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D. Ayers
L. J. Paul
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D. Ayers
L. J. Paul
B. M. Sanders

NIWA
Private Bag 14901
Wellington

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EXECUTIVE SUMMARY

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This report forms part of Ministry of Fisheries project HPB2002/01, which has the overall objective: To monitor the relative abundance of major groper and school shark Fishstocks. Objective 1 is addressed here: To evaluate indices of relative abundance for school shark derived from existing commercial bycatch data.

The emphasis is on bycatch data, as a consequence of earlier studies of CPUE from targeted school shark (SCH) fisheries proving unsatisfactory. In a few fisheries it is possible to compare targeted and bycatch CPUE.

Ten fisheries (3 trawl, 4 setnet, 2 dropline, and 1 bottom longline) were studied, selected on their likelihood of being unit fisheries and the known existence of a moderate bycatch of school shark. They were based on Statistical Areas, within or constituting a Fishstock, but non-Fishstock regions were created around Cook Strait. Target species differed between most fisheries. Coverage is for fishing years 1989–90 to 2002–03 (descriptive) or 2001–02 (CPUE).

Analyses were based on landed values from the Ministry of Fisheries catch effort database. Fisheries (by region, method, and target) were selected where school shark made up a moderate bycatch (and sometimes a targeted catch). All catch and effort data were obtained for these selected fisheries, by trip and day. School shark landing values were obtained for the same trips. Catch and landing extracts both included zero values for school shark (unsuccessful trips). Trip records were condensed into a single row. Where categorical variables differed over days within a trip, the trip's value was recorded as the value which occurred on days with the greatest daily catch. Landings (t) were thus linked to the trip's effort values.

Descriptive annual and monthly trends in landings are presented for each fishery. Trends in the proportion of unsuccessful (zero), and small (1–10 kg) trips are given in terms of catch and landing to complement CPUE analyses.

The CPUE indices are the exponentiated regression coefficients for the year term in a generalised linear model. The GLM used SCH catch as the response variable, and used a log link to model the mean response. An effort variable was always included as a predictor variable. Other variables were included in the model in a stepwise fashion, with the reduction in residual deviance as the criterion for inclusion. Properties of these models were examined in relation to the non-standard indices. There were some problems with the form of the data, which resulted in indices that have some uncertainty.

Despite differences between some fisheries, even within a single region, there is no clear evidence in the CPUE indices for any New Zealand-wide change in abundance. However, North Island landings had flat or declining CPUE indices, while South Island landings had flat or rising indices. Given the migratory abilities of school shark, and a recorded rise in sea temperatures around New Zealand from the mid to late 1990s, the opposing CPUE trends may represent a general southward shift in the distribution of this warm temperate species. If so, this supports earlier recommendations to manage the school shark population around New Zealand as a single stock, and not as administratively subdivided regional sub-stocks.

1. INTRODUCTION

School shark (*Galeorhinus galeus*) (SCH) have been caught in varying quantities by New Zealand commercial fishers for well over a century. For about two-thirds of this time they have been an unwanted bycatch and discarded at sea, their capture unrecorded but probably less than 100 t annually. From the early 1940s to about 1950 there was a target fishery for their liver oil, in common with other regions of the world where this species occurred and vitamin A was in short supply. The catch in this fishery is not documented (the fish being discarded), but from processed liver weights can be estimated at reaching 2500 t for a few years. The market for shark flesh was small from 1950 to the mid 1970s, and reported landings rose only very slowly to about 500 t, of which a moderate proportion was exported. An unknown (unrecorded) quantity was discarded at sea during this time, either live or dead. Landings increased sharply to over 1200 t in 1977 with the introduction of coastal gillnets, then after a sudden drop in 1978 and 1979 (a consequence of publicity on high mercury levels) rose again to almost 5000 t in the mid 1980s. The Quota Management System (QMS), which introduced quotas in 1986–87, brought landings down to 2000 t, but in subsequent years they have risen steadily again to about 3000 t. Landings are now constrained by regional TACCs.

The considerable fluctuations in pre-QMS catches and landings were driven by market demand, first for liver oil and then for flesh, and there is no evidence that they are related to the abundance of school shark. Recent landings (1999 to 2003) have fluctuated downwards by about 14% (Annala et al. 2003), but this may result from a readjustment of quota holdings and fishing patterns after a few years of over-catching some regional TACCs.

This makes the New Zealand school shark fishery unique among the world's fisheries for the species, and remarkable among shark fisheries in general, in maintaining its recent and current level of catches. It has supported landings of more than 2000 t for two decades, and more than 3000 t for several years on two occasions – the mid 1980s and 1996–2001 – with no sign of collapse. Fisheries for the species elsewhere have had very different outcomes (Appendix 1), almost certainly as a consequence of its low natural productivity (Appendix 2).

Recent estimates of relative abundance for school shark have been based on standardised CPUE analyses of fisheries targeting this species (Bradford 2001) or of the fisheries targeting any of the coastal shark species (school shark, rig, spiny dogfish, elephantfish) (SeaFIC 2003a, 2003b, 2003c, 2003d). However, while trends in targeted CPUE time series are currently the principal means of monitoring many New Zealand finfish species, they can be unreliable for species (such as school shark) with migratory and aggregated populations which can be easily located and targeted. This study sought to determine whether there was any merit in tracking CPUE indices in fisheries which did not target school shark directly but made moderate bycatches of the species. Standardised CPUE analyses were again used, but the procedures were exploratory and not necessarily directed at determining a standard CPUE procedure for follow-up studies.

1.1 Background: CPUE in target and bycatch fisheries

In most fisheries for any species, the relationship between CPUE and the actual abundance of fish is complex, particularly where there is a high degree of clumping or schooling. In extreme cases, CPUE indices can be highly misleading. If species '*x*' has a dispersed component plus localised areas of high abundance, targeted fishing activity is likely to move from the former to the latter as they are progressively located. CPUE indices will rise, as abundance declines. At locations where species '*x*' is abundant, the area of high abundance may shrink while catches (and CPUE) within the area remain high and stable. The converse is also true. If species '*y*' also has clumped and dispersed components, but the former are small and quickly fished down when targeted, vessels will move to the area of dispersed fish in search of new clumps, and CPUE will decline (until a new clump is located) more rapidly than does actual abundance. The review by Dunn et al. (2000) concluded, in the context of "simple recipes for calculating CPUE indices", "there are no easy answers, and every analysis requires a good understanding of both the fishery and the factors that can affect the CPUE/abundance relationship."

As with most species of shark, the distribution and aggregation patterns of school shark are not well known. It is believed to be highly aggregated, schooling by size and sex (and perhaps reproductive status), and the schools of adults in particular undergo seasonal migrations. Commercial fishers understand some of these patterns, and target-fish the localities where aggregations usually occur. Experienced fishers can locate the centre of such aggregations by setting exploratory longlines across known fishing grounds. Even if the size of these aggregations declines through overfishing, the local abundance of sharks at their centre may not, and CPUE will remain stable.

There are relatively few fishers to whom shark fishing is important, but even they have alternativee fisheries to switch to if their targeted catch rates (for any reason) decline. For these fishers, also, it is sometimes difficult to define "targeted". Line-caught school shark are taken by fishers targeting groper, although the grounds (flat seafloor cf. reefs) and gear (bottom longlines cf. droplines) usually differ. Setnet-caught school shark are taken by fishers targeting rig (*Mustelus lenticulatus*), although the grounds (location and depth) and gear (net height and mesh size) often, but not always, differ. About half the total school shark catch is nominally targeted (Paul & Sanders 2001), but much of this is taken in very small quantities over short time periods by many fishers, often apparently using up their uncaught bycatch quota at the end of the fishing year. For these and other reasons, it was not possible to develop meaningful CPUE indices for targeted school shark catches and landings (Bradford 2001).

CPUE indices are almost always calculated for target fisheries. This is presumably on the assumption that if fishers are striving to catch a certain species, a decline in their catch rate must reflect a decline in the abundance of that species. This may be true in certain situations, but reviews of how CPUE may actually be related to abundance (e.g., Hilborn & Walters 1992, Dunn et al. 2000) are strongly cautionary.

The value (or otherwise) of determining CPUE indices for bycatches is seldom proposed, but this option should at least be considered when CPUE indices for target fisheries prove inappropriate, or where there are no target fisheries. The latter situation was encountered by Pierce et al. (1994) in a review of squid fisheries in British waters; there were a few target or partially targeted fisheries, but squid was primarily a bycatch of trawling and seining. The study used correlation analyses of landings, fishing effort and CPUE data to define (and exclude) some squid fisheries where CPUE was correlated with catch or effort. The remaining squid landings were considered to be taken randomly by fisheries targeting other species, and CPUE was accepted as a reasonable index of squid abundance.

A recent study by Miranda & Vooren (2003) followed the CPUE trends of several demersal elasmobranch species in coastal waters of southern Brazil, taken by several categories of trawlers, gillnetters, and artisanal fishers. They were taken in association with teleost fish, but appear to have been targeted to some extent at different times by a complex group of fishing vessels. However, the elasmobranchs included *Galeorhinus galeus*, and a dogfish (*Mustelus schmitti*) closely related to the New Zealand rig, so the findings have some relevance to this present study.

With the exception of a recent CPUE analysis of elephantfish bycatch in a red cod fishery (Langley 2001), no other study of a bycatch CPUE has been located, but neither has any argument against this method, which has the theoretical advantage of random, non-directed effort.

The use of bycatch CPUE is worth investigating for school shark. Monitoring the abundance of this species in well defined fisheries (by area, method, and target species other than school shark) may provide an alternative means for monitoring the status of regional populations within the New Zealand stock, which is considered to be a single biological unit. Objective 1 in this project concerns the derivation of more robust indices of abundance for school shark from bycatch trends in selected fisheries.

Bradford (2001) examined a variety of CPUE measures for school shark. She fitted many different model types in an attempt to determine the best CPUE indices for school shark. She found that none of the models were particularly good, and further, she determined that the data themselves are not particularly good. In addition, she stated that the relationship between school shark CPUE and abundance is likely to show a hyperstable (Dunn et al. 2000, Hilborn & Walters 1992) relationship due to the schooling nature of these sharks. This is backed up by biological and basic catch data (Paul & Sanders 2001). Bradford stated explicitly "It should not be assumed that the standardised catch rate indices calculated in this report are directly proportional to abundance without further work."

Research from the Australian school shark fishery has also suggested caution is required when interpreting CPUE trends. Walker (1998) stated that "stock structuring patterns and targeting practices greatly affect CPUE trends, and combining data from different regions can produce misleading trends." Punt et al. (2000) made similar claims, and proceeded with a CPUE analysis that allows for varying trends in different areas.

While these studies show that CPUE trends can be inconsistent over different subsets of the data, they do not help us establish which (if any) of the trends are correct indices of abundance. To determine which index is most indicative (representative) of abundance, it is necessary to have an independent estimate of abundance, which is generally not available. In the absence of that information, we require an index that is consistent, and one that is estimated well (i.e., has small coefficients of variation (cvs)).

Catch per unit effort is defined as the amount of fish caught by a standard unit of effort. It is easy enough to define the amount of fish caught, but the standard unit of effort is a more difficult quantity to define. In some fisheries there is a natural choice, such as a single tow in a bottom trawl fishery, or a single set in a set net fishery. These choices, however, seem to be made more on the basis of convenience than anything else.

Ideally, we want the unit of effort to be consistent over time. If, for example, the unit of effort in a bottom trawl fishery was number of hours towed, and we knew that over the past decade the speed of the vessels increased, we would have a situation where the vessels in the later part of the time series covered more ground with their trawls than vessels from the early part of the survey. An increase then in the amount of fish caught would not necessarily equate to an increase in the total amount of fish in the area, but would likely represent an increase in the efficacy of a unit of effort. This is a problem, as the unit of effort is therefore not standard over all the observations. This sort of problem has led to the development of "standardised catch per unit effort analyses", which are regression models that include covariates as a method for controlling for changes in effort.

Often a "vessel" term is included in the regression. This is supposed to capture the effects due to physical characteristics of the vessel, and knowledge of the skipper/crew, etc. This, however, does not allow for changes in knowledge, or even improvements in the hardware of the vessel. Also, fishers are making a concerted effort to find fish. There are many innovations in the fishing industry that help fishers increase their efficiency, and many of these methods are not really quantifiable. Local knowledge, and the use of modern technology (improved echo-sounders and fish-finders, GPS, etc) is difficult to quantify. In addition, the vessel term does not account for changes resulting from change of owner or skipper.

2. METHODS

2.1 Choice of fisheries

Fisheries were chosen which were relatively well defined by geography, method, and target species (Figure 1). Fishstock boundaries were taken into account, but were not a major determinant. Most such fisheries lay within a Fishstock, but were a subset of its Statistical Areas; one fishery (Cook Strait) extended across several Fishstocks. They were based on the fisheries defined by Paul & Sanders (2001), and selected where a moderate quantity of school shark had been taken as bycatch by a single fishing method. Target species were chosen for each fishery on the basis of being common, associated with a school shark bycatch, and likely to define reasonably uniform fishing activity within each.

Although this study was directed at school shark catch rates when this species was not being targeted, in the four setnet fisheries it was possible to compare the non-targeted school shark CPUE with that for a targeted fishery using the same method in the same area.

Ten fisheries met these criteria (see Figure 1). There were four setnet fisheries: Kaikoura, Nelson bays (Tasman and Golden) plus the Manawatu coast, the east coast of the South Island, and the central west coast of the North Island. There were three single bottom trawl fisheries: the east coast of the South Island, the east coast of the North Island, and the northwest coast of the North Island. There were three line fisheries: a dropline fishery off the northeast North Island, a dropline fishery in Cook Strait, and a bottom longline fishery on the Chatham Rise. (Dropline combined the methods listed as dropline, dahnline, and trotline.)

2.2 Data extracts

The data for these analyses were obtained from the Ministry of Fisheries catch effort database system.

There are known problems in the estimated catch values for school shark (and for some other species which are processed at sea, and/or caught in small quantities). The values may be of processed weight, instead of the required greenweight, and many values are always missing because the species is not among the top five caught in a fishing activity, or day. Consequently, this study sought to use landing weights, which are (in theory) always greenweight, and represent the total retained catch of the species. Obtaining the bycatch landed weights of school shark in the selected fisheries was a stepwise process.

For each fishery, by fishing year:

(1) An extract was obtained of all the effort data and estimated school shark catch, including zero estimates which used the selected method, worked the selected Statistical Areas, and targeted the selected species. Each trip had a unique identifying code-number (the trip attribute selected).

(2) A second SQL script extracted the landed weights of all species taken on each trip, by Fishstock.

(3) Because of the large number of species landed (up to 150 in a fishery), data for only the most important ones for that fishery – as well as school shark – were required separately. Most were combined by category, e.g., coastal demersal, coastal pelagic, deepwater, or "other", once extracted. The extracted landings data were then summarised by trip, by these categories, and by Fishstock (only the relevant Fishstock data were retained). This procedure gave the landings by each trip, by species, or species-category, by the selected method, and by target species.

(4) Because the extract was **not** based on trips that landed school shark, it was possible to obtain data from trips which met all criteria but landed no school shark (i.e., zero landing trips).

The data required in this analysis was obtained from three different sources: Landings forms and CELR (Catch Effort Landing Returns) or TCEPR (Trawl Catch Effort Processing Returns) forms. The landings data are collected at the end of a fishing trip, the CELR data are collected daily, and the TCEPR data are collected for each individual tow. The landings forms represent complete data on catches for each trip, while the CELR and TCEPR forms represent effort data.

The landings data were reformatted, after extraction from the catch effort system, to always consist of total landed greenweight of school shark including zero catches, total landed greenweight of all species caught, and the number of different species caught on the trip. In addition, the total landed greenweight of relevant species was included separately. The species that are deemed relevant depend on the location of the fishery and the type of gear used in the fishery. Sometimes groupings of species are included (for example, in the trawl fisheries all flatfish are summed as "FLA", rather than being listed individually). Minor species were grouped by category, e.g., "coastal demersal", "deepwater".

In order to match the catch data with the effort data it was necessary to either condense the effort data into a single record that corresponds to a particular landing, or to partition the landings data into records that correspond to the individual CELR (or TCEPR) forms. While collapsing the daily effort data may result in some loss of information, it requires fewer assumptions than partitioning the landings data.

The variables on the CELR forms that we have information on are date, method, type, target, Statistical Area, estimated total catch, and estimated SCH catch. Depending on the fishery, we also have information on number of tows, length of net, duration of set, number of sets, or number of hooks. Note, however that the estimated SCH catch data are seldom complete, due to the requirement that only the five species with the highest catches be recorded on these forms.

To match these to the single landing records, continuous variables were collapsed by calculating the sum of all of the CELR records. Thus, the number of hooks variable represents the total number of hooks on all of the records, and the estimated total catch represents the total catch from the entire trip.

It was often not obvious how to collapse categorical variables from the multiple CELR forms into a single record that corresponds to the landings. For example, a vessel may spend part of its time targeting one species and the rest of its time targeting another. We must have a rule that tells us which of these target species to assign to the collapsed record. Often the decision is made to use the most commonly occurring value. This, however, is not ideal, as ties are common, and then no obvious value exists to use in the collapsed record.

The criteria we used was the maximum estimated total catch for each unique value of the variable in question. We calculated the total estimated catch for all occurrences of each level, and recorded the level with the highest total catch. We felt that using the total catch would provide an impartial method for breaking ties, and also present the "most important" (in terms of total catch) variable.

The CPUE indices for the non-zero data are constructed by taking the regression coefficients for each year from the generalised linear model (GLM). These regression coefficients are then exponentiated to put them on the same scale as the original data. This has the effect of standardising them to the geometric mean.

We did some data grooming, based on outliers and missing values, but it was not possible to locate all errors. Typographical (data-entry) errors were corrected where possible, or the data row was rejected. Transposed values in adjacent columns were reversed when this was obvious. Data for the 1989 and

2003 fishing years were excluded from CPUE analyses because those years were incomplete for all fisheries, but 2003 data were used in the descriptive fisheries accounts to extend the time series (the missing data were from the end of the fishing year and likely to be minimal).

There were obvious errors in the species codes as listed, and other undetected errors are likely. Trip landing extracts included all reported species, and a not insignificant proportion of the codes were for species unlikely to have been taken by the method employed (e.g., in trawl landings: limpet, freshwater eel, clams, rock oyster, kina, seaweed, and a number of rare fish species usually recorded only by research staff). It is suspected that these resulted from data-entry staff misinterpreting unclear handwritten species codes, such as *BCO* instead of *RCO*, *SPD* instead of *SPO*, or mis-keying a valid code as a different valid code. The known problem of confusion between *SCH* and *SCA* was almost certainly present, but could not be addressed (i.e., school shark miscoded as *SCA* were not included in extracts). Quantifying the red cod catch in the east coast South Island trawl fishery was important, so high outlier values of BCO (when RCO was targeted but not reported in the landing) were located and changed to RCO, but similar errors in smaller values of these species could not be recognised. In most other cases dubious species codes were incorporated in a general fish group "other".

There were also a number of values that did not have obvious corrections (e.g., one trip in the Nelson Bays data set claimed to have landed over 808 t of SCH). Records that had these high outlier errors were removed from the analyses. Probable errors in lower values could not be detected and necessarily remain in the data sets.

Variables were modified if they were found to be outside an acceptable range, and were generally replaced by the modal value of that variable for the trip (or neighbouring trips). Net length in a setnet fishery was constrained to be lower than 8000 m.

2.3 Descriptive analyses

Initially, the data from each fishery were tabulated by year and basic descriptive statistics were calculated. The total numbers of vessels in the fishery, and the numbers of vessels targeting specific species were determined. Summaries of the total yearly estimated and landed catches of school shark were determined for the entire fishery, and the subsets of the fishery targeting specific species. Monthly catches were also calculated for the total fishery. Furthermore, the proportion of trips that caught no school shark were summarised for the entire fishery on a monthly basis.

2.4 Standardised catch per unit effort analyses

2.4.1 CPUE models

Bradford (2001) gave a comprehensive review of the different types of models that can be used to standardise school shark CPUE. Her report is a good summary of how changing the error structure affects the indices, and how appropriate different error structures are for school shark fisheries. Specifically, she examined lognormal models, Gamma, Poisson, and Negative Binomial models. We did not concern ourselves with the particular form of the model, as she did, but rather we focused more on the different subsets of the fishery.

Although the form of the model remained constant, the response variable did not. We initially examined models with the catch rate as the response variable, with effort variables on the right hand side of the equation. These models form our "standard" indices that are the primary result of this report. Other models examined had various measures of CPUE as the response variable. These are also typical of CPUE analyses (perhaps more so). These were compared to the initial models, and these comparisons are a minor result of this work.

We examined a number of measures of CPUE, for both target and non-target fisheries. Within the target fishery, it is expected that the indices calculated from different measures should be similar (i.e., catch per tow should show the same trends as catch per distance towed, with only slight variation). We assume that including the catch from other target species would change the trend.

The typical method for accounting for the (nominated) target species of a trip (or tow, etc) is to include a term for target species on the right hand side of the regression equation. This is, in general, an adequate method. It does, however, require some assumptions and is slightly more restrictive than doing a separate analysis for each target species. The first assumption is that (in the absence of any interaction terms) the CPUE index trend is the same shape for all levels of the target factor. This assumption can be relaxed if an interaction with year is included in the model. This also holds true for the relationship between target and all other variables in the model. For example, the trend in catch rate over Statistical Areas is assumed to be the same shape for all target species. *It is only the magnitude of the response that differs between target species.*

Performing a separate analysis for each target species allows the form of the CPUE indices to differ between species. This could also be achieved using the typical method by including a target by year interaction in the model.

A strong reason for separate analyses is that the form of the regression model can be selected to specifically address the single target data. (1) The error structure can be determined accurately for only those data (specifically in terms of the error variance and the dispersion parameter). (2) Appropriate predictor variables can be selected for the specific subset of the data in hand. The effect of the other predictor variables and the dispersion *do not* need to be averaged over all target species, as they would be in a typical analysis.

Furthermore, it is assumed that there is a large proportion of fishers who hold school shark quota to cover their unintended bycatch, and only target school shark at the end of the year to use up their remaining quota (there is some evidence of this in monthly landings, where September values are higher than the adjacent months (Paul & Sanders 2001)). If this is the case, the process by which target school shark catch rate data is generated will be different from the processes that generate other types of catch data.

This difference in "process" can be seen in the proportion of zero catches in some fisheries. In the target school shark fishery, there are virtually no trips that caught no school shark; however, in non-target fisheries many trips did not. This is not surprising, but it serves to illustrate how trends can differ. In the target fishery the trend over years cannot go down (much), and the only trend that is likely is one in which the number of zero trips increases. In the non-target fishery, both upwards and downwards trends are possible, which makes it more likely to accurately index abundance.

The GLM methodology that we employed modelled the catch rate or CPUE directly (rather than a transformation of it), and employed a log link. We were interested in models with a constant coefficient of variation, so we modelled the variance as a function of the mean squared. This was implemented in R version 1.7.1 using the GLM function with the family argument equal to quasi(link=log, var= "mu^2"). This specification uses a quasi-likelihood estimation algorithm, rather than a full likelihood. For details on this type of procedure the reader is referred to chapter 11 in McCullagh & Nelder (1989).

Binomial models were used to examine the proportion of trips that recorded non-zero school shark catch. These models used the landed school shark values, not the estimated ones. These models should provide a measure for assessing the prevalence of "incidental" catches of school shark.

All models included a term for the fishing year. Other variables that were available to the stepwise prcedure included vessel, month, trip length (number of days), Statistical Area, and total number of species caught. A number of method-specific effort variables were also included. These were: number of tows in trawl fisheries, number of sets and number of lines in longline fisheries, and the duration of set and net length in setnet fisheries. The catch (kg) of other important or related species was included in some models. In the Results section, the final text under each fishery lists which variables were included in the final models.

All of the GLMs were fitted with a stepwise regression technique, that selected variables for inclusion based on the amount of residual deviance they explained (identified as R^2 in this report). Variables were included if they accounted for more than 2% of the total residual deviance. Model fits were assessed visually with standard residual plots.

Where the model and diagnostic analyses appeared satisfactory but outliers were apparent in the plots, we referred directly to the latter instead of making repetitious comment on the model and analyses.

Subsets of the data

Standardised CPUE calculations were performed on a subset of the data that represents "**core**" vessels. Vessels that fished for less than three years were excluded, as were data from years where the vessel recorded fewer than three trips.

Area is accounted for in our definition of the fisheries that we examine. These are not necessarily related to Quota Management Areas, and are usually defined on a finer scale. They are, however, related to Statistical Areas, as this is the finest level of information that we have on locations of fishing effort.

As described in Section 2.1, **fisheries** have been defined based on the physical characteristics of the area (i.e., its likelihood of being a geographic unit), or on the assumed fishing pattern of the participants (i.e., the likelihood of it being a unit fishery).

Target species is used to create data subsets because this represents the best information that we have on fisher behaviour with regard to school shark. There are no bottom trawl fisheries that target school shark, and it is considered that these fisheries will catch school shark in a more or less random fashion. Line fishers also tend not to target school shark, though they appear to concentrate their effort in areas that are reasonably likely to have school shark. These fishers should also catch school shark in a random manner, though it may be different from the pattern observed in the bottom trawls. The final set of fisheries examined were setnet fisheries that targeted sharks in general. These fisheries have target data that are somewhat suspect, because fishers tend to hold quota for many shark species, and they may actually be targeting many species at the same time. Within this subset of the data we may or may not obtain a truly random sample. Randomness is almost certainly not going to be present in the data where the nominated target is SCH. It may be present in data where the nominated target is correctly recorded as another shark species, and it is unlikely in the cases where the nominated species is incorrectly recorded (due to multiple targets on a trip, convenience, etc). Of course, we do not know which targets are recorded correctly or incorrectly. Indices calculated from the vessels targeting school shark should be considered suspect (as the CPUE-abundance relationship is almost certainly hyper-stable), and those from the other shark target data should be questioned as well.

3. RESULTS

General trends are described first. Section 3.1 considers the proportion of school shark taken (landed) in the fisheries which were not always targeting the species. Section 3.2 describes general and regional trends over time in the proportion of landings in which either no school shark were present, or there were only very small quantities. Subsequent sections describe the regional fisheries, and present CPUE results for either the whole regional fishery or subsets of it.

3.1 School shark landings as a proportion of other species landed

3.1.1 School shark as a percentage of the main species

Although not a measure of CPUE, the proportion of school shark landings within the landings of the main species in a regional fishery can be a useful indication of changes in school shark abundance. The fisheries examined in this study show all possibilities: increases, decreases, and little change (Figure 2). Most fisheries show an increase, particularly in the late 1990s and in the south. The northeastern dropline fishery shows little change until the mid 1990s and then a decline. The Nelson/Manawatu setnet fishery shows a slight but reasonably consistent decline.

The main deficiency in this analysis is the influence of large changes in the landings of other species in the fishery. For example, the apparent increase in abundance of school shark in the east coast South Island trawl fishery is partly due to a major decline in landings of the main target species, red cod.

3.1.2 School shark as a percentage of the nominated target species

Similarly, school shark landings can be shown as a proportion of only the nominated target species for each fishery (Figure 3). The resulting trends are essentially similar to those using the set of main species, though less pronounced.

3.2 Zero or small catches and landings

The proportion of unsuccessful (zero value) fishing events can be a useful measure of changes in abundance over time. The fishing events can be small, e.g., a haul, or line or net set, or large, i.e., some grouping of these into a day's fishing or a the landing from a trip. Zero values are often built into standardised CPUE analyses (mostly via the technique outlined by Vignaux (1994)), but it is also instructive to examine them separately. However, there is also a need for caution; it is not clear that "zero" values extracted from the catch_effort database had been reported and recorded in a standard way throughout the period (fishing years 1989–90 to 2002–03). For this reason, an additional indicator of "unsuccessful" events has been used, taking 1–10 kg of school shark (in a trip's estimated catch or its subsequent landing) as a measure of low success; this weight would approximate 1–3 fish. Trends in these zero or low values are shown in Figure 4. The zero values are shown as a percentage of the total number of trip values, expressed as estimated catches (incomplete) or landing (complete records). The low values are shown as a percentage of the number of non-zero trip values, to avoid any problems resulting from zero record inconsistencies. The simplest interpretation is that if the stock size is decreasing, the proportion of zero and small values should increase, and vice versa. There is an alternative interpretation: as the stock size increases, some zero values should become low values, and unless the increase is distributed evenly across all values, the proportion of low values will rise.

Northeast coast North Island, dropline
The proportion of zero catches and landings has remained relatively constant from 1991–92 onwards. The proportion of estimated small catches fluctuated but trended upwards, while the proportion of small landings fluctuated with no trend but at a low level.

East coast North Island, trawl
The proportion of zero catches and landings both declined with time, implying increasing abundance. However, the proportion of small catches rose, approximately doubling from 20% to 40%. The proportion of small landings fluctuated only slightly upwards.

East coast South Island, trawl
The proportion of zero catches was very high and changed little with time, reflecting the fact that in this mixed species trawl fishery school shark were seldom included in the top five species caught. The proportion of low catches also changed little until a drop in 2000–01, subsequent values are not yet available. The proportion of zero landings declined steadily, while the proportion of small landings increased.

East coast South Island, setnet
Zero catches declined steadily with time, while small catches remained stable and then increased from 1999–2000. The proportion of zero landings changed little, while the proportion of small landings increased slightly. (This fishery differed from most others by incorporating school shark as one of the target species.)

Chatham Rise, longline
The proportion of zero catches and landings declined and then recovered, while there were no clear trends in the proportion of small catches and landings. However, this was a small fishery with a low and variable number of vessels, and these data are not considered reliable.

Northwest North Island, trawl
The proportion of zero catches declined, as did the proportion of zero landings, the latter at a lower level because a moderate quantity of the school shark bycatch would not have been in the top five species and thus not recorded. The proportion of small catches increased slightly, but the proportion of small landings declined in parallel with zero landings.

West coast North Island, setnet
The proportion of both zero catches and landings fluctuated a little but showed no trend over time. The proportion of both small catches and landings also fluctuated, but declined slightly over time.

Nelson Bays and Manawatu, setnet
The proportion of both zero catches and landings increased at first and then declined. The proportion of both small catches and landings increased, approximately doubling. (This fishery also differed from most others by incorporating school shark as one of the target species.)

Cook Strait, dropline
The proportion of both zero catches and landings show a similar pattern, two periods of little trend, but the second at about half the level of the first; there was a relatively sudden change in the mid 1990s to higher number of successful trips (or at least a change in the pattern of recording trip data). The pattern of small catches was also paired with that of small landings, but both differed from the zero values; the trend was upwards in the early 1990s, downwards in the mid and late 1990s.

Kaikoura, setnet
The four trends (zero and small catches and landings) were reasonably similar to those in the Cook Strait dropline fishery. The zero values showed two periods, the second lower than the first, but the

catches had more variability than the Cook Strait catches. The proportion of small catches and landings showed an initial rise followed by a decline. (This fishery also differed from most others by incorporating school shark as one of the target species.)

3.2.1 Summary of trends in zero and small catches

There is limited agreement in the relationship between zero and small catches, and zero and small landings, between the different fisheries. The most common pattern is for the proportion of zero values to remain stable or decline. Thus, in theory, school shark abundance is stable or increasing. However, the differences between and within fisheries suggest that this is an over-simplification. In some fisheries zero and small catches, and/or landings, trend together. The simplest interpretation is that both are reflecting either an increase or a decrease in the abundance of school shark, or in its availability to fishers. In other fisheries the zero and the small value trends are almost reciprocal, which is difficult to interpret (see below). Some of the differences between catch and landing trends, particularly their level, can be attributed to the "top five species" issue. Other differences between catch and landing patterns also cannot be interpreted from existing information.

The trend in zero catches and landings is either stable (mainly the northern fisheries) or falling (elsewhere). The simplest explanation is that school shark abundance in the north has not changed, and that elsewhere it has increased. The trend in small catches and landings is somewhat similar, except that in three fisheries (northeast dropline, northeast trawl, and Nelson setnet) the proportion of small values increases over time, in theory indicating a decline in abundance. Elsewhere (most central and southern fisheries) there is a stable or declining trend, suggesting no change in abundance or an increase.

The reciprocal zero and small values may just mean that one or other trend is erroneous. Or it could be interpreted as reflecting a "movement" of values between categories. Thus, an increase in small values, with a decline in the proportion of zero values, could perhaps represent a change from "unsuccessful" to "marginally successful" trips, and could be an indication of an increase in stock size. The data from two fisheries were examined in more detail to determine whether the relationship between zero and small catch or landing values could be clarified (Figure 5).

In the Nelson Bays/Manawatu setnet fishery, the relationship between zero and small landings is almost reciprocal, with zero values declining after 1992–93 (suggesting an increase in available school shark), and small values increasing after 1994–95 (suggesting a decrease). Or did the number of small values increase because "zeroes" progressively became small values? The next size category of landing, 11–100 kg, had a similar pattern to the zeroes; thus the small category, 1–10 kg, could have increased at the expense of either (or both) the categories below it (zeros) or above it (11–100 kg). In the next higher category, 101–1000 kg, there was no clear trend. In the highest category of landings, 1000 kg or greater, the overall trend was downwards although after the mid 1990s it was level. Thus there is no clear evidence that the increase in small values came from the decrease in zeroes.

