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EXECUTIVE SUMMARY

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In recent years, the annual catch of ELE 3 increased from 400–500 t in the early 1990s to about 900 t between 1997–98 and 1999–2000. During this period, the annual catches consistently exceeded the TACC for ELE 3. Most of the increase in catch has been attributed to an increase in the bycatch of elephantfish from the target red cod (RCO 3) trawl fishery operating in Pegasus Bay and Canterbury Bight. The ELE 3 bycatch is principally taken during the October to March period. Between 1989–90 and 1999–2000, there has been an increase in the proportion of red cod fishing trips landing ELE 3 and a general increase in the magnitude of the bycatch landed by vessels in the fishery.

A standardised CPUE analysis of the elephantfish catch and effort data from the RCO 3 target bottom trawl fishery was undertaken. The analysis was restricted to a core group of vessels that had operated in the fishery for at least three years from 1989–90 to 1999–2000, although many of the vessels had participated in the fishery for a considerably longer period. The CPUE analysis was based on the landed catch of elephantfish from all target red cod fishing trips within Pegasus Bay and Canterbury Bight during October to March. The landed catch was used in the analysis to avoid the introduction of potential biases due to problems associated with the reliable recording of the catch of bycatch species under the current statutory reporting regime. Information concerning the corresponding fishing effort was also aggregated for each qualifying fishing trip.

Three options were investigated to model the ELE 3 CPUE from the target RCO 3 fishery. The logarithm of the landed catch of elephantfish was modelled with the inclusion (loglinear all) and exclusion (loglinear non zero) of trips with no catch of elephantfish and the presence/absence of elephantfish in the landed catch from a trip was also modelled (binomial). For each model, the variation in the landed catch of elephantfish or the presence of elephantfish in the catch was explained by the individual vessel, the number of trawls conducted, the red cod catch from the trip, and the fishing year. Model options were reviewed with respect to the diagnostics of the model fit and the magnitude of the variation between the annual CPUE indices. The preferred CPUE index indicated that standardised catch rates of elephantfish had increased by about 70% from the early 1990s. The CPUE index will assist in the ongoing monitoring of the ELE 3 fishery under the Adaptive Management Programme.

1. INTRODUCTION

Elephantfish is an important bycatch of the inshore trawl and set net fisheries operating within Canterbury Bight and Pegasus Bay (QMA 3) (Figure 1). A small target set net fishery also operates in the same area (Raj & Voller 1999).

In 1986, the initial TACC for the Elephantfish 3 Fishstock (ELE 3) was established at 280 t. Before the introduction of the QMS, it was considered that the ELE 3 stock had been subjected to heavy fishing pressure and the TACC was set at a low level to allow for stock rebuilding (Annala et al. 2001). The TACC was subsequently increased incrementally between 1986–87 and 1993–94 to 424 t. However, ELE 3 catches exceeded the TACC throughout this period, with annual catches between 400–500 t (Annala et al. 2001).

Since 1993–94, there has been a steady increase in the level of ELE 3 catch and the TACC was further increased to 500 t in 1995–96. However, landings continued to exceed the TACC by 38% in 1995–95, 47% in 1996–97, and 82% in 1997–98. Annual catches were about 900 t between 1997–98 and 1999–2000 (Annala et al. 2001).

Most of the recent increase in catch from the ELE 3 fishery has been bycatch of the RCO 3 trawl fishery (Raj & Voller 1999). From 1989–90 to 1997–98, the level of elephantfish bycatch from the RCO 3 fishery increased from about 50 t to 300 t (Figure 2). There was also a steady increase in the level of ELE 3 bycatch from the flatfish (FLA 3) trawl fishery, with catches increasing from about 50 t in 1994–95 to 150 t in 1997–98 (Figure 2).

This report investigates trends in the level of ELE 3 bycatch from the red cod (RCO 3) target trawl fishery for the period 1989–90 to 1999–2000. The report is restricted to this sector of the ELE 3 fishery for two reasons: (1) The RCO 3 fishery has accounted for the largest proportion of the total ELE 3 catch in recent years, and (2) The RCO 3 fishery has accounted for most of the increase in the total catch from the ELE 3 fishery over the period.

For the 2000–2001 fishing year, the ELE 3 fishery was included in the Adaptive Management Programme and the TACC was increased to 825 t. The objective of the report is to determine a standardised CPUE index for ELE 3 from the bycatch of the RCO 3 fishery. The development of such an index would enable trends in the relative abundance of ELE 3 to be monitored under the current Adaptive Management Programme.

2. DATA ANALYSIS

2.1 Data set

Most of ELE 3 catch from the target RCO 3 fishery is taken within statistical areas 020 and 022 during the November–February period (Raj & Voller 1999). Between 1989–90 and 1997–98, the fishery operating in statistical areas 020 and 022 between October and March accounted for about 65–75% of the annual elephantfish bycatch from the RCO 3 trawl fishery (Raj & Voller 1999).

An extract of catch and effort data from the RCO 3 trawl fishery was provided by the Ministry of Fisheries Information Management Group. The extract included all records from individual fishing trips by domestic registered vessels where at least one trawl was conducted targeting red cod within either statistical area 020 or 022 during the 1989–90 to 1999–2000 fishing years. The extract was restricted to fishing trips within the October to March period.

Data were extracted from both the TCEPR and CELR formats and included the landed catch of ELE 3 and RCO 3 from the corresponding fishing trips. The following data variables were extracted from each data format.

CELR data
CELR effort. Trip key, vessel key, overall length of vessel, year vessel built, power, gear method, target species, statistical area, fishing date, effort number (number of trawls), fishing duration, estimated ELE catch, and estimated RCO catch.
CELR landing. Trip key, vessel key, trip start date, trip end date, landing date, fishstock code, destination type, and greenweight (kg).

TCEPR data
TCEPR effort. Trip key, vessel key, overall length of vessel, year vessel built, power, gear method, target species, statistical area, start latitude, start longitude, effort depth, bottom depth, fishing start date, fishing start time, fishing end date, fishing end time, estimated ELE catch, and estimated RCO catch.
CLR landing. Trip key, vessel key, trip start date, trip end date, landing date, fishstock code, destination type, and greenweight (kg).

The initial data set was further restricted to those fishing trips that exclusively targeted red cod by bottom trawl for the entire duration of the trip. For the CELR data set, 8669 trips of the initial 9345 trips exclusively targeted red cod, while 1012 trips of the 1462 individual trips in the TCEPR data set met this criterion.

For the fishing trips exclusively targeting RCO 3, all catch and effort data from the trip were aggregated. Data from each trip were summarised to determine the fishing year and month of the first day of the trip, the trip duration (number of days), and the number of trawls completed during the trip. The total estimated elephantfish catch, the total estimated red cod catch, the total landed ELE 3 catch, and the total landed RCO 3 catch was also determined

2.2 Data checking

A number of range checks were conducted on the aggregated data from the fishing trips exclusively targeting RCO 3. The qualifying range for each variable was determined from an examination of the distribution of the total data set. The specific qualifying range for each variable was as follows.

1. The duration of the fishing trip was less than 6 days.
2. The average number of trawls per day for a trip was less than or equal to 10.
3. Total landed weight of ELE 3 for a trip less than 25 tonne greenweight.
4. Total landed weight of ELE 3 and/or RCO 3 not null.

Trip records with variables beyond the qualifying range were identified and examined in more detail. Errors in the duration of the fishing trip were often due to incorrect start or end dates. Errors in the number of trawls were often attributable to transposing the effort number (number of trawls) and fishing duration fields on the CELR form. Obvious errors were corrected, while the small number of trip records with unresolvable errors were deleted (less than 1% of all trip records).

There were a large number of trip records with no corresponding landed catch data for RCO 3 (692 records) or ELE 3 (3344 records). This is mostly due to a genuine null landing for the fishstock for the fishing trip (zero catch). However, it can also occur through an error in the generation of the unique trip key for a specific fishing trip that results in a loss of the linkage between the effort data for the trip and the landed catch.

For fishing trips with no corresponding landing data for ELE 3 or RCO 3, the landed catch was assigned equal to the sum of the estimated catch of the species for that trip. On this basis, 92% of records with no ELE 3 landing data were assigned a zero catch.

A comparison of the estimated and landed catch revealed that only 65–75% of the elephantfish catch was recorded on the effort section of the CELR and TCEPR forms (Table 1 and Figure 3). By comparison, the effort section of the form recorded 85–95% of the landed catch of red cod from the corresponding fishing trips. The difference reflects the fact that elephantfish is taken as a relatively small bycatch of the RCO 3 target fishery and catches of the species are not always recorded amongst the top five species caught (by weight) in the estimated catch section of the CELR or TCEPR form. In addition, as the catch of elephantfish is processed at sea, some fishermen may erroneously record the processed weight (dressed state) of species in the estimated catch section rather than the green weight of the catch.

During the 1989–90 and 1999–2000 period, the proportion of the ELE 3 catch recorded on the effort section of the form generally increased from about 60% to 90% of the landed catch (Table 1). Consequently, an analysis of CPUE data solely based on the estimated catch of elephantfish is likely to introduce a positive bias to the annual trend in catch rate from the fishery. It was concluded that the landed catch data represented the most reliable and consistent source of catch data from the ELE 3 fishery and that any CPUE analysis for the fishery should be restricted to the use of these data.

3. FISHERY SUMMARY

3.1 Catch composition

From 1989–90 to 1992–93, about 50% of all RCO 3 target fishing trips in October–March landed no ELE 3 catch and about 80% of trips landed less than 100 kg of ELE 3 (Figure 4). In the four subsequent years, the proportion of trips landing no ELE 3 catch declined to represent 25% of all RCO 3 target fishing trips and the proportion of trips landing a small quantity of ELE 3 (1–99 kg) increased from about 30% to 45%.

Over the 1989–90 to 1996–97 period, there was a steady increase in the proportion of RCO 3 target fishing trips landing 100–500 kg of ELE 3 from 10% to 20% of all landings (Figure 4). There was also a general increase in the proportion of larger (at least 500 kg) landings of ELE 3 from 2% to 9% of RCO 3 target fishing trips during the same period.

From 1996–97 to 1998–99, the proportion of trips with no ELE 3 catch increased from about 25% to 40% of all trips. During the same period, the proportion of landings with a small catch of ELE 3 (1–499 kg) declined from 65% to 45% (Figure 4). However, the proportion of larger (at least 500 kg) landings of ELE 3 continued to increase from 9% in 1996–97 to 24% in 1999–2000.

In 1999–2000, there was a marked decline in the proportion of landings with no elephantfish catch, with a corresponding increase in the proportion of 100–499 kg landings of ELE 3. The proportion of larger landings continued the trend evident in recent years, representing 24% of all landings in 1999–2000 (Figure 4).

3.2 Fleet composition

From 1989–90 to 1998–99, the target RCO 3 fishery operating between October and March supported a fleet of about 40–50 trawl vessels in each year (Table 2). In 1999–2000, the number of vessels declined to 33, probably due to a poor red cod fishing season compared to the previous years (Annala et al. 2001).

In 1989–90 and 1990–91, vessels operating in the RCO 3 fishery conducted about 500 fishing trips per annum during the October–March period. The number of trips steadily increased over the subsequent years to reach a peak of about 1300 fishing trips in 1994–95 (Table 2). Between 1994–95 and 1998–99, the number of trips during the October–March period remained relatively stable at between 1000–1200 per annum. There was a marked decline in the number of target RCO trips in 1999–2000, with only 509 trips conducted between October 1999 and March 2000.

The increase in the number of trawls conducted each year over the 1989–90 to 1998–99 period is consistent with the increase in the number of fishing trips during the same period. Between 1989–90 and 1994–95, the number of trawls conducted during fishing trips exclusively targeting RCO 3 increased from about 1800 to 4900 and the level of effort remained relatively constant at this level in the four subsequent years (Table 2). The total number of trawls declined to about 2800 in 1999–2000, with a corresponding decline in the number of days fished.

The level of RCO 3 catch taken during the October–March period declined slightly from about 2000 t in 1989–90 to 1000 t in 1991–92 before steadily increasing to about 4000 t in 1994–95 (Table 2). RCO 3 catches by the target fishery remained relatively stable at about 4000 t from 1994–95 to 1997–98 and subsequently increased to about 7000 t in 1998–99. The red cod catch declined to about 1000 t in 1999–2000.

