1	0
2002-03	0	0	2	0	4	12	2	0
2003-04	0	0	1	0	2	23	3	1

Table 15: Yellowbelly flounder estimated catch (t) by fishing year and subarea.

Fishing year	Lower Waikato	Manukau	Kaipara	North west	East Northland	Firth of Thames	East southern	Other
1989-90	0	0	0	0	0	0	0	0
1990-91	1	1	26	0	0	107	9	6
1991-92	0	0	27	0	1	119	8	0
1992-93	0	0	25	0	2	132	13	1
1993-94	2	8	54	15	10	115	8	1
1994-95	5	11	75	15	13	107	10	1
1995-96	4	5	41	11	9	38	6	4
1996-97	5	1	37	9	6	61	6	3
1997-98	6	2	42	9	8	57	8	5
1998-99	2	4	65	11	15	68	7	0
1999-00	1	7	118	9	24	67	6	2
2000-01	1	6	132	15	21	99	2	1
2001-02	2	4	90	14	29	52	2	0
2002-03	3	3	93	7	28	93	3	0
2003-04	4	3	106	10	25	97	3	1

Table 16: R^2 values (%) during the stepwise selection of variables for the Firth of Thames (007), sand flounder regression. See Table 6 for details.

	Step 1	Step 2	Step 3	Step 4
Vessel	31.1	-	-	-
Target	23.5	33.8	-	-
Day of year	14.4	33.1	36.2	-
Moon phase	12.0	31.3	34.0	36.4
Improvement	19.4	2.7	2.4	0.1

Table 17: R^2 values (%) during the stepwise selection of variables for the Firth of Thames (007), yellow belly flounder regression. See Table 6 for details.

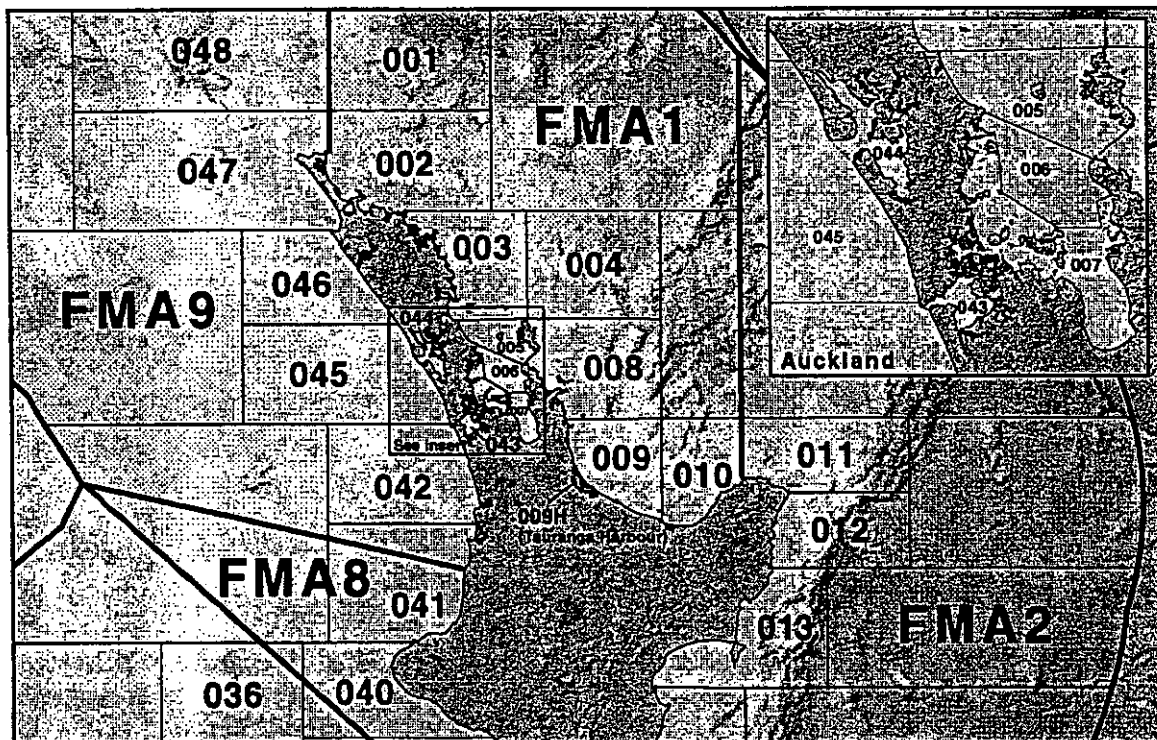|	step1	step2	step3	step4
Vessel	26.7	-	-	-
day of year	13.5	35.4	-	-
Target	10.3	31.6	39.9	-
moon phase	4.2	27.1	35.6	40.1
Improvement	23.0	8.7	4.6	0.2

Figure 1: Statistical reporting areas in the northern North Island flatfish fishery (FLA 1). FLA 1 consists of the fishery management areas (FMAs) 1 and 9. Sub areas analysed were: Lower Waikato (areas 041 & 042); Manukau (area 043); Kaipara (area 044); North west (areas 045, 046 & 047); East Northland (areas 002 & 003); Firth of Thames (area 007); East southern (areas 005, 006, 008, 009 & 010).
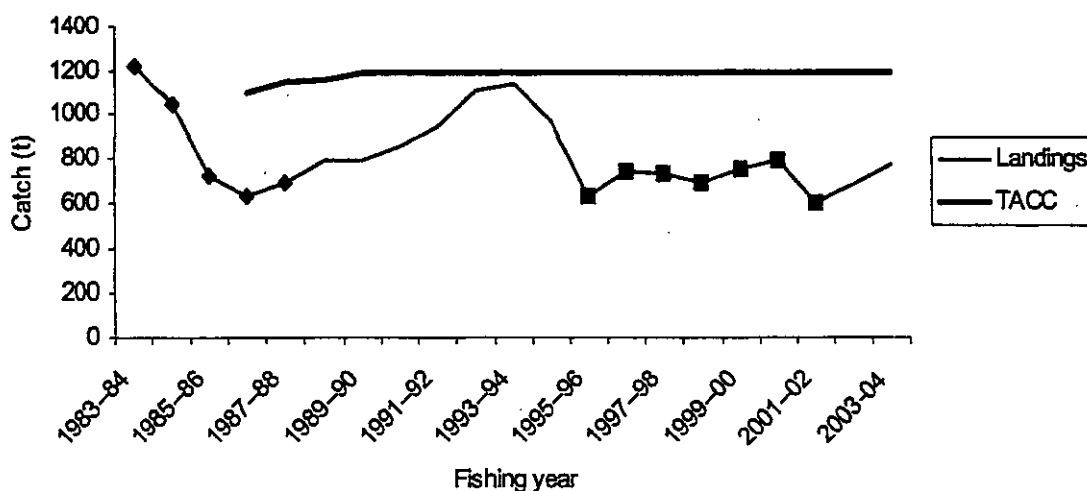

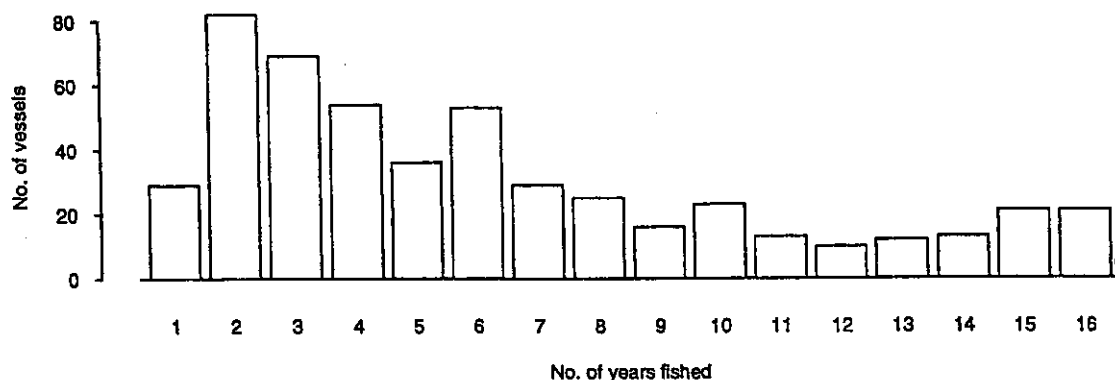Figure 2: Commercial landings from FLA 1 and the TACC.

Figure 3: Counts of vessels that fished in n years. Over all years (includes the partial year) and all areas.
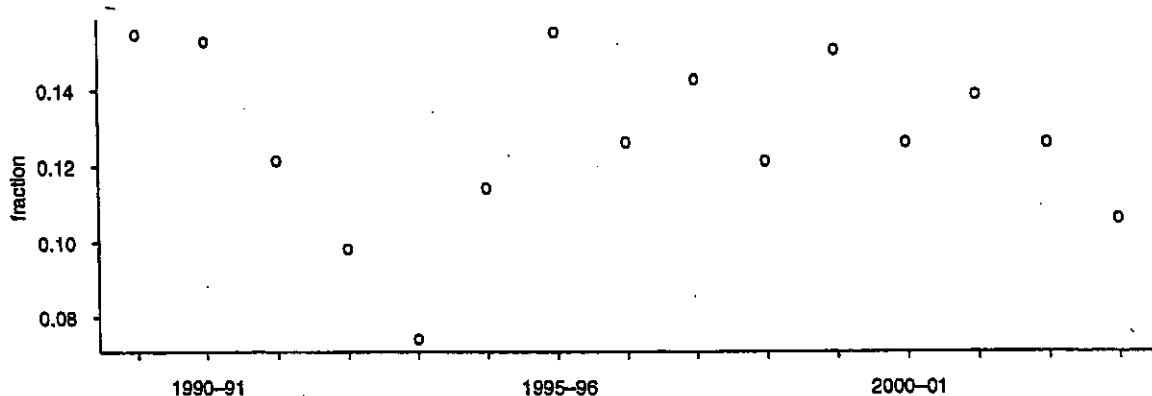

Figure 4: The fraction of vessels in more than one subarea by year.
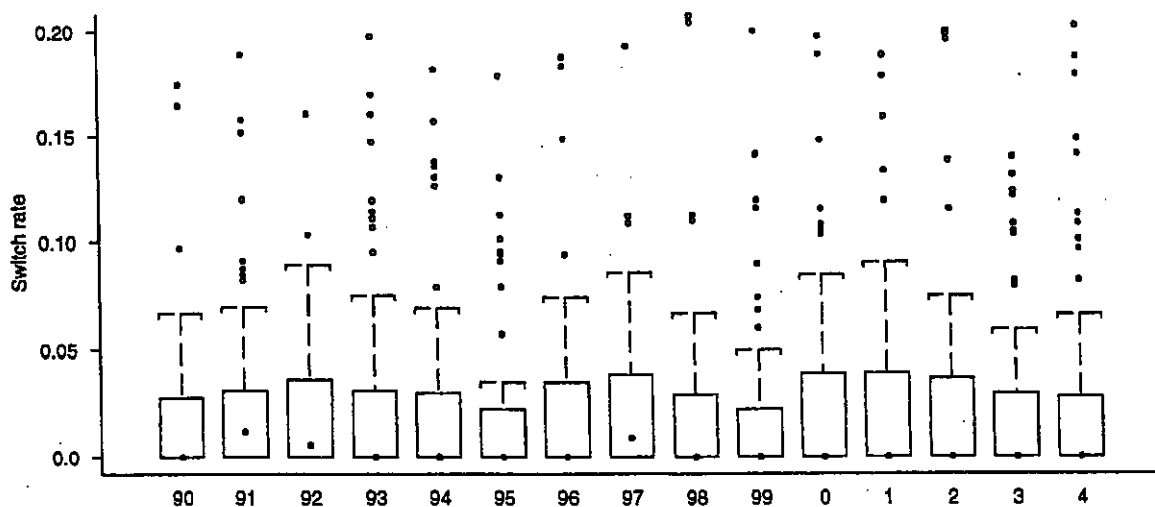
Figure 5: Boxplot depiction of the distributions of subarea switch rates from vessels with at least 50 records in the given year. The distributions are calculated independently by year. Note a few points of value greater than 0.2 are lost off the top of the figure due the choice of y axis maxima. Note, 90 = 1989–90 etc. (Note on boxplot: the bottom of box is the lower quartile; the solid circle is the median; the top of the box is the upper quartile; the dashed line extends to the nearest point that is within 1.5 * the inter quartile range; open circle are individual data points outside dashed line.)

