New Zealand Fisheries
Assessment Report
2008/57
October 2008
ISSN 1175-1584

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New Zealand Fisheries Assessment Report 2008/57
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**Published by Ministry of Fisheries**
**Wellington**
**2008**

**ISSN 1175-1584**



McKenzie, J.R.; Vaughan, M. (2008).
CPUE analysis and characterisation of grey mullet (*Mugil cephalus*)
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*New Zealand Fisheries Assessment Report 2008/57*. 36 p.

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

## EXECUTIVE SUMMARY

**McKenzie, J.R.; Vaughan, M. (2008). CPUE analysis and characterisation of grey mullet (*Mugil cephalus*) setnet fisheries in Fishstock GMU 1 between 1989 and 2006.**

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This study, conducted pursuant to Ministry of Fisheries project GMU200601, had two objectives:

1. To characterise the GMU 1 fishery,

2. To update the standardised CPUE index for grey mullet in GMU 1 with the inclusion of data up to the end of the 2005/2006 fishing year.

Analyses were undertaken of the six geographical areas where most of the GMU 1 catch was taken: Lower Waikato River and southern coastal harbours (Stat areas 41 & 42); Manukau Harbour (Stat Area 43); Kaipara Harbour (Stat area 44); Northwest coast and harbours (Stat Areas 45, 46, & 47); East Northland (Stat Areas 2 & 3); Hauraki Gulf (Stat Areas 5, 6, & 7). Commercial catch and effort information, covering the period 1990 to 2006, came from the Ministry of Fisheries catch reporting database. Standardised CPUE indices were derived using Generalised Linear Modelling analyses (GLM). The basic observational unit was daily catch and the GLMs were used to explore the level of catch variation explained by fishing year and other potentially "explanatory" parameters including fishing-effort, vessel, and season. A stepwise procedure was used to assess the overall contribution of fishing-year and other parameters in the models; parameters that failed to increase model precision by more than 3% were dropped.

Patterns seen in the CPUE indices from the six GMU 1 sub-areas show little similarity and do not correlate well. The implication is that the major GMU 1 harbours and embayments are home to distinct sub-populations of grey mullet. If this premise is correct, then the current strategy of managing these areas under a collective Northern New Zealand TACC (i.e., GMU 1) is not optimal as managers have little control over the level of fishing mortality each sub-population receives. More information is needed about sub-area mixing rates in order to develop an optimum spatial management strategy for GMU 1. In the interim it would be advisable to split GMU 1 into at least separate east and west coast components.

The Kaipara Harbour, Manukau Harbour, and East Northland (which collectively account for over 80% of the GMU 1 catch) all show an increasing trend in CPUE after 2002. In the short term, the GMU 1 CPUE data suggest that current catches are sustainable at least in the major catching areas. In the absence of a spatially stratified stock assessment of GMU 1 it is not possible to determine whether current levels of exploitation within GMU 1 will support Maximum Sustainable Yield (MSY) or move the stock toward MSY. Estimates of sub-area mixing are critical both to a formal stock assessment and the informed spatial management of GMU 1.

# 1 INTRODUCTION

Grey mullet occur around most of coastal New Zealand as far south as the Otago Peninsula, and attain the highest densities around the northern half of the North Island from where 95% of the annual commercial harvest of grey mullet is taken (MFish 2007). The northern grey mullet fishery (GMU 1) is managed as one discrete zone under a single annual commercial TAC (Figure 1). Most of the annual GMU 1 commercial catch is taken from larger harbours and embayments, these being (on the west coast) the Manukau and Kaipara Harbours and (on the east coast) Rangaunu Harbour and the Firth of Thames. Grey mullet is virtually exclusively taken by netting (ringnet or setnet).

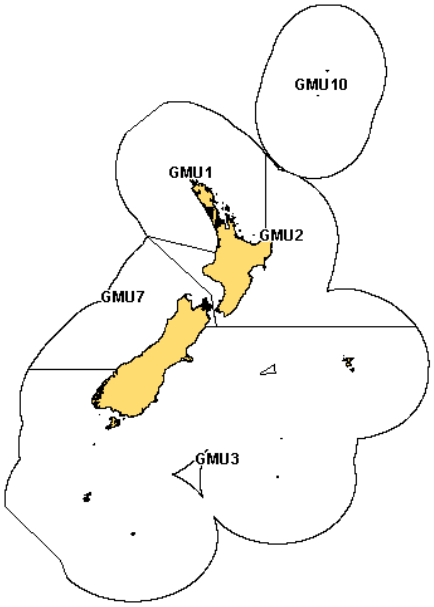



**Figure 1: New Zealand grey mullet quota management areas.**

A standardised CPUE analysis of GMU 1 setnet data was undertaken in 2005 (Watson et al. 2005). The analysis found regional differences in CPUE for the period 1989 to 2002. Evidence of CPUE decline was found in the Kaipara Harbour, the Manukau Harbour, and the Hauraki Gulf. The remaining regional zones, East Northland, Northwest coast, and Lower Waikato, had relatively flat CPUE trends. Abundance ambiguities, uncertainty as to the degree of spatial separation within GMU 1, and a limited amount of catch-at-age information are reasons why there has yet to be a viable stock assessment for New Zealand grey mullet. It is unknown whether current levels of exploitation within GMU 1 will support Maximum Sustainable Yield (MSY) or move the stock toward MSY (MFish 2007).

This report was commissioned by the Ministry of Fisheries pursuant to project GMU2006/01for which there were two objectives:

3. To characterise the GMU 1 fishery.

4. To update the standardised CPUE index for grey mullet in GMU 1 with the inclusion of data up to the end of the 2005/2006 fishing year.

## 2 GMU 1 FISHERY CHARACTERISATION

### 2.1 Methods

Data for characterising the GMU 1 fishery came from the Ministry of Fisheries Catch Effort Landing Return (CELR) database and covers 17 fishing years (1989–90 to 2005–06). The selection criteria used for data extract are given in Appendix 1. For characterising the fishery, location information (statistical reporting area; Figure 2) and method (ringnet or setnet) were critical and particular attention was placed on validating these fields in the extracts. Landing point information provided in the landed section of the CELR form was used to corroborate the statistical fishing area data provided. Where these two data fields did not match, a value judgement was made on the basis of the fisher's catch profile as to the likely fishing area and this was assigned as the "true" fishing area. Where the estimated and reported landed catch weights differed the landed catch weights were generally assumed to be correct. In most cases the estimated catch totals were used to prorate the landed catch weights by the reported spatial and temporal demographics.

### 2.2 Geographical zones

CELR catch information was stratified into seven primary geographical zones by amalgamating statistical reporting areas (Figure 2). The seven areas are:

- Lower Waikato River and southern coastal harbours (Stat areas 41 & 42)
- Manukau Harbour (Stat area 43)
- Kaipara Harbour (Stat area 44)
- Northwest coast and harbours (Stat areas 45, 46 & 47)
- East Northland (Stat areas 2 & 3)
- Hauraki Gulf (Stat areas 5, 6, & 7)
- Bay of Plenty (Stat areas 8, 9 &10)

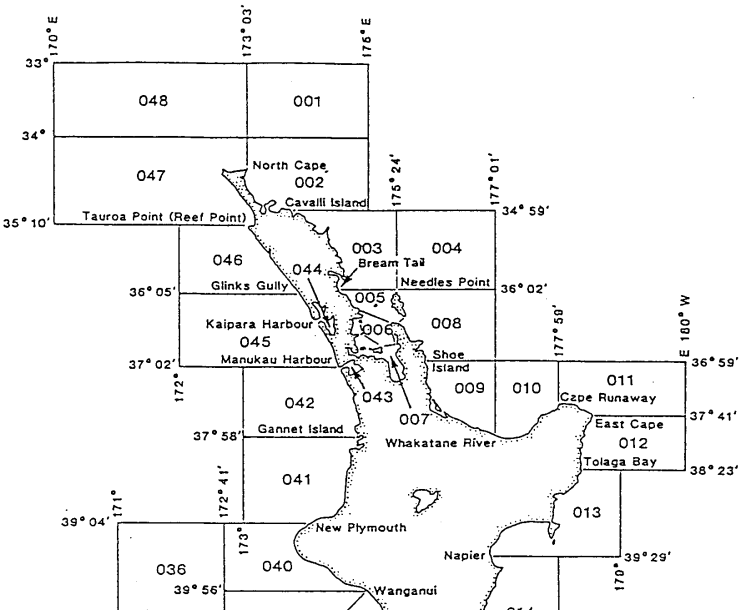



**Figure 2: Commercial grey mullet statistical reporting zones**

## 2.3 Catch history

Most (80%) of the GMU 1 annual catch between 1989 and 2006 was taken on the west coast of the North Island (Table 1). The two main fishing areas were the Kaipara (37.45%) and Manukau (26.03%) harbours (Table 1). The east coast fishery accounted for only 22.3% of the total catch over this time period; the Bay of Plenty's contribution to this was minimal (Table 1).

**Table 1: Total grey mullet catch by area from 1989 to 2006**

| area | area code | total catch (t) | % |
|---|---|---|---|
| Lower Waikato River | LWR | 1388 | 10.0 |
| Manukau | MAN | 3619 | 26.0 |
| Kaipara | KAI | 5205 | 37.5 |
| Northwest Coast | NWC | 608 | 4.4 |
| East Northland | ENL | 2300 | 16.6 |
| Hauraki Gulf | HGL | 761 | 5.6 |
| Bay of Plenty | BOP | 19 | 0.1 |
| Total | GMU 1 | 13902 | |

The total GMU 1 catch was significantly lower than the TACC in most years (Figure 3). An increase in GMU 1 annual catches over the early 2000s culminated with the TACC being exceeded for the first time in QMS history in 2004–05 (Figure 3). Most of the increase seen in latter catch series came from the Kaipara and Manukau harbours (Figure 3).

Although there appears to be no overall systematic shift in extraction between the areas over the 17 year interval, some short-term movements are evident; for example, the decline in Kaipara removals during the late 1990s is balanced by an increase in catches in other west coast areas, particularly the Lower Waikato River (Figure 3).

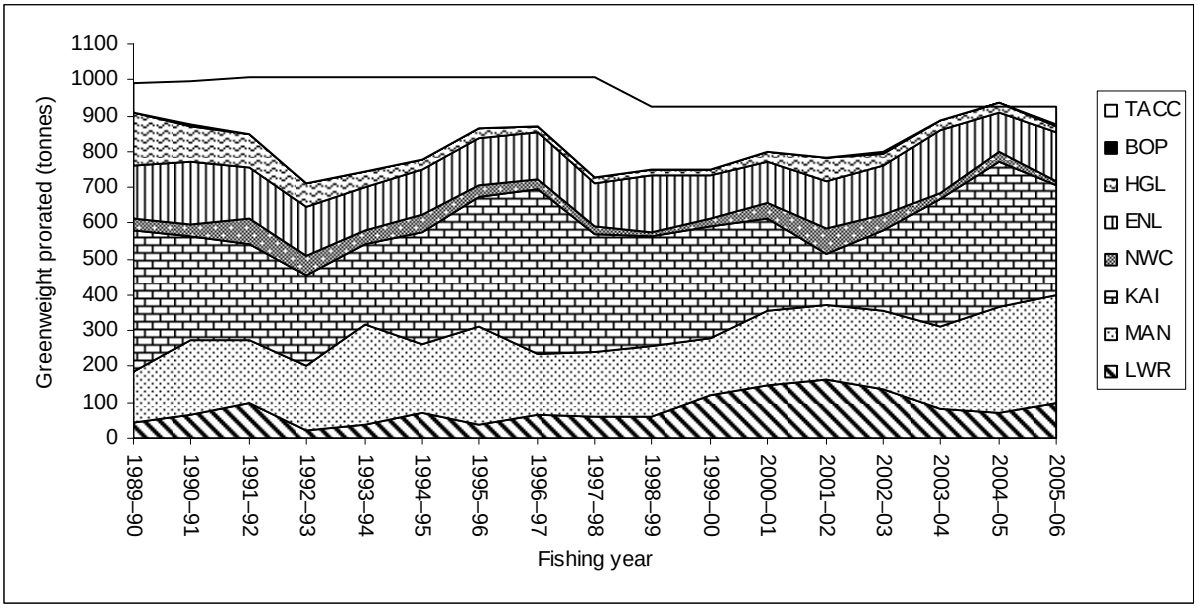



**Figure 3: Trends in commercial catch by area (1989–2006). See Table 1 for area codes**

## 2.4 Landing by method

The principal GMU 1 fishing methods between 1989 and 2006 were setnet (SN) (61.9%) and ringnet (RN) (37.9%); catches from drag net (DN) and other fishing methods (OTH) were minimal (0.2%).

Between 1989 and 2006 the division between SN and RN had altered (in 1989–90 92% SN and 8%RN; in 2005–06 47% SN and 52% RN). According to commercial fishers the shift toward ringnetting was driven by a market demand for higher quality fish. This gear shift is most pronounced in the Kaipara and Manukau harbours (Figure 4). In most other areas the shift to ringnetting has been less pronounced (Figure 4).