The bycatch of ELE 3 from the RCO 3 target fishery in October–March was less than 50 t per annum between 1989–90 and 1991–92 (Table 2). From 1991–92 to 1994–95, the level of elephantfish bycatch steadily increased from 44 t to 250 t and remained relatively steady at this level during the four subsequent years (Table 2). The level of elephantfish bycatch was maintained at this level in 1999–2000 despite the large decline in fishing effort and red cod catch.

The RCO 3 trawl fishery is dominated by a core group of vessels that accounted for most of the fishing effort in the fishery between 1989–90 and 1999–2000 period. This sector of the fleet was defined as those vessels completing at least 50 fishing trips exclusively targeting red cod and operating in the RCO 3 fishery for at least three fishing years during the study period (October to March only). The group of core vessels comprised 50 individual vessels of the total fleet of 108 trawl vessels that had participated in the fishery.

The core vessels in the RCO 3 fishery accounted for 94% of all the fishing trips conducted from October to March, 97% of the ELE 3 catch, and 92% of the RCO 3 catch landed by the entire fleet during the period 1989–90 to 1999–2000 (Table 2). Ten of these core vessels accounted for 30–45% of all fishing trips included in the total data set.

Most (90%) of the total trip records and ELE 3 landed catch included in the core vessel data set was from data reported in the CELR format (Table 3).

3.3 Areal distribution

The areal distribution of fishing effort for the RCO target fishing trips was examined to determine the extent of the fishery. Almost all fishing effort (96%) conducted during these trips was within statistical areas 020 and 022 (Table 4 and Figure 5), with a small proportion of the trawls conducted in the adjacent statistical areas (018 and 024).

The main red cod fishing grounds within statistical areas 020 and 022, based on TCEPR data only, are presented in Figure 5. The fishery in 020 is centred on an area extending northwards through Pegasus Bay from the eastern tip of Banks Peninsula in the 30–70 m depth range. In statistical area 022, fishing is concentrated in the southern Canterbury Bight off Timaru. Fishing grounds in this area extend over the shelf, although concentrated in the 30–100 m depth range, with a small amount of trawling conducted along the 200 m depth contour.

Within the red cod fishing grounds, catches of elephantfish were generally restricted to the shallower depth range, with the larger catches (at least 160 kg) taken from trawls in the Canterbury Bight within the 30–50 m depth range (Figure 6).

4. CPUE ANALYSIS

A standardised CPUE analysis of the ELE 3 bycatch of the RCO 3 target trawl fishery (October–March only) was conducted based on the methods of Vignaux (1992, 1994). The data set included all trips targeting red cod by the 50 core vessels operating in the fishery from 1989–90 to 1999–2000.

The CPUE analysis was based on an individual fishing trip representing the primary unit of effort. It was necessary to summarise the data by fishing trip due to the relatively low and variable reporting of the estimated catch of elephantfish on the effort section of the fishing returns. However, the aggregation of catch and effort data limits the number of potential explanatory variables available for inclusion in the CPUE model.

4.1 CPUE data set

The data set included in the CPUE model was limited to catch and effort data from the core vessels in the fishery. The core fleet was defined as those vessels completing a minimum number of fishing trips and participating in the fishery for a minimum of three years between 1989–90 and 1999–2000. Many of the core vessels were involved in the fishery for considerably longer than 3 years, with 34 of the 50 core vessels present in the fishery for at least 6 years. Consequently, the core fleet can be considered to be a relatively consistent group of vessels that operated in the fishery throughout the study period. Trends in the catch rate of elephantfish from these vessels are likely to be less sensitive to perturbations in the configuration of the fishing fleet and more indicative of changes in the relative abundance of elephantfish.

Most of the core vessels were within the 15–20 m length range although there was a general increase in the average length of vessels operating in the fishery from 1992–93 to 1999–2000 (Figure 7). The fishing trips were generally of 1–2 days in duration and completed 2–4 trawls, although in the 1999–2000 year there was a marked increase in the number of trawls completed per trip (Figure 7).

Between 1989–90 and 1997–98, there was a gradual increase in the average catch of elephantfish per trip. In the two subsequent years, the level of elephantfish bycatch increased considerably, particularly the proportion of trips with larger catches (greater than 400 kg) (Figure 7). The red cod catch per trip varied considerably during the 1989–90 and 1997–98 period. Catches were generally high in 1989–90 and 1990–91, declined in 1991–92, and steadily increased over subsequent years before declining in 1999–2000 (Figure 7).

4.2 CPUE modeling

Three separate CPUE models were investigated.

1. Loglinear, all. The data set included all qualifying trips, a total of 9054 records. Trips with a zero landed catch of ELE 3 were assigned a nominal catch of 1 kg. The CPUE estimate of logarithm of the landed ELE 3 catch (kg) was the dependent variable.
2. Loglinear, non zero. The data set included all records with a landed catch of elephantfish (5638 records). The CPUE estimate of logarithm of the landed ELE 3 catch (kg) was the dependent variable.
3. Binomial. The CPUE analysis modelled the presence or absence of elephantfish in the total landed catch for a trip (9054 records).

For each of the three models, the CPUE estimate was tested against the predictor variables summarised in Table 5. Continuous variables were included in the model as third order polynomial functions.

The CPUE estimate was regressed against each of the predictor variables to determine which explained the most variability in CPUE. This selected variable was then included in the model and the CPUE regressed against the selected variable and each of the other predictor variables to determine the next most powerful variable. The stepwise regression was continued until the remaining variables contributed no significant explanatory power to the model (less than 3% increase in the R^2 value). For the binomial model, the improvement in the model was determined from the change in deviance with inclusion of the predictor variable relative to the null deviance of the data set.

Due to the high number of zero catch records included in the loglinear (all) analysis, it was considered that the annual indices could be sensitive to the level of nominal catch assigned to zero catches. The sensitivity of the indices to this factor was investigated by comparing annual indices derived from the loglinear (all) model with indices determined assuming alternative levels of nominal catch (5 kg and 10 kg).

Annual indices were determined relative to a base year of 1992–93. The standard deviation of the annual indices was determined following Vignaux (1992).

4.3 Loglinear (all) model

The loglinear (all) model resulting from the stepwise regression procedure included four predictor variables. The unique vessel key was included in the model at the first iteration followed by the number of trawls, included in the model as a third order polynomial function. The landed catch of RCO 3 and fishing year were included in the model as the third and fourth variables, respectively. The final model explained 28.5% of the variation in the logarithm of catch per trip (Table 6).

There is a positive relationship between the number of trawls conducted during the fishing trip and the landed catch of ELE 3 (Figure 8). The landed catch of RCO 3 was included in the model as a third order polynomial function. The model predicts the level of elephant fish bycatch from a fishing trip declines with an increasing catch of red cod, up to a landed weight of 20 t. The level of elephantfish bycatch is predicted to increase slightly for RCO 3 landings exceeding 20 t, although the upper limit of the relationship is poorly defined due to the limited number of records with red cod landings of that magnitude (Figure 8).

The CPUE model predicts a high level of variation in the level of elephantfish landed by the individual core vessels in the data set (Figure 8).

The annual indices derived from the model are presented in Table 7. The indices were relatively constant for the 1989–90 to 1992–93 period and subsequently increased to about twice the base year in 1994–95 (Figure 9). Annual indices for the four subsequent years were variable at about the level of the 1994–95 index and increased to about 3.5 times the base year in 1999–2000. However, the 1999–2000 index and, to a lesser extent the 1996–97 index, are poorly determined with high associated standard errors.

The annual indices derived from the model are highly sensitive to the magnitude of the nominal catch assigned to the records with a zero landing of elephantfish (Figure 10). The extent of the increase in annual indices between 1992–93 and 1999–2000 is considerably greater when a nominal catch of 1 kg is assumed compared to larger nominal values (5 kg and 10 kg). This is due to a general decline in the proportion of zero landings during the period (see Figure 4).

4.4 Loglinear (non zero) model

The loglinear (non zero) model included the same variables as the loglinear (all) model, with the inclusion of the categoric variable month. The five variables included in the loglinear (non zero) model accounted for 31% of the observed variation in the logarithm of catch per trip (Table 8).

The relationships between the landed catch of elephantfish and the number of trawls completed during the fishing trip and the level of red cod catch were comparable to the loglinear (all) model (Figure 11). Relative catch rate of elephantfish is predicted to be constant through the main fishing period November to February, but low during the adjacent months (October and March) (Figure 11).

There is considerable variation in the relative bycatch rate of elephantfish for the individual vessels making up the core fleet (Figure 11). In particular, two vessels had an especially low catch rate although both recorded only a few trips with a non-zero catch of elephantfish. Most of the vessels with the higher coefficients were present in the fishery during the latter part of the study period.

The year indices derived from the model indicate a slight decline in the CPUE of elephantfish between 1989–90 and 1991–92 followed by a gradual increased over the next three years to about 15–20% above the base year of 1992–93 (Table 9 and Figure 12). The annual indices remained about this level between 1994–95 and 1996–97 before dropping slightly to below the level of the base year in 1997–98. For the 1998–99 and 1999–2000 years, the annual indices increased to a level about 50% greater than the 1992–93 base year.

4.5 Binomial model

The binomial CPUE model includes the same significant variables included in the loglinear (non zero) model; vessel, fishing year, number of trawls, red cod landed catch, and the month. These variables explained only 0.6% of the presence/absence of elephantfish in the landed catch of target red cod fishing trips (Table 10).

The annual indices derived from the model reveal a steady increase in the presence of elephantfish in the landed catch between 1989–90 and 1995–96, with the annual indices increasing by about 100% during that period (Table 11 and Figure 13). In the subsequent years, the annual indices have been variable, with high values in 1996–97 and 1999–2000 (about 2.5–3.0 times the 1992–93 base year) and lower in 1997–98 and 1998–99. The high indices for the 1996–97 and 1999–2000 are consistent with the low proportion of zero landings evident in the catch composition for these years (see Figure 4). There is a very high standard error associated with the annual indices for these two years (Figure 13).

5. DISCUSSION

During the 1990s, there was a steady increase in the level of catch of elephantfish from ELE 3 and annual catches consistently exceeded the level of the TACC throughout the period. Previous studies revealed that a high proportion of the total ELE 3 catch was taken as a bycatch of the target red cod trawl fishery and that the fishery had also accounted for most of the increase in ELE 3 catch during the 1990s (Raj & Voller 1999). By comparison, the level of ELE 3 catch from the other main target fisheries operating within ELE 3 was relatively low. On this basis, the CPUE analysis was restricted to the catch and effort data from the red cod target fishery only and further limited to the October to March period when most of the elephantfish bycatch is taken within the Canterbury Bight/Pegasus Bay area.

The CPUE analysis was also restricted to a group of core vessels operating within the fishery for an extended period. Within the red cod trawl fishery, there was a relatively stable group of vessels that operated in the fishery throughout the study period and, in many cases, for a considerably longer period. The continuity of vessels within the fleet means that trends in the bycatch of elephantfish are less likely to be attributable to changes in the configuration and operation of the fleet and more indicative of a change in the relative abundance of the species.

During the 1990s, the bycatch of elephantfish by the red cod target trawl fishery was characterised by many small catches. There was also a high proportion of red cod fishing trips that recorded no catch of elephantfish. Most of the vessels operating in the fishery recorded a summary of the daily fishing effort and catch information in the statutory CELR format. This reporting regime provides only for the recording of the catch of the five main species caught during a day of fishing and, consequently, does not adequately record the daily catches of the minor bycatch species.

During the early 1990s, when the bycatch of elephantfish was relatively low, the CELR regime captured a relatively small proportion of the elephantfish bycatch from the red cod fishery. This was presumably because other bycatch species were caught in greater quantity and elephantfish was not amongst the five main species caught. However, during the period studied there was an increase in the overall bycatch of elephantfish and also in the increase in the proportion of the proportion of the bycatch reported in the daily CELR format.

