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EXECUTIVE SUMMARY

Field, K.D.; Hanchet, S.M. (2001). Catch-per-unit-effort analysis for tarakihi (*Nemadactylus macropterus*) in TAR 1, 2, 3, and 7.

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The research reported in this document was part of a study conducted by NIWA for the Ministry of Fisheries under contract TAR 1999/01.The objective of TAR 1999/01 reported on in this document is: *To carry out a descriptive analysis of catch and effort data and develop both unstandardised and standardised indices of abundance for tarakihi in TAR 1, TAR 2, TAR 3, and TAR 7 with the inclusion of data up to the end of the 1998–99 fishing year.*

The descriptive analysis identified several important fishing grounds for tarakihi, including west and east Northland (TAR 1), the western Bay of Plenty to Cape Turnagain (TAR 1 and 2), Cook Strait to the Canterbury Bight (mainly TAR 3), and Jackson Head to Cape Foulwind (TAR 7). Around the North Island 70–80% of the tarakihi are taken in target tarakihi bottom trawl fisheries. Around the South Island only about 30% of the tarakihi are taken in target tarakihi bottom trawl fisheries; much of the remainder is taken as bycatch in target barracouta and red cod bottom trawl fisheries. In addition, there is a small target tarakihi set net fishery off Kaikoura.

Unstandardised CPUE indices (mean catch per vessel-day) were calculated by fishing method for all vessels and all target species combined, and by statistical area for successful vessel-days that targeted tarakihi in the bottom trawl fishery.

Standardised CPUE indices were estimated for the bottom trawl fisheries in TAR 1W, TAR 1E, TAR 2, TAR 3, and TAR 7, and the set net fishery in TAR 3. Various models were used depending on the nature of the fishery. The conclusions were as follows.

- CPUE indices calculated for TAR 1W are probably monitoring tarakihi abundance in the area, and could be used to track tarakihi abundance in years when there is no trawl survey. The index peaked in 1996, but has since declined slightly.
- CPUE indices calculated for TAR 1E are probably monitoring tarakihi abundance in the area. The indices have been essentially flat over the time period. We recommend that in future analyses some consideration is given to estimating separate indices for the east Northland and Bay of Plenty fisheries.
- CPUE indices calculated for TAR 2 are probably monitoring tarakihi abundance in the area. The indices have been essentially flat over the time period.
- CPUE indices calculated for TAR 3 are probably not monitoring tarakihi abundance in the area, and we recommend that these indices be treated with caution. Trawl indices peaked in 1996, and have since declined slightly, whilst set net indices have been stable.
- CPUE indices calculated for TAR 7 do not appear to be monitoring tarakihi abundance in the area, and we reject these as indices of abundance.

For the bottom trawl fisheries, standardised CPUE was estimated for all vessels combined and for a subset of vessels with a continuous representation in the fishery. In all cases there was little difference in the indices resulting from the two datasets. However, the all vessels models generally explained slightly more of the variation in CPUE than the subset models. They also had 1.5–2 times the amount of data and correspondingly lower standard deviations on the indices. Therefore it is recommended that the all vessels models be used in any modelling.

1. INTRODUCTION

Tarakihi is an important inshore commercial fish species and is caught in coastal waters off the North and South Islands, Stewart Island, and the Chatham Islands, down to depths of about 250 m. The major commercial fishing method is bottom trawling, except near Kaikoura where the main method is set netting (Annala et al. 2000).

The fishery has been relatively stable since 1968, with total annual landings ranging between about 4000 and 6500 t, and averaging about 5000 t (Annala et al. 2000). There are eight tarakihi Fishstocks (Figure 1), but 95% of the annual catch comes from TAR 1, TAR 2, TAR 3, and TAR 7. Catches in TAR 1 and TAR 2 have ranged from 1000 to 1700 t per year over the past 5 years, whilst catches in TAR 3 and TAR 7 have ranged from 500 to 1300 t per year.

A preliminary CPUE analysis was carried out for TAR 1 and 2 covering the 1989–90 to 1993–94 fishing years (Starr 1995). Standardised CPUE analyses were carried out for five separate fishing grounds in TAR 1 and one in TAR 2. Overall, CPUE showed no increase or decline over the period concerned. However, the index fluctuated considerably between years suggesting that longer time series were required to provide a more reliable index of abundance. An understanding of the dynamics of the commercial fishery is important to the interpretation of the catch statistics, and is essential before attempting to develop standardised or unstandardised indices of abundance. No complete descriptive analysis of the commercial catch and effort data has been completed for any of the tarakihi stocks.

The first part of this analysis summarises catch and effort data to provide descriptive statistics that show how the fishery operates and how it has evolved. To this end, summary statistics are produced on several aspects of the fishery, including the fishing fleet, gear used, locations fished, when fishing occurred, target species, and catch. Additionally, several experienced fishers in each of the QMAs were contacted and asked questions about the tarakihi fishery in their area. Once the descriptive analysis was completed it was possible to identify appropriate fisheries for analysis of CPUE. Standardised analyses were carried out to determine whether there were changes in CPUE after accounting for other factors such as time of year, statistical area, and vessel size.

2. DATA AND METHODS

2.1 Landings

MFish extracted all records that targeted and/or caught tarakihi from the Catch, Effort and Landing Returns (CELR) and Trawl Catch, Effort and Processing Returns (TCEPR). The catch of tarakihi reported on each of the CELR and TCEPR forms is summarised by fishing year in Table 1. Overall, about 20% of the tarakihi catch is reported on TCEPR forms. However, the proportion varies considerably between years and between Fishstocks. There has been a large increase in the amount of tarakihi catch reported on TCEPR forms in TAR 1 and 2 over the 10 year period, but a decline in the amount of tarakihi catch reported on TCEPR forms in TAR 7.

There were insufficient records to allow an analysis of the TCEPR data by themselves. The two data types were therefore combined into one series by aggregating the TCEPR tow-by-tow data into the daily format reported on CELR forms. It is believed that combination of data in this way will not lead to any bias in the indices. For example, if larger vessels (which filled out TCEPR forms in the earlier years) had higher catch rates, this should be accounted for in the model by the vessel size variable.

The following changes and deletions were made to the dataset. A total of 6680 records was deleted from the dataset because they had missing values in one or more of the following fields: QMA, target species, hours fished, number of tows (for trawl data), net length (for set net data), vessel draught, vessel power, vessel tonnage, year vessel built, vessel speed, tarakihi catch. The attribute vessel nation had 23 100 records with missing values, but rather than delete so many records from the dataset, the attribute itself was not included in any of the analyses presented here. The final dataset for all QMAs combined had 102 161 records (each record represents one vessel-day).

2.2 Descriptive analysis

The descriptive analysis was carried out separately for each Fishstock. Cape Reinga appears to form a natural boundary for many other inshore species, and so the data for TAR 1 were split at Cape Reinga into west (TAR 1W) and east (TAR 1E) and analysed separately.

For each Fishstock we first compared reported and estimated catches to determine what proportion of the total catch had corresponding detailed effort information. For each Fishstock we then summarised the catch and effort of tarakihi for each fishing method (bottom trawl, bottom pair trawl, midwater trawl, and set net). After the main fishing methods were identified for each QMA, the tarakihi catch was summarised by statistical area and target species for that main fishing method to identify the main fisheries. Monthly catches were also calculated for each area.

Fine scale data on location of catches are given only on the TCEPR forms. These data were plotted out by target species to show the location of tows catching tarakihi in TAR 1, 2, 3, and 7.

2.3 Unstandardised CPUE analysis

Two series of unstandardised CPUE indices were calculated for each QMA.

1. Mean catch per vessel-day by fishing method for all target species and all vessels combined. (Note: these were then adjusted so that the first year was 1.0 so that the trends could be compared with the standardised CPUE indices)
2. Mean catch per vessel-day by statistical area for successful vessel-days (i.e., where tarakihi was caught) for a particular method that targeted (a) tarakihi or (b) other important target fisheries (e.g., barracouta, red cod).

2.4 Standardised CPUE analysis

Standardised CPUE analyses were carried out for each fishing method in a QMA which contributed to at least 20% of the tarakihi catch in that QMA. These were the bottom trawl fisheries in all QMAs and the set net fishery in TAR 3. The CPUE was standardised using a stepwise multiple regression technique (Vignaux 1994) to remove the effects of other explanatory (predictor) variables.

Two types of analyses were run depending on the significance of zero catches in each fishery. A high proportion of records with zero catches is a mathematical problem for a linear model of regression. Such a model fitted to all the data would require the addition of an arbitrary constant value to each catch to avoid attempting to take the logarithm of zero. The addition of such a constant can result in a distortion of the regression and thereby yield unreliable results. For datasets with a high proportion of zero catches the pattern of zero catches may contain important information on the abundance of tarakihi. However, if the proportion of zeroes is very small, they can be ignored because they effectively carry no weight in the analysis. Not including records which targeted but did not catch tarakihi (zero records) also allows the target tarakihi data to be combined with those for other target species (which are represented in the dataset only when they have a tarakihi catch) and a single analysis to be run for the entire fishery.

So, in this study a combined index for the targeted tarakihi fishery, from a binomial model of success rate and a linear model of catch rate, was calculated if the proportion of zero catches for all years in the targeted tarakihi fishery was greater than 5%. If the proportion zero was less than or equal to 5% only a linear model of catch rates for all target species combined was modelled.

The combined model was proposed by Vignaux (1997) as a means of better combining catch rate information from successful tows with the proportion of tows that were unsuccessful. The combined model splits the problem in two: first, how the success rate of vessel-days has changed from year to year (where success is a non-zero vessel-day), and second, how the catch rate in the successful vessel-days has changed from year to year.

The success rate analyses were carried out using a binomial model (Vignaux 1997) in which predictor variables were regressed against a successful (denoted as 0) or unsuccessful (denoted as 1) vessel-day. A vessel-day was considered unsuccessful if it had reported targeting tarakihi but no tarakihi catch (note that only the top five species caught by weight are reported in the catch-effort data, so an unsuccessful vessel-day does not necessarily mean that no tarakihi were caught). The catch rate analyses were carried out using a log-linear model in which the predictor variables were regressed against a CPUE index of log(tonnes per hour) for all vessel-days which reported targeting *and* catching tarakihi. Hence a change in abundance may be detected in either index.

The combined index was then calculated as:

$$\text{Combined index} = (1/(1 - P0_1 * (1 - \text{binomial index}))) * \text{linear index}$$

Where $P0_1$ is the proportion of zero days in the first year, the binomial index is the exponential of the relative year effect coefficient from the binomial model, and the linear index is the exponential of the relative year effect coefficient from the linear model

Several measures of effort could have been used for the analysis including catch per trip, catch per day, catch per tow, or catch per hour. Because most of the catch and effort data are recorded on the effort part of the landing returns, and because about 20% of the data are reported on TCEPRs, we chose to summarise the catch and effort data by day. As distance towed is likely to affect the catch rate of tarakihi, catch per hour (as a proxy for distance) was chosen as the measure of CPUE for each day.

Predictor variables used in the analyses are described in Table 2. In the first iteration for each analysis, log(CPUE) was regressed against each of the variables in turn to find the variable that explained the most variation (i.e., had the highest multiple regression coefficient, R^2). This variable was included in the model. At iteration 2, log(CPUE) was regressed against the new model plus each of the other variables in turn to find the next most significant variable. First order interaction terms were offered to the model if *both* variables had been chosen by the model as having explanatory power on their own. This process was continued and variables were included in the models if they improved the explanatory power of the model by more than 0.5% or until the variable fishing year was included in the model. A similar procedure was followed in the binomial analyses, with success/failure regressed against predictor variables with variables included at each iteration if they had the lowest deviance. Variables were included in the model if they reduced the model deviance by more than 0.5% or until the variable fishing year was included in the model.

For all QMAs, analyses were run for a) all vessels, and b) a subset of vessels that had a consistent representation in the fishery. Criteria for inclusion in the subset of vessels were different in each QMA (Table 3). Selection criteria was based on the total number of records available and the distribution of fishing effort by vessels across years in that area. The vessels included in the subset for each QMA are tabulated in Appendix 1.

In summary the following analyses were carried out.

TAR 1 west coast bottom trawl fishery:
log-linear model of catch rates for successful days for all target species and all vessels
log-linear model of catch rates for successful days for all target species and subset of vessels

TAR 1 east Northland and Bay of Plenty bottom trawl fishery:
log-linear model of catch rates for successful days for all target species and all vessels
log-linear model of catch rates for successful days for all target species and subset of vessels

TAR 2 east coast North Island bottom trawl fishery:
log-linear model of catch rates for successful days for all target species and all vessels
log-linear model of catch rates for successful days for all target species and subset of vessels

TAR 3 east coast South Island bottom trawl fishery:
log-linear model of catch rates for successful days for all target species and all vessels
log-linear model of catch rates for successful days for all target species and subset of vessels
log-linear model of catch rates for successful days for target tarakihi only, all vessels
binomial model of successful and unsuccessful days for target tarakihi only, all vessels

TAR 3 east coast South Island set net fishery:
log-linear model of catch rates for successful days for all target species
log-linear model of catch rates for successful days for target tarakihi only

TAR 7 west coast South Island bottom trawl fishery:
log-linear model of catch rates for successful days for all target species and all vessels
log-linear model of catch rates for successful days for all target species and subset of vessels

2.5 Questionnaire to fishers

As part of the project, individual fishers and other industry representatives were approached to determine whether they knew of any management, economic, or other events that may have affected fishing behaviour and hence be potential problems with the CPUE analysis. At least two key fishers who had a long history of involvement with the fishery were consulted in each QMA. In QMA 1, fishers filled out the questionnaire given in Appendix 2, and this was followed up by contact over the telephone. In the other QMAs, fishers were just asked a series of questions based on the questionnaire over the telephone. A record of the discussions was summarised, and any possible problems with the CPUE analysis were identified.

The questions were aimed at two main areas: (i) identifying and characterising the tarakihi fishery in each of the QMAs, and (ii) identifying changes in fishing practices which may have occurred over the past 10 years, and which may affect the CPUE analysis. In (i) the fishing strategy used by individual fishers and/or companies was evaluated. In particular, the nature of the target versus non-target tarakihi trawls was examined in some detail, as this differed quite significantly between vessels and between QMAs. In (ii) the emphasis was on whether changes in fishing practices (such as changes in fishing strategy, target species, marketing, gear technology, and electronic gear such as GPS/plotters/sounders) may have changed the catchability of tarakihi over the past decade.

3. RESULTS

3.1 Comparison of reported and estimated landings

The proportion of the total reported catch which has corresponding effort data (i.e., is in the top half of the CELR or TCEPR form) also varies between fishing year and Fishstock (Table 4). In TAR 1, 2, and 3 from 80 to 93% of the reported catch has corresponding effort data. However, in TAR 7 on average only 56% of the catch has effort data, and in the last two years this has dropped below 50%.

The location of tarakihi catches from vessels filling out TCEPR forms are plotted by target species in Appendix 3. Tarakihi are targeted to any great extent by TCEPR vessels only around the North Island. Limited targeting also takes place off Cape Campbell, in the Canterbury Bight, and on the central west coast. Around northern New Zealand, tarakihi is taken mainly as a bycatch of the snapper, John dory, and trevally trawl fisheries. On the east coast South Island it is taken mainly as a bycatch in the barracouta fishery. In TAR 7 it is mainly taken as a bycatch in the jack mackerel fishery.

3.2 TAR 1W – west coast North Island

Catches in TAR 1W have averaged about 400 t since 1989–90. On the west coast of the North Island bottom trawling was the major method used (90% of vessel-days) and accounted for 97% of the catch of tarakihi (Tables 5 and 6). In the bottom trawl fishery effort about doubled from 1989–90 to 1998–99. However there was a corresponding increase in catch and the resulting unstandardised CPUE index fluctuates between 0.43 and 0.55 t per vessel-day with no trend through time (Table 7, Figure 2). Effort for bottom pair trawl varies from 11 to 46 vessel-days per fishing year with no trend in unstandardised CPUE. Effort by set netting was very low until 1996–97 after which 95 to 148 vessel days were carried out each year. Catch rates were very low averaging only 30 kg per vessel day, and there was no trend in unstandardised catch rates.

Catches for the bottom trawl fishery by statistical area are given in Table 8. Since 1989–90 more than half of the catch was taken from area 047 (off Ninety Mile Beach and Cape Reinga). Substantial catches were also taken from areas 042, 045, and 046. Minor catches of tarakihi were taken from the offshore areas (048, 101, 102, 103, and 104) and reported from Manukau (043) and Kaipara (044) harbours, even though they have been closed to trawling.

Catches of tarakihi in the bottom trawl fishery are given by main target species in Table 9. Sixty-eight percent of the catch since 1989–90 has been taken from tows targeting tarakihi, 14% snapper, and 7% trevally. Unstandardised CPUE was variable in each area, and showed no strong upward or downward trends over time (Table 10, Figure 3).

Due to the low catch and effort for other methods, standardised CPUE indices were estimated only for the bottom trawl fishery. Only 5% of all vessel-days targeting tarakihi had a zero. Therefore, tows targeting but not catching tarakihi were excluded, and a linear model of success rate for tarakihi catch, regardless of target species, was carried out for log (catch per hour). Statistical areas 043 and 044 were excluded because they have been closed to trawling during all years under consideration, and the offshore areas 048 and 105–107 were combined into an "other" category. The categories used for target species in the model are shown in Table 9.

The predictor variables included in the models are given in Table 11. The final R^2 for the log-linear model of successful days was 35% for all vessels and 32% for the vessel subset. The standardised CPUE indices are given in Table 12 and Figure 2. The all vessel index fluctuates between 0.9 and 1.1 from 1989–90 to 1993–94, and then increases to fluctuate between 1.2 and 1.4 for the last 5 years. Indices for the vessel subset follow a similar pattern and are slightly lower than those for all vessels. Both standardised indices were considerably higher than the unstandardised indices over the past 4 years. The diagnostic plots indicate that both standardised models are unable to capture the extremes in catch rate observed in the fishery (Appendix 4).

3.3 TAR 1E – East Northland and Bay of Plenty

The TAR 1E fishery, in east Northland and the Bay of Plenty, is the second largest in New Zealand, has averaged about 1000 t since 1989–90. Bottom trawling was the major method used (79% of vessel-days) and accounted for 93% of the catch of tarakihi (Tables 13 and 14). In the bottom trawl fishery effort was very stable with about 2200 vessel-days per year. The unstandardised CPUE index increased from 1989–90 to a peak of 0.41 t per vessel-day in 1993–94 and then steadily declined to 0.23 t per vessel-day in 1998–99 (Table 15, Figure 4). Bottom pair trawl and midwater trawl accounted for less than 1% of catch and effort in east Northland and the Bay of Plenty. Effort by set netting was very low until 1996–97, after which 95 to 148 vessel days were carried out each year. Unstandardised catch rates by set net varied from 0.05 to 0.14 t per vessel day, following the same increasing and then decreasing trend as seen in the bottom trawl.

Catches for the bottom trawl fishery by statistical area are given in Table 16. About 75% of the catch was taken in three statistical areas: 002, the east coast of the far north; 009 and 010 coastal Bay of Plenty. Substantial catches were also taken from inshore areas 003 and 008, and minor catches from the offshore areas 105, 106, and 107. Catches reported as taken in the Firth of Thames (007) are probably errors as this area is both too shallow (research surveys have never caught tarakihi here, M. Morrison, NIWA pers. comm.) and has been closed to bottom trawling since 1986.

Catches of tarakihi in the bottom trawl fishery are given by main target species in Table 17. Seventy-four percent of the catch since 1989–90 was taken from tows targeting tarakihi, 8% snapper, and 8% gemfish. Unstandardised CPUE indices were reasonably stable over the period, although some areas showed a slight decline over the last 1–2 years (Table 18, Figure 5a, b). In addition, areas 001 to 004 showed a spike in 1992, similar to that in area 047 (see Figure 3).

Due to the low catch and effort for other methods, standardised CPUE indices were estimated only for the bottom trawl fishery. Only 4% of all vessel-days targeting tarakihi had a zero catch. Therefore, tows targeting but not catching tarakihi were excluded, and a linear model of success rate for tarakihi catch, regardless of target species, was carried out for log(catch per hour). Statistical area 007 was excluded due to it being closed to trawling, and the offshore areas 105–107 were combined into an "other" category. The categories used for target species in the model are shown in Table 17.

The predictor variables included in the model are given in Table 19. The final R^2 for the log-linear model of successful days was 42% for all vessels and 38% for the vessel subset. The standardised CPUE indices are given in Table 20 and Figure 4. The index for all vessels shows a steady increase from 0.8 in 1990–91 to 1.2 in 1998–99, while the vessel subset shows a lesser increase of 0.9 to 1.1 over the same period. Both standardised indices differed from the unstandardised index which showed an increase in the early period and a subsequent decline. The diagnostic plots indicate that both standardised models are unable to capture the extremes in catch rate observed in the fishery (Appendix 4).

3.4 TAR 2 – east coast North Island

The TAR 2 fishery, on the east coast of the North Island between Cape Runaway and Cook Strait, is the largest in New Zealand, and has averaged about 1600 t since 1989–90. Bottom trawling was the major method used (94% of vessel-days) and accounted for 99% of the catch of tarakihi (Tables 21 and 22). In the bottom trawl fishery effort fluctuated between 2000 and 3200 vessel days per year, and catch between 1200 and 1600 t per year, with no trend through time. Likewise, there is no trend in the unstandardised CPUE index, which fluctuated between 0.48 and 0.62 t per vessel-day (Table 23, Figure 6). There was a minor catch of tarakihi in midwater trawls and set nets.

Catches for the bottom trawl fishery by statistical area are given in Table 24. Seventy percent of the total catch since 1989–90 was taken from areas 011 to 013, between Cape Runaway and Cape Kidnappers. Substantial catches were also taken from Cape Kidnappers to Cook Strait (areas 014 to 107), whilst minor catches were reported offshore. Note that an unknown proportion of the tarakihi catch in area 017 would be caught against the TAR 7 quota.

Catches of tarakihi in the bottom trawl fishery are given by main target species in Table 25. Eighty percent of the catch since 1989–90 has been taken from tows targeting tarakihi, with tows targeting barracouta, red gurnard, hoki, gemfish, and warehou catching a further 2–4% each. Unstandardised CPUE indices were mostly stable in each statistical area over the period (Table 26, Figure 7). However, there was a large increase in CPUE (and catch) off Cape Campbell (area 017) over the past four years.

Due to the low catch and effort for other methods, standardised CPUE indices were estimated only for the bottom trawl fishery. Only 3% of all vessel-days targeting tarakihi had a zero catch. Therefore, tows targeting but not catching tarakihi were excluded, and a linear model of success rate for tarakihi catch, regardless of target species, was carried out for log(catch per hour). The offshore statistical areas 201–205 were combined into an "other" category. The categories used for target species in the model are shown in Table 25.

The predictor variables included by the model are given in Table 27. The final R^2 for the log-linear model of successful days was 41% for all vessels and 43% for the vessel subset. The standardised CPUE indices are given in Table 28 and Figure 6. The index for all vessels shows a general decline from 1.0 in 1989–90 to a low of 0.8 in 1993–94 to 1995–96 and then rises to 1.0 again in 1998–99. The index for the vessel subset follows the same pattern but decreases to a low of only 0.9. The unstandardised index was very similar to the standardised indices. The diagnostic plots indicate that the standardised models are unable to capture the extremes in catch rate observed in the fishery (Appendix 4).

3.5 TAR 3 – east coast South Island

The TAR 3 fishery, on the east coast of the South Island between Cape Campbell and Foveaux Strait has averaged about 1000 t since 1989–90. There are substantial fisheries by both bottom trawl and set net (Tables 29 and 30).

(i) Bottom trawl fishery

Bottom trawling was the major method used (75% of vessel-days) and accounted for 75% of the catch of tarakihi. In the bottom trawl fishery effort fluctuated between 1500 and 1900 vessel days per year, and catch between 470 and 840 t per year. The unstandardised CPUE index rose from about 0.35 t per vessel-day in the early 1990s to a peak of about 0.5 t per vessel-day in 1996–97 (Table 31, Figure 8).

Catches for the bottom trawl fishery by statistical area are given in Table 32. Ninety percent of the total catch since 1989–90 was taken off Kaikoura and in the Canterbury Bight (areas 018, 020, and 022). Substantial catches were also taken off Otago, but minor catches were reported elsewhere. Note that an unknown proportion of the tarakihi catch in area 018 would be declared against the TAR 7 quota.

Catches of tarakihi in the bottom trawl fishery are given by main target species in Table 33. Only 26% (range 12–50%) of the annual catch since 1989–90 was taken from tows targeting tarakihi. Tows targeting red cod accounted for 37% of the catch and targeting barracouta a further 17%. Tows targeting flatfish, hoki, and squid caught a further 2–7% each. Unstandardised CPUE indices showed similar trends between statistical areas (Table 34, Figure 9). In most areas except 024 (off Dunedin) CPUE has been stable or shown a slight increase over the 10 year period.

Overall, 15% of all vessel-days targeting tarakihi had a zero catch. Therefore, two types of standardised analyses were run. First, as for the other QMAs, a log linear model of tarakihi catch rates for successful days regardless of target species, was carried out for log(catch per hour) for all vessels and the vessel subset. Second, a "combined" CPUE index was calculated for all vessels in the *tarakihi target* fishery. In this analysis the indices from a binomial model of success rate were combined with the indices from a log linear model of catch rates (i.e., for those days which were successful). The offshore statistical areas 201–205 were combined into an "other" category. The categories used for target species in the model are shown in Table 33.

The predictor variables included in the non-target tarakihi model are given in Table 35 and the standardised CPUE indices in Table 36 and Figure 8. The index for the log-linear model of successful days for all target species for all vessels peaks at 1.8 in 1995–96 and then drops steadily to 1.4 in 1998–99, with the index for the vessel subset following a similar pattern. The unstandardised indices show a similar trend, but were slightly lower overall. The diagnostic plots indicate that both standardised models are unable to capture the extremes in catch rate observed in the fishery (Appendix 4).

The predictor variables included in the target tarakihi linear and binomial models are given in Table 37 and the standardised CPUE indices in Table 38 and Figure 10. The combined index for the tarakihi target fishery drops initially to a low of 0.7 in 1993–94, rises to a peak of 1.4 in 1995–96, and then returns to about 1 in 1998–99.

(ii) Set net fishery

In TAR 3 set netting is also a significant method of fishing for tarakihi (37% of effort and 29% of catch). Effort by set netting ranged from about 700 to 1250 vessel-days per year and catch from about 180 to over 370 t per year between 1989–90 and 1998–99. Unstandardised CPUE varied from 190 to 340 kg per vessel day with no trend through time (see Table 31, Figure 11).

Catches for the set net fishery by statistical area are given in Table 39. Almost all (99%) of the total catch since 1989–90 was taken from the Kaikoura coast, area 018. Catches of tarakihi in the set net fishery are given by main target species in Table 40. Most of the catch (94%) since 1989–90 was taken from sets targeting tarakihi. Minor catches were also reported from sets targeting ling, spiny dogfish, and warehou.

