ISSN 1175-1584

MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

Characterisation of the GUR 2 red gurnard (*Chelidonichthys kumu*) and associated inshore trawl fisheries, 1989–90 to 2000–01

Terese H. Kendrick
Nathan Walker

New Zealand Fisheries Assessment Report 2004/21
April 2004

Characterisation of the GUR 2 red gurnard (*Chelidonichthys kumu*) and associated inshore trawl fisheries, 1989–90 to 2000–01

Terese H. Kendrick
Nathan Walker

Trophia Ltd
P O Box 60
Kaikoura

New Zealand Fisheries Assessment Report 2004/21
April 2004

Published by Ministry of Fisheries
Wellington
2004

ISSN 1175-1584

©
Ministry of Fisheries
2004

Citation:
Kendrick, T.H.; Walker, N. (2004).
Characterisation of the GUR 2 red gurnard (*Chelidonichthys kumu*) and associated inshore trawl fisheries, 1989–90 to 2000–01. *New Zealand Fisheries Assessment Report 2004/21*. 83 p.

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

EXECUTIVE SUMMARY

Kendrick, T.H.; Walker, N.A. (2004). Characterisation of the GUR 2 red gurnard (*Chelidonichthys kumu*) and associated inshore trawl fisheries, 1989–90 to 2000–01.

***New Zealand Fisheries Assessment Report 2004/21.* 83 p.**

This report characterises the red gurnard fishery in QMA 2 (GUR 2) principally through the summary of catch and effort data from the commercial fishery augmented by interviews with commercial operators. The analysis includes catch and effort data from the mid-1980s (FSU) and from the QMS for 1989–90 to 2000–01.

Red gurnard is principally caught by bottom trawling. An important target fishery operates within GUR 2 and red gurnard also represents a significant bycatch in trawl fisheries targeting flatfish and tarakihi and, to a lesser extent, snapper and trevally. Due to the interaction between these fisheries, annual and seasonal trends in each of the main species caught in association with red gurnard were also summarised. The TACC for GUR 2 is consistently under-caught and the total annual catch may be constrained by the available quota from the other species caught in association with GUR 2, principally TAR 2, SNA 2, and TRE 2.

The target red gurnard fishery accounted for about 50–70% of the annual commercial catch from GUR 2. The fishery principally operates in the central area of GUR 2 from Gisborne to Porangahau (statistical areas 012 to 014) with smaller vessels operating mainly within Hawke Bay (013). Highest catch rates are achieved in the 20–60 m depth range. There are no strong seasonal trends in the red gurnard target fishery, although seasonal trends in fishing effort in the other inshore fisheries, principally tarakihi and flatfish, will influence the operation of the target fishery.

Red gurnard is a relatively ubiquitous species and, consequently, is present in a high proportion of catches from the other inshore trawl fisheries in QMA 2. The comparatively large total catch of TAR 2 means that the TAR 2 target fishery accounts for a significant proportion of the GUR 2 catch, especially in the northern areas (statistical areas 011 and 012). However, the catch rate of red gurnard is low as the tarakihi target fishery mainly operates beyond the main depth range of red gurnard.

The flatfish target trawl fishery principally operates in the central area of GUR 2 and there is considerable overlap with the distribution of the red gurnard target fishery. Red gurnard is the second most important species caught after the target species, but the catch rate of red gurnard is also low in the flatfish fishery which operates at the shallow end of the preferred depth range of red gurnard

The SNA 2 and TRE 2 target trawl fisheries yield high catch rates of red gurnard. However, these fisheries are small and, consequently, the overall catch of GUR 2 is low.

Trends in standardised and unstandardised CPUE for red gurnard were examined for each of the main target trawl fisheries for 1989–90 to 2000–01. The lack of data concerning the designated target species prevented the inclusion of data from the earlier period. Trends in both unstandardised and standardised catch rates varied between the three main target fisheries: red gurnard, flatfish, and tarakihi. However, due to the magnitude of the target fishery and the depth range fished, it was considered that trends in catch rate from the target fishery were more likely to be representative of trends in the abundance of GUR 2.

The unstandardised and standardised CPUE from the target fishery both showed a relatively steady decline in catch rates between 1990–91 and 2000–01. The standardised index declined by 35% over this period. It is recommended that trends in catch rate from the target fishery are routinely monitored, particularly in the absence of other monitoring of the species. The CPUE time-series should also be supplemented with catch sampling of the fishery to determine the sex and age composition of the catch.

1. INTRODUCTION

Red gurnard (*Chelidonichthys kumu*) is found throughout the tropical and temporal waters in Indo Pacific coastal waters, occurring in South Korea, China, Japan, Malaysia, South Africa, Australia, and New Zealand (Smith 1953, Scott 1962, Okada 1966). In New Zealand waters, it is most abundant north of the Subtropical Convergence in shallow (depths less than 55 m) coastal waters over muddy or sandy bottom (Elder 1976). Research fishing has documented the distribution of red gurnard around the entire New Zealand coast, with the exception of the southern fiords, in depths generally less than 300 m and not greater than 500 m (Anderson et al. 1998). In New Zealand, red gurnard is a bycatch of many inshore fisheries, including trawl, longline, and setnet fisheries, and some catches have been reported by deepsea trawlers. There are red gurnard target fisheries in Pegasus Bay, off the west coast of the South Island, and off Mahia Peninsula (Blackwell 1988).

Historically, fisheries assessment has focused on determining optimum yields of individual species. This approach may not be the most appropriate in some mixed fisheries, and, in recent years, attention has started to shift towards determining the roles of species in their ecosystems, with the possibility of moving away from single-species approaches towards ecosystem-based strategies. Broad-scale characterisations of mixed fisheries are the first step towards improving our overview of mixed fisheries and understanding the interactions among fisheries that determines level of catch.

The specific objective of the current project is to characterise the GUR 2 fishery and those of associated species taken by the area 2 inshore trawl fishery by analysis of existing commercial catch and effort data and data from other sources, and to make recommendations on appropriate methods to monitor or assess the status of individual Fishstocks or groups of species combined.

1.1 The fishery

The east coast North Island red gurnard fishery GUR 2 (Figure 1), developed in the early 1930s and catches rose steadily to a peak of almost 900 t in 1968 before declining to about 500 t in 1986. Although the TAC was initially set at 610 t in 1986 and later increased to 725 t, catches averaged less than 600 t during that time, and have fluctuated within the range of 400–700 t since 1991–92 (Figure 2). Catches in 2000–01 were 86% of the TAC (Annala et al. 2002).

Most red gurnard caught by bottom trawl in QMA 2 is taken in targeted fishing off Mahia Peninsula and in Hawke Bay. Red gurnard are also taken as a bycatch of the bottom trawl fisheries for tarakihi, trevally, snapper, barracouta, and flatfish, and these in turn make up most of the bycatch in tows targeted at red gurnard. While red gurnard is a ubiquitous species occurring in most trawl shots, it is not a valuable fish and there is not a great incentive for fishers to target it. In this mixed fishery, flatfish and red gurnard catches have not been constrained by TACC directly, but by TACC of the most important associated species (snapper, tarakihi, and trevally), which have regularly exceeded quota (Annala et al. 2002),(Figure 3).

In the mid 1990s there was a voluntary agreement in GUR 2 to increase mesh size (in contrast to GUR 1, where there was a compulsory increase) and various mesh sizes are used but not recorded with catch-effort data.

1.2 Biology

Elder (1976), in a study on red gurnard taken from the Hauraki Gulf, reported that sex ratios changed greatly with depth, the proportion of males increasing as depth increased. Males were only a small proportion of the catches in the Firth of Thames (9–26 m depth), but generally dominant on the spawning ground (51–79 m depth). Sex ratios also varied with time of the year. There were distinct differences in catch rates of individual age groups between areas, and between sexes within areas.

Males recruited (moved) to the trawling ground at about a year younger than females (Elder 1976, Hanchet et al. 2000), with males being fully recruited to the fishery at 2 years of age, and females by age 3.

Elder identified a possible spawning ground, by analysis of catch rates of spawning fish, in an area of Hauraki gulf in 51–79 m of water, over a bottom of hard mud. Spawning males were present on the spawning ground throughout the year and females through most of the year, but there was a peak of spawning activity during the late spring and early summer. Catch rates of sexually mature fish at the various stages of gonad maturity suggested a seasonal migration, to and from the spawning ground, especially of females, while mature males appeared to be at least partly resident on the spawning ground. Females migrated into deeper water between September and October to spawn and emigrated inshore from the spawning ground between June and August. The timing of the peak of the spawning season varied by a month or two between the two years sampled.

Males have a slower growth rate than females, and reach sexual maturity at a smaller size (21 cm FL, fork length) compared with females (24 cm FL). Age at which the fish matures varies between areas, but over 90% are mature by their third summer in all areas (Staples 1972, Elder 1976).

Elder (1976) and Sutton (1997) both showed that female red gurnard are larger than males at corresponding ages and have a significantly greater maximum length ($L\infty$). Hanchet et al. (2000) reported that few fish caught were older than age 8.

In examining age structure in the Hauraki Gulf, Elder (1976) observed marked differences in year class strength and commented that a constant rate of recruitment was unlikely for the species.

1.3 Fisheries assessment

Very little directed research has been carried out on red gurnard stocks in New Zealand since Elder's (1976) study in the Hauraki Gulf. Blackwell (1988) reviewed the New Zealand fishery and biological data, and estimated MCY. He reported a declining annual catch during the 1980s, which he thought to be the result of fishers targeting more valuable species.

Hanchet et al. (2000) presented results from the first model-based stock assessments of red gurnard stocks GUR 1 and GUR 2. Estimates for GUR 2 were highly uncertain and were not considered further for management purposes. They compiled CPUE indices for 1989–90 to 1996–97 from all bottom trawling effort (including zero catches) targeted at red gurnard, snapper, tarakihi, and trevally fisheries combined. They excluded flatfish target tows because of a contradictory trajectory, and excluded barracouta target tows because of highly variable catch rates.

That assessment also considered the usefulness of trawl survey indices of abundance for red gurnard, but the series from the east coast of the North Island was noisy, with quite marked year-to-year variation. The model fitted a slightly declining line to the survey indices, but the series was short (four surveys) and was not considered by the working group to be useful for monitoring red gurnard. The larger mesh size (100 mm codend) used in the east coast North Island surveys precluded any estimates of recruitment or year class strength, as 1+ year class fish were not well retained. Biological samples for red gurnard were collected on just one of the four surveys.

Adjacent fishstocks GUR 7 and GUR 3 have been monitored as part of the Adaptive Management Programme and a characterisation of the fishery and updated CPUE analysis for GUR 3 has been presented by SeaFIC (2002), who used landed catch instead of estimated catch, with data amalgamated at trip level. Analyses used data from trips targeted at flatfish (FLA) or red cod (RCO) and trips with no red gurnard catch were excluded. Although a highly reported species (estimated catch was 85–98% of landed catch), he considered red gurnard to be so commonly encountered in trawl tows that zero catches were more likely a function of the top five species reporting threshold than of abundance.

Langley (2002) offered the catch of associated species as explanatory variables in his analyses and noted that the bycatch of GUR increased (to a point) with increased catch of FLA in the FLA 3 fishery, and decreased with increased catch of RCO in the RCO 3 fishery. FLA catch was significant as a predictor of GUR in both fisheries, but RCO catch was important only in the RCO 3 fishery.

The ubiquitous nature of red gurnard is confirmed in fishery-independent studies from research trawl fishing. Francis et al. (2002) studied fish assemblages around New Zealand using presence-absence data from 19 232 research bottom tows, and described red gurnard as the most commonly caught species in the inshore assemblage (80.6% of tows), with the widest latitudinal range, the third greatest depth range and a preferred depth of 50m. They placed red gurnard among the monospecific associations (unassociated with other species).

A study of fish assemblages in the Hauraki gulf in waters that are generally less than 60 m depth from 1381 trawl shots by two research vessels (Kendrick & Francis 2002) reported red gurnard encountered in 77 and 75% of the tows by the two vessels respectively, associated with blue cod and various flatfish species, and unassociated with either tarakihi or snapper.

2. DATA SOURCES AND METHODS

2.1 Definitions

For this study, the inshore trawl fishery is defined as fishing carried out by vessels under 43.5 m in length, registered in New Zealand, using trawl gear on the sea bottom, and targeting or catching snapper (SNA 2), tarakihi (TAR 2), red gurnard (GUR 2), trevally (TRE 2), flatfish (FLA), or barracouta (BAR 1) in QMA 2 (east coast of the North Island).

The code FLA represents an assemblage of species loosely referred to as flatfish. It includes all records of New zealand sole (ESO), lemon sole (LSO), sand flounder (SFL), greenback flounder (GFL), flounder (FLO), yellowbelly flounder (YBF), turbot (TUR), and black flounder (BFL).

Fishstock codes used in this document indicate a target fishery: thus TAR 2 means tows by the inshore trawl fleet, targeted at tarakihi, in FMA 2. Although fishstocks such as FLA 2 and BAR 1 extend beyond the boundaries of FMA 2, in this study statistical areas that fall wholly outside FMA 2 have been excluded. Straddle areas (that include more than one fishstock) are included and the amount of likely contamination quantified (Section 2.3.5).

2.2 FSU data 1983 to 1989

Before the introduction of the QMS, catch and effort data were collected by the Fisheries Statistics Unit (FSU) and are available at the resolution of a vessel-fishing day from 1983. Target species was not recorded before introduction of the QMS, so fisheries can be defined only by fishing method and statistical area and season.

Some error checking was carried out; all daily catches were within Ministry of Fisheries maximum verified catch per tow for GUR for bottom trawling (MFish 2002). Observations with more than 10 tows per day for bottom trawling were not used. Effort fields were range checked by comparing the minimum and maximum to the 90 percentile values; this resulted in a very few input errors being detected. Those values were replaced with the median value for that vessel. Effort 1 (the number of tows when the method is bottom trawling) and days fished are both available as measures of effort.

Effort 2 (hours when the method is bottom trawling, and metres or number of hooks when set/gill netting and long-lining, respectively) is corrupted in the database and unusable.

2.2.1 Fishing years

The proportion of the reported landings for which there is associated effort information decreased in the final few years of FSU collected data, so that not many years of FSU collected data can be considered to be representative of the fishery (Table 1). The four years 1983–84 to 1986–87 are the most complete, and were used to provide the best possible snapshot of the character of the red gurnard fishery and of the inshore bottom trawl fishery for the most important species in QMA 2 before the introduction of the QMS.

2.2.2 Statistical areas

Small parts of statistical areas 17, 18, and 19 fall within GUR 2, with most of their area falling within GUR 3. There is no additional information with which to determine fishstock retrospectively. For these reasons, only statistical areas 11 to 16 (Figure 4) are included in this description of the fishery before introduction of the QMS.

2.2.3 Species

This study of FSU data considers only the top five species of interest; red gurnard, and the four species most commonly associated with red gurnard; tarakihi, flatfish, snapper, and trevally.

2.2.4 Fishing method

The most important method employed during the four selected fishing years, 1983–84 to 1986–87, was bottom trawl: 96–100% of the estimated catch of red gurnard in each area was taken by bottom trawl, with most of the balance taken by set/gill nets and very small amounts by bottom longline (Table 2). No other type of trawl is recorded and other types of line fishing took only small amounts.

The descriptive analysis of FSU-collected data considers only the bottom trawl catches.

2.3 QMS data 1989–90 to 2000–01

Since 1989–90, more detailed catch and effort data have been available from the Ministry of Fisheries administered "Warehou" database from a variety of forms completed by commercial fishers.

Catch effort landing returns (CELR) forms used mainly by inshore fishing vessels provide estimated catch and associated effort data at the resolution of a vessel-fishing day and statistical area for the top five species caught.

Trawl catch effort processing return (TCEPR) forms used mainly by larger vessels provide estimated catch and associated effort data at the resolution of a tow and statistical area for the top five species caught.

Actual *landings* of all species are available from both reporting types (CEL and CLR respectively), at the resolution of a vessel-trip, and fishstock. Multiple landings per trip are further described by landing type, and by processing-type.

Quota management returns (QMR) provide groomed and checked total removals for quota management purposes, resolution is fishstock and month.

2.3.1 Data quality and grooming

Observations were deleted if the estimated or landed catch exceeded Ministry of Fisheries verified maximum values (MFish 2002). Respective effort fields were range checked and the number of tows

in a day set at a maximum of seven, and the duration of towing was set at a maximum of 20 hours. *Eff_num* was set to one if missing.

Other fields were set to missing if recorded as zero, including total catch and gear parameters, such as height or width.

Vessel attributes are available in a time series, but there is little benefit in trying to use them as so many fields were missing, especially for earlier years. There is also a lot of variation in the values recorded for the same vessel. Some are due to re-powering of the vessel, but many are clearly errors or misunderstanding of units to be used, especially of engine power (kilowatts). Tonnage also varied more than one might expect. To use the time series as they stand would have added unnecessary complexity to analyses. The series was collapsed to one record per vessel: in most cases the most recent values were used, with missing fields length, speed, and nationality, filled in on the basis of surrounding entries for the same vessel.

Considering that these values have a lot of leverage in CPUE standardisations where they are used repeatedly, the series merits more attention so that only re-powering or lengthening of a vessel leads to new values.

The extract, obtained in January 2002, was considered to be complete for the fishing year 2000–01.

2.3.2 Processed state

For some species that are commonly landed in a processed form, there is an additional problem of processed weight being recorded where greenweight should be calculated. Red gurnard do not suffer from this problem: 99.39 % of all GUR2 landed since 1989–90 was landed green, thus requiring no conversion to equivalent greenweight.

2.3.3 Estimated catch versus landings

Red gurnard is a ubiquitous species occurring in almost all tows within its broad habitat, and rarely not included in the top five species. It is therefore a well-reported species with estimated catches accounting for 80–90% of the reported landings. Characterising the fishery by analysis of estimated catch is attractive because of the fine resolution of the data. The likely biases by considering only estimated catch, however, are introduced by the possibility that smaller catches are excluded; possible differences in reporting rates among areas, fisheries, or over time; and the treatment of records from statistical areas that straddle two QMAs (17, 18, and 19) which must either be excluded, or if included, will be influenced by the management regime of the adjacent QMA 3.

Characterising the fishery using landings requires the data to be collapsed to trip resolution, and some information on target species, method, and statistical areas (where there are multiple values within one trip) is also compromised. Of fishing trips, 8.5% reported multiple target species or statistical areas, compared with 1 to 12% of landings of red gurnard annually that was not estimated among the top five species. The trade-offs in this instance were not clearly in favour of one method over the other, and the following analyses are based on estimated catch.

An attempt is made to quantify the extent of two of the potential problems with using estimated catch.

2.3.4 Reporting rates

In most years, between 90 and 100% of the landed catch from QMA 2 was estimated on the top part of the fisher returns with associated effort information. The exception was in 1999–2000 when this figure fell to 87 %. There has been a gradual trend since 1989–90, for total landings of red gurnard by the inshore trawl fleet to represent a smaller proportion of the QMR total for the area (Table 3) as larger vessels report more red gurnard catches.

A more detailed summary of reporting rates is given in Table 4 where estimated catch is compared with landings for red gurnard and associated species, by statistical area, within each target fishery. This summarises only those fishing trips that recorded a single method, target species, and statistical area, and represents 91.5% of trips fished in QMA 2. Red gurnard is well reported in the GUR 2, FLA 2, and SNA 2 fisheries, and most poorly in the TAR 2 fishery where 75% of landings (by weight) from area 13 were estimated in the top five species of the catch.

2.3.5 Statistical areas that straddle two QMAs

Landings from trips that fished in each of the straddle areas (17, 18, and 19) are described by fishstock. Most trips that fished in area 17 landed QMA 2 fishstocks. Most trips that fished in area 18 landed QMA 3 fishstocks. Landings from area 19 were insignificant. In an attempt to find a useful subset of trips, trips that fished in the straddle areas and that landed a QMA 2 fishstock were examined. Those trips accounted for almost all of the GUR 2, FLA 2, and SNA 2 caught in the straddle areas, and much smaller proportions of the tarakihi and trevally catch. Tarakihi and trevally from both fishstocks were commonly landed in the same trip so that estimated catch from areas 17 to 19 are not necessarily representative of TAR 2 or TRE 2. Barracouta cannot be assigned to QMA by reported fishstock, as BAR 1 also includes QMAs 1, 2, and 3.

For characterising these fisheries, trips that were fished in the straddle areas, and that landed QMA 2 fishstocks, are included. Depending on species, the extent of likely contamination by QMA 3 fish is indicated in Table 5 by the proportions seen in the landings. Eliminating rather than including trips that fished both QMAs would merely introduce a different type of non-representation.

2.3.6 Combining data sets

In order to use data from both CELR and TCEPR sources, tow-by-tow data from the TCEPR was collapsed to a single observation for a fishing day, target species, and statistical area, using total catches, tows, and duration, and average gear parameters (net height, width, etc). One record therefore might still represent less than one day's fishing if more than one area or target species was declared in a single days fishing.

Observations were included from trips that fished in areas 17, 18 or 19, and that landed QMA 2 fishstocks.

Because of the importance of target species to the analyses, FSU data from before 1989 were not included in CPUE analyses

2.3.7 CPUE standardisations

Standardised CPUE analyses were undertaken for red gurnard caught in three separate target fisheries, GUR 2, FLA 2, and TAR 2, each of which possibly exploits a different component of the red gurnard population.

For each analysis, the log of the estimated catch (kilograms) from a day's fishing, (less in some cases) was used as the CPUE estimate (response variable) in the model, and was calculated from those tows which encountered red gurnard, i.e. no zero catches were included.

Two measures of effort (number of tows and total hours duration) were offered as potential explanatory variables in the CPUE models. This enabled the model to determine the most informative unit of effort. Other potential explanatory variables offered to the model are given in Table 6. All continuous variables were offered as third order polynomials and the variable "vessel" was offered as a categorical variable to account for differences in the relative fishing success between individual vessels. A set of continuous vessel descriptors including overall length, power, and tonnage was offered together as an alternative to the categorical vessel variable. Other potential explanatory

variables included net parameters, and the estimated catch of associated species, flatfish, snapper, tarakihi, and trevally.

Core vessels were defined as those that completed at least 10 tows in the target fishery, in each of at least three years; data from other vessels were not included in the CPUE analyses.

Predictor variables were selected into the model in a forward stepwise regression until the remaining variables contributed no significant explanatory power to the model (produced less than 1% increase in R^2 value). Fishing year, being the factor of interest, was the exception, being a forced first inclusion.

Annual indices were determined from canonical coefficients following Francis (1999) Each coefficient is calculated relative to the geometric mean ($\overline{y}$) of the series, which allows the computation of standard errors for every coefficient.

3. RESULTS

3.1 Review of the inshore bottom trawl fishery of FMA 2 from FSU-collected data 1983 to 1989, prior to introduction of the QMS.

3.1.1 Red gurnard

Most red gurnard was taken from statistical areas 13 and 14: 57–66 % of the annual estimated catch in each year was taken in statistical area 13. 19–21 % was taken in area 14, and 7–11 % from area 12 (Table 7). In areas 13 and 14, gurnard was about equally abundant as tarakihi in the catch (Table 8). The pattern of catch with area was generally consistent across years, except for a peak of 47 t taken from area 15 in 1983–84 compared with to 4–7 t in the subsequent two years (Table 7). Number of tows and mean CPUE (Table 9) also peaked in that area in that year. The distribution of catch rates for red gurnard by statistical area and year are shown in Figure 5. Excluding area 15, the median CPUE was generally highest in area 13, decreased with distance in both northerly and southerly directions, and was lowest in area 11. Area 15 CPUE was, by contrast, highly variable.

Season

There was little seasonal pattern to effort expended in FMA 2, except for a strong October/November peak each year in area 13. Red gurnard was generally taken throughout the year, with no distinct seasonal pattern (not shown). The peak of catch in 1983–84 in area 15, mentioned above, was mostly (96 %) taken between June and September.

3.1.2 Associated species

In each of the four years examined, tarakihi was the most important species taken in the inshore bottom trawl fisheries of FMA 2. Tarakihi accounted for about three times the weight of the red gurnard catch, which was in turn about three times that of snapper, trevally, or flatfish (Table 10). This pattern was quite stable among years, and, for several species, relative importance was also consistent across statistical area (Table 11).

Tarakihi

Tarakihi dominated the catch in the northern two statistical areas 11 and 12, (77–92%) and in the southern two areas, 15 and 16, (47–91%) but was often equalled by the catch of red gurnard in the two central areas, 13 and 14 (Table 8, 11). Average CPUE followed a similar pattern to catch among statistical areas (Table 12, Figure 6).

Snapper

Snapper accounted for 4–11% of the catch in the northern four areas, but just 0–3% of the catch in the southern areas, 15 and 16 (Table 13). Average annual CPUE varied consistently with area in the following order: area 12 greater than area 11 greater than area 13 greater than area 14 greater than area 15 greater than area 16. The most marked feature was the low occurrence in area 16, Cook Strait. The distribution of catch rates for snapper is shown in Figure 7. Median CPUE was greatest in the two northern areas, 11 and 12, but occasional high catches and consequently greater variance in catch rates were features of the central areas, 13 and 14. Catch rates were consistently low in the southern areas 15 and 16 (Table 14).

Trevally

Trevally was most important (8–18%) in catches from area 14, and formed just 0–8% of the catch in other areas. It formed a very small component of catches in the northernmost area, 11 (Table 15). Mean annual CPUE shows no consistent pattern across statistical area (Table 16) and the distribution of catch rates (Figure 8) confirms low median values with a lot of variance caused by occasional very high catches.

Flatfish

Flatfish catch was insignificant or nonexistent around East Cape, areas 11 and 12. It was most important (3–13%) in the catches from the central areas, 13 and 14, and accounted for just 0–3% of the two southern area (15 and 16) catches (Table 17). Catches were generally small without the occasionally large catches seen in snapper and trevally. The pattern of relative abundance was more consistent across statistical area than it was among years (Table 18). Two-fold or greater differences in average catch rate between one year and the next was a common feature (Figure 9).

3.1.3 Observations

- The FMA is dividable into three subareas (northern, 11 & 12; central, 13 & 14; and southern, 15 & 16) on the basis of species composition of the catch.
- Red gurnard was most prevalent in the central two areas (13 and 14).
- Catches and catch rates for red gurnard in area 15 were highly variable.
- Proportion of red gurnard in the catch and catch rates in areas 11 and 12 was low, but consistent.
- Catch and catch rates for red gurnard varied more across statistical areas than across years.
- Tarakihi was the most important species throughout the FMA 2 bottom trawl fisheries, but was least abundant in the central two areas 13 and 14.
- Mean catch and catch rates for snapper in the central two areas were consistent, but variance was high.
- Trevally was an important component of the catch in a small area of FMA 2, but variance in CPUE was high.
- Flatfish was also most important in the central two areas (along with red gurnard), but exhibited low catch rates with high inter-annual variation.

3.2 Review of the inshore trawl fishery from QMS data since 1989–90

This section summarises the estimated catch of all species taken by the inshore bottom trawl fleet in all statistical areas of QMA 2 since introduction of the QMS. The overall catch of red gurnard is characterised, and then target fisheries for red gurnard and other associated species are described with respect to the target species and to red gurnard.

3.2.1 Distribution of effort (bottom trawl tows)

The inshore bottom trawl fisheries operate mostly in the central (Hawke Bay) areas 13 and 14, with almost three times as many tows carried out in area 13 as in area 14 (Table 19). A consistent but lower level of effort across years is evident in two northern (East Cape) areas 11 and 12, and in two southern (Cook Strait) areas 15 and 16. There has also been sporadic activity in the offshore areas 18, 19, and 201 to 206.

The number of tows carried out by this fleet of vessels increased overall from 1989–90 to 1992–93, declined the subsequent year, and has remained stable since then. Much of the increase in the early 1990s occurred in statistical areas 13 and 14 (Table 19).

3.2.2 Species composition and distribution

Overall, tarakihi is the most important species throughout the QMA, but primarily in the inshore statistical areas. Tarakihi dominates the catch (26–55%) in the northernmost three areas 11, 12, and 13, and is equally as important as barracouta in the remaining inshore areas, 13 to 19. Snapper is an important component (10–28%) of the catch in the northern areas, 11, 12, and 201, and red gurnard forms less than 10 % of the catch in all except the central area, 13. Red gurnard catch and relative importance diminishes north and south from area 13. Hoki and gemfish become important in the central areas, 14 and 15, and warehou is important in the Cook Strait region, areas 16, 17, and 18 (Table 20).

The species mix in the offshore areas is dominated by snapper in the north, and gemfish and orange roughy in the south. Although red gurnard accounts for up to 9 % of the catch in the offshore areas (by vessels less than 43.5 m in length), the actual catch in any year was less than 1 tonne and it is also very likely to include misidentified Japanese gurnard (A. Langley, Trophia Limited pers. comm.).

TCEPR records of tow locations show catches of red gurnard along most of the coast (Figure 10), with larger catches along the Wairarapa coast, in Hawke Bay, and along the coast north of Gisborne (Figure 11). Snapper catches were recorded from the northern boundary of QMA 2, south to Napier, with the larger catches around East Cape and in Hawke Bay. Some small catches of snapper reported near Wellington, and several large catches of snapper were made in Palliser Bay (Figure 12). Tarakihi were caught from East Cape south to the Wairarapa, but not inside Hawke Bay, (Figure 13). Trevally was taken in small amounts along most of the coast of QMA 2 and inside Hawke Bay, with larger catches off the Porongahau–Wairarapa coast (Figure 14). Flatfish were caught inside Hawke Bay, north to Gisborne, and along the coast from Cape Turnagain to Castle Point (Figure 15).

Snapper, red gurnard, and trevally shared similar depth ranges, being most abundant in depths less than 100 m. Flatfish occupied the shallower depths, generally below 50 m. Tarakihi were more abundant at greater depths, with a peak at 200 m, with only the "tails" of the respective depth frequency distributions of red gurnard and tarakihi overlapping (Figure 16).

3.2.3 Red gurnard catch

Most of the catch of GUR 2 in each year (55–69%) was taken in area 13, with 13–27% taken annually from its southern neighbour, area 14, and 7–14% from its northern neighbour, area 12. The northernmost area, 11, consistently accounted for just 1 to 3 % of the annual catch, and each of the Cook Strait areas, 15–19, accounted for just 1–6% of the catch in any year. The offshore areas, 201–

205, accounted for insignificant amounts of red gurnard, though there is some targeting recorded from there. The spatial distribution of the catch of red gurnard by the inshore trawl fisheries has been markedly consistent with time. Southward shifts in effort occurred in 1991–92 and in 1995–96, northward shifts in 1994–95 and 1997–98, and compression into the central area 13 is evident in 1998–99 and 1999–2000, but these shifts have been slight and red gurnard catch varied more between statistical areas than it did between years (Table 21).

Fishing method

In most years, most of the annual catch of red gurnard has been taken by bottom trawl (59–66%). Bottom longlining has accounted for 15–25% annually, with most of the balance increasingly taken by Danish seine. Bottom pair trawling took small proportions of the catch in the early 1990s (Table 22).

Season

Red gurnard is taken throughout the fishing year in QMA 2, with greater removals in spring months (September, October, and November), and lows in February and in June (Table 23). This overall pattern largely reflects the seasonal pattern to effort expended in the TAR 2 fishery in area 13 where most of the catch of red gurnard is taken. Catches in adjacent areas 12 and 14 are more evenly distributed throughout the year. In the southern areas, 15 to 19, the pattern is of a winter fishery, with lowest catches in December and January, except that in areas 17 and 18 there was little or no catch during August in most years (not shown).

Target species

Red gurnard is mostly (59%) taken in target fishing and this proportion has increased from 48% in 1989–90 to 70% in 2000–01. Roughly equal proportions of gurnard are taken as bycatch of the tarakihi and flatfish fisheries, with the flatfish target fishery being relatively more important for a period between 1992–93 and 1998–99 (Table 24). Red gurnard is mainly a bycatch of the tarakihi fishery in the northern two areas, 11 and 12, and primarily a target fishery in the central two areas, 13 and 14, and in the Cook Strait areas, 15 and 16. In the central two areas 13 and 14, where most of the annual red gurnard is taken, 16 and 14 % was taken each year as bycatch of the flatfish target fishery, and slightly less as bycatch of the tarakihi fishery. The tarakihi target fishery accounted for 36 % of the red gurnard catch in the Cook Strait area, 17, but the tonnage was relatively small. Likewise the barracouta target fishery in Cook Strait areas 17 and 19 accounted for much of the red gurnard catch in those areas, but the tonnage was small (Table 25).