The increasing trend in the proportion of the elephantfish bycatch reported to the daily CELR format means that any trends in these catch and effort data would over state the actual increase in the catch rate of elephantfish from the red cod trawl fishery. Instead, the current CPUE analysis was based on the actual landed catch of elephantfish from each qualifying fishing trip. These data are considered more reliable as all elephantfish caught and retained on board the vessel were weighed following the vessel discharge. This avoids the potential bias of small catches not being recorded amongst the five main species caught and/or the reliance on catch weights estimated on board the vessel.

Elephantfish are processed at sea (to the dressed state) and the CPUE data set indicated that a number of the core vessels were erroneously recording the processed weight on the daily CELR form rather than the unprocessed weight. The use of the landed catch data avoids this further source of uncertainty. Nevertheless, the calculation of the greenweight equivalent of the landed catch of elephantfish is dependent on a reliable conversion factor for the processed weight of elephantfish. The current analysis was based on the reported greenweight of elephantfish determined from the gazetted conversion factor that was constant throughout the study period.

The selection of a CPUE estimator based on the landed catch of elephantfish from an individual fishing trip limited the range of variables available for inclusion in the analysis. The corresponding effort data from each fishing trip were aggregated to determine the total number of trawls and the duration of the fishing trip. Most (90%) of the effort data included in the data set were derived from the CELR format, which records summary data for each day of fishing. Consequently, the amalgamation of CELR records from short fishing trips (1–2 days) is unlikely to result in a substantial loss in the definition of the effort data. However, the amalgamation of the data by fishing trip does not enable the statistical area fished (020 and/or 022) to be included in the analysis as an individual vessel may fish in both areas during an individual trip and the location of the catch of elephantfish is unknown.

Three options for the analysis of the CPUE data set were investigated. The logarithm of the landed catch of elephantfish was modelled with the inclusion (loglinear all) and exclusion (loglinear non zero) of trips with no catch of elephantfish and the presence/absence of elephantfish in the landed catch from a trip was also modelled (binomial). A comparison of the annual indices derived from the three CPUE models reveals strong similarities between the loglinear (all) and binomial models, with the exception of a deviation in the annual indices in 1998–99 (Figure 14). The similarity between the two models is likely to be attributable to the high proportion of zero records in the data set included in both analyses (see Table 2). The lower annual index derived from the binomial model for the 1998–99 year may reflect the increase in the proportion of trips with no landed catch of elephantfish despite the increase in the proportion of landings with at least 500 kg of ELE 3 (Figure 4). The high annual indices for 1996–97 and 1999–2000 derived from both models were associated with a high standard error.

The loglinear (non zero) model yielded annual indices that revealed a more gradual increase in the bycatch of elephantfish over the study period compared to either the loglinear (all) or binomial models (Figure 14). This model suggests the level of bycatch in the two most recent years was approximately twice the level in 1990–91 and 1991–92. In contrast, the loglinear (all) or binomial models indicate a 2.5 fold increase in the level of bycatch over the same period, although the indices for these models are highly variable in recent years.

Examination of the residuals from the two loglinear models reveals a poor fit to the loglinear (all) data set due to the inability of the model to fit the large number of zero records (see Figure 16 and Figure 17). The inclusion of the null catches (assigned a nominal 1 kg) results in the model significantly under estimating the non-zero component of the data set throughout the observed range of catch and also predicts a large number of very small catches (less than 1 kg). The annual indices derived from the loglinear (all) model were also highly sensitive to the magnitude of the nominal catch assigned to the zero catch component of the data set.

A comparison of the diagnostics of the loglinear models indicates a significant improvement in model behaviour when zero catches are excluded. However, the resulting model does not account for any trend in the proportion of non-zero records which may also provide an indication of trends in the abundance of the ELE 3 stock. The proportion of zero records is variable between years and the high annual indices derived from the binomial model for the 1996–97 and 1999–2000 years correspond to a substantial decline in the proportion of non-zero records in the CPUE data set. An examination of the CPUE data set revealed no strong trend in either the areal or seasonal distribution of fishing effort that may have influenced the proportion of zero catches in these recent years.

The amalgamated data set, summarising catch and effort data by fishing trip, limits the potential to investigate fine-scale changes in the operation of the RCO 3 target fishery, although some minor changes in the distribution of catch and effort are apparent during the study period. Between 1992–93 and 1995–96 there was a slight increase in the proportion of the total RCO 3 trawls in statistical area 022 and a corresponding decline in the proportion of fishing effort in 020. However, the magnitude of the change in the distribution of effort was small (about 10%) and, therefore, unlikely to have substantially influenced the overall bycatch rate of elephantfish. Further, the shift in effort in the early 1990s does not explain the persistent increasing trend in elephantfish bycatch from the fishery. Nevertheless, a future analysis of CPUE may attempt to identify fishing trips conducted entirely within each of the two statistical areas and examine trends in elephantfish catch rate by area.

Over the study period, there was an increase in the proportion of CPUE records (qualifying fishing trips) conducted during October, although this period accounted for a relatively small proportion of annual fishing trips (5–10%) and there was no strong systematic trend in the seasonal distribution of fishing effort for the remainder of the October–March period. The month variable is included in both the loglinear (non zero) and binomial CPUE models, although it was not a significant variable in the loglinear (all) model.

On the basis of the model diagnostics and the relative consistency of the indices between years, the loglinear (non zero) CPUE model is the preferred option for monitoring trends in bycatch rate of elephantfish from the RCO 3 target fishery. The level of total ELE 3 bycatch will be influenced by the annual performance of the RCO 3 fishery. However, the application of the CPUE index to monitor relative abundance of ELE 3 assumes the CPUE index is independent of the performance of the target fishery or that any significant interaction can be addressed within the CPUE model.

The CPUE model reveals a strong interaction between the catch rate of red cod during a trip and the catch of elephantfish, with larger catches of elephantfish taken during trips that landed smaller quantities of red cod. The model accounts for the effect by including the red cod total landed catch as a significant variable in the CPUE model. During the study period, there was also a general increase in the bycatch rate of elephantfish while the total catch from the RCO 3 fishery increased (Figure 15). However, the extent of the increase in the CPUE index was considerably less than the variation in RCO 3 catch and the CPUE index has remained at a high level in 1999–2000 despite a large decline in the RCO 3 catch. Therefore, it is likely that the relative increase in the bycatch rate of elephantfish represents an actual increase in the abundance of the stock rather than an artefact of the performance of the RCO 3 fishery.

Conceptually, CPUE data from a bycatch fishery has a number of properties that are favourable in applying these data to monitor changes in relative abundance. In particular, fishing effort is likely to be more randomly distributed with respect to the bycatch species than for target fisheries. Consequently, trends in the relative bycatch may be more representative of an underlying change in the relative abundance of the species compared to a CPUE index derived for a target fishery. However, this assumption is likely to be violated to some extent if the fleet changes fishing behaviour with respect to either the abundance of the target species or the bycatch species. In the latter case, this may occur if the bycatch species is constrained by the level of the TACC resulting in a change in the distribution of target fishing to avoid high catches of the bycatch species. There is anecdotal information from the trawl fishery to suggest that during years of high elephantfish abundance there was a change in the area fished to minimise the bycatch of elephantfish.

Limited information is available from the ELE 3 fishery to evaluate the reliability of the CPUE indices to monitor the relative abundance of elephantfish. During the study period, a time-series of inshore trawl surveys was conducted within the Canterbury Bight and Pegasus Bay areas. However, the relative biomass estimates derived for elephantfish were highly variable between surveys and it was concluded that the surveys were not adequately monitoring trends in the abundance of the species (Beentjes & Stevenson 2000, 2001). Nevertheless, the increase in the annual CPUE indices is consistent with the observed increase in the bycatch of elephantfish from the various target fisheries operating within ELE 3 despite a decline in the availability of ELE 3 quota to cover the increase in catch. In recent years, the trawl sector has also reported a considerable increase in the abundance of elephantfish and this is evident in the CPUE indices derived from the red cod target fishery.

In March 2000, the Inshore Fisheries Stock Assessment Working Group reviewed the results of the CPUE analysis and recommended the loglinear (non zero) CPUE model be used for on-going monitoring of the relative abundance of ELE 3. The loglinear (non zero) model was considered the preferred CPUE model due to the lower level of inter-annual variability between the CPUE indices, the absence of any assumptions regarding treatment of zero catch records, and the more gradual increase in the CPUE indices over the study period. However, the Working Group also considered that other options for developing a fishery independent index of abundance for ELE 3 should also be investigated. In the absence of an alterative index, the CPUE analysis will continue to be an important element of the annual monitoring of the elephantfish fishery under the ELE 3 Adaptive Management Programme.

6. ACKNOWLEDGMENTS

This work was funded by the South-east Finfish Management Company under the ELE 3 Adaptive Management Programme. Alistair Dunn (NIWA) provided a comprehensive review of a draft version of this document. Chris Francis (NIWA) provided the statistical software to derive predictions from the CPUE models.

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Table 1: Total reported greenweight estimated catch (t) and landed greenweight (t) of ELE 3 and RCO 3 for vessels exclusively targeting RCO by trawl from October to March by fishing year. The estimated catch of each species is also presented as a percentage of the total landed greenweight.

Fishing year		ELE 3			RCO 3	
	Estimated	Landed	Percentage	Estimated	Landed	Percentage
1989–90	17.6	27.8	63.2	1 235.1	2 046.8	60.3
1990–91	29.5	43.7	67.6	1 174.9	1 310.6	89.7
1991–92	27.1	43.8	61.9	809.1	947.1	85.4
1992–93	74.8	112.1	66.7	1 417.3	1 605.5	88.3
1993–94	94.9	146.2	64.9	2 784.1	2 929.8	95.0
1994–95	178.4	246.7	72.3	4 292.2	4 498.5	95.4
1995–96	150.2	213.5	70.3	3 337.0	3 500.5	95.3
1996–97	159.5	202.2	78.9	3 716.8	3 938.6	94.4
1997–98	205.4	289.7	70.9	3 342.4	3 772.0	88.6
1998–99	242.2	269.0	90.0	6 493.9	6 783.5	95.7
1999–2000	200.3	219.3	91.3	946.8	1 004.6	94.2

Table 2: Summary of the annual number of target RCO 3 fishing trips conducted during October–March, the number of vessels in the fishery, the total number of days fished, the total number of trawls, the total landed greenweight of ELE 3 and RCO 3 (tonnes), and the percentage of trips with no ELE 3 landed by fishing year for all vessels and for the core vessels. Core vessels are defined as vessels completing at least 50 trips and fishing in at least three years during the 1989–90 to 1999–2000 period.

											Fishing year
	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–2000
All vessels											
Trips	489	483	568	859	1 009	1 264	1 172	1 105	1 201	1 022	509
No. vessels	38	46	42	44	51	48	38	40	43	41	33
ELE 3	27.8	43.7	43.8	112.1	146.2	246.7	213.5	202.2	289.7	269.0	228.5
RCO 3	2 046.8	1 310.6	947.1	1 605.5	2 929.8	4 498.5	3 500.5	3 938.6	3 772.0	6 783.5	1 061.5
Days	668	713	848	1 264	1 386	1 845	1 582	1 612	1 736	1 442	880
Trawls	1 794	1 992	2 500	3 611	3 879	4 939	4 542	4 670	5 407	4 438	2 838
Prop zero (%)	55.2	53.0	51.4	50.2	36.4	40.3	35.6	25.6	33.0	40.5	21.6
Core vessels											
Trips	372	386	535	797	951	1 192	1 166	1 081	1 145	961	468
No. vessels	26	30	33	35	41	38	35	35	35	32	26
ELE 3	23.1	38.5	42.7	107.9	142.3	242.8	213.3	201.9	265.9	267.7	219.3
RCO 3	1 104.2	1 128.5	876.1	1 530.9	2 806.7	4 241.1	3 499.4	3 901.2	3 625.4	6 223.3	1 004.6
Days	502	575	800	1 168	1 320	1 736	1 576	1 583	1 644	1 340	819
Trawls	1 357	1 597	2 372	3 332	3 701	4 665	4 527	4 583	5 137	4 163	2 643
Prop zero (%)	55.1	53.1	50.5	49.7	36.4	39.4	35.5	25.3	32.8	38.7	19.2

Table 3: Cumulative percentage of the number of RCO 3 fishing trips conducted by the individual vessels in the fishery completing at least 50 trips and fishing in at least three years during the 1989–90 to 1999–2000 period. Vessels are ranked in order of the total number of fishing trips completed during the period.