Standardised CPUE indices were estimated for the set net fishery in area 018 only as this accounted for nearly all the tarakihi catch by set net. Also, only 2% of all vessel-days targeting tarakihi had a zero catch. Therefore, sets targeting but not catching tarakihi were excluded, and linear models of success rate for tarakihi catch for a) sets targeting tarakihi, and b) all target species, were carried out for log(catch per hour). The categories used for target species in the model are shown in Table 40.

The predictor variables included by the models are given in Table 41. The final R^2 for the log-linear model of successful days when targeting tarakihi was 49%, and for all target species, 60%. The standardised CPUE indices are given in Table 42 and Figure 11. The index for both models have similar patterns, declining to a low of about 0.75 in 1993–94 and then increasing again to about 1.15 in 1998–99. This is quite a different pattern from the unstandardised indices, which showed a large increase over the period.

The diagnostic plots indicate that the standardised model is unable to capture the extremes in catch rate observed in the fishery, and are particularly poor for this model (Appendix 4).

3.6 TAR 7 – west coast South Island

The TAR 7 fishery on the west coast of the South Island and around into Tasman and Golden Bays has averaged about 850 t since 1989–90. Bottom trawling was the major method used (94% of vessel-days) and accounted for 98% of the catch of tarakihi (Tables 43 and 44). In the bottom trawl fishery both effort and catch fluctuated with no trend through time. The unstandardised CPUE index varied between 0.29 and 0.53 t per vessel-day and was highest between 1992–93 and 1994–95 (Table 45, Figure 12). There was a minor catch of tarakihi in midwater trawling and set netting.

Catches for the bottom trawl fishery by statistical area are given in Table 46. Since 1989–90 72% of the catch has been taken from areas 033 and 034, i.e., between Cape Foulwind and Jackson Head. Substantial catches were also taken from the other coastal areas 035 to 038, i.e., north of Cape Foulwind round into Golden and Tasman Bays. We have included all the tarakihi data from statistical areas 036 and 037 in the TAR 7 analysis, but have excluded the data from statistical areas 017 and 018. The data from these areas have been included in TAR 2 and TAR 3 analyses respectively.

Catches of tarakihi in the bottom trawl fishery are given by main target species in Table 47. In TAR 7 nearly half of the tarakihi catch was taken from tows targeting barracouta, and only 27% from tows targeting tarakihi. Furthermore, the amount caught in the target tarakihi fishery has declined substantially, from about 30% in the first 5 years to about 15% over the past 5 years, whilst the amount caught in the target barracouta fishery has increased substantially over this period. The reason for this is unclear, but could reflect a change in the reporting of the target species or a change in the fish behaviour. Tows targeting jack mackerel contributed a further 11% of the tarakihi catch. Minor catches were also taken in tows targeting flatfish, red cod, stargazer, and warehou.

Unstandardised CPUE is shown by area and target fishery in Table 48 and Figure 13. Raw CPUE tends to be more erratic in TAR 7 than in the other QMAs. Tarakihi CPUE appears to have been reasonably stable in the target tarakihi fishery, but to have increased in the target barracouta fishery. However, in 5 of the last 6 years the mean catch rate of tarakihi in area 033 is actually higher in the target barracouta fishery than in the target tarakihi fishery (in the most recent year it was over double). In the last 3 years the same is true in area 034. This, combined with the increase in the tarakihi catch reported in the target barracouta fishery over the past 5–6 years, provides strong evidence that the target species has been misreported by the fishers.

Due to the low catch and effort for other methods standardised CPUE indices were estimated only for the bottom trawl fishery. Only 4% of all vessel-days targeting tarakihi had a zero catch. Therefore, tows targeting but not catching tarakihi were excluded, and a linear model of success rate for tarakihi catch, regardless of target species, was carried out for log(catch per hour). The offshore statistical areas 702–706 were combined into an "other" category. The categories used for target species in the model are shown in Table 47.

The predictor variables included by the model are given in Table 49. The final R^2 for the log-linear model of successful days was 34% for all vessels and 22% for the vessel subset. The standardised CPUE indices are given in Table 50 and Figure 12. The index for all vessels fluctuates between 1.0 and 1.5 with no trend through time: similarly the index for the vessel subset fluctuates between 0.9 and 1.2. In contrast, the unstandardised indices increased to 1995 but subsequently declined. The diagnostic plots indicate that both standardised models are unable to capture the extremes in catch rate observed in the fishery (Appendix 4).

3.7 Responses to questionnaire

All areas

Tarakihi is largely targeted by small to medium sized inshore bottom trawlers (15–25 m long) which typically carry out trips lasting 2–5 days. During each trip these vessels carry out a number of trawls targeted at a range of inshore species to cover their quota species mix. The actual target species is likely to change during the course of a trip, and can often vary within a day (a factor which cannot be captured on the CELR). Tarakihi is often the preferred (and hence) nominal target species on many trips. However, for various reasons it does not always appear as the target species on the CELR return. Another common marketing practice is that of grading tarakihi according to size. There is usually a large (twofold) price differential between "charity" tarakihi (25–30 cm long) and larger tarakihi (over 30 cm). Although this probably has a major affect on the economics of tarakihi fishing, it does not appear to have changed substantially over the last 10 years.

Most fishers in most areas said that there had been no major changes in their fishing practices over the past 10 years. The trawl nets, quota mix, and targeting practices had remained reasonably similar. Thus, although fishers are aiming more to balance a quota mix rather than to be maximising tarakihi catches, this does not appear to have changed over this period. Fishers stated that the main change in fishing practice over the past 10–15 years had been the use of GPS and position plotters. This allows fishers to repeat trawls which have yielded good tarakihi catches, and also helps them avoid areas of foul ground. This would have the effect of increasing tarakihi catchability over time.

TAR 1

Two fishers involved in the TAR 1 fishery responded to the questionnaire. They fished throughout QMA 1, and at times also fished in QMAs 2 and 8. They stated that there is a strong tarakihi target fishery in TAR 1. Targeting is usually by depth and/or location, and may take place in autumn and winter when other inshore species have been caught. However, both fishers also stated that changes in marketing meant that catches of tarakihi tended to be spread more through out the year for the fresh fish market. Both fishers gave the impression that tarakihi were abundant in the area. One fisher noted that 50–70% of the grounds they used to work are not being fished due to the shortage of quota. Both fishers considered that catch per unit effort should monitor abundance reasonably well. One fisher recorded catching juvenile tarakihi (less than 20 cm) at times between White Island and Cape Runaway. The other fisher reported catching spawning tarakihi off Hokianga in 150–250 m in Feb–March.

TAR 2

Five fishers and industry personnel involved in the TAR 2 fishery were interviewed over the phone. Most fished around East Cape (areas 011 to 013), but some fished south to Castlepoint and west into the Bay of Plenty (TAR 1E). Most companies in the area have imposed restrictions on the catch of tarakihi per trip in the past 3–4 years. Trips typically last 3–5 days, and the tarakihi catch limit for the trip can vary from 4 to 8 t per trip. This spreads the catch of tarakihi out over the year allowing a continuing supply of good quality fish for the domestic market and encourages the catch of other inshore species. The actual fishing practice on any particular trip therefore depends largely on the quota mix available. At the start of a trip fishers are more likely to target a species mix comprising perhaps 50% tarakihi, and 50% of a mix of gurnard, snapper, trevally, John dory, etc. Towards the end of the trip, they may move into a different area or slightly deeper, and carry out specific tows targeted at tarakihi. However, both types of tows would include tarakihi as the main target species. Fishers targeting flatfish in shallower water or species such as gemfish, hoki, and barracouta in deeper water have small amounts of quota to cover their bycatch of tarakihi, and may at times actively avoid tarakihi.

The introduction of trip catch limits in recent years may have affected the catchability of tarakihi. If fishers are aiming more to balance a quota mix rather than to be maximising tarakihi catches, then the catchability of tarakihi (particularly in the targeted tows) would effectively be reduced. This would be offset to some extent by improvements in GPS/plotters, etc, mentioned above.

TAR 3

Four fishers involved in the TAR 3 trawl fishery were interviewed over the phone. Most fished in the Canterbury Bight (areas 022 and 024), but some fished south to Port Chalmers and north to Cape Campbell. The east coast South Island trawl fishery is very much a multi-species fishery. The mismatch of quota to species abundance in most years means that the bycatch trade system is widely used to offset overcatch of certain species. This means that the target species reported on the CELR forms is sometimes related more to the species nominated to allow the bycatch trade (i.e., red cod) than the actual species being targeted. Therefore, the actual reported amount of targeting on tarakihi probably understates the amount of true targeting going on. Most fishers reported that they are able to take reasonably clean catches of tarakihi in most statistical areas and at most times of the year. However, the fishing strategy depends to a large extent on the quota mix available and also on the red cod fishery. In good red cod years fishers target red cod during the summer months and catch the remaining tarakihi quota during the winter. In poor red cod years fishers will target tarakihi together with a mix of other species throughout the year. The other factor affecting the trawl fishery in this QMA is the small size of the fish. South of Banks Peninsula there are large numbers of pre-recruit and small adult tarakihi, and the fishery lands mainly 25–30 cm fish. Larger fish are mainly found off Conway Ridge and Cape Campbell.

One fisher involved in the TAR 3 set net fishery was interviewed. The set net fishery is a highly targeted fishery carried out during the summer/autumn months each year. There are two main peaks each lasting about 6 weeks: one centred around January and the second centred around May. Fishers appear to intercept migrating adult fish as they pass along the narrow shelf south of Kaikoura. A code of practice has been in place since the 1980s, and vessels use a 5 inch (125 mm) mesh and a maximum of 2000 m of set net per day. Fish caught average about 35–45 cm long. This fishery appears to have been very stable with seven to ten small (9–12 m long) vessels involved in the fishery over the past 10 years.

TAR 7

Five fishers involved in the TAR 7 fishery were interviewed over the phone. Most fished on the west coast South Island (areas 033 and 034), but some also fished north of Cape Campbell (area 017). The west coast South Island trawl fishery is very much a multi-species fishery. The mismatch of quota to species abundance in most years means that the bycatch trade system is widely used to offset overcatch of certain species. This means that the target species reported on the CELR forms is sometimes related more to the species nominated to allow the bycatch trade (i.e., barracouta) than the actual species being targeted. Therefore, the actual reported amount of targeting on tarakihi is probably understated. Most fishers reported that they are able to take reasonably clean catches of tarakihi in most statistical areas and at most times of the year. However, the fishing strategy for bottom trawlers depends to a large extent on the quota mix available. Two fishers mentioned a recent increase in fishing areas 017 (see Table 24), and also a move to new grounds in area 036 and 037 since 1998–99.

4. DISCUSSION

Dunn et al. (2000) noted that calculation of CPUE indices does not necessarily result in an index which is related to abundance. They cautioned against the use of CPUE indices in stock assessment models until several aspects of the analysis had been evaluated and the CPUE indices themselves had been validated, if possible, by fishery independent data. We have followed their recommended guidelines in evaluating the use of the derived CPUE indices as a monitoring tool for the abundance of tarakihi in the various Fishstocks.

4.1 Relationship between CPUE and abundance

Tarakihi are largely taken by small to medium sized inshore bottom trawlers (15–25 m long) which typically carry out trips lasting 2–5 days. During each trip they will carry out a number of trawls targeted at a range of inshore species to cover their quota species mix. The meaning of a target species in a mixed fishery is always going to be difficult to interpret. Paul & Bradford (2000) noted that target species is used by fishers in several ways: the single species targeted, the main of several species targeted, the species for which most quota is still held, the main species actually caught (whether it was targeted or not), the species which legalises a subsequent bycatch trade, or simply just a logical species for that area and fishery.

Around the North Island (TAR 1 and usually 2) most of the tarakihi caught is recorded as being targeted. However, the fishers are usually targeting a species mix of which tarakihi is the dominant species. Therefore, on any particular day fishers may have tows targeting tarakihi, tows targeting a 50% tarakihi and 50% mix, and tows actively avoiding tarakihi. Unfortunately this level of detail cannot be captured on the CELRs. Furthermore, changes in marketing practices have led some companies to impose trip limits on tarakihi over the past few years. The fishing strategy is therefore aimed at maximising the catch of the quota mix rather than maximising the tarakihi catch. It is possible that this change in fishing practice could have led to an artificial decrease in tarakihi CPUE over recent years. However, this may have been offset by improvements in position fixing and the ability to repeat tows through the use of GPS and plotters.

In the South Island less than 30% of the tarakihi caught is targeted. Most tarakihi are taken when targeting red cod (37%) in TAR 3 and barracouta (48%) in TAR 7. However, in both QMAs the mismatch of quota to species abundance means that the bycatch trade system is widely used to offset overcatch of certain species. This means that the target species reported on the CELR forms is sometimes related more to the species nominated to allow the bycatch trade (i.e., red cod or barracouta) than the actual species being targeted. Therefore, the actual reported amount of targeting on tarakihi probably understates the amount of true targeting going on. It is unknown whether how this might affect the relationship between CPUE and abundance. However, improvements in position fixing and the ability to repeat tows through the use of GPS and plotters would have increased tarakihi catchability over time.

For the analysis and interpretation of the indices we have assumed a simple direct relationship between CPUE and abundance. Although there are specific areas and times when tarakihi are more abundant, and hence can be targeted, there appears to be little significant searching carried out or targeting of marks which could lead to a hyperstable CPUE/abundance relationship (Dunn et al. 2000). (A hyperstable relationship is one where CPUE remains high compared to abundance.) The use of data from the entire fishery (i.e., one which includes both target and non-target tarakihi) should also help reduce the sensitivity of the results to changes in targeting practices or recording of target species on the CELR forms.

4.2 Data adequacy

Data adequacy is considered here in two parts: (i) the ability of the data to provide an adequate sample of the population and (ii) the ability of the explanatory variables to allow adequate standardisation of changes in catchability (Dunn et al. 2000).

For TAR 1, TAR 2, and TAR 3 the estimated catch (i.e., that for which detailed effort data are available) forms a high proportion (80–93%) of the total reported landings. In TAR 1 and TAR 2 about 95% of the estimated catch is taken by bottom trawl and is included in the CPUE analyses. Furthermore, in both areas 70–80% of this bottom trawl catch is targeted at tarakihi. Judging by the location of tows recorded on the TCEPR forms, and the location of catches from the statistical areas, the fisheries in these two QMAs appear to be adequately covering the tarakihi population. Another feature of these two QMAs is that apart from a recent increase in effort (and catch) from area 046 (west Northland) the fishery appears to have been very stable over a long period of time. Indeed more than 15 vessels have been operating in the fisheries in TAR 1E and TAR 2 for at least 9 years.

Although a large proportion of the data in TAR 3 was available for analysis, only 71% was taken from the bottom trawl fishery, and only 26% of that was caught whilst targeting tarakihi. Most tarakihi was caught in the red cod (35%) and barracouta (17%) fisheries. This raises problems in the analysis because changes in tarakihi CPUE could reflect changes in the dynamics of the target fishery rather than changes in tarakihi abundance. Raw CPUE for each of the three target fisheries showed similar spatio-temporal trends, which does however, give some confidence in the model results. Again the location of tows recorded on the TCEPR forms, and the location of catches from the statistical areas, suggests that the data are probably adequately covering the tarakihi population in this area. An analysis was also carried out on the set net fishery in TAR 3. This is a highly specific fishery which targets tarakihi off Kaikoura. Because of this it has limited application to the TAR 3 population as a whole.

In TAR 7 the estimated catches formed only 56% of the reported landings, and only 27% of that was caught whilst targeting tarakihi. Most tarakihi was caught in the barracouta (48%) and jack mackerel (11%) fisheries. Although the two fisheries showed similar trends in raw CPUE over time, the individual indices were erratic and variable between statistical areas. There has also been a reduction in the reporting of tarakihi as a target species in the forms, probably as a result of the bycatch trades. This has resulted in CPUE values for tarakihi which are higher when it is taken as a bycatch than when it is targeted! It is unknown what effect this has had on the analysis.

Most of the data were reported on CELRs and so only a restricted number of explanatory variables were available for use in the analysis. We found that vessel characteristics were important in most of the "all vessel" analyses. As recommended by Dunn et al. (2000) we also analysed the data using subsets of vessels which had consistently fished in the various fisheries. In each "vessel subset" analysis, vessel id was either the first or second variable to enter the model. Once the vessel id/vessel characteristic had been included the variables selected by the all vessels and vessel subset models were usually very similar. CPUE trends were also broadly similar between the two models used in each QMA.

Other changes in catchability such as improvements in net and bottom rig design, GPS, fish finding equipment, fishing experience, and slight spatial changes in fishing behaviour could not be quantified and included in the model. Because of the long and stable history of the fishery, and movements of fishers in and out of the fishery, it is unlikely that factors such as fishing experience would have had a major effect on tarakihi catchability over time.

4.3 Model fitting and model validation

Model fitting and model validation are considered by comparing the explanatory variables, the variation explained (R^2), the diagnostic plots, and the results of the all vessels versus the vessel subset models. The variables entering the models were very similar, both within QMAs for different models and between QMAs. Target species was always either the first or second explanatory variable to enter each of the models. It was the most important predictor in TAR 1 and 2 where most of the tarakihi is targeted. In TAR 3 and 7, where tarakihi were mainly caught in fisheries for red cod and barracouta, target species was the second most important explanatory variable. One of the vessel characteristics (e.g., vessel length, breadth, or tonnage) for the all vessel models, and vessel id for the vessel subset model, was usually the other most important explanatory variable for each of the QMAs. Vessels operating in the inshore fishery vary considerably in their size and fishing power and the importance of this as an explanatory variable is consistent with our understanding of the fishery.

Vessels appear to target tarakihi in specific statistical areas and at specific times of the year, and the variables statistical area and month usually entered the models after target species and vessel characteristics. Statistical areas with higher catches usually had higher raw CPUE and changes in catchability due to the area effect could therefore be captured in the model. The seasonal component appeared to be strongest in TAR 1W, where tarakihi catches peak between March and May. Catches in the other areas tend to be less seasonal, with slight peaks in autumn in TAR 3, in spring in TAR 7, and in spring and autumn in TAR 2. In most analyses fishing year had weak explanatory power and was often the last variable to enter the model.

The percentage of variation explained by the model in each analysis ranged from 19% for the vessel subset analysis in TAR 3 to 60% for the target set net fishery in TAR 3. For most of the TAR 1 and TAR 2 analyses it ranged from 32 to 43%, which is moderately good compared to other CPUE analyses. Apart from the TAR 3 set net fishery, the explanatory power of the models was not particularly good for TAR 3 and TAR 7. This is possibly because these were predominantly bycatch fisheries. In most analyses in all areas the all vessel data set explained slightly more variation than the vessel subset analysis.

The diagnostic plots from the regression analyses were all similar. In general, the models developed for each of the fisheries were unable to capture the extremes in catch rate observed in the fishery. The predictive models generally underestimated the observed catches at the upper extreme of the observed range of catches, while overestimating the catch from trawls at the lower range. This appears to be a common problem for many CPUE analyses and probably reflects the sometimes patchy nature of fish and fisheries. The diagnostic plots appear to be particularly bad in this respect for the set net tarakihi fishery. For most of the other analyses the plots suggest the problem is not too serious, and the diagnostics usually improved for the vessel subset analyses.

For the bottom trawl fisheries, standardised CPUE was estimated for all vessels combined and for a subset of vessels with a continuous representation in the fishery. In all cases there was little difference in the CPUE indices resulting from the two datasets. However, the all vessels models generally explained slightly more of the variation in CPUE than the subset models. They also had 1.5–2 times the amount of data and correspondingly lower standard deviations on the indices. Therefore it is recommended that the *all vessels* models be used in any stock assessment modelling.

4.4 Evaluation of CPUE indices

Firstly, the CPUE indices calculated in this analyses are compared to other fishery independent abundance indices, and secondly their use as indices of abundance is evaluated.

The only fishery independent indices of abundance are available from trawl surveys. Only two trawl surveys have been carried out in TAR 1W covering the tarakihi depth range (Hanchet & Field 2001), and so the comparison is weak.

TAR 1W

The analysis in TAR 1W is based on a relatively small data set, which is reflected by the slightly noisy indices in the first part of the series and the large standard deviations. However, a high proportion of the tarakihi is targeted and used in the analysis, the model has reasonably high explanatory power, reasonable diagnostics and similar results between the all vessel and vessel subset analyses. CPUE appears to have increased between 1989–90 and 1995–96, followed by a slight decline. There was a similar slight (16%) decline in tarakihi abundance between two trawl surveys carried out in 1997 and 2000 (Hanchet & Field 2001). The CPUE index is probably monitoring tarakihi abundance in the area, and could be used to track tarakihi abundance in years when the trawl survey is not carried out.

TAR 1E

The analysis in TAR 1E is based on a relatively large data set. A high proportion of the tarakihi is targeted and used in the analysis, the model has reasonably high explanatory power, reasonable diagnostics, and similar results between the all vessel and vessel subset analyses. CPUE appears to have been relatively stable between 1989–90 and the present. There are no fishery independent measures of abundance, because the current trawl surveys in TAR 1E do not adequately sample tarakihi (Hanchet & Field 2001). However, trends between CPUE and trawl survey indices were consistent in TAR 1W (see above) and also in TAR 2 (see below). Both these areas have targeted tarakihi fisheries which are similar to that in area TAR 1E. This provides some indirect support for the belief that CPUE indices may be monitoring abundance in TAR 1E. We recommend that in future analyses some consideration is given to estimating separate indices for East Northland and Bay of Plenty.

TAR 2

The analysis in TAR 2 is based on a relatively large data set. A high proportion of the tarakihi is targeted and used in the analysis, the model has reasonably high explanatory power, reasonable diagnostics, and similar results between the all vessel and vessel subset analyses. CPUE appears to have been relatively stable between 1989–90 and the present. Four trawl surveys were carried out on the east coast North Island from 1993 to 1996 (Stevenson & Hanchet 2000). The indices were variable, probably due to catchability differences between years, and showed no trend over time, which is consistent with the CPUE analyses. The CPUE index appears to be monitoring tarakihi abundance in this area.

TAR 3

Although a large proportion of the data in TAR 3 was available for analysis, only a small proportion came from the target tarakihi fishery. The trawl fishery models explained only about 20% of the variation in CPUE, but had reasonable diagnostics and similar results between the all vessel, vessel subset, and target tarakihi bottom trawl analyses. Because of the high non-targeted component of the catch, it is possible that changes in tarakihi CPUE reflect changes in the red cod and barracouta fisheries rather than tarakihi abundance. The high variability in red cod catches in this area could have a large and unpredictable effect on the tarakihi CPUE in the fishery.

A CPUE index derived from a highly targeted set net fishery off Kaikoura captured most of the set net data, and explained a very high proportion of the total variation. However, the diagnostic plots showed poor fit to the data, particularly for low observed values. The fishery appears to be based on a migrating population, and it is unclear how well this may reflect abundance of the population as a whole. Furthermore, due to the selectivity of the nets it is only monitoring part of the population (i.e., 35–45 cm long), and the indices show quite different trends to the commercial trawl CPUE indices.

Two series of trawl surveys have been carried out in TAR 3, a winter series from 1991 to 1996 (Beentjes & Stevenson 2000) and a summer series from 1996–97 to 1999–00 (Beentjes & Stevenson 2001). The surveys have caught mainly pre-recruit tarakihi, the estimates have fluctuated considerably between years, possibly due to changes in catchability between years, and have showed no overall trends. It is currently believed that these trawl survey indices are not monitoring adult tarakihi abundance. In the future it may be possible to compare strong year classes in the trawl surveys with trends in CPUE once a longer time series of trawl surveys is available and the tarakihi aged. However, for the present we recommend that these CPUE indices be treated with caution.

TAR 7

In TAR 7 only a small amount of data is available from the target tarakihi fishery. Most tarakihi was caught in the barracouta (48%) and jack mackerel fisheries. Although the target tarakihi and target barracouta fisheries showed similar trends in raw CPUE over time, the individual indices were erratic and variable between statistical areas, perhaps reflecting the small amount of data. There is also considerable concern over apparent trends in the reporting of barracouta as a target species, which could have a large and unpredictable effect on tarakihi CPUE in this fishery. Although the model has moderate explanatory power, reasonable diagnostics and similar results between the all vessel and vessel subset analyses, trends in the CPUE were quite different from those from the trawl surveys. Five trawl surveys have been carried out on the west coast South Island since 1992 (Stevenson & Hanchet 2000). The indices were essentially flat from 1992 to 1995, but showed a 25% drop for 1997 and 2000. In contrast, the CPUE indices for the area have shown a general increase over the same time period. Because of the trends in the reporting of target species, the small amount of data from the target fishery, and the poor agreement with the trawl survey data, we reject these CPUE indices for monitoring tarakihi abundance in this area.

All areas

For this analysis we have essentially analysed the data by QMA, regardless of the actual stock structure or distribution of catches of tarakihi throughout the EEZ. After the analysis was completed the summed catches of tarakihi over the 10-year period (1989–90 to 1998–99) were plotted by statistical area (Figure 14). They suggest four general regions of high tarakihi abundance around the country: centred around Cape Reinga, East Cape, Hokitika and east coast South Island (including Cook Strait) (see also Hanchet & Field 2001). These are different from the tarakihi stock boundaries, and also different from the boundaries used in this analysis. We strongly recommend that further work be carried out to determine tarakihi stock structure, and in particular the relationship between these different fisheries, the areas of pre-recruit abundance, and the QMA stock boundaries. Future analyses will then need to take the results of this analysis into account.

5. CONCLUSIONS

- CPUE indices calculated for TAR 1W are probably monitoring tarakihi abundance in the area, and could be used to track tarakihi abundance in years when the trawl survey is not carried out. The index peaked in 1996, but has since declined slightly.

- CPUE indices calculated for TAR 1E are probably monitoring tarakihi abundance in the area. The indices have been essentially flat over the time period.
- CPUE indices calculated for TAR 2 are probably monitoring tarakihi abundance in the area. The indices have been essentially flat over the time period.
- CPUE indices calculated for TAR 3 are probably not monitoring tarakihi abundance in the area, and we recommend that these indices be treated with caution. Trawl indices peaked in 1996, and have since declined slightly, whilst set net indices have been stable.
- CPUE indices calculated for TAR 7 do not appear to be monitoring tarakihi abundance in the area, and we reject these as indices of abundance.

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Table 1: Catches of tarakihi (t) from the TCEPR and CELR forms by fishing year (1989–90 = 1990).