Distributions of catch rates of red gurnard are shown in Figure 17, by target species and statistical area. Statistical areas can be grouped into three latitudinal bands on the basis of species composition, targeting behaviour, and catch rates of red gurnard. Catch rates of red gurnard in the main target fisheries were generally in the following order irrespective of area or year; catch rate in GUR 2 greater than in SNA 2, greater than in TAR 2, greater than in FLA 2. The proportion of the red gurnard catch taken by the main target fisheries varies with latitudinal zone (northern,11 and 12; central,13 and 14; southern,15 and 16), but the distribution of catch rates is consistent within target fishery with two notable exceptions.

1. Catch rates of red gurnard in TRE 2 are very high in the central areas, 13 and 14, higher than in the target fishery.

2. Catch rates of red gurnard in the target fishery in southern areas, 15 and 16, are very high and variable compared with central and northern areas.

3.2.4 Snapper target fishery

The snapper target fishery is a northern fishery, existing mainly in areas 11 to 13 and in the offshore area of 201 (Table 26). It is a small component of the inshore trawl fishery, accounting for about 10%

of all tows in area 11, and 6% of tows in area 12. It accounted for only 7 to 31 % of snapper caught annually by the inshore trawl fleet; 5–24% annually of all reported landings of snapper from QMA 2 (all vessels and all methods). Six vessels targeted snapper on 10 or more days in each of at least three years, and 12 vessels targeted snapper on at least 10 days in at least 2 years. The sporadic pattern of vessel participation and the proportion of snapper declared to have been targeted suggest an opportunistic rather than dedicated target fishery.

Red gurnard was the second most abundant species in tows targeted on snapper in the central two areas, 13 and 14, the third most abundant behind tarakihi northwards in area 12, and fourth after barracouta, further north in area 11. In the Cook Strait area, 15, several other species were more abundant than snapper in tows targeted at that species (Table 27).

There were peaks of effort expended in SNA 2 in 1993–94 and in 1998–99 that did not appear to have been in response to increased availability of snapper, but coincided more with peaks in abundance of trevally (Figure 18, and see Section 3.2.8). Red gurnard was reported in most snapper tows, 76 % overall (Table 28), but the catch rate of gurnard in snapper tows declined by about 75 % between 1989–90 and 1997–98. There was a slight recovery over the following three years. There also appears to have been an increasing trend to the proportion of tows that targeted snapper but did not report gurnard among the top five species caught (Table 28, Figure 18).

The seasonal distribution of the target fishery for snapper shows the greater proportion of tows in March–May. This does not coincide with highest catch rates, which, for both the target species snapper and the bycatch of red gurnard, occur at the beginning of the fishing year, declining steadily through the fishing year (Figure 19).

3.2.5 Tarakihi target fishery

The tarakihi target fishery is the most extensive of the inshore trawl fisheries in QMA 2; it is important from area 11 in the north to area 17 in Cook Strait (Table 29) accounting for most tows carried out by the inshore trawl fleet in areas 11 and 12, and in areas 16 and 17. In each of those areas, tows targeted on tarakihi have declined as a proportion of the total inshore trawl effort. The target fishery has accounted for most (78–92% annually) of the tarakihi caught by the inshore trawl fleet, and 6–86% annually of the QMR landings of TAR 2, by all vessels and methods. There was a core fleet of 43 vessels that targeted tarakihi on 10 or more days per year, in at least 3 years, and 51 vessels that targeted tarakihi on at least 10 days in at least 2 years.

Red gurnard was generally a small component of catches from tows targeted at tarakihi (Table 30), making up only 5% of the catch in area 13. Barracouta and hoki are both more important than red gurnard in this fishery, as is snapper in the north and warehou in the south. Flatfish were rarely reported among the top five species caught (Table 30). Gurnard was estimated among the top five species in just 46% of tows overall, and at a much lower catch rate than the target species (Table 31). It is in this fishery that red gurnard suffers to some degree from underreporting as a result of not making the top five species. In tows that reported a catch of red gurnard, the rate was about 43 kg per tow.

The tarakihi target fishery is nevertheless the second most important fishery taking red gurnard, accounting for about 16% of the annual catch, and it is the major fishery taking gurnard in most areas in most years, except areas 13 and 14, where only about a quarter of the tows were targeted at tarakihi.

Annual catch of tarakihi has been maintained since 1991–92 with decreasing effort and an increasing catch rate, while the corresponding catch rate of red gurnard has stayed fairly constant (Table 31,Figure 20).

The seasonal pattern of fishing effort expended in TAR 2 was generally consistent throughout the fishing year, but greatest in October and November. Catch rates of tarakihi are greatest in March to May, when the catch rate of gurnard is lowest (Table 31, Figure 21).

3.2.6 Red gurnard target fishery

The red gurnard target fishery is concentrated in the central areas, 13 and 14, where it accounts for 37 and 29 % respectively of all tows carried out by the inshore trawl fleet it is also important in the two consecutive areas 11 (north) and 15 (south), where it accounts for 14 and 16% of the inshore trawl fishing effort respectively (Table 32). These target tows have accounted for 47–69% annually of all red gurnard taken by the inshore trawl fleet, and 35–58% of the QMR reported landings of GUR 2 by all vessels and methods. A core fleet of 48 vessels has targeted red gurnard on 10 or more days a year, in at least 3 years, and 56 vessels targeted red gurnard on at least 10 days in at least 2 years.

In the northern two areas, 11 and 12, this fishery caught snapper and tarakihi in about equal quantities to the target species. In areas 13–16, however, red gurnard was more clearly the dominant species in the catch. Tarakihi was the third most important bycatch in the north, barracouta and trevally in the south, and a wider mix of tarakihi, barracouta, trevally, and flatfish species made up the balance of the top five species reported in the central areas (Table 33).

The history of this fishery shows large shifts in the effort expended, to which CPUE appears to shows a response. Overall, CPUE has declined steadily except for a large increase in 1995–96 and in 2000–01. Effort peaked between 1991–92 and 1993–94, then declined by more than a third over the following three years (Table 34, Figure 22). This corresponded with increased targeting of flatfish (see Section 3.2.7). Catch rates of red gurnard recovered and stabilised during this period, declining once again after 1998–99. This coincided with an increase in effort back to previous levels as the fleet shifted emphasis from flatfish back to red gurnard.

There is little seasonal pattern to effort, which is expended fairly consistently throughout the year, declining towards the end of the fishing year perhaps as fishing is constrained by quota of bycatch species, and with occasionally a peak in September. Availability appears greatest in September to November, and lowest in March to May (Figure 23).

Red gurnard is generally caught in targeted trawl tows at about 100 kg per tow.

3.2.7 Flatfish target fishery

The target flatfish fishery shares the geographical distribution of the red gurnard target fishery, and is almost as important as GUR 2 in the central two areas, 13 and 14, where it accounts for about 25% of all tows in the inshore trawl fishery (Table 35). There is also some targeting in the Cook Strait area, 16. The target fishery has accounted for 60–84% of the bottom trawl caught flatfish annually, and 36–53% of the QMR reported landings from QMA 2 (FLA 2 includes QMAs 2 & 8). There was a core fleet of 23 vessels that targeted flatfish in QMA 2 on 10 or more days per year, in at least 3 years. There were 26 vessels that targeted flatfish on at least 10 days in at least 2 years.

Red gurnard is the second most important species to flatfish species in most areas (Table 36), yet it occurs in just 57 % of the trawl tows at the low rate of about 35 kg per tow (Table 37). Snapper and red cod are the other two most important species encountered in flatfish tows, tarakihi is rarely reported (Table 36).

Effort expended in this fishery has changed markedly over the period in a reciprocal pattern to that seen in the red gurnard target fishery, and in no obvious response to the catch rate of flatfish species. Catch rate of flatfish shows a steady decline from 1989–90 to 2000–01 while the catch rate for bycatch of red gurnard varies little, peaking gently in 1996–97, just as it did in the GUR 2 fishery (Table 35, Figure 24). There is, however, a trend from 1989–90 to 1997–98 of a declining proportion of the tows in which gurnard was reported among the top five species. This trend was reversed in the subsequent three years.

The seasonal pattern shows a stronger summer fishery for flatfish, especially in the last half of the decade, with effort and catch rates peaking from October to December, and lowest after April. The

seasonal pattern of catch rates of gurnard in this fishery is similar to that seen in the GUR 2 fishery, except that availability is lowest two months earlier, in February rather than in April, before increasing towards the end of the fishing year. There is no evidence that this fishery responds to increased availability of gurnard (Figure 25).

3.2.8 Trevally target fishery

Tows targeted on trevally are a low proportion (1–3%) of the effort expended in the inshore trawl fishery in most areas (Table 38). The trevally target fishery extendes sparsely over most of QMA 2, but is most important in the central areas, 13 and 14. It annually accounted for just 11–42% of trevally caught by the inshore trawl fleet, and 7–34% of the QMR reported landings from QMA 2 (by all vessels and all methods). There were only 3 vessels that targeted trevally on 10 or more days in a year in at least 3 years. There were 4 vessels that targeted trevally on at least 10 days for at least 2 years. As for snapper, there seems to be opportunistic rather than dedicated targeting of this species.

In the northern areas, 11 to 13, snapper was the most common bycatch of this fishery, and in the southern areas, 14 and 15, it was barracouta (Table 39). Red gurnard was generally the third most important species in tows targeted at trevally, but occurred in 82 % of the tows at the high rate of about 106 kg per tow (Table 40). This is higher than the catch rates normally seen in the red gurnard target fishery (see Section 3.2.6).

Effort expended by the inshore bottom trawl fishery on targeting trevally dropped markedly from 1994–95 (see Table 38). Nevertheless, the catch of trevally has continued to exceed its TACC occasionally since then. Since 1994–95, the reported catch rates for targeted trevally have fluctuated widely. The catch rates for red gurnard have also fluctuated more widely than in other target fisheries (Figure 26).

The seasonal distribution of effort confirms the sporadic nature of this fishery. Targeting ceases towards the end of the fishing year, except for an occasional peak in September. Catch rates of both trevally and gurnard show a very similar pattern, declining from a peak in October to a low in May, and remaining low for the remainder of the fishing year (Figure 27).

3.3 Standardised CPUE

In selecting target fisheries to include in an analysis of CPUE of red gurnard, the geographical distribution of the fisheries, compared with that of red gurnard, was considered, as was the adequacy of the data in terms of number of records per year, and the existence of a well determined core fleet.

SNA 2 and TRE 2 are sporadic or sparse fisheries and/or are geographically unrepresentative of the red gurnard fishery. Fisheries for TAR 2 and FLA 2 coincide with GUR 2 in the central areas 13 and take considerable amounts of red gurnard as bycatch. TAR 2 and FLA 2 each occur at the opposite extremes of the preferred depth range of red gurnard and may sample different components of the red gurnard population. CPUE standarisations were therefore attempted separately for red gurnard landed from FLA 2, GUR 2, and TAR 2.

Catches of red gurnard in the target fishery in statistical area 15 in Cook Strait are often very high and are highly variable. This pattern is confirmed from FSU data before to 1989–90, and could be a function of weather and sea conditions allowing only occasional fishing or fishing by larger vessels with heavy gear. Data from the Cook Strait areas were excluded from datasets for CPUE analysis.

3.3.1 Red gurnard CPUE in the GUR 2 target fishery

The final data set included records from statistical areas 11–14 targeted at red gurnard, from vessels that had participated in the GUR 2 target fishery for at least 10 days in at least 3 years. The final data set included a total of 13 542 days fishing and a total red gurnard catch of 2754 t (Table 41). The core fleet comprised between 19 and 33 vessels, and recorded a catch of red gurnard on 500 to 1500 days annually.

The lognormal model accounted for 42 % of the observed variance in the red gurnard catch per day. Duration was selected as the most informative measure of effort. Associated catch of tarakihi, vessel, month, and flatfish catch were also significant. The order in which variables were selected and their cumulative effect on model R^2 is given in Table 42.

The pattern of the residuals suggests a good fit to the model that is adequate for most of the observations. The model does well at capturing the very high values but overestimates the very small catches. The precision of the annual indices is very good, and the pattern is of a gradual decline since 1989–90, except for a three-year hump from 1995–96 to 1997–98, and an increase in 2000–01 (Figure 28).

The relationships between catch per day of red gurnard and the significant explanatory variables are shown in Figure 29. The catch of red gurnard increased linear relationship with total tow duration to a maximum of about 18 hours, above which there were too few values (Figure 30) for the polynomial to be well determined. Red gurnard catch is predicted to increase with increased flatfish catch, and to decline with greater tarakihi catch over the range of catches that are best represented in the data (Figure 30).

The monthly indices show a slight increase in abundance in spring and early summer.

There was no evidence of potentially confounding changes in the distribution of significant variables over the time series (Figure 30), though there was evidence of significant vessel:year interaction effects in an alternative model, not pursued further.

The effect of standardisation on the arithmetic CPUE was to steepen the decline in the series (Figure 31). Coefficients from the model and the canonical indices are given in Table 43.

3.3.2 Red gurnard CPUE in the FLA 2 target fishery

The final data set used in the CPUE model of gurnard bycatch in FLA 2 included records from statistical areas 11–14, targeted at flatfish, from vessels that had participated in the flatfish target fishery for at least 10 days in at least three years. It included 6904 days fishing and a total red gurnard catch of 540 t. The core fleet comprised between 9–19 vessels, and recorded a catch of red gurnard on about 150–1000 days annually (Table 44).

The lognormal model accounted for 42% of the observed variance in the red gurnard catch per day. The categorical variable "vessel" was selected in preference to the suite of vessel descriptors available, with duration selected as an additional measure of effort. Associated catch of tarakihi and month were significant factors, as was the associated catch of flatfish. The order in which variables were selected and their cumulative effect on model R^2 is given in Table 45.

The fit to the model appears adequate for most of observations though it does not capture the extreme low values of CPUE. The annual indices have fluctuated widely in what may be a cyclical fashion, with directions of change often being maintained over three or four years. There was an increase over three years to a pronounced peak in 1994–95, and a subsequent decline over three years to a low in 1997–98. The index then remained at about that level for the three years to 2000–01 (Figure 32). Precision of the indices is good and these features represent significant changes in availability.

The relationships between catch of red gurnard and explanatory variables are shown in Figure 33. The catch of gurnard is predicted to increase with duration up to about hours, above which there were too few records for the polynomial to be well determined. The catch of gurnard is predicted to increase with the catch of tarakihi over the range most represented in the dataset, and to decline with increased catches of flatfish. This makes sense as flatfish are most abundant well below the optimum depth for gurnard, and the inclusion of tarakihi in a catch would indicate a deeper tow. A strong seasonal pattern is evident, with greatest catches in September to November, and a small peak in May.

In the distribution of significant variables (Figure 34), a decline in larger flatfish catches over the time series is evident, and longer tow duration and greater catches of tarakihi are both features of the period 1994–95 to 1997–98, when effort in this fishery increased dramatically (see Section3.2.7).

Standardisation markedly changed the shape of the series of arithmetic CPUE. The effect was to accentuate a peak in 1994–95 and a low in 1997–98, neither of which were evident in the raw CPUE (Figure 35). Coefficients from the model and canonical indices are given in Table 46.

3.3.3 Red gurnard CPUE in the TAR 2 target fishery

The final data set included records from statistical areas 11–14 targeted at tarakihi, from vessels that had participated in the TAR 2 target fishery for at least 10 days in at least 3 years. The final data set included a total of 7015 days fishing and a total red gurnard catch of 749 t (Table 47). The core fleet comprised between 17 and 31 vessels annually, and recorded a catch of red gurnard on 400 to 700 days annually.

The lognormal model accounted for 28% of the observed variance in the red gurnard catch per day. vessel, month, and statistical area were significant, and number of tows was selected as the more informative measure of effort. The associated catch of tarakihi and of snapper both had significant explanatory power. The order in which variables were selected and their cumulative effect on model R^2 is given in Table 48.

The fit to the model is very good for most of the observations, although it doesn't estimate the very extreme low catches. The indices show a four-year decline at the beginning of the series after which the trajectory is almost perfectly flat except for a dip in 1999–2000. The precision of the indices indicates that differences among years are insignificant (Figure 36).

The catch of red gurnard is predicted to increase with the number of tows in a day, the seasonal pattern predicts catches to be smaller in April, May, and June, and greater in summer (November–January). Catches among statistical areas are predicted to increase the further south the area, and to increase with greater catches of snapper, to a point, above which there were too few data for the polynomial to be well determnined, and generally to decline as tarakihi catches increase (Figure 37). This makes sense as tarakihi is most abundant at much greater depths than the optimum for gurnard, and the inclusion of snapper in a catch might indicate a shallower tow.

Distributions of significant variables are shown in Figure 38. There was a tendency over the period towards more tows per day, and towards greater catches of snapper.

The effect of standardisation on arithmetic CPUE was very small; it showed a dip in 1999–2000 that wasn't obvious in the raw CPUE, but made no other notable difference to the series (Figure 39). Coefficients from the model and canonical indices are given in Table 49.

3.4 Trawl surveys

A series of bottom trawl surveys of inshore waters of the east coast North Island (ECNI) were carried out during the 1990s by R.V. *Kaharoa,* primarily aimed at estimating the relative abundance of

snapper, tarakihi, and trevally. Data from those surveys were examined by Hanchet et al. (2000) for applicability to red gurnard. They noted marked between-year variation, with no strong upward or downward trend over time. The trawl survey series of abundance indices considered by the Inshore Working Group to be too short and erratic to adequately monitor abundance of red gurnard

The series employed a 100 mm mesh codend and caught very few small fish. Based on gear selectivity studies by Massey (1988) for 100 mm mesh, trawl survey vulnerability and fishing selectivity ogives were calculated to be 0.35 for age 2 and 0.6–0.7 for age 3 ECNI red gurnard. Very few 1 year old fish were caught, so that recruitment and proportion-at-age were not calculable.

The four surveys, in 1993 to 1996, were generally carried out in February–March of each year, though the 1993 survey occurred in March–April. Data from the four surveys were re-examined for contrast in size and sex ratios, and it was common for red gurnard caught in a tow to be predominantly of one sex, and, within a survey, for that pattern to be consistent over large areas across depth strata, but no pattern was consistent among years.

Biological samples (reproductive stage) were not generally collected for red gurnard.

Length distributions of male and female red gurnard from the four surveys, for three depth bins, are shown in Figure 40. The three depth bins (0–50 m, 50–100 m, over 100 m) correspond approximately to the preferred depth ranges of flatfish, red gurnard, and tarakihi respectively. Although small red gurnard were not well retained in these surveys, it is clear that larger red gurnard dominated the catch in tows deeper than 100 m, and smaller red gurnard were best represented in tows carried out in less than 50 m depth.

3.5 Operator interviews

Notes from interviews of participants in the inshore trawl fishery of QMA 2 are included here relatively unedited. They were conducted before results of the characterisation were available and are therefore a collection of candid observations on the performance of the various fisheries and factors that might affect them.

3.5.1 Mike Claudatos, Director, Star Fish Supply Ltd, Interviewed on 19/6/2002

Star Fish Supply contract two vessels to fish for them, one 18.5 m long and the other 12 m. Both vessels bottom trawl to target red gurnard, tarakihi, or flatfish, and catch red gurnard as their target species or as bycatch while targeting flatfish or tarakihi.

Red gurnard is caught over mudflats from Gisborne to Porangahau. Some good areas for red gurnard are: Tunnels, Hawke Bay, Broken Hills (to the south of Cape Kidnappers), and Porangahau. Generally, only the smaller vessels fish within Hawke Bay.

Skippers trawl on known lines in known depth ranges, but the skippers do watch their sounders. The sounders are not used to the same extent as in the deep-water fisheries; the fished areas are known well.

Red gurnard is caught from the beach to 80 fathoms (150 m) and tarakihi is caught between 100 and 300 metres.

2001 was a big year for red gurnard, but the current fishing year (2001-02) is not so good. It is unlikely that red gurnard would not be among the top five species for a trawl.

Tarakihi maintain a constant distribution, but red gurnard vary depending on the weather patterns. The water clarity affects the abundance of red gurnard, if the water is too clear or too dirty (from a large swell) then less red gurnard will be caught.

The amount of snapper quota available limits the red gurnard catch. To avoid snapper bycatch, Star Fish Supply vessels move to other areas where they catch less snapper. The bycatch trade off provision in the previous management regime was more flexible than the current Actual Catch Entitlement (ACE) regime. There is now a penalty for overcatching your available ACE, and the more they overcatch, the more they will have to pay in penalties. In general, vessels now either have to move to another area where they won't catch the limiting species or discard that species.

The QMS has been good for all of the inshore fisheries. Initially there were large decreases in quota; in 1986, snapper was reduced 57%, tarakihi was reduced 19%. Over the 16 years since these cuts, the fisheries have rebuilt. Snapper TACC was increased in 1992 but could not be targeted unless you had enough quota (Sanfords was the only company allowed to target snapper). TACC's will not be increased except by Adaptive Management Programmes (AMPs) as the required research is too expensive relative to the value of the fisheries. AMPs were set up for stargazer and rig, but these did not work well as they are bycatch species and have since been dropped from the programme.

Danish seine and pair trawling methods were prohibited from East Cape to Cape Turnagain, but recently Danish seine was allowed back in and now there are some boats using this method and fishing this area for Moana Pacific. Mike is unsure how they were allowed to renter this fishery. These vessels are based in Gisborne or Tauranga, and make trips down into Hawke Bay occasionally.

3.5.2 Anonymous, interviewed on 20/6/2002

This skipper preferred to remain anonymous. He has been involved in the QMA 2 inshore fishery for several decades, although he has been fishing for part of the year for orange roughy in the last few years.

When fishing the QMA 2 inshore trawl fishery, he uses a wingtrawl net with 15 m wingspread and 3 m headline height. A trip usually lasts one day unless he is fishing further to the north during the summer.

He mainly targets tarakihi between Cape Runaway and Portland Island and mainly within statistical area 013, and usually tarakihi provides two-thirds of his catches. Red gurnard, snapper, hapuku, and flatfish are the major bycatch species. He lands at least 15 species per trip, not including discarded species.

He targets tarakihi on traditional grounds but considers the season, water clarity, wind, and sea conditions when deciding where to fish. Better catches of tarakihi occur as the dirty water clears after a southerly swell. Catches of red gurnard and snapper are bigger in the summer months and tarakihi catches are better in the summer towards East Cape and in the winter closer to Gisborne.

This skipper believes that the state of the tarakihi and snapper stocks are okay, but that the flatfish and red gurnard are in decline as there is no breeding stock for either species. He believes that the following stocks are threatened: flatfish (most threatened), red gurnard, blue moki, trevally, hapuku, gemfish, red cod (least threatened).

The fish stocks have declined since the 1960s and 1970s, and although the QMS system has helped tarakihi, this skipper believes that the biomass is now much lower. Catch rates are misleading in more recent years as the tarakihi has begun schooling more, resulting in higher catch rates. Before the 1980s this skipper used to target flatfish and red gurnard during the summer, but doesn't anymore due to the state of these fish stocks.

More trawls lately where red gurnard is not in the top five species caught but this is while targeting tarakihi.

More vessels have moved to the inshore trawl fishery recently due to the decline of the orange roughy fishery. This is lowering the amount of quota available per vessel.

The companies fishing plan is to limit the amount of tarakihi catch allowed per vessel per trip. Once this is caught the vessel will target another species. In the current fishing year they are running out of tarakihi quota and have to stop fishing earlier than normal and have a holiday.

Most fish caught in the inshore trawl fishery are marketed locally.

High percentages of tarakihi caught now seem to be in the 30–35 cm range. Lately the red gurnard caught have been mainly big fish.

There were good catches of trevally a couple of years ago but there has not been much since; this skipper caught only 3 kg in his last trip.

3.5.3 Alan Martin, Fisheries Manager, Gisborne Fisheries, Interviewed on 20/6/2002

Gisborne Fisheries owns two trawlers, *Hakuwai*, skippered by Terry Zame, and the *Bartolo*, skippered by Ian Dudley. A third vessel, the *Thelma G*, owned and operated by Pacific Trawling, is contracted to supply fish to Gisborne Fisheries.

Tarakihi provides the mainstay for Gisborne Fisheries: their boats target tarakihi earlier in each trip and target red gurnard later. Both vessels do short trips, one or two trips per week.

Gisborne Fisheries sells red gurnard on the local market, from Wanganui to Auckland, and they can not keep up with the demand. They have a wide size range of red gurnard, but the very small red gurnard are not wanted on the market. The only size grading occurs when these very small red gurnard are removed and sold for bait or to the staff. In one recent trip 5% of the catch was removed for bait. Bait fish is sold fresh or frozen to the rock lobster fishers or local recreational fishers. Often this "bait" fish is sold to the Gisborne Fisheries' staff.

3.5.4 Terry Zame, Skipper of Hakuwai, Fisheries Manager, Gisborne Fisheries, Interviewed on 20/6/2002

Terry Zame skippers the *Hakuwai*, a 16 m trawler and targets either red gurnard or tarakihi. He targets red gurnard between 15 and 30 fathoms (27 and 55 m) and the major bycatch species are tarakihi and snapper. Trevally used to be a major bycatch, but this is not the case in more recent years.

Terry fishes the area from Table Cape to East Cape, and the red gurnard fishery seems to be improving on the whole, but can be somewhat unpredictable. The fisheries for snapper and tarakihi are very healthy.

His tarakihi target fishing is limited by quota availability. Red gurnard fishing is better from September until the end of summer.

A net with a low headline height (1.8 m, wingspread of 12 m) is used to minimise the bycatch of tarakihi and snapper while fishing for red gurnard. Snapper is usually higher off the bottom than red gurnard.

Terry fishes traditional fishing grounds, but will use his echo sounder to locate feedmarks.

Gisborne and Tolaga Bay fishing grounds tend to have a higher proportion of red gurnard and lower proportions of snapper and tarakihi.

Sea swell conditions affect the efficiency of the fishing gear: the more swell the less efficient the gear and the catches are lower

3.5.5 Terry Gittings, manager –(Napier), Moana Pacific, Interviewed on 19/6/2002

Moana Pacific owns 167 t of the total 725 t of QMA 2 red gurnard quota and 11 vessels that operate from Napier and Gisborne. They caught 259 t of red gurnard in the 2000–01 fishing year and have currently caught 174 t during the 2001–02 fishing year.

Their vessels mainly target red gurnard and catch snapper, flatfish, trevally, and tarakihi as bycatch. Tarakihi is so healthy it is almost a plague. The available ACE for snapper, trevally, and rig limits the red gurnard catch. In particular, the snapper quota is regularly overcaught. Terry believes that the ACE needs to be increased for the bycatch species, particularly snapper and rig, in order to be able to catch the entire red gurnard quota.

Moana Pacific's vessels trawl in traditional fishing grounds rather than targeting marks from their echosounder. Their preferred traditional fishing ground is the source of a lot of bycatch. However ,other areas such as Riversdale and Porangahau have less snapper.

Better fishing occurs in November and December, and in El Niño conditions the northern end of Hawke Bay and the Wairarapa coast provide better catches. Porangahau used to be a good area but fishing in this area is dependent on calm sea conditions, which have not been common in the past 3 years. At present, the Riversdale area is fished by larger vessels (about 18.5 m).

In the past, the shortage of snapper quota was dealt with by the use of the bycatch trade off provision, 2.5t of red gurnard quota could be traded for 1t of snapper quota. The introduction of the ACE system (enactment of the 1996 Fisheries Management Act) has meant that this bycatch trade provision is no longer possible.

The new technology has not greatly changed the performance of the fishery, but does help the fishers to pinpoint the fish. Moana Pacific vessels use nets with 13 cm mesh with a door spread of 77 m in depths about 100 m.

Red gurnard from QMA 2 is mainly sold on the local market and some from QMA 1 is exported.

The mixed fishery within QMA 2 on the whole has improved, including red gurnard, despite lower annual catches. Skippers believe that Cyclone Bola did a lot of damage to the mixed fishery. It is difficult to catch flatfish when there is a swell; years with El Niño conditions produce the best fishing for flatfish. Best fishing for the mixed fishery occurs when the wind is blowing from the northwest.

3.5.6 Chris Robinson, Managing Director, Pacific Trawling, interviewed on 20/6/2002

Pacific Trawling operates four vessels, ranging from 18 to 40 m in overall length and each vessel has a different fishing plan.

- 40 m long, catches gemfish, rubyfish, alfonsino, bluenose, and orange roughy, fishes around the Chatham Islands.
- 29 m long, targets the inshore fishery and warehou, at Wellington and the Chatham Islands, but sometimes fishes for red gurnard.
- 25 m long, mostly catches tarakihi but also targets red gurnard, gemfish, and hoki,
- *Thelma G*, 18 m long, catches red gurnard, tarakihi, and snapper in QMA 2.

Thelma G fishes the inshore trawl fishery within QMA 2, mainly in Hawke Bay, south to Porangahau, and north to Gisborne. *Thelma G* targets the mixed inshore fishery, the declared target species depends on the depth fished, using a net with a 5 m headline height that is designed and built by Pacific Trawling.

Red gurnard fluctuates: 2000–01 was good (more concentrated) but appears to be less this year although catches are higher. This change is probably related to the weather. It is unlikely that red gurnard would not be among the top five species for a trawl. The depth range for red gurnard is from the beach to 100 m. When red gurnard is targeted, tarakihi, snapper, trevally, moki, rig, and school shark are caught as bycatch.

Tarakihi is found from the beach to 300 m deep, but most tarakihi is caught between 70 and 200 m deep. Tarakihi is increasing in abundance.

The snapper population is either recovering, or more likely the distribution is changing with the increasing sea surface temperature. Pacific Trawling bought quota to cover the snapper bycatch in this mixed fishery, although when they put a second vessel on this fishery they will try to avoid snapper.

Trevally is erratic, catches can be high although it is not targeted at all. Pacific Trawling has had to deem a lot of its trevally catch. Along with rig and school shark, trevally is a problem with the level of TACC.

Pacific Trawling sells its fish to a processor, who will reject very small red gurnard. However there is no minimum legal size (MLS) on red gurnard, Chris thinks that there should be MLS on all species or on none. Most species caught by the inshore trawl fishery in QMA 2 are sold on the local market.

The more southern areas in QMA 2, such as Porangahau, are affected by southerly winds, as small vessels have trouble fishing in the resultant swell which causes the gear to pulse. Larger boats can use heavier gear and therefore have less trouble in larger swells.

There are several ways to increase the catch of red gurnard by changing the net design. The size of mesh has a big effect on the composition of the catch. Pacific Trawling currently uses 30 cm mesh, but if the size of the mesh was reduced to 23 cm the catch of red gurnard would increase by 75%, reducing the mesh to 15 cm would increase the catch by 100%.

Longer sweeps and bridles will also increase the catch of red gurnard as you would have a greater spread. However, as it is uneconomic to catch one species and because they have a wide quota portfolio, Pacific Trawling uses a general net and gear configuration.

There are many similar vessels in GUR 1 with similar fishing gear, whereas in GUR 2 there can be large differences between boats this will affect CPUE analyses. Gear can be a huge factor, one boat can catch five times as much as an adjacent boat. In order to have a good indication of true CPUE, you would need to have similar vessels using effective gear.

GUR 2 is a relatively healthy fishery, with the catches fluctuating on natural cycles, but the TACC could be too high especially for the bycatch species. The TACC for tarakihi limits this fishery; processors have put limits on the amount of tarakihi that can be caught, as they are careful not to flood the market. Pacific Trawling directs its vessels to catch a mixture of species to control income and balance quota.

The bycatch species that cause the most trouble are trevally, rig, and school shark, due to the TACC level. Chris believes that these species are often discarded, but Pacific Trawling will pay for the fish from their vessels even if they don't have quota to cover it (most companies don't do this).

4. DISCUSSION

The inshore trawl fishery in QMA 2 is a true mixed fishery, unavoidably landing a wide range of valuable species that may co-exist in assemblages, but at present are managed individually. Fishers do target individual species and can reduce bycatch to some extent, but companies tend to hold quota for

the mix of species caught and catching the available quota on any one species can widely constrain or effect fishing effort.

The TACC for GUR 2 has never been met, but fishers consider this an effect more of mesh size (the shape of gurnard ensures relatively high escapement from larger meshes), gear types, and fishing behaviour than availability. Although red gurnard can be effectively targeted, *it is a low value species* at present, and there is no incentive to do so. It is not considered financially viable by operators to target and land gurnard exclusive of higher value associated species. Catch of GUR 2 is constrained primarily by quota availability of snapper and tarakihi, and to a lesser extent trevally, rig, and school shark.