Vessel											Fishing year
	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–2000
1	2.7	4.8	6.0	4.4	5.3	4.8	9.0	6.7	5.7	8.5	11.2
2	4.9	5.4	18.1	8.7	7.1	10.5	14.8	13.4	12.1	14.0	13.9
3	9.8	7.7	25.9	14.2	12.0	16.0	19.1	16.9	16.7	14.0	15.3
4	9.8	7.7	25.9	14.2	15.8	20.6	21.6	20.7	23.7	21.8	25.1
5	16.4	12.2	33.6	20.3	20.2	25.5	24.6	22.1	27.5	21.8	25.1
6	18.2	13.5	38.6	24.7	23.1	28.4	31.1	27.2	32.1	22.2	26.
7	21.3	17.8	41.9	27.9	25.0	31.7	34.8	31.9	36.6	25.7	27.9
8	24.1	20.3	47.2	30.8	28.1	35.6	37.9	35.5	39.3	29.2	30.5
9	24.1	20.3	49.8	36.6	32.4	38.8	41.3	38.5	41.6	33.5	34.4
10	29.2	26.9	51.4	41.1	35.9	43.1	44.7	41.4	43.4	35.1	35.0
11	31.9	28.4	52.5	44.4	39.2	47.3	49.2	44.0	48.1	37.8	35.0
12	33.7	29.4	53.3	45.4	43.0	49.0	52.2	48.6	51.9	41.6	43.8
13	39.9	33.7	57.7	52.6	46.5	52.1	54.9	51.2	51.9	41.6	43.8
14	39.9	37.5	61.6	54.6	50.3	55.2	60.9	54.7	52.2	41.7	47.3
15	39.9	37.5	61.6	54.6	50.3	59.6	66.2	59.5	55.7	45.4	47.3
16	42.5	42.4	63.6	57.2	52.2	61.6	68.8	62.5	57.9	48.5	48.9
17	42.5	45.1	64.1	58.0	54.7	63.1	71.2	66.2	60.4	53.7	53.6
18	42.5	45.1	64.3	58.3	55.9	64.7	74.6	69.2	65.3	57.3	56.8
19	42.5	45.1	64.3	58.3	55.9	64.7	74.6	72.9	70.5	63.5	63.9
20	42.5	45.1	64.3	58.3	55.9	64.7	77.7	76.7	73.6	67.8	71.3
21	42.5	45.1	64.3	59.3	59.6	67.4	80.5	79.5	75.9	69.9	71.3
22	42.5	45.1	64.3	59.3	59.6	68.6	83.4	83.3	78.9	73.4	76.0
23	42.5	45.1	66.7	65.0	63.6	71.6	84.2	83.3	78.9	73.6	76.0
24	44.4	45.8	66.9	65.8	65.4	71.6	84.2	83.3	83.2	78.6	77.6
25	45.4	49.5	67.6	67.1	68.0	77.1	84.2	83.3	83.2	78.6	77.6
26	45.4	49.5	67.6	67.1	70.6	78.9	86.6	84.4	83.8	79.3	80.9
27	45.4	49.5	68.1	67.3	72.5	80.2	87.5	86.1	86.1	80.7	81.9
28	46.0	50.3	69.7	69.2	73.0	80.5	89.2	88.0	86.6	83.0	81.9
29	47.2	51.6	69.7	69.5	74.3	81.0	92.7	89.0	88.2	83.0	81.9
30	47.2	52.6	69.7	70.0	76.9	83.5	93.0	89.7	89.8	83.9	81.9
31	53.4	56.9	72.5	73.6	77.0	83.5	93.0	89.7	89.8	83.9	81.9
32	53.4	57.8	73.2	73.8	77.6	86.5	93.5	89.8	91.2	85.3	81.9
33	53.4	57.8	73.2	73.8	77.6	87.0	94.6	91.6	92.2	87.8	82.7
34	53.4	57.8	73.2	73.8	77.6	87.6	94.6	91.6	93.7	90.1	88.2
35	53.4	57.8	76.2	78.2	79.7	87.6	94.6	91.6	93.7	90.1	88.2
36	55.0	62.3	81.2	79.5	80.2	87.6	94.6	91.6	93.7	90.1	88.2
37	55.0	62.3	81.2	79.5	81.5	90.7	96.4	91.6	93.7	90.1	88.2
38	55.0	62.3	87.5	82.0	82.3	91.0	96.4	91.6	93.8	90.1	88.2
39	55.0	62.3	87.5	85.2	86.0	91.1	96.4	91.6	93.8	90.1	88.2
40	55.0	62.3	87.5	85.2	87.3	91.7	98.0	91.7	93.8	90.9	90.0
41	58.9	70.2	87.5	85.2	87.3	91.7	98.0	91.7	93.8	90.9	90.0
42	66.1	72.9	89.1	85.2	87.3	91.7	98.0	91.7	93.8	90.9	90.0
43	71.2	74.3	91.0	86.8	87.3	91.7	98.0	91.7	93.8	90.9	90.0
44	71.4	74.5	91.5	89.4	90.3	91.7	98.0	91.7	93.8	90.9	90.0
45	71.4	74.7	91.7	89.6	91.1	92.5	98.4	92.8	94.0	92.2	90.4
46	72.4	75.4	91.9	89.6	91.6	93.0	98.8	93.1	94.7	93.2	91.4
47	73.0	75.4	92.1	89.6	92.0	93.6	99.2	94.1	95.3	94.0	91.9
48	73.0	79.7	92.1	89.6	92.6	93.6	99.2	96.3	95.3	94.0	91.9
49	73.4	79.9	92.1	90.6	93.7	94.3	99.5	97.8	95.3	94.0	91.9
50	76.1	79.9	94.2	92.8	94.3	94.3	99.5	97.8	95.3	94.0	91.9
Other	23.9	20.1	5.8	7.2	5.7	5.7	0.5	2.2	4.7	6.0	8.1

Table 4: Percentage distribution of the total number of trawls by statistical area from RCO 3 target fishing trips during October–March by statistical area (CELR and TCEPR data).

Fishing year	Statistical area				
	018	020	022	024	Other
1989–90	0.0	37.8	61.5	0.0	0.6
1990–91	0.0	38.5	60.6	0.9	0.1
1991–92	0.5	37.4	61.8	0.2	0.0
1992–93	1.2	39.8	58.2	0.5	0.3
1993–94	0.1	35.1	63.7	0.7	0.4
1994–95	0.1	32.4	66.3	1.0	0.2
1995–96	0.7	26.7	70.	2.1	0.5
1996–97	0.4	25.6	70.5	3.0	0.5
1997–98	1.1	34.9	62.4	1.4	0.2
1998–99	0.1	26.0	71.0	2.5	0.3
1999–2000	0.7	25.6	71.5	2.1	0.2

Table 5: A summary of the variables tested in the regression models. The numbers in parentheses are the number of categories.

Variable	Type	Description
Month	Categorical (6)	Month of the year
Vessel	Categorical (50)	Vessel code number
Fishing_Year	Categorical (11)	Fishing year
Form Type	Categorical (2)	Data recorded on TCEPR or CELR forms.
Duration	Polynomial	The duration (days) of the fishing trip.
Trawls	Polynomial	The number of trawls completed during the trip.
RCO_catch	Continuous	The total landed weight of RCO 3 for the trip (kg).

Table 6: Variables included in the stepwise regression for the loglinear (all) model in order of importance.

Variable	R^2 at iteration				
	1	2	3	4	5
Vessel	0.1293				
Trawls	0.0954	0.2017			
RCO_catch	0.0229	0.1773	0.2691		
Fishing_year	0.0431	0.1502	0.2225	0.2851	
Month	0.0119	0.1447	0.2134	0.2768	0.2851
Duration	0.0792	0.1935	0.2084	0.2723	0.2882
Form type	0.0000	0.1293	0.2029	0.2691	0.2851
% Improvement		56.0	33.4	5.9	NS

Table 7: Year indices with standard deviation and regression coefficients for the loglinear (all) ELE 3 CPUE model. *n*, number of records.

Fishing year	*n*	Regression coefficient	Year index	S.D.
1989–90	372	-0.135	0.87	0.127
1990–91	386	-0.084	0.92	0.132
1991–92	535	-0.049	0.95	0.118
1992–93	797	0.000	1.00	NA
1993–94	951	0.520	1.68	0.179
1994–95	1 192	0.686	1.99	0.208
1995–96	1 166	0.610	1.84	0.195
1996–97	1 081	0.960	2.61	0.282
1997–98	1 145	0.465	1.59	0.172
1998–99	961	0.864	2.37	0.270
1999–2000	468	1.256	3.51	0.483

Table 8: Variables included in the stepwise regression for the loglinear (non zero) model in order of importance.

Variable						R^2 at iteration
	1	2	3	4	5	6
Trawls	0.1350					
Vessel	0.1180	0.2215				
RCO_catch	0.0215	0.1955	0.2787			
Month	0.0238	0.1528	0.2396	0.2966		
Fishing_year	0.0273	0.1545	0.2369	0.2902	0.3064	
Duration	0.1227	0.1414	0.2268	0.2824	0.3008	0.3106
Form type	0.0000	0.1350	0.2216	0.2787	0.2967	0.3064
% Improvement		64.1	25.8	6.4	3.3	NS

Table 9: Year indices with standard deviation and regression coefficients for the loglinear (non zero) ELE 3 CPUE model, *n* = number of records.

Fishing year	*n*	Regression coefficient	Year index	S.D.
1989–90	167	0.021	1.02	0.149
1990–91	181	-0.173	0.84	0.120
1991–92	265	-0.258	0.77	0.093
1992–93	401	0.000	1.00	NA
1993–94	605	-0.063	0.94	0.093
1994–95	722	0.165	1.18	0.115
1995–96	752	0.129	1.14	0.111
1996–97	808	0.106	1.11	0.108
1997–98	770	-0.063	0.94	0.092
1998–99	589	0.448	1.57	0.163
1999–2000	378	0.419	1.52	0.177

Table 10: Variables included in the stepwise regression for the binomial model in order of importance.

Variable	Percentage improvement
Vessel	8.38
RCO_catch	11.74
Trawls	13.93
Fishing_year	15.48

Table 11: Year indices with standard deviation and regression coefficients for the binomial ELE 3 CPUE model, *n* = number of records.

Fishing year	*n*	Regression coefficient	Year index	S.D.
1989–90	372	-0.223	0.80	0.124
1990–91	386	-0.090	0.91	0.139
1991–92	535	0.056	1.06	0.141
1992–93	797	0.000	1.00	NA
1993–94	951	0.686	1.98	0.236
1994–95	1 192	0.555	1.74	0.199
1995–96	1 166	0.628	1.87	0.216
1996–97	1 081	1.103	3.01	0.367
1997–98	1 145	0.510	1.67	0.197
1998–99	961	0.473	1.60	0.199
1999–2000	468	0.968	2.63	0.433

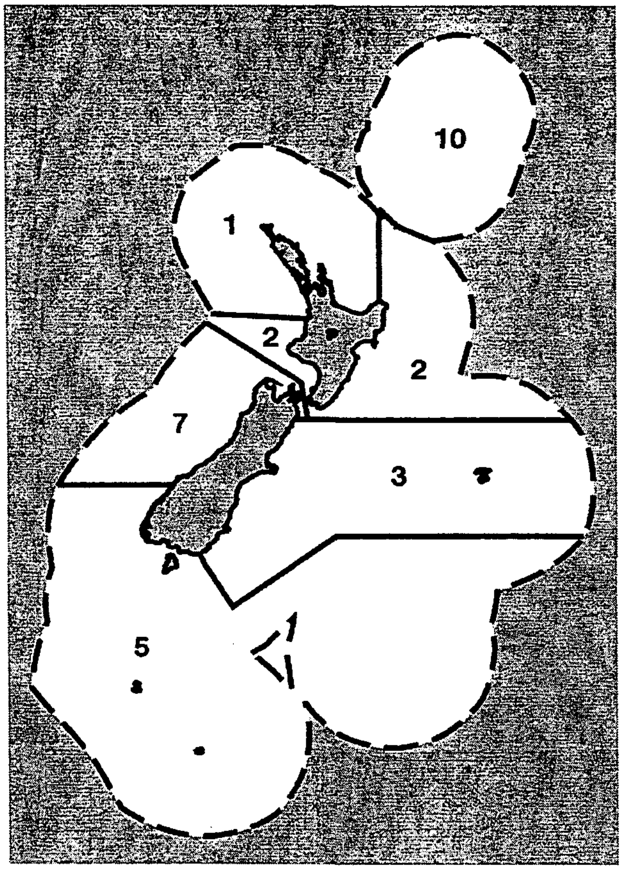


Figure 1: Fishstock areas for elephantfish (from Annala et al. 2001).