	TCEPR				CELR			
	TAR 1	TAR 2	TAR 3	TAR 7	TAR 1	TAR 2	TAR 3	TAR 7
1990	29	11	110	120	627	1 184	445	243
1991	16	116	199	119	882	1 443	460	285
1992	21	108	193	107	1 154	1 490	493	339
1993	58	91	118	199	1 157	1 493	354	438
1994	196	181	71	175	1 059	1 230	453	386
1995	304	242	86	346	862	1 232	531	263
1996	861	454	186	76	305	1 036	653	337
1997	816	380	212	63	386	1 133	618	473
1998	878	354	114	52	297	1 279	575	260
1999	719	380	89	52	121	1 045	607	433
Total	3 899	2 319	1 381	1 316	6 851	12 567	5 192	3 464

Table 2: Definitions of variables used for the standardised CPUE regression analyses of the bottom trawl fisheries. cat, categorical with number of categories; cont, continuous.

Variable	Type	Description
Fishing year	cat 10	fishing year (1 October to 30 September) in which the tow took place
Month	cat 12	month in which the vessel-day took place
Area	cat*	statistical area in which the vessel-day took place
Target species	cat*	species targeted by the vessel-day
Vessel id	cat*	individual vessel
Year vessel built	cont	year the vessel was built
Vessel tonnage	cont	gross tonnage of the vessel
Vessel power	cont	power of the vessel in kilowatts
Vessel length	cont	overall length of the vessel in metres
Vessel breadth	cont	breadth of the vessel in metres
Vessel draught	cont	draught of the vessel in metres

*number of categories dependent on particular fishery

Table 3: Selection criteria for subset of vessels in the single bottom trawl fishery having a continuous representation in each QMA.

		Subset		All vessels	
Area	Vessel selection criteria	Vessels	Vessel-days	Vessels	Vessels-days
TAR 1W	≥10 vessel-days for ≥ 5 years	15	3 463	86	5 431
TAR 1E&BOP	≥10 vessel-days for ≥ 9 years	20	10 569	163	21 652
TAR 2	≥10 vessel-days for ≥ 7 years	23	13 923	226	27 873
TAR 3	≥10 vessel-days for ≥ 7 years	26	7 984	235	16 454
TAR 7	≥10 vessel-days for ≥ 6 years	21	6 802	235	12 032

Table 4: Comparison of reported landings (t) with total estimated catches (t) of tarakihi for all methods from both CELR and TCEPR catch effort forms from 1989–90 to 1998–99.

	TAR 1		TAR 2		TAR 3		TAR 7	
Fishing Year	Reported landings	Estimated catch	Reported landings	Estimated catch	Reported landings	Estimated catch	Reported landings	Estimated catch
1989–90	973	665	1 374	1 195	1 007	736	793	362
1990–91	1 125	897	1 729	1 559	1 070	952	710	404
1991–92	1 415	1 176	1 700	1 597	1 132	1 054	929	447
1992–93	1 477	1 214	1 654	1 572	813	815	629	639
1993–94	1 431	1 244	1 594	1 411	735	742	780	561
1994–95	1 390	1 166	1 580	1 475	849	926	978	609
1995–96	1 422	1 166	1 551	1 490	1 125	1 061	890	413
1996–97	1 425	1 204	1 639	1 512	1 088	1 039	1 013	537
1997–98	1 509	1 174	1 678	1 633	1 026	971	685	312
1998–99	1 436	842	1 594	1 425	1 097	933	1 041	484
Total	13 606	10 748	16 093	14 869	9 942	9 229	8 448	4 768
% est.	80		92		93		56	

Table 5: Summary of effort (vessel-days caught and/or targeted TAR) for tàrakihi by fishing method in TAR 1 on the west coast from 1989–90 to 1998–99.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	319	39	0	3
1990–91	334	34	0	2
1991–92	374	21	0	4
1992–93	582	26	0	3
1993–94	559	46	0	2
1994–95	540	38	0	11
1995–96	621	38	0	9
1996–97	752	16	0	95
1997–98	739	11	0	95
1998–99	611	27	0	148
Total	5 431	296	0	372
% of total	90	4	0	6

Table 6: Summary of estimated catches (t) of tarakihi in TAR 1 on the west coast by fishing method.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	144	8	–	<1
1990–91	154	14	–	<1
1991–92	200	4	–	<1
1992–93	273	9	–	<1
1993–94	242	9	–	<1
1994–95	299	7	–	<1
1995–96	318	7	–	1
1996–97	338	2	–	3
1997–98	339	2	–	4
1998–99	297	10	–	3
Total	2 604	71	–	10
% of total	97	3	–	<1

Table 7: Unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 1 on the west coast by fishing method.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	0.45	0.20	–	0.02
1990–91	0.46	0.40	–	0.06
1991–92	0.53	0.19	–	0.03
1992–93	0.47	0.36	–	0.01
1993–94	0.43	0.20	–	0.03
1994–95	0.55	0.19	–	0.03
1995–96	0.51	0.17	–	0.07
1996–97	0.45	0.10	–	0.03
1997–98	0.46	0.14	–	0.04
1998–99	0.49	0.38	–	0.02

Table 8: Summary of estimated catches (t) of tarakihi for the bottom trawl fishery by statistical area in TAR 1 *on the west coast from 1989–90 to 1998–99.*

Fishing year	*042*	*043*	*044*	*045*	*046*	*047*	*048*	*101*	*102*	*103*	*104*
1989–90	5	<1	–	11	18	110	–	<1	–	–	–
1990–91	5	–	–	53	28	67	1	–	–	–	–
1991–92	3	<1	<1	28	4	163	–	–	–	–	–
1992–93	14	–	<1	54	42	160	3	–	–	–	<1
1993–94	11	<1	–	53	41	131	4	1	1	1	–
1994–95	10	<1	–	42	56	188	1	2	–	<1	–
1995–96	8	7	–	46	78	173	6	1	–	–	–
1996–97	13	<1	<1	39	88	195	<1	1	–	–	1
1997–98	29	<1	5	38	107	159	<1	<1	<1	–	–
1998–99	8	5	–	40	105	138	–	<1	–	–	–
Total	107	13	6	403	567	1 486	15	5	1	1	1
% of total	4	<1	<1	15	22	57	<1	<1	<1	<1	<1

Table 9: Summary of estimated catches of tarakihi for the bottom trawl fishery by main target species in TAR 1 on the west coast from 1989–90 to 1998–99. BAR, barracouta; GUR, red gurnard; JMA, jack mackerel; SKI, gemfish; SNA, snapper; TAR, tarakihi; TRE, trevally.

Fishing year	TAR	BAR	GUR	JMA	SKI	SNA	TRE	All other
1989–90	92	7	–	1	1	25	16	2
1990–91	101	10	1	–	1	20	22	–
1991–92	112	6	6	–	1	61	12	–
1992–93	164	9	10	8	3	43	36	2
1993–94	168	11	2	2	5	38	15	2
1994–95	179	11	4	3	14	77	8	3
1995–96	235	12	1	3	19	34	8	6
1996–97	251	6	9	7	10	33	19	3
1997–98	236	6	3	24	14	25	23	8
1998–99	239	10	8	–	8	16	11	3
Total	1 777	88	44	47	77	372	169	29
% of total	68	3	2	2	3	14	7	1

Table 10: Comparison of unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 1 on the west coast single bottom trawl fishery by statistical area for successful vessel-days that targeted tarakihi.

Fishing Year	042	045	046	047
1989–90	NA	0.48	0.57	0.80
1990–91	0.16	0.72	0.95	0.61
1991–92	0.32	0.65	0.70	1.15
1992–93	0.34	0.58	0.60	0.58
1993–94	0.25	0.58	0.71	0.84
1994–95	0.34	0.36	1.05	0.96
1995–96	0.11	0.56	0.79	0.93
1996–97	0.19	0.46	0.78	0.77
1997–98	0.45	0.79	0.86	0.75
1998–99	0.44	0.69	0.81	0.83

Table 11: Predictor variables included in the stepwise regression model used to estimate the CPUE index of log(t/hr) for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 1 on the west coast from 1989–90 to 1998–99. R^2, cumulative variation explained by the model.

All vessels		Vessel subset	
Variable	R^2	Variable	R^2
target species	18.38	target species	15.80
month	23.13	vessel id	21.61
area	26.70	month	26.89
vessel power	29.78	fishing year	30.18
fishing year	31.30	area	32.03
target species* vessel power	32.94		
area*month	34.11		
year vessel built	34.68		

Table 12: Standardised CPUE indices for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 1 on the west coast from 1989–90 to 1998–99.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	309	1.00	–	102	1.00	–
1990–91	332	0.88	0.073	124	0.74	0.106
1991–92	362	1.07	0.088	221	1.04	0.132
1992–93	560	0.85	0.064	400	0.73	0.086
1993–94	544	1.05	0.080	385	0.85	0.103
1994–95	528	1.27	0.097	407	1.19	0.142
1995–96	592	1.40	0.105	429	1.33	0.160
1996–97	723	1.38	0.100	533	1.33	0.156
1997–98	716	1.25	0.092	483	1.15	0.137
1998–99	597	1.23	0.092	379	1.30	0.160

Table 13: Summary of effort (vessel-days caught and/or targeted TAR) for tarakihi by fishing method in TAR 1 on East Northland and the Bay of Plenty from 1989–90 to 1998–99.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	1 557	83	0	304
1990–91	2 128	53	0	408
1991–92	2 413	39	1	575
1992–93	2 256	5	0	909
1993–94	2 125	22	0	824
1994–95	2 011	38	0	651
1995–96	2 145	15	6	582
1996–97	2 353	8	1	599
1997–98	2 412	5	1	411
1998–99	2 252	3	1	118
Total	21 652	271	10	5 381
% of total	79	1	<1	20

Table 14: Summary of estimated catches (t) of tarakihi in TAR 1 on East Northland and the Bay of Plenty by fishing method.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	472	14	–	17
1990–91	683	10	–	36
1991–92	906	4	1	61
1992–93	822	1	–	109
1993–94	882	4	–	117
1994–95	771	5	–	84
1995–96	792	1	<1	47
1996–97	818	1	<1	42
1997–98	801	<1	<1	28
1998–99	523	<1	<1	9
Total	7 469	41	1	549
% of total	93	<1	<1	7

Table 15: Unstandardised CPUE (mean catch in t per vessel-day) of tarakihi in TAR 1 on East Northland and the Bay of Plenty by fishing method.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	0.30	0.17	–	0.05
1990–91	0.32	0.18	–	0.09
1991–92	0.38	0.11	0.68	0.11
1992–93	0.36	0.28	–	0.12
1993–94	0.41	0.20	–	0.14
1994–95	0.38	0.13	–	0.13
1995–96	0.37	0.07	0.07	0.08
1996–97	0.35	0.07	0.02	0.07
1997–98	0.33	0.09	0.03	0.07
1998–99	0.23	0.06	0.04	0.07

Table 16: Summary of estimated catches (t) of tarakihi for the bottom trawl fishery by statistical area in TAR 1 on the East Northland and Bay of Plenty from 1989–90 to 1998–99.

Fishing	East Northland									Bay of Plenty			
year	001	002	003	004	005	006	007	105	106	008	009	010	107
1989–90	25	64	45	7	19	7	58	–	–	56	85	107	–
1990–91	13	109	69	14	23	4	9	–	–	44	181	219	–
1991–92	32	147	117	61	13	3	7	–	–	138	163	225	–
1992–93	19	111	73	18	8	2	3	–	<1	112	231	243	–
1993–94	26	166	85	22	10	1	2	–	<1	59	188	322	–
1994–95	39	147	83	13	7	4	3	–	1	47	202	224	1
1995–96	30	164	70	5	7	<1	2	<1	2	94	156	260	<1
1996–97	46	256	51	4	10	<1	10	<1	<1	37	180	224	<1
1997–98	29	224	76	3	11	<1	1	–	3	34	247	172	<1
1998–99	1	100	67	4	10	<1	11	1	1	46	161	122	–
Total	261	1 487	735	150	118	22	105	1	9	667	1 794	2 117	1
% of total	3	20	10	2	2	<1	1	<1	<1	9	24	28	<1

Table 17: Summary of estimated catches of tarakihi for the bottom trawl fishery by main target species in TAR 1 on East Northland and the Bay of Plenty from 1989–90 to 1998–99. BAR, barracouta; HOK, hoki; JDO, john dory; SKI, gemfish; SNA, snapper; TAR, tarakihi; TRE, trevally.

Fishing year	TAR	BAR	HOK	JDO	SKI	SNA	TRE	All other
1989–90	284	13	5	10	33	99	11	16
1990–91	520	21	–	6	51	69	6	10
1991–92	664	14	8	13	83	84	3	37
1992–93	592	14	15	11	110	57	6	15
1993–94	704	8	6	8	57	69	17	13
1994–95	609	23	12	11	53	41	12	9
1995–96	584	8	10	11	93	70	8	8
1996–97	636	7	31	27	50	30	19	19
1997–98	576	19	57	37	27	37	31	17
1998–99	355	18	12	26	19	56	27	9
Total	5 524	146	156	158	577	612	141	154
% of total	74	2	2	2	8	8	2	2

Table 18: Comparison of unstandardised CPUE (mean t per vessel-day) of tarakihi in TAR 1 on East Northland and the Bay of Plenty single bottom trawl fishery by statistical area for successful vessel-days that targeted tarakihi.

Fishing	East Northland					Bay of Plenty		
Year	001	002	003	004	005	008	009	010
1989–90	0.62	0.76	0.25	0.35	0.22	0.74	0.47	0.81
1990–91	0.19	0.70	0.33	0.27	0.24	0.49	0.54	0.73
1991–92	0.93	1.16	0.51	1.45	0.19	0.48	0.35	0.72
1992–93	0.35	0.76	0.47	0.44	0.48	0.46	0.56	0.68
1993–94	0.39	0.81	0.38	0.49	0.41	0.57	0.48	0.84
1994–95	0.53	0.87	0.58	0.34	0.40	0.44	0.46	0.66
1995–96	0.40	0.68	0.37	0.12	0.06	0.69	0.55	0.83
1996–97	0.67	0.92	0.25	0.33	0.05	0.39	0.44	0.80
1997–98	0.62	0.83	0.32	0.12	0.21	0.20	0.61	0.66
1998–99	0.27	0.56	0.15	0.26	0.06	0.33	0.38	0.57

Table 19: Predictor variables included in the stepwise regression model to estimate the CPUE index of log(t/hr) for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 1 on East Northland and Bay of Plenty from 1989–90 to 1998–99. R^2, cumulative variation explained by the model.

All vessels		Vessel subset	
Variable	R^2	Variable	R^2
target species	30.81	target species	26.28
vessel tonnage	35.06	vessel id	34.82
area	37.10	month	36.44
year vessel built	38.13	area	37.77
month	39.00	fishing year	38.06
target species*month	41.19		
fishing year	41.58		

Table 20: Standardised CPUE indices for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 1 on East Northland and Bay of Plenty from 1989–90 to 1998–99.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 485	1.00	–	791	1.00	–
1990–91	2 052	0.77	0.028	954	0.89	0.043
1991–92	2 320	0.86	0.031	1 101	0.89	0.041
1992–93	2 193	0.90	0.033	920	0.96	0.047
1993–94	2 088	0.97	0.036	1 008	1.03	0.050
1994–95	1 955	1.04	0.039	1 076	0.99	0.047
1995–96	2 107	1.05	0.038	1 139	0.98	0.046
1996–97	2 279	1.08	0.040	1 204	1.01	0.047
1997–98	2 351	1.19	0.043	1 273	1.03	0.048
1998–99	2 205	1.16	0.043	1 100	1.13	0.054

Table 21: Summary of effort (vessel-days caught and/or targeted TAR) for tarakihi by fishing method in TAR 2 from 1989–90 to 1998–99.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	2 032	0	0	165
1990–91	2 663	0	2	155
1991–92	3 103	0	2	172
1992–93	2 875	0	3	197
1993–94	2 877	1	6	255
1994–95	3 147	0	18	205
1995–96	2 922	0	32	158
1996–97	3 163	0	7	160
1997–98	2 790	0	16	122
1998–99	2 301	0	11	55
Total	27 873	1	97	1 643
% of total	94	<1	<1	5

Table 22: Summary of estimated catches (t) of tarakihi in TAR 2 by fishing method.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	1 188	–	–	7
1990–91	1 556	–	<1	3
1991–92	1 589	–	<1	8
1992–93	1 571	–	<1	12
1993–94	1 389	<1	1	21
1994–95	1 466	–	1	8
1995–96	1 480	–	2	8
1996–97	1 504	–	<1	8
1997–98	1 626	–	1	6
1998–99	1 424	–	<1	1
Total	14 793	<1	5	84
% of total	99	<1	<1	1

Table 23: Unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 2 by fishing method

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	0.58	–	–	0.04
1990–91	0.58	–	0.22	0.02
1991–92	0.51	–	0.01	0.04
1992–93	0.55	–	0.03	0.06
1993–94	0.48	0.20	0.11	0.08
1994–95	0.47	–	0.05	0.04
1995–96	0.51	–	0.05	0.05
1996–97	0.48	–	0.07	0.05
1997–98	0.58	–	0.04	0.05
1998–99	0.62	–	0.03	0.02

Table 24: Summary of estimated catches (t) of tarakihi for the bottom trawl fishery by statistical area in TAR 2 from 1989–90 to 1998–99.

Fishing year	011	012	013	014	015	016	017	201	202	203	204	205
1989–90	167	261	356	101	107	99	97	–	–	–	–	–
1990–91	208	456	518	120	114	81	56	1	–	–	<1	<1
1991–92	273	271	571	170	42	171	90	–	<1	–	<1	–
1992–93	274	403	443	201	43	95	113	<1	–	–	–	–
1993–94	303	351	325	185	42	85	97	–	–	–	<1	<1
1994–95	241	436	311	180	37	95	166	<1	<1	–	<1	–
1995–96	266	456	264	157	43	111	183	1	–	–	<1	–
1996–97	217	363	459	143	44	73	202	<1	–	–	1	1
1997–98	232	470	440	142	74	58	208	1	<1	–	1	–
1998–99	235	199	466	173	56	70	253	<1	–	1	–	–
Total	2 417	3 666	4 152	1 543	604	939	1 464	2	1	1	4	1
% of total	16	25	28	10	4	6	10	<1	<1	<1	<1	<1

Table 25: Summary of estimated catches (t) of tarakihi for the bottom trawl fishery by main target species in TAR 2 from 1989–90 to 1998–99. BAR, barracouta; GUR, red gurnard; HOK, hoki; SKI, gemfish; TAR, tarakihi; WAR, warehou.

Fishing year	TAR	BAR	GUR	HOK	SKI	WAR	All other
1989–90	1 037	51	12	18	27	19	24
1990–91	1 391	39	29	7	37	22	31
1991–92	1 338	22	75	7	73	40	34
1992–93	1 288	45	55	6	82	42	53
1993–94	1 129	159	33	47	42	32	46
1994–95	1 176	41	38	66	56	33	56
1995–96	1 105	54	40	105	110	30	36
1996–97	982	120	95	124	95	37	51
1997–98	1 252	27	85	102	78	40	41
1998–99	1 206	43	53	14	39	22	48
Total	11 904	500	515	498	639	317	420
% of total	81	3	4	3	4	2	3

Table 26: *Comparison of unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 2 single* bottom trawl fishery by statistical area for successful vessel-days that targeted tarakihi.

Fishing Year	011	012	013	014	015	016	017
1989–90	1.28	1.05	0.79	0.47	0.88	0.49	0.65
1990–91	1.13	1.17	0.79	0.51	0.63	0.38	0.51
1991–92	1.03	0.97	0.66	0.51	0.47	0.55	0.69
1992–93	1.29	1.27	0.72	0.47	0.54	0.44	0.76
1993–94	1.17	1.09	0.57	0.39	0.44	0.38	0.51
1994–95	0.99	1.01	0.62	0.39	0.40	0.37	0.51
1995–96	1.00	1.07	0.60	0.48	0.48	0.46	0.83
1996–97	1.20	1.04	0.67	0.36	0.76	0.25	0.80
1997–98	1.09	1.25	0.77	0.49	0.70	0.27	1.09
1998–99	1.35	1.06	0.83	0.54	0.79	0.31	1.35

Table 27: Predictor variables included in the stepwise regression model to estimate the CPUE index of log (t/hr) for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 2 from 1989–90 to 1998–99.

	All vessels		Vessel subset
Variable	R^2	Variable	R^2
target species	26.05	vessel id	24.61
vessel breadth	34.97	target species	38.53
area	38.32	area	41.48
target species* vessel breadth	39.38	month	41.77
year vessel built	40.05	month*target species	43.02
area*year vessel built	40.61	fishing year	43.15
fishing year	40.94		

Table 28: Standardised CPUE indices for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 2 from 1989–90 to 1998–99. R^2, cumulative variation explained by the model.

		All vessels			Vessel subset	
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 977	1.00	–	740	1.00	–
1990–91	2 609	0.94	0.029	1 155	0.92	0.042
1991–92	3 061	0.85	0.026	1 337	0.91	0.041
1992–93	2 832	0.87	0.027	1 239	0.90	0.041
1993–94	2 831	0.81	0.025	1 341	0.89	0.040
1994–95	3 076	0.81	0.025	1 646	0.87	0.038
1995–96	2 878	0.82	0.025	1 636	0.90	0.040
1996–97	3 118	0.95	0.029	1 654	0.98	0.043
1997–98	2 716	0.94	0.030	1 739	0.98	0.043
1998–99	2 241	1.02	0.033	1 435	1.00	0.046

Table 29: Summary of effort (vessel-days caught and/or targeted TAR) for tarakihi by fishing method in TAR 3 from 1989–90 to 1998–99.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	1 619	1	0	972
1990–91	1 820	0	0	1 088
1991–92	1 925	0	0	1 243
1992–93	1 528	0	0	1 152
1993–94	1 628	1	0	1 019
1994–95	1 529	0	2	1 033
1995–96	1 604	0	3	825
1996–97	1 578	0	3	814
1997–98	1 661	0	2	1 017
1998–99	1 562	0	0	696
Total	16 454	2	10	9 859
% of total	63	<1	<1	37

Table 30: Summary of estimated catches (t) of *tarakihi* in TAR 3 by *fishing method*.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	555	<1	–	181
1990–91	660	–	–	292
1991–92	686	–	–	368
1992–93	470	–	–	345
1993–94	522	<1	–	220
1994–95	617	–	<1	309
1995–96	838	–	2	222
1996–97	831	–	1	208
1997–98	689	–	<1	282
1998–99	696	–	–	237
Total	6 563	<1	3	2 663
% of total	71	<1	<1	37

Table 31: Unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 3 by fishing method.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	0.34	0.06	–	0.19
1990–91	0.36	–	–	0.27
1991–92	0.36	–	–	0.30
1992–93	0.31	–	–	0.30
1993–94	0.32	0.02	–	0.22
1994–95	0.40	–	0.22	0.30
1995–96	0.52	–	0.51	0.27
1996–97	0.53	–	0.17	0.26
1997–98	0.41	–	0.13	0.28
1998–99	0.45	–	–	0.34

Table 32: Summary of estimated catches (t) of tarakihi for the bottom trawl fishery by statistical area in TAR 3 from 1989–90 to 1998–99.

Fishing year	018	019	020	021	022	023	024	026	302	303
1989–90	78	<1	216	2	199	<1	49	11	–	–
1990–91	186	<1	130	1	251	<1	86	5	–	–
1991–92	147	–	207	2	249	<1	71	9	–	–
1992–93	168	–	145	17	130	–	8	3	–	–
1993–94	111	<1	201	7	170	<1	27	6	–	1
1994–95	239	3	179	4	129	–	59	3	–	<1
1995–96	211	–	173	4	370	<1	68	12	–	–
1996–97	112	–	314	2	368	<1	62	2	–	–
1997–98	99	–	229	4	290	–	56	10	<1	–
1998–99	98	<1	208	1	337	–	43	9	–	–
Total	1 448	4	2 003	44	2 494	1	499	70	<1	1
% of total	22	<1	31	1	38	<1	8	1	<1	<1

Table 33: Summary of estimated catches (t) of tarakihi for the bottom trawl fishery by main target species in TAR 3 from 1989–90 to 1998–99. BAR, barracouta; FLA, flatfish; HOK, hoki; RCO, red cod; TAR, tarakihi; SQU, squid.

Fishing year	TAR	BAR	FLA	HOK	RCO	SQU	All other
1989–90	271	89	26	15	94	3	57
1990–91	162	175	41	27	176	22	57
1991–92	133	148	31	8	263	39	64
1992–93	84	74	11	28	197	10	67
1993–94	191	29	31	10	211	16	34
1994–95	156	127	40	29	234	8	22
1995–96	192	144	62	38	330	27	44
1996–97	230	124	28	44	332	42	30
1997–98	84	76	72	21	409	7	21
1998–99	208	141	119	7	185	15	21
Total	1 711	1 127	460	228	2 431	190	417
% of total	26	17	7	3	37	3	6

Table 34: Comparison of unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 3 single bottom trawl fishery by statistical area for all vessel-days that targeted tarakihi (TAR), barracouta (BAR) or red cod (RCO), and caught tarakihi.

Fishing	Target TAR				Target BAR			
Year	018	020	022	024	018	020	022	024
1989–90	0.53	0.79	0.72	0.58	0.38	0.40	0.19	0.11
1990–91	0.63	0.64	0.82	0.28	0.33	0.30	0.31	0.42
1991–92	0.65	0.40	0.55	0.38	0.52	0.32	0.33	0.18
1992–93	0.63	0.42	0.39	0.05	0.50	0.39	0.22	0.06
1993–94	0.50	0.41	0.53	0.03	0.34	0.33	0.22	0.02
1994–95	0.67	0.62	0.24	0.32	0.69	0.25	0.40	0.07
1995–96	0.88	0.70	0.83	0.82	0.69	0.36	0.69	0.29
1996–97	0.41	0.99	0.95	0.18	0.37	0.78	0.68	0.42
1997–98	0.83	0.72	0.61	0.07	0.31	0.26	0.72	NA
1998–99	0.89	0.72	0.91	0.01	0.36	1.17	0.93	0.13

Fishing	Target RCO			
Year	018	020	022	024
1989–90	0.09	0.40	0.20	0.19
1990–91	0.36	0.37	0.41	0.34
1991–92	0.44	0.41	0.29	0.18
1992–93	0.38	0.32	0.22	0.05
1993–94	0.20	0.51	0.24	0.08
1994–95	0.35	0.44	0.31	0.20
1995–96	0.71	0.57	0.53	0.29
1996–97	0.32	0.61	0.56	0.20
1997–98	0.24	0.58	0.57	0.27
1998–99	0.46	0.38	0.47	0.11

Table 35: Predictor variables included in the stepwise regression model to estimate the CPUE indices of log(t/hr) for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 3 from 1989–90 to 1998–99 for all target species. R^2, cumulative variation explained by the model.