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North west

East Northland

Kaipara

Firth of Thames

Manukau

East southern

Lower Waikato
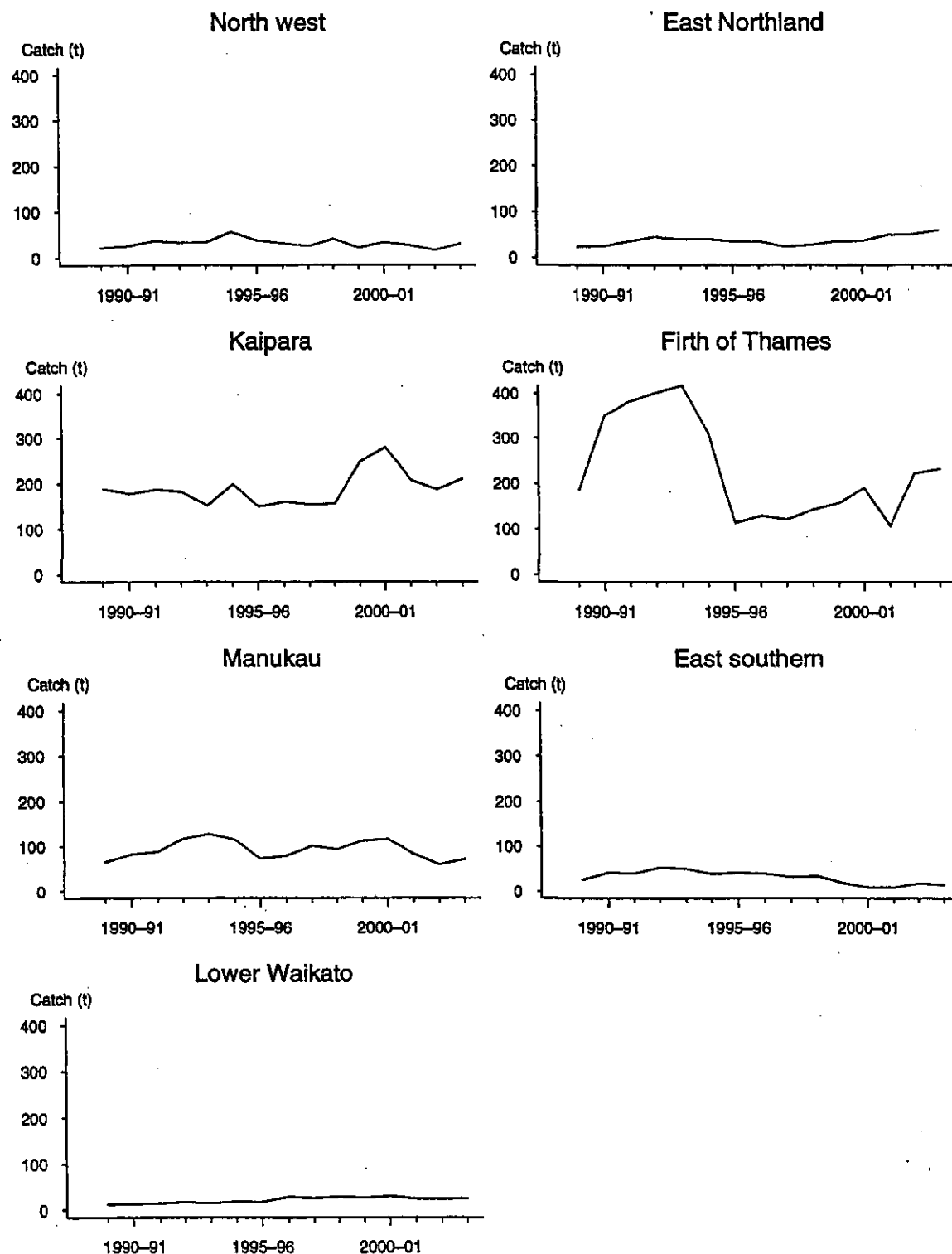
Figure 6: Annual catches (t) of FLA from the subareas.
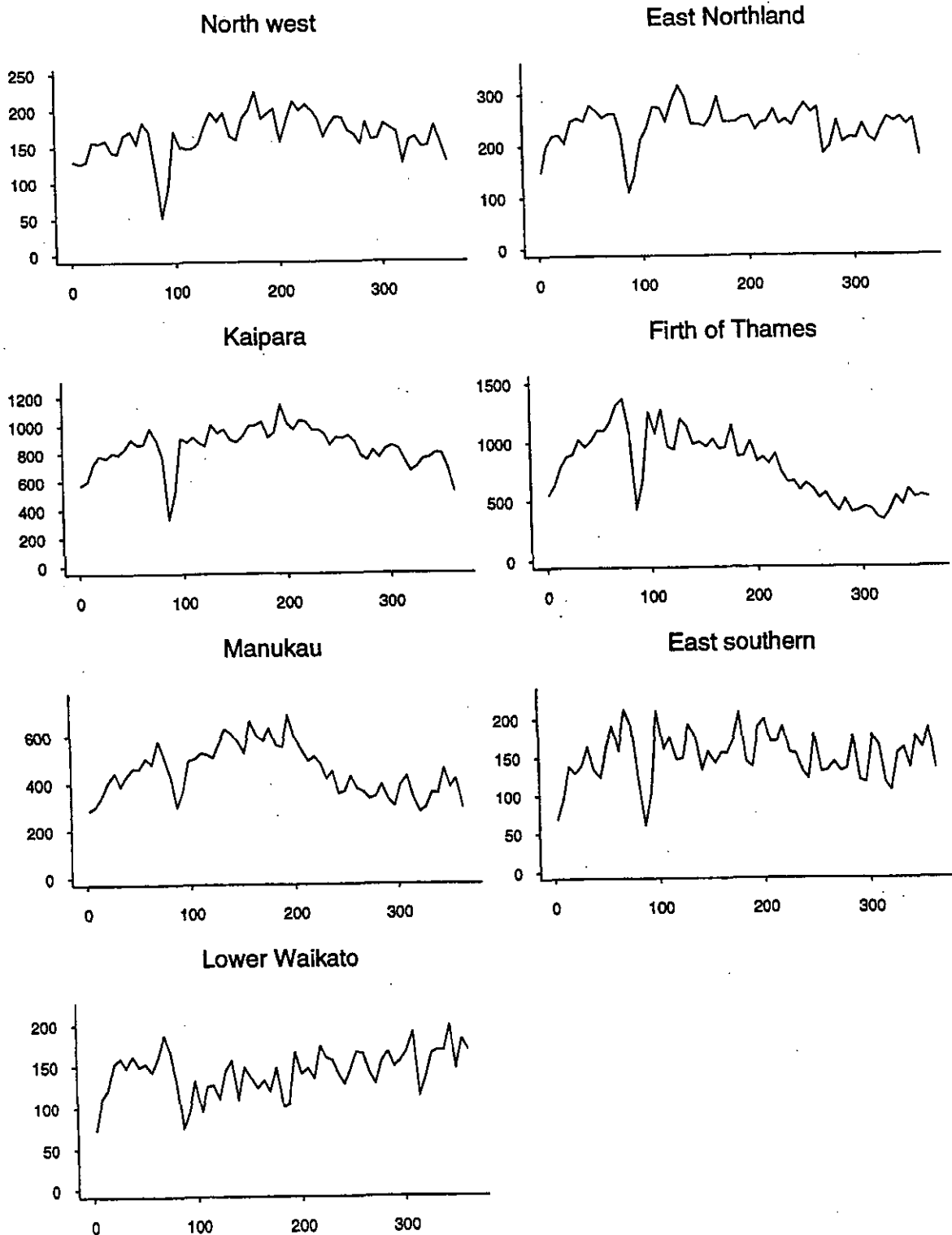
Figure 7: The seasonal pattern of effort from each of the subareas. X-scale is day of fishing year (1 = 1 Oct, ect.). y-scale is number of records (vessel-days) in six day periods into which the year is broken.
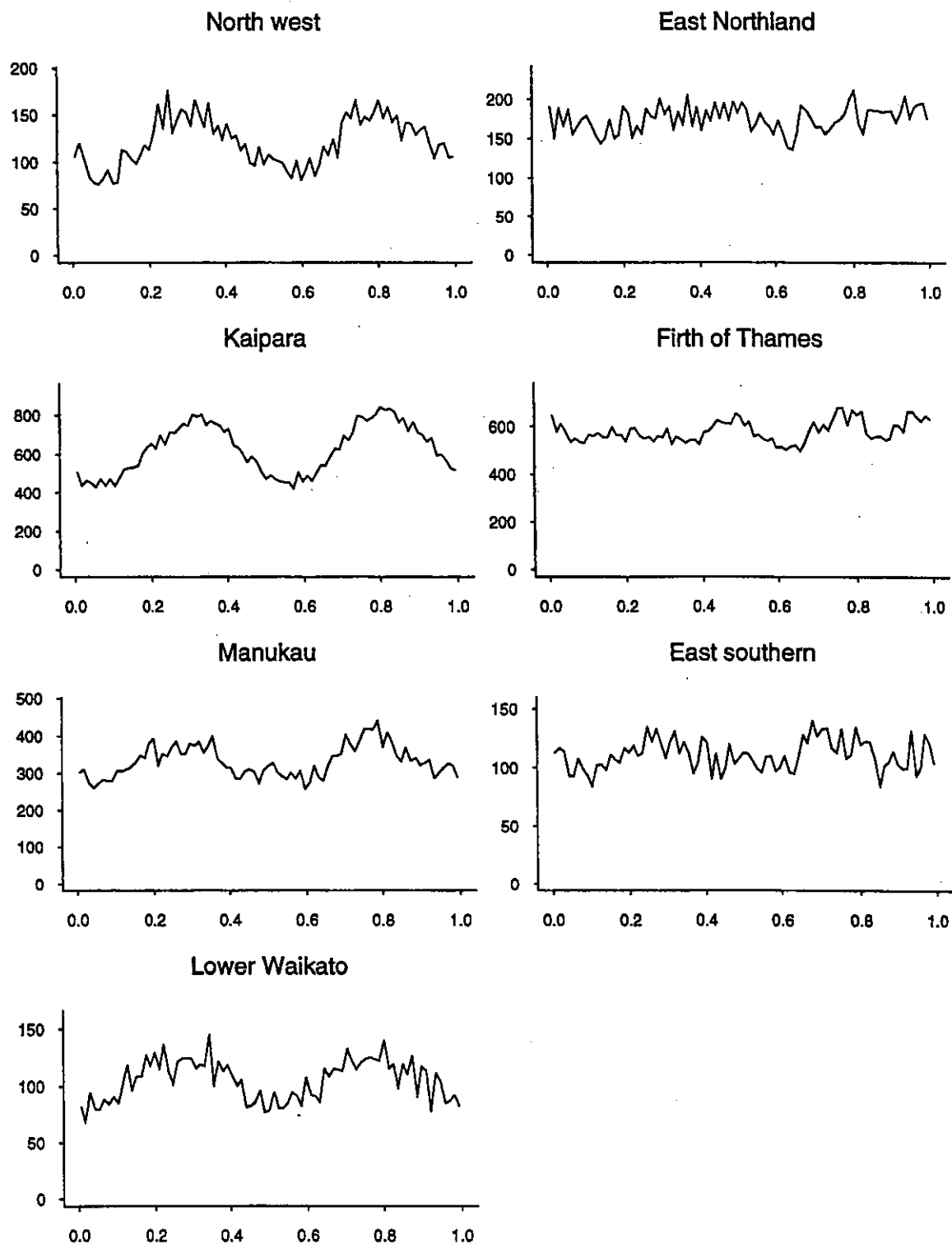
Figure 8: The pattern of effort over the lunar cycle for each subarea. X-scale is moon phase: 0 & 1=new moon; 0.5=full moon; 0.25=1st quarter; 0.75=last quarter. The lunar period has been divided into 84 equal period bins and the y-scale shows counts of records from each bin.