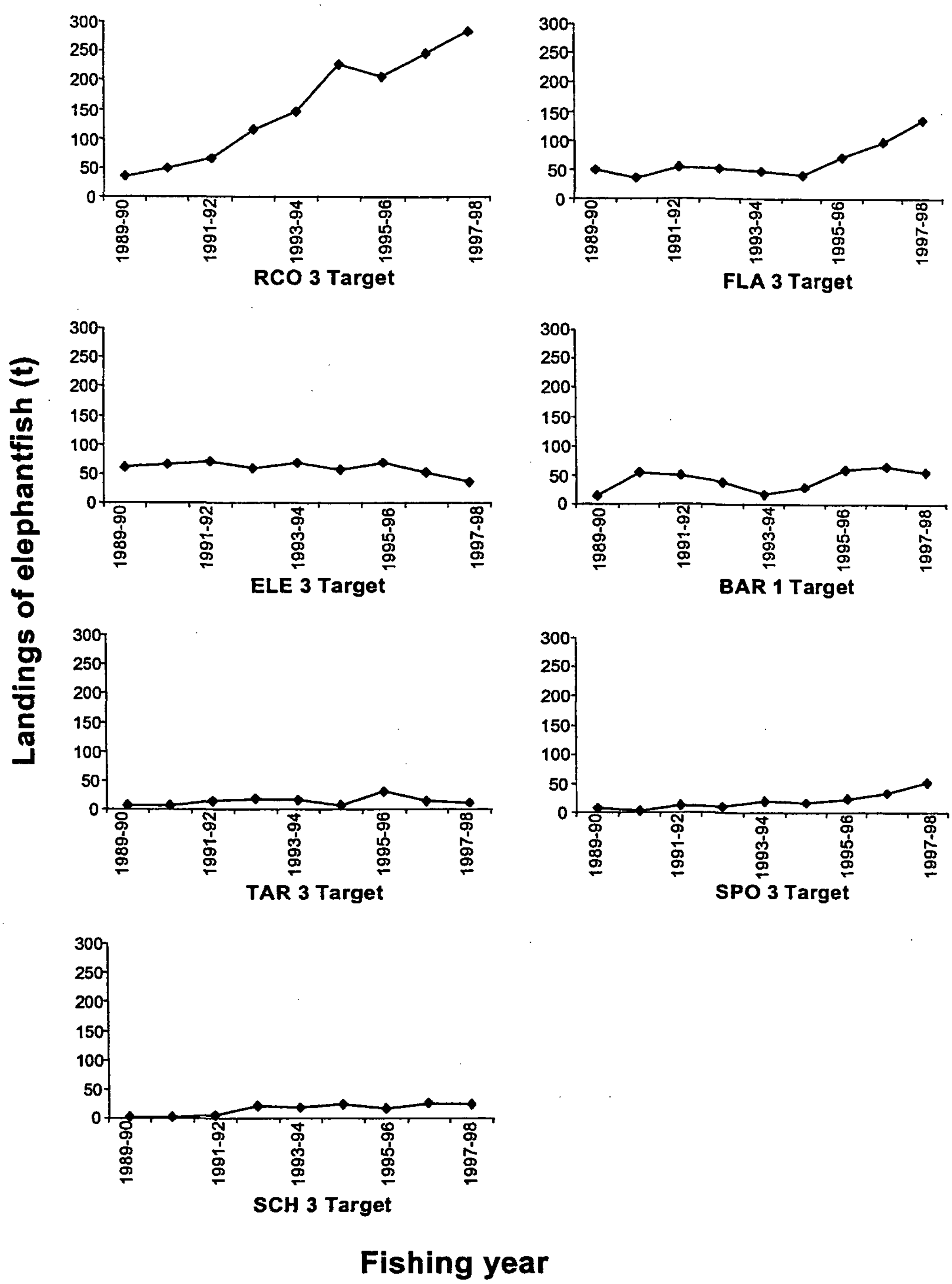


Figure 2: Trends in ELE 3 catch (tonnes) by target fishery for the period 1989–90 to 1997–98 (from Raj & Voller 1999).

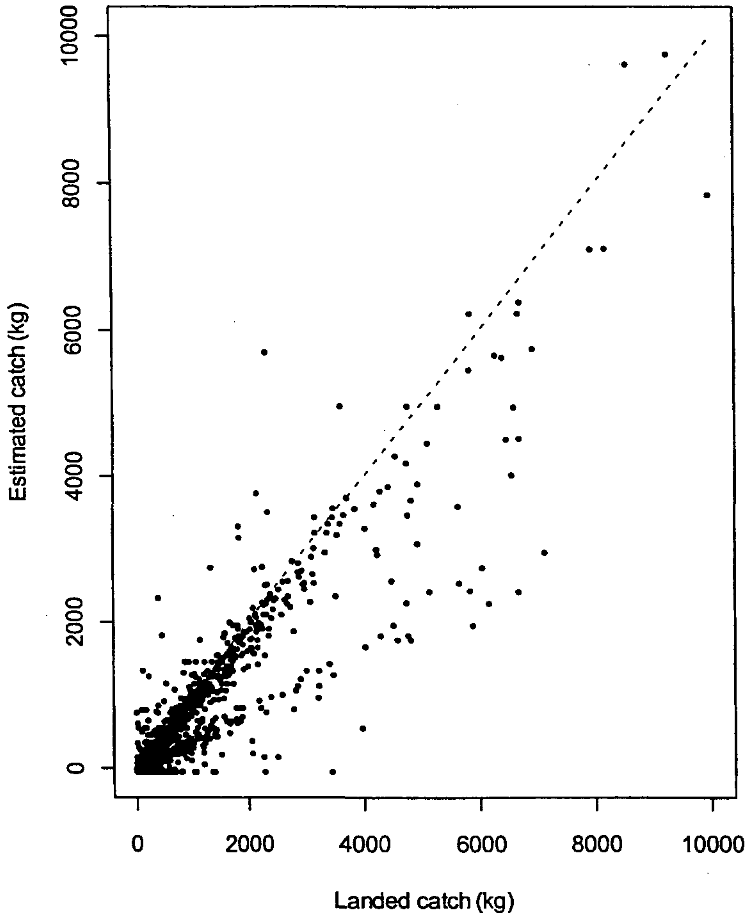


Figure 3: Comparison between the total estimated (kg) and landed weight (kg) of ELE 3 from individual target RCO 3 fishing trips. The dotted line represents unity.

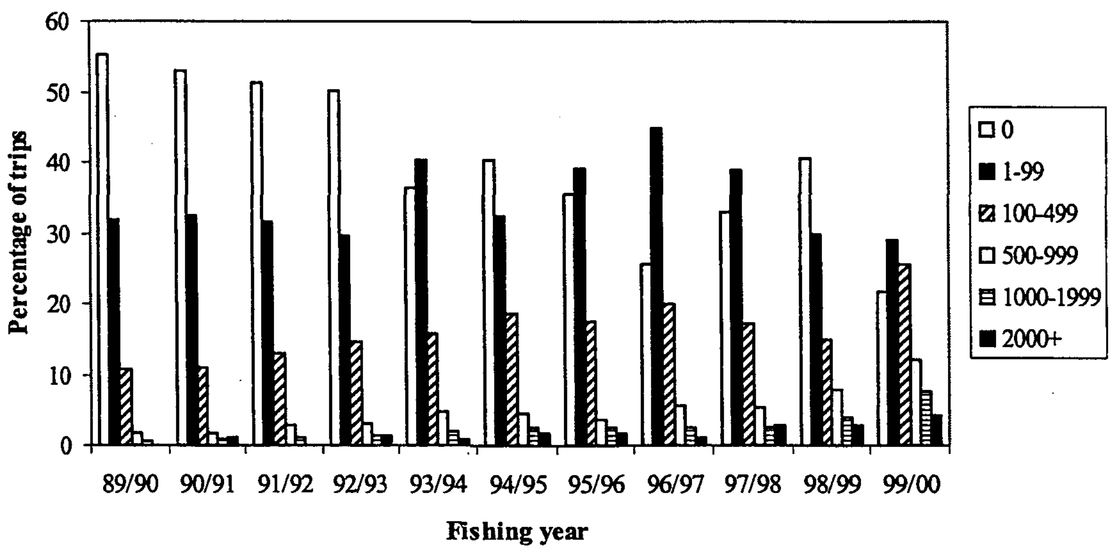


Figure 4: Distribution of landed catch (kilogrammes) of ELE 3 by size category from RCO 3 fishing trips during October to March by fishing year for the 1989–90 to 1999–2000 period.

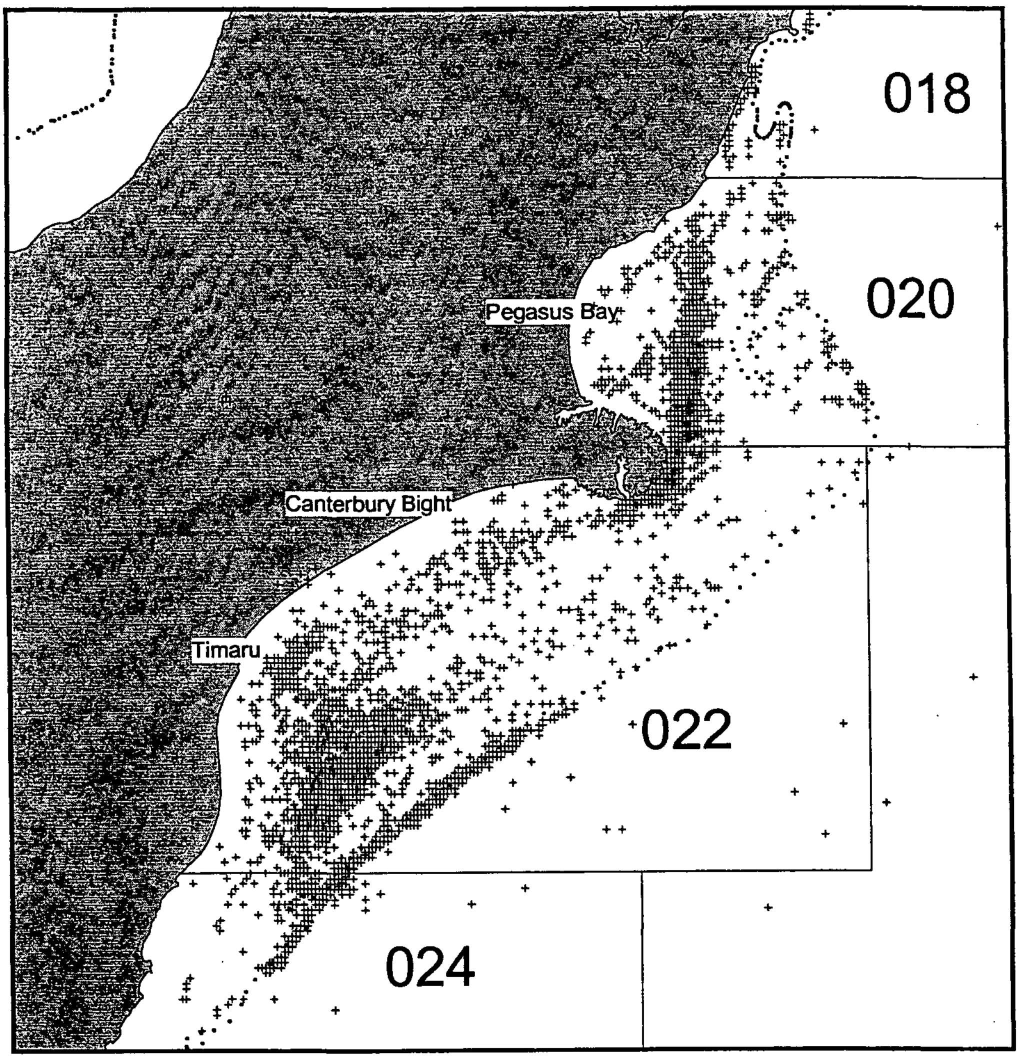


Figure 5: Distribution of RCO 3 target trawls (October to March) from fishing trips exclusively targeting red cod for the period 1989–90 to 1998–99 combined (TCEPR data only). The dotted line represents the 200 m depth contour.