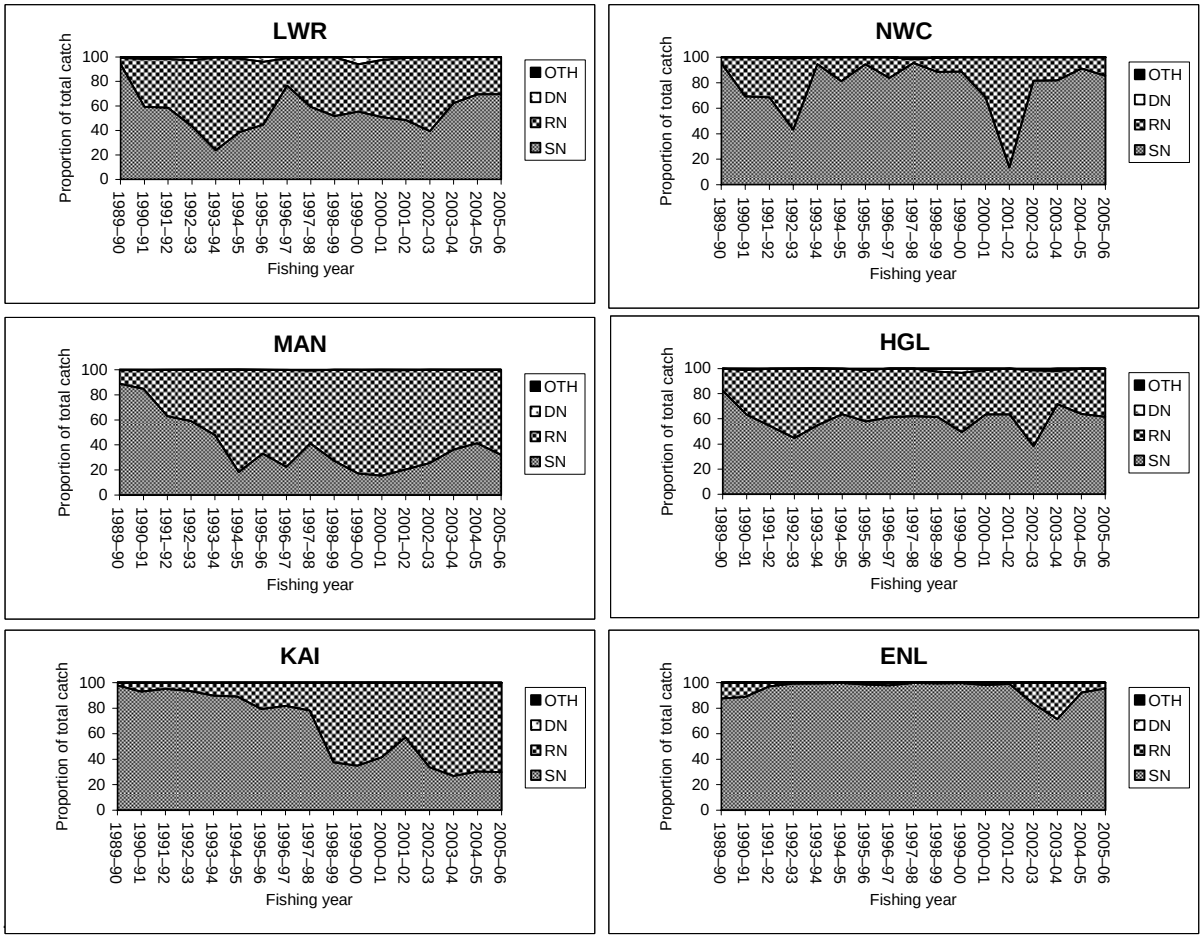



**Figure 4: Shifts in proportional grey mullet catches by method across fishing years. See Table 1 for area codes**

## 2.5 Level of area itinerancy in the GMU 1 fishery

GMU 1 covers a huge number of harbours and fishing areas; fishers have the freedom to move to good fishing areas or fish a preferred location without being encumbered by local catch restrictions.

Due to privacy issues the Ministry of Fisheries will not release information on individual fishers; coded vessel-id information is provided instead. The assumption has been made that the vessel catch and effort information provided by the Ministry of Fisheries was largely representative of individual fishers, or at least the actions of individual fishers for significant periods of time.

The proportion of catch taken by itinerant vessels in East Northland was low (Figure 5). This in part may be due to the area's geographic isolation. However, in interviews, fishers have claimed to have been intimidated by East Northland locals and many perceive the area as "unsafe".

In the Kaipara Harbour the average proportion of the catch taken by resident vessels was also high at 61% (Figure 5). This is in stark contrast to the adjacent Manukau Harbour where the resident catching average was only 13% (Figure 5). The resident average was lower again in the Lower Waikato River and Northwest Coast areas (Figure 5). The Hauraki Gulf fishery was initially largely fished by itinerant vessels with a greater proportion of the catch taken by resident vessels in more recent years (Figure 5).

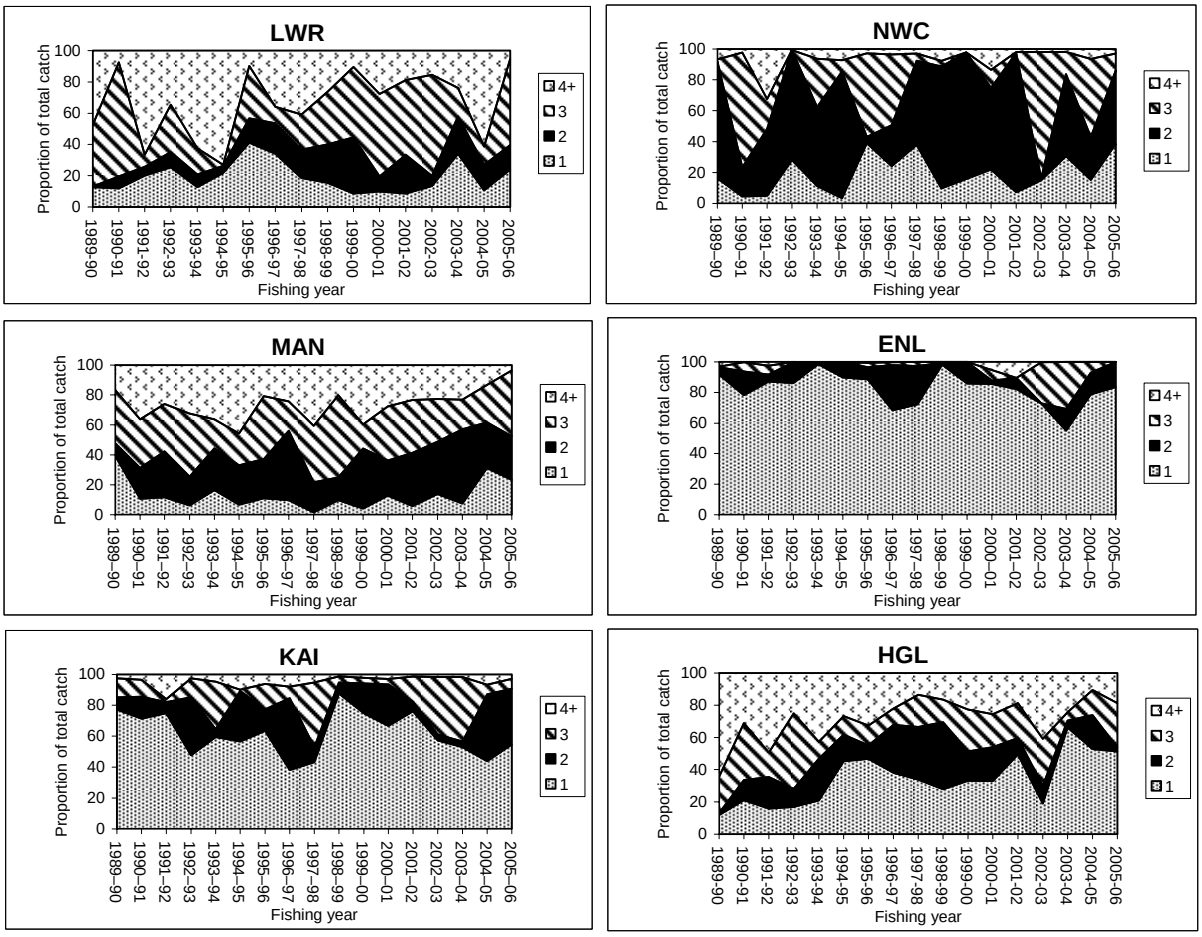



**Figure 5: Proportion of catch taken by vessels which fish 1, 2, 3, or 4+ fishing areas; i.e. ratio of extraction by local verses itinerant vessels. See Table 1 for area codes**

## 2.6 Catch relative to vessel numbers as a percentage

On average, a high proportion of the catch is taken by less than 12.5% of the total vessels in most areas (Table 2). This ratio has been reasonably consistent through time (Figure 6)

**Table 2: Average percentage of GMU 1 catch relative to percentage of vessels taking it 1989-2006**

| Area | 12.5% of vessels | 25% of vessels | 50% of vessels |
|---|---|---|---|
| LWR | 66 | 84 | 96 |
| MAN | 50 | 75 | 96 |
| KAI | 68 | 84 | 97 |
| NWC | 74 | 88 | 97 |
| ENL | 56 | 80 | 97 |
| HGL | 66 | 86 | 97 |

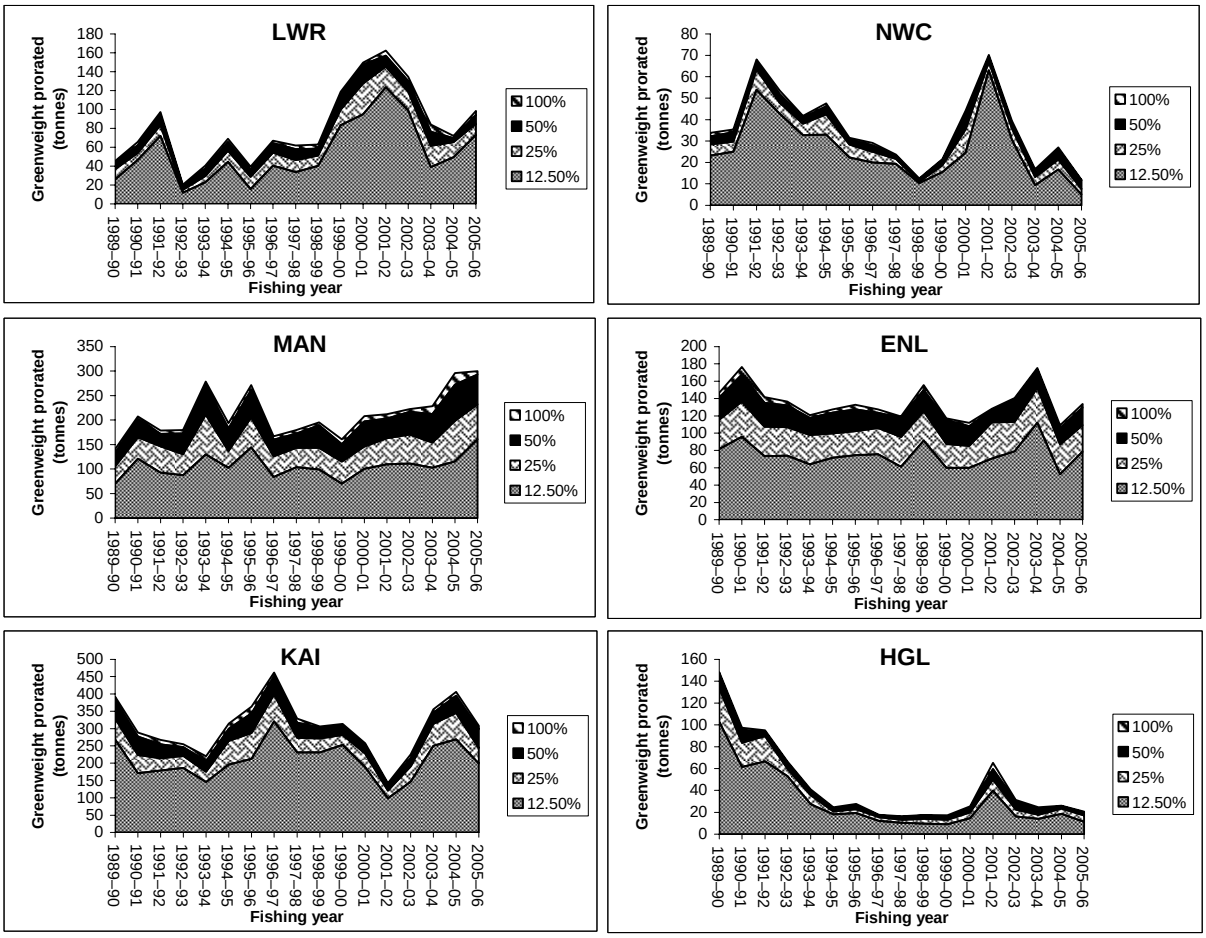



**Figure 6: Total annual grey mullet catch relative to the percentage of vessels taking it by area and fishing year. See Table 1 for area codes**

## 3 GMU 1 CATCH PER UNIT EFFORT ANALYSIS

### 3.1 Methods

Grey mullet and setnet catch per unit effort (CPUE) information was obtained from the Ministry of Fisheries. The spatial resolution of the data was statistical reporting area. Effort information was net length, set duration, and mesh size. Included with these data were a number of ancillary characters, e.g., fisher-ids and bycatch information. Ancillary characteristics were used as covariates in the analysis and as a data validation aid.

CPUE data were available for fishing years 1989–90 to 2005–06 (17 years). However, the 1989–90 year was dropped from the analysis because of the likely inclusion of ringnetting method in the data. Fishers were not legally required to report ringnetting as a separate method until October 1990, i.e. the 1990–91 fishing year.

Annual catch indices (assumed to represent grey mullet availability) were derived using generalised linear modelling (GLM) procedures (Vignaux 1994, Francis 1999). The GLMs were conducted using the statistical software package R. The stepwise regression procedure (StepAIC) was used to select parameters (covariates) for inclusion in the final catch model. This procedure adds and removes parameters on the basis of improvement in Akaike's Information Criterion score (AIC: Sakamoto et al. 1986). The net improvement in the overall model R-square was calculated for each parameter added by the StepAIC process. Parameters resulting in less than a 3% improvement in model R-square were rejected. A set of Cook's distance scores (Cook & Weisberg 1982) was derived for the final model as a way of identifying datum observations with 'unacceptable' influence on the model fit. Observations with a Cook's scores greater than 0.05 were rejected and the models refitted.

The approach taken with all the GLMs was to enter the fishing 'effort' terms as a covariate (i.e., "right-hand" model term), thus the regressor variable was simply log-catch (kg); this is algebraically analogous to subtracting log effort from log catch. To understand what the GLM results may mean in stock abundance terms, it is important to understand what a significant 'effort' term would imply. Under a scenario in which there has been no change in abundance between years yet fishing effort has been variable, the GLM should identify 'effort' as explanatory whereas the 'fishing-year' term should have very low explanatory power. Conversely, if fishing effort had been relatively constant between years yet catches have changed the GLM should find 'fishery-year' explanatory whereas 'effort' should be shown to have little or no explanatory power. The important point to realise is that although, logically, catch and effort should be correlated at some fundamental level, the failure of a GLM selection process to identify 'effort' as important does not necessarily diminish the relevance of the 'fishing year' index as a relative abundance measure. The critical thing is 'effort' covariates **must** have been 'offered' in the GLM selection process.

## 3.2 GLM variables

The response dependent variable used in the GLM analyses was the log of the daily grey mullet catch (kg). Covariates investigated in the setnet GLM models were:

| | |
|---|---|
| fishing-year (16) | Categorical |
| season (4) | Categorical |
| vessel | Categorical |
| target species | Categorical |
| log net length (m) | Continuous |
| logset duration (hours up to 24) | Continuous |
| log mesh size (mm) | Continuous |

Second order interaction parameters were also investigated being combinations of the above parameters excluding "fishing year" (15 additional parameters).

## 3.3 Data grooming and validation

Ringnet fishing effort is distinct from setnet effort in that ringnetting involves an active searching component. Before October 1990, ringnet and setnet effort were recorded on Ministry forms under the one code "setnet"; because of this, data from the 1989–90 fishing year were dropped from the analyses.

Setnet catch and effort information were included in the analysis under the criteria that grey mullet appeared in the effort section of the reporting form either as one of the top five species caught in a set and/or was designated as the target species. The setnet fisheries report solely on Ministry Catch Effort Landing Return (CELR) forms. Because of the CELR form structure, grey mullet trip catch and effort information is aggregated at the daily level at the spatial resolution of Ministry statistical reporting areas. The basic observational unit (record) used in the GLM analysis was the total grey mullet catch (kg) per day.

