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EXECUTIVE SUMMARY

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This report examines changes in the SPO 1 and 8 fisheries for rig between 1989–90 and 2003–04, using target set net catch per unit effort (CPUE) data from the commercial fishery, and available data from trawl surveys. It fulfils the requirements of Objective 1 of the Ministry of Fisheries project SPO2003/01.''To monitor the SPO 1 and SPO 8 fisheries using:

a. standardised set net catch per unit effort (CPUE) updated to 2003/04
b. trawl survey data

Rig (*Mustelus lenticulatus*) is a small shark that aggregates in near inshore waters to breed during spring and summer. It supports several locally important target set net fisheries. As rig is routinely processed at sea to the "trunked" processed state, reported greenweight is calculated by fishers using a conversion factor. Separate substocks have been identified within SPO 1 (Thames, east coast North Island, Manukau, Kaipara, west coast North Island), and separate standardised CPUE models were completed for these areas, and for SPO 8. As many vessels fished for only a brief time in these fisheries, a group of core vessels was also identified and separately analysed for each area.

Two separate analyses were completed. The first analysis, which examined estimated greenweight catch (kg per set) indicated apparently declining trends in annual CPUE indices for each substock of SPO 1 and for SPO 8, that were consistent with previous data. However, these trends were confounded with conversion factor changes during the review period (from 2.0 in 1989–90, to 1.55 in 1999–2000) that had not been consistently applied to the data. Other data errors and inconsistencies were found which compromised the use of calculated greenweight data for CPUE analysis.

An alternative analysis is presented where landed greenweight (kg) was calculated directly from the reported processed catch data (kg per trip), using the current conversion factor (1.55) for all years in the analysis. This method required the restratification, re-allocation, and merging of the available data. It has more usually been applied to the analysis of bycatch fisheries. While a similar number of records (29 076 and 30 267 records respectively) were extracted in both analyses, a considerably higher greenweight (4923 t and 7747 t respectively) was extracted in the second analysis. The annual CPUE indices of this model of greenweight CPUE (log (kg)) showed little change between 1990–91 and 2003–04 for the substocks of SPO 1 (except for the Manukau subregion, where a declining trend was apparent), and for SPO 8. As approximately equal numbers of rig were taken in each SPO 1 subregion, the apparent decline in Manukau may represent reduced numbers of rig entering this harbour, rather than any change in overall rig abundance.

The effect of conversion factor changes on trends in CPUE data raise significant concerns for other rig fishstocks, and for CPUE analyses for other species, such as stargazer, ling, and other elasmobranchs, where conversion factors used to calculate greenweight may have changed over time.

An investigation of the trawl survey series conducted off the east and west coasts of the North Island confirmed that trawl surveys targeted at certain year classes of various finfish species in waters less than 400 m deep are not an appropriate tool to monitor the abundance of either juvenile or adult rig.

1. INTRODUCTION

Rig (*Mustelus lenticulatus*) is a small shark that occurs widely throughout New Zealand coastal waters. It commonly aggregates in near-inshore waters (to 50 m) to breed during spring and summer (Hendry 2004), and these aggregations support several locally important inshore fisheries. Rig is currently managed as six fishstocks (Figure 1), of which the two northern fishstocks, SPO 1 and SPO 8, were examined in this analysis. Rig is also taken in other areas of New Zealand, including the west coast from the South Taranaki Bight to Tasman Bay, the Canterbury Bight, and Kaikoura (Hartill 2002, Annala et al. 2004).

The SPO 1 fishstock can be divided into two sub-regions (Paul 2003), SPO 1-east, and SPO 1-west (Figure 2). SPO 1-east includes the inshore statistical areas 1–10 off the east coast of the North Island (ECNI). Important fisheries occur in the Hauraki Gulf (areas 005 and 006), and Thames (area 007). The SPO 1-west sub-stock includes the coastal inshore statistical areas (42–48) off the west coast of the North Island (WCNI), and locally important fisheries occur off Ninety-Mile Beach (area 47), in Kaipara Harbour (area 44), and the Manukau Harbour in area 43 (Figure 2).

The SPO 8 fishstock includes the coastal inshore statistical areas 37–41 off the ECNI, with no major harbours. This analysis included only rig declared as SPO 8, as some rig catch from areas 37 and 39 has been reported as the SPO 7 (west coast South Island) fishstock, and some of the catch from the northern waters of area 41 has been landed to the SPO 1 fishstock (see Figures 1 & 2).

Most rig is taken by setnet fishing (Paul 2003), and most is taken in target fishing (Appendix 1). Rig is a minor bycatch of inshore trawl, Danish seine, net, and line fisheries (Paul 2003, Manning et al. 2004, Watson et al. 2005), but the exact composition of landings by method is unknown, as method data are available for only a portion of the rig catch in the CELR database (Annala et al. 2004).

Rig is considered to have relatively low productivity and may be prone to overfishing (Annala et al. 2004). The rig fisheries in New Zealand were considered to be overfished during the mid 1980s, and rig was introduced into the QMS (Quota Management System) in 1985–86 with the TACCs (Total Allowable Commercial Catches) for each fishstock set under the precautionary principle to allow for stocks to rebuild (Francis & Smith 1988, Paul 2003). By the early 1990s anecdotal information suggested that the rig fishstocks (other than SPO 10) had recovered (Paul 2003), and these were subsequently included in the Adaptive Management Programme (AMP) in 1991–92. The TACC for the northern fishstock (SPO 1) was increased from 688 t to 829 t in 1991–92, to 829 t in 1993–94, an increase of 17%. The TACC for the Taranaki fishstock (SPO 8) was increased from 310 to 370 t in 1990–91, an increase of 16% (Annala et al. 2004). Catch and non-standardised CPUE indices for SPO 1 and SPO 8 subsequently declined (Vignaux 1997), and these fishstocks were removed from the AMP in 1997–98, when the TACCs reverted to the 1990–91 levels.

Subsequent analysis of trends in catch and non-standardised CPUE indices indicated a continuing decline in catch and relative abundance between 1996–97 and 2000–01 (Paul 2003). Recent catches have remained below the reduced TACC (692 t in SPO 1 and 310 t in SPO 8), with catches of 436 t in 2001–02 and 476 t in 2003–04 for SPO 1, and 216 t in 2001–02 and 208 t in 2003–04 for SPO 8.

The specific objective of Project SPO2003/01 was to monitor rig fisheries in SPO 1 and SPO 8 using:

a. standardised setnet catch per unit effort (CPUE) updated to 2003–04
b. trawl survey data.

This analysis of standardised CPUE [log (kg)] for rig in SPO 1 and 8 was based on recalculated greenweight catch, derived from the reported processed catch using the current conversion factor (CF) of 1.55, where effort variables "net length" and "duration" were log transformed. It involved the restratification, re-allocation, and merging of the available CELR data. The methods generally follow Paul (2003) and Starr (2003), who used similar methods for the CPUE analysis of bycatch data, where not all of the catch per set may be correctly reported on the Catch Effort and Landing Form (CELR). In this case, the approach was found necessary due to errors in the CELR data that were used for an initial standardised CPUE analysis of estimated greenweight catch (kg per set), which was discarded. This initial analysis was consistent with previous reviews of CPUE completed for the Kaipara sub-region of SPO 1 (Hartill 2002, Paul 2003), and updates these data to 2003–04. However, these previous reports were also based on reported greenweight catches, where changes in CF were not taken into account, and trends in CPUE indices from these reports should therefore also be interpreted with caution.

Other information on rig distribution and relative abundance may be available from trawl surveys carried out in SPO 1 and SPO 8. This report also briefly summarises available data.

Setnet fishing has been implicated in the deaths of marine mammals.The Ministry of Fisheries closed several areas of the WCNI to all recreational and commercial setnet fishing in 2003. These areas include known rig breeding grounds (Paul 2003), and these changes may have implications in the interpretation of standardised CPUE indices for the 2003–04 fishing year.

2. METHODS

2.1 Conversion factors

Rig, like most elasmobranchs, is routinely processed at sea to the "dressed" landed state to remove the blood from the flesh before it can break down to ammonia and taint the flesh. The landed weight of processed rig is scaled up to a greenweight equivalent by applying a legally defined conversion factor (CF). This was set at 2.0 between 1960 and the 1991–92 fishing year, then reduced to 1.75 for the 1992–93 to 1998–99 fishing years, and further reduced to the present value of 1.55 from the 1999–2000 fishing year. Even though these different conversion factors have been used to convert processed weight to green weight during the analysis period, it has been assumed that the "dressing" procedures used by fisher's had not changed during this time.

2.2 CELR data

All commercial setnet catch-effort and landings data in New Zealand are recorded on the CELR form. This form comprises two parts, which are separately entered into the CELR database. The upper portion records the skipper's estimate of greenweight catch (kg) of the target species, and four bycatch species for each set. It also provides effort data (number of sets per day, and the length of net) on a daily basis. For species such as rig, where greenweight product is almost never landed, the lower portion of the form reports the actual weight of the "dressed" processed product that was landed at the end of the trip (Duckworth 2002). This is then pro-rated up to greenweight, using the conversion factor. The landed greenweight catch per trip is also reported on the Licensed Fish Receiver Return (LFRR).

2.3 Data selection

The data were derived from an extract of the Ministry of Fisheries (MFish) catch-effort and landings database, w*arehou.* Fishing trips where at least one setnet fishing event targeting rig in any statistical area in SPO 1 and 8 *or* where a landing of rig caught in SPO 1 or 8 was recorded between 1 October 1989 and 30 September 2004 were identified and all fishing and landing events associated with these trips were extracted from the database.

2.4 Preliminary standardised CPUE analysis of estimated catch

A preliminary standardised analysis of estimated greenweight CPUE (kg/set) was completed for each sub-region of SPO 1 and SPO 8 between 1989–90 and 2003–04, following the methods of Hartill (2002), but this analysis was discarded due to concerns about the estimated greenweight data as reported on the Quota Management System (QMS) database. However, the methods and results are briefly reported (see Appendix 2), as both the data available, and the methods used, are consistent with previous CPUE analyses in SPO 1 and 8.

2.5 Data integrity

Several issues were identified concerning the estimated greenweight catch data on the CELR database. Firstly, it was assumed that fishers directly estimated their reported greenweight catches after each set. This appeared to be invalid, as many fishers appeared to have delayed reporting their estimated greenweight catch until the completion of the trip. These data were then pro-rated from the landed processed catch data, and then applied to the catch per set data for the trip.

Secondly, the calculated greenweight (either as "estimated greenweight catch" or "calculated greenweight landings", as reported on the QMS database appears to be the uncorrected data as supplied by fishers. These data have not been corrected for changes in CF that have occurred during the review period. Thirdly, the application of conversion factors in the database has not been consistent across the fishery. In any one year a range of values exists on the QMS database, including reported greenweight catch that appears to represent processed catch. Due to these inconsistencies, both the estimated greenweight catch and the greenweight landings data reported on the CELR database were considered unreliable.

2.6 Data processing

To avoid these problems, an alternative approach was used, which generally followed the methods of Paul (2003), Starr (2003), and Manning et al. (2005). This involved the re-stratification, re-allocation, and merging of the landed catch data by trip, with the effort data for each set. This approach has previously been used in the analysis of bycatch fisheries, to overcome a major limitation of the CELR reporting system, where fishers are required to report only the top five species in their catches by weight, resulting in the frequent non- or under-reporting of species which make up only a minor component of the catch. In this case, however, the method was applied to a target fishery because it was considered to be the best way to reallocate the reported landed processed catch by trip to individual set records. At this time, Starr's algorithm is believed to allow the maximum amount of information to be extracted from a CELR-derived dataset, but extensive (e.g., simulation) testing of the benefits of his approach has not yet been carried out to our knowledge.

2.6.1 Restratification and the catch-allocation procedure

The basic unit of data within Starr's algorithm is the fishing trip. The algorithm links valid landings data from a valid fishing trip with the corresponding valid fishing effort for that trip. The major steps in the algorithm are described below.

- The fishing-effort and landings data are first groomed separately. Outlier values failing range checks are corrected using median imputation. The range checks used in this analysis are given in Table 1.

- The fishing effort within each valid trip is then restratified by statistical area, method, and target species.

- The greenweight landings are then mapped to the effort strata using the relationship between the statistical area for each effort stratum and the statistical areas contained within each fishstock.

- The greenweight landings are then allocated to each associated effort stratum using the total estimated catch in each stratum as a proportion of the total estimated catch for each trip. If estimated catches were not recorded for a given trip, but a landing in either SPO 1 or 8 was recorded, then the total fishing effort (total amount of net set in metres) in each stratum as a proportion of the total fishing effort for the trip is used to allocate the greenweight landed catch.

A step-by-step summary of the algorithm is given in appendix B of Manning et al. (2004). Data were stored in a Microsoft Access database and the algorithm was implemented using SQL statements and the "R" statistical programming language (R Development Core Team 2004). Given the concerns about mis-reporting of estimated catch due to the changes in rig conversion factors discussed above, during our grooming of the landings data, we applied a "catch consistency" algorithm to cross-check the total estimated, total processed, and total greenweight landed catch for each trip.

2.6.2 Catch-consistency checking algorithm

The aim of the catch-consistency algorithm run is to cross-check the total estimated, total processed, total recorded greenweight, and rig conversion factors for each fishing trip in the dataset against each other and so estimate a "most-plausible" total rig greenweight for each trip and thereby overcome any recording errors in the data for each trip that might be associated with the conversion factor changes described above. There are four steps in the algorithm. For each fishing trip in the dataset, these are:

```
step one:
if (land ≈ cf_old × proc || land ≈ cf_old × est || land ≈ est && !land ≈ proc)
then use = (cf_new / cf_old) × land
else go to step two;

step two:
if (land ≈ proc)
then use = cf_new × land
else go to step three;

step three:
if (est ≈ proc || est ≈ cf_old × proc)
then use = cf_new × proc
else go to step four;

step four:
reject trip;
```

where land is the total landed catch per trip, proc is the total processed catch per trip, est is the total estimated catch per trip, cf_old is the old rig conversion factor, cf_new is the new rig conversion factor, use is the most-plausible total landed catch per trip, "||" is a logical "or" statement, "&&" is a logical "and" statement and "!" is a logical "not" statement.

2.6.3 Criteria used to select effort strata from the groomed, restratified, and merged dataset for the CPUE model fits

The effort strata SPO 1 (east), SPO 1 (west) and SPO 8 used in the analysis are defined in Table 2. They comprise several statistical areas, as shown in Figure 2. All records within these strata where the landing date was between 1 October 1989 and 30 September 2004 (inclusive), and where at least 1 t of total catch occurred over the dataset, were included in the analysis.

2.7 Description of variables offered to the CPUE models

The extracted and derived variables used in the CPUE analysis are listed in Table 3, and frequency distributions were generated for the main variables. Most variables are self-explanatory, but some require further definition. The dependent variable was greenweight (kg) of rig. Predictor variables included vessel key (vessels were not identified by name) and date and location of fishing (statistical area, see Figure 2). The predictor variables "net length", "duration", and the estimated catch were summed within each stratum, where the number of records represented the number of fishing trips per stratum, to ensure that each record of catch and effort referred to a unique fishing operation. From this new data extract, a total of 94 304 unique effort data records and 116 079 landings data records were available. Both "net length" and "duration" were log transformed in the model.

Many of the sets may be influenced by tidal cycles, particularly in tidal harbours such as Kaipara and Manukau, where placement may be limited to deeper water channels, and the effective fishing time may be reduced at certain points in the lunar cycle. Lunar periodicity (illuminated portion of the moon) was included as an explanatory variable. This was calculated from the data using an S function (R. Coburn, NIWA, pers. comm. 2005) and the derived data were checked with the New Zealand Nautical Almanac for accuracy.

The 2049 zero catch records may represent gear failure, and they were excluded from the analysis. These data fall well below the nominal 10% threshold where separate analysis of fishing success and fishing effort is recommended (Doonan 1991). The distribution of these zero catch records was non-random, and unlikely to reflect patterns in fishing activity. A similar pattern in zero catch data was discovered in the recent FLA 1 and FLA 8 setnet CPUE analysis (R. Coburn, pers comm. 2005).

2.8 Models used in the analysis of calculated greenweight catch

Rig landings from the target setnet fishery are split approximately equally (0.44: 0.56) between the east and west coasts. Within SPO 1-east, Hartill (2002) and Paul (2003) recognised a major fishery in the Firth of Thames, and this sub-region accounted for 63% of the SPO1-east landed greenweight catch of 2299 t (Table 4) between 1989–90 and 2003–04. Separate analyses were completed for the Thames and adjacent open coast ("Other-east") sub-regions of SPO 1-east.

In the SPO 1-west region, landed greenweight catch of 2932 t was taken almost equally (0.29: 0.33: 0.38) among the three sub-regions, Kaipara, Manukau, and the open coast ("Other-west"). Separate analyses were completed for these three sub-regions.

The landed greenweight catch of 2515 t from SPO 8 represents 32% of the total combined landings from SPO 1 and SPO 8. A separate analysis was competed for this fishstock (Table 4).

2.9 Determination of core vessels

Many of the vessels that reported rig catch in SPO 1 and SPO 8 during the 1989–90 to 2003–04 review period were involved in the fishery for a relatively short time (1–2 years). These vessels commonly had a very small rig catch, and their effort is likely to contribute little to the CPUE analysis. Vessels with a total catch of less than 1 t in each substock during the review period were excluded from analysis.

Core vessels were defined for each sub-region (SPO 1) or fishstock (SPO 8). Vessel catch and fishing experience (integer number of years in the fishery) were tabulated, and vessels were grouped by fishing experience to identify the level of fishing experience that corresponded with a minimum of 75% of the total catch of the sub-region. All vessels with the minimum fishing experience were included as core vessels. Relatively few of the core vessels actually fished in more than one sub-region, and their fishing history was allocated to each sub-area accordingly.

2.10 Movement of core vessels

The level of mobility of rig fishing outside the main sub-regions of SPO 1 (Thames, Manukau, and Kaipara) and in SPO 8 may change over time and indicate local depletion of rig. Given the many unique vessels involved in the fishery, data were confined to core vessels only. The number of times that each core vessel fished in more than one statistical area in any year was summarised to assess the changes in the fishery over time.

2.11 Model structure

A stepwise linear regression modelling approach was used (Doonan 1991, Vignaux 1994) to review the extent to which the variability in rig catch may be explained by available predictor variables. The dependent variable was catch (kg), and the catch data were log transformed to stabilise the variance. The effort variables "net length" and "duration" were log transformed, and the remaining predictor variables entered the model as categorical variables.

The vessel, gear, and environmental parameters were plotted against raw CPUE to review the data structure and identify outliers. Estimates of the relative seasonal effects were obtained from a stepwise multiple regression method, where the data were modelled with a loglinear model. A manual forward stepwise multiple regression algorithm was used (Doonan 1991) using the Proc GLM (General Linear Modelling) procedure of the SAS statistical software (SAS 2005). The model excluded observations with missing values from analysis. The number of observations available to the model thus varied depending upon which particular set of variables was included in the model. Variables were progressively added to the model until less than 1% improvement was seen in R^2 (percentage of variance explained by the model) following the inclusion of each additional variable. As the number of observations available for analysis in some sub-regions was low, the F statistic was also examined for each additional variable. If this was not significant at the 5% level, the variable was excluded from the model, even if it explained more than 1% of the data variability.

Analysis was confined to the main effects only, because including interaction terms with data of this type was more likely to result in over-fitting than in producing genuine improvements in the explanatory power of the model. Residual plots were examined for evidence of departures from model assumptions.

3. RESULTS

3.1 Preliminary data analysis

The initial analysis was based on an extract of 29 076 records of estimated greenweight catch from target setnet fishing in SPO 1 and 8 that represented a total greenweight catch of 4293 t. This is substantially lower than the recalculated restratified greenweight total of 7747 t derived from 30 267 records in the second analysis.

3.2 Results of the restratification and merging algorithm

The restratification procedure was based on a unique trip key. From the unprocessed data, 116 079 unique trip keys were present in the *Landings* table, and 94 304 effort strata were present in the *Effort* table, but only 88 902 records occurred in both data tables (Table 5). The grooming process analysis was confined to these records, and the remaining data were discarded.

There was slightly more than one effort stratum per trip (Table 5). After the grooming procedure, 55 912 unique setnet fishing effort strata remained in the *Effort* table, and 54 800 unique setnet fishing trip keys remained in the *Landings* table. Analysis was restricted to records that appeared in both datasets.