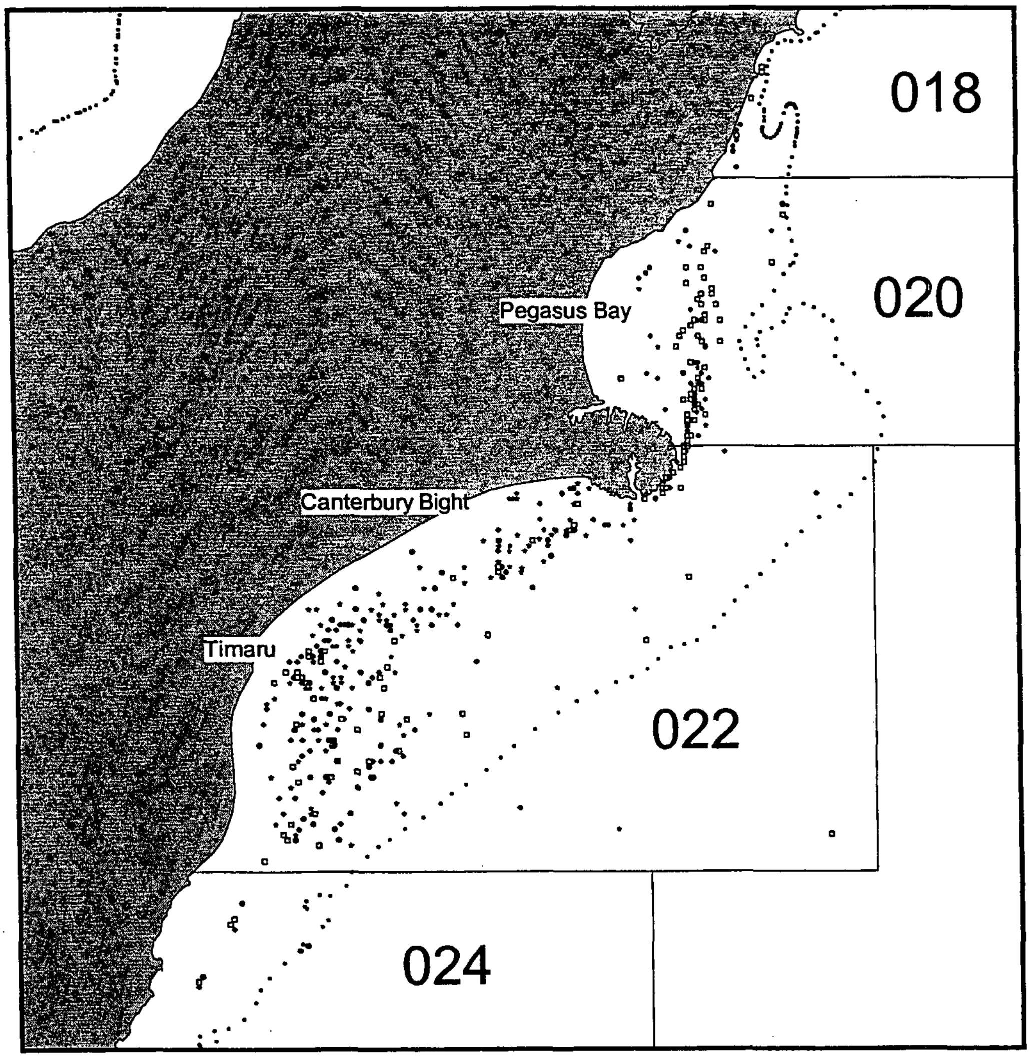


Figure 6: Distribution of RCO 3 target trawls (October to March) where elephantfish catch reported for the period 1989–90 to 1998–99 (TCEPR data only). Squares denote elephantfish catches 1–40 kg (116 records), diamonds 40–100 kg (117 records), circles 100–160 kg (75 records), and stars 160+ kg (129 records). The dotted line represents the 200 m depth contour.

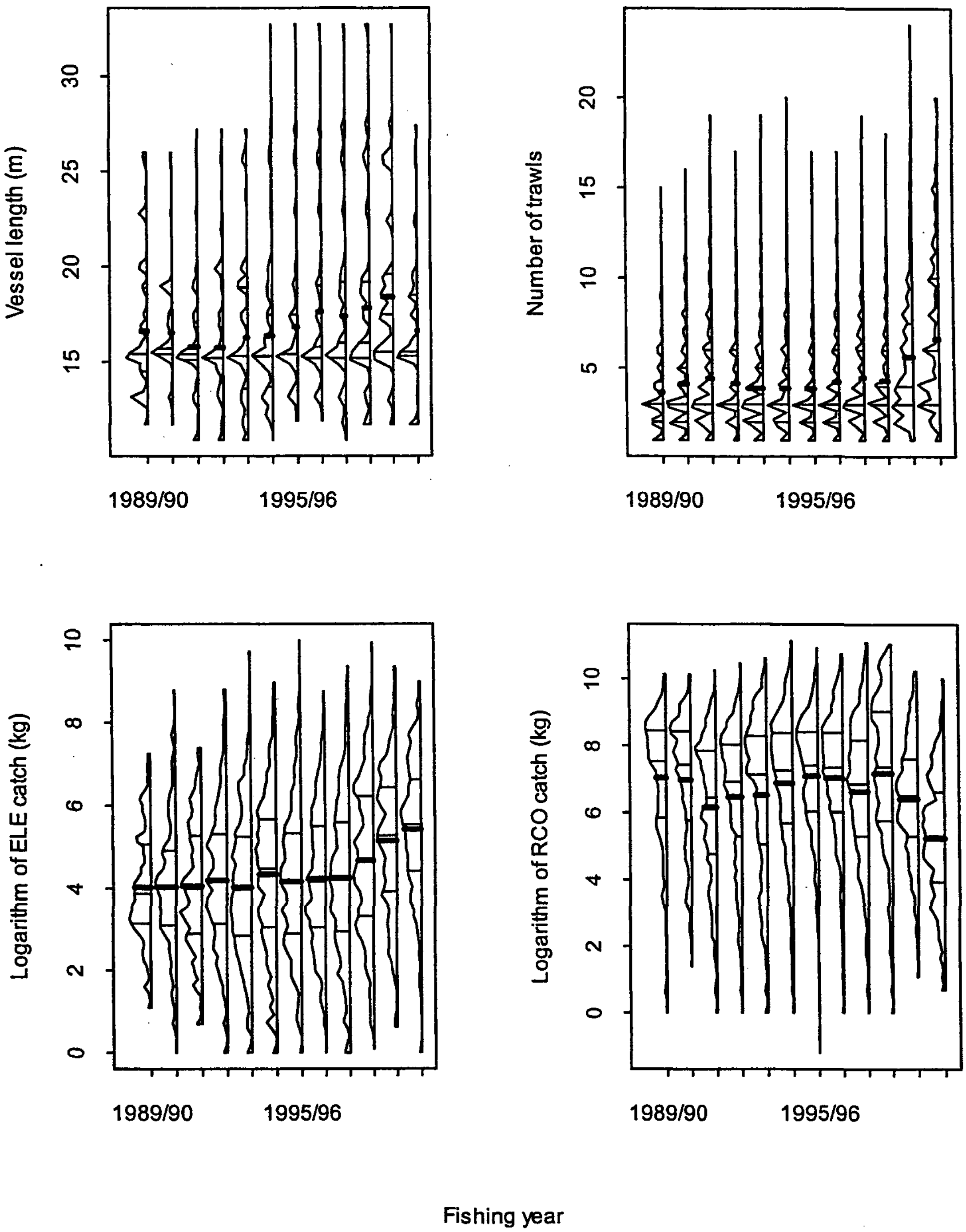


Figure 7: Annual distribution of the core vessel data records with respect to vessel length (m), number of trawls per trip, and landed catch of elephantfish and red cod. Zero catch records of elephantfish and red cod are excluded from the respective catch distributions. The lines represent the 25% quantile, the median, and the 75% quantile; the heavy line represents the mean value.

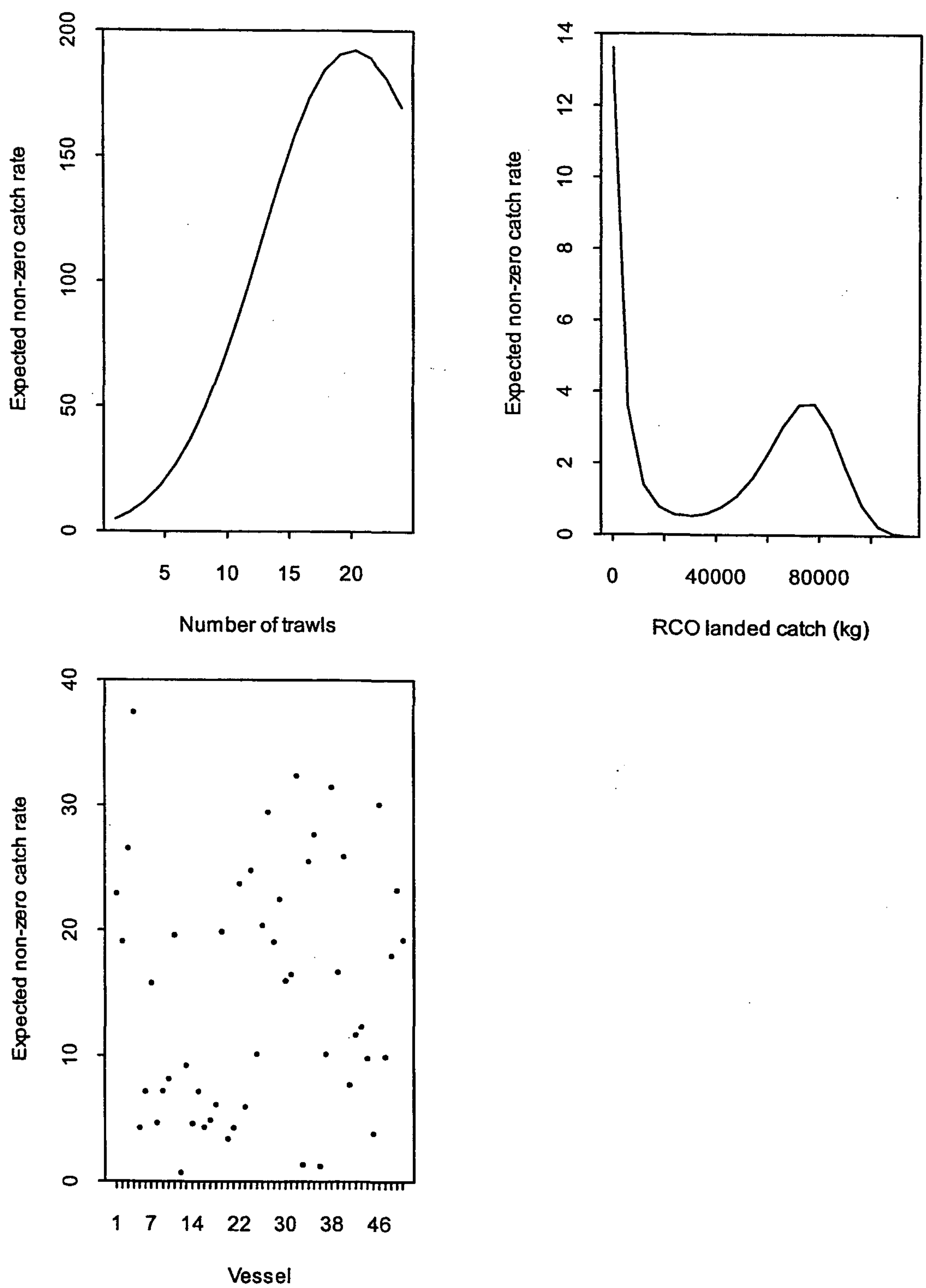


Figure 8: The predicted relationships between the landed catch of elephantfish (kg) and the significant variables included in the loglinear (all) model.