In the eastern North Island trawl fishery, there was a slight decrease in the proportion of zero catches, against a slight rise in small (1–10 kg) catches. Again, the category of 11–100 kg values matched the zeroes, and there was no trend in the higher (101–1000 kg) category. Similarly, there is no clear evidence that zero values are converting into small values over time.

3.3 Regional fisheries: general account, and CPUE trends

3.3.1 East coast South Island setnet fishery

This fishery comprises setnet vessels targeting rig, elephantfish, spiny dogfish, and school shark along the Canterbury coast (in Statistical Areas 20, 22, and 24 – the central region of QMA 3). Most of their catches were recorded as Fishstock 3 landings. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 1.

The landings are mainly of coastal demersal species, dominated by spiny dogfish (which has a depth range extending beyond the shelf), with moderate quantities of rig, elephantfish, and school shark. Although often a bycatch, school shark was the fourth species by weight in the selected trips, making up 9% of their total landings.

The fishery (as reflected in the subset of selected trips) underwent some changes during the 1990s (Figure 6a). Total annual landings increased in the early 1990s, remained steady from the mid to late 1990s, then dropped suddenly to about half this level from 1999–2000 onwards. The main changes were driven by fluctuations in landings of the main species, spiny dogfish. Landings of the other main species, elephantfish and rig, increased to the mid 1990s and then remained steady or declined a little. School shark landings were steady through to the mid 1990s and then rose steadily (but with three significantly higher years during the period. The trend in fishing effort (trips and days) was broadly similar to the trend in total landings; a slight rise, a stable period, and then a decline. In summary, total annual landings appeared to depend on effort; landings of the main species fluctuated in different ways; and landings of school shark increased rather steadily over the time period, and appears not to have been influenced by total effort or the size of total landings.

There are strong seasonal trends in total landings, which are highest from November to February, then decline through to May and remain at a low level from May to September (Figure 6b). This follows the trend in effort (number of landings). There are differences between some species. The main species, spiny dogfish, is mainly landed from January to May, sometimes with a peak in the latter month. Rig and elephantfish are mostly landed between November and January, with low landings for most other months. School shark are also mainly landed during these months, but with the peak in January, one month later than the others. Seasonal school shark landings follow the trend in total effort and total landings, the latter dominated by spiny dogfish.

This is a large shark fishery, and generally many vessels were involved (Table 2). These vessels made over 10 000 trips during the 13 year study period, which makes it the most active fishery involved in this study. School shark was targeted on 1835 of these trips, rig on 4654, spiny dogfish on 2801, and elephantfish on 1376 trips. Catches have been high (Tables 3 & 4), but they have been exceeded by some other fisheries during this period (for example, the fisheries on the west coast of the North Island). The proportions of trips that caught no school shark are presented in Table 5.

The binomial indices suggest a stable pattern of incidental catch, with perhaps a slight increase over the course of the study (Figure 7). The magnitude of the increase in the last year of the school shark index is a result of few observations. There were only 47 valid records, and only one of these caught no school shark. These data show in increase in the probability of catching school shark, though the size of the effect is not estimated particularly well. This again underscores the unsuitable nature of using school shark targeting vessels in the construction of CPUE indices. A similar result explains the high point in the elephantfish index.

The binomial models tended to fit well. R^2 values were between 31 and 39%. Using the subset of core vessels retained 77.3–86.6% of the records.

The non-zero indices show varying trends (Figure 8). The rig target index suggests that school shark abundance is decreasing, while the spiny dogfish target fishery suggests the opposite.

These models included terms for vessel and month, and in the case of the elephantfish targets, area. The use of core vessels did not reduce the number of observations greatly, as 80–87% of the records were retained. Despite this, R^2 values were moderately low, ranging between 28.4 and 37.3%.

3.3.2 Kaikoura setnet fishery

This fishery comprises setnet vessels targeting rig and school shark near Kaikoura (Statistical Area 18, partly in QMA 3 and partly in QMA 7). Most of their catches were recorded as Fishstock 3 landings. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 6.

The landings are mainly of coastal demersal species, dominated by spiny dogfish, with moderate quantities of rig, tarakihi, and school shark. Although often a bycatch, school shark was the fourth species by weight in the selected trips, making up 14% of their total landings.

The fishery (as reflected in the subset of selected trips) has altered during the 1990s (Figure 9a). Total landings increased about six-fold from 1989–90 to 1993–94, dropped by almost half but was reasonably steady for the six years 1994–95 to 1999–2000, then doubled again for the three years 2001–03. Landings of the main species showed some exceptions to this overall pattern. After the high year of 1993–94 spiny dogfish landings remained relatively high, but fluctuated. Rig landings increased reasonably steadily over the whole time period, as did school shark landings. Tarakihi, and to a lesser extent seal shark (deepwater) landings, trended in parallel with total landings. The trend in fishing effort (trips and days), was similar to the trend in total landings. In summary, total annual landings appeared to depend on effort; landings of the main species fluctuated in different ways; and landings of school shark increased rather steadily over the time period, and was not greatly influenced by total effort or the size of total landings.

There are strong seasonal trends, with a peak in total landings usually in November and a low period from May to September (Figure 9b). It broadly follows the trend in effort (number of landings). There is some difference between species. The main species, spiny dogfish, shows no seasonal peak, but a low season from June to August. Rig landings peak in November and are low for most other months, and tarakihi landings peak in December and January. School shark show some variability, but usually peak in November-December and again in February-March. Seasonal school shark landings, therefore, do not appear closely linked to the landings of other species, but the first peak (November-December) does correspond with relatively high effort, some of which will be targeted.

The Kaikoura setnet fishery consists of a small number of vessels (Table 7) operating in a small geographical area. These few vessels completed over 4200 trips over the study period (678 of these targeted schoolshark; 3546 targeted rig), which is proportionally more than most of the other fisheries studied here. This suggests that these fishers are fishing shark almost exclusively, and not part of a larger more variable fishery. The total yearly and monthly catches are small compared to the other fisheries though (Tables 8 and 9). The proportions of trips that caught no school shark are presented in Table 10.

The Kaikoura set net fishery is managed as part of the QMA 3 fishery. This analysis considered it separately from the Canterbury fishery because of the differences in the behaviour of the fishers, and the differences in the structure of the shark habitat. The results of this analysis justify this choice, as the CPUE trends appear to be quite different from the trends observed in the Canterbury fishery, and more in line with results from the Cook Strait area.

The analysis of trips that caught no school shark showed trends that were not surprising. The core rig target vessels made up 18% of the total rig targeting vessels, and accounted for over 86% of the records. School shark core vessels were 30% of the fleet, and 84% of the records.

The final model for the rig target fishery included fishing year, month, vessel, and species count. This model had an R^2 of 33%. The model for the school shark target fishery included the same variables and had an R^2 of 48%. Neither of these models fit very well because of lack of data. There are some fitted probabilities that are near 1.

The non-zero GLM for rig targeting vessels used a set of core vessels that comprised 21% of the fleet and 85% of the trips. The school shark core vessels accounted for 27% and 85% of the fleet and the records, respectively. The indices from the school shark target analysis are incomplete, due to the non-estimability of some years. The remaining years show a fairly static trend (Figure 10). The rig target index is slightly more dynamic, showing an initial decline, and then an increase in the later years. Most confidence intervals imply that there is no significant difference between the years.

3.3.3 Nelson Bays/ Manawatu setnet fishery

This fishery comprises setnet vessels targeting rig and school shark in Tasman and Golden Bay and off the Manawatu coast (Statistical Areas 37–39, in QMAs 7 and 8). Most of their catches were recorded as these two Fishstocks. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 11.

The landings are mainly of coastal demersal species, dominated by the two target species, rig and school shark, with small quantities of spiny dogfish. Even though a bycatch on many trips, school shark was the main species landed by weight from the selected trips, at 43% of their total landings.

The fishery (as reflected in the subset of selected trips) has changed little during the 1990s (Figure 11a). Landings have fallen slightly in the most recent two years, reflecting a decline in each of the three main species. School shark landings fluctuated through to the mid 1990s, then (with one exception) have fallen. The trends in fishing effort (trips and days) essentially parallel those in total landings. In summary, total annual landings appeared to depend on effort; landings of the main species fluctuated a little but in different ways; and landings of school shark (as one of the main species) did show a relationship with total effort.

There is moderate seasonality in the landings trends, with total landings being greatest from November to April but with considerable monthly variability (Figure 11b). It broadly follows the trend in effort (landings). There is considerable difference between species, and within species by year. The main species, rig, usually peaks – although not strongly – in November and January, but moderate landings occur until April. Spiny dogfish, conversely, peak variably from June to November. School shark show little seasonality, being landed from September to June, with considerable interannual variability. Their landings appear to be somewhat independent of other species.

The Nelson Bays/ Manawatu setnet fishery was small, but effective, and targeted only rig and school shark. There were between 16 and 25 vessels involved in this fishery each year (Table 12). These vessels made slightly more than 4000 trips (individual records) over the past 13 years, of which 380 targeted school shark and the remaining 3733 targeted rig. This fishery had some of the highest catches of all of the fisheries examined. The total landed and estimated school shark catch by year is presented in Table 13; the landings are further broken down by month in Table 14. Table 15 presents the proportion of trips that caught no school shark.

Standardised presence/absence indices were not calculated for vessels targeting school shark. Almost all of these vessels caught school shark, and therefore any index calculated from them is going to be unnecessary. Unstandardised yearly averages are plotted in Figure 12. The standardised binomial CPUE index from the rig target fishery is presented in Figure 13. This index suggests that there has been an increase in the accidental catch of school shark over the past 13 years.

The calculation of the standardised CPUE indices for strictly positive quantities of landed school shark was hampered slightly by the use of core vessel criteria. In the school shark target fishery there were not enough data in this subset to calculate an index for the 1994 fishing year. There were only seven vessels that met the core vessels criteria; this is 18% of the entire fleet, though these vessels accounted for over 51% of the trips targeting school shark. The rig targeting core vessels made up 38% of the fleet and 83% of the trips.

Both the core vessels index and the all vessels index are presented; there is not much difference between the two. The school shark target vessels produced a somewhat erratic index, with a slight increase in later years. In both all vessels and core vessels analysis, the rig targeting vessels showed a consistently increasing, but non-significant, trend (Figure 14). Model fits were acceptable.

3.3.4 West North Island setnet fishery

This fishery comprises setnet vessels targeting rig and school shark north and south of Cape Egmont (Statistical Areas 40 and 41, lying mostly in QMA 8). Most of their catches were recorded as Fishstock 8 landings. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 16.

The landings are mainly of coastal demersal species, dominated by the two target species, rig and school shark, with small quantities of spiny dogfish, red gurnard, trevally, and snapper. Even though a bycatch on many trips, school shark was the main species landed by weight from the selected trips, at 50% of their total landings.

The fishery (as reflected in the subset of selected trips) changed in magnitude during the 1990s (Figure 15a). Total landings during the mid 1990s were more than double those of the early 1990s, decreased very slightly to 1998–99, then dropped a little for the next four years. All the main species (but mainly rig and school shark) contributed to this pattern, with school shark landings being more consistent than those of rig from the mid 1990s onwards. The trend in fishing effort (trips and days) was similar to the trend in rig landings. In summary, total annual landings was related to effort but did not decline as greatly from 1992–93 onwards; rig landings were most closely related to effort, and school shark landings remained reasonably stable as effort declined.

There is variable seasonality (Figure 15b). Total landings are high but fluctuating from September to April, and low from May to August, paralleling the trend in effort (landings). This is the general pattern for the three main species, rig, spiny dogfish, and school shark.

On average there were 25 vessels in this fishery each year (Table 17); they targeted school shark on 1033 trips and rig on 4641 trips. These vessels consistently landed a large amount of school shark (see Table 18 for a breakdown by landings and estimated catch, and Table 19 for monthly landings). The proportions of trips that caught no school shark are presented in Table 20.

In the binomial model, school shark targeting vessels accounted for 26% of the vessels and 77% of the records. Variables in this model included vessel, month, and rig catch, and the R^2 was 68.5%. The core vessels from the binomial analysis of the rig targeting vessels used 39% of the vessels and 84%

of the observations. Vessel and species count were the only variables selected by the model, and they produced an R^2 only 36.4%.

For the non-zero catch indices, the SCH target vessels accounted for 26% of the vessels and 71% of the records. The rig (SPO) target analysis used a core vessel subset of 30% of the available vessels, accounting for 80% of the records. Variables included in the models were vessel (for the rig target; R^2=41%), and vessel and month for SCH targets (R^2=56%).

The two binomial indices are flat and do not indicate any trend in the proportion of non-zero catches (Figure 16). The non-zero indices, however, do indicate trends. The SCH target index suggests that the CPUE is increasing steadily over the period of the study, while the SPO index suggests an initial rise, and then a drop to the original levels in 1999 (Figure 17).

3.3.5 East coast South Island bottom trawl fishery

This fishery comprises trawlers targeting red cod, flatfish, gurnard, and stargazer along the Canterbury coast (in Statistical Areas 20, 22, and 24 – the central part of QMA 3). Most of their catches were recorded as Fishstock 3 landings. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 21.

The fishery (as reflected in total landings from the subset of selected trips) was reasonably stable through most of the 1990s after an initial rise (Figure 18a). In the three fishing years 1999–2000 to 2001–02 landings fell sharply to about half their previous level, mainly because of lower landings of red cod (the major species), but some moderately important other species (barracouta, blue and silver warehou, flatfish) also declined in a similar manner (Figure 18b). A variety of landing trends is shown by the other species in the fishery (Figure 18b). A few species (school shark, elephantfish, and tarakihi) and "other deepwater" fluctuated upwards through the 1990s. Spiny dogfish increased markedly from 1999–2000 onwards, perhaps as a consequence of a lower discarding rate. Several species or groups maintained level or only moderately fluctuating landings. The species which declined after 2000 generally had a similar landing trend: low in the early 1990s, higher through the mid 1990s, before dropping. There is no obvious explanation for this pattern. It does not seem to reflect a shift in fishing depth; shallow and deep water species occur within each set of landing trends. Fishing effort and total catch show parallel trends (see Figure 18a), although effort (trips and days) declined from fishing year 1998–99 onwards.

Trends in the bycatch of school shark when each of the main target species (red cod and "flatfish" (several flounders and soles)) were nominated as the predominant target for the trip are shown in Figure 18c. The number of trips targeting flatfish trended down with some small fluctuations during the 1990s, and the size of flatfish landings followed a similar pattern. The associated bycatch of school shark followed a very similar trend to the number of flatfish-targeted trips. The number of trips targeting red cod, and the landings of red cod, also trended together, peaking in the early to mid 1990s and then declining. The associated bycatch of school shark, however, increased erratically over the whole time period.

The seasonal trends are also variable, moderate to large landings are made in all months except (usually) August to October (Figure 18d). The effort (landings) trend is similar, though the drop in these three months is smaller. There are no strong seasonal peaks for the main species; red cod and barracouta are taken from November to May or June, and flatfish through the whole year. Landings of school shark peak from November to January, then decline steadily until June or July; there is no strong link between this and total effort, or the landings of another species.

The east coast South Island bottom trawl fishery is very large. The average number of vessels each year is over 108 (Table 22). It contains data on over 74 000 fishing trips. Most trips targeted either flatfish (45 989 trips) or red cod (27 009 trips). About 1000 trips targeted either gurnard or stargazer. Despite the size of the data set, catches of school shark are not particularly large. Landed and estimated school shark catches by year are presented in Table 23. The monthly distribution of the landed school shark catches is presented in Table 24. The proportion of trips that caught no school shark is presented in Table 25.

The binomial model for vessels targeting flatfish used a group of 116 core vessels. This accounts for 55% of vessels that targeted flatfish, but over 94% of all trips targeting flatfish.

Lognormal based GLMs were used for indices based on flatfish and red cod targeting vessels; the other two targets did not have enough observations to accurately estimate GLM parameters. Both of these indices suggest an initial drop and a possible rebuilding later in the series (Figure 19). However, these models can likely be improved on, as the R^2 values are 36% and 18% for flatfish and red cod, respectively, and the diagnostic plots suggest a poor fit for the distribution of the residuals.

3.3.6 Northwest North Island bottom trawl fishery

This fishery comprises trawlers targeting trevally, snapper, and gurnard along the northwest coast of the North Island (Statistical Areas 42, and 45–47 – the coastal region of QMA 9). Most of their catches were recorded as Fishstock 9 landings, although some trips extended into QMAs 1, 7 and 8 (only QMA 9 data were retained from these trips). The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 26.

The landings are mainly of coastal demersal species, dominated by trevally and snapper, with moderate quantities of gurnard, tarakihi, and barracouta, and some school shark. The selected trips sometimes extended into deeper water, taking gemfish, hoki, ling, and frostfish. Some coastal semi-pelagic species (mainly kahawai and jack mackerels) also contributed to landings. School shark was only a bycatch, and the sixth coastal demersal species by weight in the selected trips, making up 4% of their total landings.

The fishery (as reflected in the subset of selected trips) was reasonably stable through the 1990s after an initial rise (Figure 20a). Fishing effort (trips and days) paralleled the upward rise in total landings to 1997–98, but fell more sharply during following years. Landings of most main species rose until the mid 1990s, and then either remained relatively stable or declined a little. The landings of school shark generally followed this overall trend.

There is a seasonal trend in the total landings, which are at a maximum from November to March then decline to a low season from May to August (Figure 20b). It broadly follows the trend in effort (landings), although these tend to be more uniform through the year. There are differences between the main species. Snapper are caught from October to December, trevally from November to March, and gurnard show no seasonal trend. School shark peak sometimes in September, sometimes in October, and sometimes in November. There is only a partial relationship between school shark landings and seasonal effort.

This fishery was the only one that posed a problem with regards to the collapsing of event-based data into a trip-based form. There was a great deal of variability in the nominated target species and Statistical Area within a trip. This has resulted in the loss of a great deal of information, and potentially the obfuscation of important trends. In the interest of consistency, the data were examined similarly to the other data sets.

The number of unique vessels participating in the fishery, and the number of vessels targeting important species, is presented in Table 27. Thirteen trips were reported to target school shark, though the most common target was snapper (3356 trips). Other common targets were trevally (1996 trips) and gurnard (1530 trips). The yearly catches in this fishery were high relative to those in the other fisheries that we examined (Table 28). Monthly school shark catches are presented in Table 29. The proportions of trips that caught no school shark are presented in Table 30.

Examination of the trends in this fishery suggests that the school shark population is in decline in this area. For the binomial index with snapper there is an obvious decline over the period of time that we are examining. The trends with gurnard and trevally are flatter, though they fluctuate quite erratically (Figure 21).

The non-zero GLM indices corroborate the binomial results. The snapper and trevally fisheries suggest a slight a decline in the CPUE, though the gurnard index remains near 1 (but it is quite variable). It appears that the vessels are catching school shark less frequently, and they are taking smaller catches.

The core vessel subsets for these analyses selected, depending on the species examined, 30–54% of the vessels and 80–94% of the records. The models included vessel, month, total catch and rig catch, and typically had R^2 values between 45% and 60%. The indices are presented in Figure 22. Diagnostic plots for the models are shown in Appendix 3.

3.3.7 East North Island bottom trawl fishery

This fishery comprises trawlers targeting tarakihi along the east coast of the North Island (Statistical Areas 11–14 – all but the Cook Strait region of QMA 2). Most of their catches were recorded as Fishstock 2 landings. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 31.

The landings are mainly of coastal demersal species, dominated by the target species tarakihi, with moderate quantities of barracouta, gurnard, snapper, and trevally, and lesser quantities of several other species. The selected trips sometimes extended into deeper water, taking hoki, gemfish, rubyfish, and (at greater depth) orange roughy. Some coastal semi-pelagic species (mainly jack mackerels and kingfish) also contributed to landings. School shark was only a small bycatch, making up 1% of the total landings.

The fishery (as reflected in the subset of selected trips) changed relatively little during the 1990s (Figure 23a). Total landings and fishing effort (trips and days) rose initially and then remained stable. Tarakihi (the nominal target species) declined a little in the mid 1990s, associated with a brief increase in barracouta landings. The selected trips included some landings of deepwater species, presumably when part of the trip was spent working the shelf, part working in deep water. Landings of the main such species, hoki, fluctuated and decreased with time, and the landings of all deepwater species declined after 1999–2000. The bycatch landings of school shark increased fairly steadily over the whole period.

There is little seasonal trend in total landings, although values are usually highest in October-November and then undergo a fluctuating decline until the end of the fishing year in September (Figure 23b). It broadly follows the trend in effort (landings). There are differences between species. The main species, spiny dogfish, shows little seasonality. Barracouta peak from July to September. Hoki landings are usually highest in November and decline slowly until May. There is no apparent seasonality, and considerable monthly variability, in school shark landings.

This fishery consisted of vessels targeting tarakihi. Up to 51 vessels were involved each year (Table 32), and these made 6789 trips over the entire study period. Total landed and estimated school shark catch is presented in Table 33, and monthly landings are presented in Table 34. The proportions of trips that caught no school shark are presented in Table 35.

The core vessel subset contained almost 49% of the vessels targeting tarakihi, which accounted for over 92% of the trips. The binomial model selected by the stepwise procedure included a term for vessel and one for number of species caught. This model had an R^2 of 18%. The binomial trend in this fishery suggests that there was a period of low incidental catches in the early 1990s, followed by an increase in the late 90s. The last two years in the sequence (2000–01 and 2001–02) are similar to the baseline year (1989–90) (Figure 24).

The positive catch analysis used 43% of the vessels and 89% of the records. This CPUE index clearly shows a declining trend. There is a slight increase around 1996, though the decline continues after this. In 2001–02, the index is almost half of its initial value (Figure 25).

3.3.8 Cook Strait line fishery

This fishery comprises dropline (dahnline and trotline) vessels targeting groper and bluenose in Cook Strait (Statistical Areas 15–19 and 37–39 – segments of QMAs 2, 7, and 8). Most of their catches were recorded as landings into these Fishstocks. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 36.

The landings are mainly of coastal demersal species, dominated by the target species groper. Although nominally a bycatch, school shark was the second most important species by weight, with only moderate quantities of the other target species bluenose. It was 23% of the total landings from the selected trips.

The fishery (as reflected in the subset of selected trips) changed relatively little during the 1990s (Figure 26a). Total landings, effort (trips and days), and landings of the main species, groper, trended together. The bycatch of school shark also changed little, apart from two years of high landings which coincided with high groper landings.

There is little seasonal pattern in total landings, apart from a decline towards the end of the fishing year (June to September), which is somewhat similar to the seasonal pattern in effort (landings) although the latter peak more clearly in January–March (Figure 26b). The pattern of groper landings, understandably, is similar to that of total landings. The relatively small bluenose and ling landings had little or no seasonal pattern. School shark landings follow the pattern for groper, but with greater variability.

The Cook Strait line fishery was predominantly a groper fishery, though there were vessels that targeted bluenose and school shark. There were a moderate number of vessels involved in the fishery (Table 37), most of which targeted only groper, though roughly 20% of them targeted the other two species as well. School shark was targeted on only 257 trips, while groper was targeted on 4227. Bluenose was targeted on 357 trips.

Total estimated and landed catches are given in Table 38, and the monthly catches in Table 39. The proportions of trips that caught no school shark are seen in Table 40.

Generalised linear models for the proportion of non-zero catches were examined for the three different target species. The data for school shark and bluenose were not sufficient to fit any models, due to both sparseness and (in the case of targeted school shark) a high proportion of trips that always caught school shark.

The index of positive school shark catch in the groper target fishery suggests that there has been a period of relative stability, followed by a sharp increase in trips catching school shark over the past three years (Figure 27). This model fits reasonably well, and includes terms for fishing year, vessel, species count, and month.

Indices of non-zero catch per unit effort were calculated in a similar fashion. Again, the bluenose and school shark indices are not as reliable as the groper. The non-zero CPUE index was calculated by modelling the landed school shark catch, and putting effort variables on the right hand side of the equation. The model includes terms for fishing year, total catch, and vessel. It has an R^2 of over 70%. Again, the indices calculated in this way are quite similar to indices calculated by modelling catch/effort directly. This CPUE index is presented in Figure 28, and diagnostic plots are presented in Appendix 3. It is interesting to note that this trend is very similar to that observed for the Kaikoura setnet fishery.

3.3.9 Northeast North Island line fishery

This fishery comprises dropline (dahnline and trotline) vessels targeting groper and bluenose along the northeast coast of the North Island (Statistical Areas 1–10 – the entirety of QMA 1). Most of their catches were recorded as Fishstock 1 landings. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 41.

The landings are mainly of coastal demersal species, dominated by the two target species, groper and bluenose, with school shark, even when taken as bycatch, the third species landed by weight from the selected trips, at 11% of their total landings.

The fishery (as reflected in the subset of selected trips) has undergone moderate changes during the 1990s (Figure 29a). Total landings were stable until 1997–98, and then declined to about half their former level; this parallels changes in fishing effort (days and landings). The decline is shown by the three target species, groper (hapuku and bass) and bluenose, and also – more markedly – for the bycatch of school shark.

There is no strong seasonality in total landings, apart from a moderate and variable peak from September to November (Figure 29b), which broadly follows the trend in effort (landings). The main species all contribute to this, with bluenose the most variable.

This line fishery involved between 29 and 60 vessels each year; most of these targeted groper, but there was also some targeting of bluenose and school shark (Table 42). As with the previous fishery, only a few trips targeted school shark (28 trips), and most targeted groper (2922 trips). Bluenose was targeted infrequently (653 trips).

Despite the large number of vessels, the total catches of school shark were relatively small compared to the other fisheries. In addition, there has been a steady decline in total catches since the 1994 fishing year (Table 43). Table 44 shows that same trend, in addition to identifying a moderate seasonal trend within each year. There does not appear to be a trend in the proportion of vessels that caught no school shark (Table 45).

The standardised analyses agree with the unstandardised catch rates, but disagree with the proportion of zeros caught. The standardised index suggests a declining probability of catching school shark, while the unstandardised average proportions suggest that more school shark are being caught (Figure 30).

The non-zero index is clearly showing a declining catch of school shark over the 13 year period of the study (Figure 31). This model was constructed with a core vessel subset of 14% of the vessels, accounting for 64.5% of the records. Variables selected in the model include total catch and vessel. This model had an R^2 of 61.4%. Diagnostics show that the model fits well; plots are presented in Appendix 3.

3.3.10 Chatham Rise bottom longline fishery

This fishery comprises longline vessels targeting ling on the Chatham Rise (Statistical Areas 20, 21, 23, and 401–412 – QMA 4 and the easternmost part of QMA 3). Most of their catches were recorded as Fishstock 4 landings. The landings from the selected trips in this study, by depth/habitat category, are summarised in Table 46.

The landings are dominated by the target species ling. Moderate quantities of spiny dogfish and ribaldo are landed, with lesser quantities of sea perch, skates, school shark, and ghost sharks. School shark are only a minor bycatch, at 1% by weight of total landings from the selected trips.

The fishery (as reflected in the subset of selected trips) has undergone several changes; it developed or was revived in the early 1990s, increased to a peak in 1995–96, and then declined (Figure 32a). This reflects the landings of the main species, ling; spiny dogfish landings increased from the mid 1990s, smaller landings of ribaldo bycatch increased slightly through the 1990s, and even smaller landings of sea perch have remained reasonably steady since the mid 1990s. School shark landings rose to peak in 1996–97, then dropped and trended slightly downwards in subsequent years. Fishing effort (as days) approximates the total and ling landing trends but with a less obvious fall after 1999–2000. The effort value (as trips) is not as clearly related to days as in other fisheries and increases after 1998–99, but this may represent a difference in trip length (shorter trips) rather than true effort.

Total landings and effort (number of landings) show a similar pattern for most years, with a peak from August to November and a secondary peak in February–March (Figure 32b). Landings of ling, spiny dogfish, and school shark peak from August to October – school shark sometimes one month earlier than the other species, while there is no pattern in ribaldo. Sea perch and most other species (not shown) simply follow the trend in effort.

This fishery differs from the others as it occurs in deeper waters. Ling is the primary target, and fishing occurs away from the coastline. As a consequence, relatively few school sharks are captured. In addition, there are few vessels involved in this fishery (Table 47). There is an interesting trend in that many vessels operated in the middle portion of the series, and then the numbers dropped back to their original values by the end of the series. The vessels at the start of the series are generally not the same as those at the end. This means that the "busy" period in the middle is the overlap of early vessels (about to finish) and late vessels (just starting). There were only 1134 recorded trips over the past 13 years; a negligible proportion targeted school shark, while most (1120) targeted ling.

The total catch and monthly catches of school shark were low (Tables 48 and 49), but not dissimilar to the other catches on the east side of New Zealand. This is surprising given the newness of the fishery. Proportions of zero catches were high, and are presented in Table 50.

The high proportion of zero catches made generalised linear modelling difficult. The binomial index was not calculated at all, and the non-zero index was calculated with only 203 records (there were actually 276 non-zero records in the data set, but 73 were removed after selecting only the seven core vessels). This index was also calculated excluding 1990 and 1991, as there were too few data in those years. The index itself shows an increasing trend (Figure 33), though the confidence intervals are large. The diagnostic plots from this model suggest that it fits quite well, despite the paucity of data.

3.4 Other features of the school shark fishery

3.4.1 Changes in fishing fleet size

In some fisheries the number of participating vessels (those recording at least one landing of school shark in a year) was relatively stable over the study period (fishing years 1989–90 to 2002–03), while in others there were moderate to large changes and trends (Figure 34). In all cases, however, there was a decline starting from at least the late 1990s.

Of the four setnet fisheries, the Kaikoura fleet remained moderately stable, increasing a little until the mid 1990s, then declining to a little less than the original number. The other fleets declined from at least the mid 1990s.

3.4.2 Landings by QMA

In all but the Chatham Fishstock, where there was no existing fishery, school shark landings dropped suddenly when the QMS was introduced in 1986–87, either to the level of the new TACC or to below it (Figure 35). They subsequently rose to equal the TACC or to exceed it. Again, in all but the Chatham Fishstock, it is highly probable that the TACCs constrain landings.

When Fishstocks are grouped as "northern" and "southern", with Chatham kept separate, it is clear that they are approximately equal in tonnage, general upward trend after 1987, and fluctuations (Figure 36). Overall, landings from southern Fishstocks have been 4% higher than from northern Fishstocks.

3.4.3 Landing and CPUE trends, north to south

When plots of standardised CPUE indices are arranged to correspond with the geographic distribution of the fisheries (Figure 37, top panel), there is an apparent trend for the higher CPUE values to occur progressively later, from north to south, on both the east and west coasts. The western and southernmost South Island regions are not represented because they do not have fisheries with a sufficient bycatch of school shark to be analysed. However, the geographic pattern is completed elsewhere by analyses of targeted "shark" (school shark + rig + elephantfish) fisheries around the South Island, which generally have their highest CPUE values in the late 1990s (SeaFIC, unpublished).

In broad terms, CPUE values decline in northern fisheries in the late 1990s, and increase in southern fisheries. We suggest that this could represent a southward redistribution of New Zealand's school shark population in response to rising sea temperatures that occurred during this time (Figure 37, lower panel). The preferred temperature range of the species is not well defined; it is listed as subtropical by FishBase (2005), but in New Zealand it is considered to be warm-temperate (cf. cool-temperate). Although school shark occur around the entire coastline, commercial fishery records (targeted catches and total landings) suggest they retreat northwards from the southern South Island in winter (Paul & Sanders 2001), and extensive movements can be inferred from tagged fish recaptures (Hurst et al. 1999). Similar latitudinal migration occurs in Australia (Olsen 1954) and southwestern South America (Miranda & Vooren 2003). The rise of almost 2 °C (regional range 1.6–2.1 °C) in mean annual surface water temperature from 1992 to 1999 over the fishing grounds included in this study is considered sufficient to have had some influence on the population's distribution.

There are similarities between the CPUE trends in fisheries from some adjacent regions, even when the fishing method and target species differ (Figures 37 and 38). However, there are also some marked differences between some fisheries within the same region (Figure 38); it is not clear why this should be so, but it cautions against using only a small number of CPUE indices to track stock abundance.

3.4.4 School shark size frequencies

There is a paucity of information on the size distribution of school shark taken in regional commercial fisheries. The most complete time series comes from fish samples measured voluntarily by commercial fishers in a logbook programme instituted as a requirement in an Adaptive Management Programme (AMP) for rig setnet fisheries in two South Island Fishstocks (QMA 3 and QMA 5), fishing years 1995–96 to 2001–02 (but missing 1997–98). Length frequencies of the school shark taken in some association with these fisheries – as bycatch, or a primary or secondary target – are summarised in Figure 39.

In SCH 3, eastern South Island, the catch of both males and females is bimodal. Both sexes have a clear mode at 90–100 cm, which will comprise immature fish. Males have a less distinct mode at 130–140 cm, representing mature but probably relatively young adults, assuming length at maturity of 120 cm. Females have a second clear mode at 140–160 cm, of predominantly mature adults, assuming maturity at 130 cm. The modes are consistent through all years.

In SCH 5, southern South Island, there is only a single mode for both sexes. The male mode at 120–150 cm would comprise mainly mature fish. There is a slight decrease in modal size during this time period, from 140–150 cm to 130–140 cm. The female mode is essentially similar, also with a slight decrease, from 130–140 cm to 120–130 cm during the same years. About half the females would be mature.

Trawl surveys capture predominantly juvenile school sharks. It is believed that adult fish are sufficiently active swimmers to avoid the net; only small numbers are caught, with very occasional larger catches, perhaps part of a school. Trawl surveys thus have no value in monitoring adult or total biomass, but they are useful in defining the presence and distribution of juveniles, and can provide some general information on the abundance of pre-recruits and the relative strength of year classes.