The tables were merged, providing 54 800 unique records. As statistical areas do not exactly match the Quota Management Areas (QMAs) for rig, data were excluded from analysis due to boundary statistical area errors. The amount of the catch merged (Recovery rate) varied among fishing years in the time series (Table 6), due to variability in the number of such boundary statistical areas in each fishstock.

3.3 CPUE analysis

3.3.1 Description of major variables

Frequency histograms of the major variables log net length (m), log duration (hours fished), and log catch (kg) are presented (Appendix 3) for each sub-region of SPO 1 and for SPO 8.

3.3.2 Core vessels

The report presents analyses of CPUE from the core vessels, determined from each sub-region of SPO 1 and for SPO 8 (Table 7). The results for the all-vessels analysis for each of these areas were substantially similar, but with a slightly less well behaved error structure. These data have not been reported here.

The proportion of rig greenweight landings reported by the core vessels varied between 80% (SPO 8) and 86% (Other-west) (see Table 7). Frequency histograms (see Appendix 3) indicate considerable variability in fishing experience (years in the fishery) among vessels. Most vessels had short-medium term experience, and few vessels were present during the entire survey period.

The 2005 Inshore Working Group meeting noted that any increase in the spread of fishing activity during the review period could be suggestive of local depletion of rig. The CELR data reports represent a crude estimate of fishing location by statistical area only. Changes in the location of fishing (statistical area) were analysed for core vessels where fishing occurred in the offshore coastal sub-regions of SPO 1 (Other-east, and Other-west) and SPO 8, which included several statistical areas. The data (not presented here) showed no trend in vessel movements between statistical areas consistent with local depletion of rig during the review period.

3.3.3 CPUE analysis of calculated greenweight landings

3.3.3.1 SPO 1-east

Four variables entered the model (vessel, month, net length, and fishing year) and together they explained 42% of data variability in landed catch for Thames (Statistical area 007) (Table 8). The vessel indices were variable, and seasonal indices show the highest catch rate in October and November. CPUE was positively associated with net length and the annual indices are variable with little trend (Figure 3).

Four variables also entered the model for Other-east. Variables "vessel", "duration", "fishing year", and "month" entered the model and explained 41% of data variability (Table 9). The relative indices and standard errors (Table 9) follow similar patterns to the Thames region. The annual indices are variable with a slightly rising trend (Figure 4).

3.3.3.2 SPO 1-west

Five variables (net length, vessel, month, fishing year, and duration) entered the model for Kaipara (Statistical area 44) and together they explained 55% of data variability in landed catch (Table 10). Vessel indices were variable, and catch rate was highest in October-November. Catch rate was positively associated with net length and duration. The annual indices were variable, with a peak in 1995–96 (Figure 5).

Five variables (vessel, month, net length, fishing year, duration) entered the Manukau (Statistical area 45) model and explained 53% of data variability (Table 11). The vessel indices were variable, and highest catch rates occurred during September and October. Annual indices indicated a declining trend (Figure 6), and both duration of fishing and net length were positively associated with catch rate. Because few records were available for the 1989–90 fishing year, the 2005 Inshore Working Group Meeting requested that the analysis be repeated with the 1989–90 fishing year excluded. This revised analysis (Table 12, Figure 7) provided a similar rate of decline in annual indices to the all-years analysis (see Figure 6).

Four variables entered the Other-west model (vessel, month, net length, and statistical area), and fishing year was forced into the model to derive annual indices. The model explained 37% of data variability (Table 13). The vessel indices were variable, and the monthly indices were consistent with a spring-summer fishery. Net length was positively associated with CPUE and catch rates varied among statistical areas. The annual indices were flat with little trend (Figure 8).

3.3.3.3 Comparison among sub-regions in SPO 1

Annual indices, scaled to a mean of 1, for the Thames and Other-east sub-regions of SPO 1-east are flat with little trend (Figure 9). The annual indices for the Kaipara and Other-west sub-regions of SPO1-west are variable with little trend, and contrast with the declining trend indicated from the two analyses completed for the Manukau sub-region.

3.3.3.4 SPO 8 fishstock

Three variables entered the SPO 8 model (vessel, net length, and duration), and fishing year was forced into the model to provide annual indices. The model explained 50% of data variability in landed catch (Table 14). The vessel indices also were variable, and catch rate was positively associated with net length and duration of fishing. The annual indices were flat with little trend (Figure 10). These indices are compared with the annual indices for the three sub-regions of SPO 1 in Figure 11.

3.4 Diagnostics

Diagnostics for the core vessel models for the SPO1 and SPO 8 fishstocks and their sub-regions are consistent with the statistical assumptions (Appendix 4). The residuals show no unsatisfactory patterns when plotted against the predicted values of each model and the Q-Q normal plots are linear or nearly so over their full range (about ± 4 standard errors).

4. Distribution data from recent trawl surveys

Paul (2003) suggested that, though rig are poorly monitored by trawl surveys, some indication of juvenile rig abundance may be provided through trawl survey data collection, because immature rig are caught during surveys off the North Island.

Mean lengths at maturity for rig were 87 cm for males (age 5–6 y) and 102 cm for females (age 7–8 y) trawled from the Pegasus Bay (east coast South Island) and 85 cm and 100 cm for west coast South Island rig (Francis & Francis 1992). No comparable data are available for rig in more northern waters, though Francis & Francis (1992) suggested that males in the Hauraki Gulf may mature at 72 cm in length (3.7 y) and females at about 82 cm in length (4.7 y).

Recent trawl survey series off the west and east coasts of the North Island have used 90 cm as the upper measurement for rig that are considered pre-recruits and are classed as juveniles. These survey series usually targeted specific year classes of various finfish species such as snapper (*Pagrus auratus*), jack mackerels (*Trachurus* spp.), John dory (*Zeus faber*), red gurnard (*Chelidonichthys kumu*), tarakihi (*Nemadactylus macropterus*), trevally (*Pseudocaranx dentex*), and gemfish (*Rexea solandri*), and the available rig data from these surveys are reviewed in Appendix 5. The lack of rig data indicated that the trawl surveys are not a useful method for monitoring the abundance of juvenile or adult rig.

5. DISCUSSION

The inshore setnet fisheries of the northern North Island are seasonally and spatially complex, involving multiple target species and methods. Most rig is taken by setnetting (Annala et al. 2004), and over 90% of this is taken in target fisheries, mainly during spring and early summer. The fishers often move to other setnet fisheries such as flatfish, in other seasons (Hartill 2002). Many of these fishers are also involved in other fishing methods such as ring net fishing for grey mullet, and longline fishing for school shark and snapper (Hartill 2002).

Initial studies of unstandardised rig CPUE showed little change for the period 1974–75 to 1984–85 for the ECNI (Hauraki Gulf) and Kaipara Harbour (WCNI) fisheries, but a decline in CPUE was noted for the Manukau Harbour (Francis & Smith 1988). The rig fisheries were included in the AMP programme from 1991–92, with a TACC increase of 200 t for each fishstock (Annala et al. 2004).

Catch rates were not able to be maintained at these higher levels, and SPO 1 and SPO 8 were removed from the AMP in 1997–98, when TACCs reverted to the original levels (Paul 2003). Since 1997–98 raw CPUE has continued to decline in SPO 1, but Paul (2003) noted this trend may be influenced by high catch rates in the initial fishing years (1990–91 and 1991–92). Raw CPUE in SPO 8 appeared to change relatively little between 1992–93 and 1994–95, with a possible declining trend between 1995–96 and 2000–01.

The initial standardised CPUE indices used estimated greenweight catches for the SPO 1 and SPO 8 fishstocks (Appendix 4) as the fisher's best available estimate of greenweight catch. These data suggested a generally declining trend for both fisheries that was consistent with these earlier CPUE studies. However, further examination revealed inaccuracies in the greenweight data used for analysis, both in the estimated greenweight, and in the landed greenweight as derived from the landed processed catch data. Firstly these data did not account for changes in CF during the review period. While Paul (2003) noted that CF had been revised (CF=2.00, from 1989–90 to 1991–92; CF=1.75 from 1992–93 to 1998–99; and CF=1.55 from 1999–00 to 2003–04), these changes were not properly completed on the CELR database in determining calculated greenweight landings. This effectively scaled the calculated greenweight, creating an apparent decline in the annual indices for rig (see Appendix 3). A similar effect was noted for the 2005 SPO 7 CPUE analysis (P. Starr, SEAFIC, pers. comm., 2005). Secondly, there were many other errors and inconsistencies in how the CF and landed state data were reported on the database. Thirdly, the assumptions around the recording of estimated catches were invalid in many cases, as fishers effectively back-calculated these data from the landed processed weight catch as well. As a result of these errors, the calculated greenweight data available on the CELR database for rig were considered inaccurate, and the initial standardised CPUE analysis based on estimated greenweight catch was discarded.

An alternative approach was then pursued, which avoided the need to use the CELR greenweight data. This generally followed the methods of Paul (2003), Starr (2003), and Manning et al. (2004) to pro-rate the aggregate landed trip-level weight data back to individual sets, and then merge these data with the effort data. This approach has generally been used for the analysis of bycatch species, where not all of the landed catch may be reported in the daily catch part of the CELR form. In this case, however, the method was used in a target setnet fishery because it represented the best possible method of re-allocating and re-stratifying available processed catch data to greenweight, and then merging these set-level greenweight catch data with the available effort data. Similar numbers of records were available from each method (estimated catch or pro-rated landed catch), but the total estimated greenweight catch was substantially lower than the pro-rated landed catch. It is likely that this difference related to the use of different conversion factors in the estimated catch data.

Relative CPUE indices from the revised analysis of calculated greenweight showed relatively little change for the SPO 1 and SPO 8 fishstocks, except for Manukau Harbour. As this appeared to be anomalous, the 2005 Inshore Working Group (IWG) meeting requested that the Manukau analysis be repeated, excluding the 1989–90 data, as few data points were available for analysis. The results were similar to the main analysis. As rig is caught in the Kaipara and Manukau Harbours, and further offshore in SPO 1-west in almost equal proportions, the IWG considered it unlikely that rig taken in Manukau represents a separate stock. It was considered that this declining trend was more likely to reflect the numbers of fish entering the harbour than a change in overall abundance in SPO 1.

Calculation of CPUE indices does not necessarily result in an index that is related to stock abundance (Dunn et al. 2000). To determine whether the CPUE indices estimated in the current analysis monitor relative abundance, the following should be considered: assessment of data adequacy, the model fitting procedure including the diagnostics, and the validation of the CPUE index through fishery independent methods.

The available data for the rig SPO 1 fishstock are extensive, but highly variable, with few explanatory variables available on the CELR database. The analysis was restricted to records with positive rig catch, as the unbalanced nature of records with zero rig catch is suggestive of underlying data integrity problems inherent in the CELR database, a feature apparent in the recent CPUE analysis in FLA 1 which used substantially similar data. The fishery has involved many vessels, but few have fished consistently between 1989–90 and 2003–04, and analysis of core vessels identified within each sub-region provided the best model fit to the data. The model fits were reasonable, generally explaining 30–55% of data variability, though there was slightly higher variability in the Kaipara sub-region of SPO 1.

The variables included in the analysis (vessel, month, fishing year, net length, statistical area, and duration of fishing) are variables that would be expected to affect catch rate. The vessel indices were variable, and monthly indices were consistent with a spring/summer target fishery (Paul 2003). CPUE was positively associated with net length and duration of fishing. The fishing year indices were broadly similar amongst a variety of models, suggesting that the data analysis is moderately robust. Diagnostics for the core vessels model were consistent with the statistical assumptions.

The revised analysis of standardised CPUE suggests annual indices have shown little change between 1989–90 and 2003–04. The differences between the annual indices from the two analyses presented highlight the importance of ancillary data, such as conversion factors, in the interpretation of CPUE trends. Further monitoring including validation of these CPUE indices is recommended for this fishery to determine whether these trends monitor the relative abundance of rig in SPO 1 and SPO 8.

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Table 1: Range checks performed on the (A) fishing events and (B) landing events data during the re-stratification and catch allocation algorithm. The final datasets to which the CPUE models were fitted were subsets of the groomed, restratified, and merged dataset (see Table 2).

(A) Fishing events	All fishstocks
Fishing duration (hours)	< 3 or > 72
Total amount of net set (m)	< 100 or > 7500
Estimated SPO catch (kg)	> 7070

(B) Landing events	All fishstocks
Landing date	1 October 1989 to 30 September 2004
Landed SPO greenweight (kg)	*Catch-consistency checking algorithm applied (see Section 0)*

Table 2: Criteria used to select effort strata from the groomed, restratified, and merged dataset for the CPUE model fits.

			Fishstock
Field	SPO 1(E)	SPO 1(W)	SPO 8
Statistical area	001–010	042–048	039–041
Fishing year	Valid landing date (1 Oct 1989 to 30 Sep 2004; all fishstocks)		
Vessel total catch (t)			> 1 (all fishstocks)

Table 3: Summary of predictor variables used in the analysis of rig calculated greenweight CPUE.

Variable	**Type**	**Level**	**Description**
Vessel	Categorical	357	Fishing vessel
Year	Categorical	15	Fishing year
Month	Categorical	12	Month in year
Duration	Continuous		Hours fished
Net length	Continuous		Length of net set (m)
Experience	Categorical	15	Years in fishery
Moon phase	Continuous		Proportion of lunar face exposed
Statistical area	Categorical	19	Fisheries statistical reporting area

Table 4: Greenweight catch (kg) and number of sets in target setnet fishing, by region and sub-region of the rig (SPO 1 and SPO 8) fishstocks, 1988–89 to 2003–04.

Greenweight rig catch (kg)

	SPO-east		SPO-west			SPO 1 Total	SPO 8	
Fishing year	ECNI_Other	Thames	Kaipara	Manukau	WCNI_Other		Egmont	Grand Total
1989–90	66 922	43 673	22 840	71 161	45 730	250 325	119 538	369 863
1990–91	32 444	122 478	19 085	61 250	39 182	274 439	146 790	421 229
1991–92	52 220	167 755	32 679	63 362	40 056	356 072	90 521	446 593
1992–93	72 061	158 181	33 458	40 886	48 341	352 926	185 672	538 598
1993–94	144 127	92 141	41 298	84 796	48 028	410 390	209 232	619 621
1994–95	128 915	83 595	72 919	114 061	57 603	457 094	221 632	678 725
1995–96	39 388	96 777	65 186	58 922	93 711	353 984	243 845	597 829
1996–97	50 306	84 499	56 270	68 105	181 699	440 878	177 057	617 935
1997–98	40 854	74 268	45 121	40 178	136 914	337 334	203 267	540 601
1998–99	29 065	80 723	72 819	62 660	65 419	310 687	155 274	465 961
1999–00	37 732	92 592	99 349	86 512	52 437	368 623	153 333	521 955
2000–01	37 298	77 729	101 800	66 589	89 402	372 818	136 890	509 708
2001–02	30 669	114 875	60 707	47 348	83 610	337 209	161 294	498 502
2002–03	34 855	91 210	71 178	53 097	60 515	310 855	155 356	466 211
2003–04	48 851	73 048	58 091	36 791	81 744	298 526	155 607	454 133
Grand total	845 706	1453 546	852 799	955 717	1124 391	5232 159	2515 305	7747 465
Proportion	0.37	0.63	0.29	0.33	0.38	1.00		
Regional total		2299 252			2932 907			
Proportion		0.44			0.56			

Numbers of sets

	SPO 1-east		SPO 1-west			SPO1 total	SPO 8	
Fishing year	ECNI_Other	Thames	Kaipara	Manukau	WCNI_Other		Egmont	Grand Total
1989–90	178	174	73	227	265	917	376	1 293
1990–91	266	513	67	257	200	1 303	365	1 668
1991–92	300	622	87	270	228	1 507	458	1 965
1992–93	403	822	101	221	240	1 787	648	2 435
1993–94	432	533	120	306	255	1 646	591	2 237
1994–95	307	413	171	382	278	1 551	544	2 095
1995–96	235	377	153	351	384	1 500	412	1 912
1996–97	293	384	207	389	580	1 853	408	2 261
1997–98	272	393	224	329	386	1 604	370	1 974
1998–99	260	428	313	331	338	1 670	380	2 050
1999–00	277	558	405	471	311	2 022	356	2 378
2000–01	225	457	438	471	420	2 011	292	2 303
2001–02	149	476	366	381	334	1 706	353	2 059
2002–03	162	524	448	396	213	1 743	302	2 045
2003–04	152	414	259	238	255	1 318	274	1 592
Grand total	3 911	7 088	3 432	5 020	4 687	24 138	6 129	30 267
Proportion		1						
Regional total		10 999			13 139			
Proportion		0.54			0.54			

Table 5: Numbers of unique trip keys available for analysis in SPO 1 and 8 in the raw data, and after the grooming, restratification, and the method and target fishing selection procedures.

Data table		Effort	Landings
Raw data	All methods		
	Effort	94 304	88 902
	Landing	88 902	116 079
Groomed data	All methods	87 711	84 177
	Set net only	55 912	54 800
	Target fishing	30 267	30 267

Table 6: Percentage of SPO 1 and SPO 8 catch merged between the *Effort* and *Landings* data tables (Recovery rate), overall, and by fishing year.

Fish. year	Recovery rate (RR) (%)
1989-90	88
1990-91	48
1991-92	74
1992-93	81
1993-94	96
1994-95	93
1995-96	90
1996-97	86
1997-98	76
1998-99	78
1999-00	84
2000-01	91
2001-02	95
2002-03	93
2003-04	91
Total	82

Table 7: Greenweight target rig catch (kg), number of sets, and number of vessels by vessel category (all vessels, core vessels), sub-region of SPO 1 and SPO 8 fisheries 1989–90 to 2003–04.

Vessel category		SPO-east		SPO-west			SPO 8	
		ECNI_Oth	Thames	Kaipara	Manukau	WCNI_Oth	Egmont	Total
Greenweight catch (kg)								
All vessels	Total	845 706	1453 546	852 799	955 717	1124 391	2515 305	7747 465
Core vessels	Total	727 307	1198 307	724 879	772 572	912 111	2007 910	6 343 086
	Percent	86	82	85	81	81	80	80
Numbers of sets								
All	Total	3 911	7 088	3 432	5 020	4 687	6 129	30 267
Core	Total	3 097	5 480	2 859	3 894	3 860	4 417	23 607
	Percent	79	77	83	78	82	72	78
Number of vessels								
All	Total	120	87	90	91	113	120	
No. vessels								
Core	Total	25	41	33	24	32	29	
	Percent	21	47	37	26	28	24	
	Minimum experience	3	4	4	5	3	5	

Table 8: Choice of variables in order of importance in regression analysis of log (calculated greenweight catch) for core vessels in the Thames sub-region of the SPO 1-east rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

					R^2 at iteration
	1	2	3	4	5
Variable					
Vessel key	**0.282**				
Month	0.162	**0.382**			
Net length	0.183	0.322	**0.407**		
Fishing year	0.016	0.301	0.395	**0.423**	
Duration	0.117	0.316	0.401	0.412	0.429
% variability	28.40	10.02	2.52	1.57	0.65

Fishing year	Relative index	s.e
1989–90	1.00	
1990–91	1.45	0.18
1991–92	1.51	0.18
1992–93	0.99	0.12
1993–94	0.96	0.12
1994–95	1.25	0.16
1995–96	1.16	0.15
1996–97	1.24	0.15
1997–98	1.52	0.19
1998–99	1.26	0.16
1999–00	1.25	0.16
2000–01	1.28	0.16
2001–02	1.36	0.17
2002–03	0.96	0.12
2003–04	1.25	0.16

Table 9: Choice of variables in order of importance in regression analysis against log (calculated greenweight catch) for core vessels in the Other sub-region of the SPO 1-east rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Table					R^2 at iteration
	1	2	3	4	5
Variable					
Vessel key	**0.303**				
Duration	0.093	**0.370**			
Fishing year	0.048	0.332	**0.392**		
Month	0.000	0.325	0.388	**0.407**	
Net length	0.143	0.348	0.376	0.400	0.416
% variability	30.37	6.66	2.21	1.51	0.85

Fishing year	Relative index	s.e
1989–90	1.00	
1990–91	1.20	0.17
1991–92	1.73	0.23
1992–93	0.88	0.11
1993–94	1.08	0.14
1994–95	0.90	0.13
1995–96	0.74	0.11
1996–97	1.00	0.16
1997–98	1.48	0.24
1998–99	1.00	0.15
1999–00	0.91	0.14
2000–01	1.42	0.25
2001–02	1.91	0.32
2002–03	1.64	0.28
2003–04	1.51	0.26

Table 10: Choice of variables in order of importance in regression analysis against log (calculated greenweight catch) for core vessels in the Kaipara sub-region of the SPO 1-west rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

	R^2 at iteration				
	1	2	3	4	5
Variable					
Net length	**0.319**				
Vessel key	0.234	**0.461**			
Month	0.123	0.375	**0.516**		
Fishing year	0.056	0.367	0.481	**0.538**	
Duration	0.100	0.320	0.472	0.527	**0.550**
% variability	31.95	14.17	5.48	2.20	1.22

Fishing year	Relative index	s.e
1989–90	1.00	
1990–91	0.68	0.11
1991–92	1.05	0.16
1992–93	0.97	0.14
1993–94	1.11	0.16
1994–95	1.28	0.18
1995–96	1.48	0.21
1996–97	1.16	0.17
1997–98	0.96	0.14
1998–99	0.90	0.13
1999–00	0.98	0.14
2000–01	0.86	0.12
2001–02	0.70	0.10
2002–03	0.66	0.09
2003–04	0.91	0.13

Table 11: Choice of variables in order of importance in regression analysis against log (calculated greenweight catch) for core vessels in the Manukau sub-region of the SPO 1-west rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

	R^2 at iteration				
	1	2	3	4	5
Variable					
Vessel key	**0.330**				
Month	0.173	**0.431**			
Net length	0.155	0.410	**0.489**		
Fishing year	0.068	0.382	0.469	**0.524**	
Duration	0.004	0.351	0.450	0.498	**0.534**
% variability	33.05	10.38	5.86	3.45	1.03

Fishing year	Relative index	s.e
1989–90	1.00	
1990–91	0.67	0.07
1991–92	0.60	0.06
1992–93	0.55	0.05
1993–94	0.58	0.05
1994–95	0.47	0.04
1995–96	0.36	0.04
1996–97	0.39	0.04
1997–98	0.30	0.03
1998–99	0.30	0.03
1999–00	0.40	0.04
2000–01	0.33	0.03
2001–02	0.31	0.03
2002–03	0.29	0.03
2003–04	0.31	0.04

Table 12: Choice of variables in order of importance in regression analysis against log (calculated greenweight catch) for core vessels in the Manukau sub-region of the SPO 1-west rig fishery, 1990–91 to 2003–04. Variables in bold entered the model.