Because the catch weights recorded in the effort section of CELR forms are estimated, the total landed catch of grey mullet from trips where grey mullet was targeted or caught were also extracted as a way to validate the estimated catch totals. The full list of fields in the raw extract data tables is given in Appendix 1. The catch figures used in the GLM analyses were the landed green weight totals prorated by the estimated catches.

### 3.4 False-zero catch record identification

A high proportion of the raw grey mullet effort information in the in the CELR data series contained errors as a result of fishers incorrectly filling the out CELR reporting form's effort section and the Ministry of Fisheries subsequently failing to enforce rigorous reporting standards. In the column titled "Target Species" on the CELR effort form (Appendix 2) fishers are required to enter the target species code and under that the total weight of all species caught including the target species. In the next five columns fishers are required to enter the species codes and weights of the top five species caught in descending weight order. Where GMU is both targeted and the only species caught fishers essentially enter the same information twice (Appendix 2). A reporting error occurs when a fisher fails to complete the estimated catch section (possibly they perceive repeating the information is needless). If this erroneous record is entered "verbatim" into the Ministry CELR database it appears in subsequent extracts as GMU targeted but zero catch. The usual practice of prorating the landed catch weight by the estimated will also produce a zero catch weight even when the correct landed weight is reported. It is possible to identify false target zero records by linking the estimated and landed catch records; if a non-zero landed value is obtained, the null estimated catch record is likely to be erroneous. A plot of the number of false-zero grey mullet target catches expressed as a proportion of all targeted records shows a spike between 1995–96 and 1999–2000 fishing years with almost a quarter of the target records affected in 1997–98 and 1998–99 (Figure 7). Target sets with zero estimated catch for the target species are possibly legitimate if no landed catch was reported. The percentage of "plausible" legitimate target zeros in the grey mullet catch series, although showing a slight upward trend, was less than 5% in most years (Figure 7).

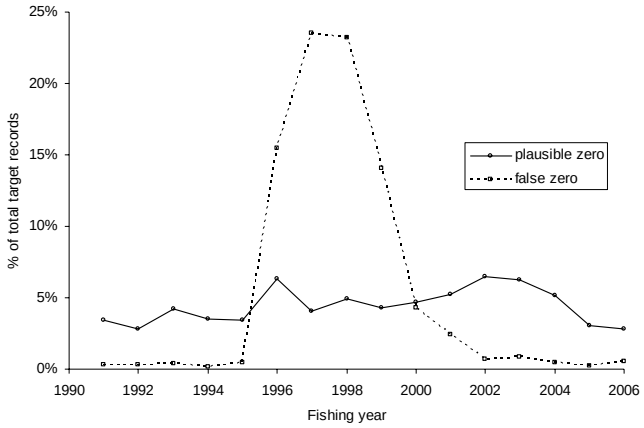



**Figure 7: Percentage of misreported and "plausible" zero catch records in the target GMU CELR data series**

The dramatic rise in the incidence of grey mullet false-zero records corresponds to the centralisation of Ministry of Fisheries data management systems in Wellington in 1995. The high proportion of false-zero errors is likely due to a failure by the central unit team to force fishers to comply with legal reporting requirements. In 1999–2000 more rigorous data reporting standards and specifications were developed and in October 2001 the Ministry data management system was transferred to a subsidiary contractor. These changes correspond to a marked reduction in false-zeros in the GMU 1 data after 1999 (Figure 7). It is highly likely that the problem of misreported estimated catch is endemic across the entire CELR database; those intending to work with CELR records are advised to extract records not only on the basis of estimated reported catches but also obtain a separate extract using landed-catch selection criteria. In the case of grey mullet, only by combining these two extracts could the false-zero records be identified and a complete catch effort series obtained.

To correct the false-zero catch information in the GMU data series the estimated catch was assigned the "total catch" value. Although this value potentially included the weights of other species taken in the set, the procedure was unlikely to have biased the analyses as the estimate catch total was used only to prorate the actual GMU landed green-weight values. All "plausible-zero" records were removed from the data series (1818 records).

## 3.5 Data selection

Data were divided spatially into the six geographical areas described in Section 2.2. Important target species were identified on the basis of the total associated grey mullet catch. Target species were grouped on the basis of similarity in catch location and degree of commonality in gear configurations. For example, grey mullet was often taken as bycatch in flounder target fisheries in harbours; however, it was considered that differences in gear configurations between these two target fisheries warranted their separation into distinct target classes.

Data from vessels recording fewer than five grey mullet catching days in a given year were deleted for that year. The catch histories of all the vessels remaining in the reduced dataset were calculated; data pertaining to vessels with fewer than two years history in the fishery were deleted. The remaining vessels were sorted in descending order by total grey mullet catch. The guidelines used for the final vessel selection were either the top 20 vessels or up to the number of vessels necessary to include 80% of the total grey mullet catch. However, additional vessels with long history (over 5 years) in the fishery were often included.

### 3.5.1 Lower Waikato River and harbours

Before data sub-setting, the initial dataset consisted of 4425 records. The total tonnage of grey mullet taken in other target fisheries was about 1% (Appendix 3) and this was deemed insufficient to incorporate a separate "non-target" class into the analysis, therefore data pertaining to non-target catches were dropped (387 records).

Data from vessels fishing fewer than 5 days in a given fishing year were deleted (264 records). Dropping vessels with fewer than 2 years history in the fishery removed a further 239 records. The 23 long-history vessels included in the final data set (3348 records: Appendix 4) accounted for 98.56 % of the landed historical catch.

The estimated catches, although being slightly below the true landed values in most years, were reasonably well correlated in the final dataset (Figure 8).

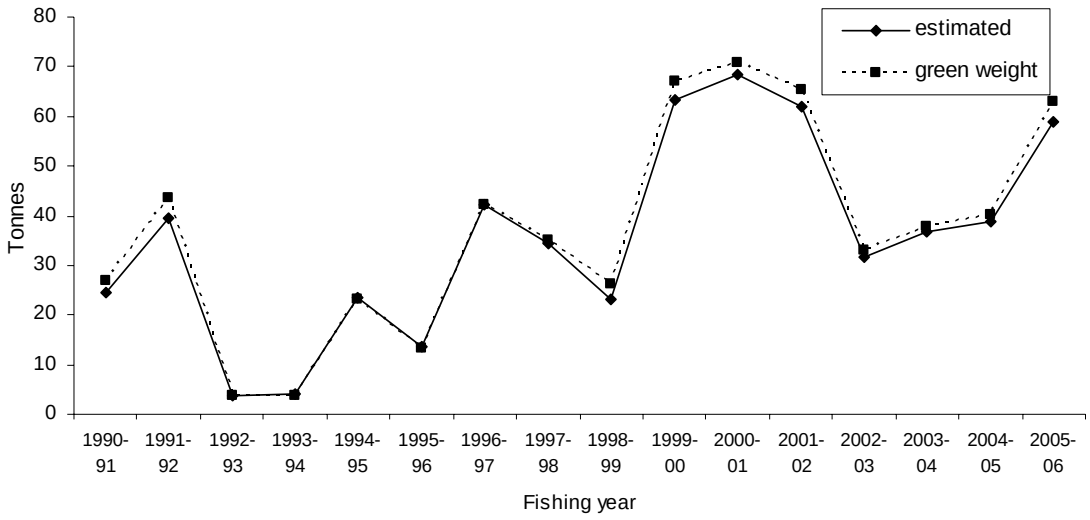



**Figure 8: Estimated and landed grey mullet green-weight totals from the Lower Waikato River and harbours setnet fisheries.**

### 3.5.2 Manukau Harbour

Before data sub-setting, the initial dataset consisted of 8408 records. The total tonnage of grey mullet taken in other target fisheries was about 1% (Appendix 5) and this was deemed insufficient to accommodate a separate "non-target" class in the GLM analysis and data pertaining to non-target catches were dropped (1176 records).

Data from vessels fishing fewer than 5 days in a given fishing year were deleted (324 records). Dropping vessels with fewer than 2 years history in the fishery removed a further 464 records. The 16 top vessels accounted for 86% of the landed historical catch; three additional long-history vessels were also included in the final data set (5352 records; Appendix 6).

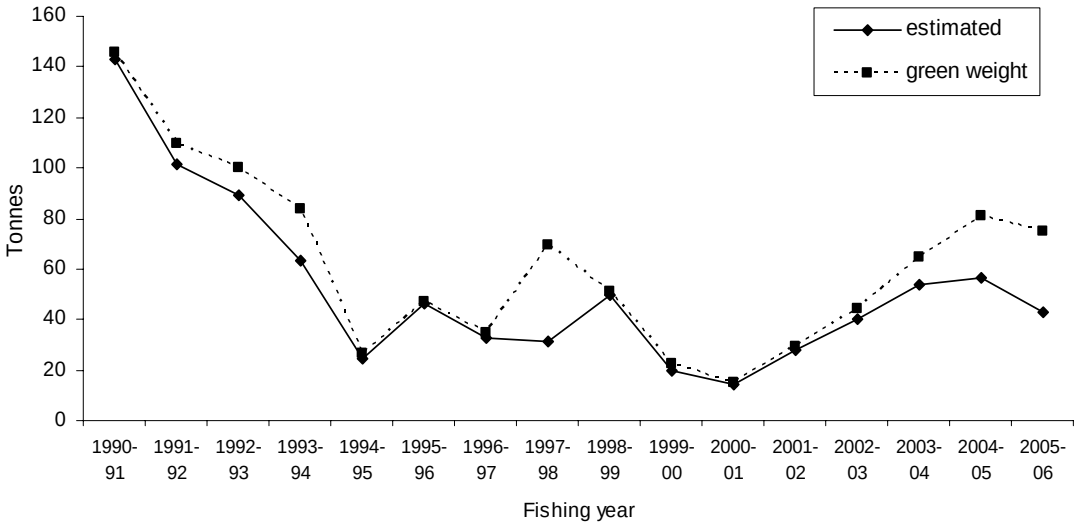



**Figure 9: Estimated and landed grey mullet greenweight totals from the Manukau Harbour setnet fishery.**

The estimated catches totals are similar to the true landed values over the first 12 years (Figure 9). It is not clear what caused the systematic trend to under-estimate catches over the last four fishing years. An examination of the data series of the nine vessels that contributed to the 2005–06 terminal year found six had identical departures in their estimated catch totals while three exhibited no departure. The information needed to determine whether the six departing vessels were owned by the same company or quota holder was deemed by the Ministry to be confidential and was not released. The prorating procedure resulted in the true catch (bottom) trajectory being used in the analysis.

### 3.5.3 Kaipara Harbour

Before data sub-setting, the initial dataset consisted of 16650 records. The total tonnage of grey mullet taken in other target fisheries was about 1% (Appendix 7) and this was deemed insufficient to accommodate a separate "non-target" class in the GLM analysis and data pertaining to non-target catches were dropped (2387 records).

Data from vessels fishing fewer than 5 days in a given fishing year were deleted (411 records). Dropping vessels with fewer than 2 years history in the fishery removed a further 422 records. In addition to the 20 top vessels (78% of the landed historical catch), four long-history vessels were also included in the final data set (8860 records; Appendix 8).

The estimated catches, although being slightly below the true landed values in most years, were reasonably well correlated in the final dataset (Figure 10).

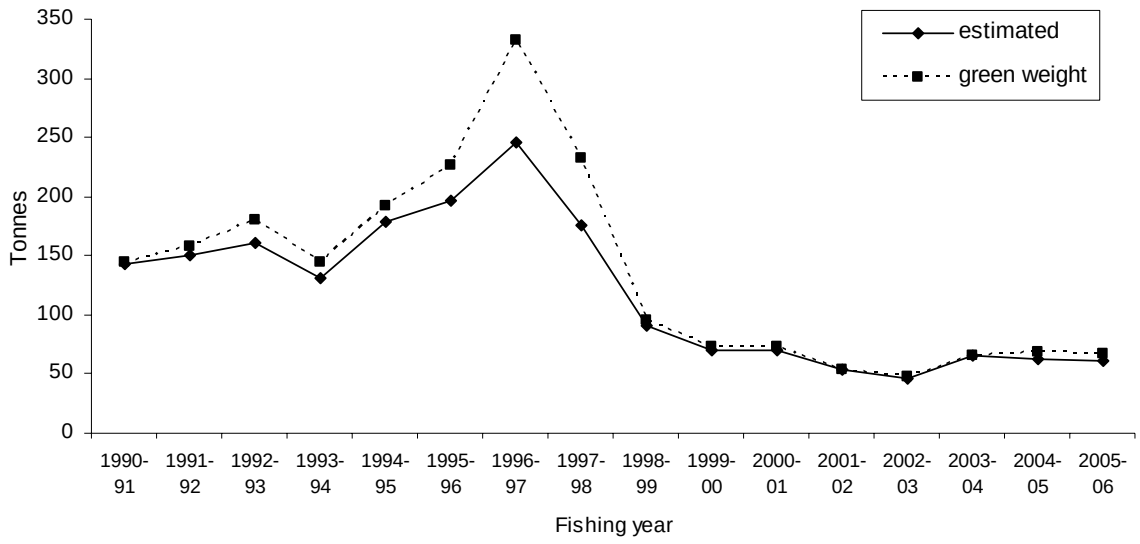



**Figure 10: Estimated and landed grey mullet greenweight totals from the Kaipara Harbour setnet fishery.**

### 3.5.4 Northwest Coast harbours

Before data sub-setting, the initial dataset consisted of 3001 records. The total tonnage of grey mullet taken in other target fisheries was less than 4% (Appendix 9) and this was deemed insufficient to incorporate a separate "non-target" class into the analysis, therefore data pertaining to non-target catches were dropped (335 records).

Data from vessels fishing less than 5 days in a given fishing year were deleted (140 records). Dropping vessels with less than 2 years history in the fishery excluded a further 223 records. Data from all 20 remaining vessels were retained for the final analysis (2303 records; Appendix 10).

The estimated catches, although being slightly below the true landed values in most years, were reasonably well correlated in the final dataset (Figure 11).