Ten trawl surveys on the continental shelf of the South Island's east coast, approximating the central region of SCH 3 used in this study, provide length frequency data from 1991 to 2001 in which up to four age groups can be recognised from length modes (Figure 40). The first five surveys were in winter, with small numbers of school shark and poorly defined modes from which only a few age groups can be recognised. The second five surveys, in summer, yielded larger samples and clearer length modes. Three distinct modes are usually present, representing 0+, 1+, and 2+ fish, and a fourth mode is sometimes recognisable at about 70 cm, just before the age groups blend into a combination of age groups between 75 and 100 cm. The smallest mode, at about 30 cm, comprises new-born pups; the main pupping period is November–December, but for convenience the year classes are named from the January of the following year. Because total sample sizes vary from year to year it is difficult to quantify year classes, but all year classes from 1994 to 2001 were caught one or more times, thus there were no missing or obviously week year classes. The 1997 year class appeared to be relatively strong (Figure 40), particularly when caught as age 2+ and 3+ in January 1998 and 1999. In January 2000 and 2001 it was merging into the 75+ cm group, and it is likely that it recruited into the commercial catch in at least 2001, contributing to the rising landings and CPUE indices. Only 1.5% of the total number of school sharks were larger than 100 cm, and only a few fish were likely to be mature (based on size).

A smaller number of coastal trawl surveys on the west coast of the South Island and in Tasman and Golden Bays has also yielded juvenile school shark; the modal sizes are less easy to distinguish there, but Stevenson & Hanchet (2000) commented on some apparent variations in year class strength. The data were not re-examined in this present study because they do not complement any study of a commercial bycatch fishery in the West Coast region, and the Tasman Bays series is too short.

4. DISCUSSION

4.1 General trends

Since 1996, there has been a reduction in the number of vessels fishing in almost every fishery. However, most of the fisheries continued to have fairly constant catch rates, which suggests that the ability of the remaining vessels to catch fish has increased. Or alternatively, the most successful vessels remained in the fishery.

Total school shark catch seems to be higher on the west coast of New Zealand than on the east. The three highest total catches were observed in the two west coast North Island fisheries, and in Nelson bays/ Manawatu. The lowest catches were found in Kaikoura and on the east coast of the North Island.

Examination of different measures of CPUE suggested that the results were robust. There were no major differences in the indices that were produced with different measures of CPUE. So, for example, if an increasing trend was observed using catch per tow an increasing trend would also be observed using, say, catch per day. This indicates that the different measures are all indexing the same or correlated trends in shark capture rates. No further discussion of this point is presented.

4.2 Variability in CPUE

Much has been made about the dangers of using CPUE as an index of abundance (Dunn et al. 2000, Hilborn & Walters 1992), though it is still used extensively in stock assessments. These analyses show that measures, ostensibly indexing the same trend, do not always agree.

The results of these analyses show various trends. Most CPUE trends showed only marginal statistical significance. However, the trends observed were generally consistent across geographical locations. The non-target species trends from the North Island tended to show a decreasing trend, while the South Island trends appeared to increase (with the exception of the east coast set net fishery, which was decidedly negative).

An interesting observation is that the CPUE indices from the Cook Strait line fishery and the Kaikoura set net fishery are virtually identical. The geographical proximity of these two fisheries suggests that they are operating on the same population of school shark. What is relevant is that the two fisheries use different fishing methods. This suggests that both of the methods are "sampling" the shark population in the same way (or in the same proportions; the line fishery caught more shark in total, so the sample is not technically the same). Therefore, the two methods seem to be indexing the same thing, which supports the use of the CPUE index.

It is unfortunate that this correspondence between indices does not appear to be universal. Within the east coast South Island indices there is discrepancy. The indices from the setnet fishery suggest a declining population, while the indices from the bottom trawl suggest an increasing (within the later years at least) population. It is unclear what implications this has. Because the two fishing methods are working in slightly different areas (setnets are in shallower water) it is possible that both trends are accurate (i.e., sharks have moved from shallow to deep water during the past decade).

It is clear from examining the absolute values of the CPUE indices that the vessels targeting school shark catch more school shark than those targeting other species. Thus, a unit effort for SCH targeting vessels is not equivalent to a unit effort for a vessel targeting other species. For example, one hour fishing for SCH involves other (potentially immeasurable) factors than one hour of fishing for SPO. These other factors complicate the issue when more than one target species occurs in the same or closely linked fisheries, and the standardisation procedure may not be able to resolve them. It is self-evident that no CPUE index will represent absolute abundance, but when fishers switch, either seasonally or randomly, between two or more target species it is still unclear whether even relative abundance is being measured well.

There is much variation in the observed trends, depending on the subset of the data used. Taking, for example, the standardised CPUE indices from the east coast South Island setnet fishery (see Figure 7), it is clear that the use of data from vessels targeting other species produces very different indices. Even if we assume that these indices actually track abundance we cannot identify the status of the stock. The index calculated from the vessels targeting school shark increases for the first few years, and then undergoes a sharp drop to roughly half of the baseline value. It remains near here until the last year, when it abruptly rises back to the baseline value. If this is taken to be indicative of the abundance of school shark, a trend like this suggests that the school shark population is subject to large perturbations. These are likely to result from migration, but could also result from localised overfishing.

If the rig index is used, a consistent decline in abundance is observed. The elephantfish index provides a conflicting picture. It suggests that the abundance remained constant over the initial years, and is currently increasing. The index based on vessels targeting spiny dogfish suggests more or less random changes in abundance. It is unclear which of these represents the true state of the school shark population.

It is also very important to correctly identify the extent of the fisheries before an analysis is carried out. Comparison of the Kaikoura and the east coast South Island fisheries is a case in point. These two fisheries are managed together as QMA 3, though they seem to be distinct in most regards. The CPUE trends suggests that the Kaikoura fishery is more similar to the Cook Strait fishery, suggesting that both are fishing the same population of school shark, or that the Kaikoura fishers are behaving more like those to the north of them than those to the south.

When situations such as this present themselves, one must also be wary of the use of generalised linear models. The mechanisms by which the model parameters are estimated may be affected by the differences in the fisheries. For example, it can be seen that the vessels involved in the Kaikoura and east coast South Island fisheries stay almost exclusively in their respective areas. This can lead to problems in parameter estimation if there is a term for both vessel and Statistical Area in the GLM. The effects of these two variables will be confounded, which can seriously affect the accuracy of the parameter estimation. Using a GLM with these terms may then give the impression that their effects are being controlled for, but in reality they may not be.

The main problem with examining "combined" fisheries is that the trends/effects from the CPUE models actually represent a "weighted average" effect. This is not a problem if the trends from the smaller fisheries are similar, but it is potentially misleading if the fisheries show different patterns. Under this scenario, the observed trends are not necessarily indicative of anything. If the fisheries are weighted more or less equally, the observed trend will not represent any true trend. If the fisheries are not weighted equally, the trend from the more heavily weighted fishery will be ascribed to the lesser weighted fishery as well.

Can any data sets yet be recommended for routine CPUE monitoring?

Based on the diagnostic analyses and the amount of residual deviance explained, it is clear that some data sets are better fitted by their GLM. However, we are reluctant to claim that a well-fitting model is accurately measuring school shark abundance. With an aggregated species where the aggregations can be relatively easily located by fishers, it is not clear what the models are measuring. Does a CPUE index from a bycatch fishery measure school shark abundance better than an index from a target fishery? The diagnostics from these two models cannot answer this question. As commented above, during this study a large number of models were run, some with different target species within a GLM, some with separate GLMs for each target species. Many of these produced very different results, even though they all ostensibly measured abundance. Our data were taken from what appeared to be discrete fisheries (by region and method), rather than administrative Fishstocks. We still obtained quite different CPUE trends from fisheries by method in a single region, notably the east coast of the South Island, within SCH 3. It is possible that these fisheries were exploiting different components of the stock within a region, and probable that the fisher groups (by method) behaved differently over time. Until this issue is more clearly understood, we can only recommend that each fishery, defined by method and region (not Fishstock), be considered separately. We cannot yet nominate those fisheries which provide CPUE indices likely to be good measures of abundance.

Should school shark be managed as separate Fishstocks?

To date, stock assessments of school shark have been done by Fishstock (SeaFIC 2003a–d) or by defined regions within or across Fishstock boundaries (Bradford 2001; this study). Tagging studies strongly suggest that the species is a single biological population within New Zealand waters, undergoing extensive migration, with some trans-Tasman movement into the Australian population. Our hypothesis that there is also a north-south shift in response to seawater temperature raises the question of whether regional assessments, alone, are appropriate. We believe that although it is necessary to continue with studies on discrete fisheries, the implications for the entire New Zealand population (or "stock") should be considered. Eventually, it may be possible to derive weighted values (CPUE, or some other measure of biomass) for the New Zealand stock as a whole.

4.3 Productivity issues

Some generalisations on sharks are relevant to this and other studies on the New Zealand fishery for school shark. Throughout the world, few shark fisheries have been well managed. This results partly from their limited commercial value until recent decades, partly from inadequate identification of species in multi-species or general fisheries (and consequently limited research and management attention), and partly from some important biological differences between elasmobranchs (sharks, skates, rays, and chimaeras) and bony fishes. The last point is considered here.

Sharks produce few young annually (or at longer intervals), and there is a strong relationship between stock size and recruitment. There is a positive aspect to this: newborn pups are large enough to have a high natural survival rate, and recruitment is less variable than for bony fishes with pelagic eggs and larvae susceptible to strong predation and a fluctuating environment. The faster-growing species of shark may be able to support moderate fishing pressure, and their steady recruitment should make them more predictable to manage, as long as other aspects of their life history are reasonably well known. The converse is probably more important: because of the strong stock/recruit relationship, biomass will decline immediately and inexorably at the start of fishing, with limited opportunity to rebuild from strong new yearclasses recruiting into the population. Any period of *growth overfishing*, i.e., harvesting fish before they reach their full growth potential, creating a sub-optimal but stable population, is likely to be short. *Recruitment overfishing*, i.e., harvesting fish more rapidly than they can be replaced by recruitment, may occur earlier in shark stocks than expected.

This creates a dilemma for managers. It is not easy to interpret CPUE signals in shark fisheries. Theoretically, because of the strong stock recruit relationship, CPUE should decline shortly after fishing begins, and – unless some compensatory growth, mortality, or reproductive strategy occurs – continue to decline. In reality, a decline in the CPUE signal is usually delayed because shark populations usually aggregate and are easily targeted.. There may be more value in bycatch CPUE indices, in fisheries where sharks should be encountered randomly, but our study showed greater complexity than anticipated. Shark fisheries qualify for precautionary management, with controls imposed before a decline in CPUE becomes serious, or when some other indicator of stock size (e.g., number of mature females, or juvenile abundance) suggests that the population is in difficulty.

It is also necessary to recognise that shark species differ in their biological characteristics, and their response to exploitation. In a study of the productivity, or "rebound potential", of shark stocks, Smith et al. (1998) modelled the relative ability of 26 species to recover from fishing pressure, using female age at maturity, maximum reproductive age, and average fecundity. Rebound potential was strongly influenced by age at maturity, and little affected by maximum age. The species formed three groups: (1) good rebound potential was predicted for small, early-maturing coastal sharks such as smoothhounds (e.g., rig), (2) moderate recovery was possible for medium to large pelagic sharks with low ages at maturity, and (3) slow recovery was predicted for late-maturing, medium to large sharks. The school shark was placed in the last group by this study.

For low productivity sharks, Smith et al. (1998) suggested that a management priority be to preserve their breeding capacity by protecting the mature females during their years of greatest productivity. For school shark, this means protecting the largest females, as there is no evidence for senescence, and no evidence that the continuing presence of large fish constrains population size. The reproductive output of female New Zealand school sharks during their life-span is not known, and may be considerably lower than is generally assumed. Litter size, from limited observations (NIWA, unpublished data), seems to be lower than that described from elsewhere. The species is long-lived, up to an estimated 60 years in Australia, but the longevity of fish in the New Zealand population is unknown, and likely to be lower if the fish which migrate from New Zealand to Australia are the older individuals. The modal life-span in an exploited population may be half or less of the maximum, perhaps 25 years, which means that an average female has 15 breeding years. Reproductive periodicity is unlikely to be annual, and may be every two years (assumed for Australia) or three years (more convincingly demonstrated in Brazil by Peres & Vooren (1991)). It is therefore possible that the average female may have only five breeding cycles.

The sensitivity analysis by Smith et al. (1998) showed that productivity of the slow-growing and late-maturing shark species is less influenced by age at maturity and maximum reproductive age than by fecundity (litter size) and reproductive periodicity. The latter values are, unfortunately, not well known for New Zealand school shark.

It is self-evident that the harvest of school sharks can be more safely taken from the more numerous immature fish in the population, provided that adequate recruitment into the mature stock is maintained. Although data are limited, it seems likely that a reasonable proportion of the landings in the existing fishery are males and immature females, and some voluntary release of mature females does take place. A reasonable case could be made to acquire more information on the size structure and sex ratio of the commercial catch, in order to determine and monitor the number of mature females caught and landed. There is, unfortunately, a significant and probably insurmountable problem (in addition to difficult logistics). In theory, it would be desirable to monitor the proportion of biologically important breeding females in the population to ensure that it does not decline too far, although that threshold is not known. In practice, the proportion of such females landed will change with fishing practices, and with the success or otherwise of fishers' attempts to avoid catching them, and/or by changes in their practice of releasing some large females alive. Although better characterisation of the size of sharks taken in the fishery will provide useful knowledge, it will not address this particular issue.

5. CONCLUSIONS

Bradford (2001) concluded her report on targeted school shark CPUE with the statement that "none of the standardised indices are acceptable without reservation", and our results suggest essentially the same. Indices calculated in the same area with different fishing methods do not necessarily correspond to each other, nor do indices calculated with the same fishing methods but different target species.

The observation that bottom trawl series show a decline in their CPUE index, while set net fisheries do not, suggests that the indices calculated from shark target setnet (and perhaps line) fisheries are displaying a hyperstable pattern.

Despite encountering unexpected complexity when different target and bycatch fisheries within a region are examined closely, we found no overall trend we could interpret as a change in abundance for the New Zealand stock as a whole. However, North Island "stocks" (regional landings) tended to have flat or declining CPUE indices, while South Island "stocks" had flat or increasing indices, perhaps reflecting a southward shift of the main population. We recommend that because of the mobility of school sharks the species should continue to be managed as a single stock, and that New Zealand-wide trends in landings or CPUE take precedence over regional trends. In addition, when regional fisheries must be assessed independently, we recommend that well defined, logical unit fisheries be used, and not the standard Fishstocks with their purely administrative boundaries.

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Table 1: Landings (t) of all fish from the selected trips in the east coast South Island setnet fishery.

Category	Total landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore	3	Flatfish	3	< 1
Coastal demersal	1 037	Spiny dogfish	597	59
		Rig	153	
		Elephantfish	131	
		School shark	97	
Coastal pelagic	5	Kahawai	4	1
Deepwater	27	Ling	14	3
		Sharks	7	
		Ghost sharks	3	
Oceanic	1	Tunas, Sharks	< 1	< 1
Other	3	Various		
Total	1 076			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 2: Number of vessels operating in the east coast South Island setnet fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	33	32	26	25	32	35	28	24	24	24	19	21	20
Vessels targeting SPD	19	16	12	8	15	14	14	11	8	8	3	4	8
Vessels targeting SPO	24	21	21	21	22	28	22	20	21	20	18	20	17
Vessels targeting SCH	16	13	17	14	20	17	16	14	15	15	13	15	8
Vessels targeting ELE	10	17	10	8	9	10	14	11	9	7	6	6	7

Table 3: Total landed and estimated school shark catch (t) in the east coast South Island setnet fishery. Fishing year 1989–90 is listed as 1990. (SPD, spiny dogfish; SPO, rig; SCH, school shark; ELE, elephant fish.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	80	70	128	68	76	101	87	86	87	128	106	110	105
Estimated catch	61	66	94	58	56	81	66	75	69	90	80	92	96
Vessels targeting SPD													
Total landings	18	16	31	21	22	10	22	10	8	25	5	6	11
Estimated catch	14	16	10	13	15	8	10	9	5	10	3	3	8
Vessels targeting SPO													
Total landings	30	19	27	12	28	48	39	30	49	34	50	59	58
Estimated catch	22	19	27	12	18	39	38	27	38	29	30	50	54
Vessels targeting SCH													
Total landings	28	29	60	30	24	36	22	41	28	66	49	43	35
Estimated catch	22	30	52	30	21	28	16	37	24	49	45	38	34
Vessels targeting ELE													
Total landings	4	7	10	4	3	7	5	5	3	3	3	2	2
Estimated catch	3	4	6	4	2	7	3	2	2	1	2	2	1

Table 4: Total school shark catch (t) by month and year in the east coast South Island setnet fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	2.2	16.5	27.3	15.0	10.7	5.3	1.8	0.1	0.4	0.3	0.0	0.1	79.6
1991	2.7	21.0	16.2	16.0	8.5	1.8	2.8	0.8	0.1	0.3	0.0	0.2	70.3
1992	0.4	8.3	25.4	56.6	29.8	5.2	0.7	0.8	0.4	0.0	0.0	0.1	127.6
1993	0.6	9.7	17.3	23.4	8.4	4.4	2.3	0.9	0.5	0.1	0.0	0.0	67.6
1994	0.2	7.5	18.9	32.8	4.5	8.8	2.3	1.1	1.3	0.1	0.0	0.0	77.5
1995	0.1	13.8	25.4	37.5	10.7	4.9	4.2	3.5	0.2	0.0	0.0	0.1	100.5
1996	0.1	8.7	22.5	21.9	9.7	15.3	3.2	3.9	0.6	0.5	0.1	0.3	86.7
1997	0.6	14.2	21.4	27.8	11.1	6.8	1.4	1.6	0.5	0.4	0.0	0.1	85.8
1998	0.9	10.7	21.2	19.3	16.4	11.1	5.9	0.5	0.4	0.0	0.0	0.4	87.0
1999	8.6	15.0	39.7	20.7	18.2	16.0	0.8	1.0	2.7	5.1	0.3	0.0	128.0
2000	1.1	27.0	27.1	12.1	17.8	9.1	5.3	2.9	0.4	3.3	0.0	0.0	106.1
2001	0.7	7.6	26.6	32.0	20.8	8.6	3.9	1.3	2.3	4.4	0.5	1.0	109.9
2002	2.7	11.3	21.6	27.3	25.2	3.1	7.4	5.4	0.7	0.3	0.1	0.2	105.2

Table 5: Proportion of trips that caught no school shark in the east coast South Island setnet fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.53	0.36	0.37	0.37	0.36	0.42	0.60	0.79	0.38	0.50	0.93	0.90	0.43
1991	0.61	0.33	0.39	0.39	0.56	0.40	0.29	0.58	0.71	0.85	1.00	0.72	0.45
1992	0.68	0.31	0.18	0.30	0.26	0.33	0.78	0.57	0.43	0.50	1.00	0.71	0.35
1993	0.36	0.22	0.10	0.17	0.31	0.36	0.44	0.59	0.27	0.67	0.60	0.86	0.28
1994	0.63	0.21	0.14	0.12	0.32	0.27	0.45	0.38	0.28	0.77	1.00	1.00	0.27
1995	0.45	0.24	0.10	0.12	0.22	0.45	0.31	0.31	0.70	0.80	0.86	0.85	0.24
1996	0.79	0.23	0.11	0.14	0.29	0.30	0.25	0.37	0.40	0.45	0.83	0.82	0.26
1997	0.63	0.17	0.07	0.06	0.24	0.27	0.28	0.35	0.46	0.72	0.89	0.78	0.24
1998	0.51	0.15	0.08	0.13	0.14	0.18	0.26	0.48	0.36	0.91	0.95	0.91	0.23
1999	0.61	0.13	0.11	0.09	0.11	0.26	0.57	0.49	0.32	0.35	0.50	0.92	0.22
2000	0.13	0.08	0.10	0.29	0.10	0.42	0.44	0.11	0.27	0.17	1.00	0.67	0.20
2001	0.08	0.13	0.09	0.11	0.15	0.30	0.39	0.17	0.10	0.20	0.27	0.62	0.17
2002	0.24	0.17	0.13	0.09	0.06	0.30	0.21	0.25	0.07	0.22	0.58	0.40	0.16

Table 6: Landings (t) of all fish from the selected trips in the Kaikoura setnet fishery.

Category	Total landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore	< 1	Flatfish	< 1	
Coastal demersal	186	Spiny dogfish	57	17
		Rig	34	
		Tarakihi	29	
		School shark	26	
		Warehou	12	
		Moki	12	
Coastal pelagic	2	Kahawai	1	1
Deepwater	35	Seal shark	16	9
		Ling	10	
Oceanic	< 1			
Other	2			
Total	191			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 7: Number of vessels operating in the Kaikoura setnet fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	12	14	15	14	14	16	16	14	13	13	8	11	12
Vessels targeting SPO	11	13	13	14	10	14	13	13	10	10	7	10	12
Vessels targeting SCH	2	2	5	3	5	5	8	8	8	7	4	7	4

Table 8: Total landed and estimated school shark catch (t) in the Kaikoura setnet fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	2	3	6	9	24	9	23	18	26	34	28	48	30
Estimated catch	2	2	6	8	36	11	32	14	21	31	26	41	26
Vessels targeting SPO													
Total landings	2	2	5	6	7	3	5	7	18	10	12	29	13
Estimated catch	2	2	4	4	7	2	5	5	11	11	10	21	11
Vessels targeting SCH													
Total landings	< 1	1	1	4	16	7	19	12	8	24	16	20	16
Estimated catch	< 1	1	2	4	29	9	27	9	10	20	16	20	15

Table 9: Total school shark catch (t) by month and year in the Kaikoura setnet fishery. Dashes indicate that no trips were made in that month; zeros indicate that trips were made, but school shark catches totalled less than 50 kg. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.6	1.3	0.4	0.0	0.1	0.0	0.0	–	0.0	–	–	0.0	2.4
1991	1.0	1.0	0.3	–	–	0.0	0.6	–	–	–	0.0	0.0	2.9
1992	0.4	1.1	0.9	2.1	0.1	1.1	0.0	0.0	0.0	–	0.0	0.0	5.9
1993	1.2	0.9	2.4	0.7	0.1	1.0	1.9	–	–	–	0.9	0.4	9.4
1994	0.3	1.6	2.2	2.8	0.7	0.5	3.6	4.9	7.1	–	0.0	0.1	23.6
1995	0.3	1.3	1.2	0.2	1.0	1.2	0.0	1.4	0.0	–	0.1	2.9	9.5
1996	0.2	2.6	1.7	0.6	0.6	9.7	4.3	0.0	–	0.3	3.3	0.2	23.3
1997	1.3	1.8	2.2	7.5	2.0	0.1	3.3	–	0.0	0.0	0.0	0.0	18.3
1998	0.1	4.9	7.0	0.4	2.5	6.2	4.8	0.1	–	0.0	–	0.0	25.9
1999	0.3	3.3	3.4	1.4	11.2	7.9	5.6	–	0.4	–	0.2	0.0	33.6
2000	1.3	6.0	4.7	3.6	4.8	6.8	0.6	–	–	–	–	0.0	27.6
2001	0.6	8.2	10.3	3.4	6.8	4.0	4.8	0.2	3.1	4.5	2.2	0.2	48.3
2002	0.9	5.4	5.3	2.6	4.8	1.9	5.7	2.0	0.6	0. 0	0.5	0.1	29.8

Table 10: Proportion of trips that caught no school shark in the Kaikoura setnet fishery. Dashes indicate that no trips were made in that month. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.33	0.32	0.42	0.89	0.50	0.00	1.00	–	0.00	–	–	0.75	0.40
1991	0.47	0.26	0.09	–	–	1.00	0.33	–	–	–	1.00	0.86	0.42
1992	0.45	0.40	0.39	0.27	0.67	0.56	1.00	1.00	1.00	–	1.00	0.94	0.47
1993	0.77	0.25	0.21	0.43	0.68	0.43	0.45	–	–	–	0.00	0.79	0.46
1994	0.83	0.26	0.24	0.28	0.56	0.54	0.51	0.88	0.00	–	1.00	0.56	0.48
1995	0.73	0.47	0.30	0.61	0.00	0.00	1.00	0.00	1.00	–	0.00	0.25	0.53
1996	0.79	0.15	0.19	0.32	0.22	0.61	0.00	1.00	–	0.50	0.33	0.77	0.40
1997	0.67	0.44	0.21	0.38	0.50	0.00	0.00	–	1.00	0.00	0.82	0.73	0.47
1998	0.90	0.35	0.28	0.00	0.06	0.77	0.13	0.67	–	1.00	–	1.00	0.45
1999	0.62	0.15	0.02	0.08	0.00	0.04	0.53	–	0.00	–	0.00	0.70	0.21
2000	0.23	0.11	0.05	0.08	0.04	0.03	0.08	–	–	–	–	0.80	0.12
2001	0.53	0.16	0.07	0.16	0.13	0.06	0.17	0.00	0.00	0.00	0.00	0.67	0.18
2002	0.59	0.22	0.15	0.21	0.06	0.13	0.22	0.00	0.00	1.00	0.50	0.78	0.27

Table 11: Landings (t) of all fish from the selected trips in the Nelson Bays and Manawatu setnet fishery.

Category	Total landing (t) [1]	Main species(t) [1]		Others (t) [1]
Inshore	< 1			
Coastal demersal	474	School shark	211	20
		Rig	206	
		Spiny dogfish	27	
		Trevally	5	
		Snapper	5	
Coastal pelagic	5	Kingfish	2	1
		Trevally	2	
Deepwater	8	Sharks	6	2
Oceanic	5			
Other	2			
Total	494			

Note:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 12: Number of vessels operating in the Nelson Bays/Manawatu setnet fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	25	22	21	18	23	23	23	19	27	17	16	18	19
Vessels targeting SPO	20	20	14	18	21	20	23	19	25	16	15	17	17
Vessels targeting SCH	11	10	12	4	7	7	9	6	9	7	6	5	10

Table 13: Total landed and estimated school shark catch (t) in the Nelson Bays/Manawatu setnet fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	156	162	114	143	173	118	227	105	167	156	149	186	129
Estimated catch	119	135	77	104	95	84	100	49	79	77	85	80	70
Vessels targeting SPO													
Total landings	8	22	42	92	115	100	92	73	84	94	55	63	55
Estimated catch	7	24	35	74	65	71	36	29	36	51	27	42	35
Vessels targeting SCH													
Total landings	148	140	73	52	58	18	135	31	83	61	94	123	74
Estimated catch	112	111	41	30	30	13	64	20	43	26	58	39	35

Table 14: Total school shark catch (t) by month and year in the Nelson Bays/Manawatu setnet fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.1	3.7	0.0	22.9	32.5	16.1	31.4	7.5	16.9	0.8	0.0	24.5	156.3
1991	7.4	8.1	5.7	6.5	26.7	56.0	6.8	19.9	10.9	2.2	0.3	11.8	162.2
1992	3.1	4.7	28.5	7.6	6.6	13.9	33.2	14.0	0.1	0.1	0.1	2.2	114.1
1993	3.2	21.4	9.0	5.0	19.0	37.8	7.5	0.6	0.3	3.0	5.1	31.3	143.2
1994	2.6	38.9	22.3	5.6	21.0	24.2	36.4	7.55	3.6	4.1	0.5	5.9	172.9
1995	9.9	5.6	16.1	15.7	32.1	6.7	16.9	5.0	4.8	2.3	0.0	3.0	117.9
1996	0.5	24.4	36.1	78.3	15.3	1.4	12.8	20.8	2.8	6.4	12.1	15.9	226.7
1997	8.6	6.8	22.6	28.1	0.6	17.3	3.3	4.6	2.4	3.7	5.2	1.5	104.7
1998	6.6	7.0	15.9	24.4	16.0	44.0	34.1	5.1	1.2	2.2	0.4	10.0	166.8
1999	0.4	11.0	7.6	13.9	14.1	21.8	9.7	26.3	39.7	3.4	5.8	2.2	155.6
2000	23.6	12.9	33.9	9.4	6.0	14.9	9.0	24.7	4.5	3.7	4.8	1.5	148.8
2001	13.6	5.9	10.9	34.0	31.1	48.5	19.3	0.2	10.9	4.0	0.1	7.6	185.9
2002	10.4	3.1	4.7	50.4	10.7	13.0	10.1	3.0	2.7	14.1	2.4	4.0	128.5

Table 15: Proportion of trips that caught no school shark in the Nelson Bays/Manawatu setnet fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.50	0.40	1.00	0.70	0.47	0.45	0.32	0.22	0.29	0.88	0.86	0.27	0.46
1991	0.32	0.41	0.35	0.74	0.65	0.53	0.48	0.40	0.46	0.75	0.83	0.43	0.54
1992	0.53	0.52	0.48	0.68	0.75	0.52	0.22	0.71	0.67	0.78	0.86	0.75	0.58
1993	0.83	0.77	0.20	0.46	0.82	0.47	0.61	0.38	0.33	0.83	0.62	0.61	0.64
1994	0.69	0.49	0.29	0.66	0.62	0.65	0.73	0.65	0.68	0.75	0.44	0.75	0.58
1995	0.86	0.31	0.40	0.71	0.56	0.67	0.75	0.76	0.50	0.56	1.00	0.80	0.61
1996	0.79	0.47	0.26	0.52	0.60	0.65	0.59	0.42	0.47	0.61	0.50	0.59	0.53
1997	0.80	0.40	0.40	0.60	0.74	0.45	0.33	0.50	0.71	0.67	0.71	0.76	0.60
1998	0.74	0.57	0.32	0.61	0.52	0.32	0.46	0.22	0.20	0.57	0.55	0.31	0.49
1999	0.76	0.44	0.27	0.46	0.57	0.42	0.19	0.41	0.24	0.56	0.64	0.71	0.48
2000	0.55	0.33	0.43	0.43	0.44	0.38	0.17	0.24	0.50	0.76	0.58	0.75	0.47
2001	0.56	0.13	0.30	0.43	0.55	0.29	0.32	0.71	0.38	0.58	0.60	0.83	0.44
2002	0.55	0.18	0.32	0.55	0.44	0.50	0.37	0.27	0.09	0.41	0.63	0.20	0.41

Table 16: Landings of all fish (t) from the selected trips in the west coast North Island setnet fishery.

Category	Landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore	1	Flatfish	1	
Coastal demersal	400	School shark	205	16
		Rig	116	
		Spiny dogfish	23	
		Red gurnard	15	
		Trevally	14	
		Snapper	11	
Coastal pelagic	8	Kingfish	4	2
		Kahawai	2	
Deepwater	2	Sharks	1	1
Oceanic	1			
Other	2			
Total	414			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 17: Number of vessels operating in the west coast North Island setnet fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	24	24	24	32	32	24	26	26	24	23	21	18	22
Vessels targeting SPO	20	21	22	28	27	22	23	23	23	21	20	17	20
Vessels targeting SCH	16	13	16	19	15	13	15	11	11	10	8	10	11

Table 18: Total landed and estimated school shark catch (t) in the west coast North Island setnet fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	85	63	110	182	104	116	143	136	142	147	109	116	116
Estimated catch	101	70	120	183	144	163	149	150	153	191	169	179	177
Vessels targeting SPO													
Total landings	23	12	47	78	57	86	78	64	89	62	66	49	48
Estimated catch	17	8	42	58	44	76	69	53	59	57	57	43	36
Vessels targeting SCH													
Total landings	62	51	63	104	47	30	66	73	53	86	43	67	69
Estimated catch	84	62	78	126	100	87	79	97	94	134	112	137	141

Table 19: Total school shark catch (t) by month and year in the west coast North Island setnet fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	1.1	3.1	0.7	16.4	2.2	2.0	1.9	1.6	20.7	0.9	3.2	31.8	85.4
1991	14.6	15.1	4.6	9.1	2.6	5.1	1.2	2.2	0.2	3.5	1.1	3.3	62.5
1992	3.6	10.1	14.3	20.8	12.7	4.0	36.0	1.2	2.0	3.9	0.0	0.9	109.5
1993	24.1	51.9	6.7	9.9	32.7	27.7	15.8	2.5	0.8	1.1	0.5	8.5	182.0
1994	8.6	7.1	14.6	18.0	12.4	8.6	4.9	8.3	6.6	0.5	14.1	0.7	104.3
1995	19.0	20.6	10.7	14.4	5.5	11.7	6.4	2.1	1.4	0.2	4.5	19.4	115.9
1996	17.7	3.8	17.7	21.4	18.5	29.7	12.6	14.3	2.6	0.9	0.0	4.1	143.2
1997	5.0	7.2	15.4	4.4	36.1	18.7	10.0	28.2	0.7	3.4	0.1	7.3	136.2
1998	3.8	13.5	14.6	39.7	12.0	19.0	7.4	13.0	2.4	2.1	5.7	8.6	141.6
1999	16.6	32.8	9.1	15.3	14.9	22.6	12.8	9.4	8.0	0.7	9.6	1.8	153.5
2000	13.3	26.3	16.0	3.4	12.3	20.4	12.4	1.0	2.6	0.2	0.2	0.9	109.0
2001	2.1	10.1	35.0	18.7	3.0	6.0	7.3	14.9	15.4	0.6	0.5	3.0	116.4
2002	3.7	21.2	5.2	16.5	3.3	11.8	27.3	14.0	2.2	5.4	4.9	0.9	116.4

Table 20: Proportion of trips that caught no school shark in the west coast North Island setnet fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.33	0.63	0.69	0.59	0.61	0.44	0.43	0.17	0.44	0.50	0.50	0.52	0.53
1991	0.47	0.35	0.45	0.49	0.54	0.62	0.67	0.50	0.60	0.56	0.50	0.48	0.52
1992	0.44	0.32	0.31	0.20	0.64	0.63	0.64	0.57	0.65	0.36	1.00	0.79	0.53
1993	0.55	0.53	0.53	0.36	0.66	0.48	0.40	0.36	0.31	0.50	0.87	0.83	0.52
1994	0.29	0.40	0.38	0.55	0.69	0.67	0.43	0.16	0.42	0.63	0.41	0.67	0.51
1995	0.55	0.30	0.58	0.74	0.73	0.50	0.45	0.52	0.55	0.50	0.72	0.64	0.57
1996	0.53	0.50	0.48	0.73	0.76	0.40	0.39	0.08	0.29	0.78	1.00	0.58	0.56
1997	0.52	0.46	0.70	0.80	0.64	0.67	0.45	0.30	0.75	0.74	0.89	0.78	0.64
1998	0.64	0.49	0.54	0.61	0.63	0.41	0.27	0.00	0.00	0.00	0.24	0.50	0.45
1999	0.38	0.50	0.71	0.52	0.57	0.46	0.41	0.38	0.64	0.50	0.42	0.80	0.55
2000	0.55	0.47	0.45	0.64	0.51	0.42	0.41	0.68	0.43	0.67	0.80	0.50	0.53
2001	0.86	0.76	0.45	0.75	0.84	0.83	0.55	0.43	0.33	0.62	0.64	0.85	0.71
2002	0.56	0.65	0.55	0.54	0.50	0.58	0.30	0.29	0.42	0.63	0.46	0.54	0.51

Table 21: Landings (t) of all fish from the selected trips in the east coast South Island trawl fishery.