	R^2 at iteration				
	1	2	3	4	5
Variable					
Vessel key	**0.330**				
Month	0.177	**0.433**			
Net length	0.169	0.410	**0.492**		
Fishing year	0.047	0.375	0.465	**0.520**	
Duration	0.008	0.354	0.456	0.502	**0.532**
% variability	33.01	10.38	5.84	2.86	1.11

Fishing year	Relative index	s.e
1989–90		
1990–91	1.00	
1991–92	0.90	0.08
1992–93	0.82	0.07
1993–94	0.85	0.07
1994–95	0.69	0.06
1995–96	0.53	0.05
1996–97	0.57	0.05
1997–98	0.44	0.04
1998–99	0.44	0.04
1999–00	0.59	0.05
2000–01	0.48	0.04
2001–02	0.45	0.04
2002–03	0.43	0.04
2003–04	0.45	0.05

Table 13: Choice of variables in order of importance in regression analysis against log (calculated greenweight catch) for core vessels in the rig fishery in the Other sub-region of the SPO 1-west rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

	R^2 at iteration				
	1	2	3	4	5
Variable					
Vessel key	**0.243**				
Month	0.100	**0.325**			
Net length	0.182	0.277	**0.353**		
Statistical area	0.071	0.271	0.348	**0.369**	
Fishing year	0.037	0.267	0.346	0.368	**0.375**
% variability	24.38	8.13	2.83	1.57	0.68

Fishing year	Relative index	s.e
1989–90	1.00	
1990–91	1.14	0.13
1991–92	0.99	0.10
1992–93	1.16	0.12
1993–94	1.31	0.16
1994–95	1.00	0.12
1995–96	0.96	0.10
1996–97	1.04	0.11
1997–98	1.13	0.12
1998–99	0.92	0.10
1999–00	0.83	0.09
2000–01	0.87	0.09
2001–02	0.84	0.10
2002–03	0.88	0.10
2003–04	0.98	0.11

Table 14: Choice of variables in order of importance in regression analysis against log (calculated greenweight catch) for core vessels in the SPO 8 rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Table					R^2 at iteration
	1	2	3	4	5
Variable					
Vessel key	**0.442**				
Net length	0.349	**0.480**			
Duration	0.058	0.478	**0.496**		
Fishing year	0.039	0.453	0.489	**0.506**	
Statistical area	0.058	0.455	0.492	0.505	**0.512**
% variability	44.29	3.72	1.62	0.97	0.63

Fishing year	Relative index	s.e
1989–90	1.00	
1990–91	1.34	0.15
1991–92	0.76	0.08
1992–93	0.94	0.09
1993–94	1.05	0.10
1994–95	0.88	0.08
1995–96	1.08	0.11
1996–97	1.12	0.12
1997–98	1.32	0.14
1998–99	1.01	0.10
1999–00	1.22	0.13
2000–01	0.94	0.11
2001–02	1.22	0.14
2002–03	1.39	0.17
2003–04	1.29	0.17

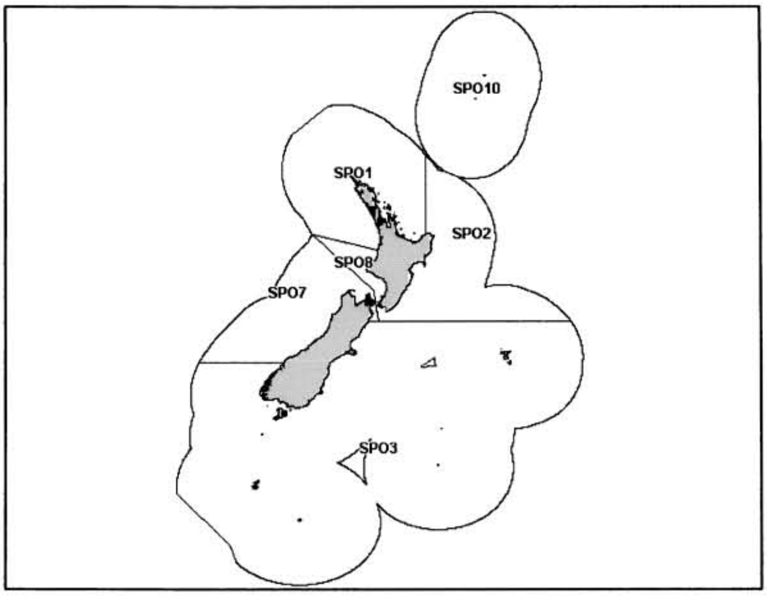


Figure 1: Management areas for the rig (SPO) fishery in New Zealand (after Annala at al. 2004).

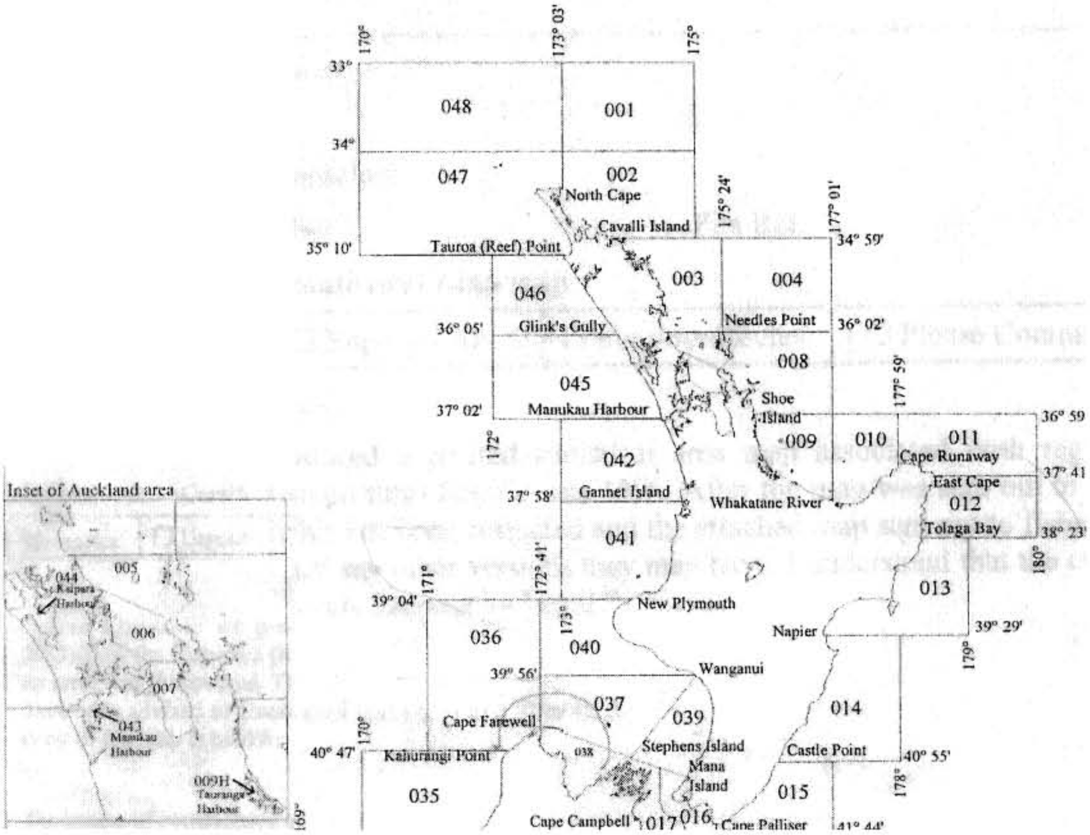


Figure 2: Statistical reporting areas of the northern North Island rig fishery. Areas 001–010 were coded as SPO1-east, 042–048 were coded as SPO 1-west, and 037–041 were coded as SPO 8. Separate analyses were also completed for Thames (area 007), Manukau Harbour (043) (inset), and Kaipara Harbour (044).

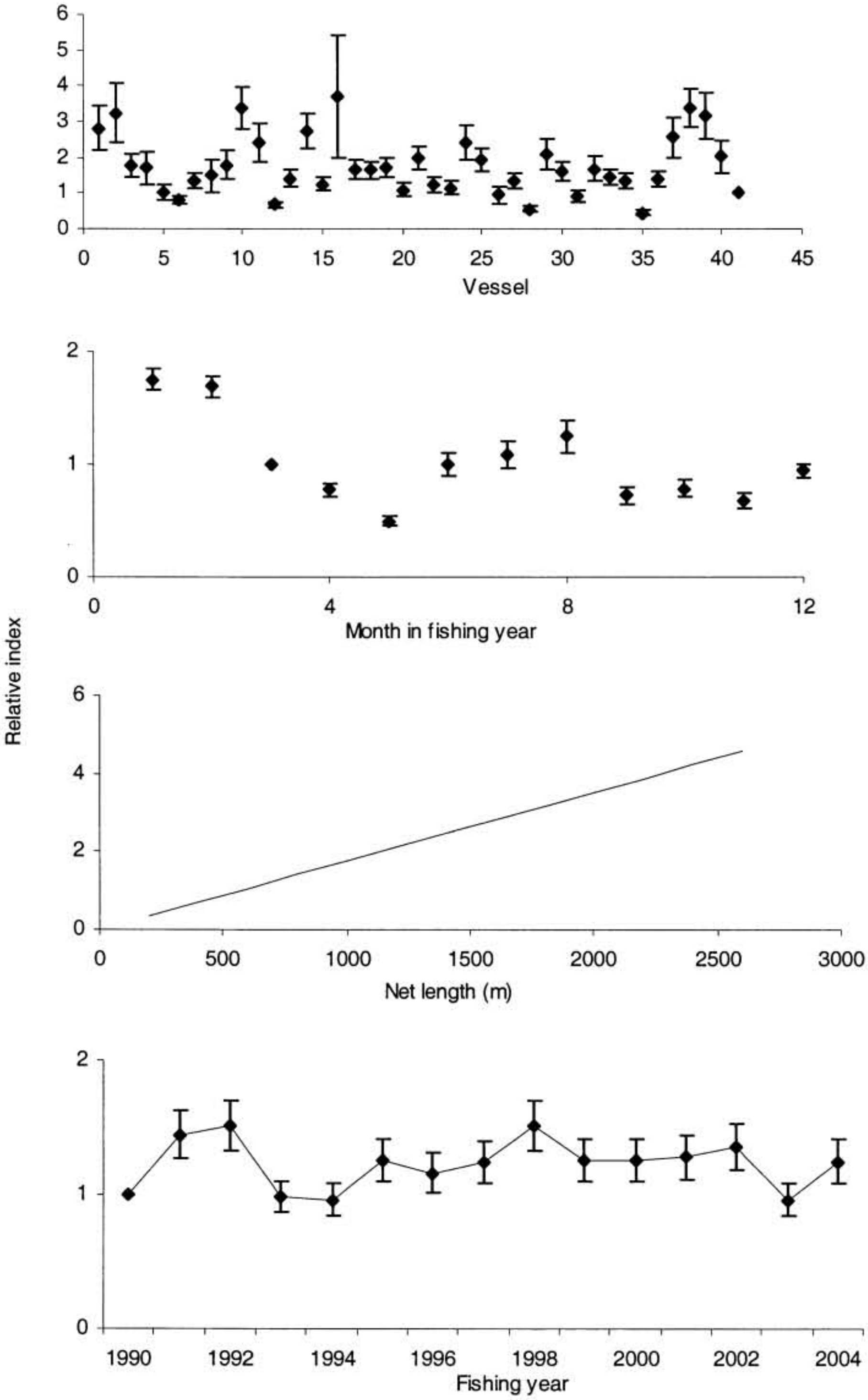


Figure 3: Relative indices for variables that entered the core vessels calculated greenweight rig catch model for the Thames sub-region of the SPO 1-east rig fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year, and month 1=October. Error bars represent 1 s.e.

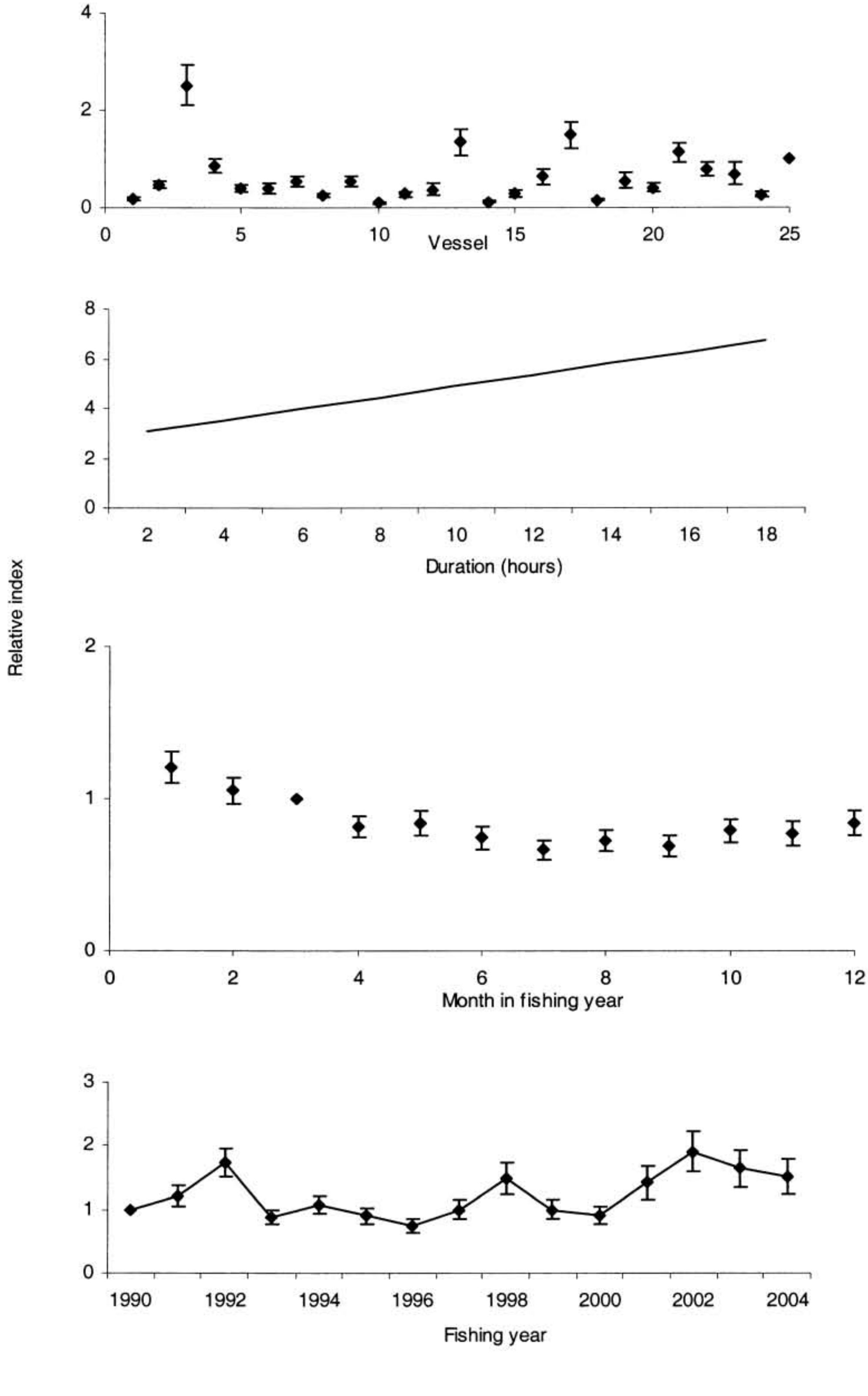


Figure 4: Relative indices for variables that entered the core vessels calculated greenweight rig catch model for the Other sub-region of the SPO 1-east rig fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year, and month 1=October. Error bars represent 1 s.e.

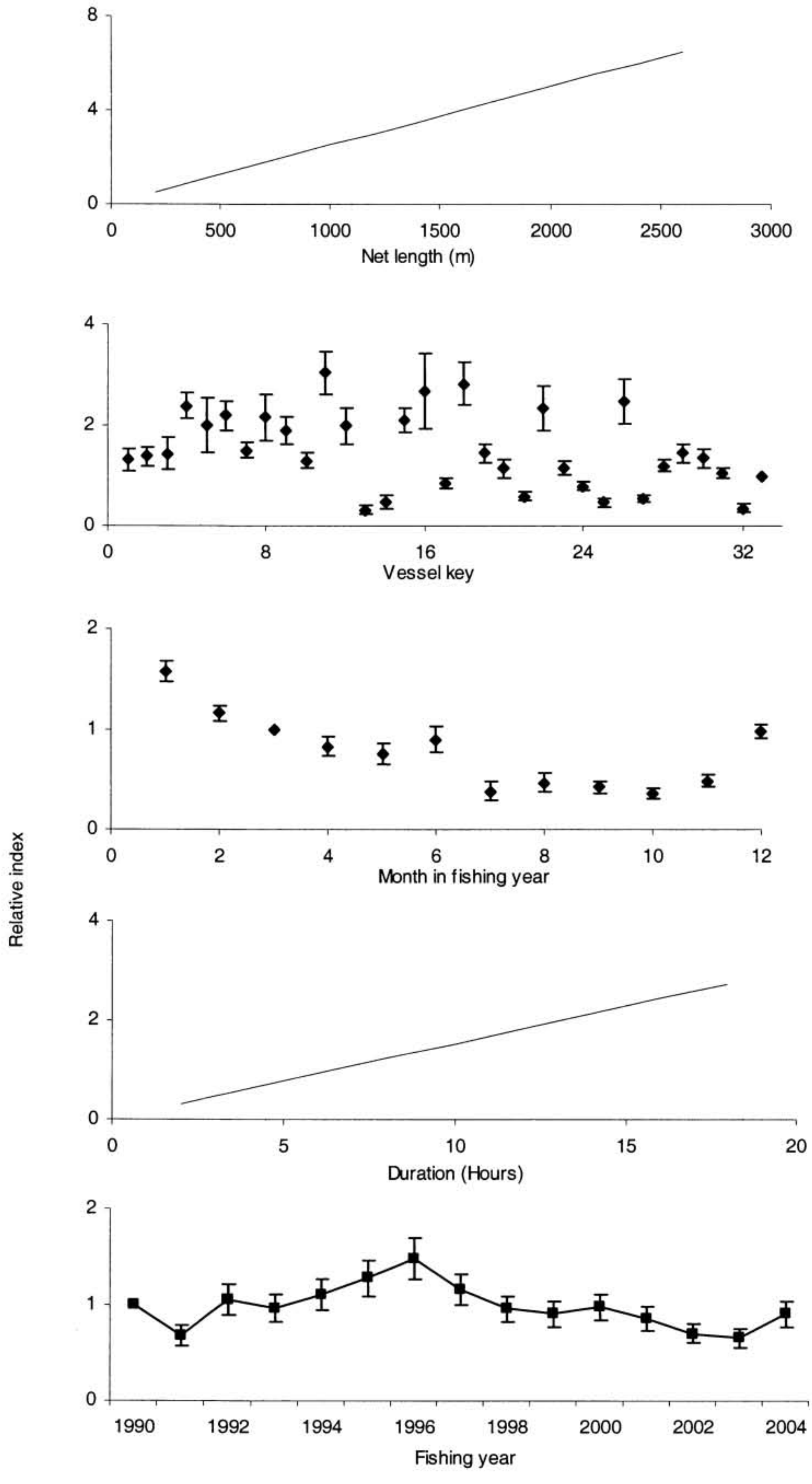


Figure 5: Relative indices for variables that entered the core vessels calculated greenweight rig catch model for the Kaipara sub-region of the SPO 1-west fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year, and month 1 = October. Error bars represent 1 s.e.