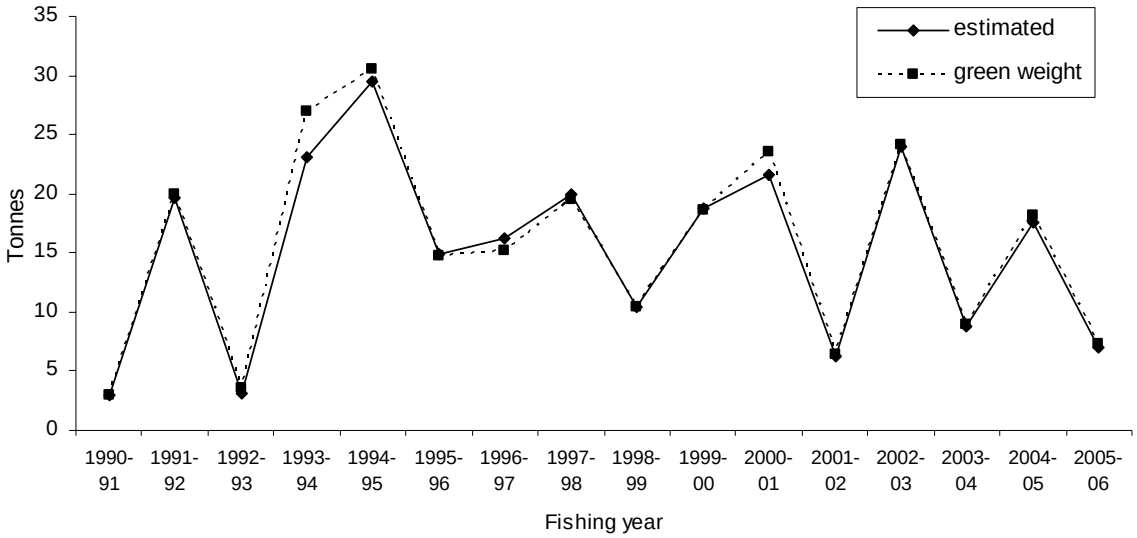



**Figure 11: Estimated and landed grey mullet greenweight totals from the Northwest Coast harbour setnet fisheries.**

### 3.5.5 East Northland

Before data sub-setting, the initial dataset consisted of 11912 records. The total tonnage of grey mullet taken in other target fisheries was less than 1% (Appendix 11) and this was deemed insufficient to incorporate a separate "non-target" class into the analysis, therefore data pertaining to non-target catches were dropped (541 records).

Data from vessels fishing fewer than 5 days in a given fishing year were deleted (404 records). Dropping vessels with fewer than 2 years history in the fishery removed a further 804 records. Nineteen vessels accounted for 74% of the landed historical catch; an additional four long history vessels were also included in the analysis (7201 records; Appendix 12).

The estimated catches, although being slightly below the true landed values in most years, were reasonably well correlated in the final dataset (Figure 12).

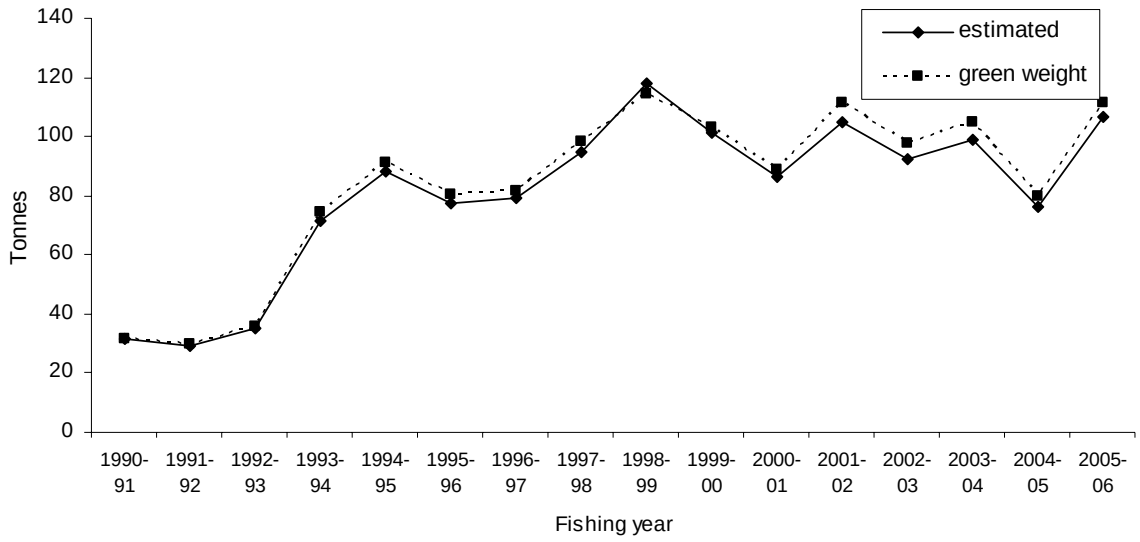



**Figure 12: Estimated and landed grey mullet green-weight totals from the East Northland harbour setnet fisheries.**

### 3.5.6 Hauraki Gulf

Before data sub-setting, the initial dataset consisted of 2540 records. The total tonnage of grey mullet taken in other target fisheries was about 5% (Appendix 13) and this was deemed insufficient to incorporate a separate "non-target" class into the analysis therefore data pertaining to non-target catches were dropped (572 records).

Data from vessels fishing fewer than 5 days in a given fishing year were deleted (326 records). Dropping vessels with fewer than 2 years history in the fishery removed a further 291 records. The 18 top vessels, accounting for 98% of the landed historical catch, were included in the final analysis plus one additional longer history vessel (1326 records; Appendix 14).

The estimated catches, although being slightly below the true landed values in most years, were reasonably well correlated in the final dataset (Figure 13).

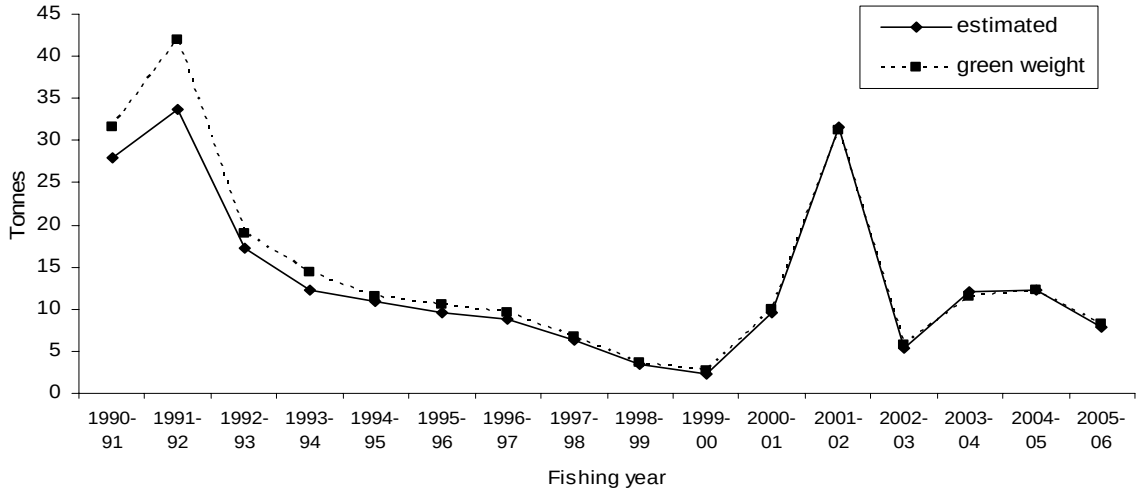



**Figure 13: Estimated and landed grey mullet greenweight totals from the Hauraki Gulf setnet fisheries.**

# 4 RESULTS

## 4.1 Lower Waikato River and harbours

Two observations produced inference (Cook's distance) scores higher than 0.05 in the terminating model. These observations were removed from the dataset and the stepwise process repeated. Three parameters were selected for the final GLM model on the bases of the 3% R-square improvement criteria (Table 3). Fyear was mandatorily included in the final GLM although it failed to meet the 3% R-square improvement criteria.

**Table 3: Stepwise regression results for Lower Waikato River & harbours setnet catches. Parameters chosen for the final GLM are shaded.**

| | AIC | % improvement | R-square | % improvement |
|---|---|---|---|---|
| | 11188.38 | | | |
| vessel | 8825.89 | 21.12 | 0.5094 | |
| net-length | 8658.36 | 1.90 | 0.5335 | 4.73 |
| vessel:net-length | 8537.05 | 1.40 | 0.5530 | 3.66 |
| duration | 8471.17 | 0.77 | 0.5619 | 1.61 |
| Fyear | 8416.73 | 0.64 | 0.5708 | 1.58 |
| vessel:duration | 8390.97 | 0.31 | 0.5766 | 1.02 |
| season | 8367.00 | 0.29 | 0.5800 | 0.59 |

The departure from the qq-line over the lower quantile range (Figure 14) is due to a lack of normality amongst the lower CPUE residuals and is indicative of process error in the GLM fit.

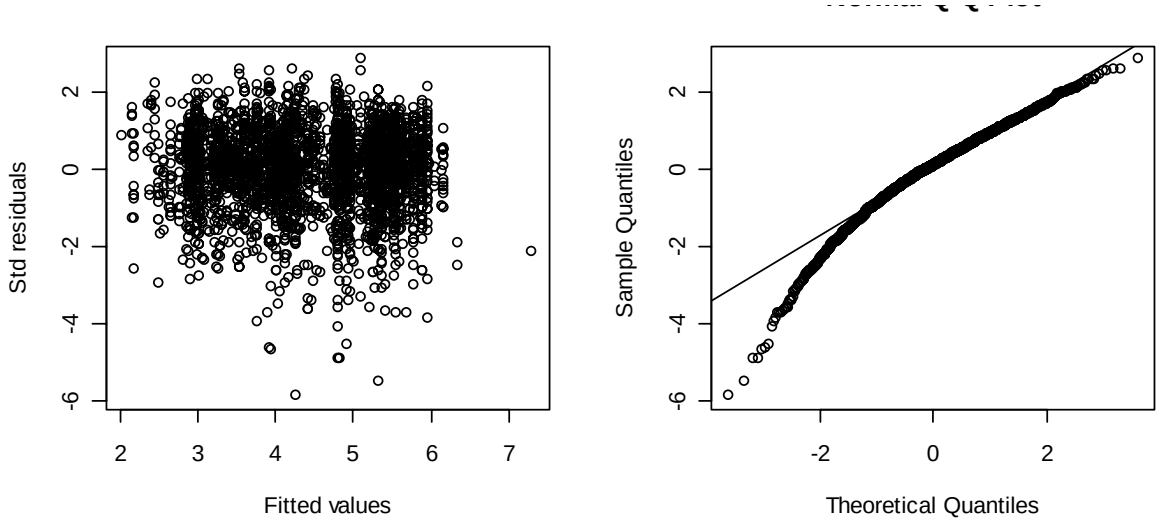



**Figure 14: Standardised residual and quantile-quantile plots for the Lower Waikato River & harbours final model fit.**

Lower Waikato River and harbours canonical year indices for the grey mullet setnet fishery are given in Appendix 15 and Figure 15.

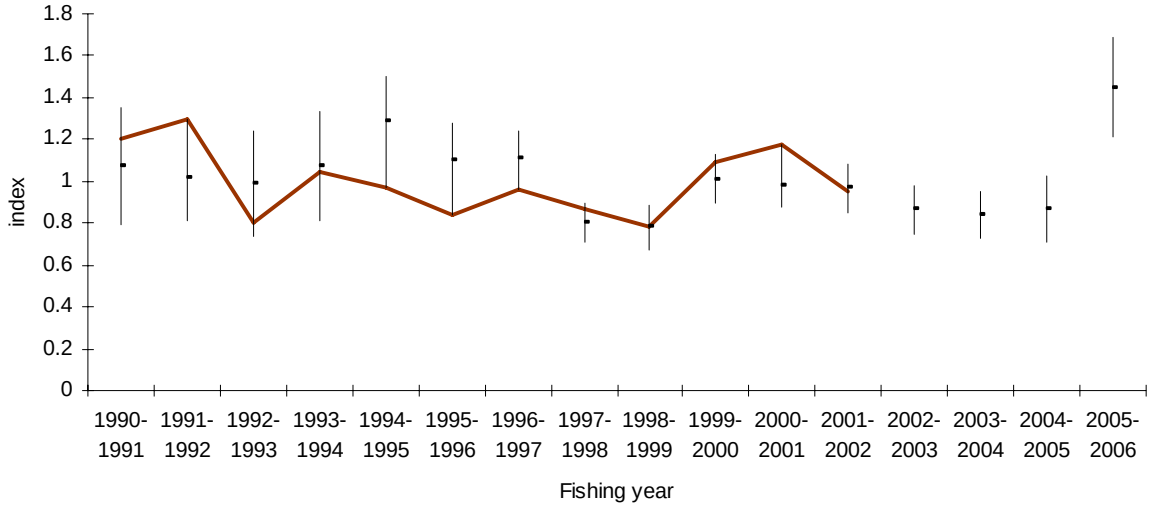



**Figure 15: Canonical year indices for Lower Waikato River and harbours with 95% confidence intervals (analytical); lines are the Watson et al. (2005) indices.**

## 4.2 Manukau Harbour (GMU 1)

No observations produced inference (Cook's distance) scores higher than 0.05 in the terminating model. Four parameters were selected for the final GLM model on the bases of the 3% R-square improvement criteria (Table 4).

**Table 4: Stepwise regression results for Manukau harbour setnet catches. Parameters chosen for the final GLM are shaded.**

| | AIC | % improvement | R-square | % improvement |
|---|---|---|---|---|
| | 17505.25 | | | |
| vessel | 15806.04 | 9.71 | 0.2745 | |
| Fyear | 15707.41 | 0.62 | 0.2897 | 5.54 |
| net-length | 15629.72 | 0.49 | 0.3001 | 3.59 |
| vessel:net-length | 15489.40 | 0.90 | 0.3204 | 6.76 |
| season | 15430.86 | 0.38 | 0.3282 | 2.43 |
| duration | 15418.48 | 0.08 | 0.3299 | 0.52 |
| vessel:duration | 15407.36 | 0.07 | 0.3335 | 1.09 |

The departure from the qq-line over the lower quantile range (Figure 16) is due to a lack of normality amongst the lower CPUE residuals and is indicative of process error in the GLM fit.

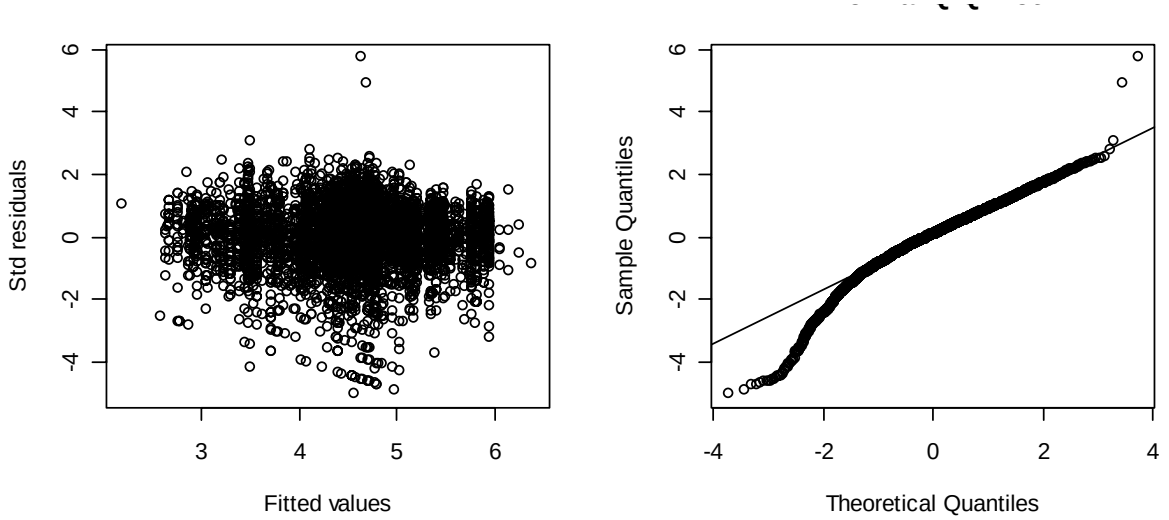



**Figure 16: Standardised residual and quantile-quantile plots for the Manukau Harbour final model fit.**

Manukau Harbour canonical year indices for the grey mullet setnet fishery are given in Appendix 15 and Figure 17.