Category	Landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore	1			
Coastal demersal	13 955	Red cod	5 425	1 499
		Barracouta	2 932	
		Flatfish	1 131	
		Spiny dogfish	854	
		Skates	517	
		Elephantfish	425	
		Tarakihi	402	
		Stargazers	397	
		Gurnard	373	
Coastal pelagic	257	Jack mackerels	246	11
Deepwater	2 601	Hoki	1 378	325
		Silver warehou	384	
		Ghost sharks	293	
		Ling	221	
Oceanic	2			
Other	49			
Total	16 866			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 22: Number of vessels operating in the east coast South Island trawl fishery. Fishing year 1989–90 is listed as 1990. (FLA, flatfish; RCO, red cod; STA, stargazer; GUR, red gurnard.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
All vessels	131	108	123	122	123	114	104	103	101	100	89	85	81	85
Vessels targeting FLA	104	83	92	94	96	85	79	80	75	79	70	65	62	61
Vessels targeting RCO	89	81	90	84	89	92	72	67	70	63	51	53	43	50
Vessels targeting STA	15	8	14	3	8	2	4	6	3	3	6	6	7	4
Vessels targeting GUR	31	20	18	14	8	11	11	7	8	7	5	8	14	13

Table 23: Total landed and estimated school shark catch (t) in the east coast South Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
All vessels														
Total landings	58	44	55	68	49	63	66	59	82	68	95	97	83	85
Estimated catch	20	15	17	22	19	18	22	13	32	26	33	35	28	31
Vessels targeting FLA														
Total landings	15	13	16	16	12	7	12	11	21	29	33	20	10	16
Estimated catch	7	6	8	8	7	3	8	7	15	15	15	10	5	8
Vessels targeting RCO														
Total landings	40	28	36	50	37	56	53	47	60	39	60	72	70	64
Estimated catch	13	7	8	13	11	15	13	6	16	10	16	22	22	19
Vessels targeting STA														
Total landings	2	1	1	0	< 1	< 1	< 1	1	1	< 1	1	3	2	1
Estimated catch	< 1	1	< 1	0	1	< 1	0	0	< 1	< 1	2	3	1	< 1
Vessels targeting GUR														
Total landings	1	1	1	2	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1.21	1	5
Estimated catch	1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	4

Table 24: Total school shark catch (t) by month and year in the east coast South Island bottom trawl fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	2.2	5.5	6.1	11.2	8.6	6.1	6.7	3.6	5.6	0.6	0.3	1.4	57.8
1991	2.8	6.4	6.9	5.8	3.7	6.4	4.7	1.9	1.7	0.7	0.9	1.8	43.6
1992	2.2	3.6	6.9	9.2	11.2	8.5	5.3	2.4	1.4	1.0	0.8	2.4	55.1
1993	2.0	8.8	6.1	13.4	8.8	10.7	10.8	1.5	1.6	3.2	0.9	0.3	68.0
1994	2.1	3.4	10.0	9.4	6.7	6.2	5.5	1.7	1.2	0.9	0.8	1.6	49.5
1995	3.0	13.8	16.3	10.1	3.1	7.5	2.3	3.7	1.5	0.3	0.7	0.5	62.8
1996	3.0	9.8	18.3	7.3	8.7	5.3	3.9	3.4	3.5	2.3	0.6	0.2	66.1
1997	2.0	5.9	6.0	13.7	10.8	5.2	4.8	4.6	1.4	2.0	0.9	1.5	58.5
1998	4.9	15.1	10.5	13.4	9.5	7.6	6.2	4.4	4.3	1.4	2.1	2.7	82.2
1999	3.7	9.9	7.1	11.1	7.0	6.7	4.8	6.2	8.1	0.8	0.6	1.7	67.8
2000	4.8	9.4	11.0	13.0	9.8	13.2	5.2	9.8	9.1	5.1	1.3	3.0	94.5
2001	4.0	9.9	11.4	17.5	12.2	11.4	9.5	9.0	5.9	2.2	1.9	2.4	97.3
2002	8.8	9.7	6.0	7.5	5.7	9.9	13.2	9.8	4.6	1.8	0.7	5.0	82.6
2003	4.3	8.3	10.8	9.8	10.5	13.8	10.5	7.4	5.4	2.4	1.5	0.6	85.3

Table 25: Proportion of trips that caught no school shark in the east coast South Island bottom trawl fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.84	0.76	0.77	0.74	0.77	0.79	0.89	0.93	0.93	0.97	0.96	0.97	0.86
1991	0.85	0.70	0.61	0.76	0.79	0.76	0.87	0.92	0.93	0.96	0.97	0.94	0.85
1992	0.87	0.76	0.67	0.65	0.69	0.79	0.81	0.90	0.92	0.93	0.93	0.90	0.82
1993	0.87	0.69	0.71	0.63	0.69	0.70	0.76	0.90	0.94	0.92	0.93	0.96	0.81
1994	0.86	0.75	0.68	0.70	0.74	0.76	0.86	0.90	0.94	0.93	0.94	0.95	0.83
1995	0.84	0.72	0.72	0.64	0.76	0.71	0.81	0.88	0.93	0.97	0.92	0.94	0.81
1996	0.83	0.68	0.68	0.62	0.72	0.75	0.77	0.92	0.90	0.92	0.96	0.93	0.80
1997	0.78	0.67	0.66	0.54	0.65	0.76	0.81	0.86	0.90	0.94	0.94	0.91	0.79
1998	0.76	0.57	0.55	0.61	0.68	0.69	0.81	0.85	0.86	0.89	0.92	0.88	0.75
1999	0.69	0.61	0.53	0.60	0.60	0.72	0.78	0.85	0.90	0.96	0.92	0.88	0.75
2000	0.68	0.54	0.58	0.58	0.57	0.69	0.76	0.79	0.77	0.84	0.90	0.80	0.71
2001	0.73	0.53	0.46	0.47	0.58	0.61	0.67	0.70	0.80	0.82	0.85	0.81	0.67
2002	0.67	0.55	0.59	0.60	0.61	0.70	0.72	0.73	0.80	0.85	0.88	0.83	0.71
2003	0.64	0.60	0.57	0.58	0.60	0.68	0.75	0.80	0.85	0.90	0.90	0.92	0.73

Table 26: Landings of all fish from the selected trips in the northwest North Island trawl fishery.

Category	Landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore	6	Flatfish	6	< 1
Coastal demersal	2 998	Trevally	926	46
		Snapper	784	
		Gurnard	382	
		Tarakihi	296	
		Barracouta	285	
		School shark	136	
		John dory	99	
		Rig	45	
Coastal pelagic	186	Kahawai	118	11
		Jack mackerels	57	
Deepwater	102	Gemfish	39	10
		Hoki	21	
		Ling	14	
		Frostfish	10	
Oceanic	2	Hammerhead shark	1	1
Other	22	Squid	18	4
Total	3 316			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 27: Number of vessels operating in the northwest North Island trawl fishery. Fishing year 1989–90 is listed as 1990. (SNA, snapper; TRE, trevally.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	27	25	28	33	33	25	32	31	30	30	25	23	23
Vessels targeting SNA	21	22	25	26	25	23	27	23	24	21	17	12	15
Vessels targeting TRE	15	14	19	18	19	15	16	18	26	23	18	17	15
Vessels targeting GUR	7	9	10	14	13	9	9	17	15	13	16	11	9
Vessels targeting SCH	1	1	–	2	–	–	2	–	–	–	–	2	1

Table 28: Total landed and estimated school shark catch (t) in the northwest North Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	62	54	86	186	129	118	148	186	173	169	150	115	167
Estimated catch	22	19	35	68	39	38	31	46	71	43	34	31	46
Vessels targeting SNA													
Total landings	41	28	57	106	91	77	118	93	93	87	63	55	79
Estimated catch	12	11	20	34	27	27	25	23	44	18	14	13	17
Vessels targeting TRE													
Total landings	13	20	15	48	19	32	21	65	68	54	52	33	53
Estimated catch	5	5	7	23	7	9	4	17	25	14	14	9	17
Vessels targeting GUR													
Total landings	6	6	15	26	18	9	9	27	13	29	36	26	28
Estimated catch	4	3	8	7	6	2	2	6	3	12	6	9	11
Vessels targeting SCH													
Total landings	2	1	–	7	–	–	1	–	–	–	–	2	7
Estimated catch	2	< 1	–	5	–	–	< 1	–	–	–	–	1	2

Table 29: Total school shark catch (t) by month and year in the northwest North Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	11.0	6.4	0.7	2.5	4.1	9.4	3.6	4.7	1.4	2.7	9.4	6.4	62.0
1991	7.3	2.0	2.0	6.1	5.7	2.4	2.1	4.1	3.5	3.9	2.8	12.6	54.4
1992	17.6	8.3	14.9	4.0	6.9	3.9	1.0	0.9	8.9	2.7	4.7	12.6	86.3
1993	29.9	16.6	17.8	13.9	21.4	22.0	5.9	2.8	11.0	13.2	8.7	23.3	186.4
1994	17.4	9.5	10.5	13.7	6.8	10.6	11.6	11.5	16.8	10.1	3.6	6.3	128.5
1995	18.9	7.7	6.6	10.6	22.8	2.5	6.5	4.0	6.5	5.8	8.3	18.0	118.2
1996	6.9	12.6	24.0	15.8	14.2	12.1	12.8	15.8	7.5	5.2	1.9	19.5	148.2
1997	14.0	10.1	11.5	12.9	8.7	11.7	15.9	12.4	16.9	19.3	6.9	45.3	185.5
1998	13.5	38.5	12.5	9.0	11.5	19.0	10.5	15.4	5.5	12.6	12.0	13.2	173.2
1999	17.7	40.7	9.9	7.8	11.8	16.9	12.3	13.2	7.0	5.0	12.9	14.4	169.4
2000	23.2	13.0	11.6	12.5	9.8	21.4	16.1	14.7	8.3	8.7	5.6	5.3	150.4
2001	8.8	6.2	5.0	12.5	5.5	14.0	9.3	8.8	10.8	8.9	10.7	14.5	114.9
2002	14.6	16.2	9.0	11.5	7.9	5.0	9.4	11.4	3.4	20.7	24.0	34.1	167.2

Table 30: Proportion of trips that caught no school shark in the northwest North Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.29	0.53	0.71	0.21	0.54	0.21	0.20	0.21	0.15	0.29	0.22	0.10	0.32
1991	0.35	0.39	0.17	0.19	0.14	0.29	0.36	0.25	0.33	0.32	0.36	0.31	0.30
1992	0.19	0.27	0.25	0.32	0.21	0.28	0.32	0.29	0.28	0.65	0.68	0.13	0.30
1993	0.07	0.38	0.47	0.43	0.23	0.26	0.21	0.24	0.35	0.19	0.15	0.26	0.29
1994	0.29	0.31	0.26	0.27	0.37	0.49	0.27	0.32	0.29	0.31	0.26	0.39	0.32
1995	0.09	0.19	0.31	0.37	0.58	0.45	0.34	0.06	0.27	0.32	0.22	0.21	0.29
1996	0.14	0.49	0.42	0.43	0.35	0.27	0.22	0.20	0.17	0.22	0.20	0.19	0.31
1997	0.16	0.34	0.29	0.39	0.42	0.33	0.29	0.26	0.21	0.22	0.43	0.24	0.29
1998	0.21	0.20	0.31	0.27	0.42	0.29	0.20	0.18	0.25	0.14	0.17	0.16	0.24
1999	0.06	0.42	0.32	0.22	0.28	0.13	0.17	0.06	0.04	0.31	0.29	0.17	0.23
2000	0.06	0.17	0.17	0.11	0.05	0.04	0.02	0.13	0.15	0.19	0.21	0.13	0.12
2001	0.15	0.24	0.19	0.28	0.21	0.04	0.14	0.13	0.03	0.19	0.14	0.18	0.16
2002	0.48	0.19	0.27	0.13	0.20	0.23	0.19	0.08	0.06	0.13	0.04	0.04	0.19

Table 31: Landings (t) of all fish from the selected trips in the east coast North Island trawl fishery.

Category	Landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore	15	Flatfish	15	
Coastal demersal	2 549	Tarakihi	1 221	34
		Barracouta	363	
		Gurnard	178	
		Snapper	176	
		Trevally	114	
		Moki	84	
		Alfonsino	79	
		Bluenose	59	
		John dory	53	
		Warehou	47	
		Groper	43	
		School shark	38	
		Red cod	38	
		Rig	25	
Coastal pelagic	84	Jack mackerels	48	< 1
		Kingfish	28	
		Kahawai	12	
Deepwater	643	Hoki	245	11
		Gemfish	186	
		Rubyfish	67	
		Orange roughy	66	
		Ling	29	
		Frostfish	25	
		Cardinalfish	14	
Oceanic	1			
Other	19			
Total	3 311			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 32: Number of vessels operating in the east coast North Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	31	51	47	50	50	42	41	37	38	40	34	38	34

Table 33: Total landed and estimated school shark catch (t) in the east coast North Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	25	24	26	43	32	28	30	39	35	58	68	41	41
Estimated catch	9	6	7	12	8	7	8	15	9	16	13	10	9

Table 34: Total school shark catch (t) by month and year in the east coast North Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	2.2	3.2	2.7	2.0	2.1	1.2	1.5	1.0	3.2	2.1	1.2	2.5	24.9
1991	1.9	1.8	2.7	1.3	1.2	1.2	2.4	4.6	1.1	2.3	2.0	2.1	24.4
1992	4.6	1.7	2.0	2.2	2.2	2.2	3.0	3.1	1.2	2.6	0.4	0.9	26.3
1993	2.0	3.9	4.8	5.7	2.9	5.5	2.9	4.8	7.1	1.6	0.6	1.3	43.1
1994	2.7	4.9	7.5	3.8	2.3	1.8	2.4	3.0	2.1	0.3	1.1	0.6	32.3
1995	0.6	4.9	2.7	5.2	2.1	1.9	1.9	3.1	1.8	1.1	0.7	2.1	28.0
1996	2.1	3.9	3.9	4.5	1.7	1.7	2.2	3.2	2.5	1.1	1.9	1.3	30.0
1997	4.3	5.4	3.4	4.2	3.0	2.2	2.7	3.6	0.9	2.6	2.0	4.3	38.5
1998	4.2	2.8	2.8	2.8	3.0	3.3	2.4	3.6	2.3	3.0	1.0	3.9	35.0
1999	2.7	3.9	2.9	2.6	3.3	8.7	8.6	4.3	7.4	2.1	3.8	7.3	57.7
2000	6.3	6.0	5.0	4.6	6.4	8.6	7.2	8.2	3.7	1.5	7.2	3.2	67.8
2001	4.8	2.5	4.0	6.6	4.1	4.4	4.2	4.8	2.3	1.9	1.1	0.5	41.1
2002	3.8	5.1	4.1	3.3	1.0	3.2	5.6	5.3	6.3	1.9	1.2	0.7	41.3

Table 35: Proportion of trips that caught no school shark in the east coast North Island trawl fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.40	0.29	0.19	0.25	0.33	0.22	0.23	0.48	0.32	0.31	0.53	0.52	0.36
1991	0.62	0.39	0.46	0.46	0.54	0.50	0.60	0.46	0.49	0.48	0.64	0.48	0.51
1992	0.42	0.52	0.45	0.46	0.47	0.48	0.52	0.48	0.63	0.49	0.75	0.67	0.53
1993	0.52	0.33	0.28	0.16	0.27	0.29	0.19	0.21	0.34	0.45	0.70	0.54	0.35
1994	0.45	0.42	0.41	0.07	0.26	0.27	0.34	0.31	0.58	0.73	0.58	0.69	0.45
1995	0.74	0.44	0.22	0.23	0.52	0.39	0.35	0.36	0.57	0.56	0.52	0.59	0.48
1996	0.55	0.46	0.35	0.42	0.30	0.40	0.42	0.22	0.40	0.37	0.41	0.52	0.41
1997	0.42	0.35	0.29	0.38	0.26	0.47	0.41	0.26	0.38	0.50	0.54	0.59	0.42
1998	0.35	0.34	0.38	0.35	0.17	0.21	0.24	0.36	0.29	0.47	0.55	0.47	0.35
1999	0.39	0.29	0.31	0.34	0.29	0.27	0.13	0.14	0.36	0.48	0.52	0.43	0.34
2000	0.35	0.23	0.22	0.29	0.23	0.07	0.17	0.11	0.22	0.19	0.31	0.29	0.22
2001	0.33	0.46	0.36	0.15	0.17	0.29	0.24	0.15	0.32	0.44	0.33	0.41	0.31
2002	0.47	0.36	0.12	0.28	0.25	0.25	0.28	0.24	0.34	0.31	0.33	0.46	0.32

Table 36: Landings (t) of all fish from the selected trips in the Cook Strait dropline fishery.

Category	Landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore[2]	3	Butterfish	3	< 1
Coastal demersal	182	Groper	113	5
		School shark	46	
		Bluenose	12	
		Conger eel	5	
Coastal pelagic	< 1			
Deepwater	17	Ling	15	2
Oceanic	< 1			
Other	1			
Total	204			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.
2. These species would not have been caught by line, but in setnets fished by line vessels during the same trip. They are incorrectly recorded on the CELR forms, and are included here only to illustrate the unreliability of some data sets.

Table 37: Number of vessels operating in the Cook Strait dropline fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	26	29	26	28	36	32	27	20	14	17	13	16	13
Vessels targeting HPB	24	28	25	28	35	31	23	17	12	14	13	15	13
Vessels targeting BNS	4	4	4	2	8	11	9	5	2	3	1	4	2
Vessels targeting SCH	8	8	5	3	5	5	9	8	3	4	3	5	1

Table 38: Total landed and estimated school shark catch (t) in the Cook Strait dropline fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	39	43	36	35	39	46	41	53	35	90	40	48	32
Estimated catch	13	16	12	9	10	7	8	10	14	24	15	13	7
Vessels targeting HPB													
Total landings	31	33	32	31	34	42	39	45	24	78	37	43	31
Estimated catch	7	9	8	5	5	5	6	4	7	20	13	9	7
Vessels targeting BNS													
Total landings	1	< 1	0	< 1	< 1	2	< 1	1	< 1	< 1	< 1	< 1	< 1
Estimated catch	< 1	< 1	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Vessels targeting SCH													
Total landings	7	10	4	4	5	2	3	7	11	12	2	5	< 1
Estimated catch	6	7	4	4	4	2	1	6	7	3	2	4	< 1

Table 39: Total school shark catch (t) by month and year in the Cook Strait dropline fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.5	2.7	1.2	3.2	7.7	5.2	2.9	5.2	7.0	0.8	0.7	1.9	38.9
1991	6.2	0.8	2.8	3.5	5.0	6.6	6.1	8.3	1.1	0.1	0.1	2.3	42.8
1992	0.4	2.9	2.9	4.4	2.2	7.9	10.8	2.9	1.2	0.3	0.1	0.1	36.0
1993	0.2	0.1	3.2	1.8	3.9	6.6	2.2	1.6	2.8	0.4	0.4	12.4	35.4
1994	0.2	2.8	8.2	4.1	7.0	5.6	1.7	3.6	5.4	0.1	0.1	0.5	39.3
1995	0.4	18.3	3.0	5.2	3.5	6.2	2.9	2.1	3.5	0.5	0.4	0.1	46.1
1996	0.6	4.3	5.0	0.9	5.8	10.2	11.5	1.9	0.4	0.3	0.1	0.5	41.4
1997	7.4	9.1	5.7	3.5	4.2	5.3	6.0	9.8	0.9	0.0	0.3	0.5	52.6
1998	2.2	3.9	5.9	0.5	5.8	4.3	5.8	3.0	2.3	0.5	0.9	0.1	35.1
1999	0.1	18.7	4.8	16.1	12.9	16.7	8.9	8.1	1.2	1.0	1.2	0.6	90.3
2000	1.3	7.5	2.9	5.8	10.3	5.0	2.3	3.6	0.3	0.3	0.6	0.2	40.0
2001	1.3	1.2	2.7	1.4	26.6	7.1	2.9	1.7	1.3	0.7	0.4	0.5	47.7
2002	0.4	3.3	1.0	0.9	0.6	5.1	7.2	7.8	3.8	0.5	0.2	1.1	31.6

Table 40: Proportion of trips that caught no school shark in the Cook Strait dropline fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.62	0.48	0.59	0.37	0.38	0.43	0.49	0.32	0.31	0.57	0.50	0.57	0.44
1991	0.52	0.61	0.46	0.16	0.53	0.52	0.53	0.48	0.45	0.75	0.92	0.78	0.52
1992	0.53	0.52	0.44	0.63	0.54	0.35	0.36	0.47	0.63	0.84	0.86	0.74	0.52
1993	0.61	0.67	0.61	0.50	0.50	0.39	0.51	0.47	0.50	0.66	0.88	0.69	0.54
1994	0.61	0.41	0.57	0.69	0.68	0.59	0.32	0.35	0.39	0.68	0.65	0.43	0.53
1995	0.63	0.48	0.60	0.66	0.67	0.67	0.49	0.50	0.38	0.55	0.84	0.82	0.61
1996	0.71	0.63	0.62	0.70	0.63	0.69	0.20	0.46	0.64	0.45	0.64	0.71	0.60
1997	0.71	0.62	0.43	0.48	0.48	0.61	0.72	0.48	0.76	0.89	0.50	0.61	0.58
1998	0.57	0.47	0.32	0.48	0.44	0.35	0.26	0.27	0.38	0.45	0.46	0.67	0.39
1999	0.62	0.38	0.17	0.25	0.31	0.20	0.11	0.39	0.47	0.13	0.50	0.14	0.31
2000	0.32	0.28	0.42	0.27	0.22	0.42	0.33	0.34	0.57	0.60	0.43	0.71	0.36
2001	0.62	0.31	0.31	0.05	0.22	0.36	0.19	0.53	0.55	0.68	0.36	0.88	0.39
2002	0.25	0.48	0.50	0.62	0.55	0.42	0.32	0.04	0.28	0.68	0.69	0.75	0.44

Table 41: Landings (t) of all fish from the selected trips in the northeast North Island dropline fishery.

Category	Total landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore	< 1			
Coastal demersal	251	Groper	138	
		Bluenose	64	
		School shark	30	
		Tarakihi	8	
Coastal pelagic	2	Kingfish	2	
Deepwater	5	Ling	2	< 1
		Gemfish	2	
Oceanic	7	Albacore	4	3
Other	1			
Total	266			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.

Table 42: Number of vessels operating in the northeast North Island dropline fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	30	40	46	60	60	57	40	47	41	31	28	33	31
Vessels targeting HPB	24	37	39	59	53	45	35	40	31	28	23	28	23
Vessels targeting BNS	14	13	13	8	18	21	10	19	16	10	9	9	12
Vessels targeting SCH	2	4	2	3	–	4	1	–	2	–	2	–	1

Table 43: Total landed and estimated school shark catch (t) in the northeast North Island dropline fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	29	40	34	41	45	42	31	36	33	36	24	11	11
Estimated catch	21	27	18	23	23	24	16	12	18	25	17	5	5
Vessels targeting HPB													
Total landings	27	37	33	41	41	37	30	29	32	35	21	11	11
Estimated catch	20	24	17	22	22	21	15	12	17	24	14	5	5
Vessels targeting BNS													
Total landings	1	1	< 1	< 1	4	< 1	< 1	7	1	1	< 1	< 1	< 1
Estimated catch	1	< 1	< 1	< 1	1	< 1	< 1	< 1	1	1	0	< 1	< 1
Vessels targeting SCH													
Total landings	< 1	2	< 1	1	–	5	0	–	< 1	–	3	–	0
Estimated catch	< 1	2	< 1	< 1	–	3	0	–	< 1	–	2	–	0

Table 44: Total school shark catch (t) by month and year in the northeast North Island dropline fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	3.3	4.1	3.3	2.4	0.8	1.3	0.4	5.2	1.7	2.3	1.3	2.7	28.6
1991	2.9	5.5	5.0	5.3	2.2	4.7	2.3	1.0	1.6	2.1	1.1	6.1	39.8
1992	4.2	1.9	2.6	2.0	1.7	0.4	2.7	2.3	3.9	2.2	2.0	7.8	33.7
1993	8.9	4.0	3.5	2.0	0.6	2.2	1.2	2.7	0.3	3.0	8.6	4.4	41.3
1994	4.1	3.1	2.3	0.4	0.9	1.2	2.4	0.8	3.3	5.4	7.0	13.8	44.7
1995	6.0	7.9	0.8	0.4	0.5	1.6	1.7	0.6	1.8	3.5	4.0	13.3	42.1
1996	7.3	3.7	5.1	0.5	0.8	1.4	3.1	0.5	1.7	2.4	1.1	3.0	30.6
1997	1.1	2.1	1.6	0.6	1.2	0.6	0.4	1.5	3.1	4.2	8.6	11.0	35.9
1998	4.3	4.7	1.3	2.6	1.2	4.1	1.8	1.0	3.7	2.4	0.7	5.1	33.0
1999	4.9	5.0	2.9	3.3	1.5	4.4	1.9	3.2	1.8	1.3	2.4	3.8	36.3
2000	4.8	4.6	3.3	3.5	2.7	1.2	0.8	1.0	0.5	0.7	0.5	0.7	24.2
2001	0.6	0.6	0.4	1.6	2.3	0.6	0.5	0.8	1.2	1.5	0.5	0.8	11.4
2002	1.7	0.6	0.3	0.8	0.6	1.0	0.8	0.8	0.8	0.8	1.0	2.3	11.3

Table 45: Proportion of trips that caught no school shark in the northeast North Island dropline fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.40	0.38	0.31	0.42	0.36	0.59	0.74	0.64	0.52	0.50	0.17	0.30	0.51
1991	0.50	0.40	0.41	0.33	0.63	0.74	0.55	0.86	0.85	0.50	0.54	0.66	0.60
1992	0.59	0.60	0.40	0.50	0.70	0.82	0.87	0.74	0.66	0.60	0.71	0.60	0.68
1993	0.52	0.52	0.70	0.67	0.92	0.60	0.64	0.65	0.88	0.68	0.44	0.59	0.64
1994	0.55	0.46	0.50	0.71	0.67	0.71	0.51	0.55	0.56	0.53	0.58	0.59	0.58
1995	0.27	0.46	0.68	0.71	0.72	0.69	0.71	0.77	0.79	0.73	0.64	0.48	0.63
1996	0.29	0.50	0.42	0.42	0.59	0.56	0.55	0.70	0.67	0.42	0.58	0.44	0.52
1997	0.26	0.56	0.50	0.43	0.69	0.74	0.79	0.74	0.51	0.68	0.43	0.54	0.60
1998	0.41	0.45	0.65	0.67	0.61	0.57	0.64	0.72	0.53	0.56	0.67	0.50	0.58
1999	0.58	0.49	0.33	0.35	0.45	0.46	0.67	0.56	0.50	0.77	0.65	0.57	0.53
2000	0.43	0.44	0.44	0.31	0.20	0.64	0.50	0.67	0.75	0.40	0.92	0.88	0.56
2001	0.78	0.67	0.64	0.36	0.00	0.27	0.57	0.40	0.38	0.57	0.71	0.56	0.52
2002	0.62	0.70	0.63	0.47	0.70	0.54	0.33	0.56	0.33	0.69	0.73	0.64	0.58

Table 46: Landings (t) of all fish from the selected trips in the Chatham Rise longline fishery.

Category	Landing (t) [1]	Main species (t) [1]		Others (t) [1]
Inshore [2]	< 1			
Coastal demersal [3]	705	Spiny dogfish	421	28
		Sea perch	84	
		Skates	69	
		School shark	44	
		Red cod	22	
		Gropers	19	
		Bluenose	18	
Coastal pelagic [2]	< 1			
Deepwater	3 139	Ling	2 840	25
		Ribaldo	240	
		Ghost sharks	33	
Oceanic	3	Rays bream	3	> 1
Other	2			
Total	3 849			

Notes:
1. Mean of values for fishing years 1989–90 to 2002–03.
2. Recorded from trips, but unlikely to be directly associated with Chatham Rise longlining.
3. Recorded as "coastal" for conformity with other fisheries, but these species have broad depth ranges and would have been taken on the deeper (~400 m) Chatham Rise grounds.