	All vessels		Vessel subset
Variable	R^2	Variable	R^2
vessel breadth	14.70	vessel id	10.64
target species	20.20	target species	14.22
fishing year	22.41	fishing year	17.73
month	23.40	month	19.21
vessel breadth*month	24.24		
area	25.07		

Table 36: Standardised CPUE indices for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 3 from 1989–90 to 1998–99 for all target species.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 561	1.00	–	611	1.00	–
1990–91	1 793	1.15	0.047	734	0.99	0.061
1991–92	1 907	1.15	0.047	916	1.28	0.076
1992–93	1 504	1.01	0.044	826	1.07	0.065
1993–94	1 545	1.08	0.046	850	1.16	0.070
1994–95	1 491	1.49	0.064	802	1.45	0.089
1995–96	1 576	1.83	0.077	850	2.02	0.122
1996–97	1 537	1.59	0.067	807	1.80	0.110
1997–98	1 627	1.49	0.063	790	1.78	0.112
1998–99	1 501	1.37	0.059	798	1.52	0.095

Table 37: Predictor variables included in the stepwise regression model to estimate the CPUE indices in the target tarakihi single bottom trawl fishery in TAR 3 from 1989–90 to 1998–99 for the linear regression of log(t/hr) for successful vessel–days and the binomial regression of successful vs unsuccessful vessel–days. R^2, cumulative variation explained by the model.

	Linear regression		Binomial regression
Variable	R^2	Variable	deviance
vessel breadth	5.24	month	2166
month	9.22	area	2039
vessel size	12.72	month*area	1848
month*vessel size	16.22	vessel length	1766
fishing year	18.03	vessel size	1731
area	19.44	vessel draught	1709
year vessel built	20.16	vessel draught*size	1604
vessel power	20.82	fishing year	1590
vessel breadth*year built	21.47		

Table 38: Standardised and unstandardised CPUE indices for the single bottom trawl, target tarakihi fishery in TAR 3 from 1989–90 to 1998–99.

Fishing year	Vessel–days			Standardised indices			Unstandardised index
	total	zero catch	P(0)	linear	binomial	combined	
1989–90	384	58	0.15	1.00	1.00	1.00	0.71
1990–91	273	26	0.10	0.86	0.96	0.87	0.59
1991–92	260	18	0.07	0.97	0.39	1.07	0.51
1992–93	177	24	0.14	0.73	0.82	0.75	0.48
1993–94	440	83	0.19	0.73	0.98	0.73	0.43
1994–95	302	38	0.13	0.99	0.82	1.02	0.52
1995–96	243	27	0.11	1.36	1.04	1.35	0.79
1996–97	295	40	0.14	1.36	1.14	1.33	0.78
1997–98	145	34	0.23	1.25	0.93	1.26	0.58
1998–99	283	61	0.22	1.01	1.33	0.96	0.74

Table 39: Summary of estimated catches (t) of tarakihi for the set net fishery by statistical area in TAR 3 from 1989–90 to 1998–99.

Fishing year	018	019	020	021	022	024	026
1989–90	180	<1	<1	–	<1	2	–
1990–91	288	<1	<1	1	<1	3	<1
1991–92	362	<1	1	–	–	4	–
1992–93	342	–	1	–	<1	1	–
1993–94	216	–	1	<1	1	2	–
1994–95	308	–	<1	–	<1	<1	–
1995–96	219	–	1	–	<1	1	–
1996–97	206	<1	1	–	<1	<1	–
1997–98	281	–	1	–	–	<1	–
1998–99	236	<1	1	–	–	<1	–
Total	2640	<1	7	1	2	13	<1
% of total	99	<1	<1	<1	<1	<1	<1

Table 40: Summary of estimated catches (t) of tarakihi for the set net fishery by main target species in TAR 3 from 1989–90 to 1998–99. LIN, ling; SPD, spiny dogfish; TAR, tarakihi; WAR, warehou.

Fishing year	TAR	LIN	SPD	WAR	All other
1989–90	176	5	1	<1	1
1990–91	284	2	1	1	5
1991–92	354	4	4	<1	9
1992–93	333	2	7	–	10
1993–94	199	<1	15	2	18
1994–95	275	<1	30	1	33
1995–96	205	3	10	3	11
1996–97	176	1	24	4	27
1997–98	258	6	13	–	19
1998–99	232	3	<1	<1	2
Total	2492	26	105	11	134
% of total	90	1	4	<1	5

Table 41: Predictor variables included in the stepwise regression model to estimate the CPUE index of log(t/hr) for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi set net fishery in TAR 3 from 1989–90 to 1998–99. R^2, cumulative variation explained by the model.

Target tarakihi		Target all species	
Variable	R^2	Variable	R^2
net length	27.17	vessel	37.50
vessel	41.65	month	50.35
month	47.63	net length	53.18
fishing year	48.54	target species	57.27
		vessel*net length	59.27
		fishing year	59.93

Table 42: Standardised CPUE indices for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi set net fishery in TAR 3 from 1989–90 to 1998–99.

	Target tarakihi			Target all species		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	789	1.00	–	839	1.00	–
1990–91	869	1.00	0.045	978	1.09	0.051
1991–92	862	1.06	0.049	1 023	1.21	0.058
1992–93	841	0.98	0.048	1 025	0.99	0.050
1993–94	676	0.69	0.035	876	0.79	0.041
1994–95	700	0.91	0.046	917	0.97	0.050
1995–96	557	0.87	0.047	739	0.82	0.046
1996–97	518	0.85	0.046	750	0.81	0.045
1997–98	680	1.01	0.056	932	0.99	0.055
1998–99	497	1.13	0.073	540	1.17	0.077

Table 43: Summary of effort (vessel-days caught and/or targeted TAR) for tarakihi by fishing method in TAR 7 from 1989–90 to 1998–99.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	1 135	43	3	51
1990–91	1 250	69	14	44
1991–92	1 214	0	10	29
1992–93	1 403	0	9	43
1993–94	1 130	0	35	82
1994–95	1 147	0	17	78
1995–96	1 169	0	31	59
1996–97	1 444	0	30	28
1997–98	883	0	6	23
1998–99	1 257	0	7	60
Total	12 032	112	162	497
% of total	94	1	1	4

Table 44: Summary of estimated catches (t) of tarakihi in TAR 7 by fishing method

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	334	27	<1	1
1990–91	379	22	3	<1
1991–92	445	–	2	<1
1992–93	635	–	3	1
1993–94	541	–	18	2
1994–95	604	–	3	2
1995–96	405	–	7	1
1996–97	530	–	7	<1
1997–98	311	–	1	<1
1998–99	482	–	1	1
Total	4 665	49	45	8
% of total	98	1	1	<1

Table 45: Unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 7 by fishing method.

Fishing year	Bottom trawl	Bottom pair trawl	Midwater trawl	Set net
1989–90	0.29	0.63	0.08	0.02
1990–91	0.30	0.32	0.20	0.01
1991–92	0.37	–	0.20	0.01
1992–93	0.45	–	0.31	0.02
1993–94	0.48	–	0.51	0.02
1994–95	0.53	–	0.20	0.02
1995–96	0.35	–	0.23	0.02
1996–97	0.37	–	0.23	0.01
1997–98	0.35	–	0.09	0.01
1998–99	0.38	–	0.13	0.01

Table 46: Summary of estimated catches (t) of tarakihi for the bottom trawl fishery by statistical area in TAR 7 from 1989–90 to 1998–99.

Fishing year	033	034	035	036	037	038	702	703	704	705	706
1989–90	49	156	35	34	32	27	–	–	–	1	–
1990–91	130	114	35	26	46	12	2	2	–	1	–
1991–92	152	186	47	28	25	12	–	2	–	–	–
1992–93	192	312	40	41	25	6	–	–	<1	1	–
1993–94	155	181	59	45	34	55	–	1	–	4	–
1994–95	241	149	67	32	21	71	–	<1	–	2	<1
1995–96	124	183	87	19	32	19	–	–	<1	<1	–
1996–97	225	206	27	38	20	14	–	–	–	<1	–
1997–98	82	173	27	15	14	19	–	–	–	–	–
1998–99	136	230	21	63	20	13	–	–	–	–	–
Total	1 485	1 890	417	340	268	248	2	5	<1	9	<1
% of total	32	41	9	7	6	6	<1	<1	<1	<1	<1

Table 47: Summary of estimated catches of tarakihi for the bottom trawl fishery by main target species in TAR 7 from 1989–90 to 1998–99. BAR, barracouta; FLA, flatfish; JMA, jack mackerel; RCO, red cod; STA, stargazer; TAR, tarakihi; WAR, warehou.

Fishing year	TAR	BAR	FLA	JMA	RCO	STA	WAR	All other
1989–90	96	87	8	69	5	26	11	32
1990–91	127	131	1	72	10	13	7	18
1991–92	187	134	2	55	24	16	5	21
1992–93	179	289	10	78	39	1	5	34
1993–94	165	282	9	54	8	4	5	14
1994–95	197	243	12	74	28	9	18	24
1995–96	90	213	22	48	15	1	8	8
1996–97	81	363	41	12	11	2	13	8
1997–98	31	208	35	15	2	4	6	10
1998–99	86	292	67	13	5	5	<1	13
Total	1 238	2 243	206	490	148	80	77	183
% of total	27	48	4	11	3	2	2	4

Table 48: Comparison of unstandardised CPUE (mean catch t per vessel-day) of tarakihi in TAR 7 single bottom trawl fishery by statistical area for all vessel-days that targeted tarakihi(TAR), and all vessel-days that targeted barracouta (BAR) and caught tarakihi.

Fishing	target TAR						target BAR					
Year	033	034	035	036	037	038	033	034	035	036	037	038
1989–90	0.49	0.53	0.16	0.13	0.41	0.19	0.19	0.37	0.37	0.29	0.14	0.20
1990–91	0.47	0.36	0.07	0.52	0.37	0.16	0.32	0.50	0.50	0.27	0.19	0.11
1991–92	0.49	0.62	0.36	0.72	–	0.77	0.35	0.45	0.45	0.47	0.13	0.10
1992–93	0.53	0.71	0.67	0.52	0.39	0.80	0.48	0.54	0.54	0.18	0.12	0.14
1993–94	0.49	0.53	0.27	0.74	0.50	1.06	0.61	0.51	0.51	0.21	0.55	0.93
1994–95	0.87	0.48	0.10	0.46	–	2.57	1.04	0.33	0.33	0.31	0.29	0.44
1995–96	0.39	0.37	0.72	0.07	–	0.25	0.64	0.25	0.25	0.23	0.20	0.30
1996–97	0.59	0.33	0.28	0.78	0.33	0.30	0.57	0.42	0.42	0.49	0.17	0.23
1997–98	0.28	0.31	0.37	1.09	0.69	–	0.53	0.53	0.20	0.47	0.14	0.19
1998–99	0.24	0.40	0.40	0.83	0.70	0.31	0.59	0.43	0.42	0.87	0.27	0.32

***Table 49: Predictor variables included in the stepwise regression model to estimate the CPUE index of* log(t/hr) for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 7 from 1989–90 to 1998–99. R^2, cumulative variation explained by the model.**

	All vessels		Vessel subset
Variable	R^2	Variable	R^2
vessel breadth	19.04	vessel id	14.01
target species	26.99	target species	19.19
area	28.40	area	20.52
vessel breadth*area	30.21	month	21.69
vessel length	31.98	fishing year	22.19
fishing year	33.01		
target species*vessel length	33.69		
month	34.23		

Table 50: Standardised CPUE indices for successful vessel-days (i.e., catch of TAR >0 t) in the tarakihi single bottom trawl fishery in TAR 7 from 1989–90 to 1998–99.

	All vessels			Vessel subset		
Fishing year	*n*	Index	s.d.	*n*	Index	s.d.
1989–90	1 116	1.00	–	539	1.00	–
1990–91	1 238	1.04	0.045	660	0.98	0.059
1991–92	1 202	1.07	0.047	643	0.90	0.055
1992–93	1 393	1.29	0.055	862	1.03	0.062
1993–94	1 121	1.29	0.058	681	1.02	0.064
1994–95	1 143	1.37	0.063	545	1.19	0.079
1995–96	1 160	1.05	0.047	822	1.00	0.060
1996–97	1 436	1.17	0.051	887	1.10	0.067
1997–98	881	1.26	0.061	502	1.19	0.079
1998–99	1 252	1.46	0.065	661	1.17	0.075

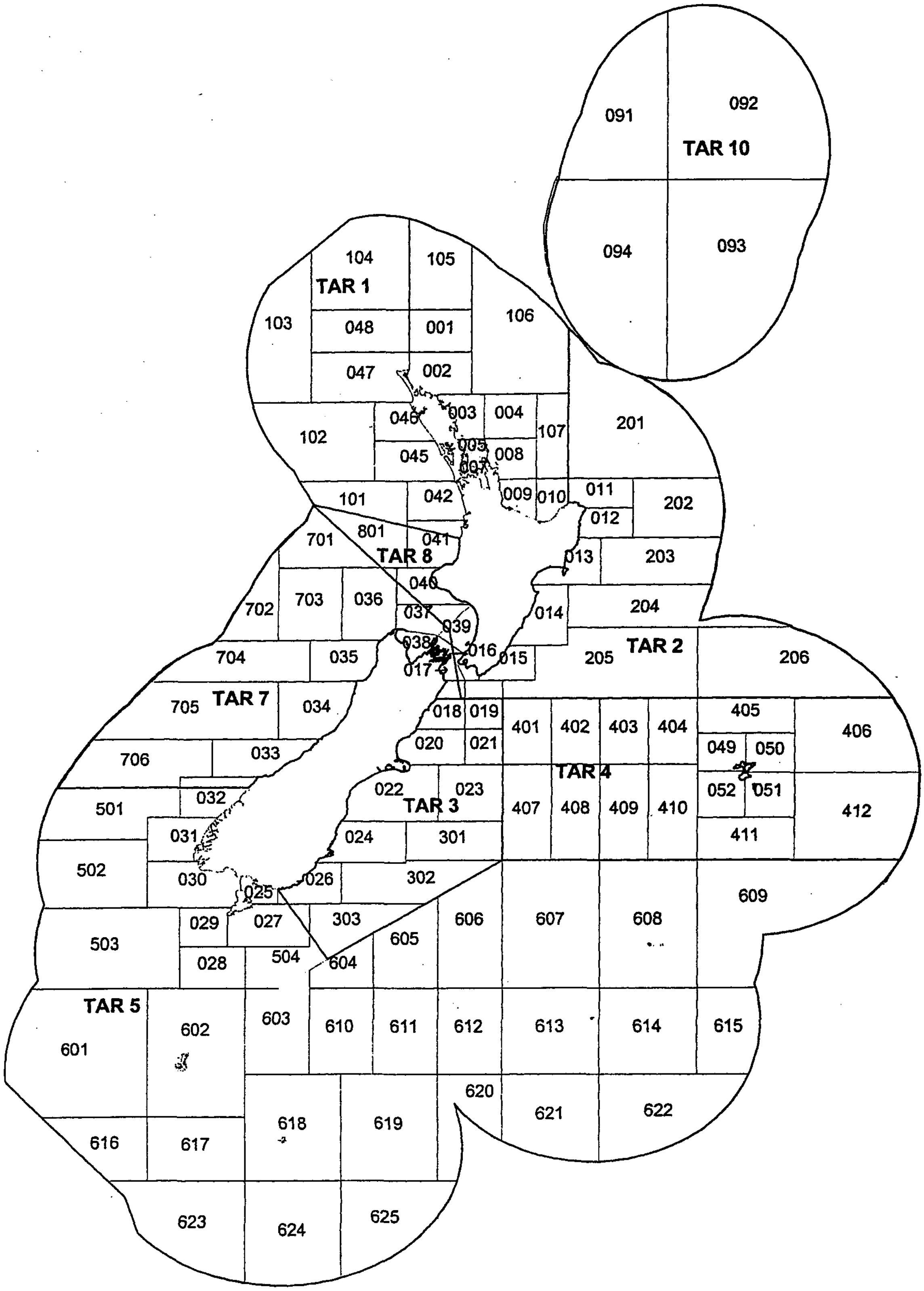


Figure 1: Statistical areas with QMA boundaries.

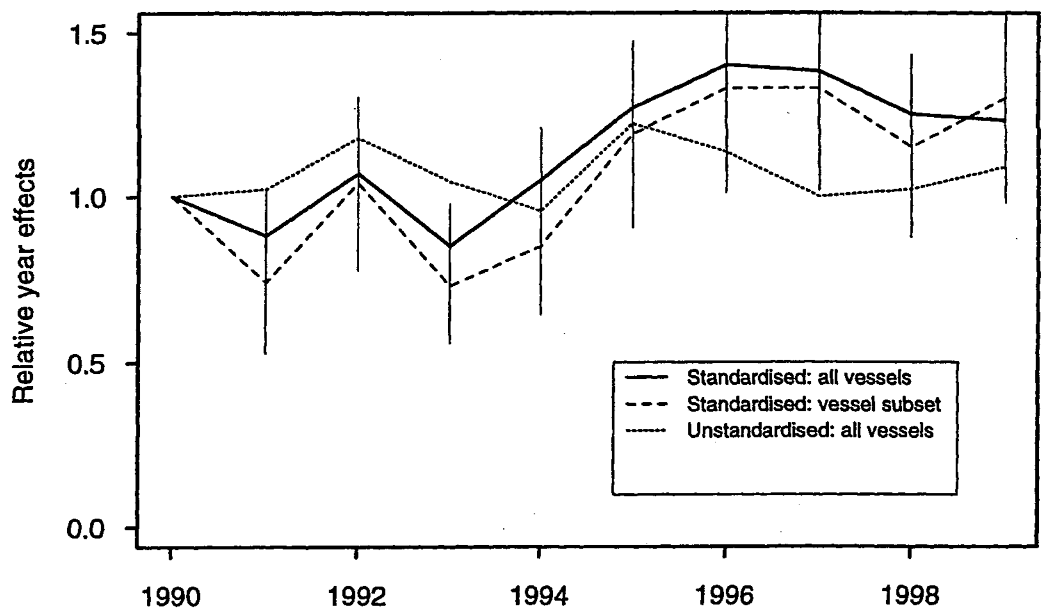


Figure 2: Comparison of standardised and unstandardised CPUE for the single bottom trawl tarakihi fishery in TAR 1 on the west coast. Standardised indices ± 2 s.e.

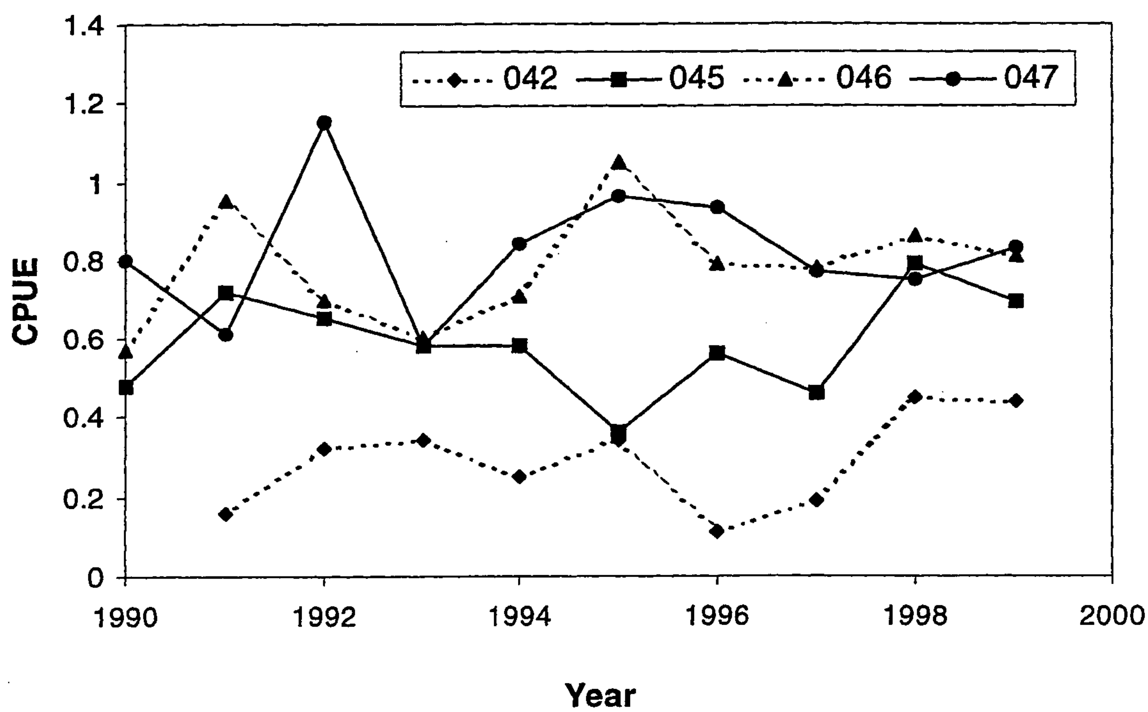


Figure 3: Unstandardised CPUE (mean t per vessel-day) of tarakihi in TAR 1W by statistical area.

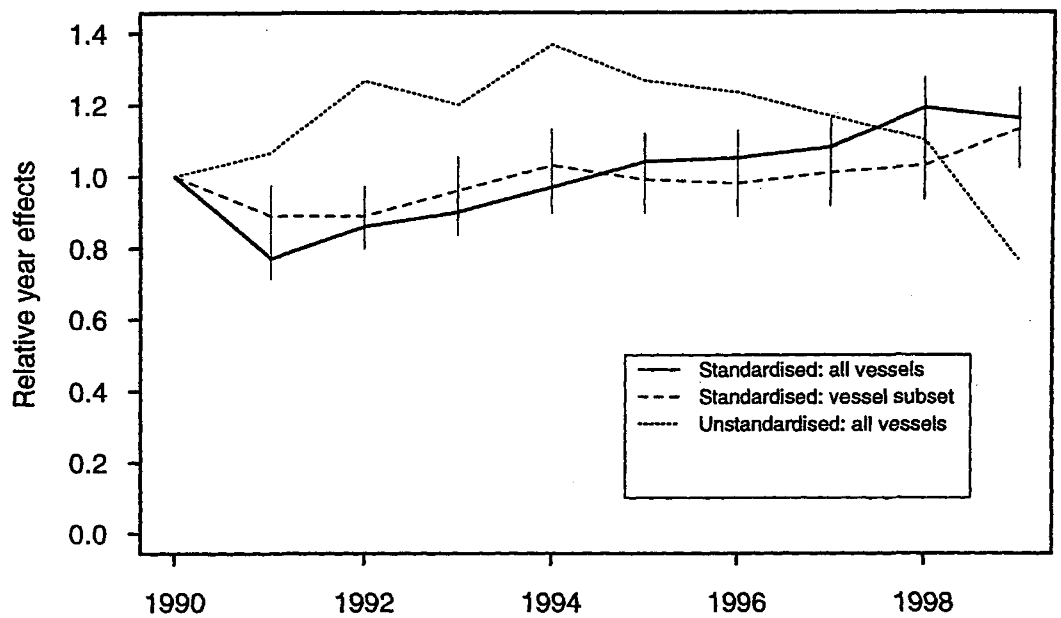


Figure 4: Comparison of standardised and unstandardised CPUE for the single bottom trawl tarakihi fishery in TAR 1 East Northland and Bay of Plenty. Standardised indices ± 2 s.e.

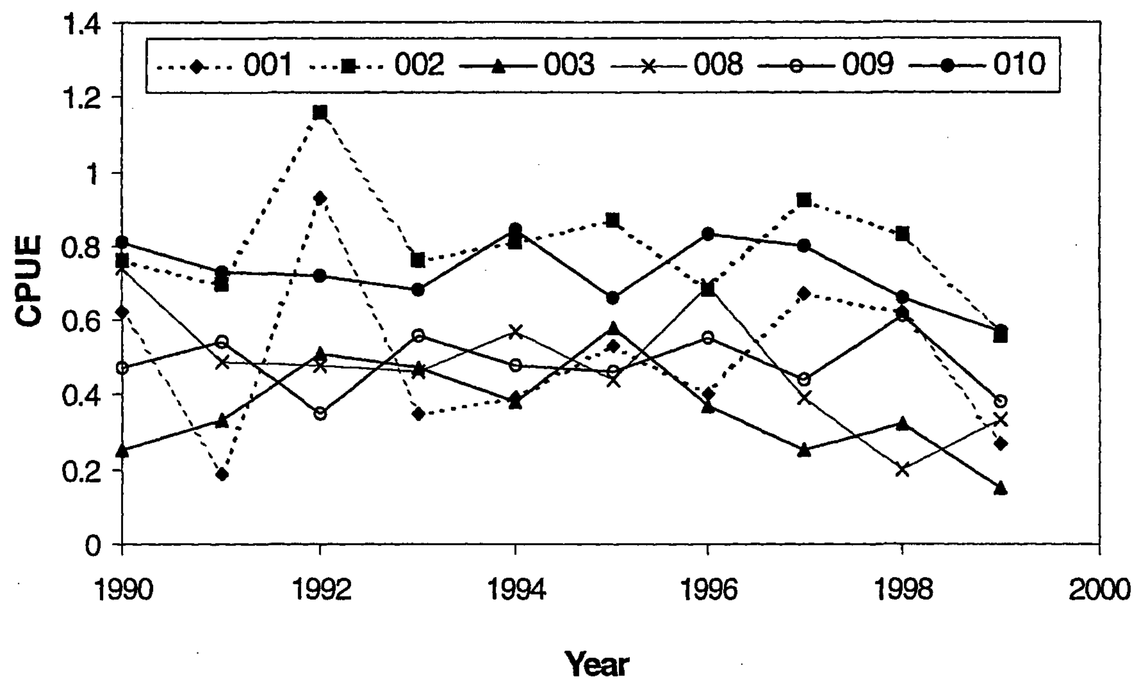


Figure 5: Unstandardised CPUE (mean t per vessel-day) of tarakihi in TAR 1E by statistical area.

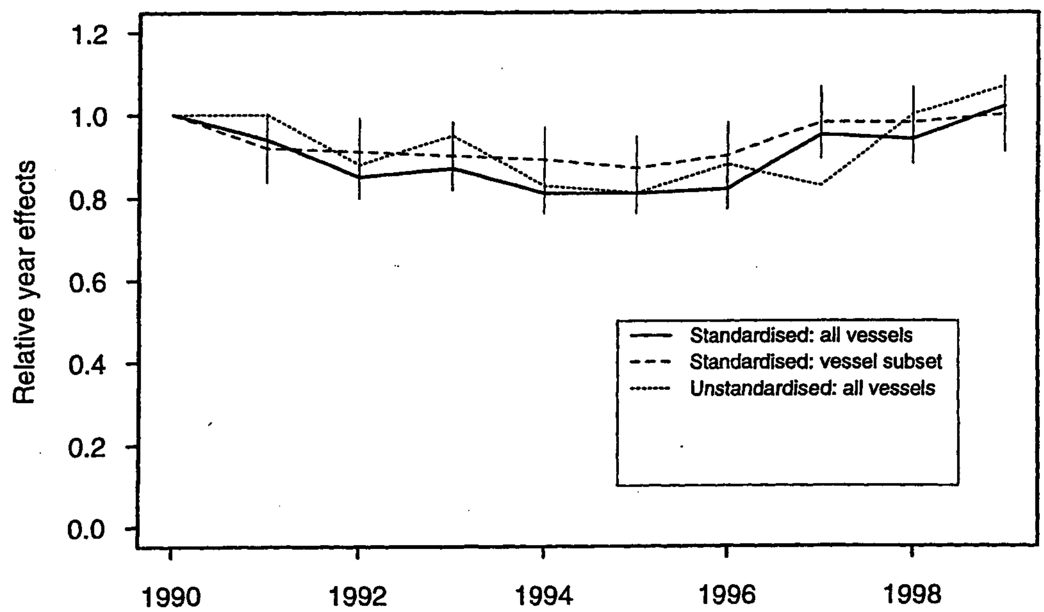


Figure 6: Comparison of standardised and unstandardised CPUE for the single bottom trawl tarakihi fishery in TAR 2. Standardised indices ± 2 s.e.