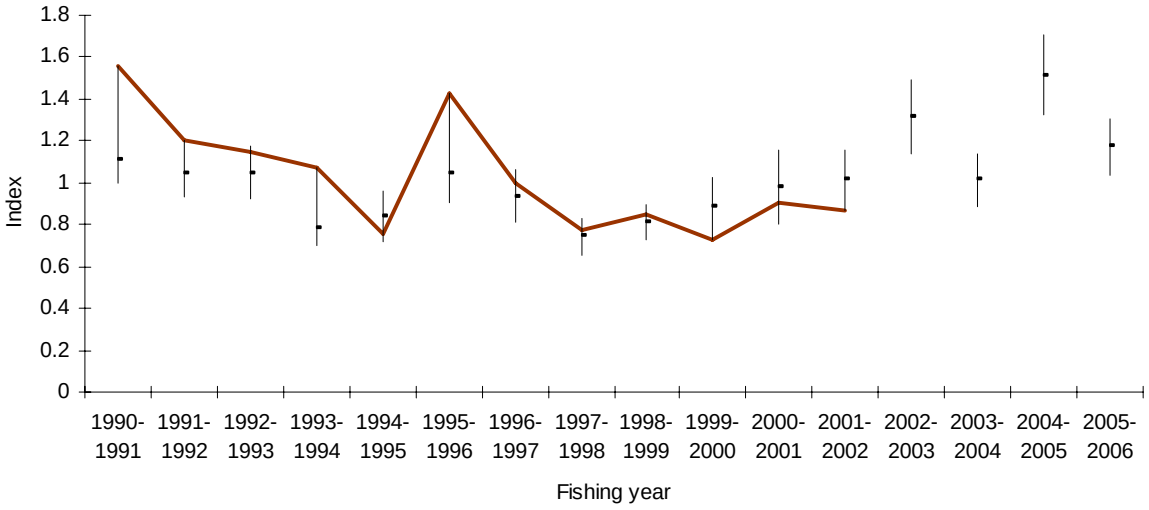



**Figure 17: Canonical year indices for Manukau Harbour with 95% confidence intervals (analytical); lines are the Watson et al. (2005) indices.**

## 4.3 Kaipara Harbour (GMU 1)

No observations produced inference (Cook's distance) scores higher than 0.05 in the terminating model. Five parameters were selected for the final GLM model on the bases of the 3% R-square improvement criteria (Table 5).

**Table 5: Stepwise regression results for Kaipara Harbour setnet catches. Parameters chosen for the final GLM are shaded.**

| | AIC | % improvement | R-square | % improvement |
|---|---|---|---|---|
| | 29068.48 | | | |
| vessel | 26001.32 | 10.55 | 0.2944 | |
| net-length | 25322.45 | 2.61 | 0.3465 | 17.70 |
| Fyear | 24837.27 | 1.92 | 0.3824 | 10.36 |
| vessel:net-length | 24559.27 | 1.12 | 0.4029 | 5.36 |
| duration | 24433.51 | 0.51 | 0.4114 | 2.11 |
| vessel:duration | 23722.16 | 2.91 | 0.4581 | 11.35 |
| season | 23669.50 | 0.22 | 0.4615 | 0.74 |
| vessel:season | 23517.58 | 0.64 | 0.4743 | 2.77 |

The departure from the qq-line over the lower quantile range (Figure 18) is due to a lack of normality amongst the lower CPUE residuals and is indicative of process error in the GLM fit.

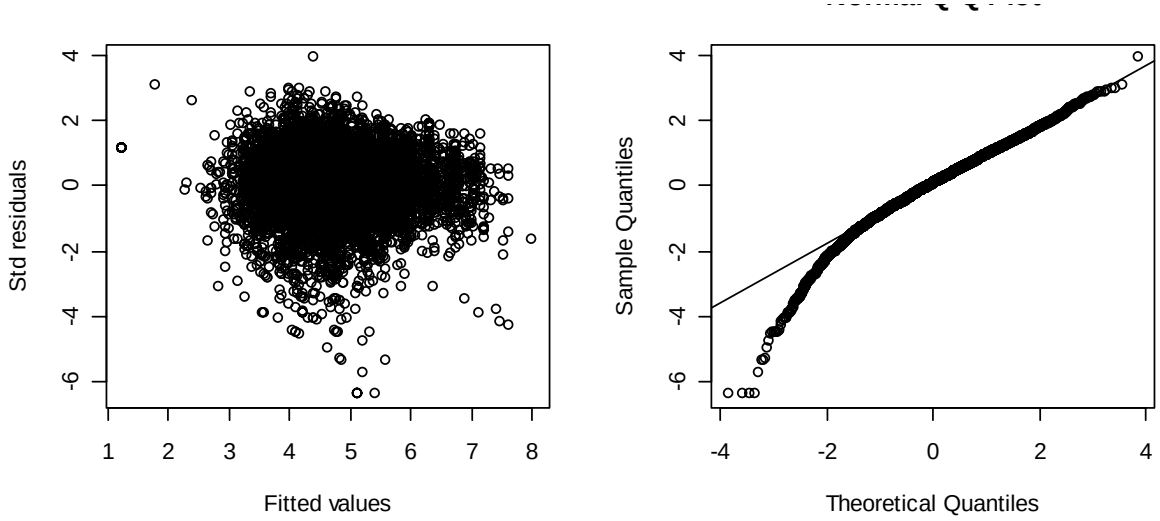



**Figure 18: Standardised residual and quantile-quantile plots for the Kaipara Harbour final model fit.**

Kaipara harbour canonical year indices for the grey mullet setnet fishery are given in Appendix 15 and Figure 19.

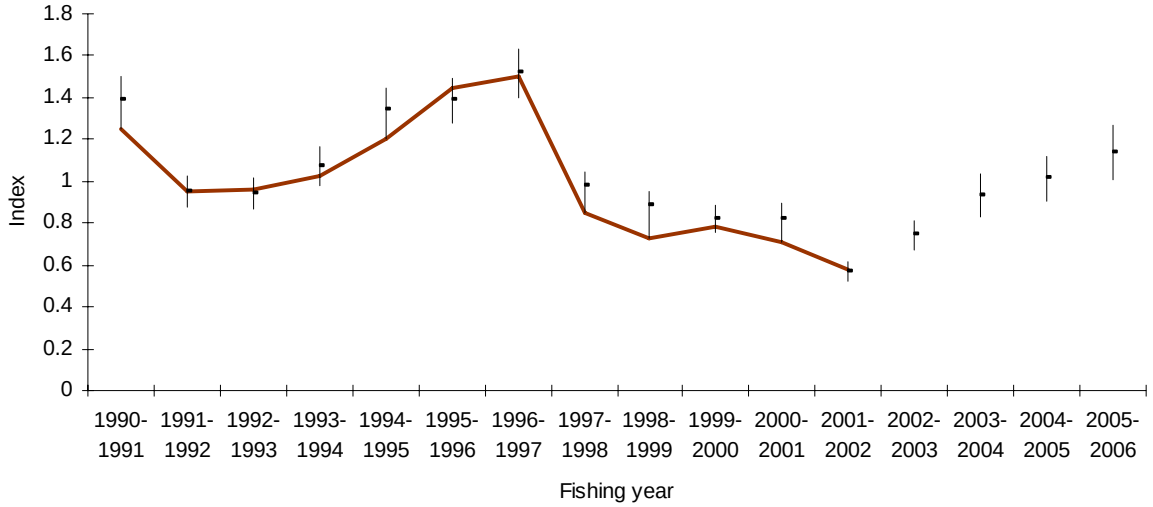



**Figure 19: Canonical year indices for Kaipara Harbour with 95% confidence intervals (analytical); lines are the Watson et al. (2005) indices.**

## 4.4 Northwest Coast harbours (GMU 1)

No observations produced inference (Cook's distance) scores higher than 0.05 in the terminating model. Four parameters were selected for the final GLM model on the bases of the 3% R-square improvement criteria (Table 6).

**Table 6: Stepwise regression results for Northwest Coast harbour setnet catches. Parameters chosen for the final GLM are shaded.**

| | AIC | % improvement | R-square | % improvement |
|---|---|---|---|---|
| | 7993.97 | | | |
| vessel | 6419.12 | 19.70 | 0.4994 | |
| Fyear | 6117.88 | 4.69 | 0.5636 | 12.86 |
| net-length | 5977.72 | 2.29 | 0.5896 | 4.61 |
| season | 5920.03 | 0.97 | 0.6002 | 1.80 |
| vessel:season | 5853.55 | 1.12 | 0.6194 | 3.20 |
| vessel:net-length | 5812.83 | 0.70 | 0.6287 | 1.50 |

The departure from the qq-line over the lower quantile range (Figure 20) is due to a lack of normality amongst the lower CPUE residuals and is indicative of process error in the GLM fit.

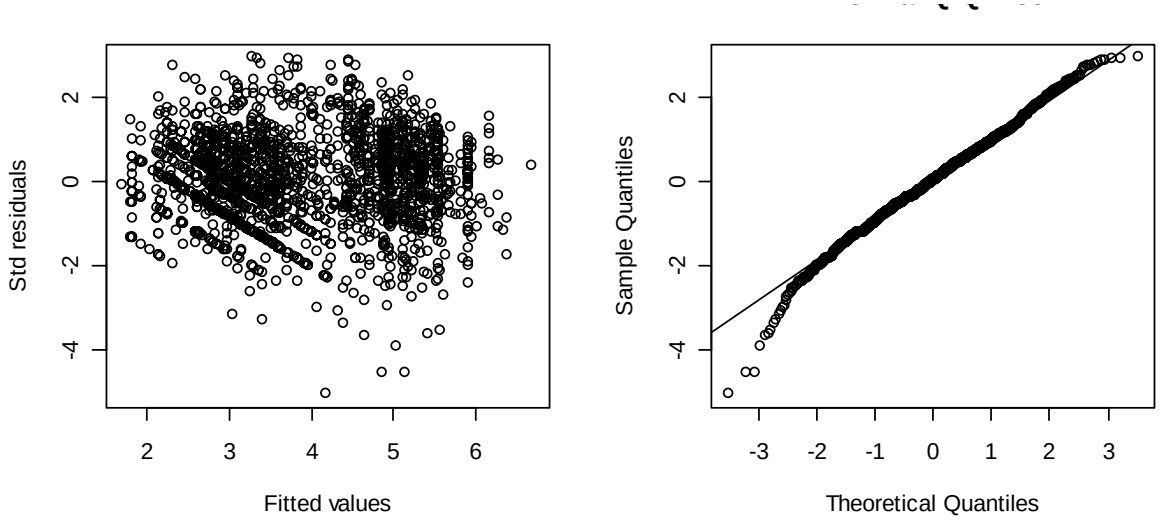



**Figure 20: Standardised residual and quantile-quantile plots for Northwest Coast harbours final model fit.**

Northwest Coast harbours canonical year indices for the grey mullet setnet fishery are given in Appendix 15 and Figure 21.

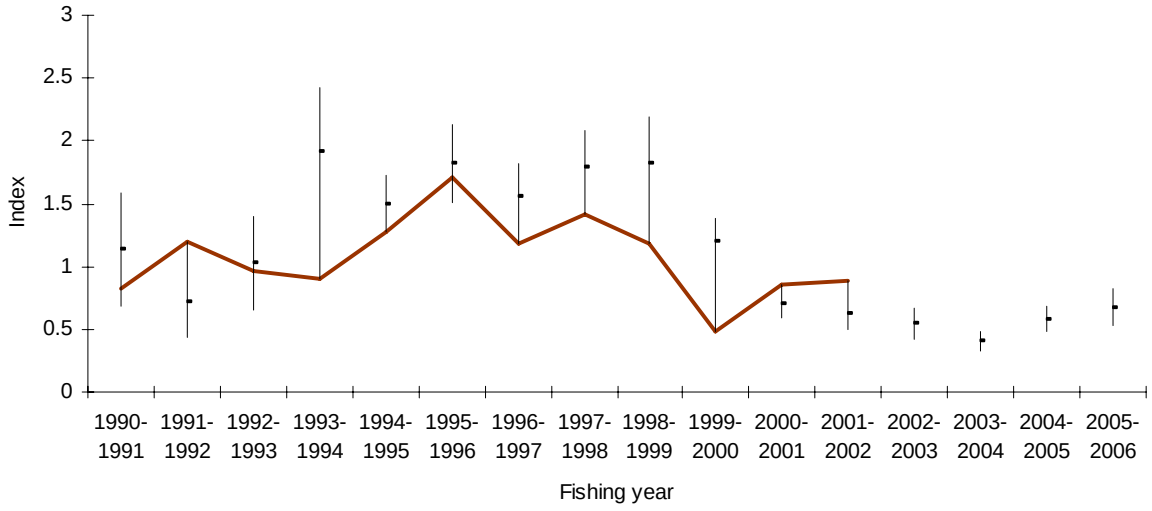



**Figure 21: Canonical year indices for Northwest Coast harbours with 95% confidence intervals (analytical); lines are the Watson et al. (2005) indices**

## 4.5 East Northland (GMU 1)

No observations produced inference (Cook's distance) scores higher than 0.05 in the terminating model. Three parameters were selected for the final GLM model on the bases of the 3% R-square improvement criteria (Table 7). Fyear was mandatorily included in the final GLM although it failed to meet the 3% R-square improvement criteria.

**Table 7: Stepwise regression results for East Northland setnet catches. Parameters chosen for the final GLM are shaded.**

| | AIC | % improvement | R-square | % improvement |
|---|---|---|---|---|
| | 24592.56 | | | |
| vessel | 21613.88 | 12.11 | 0.3408 | |
| duration | 20929.66 | 3.17 | 0.4006 | 17.55 |
| vessel:duration | 20783.74 | 0.70 | 0.4144 | 3.44 |
| fyear | 20680.43 | 0.50 | 0.424 | 2.32 |
| net-length | 20585.42 | 0.46 | 0.4316 | 1.79 |
| vessel:net-length | 20458.20 | 0.62 | 0.4431 | 2.66 |

The departure from the qq-line over the lower quantile range (Figure 22) is due to a lack of normality amongst the lower CPUE residuals and is indicative of process error in the GLM fit.