Table 47: Number of vessels operating in the Chatham Rise bottom longline fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels	7	8	12	17	12	14	18	11	12	9	10	7	7
Vessels targeting LIN	7	7	12	16	12	14	18	11	12	9	10	7	7
Vessels targeting SCH	–	1	–	1	1	2	1	1	–	–	–	–	–

Table 48: Total landed and estimated school shark catch (t) in the Chatham Rise bottom longline fishery. Fishing year 1989–90 is listed as 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All vessels													
Total landings	< 1	7	24	22	20	34	62	78	47	58	44	52	44
Estimated catch	< 1	4	11	17	6	25	32	28	23	41	36	30	30
Vessels targeting LIN													
Total landings	< 1	6	24	15	17	34	62	74	47	58	44	52	44
Estimated catch	< 1	4	11	5	5	22	29	24	23	41	36	30	30
Vessels targeting SCH													
Total landings	–	1	–	7	3	0	0	4	–	–	–	–	–
Estimated catch	–	< 1	–	12	1	3	2	4	–	–	–	–	–

Table 49: Total school shark catch (t) by month and year in the Chatham rise bottom longline fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
1991	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.1	3.6	0.1	2.3	6.6
1992	1.3	9.0	3.1	0.0	0.0	0.0	0.0	0.5	4.4	1.0	2.7	2.3	24.3
1993	1.4	0.0	0.0	–	0.6	3.9	0.0	0.2	4.7	5.3	5.2	1.2	22.4
1994	0.3	1.1	3.1	0.0	0.1	3.7	0.0	0.6	3.6	1.8	2.2	3.1	19.5
1995	7.8	2.1	0.0	0.6	0.0	2.1	1.7	2.2	1.5	3.1	10.8	2.3	34.2
1996	29.9	9.2	0.0	0.0	3.1	0.8	3.1	0.9	0.7	0.2	8.1	6.4	62.4
1997	7.6	9.4	0.5	0.0	0.1	0.0	5.6	0.9	4.7	6.0	13.3	30.1	78.2
1998	17.1	6.2	2.4	5.1	0.6	0.0	0.0	0.1	0.5	0.3	6.3	8.8	47.1
1999	11.8	3.2	7.2	0.0	0.4	0.0	0.2	3.5	0.0	1.9	4.1	25.3	57.6
2000	9.2	7.8	1.4	0.2	0.0	0.0	0.0	0.0	2.1	0.9	11.2	11.3	43.8
2001	11.0	0.0	1.2	0.0	0.0	0.0	0.0	4.1	0.3	2.6	22.5	9.9	51.6
2002	16.9	0.1	0.7	0.0	0.1	–	0.4	0.0	1.6	0.0	15.9	8.0	43.5

Table 50: Proportion of trips that caught no school shark in the Chatham rise bottom longline fishery. Fishing year 1989–90 is listed as 1990.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	1.00	1.00	1.00	1.00	0.99
1991	1.00	1.00	0.80	1.00	0.50	0.67	1.00	0.89	0.67	0.83	0.91	0.85	0.87
1992	0.78	0.64	0.80	1.00	1.00	1.00	1.00	0.80	0.71	0.79	0.95	0.86	0.84
1993	0.86	1.00	1.00	–	0.67	0.78	1.00	0.80	0.80	0.78	0.72	0.88	0.82
1994	0.83	0.67	0.60	1.00	0.00	0.00	1.00	0.33	0.67	0.71	0.85	0.86	0.73
1995	0.67	0.78	1.00	0.83	1.00	0.75	0.50	0.33	0.82	0.77	0.71	0.83	0.78
1996	0.79	0.75	1.00	0.67	0.50	0.00	0.25	0.86	0.57	0.87	0.88	0.81	0.76
1997	0.42	0.67	0.17	0.00	0.00	1.00	0.00	0.40	0.25	0.62	0.55	0.46	0.45
1998	0.45	0.25	0.14	0.00	0.50	1.00	1.00	0.83	0.88	0.67	0.40	0.29	0.48
1999	0.00	0.43	0.20	1.00	0.00	1.00	0.67	0.00	1.00	0.83	0.43	0.33	0.43
2000	0.33	0.45	0.75	0.86	1.00	1.00	1.00	1.00	0.71	0.78	0.71	0.63	0.70
2001	0.33	0.75	0.83	1.00	1.00	1.00	1.00	0.67	0.75	0.75	0.43	0.50	0.69
2002	0.13	0.67	0.33	1.00	0.00	–	0.00	1.00	0.78	1.00	0.81	0.91	0.77

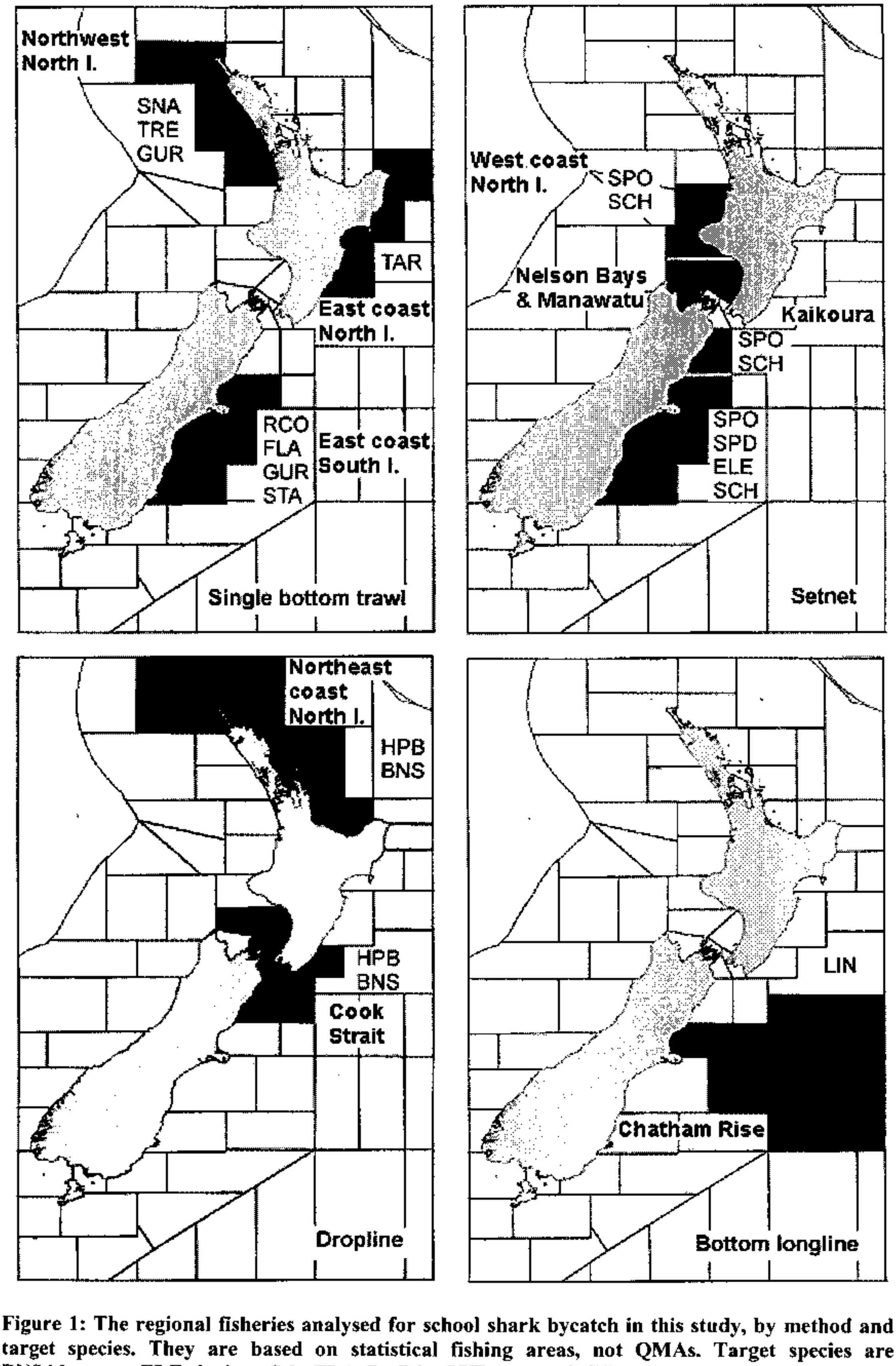

Figure 1: The regional fisheries analysed for school shark bycatch in this study, by method and target species. They are based on statistical fishing areas, not QMAs. Target species are BNS bluenose, ELE elephantfish, FLA flatfish, GUR gurnard, HPB groper, LIN ling, RCO red cod, SCH school shark, SNA snapper, SPD spiny dogfish, SPO rig, STA stargazer, TAR tarakihi, TRE trevally.

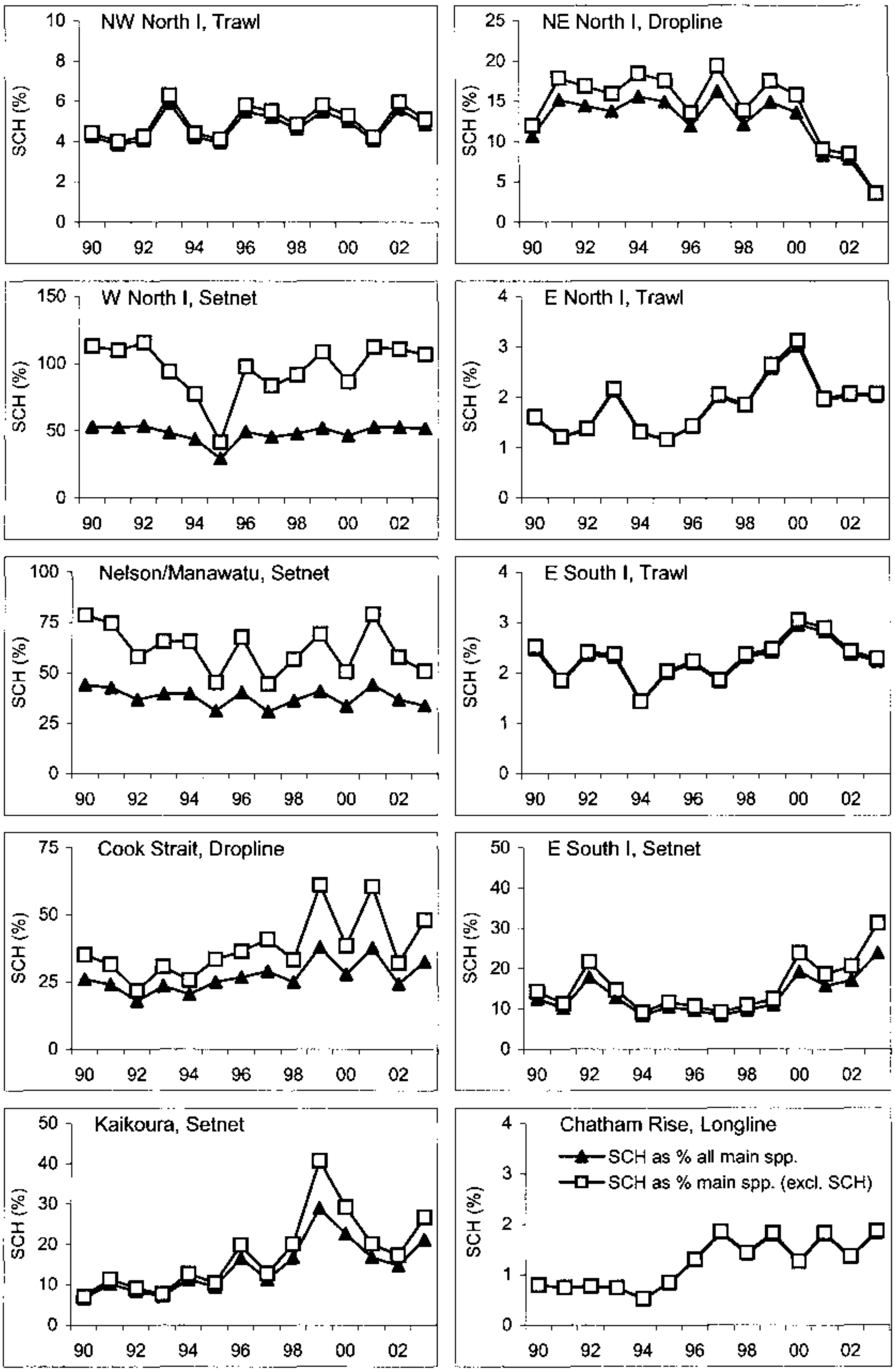

Figure 2: Trends in the landings of school shark as bycatch in regional fisheries, expressed as a percentage of the landings of the main (mainly inshore) species. Two calculations were made, with the "main species" total first including school shark, and then excluding school shark.

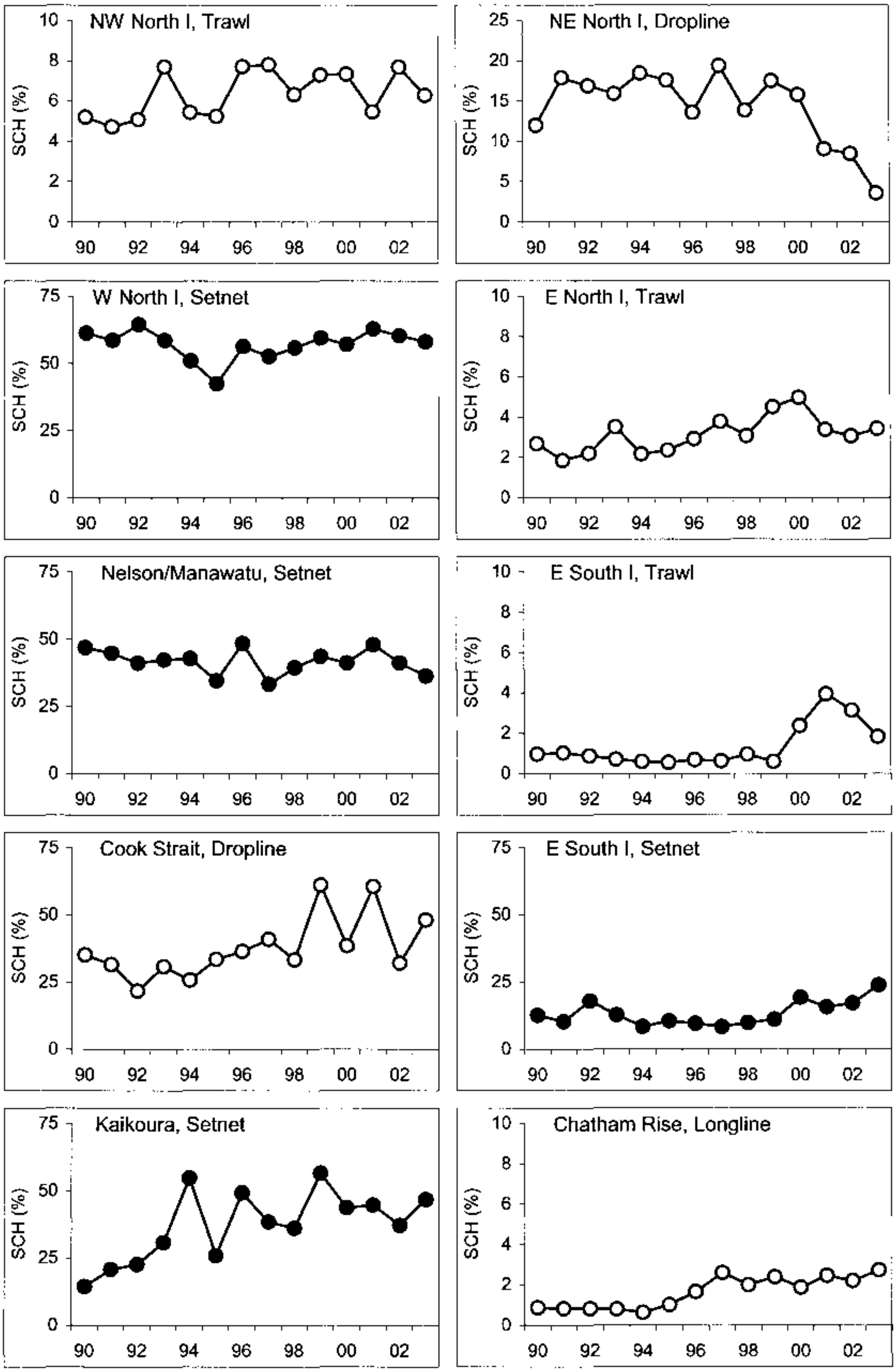

Figure 3: Trends in the landings of school shark as a bycatch in regional fisheries, expressed as a percentage of the landings of the nominated target species (single or multiple). Closed circle symbols represent fisheries where school shark is included among the target species.

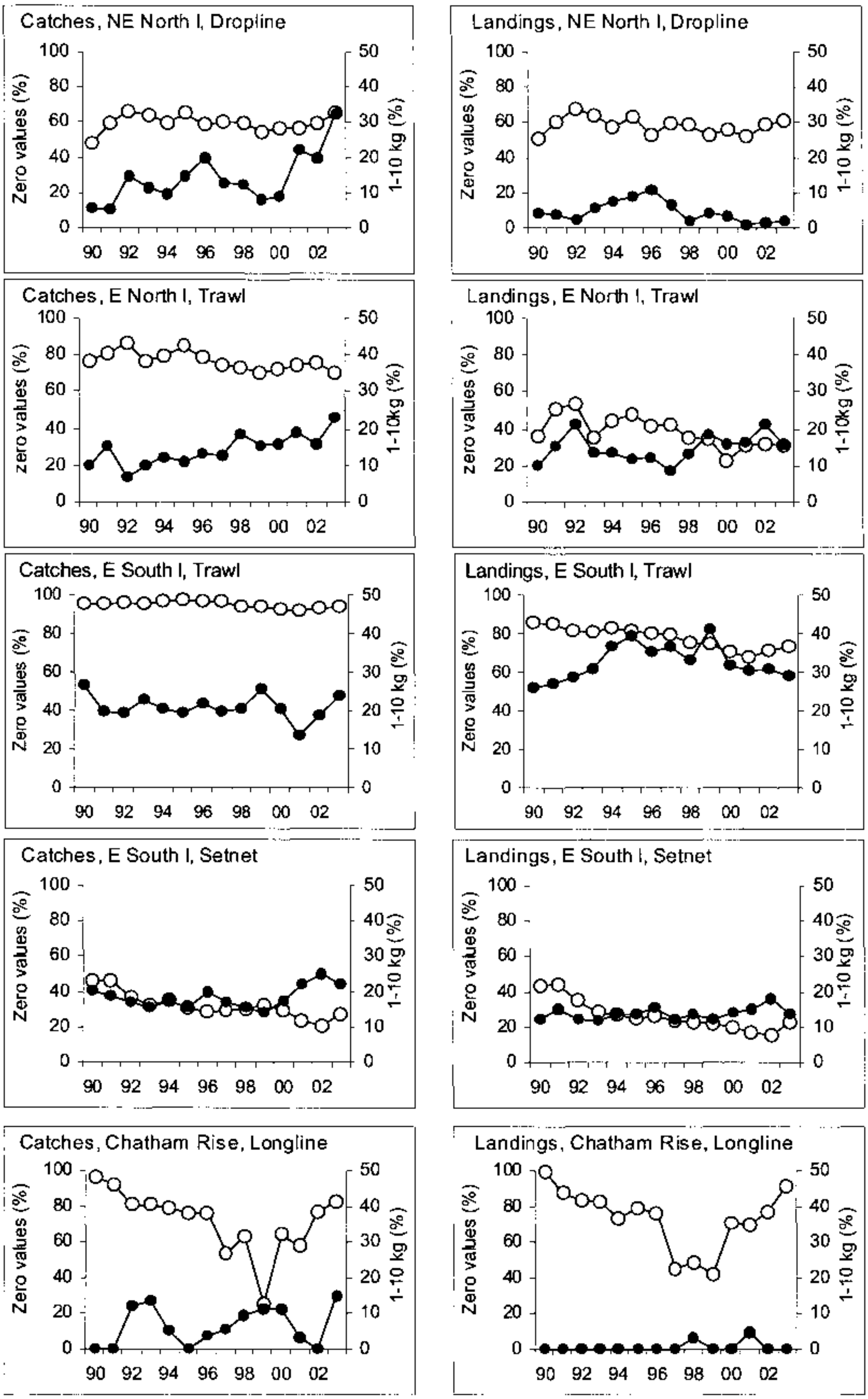

Figure 4: Trends in the relative number of zero catches and landings, and small (1 to 10 kg) catches and landings, of school shark taken as bycatch in regional fisheries. Zero values are shown as a percentage of all values, small catches and landings are shown as a percentage of non-zero catches and landings. Open circles, zero values; closed circles, small (1–10 kg) values. Eastern coast fisheries.

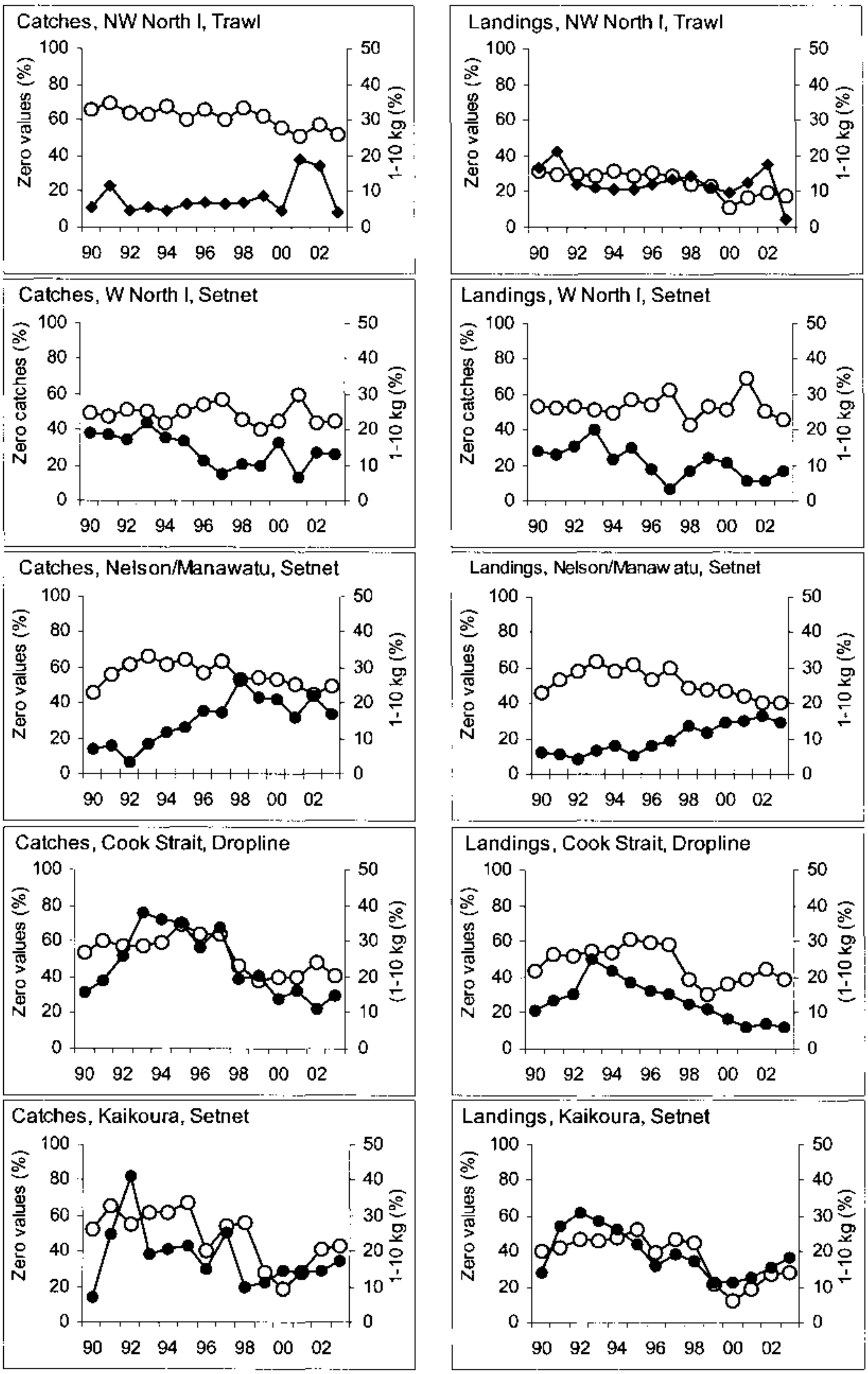

Figure 4 (continued): Western, Cook Strait, and Kaikoura fisheries.

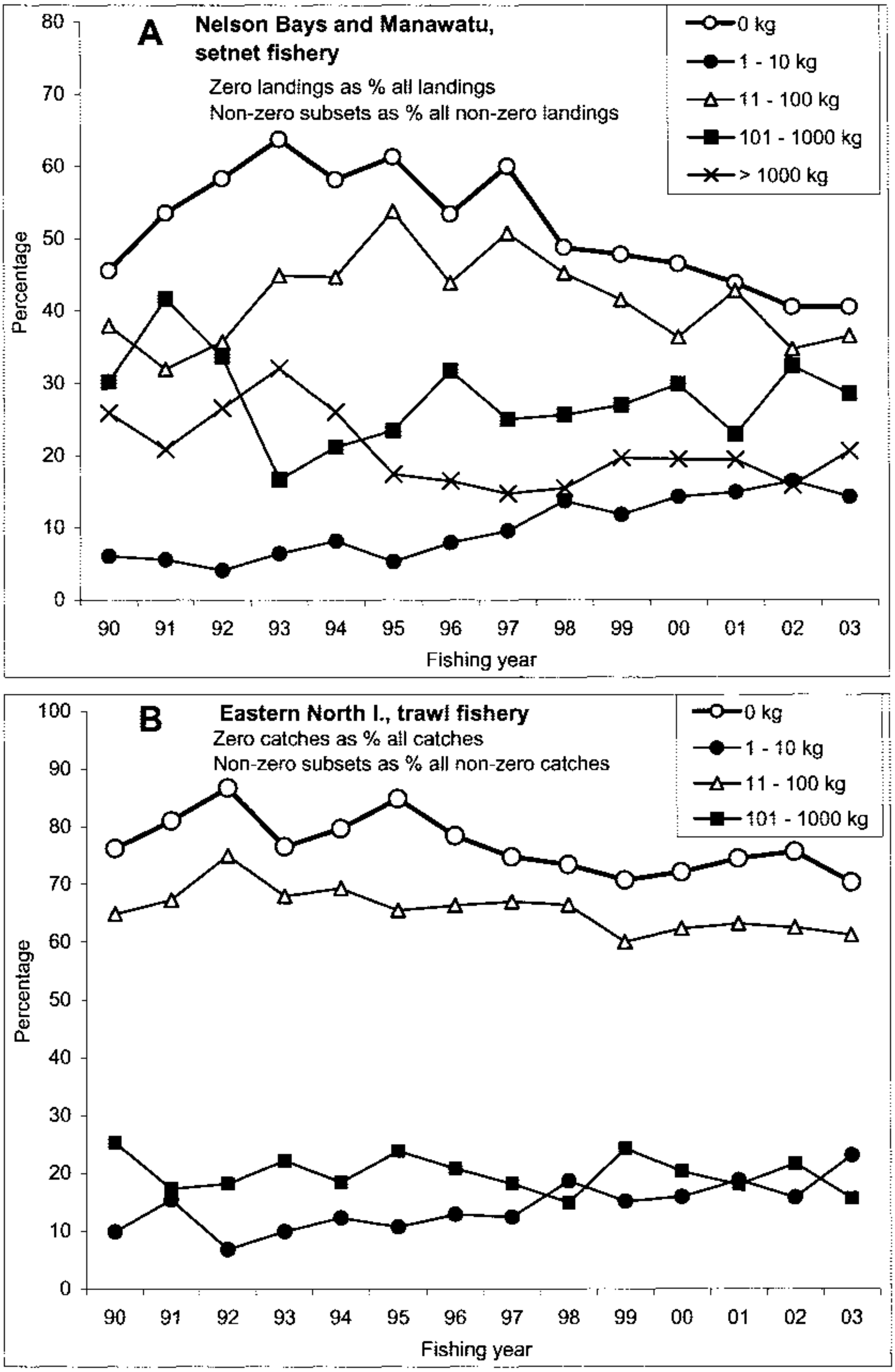

Figure 5: Two examples of the relationship between the trend in zero landings (or catches) and the trend in non-zero size groupings of landings (or catches). A, Nelson Bays and Manawatu setnet landing trends; B, eastern North Island trawl catch trends.

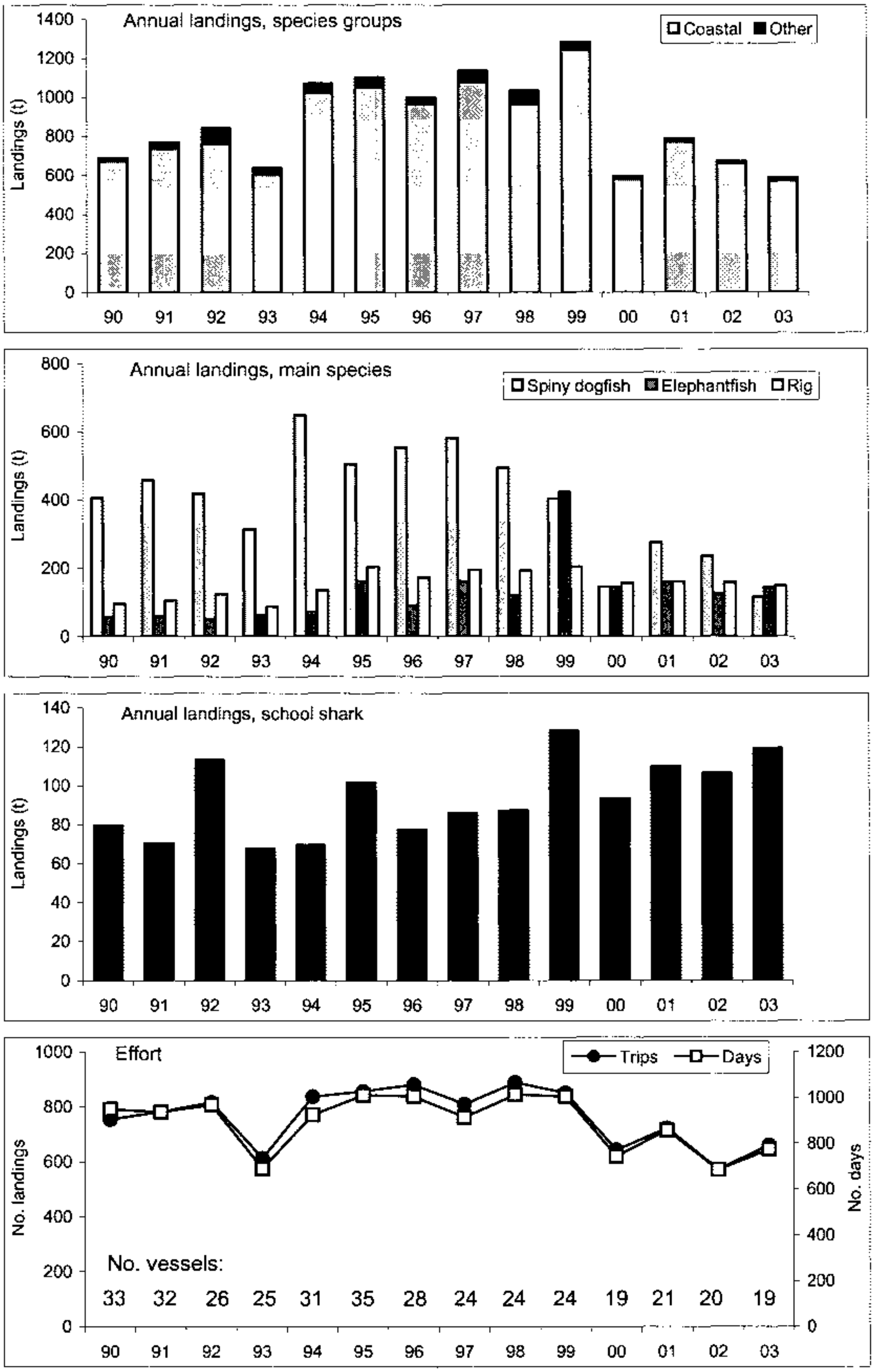

Figure 6a: Annual landings (t) and fishing effort for the eastern South Island setnet fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

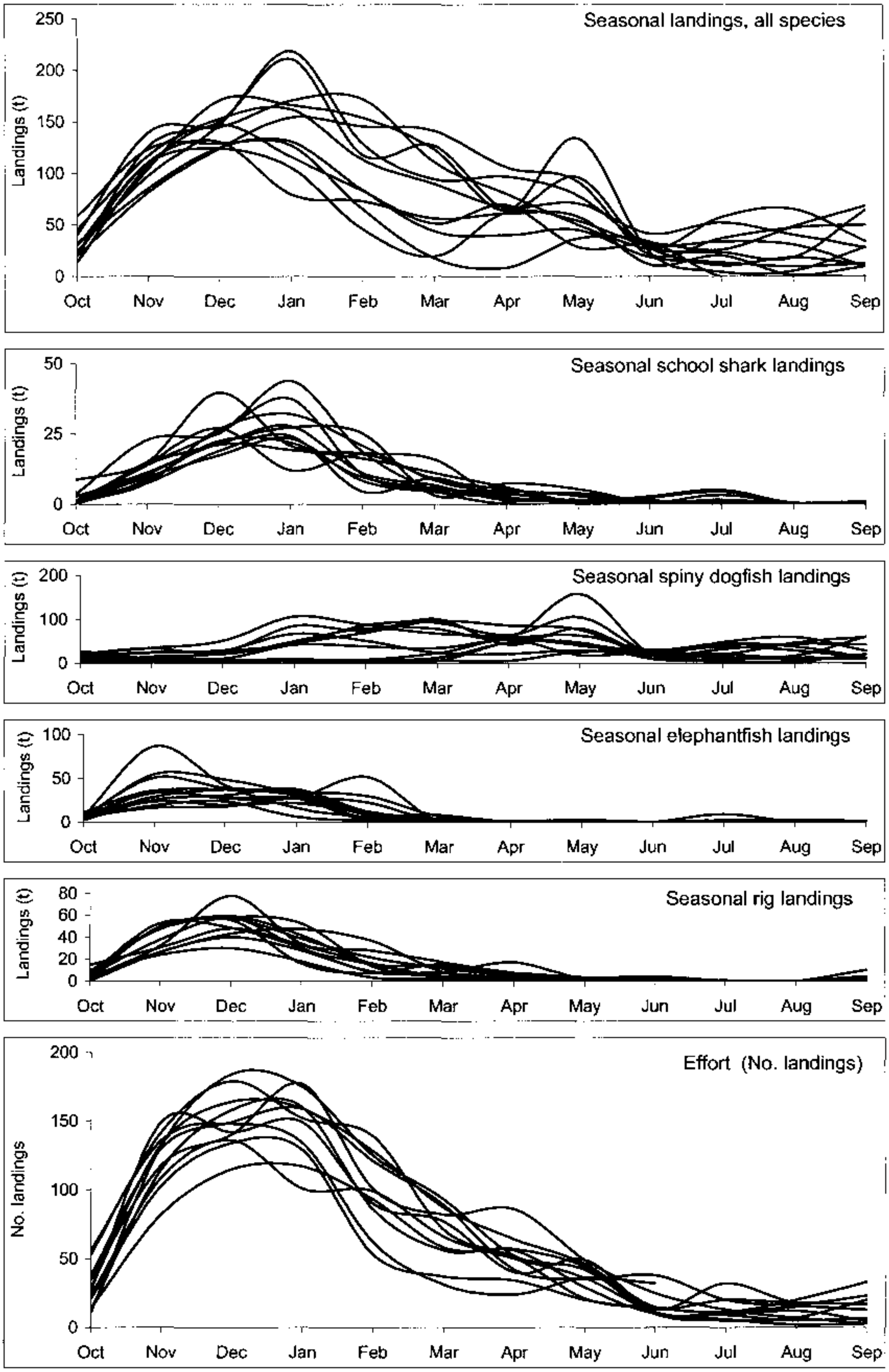

Figure 6b: Seasonal landings (t) and fishing effort for the eastern South Island setnet fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

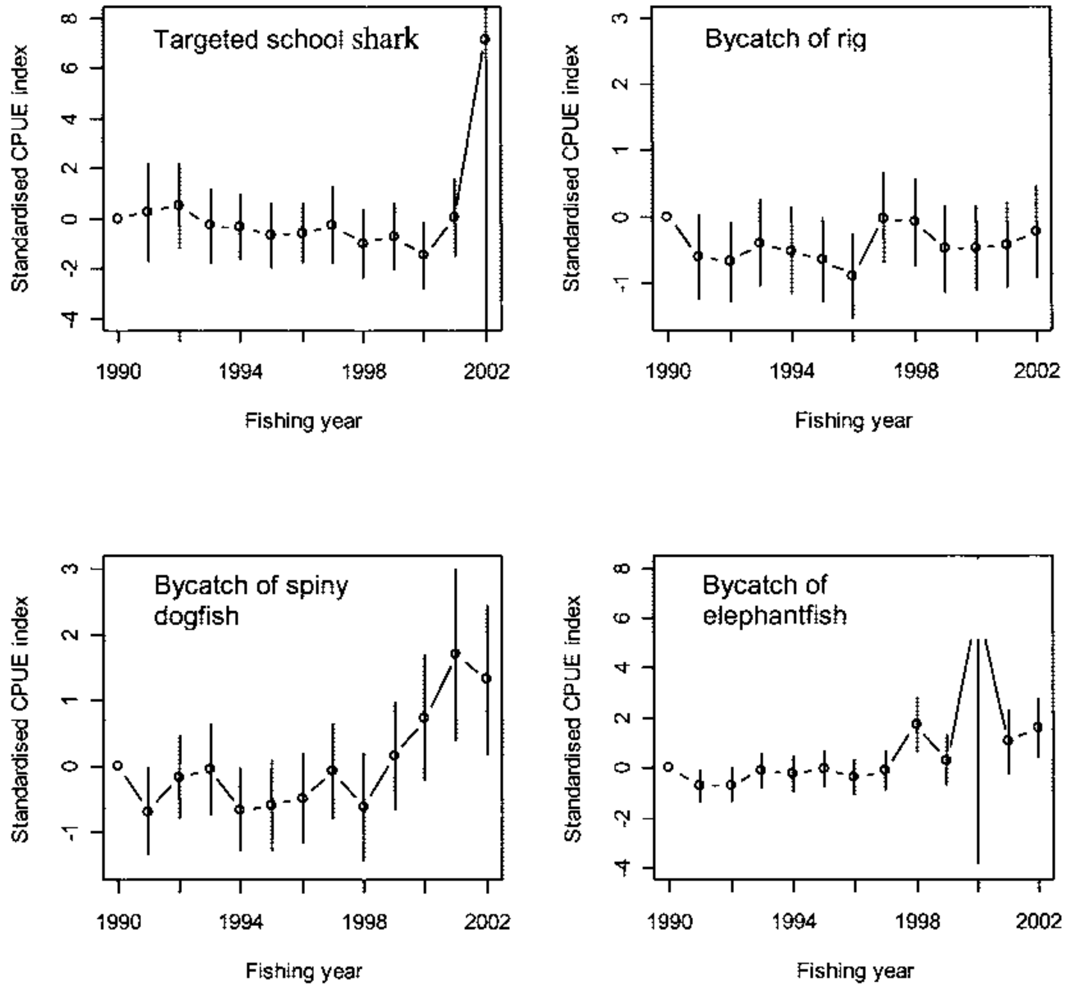

Figure 7: Binomial indices for school shark from the eastern South Island setnet fishery.