Snapper catch has exceeded TACC in every year since introduction of the QMS. Tarakihi and trevally TACCs are both constrained by TACC, exceeding it occasionally, whereas neither flatfish nor gurnard catch in area 2 has yet reached TACC levels.

Effort is targeted at flatfish and gurnard all year round, at snapper primarily from March to April, at tarakihi mainly in October and November, and at trevally sporadically through the first 8 months of the year, with little targeting towards the end of the fishing year.

Red gurnard is caught in most bottom trawl tows across a wide range of depths fished and species targeted. In the GUR 2 target fishery, gurnard is caught mainly in association with snapper, tarakihi, barracouta, trevally, and flatfish, and is an important bycatch in fisheries targeted on those species.

Gurnard and trevally share a very similar distribution with depth and with season, and it is in the trevally target fishery that the highest catch rates (over 100 kg per tow on average) and encounter rates (proportion of tows in which gurnard is reported among the top five species) for gurnard are seen. Annual average catch rate in tows targeted at snapper (which has a shallower preferred depth range) has varied between 80 and 25 kg per tow. Catch rates are much lower (about 20 kg per tow) in tows targeted at flatfish and at tarakihi, for which the preferred depths are in the shallower and deeper tails of the gurnard depth range respectively.

The encounter rate is, on average, over 80% in the flatfish, snapper and tarakihi target fisheries, and considerably lower (about 45%) in the tarakihi target fishery. Catch rates for gurnard have declined since 1989–90 in the target fishery, and in the snapper and trevally target fisheries. Encounter rates have also declined in the flatfish, snapper, and, recently, in the trevally target fisheries, although this is relative to other species, and could therefore, just as possibly, be the result of relative increases in abundance of other species as of a decline in abundance of gurnard.

Gurnard is generally most abundant in spring and early summer, when females are thought to migrate to join resident males on spawning grounds. Availability is lowest in winter when females may emigrate back to shallower water after an extended spawning season. This seasonal pattern of relative abundance of gurnard is most pronounced in SNA 2 and FLA 2. The features of highest and lowest availability of gurnard also occur a month or two earlier in those fisheries than in TAR 2. The least seasonal contrast is seen in the GUR 2 target fishery. There is no indication that any of these fisheries respond to the availability of red gurnard.

Monitoring abundance of GUR 2 by changes in CPUE may be confounded by differences in gear used in QMA 2, particularly mesh size which is subject to a voluntary agreement in this QMA, and also by bias introduced by occasionally high catch rates in those southern areas that can be fished only irregularly by smaller vessels.

Much of the fishing targeted on associated species, snapper, and trevally, is sporadic and the lack of a dedicated core fleet of vessels suggests much of the effort (or choice of target) may be opportunistic rather than true targeting. Catch rates of red gurnard in tows targeted at trevally are high compared with other target fisheries. One reason may be that trevally and tarakihi are the targets of choice at the

start of the fishing year when red gurnard is most abundant. Red gurnard catch is also generally overestimated in the trevally fishery.

Most red gurnard is taken in the target fishery (in contrast to previous reports), and the GUR 2 data set is adequate for CPUE analysis. Other possibly adequate datasets include the (shallower) flatfish target fishery and the (deeper) tarakihi target fishery, with the following reservations.

1. The season of highest abundance for red gurnard is September to November, but at the end of the fishing year the fishery is often constrained by the TACC of associated species, and at the beginning of the fishing year effort is directed towards more valuable species, so that the target red gurnard fishery is not directed at the period of greatest abundance.

2. The second most important fishery landing red gurnard, TAR 2, lands significant amounts of red gurnard largely as a function of its size. In fact, it samples only one tail of the red gurnard depth distribution, and seasonal trends in catch rate and model results both confirm an inverse relationship between abundance of the two species. Red gurnard is not always in the top five species in tows targeted at tarakihi, the encounter rates and the reporting rates are low, and the catch rate in successful tows is low.

3. FLA 2 appears to be a more similar fishery to GUR 2, though species composition and catch rates imply that they are distinctly different. The difference between the flatfish and red gurnard target fisheries is indicated by the importance of red cod in flatfish tows, a species that doesn't feature predominantly in GUR 2 tows. The difference in parameterisation between the two models also distinguishes them. Effort has shifted markedly between the two target fisheries over time, which could confound CPUE indices of abundance if not implicitly allowed for. This fishery also suffers from a lack of attention at the end of the fishing year, and thus misses the peak of abundance of red gurnard

These three fisheries are all very different in nature, as seen in the different parameterisation of the respective CPUE models. The species composition of their catches also distinguishes them, and the average catch rate of red gurnard varies markedly among them, consistent with the respective depth preference of the target species. It is possible that each fishery exploits a different age-sex component of the red gurnard population. There may be progressive exploitation of those age-sex components as they mature and become vulnerable to deeper tows. The distinct highs and lows of red gurnard abundance that are seen in the shallower flatfish fishery, can also be seen in subsequent years in the deeper red gurnard and tarakihi fisheries, though blurred by differences in growth rates and migrational behaviour between the sexes (Figure 41).

Little is known about the spawning and migrational behaviour of red gurnard on the east coast of the North Island, as that would require monitoring the catch rates of each reproductive stage at a fairly intensive spatial and temporal scale. It is likely, however, that the size and age distribution of red gurnard vary as markedly with depth and season on this coast as they do in the Hauraki Gulf. For these reasons, the data from the chosen target fisheries have not been combined. The pattern of annual indices in the flatfish fishery is of large, possibly cyclical, differences, the pattern in the red gurnard target fishery is one of gradual decline, and in the tarakihi fishery the trajectory is flat.

Red gurnard is a fast growing species that is unlikely to enjoy constant recruitment. Year class strength may vary significantly, but is difficult to assess in commercial catches because of the differing growth rates and depth distributions of the sexes. Recruitment variation is more likely to be seen in the CPUE index from the flatfish target fishery than in others, as it operates in shallower waters, where red gurnard are likely to be younger and more predominantly of one sex (female) and age group.

The series calculated from the tarakihi target fishery shows very little fluctuation from year to year, and no trend. This is not surprising as the fishery operates on the deeper edge of the depth distribution of red gurnard, presumably sampling mostly older fish. Catch rates of red gurnard in this fishery are

small, and the fishery accounts for a large proportion of the annual catch of red gurnard mainly as a function of its extensive coverage.

The red gurnard target fishery best samples the depth range of red gurnard, and is not concentrated on the peak of spawning or migration activity, it should therefore sample a largely resident population of older fish. In the CPUE indices from this fishery, it might be expected that different year class strengths would be smoothed out by the different growth rates of the sexes and the one-year age difference at which they recruit to the trawling-spawning grounds. Gear changes among vessels, in particular, different codend mesh sizes are likely to have added noise to the series, and significant vessel-year interaction terms in an alternative model gave evidence of this, but the precision of the annual indices suggest that this series does monitor abundance of red gurnard.

Improvements on previous CPUE analyses for this stock include: the focus on an adequate target fishery, with records of associated target fisheries examined separately for confirmation of patterns, the use of records from a core fleet of vessels with a history of participation in the fishery, the inclusion of an additional effort variable (number of tows or tow duration) in the model of catch per day, the inclusion of the catch of associated species as explanatory variables in models of red gurnard catch, the exclusion of zero catches, and therefore of the difficulties in modelling them from the data set, and the exclusion of statistical areas 15 and 16, which are subject to additional bias due to weather extremes.

Genuine non-reporting (only the top five species are recorded on TCEPR and CELR forms) is problematical for monitoring individual fish species. Red gurnard is a well-reported species however, it is mostly taken (by the inshore trawl fleet) in targeted fishing, but even as a bycatch, it is generally among the top five species caught. CPUE indices of abundance based on estimated catch in the target fishery appear to be an adequate method for monitoring the status of the stock. Other predominantly bycatch species in this mixed fishery may best be monitored using CPUE calculated from actual landings. Further development of a series of abundance indices for red gurnard requires better understanding of the age-sex stratification of the species and eventually monitoring within a defined area/depth/season window that is not currently possible using data collected on CELRs.

5. RECOMMENDATIONS

The CPUE index of abundance based on the target red gurnard fishery in the inshore statistical areas 11 to 14 should continue to be monitored and further developed, perhaps based on a core fleet of vessels that can show a history of similar codend mesh sizes, or at least no change in codend mesh size. Alternatively, a logbook maintained on selected vessels and within selected depth ranges might offer a viable alternative to a targeted trawl survey. This might best be achieved by the introduction of TCEPR forms to vessels currently reporting on CELRs because of the potential importance of depth information.

Migrational behaviour, or at least sex-age distribution across depth and season should be established by catch sampling or by a dedicated trawl survey, and would be useful for refining a geographical-seasonal window in which to best monitor CPUE to obtain a representative index of abundance.

6. ACKNOWLEDGMENTS

Our thanks to Adam Langley for advice and useful comments on previous versions of this manuscript. Many thanks to Nokome Bentley for technical support. This work was funded by the Ministry of Fisheries under Project GUR2001/01.

7. REFERENCES

Anderson, O.F.; Bagley, N.W.; Hurst, R.J.; Francis, M.P.; Clark, M.R.; McMillan, P.J. (1998) Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report 42.* 303 p.

Annala, J.H.; Sullivan, K.J.; O'Brien, C.J.; Smith, N.W.McL.; Varian, S.J.A (comps.) (2002) Report from the Fishery Assessment Plenary, May 2002: stock assessments and yield estimates. 640 p. (Unpublished report held in NIWA library, Wellington.)

Blackwell, R. (1988). Red gurnard. New Zealand Fisheries Assessment Research Document 88/23. 18 p. (Unpublished report held in NIWA library, Wellington.)

Elder, R.D. (1976). Studies on age and growth, reproduction, and population dynamics of red gurnard, Chelidonichthys kumu (Lesson and Garnot), in the Hauraki Gulf, New Zealand. *Fisheries Research Bulletin No. 12.* 77 p.

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

Francis, M.P.; Hurst, R.J.; McArdle, B.H.; Bagley, N. W.; Anderson, O. F. (2002) New Zealand demersal fish assemblages. *Environmental Biology of Fishes 65:* 215–274.

Hanchett, S.M.; Coburn, R.P.; Field, K.D.; Horn, P.L.; Ó Maolagáin, C.; Paul, L.J.; Stevenson, M.L. (2000). Assessment of red gurnard (*Cheliodonichthys kumu*) stocks GUR 1 and GUR 2. *New Zealand Fisheries Assessment Report 2000/40.* 51 p.

Kendrick, T.H.; Francis, M.P. (2002) Fish assemblages in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research 36:* 699–717.

Massey. B.R. 1988: Trawl mesh selection of some important commercial species in New Zealand. *New Zealand Journal of Marine and Freshwater Research 22:* 75–84.

MFish (2002). Research Data Management Group: catch effort reference library Version 1.0 – July 2002. Available on compact disc from Ministry of Fisheries, Wellington.

Okada, Y. (1966). Fishes of Japan. Uno Shoten Co., Toyko. 458 p.

Scott, T.D. (1962). The marine and fresh water fishes of South Australia. Government Printer, Adelaide. 338pp.

SeaFIC (2002). Report to the Adaptive Mangement Programme Fishery Assessment Working Group. Analysis of catch and effort data from the GUR 3 trawl fishery, 1989/90 to 2000/01 (dated 19 February 2002). Copies held by MFish.

Smith, J.L.B. (1953). The sea fishes of Southern Africa. 2nd ed. Central News Agency, South Africa. 564 p.

Staples, D.J. (1972) Growth of red gurnard (Teleostei: Triglidae) from Pegasus Bay, Canterbury, New Zealand. *New Zealand Journal of Marine and Freshwater Research 6(3):* 365–374.

Sutton, C.P. (1997). Growth parameters and estimates of mortality for red gurnard (Chelidonichthys kumu) from the east and west coasts of the South Island. New Zealand Fisheries Assessment Research Document 97/1. (Unpublished report held in NIWA library, Wellington.)

Table 1: Representation of FSU–collected data by fishing year. Total landings of GUR 2 (Annala et al. 2002), FSU-collected estimated catch (areas 11 to 16) with associated effort information, FSU-collected catch as percent of total landings. The years used in subsequent descriptive analysis are in bold.

Fishing year	Landings (t)	Estimated catch w/effort	% reported
1982–83	–	253	–
1983–84	**782**	**443**	**57**
1984–85	**665**	**422**	**63**
1985–86	**495**	**412**	**83**
1986–87	**592**	**363**	**61**
1987–88	596	225	38
1988–89	536	81	15
1989–90	451	0	0

Table 2: Percentage of the total red gurnard catch from 1983–84 to 1986–87 in statistical areas 11 to 16 by fishing method.

Statistical area	11	12	13	14	15	16
Bottom trawl	98	98	98	96	100	99
Set Nets/gill nets	1	2	1	3	0	1
Bottom Longline	1	0	0	1	–	0

Table 3: Landings and reporting rates for red gurnard in QMA2 inshore trawl fisheries. Total QMR landings (Annala et al. 2002), actual landings of GUR 2 reported by the inshore trawl fleet, The percentage of landings by reporting form type, estimated catch as a percentage of landings, and as a percentage of QMR totals which includes landings by larger vessels and other methods.

Fishing	QMR	Landings	%	%	Estimated catch	
year	(t)	(t)	CEL	CLR	% of landings	% of QMR
1989–90	451	344	100	0	96.6	73.7
1990–91	490	463	96	4	99.6	94.1
1991–92	663	617	92	8	95.3	88.7
1992–93	618	593	95	5	94.8	91.0
1993–94	635	603	85	15	94.6	89.8
1994–95	559	519	84	16	91.2	84.7
1995–96	567	514	81	19	92.8	84.1
1996–97	503	446	88	12	94.7	84.0
1997–98	482	434	90	10	95.1	85.7
1998–99	469	411	89	11	93.3	81.8
1999–00	521	464	95	5	87.0	77.5
2000–01	623	494	87	13	95.5	75.8

Table 4: Reporting rates for the main species, by target species and statistical area 1989–90 to 2000–01, landings (t), and estimated catch as a percentage of landings. This was calculated only where landings greater than 1 t, and one target species, method and statistical area recorded for entire fishing trip.

		Landings (t)					Estimated as % of landings				
Target	Stat. area	GUR	SNA	TAR	TRE	FLA	GUR	SNA	TAR	TRE	FLA
GUR	11	1	1	1	0	0	27	–	–	–	–
	12	34	15	52	17	2	94	84	93	79	41
	13	1442	379	250	228	487	95	87	71	79	81
	14	407	49	76	50	146	95	83	76	71	78
	15	23	1	4	8	3	98	98	80	99	71
	16	12	0	3	3	8	89	–	84	85	80
	18	21	0	2	0	7	93	–	45	–	99
SNA	11	2	12	1	3	0	100	77	–	92	–
	12	6	15	6	5	0	87	94	80	34	–
	13	26	43	9	13	3	87	100	76	79	64
	14	1	0	0	0	0	–	–	–	–	–
	15	1	0	2	1	0	–	–	34	89	–
	16	0	3	0	0	1	–	101	–	–	–
	18	0	0	0	0	0	–	–	–	–	–
TAR	11	6	18	286	7	0	63	76	89	58	–
	12	76	104	1216	29	2	84	82	91	83	33
	13	264	255	2670	182	16	75	80	92	66	43
	14	42	4	332	29	2	83	50	94	72	26
	15	8	0	188	5	1	71	–	92	94	–
	16	12	4	497	14	9	85	71	99	74	53
	18	6	0	217	0	8	65	–	96	–	26
TRE	12	0	0	0	1	0	–	–	–	–	–
	13	37	58	7	92	6	93	94	58	98	56
	14	8	3	3	26	0	84	100	101	93	–
	15	1	0	0	1	0	–	–	–	–	–
	16	2	0	2	10	0	117	–	88	111	–
	18	1	0	3	6	0	–	–	29	139	–
FLA	11	0	0	0	0	0	–	–	–	–	–
	12	2	0	0	0	10	94	–	–	–	91
	13	489	66	20	61	1414	95	82	81	88	88
	14	130	13	5	9	532	94	83	77	66	85
	15	0	0	0	0	0	–	–	–	–	–
	16	15	0	1	1	49	95	–	–	–	84
	18	24	0	13	0	108	100	–	56	–	88
	19	0	0	0	0	0	–	–	–	–	–
OTH	12	1	2	12	1	0	39	43	47	–	–
	13	73	30	149	40	14	79	57	67	54	87
	14	45	6	116	21	4	77	65	77	76	42
	15	2	0	6	0	0	38	–	84	–	–
	16	7	2	21	3	5	102	78	88	83	57
	18	104	0	148	0	91	99	–	93	–	82
	19	0	0	0	0	2	–	–	–	–	64

Table 5: Landings (t) 1989–90 to 2000–01 of QMA 2 and QMA 3 fishstocks, by species, from trips that fished straddle areas (17–19) (A), and QMA 3 fishstocks (as percentage of QMA 2 fishstocks) in data selected from trips that fished straddle areas (17–19), and landed QMA 2 fishstocks (B).

	A (t)		B (%)
Area 17	QMA 2	QMA 3	QMA 3
FLA	34.9	1.2	1
GUR	134.0	6.4	1
SNA	4.8	0.3	6
TAR	398.2	163.8	35
TRE	111.3	12.6	11
Area 18			
FLA	20.5	183.4	6
GUR	59.6	189.3	3
SNA	0.9	2.8	33
TAR	213.2	637.8	116
TRE	43.3	356.6	56
Area 19			
FLA	0.4	1.7	0
GUR	1.3	4.8	0
SNA	0.0	0.0	0
TAR	0.2	14.6	200
TRE	–	–	–

Table 6: Explanatory variables considered for inclusion in the models.

Variable	Data type	Description
GUR	Response variable	Estimated catch of red gurnard per day (kg)
Fyear	Categorical	Fishing year
Duration	Polynomial (3)	Hours towed
Effnum	Polynomial (3)	Number of tows
Vessel	Categorical	Unique vessel ID
Power	Polynomial (3)	Kilowatts
Olength	Polynomial (3)	Overall length of vessel
Tonnage	Polynomial (3)	Tonnage of vessel
Month	Categorical	Calendar month
Area	Categorical	Statistical area
Height	Polynomial (3)	Net height (m)
Width	Polynomial (3)	Net doorspread (m)
TAR	Polynomial (3)	Estimated catch of tarakihi
FLA	Polynomial (3)	Estimated catch of flatfish
SNA	Polynomial (3)	Estimated catch of snapper
RCO	Polynomial (3)	Estimated catch of red cod

Table 7: Percentage of annual red gurnard catch in the inshore bottom trawl fishery of FMA 2 by statistical area for four years before introduction of the QMS.

Statistical Area	1983–84	1984–85	1985–86	1986–87
11	2	3	2	2
12	9	7	11	12
13	57	66	61	68
14	19	19	20	16
15	11	1	2	0
16	2	3	4	1

Table 8: Red gurnard as a percentage of the annual catch, in the bottom trawl fishery in FMA 2, of the five species of interest, within statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	4	4	4	3
12	10	8	8	11
13	33	37	27	35
14	26	33	36	38
15	41	8	20	7
16	6	8	12	7

Table 9: Simple CPUE (kg/tow) for red gurnard in the inshore bottom trawl fishery of FMA 2 by statistical area, for four years before introduction of the QMS .

Statistical area	1983–84	1984–85	1985–86	1986–87
11	47	47	33	43
12	72	74	84	117
13	87	101	93	118
14	79	108	117	87
15	304	63	179	8
16	49	93	93	21

Table 10: Catch (t) of the five main species of interest in inshore bottom trawl tows in FMA 2, in statistical areas 11 to 16, for four years before introduction of the QMS.

	1983–84	1984–85	1985–86	1986–87
GUR	429	413	401	361
SNA	124	132	150	84
TAR	1 134	1 111	1 311	1 007
TRE	94	116	149	91
FLA	139	87	64	42

Table 11: Tarakihi catch as a percentage of the annual catch (of the five species of interest), in the inshore trawl fishery of FMA 2, within statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	88	88	89	92
12	77	79	77	80
13	42	37	53	46
14	46	36	28	39
15	47	86	71	91
16	88	91	83	91

Table 12: Simple CPUE (kg/tow) for tarakihi in the inshore bottom trawl fishery of FMA 2, by statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	253	312	338	469
12	294	339	447	433
13	165	155	243	185
14	148	189	153	137
15	164	206	243	101
16	204	309	200	172

Table 13: Snapper catch as a percentage of the annual catch (of the five species of interest) in the inshore trawl fishery of FMA 2, by statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	6	6	6	4
12	9	7	7	5
13	8	10	8	7
14	6	7	12	3
15	1	3	1	1
16	0	0	0	0

Table 14: Simple CPUE (kg/tow) for snapper in the inshore bottom trawl fishery of FMA 2, by statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	42	54	54	53
12	61	59	65	50
13	27	36	29	34
14	20	26	51	12
15	4	28	13	4
16	2	3	2	3

Table 15: Trevally catch as a percentage of the annual catch (of the five species of interest) in the inshore trawl fishery of FMA 2, by statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	2	1	1	2
12	4	6	7	4
13	4	6	7	8
14	10	18	16	8
15	8	2	8	1
16	4	0	4	1

Table 16: Simple CPUE (kg/tow) for trevally, in the inshore bottom trawl fishery of FMA 2, by statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	23	10	17	25
12	32	46	75	42
13	21	32	36	35
14	49	131	111	23
15	26	17	107	5
16	107	12	70	8

Table 17: Flatfish catch as a percentage of the annual catch (of the five species of interest) in the inshore trawl fishery of FMA 2, by statistical area, for four years before introduction of the QMS.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	0	0	0	0
12	0	0	0	0
13	13	10	5	3
14	12	6	8	12
15	3	0	1	0
16	2	1	1	0

Table 18: Simple CPUE (kg/tow) for flatfish, in the inshore trawl fishery of FMA 2 in the inshore trawl fishery of FMA 2, by statistical area, for four years before introduction of the QMS. – not enough data to calculate.

Statistical area	1983–84	1984–85	1985–86	1986–87
11	1	2	1	1
12	0	–	15	29
13	52	31	21	22
14	30	15	19	23
15	11	3	14	1
16	11	7	16	6

Table 19: Total number of bottom trawl tows carried out by vessels under 43.5 m length in QMA2 by fishing year and statistical area. Areas 17 to 19 include all trips that landed QMA 2 fishstocks, and include an unknown number of tows from QMA 3.

Fyear Area	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	Area Tot. (x100)
11	2 111	3 214	3 879	3 883	4 196	3 502	3 177	2 657	2 695	2 819	2 628	2 016	367.8
12	4 051	5 891	4 194	5 562	5 998	6 968	5 793	5 764	6 253	4 639	5 625	4 962	657.0
13	15 046	21 163	27 146	26 708	25 424	28 627	26 123	24 881	23 977	26 821	25 433	21 535	2 928.8
14	6 741	6 220	10 304	13 621	12 396	9 381	8 407	9 966	8 234	8 346	9 522	9 413	1 125.5
15	1 593	3 071	1 729	1 589	1 621	1 895	1 632	1 344	1 896	1 721	1 011	1 397	205.0
16	1 762	2 019	3 710	2 684	2 937	2 888	2 382	2 187	2 736	3 025	3 027	2 080	314.4
17	96	125	476	488	290	809	437	759	1 450	899	933	1 319	80.8
18	287	297	118	128	263	198	252	483	561	432	203	328	35.5
19	3	22	0	0	0	15	0	5	2	5	0	0	0.5
201	2	20	17	5	3	0	42	38	48	36	28	0	2.4
202	0	0	3	0	2	11	0	0	24	0	0	0	0.4
203	0	0	0	0	1	7	4		5	54	18	0	0.9
204	30	36	6	25	53	82	15	53	69	34	150	89	6.4
205	0	2	0	0	15	0	18	18	15	0	3	5	0.8
Annual tot. Total (x 100)	317.2	420.8	515.8	546.9	532	543.8	482.8	481.6	479.7	488.3	485.8	431.4	

Table 20: The top 12 species (overall) as percentage of total estimated catch (1989–90 to 1999–2000) by statistical area, in the inshore trawl fishery of QMA 2.

Area	TAR	BAR	GUR	HOK	SKI	SNA	TRE	WAR	FLA	RCO	ORH	MOK	OTH
11	51	7	2	10	2	10	2	0	0	1	5	0	9
12	55	7	6	3	3	10	3	0	0	1	3	2	8
13	26	9	17	4	3	7	5	1	6	3	3	3	13
14	15	17	9	13	14	1	4	1	3	2	1	2	19
15	16	17	6	12	8	0	4	3	0	2	4	4	24
16	22	16	3	7	1	0	2	22	2	6	0	6	13
17	30	18	1	8	0	0	2	17	0	8	0	1	13
18	15	24	0	7	3	0	1	11	0	9	4	1	23
19	17	12	0	8	14	0	0	0	0	0	20	0	30
201	7	13	6	2	2	28	14	0	0	0	0	0	27
202	2	0	0	1	1	0	0	0	0	0	1	0	95
203	5	0	9	0	29	2	0	0	0	0	0	0	55
204	2	0	1	1	1	1	1	0	0	0	76	0	17
205	2	7	9	7	39	0	0	0	1	2	0	0	32
% overall	29	12	9	7	5	5	4	3	3	3	3	2	

Table 21: Percentage of annual estimated red gurnard catch taken by the inshore trawl fleet, by statistical area. 0=less than 1% of annual estimated red gurnard catch. Total annual estimated red gurnard catch (t).

Statistical area	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01
11	2	2	2	2	2	2	2	1	1	3	2	3
12	13	14	7	8	6	10	7	9	13	7	9	11
13	58	62	62	55	60	63	64	62	66	69	69	58
14	18	14	22	27	22	17	22	23	13	14	16	19
15	5	6	5	4	5	5	2	3	2	4	2	6
16	4	2	3	3	4	2	2	1	3	2	2	2
17	0	0	0	0	1	1	2	0	1	1	0	1
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0
202	0	0	0	0	0	0	0	0	0	0	0	0
203	0	0	0	0	0	0	0	0	0	0	0	0
204	0	0	0	0	0	0	0	0	0	0	0	0
205	0	0	0	0	0	0	0	0	0	0	0	0
Total catch (t)	332	461	588	562	563	474	477	422	413	383	403	472

Table 22: Percentage of annual estimated red gurnard catch by fishing method taken by all vessels, in all statistical areas of QMA 2.

Method	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01
Bottom trawl	66	60	61	60	63	61	65	61	60	61	59	63
Bottom longline	17	17	21	25	21	19	17	18	19	16	15	15
Danish Seine	7	12	13	12	12	16	12	16	17	18	19	18
Bottom pair trawl	6	7	3	2	2	3	1	0	0	0	0	0
set net	2	3	2	2	2	2	3	2	2	2	2	2

Table 23: Percentage of annual estimated red gurnard catch taken by the inshore trawl fleet, by month. All statistical areas combined. See Table 21 for total annual catch.

Month	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	% overall
Oct	12	9	12	11	12	9	9	11	9	9	8	12	10
Nov	14	9	14	12	9	11	10	13	10	12	8	7	11
Dec	7	6	9	6	10	7	8	8	8	10	9	5	8
Jan	8	7	11	6	5	8	10	13	9	8	8	6	8
Feb	6	8	9	6	7	6	8	9	6	9	6	6	7
Mar	7	4	8	9	6	9	9	9	8	10	9	8	8
Apr	10	7	6	8	8	7	10	6	8	7	9	9	8
May	10	5	4	8	7	8	10	8	7	8	10	8	8
Jun	5	2	8	9	7	5	6	4	6	6	8	9	6
Jul	5	13	6	11	8	8	3	7	7	7	9	7	8
Aug	7	15	7	6	10	10	7	6	8	5	5	12	8
Sep	9	15	7	7	10	13	11	5	12	8	11	11	10

Table 24: Percentage of annual estimated red gurnard catch taken by the inshore trawl fleet, by target species. All statistical areas combined. 0=less than 1% of annual red gurnard catch. See Table 21 for total annual catch.

Target species	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	% overall
GUR	48	61	63	64	64	55	55	52	55	57	65	70	59
TAR	28	21	19	15	11	15	12	14	14	18	18	17	16
FLA	9	8	7	10	10	16	25	26	21	16	11	4	13
TRE	7	3	4	5	4	4	3	2	2	1	1	1	3
SNA	5	2	1	2	5	3	1	1	1	4	2	2	2
WAR	0	1	1	1	1	1	1	2	2	2	1	4	1
BAR	1	2	2	2	1	0	1	1	1	1	1	1	1
Other	3	3	3	2	3	5	3	3	4	1	2	1	3

Table 25: Percentage of total red gurnard catch (1989–90 to 1999–2000), by statistical area, and target species. 0=less than 1% of total red gurnard catch in area. Total estimated catch (t) of red gurnard by statistical area.

Statistical area	GUR	TAR	FLA	TRE	SNA	WAR	BAR	Other	Total GUR catch (t)
11	22	58	0	1	15	0	1	2	111
12	42	46	1	2	8	0	1	1	514
13	63	12	16	3	2	1	1	3	3447
14	64	11	14	3	0	2	2	4	1066
15	66	15	0	6	0	8	1	2	225
16	41	16	23	6	0	9	3	2	142
17	17	36	2	12	0	14	10	9	33
18	8	17	0	0	0	11	28	36	5
19	0	0	0	0	0	0	100	0	0
201	20	7	0	14	51	0	3	5	2
202	0	50	21	0	0	0	0	29	0
203	85	0	0	15	0	0	0	0	2
204	71	15	0	0	0	0	0	13	2
205	59	1	19	0	0	0	21	0	1

Table 26: The relative importance (percentage trawl tows) of the snapper target fishery (SNA 2) to the inshore bottom trawl fishery of QMA 2, by statistical area, and fishing year. See Table 19 for the total number of inshore trawl tows in each area/year.

Statistical area	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	% overall
11	2	1	3	10	14	12	16	13	11	15	12	6	10
12	2	2	2	1	17	5	8	5	4	9	8	9	6
13	4	2	1	2	4	1	0	1	1	2	1	1	2
14	1	0	1	0	0	0	0	0	0	0	0	0	0
15	0	0	0	3	0	1	0	0	0	0	0	0	0
16	2	1	0	0	0	0	0	0	1	1	0	0	0
17	0	0	0	0	0	0	0	1	0	0	0	2	0
18	0	0	0	0	0	4	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	29	39	23	44	11	0	24
202	0	0	0	0	0	0	0	0	0	0	0	0	0
203	0	0	0	0	0	0	0	0	0	0	0	0	0
204	0	0	0	0	0	0	0	0	0	0	0	0	0
205	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 27: Species composition (percentage) of catch in the inshore trawl snapper target fishery (SNA 2) 1989–90 to 2000–01 by statistical area. Total arial catch (t), all species combined.

Statistical area	SNA	TAR	GUR	BAR	TRE	MOK	JDO	KIN	RCO	Other	All species (t)
11	50	17	4	13	6	0	2	2	1	5	394
12	45	14	12	11	5	2	2	2	1	5	356
13	42	5	19	7	10	5	2	1	1	9	375
14	32	3	19	8	16	3	8	1	1	9	11
15	7	9	10	23	21	0	13	0	0	17	6
16	48	0	6	5	0	5	9	10	5	12	6
17	83	0	3	4	0	3	4	0	0	3	2
18	3	0	0	0	0	0	0	0	0	97	1
201	72	0	12	3	0	0	5	1	0	6	7

Table 28: Summary of the inshore trawl snapper target fishery (SNA 2) by fishing year: number of vessels that participated, number of days and tows, catch of the target species and bycatch of red gurnard, catch rates over all tows, number of tows that reported bycatch of red gurnard, catch rate for red gurnard in successful tows, and the percentage of tows in which red gurnard were encountered.

Fishing	No.	No.	No.	Catch (t)		kg / tow		GUR bycatch		
year	vessels	days	tows	SNA	GUR	SNA	GUR	tows	kg / tow	hit rate
89–90	19	72	189	36.0	16.4	190	87	164	100	87
90–91	12	37	114	21.2	8.6	186	76	95	91	83
91–92	14	32	119	24.4	6.9	205	58	91	76	76
92–93	12	64	190	21.6	9.4	114	50	178	53	94
93–94	26	194	541	68.7	30.4	127	56	461	66	85
94–95	18	78	245	40.4	12.3	165	50	189	65	77
95–96	15	80	260	59.1	7.1	227	27	169	42	65
96–97	11	58	191	59.0	6.2	309	32	122	51	64
97–98	11	61	216	47.4	5.0	219	23	115	44	53
98–99	16	128	318	66.7	14.0	210	44	254	55	80
99–00	13	71	233	50.0	9.5	215	41	153	62	66
00–01	11	53	155	32.0	9.1	207	58	130	70	84

Table 29: The relative importance (percentage trawl tows) of the tarakihi target fishery (TAR 2) to the inshore bottom trawl fishery of QMA 2, by statistical area, and fishing year. See Table 19 for the total number of inshore trawl tows in each area/year.