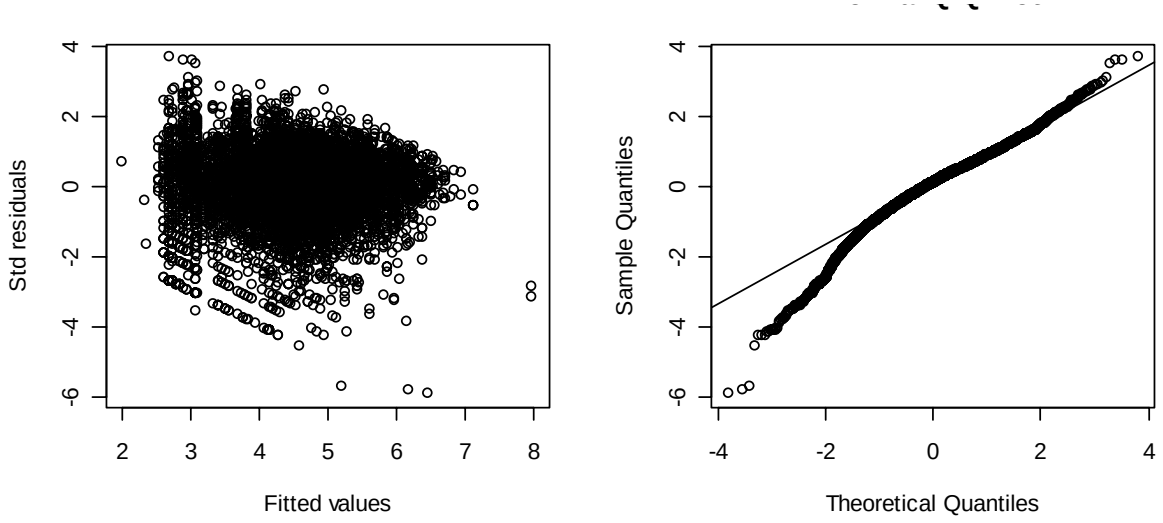



**Figure 22: Standardised residual and quantile-quantile plots for the East Northland final model fit.**

East Northland harbour canonical year indices for the grey mullet setnet fishery are given in Appendix 15 and Figure 23.

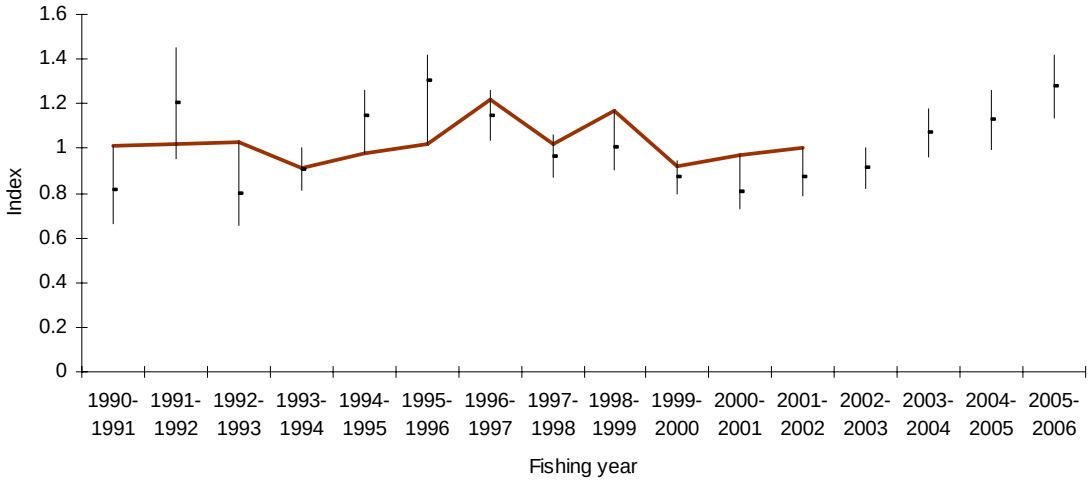



**Figure 23: Canonical year indices for East Northland with 95% confidence intervals (analytical); lines are the Watson et al (2005) indices.**

## 4.6 Hauraki Gulf (GMU 1)

No observations produced inference (Cook's distance) scores higher than 0.05 in the terminating model. Four parameters were selected for the final GLM model on the bases of the 3% R-square improvement criteria (Table 8).

**Table 8: Stepwise regression results for Hauraki Gulf setnet catches. Parameters chosen for the final GLM are shaded.**

| | AIC | % improvement | R-square | % improvement |
|---|---|---|---|---|
| | 5267.61 | | | |
| vessel | 4641.44 | 11.89% | 0.3856 | |
| season | 4605.90 | 0.77% | 0.4032 | 4.56% |
| vessel:season | 4546.01 | 1.30% | 0.4507 | 11.78% |
| fyear | 4526.19 | 0.44% | 0.4645 | 3.06% |
| net-length | 4525.99 | 0.00% | 0.4650 | 0.11% |
| season:net-length | 4518.91 | 0.16% | 0.4689 | 0.84% |

The departure from the qq-line over the lower quantile range (Figure 24) is due to a lack of normality amongst the lower CPUE residuals and is indicative of process error in the GLM fit.

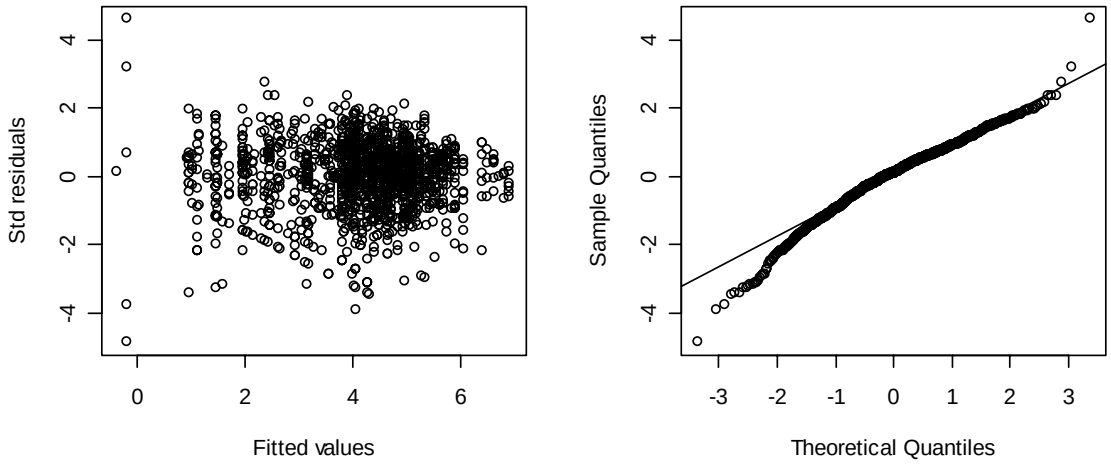



**Figure 24: Standardised residual and quantile-quantile plots for the Hauraki Gulf final model fit.**

Hauraki Gulf canonical year indices for the grey mullet setnet fishery are given in Appendix 15 and Figure 25.

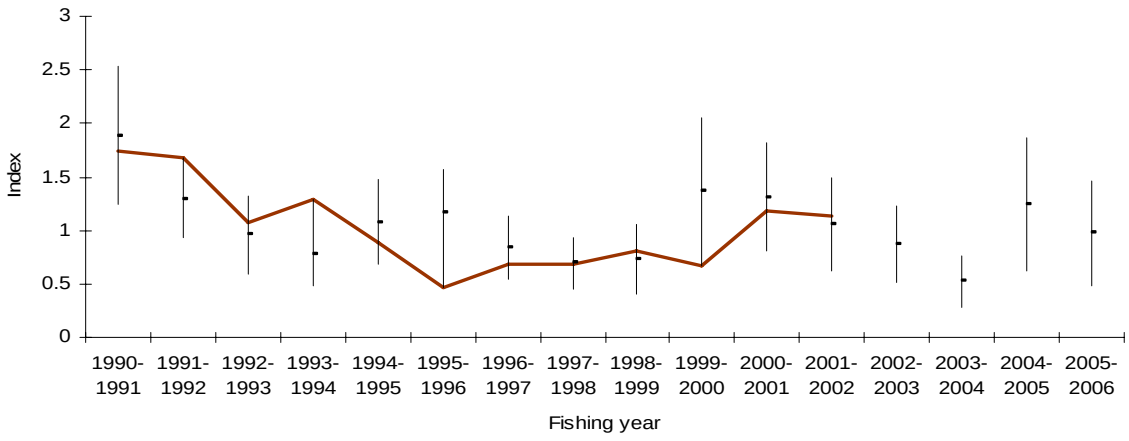



**Figure 25: Canonical year indices for Hauraki Gulf with 95% confidence intervals (analytical); lines are the Watson et al. (2005) indices.**

## 4.7 Area comparisons

None of the area indices are strongly positively correlated (Table 9; Figure 26) and the implication is that abundance signals across the GMU 1 sub-areas differ, i.e., there is no clear stock-wide trend.

**Table 9: Area index cross correlations. See Table 1 for area codes.**

| | MAN | KAI | NWC | ENL | HGL |
|---|---|---|---|---|---|
| LWR | -0.001 | 0.534 | 0.050 | 0.425 | 0.269 |
| MAN | - | -0.082 | -0.689 | 0.173 | 0.311 |
| KAI | -0.082 | - | 0.480 | 0.489 | 0.194 |
| NWC | -0.689 | 0.480 | - | 0.074 | -0.165 |
| ENL | 0.173 | 0.489 | 0.074 | - | -0.183 |

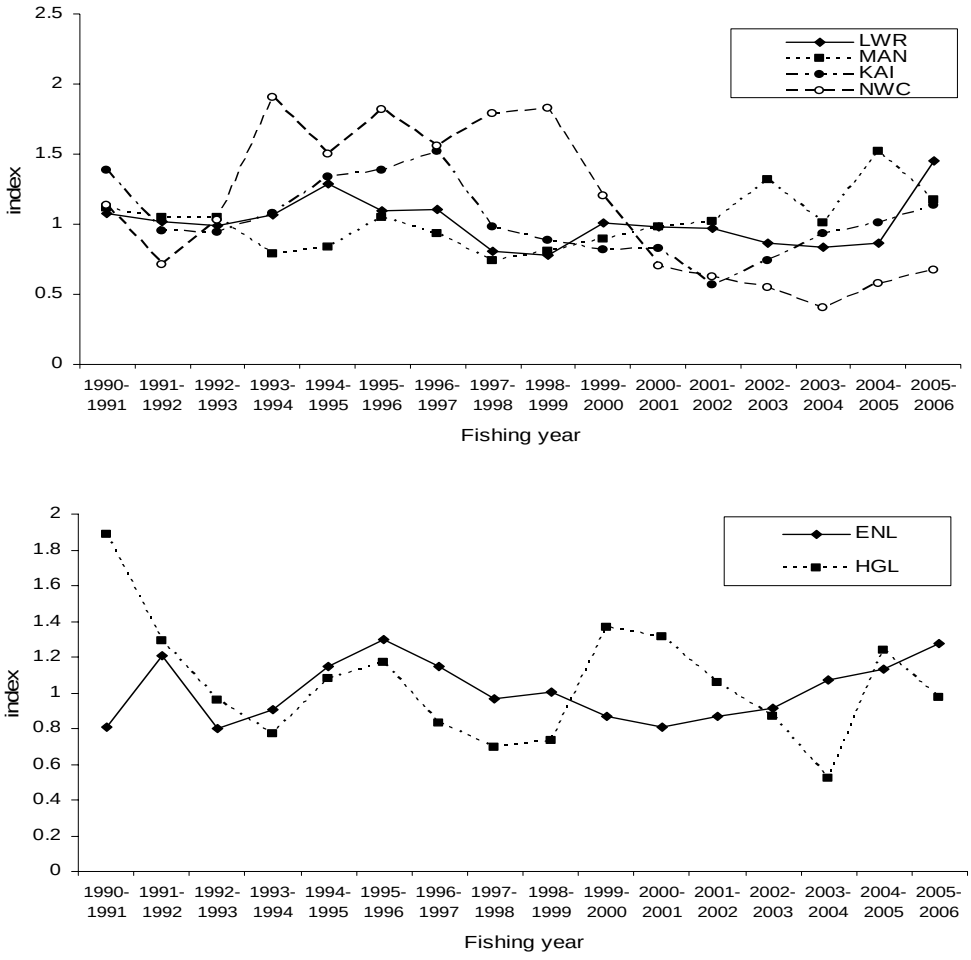



**Figure 26: Overlay of GMU 1 area indices by east and west coast showing the general lack of correlation.**

# 5 DISCUSSION

Most of the sub-area GLMS showed departures from normality in the CPUE data range tails. Departures were typically pronounced in the lower catch-weight residuals. This is evidence that the final models were not necessarily appropriate over the entire data range or more specifically there are significant levels of process error in the GLM fits. This should not be taken to mean that the tests of significance of the fishing-year parameter and the individual year indices themselves are invalid; the GLM approach is relatively robust to data non-normality. What it does mean is the variation on the individual year indices are likely to be wider than the analytical c.v.s suggest.

Fishing-year was an important explanatory parameter in the GLM fits for the Kaipara and Manukau harbours. Both these areas (which collectively account for over 65% of the average annual GMU 1 catch) show increasing trends in CPUE after 2002. This trend is also reflected in total annual GMU 1 catches over the same period with the TACC being reached for the first time in QMS history in 2004–05. The characterisation analysis showed most of the recent increase in GMU 1 catch came from the Kaipara and Manukau harbours. The overall conclusion is that the abundance of grey mullet within the Kaipara and Manukau harbours probably increased between 2002 and 2006. The collective GMU 1 fishery now appears to be constrained by the TACC, with further catch increases no longer possible.

The fishing-year parameter in the Lower Waikato River, East Northland and Hauraki Gulf GLM fits was only marginally explanatory, the inference being that there was no significant change in grey mullet abundance in these areas over the 16 year data period.

Cyclic trends in abundance were evident in the 16 year standardised CPUE indices from most areas. The Kaipara Harbour index suggests an abundance cycle spanning at least 10 years. Overall, the standardised CPUE indices from the six GMU 1 sub-areas show little similarity and do not correlate well, the implication being that the major GMU 1 harbours and embayments are home to relatively distinct sub-populations of grey mullet, distinct at least in terms of fishing pressures environmental constraints and recruitment success. If this premise is correct then the current strategy of managing these areas under a collective Northern New Zealand TACC (i.e., GMU 1) is sub-optimal as managers have little control over the level of fishing mortality each sub-population receives. Although historically no significant systematic shift in fishing pressure between areas has occurred, there is nothing legislatively to stop this from happening in the future. More information is needed about sub-area mixing rates to develop an optimum spatial management strategy for GMU 1. In the interim it would be advisable to split GMU 1 into separate east and west coast components.