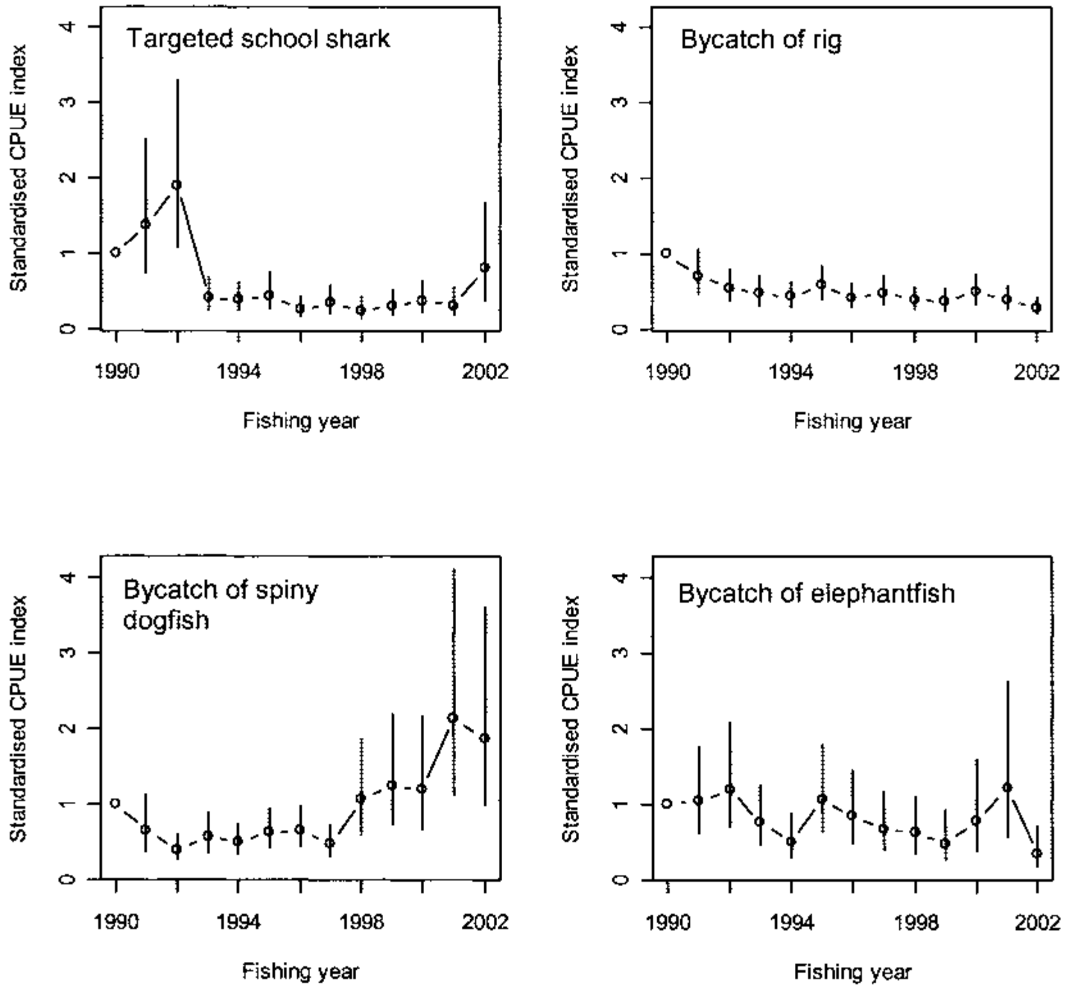

Figure 8. Non-zero indices for school shark from the eastern South Island setnet fishery.

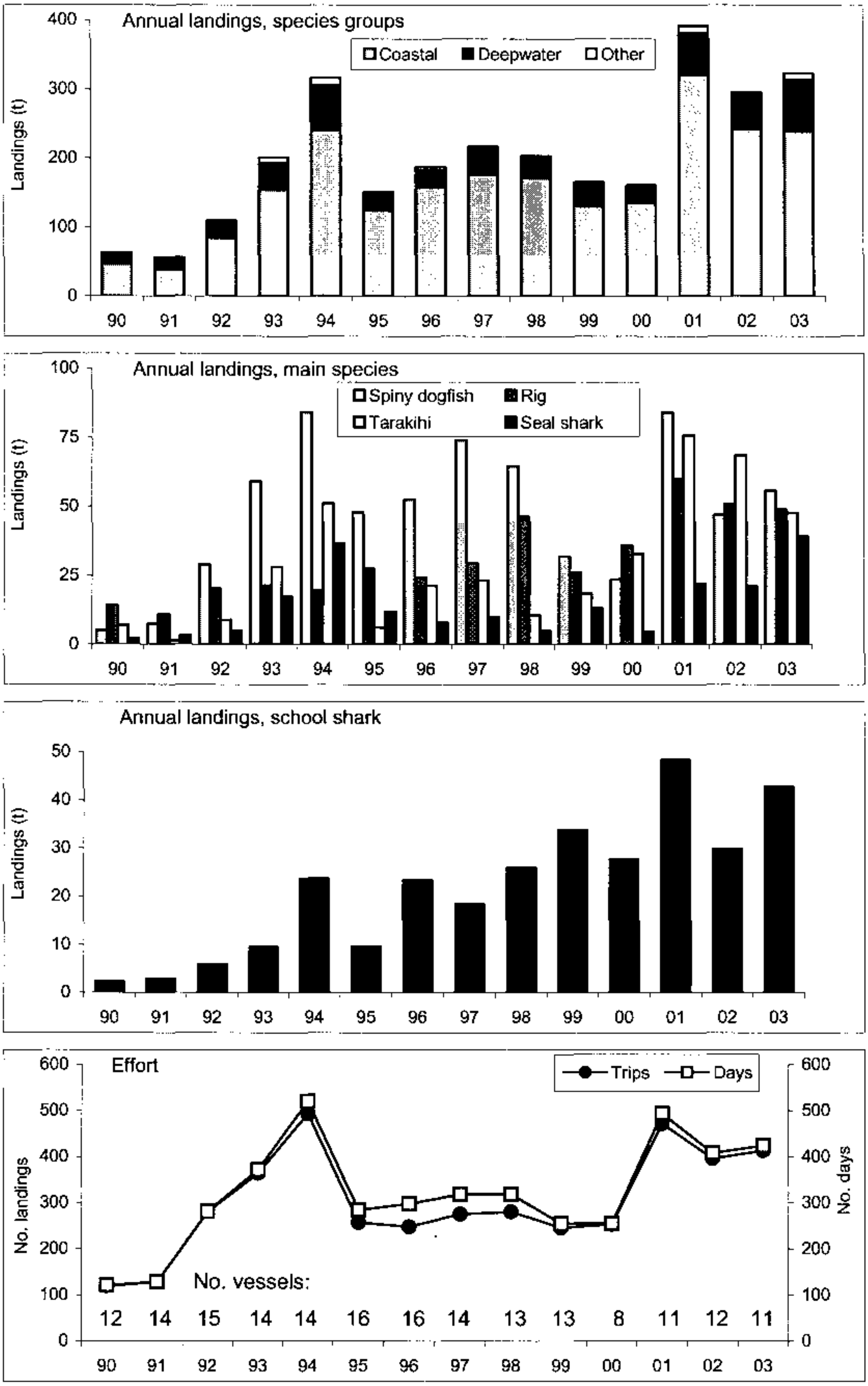

Figure 9a: Annual landings (t) and fishing effort for the Kaikoura setnet fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

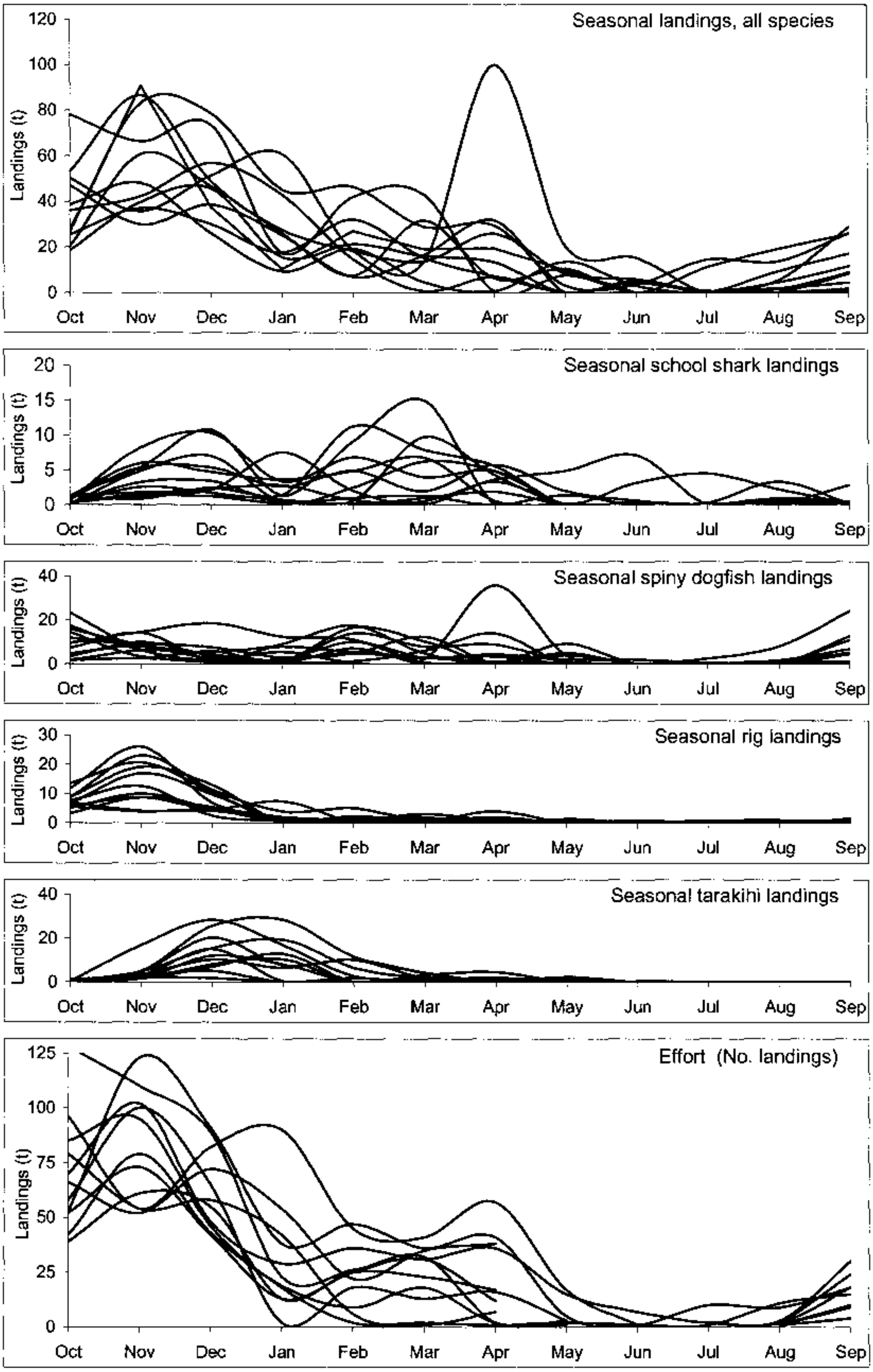

Figure 9b: Seasonal landings (t) and fishing effort for the Kaikoura setnet fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

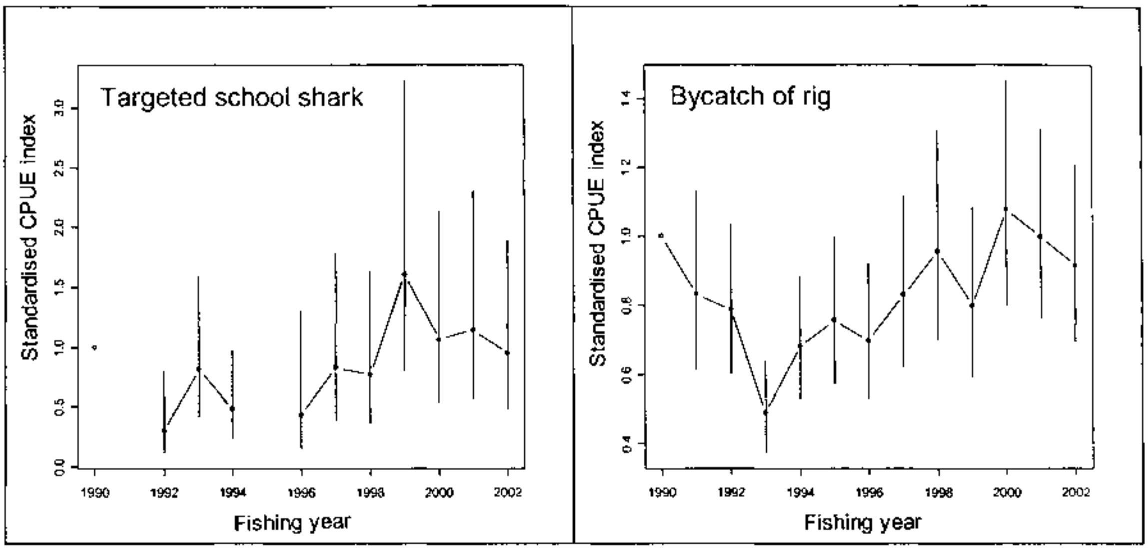

Figure 10: Non-zero indices for school shark from the Kaikoura setnet fishery.

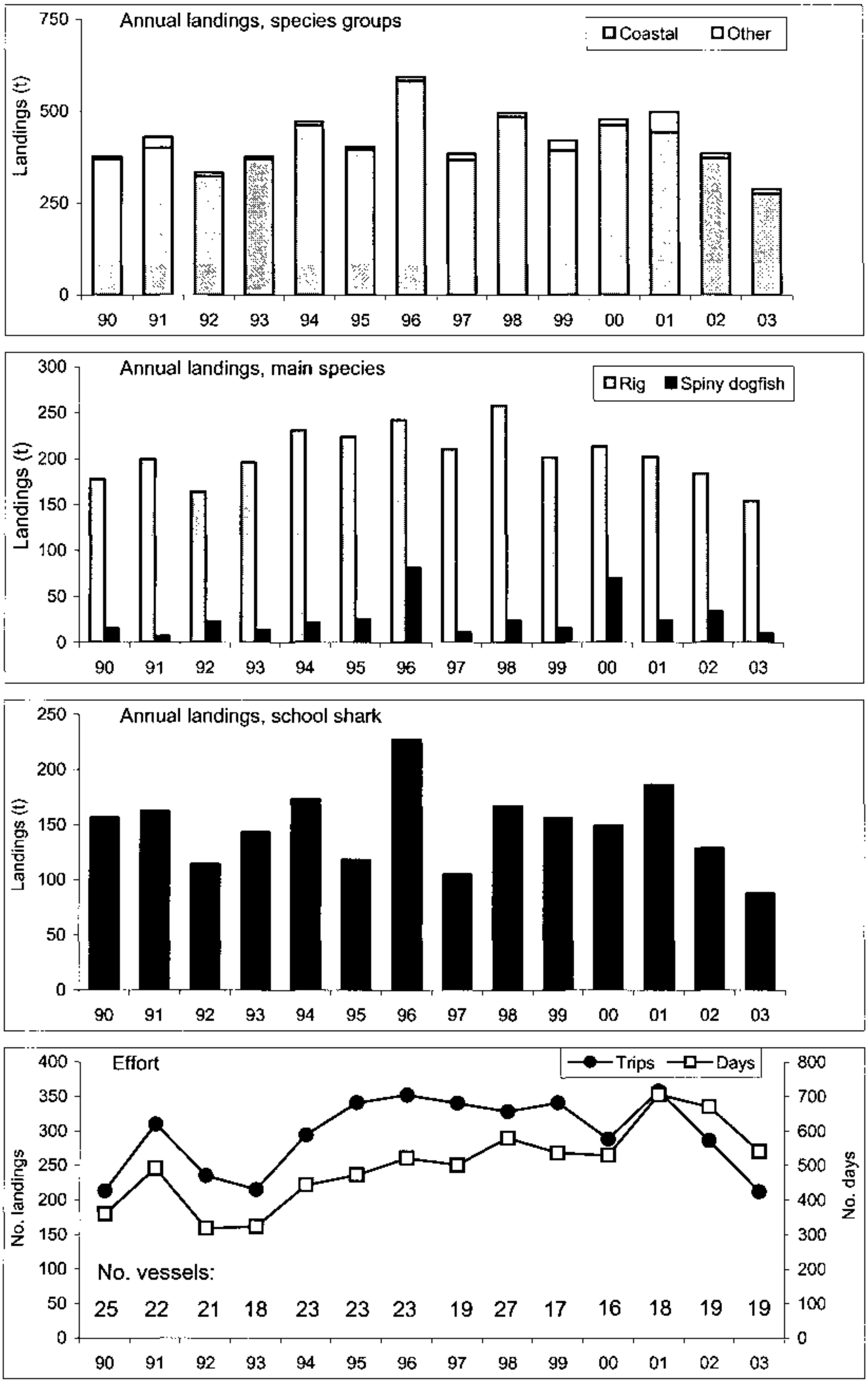

Figure 11a: Annual landings (t) and fishing effort for the Nelson Bays and Manawatu setnet fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

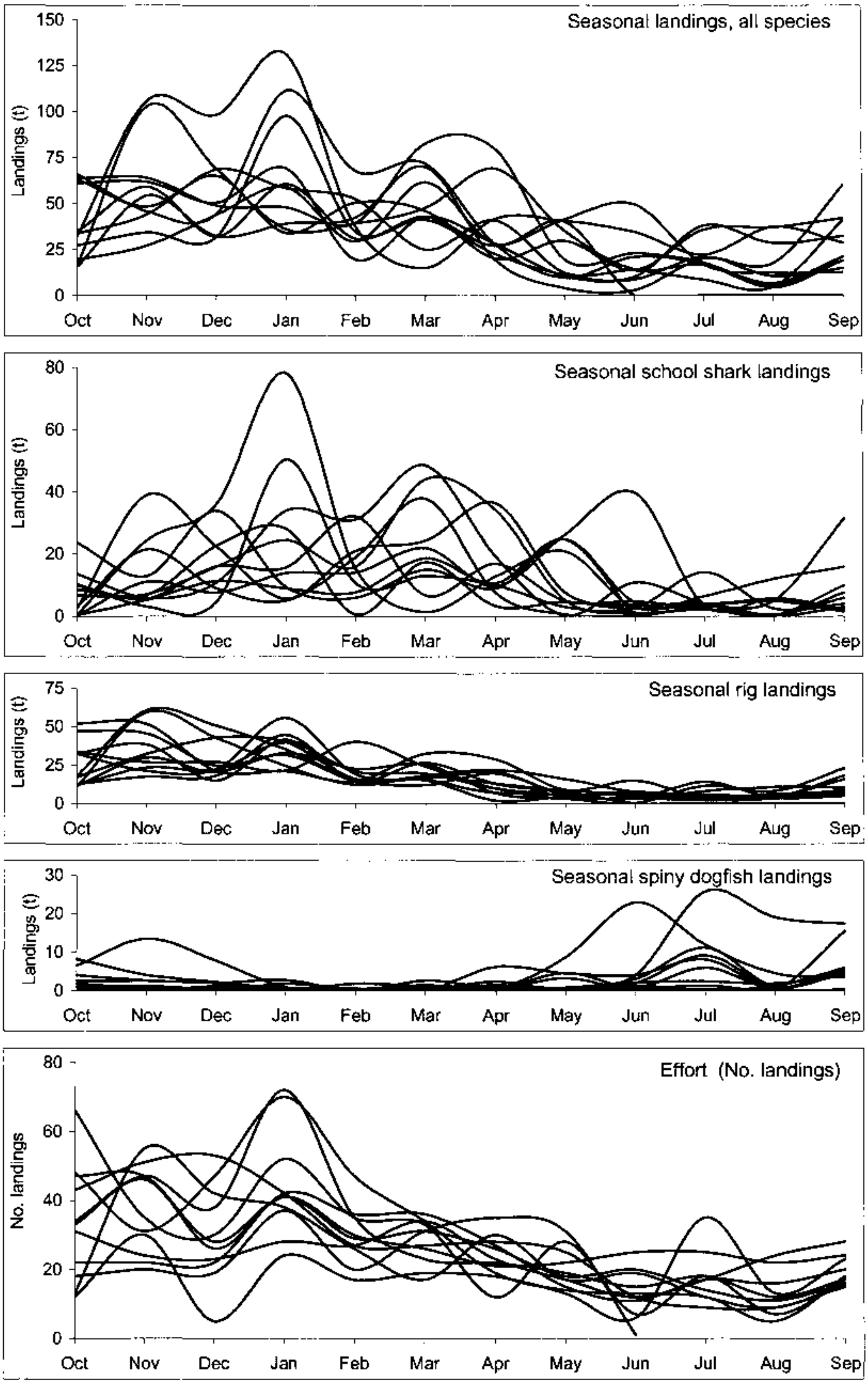

Figure 11b: Seasonal landings (t) and fishing effort for the Nelson Bays and Manawatu setnet fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

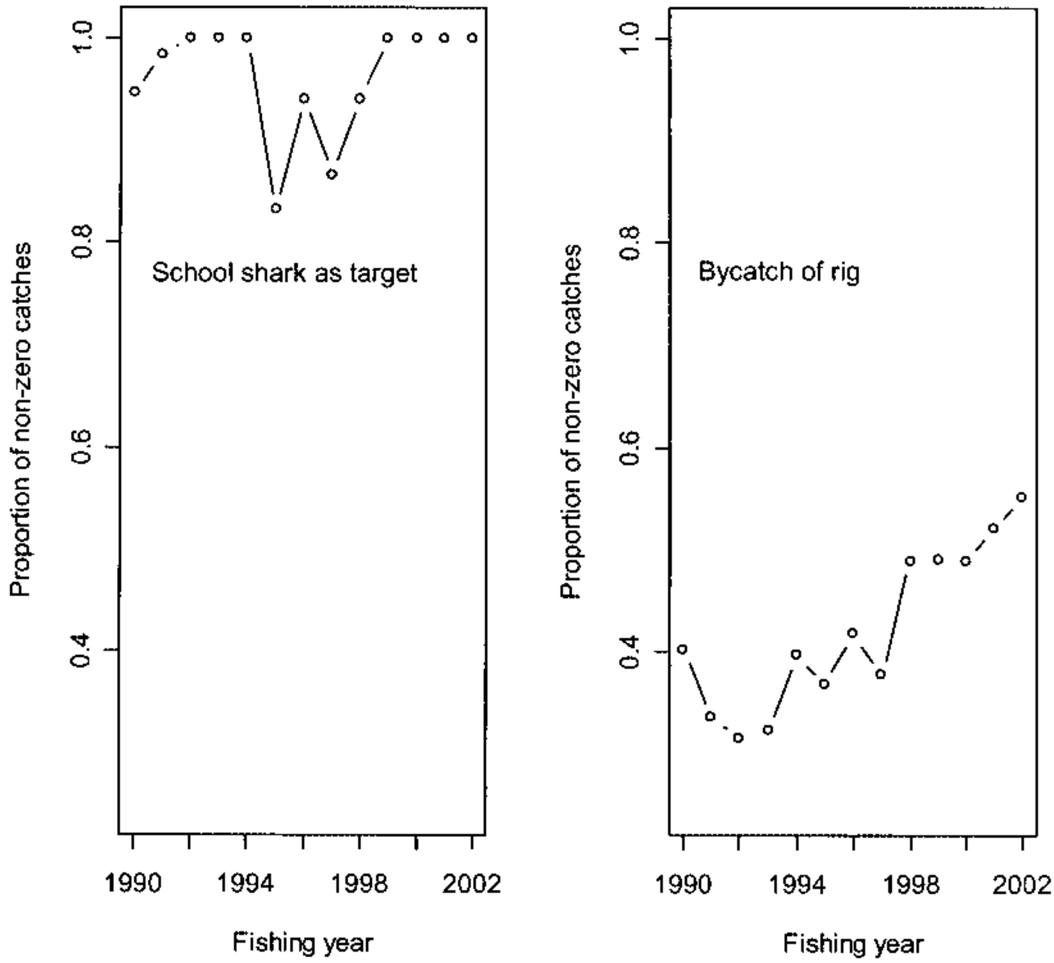

Figure 12: Average proportion of trips catching school shark in the Nelson Bays and Manawatu setnet fishery.

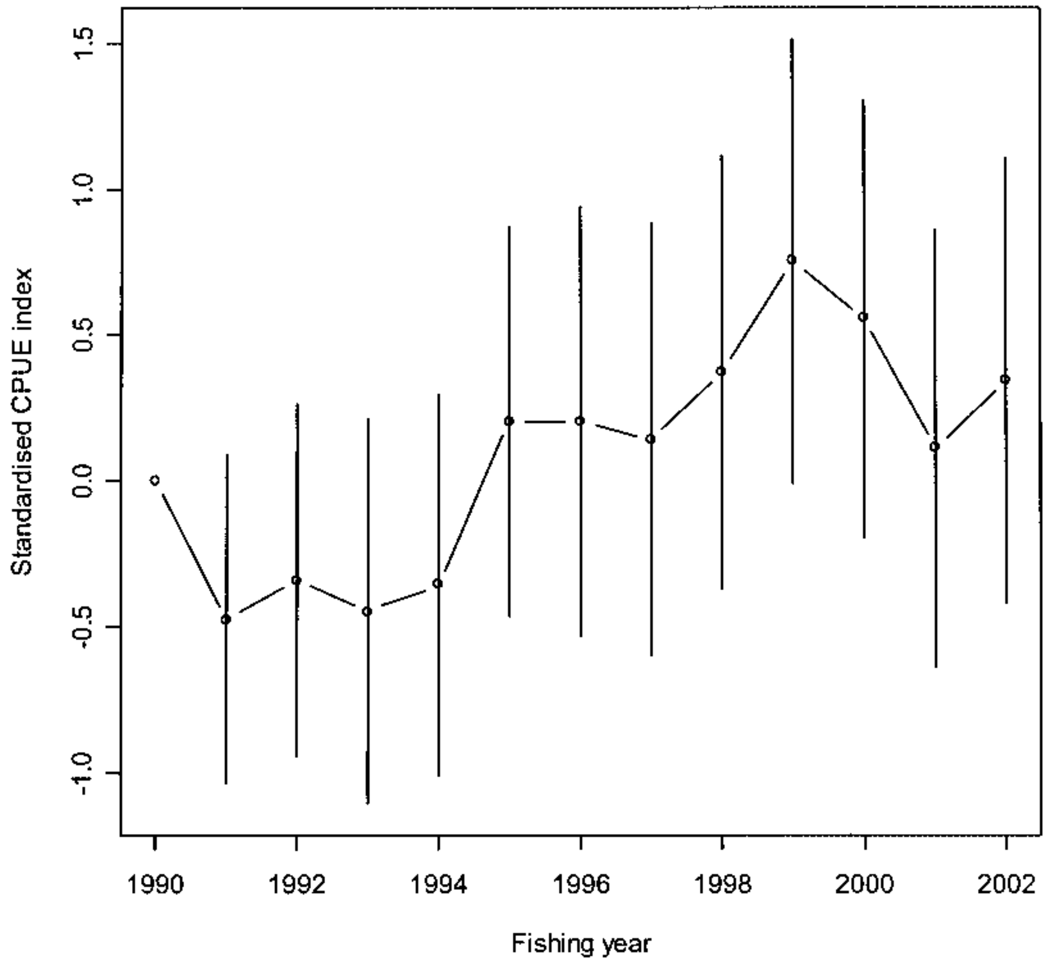

Figure 13: Binomial indices school shark from the Nelson Bays and Manawatu setnet fishery.

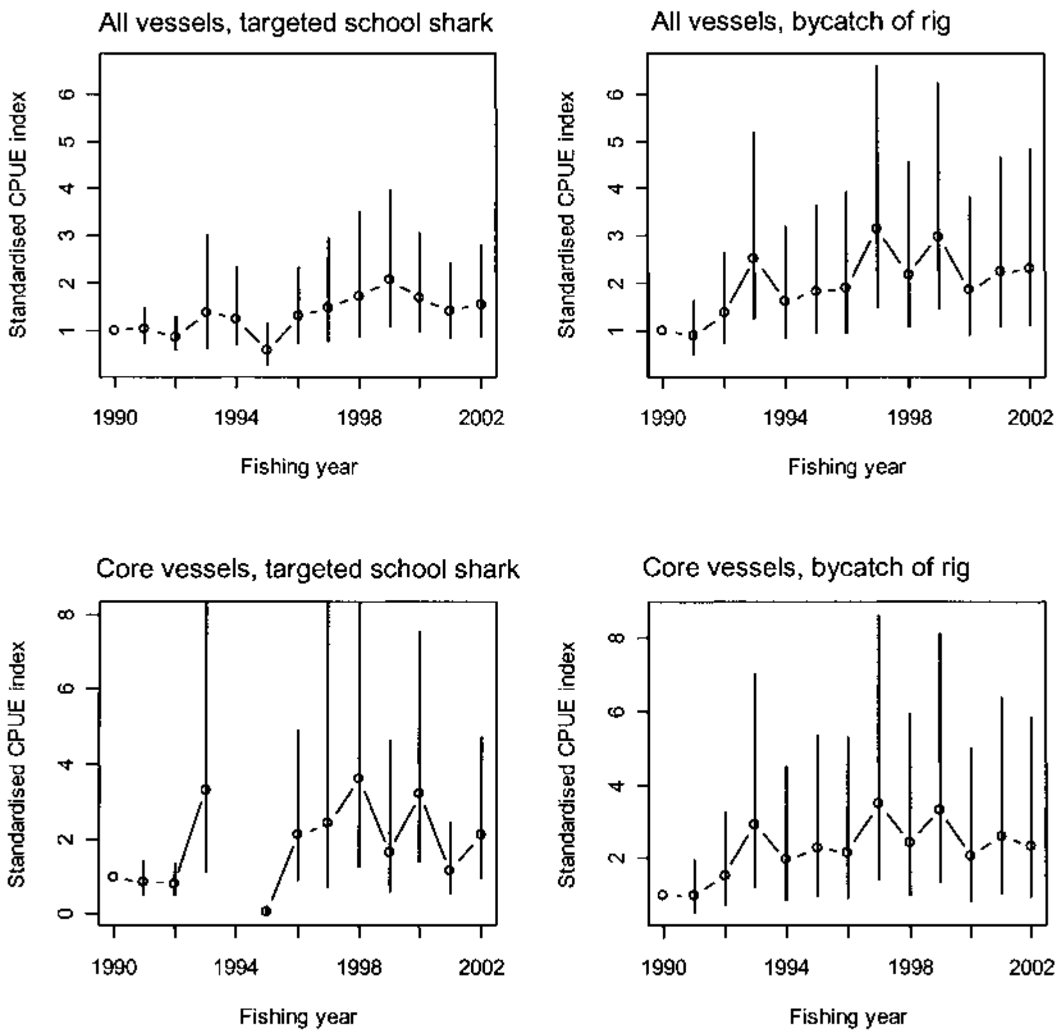

Figure 14: Standardised CPUE indices for the non-zero catch of school shark from the Nelson Bays and Manawatu setnet fishery. Left panels, school shark as target; right panels, rig as target. Top panels, all vessels; lower panels, core vessels. Core vessels are those that fished for more than three years, and for more than three trips within one year.