Statistical area	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	% overall
11	91	95	90	81	80	71	72	66	57	71	70	64	77
12	81	78	77	77	65	76	74	62	63	69	65	59	70
13	35	34	33	24	20	18	17	25	24	28	27	31	26
14	24	27	15	13	22	28	17	11	18	23	22	23	20
15	58	63	43	34	34	27	28	26	65	53	42	35	44
16	73	68	70	65	58	64	61	52	58	56	53	55	61
17	90	45	60	92	46	45	57	59	55	77	47	71	61
18	5	51	25	35	67	41	45	33	19	38	24	27	33
19	0	18	0	0	0	0	0	0	0	0	0	0	8
201	0	100	0	0	0	0	19	16	13	8	0	0	18
202	0	0	100	0	0	45	0	0	0	0	0	0	20
203	0	0	0	0	0	0	0	0	0	7	0	0	4
204	0	6	0	0	21	11	20	28	28	0	7	0	11
205	0	0	0	0	33	0	0	0	0	0	0	0	7

Table 30: *Species composition* (percentage) of catch in the inshore trawl tarakihi target fishery (TAR 2) 1989–90 to 2000–01 by statistical area. Total arial catch (t), all species combined.

Statistical area	TAR	BAR	HOK	SNA	GUR	MOK	WAR	TRE	RCO	SKI	JMA	JDO	All species (t)
11	65	6	8	7	2	0	0	1	1	2	1	1	4 083
12	69	6	3	7	4	2	0	2	1	1	1	1	5 691
13	60	7	5	5	5	5	1	3	1	2	1	2	7 578
14	41	24	6	0	4	4	3	4	1	5	1	2	2 808
15	43	23	7	0	3	5	3	2	4	2	2	0	1 238
16	39	11	7	0	1	9	11	1	8	0	4	1	2 137
17	52	18	3	0	1	0	12	0	6	0	1	0	1 260
18	47	12	5	0	0	4	9	0	5	0	1	0	256
19	60	0	0	0	0	0	0	0	0	0	0	0	0
201	45	13	1	17	3	0	0	0	0	0	5	2	3
202	56	0	16	0	4	0	0	0	0	18	0	1	1
203	85	3	0	0	0	0	0	0	0	0	6	0	1
204	55	5	5	4	5	0	0	0	1	0	2	1	7
205	67	17	0	0	4	0	0	0	0	0	0	0	0

Table 31: Summary of the inshore trawl tarakihi target (TAR 2) fishery by fishing year: number of vessels that participated, number of days and tows, catch of the target species and bycatch of red gurnard, catch rates over all tows, number of tows that reported a bycatch of red gurnard, catch rate for red gurnard in those tows, and the percentage of tows in which red gurnard were encountered (hit rate).

	No.	No.	No.	Catch (t)		kg / tow		GUR bycatch		
F year	vessels	days	tows	TAR	GUR	TAR	GUR	tows	kg / tow	hit rate
89–90	30	1 250	3 291	1 022.6	92.8	311	28	1 516	61	46
90–91	47	1 700	4 556	1 415.8	97.6	311	21	2 152	45	47
91–92	47	1 765	4 644	1 300.2	113.5	280	24	2 297	49	49
92–93	48	1 474	3 902	1 246.8	82.4	320	21	1 964	42	50
93–94	51	1 481	3 742	1 075.1	61.1	287	16	1 737	35	46
94–95	44	1 577	3 845	1 138.6	68.7	296	18	1 519	45	40
95–96	34	1 262	3 145	1 051.1	56.9	334	18	1 262	45	40
96–97	33	1 288	3 088	996.5	58.1	323	19	1 469	40	48
97–98	32	1 400	3 447	1 222.9	58.7	355	17	1 488	39	43
98–99	38	1 623	3 806	1 377.7	69.4	362	18	1 755	40	46
99–00	36	1 494	3 510	1 316.0	71.2	375	20	1 767	40	50
00–01	40	1 480	3 245	1 249.5	78.4	385	24	1 795	44	55

Table 32: The relative importance (percentage trawl tows) of the red gurnard target fishery (GUR 2) to the inshore bottom trawl fishery of QMA 2, by statistical area, and fishing year. See Table 19 for the total number of inshore trawl tows in each area/year.

Statistical area	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	% overall
11	2	1	0	2	2	1	3	3	3	4	5	20	3
12	11	13	15	16	6	8	8	16	23	13	17	22	14
13	24	34	40	39	44	33	30	26	31	39	53	51	37
14	27	34	35	32	31	27	32	24	23	30	22	31	29
15	15	11	30	22	19	19	7	20	8	13	18	19	16
16	7	11	11	8	5	4	6	5	6	7	7	3	7
17	0	0	3	3	5	3	3	2	1	1	2	0	2
18	0	0	0	0	0	0	0	1	0	0	0	18	2
19	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	100	0	0	0	0	0	0	14	18	0	11
202	0	0	0	0	0	0	0	0	0	0	0	0	0
203	0	0	0	0	0	0	100	0	0	93	0	0	61
204	0	0	0	0	19	0	33	28	0	0	0	0	5
205	0	0	0	0	0	0	28	0	0	0	0	0	7

Table 33: Species composition (percentage) of catch in the inshore trawl red gurnard target fishery (GUR 2) 1989–90 to 2000–01 by statistical area. Total ariel catch (t), all species combined.

Statistical area	GUR	SNA	TAR	BAR	TRE	FLA	RCO	MOK	JDO	SPO	HOK	Other	All species (t)
11	15	34	21	18	3	0	0	1	1	0	1	5	159
12	26	22	29	5	7	0	1	3	1	1	1	4	822
13	39	12	7	8	7	9	5	2	4	1	1	4	5521
14	39	4	9	11	9	8	5	3	3	1	1	6	1729
15	36	1	7	9	17	2	2	10	1	2	1	14	414
16	29	1	7	10	9	9	3	10	1	2	2	17	198
17	21	0	27	16	6	2	9	4	1	0	1	12	27
18	11	2	30	10	7	0	19	9	1	2	0	8	3
201	22	44	5	0	9	1	0	1	6	0	0	12	1
203	62	3	1	0	1	11	0	0	2	9	0	11	2
204	24	31	4	2	26	0	1	3	0	4	0	5	6
205	48	0	0	28	0	3	0	0	0	7	0	14	1

Table 34: Summary of inshore trawl red gurnard target fishery (GUR 2) by fishing year: number of vessels that participated, number of days and tows, catch and the catch rate for red gurnard.

F year	No. vessels	No. days	No. tows	Catch (t)	kg / tow
89–90	35	667	1 433	158.6	111
90–91	41	1 009	2 407	279.9	116
91–92	54	1 508	3 554	369.7	104
92–93	52	1 413	3 420	358.7	105
93–94	48	1 563	3 554	357.6	101
94–95	46	1 291	2 767	262.1	95
95–96	43	1 073	2 372	260.6	110
96–97	38	993	2 181	218.2	100
97–98	36	1 102	2 469	226.5	92
98–99	40	1 393	3 108	218.1	70
99–00	38	1 675	3 567	259.9	73
00–01	38	1 806	3 404	330.0	97

Table 35: The relative importance (percentage trawl tows) of the flatfish target fishery (FLA 2) to the inshore bottom trawl fishery of QMA 2, by statistical area, and fishing year. See Table 19 for the total number of inshore trawl tows in each area/year.

Statistical area	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	% overall
11	0	0	0	0	0	1	0	0	0	0	0	0	0
12	2	2	0	0	1	1	1	0	0	2	1	1	1
13	24	18	15	21	20	35	45	39	36	25	11	10	25
14	20	5	20	26	14	19	31	37	40	27	38	25	25
15	0	0	0	1	1	13	0	1	0	3	0	0	2
16	4	3	1	10	20	8	10	4	7	4	1	1	6
17	0	0	8	0	0	23	11	5	1	2	0	0	4
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0
202	0	0	0	0	0	0	0	0	100	0	0	0	60
203	0	0	0	0	0	0	0	0	0	0	0	0	0
204	0	0	0	0	0	0	0	0	0	0	0	0	0
205	0	0	0	0	0	0	0	83	100	0	0	0	39

Table 36: Species composition (percentage) of catch in the inshore trawl flatfish target fishery (FLA 2) 1989–90 to 2000–01 by statistical area. Total arial catch (t), all species combined.

Statistical area	FLA	GUR	RCO	SNA	BAR	TRE	KAH	SPO	MOK	TAR	Other	All species (t)
11	60	30	3	0	2	0	0	0	0	0	5	1
12	50	16	9	11	0	0	2	1	0	2	9	26
13	54	22	10	3	2	2	2	1	1	1	4	2553
14	60	17	12	2	2	1	1	1	1	1	3	850
15	49	6	12	6	1	0	0	1	0	6	17	16
16	42	20	10	0	13	2	0	1	1	1	9	160
17	18	5	43	1	11	1	0	2	2	7	10	18
202	0	12	24	0	0	0	8	0	0	0	56	0
205	34	28	30	6	3	0	0	0	0	0	0	1

Table 37: Summary of the flatfish target fishery (FLA 2) by fishing year: number of vessels that participated, number of days and tows, catch of the target species and bycatch of red gurnard, catch rates over all tows, number of tows that reported a bycatch of red gurnard, catch rate for red gurnard in those tows, and the percentage of tows in which red gurnard were encountered.

	No.	No.	No.	Catch (t)		kg / tow		GUR bycatch		
F year	vessels	days	tows	FLA	GUR	FLA	GUR	tows	kg / tow	hit rate
89–90	16	668	1 412	135.0	28.6	96	20	1 241	23	88
90–91	21	583	1 440	118.9	35.4	83	25	981	36	68
91–92	22	889	1 967	118.6	40.4	60	21	1 352	30	69
92–93	28	1 383	3 692	219.6	55.6	59	15	1 992	28	54
93–94	33	1 080	2 612	156.5	56.0	60	21	1 408	40	54
94–95	35	1 539	4 193	218.3	77.7	52	19	2 211	35	53
95–96	32	1 965	4 816	233.6	118.6	49	25	2 745	43	57
96–97	32	2 172	5 137	195.8	108.8	38	21	2 288	48	45
97–98	27	2 168	5 100	292.5	88.2	57	17	2 068	43	41
98–99	31	1 598	3 698	129.9	60.7	35	16	1 719	35	46
99–00	17	1 078	2 180	82.8	44.5	38	20	1 436	31	66
00–01	20	954	2 004	68.6	21.1	34	11	914	23	46

Table 38: The relative importance (percentage trawl tows) of the trevally target fishery (TRE 2) to the inshore bottom trawl fishery of QMA 2, by statistical area, and fishing year. See Table 19 for the total number of inshore trawl tows in each area/year.

Statistical area	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	% overall
11	0	0	0	1	0	0	1	1	0	1	2	2	0.5
12	2	1	3	3	2	1	1	1	0	0	1	1	1.2
13	4	3	2	3	3	3	1	2	1	1	1	0	2.0
14	2	4	2	3	3	2	2	1	1	0	0	0	1.6
15	2	2	1	7	3	2	3	2	3	2	3	3	2.6
16	6	4	2	2	2	2	0	2	1	2	2	4	2.3
17	0	0	7	0	17	0	0	0	2	0	5	3	2.5
18	1	5	0	0	0	0	0	0	0	0	4	0	0.8
19	0	0	0	0	0	0	0	0	0	0	0	0	0.0
201	0	0	0	0	0	0	31	24	0	8	32	0	14.2
202	0	0	0	0	0	0	0	0	0	0	0	0	0.0
203	0	0	0	0	0	0	0	0	100	0	0	0	5.6
204	0	0	0	16	0	0	0	0	0	0	0	0	0.6
205	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Table 39: Species composition (percentage) of catch in the inshore trawl trevally target fishery (TRE 2) 1989–90 to 2000–01 by statistical area. Total arial catch (t), all species combined.

Statistical area	TRE	SNA	GUR	BAR	TAR	MOK	JMA	JDO	RCO	Other	All species (t)
11	21	31	5	4	31	1	0	2	0	5	27
12	42	26	10	3	13	3	1	1	1	2	86
13	41	19	15	6	5	4	1	2	1	6	708
14	42	4	11	16	8	6	3	1	2	8	346
15	44	0	12	16	5	6	4	1	1	12	112
16	46	1	10	6	7	7	6	1	1	15	78
17	64	3	6	4	13	2	0	1	0	8	71
18	80	0	0	0	2	0	0	4	0	14	5
201	50	4	3	16	0	0	0	3	0	23	7
203	6	33	36	0	0	0	0	0	0	24	1
204	76	0	0	18	0	0	0	0	0	6	2

Table 40: Summary of the inshore trawl trevally target fishery (TRE 2) by fishing year: number of vessels that participated, number of days and tows, catch of the target species and bycatch of red gurnard, catch rates over all tows, number of tows that reported bycatch of red gurnard, catch rate for red gurnard in those tows, and the percentage of tows in which red gurnard were encountered (hit rate).

	No.	No.	No.	Catch (t)		kg / tow		GUR bycatch		
F year	vessels	days	tows	TRE	GUR	TRE	GUR	tows	kg / tow	hit rate
89–90	18	85	213	70.6	22.5	331	106	180	125	85
90–91	15	82	226	73.7	14.3	326	63	166	86	73
91–92	15	85	214	56.2	21.5	263	101	188	114	88
92–93	20	145	291	84.5	28.3	290	97	251	113	86
93–94	19	125	248	78.5	24.8	316	100	226	110	91
94–95	19	99	218	38.5	20.0	177	92	204	98	94
95–96	12	47	96	50.9	12.1	530	126	83	145	86
96–97	14	62	120	38.0	9.0	317	75	98	91	82
97–98	10	39	92	26.6	9.1	289	99	76	120	83
98–99	12	53	71	45.8	5.5	645	78	58	95	82
99–00	7	47	99	41.2	4.6	416	46	67	69	68
00–01	11	37	71	15.7	4.4	221	62	44	100	62

Table 41: Summary of the final dataset created from core vessels (> 10 trips in each of at least 3 years) used for standardised CPUE analysis of red gurnard in the inshore trawl target fishery: number days, total GUR 2 catch, total tows, number vessels, and raw CPUE as kg/tow.

Fishing year	Days	Catch GUR (t)	Tows	Vessels	kg / tow
89–90	517	121.5	1112	19	109.2
90–91	799	222.7	1953	25	114.0
91–92	1265	292.9	2961	31	98.9
92–93	1245	303.8	3087	33	98.4
93–94	1402	298.9	3215	31	93.0
94–95	1160	221.1	2543	28	86.9
95–96	940	217.8	2184	27	99.7
96–97	879	192.5	1996	26	96.4
97–98	1024	212.6	2335	29	91.1
98–99	1241	187.4	2832	26	66.2
99–00	1548	240.7	3329	24	72.3
00–01	1544	252.5	2929	25	86.2

Table 42: Significant variables included in the standardised CPUE model of red gurnard catch in the inshore trawl target fishery, and the sequential effect of inclusion each variable on the model R^2 at each model iteration. Threshold for inclusion was a 1 % improvement to the model R^2. Final model R^2 is in bold.

Variable	R^2
Fishing year	0.036
Duration	0.293
Catch of tarakihi	0.296
Vessel	0.410
Month	0.416
Catch of flatfish	**0.421**

Table 43: Coefficients (year effects) and standard errors from the standardised CPUE model for the GUR 2 target fishery, the canonical indices and 95 % confidence limits.

Fishing year	Coeffs	SE	Canonical Index	upper	lower
89–90	0.00000	0.00000	1.101	1.165	1.036
90–91	0.07701	0.04151	1.189	1.242	1.136
91–92	0.02009	0.03910	1.123	1.165	1.081
92–93	–0.08178	0.04021	1.014	1.057	0.972
93–94	–0.08174	0.04017	1.014	1.055	0.974
94–95	–0.15019	0.04102	0.947	0.990	0.905
95–96	0.00523	0.04272	1.107	1.154	1.059
96–97	–0.09895	0.04325	0.997	1.046	0.948
97–98	–0.11239	0.04274	0.984	1.030	0.938
98–99	–0.26977	0.04244	0.841	0.884	0.797
99–00	–0.27699	0.04174	0.835	0.877	0.793
00–01	–0.18371	0.04177	0.916	0.958	0.874

Table 44: Summary of the final dataset created from core vessels (> 10 trips in each of at least 3 years) used for standardised CPUE analysis of red gurnard as bycatch of the inshore trawl flatfish target fishery (FLA 2): number days, total GUR 2 catch, total tows, number vessels, and raw CPUE as kg/tow.

Fishing year	Days	Catch GUR (t)	Tows	Vessels	kg / tow
89–90	496	22.0	1042	9	21.1
90–91	362	25.8	806	10	32.0
91–92	576	31.9	1222	12	26.1
92–93	606	40.9	1482	15	27.6
93–94	425	33.9	1031	11	32.9
94–95	651	53.6	1754	16	30.5
95–96	933	90.7	2402	17	37.7
96–97	886	95.2	2128	19	44.7
97–98	783	74.1	1776	16	41.7
98–99	608	46.9	1400	13	33.5
99–00	437	20.2	880	12	22.9
00–01	159	7.1	333	9	21.3

Table 45: Significant variables included in the standardised CPUE model of red gurnard as bycatch of the inshore trawl target flatfish fishery (FLA 2), and the sequential effect of inclusion each variable on the model R^2 at each model iteration. Threshold for inclusion was a 1 % improvement to the model R^2. Final model R^2 is in bold.

Variable	R^2
Fishing year	0.035
Vessel	0.191
Duration	0.399
Catch of tarakihi	0.443
Month	0.416
Catch of flatfish	0.421

Table 46: Coefficients (year effects) and standard errors from the standardised CPUE model of red gurnards bycatch of the inshore trawl flatfish target fishery (FLA 2), the canonical indices and 95 % confidence limits.

Fishing year	Coeffs	SE	Canonical Index	upper	lower
89–90	0.0000	0.0000	0.938	1.036	0.840
90–91	0.2260	0.0687	1.176	1.285	1.066
91–92	0.0219	0.0626	0.959	1.044	0.874
92–93	0.1497	0.0670	1.089	1.171	1.008
93–94	0.2145	0.0728	1.162	1.256	1.068
94–95	0.4051	0.0692	1.406	1.488	1.325
95–96	0.3431	0.0629	1.322	1.390	1.254
96–97	0.2240	0.0636	1.173	1.243	1.103
97–98	–0.2475	0.0668	0.732	0.810	0.654
98–99	–0.2535	0.0705	0.728	0.813	0.643
99–00	–0.1041	0.0735	0.845	0.941	0.750
00–01	–0.2094	0.0961	0.761	0.910	0.611

Table 47: Summary of the final dataset created from core vessels (> 10 trips in each of at least 3 years) used for standardised CPUE analysis of red gurnard as bycatch of the inshore trawl tarakihi target fishery (TAR 2): number days, total GUR 2 catch, total tows, number vessels, and raw CPUE as kg/tow..

Fishing year	Days	Catch GUR (t)	Tows	Vessels	kg/tow
89–90	448	75.3	1265	17	59.5
90–91	640	82.9	1778	25	46.6
91–92	708	92.2	1899	27	48.5
92–93	640	67.6	1759	30	38.4
93–94	549	47.5	1508	31	31.5
94–95	513	55.9	1363	29	41.0
95–96	468	47.1	1267	24	37.2
96–97	516	51.7	1390	23	37.2
97–98	503	48.0	1306	22	36.7
98–99	664	58.6	1583	24	37.0
99–00	662	62.7	1635	21	38.3
00–01	722	64.2	1534	20	41.8

Table 48: Significant variables included in the standardised CPUE model of red gurnard as bycatch of the inshore trawl target tarakihi fishery (TAR 2), and the sequential effect of inclusion each variable on the model R^2 at each model iteration. Threshold for inclusion was a 1 % improvement to the model R^2. Final model R^2 is in bold..

Variable	R^2
Fishing year	0.022
Vessel	0.124
Number of tows	0.194
Catch of tarakihi	0.215
Catch of snapper	0.239
Month	0.261

Table 49: Coefficients (year effects) and standard errors from the standardised CPUE model of red gurnard as bycatch of the inshore trawl tarakihi target fishery (TAR 2), the canonical indices and 95 % confidence limits.

Fishing year	Coeffs	SE	Canonical Index	upper	lower
89–90	0.0000	0.0000	1.194	1.281	1.107
90–91	–0.0931	0.0539	1.088	1.160	1.016
91–92	–0.1542	0.0534	1.024	1.091	0.956
92–93	–0.1655	0.0558	1.012	1.082	0.943
93–94	–0.2996	0.0590	0.885	0.959	0.811
94–95	–0.1991	0.0615	0.979	1.054	0.903
95–96	–0.2367	0.0626	0.942	1.020	0.865
96–97	–0.1888	0.0616	0.989	1.063	0.914
97–98	–0.2049	0.0625	0.973	1.048	0.898
98–99	–0.1612	0.0616	1.016	1.087	0.946
99–00	–0.2849	0.0623	0.898	0.971	0.826
00–01	–0.1420	0.0623	1.036	1.109	0.964

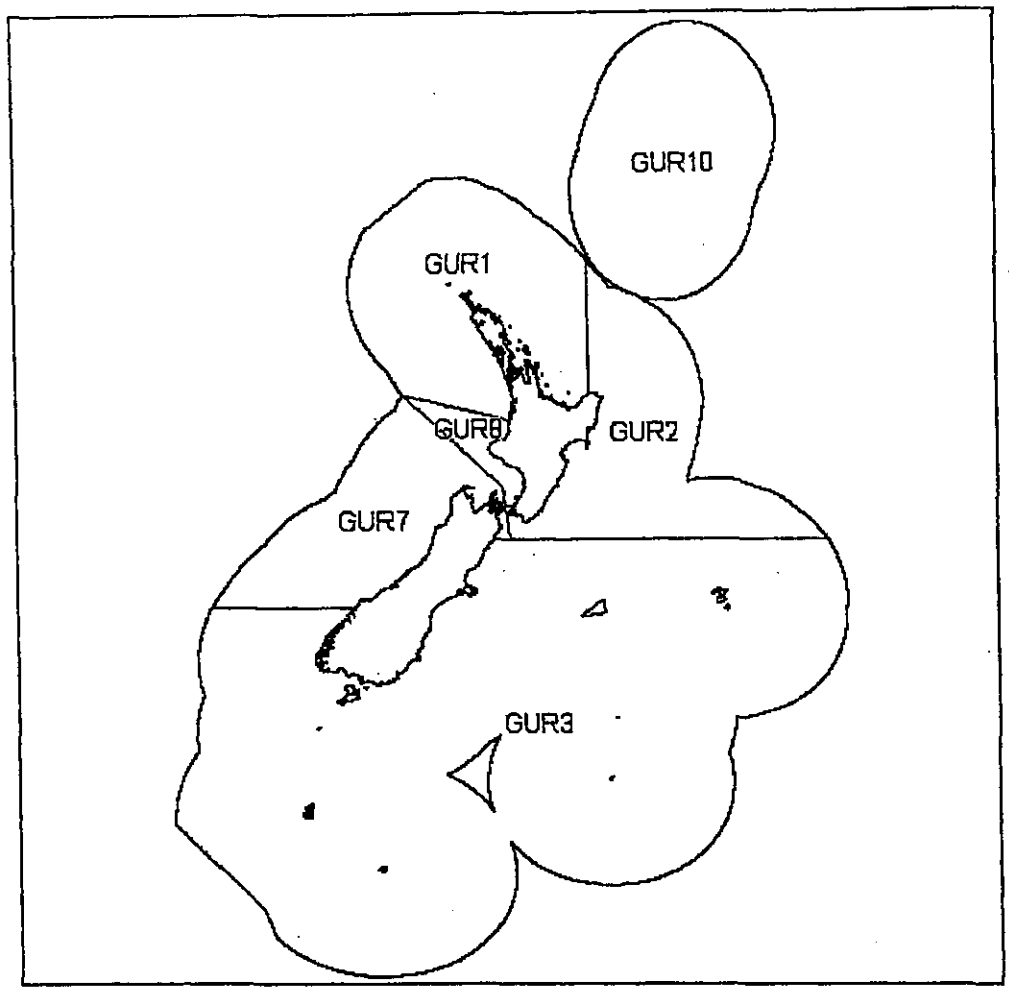

Figure 1: Location of gurnard quota management areas within the New Zealand EEZ .

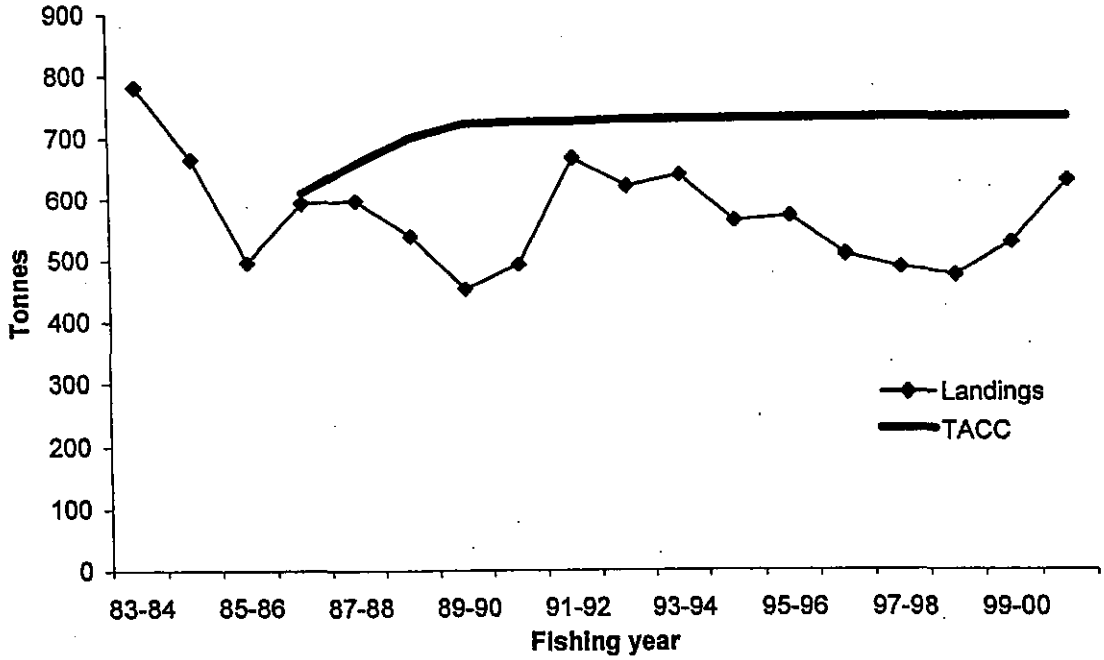

Figure 2: Total GUR 2 QMR landings (t) and actual TACC (see Table 3 for values; Annala et al. 2002)

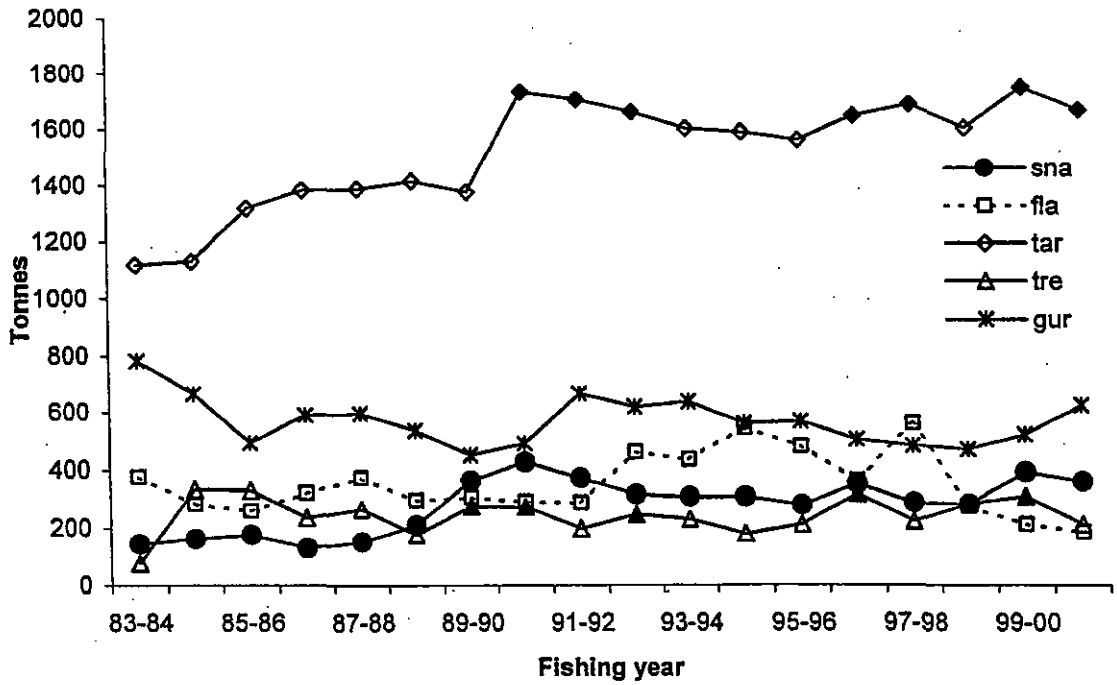

Figure 3: Total landings of snapper (SNA 2), flatfish (FLA 2), tarakihi (TAR 2), trevally (TRE 2), and gurnard (GUR 2) from QMA 2 from 1983–84 to 2000–01 from Annala et al. (2002). Solid symbols represent years in which landings exceeded TACC for that species. Flatfish landings include landings from QMA 8.

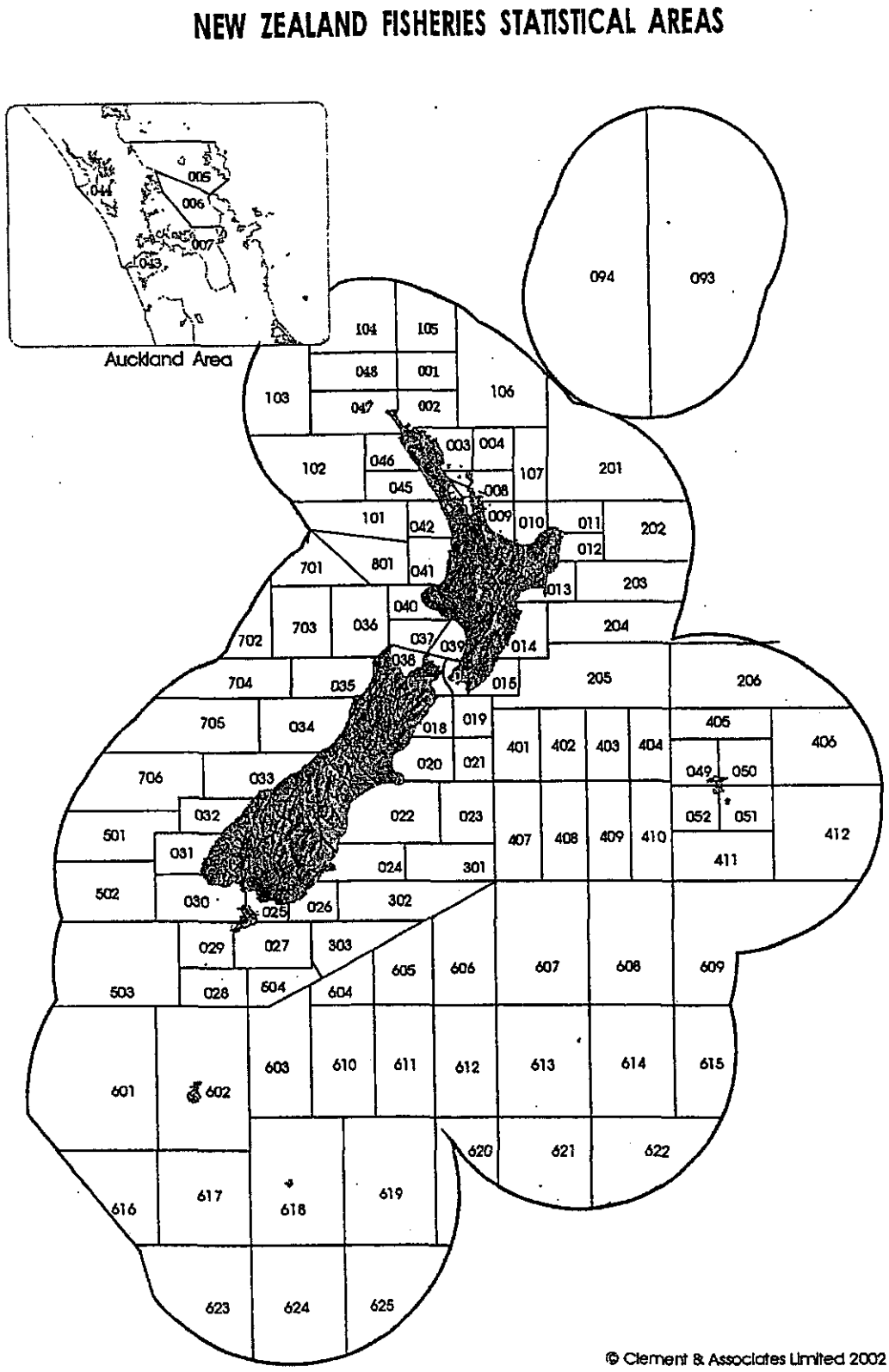

Figure 4: Boundaries of statistical areas referred to in this report.