North west

East Northland

Kaipara

Firth of Thames

Manukau

East southern

Lower Waikato
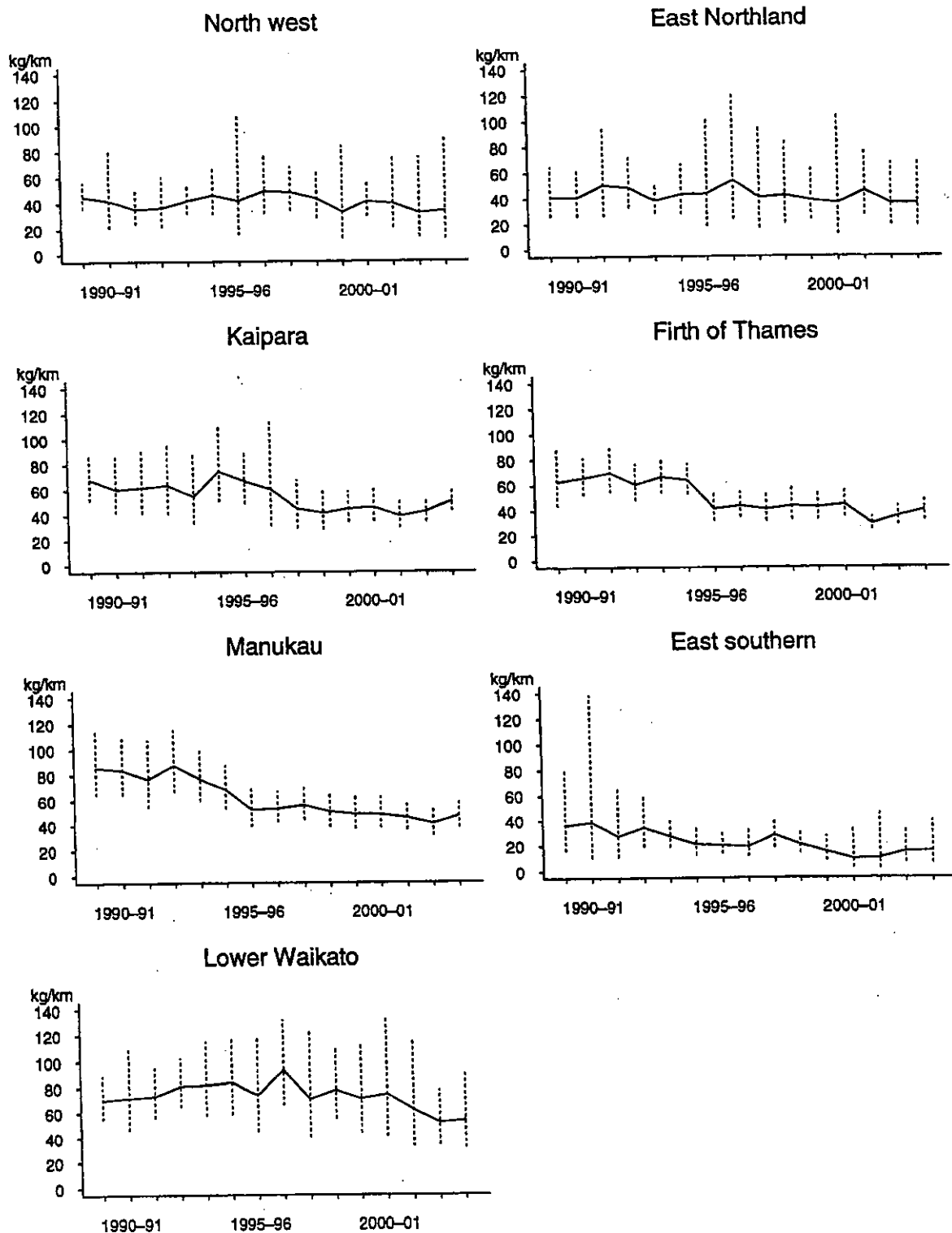
Figure 9: Standardised CPUE index for each subarea (solid line) shown with +/- 2 standard error jackknife confidence intervals (dotted lines).