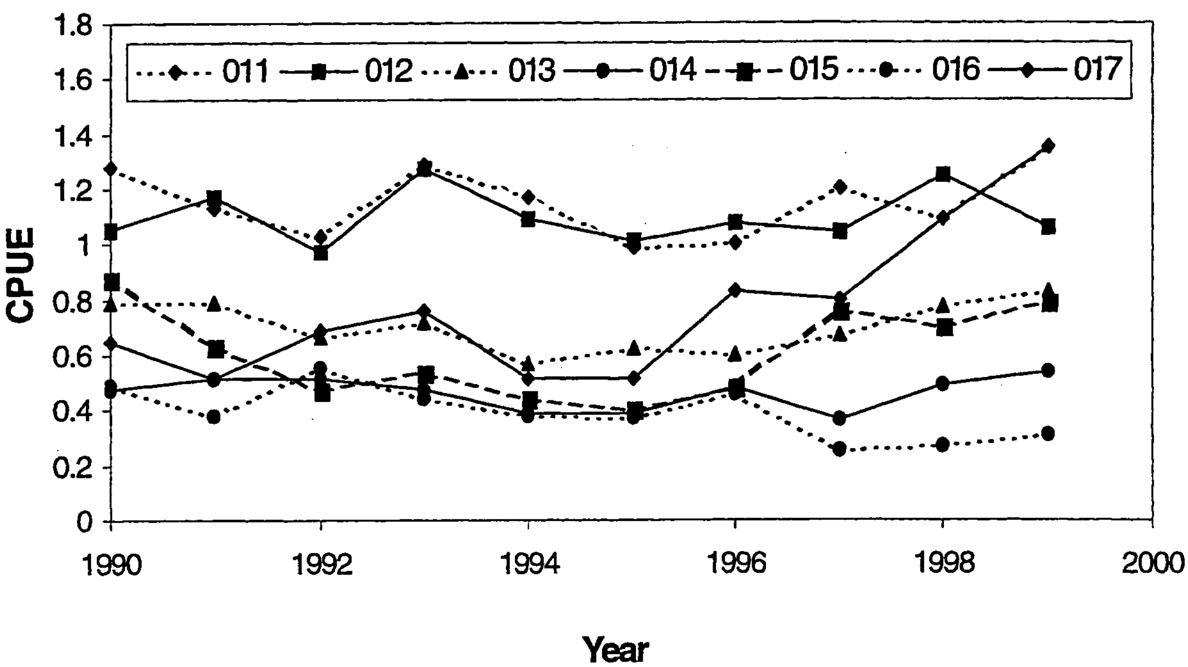


Figure 7: Unstandardised CPUE (mean t per vessel-day) of tarakihi in TAR 2 by statistical area.

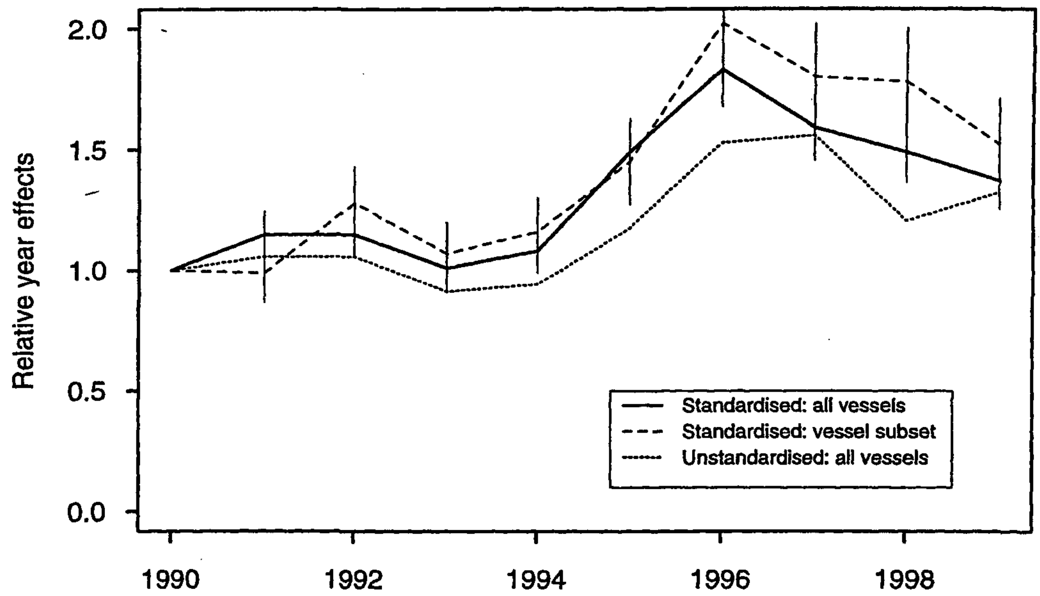


Figure 8: Comparison of standardised and unstandardised CPUE for all target species in the single bottom trawl tarakihi fishery in TAR 3. Standardised indices ± 2 s.e.

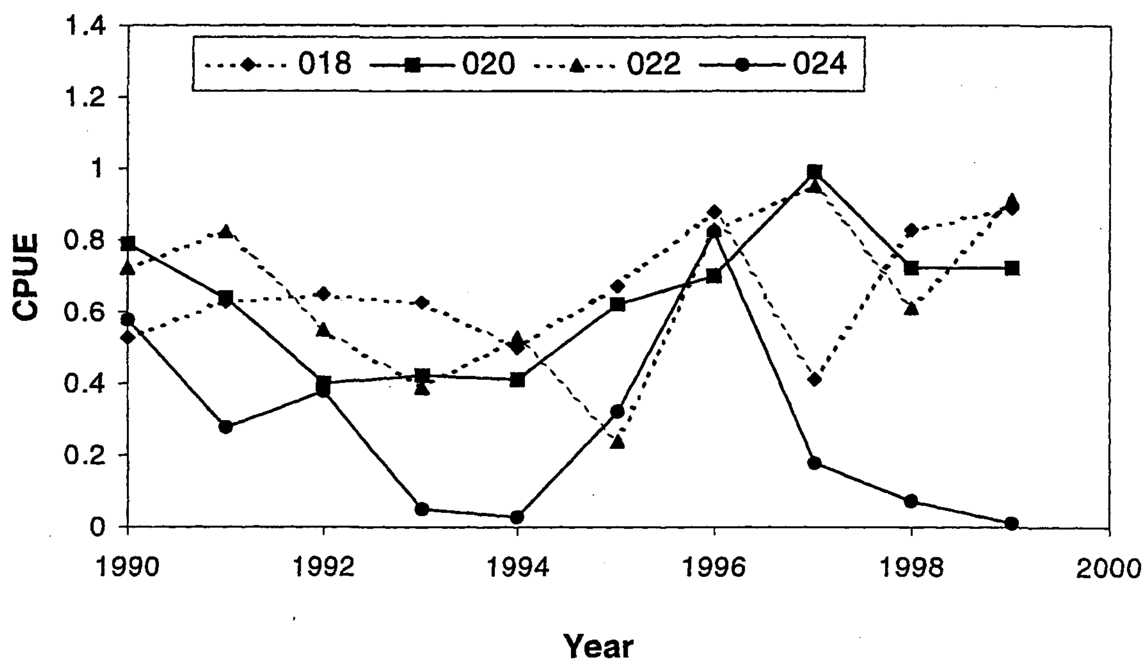


Figure 9: Unstandardised CPUE (mean t per vessel-day) of tarakihi in TAR 3 by statistical area.

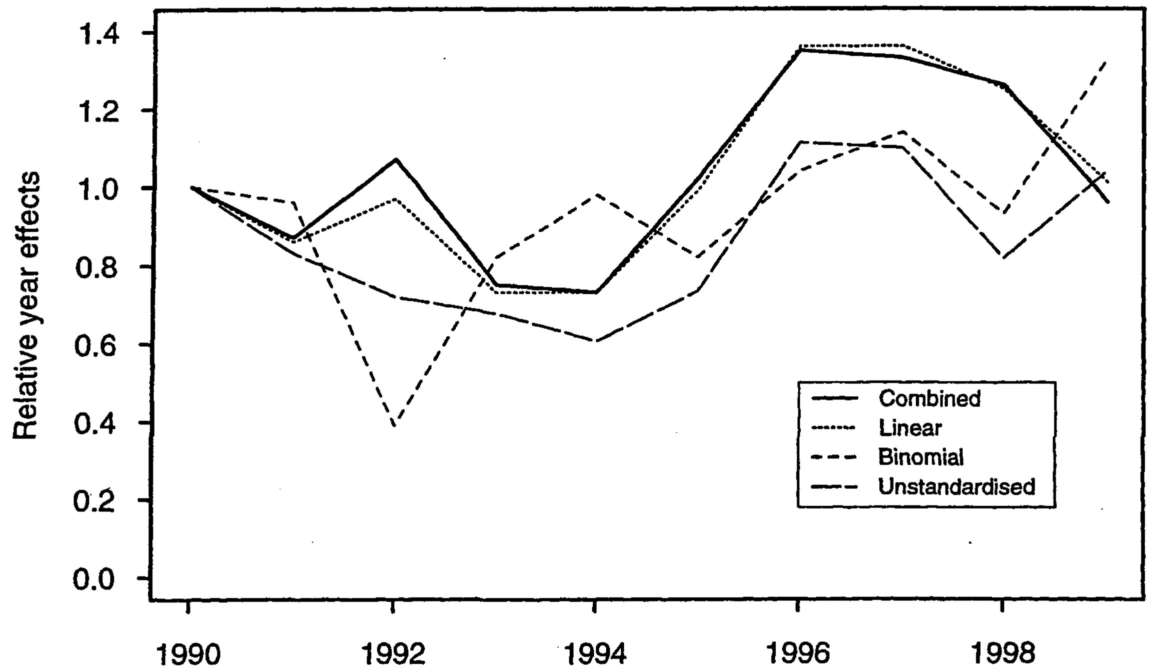


Figure 10: Comparison of standardised and unstandardised CPUE for the single bottom trawl tarakihi target fishery in TAR 3. Standardised indices ± 2 s.e.

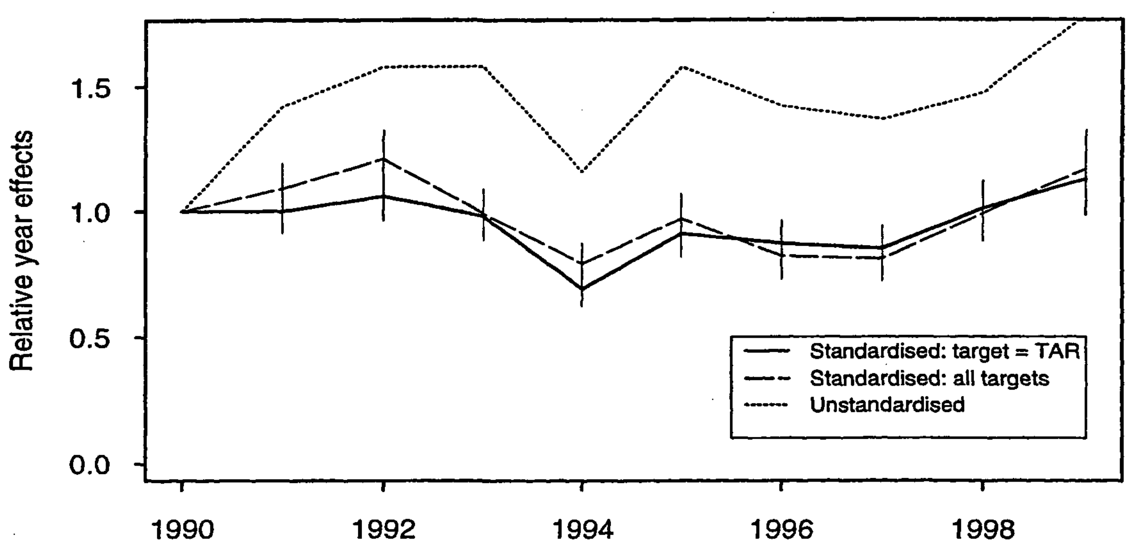


Figure 11: Comparison of standardised and unstandardised CPUE for the set net tarakihi fishery in TAR 3. Standardised indices ± 2 s.e.

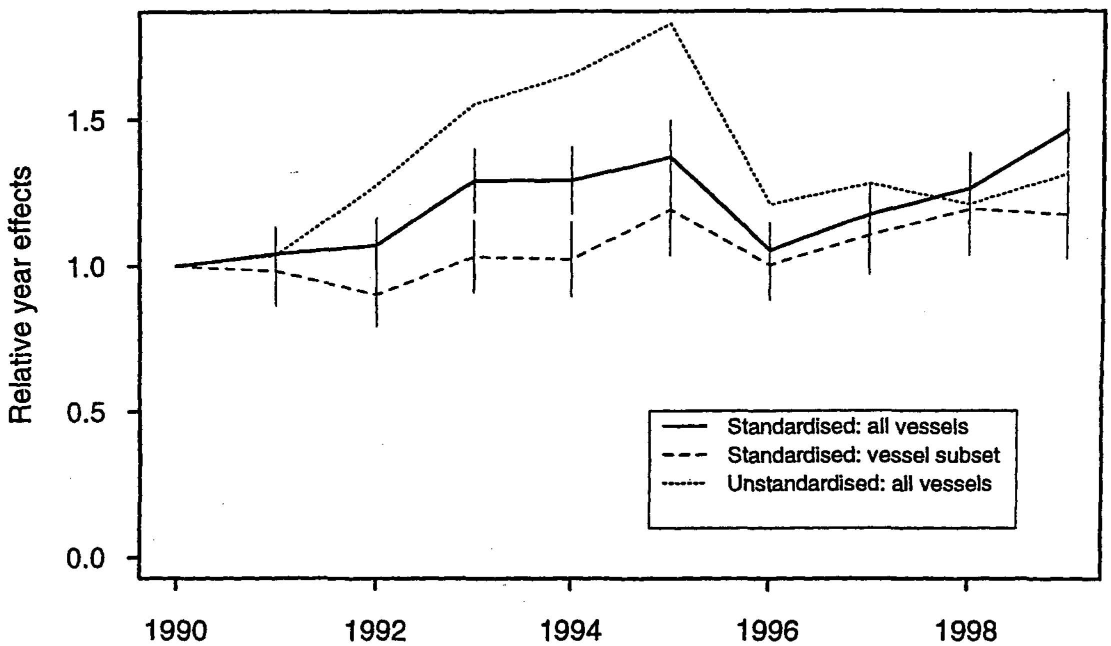


Figure 12: Comparison of standardised and unstandardised CPUE for the single bottom trawl tarakihi fishery in TAR 7. Standardised indices ± 2 s.e.

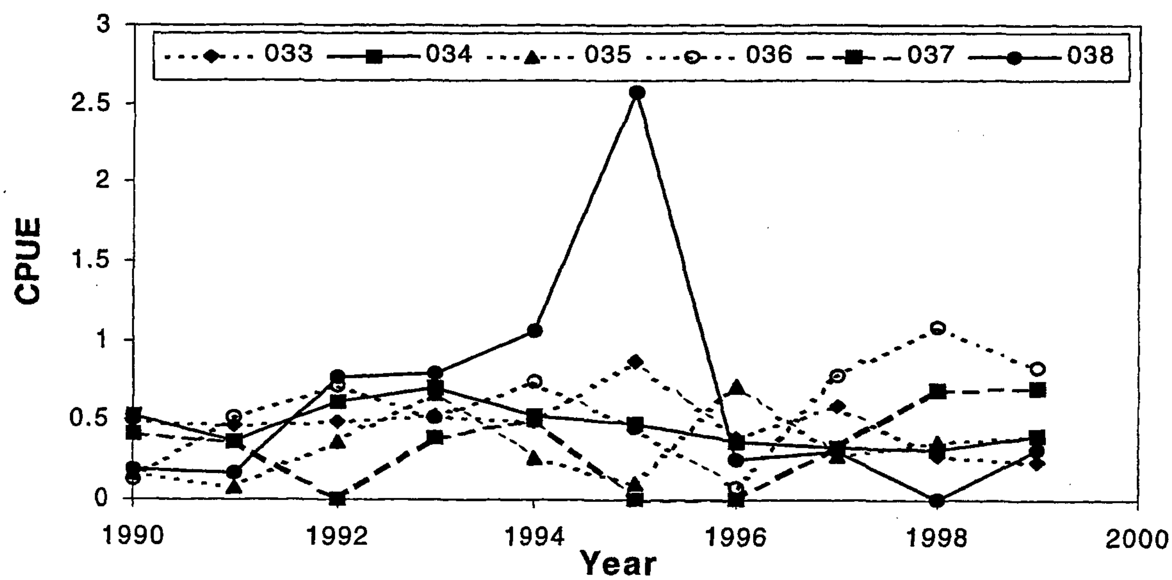


Figure 13: Unstandardised CPUE (mean t per vessel-day) of tarakihi in TAR 7 by statistical area.

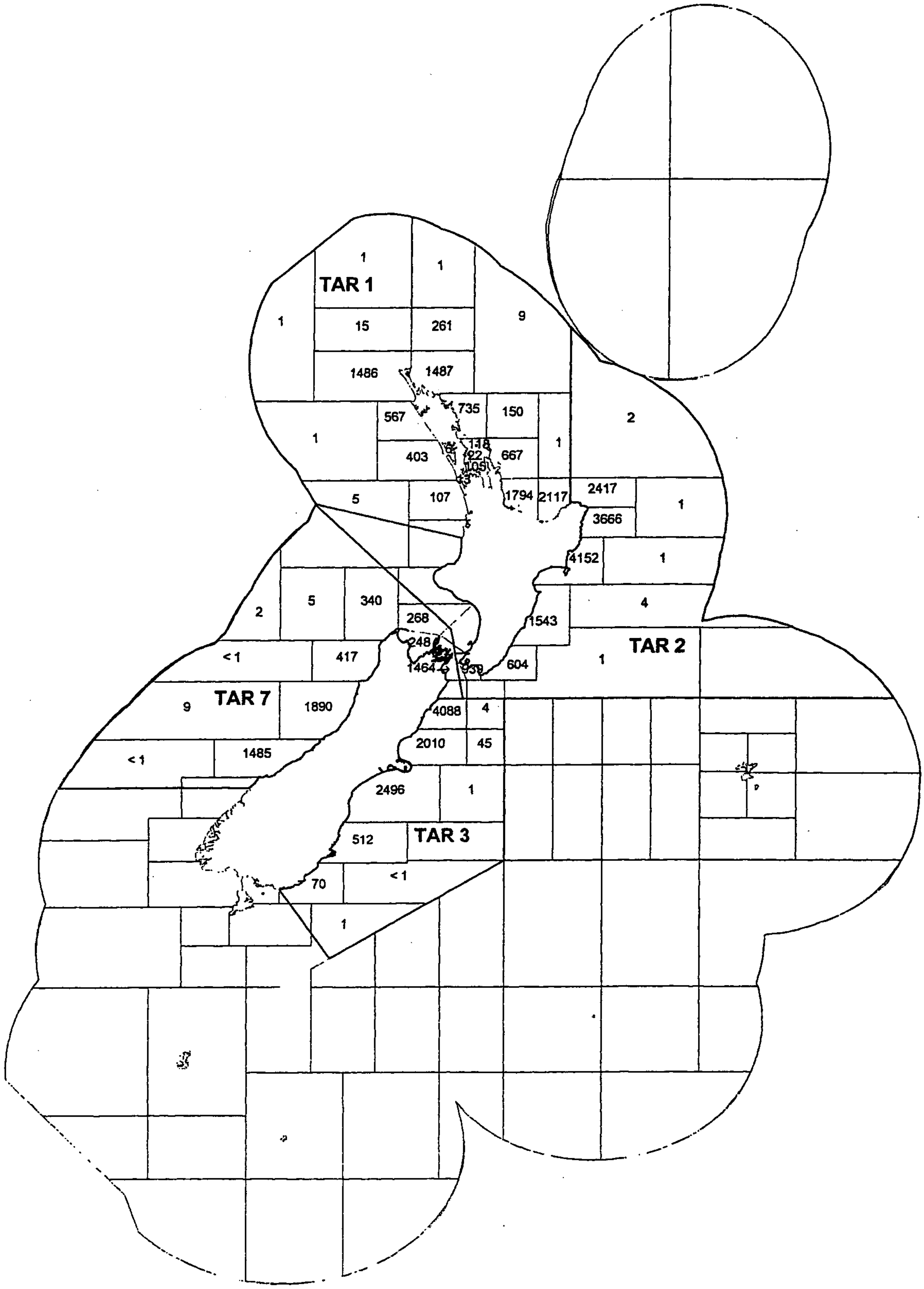


Figure 14: Total catch (t) of tarakihi for 1989–90 to 1998–99 fishing years by statistical area for TAR 1, TAR 2, TAR 3, and TAR 7, with FMA boundaries. Catches for blank areas are not available.

Appendix 1: Summary of effort (vessel-days) by vessel for the bottom trawl fishery in TAR 1 on the west coast from 1989–90 to 1998–99 for vessels included in the vessel subset. Vessels were included in the subset of vessels that had a 'consistent representation' in the fishery if they fished for 10 days or more for at least 5 years.

	Number of records (vessel-days)											Years >10
Vessel	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	Total	records
3221	17	46	49	61	69	16	42	64	105	52	521	10
356	42	17	37	81	52	46	50	40	26	3	394	9
312	13	22	29	16	11	30	6	50	69	82	328	9
455	0	4	10	25	52	48	68	44	23	36	310	8
2089	0	14	33	37	55	64	47	31	9	2	292	7
324	2	3	3	6	10	28	42	33	16	90	233	6
1045	0	0	31	46	22	34	41	50	4	0	228	6
3036	0	0	6	7	10	14	10	42	42	62	193	6
5468	0	0	0	27	22	18	44	30	36	0	177	6
359	0	0	0	12	10	35	4	28	49	28	166	6
327	25	12	16	28	15	25	7	16	13	9	166	8
344	0	6	10	7	23	9	28	25	43	6	157	5
336	0	0	0	17	21	15	16	25	16	0	110	6
347	0	0	0	8	13	12	14	36	12	0	95	5
360	3	0	0	21	0	13	10	18	20	9	94	5

Appendix 1 cont.: Summary of effort (vessel-days) by vessel for the bottom trawl fishery in TAR 1 in east Northland and the Bay of Plenty from 1989–90 to 1998–99 for vessels included in the vessel subset. Vessels were included in the subset of vessels that had a 'consistent representation' in the fishery if they fished for 10 days or more for at least 9 years.

	Number of records (vessel-days)											Years >10
Vessel	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	Total	records
1856	32	124	107	118	133	149	111	153	187	148	1262	10
442	112	86	116	110	72	119	102	119	116	105	1057	10
455	76	21	72	49	50	71	122	180	98	65	804	10
3903	45	76	84	38	45	67	66	89	90	117	717	10
292	29	24	77	51	52	47	74	72	99	77	602	10
794	78	75	53	52	33	77	33	51	82	14	548	10
312	42	68	88	53	82	20	57	47	42	17	516	10
329	24	11	57	45	50	34	55	28	48	29	381	10
529	17	19	14	47	42	27	15	16	39	49	285	10
324	32	23	20	33	20	24	24	10	33	60	279	10
508	5	90	81	84	145	146	126	155	134	49	1015	9
347	81	108	96	56	31	65	69	36	33	0	575	9
2089	10	56	51	10	0	53	60	53	40	159	492	9
316	31	24	46	30	60	19	17	8	26	87	348	9
3221	18	6	41	22	18	26	84	28	47	26	316	9
307	38	26	12	31	50	33	17	7	38	62	314	9
460	12	10	11	38	63	36	36	60	32	0	298	9
356	29	44	15	17	22	21	22	68	40	1	279	9
344	44	41	38	16	21	33	11	18	34	5	261	9
327	36	23	22	20	19	11	38	6	15	30	220	9

Appendix 1 cont.: Summary of effort (vessel-days) by vessel for the bottom trawl fishery in TAR 2 from 1989–90 to 1998–99 for vessels included in the vessel subset. Vessels were included in the subset of vessels that had a 'consistent representation' in the fishery if they fished for 10 days or more for at least 7 years.

	Number of records (vessel-days)											Years >10
Vessel	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	Total	records
539	20	48	48	130	142	90	133	194	163	205	1173	10
4662	56	88	104	91	96	107	111	117	124	109	1003	10
4665	73	61	105	64	61	96	140	140	133	122	995	10
1512	54	83	83	105	18	108	117	116	139	122	945	10
673	91	75	88	89	94	86	85	73	72	92	845	10
560	94	108	80	51	81	75	69	69	68	41	736	10
522	60	79	112	56	61	55	20	78	42	32	595	10
1960	44	34	48	46	40	69	57	50	67	62	517	10
575	32	41	45	39	39	37	35	26	34	49	377	10
509	111	190	195	141	148	137	129	159	139	0	1349	9
4594	35	40	50	75	129	131	97	115	103	0	775	9
5002	4	19	46	13	19	58	71	76	116	209	631	9
5514	2	32	50	21	40	38	30	47	58	75	393	9
581	10	8	47	39	53	42	21	25	76	53	374	9
353	24	127	53	1	26	92	63	66	74	0	526	8
1795	0	39	76	61	60	87	43	58	14	0	438	8
289	5	14	15	11	32	41	31	46	16	0	211	8
3006	0	2	0	66	67	85	96	65	100	102	583	7
3059	11	0	0	0	11	34	56	54	124	125	415	7
357	1	0	21	53	57	69	100	44	52	0	397	7
2022	8	44	35	51	23	58	80	19	1	0	319	7
442	3	2	0	24	28	42	31	17	13	18	178	7
3036	2	22	36	12	16	9	21	0	11	19	148	7

Appendix 1 cont.: Summary of effort (vessel-days) by vessel for the bottom trawl fishery in TAR 3 from 1989–90 to 1998–99 for vessels included in the vessel subset.. Vessels were included in the subset of vessels that had a 'consistent representation' in the fishery if they fished for 10 days or more for at least 7 years.