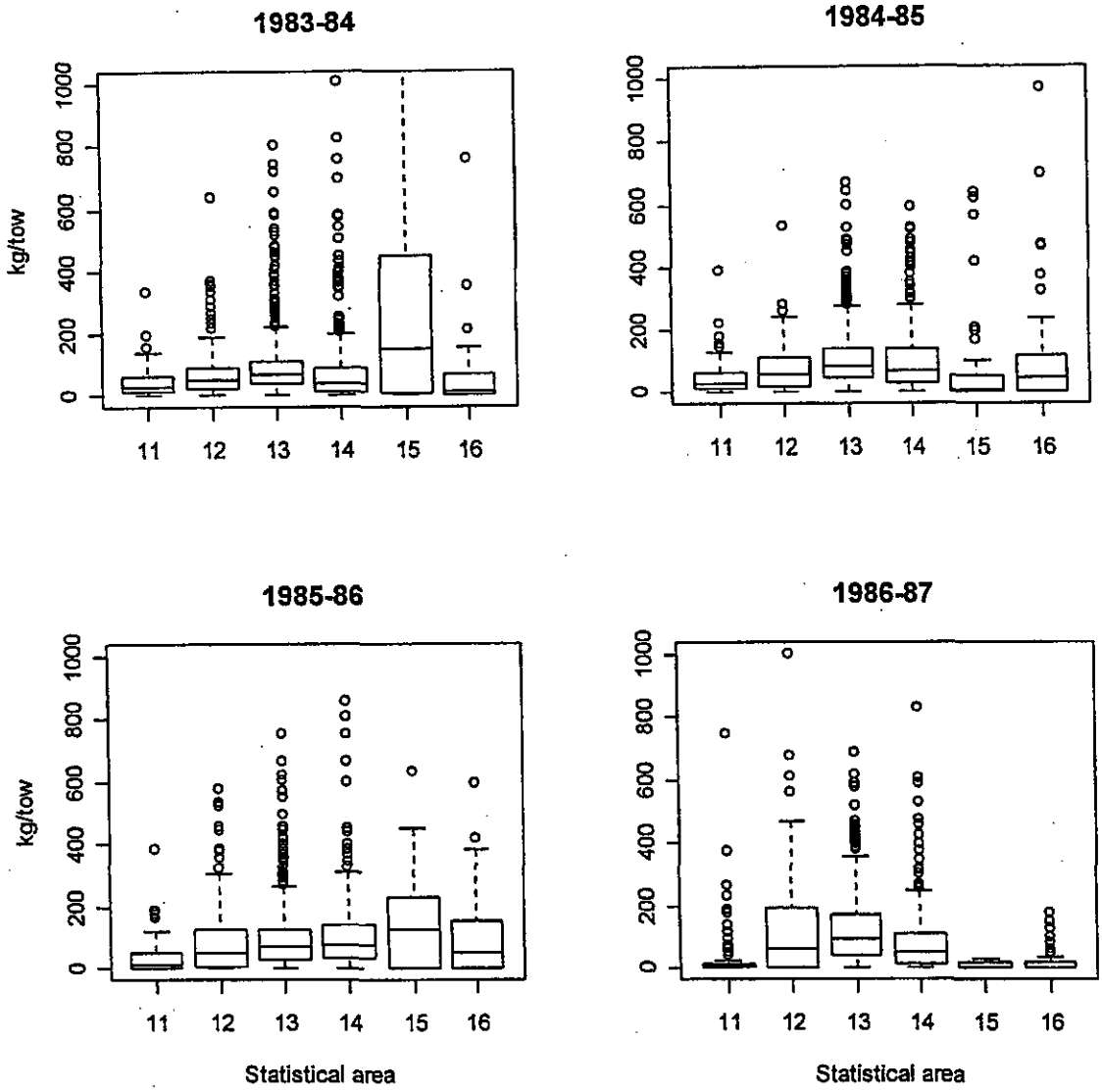

Figure 5: Distributions of raw CPUE (kg/tow) of red gurnard by statistical area in the FMA 2 inshore bottom trawl fishery, in four years before the introduction of the QMS. The box describes the interquartile range of the data, bisected by the median. The whiskers describe 95% of the data, points are outliers.

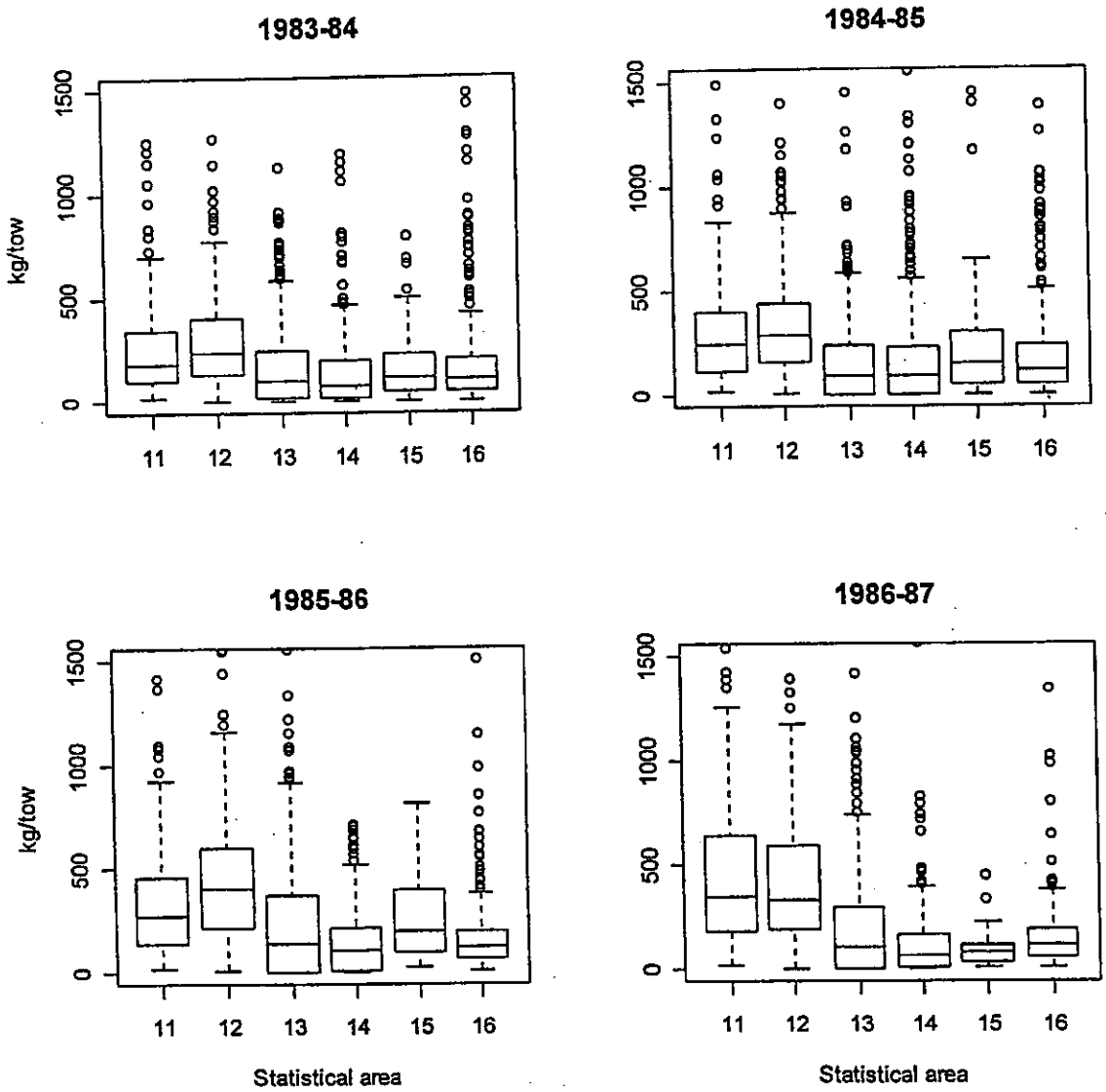

Figure 6: Distributions (truncated) of raw CPUE (kg/tow) for tarakihi by statistical area in the FMA 2 inshore bottom trawl fishery, in four years before the introduction of the QMS. The box describes the interquartile range of the data, bisected by the median. The whiskers describe 95% of the data, points are outliers.

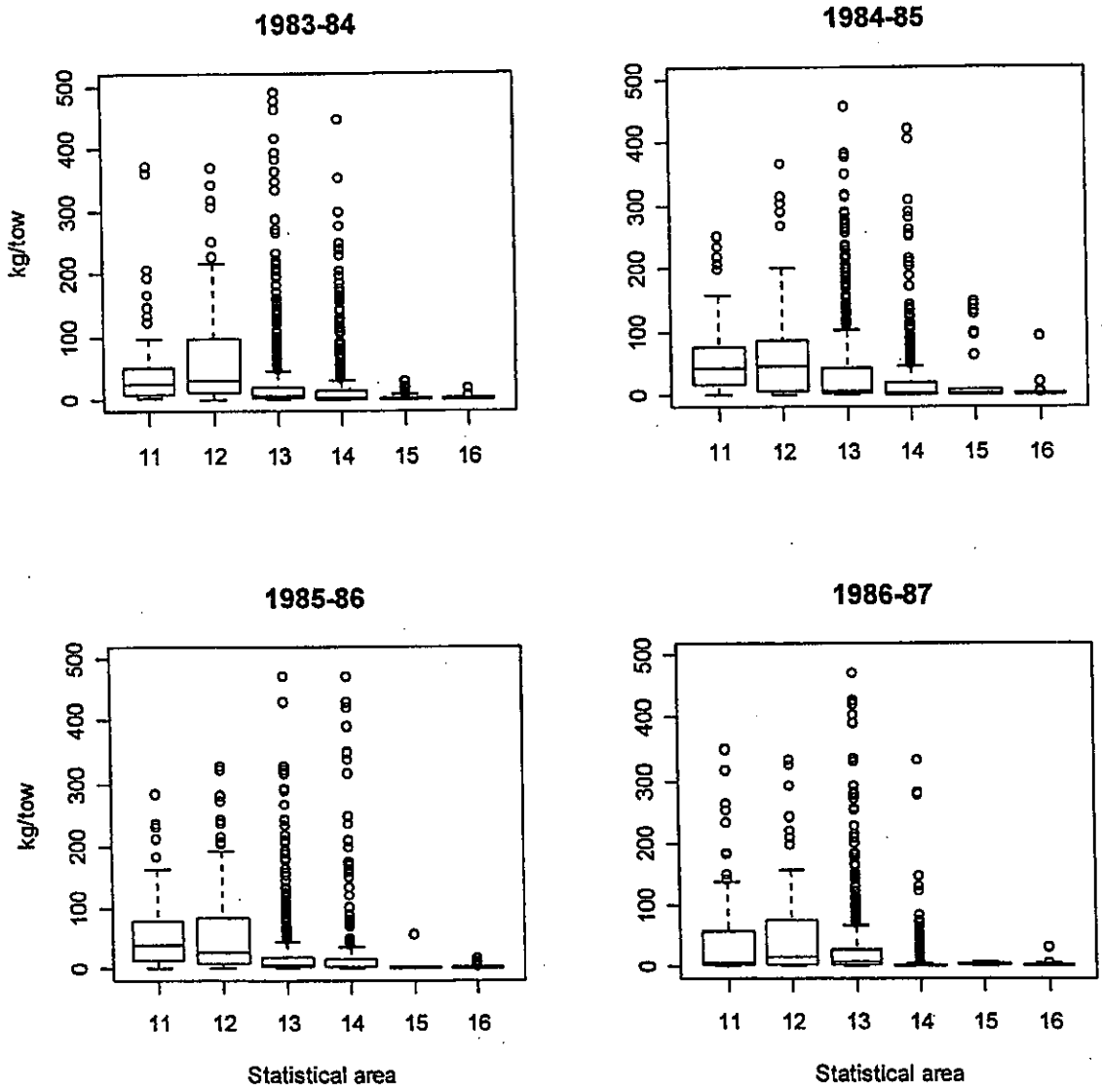

Figure 7: Distributions of raw CPUE (kg/tow) for snapper by statistical area, in the FMA 2 inshore bottom trawl fishery, in four years before the introduction of the QMS. The box describes the interquartile range of the data, bisected by the median. The whiskers describe 95% of the data, points are outliers.

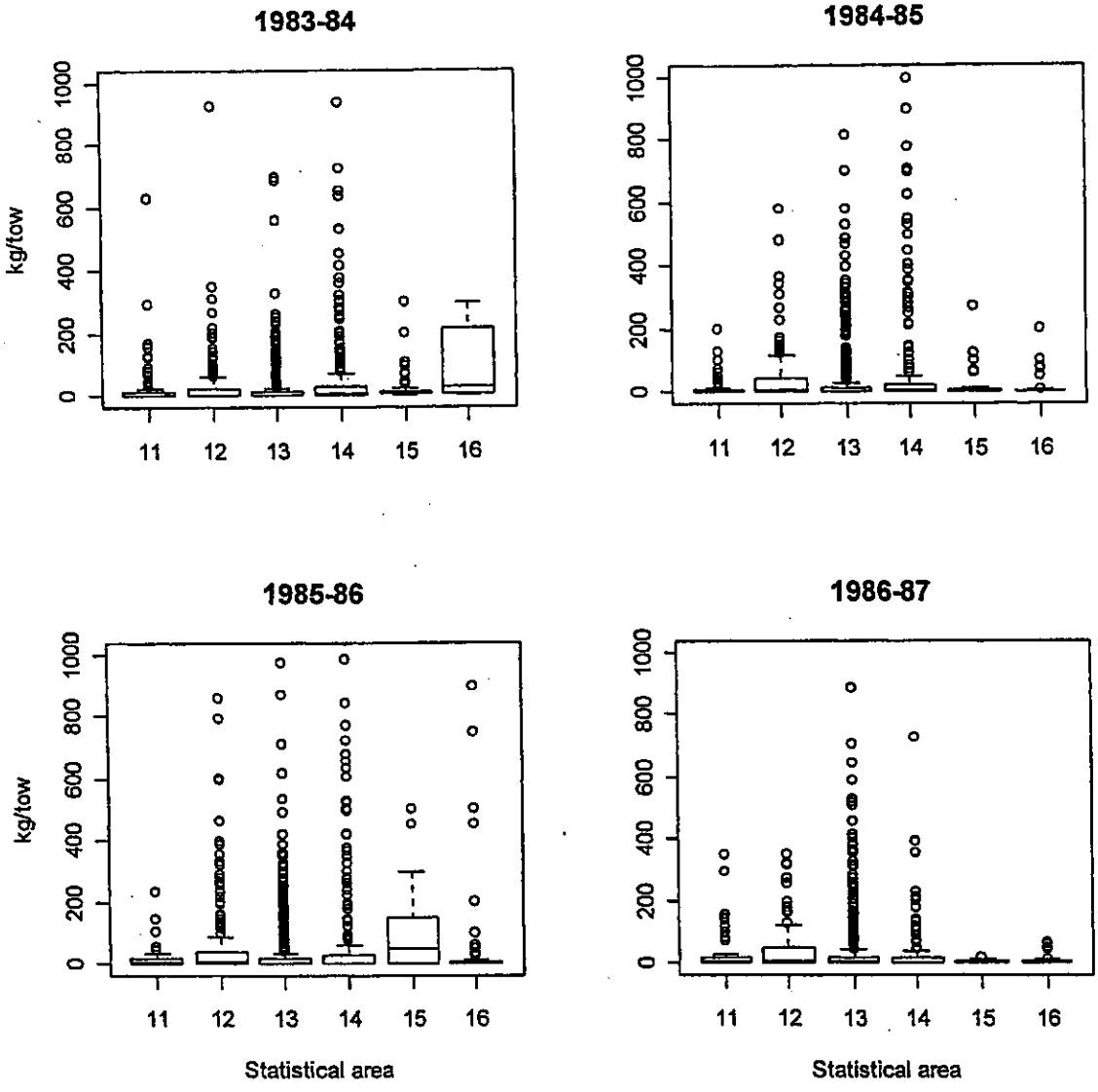

Figure 8: Distributions of raw CPUE (kg/tow) for trevally by statistical area, in the inshore bottom trawl fisheries of FMA 2 in four years before the introduction of the QMS. The box describes the interquartile range of the data, bisected by the median. The whiskers describe 95% of the data, points are outliers.

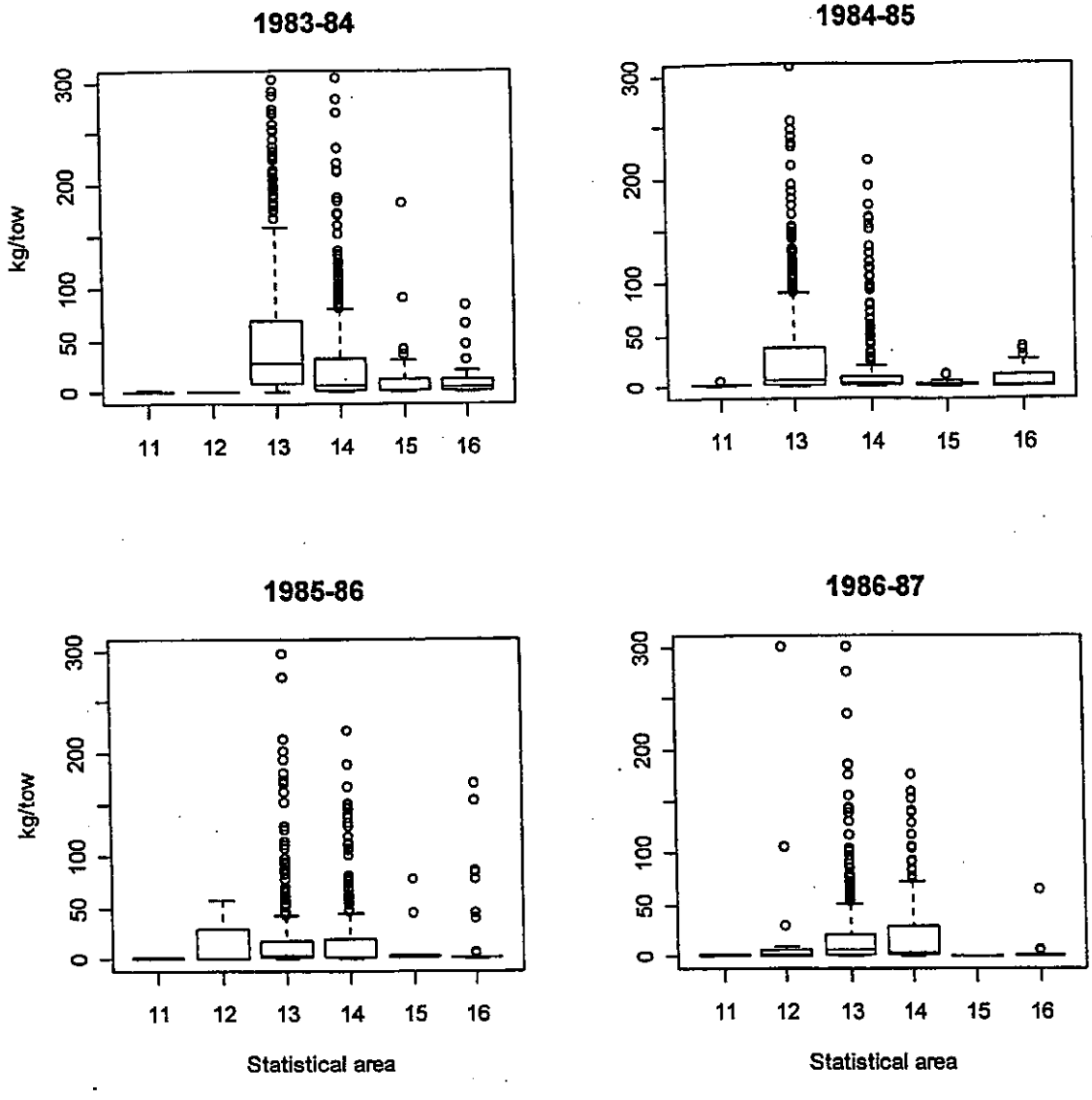

Figure 9: Distribution of raw CPUE (kg/tow) of flatfish by statistical area, in the inshore bottom trawl fisheries of FMA 2 in four years before the introduction of the QMS. The box describes the interquartile range of the data, bisected by the median. The whiskers describe 95% of the data, points are outliers.

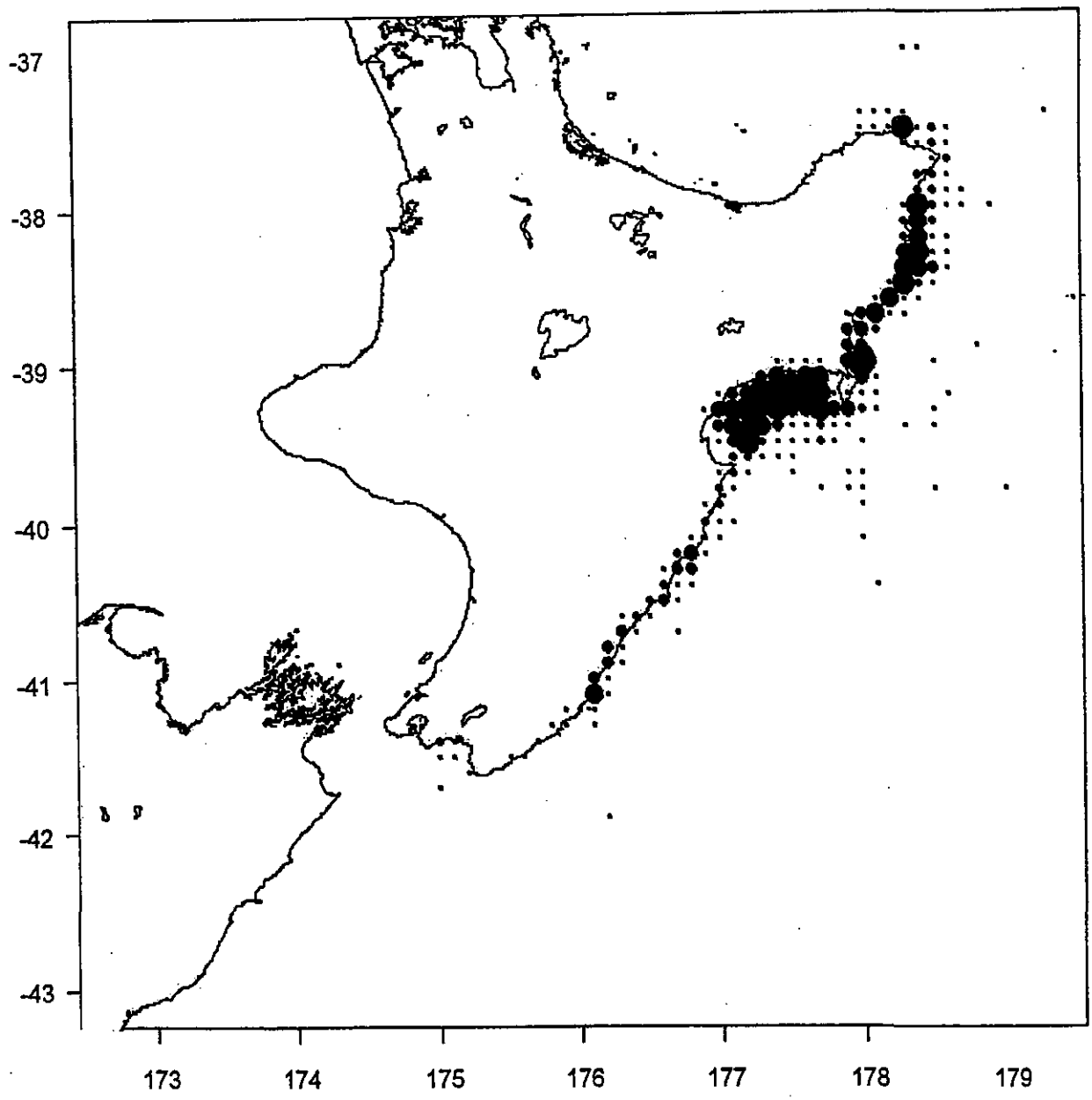

Figure 10: Location and number of bottom trawls catching over 50 kg red gurnard in QMA 2 for all TCEPR data from 1989–90 to 2000–01 (source: MFish TCEPR data). The size of the point indicates the relative number of trawls. Locations are rounded to 6 minute intervals due to commercial sensitivity.

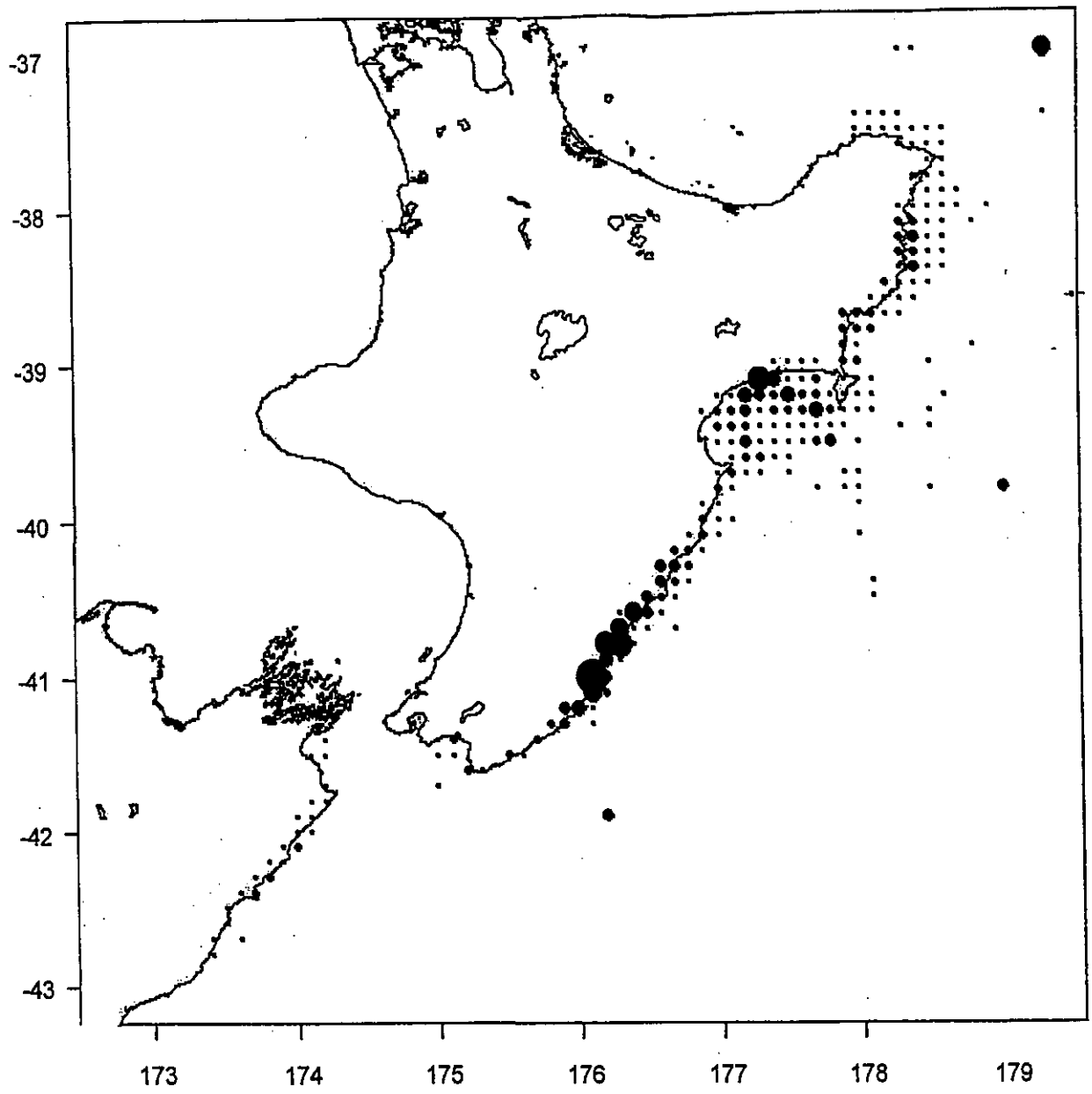

Figure 11: Location and size of red gurnard catches in QMA 2 for all TCEPR data from 1989–90 to 2000–01 (source: MFish TCEPR data). The size of the point indicates the relative size of the catch. Locations are rounded to 6 minute intervals due to commercial sensitivity.

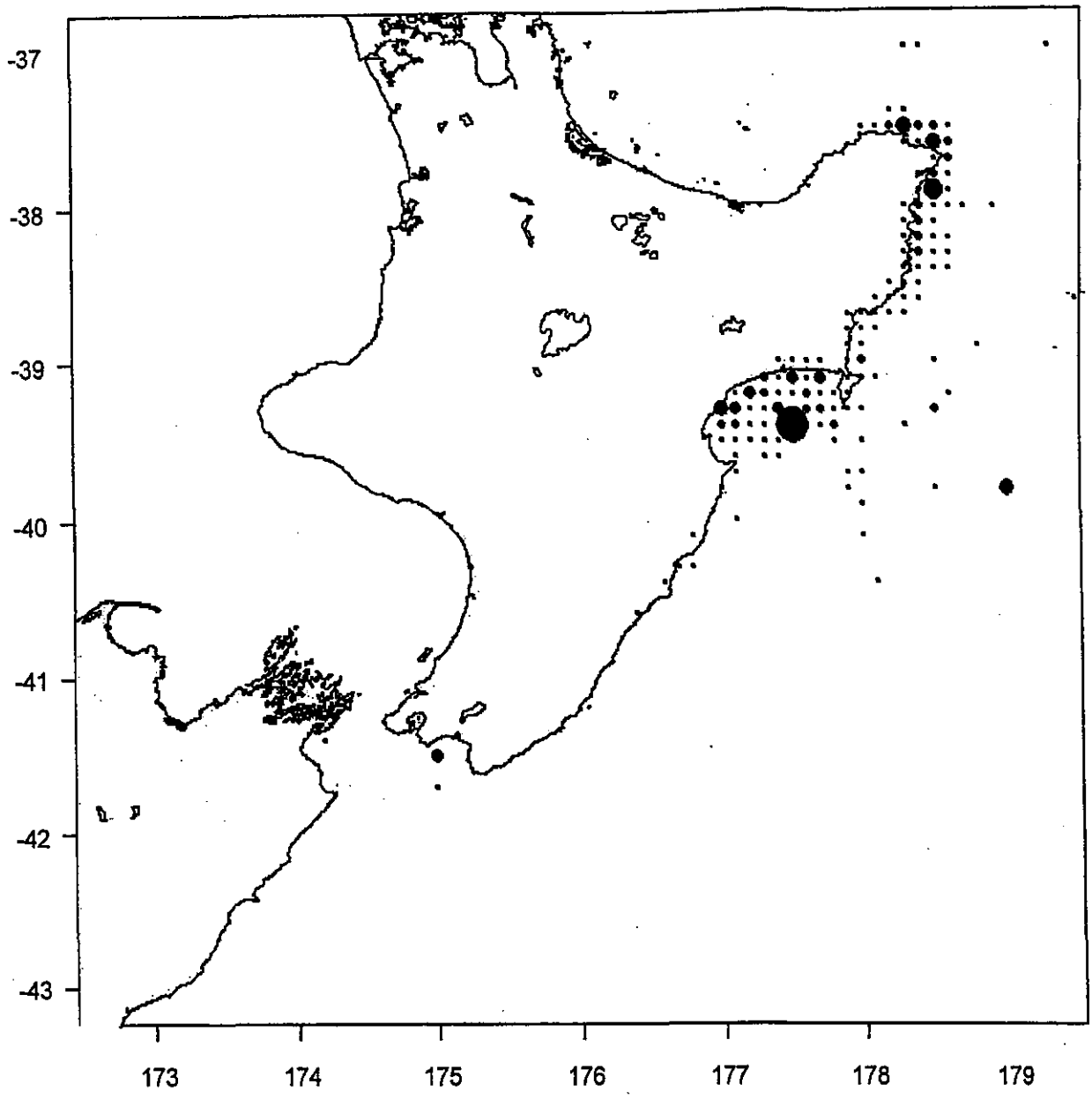

Figure 12: Location and size of snapper catches in QMA 2 for all TCEPR data from 1989–90 to 2000–01 (source: MFish TCEPR data). The size of the point indicates the relative size of the catch. Locations are rounded to 6 minute intervals due to commercial sensitivity.