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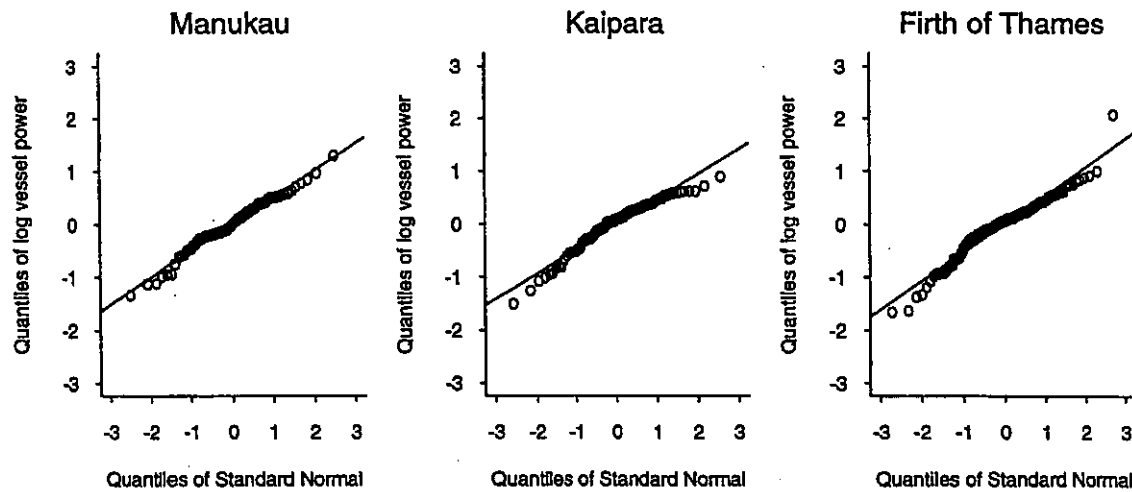
Figure 10: Quantile-quantile normal plots of vessel effects from Manukau, Kaipara, and the Firth of Thames analyses.
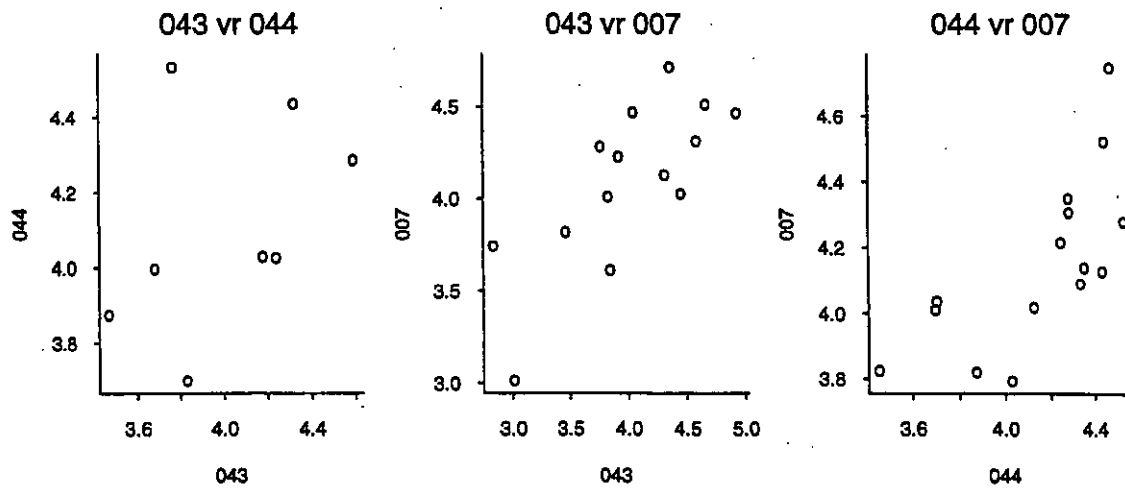
Figure 11: Common vessel effects between the Manukau (043), Kaipara (044), and the Firth of Thames (007) analyses. The x & y scales are log of vessels effect (kg.km^{-1}).
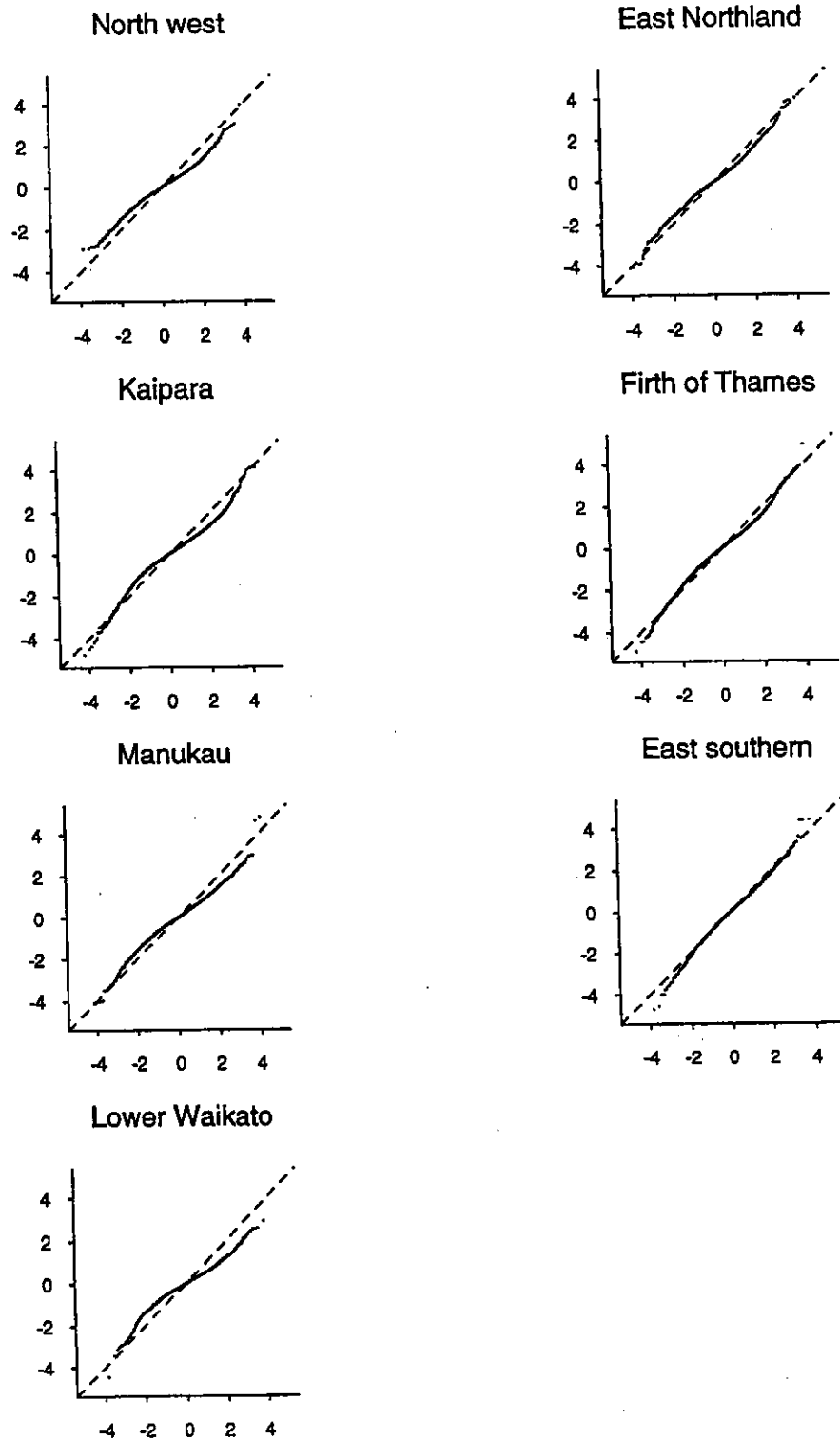
Figure 12: Quantile-quantile normal plots of the residuals of each subarea analysis. The model residuals (y-axis) are mapped against the normal distribution (x-axis). The dashed line is through the origin with a slope of 1.
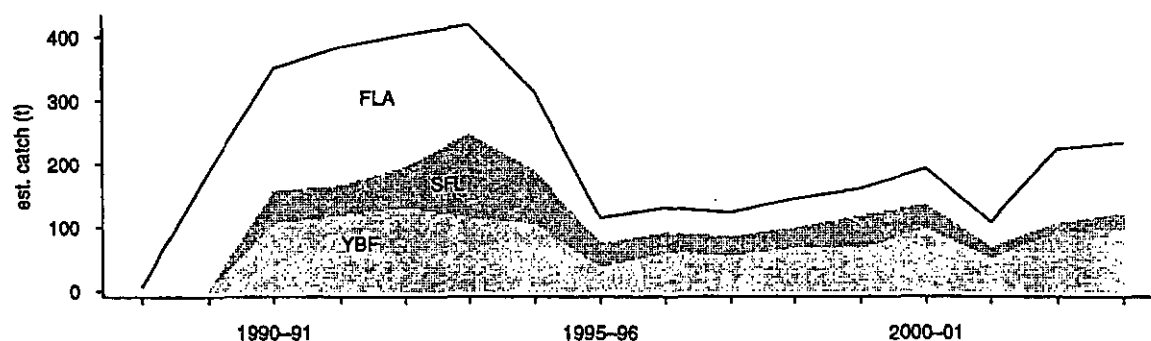
Figure 13: Estimated catches by species from Firth of Thames. Yellowbelly flounder catch is shown in pale gray, sand flounder catch in dark gray, and FLA catch is below the top line (includes SFL, YBF and generic flatfish catch)
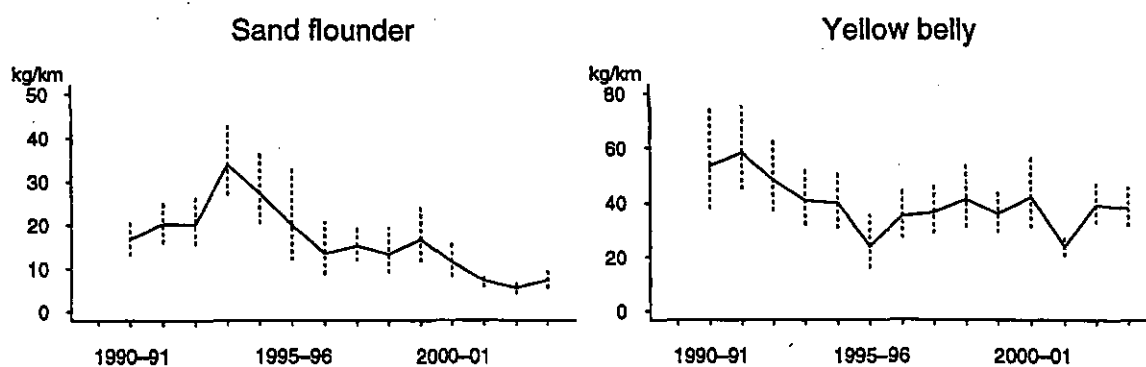
Figure 14: Standardised CPUE index for the Firth of Thames sand flounder and yellowbelly flounder analyses (solid line) shown with +/- 2 standard error jackknife confidence interval (dotted lines).
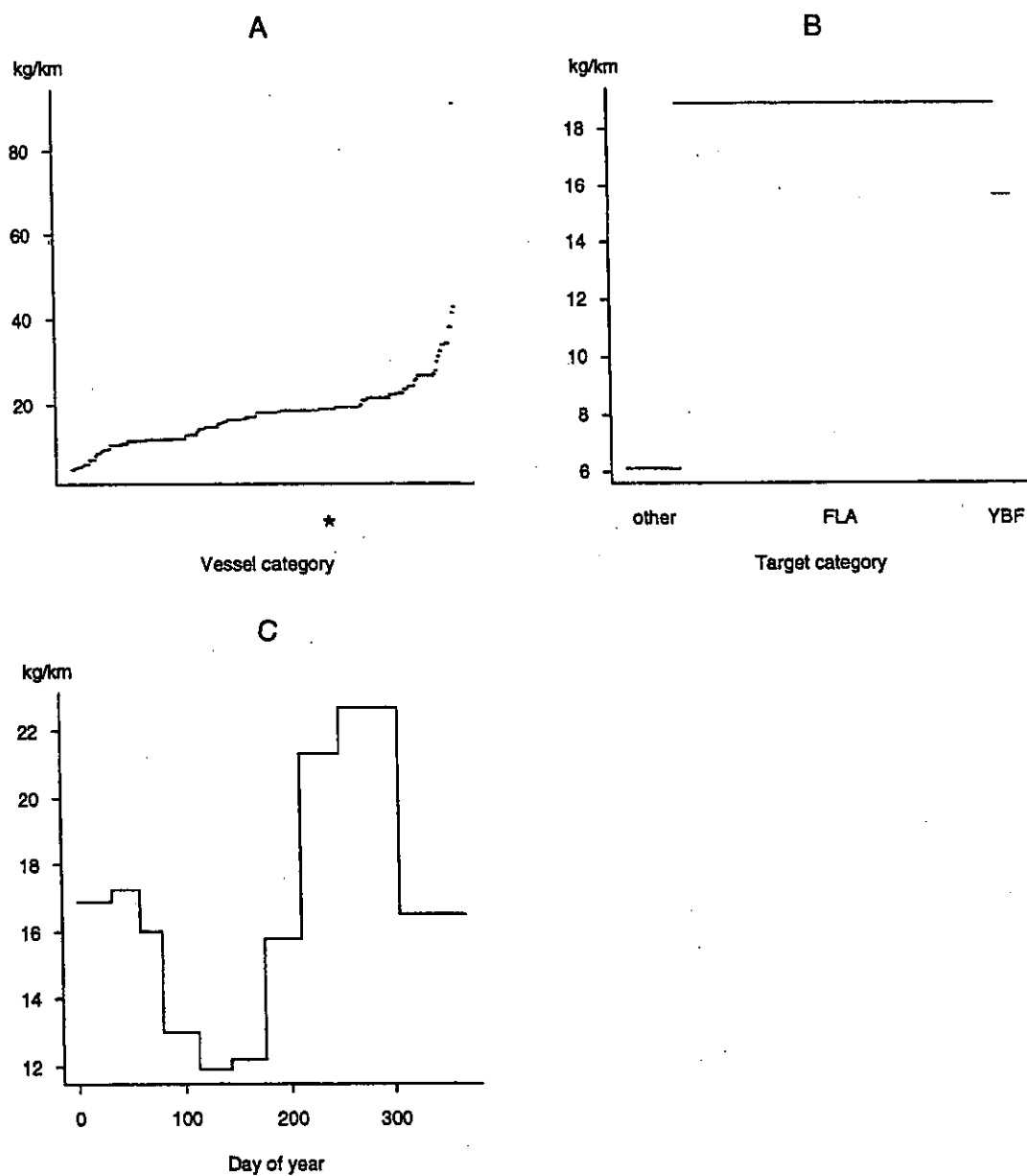
Figure 15: The non-year effects of the sand flounder regression of Firth of Thames. A: The vessel effect. Horizontal lines show the effect value for each vessel category. The width of each step is proportional to the number of records in each category. * marks the aggregate vessel group. B: The target effect. Horizontal lines show the effect value for each target category. The width of each step is proportional to the number of records in each category. C: The day effect (1 = 1 Oct, ect.). Steps show the effect value at each of the ten bins.