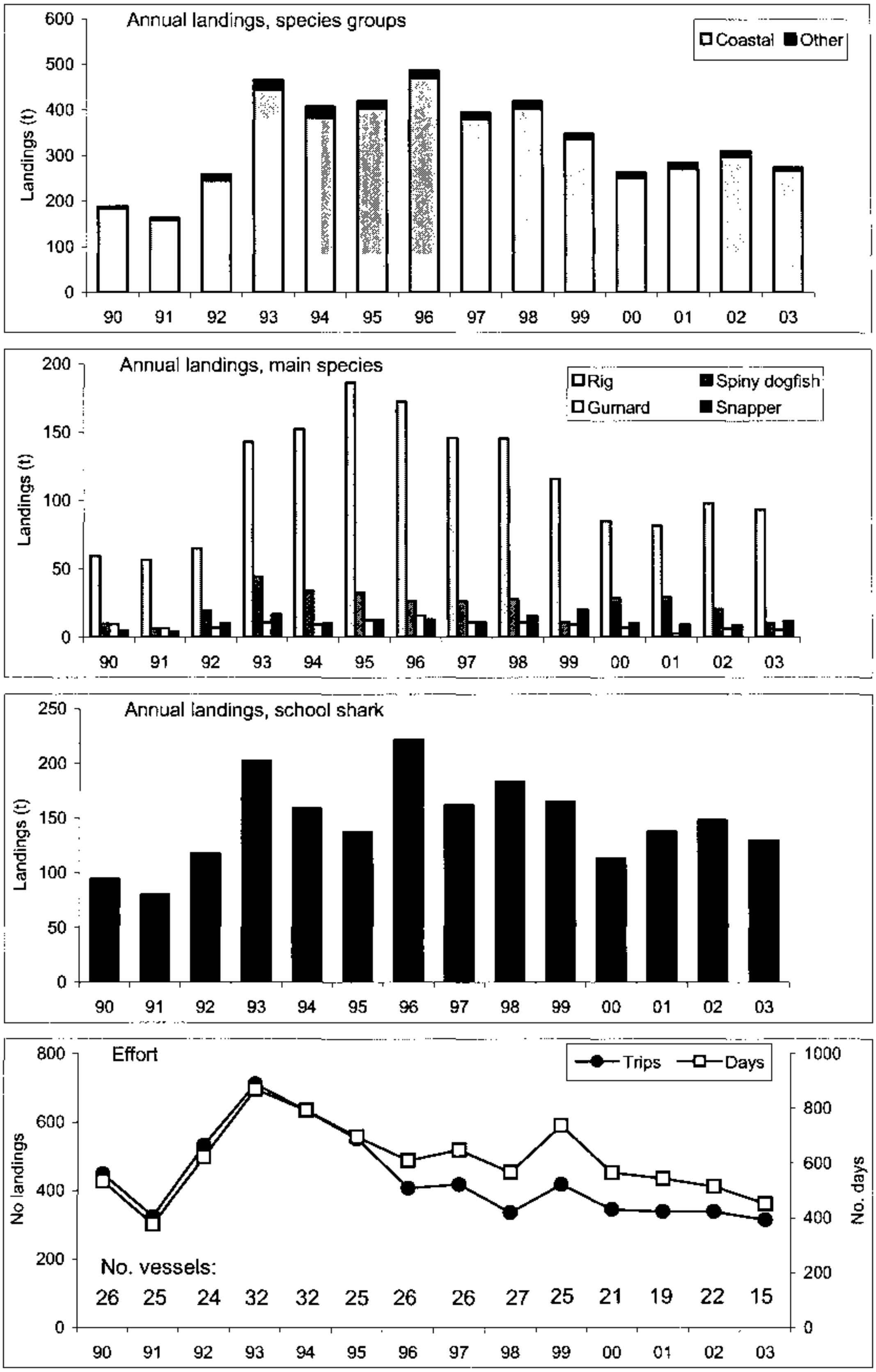

Figure 15a: Annual landings (t) and fishing effort for the western North Island setnet fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

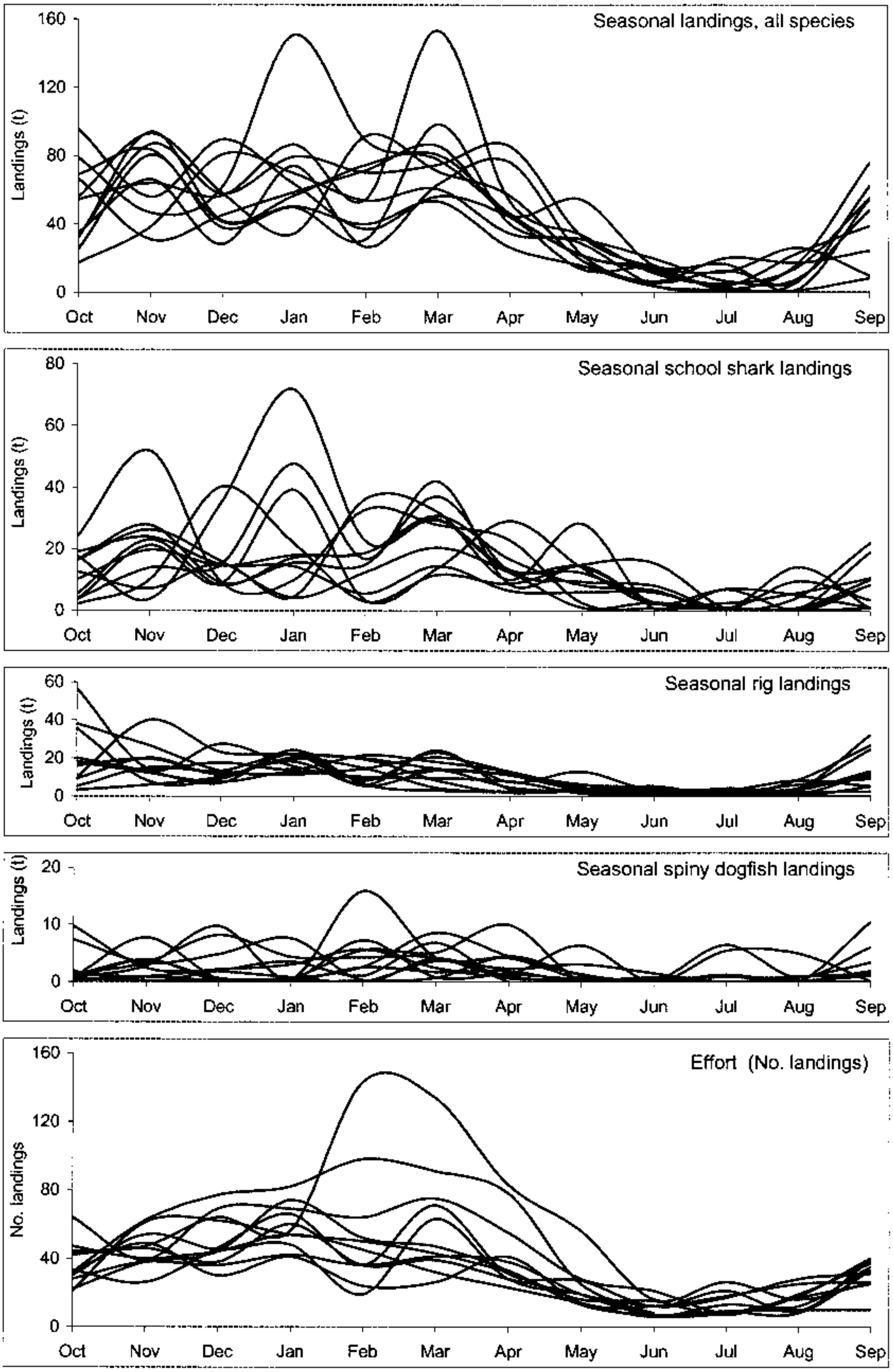

Figure 15b: Seasonal landings (t) and fishing effort for the western North Island setnet fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

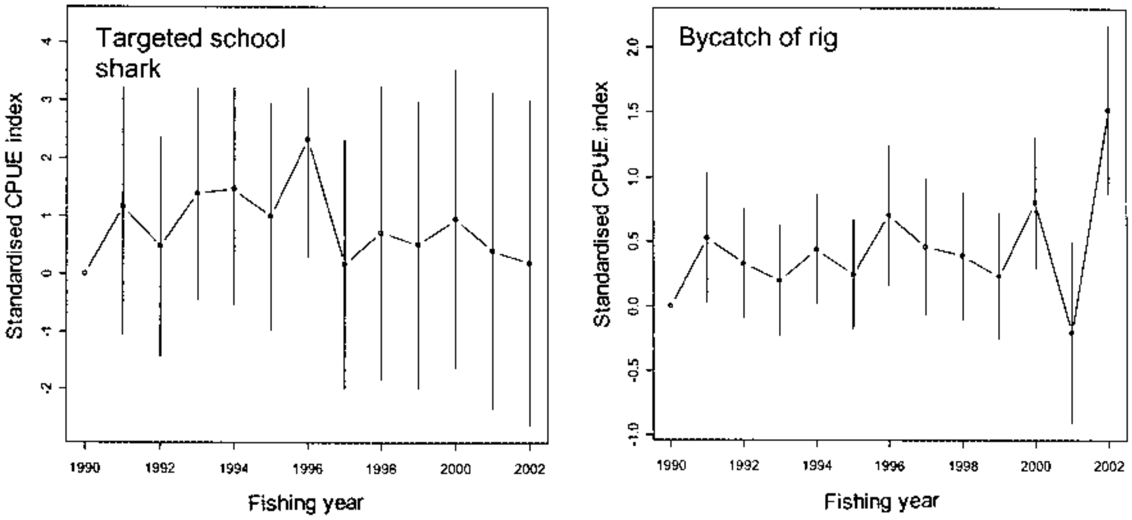

Figure 16: Binomial indices for school shark from the western North Island setnet fishery.

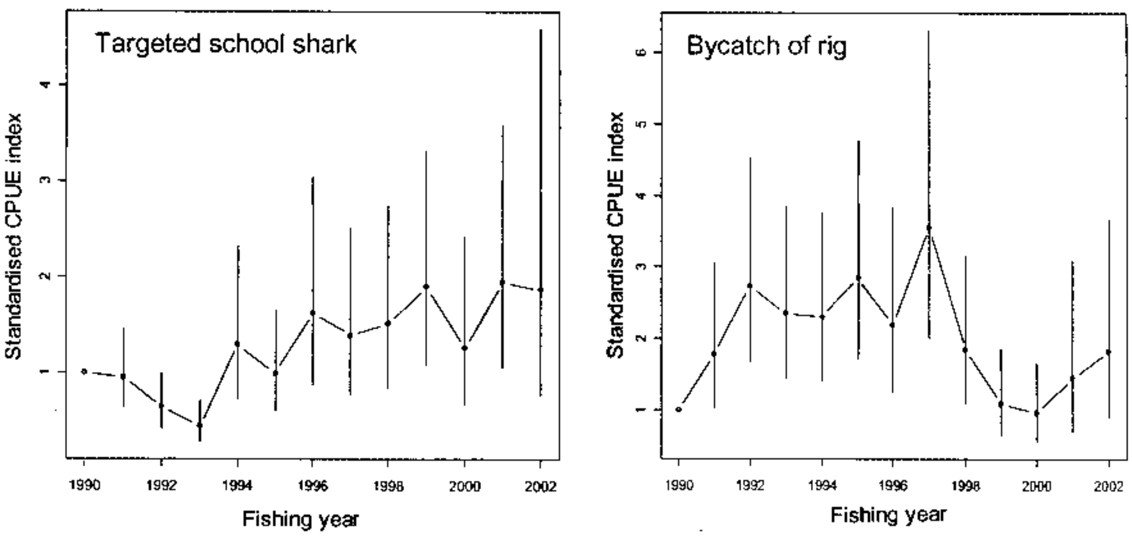

Figure 17: Non-zero CPUE indices for school shark from the western North Island setnet fishery.

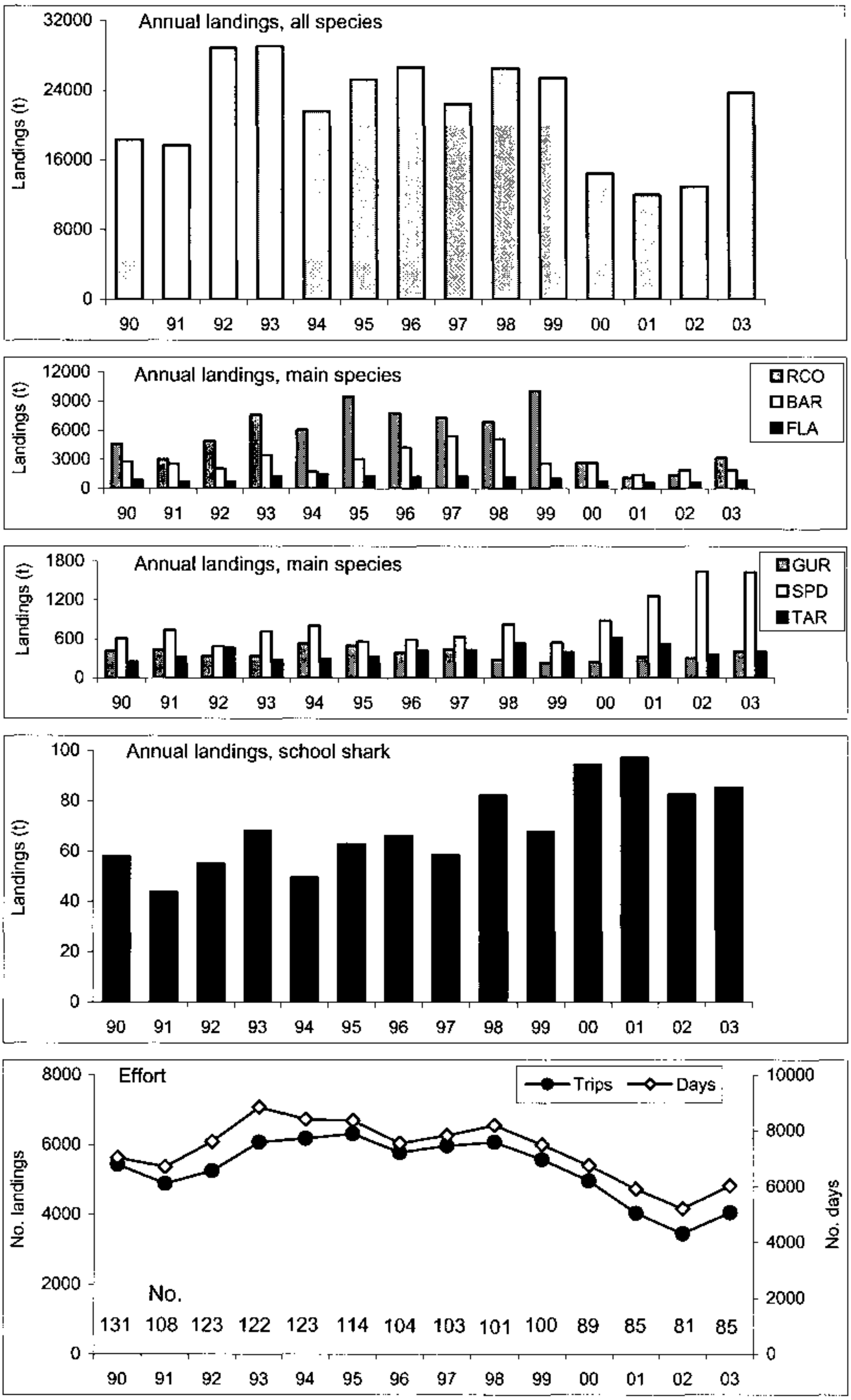

Figure 18a: Annual landings (t) and fishing effort for the eastern South Island trawl fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

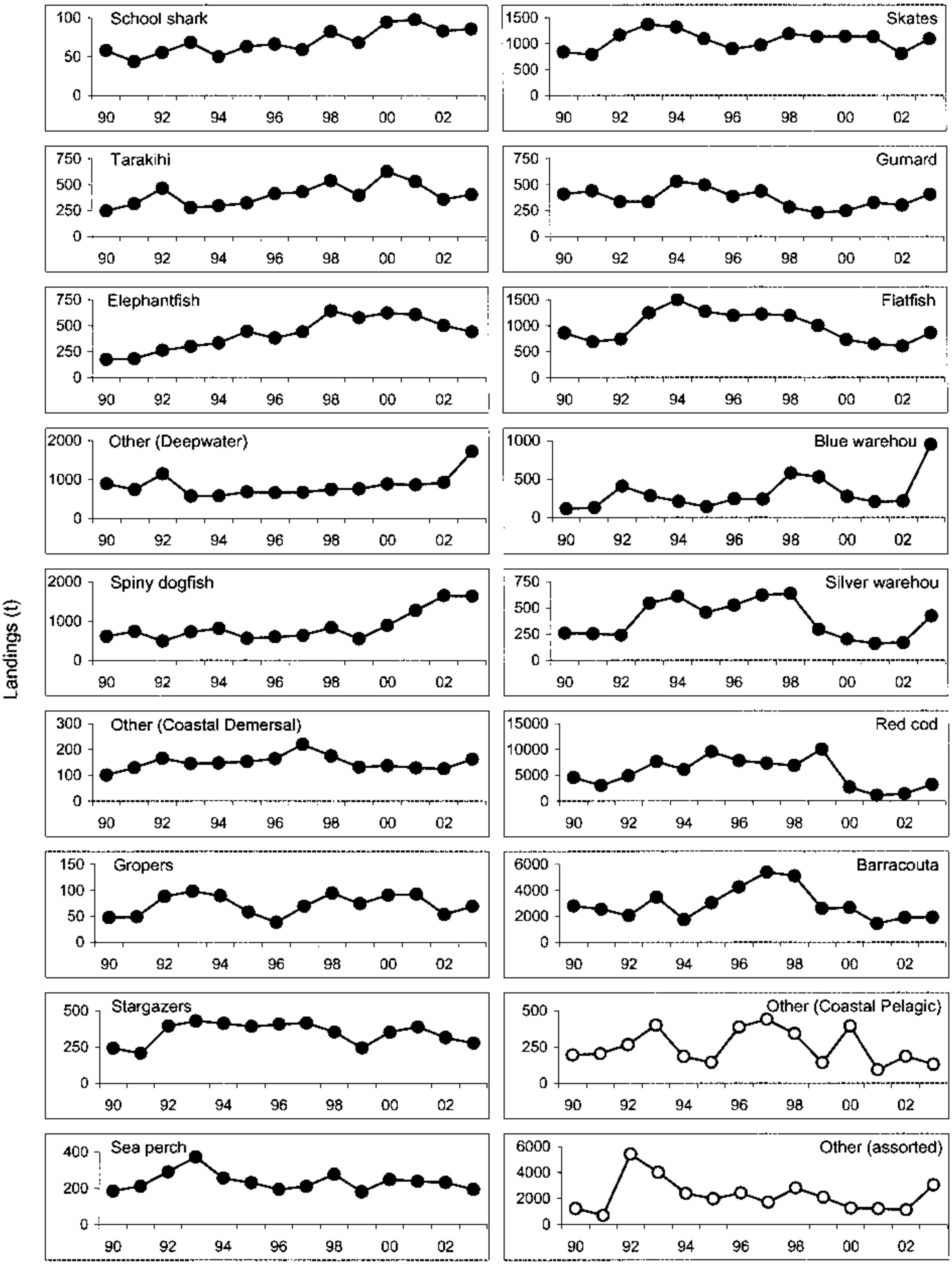

Figure 18b: Annual landings of the main species and species groups in the eastern South Island trawl fishery, fishing years 1989–90 to 2002–03. Arrangement from top left is by similarity of landing trend. Solid circles, main species or groups; open circles, two groups of assorted species.

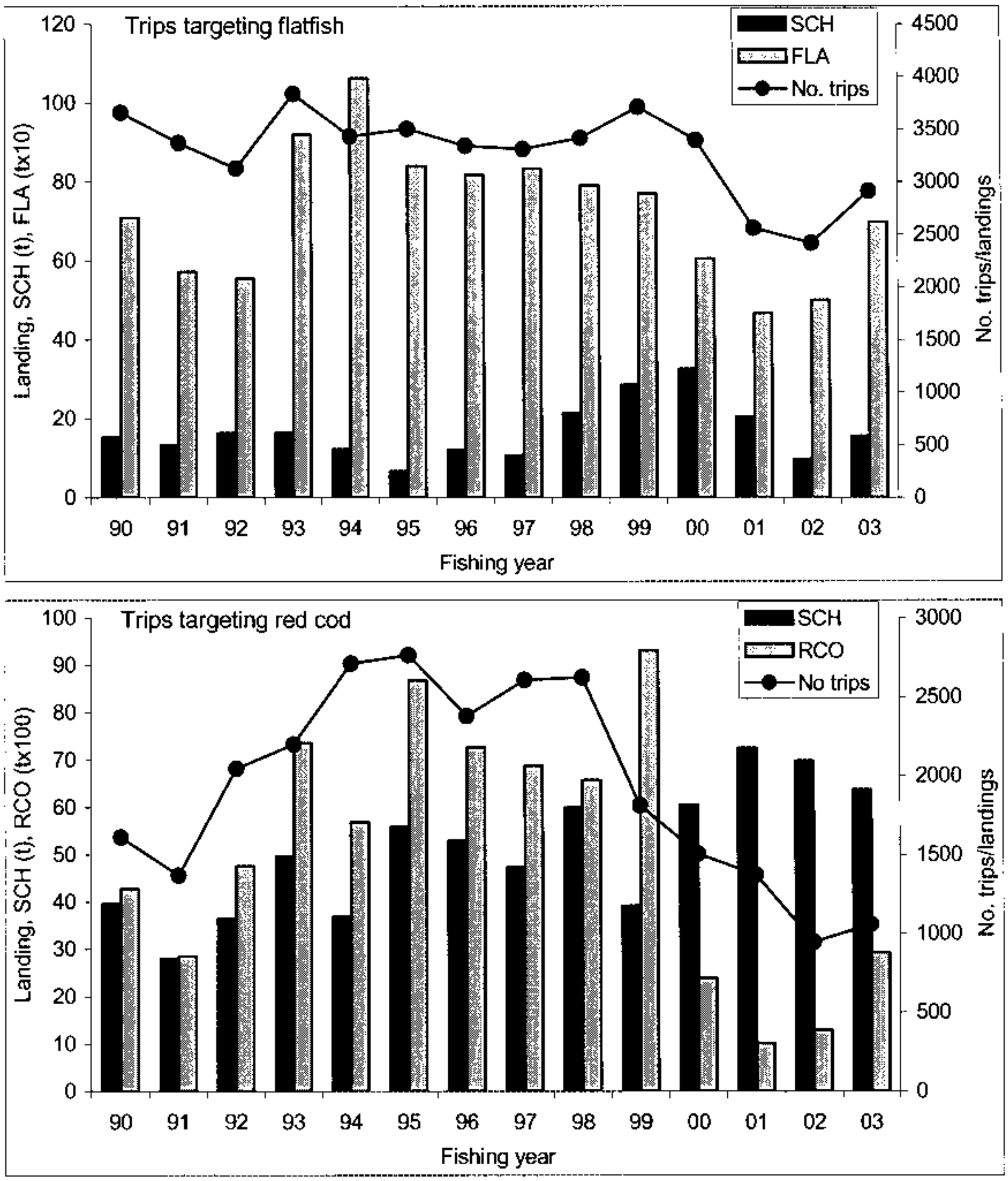

Figure 18c: Landings (t) of the target species and associated school shark in the two main targeted components of the eastern South Island trawl fishery (flatfish and red cod), and the number of trips predominantly targeting each of these species.

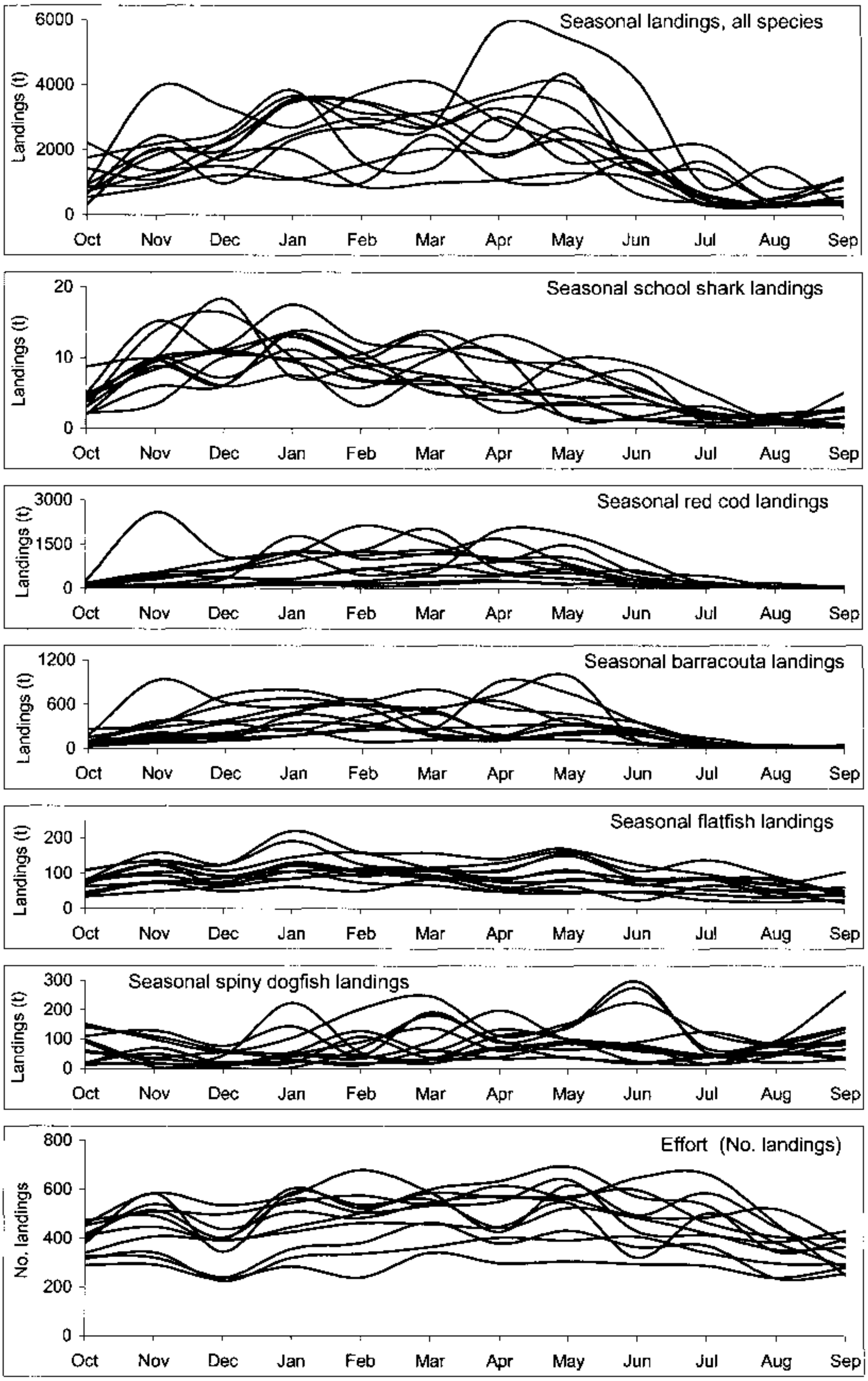

Figure 18d: Seasonal landings (t) and fishing effort for the eastern South Island trawl fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

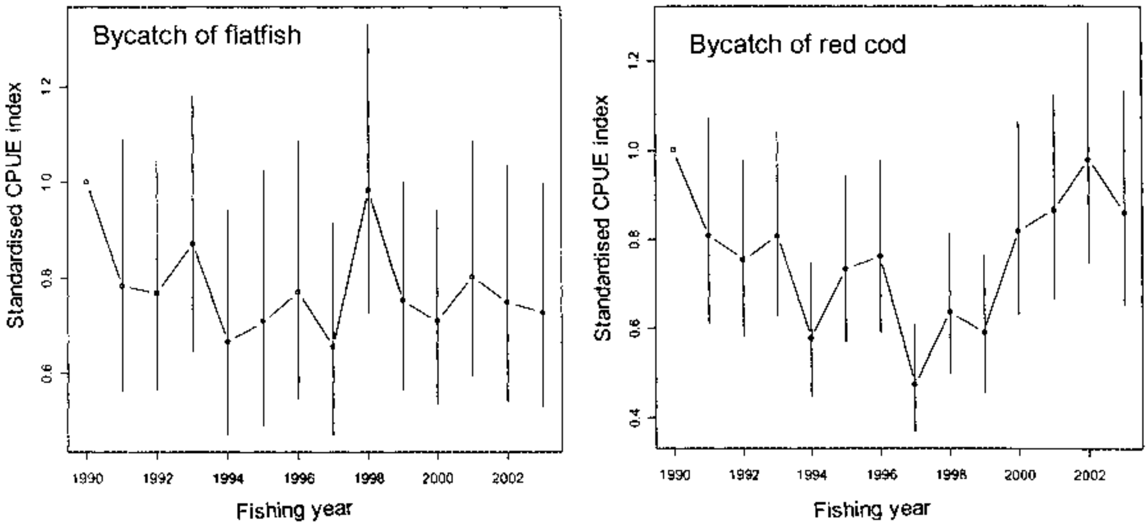

Figure 19: Log-normal indices for school shark from the eastern South Island trawl fishery.