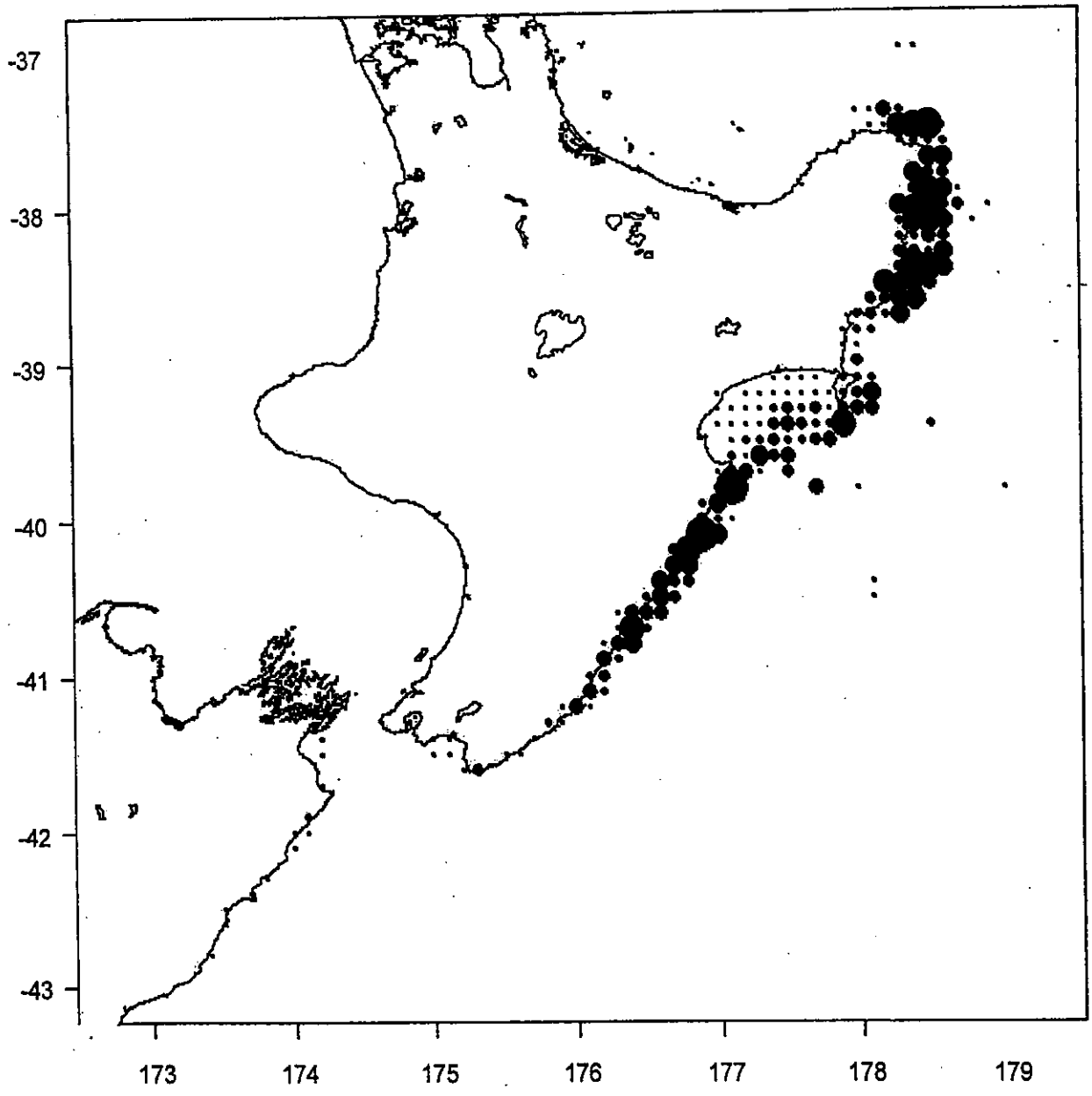

Figure 13: Location and size of tarakihi catches in QMA 2 for all TCEPR data from 1989–90 to 2000–01 (source: MFish TCEPR data). The size of the point indicates the relative size of the catch. Locations are rounded to 6 minute intervals due to commercial sensitivity.

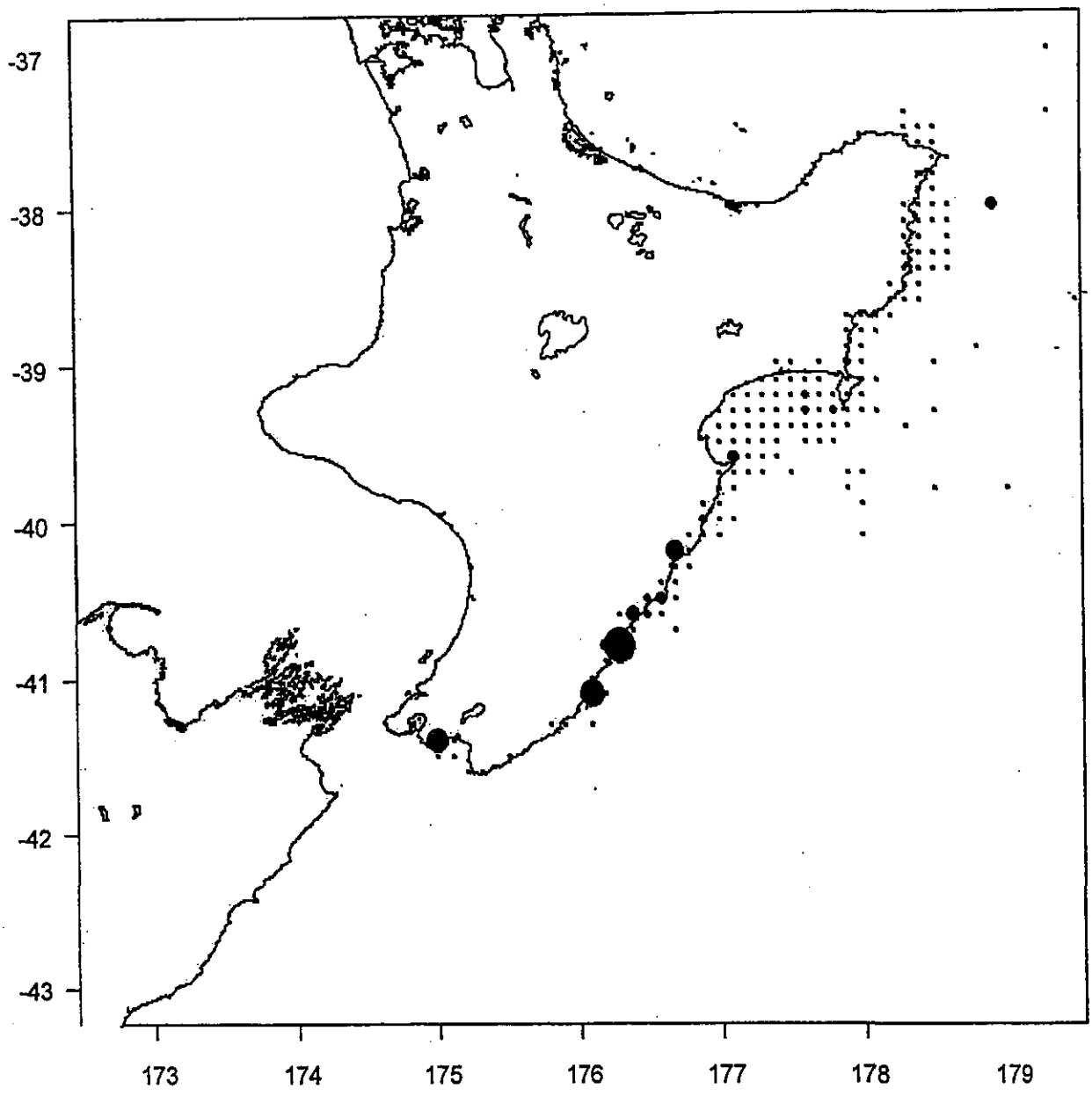

Figure 14: Location and size of trevally catches in QMA 2 for all TCEPR data from 1989–90 to 2000–01 (source: MFish TCEPR data). The size of the point indicates the relative size of the catch. Locations are rounded to 6 minute intervals due to commercial sensitivity.

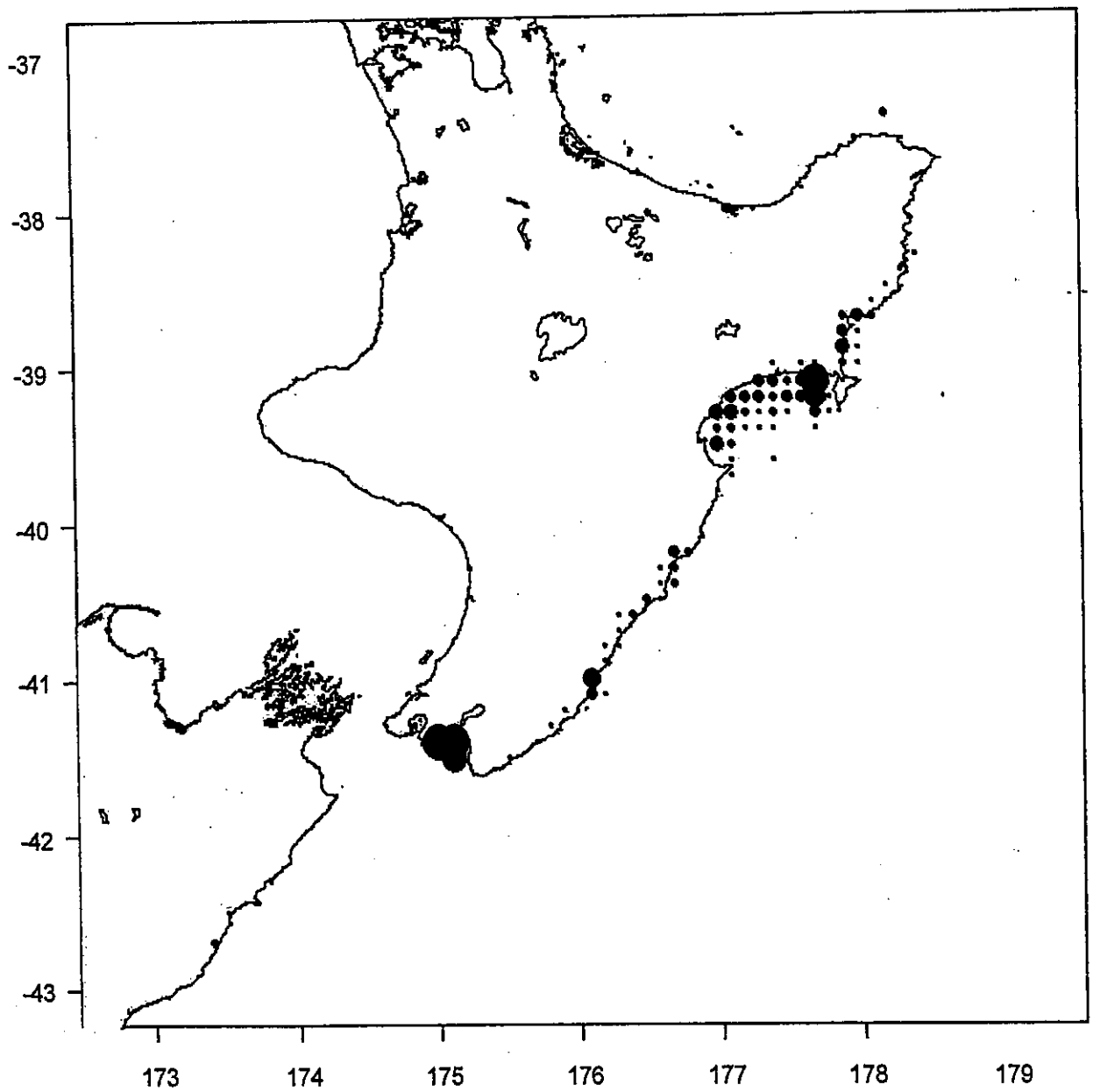

Figure 15: Location and size of flatfish catches in QMA 2 for all TCEPR data from 1989–90 to 2000–01 (source: MFish TCEPR data). The size of the point indicates the relative size of the catch. Locations are rounded to 6 minute intervals due to commercial sensitivity.

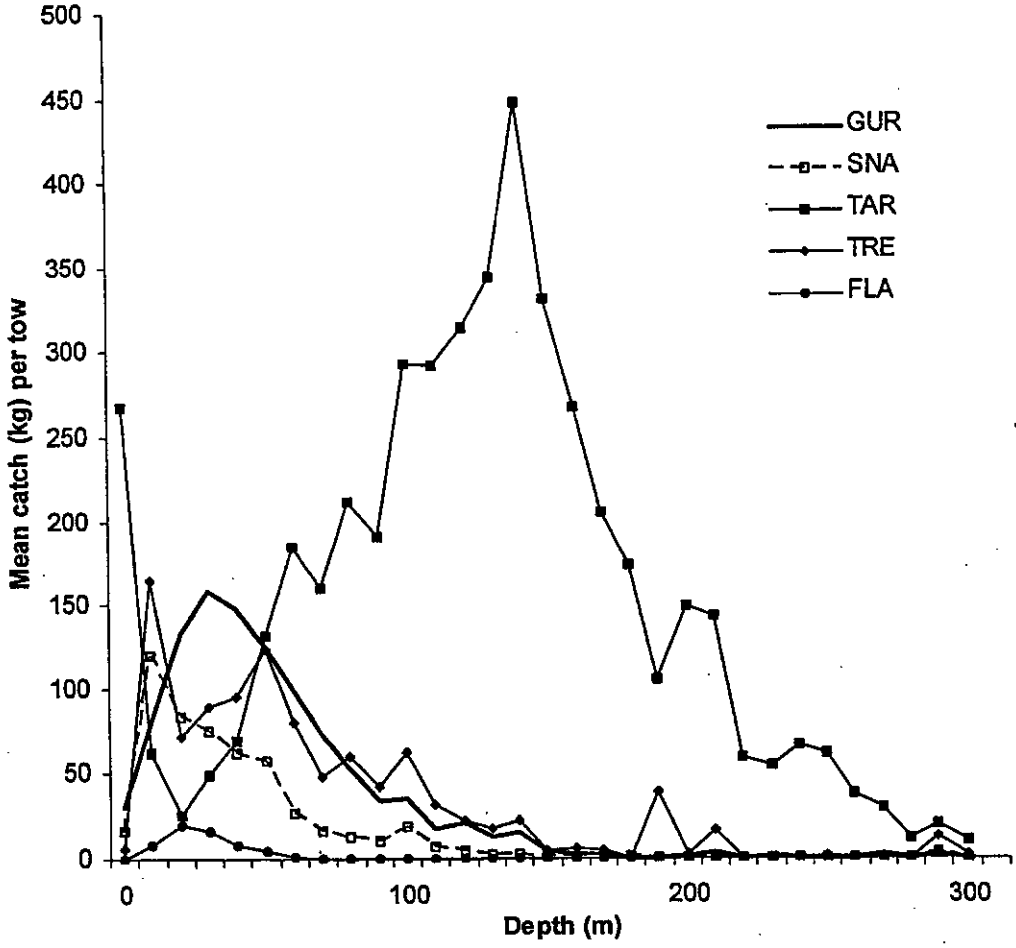

Figure 16: Average catch rates (kg/tow) of GUR, SNA, TAR, TRE, and FLA by 10 m depth bins in statistical areas 13 and 14, from TCEPR data 1989–90 to 2000–01.

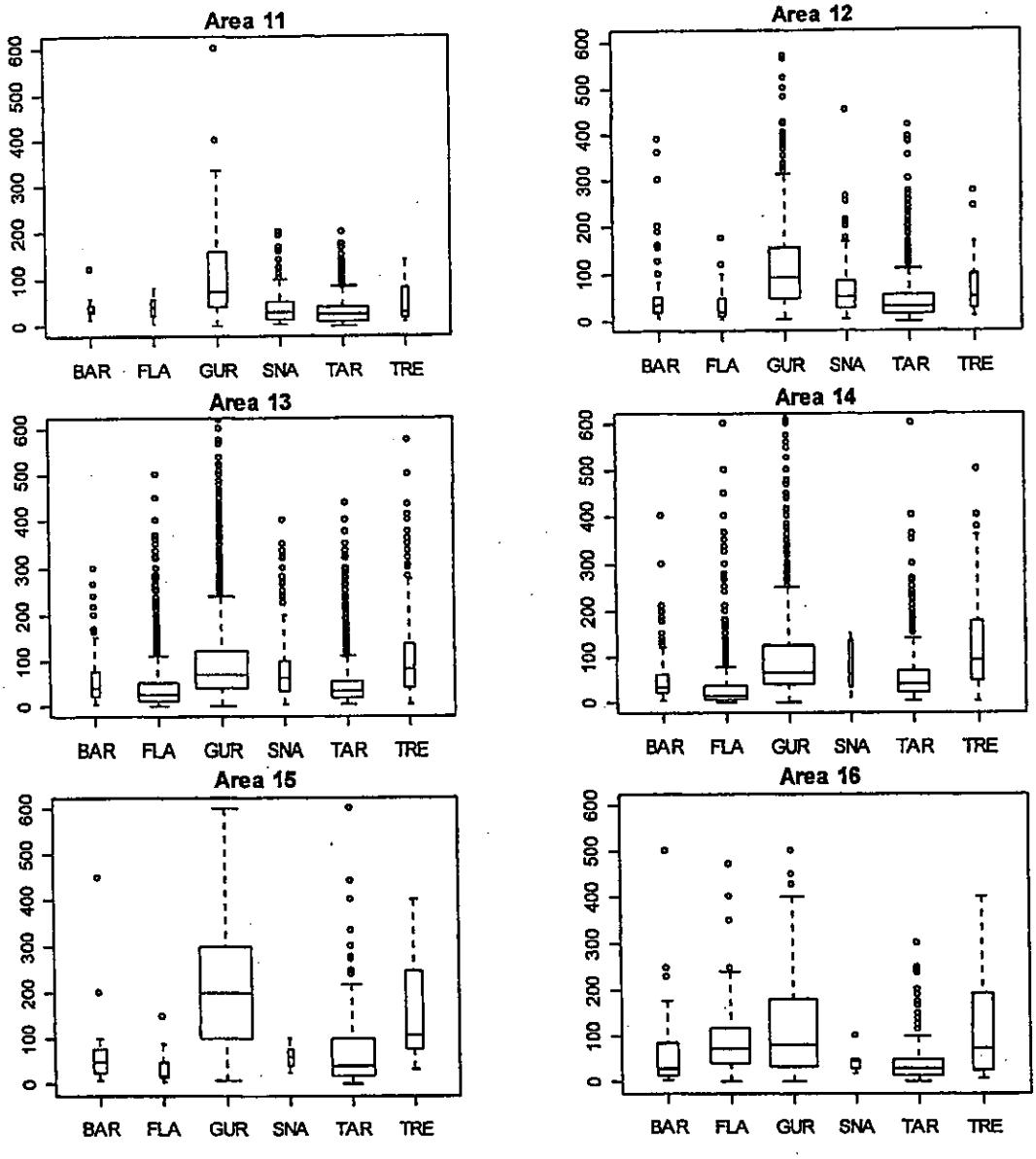

Figure 17: Distributions of catch rate of red gurnard (kg per tow; vertical axes) by target fishery, within statistical areas, for 1989–90 to 2000–01. The box describes the interquartile range of the data, bisected by the median. The whiskers describe 95% of the data, points are outliers.

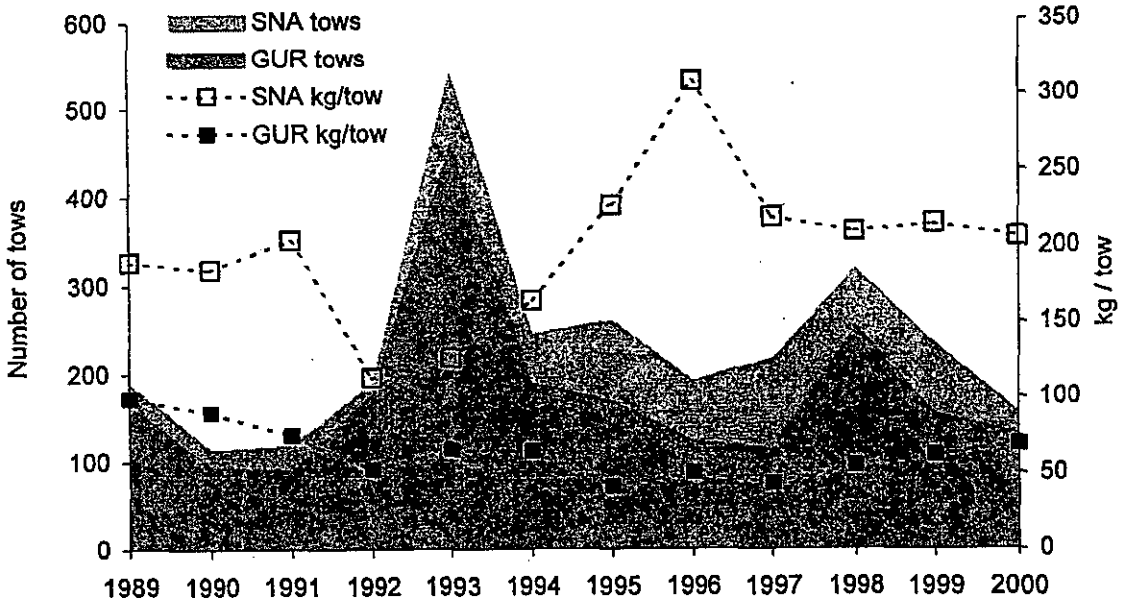

Figure 18: Total annual effort (tows) expended in SNA 2, number of tows that encountered red gurnard, simple annual catch rate for the target species (snapper) and for red gurnard as bycatch.

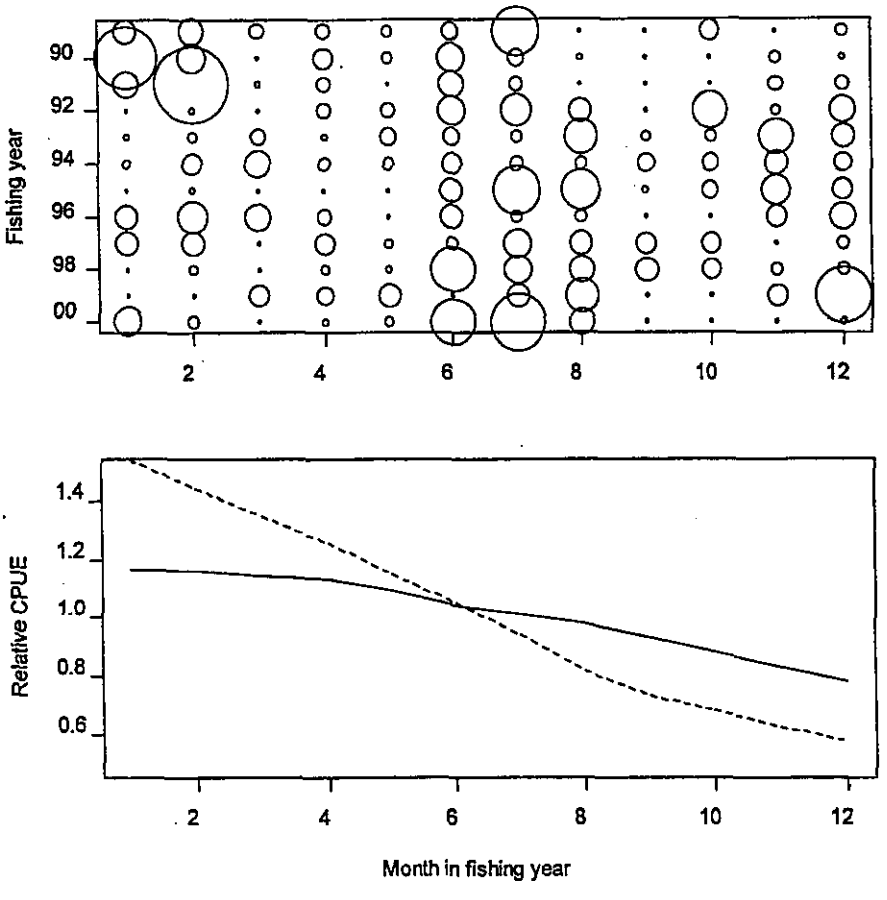

Figure 19: The seasonal pattern of effort (proportion of annual tows by month) expended in the SNA 2 target fishery by fishing year [top], and seasonal catch rates for the target species (snapper) [solid line] and for red gurnard as a bycatch [dotted line] [bottom]. Months 1–12 are October–September. Relative CPUEs are lowess curves through simple arithmetic CPUE (kg/tow), all years combined, relative to the geometric mean of the series. Thus the two series are not to scale relative to each other.

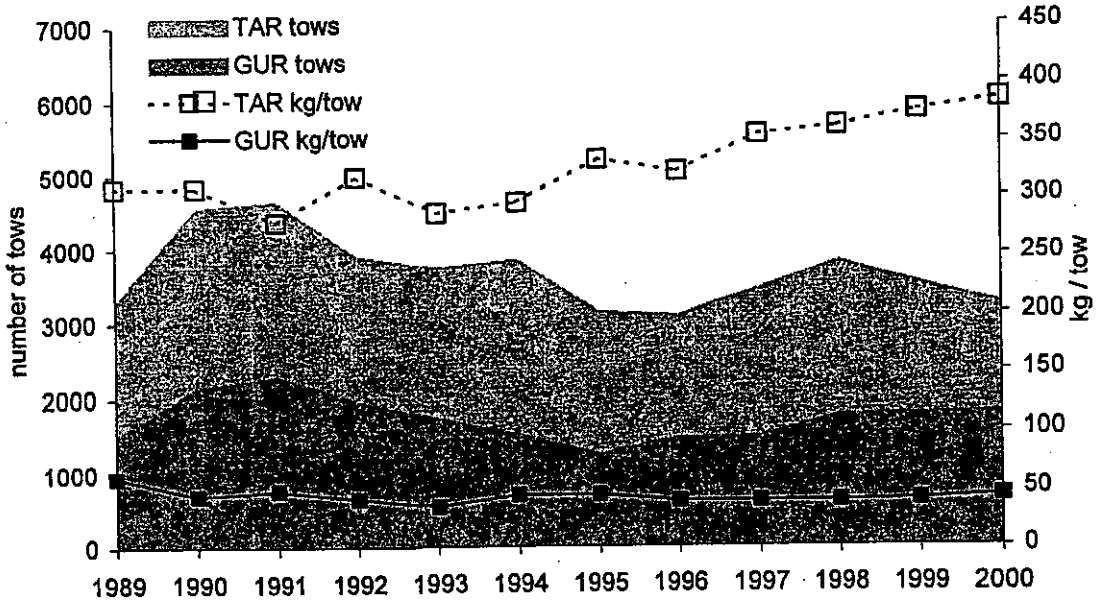

Figure 20: Total annual effort (tows) expended in TAR 2, tows that encountered red gurnard, simple annual catch rate for the target species (tarakihi) and for red gurnard as bycatch.

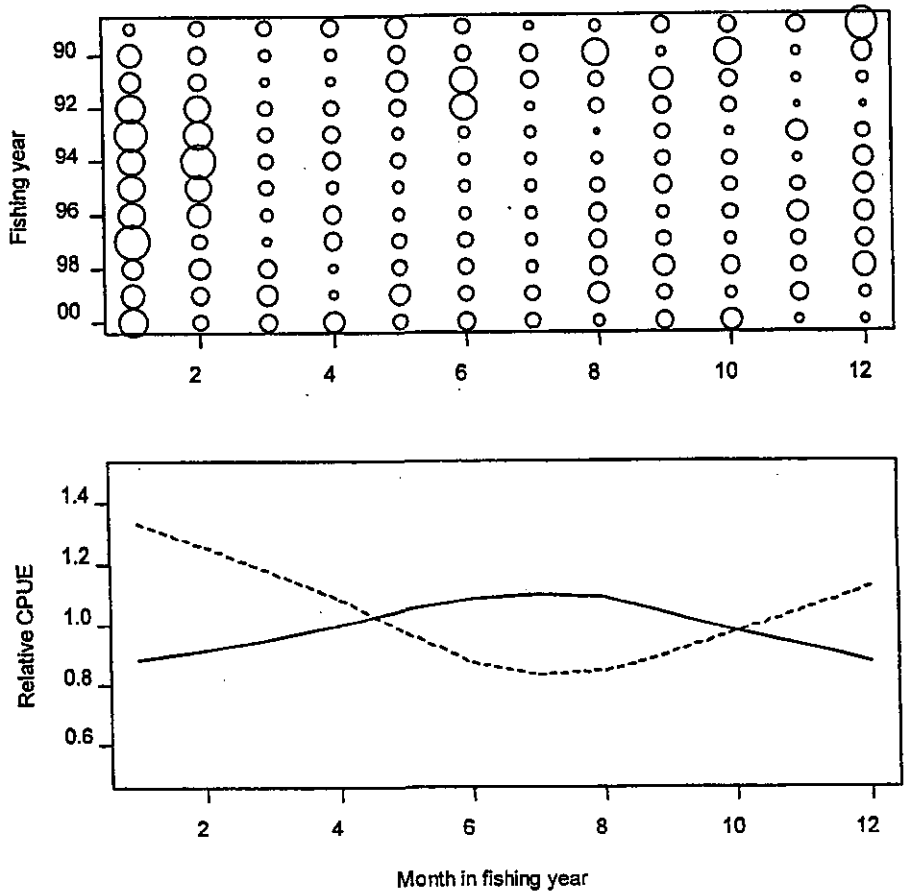

Figure 21: The seasonal pattern of effort (proportion of annual tows by month) expended in the TAR 2 target fishery by fishing year [top], and seasonal catch rates for the target species (tarakihi) [solid line] and for red gurnard as a bycatch [dotted line] [bottom]. Months 1–12 are October–September. Relative CPUEs are lowess curves through simple arithmetic CPUE (kg/tow), all years combined, relative to the geometric mean of the series. Thus the two series are not to scale relative to each other.

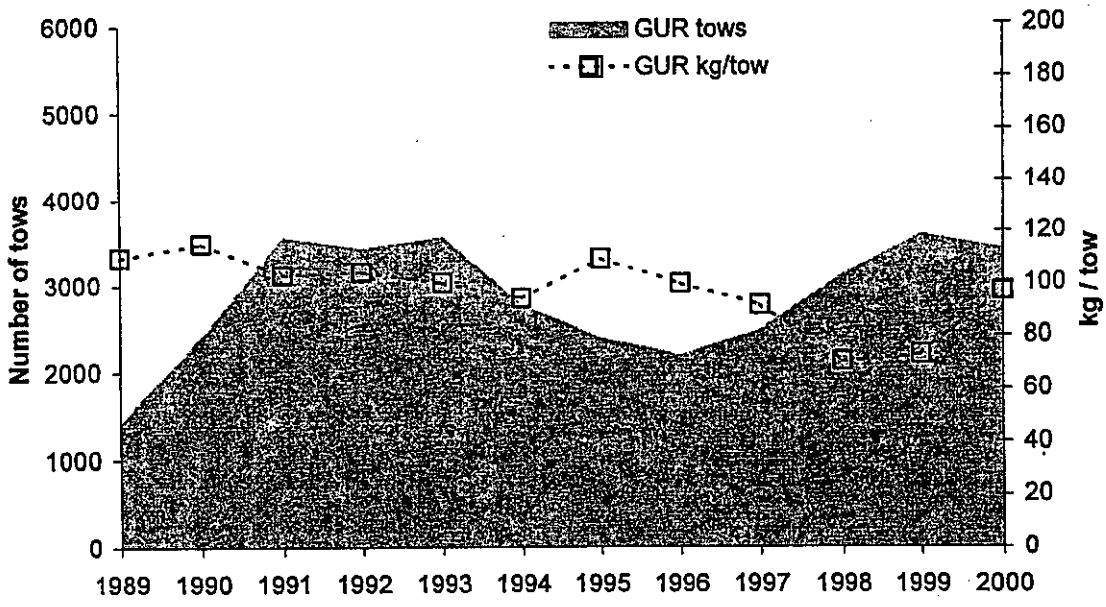

Figure 22: Annual effort (tows) expended in the red gurnard target fishery, and the total annual catch rate for targeted red gurnard.