	Number of records (vessel-days)											Years >10
Vessel	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	Total	records
949	72	24	72	86	78	60	62	79	57	69	659	10
874	49	33	60	47	66	88	68	78	66	82	637	10
1035	68	57	57	49	19	21	42	45	27	41	426	10
1320	14	45	85	46	57	32	39	25	23	44	410	10
1018	53	41	31	22	23	11	31	28	28	41	309	10
1211	7	49	80	117	78	70	82	32	93	79	687	9
586	55	52	67	54	21	43	32	26	21	0	371	9
466	0	46	46	15	22	36	43	29	36	64	337	9
5512	52	26	38	22	31	63	16	16	13	5	282	9
1012	17	21	11	17	13	0	18	14	10	22	143	9
1785	40	38	43	36	41	7	22	37	57	0	321	8
1761	0	0	54	34	42	12	23	32	47	26	270	8
581	0	1	15	33	22	48	37	48	21	36	261	8
322	1	29	19	15	36	27	17	25	34	0	203	8
1043	14	10	11	3	16	22	16	3	20	14	129	8
1752	0	0	6	52	102	79	107	128	96	133	703	7
1124	9	0	37	30	53	36	47	45	27	0	284	7
913	36	25	41	22	27	34	24	1	0	0	210	7
1794	48	34	31	28	6	2	18	20	8	15	210	7
1041	41	34	12	6	5	9	22	11	31	23	194	7
6991	13	66	26	33	12	19	8	16	0	0	193	7
814	0	0	0	11	19	21	22	20	35	58	186	7
1042	18	58	14	10	3	14	16	6	4	22	165	7
1021	0	25	34	16	20	6	11	15	0	13	140	7
6285	1	8	12	8	16	21	16	20	25	11	138	7
938	3	12	14	14	22	21	11	8	11	0	116	7

Appendix 1 cont.: Summary of effort (vessel-days) by vessel for the bottom trawl fishery in TAR 7 from 1989–90 to 1998–99 for vessels included in the vessel subset. Vessels were included in the subset of vessels that had a 'consistent representation' in the fishery if they fished for 10 days or more for at least 6 years.

	Number of records (vessel-days)											Years >10
Vessel	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	Total	records
5713	28	46	92	49	85	51	62	128	55	94	690	10
446	28	65	59	26	25	36	21	51	12	39	362	10
707	83	56	81	122	26	6	87	86	82	91	720	9
533	0	66	93	51	87	78	60	58	34	33	560	9
1771	103	82	23	19	15	15	35	19	4	28	343	9
5512	10	10	9	18	12	23	11	45	15	56	209	9
7002	95	93	81	112	44	3	70	112	67	0	677	8
335	0	0	17	47	28	30	44	22	30	73	291	8
5458	21	14	11	13	22	26	37	13	9	0	166	8
4672	0	0	0	59	47	31	89	91	61	95	473	7
358	0	0	0	60	39	41	62	61	33	66	362	7
1867	0	0	0	57	47	37	54	53	46	66	360	7
1789	26	56	44	25	23	32	39	6	0	0	251	7
1193	0	0	14	30	28	71	44	27	16	0	230	7
566	0	17	23	16	14	16	8	18	11	5	128	7
5296	12	23	11	9	16	17	12	4	6	15	125	7
5530	113	34	26	15	20	0	0	7	19	0	234	6
5599	5	27	20	25	53	3	54	17	2	0	206	6
5802	5	32	8	87	25	5	0	0	0	0	162	6
1859	10	24	21	7	5	19	16	26	0	0	128	6
639	0	15	10	15	20	5	17	43	0	0	125	6

Appendix 2: Questionnaire distributed to tarakihi fishers and used as basis for telephone interviews.

QUESTIONNAIRE

We start with a general statement on each issue, and then pose one or more numbered questions. We have tried to arrange these so that only a short answer is required. However, should you wish to provide additional information please do so, referring back to one or more of the question numbers. There is inevitably some overlap between our questions. Most issues are linked.

NAME AND CONTACT PHONE NUMBER/ADDRESS

GENERAL

(1) What method(s) do you use when fishing for tarakihi?

(2) Where do you mainly fish, and what are your main target species? Please give statistical areas and approximate depths.

DEFINING THE TARAKIHI FISHERY: TARGET SPECIES

Background
Target species appears to be a term used by fishers (on their CELR or TCEPR forms) in several ways: the single species targeted, the main of several species targeted, the species for which most quota is still held, the main species actually caught, whether it was targeted or not, or simply just a logical species for that area and fishery.

(3) Is there a distinctive tarakihi target fishery in your QMA? How is it defined?

Background
For our work on catch rate (or CPUE – catch per unit effort), we have analysed three sets of data from the tarakihi fishery in each QMA:
(a) All bottom trawls where tarakihi are caught.
(b) Only used data from a subset of vessels which have been involved in the bottom trawl fishery for more than 8-10 years.
(c) Only bottom trawls where tarakihi is the nominated target species on the catch and effort form.

(4) Can you see any problems with using any of these indices to monitor the tarakihi abundance?

FISHING GROUNDS

Background
The information we are working with identifies fishing activities only to the standard Fishing Statistical Areas. Consequently, we are only able to pick up very large changes, over time, in the geographical

distribution of fishing effort and catch. That is, movement between these areas. We don't expect you to go into detail (which we accept is your confidential information), but we are interested in knowing about any changes in the fishing grounds being worked within an area, either as different localities along the coast, or as different depths.

(5) Have you, or the fishers in your area, shifted your targeted fishing for tarakihi during the 1980s or 1990s, either to new positions along the coast, or into a different depth range?

FISHING GEAR

Background

Fishing gear inevitably improves over time, in both structure and operation, often in ways that are not easily recorded in the CELR and TCEPR forms. We will be using catch and effort data only from the late 1980s onwards. However, there may have been changes in net construction or fishing practices we should take into account. There have also been improvements in fish finding and navigation aids (GPS, etc.).

(6) Have there been any major changes in tarakihi fishing methods since the 1980s? If so what were they?

(7) Has GPS, or an improved sounder/fish finder, etc. altered the way you fish for tarakihi? If so, very briefly describe how.

SEASON

Background There is a moderate to strong seasonal pattern in the catches in many tarakihi fisheries, with some regional differences. We were interested in finding out whether this seasonality reflected the real abundance of tarakihi in a region, or resulted from fishers switching to targeting tarakihi when the season for more profitable fisheries had finished, or perhaps some other reason.

(8) Do you specifically target for tarakihi

(a) when it is abundant in your region, or

(b) to fill your quota, or

(c) for some other reason?

NURSERY/SPAWNING GROUNDS

Background
There is uncertainty over the distribution and relative importance of tarakihi nursery and spawning grounds around New Zealand. Spawning grounds have been identified around East Cape, Cape Campbell to Pegasus Bay, and Jackson Head to Hokitika. No spawning grounds have been identified around Cape Reinga, although we believe tarakihi probably do spawn there. We know from trawl survey data that juvenile tarakihi (<20 cm) are mainly found in shallow coastal waters on the east coast of the South Island and in Tasman Bay/Golden Bay.

(9) Do you know any areas where large numbers of juvenile tarakihi (less than 20 cm or 8") are found?

(9) Have you ever found female tarakihi spawning in the Cape Reinga area, or in other areas not mentioned above?

MARKET OR OTHER NON-QMS RESTRICTIONS ON TARAKIHI CATCH

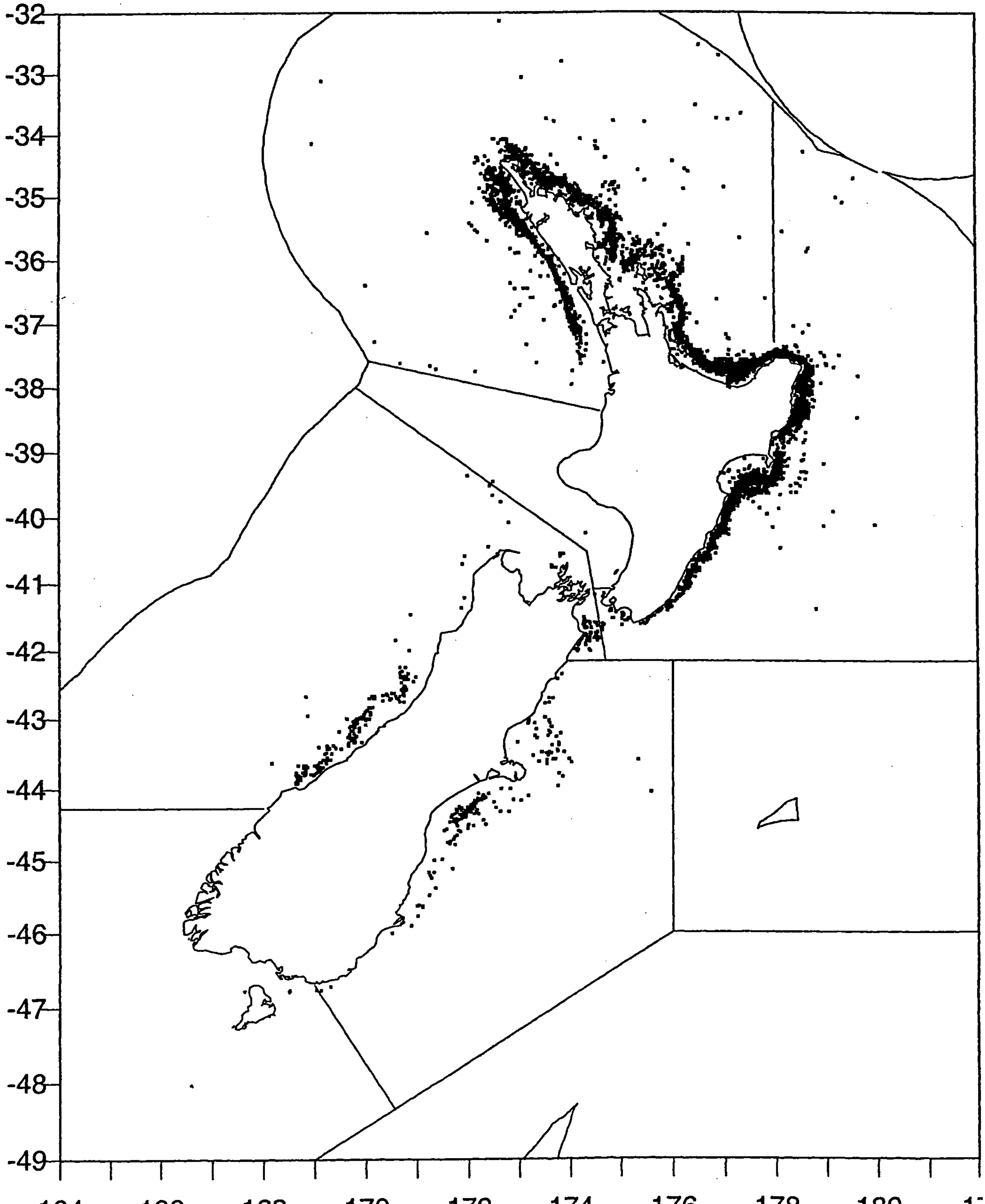
Background As in many fisheries, market requirements and changes in management practices and other events drive some aspects of fishing behaviour, and must be taken into account when interpreting catch trends.

(10) Are there any marketing or economic restrictions which have caused you to change your fishing activities since the late 1980s?

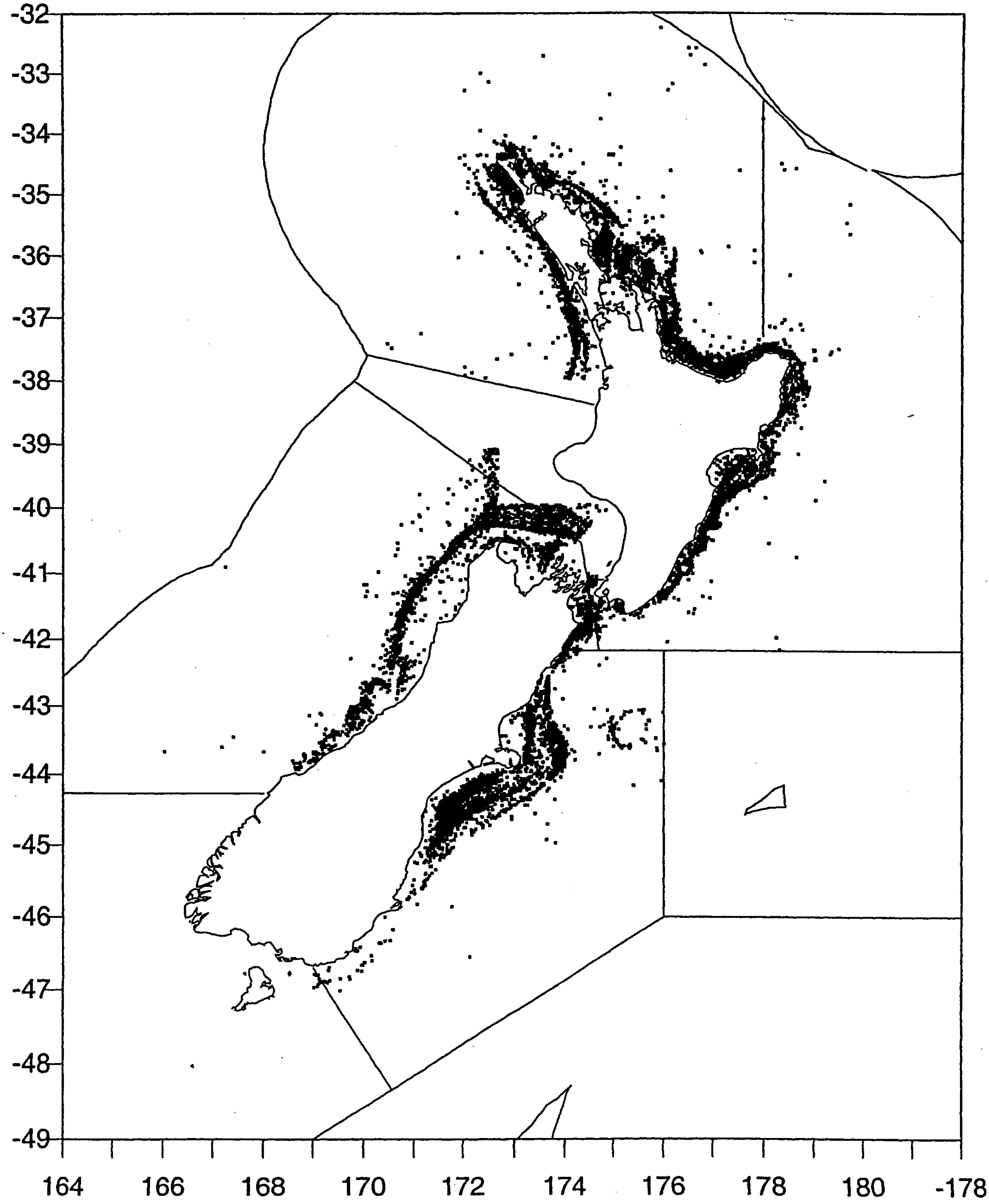
(11) Are there any fisheries management changes or any other events which have caused you to change your fishing activities since the late 1980s?

ANY OTHER COMMENTS YOU WOULD LIKE TO MAKE

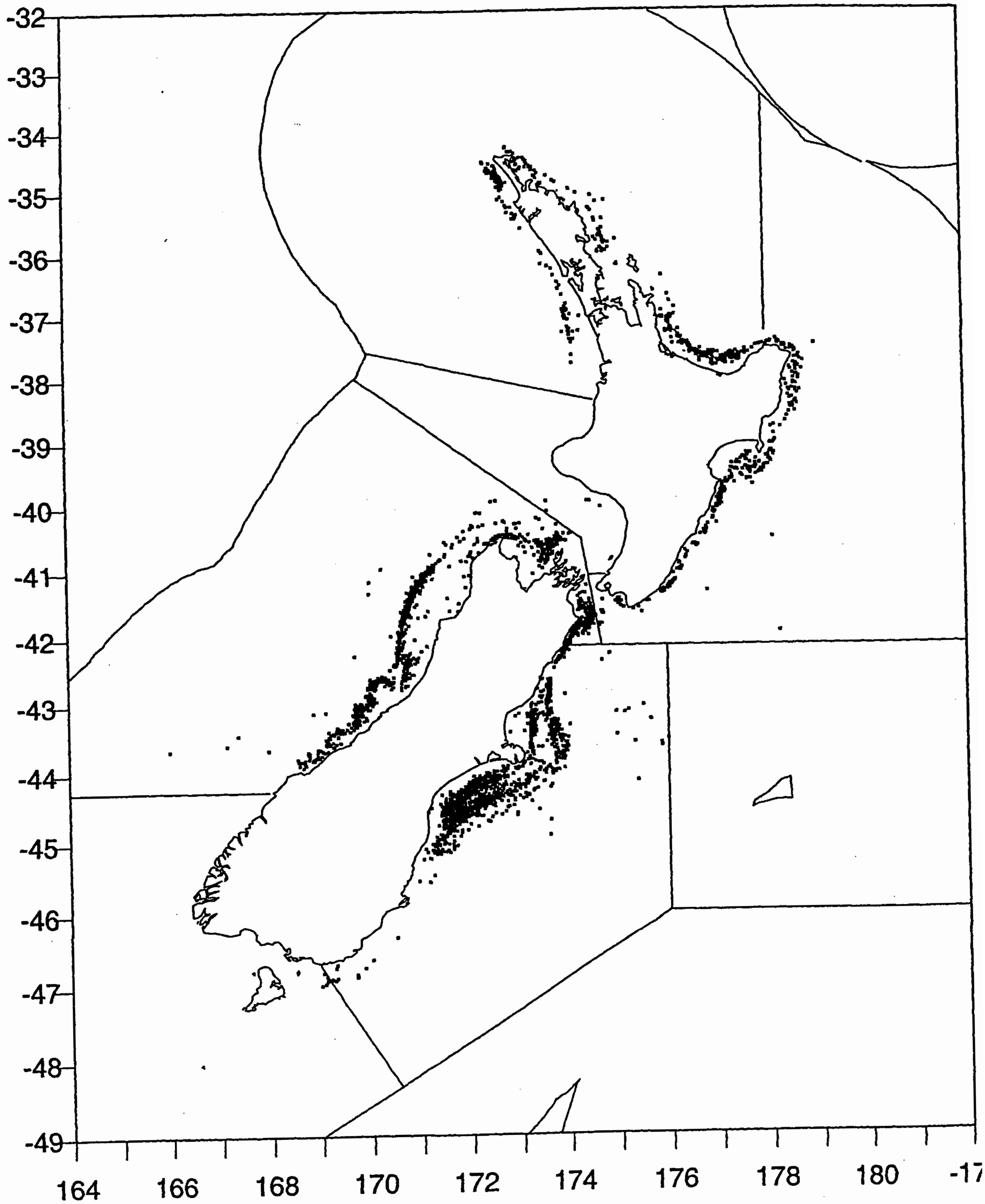
Appendix 3: Location of start positions of trawls reported on TCEPR forms targeting tarakihi from 1990 to 1999.



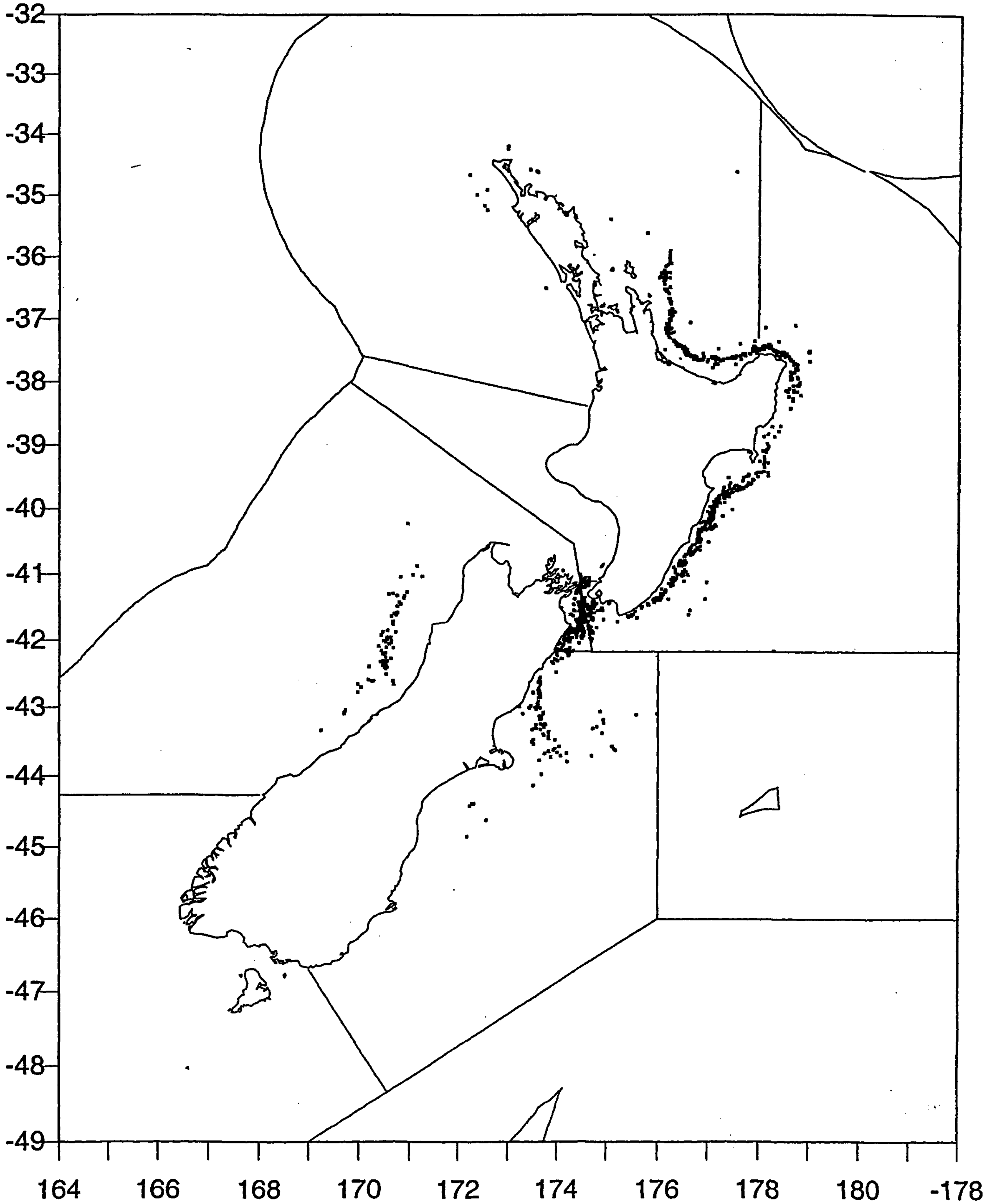
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms not targeting tarakihi from 1990 to 1999.



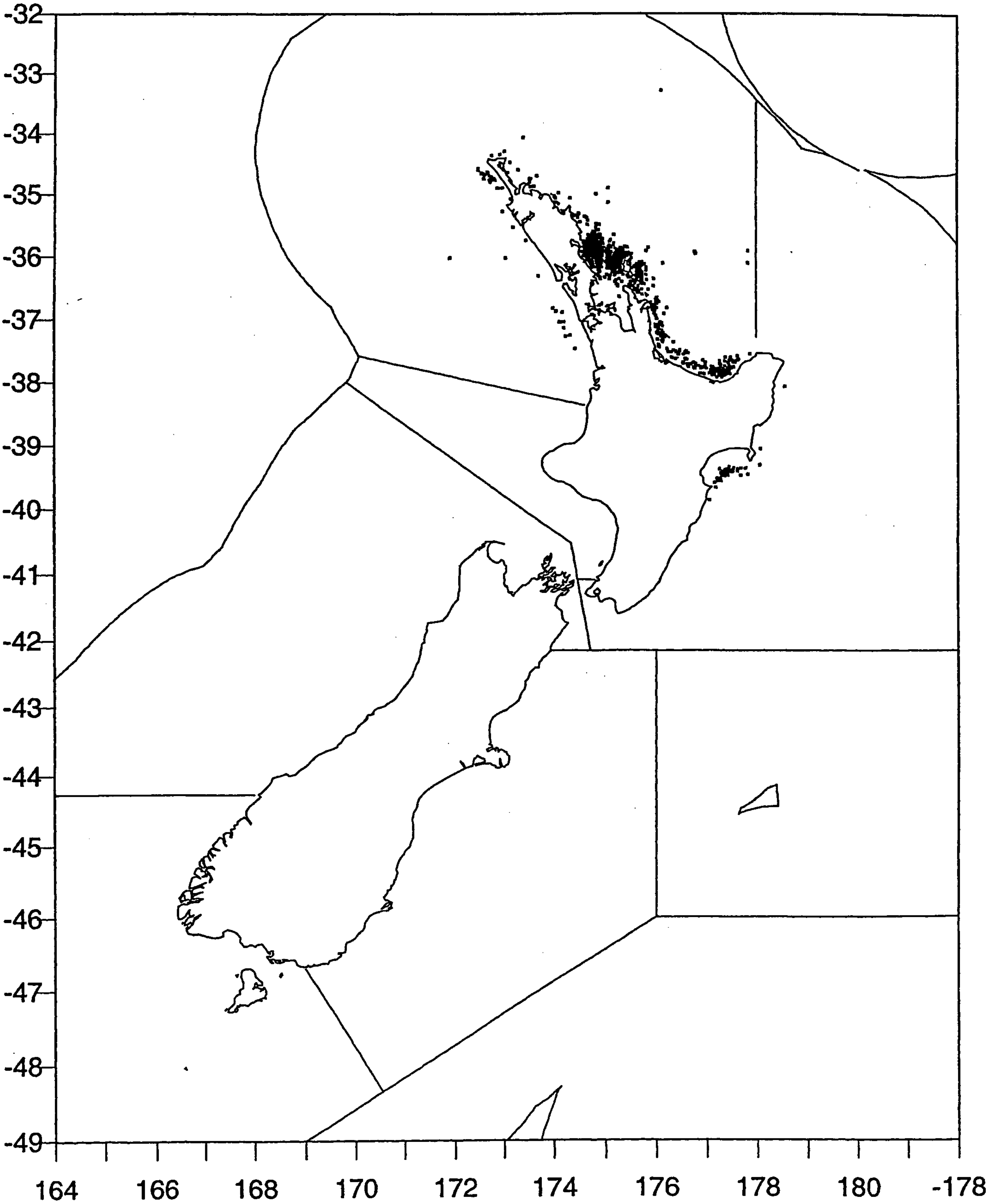
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms targeting barracouta from 1990 to 1999.