In the short term, the GMU 1 CPUE data suggest that current catches are sustainable at least in the major catching areas. In the absence of a spatially stratified stock assessment of GMU 1 it is not possible to determine whether current levels of exploitation within GMU 1 will support Maximum Sustainable Yield (MSY) or move the stock toward MSY. Estimates of sub-area mixing are critical both to a formal stock assessment and the informed spatial management of GMU 1. Methods available to quantify sub-stock connectivity are tagging, otolith micro-chemistry profiling, or a combination of both. Additional information required to develop a spatially structured stock assessment model for GMU 1 are at least three years of catch-at-age information from the various GMU 1 sub-areas and data on the selectivity characteristics of ringnets and setnets.

## 6 ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries (project GMU200601). Special thanks to Bruce Hartill who provided assistance with data validation and grooming, Shelton Harley, whose query at a working group lead to the discovery of the “false-zero” problem, and Mike Beardsell for the final editorial review.

## 7 REFERENCES

Cook, R. D.; Weisberg, S. (1982). Residuals and influence in regression. Chapman and Hall, London.

Francis, R.I.C.C. (1999). The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 99/42. 30 p. (Unpublished report held in NIWA library, Wellington)

Ministry of Fisheries, Science Group (comps.) (2007). Report from the Fishery Assessment Plenary, May 2007: stock assessments and yield estimates. 875 p. (Unpublished report held in NIWA library, Wellington.)

Sakamoto, Y.; Ishiguro, M.; Kitagawa, G. (1986). Akaike Information Criterion statistics. D. Reidel Publishing Company.

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.)

Watson, T.; McKenzie, I.; Hartill, B. (2005). Catch per unit effort analysis of the notthem (GMU 1) grey mullet (*Mugil cephalus*) setnet fishery, 1989–2002. *New Zealand Fisheries Assessment Report 2006/22.* 36 p.

## Appendix 1: List of fields requested in the CELR database extract.

**Effort and estimated catch:**

Client_key
Vessel_key
DCF_key (linking key)
Rec Trip Start Date
Rec Trip End Date
Rec Landing Date
Trip Key
Fishing Date
Method Code
Statistical Area
Mesh size
Total Net Length
Duration
Target Species
Total Catch Weight (kg)
Top five Species
Top five Estimated Weight (kg)

**Landed catch**

Client_key
DCF_key (linking key)
Trip Key
Form Number
Rec Trip Start Date
Rec Trip End Date
Rec Landing Date
Rec Landing Point
Trip Key
Fishstock
Greenweight (kg)

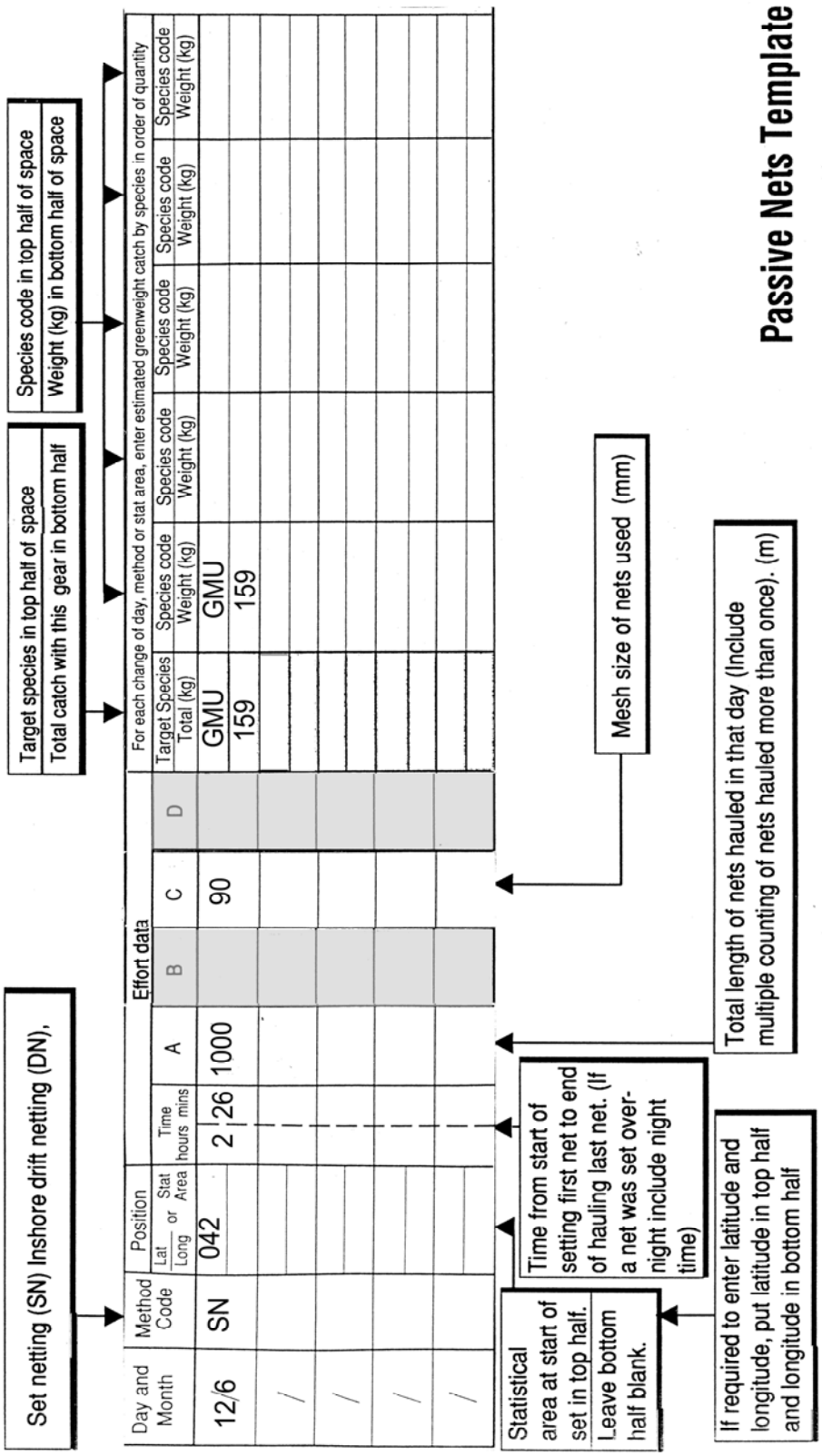
**Extract criteria**

1. Details from all trips where grey mullet (GMU 1) was landed

2. Details from all trips where grey mullet (GMU) was listed as a target species or listed in the top five species caught

This request consisted of two components:
- Effort data and estimated catch totals (CELR)
- Associated landed greenweight totals (CELR)

**Appendix 2: CELR effort form: Example of a correctly completed line of setnet effort**



**Appendix 3: Total grey mullet catch (t) in relation to target species from the Lower Waikato River setnet fishery 1990 to 2005; data for shaded species included in CPUE analysis.**

| target | catch (t) | records | % cum |
|---|---|---|---|
| GMU | 694 | 4038 | 97.98 |
| KAH | 7 | 118 | 98.94 |
| FLA | 6 | 229 | 99.72 |
| TRE | 1 | 15 | 99.86 |
| OTH | 1 | 12 | 99.95 |
| SPO | 0 | 10 | 100.00 |
| SNA | 0 | 3 | 100.00 |

**Appendix 4: Total grey mullet catch (t) in relation to vessel from the Lower Waikato River setnet fishery 1990 to 2006; data from the shaded vessels were used in the final analysis.**

| rank order | vessel id | history (yrs) | catch (t) | % cum |
|---|---|---|---|---|
| 1 | 15252 | 7 | 111 | 18.34 |
| 2 | 20577 | 4 | 79 | 31.39 |
| 3 | 15044 | 5 | 78 | 44.34 |
| 4 | 3161 | 3 | 66 | 55.35 |
| 5 | 3612 | 4 | 38 | 61.59 |
| 6 | 3106 | 2 | 37 | 67.70 |
| 7 | 8546 | 5 | 34 | 73.40 |
| 8 | 3797 | 10 | 22 | 77.09 |
| 9 | 3145 | 4 | 18 | 80.06 |
| 10 | 3880 | 3 | 14 | 82.31 |
| 11 | 8504 | 2 | 12 | 84.29 |
| 12 | 3693 | 9 | 11 | 86.06 |
| 13 | 15297 | 4 | 11 | 87.81 |
| 14 | 2910 | 10 | 9 | 89.26 |
| 15 | 3671 | 3 | 9 | 90.70 |
| 16 | 4597 | 7 | 8 | 92.11 |
| 17 | 3187 | 3 | 8 | 93.41 |
| 18 | 3055 | 4 | 7 | 94.52 |
| 19 | 3483 | 12 | 6 | 95.49 |
| 20 | 3268 | 4 | 6 | 96.45 |
| 21 | 3443 | 6 | 5 | 97.24 |
| 22 | 4992 | 7 | 4 | 97.93 |
| 23 | 20561 | 5 | 4 | 98.56 |
| 24 | 20794 | 2 | 3 | 99.10 |
| 25 | 15029 | 2 | 2 | 99.46 |
| 26 | 15567 | 2 | 2 | 99.74 |
| 27 | 237 | 2 | 1 | 99.95 |
| 28 | 4585 | 3 | 0 | 100.00 |

**Appendix 5: Total Grey mullet catch (t) in relation to target species from the Manukau Harbour setnet fishery 1990 to 2005; data for shaded species included in CPUE analysis.**

| target | catch (t) | records | % cum |
|---|---|---|---|
| GMU | 1263 | 7232 | 98.34 |
| FLA | 9 | 714 | 99.08 |
| SPO | 5 | 238 | 99.51 |
| TRE | 4 | 126 | 99.79 |
| KAH | 2 | 83 | 99.96 |
| SNA | 0 | 5 | 99.98 |
| OTH | 0 | 10 | 100.00 |

**Appendix 6: Total grey mullet catch (t) in relation to vessel from the Manukau Harbour setnet fishery 1990 to 2006; data from the shaded vessels were used in the final analysis.**

| rank order | vessel id | history (yrs) | catch (t) | % cum |
|---|---|---|---|---|
| 1 | 3223 | 15 | 137 | 12.17 |
| 2 | 237 | 8 | 120 | 22.81 |
| 3 | 3187 | 8 | 91 | 30.86 |
| 4 | 3612 | 9 | 91 | 38.91 |
| 5 | 3145 | 8 | 84 | 46.32 |
| 6 | 3121 | 5 | 81 | 53.45 |
| 7 | 3161 | 4 | 70 | 59.63 |
| 8 | 15252 | 8 | 67 | 65.52 |
| 9 | 15677 | 5 | 41 | 69.17 |
| 10 | 3353 | 9 | 34 | 72.17 |
| 11 | 15703 | 5 | 31 | 74.92 |
| 12 | 3055 | 12 | 26 | 77.24 |
| 13 | 3750 | 2 | 25 | 79.49 |
| 14 | 3640 | 10 | 24 | 81.61 |
| 15 | 3268 | 13 | 23 | 83.63 |
| 16 | 3689 | 9 | 22 | 85.60 |
| 17 | 20634 | 3 | 22 | 87.51 |
| 18 | 3589 | 3 | 20 | 89.27 |
| 19 | 15674 | 4 | 15 | 90.62 |
| 20 | 3336 | 8 | 13 | 91.76 |
| 21 | 3478 | 4 | 12 | 92.85 |
| 22 | 3443 | 13 | 10 | 93.76 |
| 23 | 3839 | 12 | 10 | 94.66 |
| 24 | 3769 | 4 | 9 | 95.44 |
| 25 | 3757 | 5 | 8 | 96.15 |
| 26 | 8676 | 5 | 8 | 96.81 |
| 27 | 408 | 2 | 6 | 97.35 |
| 28 | 15330 | 2 | 6 | 97.88 |
| 29 | 3173 | 4 | 5 | 98.35 |
| 30 | 3598 | 3 | 4 | 98.70 |
| 31 | 3582 | 5 | 3 | 99.01 |
| 32 | 15247 | 4 | 3 | 99.30 |
| 33 | 3144 | 3 | 3 | 99.58 |
| 34 | 3146 | 7 | 3 | 99.83 |
| 35 | 3820 | 3 | 2 | 100.00 |

**Appendix 7: Total Grey mullet catch (t) in relation to target species from the Kaipara Harbour setnet fishery 1990 to 2005; data for shaded species included in CPUE analysis.**

| target | catch t | records | % cum |
|---|---|---|---|
| GMU | 2817 | 14400 | 98.43% |
| FLA | 36 | 2085 | 99.70% |
| KAH | 6 | 96 | 99.90% |
| SPO | 2 | 43 | 99.97% |
| TRE | 1 | 20 | 99.99% |
| OTH | 0 | 6 | 100.00% |

**Appendix 8: Total grey mullet catch (t) in relation to vessel from the Kaipara Harbour setnet fishery 1990 to 2006; data from the shaded vessels were used in the final analysis.**