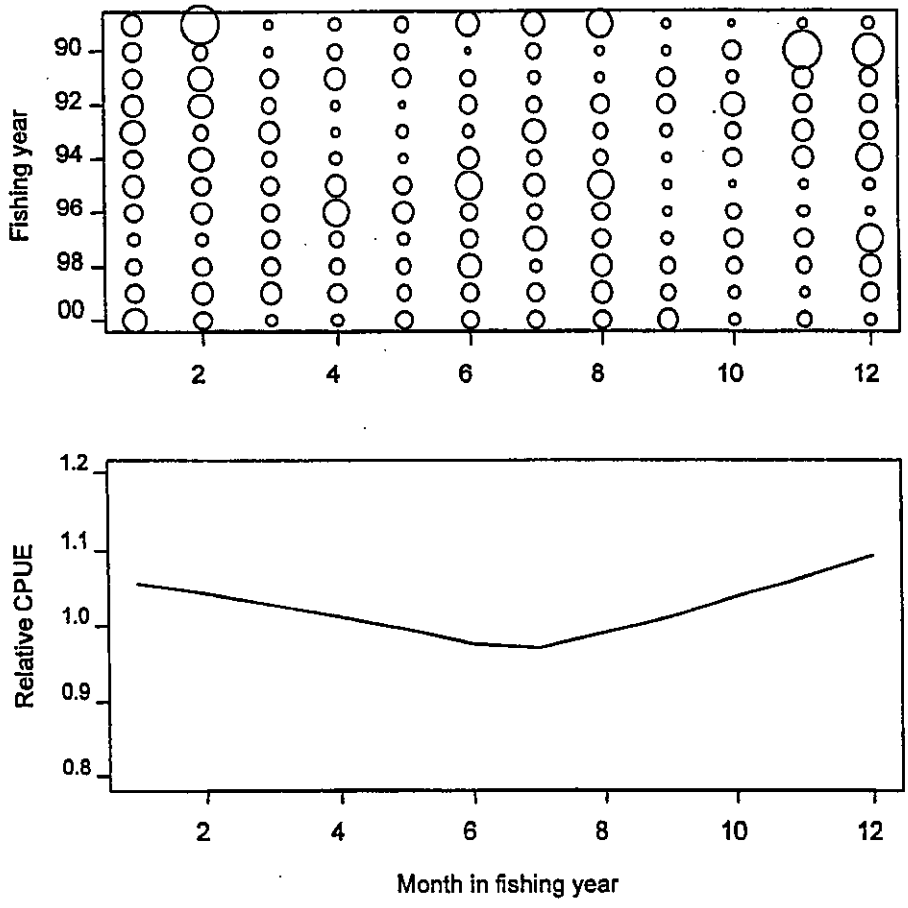

Figure 23: The seasonal pattern of effort (proportion of annual tows by month) expended in the GUR 2 target fishery by fishing year [top], and seasonal catch rates for the target species gurnard [bottom]. Months 1–12 are October–September. Relative CPUE is a lowess curves through the simple arithmetic CPUE (kg / tow), all years combined, relative to the geometric mean of the series.

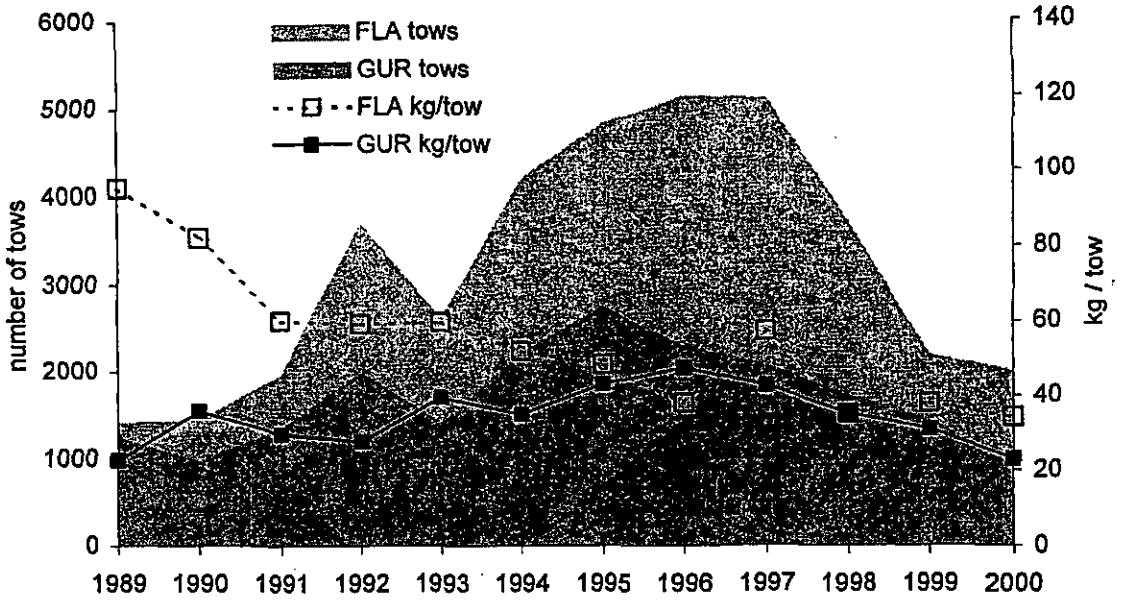

Figure 24: Annual effort (tows) expended in FLA 2, tows that encountered red gurnard, total annual catch rate for the target species (flatfish) and for red gurnard as bycatch.

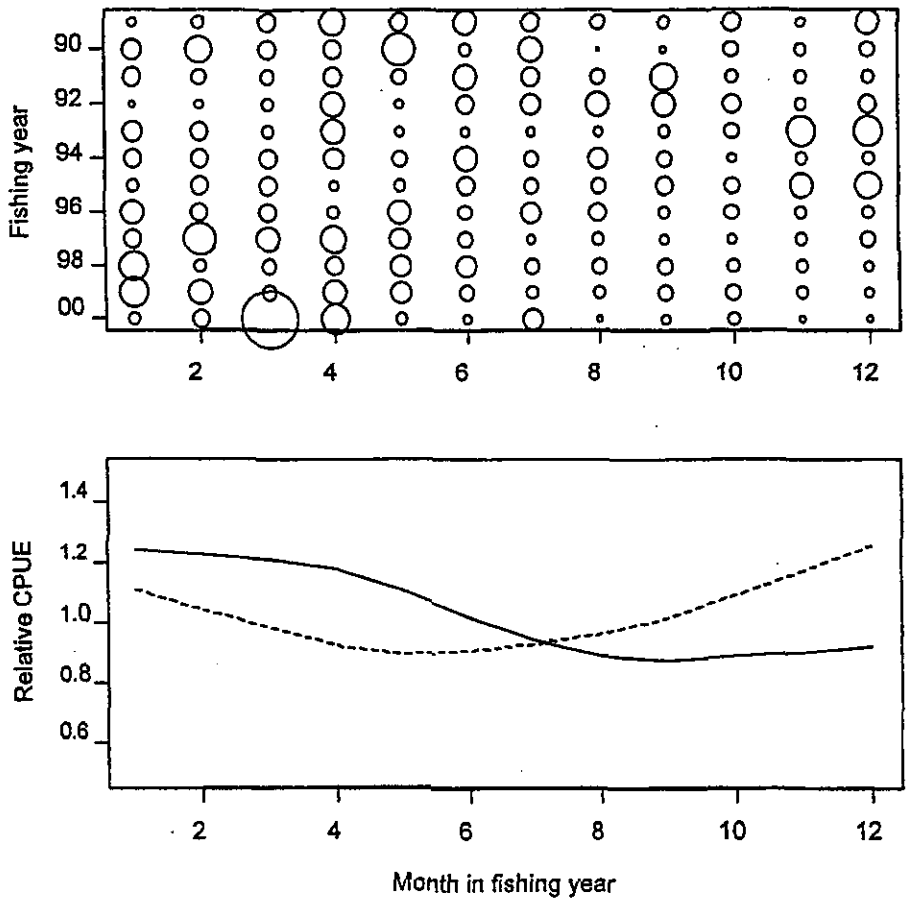

Figure 25: The seasonal pattern of effort (proportion of annual tows by month) expended in the FLA 2 target fishery by fishing year [top], and seasonal catch rates for the target species (flatfish) [solid line] and for red gurnard as a bycatch [dotted line] [bottom]. Months 1–12 are October–September. Relative CPUEs are lowess curves through simple arithmetic CPUE (kg / tow), all years combined, relative to the geometric mean of the series. Thus the two series are not to scale relative to each other.

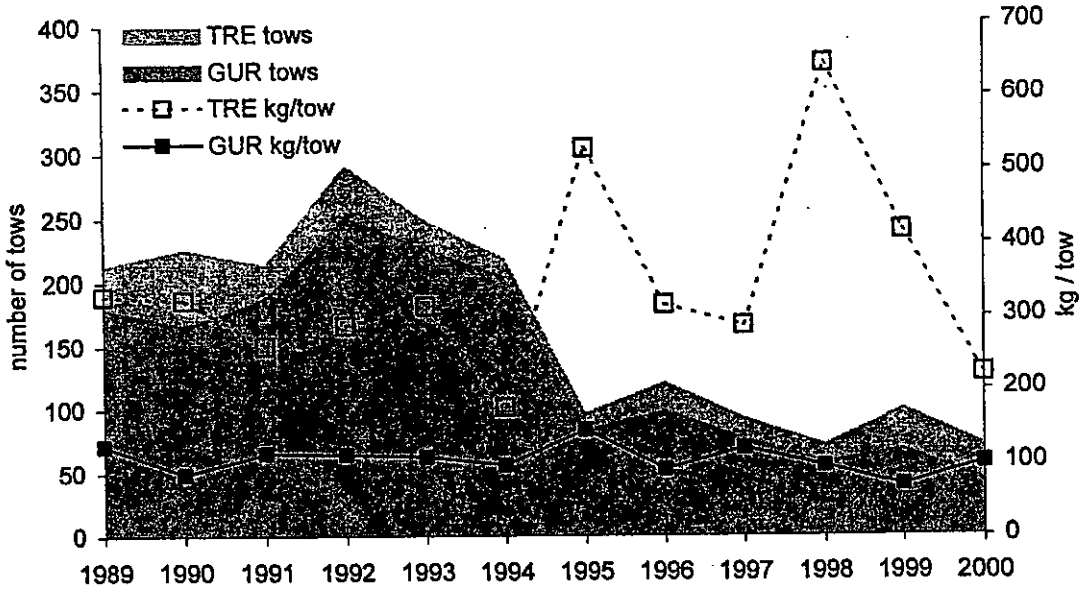

Figure 26: Annual effort (tows) expended in TRE 2, tows that encountered red gurnard, total annual catch rate for the target species (trevally) and for red gurnard as bycatch.

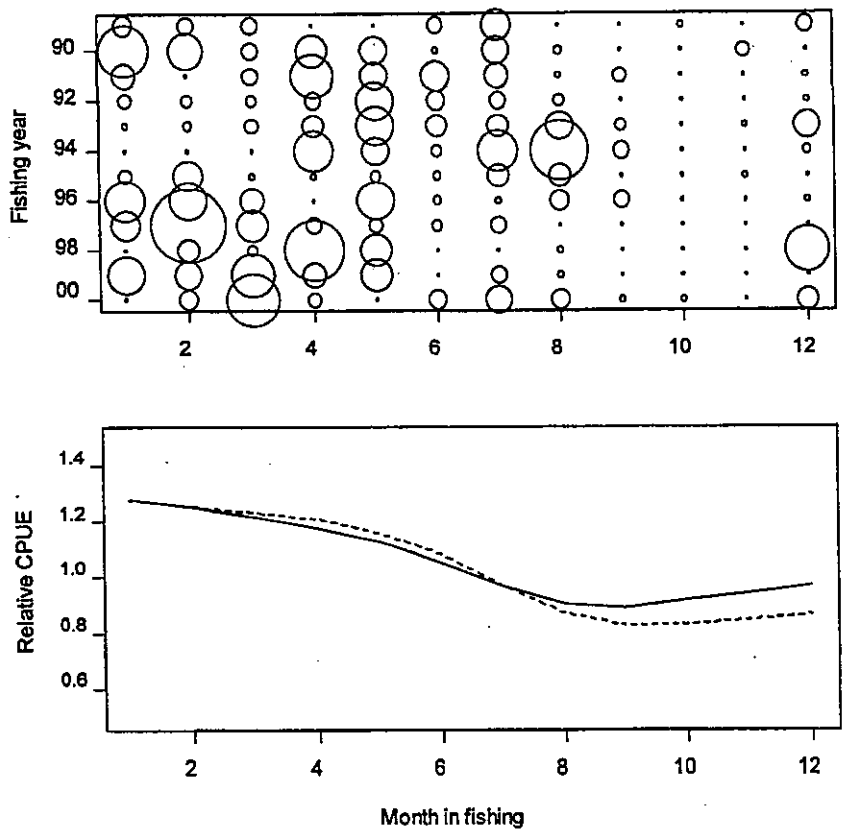

Figure 27: The seasonal pattern of effort (proportion of annual tows by month) expended in the TRE 2 target fishery by fishing year [top], and seasonal catch rates for the target species (trevally) [solid line] and for red gurnard as a bycatch [dotted line] [bottom]. Months 1–12 are October–September. Relative CPUEs are lowess curves through simple arithmetic CPUE (kg/tow), all years combined, relative to the geometric mean of the series. Thus the two series are not to scale relative to each other.

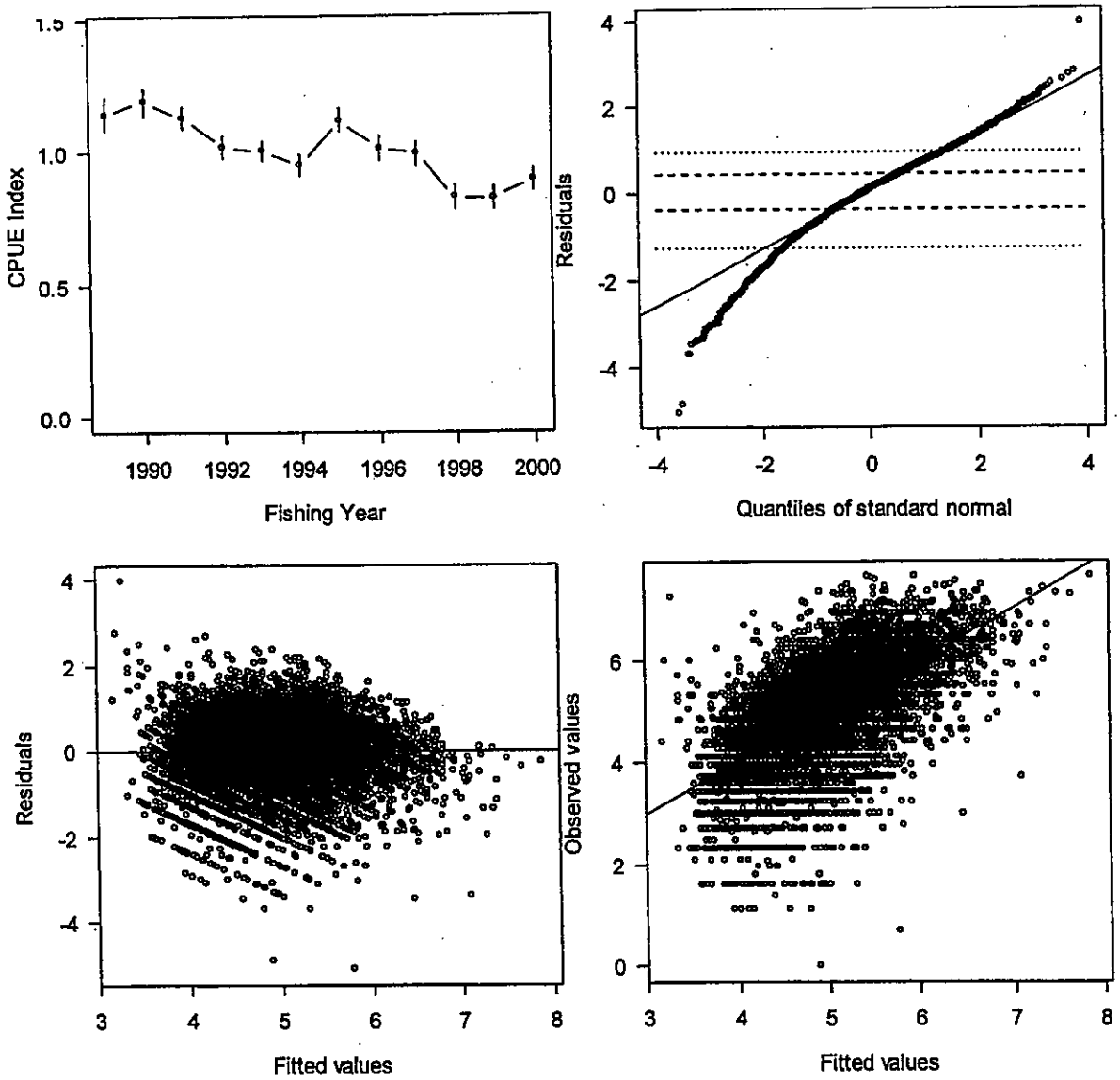

Figure 28: Plots of the fit of the standardised CPUE model to the GUR 2 target fishery data. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q–Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip

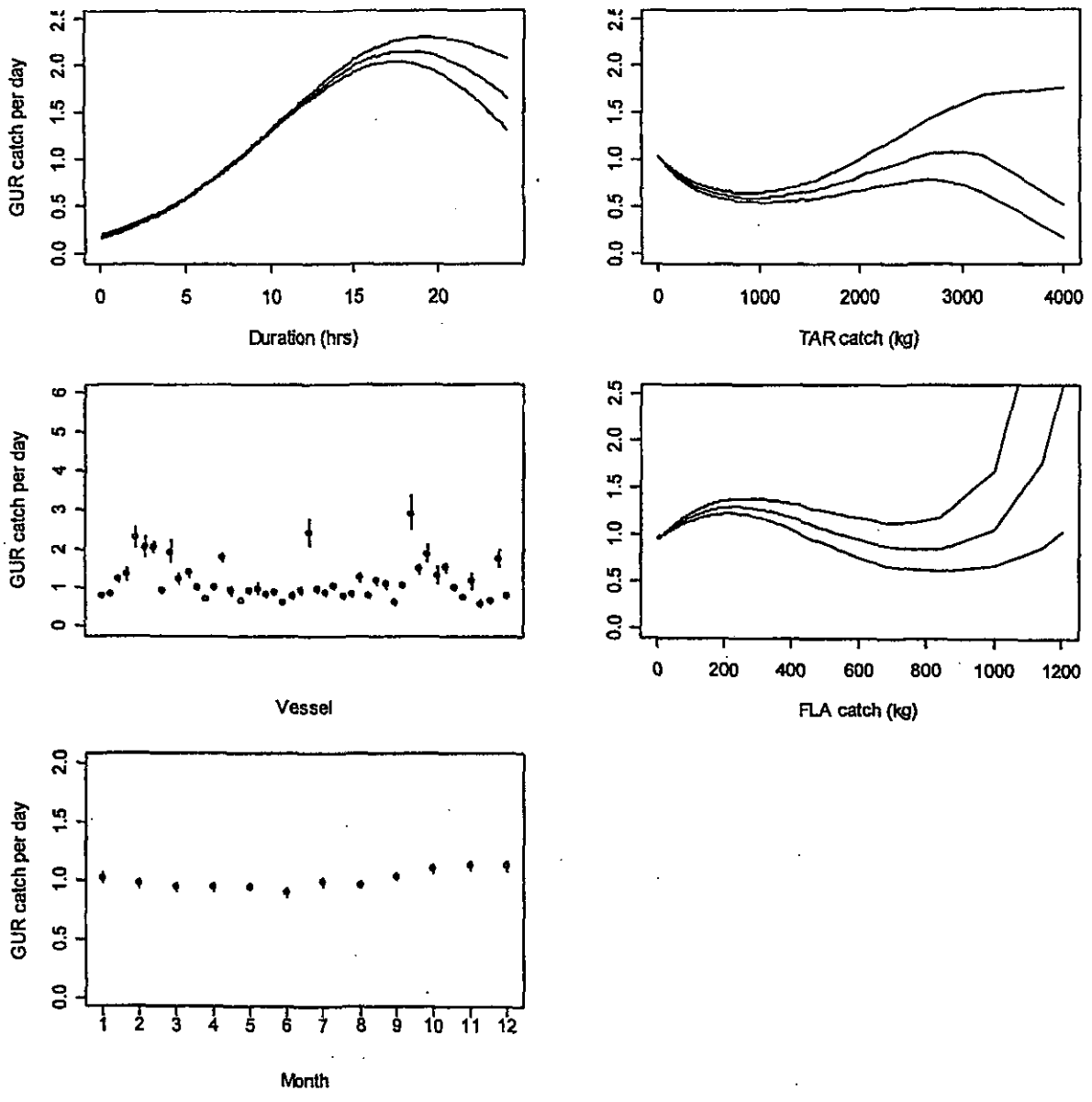

Figure 29: Plots of predicted relative catch (per day) for the categorical and continuous variables included in the standardised CPUE model of the GUR 2 target fishery with 95% confidence intervals. A key for the target species codes is provided in Appendix 1. 1=January in the month categorical plot.

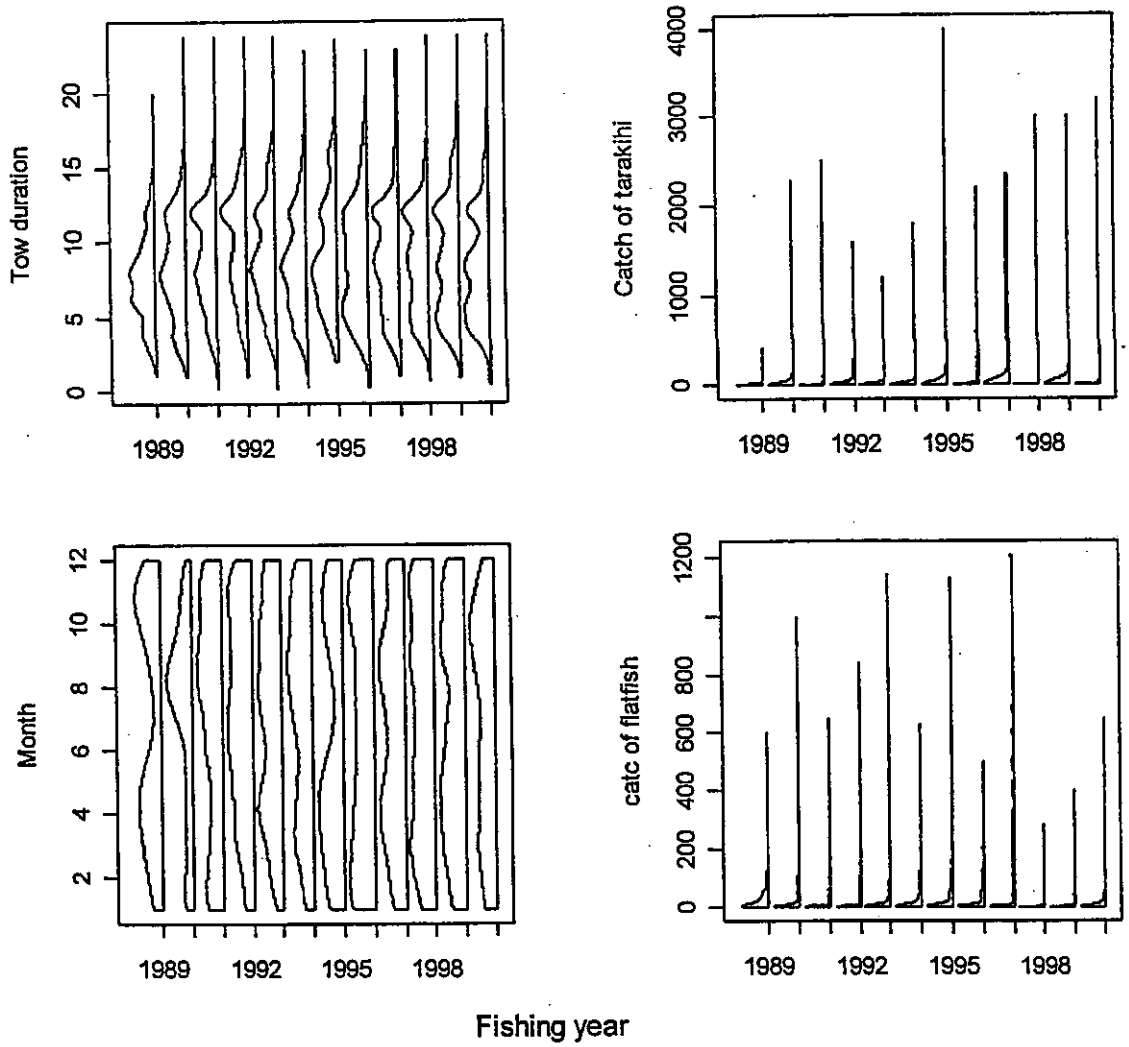

Figure 30: Distribution of the selected explanatory variables included in the standardised CPUE model of the inshore trawl GUR 2 target fishery. Fishing years are coded using the first year of the pair. 1=January in the month categorical plot.

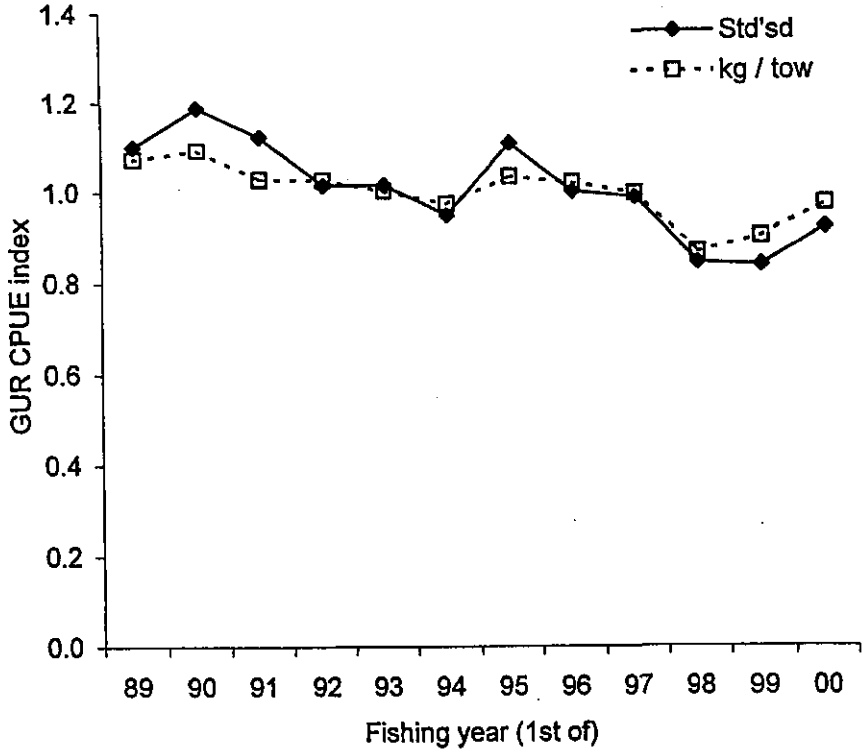

Figure 31: The effect of standardisation on CPUE of gurnard catch in the inshore trawl gurnard target fishery. The measure of simple arithmetic CPUE [kg/tow] is based on the analysis dataset using core vessels, and is scaled relative to the geometric mean of the series.

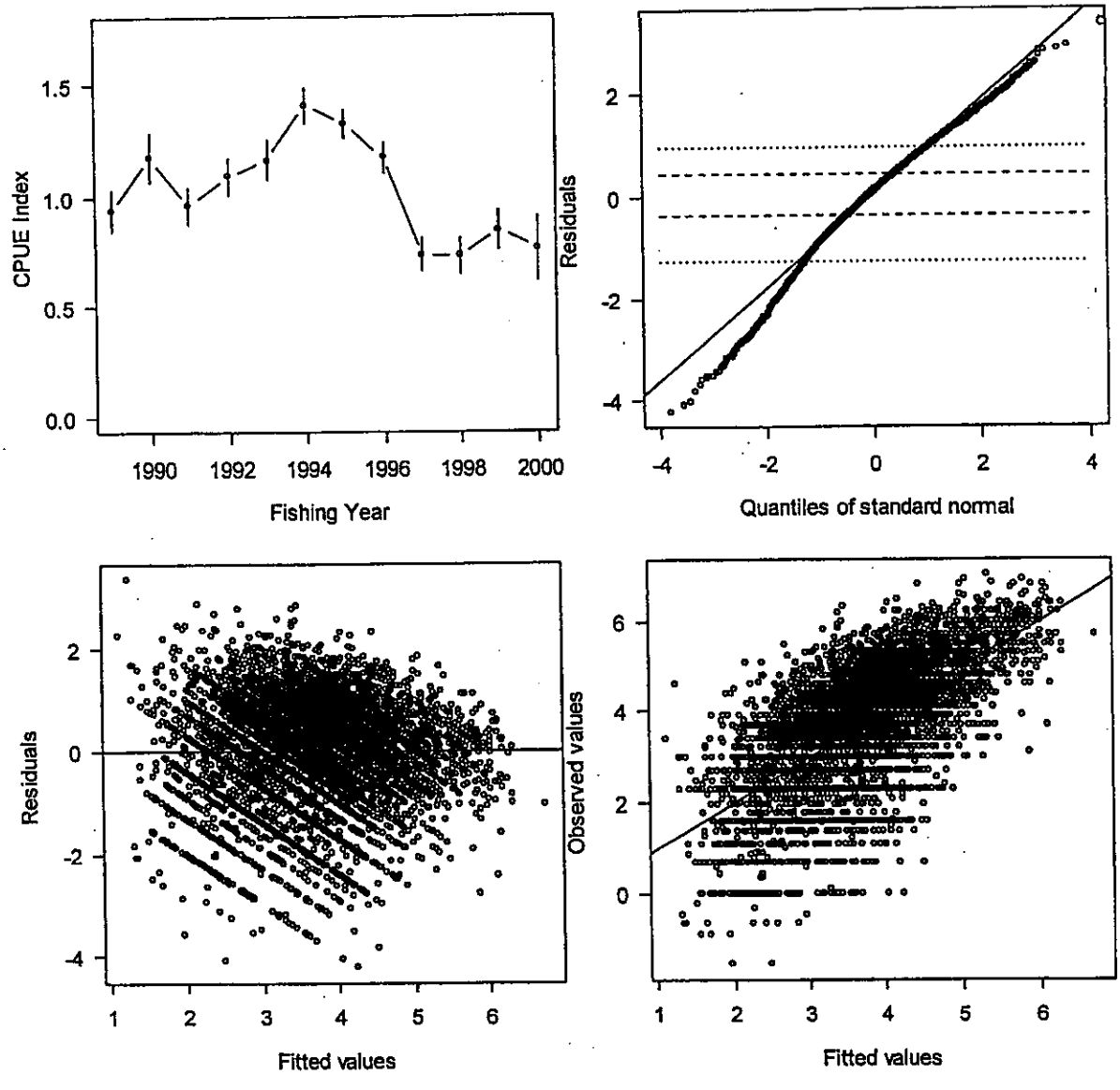

Figure 32: Plots of the fit of the standardised CPUE model to red gurnard (as bycatch of the FLA 2) fishery data. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q–Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

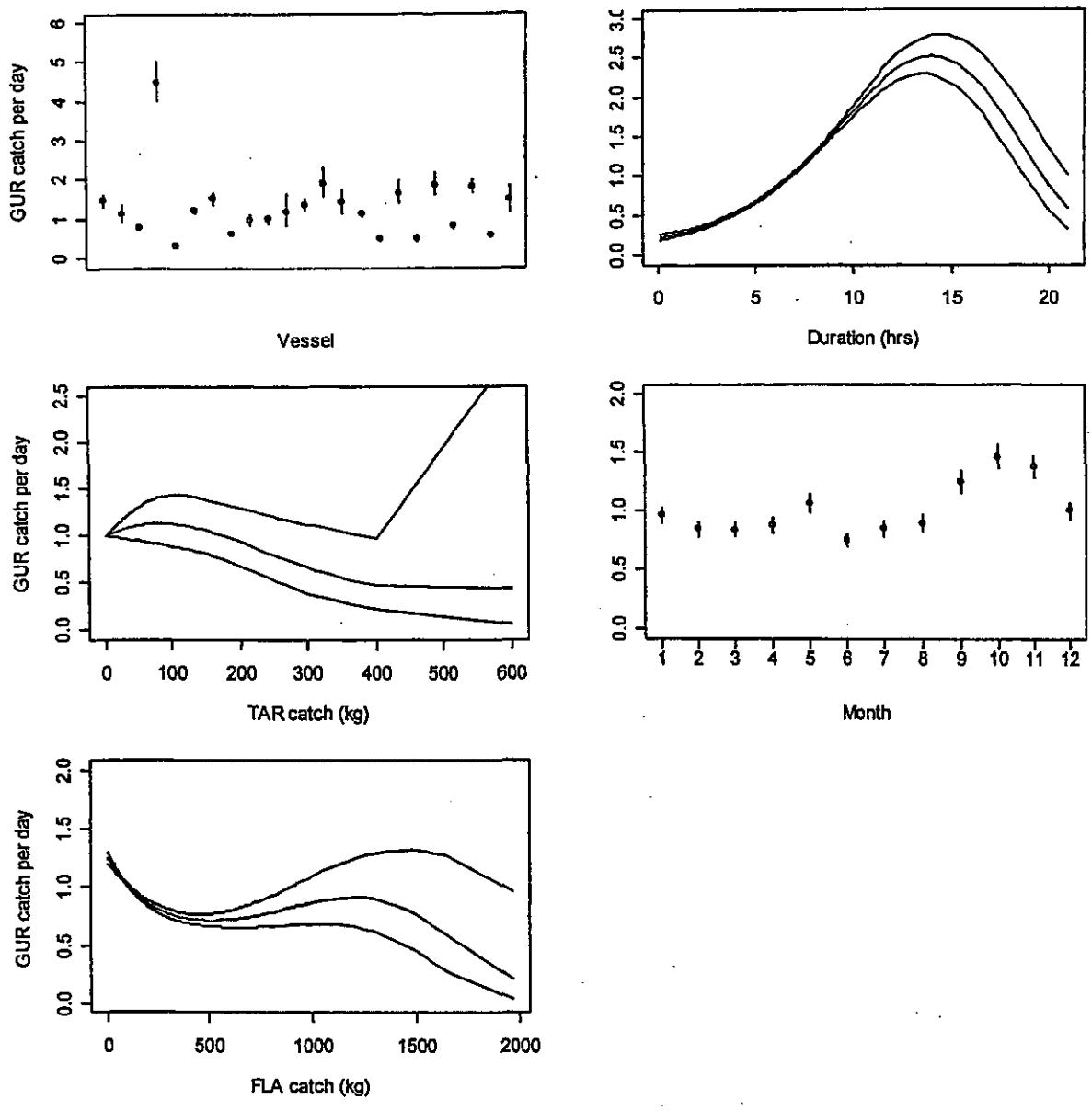

Figure 33: Plots of predicted relative catch (per day) for the categorical and continuous variables included in the standardised CPUE model of red gurnard as bycatch of the FLA 2 target fishery with 95% confidence intervals. A key for the target species codes is provided in Appendix 1. 1=January in the month categorical plot.