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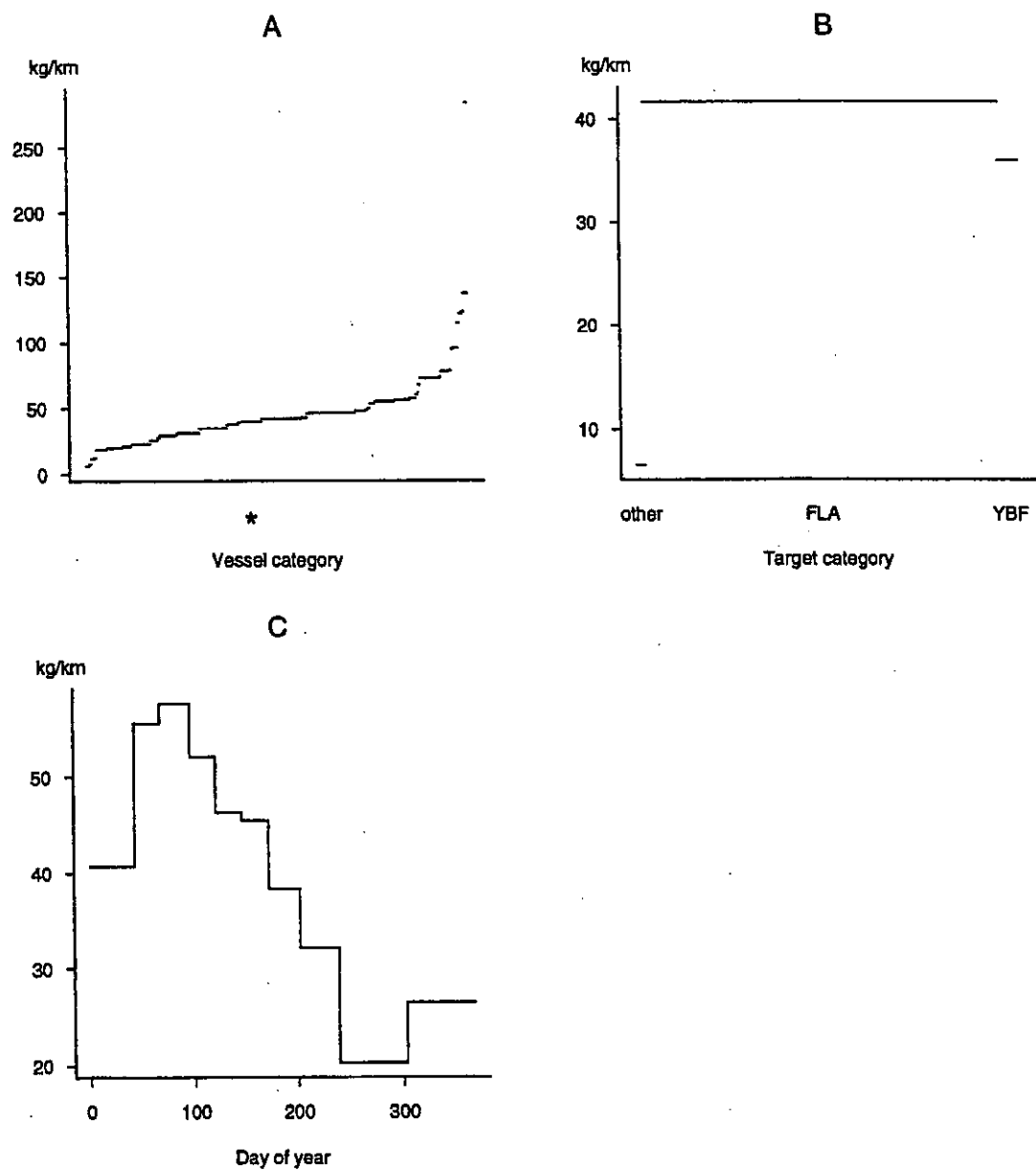
Figure 16: The non-year effects of the yellow belly flounder regression of Firth of Thames. See Figure 15 for details.
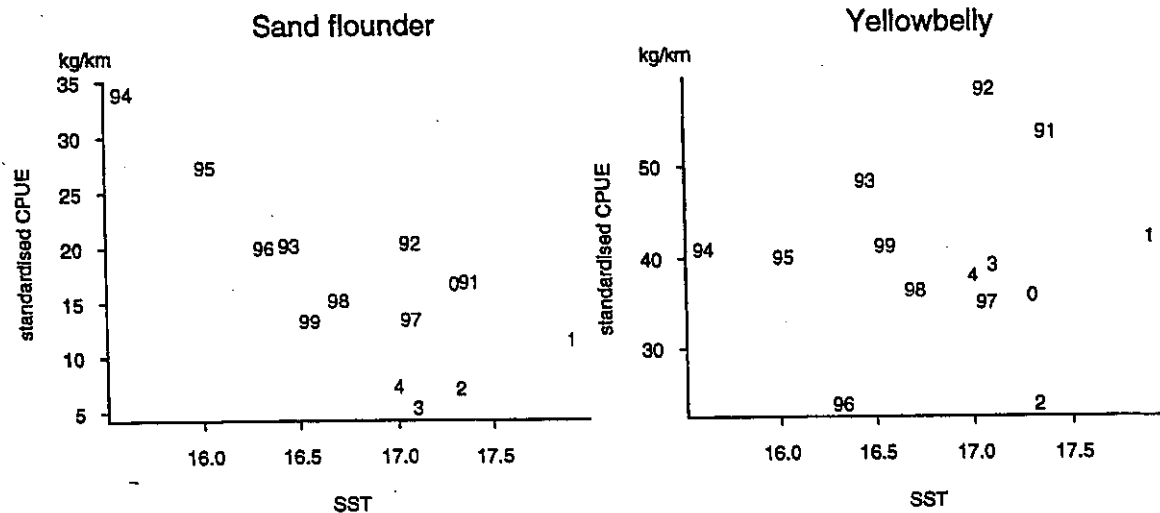
Figure 17: Firth of Thames CPUE indices against sea surface temperature (SST) recorded in winter at Leigh two years previously. The numbers plotted are the years of the CPUE index, e.g., 94 = 1993–94, 2 = 2001–02.

APPENDIX 1

Vessel-year cross tables are given for each subarea. These show the number of vessels that link each pair of years and the mean linkage for all years. For example, for the lower Waikato, seven vessels linked 1989–90 to 1990–91. Hence the tables are symmetric (excepting the rightmost column which gives the mean linkage values of each year). A link was deemed established when a vessel had at least 10 records (vessel days) in each of the pair years.

Lower Waikato

|	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Mean linkage
89-90	-	7	8	8	7	7	7	7	5	4	4	5	4	4	5	5.9
90-91	7	-	9	7	6	6	6	6	4	3	3	4	3	3	4	5.1
91-92	8	9	-	9	8	8	8	8	6	6	5	6	5	4	5	6.8
92-93	8	7	9	-	9	10	10	10	7	6	6	6	5	5	5	7.4
93-94	7	6	8	9	-	9	10	10	7	6	6	6	5	5	5	7.1
94-95	7	6	8	10	9	-	11	11	8	7	7	7	6	6	6	7.8
95-96	7	6	8	10	10	11	-	12	8	7	7	7	6	6	6	7.9
96-97	7	6	8	10	10	11	12	-	9	8	7	7	6	6	6	8.1
97-98	5	4	6	7	7	8	8	9	-	8	7	6	6	6	5	6.6
98-99	4	3	6	6	6	7	7	8	8	-	9	8	7	6	5	6.4
99-00	4	3	5	6	6	7	7	7	7	9	-	8	7	7	6	6.4
00-01	5	4	6	6	6	7	7	7	6	8	8	-	10	8	8	6.9
01-02	4	3	5	5	5	6	6	6	6	7	7	10	-	9	8	6.2
02-03	4	3	4	5	5	6	6	6	6	6	7	8	9	-	9	6.0
03-04	5	4	5	5	5	6	6	6	5	5	6	8	8	9	-	5.9

Manukau Harbour

	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Mean linkage
89-90	-	18	15	16	17	12	12	12	11	11	10	10	8	7	6	11.8
90-91	18	-	23	23	23	18	18	15	15	13	12	11	10	9	8	15.4
91-92	15	23	-	26	25	20	21	17	16	14	14	12	11	8	8	16.4
92-93	16	23	26	-	25	21	21	18	16	14	13	11	9	8	7	16.3
93-94	17	23	25	25	-	24	22	19	18	15	14	11	10	9	9	17.2
94-95	12	18	20	21	24	-	22	19	17	13	13	11	10	8	6	15.3
95-96	12	18	21	21	22	22	-	21	17	14	15	13	11	9	7	15.9
96-97	12	15	17	18	19	19	21	-	20	16	15	14	12	10	7	15.4
97-98	11	15	16	16	18	17	17	20	-	20	16	16	14	10	9	15.4
98-99	11	13	14	14	15	13	14	16	20	-	22	20	14	12	11	14.9
99-00	10	12	14	13	14	13	15	15	16	22	-	29	25	15	15	16.3
00-01	10	11	12	11	11	11	13	14	16	20	29	-	25	16	15	15.3
01-02	8	10	11	9	10	10	11	12	14	14	25	25	-	18	20	14.1
02-03	7	9	8	8	9	8	9	10	10	12	15	16	18	-	20	11.4
03-04	6	8	8	7	9	6	7	7	9	11	15	15	20	20	-	10.6

Kaipara Harbour

	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Mean linkage
89-90	-	26	24	21	17	15	13	12	13	12	10	10	11	12	11	14.8
90-91	26	-	33	24	18	16	13	13	12	11	10	9	9	10	9	15.2
91-92	24	33	-	30	20	18	15	14	13	11	10	10	10	10	9	16.2
92-93	21	24	30	-	23	21	19	17	16	14	12	12	11	11	10	17.2
93-94	17	18	20	23	-	26	21	19	18	17	14	15	14	12	13	17.6
94-95	15	16	18	21	26	-	26	24	22	21	16	19	18	15	15	19.4
95-96	13	13	15	19	21	26	-	29	27	26	22	23	22	17	16	20.6
96-97	12	13	14	17	19	24	29	-	31	28	25	25	25	17	18	21.2
97-98	13	12	13	16	18	22	27	31	-	38	31	30	28	23	21	23.1
98-99	12	11	11	14	17	21	26	28	38	-	40	36	34	28	26	24.4
99-00	10	10	10	12	14	16	22	25	31	40	-	41	36	28	27	23.0
00-01	10	9	10	12	15	19	23	25	30	36	41	-	44	33	29	24.0
01-02	11	9	10	11	14	18	22	25	28	34	36	44	-	37	33	23.7
02-03	12	10	10	11	12	15	17	17	23	28	28	33	37	-	37	20.7
03-04	11	9	9	10	13	15	16	18	21	26	27	29	33	37	-	19.6

North west coast

	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Mean linkage
89-90	-	6	6	7	7	7	3	5	6	3	3	2	2	2	2	4.4
90-91	6	-	6	7	7	7	3	4	5	3	3	2	2	2	2	4.2
91-92	6	6	-	10	9	7	2	5	5	2	2	1	1	1	1	4.1
92-93	7	7	10	-	10	8	3	5	6	3	3	2	2	2	2	5.0
93-94	7	7	9	10	-	10	5	5	6	3	4	3	3	2	3	5.5
94-95	7	7	7	8	10	-	9	8	8	5	5	4	3	2	3	6.1
95-96	3	3	2	3	5	9	-	5	5	3	4	4	3	1	2	3.7
96-97	5	4	5	5	5	8	5	-	11	9	7	5	5	3	3	5.7
97-98	6	5	5	6	6	8	5	11	-	10	7	5	5	3	3	6.1
98-99	3	3	2	3	3	5	3	9	10	-	8	6	6	4	4	4.9
99-00	3	3	2	3	4	5	4	7	7	8	-	9	8	4	5	5.1
00-01	2	2	1	2	3	4	4	5	5	6	9	-	9	6	7	4.6
01-02	2	2	1	2	3	3	3	5	5	6	8	9	-	6	7	4.4
02-03	2	2	1	2	2	2	1	3	3	4	4	6	6	-	7	3.2
03-04	2	2	1	2	3	3	2	3	3	4	5	7	7	7	-	3.6