| rank order | vessel id | history (yrs) | catch (t) | % cum |
|---|---|---|---|---|
| 1 | 3579 | 10 | 666 | 25.12 |
| 2 | 50 | 14 | 386 | 39.69 |
| 3 | 15096 | 8 | 111 | 43.87 |
| 4 | 15055 | 6 | 98 | 47.57 |
| 5 | 3206 | 7 | 93 | 51.06 |
| 6 | 3344 | 12 | 71 | 53.73 |
| 7 | 15058 | 8 | 65 | 56.19 |
| 8 | 3121 | 3 | 62 | 58.52 |
| 9 | 8797 | 12 | 59 | 60.75 |
| 10 | 3118 | 16 | 54 | 62.77 |
| 11 | 3008 | 6 | 48 | 64.60 |
| 12 | 3637 | 11 | 47 | 66.37 |
| 13 | 45 | 14 | 47 | 68.13 |
| 14 | 4271 | 8 | 44 | 69.80 |
| 15 | 32 | 14 | 43 | 71.43 |
| 16 | 3420 | 5 | 42 | 73.02 |
| 17 | 3696 | 3 | 40 | 74.52 |
| 18 | 3597 | 3 | 35 | 75.85 |
| 19 | 159 | 5 | 33 | 77.11 |
| 20 | 3187 | 6 | 32 | 78.31 |
| 21 | 3835 | 11 | 30 | 79.43 |
| 22 | 35 | 9 | 27 | 80.44 |
| 23 | 3678 | 4 | 27 | 81.46 |
| 24 | 2210 | 5 | 25 | 82.42 |
| 25 | 15263 | 7 | 25 | 83.35 |
| 26 | 3666 | 6 | 23 | 84.20 |
| 27 | 3612 | 3 | 20 | 84.96 |
| 28 | 3263 | 4 | 20 | 85.71 |
| 29 | 2744 | 12 | 20 | 86.46 |
| 30 | 14 | 5 | 19 | 87.19 |
| 31 | 3881 | 2 | 19 | 87.91 |
| 32 | 15057 | 6 | 18 | 88.60 |
| 33 | 20523 | 5 | 18 | 89.27 |
| 34 | 3266 | 5 | 16 | 89.85 |
| 35 | 15252 | 2 | 15 | 90.43 |
| 36 | 2672 | 4 | 15 | 91.00 |
| 37 | 3147 | 7 | 14 | 91.52 |
| 38 | 3706 | 2 | 12 | 91.95 |
| 39 | 15136 | 4 | 11 | 92.38 |
| 40 | 15461 | 4 | 10 | 92.78 |
| 41 | 13632 | 2 | 10 | 93.17 |
| 42 | 2733 | 6 | 10 | 93.55 |
| 43 | 2536 | 2 | 10 | 93.92 |
| 44 | 2318 | 2 | 9 | 94.27 |
| 45 | 3274 | 3 | 9 | 94.62 |
| 46 | 9818 | 2 | 9 | 94.95 |
| 47 | 20594 | 5 | 8 | 95.25 |
| 48 | 2459 | 9 | 7 | 95.52 |
| 49 | 408 | 2 | 7 | 95.78 |
| 50 | 2593 | 2 | 7 | 96.02 |
| 51 | 3598 | 3 | 7 | 96.27 |
| 52 | 2651 | 2 | 6 | 96.51 |
| 53 | 15337 | 3 | 6 | 96.74 |
| 54 | 3832 | 4 | 6 | 96.97 |
| 55 | 4582 | 2 | 5 | 97.17 |
| 56 | 10337 | 7 | 5 | 97.37 |
| 57 | 3428 | 3 | 5 | 97.56 |
| 58 | 8926 | 6 | 5 | 97.75 |
| 59 | 13840 | 2 | 5 | 97.92 |
| 60 | 4 | 3 | 5 | 98.10 |
| 61 | 10329 | 2 | 4 | 98.26 |
| 62 | 3829 | 3 | 4 | 98.40 |
| 63 | 3145 | 2 | 4 | 98.54 |
| 64 | 2265 | 3 | 4 | 98.68 |
| 65 | 109 | 2 | 4 | 98.81 |
| 66 | 4568 | 2 | 3 | 98.94 |
| 67 | 2073 | 2 | 3 | 99.06 |
| 68 | 20720 | 3 | 3 | 99.16 |
| 69 | 3246 | 2 | 3 | 99.27 |
| 70 | 3247 | 2 | 3 | 99.37 |
| 71 | 2656 | 2 | 3 | 99.47 |
| 72 | 3100 | 7 | 2 | 99.56 |
| 73 | 3831 | 2 | 2 | 99.65 |
| 74 | 15140 | 3 | 2 | 99.72 |
| 75 | 2317 | 3 | 2 | 99.79 |
| 76 | 15176 | 2 | 2 | 99.85 |
| 77 | 8510 | 3 | 1 | 99.90 |
| 78 | 2649 | 2 | 1 | 99.95 |
| 79 | 13837 | 2 | 1 | 99.98 |
| 80 | 2516 | 2 | 1 | 100.00 |

**Appendix 9: Total Grey mullet catch (t) in relation to target species from the Northwest Coast harbour setnet fisheries 1990 to 2005; data for shaded species included in CPUE analysis.**

| Target | catch (t) | records | % cum |
|---|---|---|---|
| GMU | 294 | 2728 | 96.67 |
| FLA | 8 | 286 | 99.20 |
| SPO | 1 | 32 | 99.54 |
| OTH | 1 | 6 | 99.83 |
| TRE | 1 | 11 | 100.00 |
| KAH | 0 | 1 | 100.00 |

**Appendix 10: Total grey mullet catch (t) in relation to vessel from the Northwest Coast harbour setnet fisheries 1990 to 2006; data from the shaded vessels were used in the final analysis.**

| rank order | vessel id | history (yrs) | catch (t) | % cum |
|---|---|---|---|---|
| 1 | 2714 | 6 | 54 | 21.56 |
| 2 | 2210 | 10 | 39 | 37.08 |
| 3 | 2615 | 6 | 30 | 48.98 |
| 4 | 3579 | 2 | 25 | 59.13 |
| 5 | 20613 | 3 | 23 | 68.46 |
| 6 | 109 | 7 | 13 | 73.59 |
| 7 | 2593 | 2 | 13 | 78.59 |
| 8 | 2588 | 2 | 10 | 82.48 |
| 9 | 2743 | 2 | 9 | 85.95 |
| 10 | 2672 | 2 | 7 | 88.62 |
| 11 | 2649 | 6 | 5 | 90.68 |
| 12 | 15461 | 2 | 5 | 92.67 |
| 13 | 20649 | 3 | 5 | 94.47 |
| 14 | 20661 | 3 | 3 | 95.75 |
| 15 | 2802 | 4 | 3 | 96.76 |
| 16 | 2504 | 4 | 2 | 97.56 |
| 17 | 162 | 2 | 2 | 98.35 |
| 18 | 54 | 2 | 2 | 99.14 |
| 19 | 2384 | 2 | 1 | 99.70 |
| 20 | 2083 | 5 | 1 | 100.00 |

**Appendix 11: Total Grey mullet catch (t) in relation to target species from the East Northland harbour setnet fisheries 1990 to 2005; data for shaded species included in CPUE analysis.**

| Target | catch t | records | % cum |
|---|---|---|---|
| GMU | 1871 | 11487 | 99.26 |
| FLA | 6 | 376 | 99.60 |
| SNA | 3 | 70 | 99.75 |
| OTH | 2 | 64 | 99.85 |
| TRE | 2 | 32 | 99.95 |
| KAH | 1 | 12 | 99.99 |
| SPO | 0 | 6 | 100.00 |

**Appendix 12: Total grey mullet catch (t) in relation to vessel from the East Northland harbour setnet fisheries 1990 to 2006; data from the shaded vessels were used in the final analysis.**

| rank order | vessel id | history(yrs) | catch (t) | % cum | rank order | vessel id | history(yrs) | catch (t) | % cum |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 90 | 10 | 227 | 13.20 | 34 | 2309 | 3 | 14 | 90.45 |
| 2 | 2615 | 15 | 108 | 19.51 | 35 | 2672 | 4 | 14 | 91.23 |
| 3 | 2150 | 16 | 96 | 25.07 | 36 | 2414 | 4 | 13 | 91.97 |
| 4 | 5240 | 6 | 92 | 30.44 | 37 | 2076 | 4 | 12 | 92.68 |
| 5 | 2747 | 8 | 84 | 35.30 | 38 | 2593 | 3 | 10 | 93.26 |
| 6 | 15399 | 6 | 83 | 40.11 | 39 | 2685 | 2 | 9 | 93.78 |
| 7 | 19 | 4 | 77 | 44.58 | 40 | 2579 | 2 | 9 | 94.29 |
| 8 | 2714 | 9 | 66 | 48.40 | 41 | 8535 | 4 | 9 | 94.79 |
| 9 | 2302 | 5 | 63 | 52.09 | 42 | 15449 | 2 | 8 | 95.26 |
| 10 | 2352 | 4 | 56 | 55.34 | 43 | 2374 | 5 | 8 | 95.73 |
| 11 | 15510 | 5 | 46 | 58.02 | 44 | 3090 | 2 | 8 | 96.19 |
| 12 | 2778 | 7 | 42 | 60.47 | 45 | 2487 | 3 | 7 | 96.57 |
| 13 | 91 | 5 | 40 | 62.82 | 46 | 2588 | 3 | 6 | 96.94 |
| 14 | 4660 | 5 | 37 | 64.97 | 47 | 2601 | 2 | 6 | 97.30 |
| 15 | 2233 | 5 | 34 | 66.95 | 48 | 2517 | 2 | 6 | 97.66 |
| 16 | 2711 | 4 | 33 | 68.86 | 49 | 2590 | 2 | 6 | 98.01 |
| 17 | 15461 | 4 | 30 | 70.59 | 50 | 2516 | 10 | 5 | 98.29 |
| 18 | 15292 | 6 | 28 | 72.25 | 51 | 2238 | 4 | 4 | 98.54 |
| 19 | 2728 | 8 | 24 | 73.67 | 52 | 2328 | 3 | 4 | 98.79 |
| 20 | 2351 | 3 | 24 | 75.06 | 53 | 20811 | 2 | 4 | 99.01 |
| 21 | 2684 | 3 | 23 | 76.41 | 54 | 2766 | 2 | 4 | 99.22 |
| 22 | 2375 | 3 | 23 | 77.75 | 55 | 2681 | 2 | 3 | 99.39 |
| 23 | 2809 | 7 | 23 | 79.09 | 56 | 2510 | 2 | 3 | 99.56 |
| 24 | 2552 | 2 | 22 | 80.38 | 57 | 2789 | 2 | 3 | 99.72 |
| 25 | 15227 | 6 | 20 | 81.55 | 58 | 2570 | 2 | 2 | 99.84 |
| 26 | 2465 | 4 | 19 | 82.68 | 59 | 2481 | 3 | 1 | 99.91 |
| 27 | 2564 | 3 | 19 | 83.78 | 60 | 15687 | 2 | 0 | 99.94 |
| 28 | 2376 | 8 | 19 | 84.86 | 61 | 88 | 2 | 0 | 99.96 |
| 29 | 386 | 3 | 17 | 85.86 | 62 | 74 | 2 | 0 | 99.98 |
| 30 | 2548 | 2 | 17 | 86.84 | 63 | 10530 | 2 | 0 | 99.99 |
| 31 | 2360 | 3 | 16 | 87.80 | 64 | 2459 | 2 | 0 | 100.00 |
| 32 | 2674 | 3 | 16 | 88.71 | | | | | |
| 33 | 20613 | 4 | 15 | 89.61 | | | | | |

**Appendix 13:** **Total Grey mullet catch (t) in relation to target species from the Hauraki Gulf setnet fisheries 1990 to 2005; data for shaded species included in CPUE analysis.**

| Target | catch t | records | % cum |
|---|---|---|---|
| GMU | 312 | 2022 | 94.51 |
| FLA | 7 | 307 | 96.65 |
| SPO | 4 | 46 | 97.76 |
| SNA | 3 | 69 | 98.57 |
| KAH | 2 | 96 | 99.30 |
| TRE | 2 | 47 | 99.86 |
| OTH | 0 | 18 | 100.00 |

**Appendix 14:** **Total grey mullet catch (t) in relation to vessel from the Hauraki Gulf setnet fisheries 1990 to 2006; data from the shaded vessels were used in the final analysis.**

| rank order | vessel id | history (yrs) | catch (t) | % cum |
|---|---|---|---|---|
| 1 | 570 | 8 | 52 | 22.37 |
| 2 | 3161 | 3 | 25 | 33.11 |
| 3 | 3640 | 11 | 24 | 43.52 |
| 4 | 2210 | 3 | 20 | 52.07 |
| 5 | 15605 | 2 | 18 | 59.89 |
| 6 | 15657 | 2 | 14 | 66.04 |
| 7 | 15252 | 7 | 14 | 72.14 |
| 8 | 3612 | 3 | 14 | 78.09 |
| 9 | 3237 | 2 | 10 | 82.25 |
| 10 | 3145 | 2 | 8 | 85.68 |
| 11 | 3485 | 9 | 7 | 88.54 |
| 12 | 3121 | 2 | 5 | 90.78 |
| 13 | 15023 | 2 | 5 | 92.89 |
| 14 | 15481 | 4 | 4 | 94.82 |
| 15 | 15058 | 2 | 3 | 95.99 |
| 16 | 3581 | 2 | 3 | 97.15 |
| 17 | 20647 | 2 | 2 | 97.84 |
| 18 | 2970 | 5 | 1 | 98.45 |
| 19 | 20634 | 2 | 1 | 98.99 |
| 20 | 15336 | 2 | 1 | 99.30 |
| 21 | 3044 | 4 | 1 | 99.60 |
| 22 | 15593 | 2 | 1 | 99.86 |
| 23 | 15269 | 2 | 0 | 100.00 |

**Appendix 15: Setnet annual canonical indices for the main GMU 1 sub-stock areas; bracketed numbers are c.v.s.**

| fishing year | Lower Waikato | Manukau Harbour | Kaipara Harbour | Northwest Coast | East Northland | Hauraki Gulf |
|---|---|---|---|---|---|---|
| 1990-1991 | 1.08 (0.13) | 1.11 (0.05) | 1.39 (0.04) | 1.13 (0.2) | 0.81 (0.09) | 1.88 (0.17) |
| 1991-1992 | 1.02 (0.1) | 1.05 (0.06) | 0.95 (0.04) | 0.71 (0.19) | 1.2 (0.1) | 1.29 (0.14) |
| 1992-1993 | 0.99 (0.13) | 1.05 (0.06) | 0.94 (0.04) | 1.03 (0.18) | 0.8 (0.09) | 0.96 (0.19) |
| 1993-1994 | 1.07 (0.12) | 0.79 (0.05) | 1.07 (0.04) | 1.91 (0.13) | 0.91 (0.05) | 0.77 (0.19) |
| 1994-1995 | 1.28 (0.08) | 0.84 (0.07) | 1.34 (0.04) | 1.5 (0.07) | 1.14 (0.05) | 1.08 (0.18) |
| 1995-1996 | 1.1 (0.08) | 1.05 (0.07) | 1.39 (0.04) | 1.81 (0.09) | 1.3 (0.05) | 1.17 (0.17) |
| 1996-1997 | 1.11 (0.06) | 0.94 (0.07) | 1.52 (0.04) | 1.56 (0.09) | 1.15 (0.05) | 0.83 (0.18) |
| 1997-1998 | 0.8 (0.06) | 0.74 (0.06) | 0.98 (0.03) | 1.79 (0.08) | 0.96 (0.05) | 0.7 (0.17) |
| 1998-1999 | 0.78 (0.07) | 0.81 (0.05) | 0.88 (0.04) | 1.83 (0.1) | 1 (0.05) | 0.73 (0.22) |
| 1999-2000 | 1.01 (0.06) | 0.89 (0.08) | 0.82 (0.04) | 1.2 (0.08) | 0.87 (0.04) | 1.36 (0.25) |
| 2000-2001 | 0.98 (0.05) | 0.98 (0.09) | 0.82 (0.04) | 0.7 (0.08) | 0.81 (0.05) | 1.31 (0.19) |
| 2001-2002 | 0.97 (0.06) | 1.02 (0.07) | 0.57 (0.04) | 0.63 (0.11) | 0.87 (0.05) | 1.06 (0.21) |
| 2002-2003 | 0.87 (0.07) | 1.32 (0.07) | 0.74 (0.05) | 0.55 (0.12) | 0.91 (0.05) | 0.87 (0.21) |
| 2003-2004 | 0.84 (0.07) | 1.01 (0.06) | 0.93 (0.06) | 0.4 (0.1) | 1.07 (0.05) | 0.52 (0.23) |
| 2004-2005 | 0.87 (0.09) | 1.52 (0.06) | 1.01 (0.05) | 0.58 (0.09) | 1.13 (0.06) | 1.24 (0.25) |
| 2005-2006 | 1.45 (0.08) | 1.17 (0.06) | 1.14 (0.06) | 0.68 (0.11) | 1.28 (0.05) | 0.97 (0.25) |