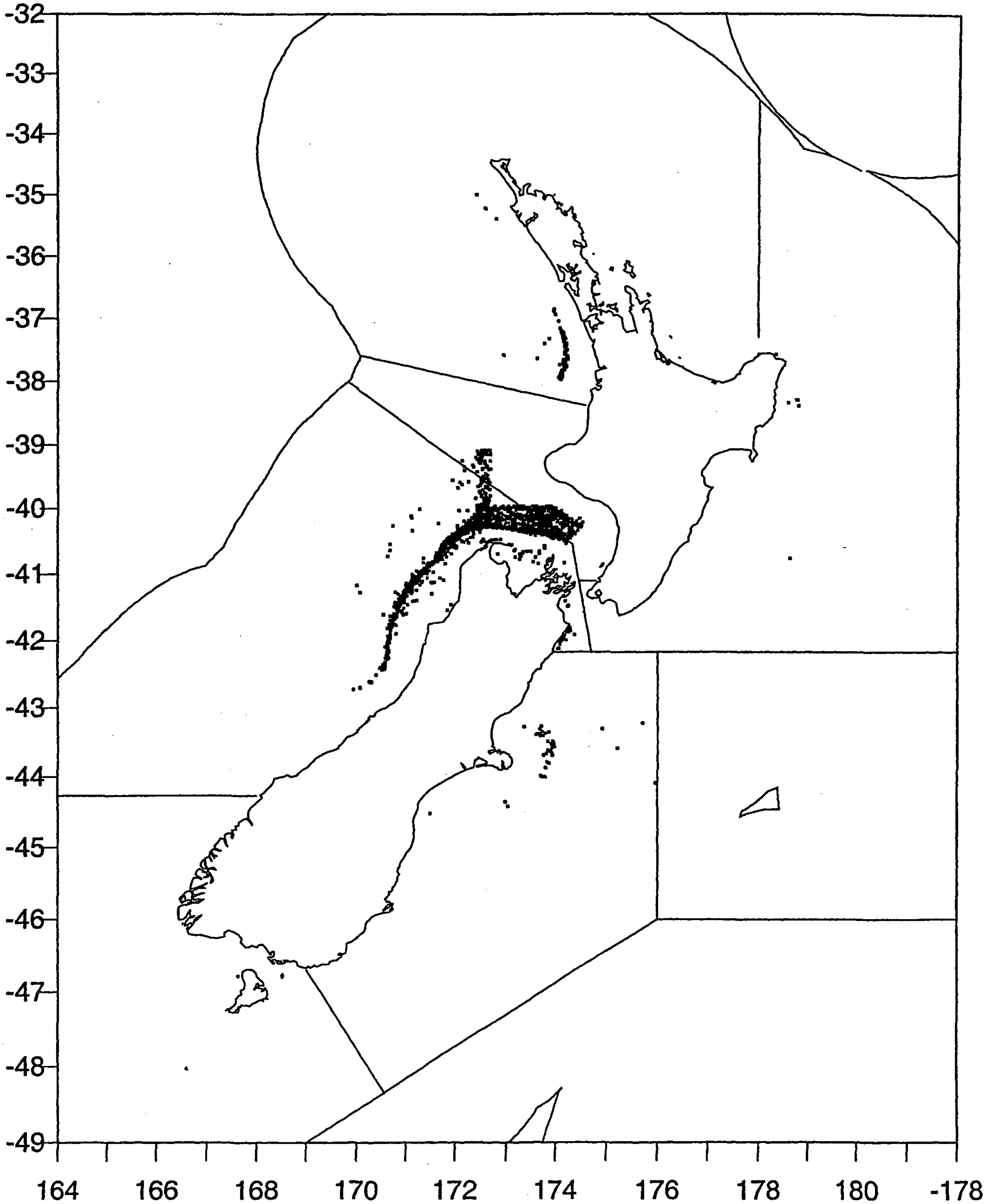
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms targeting hoki from *1990* to *1999*.



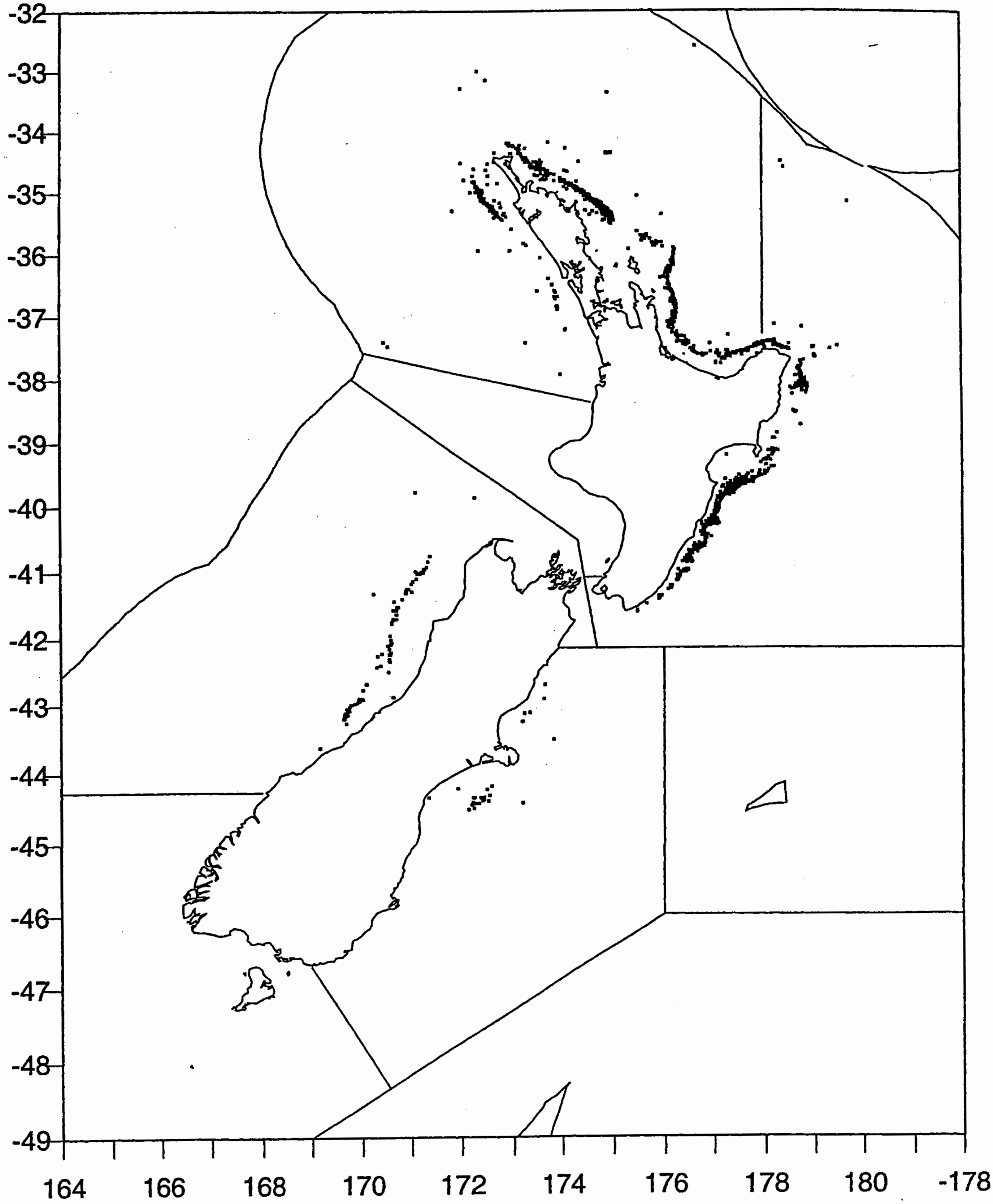
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms targeting John dory from 1990 to 1999.



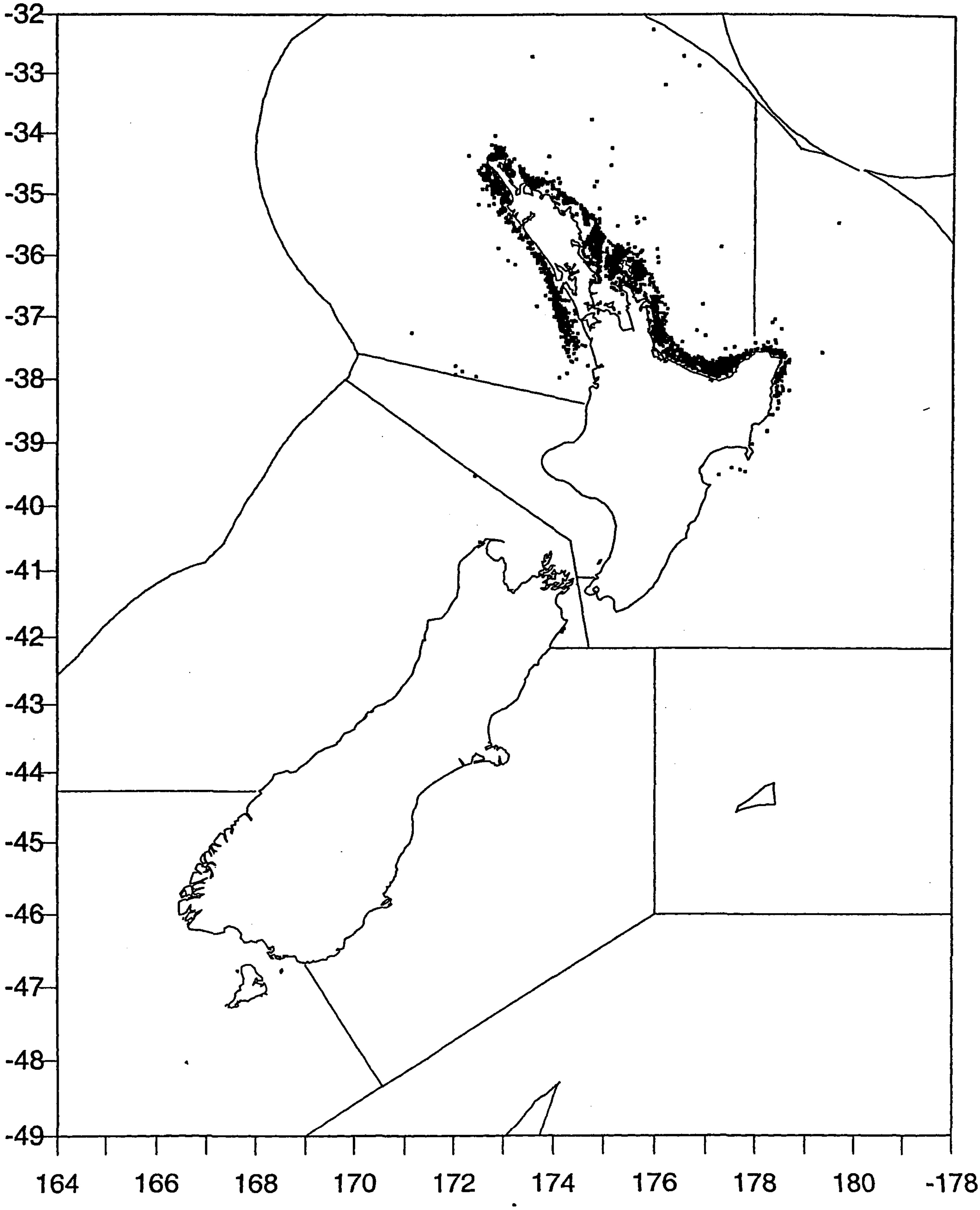
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms targeting jack mackerel from 1990 to 1999.



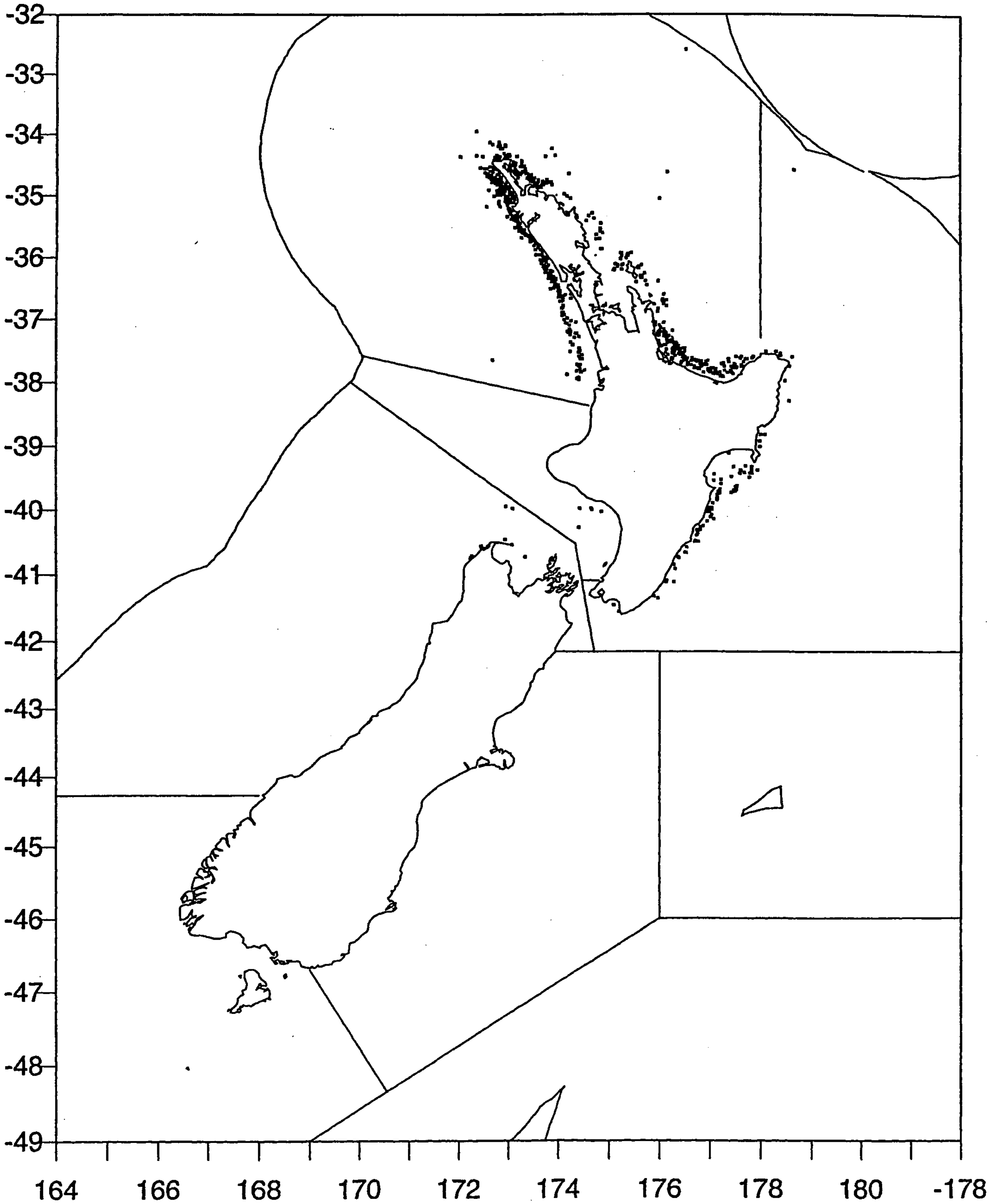
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms targeting gemfish from 1990 to 1999.



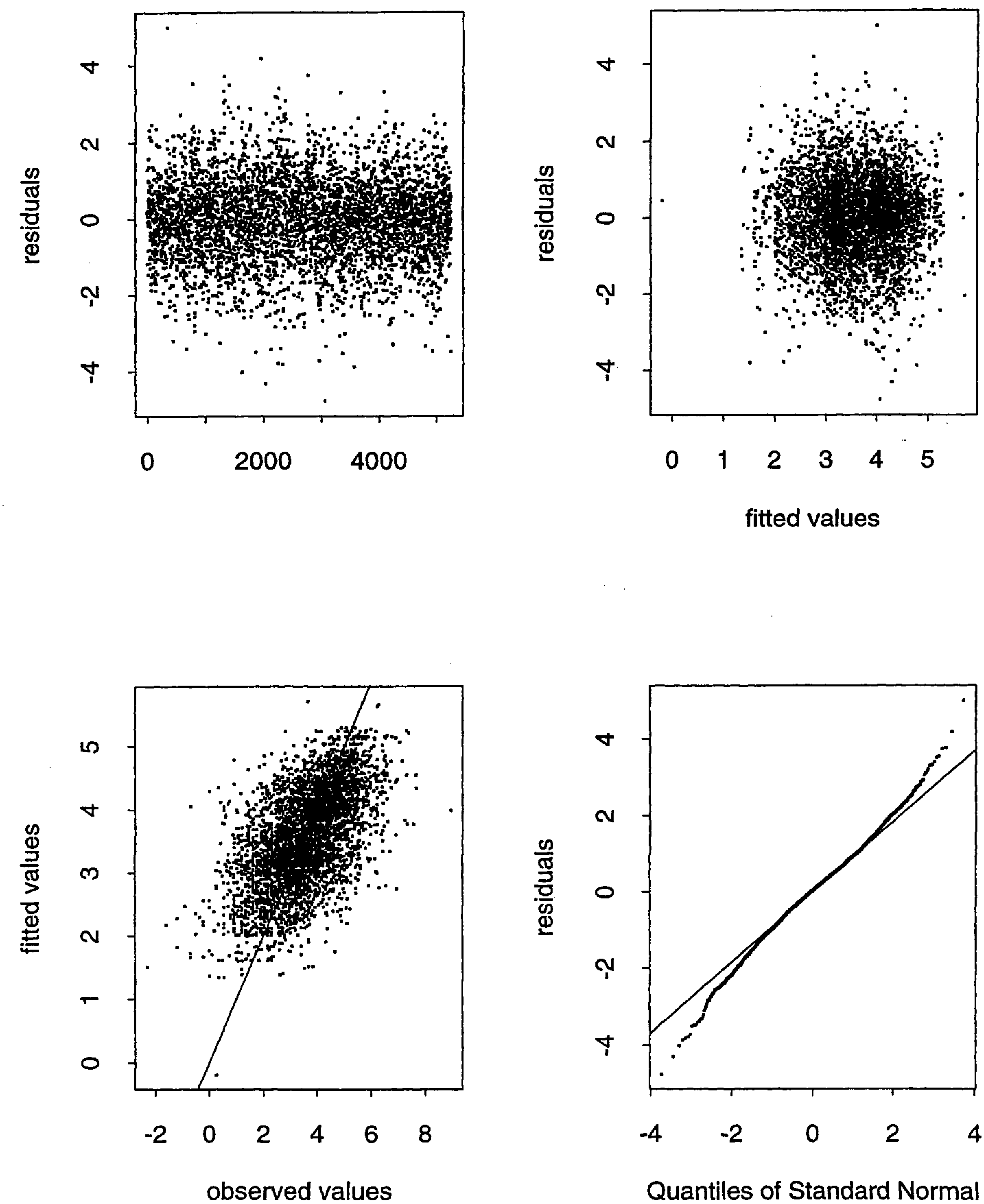
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms targeting snapper from 1990 to 1999.



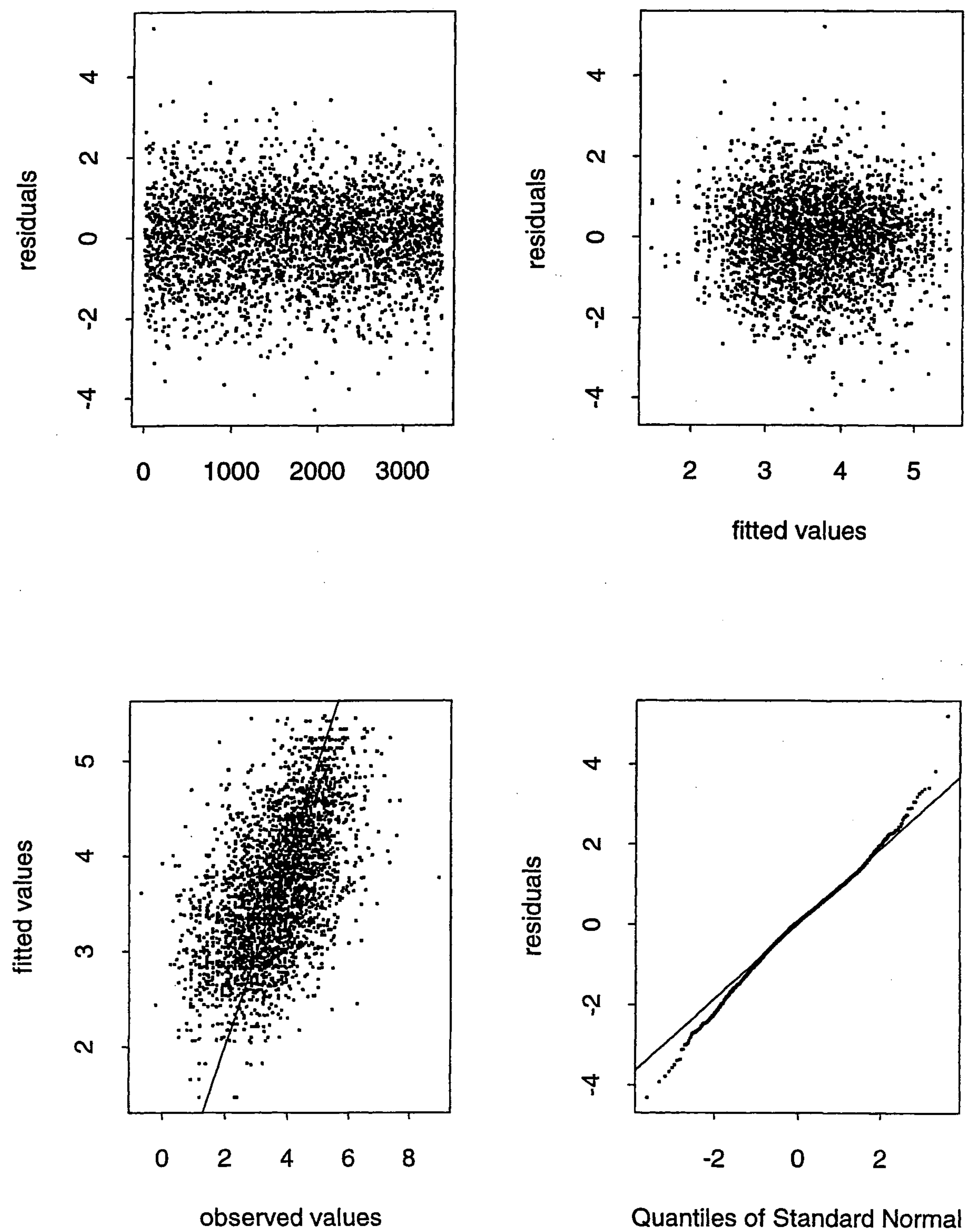
Appendix 3 continued: Location of start positions of trawls reported on TCEPR forms targeting trevally from 1990 to 1999.



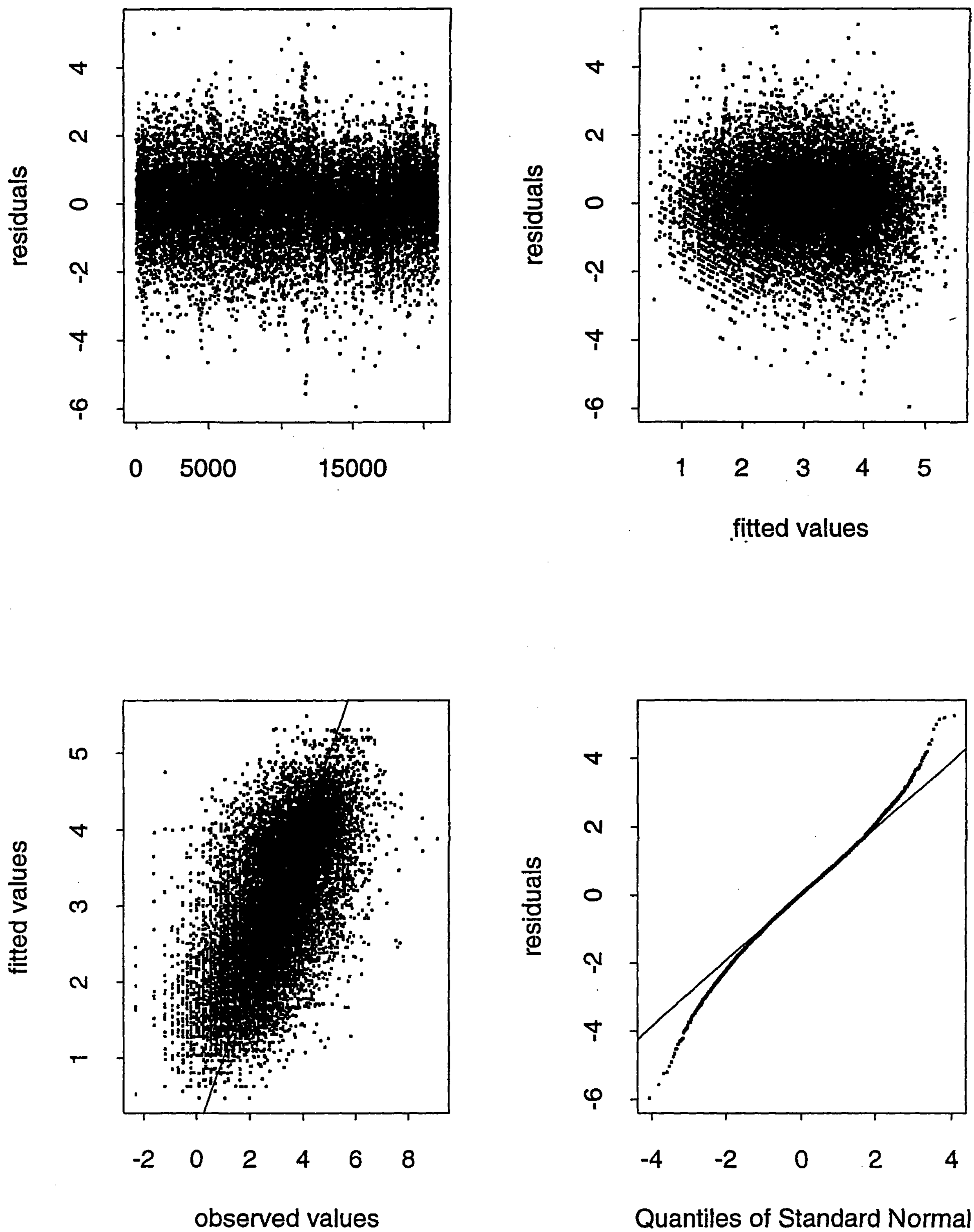
Appendix 4: Diagnostic plots for the standardised linear regression for all vessels in the single bottom trawl tarakihi fishery in TAR 1 on the west coast.