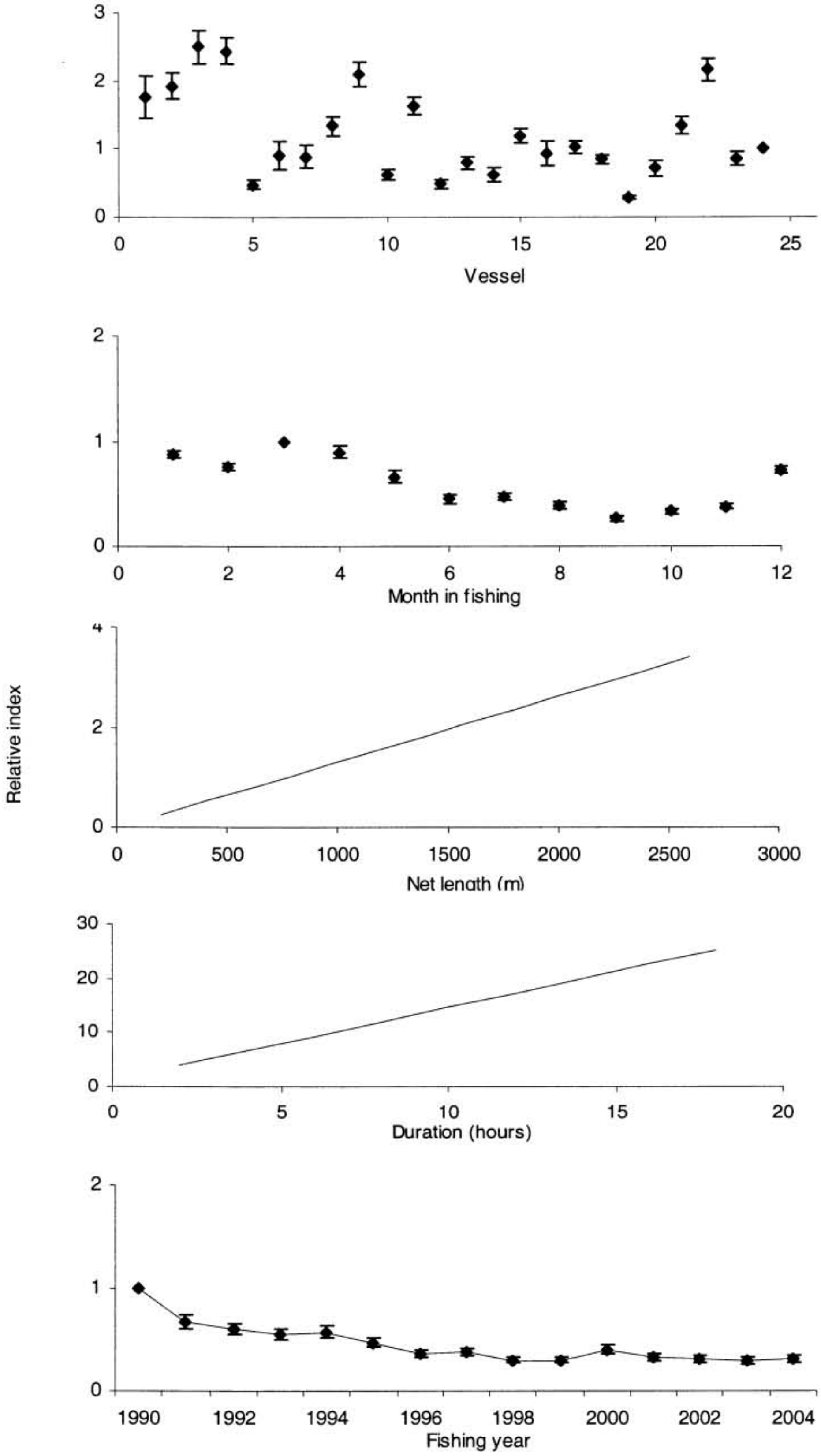


Figure 6: Relative indices for variables that entered the core vessels calculated greenweight rig catch model for the Manukau sub-region of the SPO 1-west fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year, and month 1 = October. Error bars represent 1 s.e.

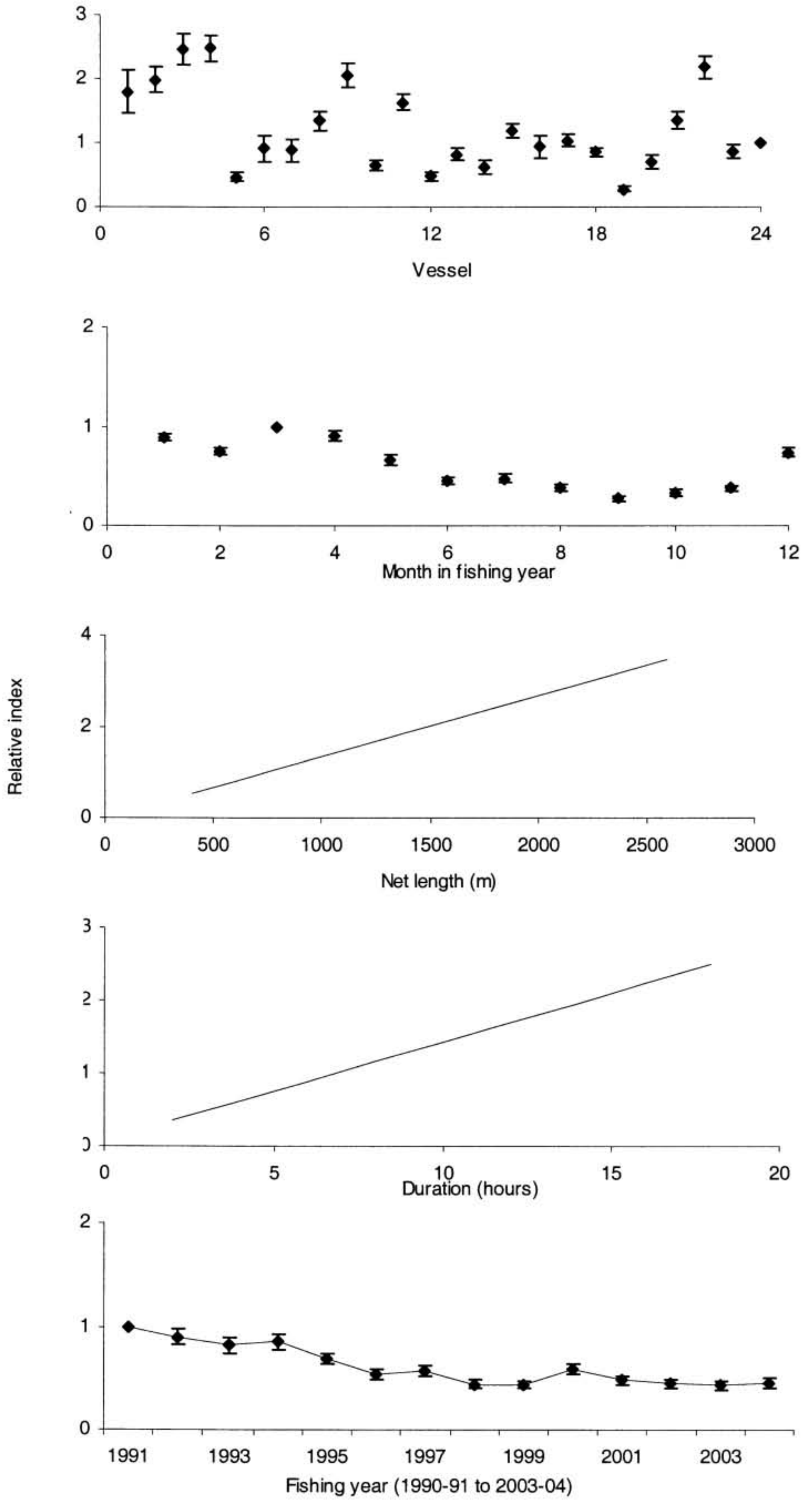


Figure 7: Relative indices for variables that entered the core vessels calculated greenweight rig catch model for the Manukau sub-region of the SPO 1-west rig fishery, 1990–91 to 2003–04., where 1990 represents the 1989–90 fishing year, and month 1=October. Error bars represent 1 s.e.

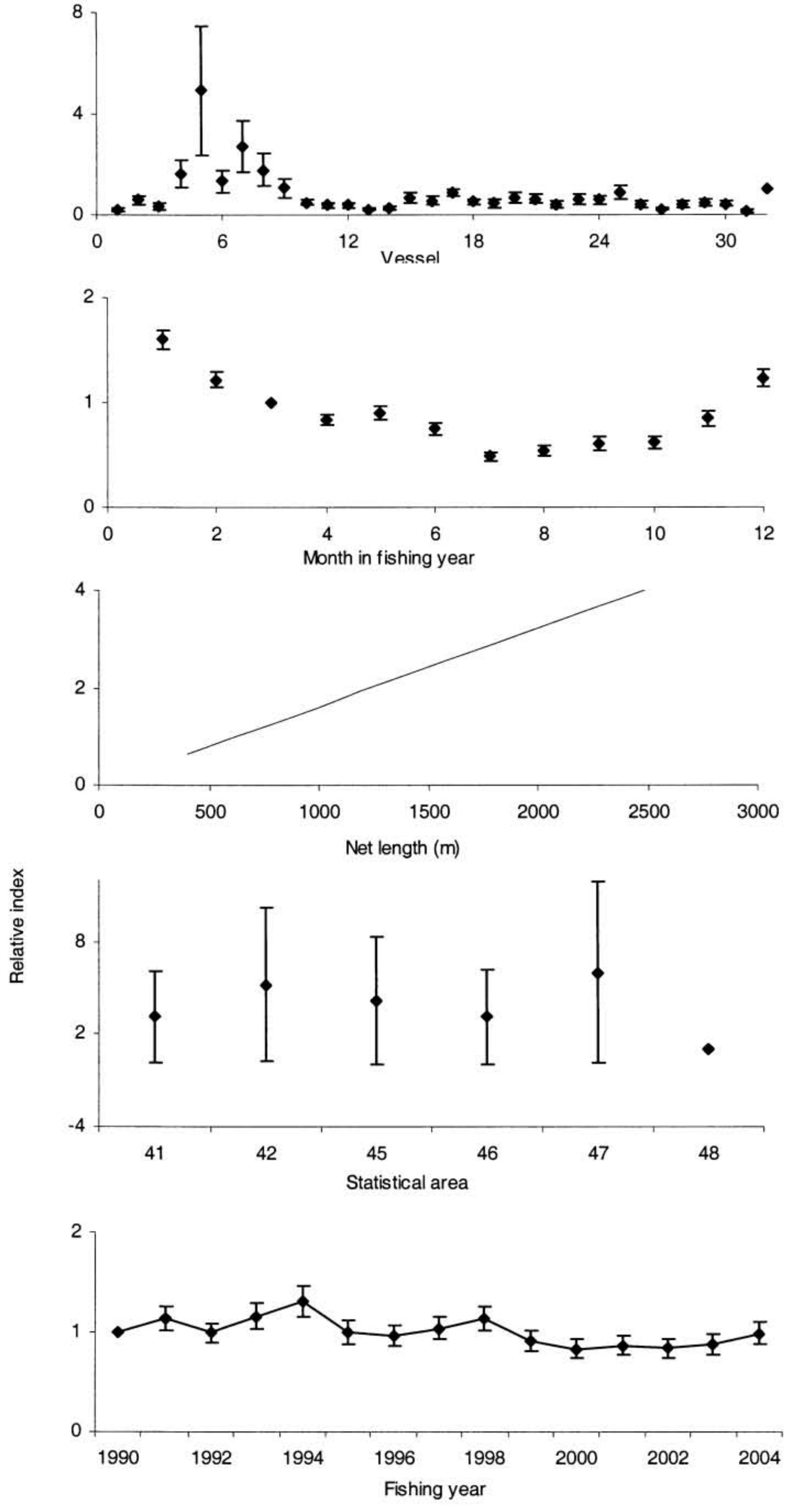
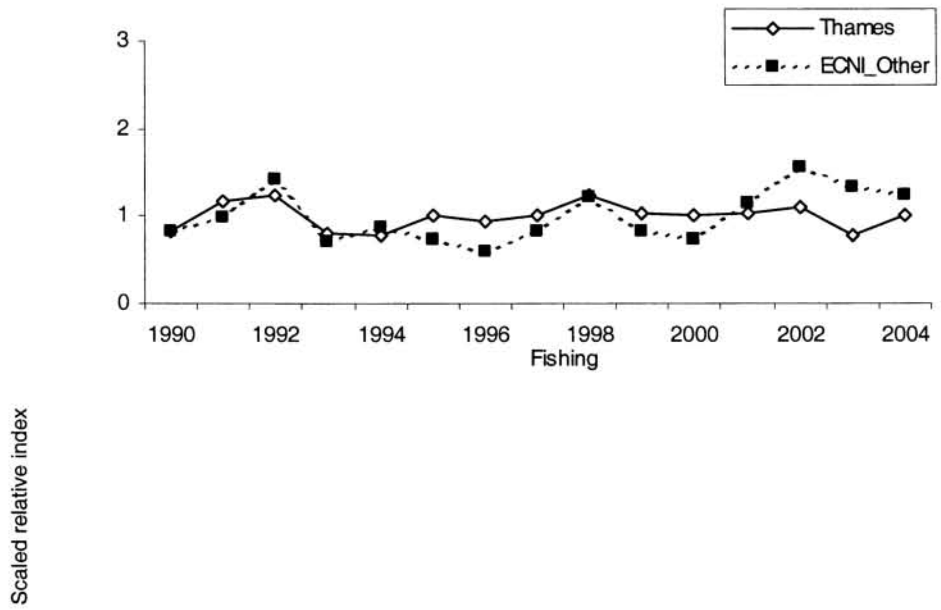


Figure 8: Relative indices for variables that entered the core vessels calculated greenweight rig catch model for the WCNI-other sub-region of the rig (SPO 1-west) fishery, 1998–99 to 2003–04, where 1990 represents the 1989–90 fishing year, and month 1=October. Error bars represent 1 s.e.

SPO 1-east sub-regions (Thames, Other)



SPO 1- west sub-regions (Kaipara, Manukau, Other)

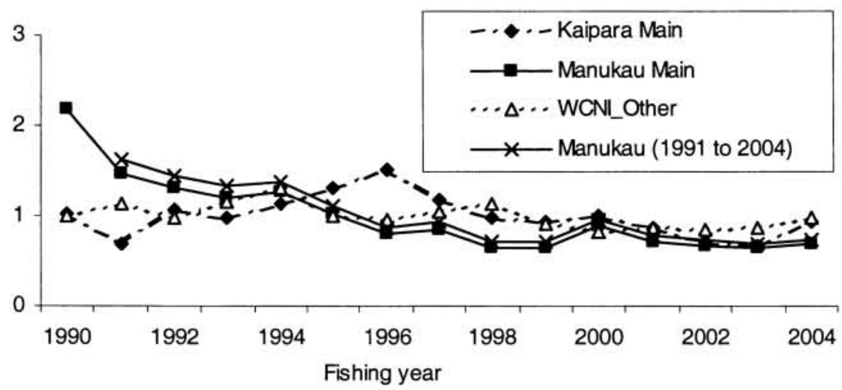


Figure 9: Comparison of standardised catch (kg) for the core vessel calculated greenweight rig catch models analysed for the sub-regions of the SPO 1-east and SPO 1-west rig fisheries, 1988–89 to 2003–04, where 1990 represents the 1989–90 fishing year. Also shown is the alternative analysis for the Manukau sub-region, 1990–91 to 2003–04. Both figures are scaled to a mean of 1.

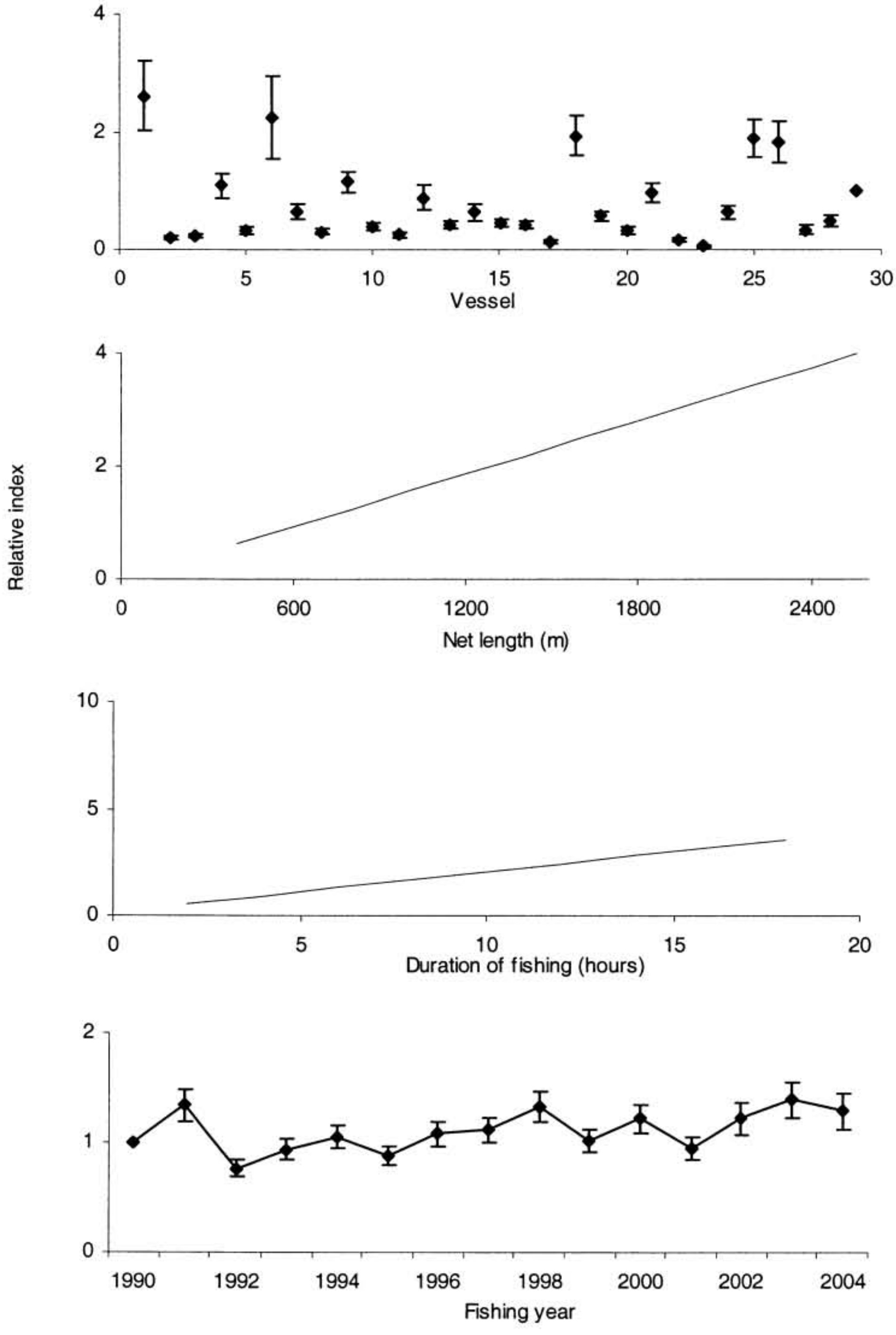


Figure 10: Relative indices for variables that entered the core vessels calculated greenweight rig catch model of rig log (kg) for the SPO 8 rig fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year. Error bars represent 1 s.e.