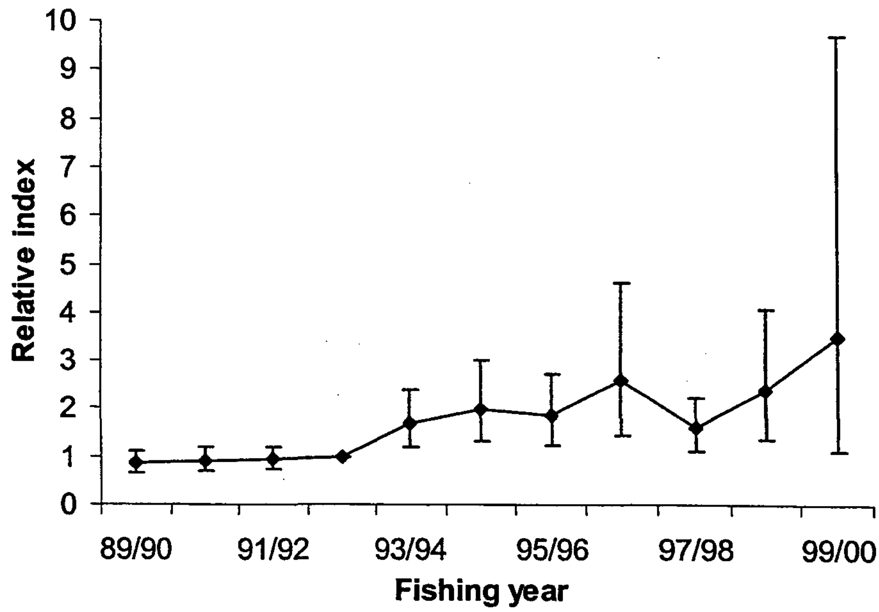


Figure 9: Relative year effects for the loglinear (all) CPUE regression analysis with error bars representing the 95% confidence interval.

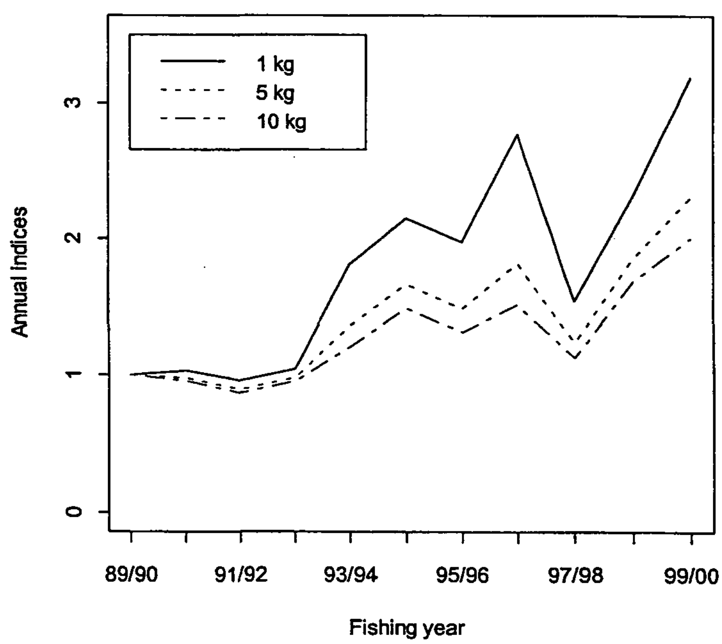


Figure 10: Comparison of annual indices from the loglinear (all) model with different levels of catch (1, 5, and 10 kg) nominally assigned to the records with zero elephantfish catch.

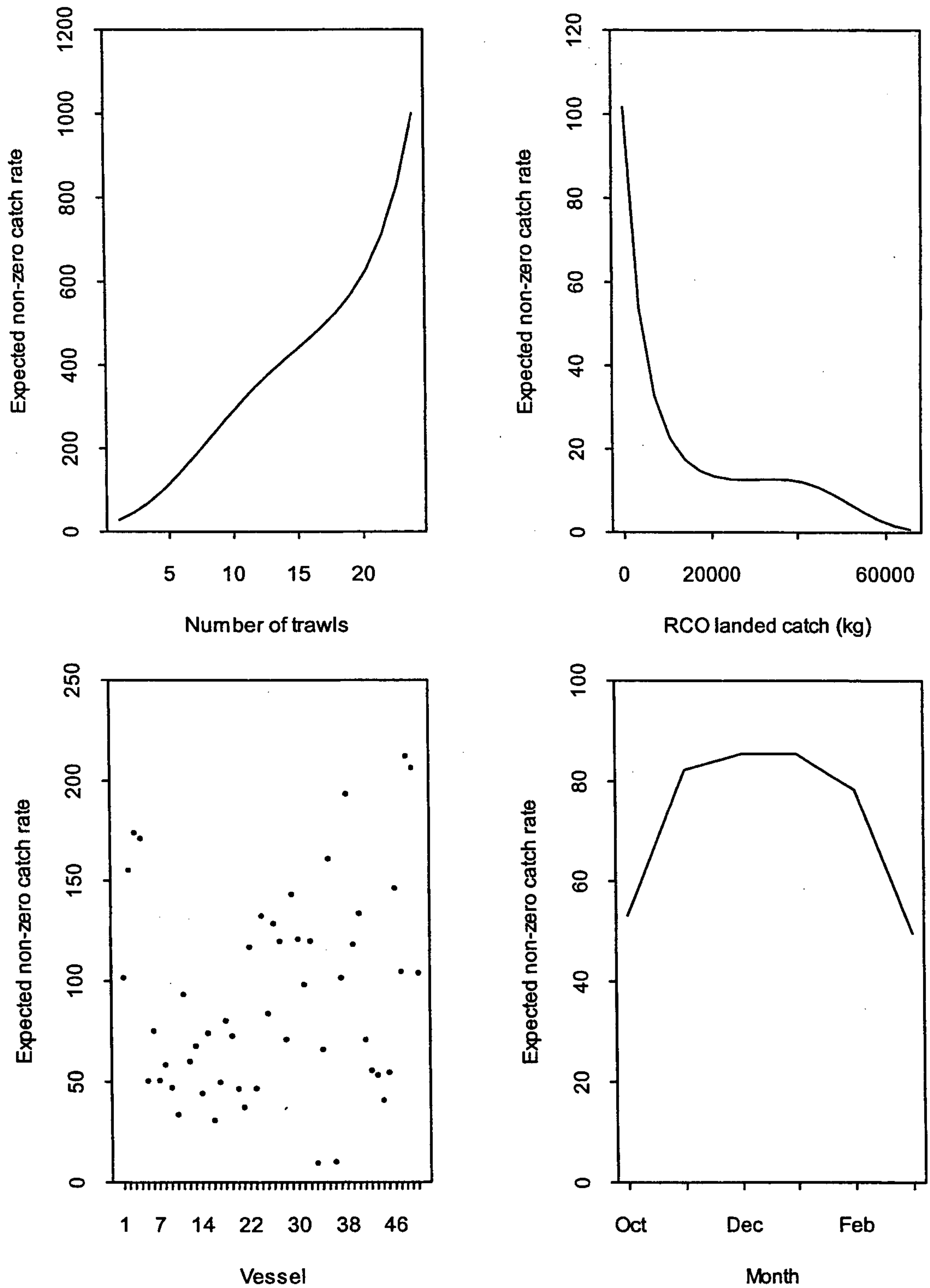


Figure 11: The predicted catch of elephantfish (kg) with respect to each of the significant variables included in the loglinear (non zero) model.

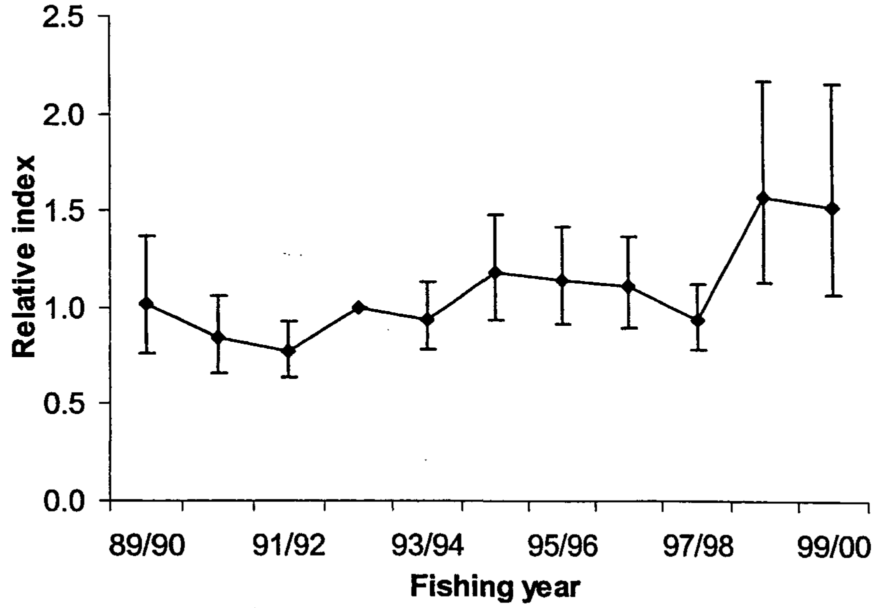


Figure 12: Relative year effects for the loglinear (non zero) CPUE regression analysis with error bars representing the 95% confidence interval.

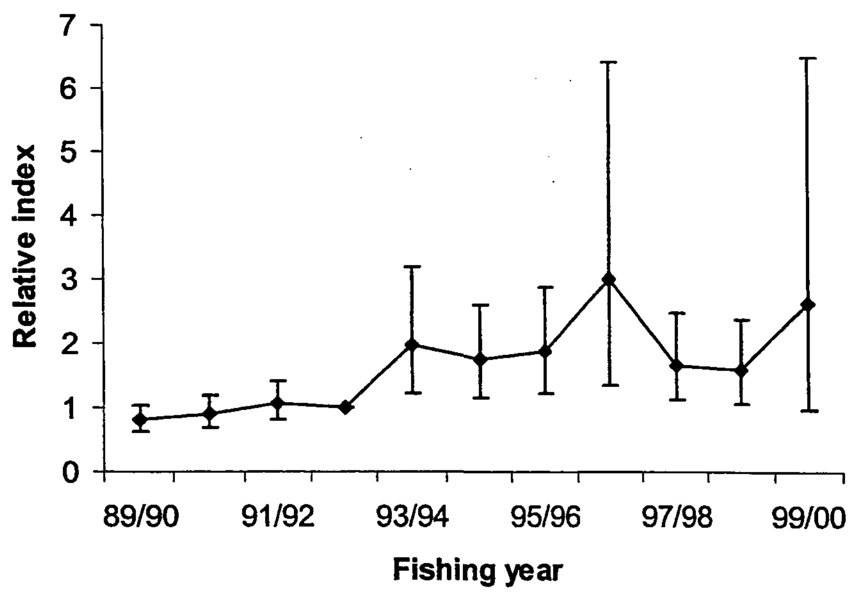


Figure 13: Relative year effects for the binomial CPUE regression analysis with error bars representing the 95% confidence interval.