East Northland

	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Mean linkage
89-90	-	10	7	7	7	6	6	6	5	6	6	6	5	5	4	6.1
90-91	10	-	11	10	9	7	7	8	5	7	7	7	6	6	5	7.5
91-92	7	11	-	18	15	10	10	10	7	10	10	8	7	7	5	9.6
92-93	7	10	18	-	16	11	11	9	7	10	10	8	7	7	5	9.7
93-94	7	9	15	16	-	12	11	10	7	10	11	8	7	7	6	9.7
94-95	6	7	10	11	12	-	10	10	7	10	11	9	7	7	6	8.8
95-96	6	7	10	11	11	10	-	12	6	8	8	7	6	6	4	8.0
96-97	6	8	10	9	10	10	12	-	6	8	8	7	6	6	4	7.9
97-98	5	5	7	7	7	7	6	6	-	7	7	6	5	5	3	5.9
98-99	6	7	10	10	10	10	8	8	7	-	13	10	8	7	5	8.5
99-00	6	7	10	10	11	11	8	8	7	13	-	11	9	8	7	9.0
00-01	6	7	8	8	8	9	7	7	6	10	11	-	12	9	6	8.1
01-02	5	6	7	7	7	7	6	6	5	8	9	12	-	11	7	7.4
02-03	5	6	7	7	7	7	6	6	5	7	8	9	11	-	11	7.3
03-04	4	5	5	5	6	6	4	4	3	5	7	6	7	11	-	5.6

Firth of Thames

	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Mean linkage
89-90	-	40	35	30	27	23	21	19	17	13	12	10	7	7	8	19.2
90-91	40	-	58	50	45	35	31	30	26	21	21	18	13	13	14	29.6
91-92	35	58	-	69	55	44	34	31	27	21	21	21	15	15	16	33.0
92-93	30	50	69	-	63	47	36	33	31	23	25	22	17	17	19	34.4
93-94	27	45	55	63	-	52	38	33	31	22	25	22	16	17	19	33.2
94-95	23	35	44	47	52	-	41	36	34	25	27	23	19	19	21	31.9
95-96	21	31	34	36	38	41	-	36	34	27	24	23	17	18	19	28.5
96-97	19	30	31	33	33	36	36	-	35	28	24	22	18	18	20	27.4
97-98	17	26	27	31	31	34	34	35	-	29	28	26	20	21	23	27.3
98-99	13	21	21	23	22	25	27	28	29	-	30	28	21	23	23	23.9
99-00	12	21	21	25	25	27	24	24	28	30	-	36	30	29	32	26.0
00-01	10	18	21	22	22	23	23	22	26	28	36	-	34	31	30	24.7
01-02	7	13	15	17	16	19	17	18	20	21	30	34	-	38	34	21.4
02-03	7	13	15	17	17	19	18	18	21	23	29	31	38	-	42	22.0
03-04	8	14	16	19	19	21	19	20	23	23	32	30	34	42	-	22.9

East southern

	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Mean linkage
89-90	-	8	7	4	3	1	2	2	1	1	1	1	1	1	1	2.4
90-91	8	-	6	3	3	1	2	2	1	1	1	1	1	1	1	2.3
91-92	7	6	-	6	6	4	4	4	2	1	1	1	1	1	1	3.2
92-93	4	3	6	-	9	7	6	6	2	2	3	1	1	1	1	3.7
93-94	3	3	6	9	-	11	10	7	4	3	5	2	2	2	1	4.9
94-95	1	1	4	7	11	-	10	8	4	3	5	2	2	1	1	4.3
95-96	2	2	4	6	10	10	-	12	7	4	6	3	3	4	3	5.4
96-97	2	2	4	6	7	8	12	-	10	6	7	3	4	4	4	5.6
97-98	1	1	2	2	4	4	7	10	-	6	6	3	3	2	2	3.8
98-99	1	1	1	2	3	3	4	6	6	-	8	3	4	3	3	3.4
99-00	1	1	1	3	5	5	6	7	6	8	-	3	4	3	3	4.0
00-01	1	1	1	1	2	2	3	3	3	3	3	-	3	2	2	2.1
01-02	1	1	1	1	2	2	3	4	3	4	4	3	-	4	4	2.6
02-03	1	1	1	1	2	1	4	4	2	3	3	2	4	-	5	2.4
03-04	1	1	1	1	1	1	3	4	2	3	3	2	4	5	-	2.3

APPENDIX 2

Standardised CPUE (kg per km of net set) and jackknife c.v. (%) for the the seven subarea analyses of FLA.

West coast subareas

Fishing year	Lower Waikato		Manukau		Kaipara		North west	
	kg/km	c.v. %	kg/km	c.v. %	kg/km	c.v. %	kg/km	c.v. %
89-90	69	12	86	14	68	14	45	11
90-91	71	22	83	13	60	18	42	34
91-92	73	13	76	17	62	20	35	19
92-93	81	11	88	14	64	22	37	25
93-94	81	17	77	13	55	25	42	13
94-95	84	18	68	12	75	19	46	19
95-96	73	25	52	15	67	15	42	51
96-97	93	18	53	11	60	33	49	22
97-98	70	28	56	12	45	21	48	17
98-99	78	17	51	14	41	18	43	21
99-00	71	24	49	14	45	13	33	49
00-01	74	30	48	12	46	13	41	16
01-02	61	32	46	11	39	13	40	33
02-03	52	20	41	13	42	10	32	45
03-04	53	27	47	11	51	8	34	53

East coast subareas

Fishing year	East Northland		Firth of Thames		East southern	
	kg/km	c.v. %	kg/km	c.v %	kg/km	c.v. %
89-90	41	22	62	18	36	42
90-91	41	22	65	11	39	71
91-92	50	32	69	12	27	46
92-93	48	20	60	12	34	29
93-94	38	14	66	10	27	19
94-95	43	22	63	9	21	26
95-96	43	44	41	13	20	20
96-97	54	43	43	11	19	26
97-98	40	45	41	13	28	21
98-99	42	37	43	14	21	20
99-00	38	24	42	13	15	31
00-01	36	58	44	12	9	74
01-02	45	27	29	8	10	88
02-03	36	32	35	11	15	43
03-04	36	34	40	11	15	50

APPENDIX 3

Standardised CPUE (kg per km of net set) and jackknife c.v. (%) for the Firth of Thames (007), sand flounder, and yellowbelly flounder analyses.

Fishing year	Sand flounder		Yellowbelly	
	kg/km	c.v. %	kg/km	c.v. %
90-91	17	12	54	17
91-92	20	12	58	13
92-93	20	13	48	13
93-94	34	11	41	12
94-95	27	14	40	13
95-96	20	26	24	20
96-97	13	22	35	13
97-98	15	12	36	12
98-99	13	19	41	14
99-00	17	18	36	10
00-01	11	16	42	15
01-02	7	11	24	7
02-03	5	13	39	9
03-04	7	14	38	9

APPENDIX 4

Set net gear usage in the FLA 1 fisheries between 1989-90 and 2004-05

Introduction

This work was requested by Ministry of Fisheries to provide background information relating to possible management decisions for the FLA 1 set net fisheries. Its purpose was to obtain information on changes to fishing gear that have occurred between 1989–90 and 2003–04, the period over which putative catch per unit effort abundance indices have been obtained. Two kinds of information were obtained. Firstly, average mesh sizes recorded on set net Catch Effort and Landing Returns (CELRs) by area and year were obtained. Secondly, four fishers and two net suppliers were interviewed regarding gear usage over the period.

Data

CELRs were provided by the Ministry of Fisheries for set net fishing for 1989–90 to 2004–05 for the statistical areas 001–010 and 041–047. Mesh size was obtained for records where the target species was one of the flatfish codes FLA, YBF, SFL, GFL, ESO, LSO, TUR, BRI, BFL, FLO, or SOL. Where mesh size was recorded as >=3 but <7 (2% of the data) the value was assumed to have been recorded in inches and was converted to millimetres by multiplying by 25.4. Statistical area was used to divide the data into areas: Waikato (041 & 042), Manukau (043), Kaipara (044), Northwest (045–047), East Northland (002 & 003), Thames (007), and Hauraki Gulf/Bay of Plenty (005, 006, 008–010).

Results

Because a small proportion of mesh size data is wildly implausible even after converting inches to millimetres, two alternative robust estimates of the average mesh size were used. The first was a trimmed mean, where the highest 10% of values and the lowest 10% of values had been deleted before the mean was calculated. The second was the median. For each area these were plotted by fishing year. For convenience we refer to a fishing year by the latter of the calendar years, e.g., 2000–01 is referred to as 2001.

Interviews

Four experienced fishers and two net suppliers were interviewed by Cameron Walsh (NIWA, Auckland). These covered several fishing areas within FLA 1. The information was provided voluntarily and focussed primarily on gear usage, but included general comments on the fisheries. Notes from the interviews (lightly edited) are provided at the end of this appendix. General comments have been retained.

Discussion

Manukau, Kaipara, east Northland, and Thames show increases in mesh size between 1989–90 and 2003–04 of about 5 mm, the eastern areas to 120 mm and the western areas to 125 mm. The other areas show no systematic increase. Hauraki Gulf/Bay of Plenty mesh sizes are about 25 mm (1 in) larger than for the other areas. Fishers on the east coast generally use larger mesh than those on the west coast. This is confirmed by the interviews.

The interviewees described quite a varied scene with fishers selecting mesh type and size in response to the market, the prevailing abundance of fish, the amount of fouling material they encounter in the water, and personal preference. The slight increase in mesh size in several of the areas is consistent with comments on the recent higher market prices for larger fish.