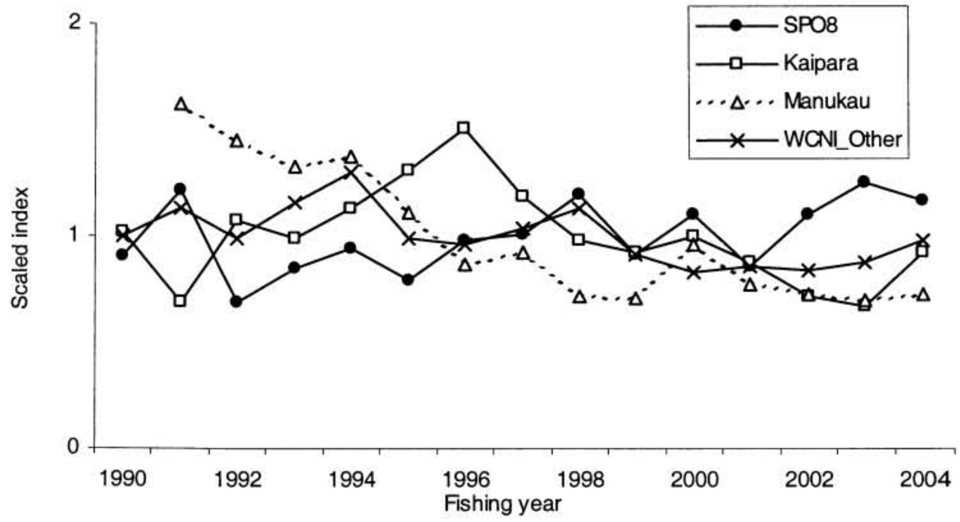


Figure 11: Comparison of the standardised greenweight rig catch indices derived for the three sub-regions (Kaipara, Manukau, WCNI-Other) of the SPO 1-west rig fishery with the indices derived for the SPO 8 fishstock, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year. Both data series are scaled to a mean of 1.

Appendix 1.

Figure A1.1: Summary of calculated greenweight setnet catch (kg) of rig in SPO 1 and SPO 8 (combined) by target species, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year.

Target species		Fishing year															
Code	Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
SPO	Rig	369 858	421 180	446 566	538 618	619 589	678 691	597 738	617 892	540 579	465 986	521 984	509 665	498 458	466 187	454 107	7 747 098
GUR	Red gurnard	2 882	6 340	11 673	11 504	8 110	18 735	20 155	26 586	38 073	27 002	21 036	30 895	16 858	40 163	46 928	326 941
SCH	School shark	25 877	21 344	13 765	19 273	15 245	16 161	24 947	22 959	28 421	15 941	13 328	10 191	8 483	9 030	16 627	261 591
TRE	Trevally	8 035	18 094	17 557	23 797	18 885	15 619	18 016	21 726	24 966	17 456	8 651	7 246	5 000	3 872	13 384	222 305
SNA	Snapper	22 707	25 115	41 206	29 168	13 950	7 293	6 012	4 373	6 436	3 594	3 276	2 926	4 955	3 215	9 157	183 381
FLA	Flounder	3 335	6 582	8 974	14 517	9 923	6 959	5 170	6 892	12 012	9 118	17 767	10 312	7 976	10 233	7 376	137 146
WAR	Blue warehou	1 923	1 987	4 929	6 347	5 064	3 540	6 048	5 716	5 178	2 820	7 263	7 723	9 895	6 579	3 751	78 763
KAH	Kahawai	1 705	2 642	3 102	6 808	4 726	4 318	2 588	593	2 285	128	472	98	158	70	41	29 735
GMU	Gry mullet	1 140	1 861	1 957	1 282	937	1 304	508	748	1 495	1 263	2 314	2 076	1 950	973	1 998	21 808
KIN	Kingfish	3 737	4 121	2 477	3 462	914	1 799		148							29	16 687
SPD	Spiny dogfish	399	707	265	40	348	1 088	3 110	745	927	459	1 383	1 132	402	1 837	233	13 074
YBF	Yellowbelly flounder		916	329	110	176	131	220	684	1 085	1 754	1 992	618	695	743	376	9 829
POR	Porae	8 623	51	36	53	15						17			2	37	8 834
TAR	Tarakihi	57	160	267	966	1 979	889	325	261	887	652	322	67	100	186	156	7 271
JMA	Jack mackerel	56		59	430	9	1 306	132		3 593	1 038						6 622
NSD	Northern spiny d	193	581	404	156	2 350	501		32	419	677						5 313
JDO	John dory	28	4	5	106	196	5	48	33	1 783	28	97	99	59	17	6	2 514
HPB	Hapuku/bass	20	9	8		9	62	2 277			104						2 489
MOK	Blue moki	53	26	19	152	1 695		20	5	108		18					2 095
PAD	Paddle crab		79	20	18	133	437	271	42		71	144	624	129	28		1 996
SDO	Silver dory				117	280									299	966	1 662
SPE	Sea perch					71						694	398			87	1 250
SPI	Spider crab		72	50	208	679											1 008
Total ≥ 1 t		450 628	511 872	553 667	657 132	705 282	758 838	687 586	709 434	668 246	548 090	600 757	584 071	555 118	543 432	555 258	9 089 411
% ≥ 1 t		99.98	99.77	99.89	99.79	99.96	99.97	99.84	99.99	99.93	99.92	99.91	100.00	100.00	99.87	100.00	97.89
Total (All)		450 724	513 044	554 300	658 501	705 540	759 083	688 658	709 494	668 743	548 526	601 286	584 073	555 138	544 123	555 263	9 285 109
% target catch (All)		82.06	82.09	80.56	81.79	87.82	89.41	86.80	87.09	80.84	84.95	86.81	87.26	89.79	85.68	81.78	83.44

Appendix 2: Initial analysis of estimated SPO catch in SPO 1 and SPO 8

A2.1 Introduction

The initial CPUE analysis of estimated greenweight catch assumed that fishers reported the estimated greenweight catch from each day on the CELR forms. It assumed that where appropriate the processed catch data were scaled by the relevant conversion factor.

A2.2 Methods

A2.2.1 Data used in the analysis

The data extract (December 2004) included all records that reported target fishing and/or landings for rig between 1988–89 and 2004–05 in SPO 1 and SPO 8. The effort and landings data were linked, then the landings data were allocated to effort, stratified by trip, target statistical area, method, and target species, to provide total estimated greenweight catch per day of fishing, the duration of fishing (hours) and the length of net set (m) per day. This provided greenweight (estimated, caught) catch, and CPUE (kg/ km of net set) for each day of fishing.

Predictor variables included vessel key (vessels were not identified by name), date, and location of fishing (statistical area, see Figure 2). The predictor variables "net length" and "duration", and the estimated catch were summed within each stratum, where the number of records (n) represented the number of fishing trips per stratum, to ensure that each record of catch and effort referred to a unique fishing operation. A total of 111 855 unique raw data records were extracted.

A2.2.2 Error checking

Data with obvious errors such as missing statistical area, vessel key, date, fishing year, or where fishing occurred in more than one statistical area were deleted from the analysis. Median imputation was used to correct for missing values, or for values that failed the range and edit checks (Table 1). Fishing duration (soaktime) shorter than 0.5 hour were excluded as being errors or representing gear failure, and those over 18 hours were excluded as being errors or representing the retrieval of lost gear. From the 111 855 raw data records extracted, (9352 t of rig catch), a total of 49 737 groomed records of target setnet fishing (5269 t of rig catch) were available after grooming, a retention rate of 44% by numbers of records, and 56% by weight of catch.

A2.2.3 Description of variables

The extracted and derived variables used in the CPUE analysis are listed in Table 2. Most are self-explanatory, but some require further definition. For the standardised CPUE analysis of estimated catch, the dependent variable was estimated greenweight (kg of rig per km of net). This was log transformed in the model. The predictor variable "duration" refers to the total reported time (hours) between the end of setting and the start of hauling of the net per stratum. This was fitted to the model as a cubic function.

A2.2.4 Determination of core vessels

Many of the vessels that reported rig catch in SPO 1 and SPO 8 during 1989–90 to 2003–04 were involved in the fishery for a relatively short time (1–2 years), often with a very small rig catch. Such vessels commonly contribute little to CPUE analysis, and the data analysis was confined to core vessels in the fishery. The definition of the core vessels differs from the revised analysis.

The aggregate catch by fishing year for each vessel was determined for SPO 1-east, and SPO 1-west (including SPO 8). Firstly, vessels that caught less than 1t of rig during the survey period were excluded, then the remaining vessels were sorted, in descending order, by the number of years they had been present in the fishery (experience), and then by total catch. From the cumulative greenweight data, a group of core vessels was identified which included vessels that had fished more than 5 years in these fisheries between 1989–90 and 2003–04. These accounted for most of the estimated catch in each sub-area. In SPO 1 east, the 42 core vessels (of 87) from Thames took 76% of the catch. For the other areas of SPO 1 east, the 47 core vessels (of 96) took 78% of the catch. In SPO 1 west, the 26 core vessels (of 50) from Kaipara took 98% of the catch. In Manukau the 26 core vessels (of 51 total) took 81% of the catch. For SPO 1 west-other, the 28 core vessels (of 33 total) represented 62% of total catch. In SPO 8 the 13 core vessels (of 21 total) represented 81% of total catch.

A2.2.5 Model structure

The modelling approach generally followed that previously described for the main analysis, except the dependent variable was catch (kg) per km of net. The vessel, gear, and environmental parameters were plotted against raw CPUE to determine whether data transformations were required. Cubic or quadratic transformations were carried out on the data, and variables were added to the model as polynomials where appropriate.

Analysis was also confined to the main effects only. Residual plots were examined for evidence of departures from model assumptions.

A2.3 RESULTS

This analysis of estimated rig catch was subsequently discovered to be biased by changes in conversion factor (CF), and the trends should be interpreted with caution.

A2.3.1 SPO 1-east Thames (Statistical area 007)

Three variables entered this model (vessel, month, and fishing year) and together explained 30% of data variability (Table A2.1). The relative indices and standard errors (Figure A2.1) peak in 1990–91 then follow a declining trend.

Table A2.1: Choice of variables in order of importance in regression analysis of estimated catch: log CPUE (kg/km of net) for core vessels in the Thames sub-region of the SPO 1-east rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Variable	Iteration 1	2	R^2 at iteration 3	4
Vessel	**0.18**			
Month	0.14	**0.27**		
Year	0.04	0.21	**0.30**	
Moon phase	0.00	0.18	0.27	0.30
Percentage increase in R^2	18.6	9.0	3.0	0.5

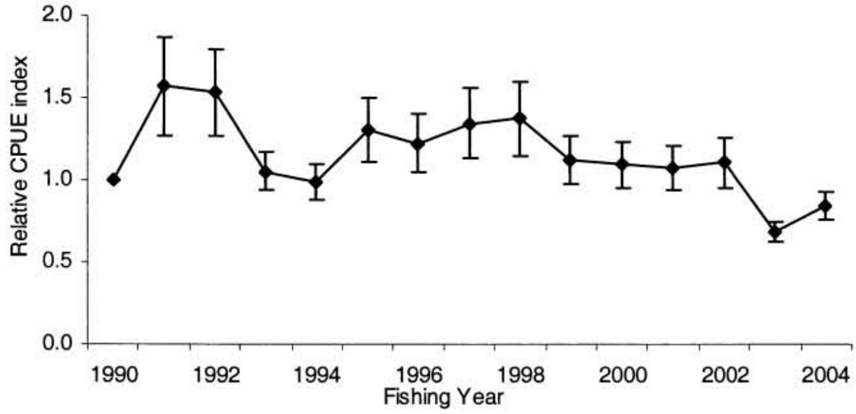


Figure A2.1: Relative indices for variables that entered the core vessels model of estimated catch: log CPUE (kg/km) for the Thames sub-region of the SPO 1-east rig fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year. Error bars represent 1 s.e.

A2.3.2 SPO 1-east Other sub-region

The three variables vessel, month, and fishing year entered this model and together explained 45% of data variability (Table A2.2). The relative indices (Figure A2.2) peak in 1991–92, then remain relatively stable with little trend.

Table A2.2: Choice of variables in order of importance in regression analysis of estimated catch: log CPUE (kg/km of net) for core vessels in the Other sub-region of the SPO 1-east rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Variable	Iteration 1	2	3	R^2 at iteration 4
Vessel	**0.39**			
Year	0.09	**0.44**		
Month	0.01	0.41	**0.45**	
Duration	0.01	0.39	0.44	0.45
Percentage increase in R^2	39.4	5.0	1.0	0.5

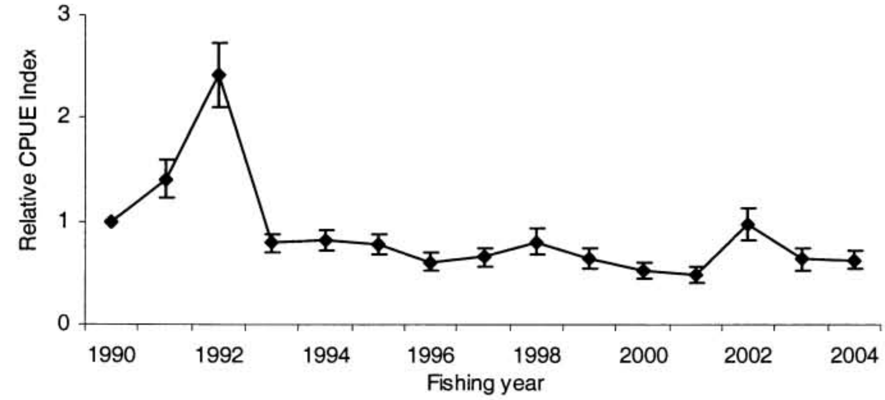


Figure A2.2: Relative indices for variables that entered the core vessels model of estimated catch: log CPUE (kg/km of net), for the SPO 1-east region of the rig fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year. Error bars represent 1 s.e.

A2.3.3 SPO 1-west Kaipara (Statistical area 044)

Three variables entered the model (vessel, month, and fishing year), and together explained 36% of data variability (Table A2.3). The annual indices peaked in 1995–96, then followed a declining trend, with an increase in 2003–04 (Figure A2.3).

Table A2.3: Choice of variables in order of importance in regression analysis of estimated catch: log CPUE (kg/km of net) for core vessels in the Kaipara sub-region of the SPO 1-west rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Variable	Iteration		R^2 at iteration	
	1	2	3	4
Vessel	**0.25**			
Month	0.08	**0.33**		
Year	0.09	0.287	**0.36**	
Duration	0.03	0.26	0.33	0.37
Percentage increase in R^2	25.1	8.0	4.0	0.8

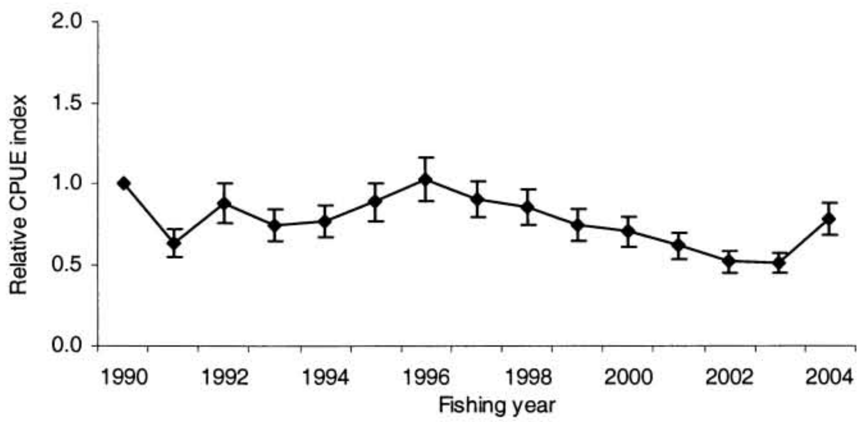


Figure A2.3: Relative indices for variables that entered the core vessels model of estimated catch: log CPUE (kg/km of net), for the Kaipara sub-region of the rig (SPO 1-west) fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year. Error bars represent 1 s.e.

A2.3.4 SPO 1-west Manukau (Statistical area 043)

Four variables entered this model, vessel, month, fishing year, and duration of fishing (modelled as a cubic function), and together explained 40% of data variability (Table A2.4). Annual indices followed a declining trend (Figure A2.4).

Table A2.4: Choice of variables in order of importance in regression analysis of estimated catch: log CPUE (kg/km of net) for core vessels in the Manukau sub-region of the SPO 1-west rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Variable	Iteration			R^2 at iteration	
	1	2	3	4	5
Vessel	**0.25**				
Month	0.14	**0.34**			
Year	0.11	0.31	**0.38**		
Duration	0.01	0.27	0.35	**0.40**	
Moonphase	0.01	0.25	0.34	0.38	0.40
Percentage increase in R^2	25.6	8.5	4.5	1.6	0.1

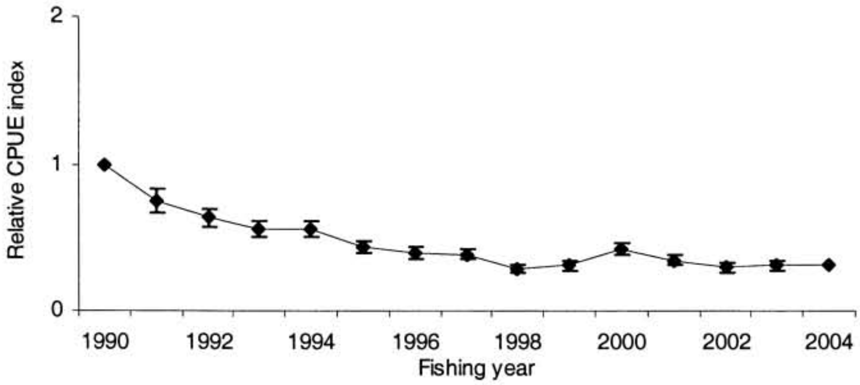


Figure A2.4: Relative indices for variables that entered the core vessels model of estimated catch: log CPUE (kg/km of net) for the Manukau sub-region of the rig (SPO 1-west) fishery, 1998–99 to 2003–04, where 1990 represents the 1989–90 fishing year. Error bars represent 1 s.e.

A2.3.5 SPO 1-west Other sub-region

Three variables entered this model (month, vessel, and fishing year) and together explained only 22% of data variability (Table A2.5). The vessel indices also were variable, and the monthly indices showed highest catch rates occurred between September and November. Annual indices followed a declining trend (Figure A2.5).

Table A2.5: Choice of variables in order of importance in regression analysis of estimated catch: log CPUE (kg/km of net) for core vessels in the rig fishery in the Other sub-region of the SPO 1-west rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Variable	Iteration		R^2 at iteration	
	1	2	3	4
Month	**0.10**			
Vessel	0.09	**0.20**		
Year	0.04	0.15	**0.23**	
Statistical area	0.03	0.14	0.21	0.23
Percentage increase in R^2	10.4	10.2	3.0	0.2

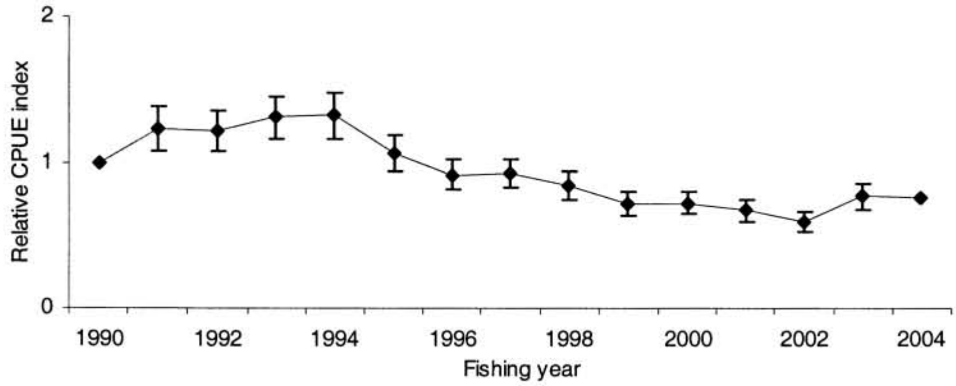


Figure A2.5: Relative indices for variables that entered the core vessels model of estimated catch: log CPUE (kg/km of net) for the Other sub-region of the rig (SPO 1-west) fishery, 1989–90 to 2003–04., where 1990 represents the 1989–90 fishing year. Error bars represent 1 s.e.