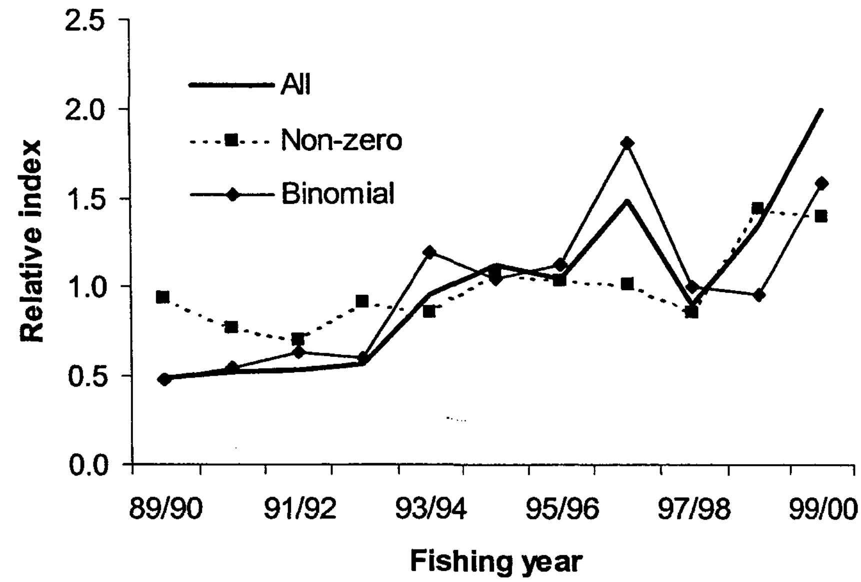


Figure 14: Comparison of the ELE 3 annual indices derived from the loglinear (all), loglinear (non zero) and binomial CPUE models. For comparison, all indices were scaled by the average of the entire series.

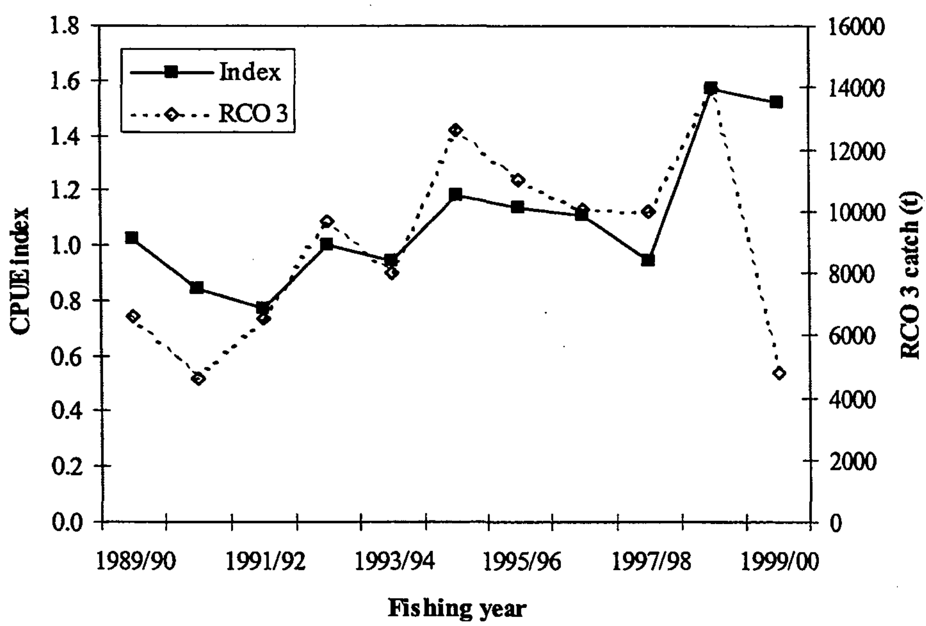
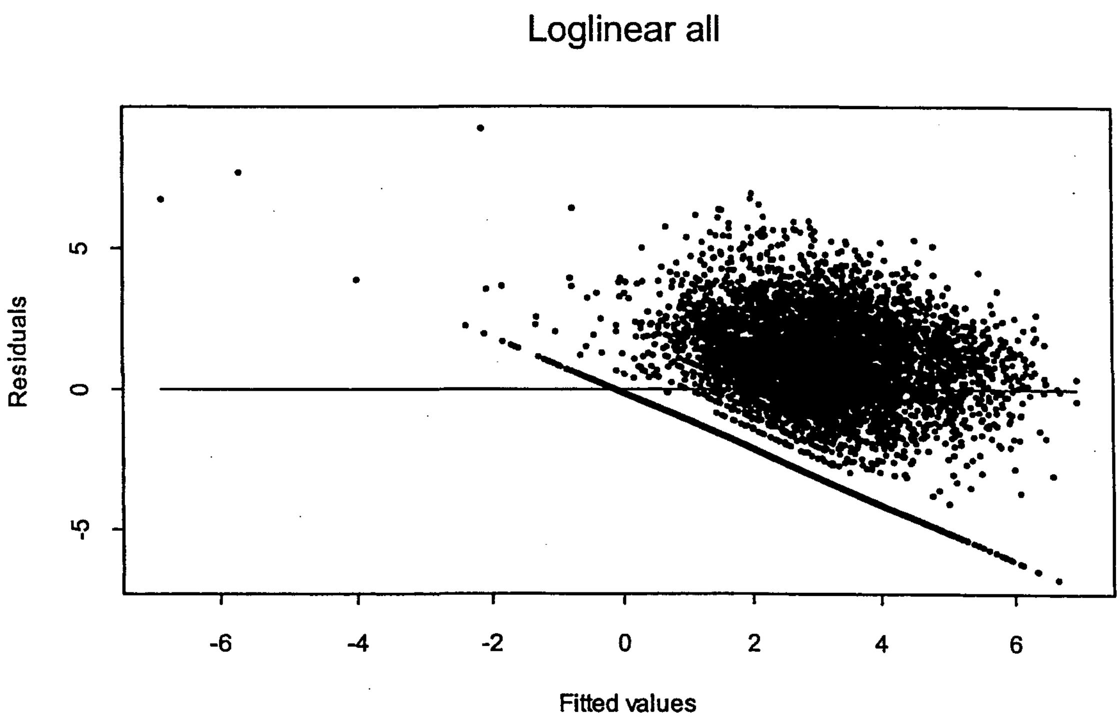


Figure 15: Comparison between the annual indices derived from the loglinear (non zero) ELE 3 CPUE model and the annual catch from the RCO 3 fishery (QMR) for the period 1989–90 to 1999–2000.



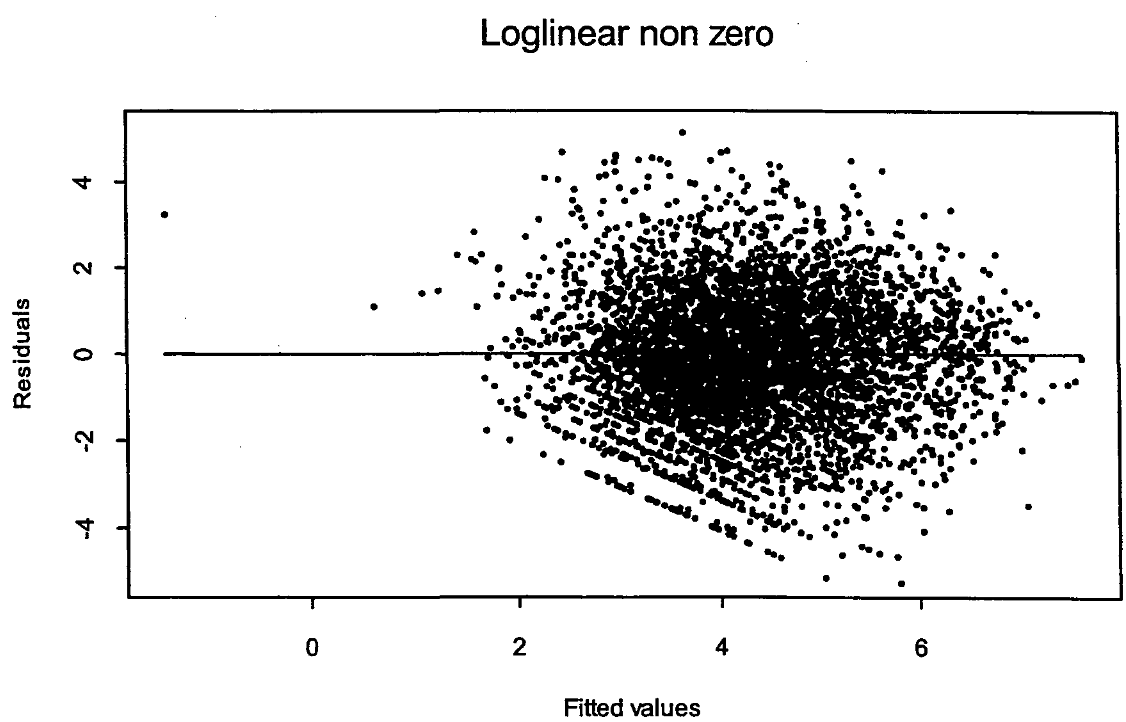


Figure 16: Residual plots for the loglinear (all) and loglinear (non zero) ELE 3 CPUE models.

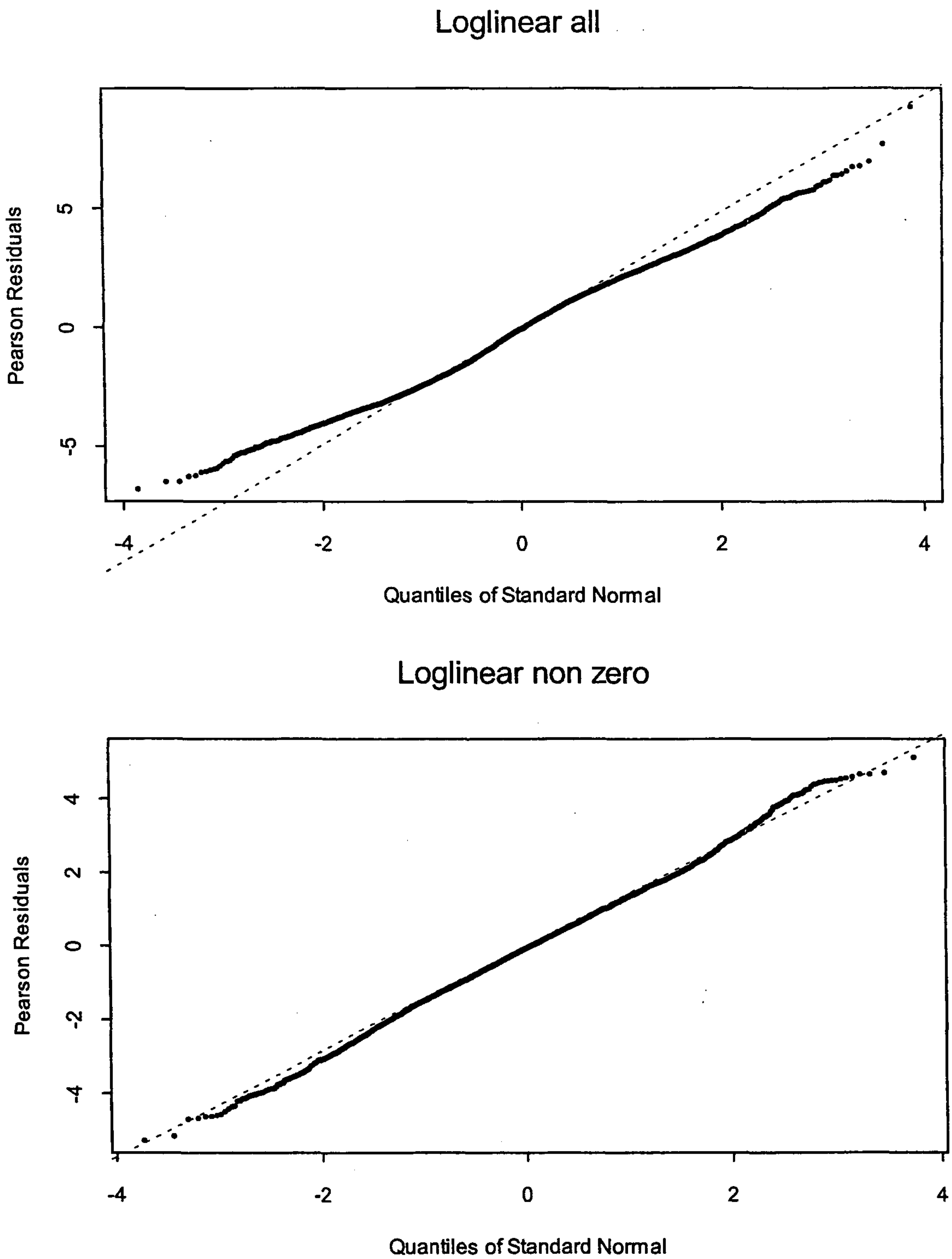


Figure 17: Quantile-quantile plots for the loglinear (all) and loglinear (non zero) ELE 3 CPUE models.