Fishers' emphasised the year to year variability of the flatfish fishery and the considerably increased abundance in 2004–05. Unfortunately 2004–05 was not included in our CPUE analyses as the full year's data are not yet available.
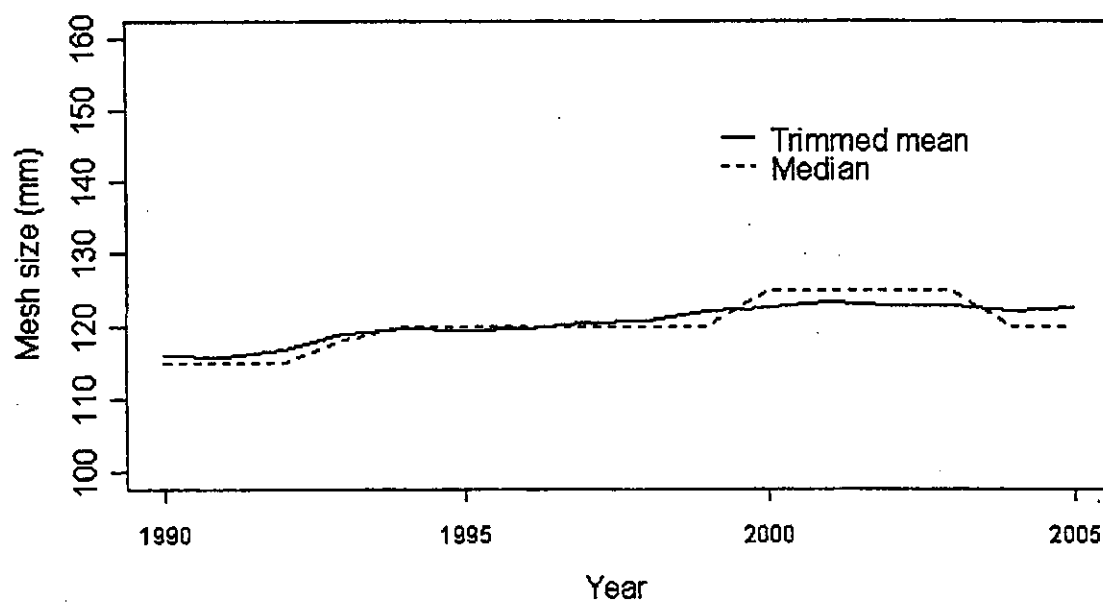
Acknowledgment

We wish to thank the six fishing industry people who freely gave of their time to provide some of their knowledge for this report.
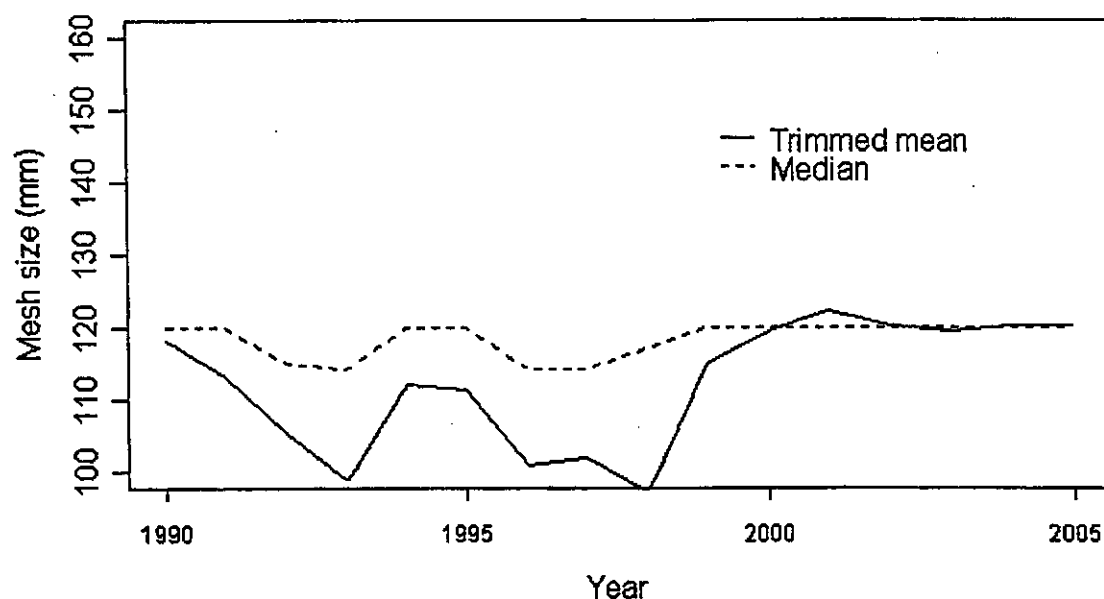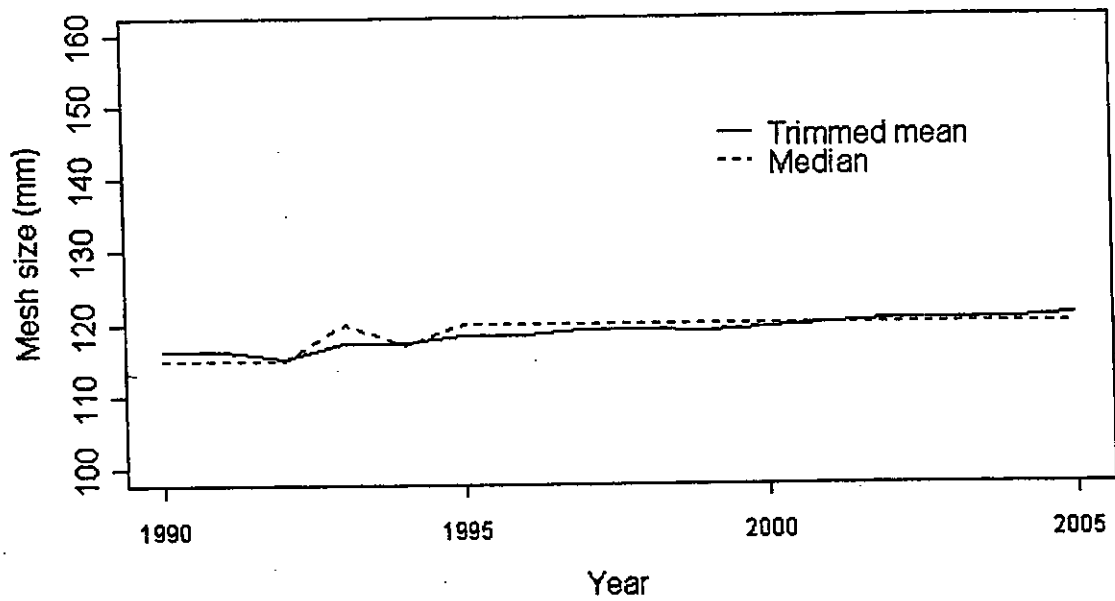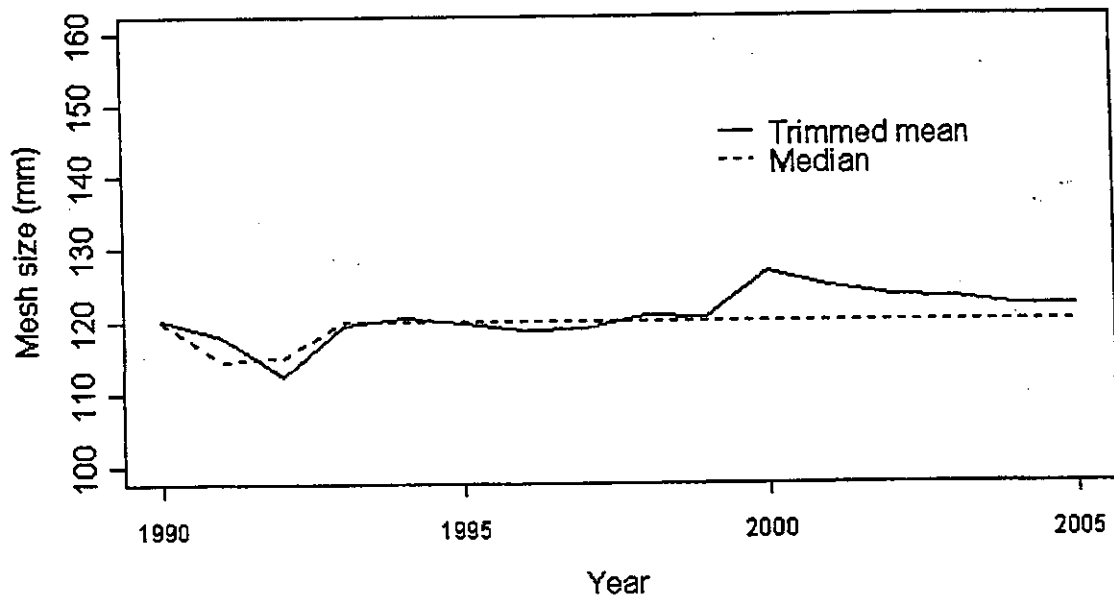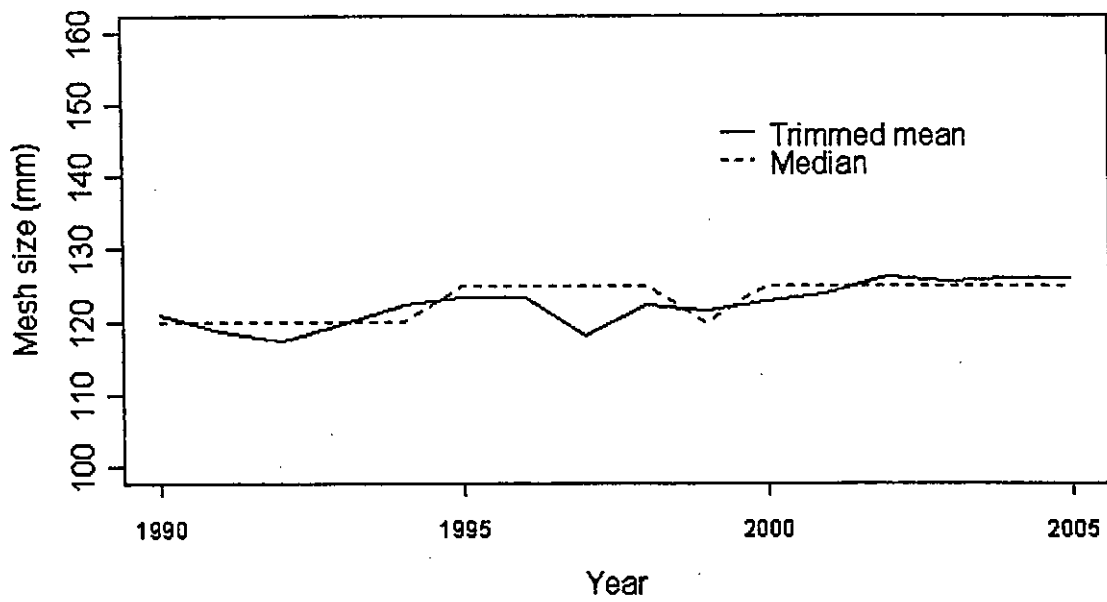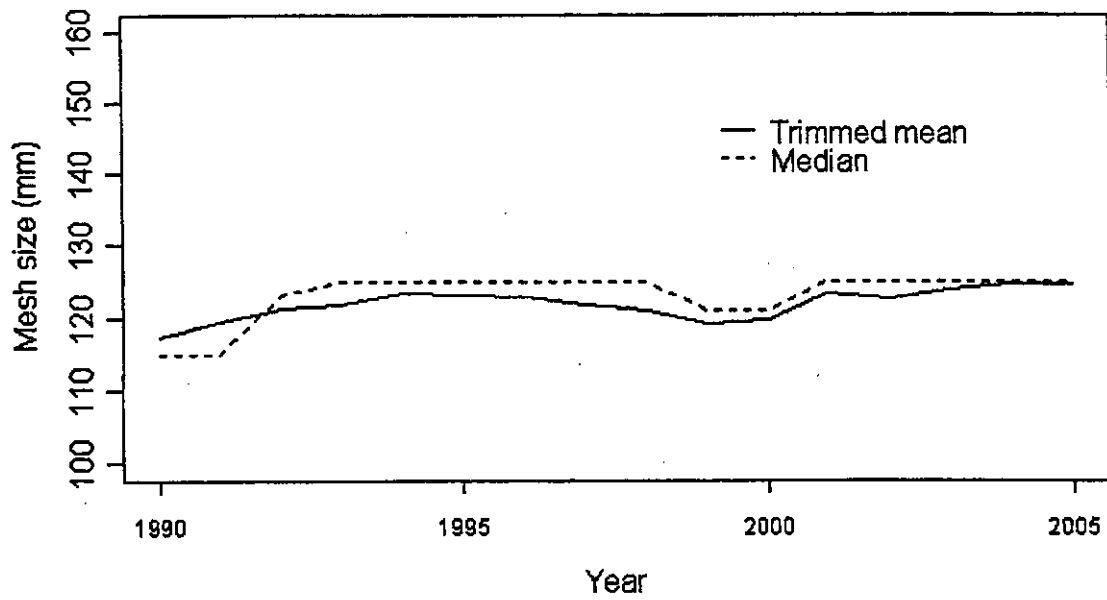
Waikato

Manukau

Trimmed mean (10%) and median mesh size recorded on CELRs by set net fishers targeting flatfish for 1989–90 to 2004–05. Statistical areas are: Waikato (041 & 042), Manukau (043), Kaipara (044), Northwest (045–047), east Northland (002 & 003), Thames (007), Hauraki Gulf/Bay of Plenty (005, 006, 008–010).