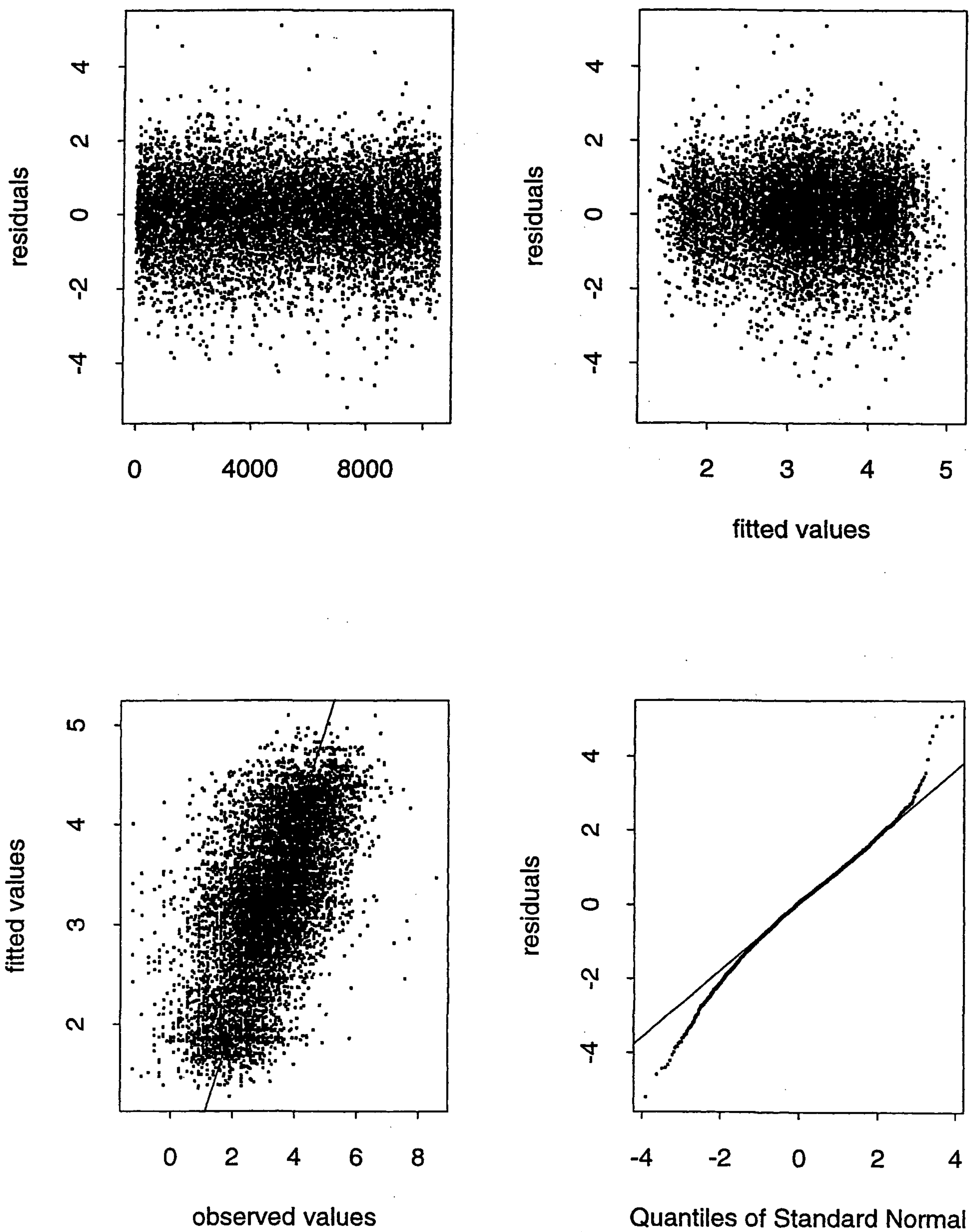
Appendix 4 cont.: Diagnostic plots for the standardised linear regression for the vessel subset in the single bottom trawl tarakihi fishery in TAR 1 on the west coast.



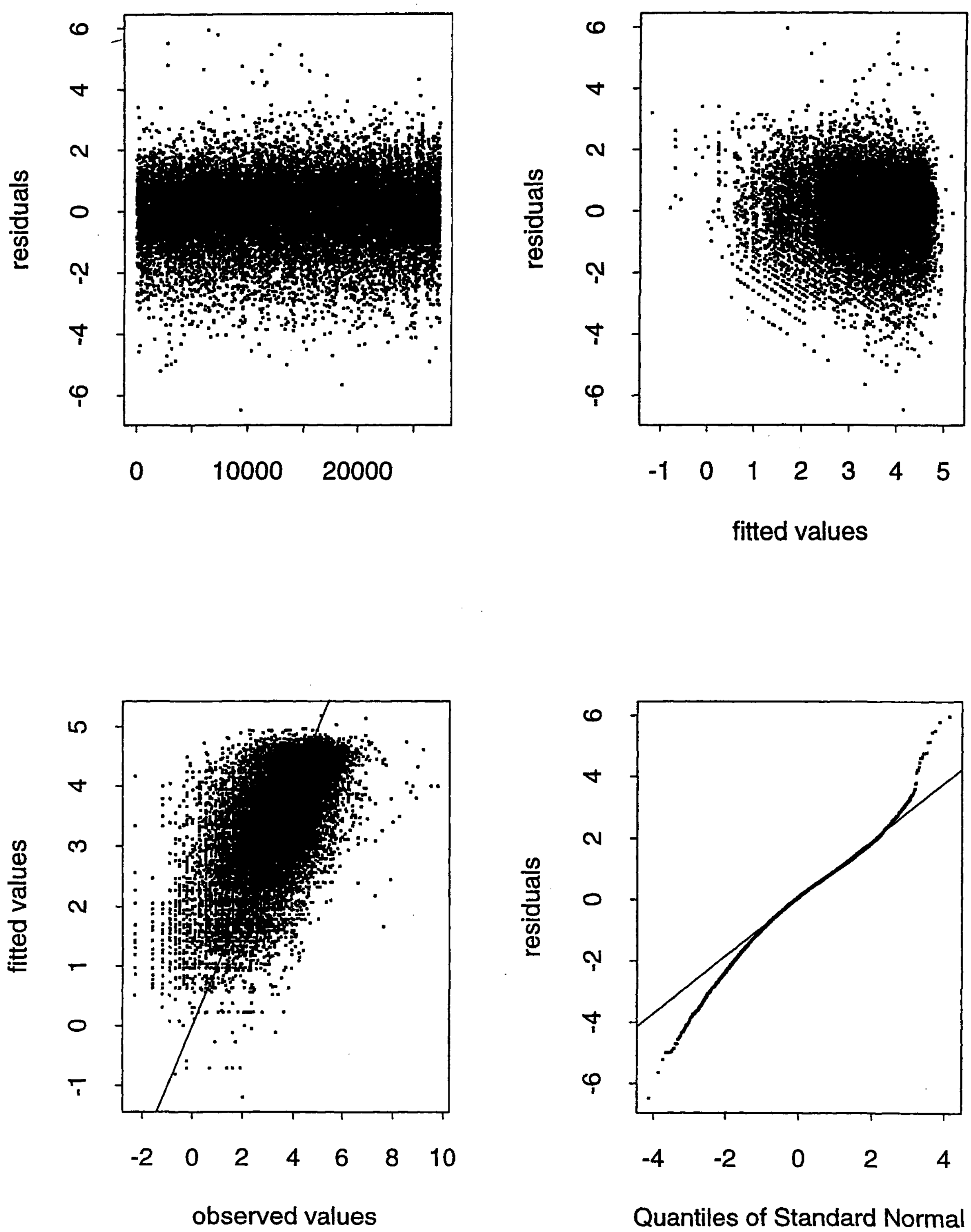
Appendix 4 cont.: Diagnostic plots for the standardised linear regression for all vessels in the single bottom trawl tarakihi fishery in TAR 1 on east Northland and the Bay of Plenty.



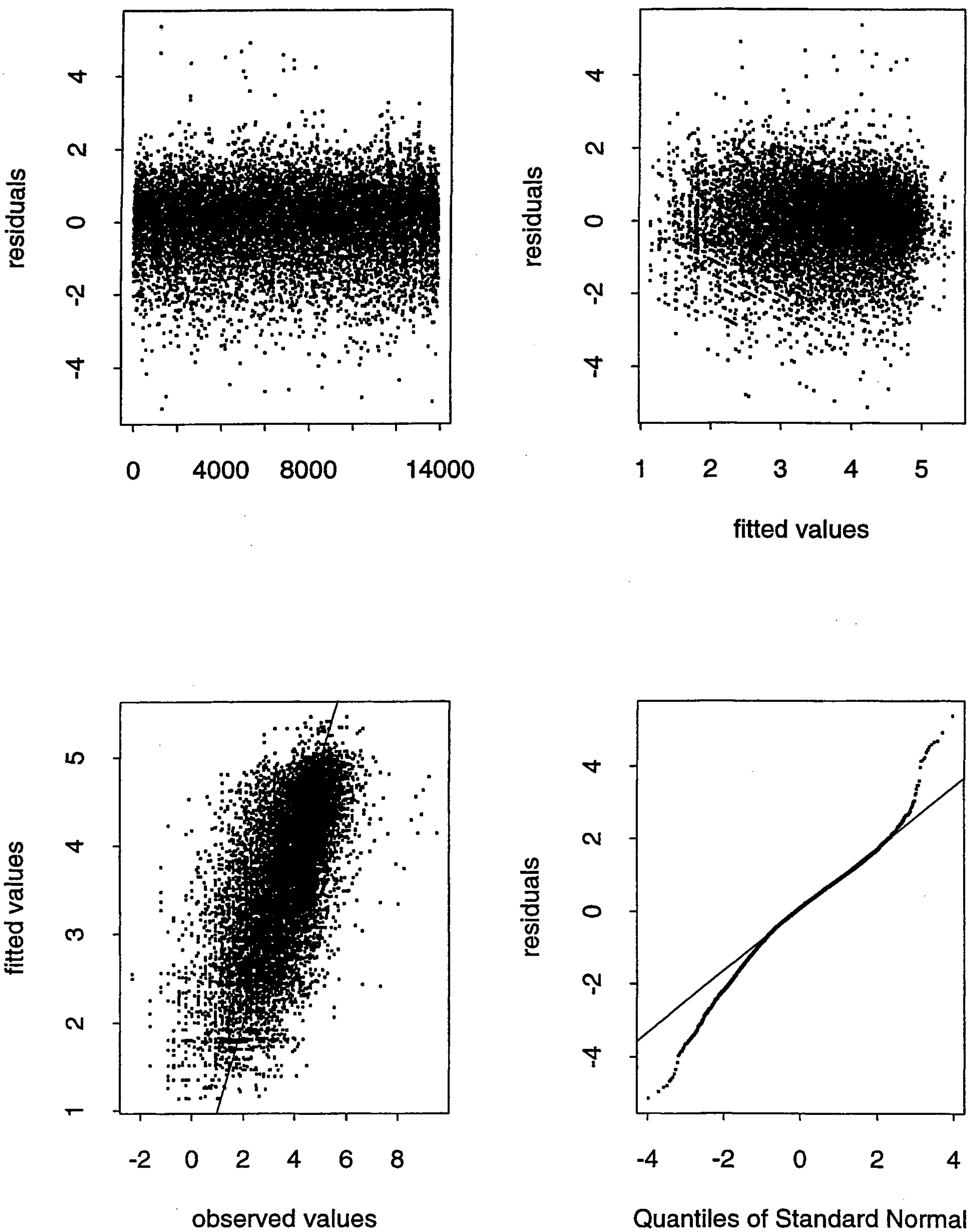
Appendix 4 cont.: Diagnostic plots for the standardised linear regression for the vessel subset in the single bottom trawl tarakihi fishery in TAR 1 on east Northland and the Bay of Plenty.



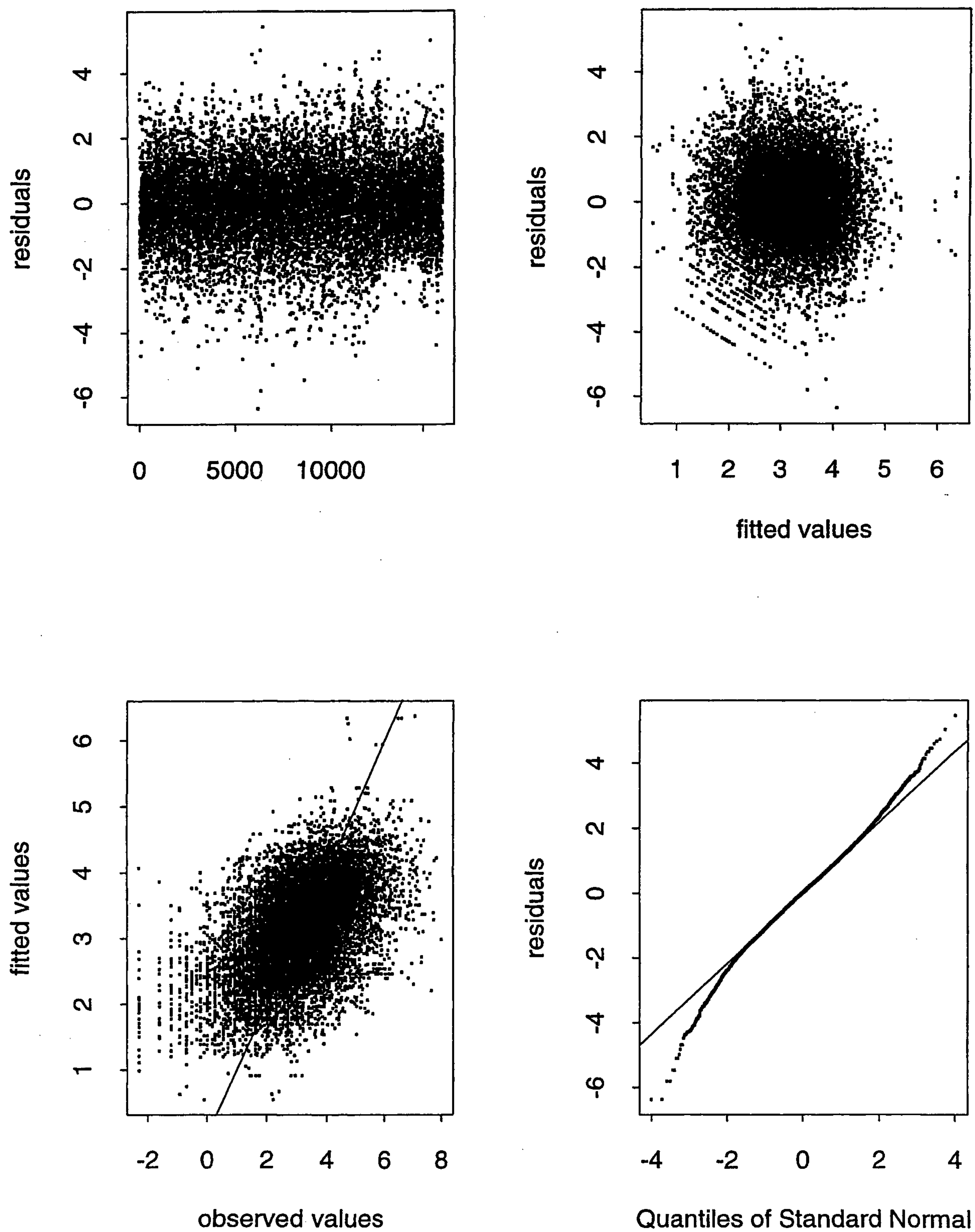
Appendix 4 cont.: Diagnostic plots for the standardised linear regression for all vessels in the single bottom trawl tarakihi fishery in TAR 2.



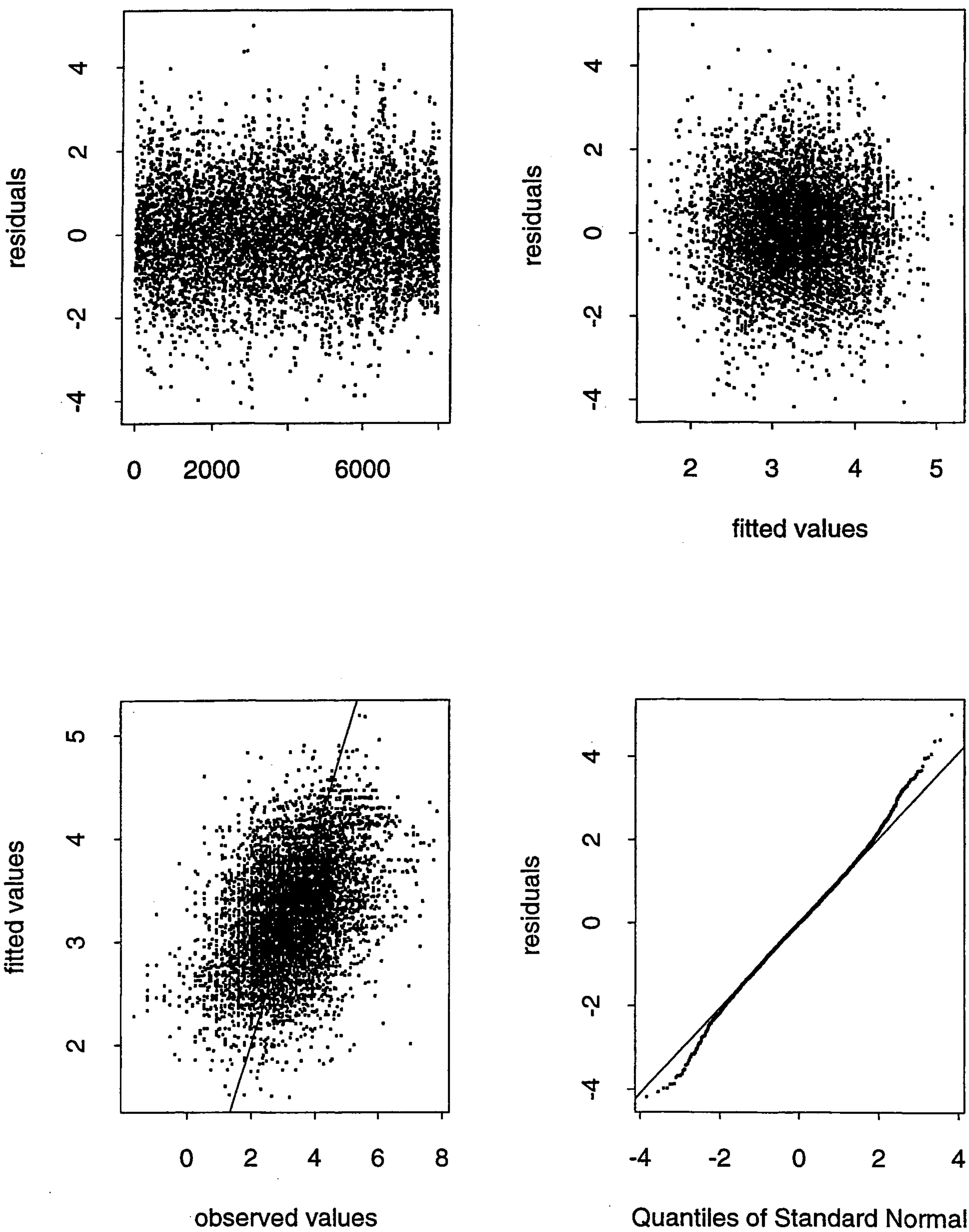
Appendix 4 cont.: Diagnostic plots for the standardised linear regression for the vessel subset in the single bottom trawl tarakihi fishery in TAR 2.



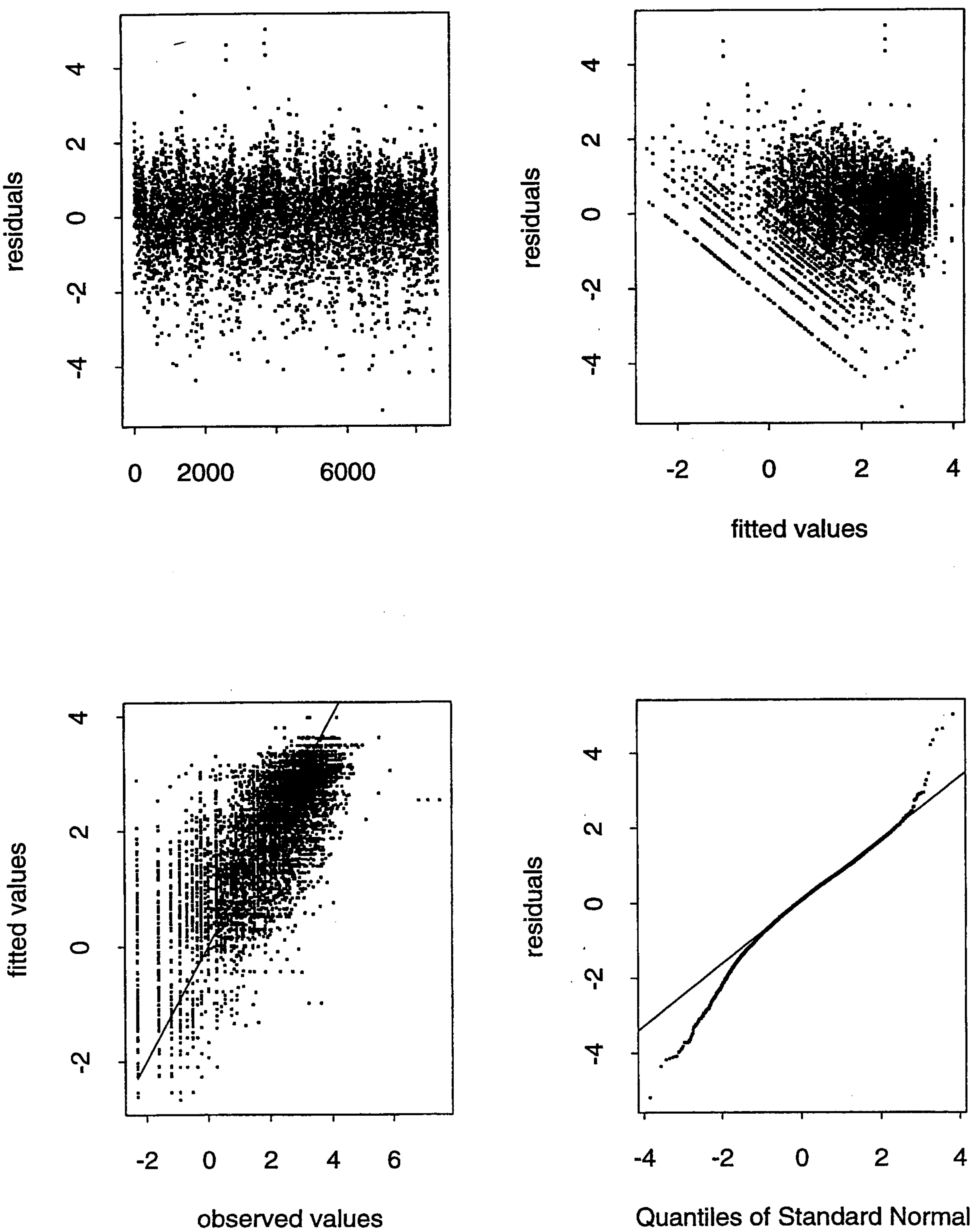
Appendix 4 cont.: Diagnostic plots for the standardised linear regression for all vessels in the single bottom trawl tarakihi fishery in TAR 3.



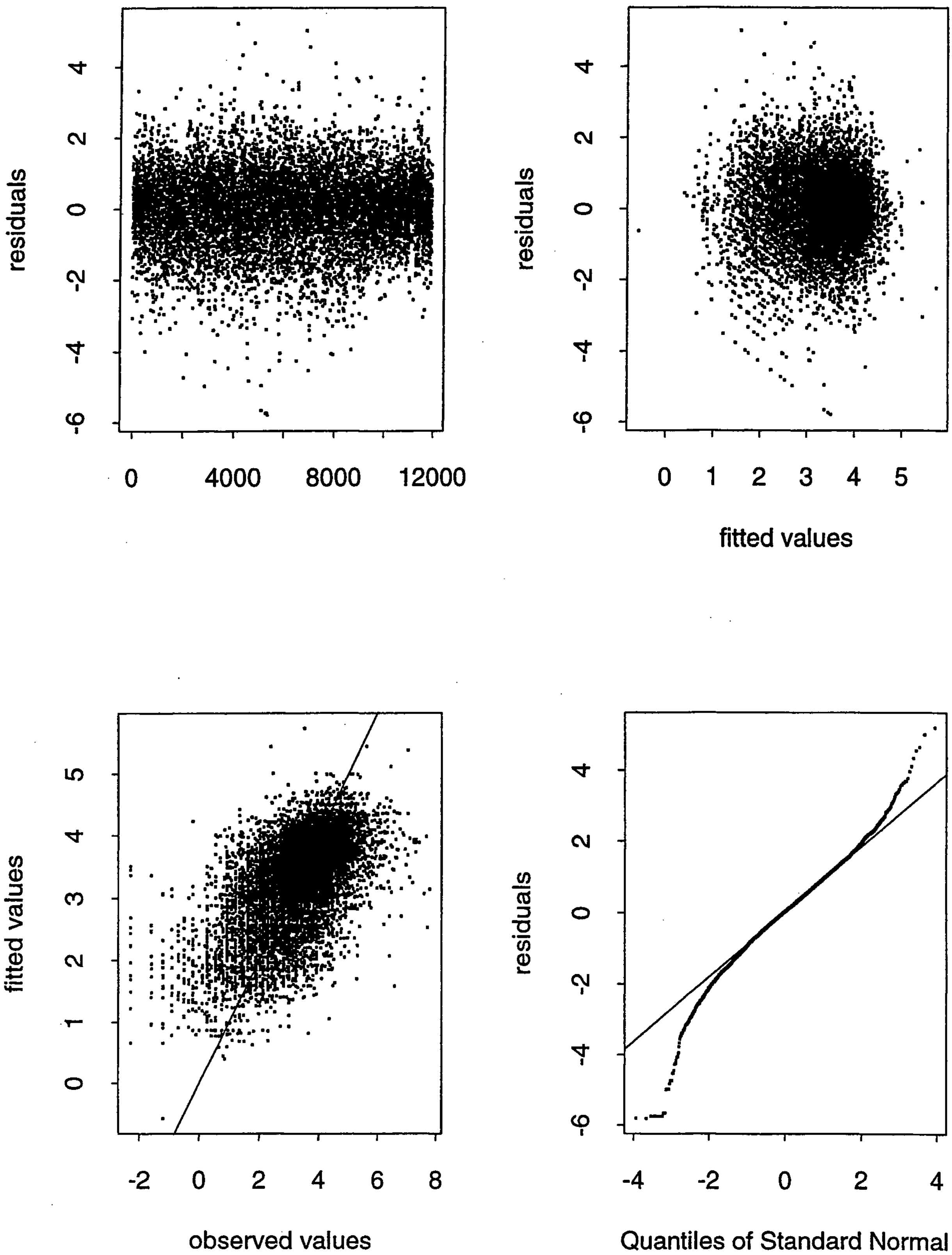
Appendix 4 cont.: Diagnostic plots for the standardised linear regression for the vessel subset in the single bottom trawl tarakihi fishery in TAR 3.



Appendix 4 cont.: Diagnostic plots for the standardised linear regression for all vessels and all target species in the set net tarakihi fishery in TAR 3.



Appendix 4 cont.: Diagnostic plots for the standardised linear regression for all vessels in the single bottom trawl tarakihi fishery in TAR 7.



Appendix 4 cont.: Diagnostic plots for the standardised linear regression for the vessel subset in the single bottom trawl tarakihi fishery in TAR 7.