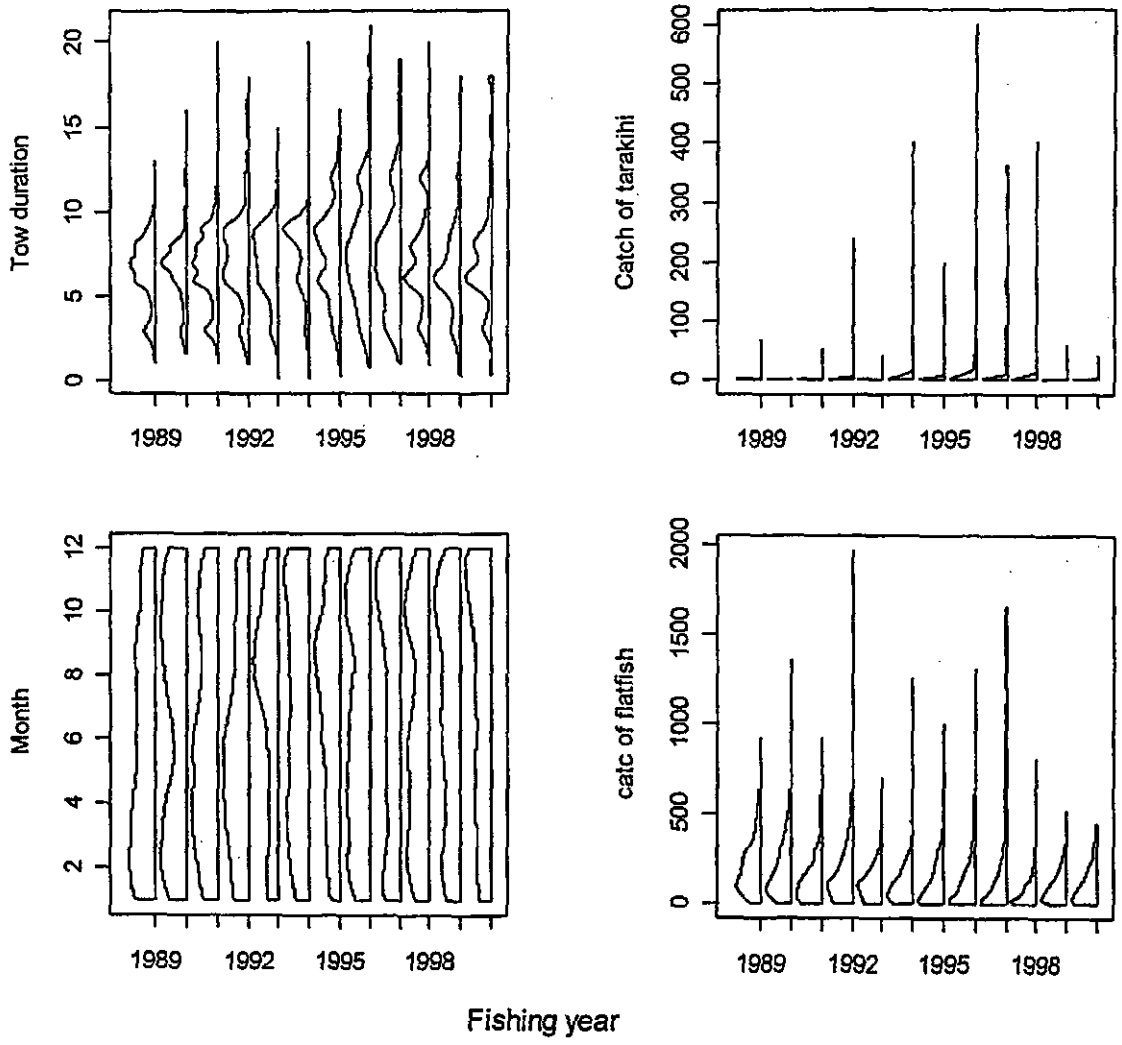

Figure 34: Distribution of the selected explanatory variables included in the standardised CPUE model of gurnard as bycatch of the inshore trawl FLA 2 target fishery. Fishing years are coded using the first year of the pair. 1=January in the month categorical plot.

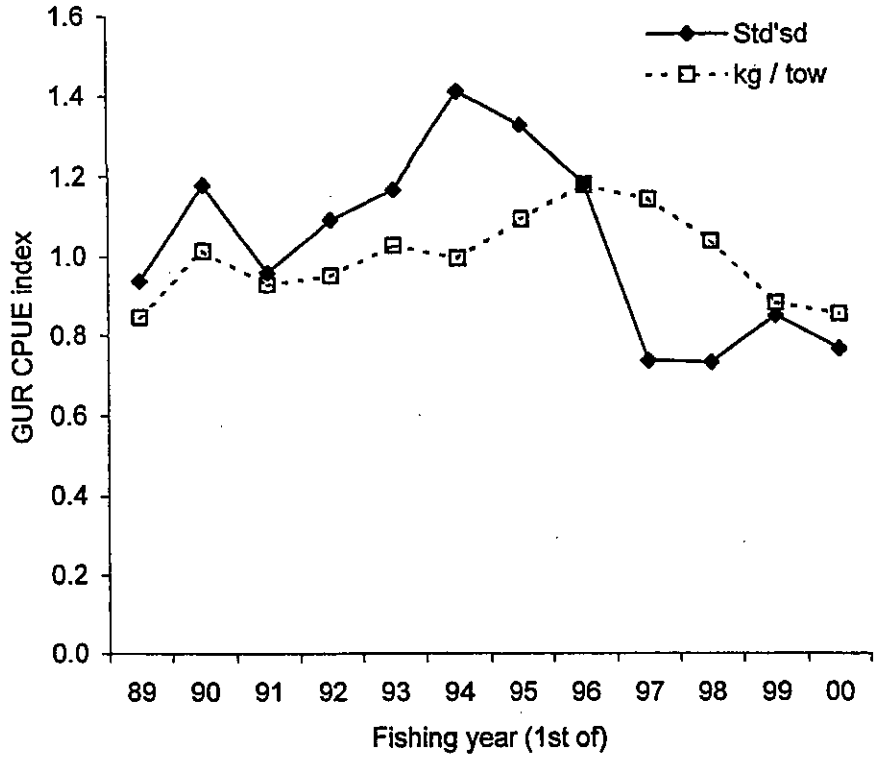

Figure 35: The effect of standardisation on CPUE of gurnard as bycatch of the inshore trawl flatfish target fishery. The measure of simple arithmetic CPUE [kg/tow] is based on the analysis dataset using core vessels, and is scaled relative to the geometric mean of the series

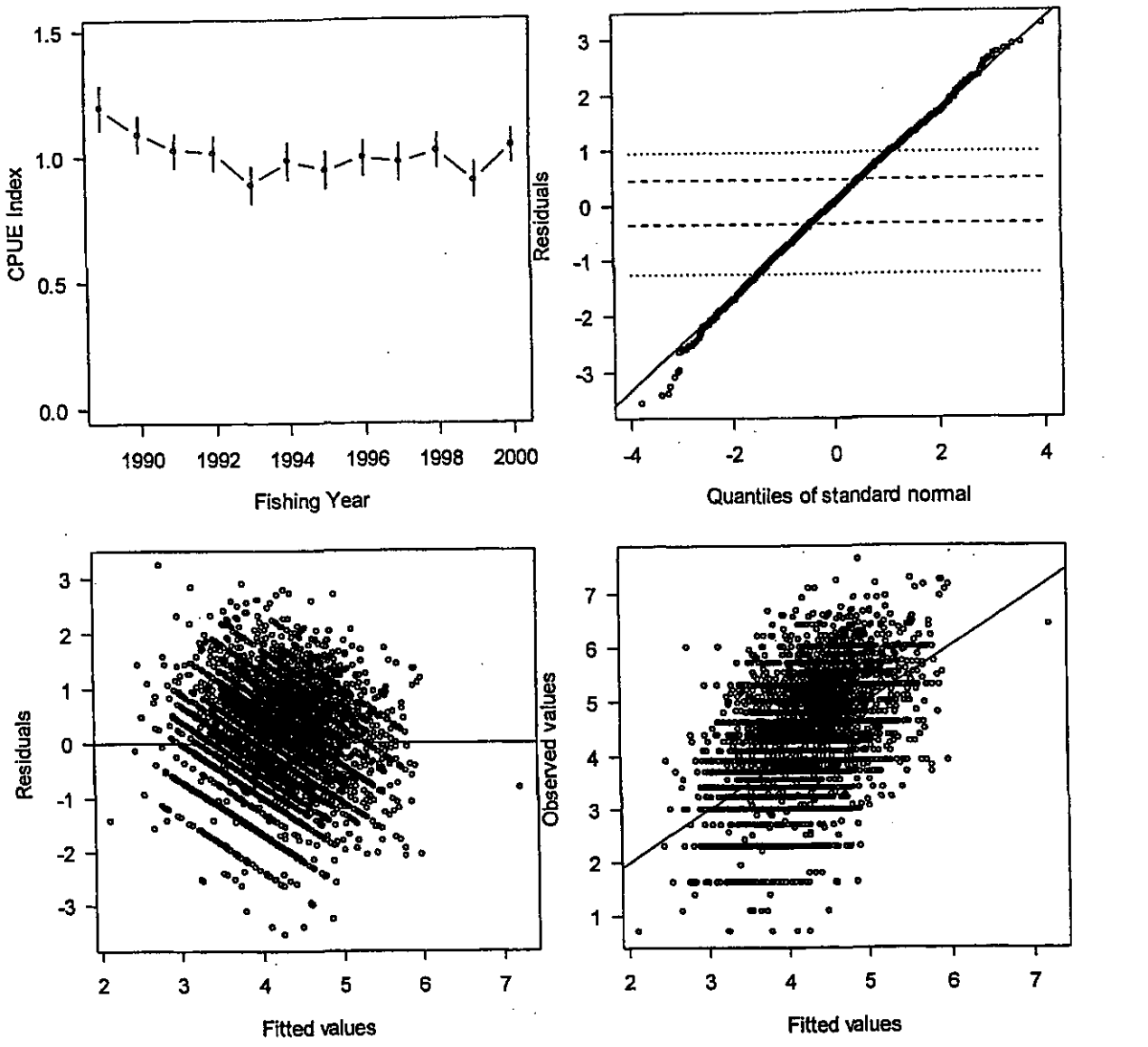

Figure 36: Plots of the fit of the standardised CPUE model to red gurnard (as bycatch of the TAR 2) fishery data. [Upper left] Fishing year abundance indices with ± 2*SE; [Upper right] Q–Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per trip plotted against the predicted catch per trip.

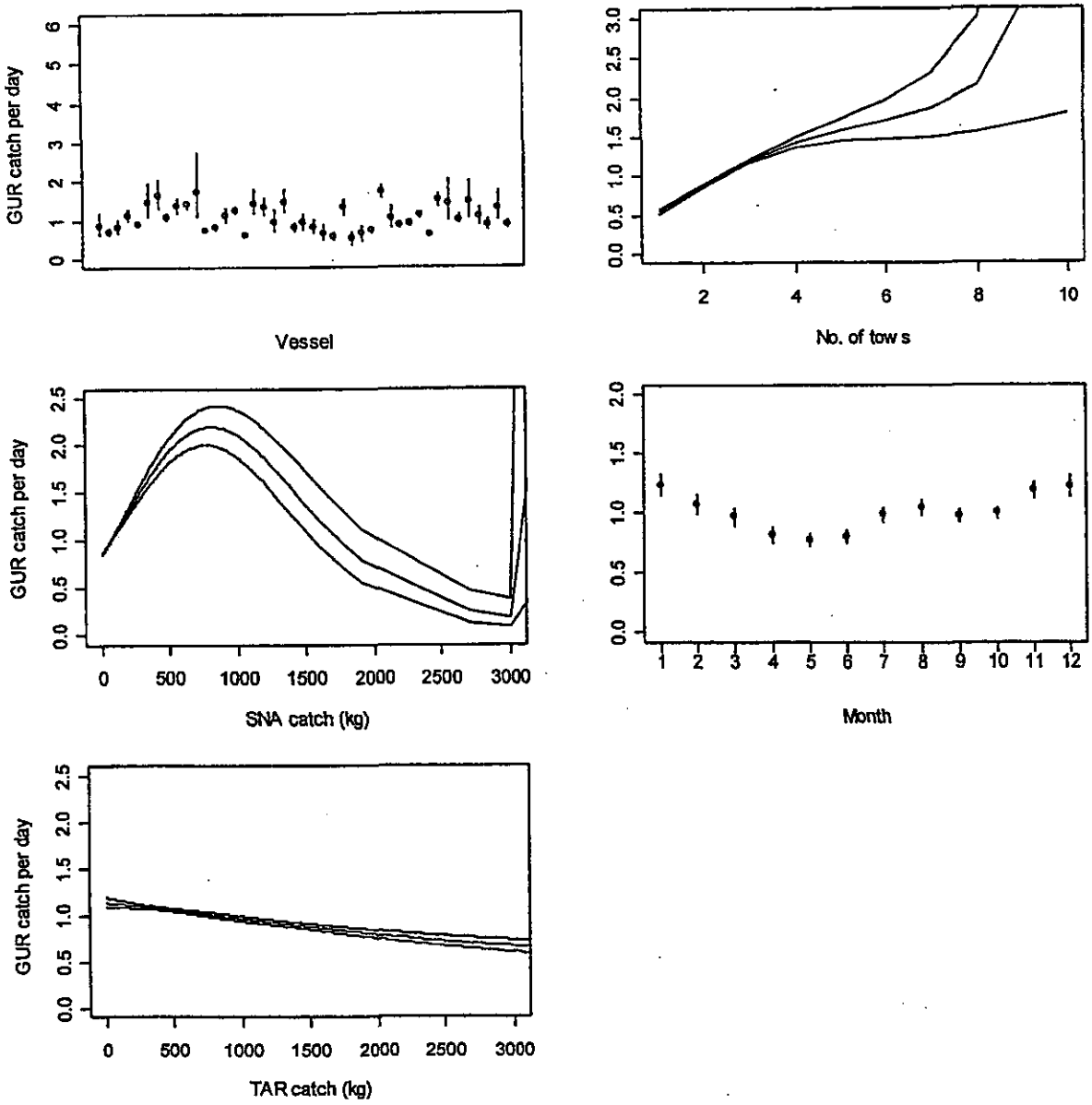

Figure 37: Plots of predicted relative catch (per day) for the categorical and continuous variables included in the standardised CPUE model of red gurnard as bycatch of the TAR 2 target fishery with 95% confidence intervals. A key for the target species codes is provided in Appendix 1. 1=January in the month categorical plot.

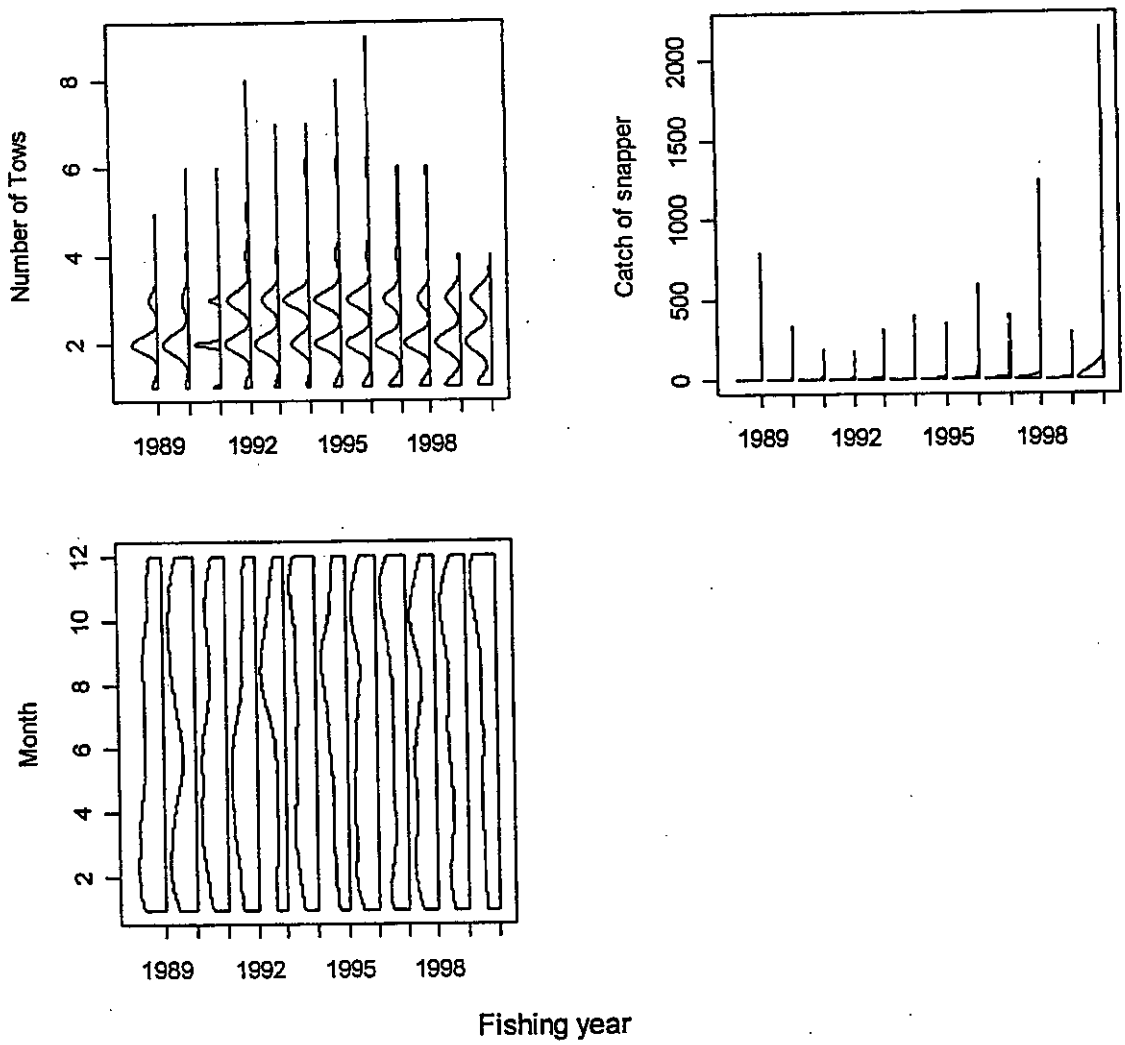

Figure 38: Distribution of the selected explanatory variables included in the standardised CPUE model of gurnard as bycatch of the inshore trawl TAR 2 target fishery. Fishing years are coded using the first year of the pair. 1=January in the month categorical plot.

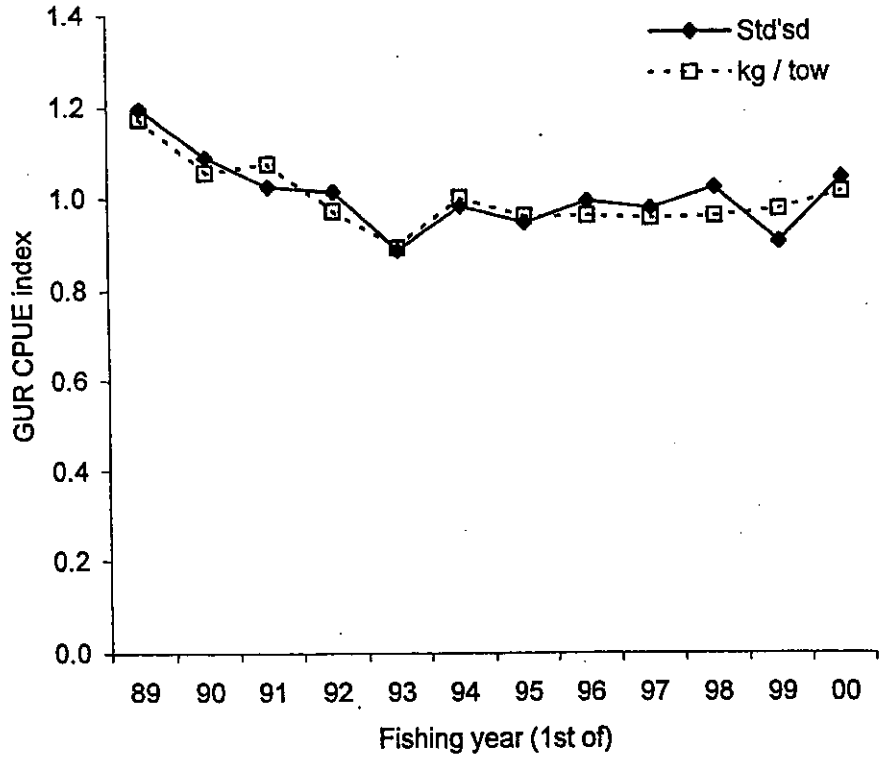

Figure 39: The effect of standardisation on CPUE of gurnard as bycatch of the inshore trawl tarakihi target fishery. The measure of simple arithmetic CPUE [kg/tow] is based on the analysis dataset using core vessels, and is scaled relative to the geometric mean of the series

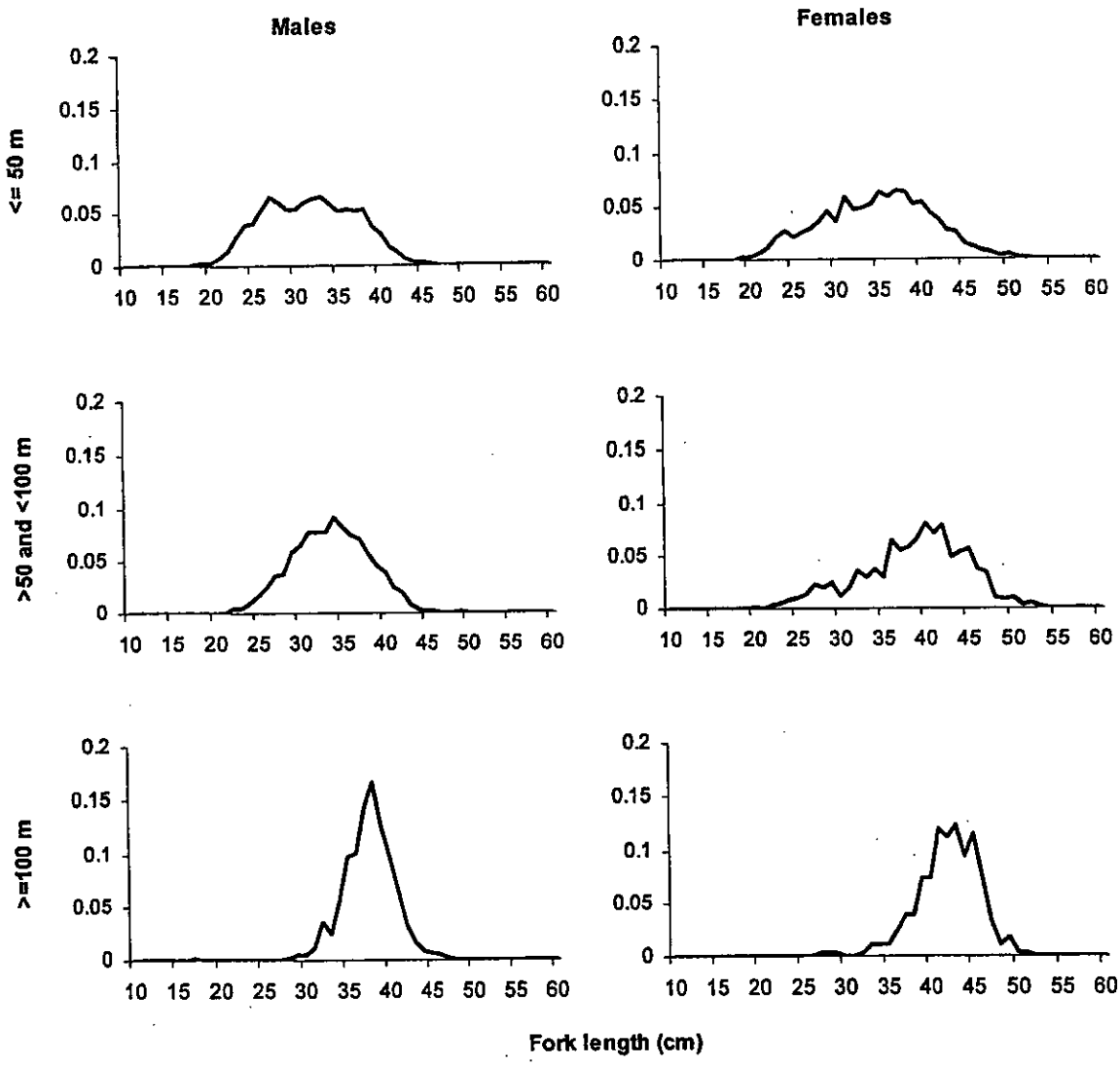

Figure 40: Proportional length frequency of male and female red gurnard from ECNI trawl surveys, in three depth bins that correspond approximately to depth ranges of greatest abundance of flatfish (less than 50 m), tarakihi (more than 100 m), and a mid range (50–100 m) of red gurnard distribution (see Figure 16).

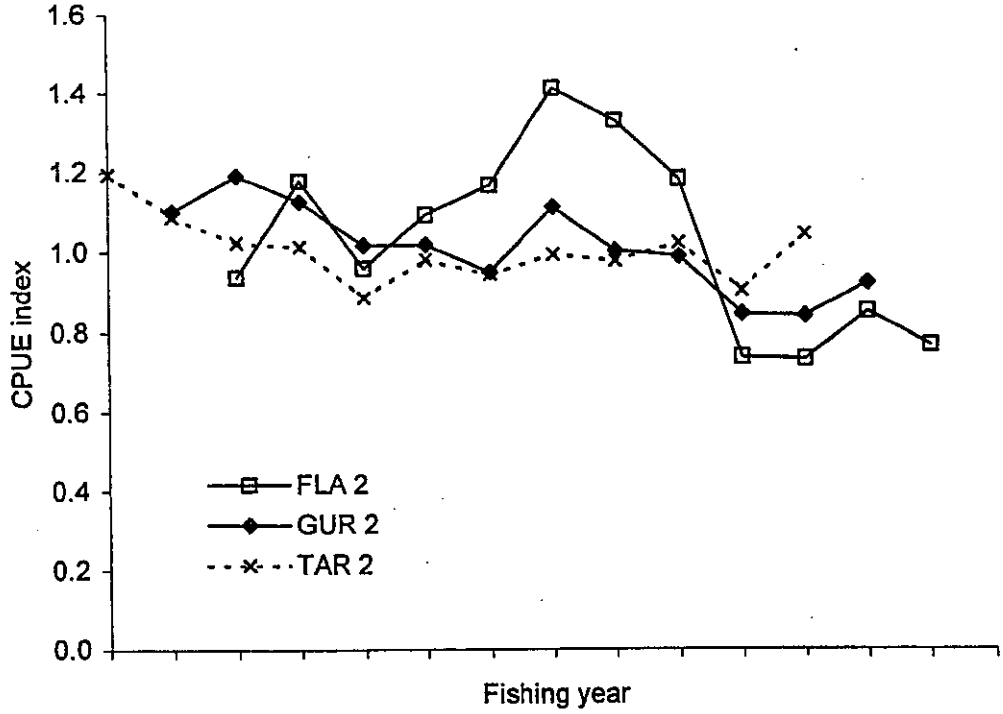

Figure 41: Standardised CPUE indices of gurnard abundance from the flatfish (FLA 2) target fishery, the gurnard (GUR 2) target fishery (lagged one year), and the tarakihi (TAR 2) target fishery (lagged 2 years).

Appendix 1: List of species names and codes

Species code	Common name	Scientific name
GUR	Red gurnard	*Chelidonichthys kumu*
BAR	Barracouta	*Thyrsites atun*
SNA	Snapper	*Pagrus auratus*
TRE	Trevally	*Pseudocaranx dentex*
TAR	Tarakihi	*Nemadactylus macropterus*
MOK	Blue moki	*Latridopsis ciliaris*
RCO	Red cod	*Pseudophycis bachus*
HOK	Hoki	*Macruronus novaezelandiae*
ORH	Orange roughy	*Hoplostethus atlanticus*
WAR	Warehou	*Seriolella* spp
SKI	Gemfish	*Rexea solandri*
FLA	Flatfish	(includes all species listed below)
ESO	New Zealand sole	*Peltorhamphus novaezeelandiae*
BFL	Black flounder	*Rhombosolea retiaria*
GFL	Greenback flounder	*Rhombosolea tapirina*
LSO	Lemon sole	*Pelotretis flavilatus*
SFL	Sand flounder	*Rhombosolea plebeia*
TUR	Turbot	*Colistium nudipinnis*
YFL	Yellow–belly flounder	*Rhombosolea leporina*
FLO	Flounder	
BRI	Brill	*Colistium guntheri*