Kaipara

Northwest

East Northland

Thames

Hauraki Gulf/Bay of Plenty

Figure showing Mesh size (mm) versus Year with two lines: Trimmed mean (solid) and Median (dashed).
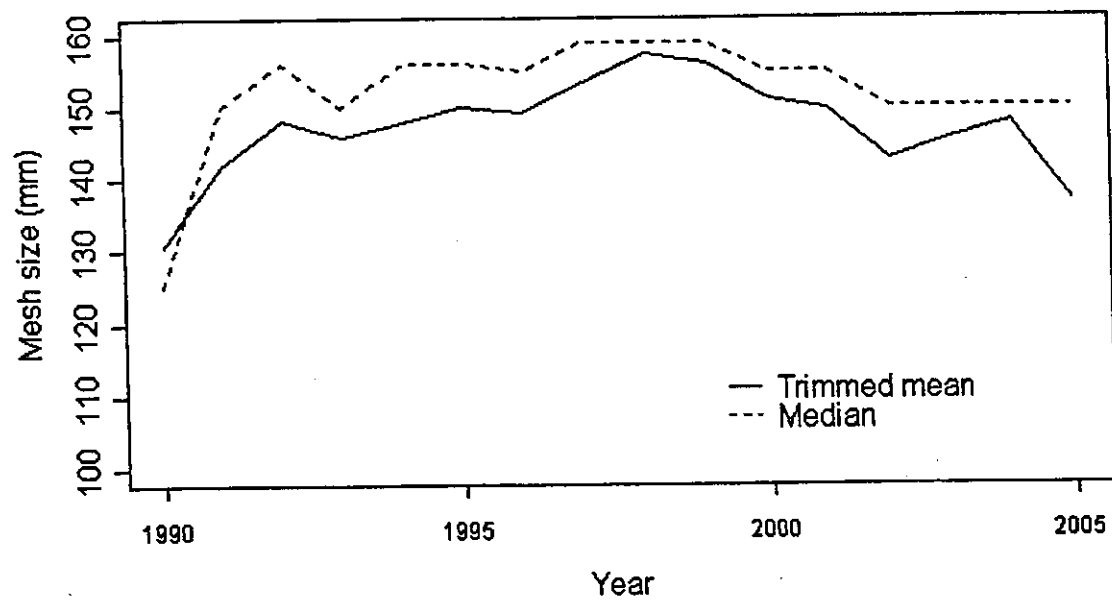
Notes of interviews with set net fishers and net suppliers, 2 June 2005

General areas for discussion
1. Any changes in set net mesh size (114 mm) OR mesh type (mono vs multifilament) for flounder since 1989–90?
2. Changes in CPUE (catch per km net set). Changes in the amount of net set.
3. Do fishers make their own set nets? Which manufacturers provide the net mesh?

Fisher A (Ruawai, Kaipara Harbour)

Multimono (1 major strand from knot to knot comprised of 6–8 minor strands) mono between knots) has been used to some degree, but most fishers from Ruawai choose monofilament for fewer tangles, less fouling on oysters, etc, and less contamination by weed. Mono nets took over from "rag" (braided nylon) nets about 1990–91.

The A family (with about 60 years of experience) use mainly 7–8 x 100 m nets, not one 1000 m net, although other fishers do. This depends largely on the area available to set, large open spaces can take longer nets, compared to narrow channelled waters.

Nets are made by each fisher or known net-maker, slung 25 meshes high.

Live export of flatfish, although considered lucrative, is seen as only a small aspect of the overall fishery.

Fisher B (Port Albert, Kaipara Harbour)

Ex-director of a fishing company. Uses only multimono, says it fishes much better than normal mono which fish bounce off. Used to use "rag" nets in the early 1990s. He sets 3 x 300 m nets around the Kaipara Harbour, mostly 120 mm mesh. If the fishing is good they may increase it to 125 mm, to reduce the catch of smaller fish.

Major change in flatfish fishing now is that many fishers also chase GMU, RIG etc, so diversifying into other species using hydraulic haulers (except FLA, still hand-hauled), spending less time compared to the past when they targeted only FLA. Has witnessed huge changes in SFL abundance from year to year, but product was never much sought after in the early days as it was often too small. SFL in more recent times floods the market, reducing prices.

Used to set 500–600 m of net for 5–6 bin returns, now gets 2 bins for about the same effort. Believes there have been considerable changes in the seasonal abundance patterns in the fishery over time.

In recent years there has been a large influx of inexperienced fishers into the fishery (leasing quota and fishing on behalf of large quota holders) with many of the older fishers (pre-QMS) either retiring, selling up, or fishing less.

Fisher C (Weymouth, Manukau Harbour)

C comes from a well known large family of set netters around the Auckland area, particularly the Manukau Harbour. C fishes for YBFs in autumn (March to May) and chases GMU at other times. C agrees with most things mentioned above by B. C used to use rag nets, but started on mono and multimono about 1989–90. Rag nets catch a lot of rubbish, as do multimono, so prefers mono, but uses both and agrees multimono has a better catch rate. Uses a 120 mm mesh, believing he lets a few of the smaller ones go for another day that would normally be caught using 114 mm regulation size. C currently sets 7–9 x 70 m nets, but records 700 m in effort as he always has done. Agrees catches are probably not as good as they were, but can remember lean years in his father's time fishing the same areas.

In recent times the market has demanded bigger fish. He believes there are fewer fishers than a few years ago. A lot of younger, inexperienced fishers come into the fishery, don't last long, and usually find better work outside fishing. The younger fishers would set more net (increased effort), to make it worthwhile, than older fishers like himself.

Agrees with B regarding dabs not being wanted earlier on, but they are now caught in abundance in some years.

Fisher D (Waitemata Harbour)

D has been fishing the Waitemata, Manukau, Kaipara, and Hauraki Gulf areas for YBF, GMU, and KAH for about 30 years. He fishes 7–8 x 70 m nets, always writing 500 m in the effort section. He went on to mono about 1990 and mainly uses multimono which fishes better than mono, especially over night sets with changing tides. He slings his own net. The reason for 70–75 m nets being common in the fishery is that the mesh is purchased as 180 m (200yard) length lots (hanks) which when slung gives a net length of about 70 m.

D uses 125 mm mesh in the Waitemata and 120 mm (actually 118–119 from suppliers) for the Kaipara and Manukau Harbours, where he says the fish are of a smaller average size and always have been. Like SFL abundance fluctuations, changes in YBF abundance also occur from year to year, this year being particularly good in the Firth by all accounts. The YBF fishery is generally good over autumn, but then goes quiet as it has done recently.

His comments regarding changes in dab (SFL) abundance over the years were similar to those of the other fishers. They are sometimes targeted in the outer Firth by a particular Danish seine boat that has the expertise.

D agrees that young and keen fishers enter the fishery and fish much harder than he ever has. Is there some dispensation for over 1000 m nets in Firth? Some fishers are running more than one boat (using a dory?) for YBF.

Net supplier E (Supplier of nets and equipment to fishers)

Nets come in 4¾ inch mesh (mono (0.28 thickness/gauge)) and 119 mm mesh (multimono (0.12 thickness/gauge, 6 strands)). Both come in 180 m (200yard) hanks. "Rag" nets were popular before 1990, some fishers still use them today. Mono was popular from 1990 onwards, but in recent years multimono accounts for a higher proportion of sales (~70:30) than mono.

Net supplier F (ex flatfish fisher, net importer; supplies and hangs lots of net for fishers)

F gave me a good summary of the history on flatfish and nets. Major point he made is that there has been a considerable change in mesh size used in some fisheries, especially in the Firth. Used to sell a lot of 4¾ in, but now sells mainly 5¼ to 5½ in, mostly as a result of the market demand for larger fish. Unsold 4¾ in is still on his shelves. A high proportion of the fish is sold on the local market. **Company X** export overseas mostly larger YBFs. There are 4 sizes: A–D. D is the largest, fetching the highest price. Most other catch is sold locally. There have been some requests by fishing companies for fishers to stop fishing (this year especially and over weekends) as they can't sell the volume that is being supplied. This year's fishing has probably been the best in 30 years.

The mesh is purchased from Thailand. F says that he has to watch what size mesh he receives as it is often different from that asked for, usually smaller. There are also problems with imperial vs metric measurements.

Kaipara/Manukau Harbours: Most fishers request 4⅝ in (117 mm) or 4¾ (121 mm) because of the high abundance of smaller fish there.

Thames coast (north of Thames): Fishers use 5¼ in mesh because of the bigger fish (YBF) and it becomes more economic to catch them than SFL ($6–8/kg for YBF versus $3–4 for SFL). SFL are half the price and you have to clean twice as many too. Many are fishing in up to 40 ft water.
Firth of Thames fishers generally use a mesh size of either 5 in (127 mm), 5¼ or 5½ in.

Top of the Firth: Actually the southernmost end – also known as the flats. Shallow muddy area, smaller fish, and 4¾ in mesh commonly used.

F's background: started in 1979 with 5½ to 6 in rag nets. Early–mid 1980s went to 5½ in mono, by 1990 mono and multimono were available. Used 5¼ to 5½ in multimono (8 strand stuff) as do most fishers now in the Firth, although some still prefer mono alone. Rag net still in use, with one fisher recently buying in 30 000 m. Fishers go through a lot of mesh. The mussel industry has a spill over of mussels and "beard" recruiting around the Firth coastline which is hard on the gear. One fisher sets up to 6000 m of mesh using three boats; catches a lot of flats. Regulations allow him to fish 1000 m net in <2 m water depth, 2000 m net >2 m water depth.