A2.3.6 Comparison among sub-regions in SPO 1

Comparison of the annual indices for the sub-regions of SPO 1-east and SPO 1-west (A2.6), scaled to a mean of 1, suggest a declining trend in standardised CPUE between 1989–90 and 2003–04.

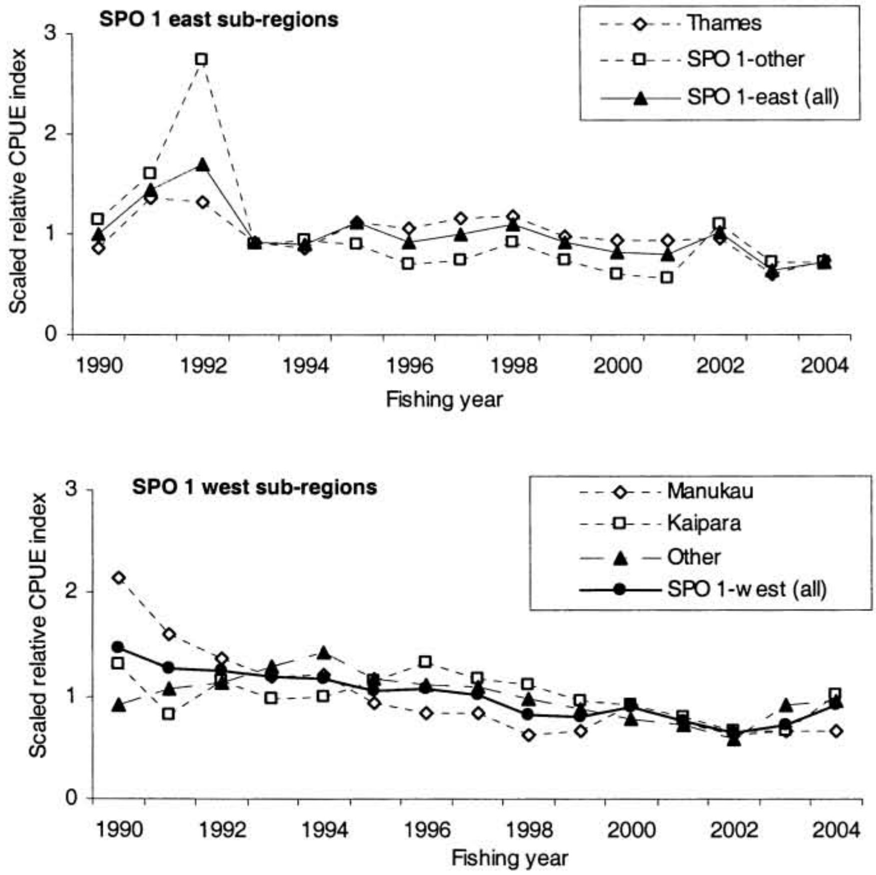


Figure A2.6: Comparison of standardised estimated rig CPUE (kg/km of net) by region (SPO 1-east, SPO 1-west) and by sub-region, 1988–89 to 2003–04, where 1990 represents the 1989–90 fishing year. Both figures are scaled to a mean of 1.

A2.3.7 SPO 8 fishstock

Three variables entered the core vessels model (month, vessel, and fishing year) and together explained 32% of data variability (Table A2.7). Annual indices (Figure A2.7) are suggestive of a declining trend, but the data are variable with high error bars, possibly due to the small sample size available for this fishstock. These trends should be interpreted with caution.

Table A2.7: Choice of variables in order of importance in regression analysis of estimated catch: log CPUE (kg/km of net) for core vessels in the SPO 8 rig fishery, 1989–90 to 2003–04. Variables in bold entered the model.

Variable	Iteration		R^2 at iteration	
	1	2	3	4
Month	**0.23**			
Vessel	0.12	**0.29**		
Year	0.03	0.27	**0.32**	
Statistical area	0.01	0.24	0.29	0.32
Percentage increase in R^2	23.5	6.0	4.0	0.1

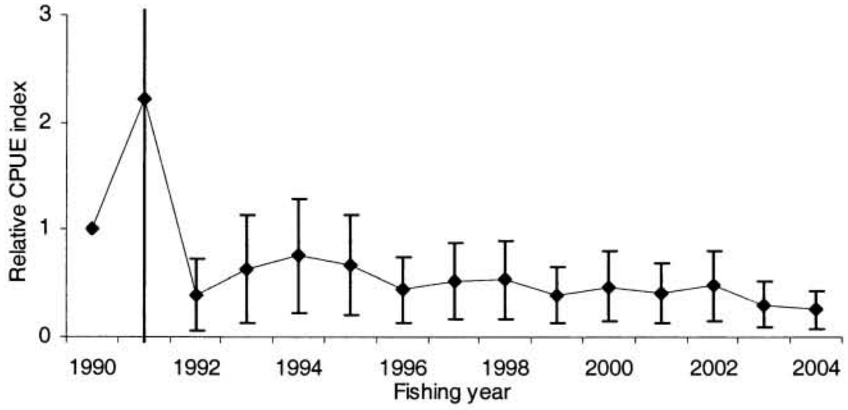


Figure A2.7: Relative indices for variables that entered the core vessels model of estimated catch: log CPUE (kg/km of net) for the rig (SPO 8) fishery, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year. Error bars represent 1 s.e. The upper and lower bounds of the 1991–92 indices have been deleted for clarity.

A2.4 Comparison with previous standardised CPUE indices of estimated catch

The rate of decline in the annual indices for the Kaipara sub-region of SPO 1-west is consistent with the trends in annual standardised CPUE indices previously noted by Hartill (2002) (Figure A2.8).

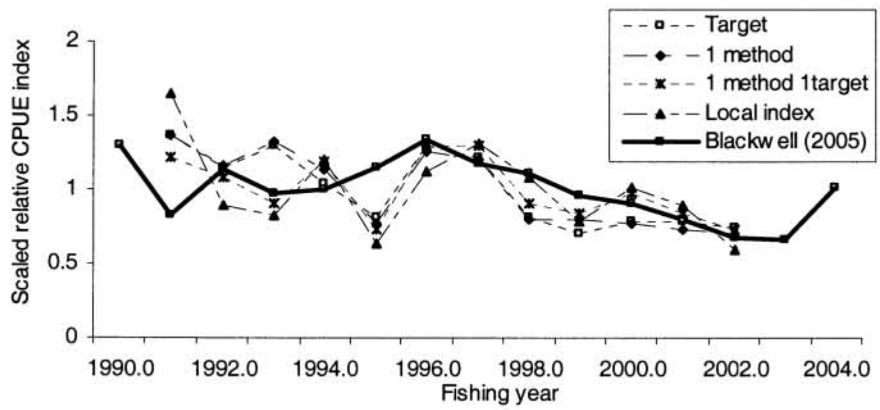


Figure A2.8: Comparison of the standardised estimated CPUE indices derived for the Kaipara sub-region of the rig (SPO 1-west) fishery, 1989–90 to 2003–04, with the standardised indices derived by Hartill (2002) for the Kaipara Harbour. Both data series are scaled to a mean of 1.

A2.5 Comparison between initial (uncorrected) estimated catch indices, with the revised analysis of calculated greenweight catch

Data are presented for each sub region of SPO 1, and for SPO 8 comparing annual indices from the two analyses competed in this report (Figure A2.9). The annual indices from the estimated catch data are higher in the early part of the time series (prior to 1997), and lower for more recent years, which has created an anomalous decline in relative CPUE indices.

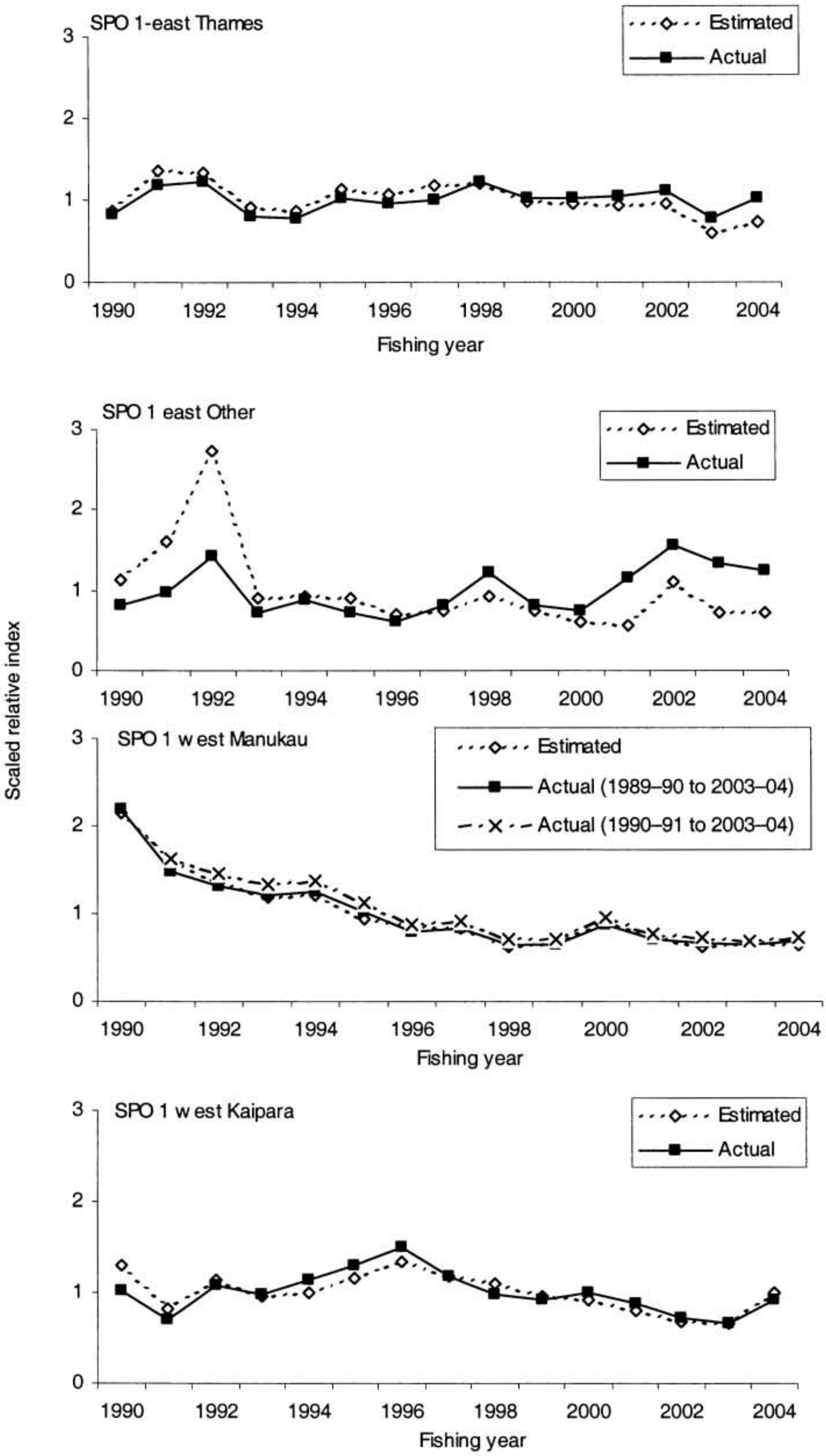
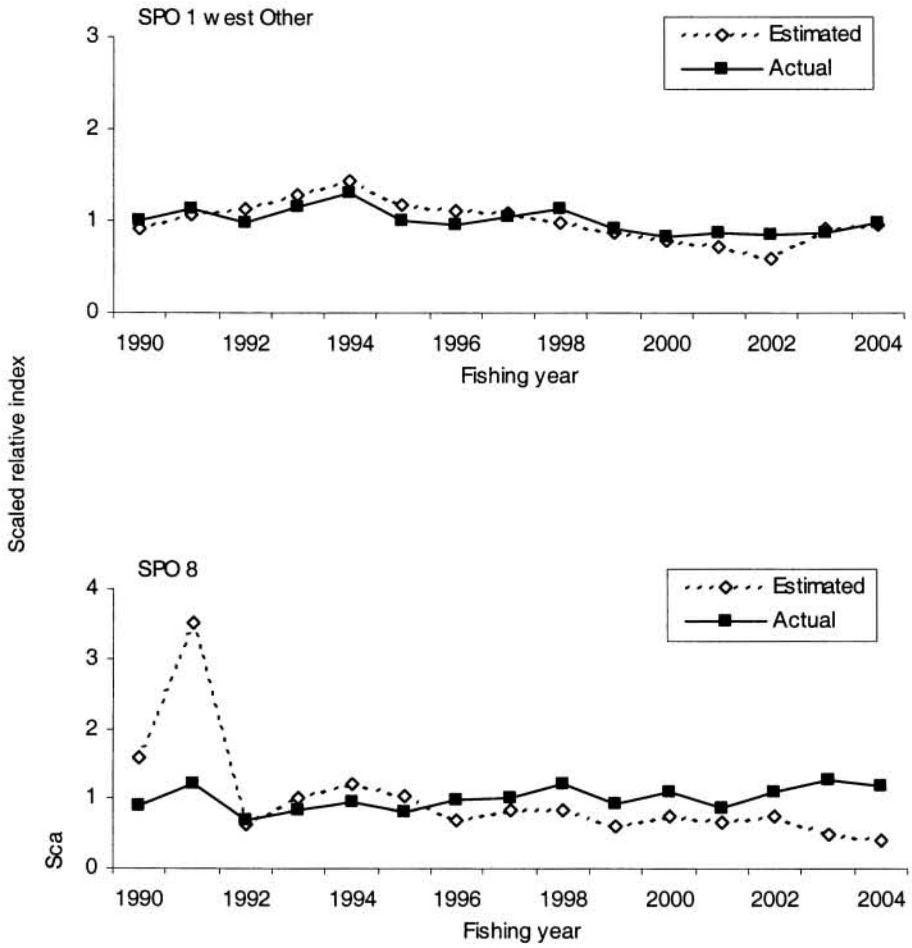


Figure A2.9: Comparison of annual indices from the initial analysis of estimated rig catch CPUE (kg/km), and the revised analysis of calculated (actual) greenweight rig catch (kg) by sub-region of the SPO 1, and the SPO 8 fisheries, 1989–90 to 2003–04, where 1990 represents the 1989–90 fishing year. Each data series is scaled to a mean of 1.


SPO 1 w est Other
Estimated
Actual
3
2
1
0
1990
1992
1994
1996
1998
2000
2002
2004
Fishing year
Scaled relative index
SPO 8
Estimated
Actual
4
3
2
1
0
1990
1992
1994
1996
1998
2000
2002
2004
Fishing year
Sca

Appendix 3: Summary of main variables by sub-region of SPO 1, and SPO 8, 1989–90 to 2003–04

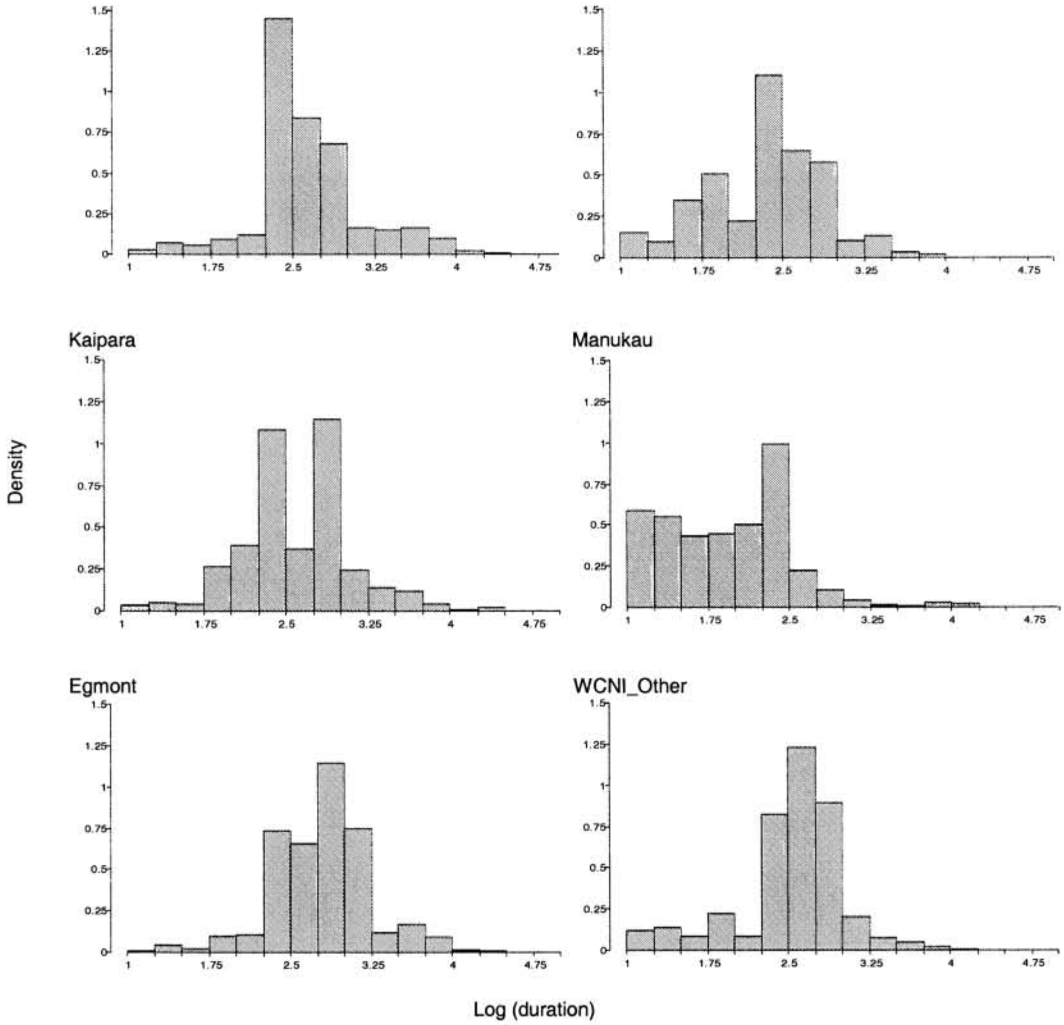


Figure A3.1: Density distribution of log (duration of fishing) in the rig target setnet fishery, 1989–90 to 2003–04, by sub-area of SPO 1 (Thames, ECNI-Other, Kaipara, Manukau, WCNI-Other), and SPO 8 (Egmont).

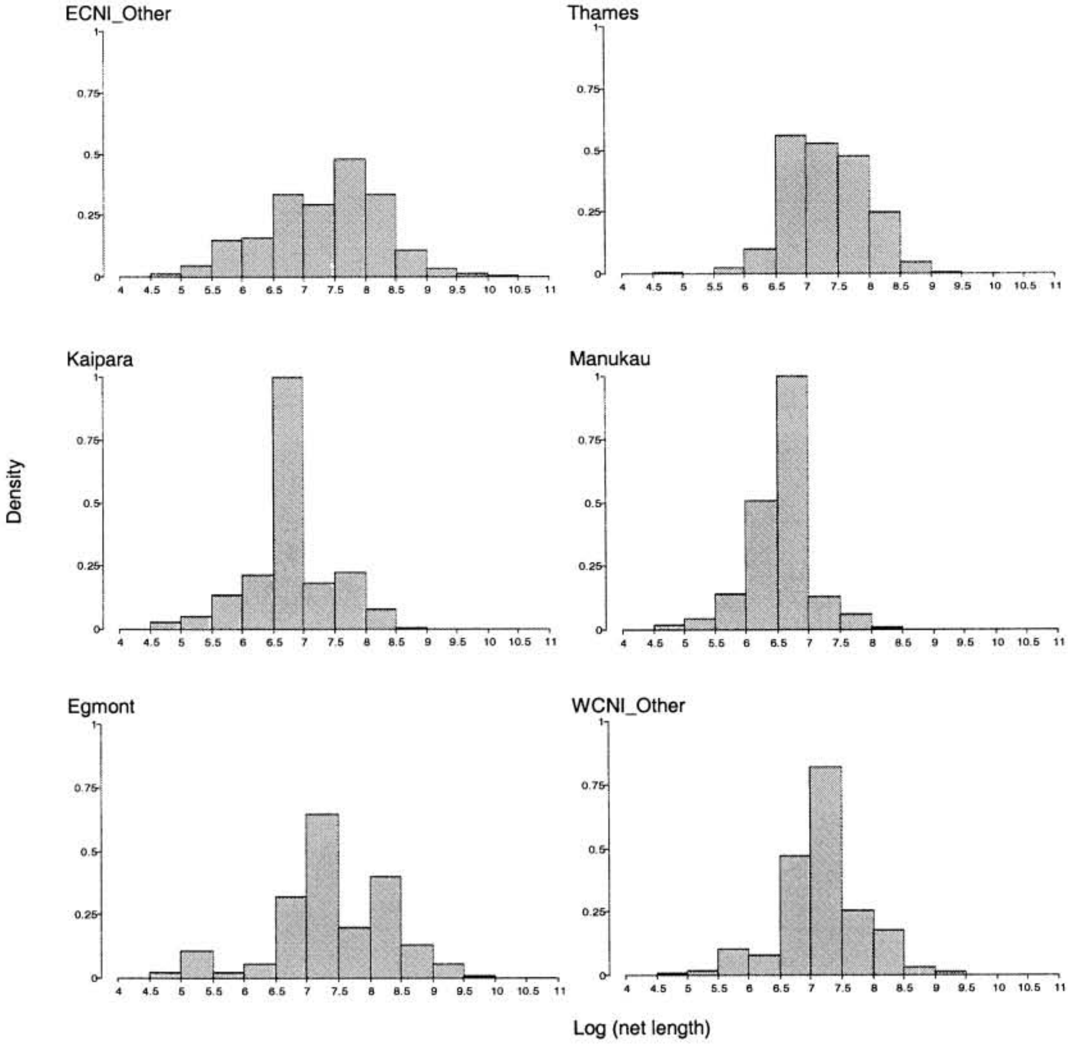


Figure A3.2: Density distribution of log (net length) in the rig target setnet fishery, 1989–90 to 2003–04, by sub-area of SPO 1 (Thames, ECNI-Other, Kaipara, Manukau, WCNI-Other), and SPO 8 (Egmont).

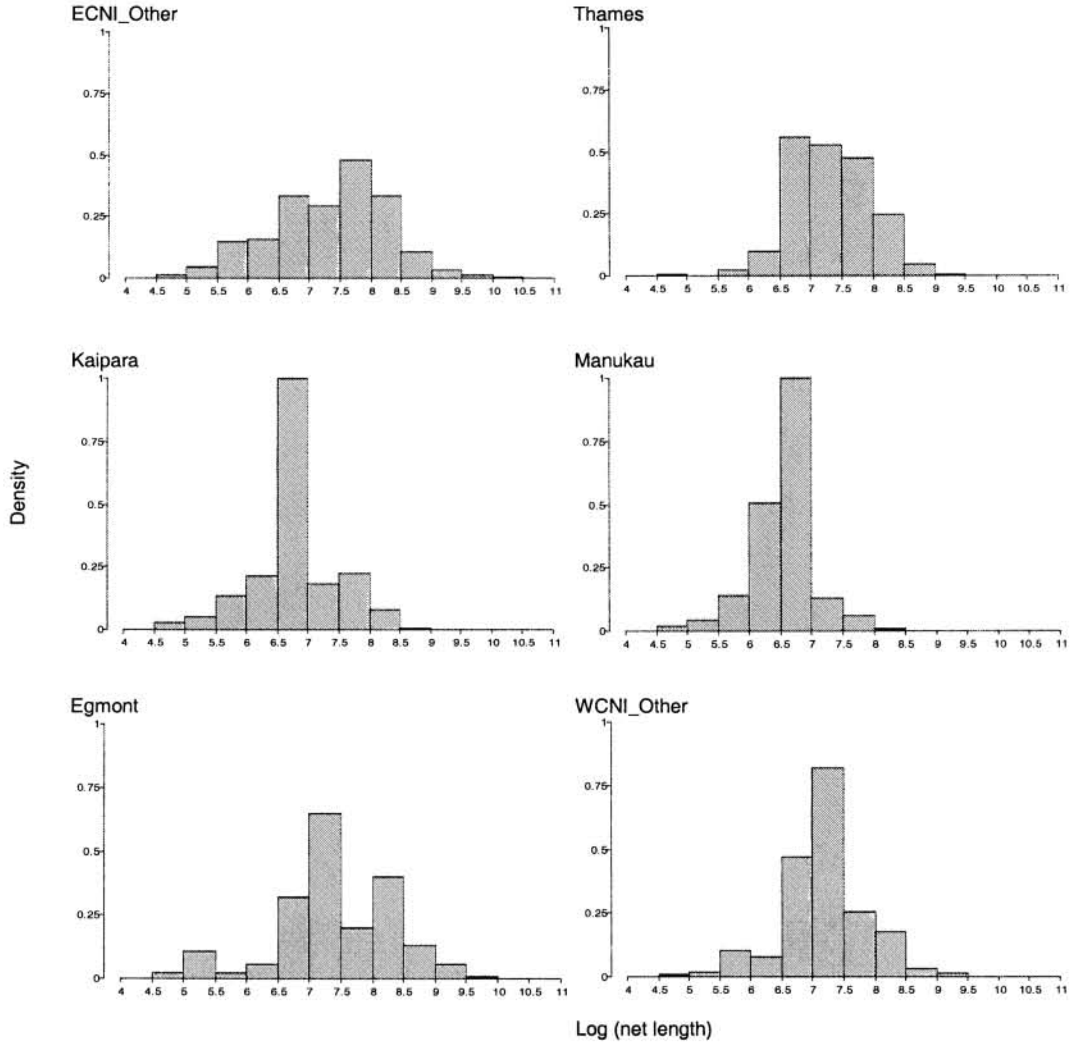


Figure A3.3: Density distribution of log (catch (kg)) in the rig target setnet fishery, 1989–90 to 2003–04, by sub-area of SPO 1 (Thames, ECNI-Other, Kaipara, Manukau, WCNI-Other), and SPO 8 (Egmont).

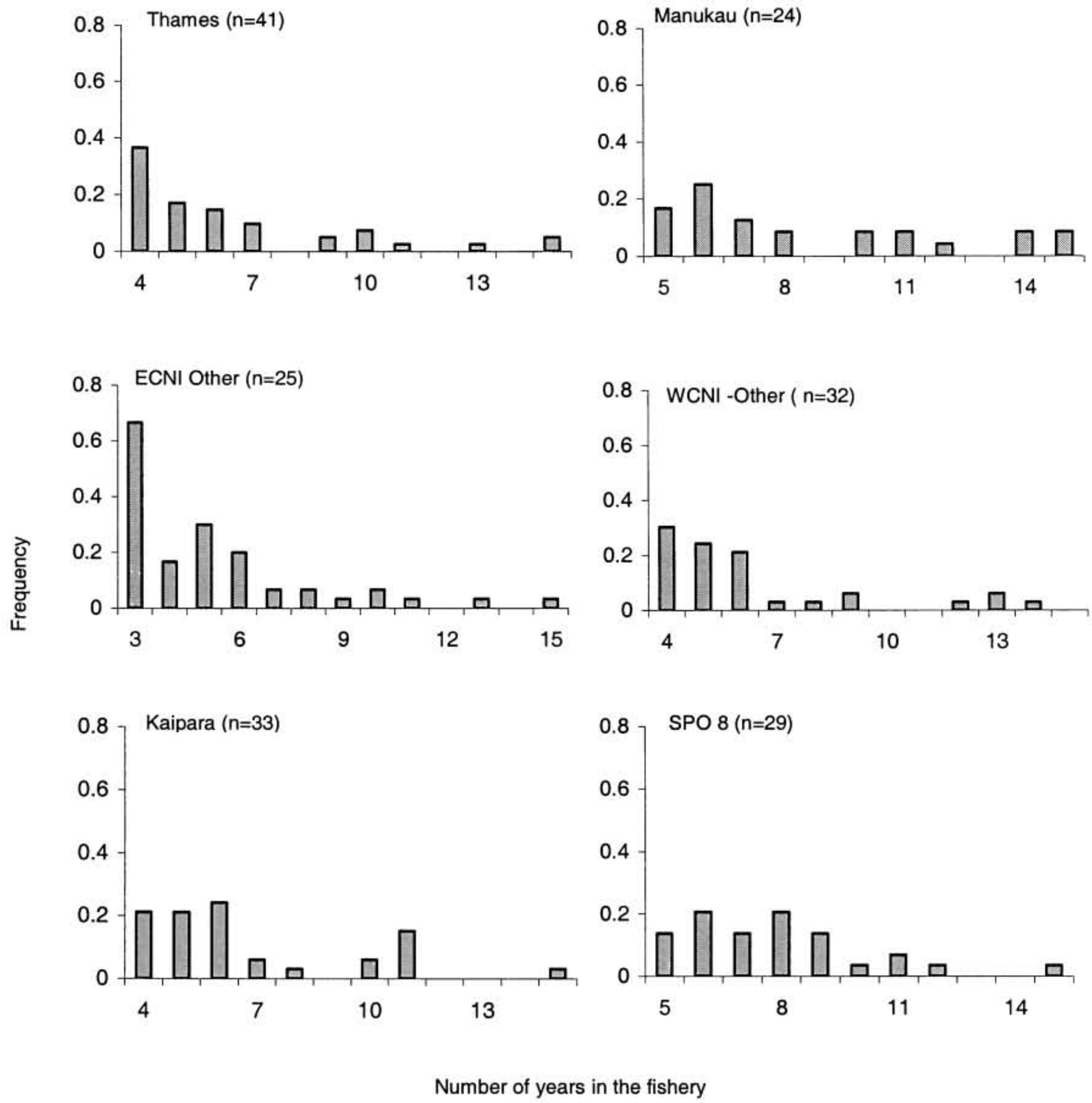
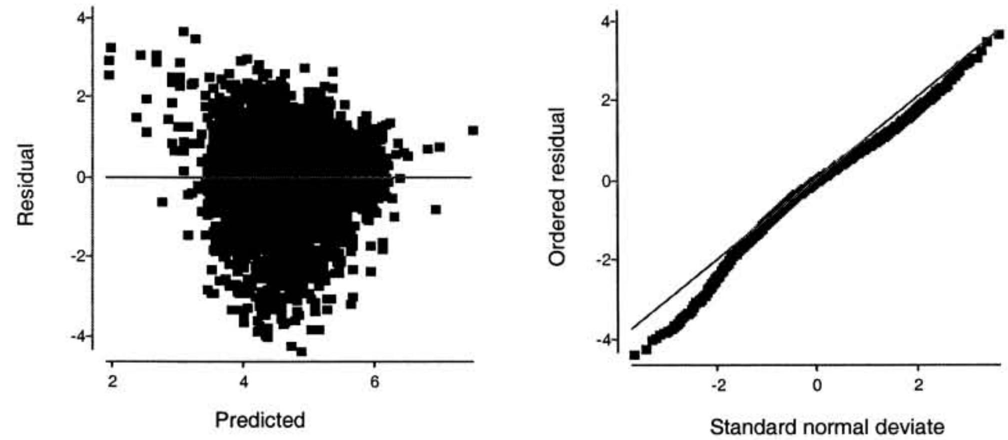


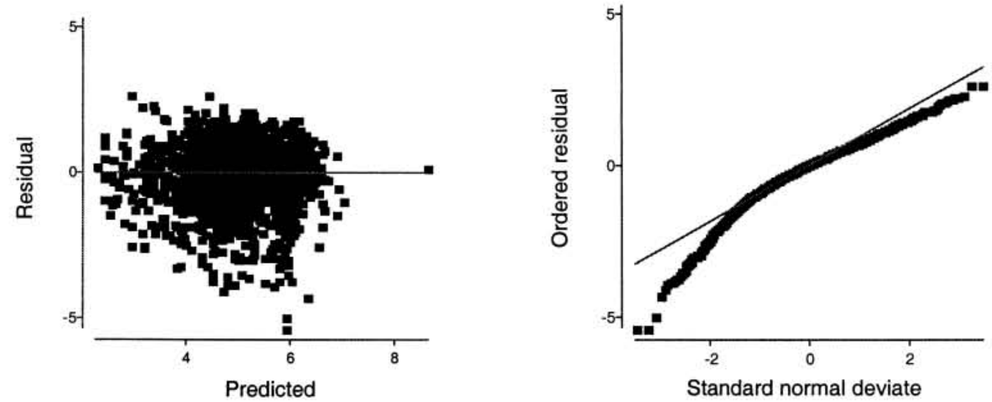
Figure A3.4: Frequency histograms of the number of years of fishing experience for core vessels in the target rig setnet fishery, by sub-region of SPO 1, and SPO 8.

Appendix 4: Diagnostic plots from the standardised CPUE models of calculated rig greenweight

Thames sub-region of SPO 1-east



Other sub-region of SPO 1-east



Kaipara sub-region of SPO 1-west

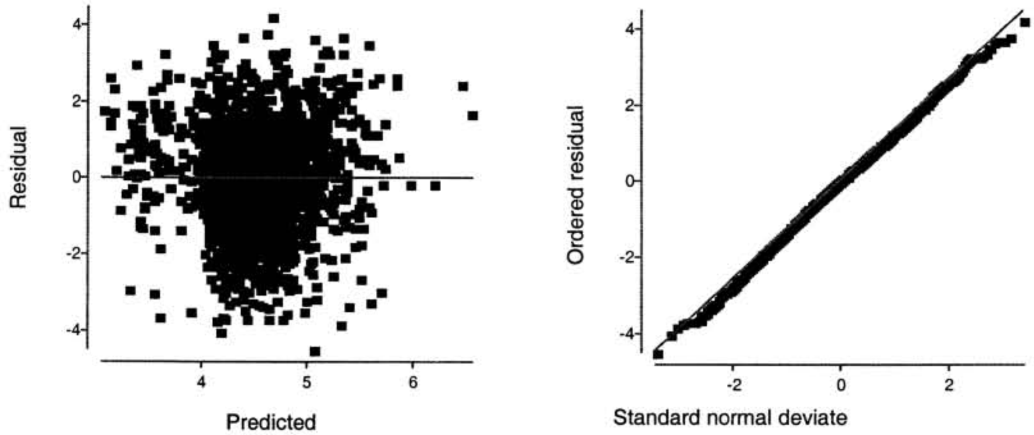
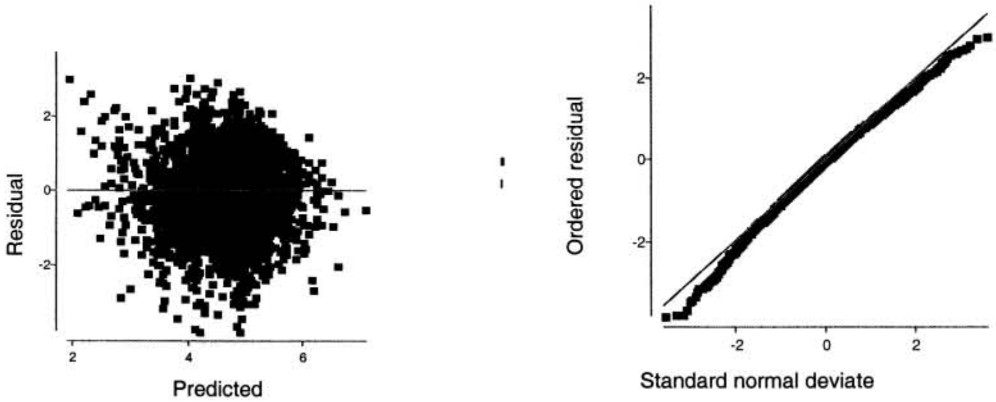
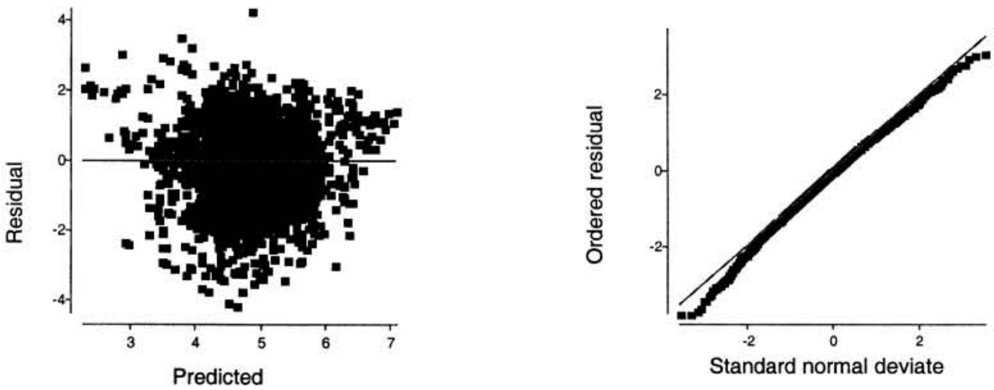


Figure A4.1: Diagnostic plots (log scale) for the lognormal linear standardised rig CPUE model core vessels analysis, excluding zero catch records, by fishstock region and sub-region, 1998–99 to 2003–04. The left figure shows the fitted values versus the residuals, and the right figure shows normal quartile versus quartile (Q–Q) plots of the residuals.

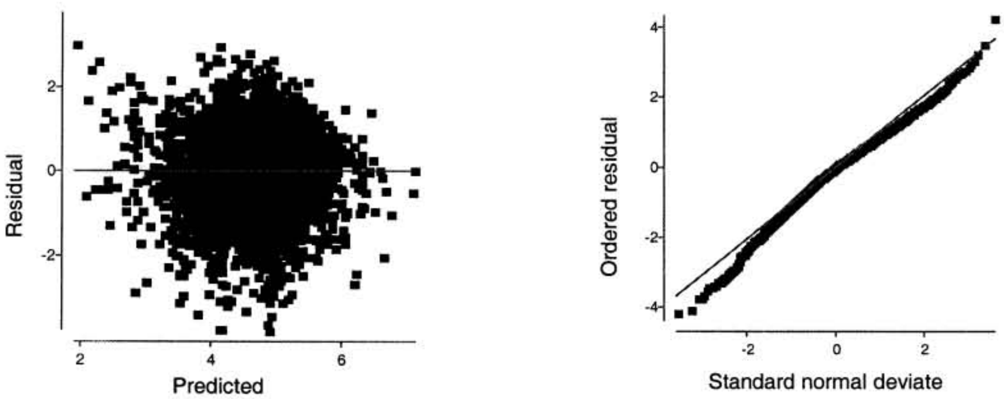
Manukau sub-region of SPO 1-west (1989–90 to 2003–04)



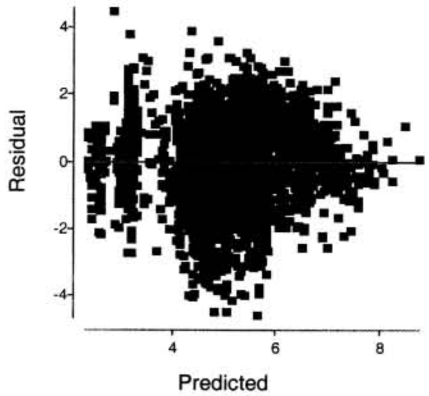
Manukau sub-region of SPO 1-west (1990–91 to 2003–04)

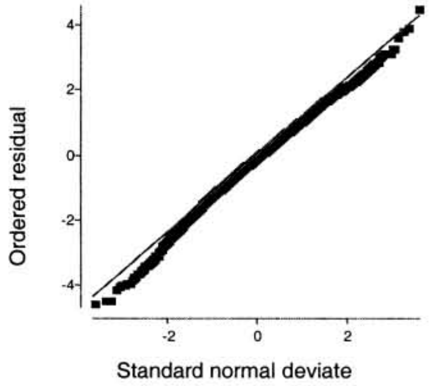


Other sub-region of SPO 1-west



SPO 8 fishstock





Appendix 5: Summary of the relevant trawl survey series in SPO 1-west, SPO 8, and SPO 2

A5.1 Relevant trawl survey series

Trawl surveys that target snapper (*Pagrus auratus*), jack mackerels (*Trachurus* spp.), John dory (*Zeus faber*), red gurnard (*Chelidonichthys kumu*), tarakihi (*Nemadactylus macropterus*), trevally (*Pseudocaranx dentex*), and gemfish (*Rexea solandri*) are considered an invalid method of monitoring the abundance of rig (Paul 2003). However, the suggestion that trawl surveys potentially provide a method of monitoring the abundance of juvenile rig led to an investigation of the results from trawl surveys conducted off the east and west coasts of the North Island. This appendix presents a review and summary of the rig data from relevant trawl surveys. Specific details of the trawl gear and survey designs and the assumptions used in the biomass estimation are given in the relevant reports cited below.

Trawl survey series conducted within SPO 1 and SPO 8 were primarily spring-summer surveys off the west coast of the North Island (SPO 8 and SPO 1-west). The survey series discussed here (with relevance to rig catch) are limited to those in SPO 1-west and SPO 8 (reviewed by Morrison et al. 2001a, Morrison & Parkinson 2001) and SPO 2 (Stevenson & Hanchet 2000) (Figure A5.1). Although surveys were conducted waters off the east coast of Northland (see Drury & McKenzie 1992a), Hauraki Gulf (see, for example, Drury & McKenzie 1992b), and in the Bay of Plenty (see Morrison et al. 2001b), rig catches were low and not described. The series in SPO 2, though outside the scope of the project, is included because it offers a little more information on the abundance of rig as measured by trawl surveys.

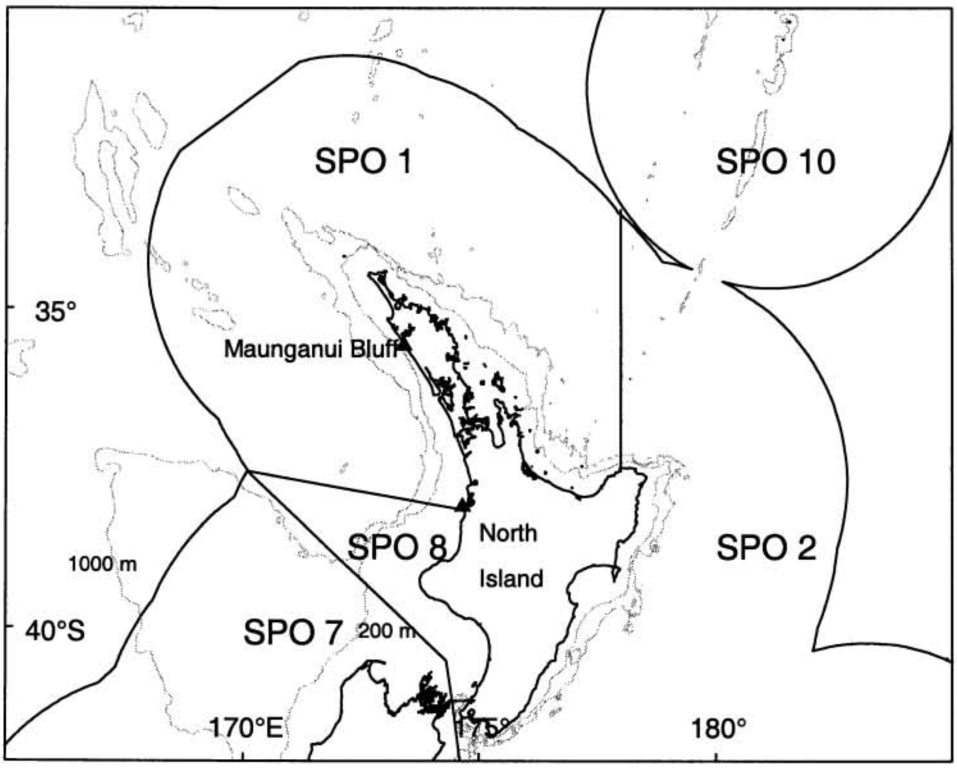


Figure A5.1: Northern SPO fisheries management areas and the core area (Maunganui Bluff to the SPO 1/SPO 8 boundary, as indicated by ▲) used in the analysis of the west coast North Island trawl survey series.

A5.2 Trawl survey series off the west coast of the North Island

Between 1986 and 1994, *Kaharoa* undertook five single-phase, stratified random trawl surveys during October-December and two two-phase surveys in 1996 and 1999 (see reviews by Morrison et al. 2001a and Morrison & Parkinson (2001). A high-opening bottom trawl net with a 40 mm codend mesh was used in these surveys. These surveys were targeted at 2+ and 3+ snapper, John dory, red gurnard, and, since 1996, tarakihi. Data from the trawl survey series are separated below into the western half of SPO 1 (SPO 1-west) and SPO 8.

A5.2.1 SPO 1-west

The area surveyed was not consistent in each year and, in their review of this survey series from 1989 to 1996, Morrison et al (2001a) used the smaller area surveyed in 1987 as the "core area" (see Figure A5.1). This core area represents most of the area in SPO 1-west, and is defined by Maunganui Bluff to the boundary of SPO 1 and SPO 8 in waters between 10 and 100 m. We re-ran the trawl survey program (Vignaux 1994) to produce biomass estimates for rig for 1999, because those given by Morrison & Parkinson (2001) were for the whole west coast survey area, rather than just the core area.

A5.2.1.1 Length frequency results

In all years, except 1989 when few rig were caught, rig were caught at over 50% of stations (range 44–76%), and between 44 and 363 rig were caught per survey (Table A5.1). All rig were measured and sexed, where possible. Females were less commonly caught than males, contributing to between 33 and 64% of the total fish per survey. There appear to be large differences in the numbers of males and females caught between surveys, with varying effects on the scaled numbers (compare 1991 and 1994 in Table A5.1).

Rig under 90 cm total length were classed as "pre-recruits", and the highest percentage biomass of pre-recruits was generally in waters less than 25 m deep outside harbour entrances and in depths of 26–100 m south of Manukau Harbour. The exception to this was in 1991 when a large percentage of the pre-recruits were from waters up to 50 m deep north of Kaipara Harbour.

In all years most of the rig were pre-recruits, as is shown by the dominance of smaller rig in the plot of scaled length frequencies, as presented by Morrison et al. (2001a) and updated for 1999 (Figures A5.2 & A5.3). No clear length modes are evident in these data; the spike in 1999 reflects the measurement at 72 cm of 50% of the males caught in that survey.

Table A5.1: Summary data for the core area of SPO 1-west for all rig, 1986–99.

Survey year	No. stations with rig (% all core area stations)	Scaled no. fish x 1000 (actual no.)* All	Males	Females
1986	28 (56)	59 (72)	38 (46)	21 (26)
1987	31 (55)	140 (136)	96 (72)	44 (64)
1989	22 (44)	23 (44)	11 (20)	10 (20)
1991	28 (68)	94 (152)	48 (53)	46 (99)
1994	35 (73)	95 (114)	55 (68)	40 (46)
1996	39 (76)	132 (363)	71 (154)	61 (205)
1999	26 (50)	47 (97)	24 (36)	15 (46)

* The "All" column includes those rig that were not sexed.

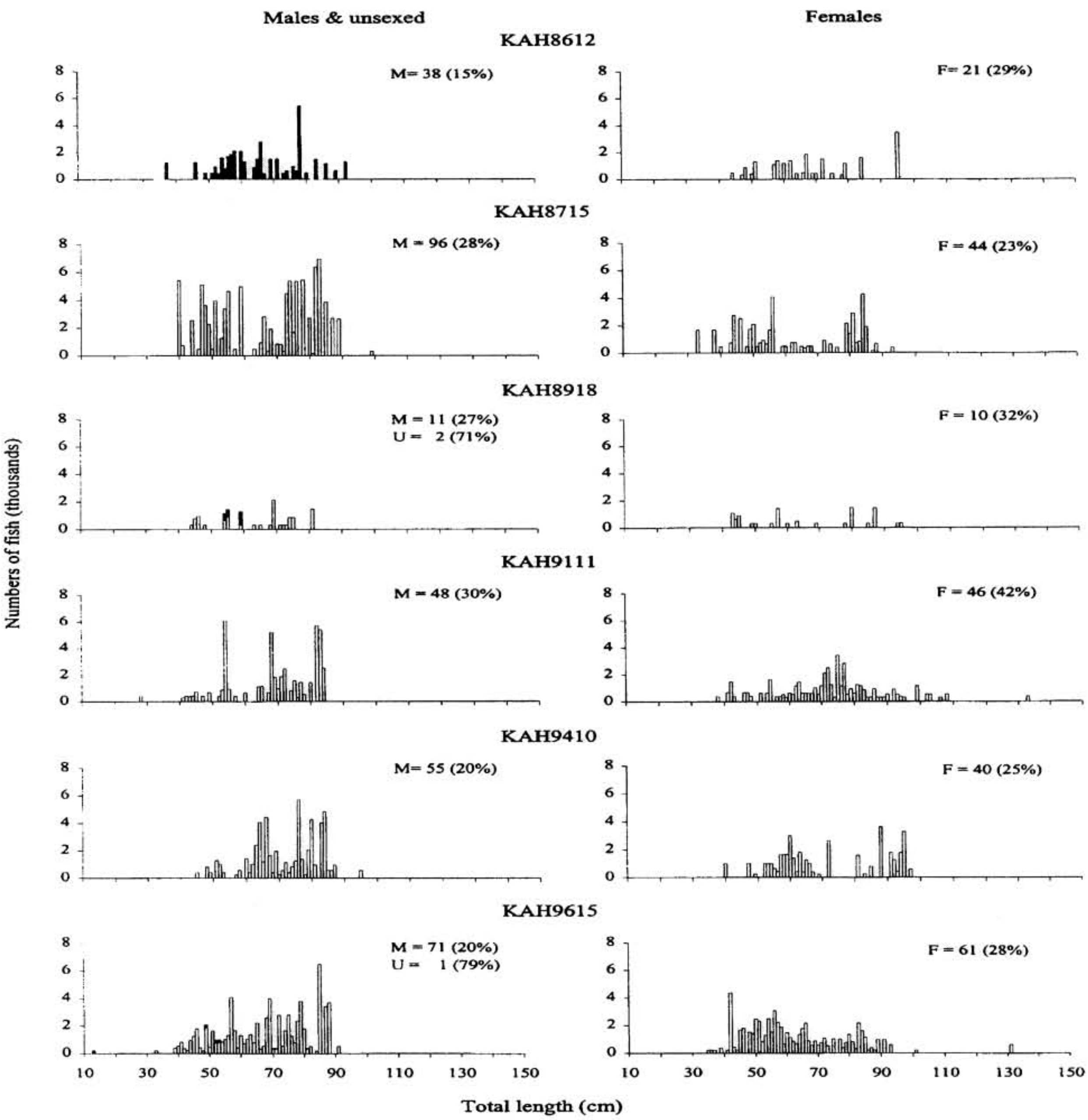


Figure A5.2: Scaled length frequency for the core area of SPO 1-west (as shown by Morrison et al. (2001a), 1986-1996.

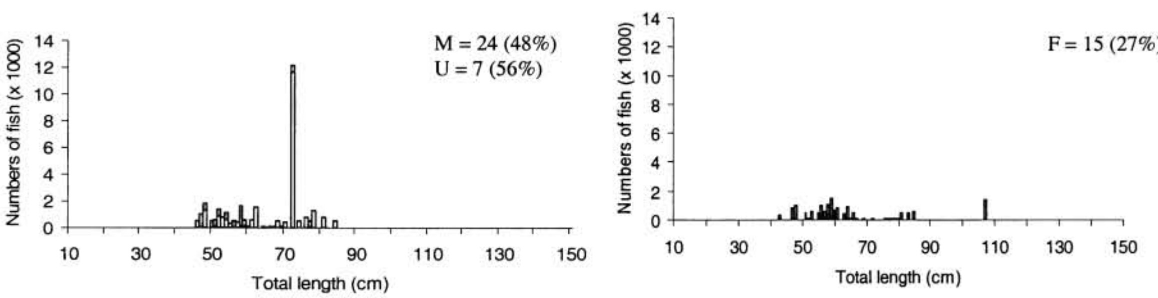


Figure A5.3: Scaled length frequency for the core area of SPO 1-west, 1999.

A5.2.1.2 Biomass estimates

The biomass estimates for recruited fish are small and show few differences between surveys (Figure A5.4). These trawl surveys are known to be an unreliable sampling tool for adults (Paul 2003).

Biomass estimates for the pre-recruits show substantial differences between surveys completed in 1986, 1987, and 1989 (see Figure A5.4). The pre-recruit estimates for 1991, 1994, and 1996 are very similar, but that for 1999 is substantially less than that estimated in 1996. Little can be deuced from these results. Any fluctuations could be viewed as spurious, given the few data. It should be noted that biomass estimates of other main catch species were low in 1986, and similarly for snapper, red gurnard, barracouta (*Thyrsites atun*), and school shark (*Galeorhinus galeus*) in 1989, when sea surface temperatures were at least 1 °C higher.

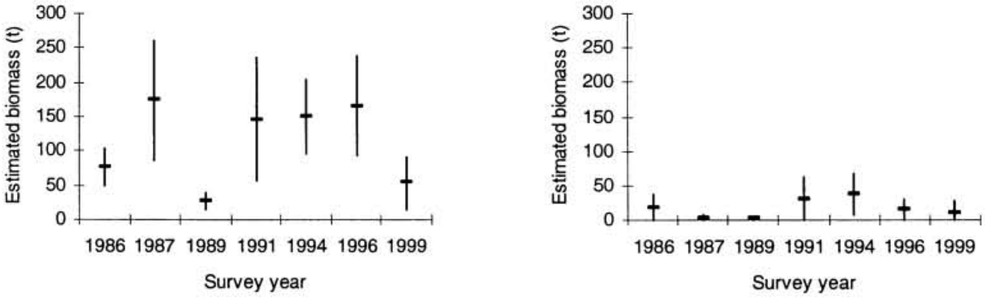


Figure A5.4: Estimated rig biomass (t) with 95% confidence intervals for the six *Kaharoa* surveys reviewed by Morrison et al. (2001a), for pre-recruited rig (< 90 cm) (left), and for recruited rig (≥ 90 cm) (right). Data are from the output from the analyses run for each survey (as supplied by M. Stevenson, NIWA, Nelson).

A5.2.2 Trawl survey series in SPO 8

Few data were available for SPO 8 (Table A5.2) and the length frequency data show that nearly all rig caught in this area were pre-recruits (see figure 6d in Morrison et al. (2001a)). The few data and the associated biomass estimates (Figure A5.5) indicate that no conclusions can be reached.

Table A5.2: Summary data for SPO 8 for all rig, 1989–96*.

Survey year	No. stations with rig (%)	Scaled no. fish x 1000 (actual no.)		
		All	Males	Females
1989	7 (33)	15 (21)	8 (11)	4 (7)
1991	7 (64)	31 (15)	28 (11)	3 (4)
1994	7 (54)	69 (42)	5 (5)	64 (37)
1996	8 (54)	6 (12)	3 (5)	3 (7)

* Data are from the trawl analysis program results supplied by M. Stevenson.

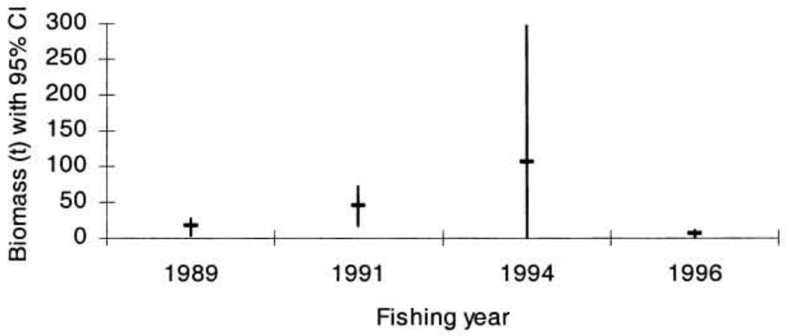


Figure A5.5: Estimated rig biomass (t) with 95% confidence intervals for the four *Kaharoa* surveys in SPO 8 reviewed by Morrison et al. (2001a), for pre-recruited rig (< 90 cm). Recruited rig were caught only in the 1996. Data are from the output from analyses run for each survey (as supplied by M. Stevenson).

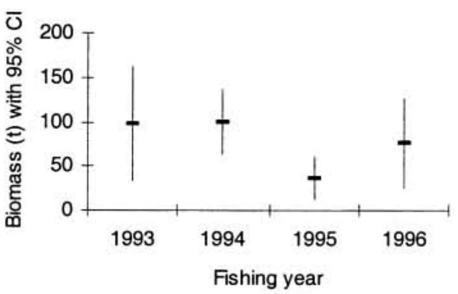
A5.3 Trawl survey series off the east coast North Island in SPO 2

This series of four two-phase stratified random trawl surveys took place during February-March of 1993–96 between Cape Runaway and Turakirae Head in SPO 2 (see review by Stevenson & Hanchet 2000). Specific depth ranges were surveyed with a 80 mm codend: 20–100 m, 100–200 m, and 200–400 m, with the main objective to target gemfish (*Rexea solandri*), snapper, tarakihi, and trevally (*Pseudocaranx dentex*).

Rig were caught mainly in waters less than 100 m deep, and between 117 and 246 rig were caught per survey (Table A5.3). There were no clear modes in the length frequency data because of the low number of fish caught (see figure 7i in Stevenson & Hanchet 2000). Males were dominant in the catch of rig, and Stevenson & Hanchet (2000) suggested that the trawl gear under-sampled the larger fish in the population as well as the female component. However, there was a more even mix of pre-recruits and recruited fish in this series than in the west coast North Island survey.

Table A5.3: Summary data for SPO 2 for all rig, 1994–96.

Survey	No. stations	Scaled no. fish x 1000 (actual no.)		
year	with SPO (%)	All	Males	Females
1993	38 (57)	86 (153)	55 (107)	30 (46)
1994	62 (63)	83 (246)	66 (190)	17 (56)
1995	38 (32)	34 (117)	25 (84)	9 (33)
1996	52 (54)	69 (156)	47 (120)	22 (36)



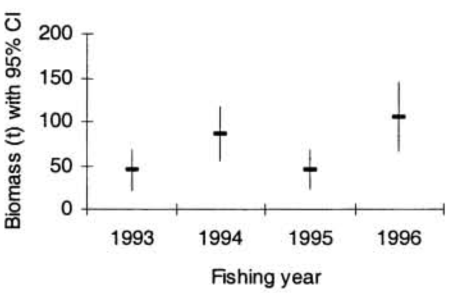


Figure A5.6: Estimated rig biomass (t) with 95% confidence intervals for the four *Kaharoa* surveys reviewed by Stevenson & Hanchet (2000), for pre-recruited rig (< 90 cm) (left) and the recruited rig (≥ 90 cm) (right). Data are from the output from analyses run for each survey (as supplied by M. Stevenson).

A5.4 Conclusions

All the trawl surveys used R.V. *Kaharoa* and have been directed primarily at certain year classes of various shallow water finfish species. Although there were some variations in the gear used between survey series, the numbers of rig caught were not large enough to support any conclusions. Thus, trawl surveys off the west coast of the North Island (SPO 1-west) and the east coast of the lower North Island (SPO 2) do not appear to be useful for monitoring the abundance of juvenile or adult rig.

Other trawl survey series carried out in eastern waters (SPO 1-east) resulted in very small rig catches and were therefore of no use in this investigation. For completeness, these are briefly summarised.

- In November–December 1990, a trawl survey undertaken off the east coast of the North Island north of Bream Head then down the west coast to Tauroa Point on Ninety Mile Beach in waters less than 200 m deep resulted in a total rig catch of 7.7 kg from 5% of the 57 stations (Drury & McKenzie 1992a).
- Less than 10% of the 77 stations in a survey in February 1993 in waters off the east coast north of Bream Head, caught a total of 13.7 kg of rig; these data were not analysed (Drury & Hartill 1994).
- Five Hauraki Gulf surveys took place during October-November between 1990 and 2000. Rig catches were briefly summarised in four of the survey reports: in 1990, 294.6 kg were caught at 15% of 75 stations (Drury & McKenzie 1992b); in 1994, 74 kg of rig were caught at 28% of 70 stations (Langley 1995); in 1997, 31 kg of rig were caught at 29% of 48 stations; and in 2000, 5.6 kg of rig were caught at 6% of 52 stations (Morrison et al. 2002). No summary was provided for the 1992 survey (Langley 1994).
- Six trawl surveys were conducted in the Bay of Plenty during February-March in years between 1983 and 1999. No rig data were summarised in the review report (Morrison et al. 2001b). In 1990, 82.2 kg of rig were caught from 19% of 64 stations (Drury & McKenzie 1992c). In 1992, 74 kg of rig was caught in 18% of 79 stations (Drury & Hartill 1993). In 1996, 13.8 kg of rig was caught at 5% of 78 stations (Morrison 1997), and in 1999, 24 kg of rig was caught at 8% of 78 stations (Morrison & Parkinson 2000).