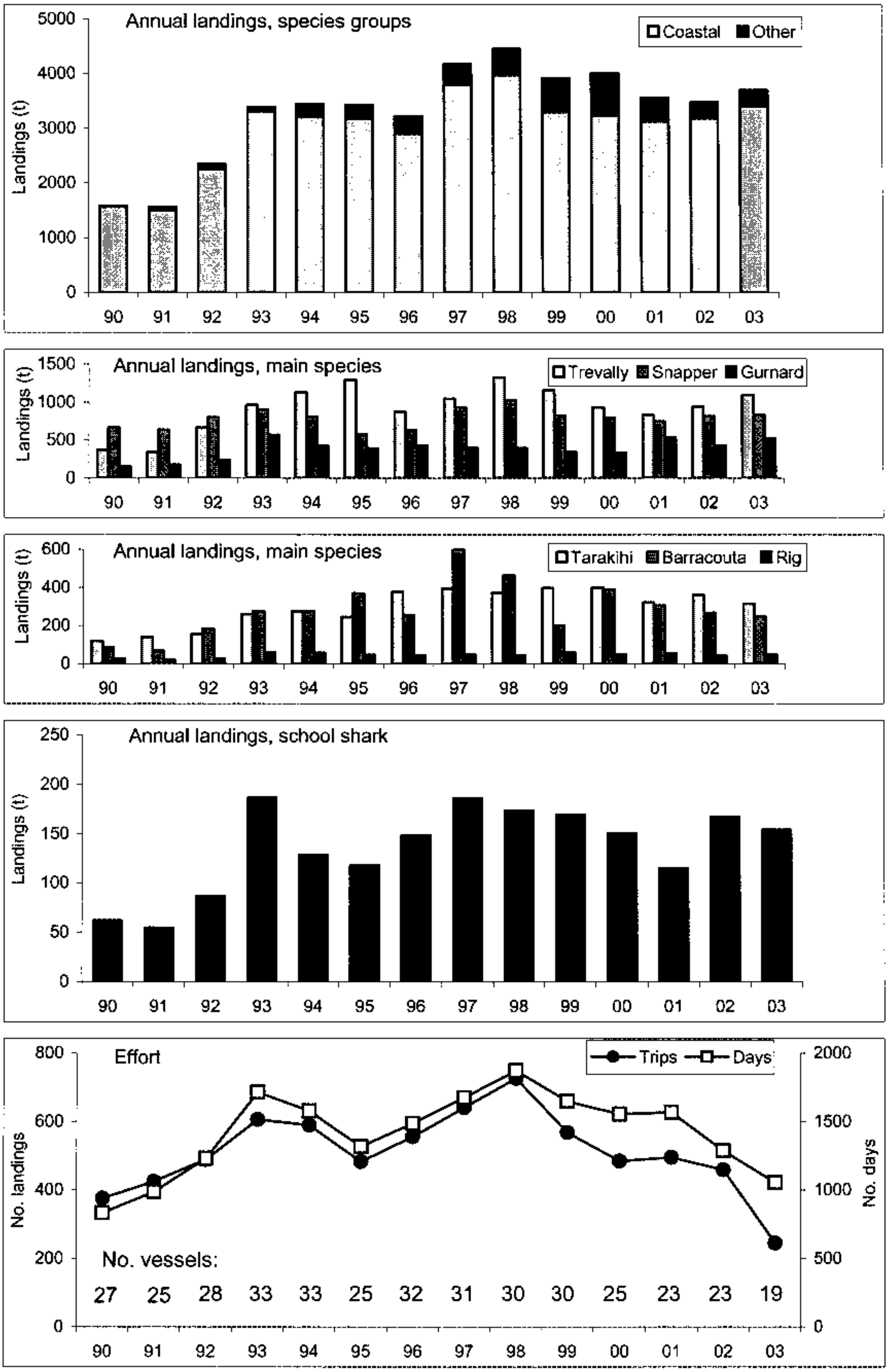

Figure 20a: Annual landings (t) and fishing effort for the northwest North Island trawl fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken from selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

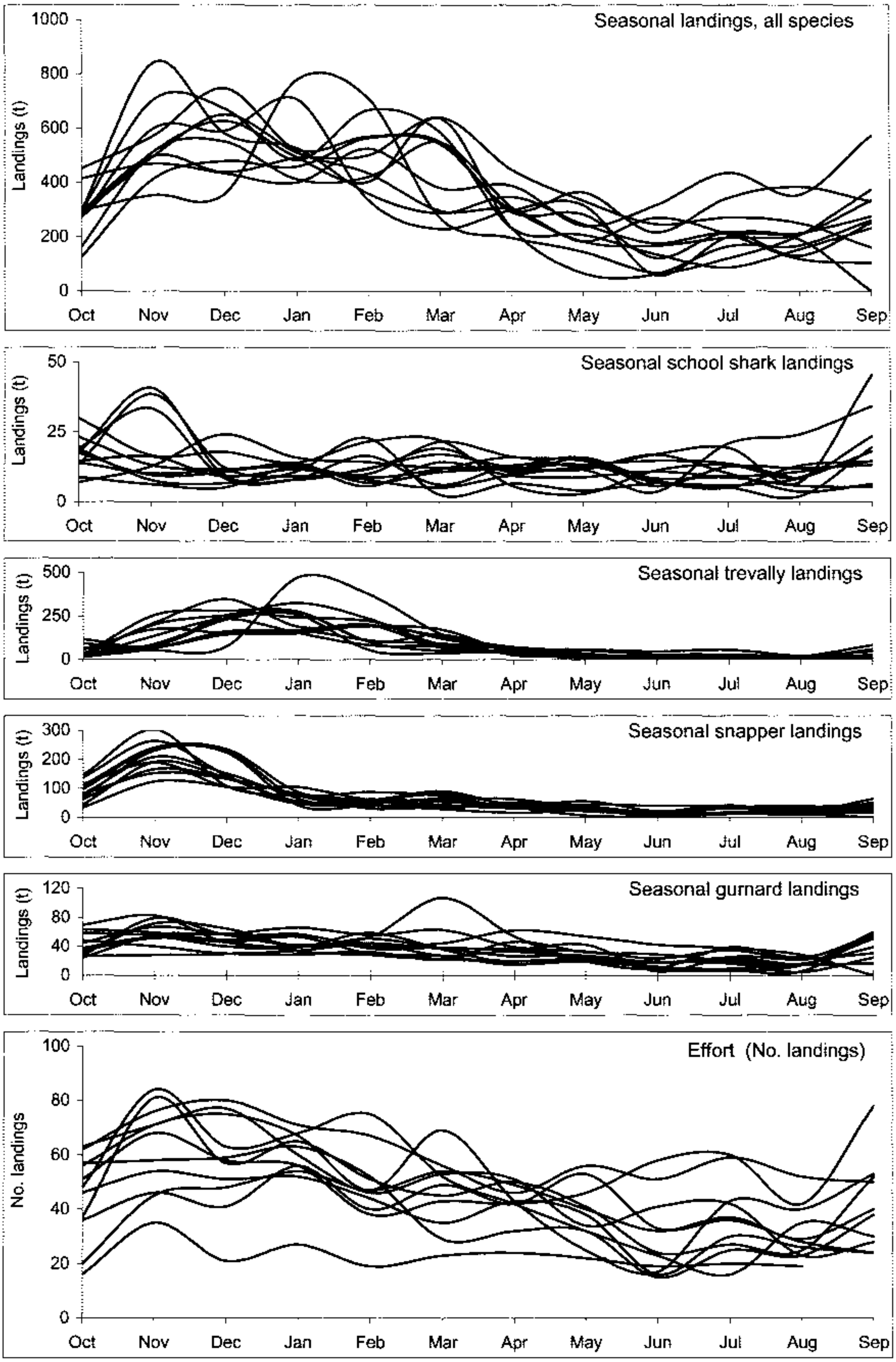

Figure 20b: Seasonal landings (t) and fishing effort for the northwest North Island trawl fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

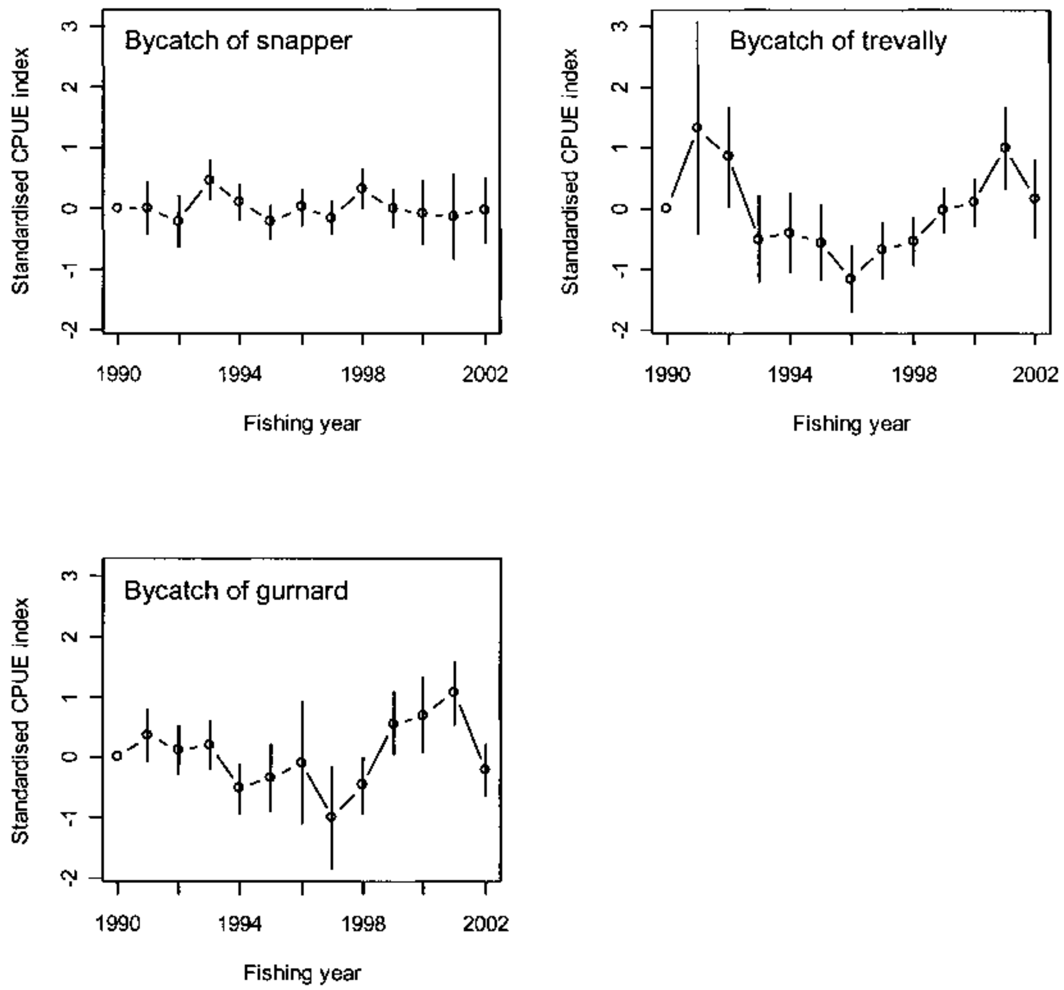

Figure 21: Binomial indices for school shark from the northwest North Island trawl fishery.

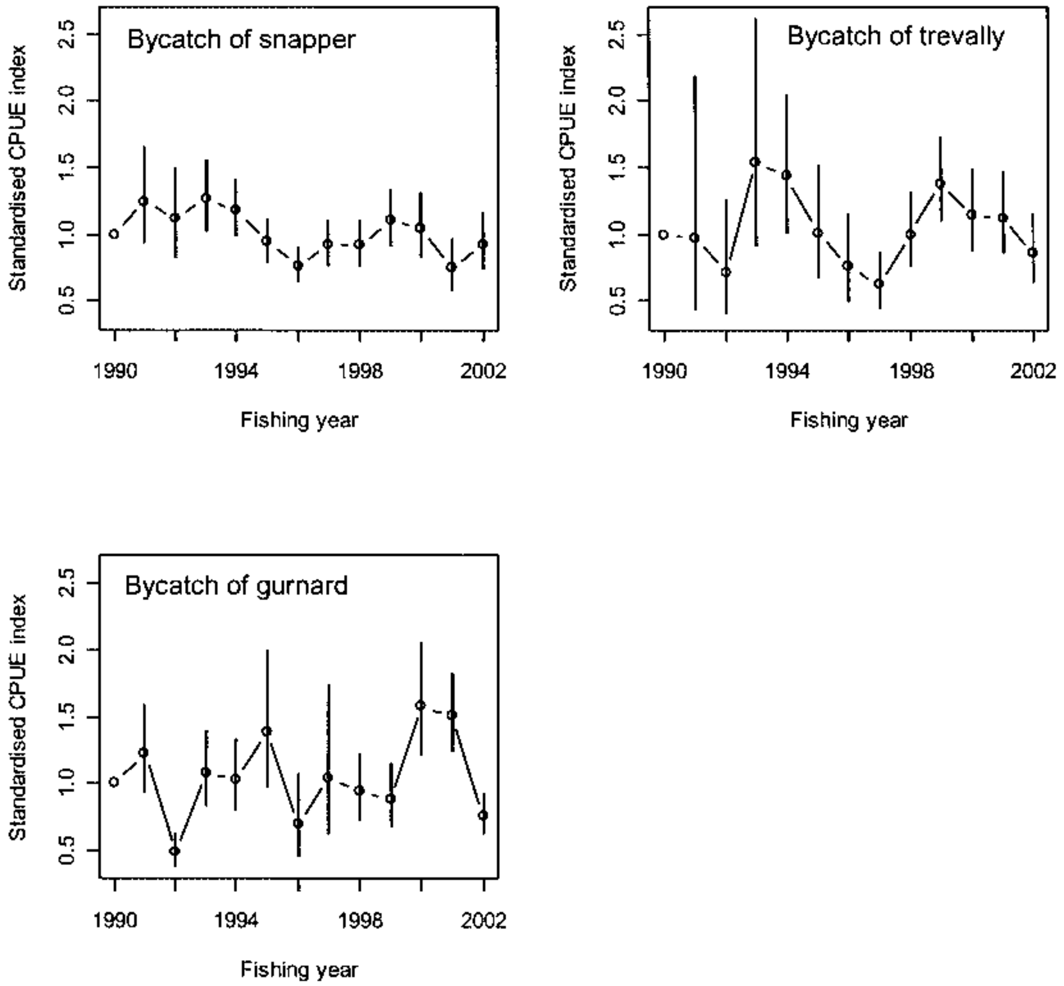

Figure 22. Standardised CPUE indices for the non-zero catches of school shark from the northwest North Island trawl fishery.

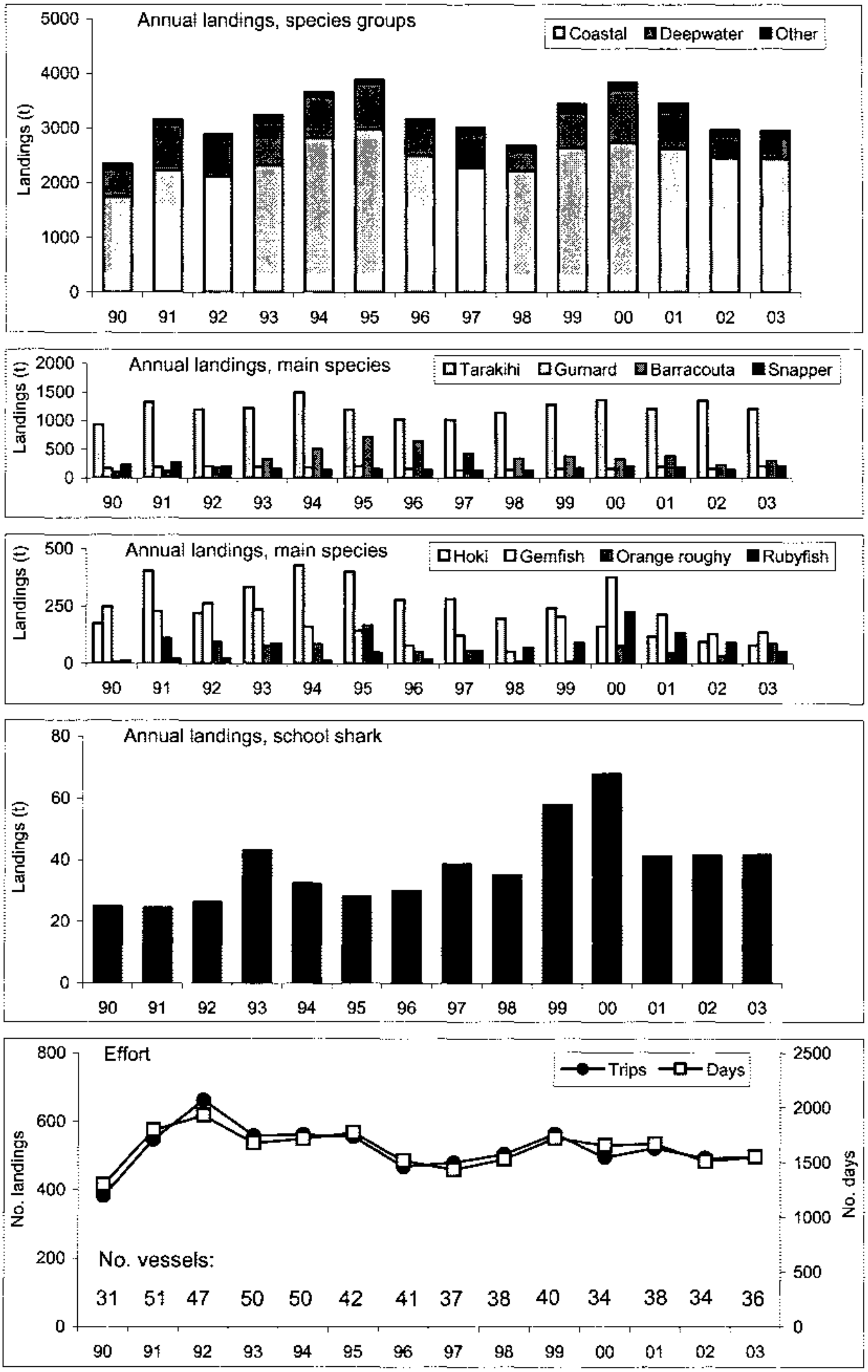

Figure 23a: Annual landings (t) and fishing effort for the eastern North Island trawl fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

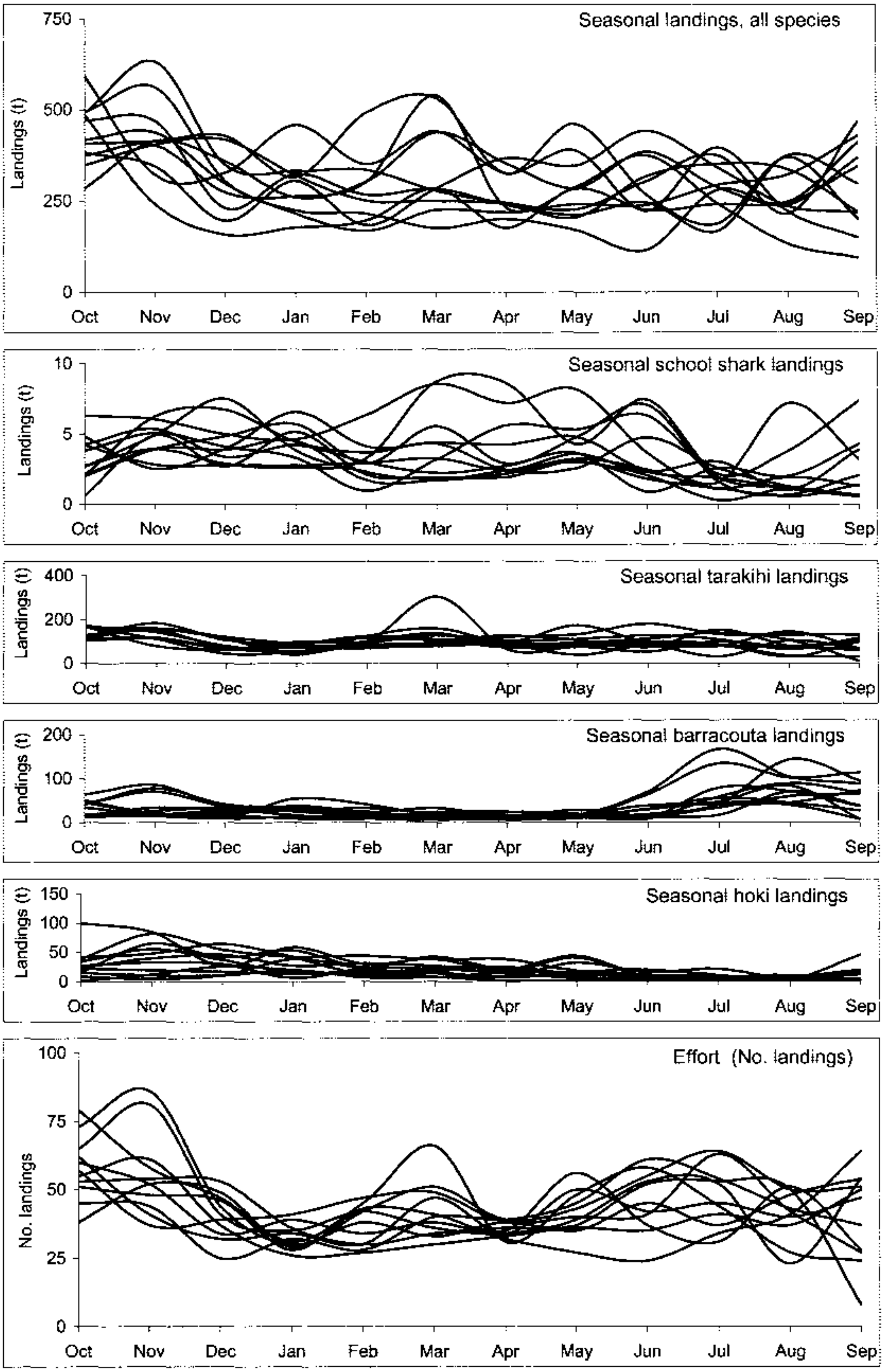

Figure 23b: Seasonal landings (t) and fishing effort for the eastern North Island trawl fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

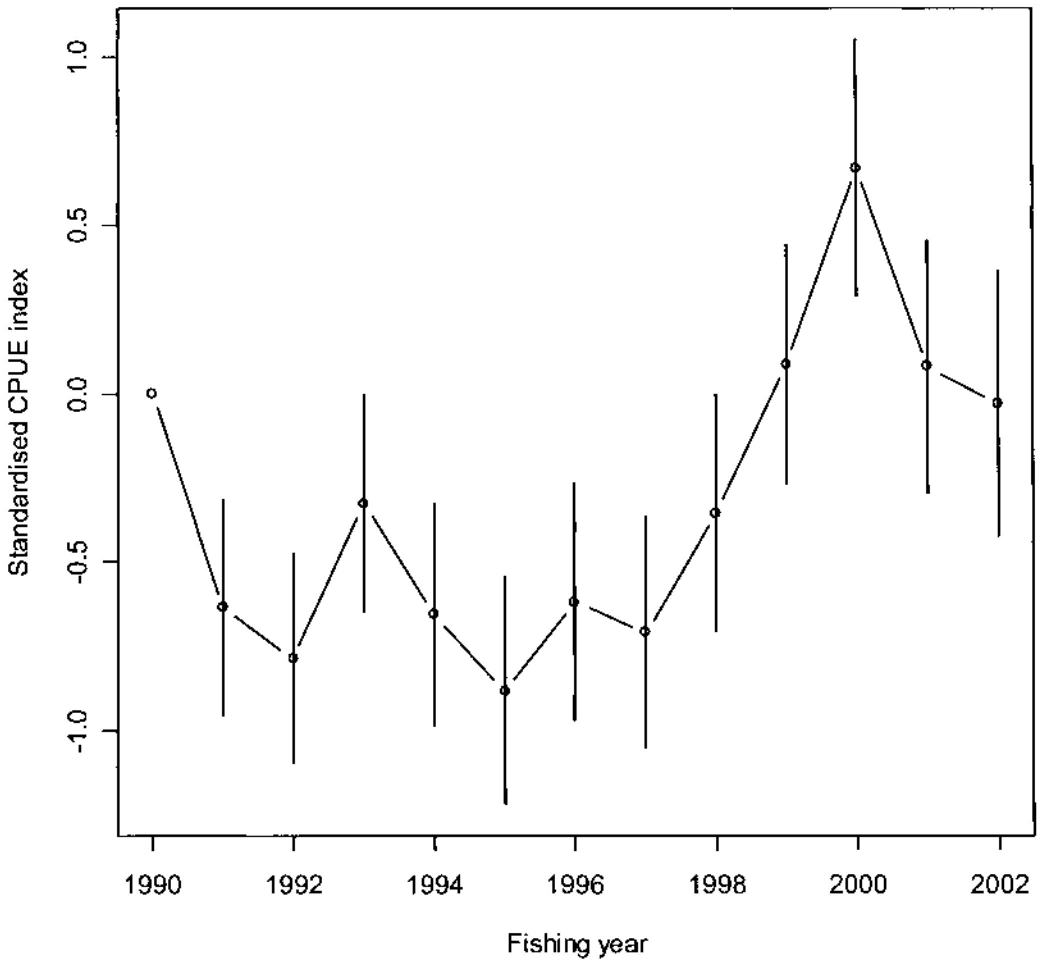

Figure 24: Binomial indices for school shark from the eastern North Island trawl fishery.

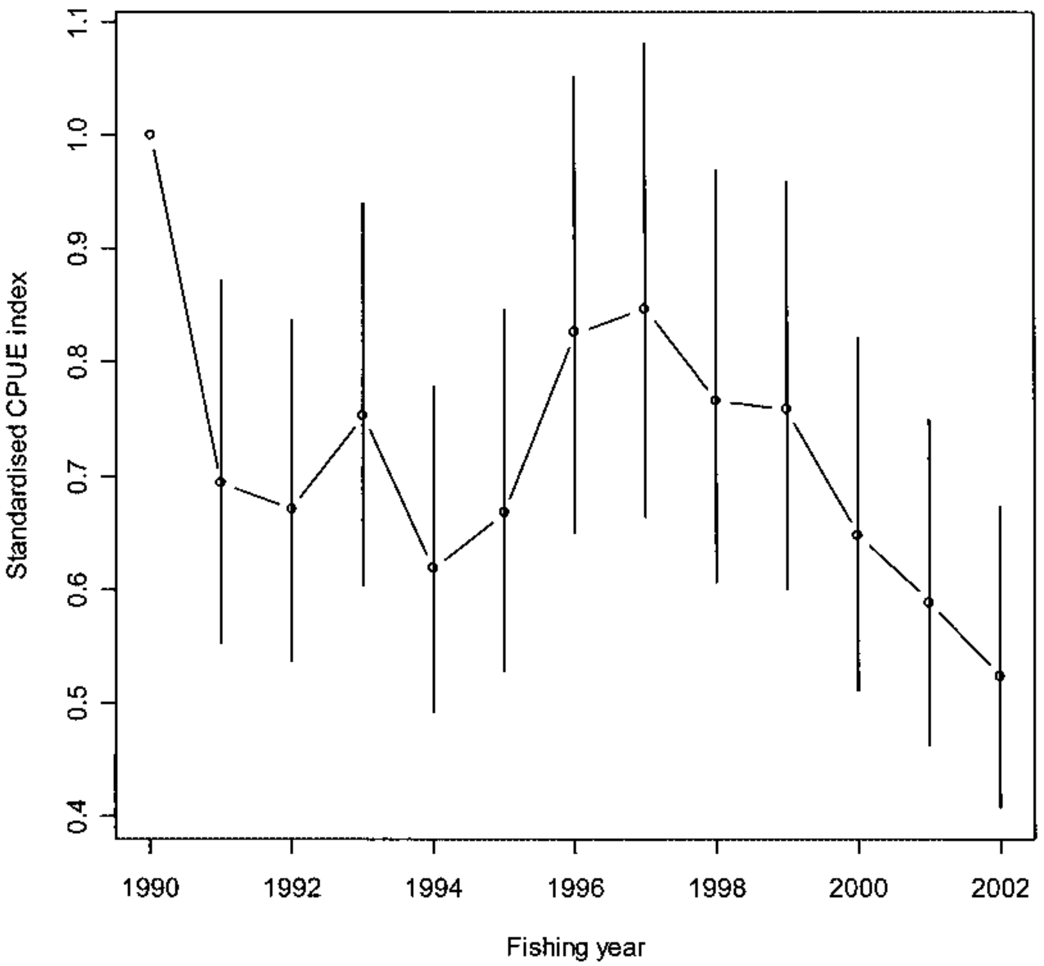

Figure 25: Non-zero indices for school shark from the eastern North Island trawl fishery.

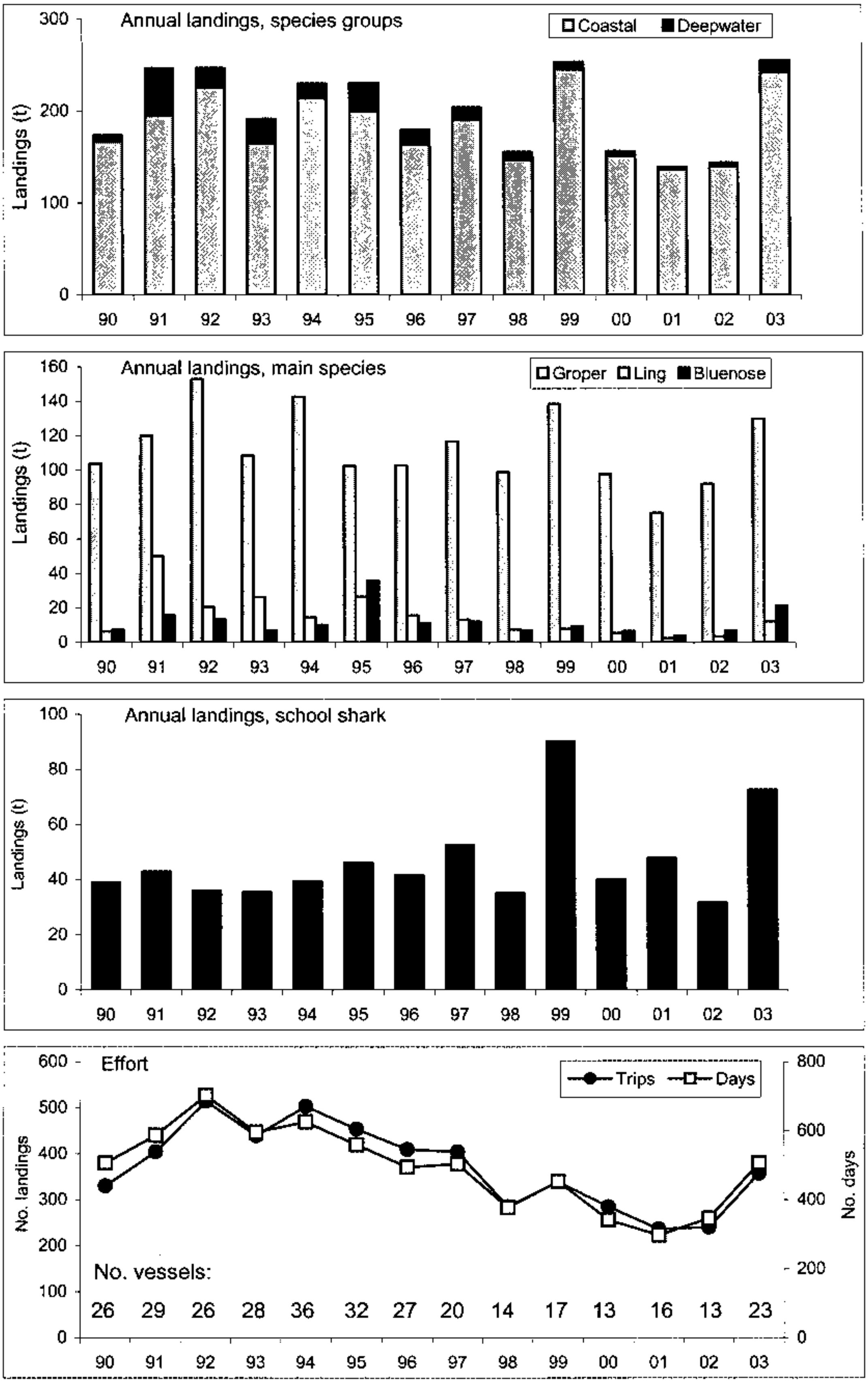

Figure 26a: Annual landings (t) and fishing effort for the Cook Strait dropline fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken from selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

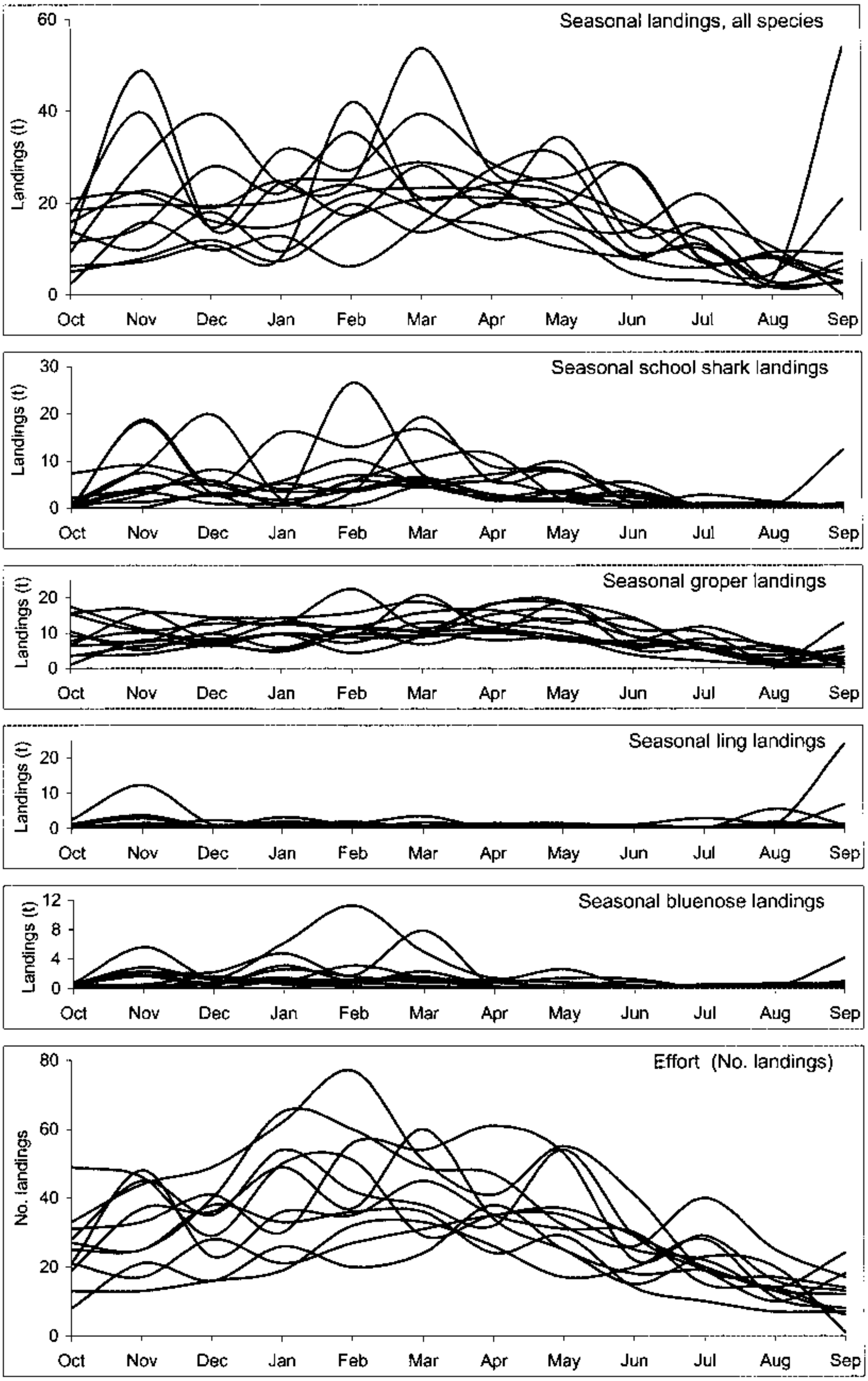

Figure 26b: Seasonal landings (t) and fishing effort for the Cook Strait dropline fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

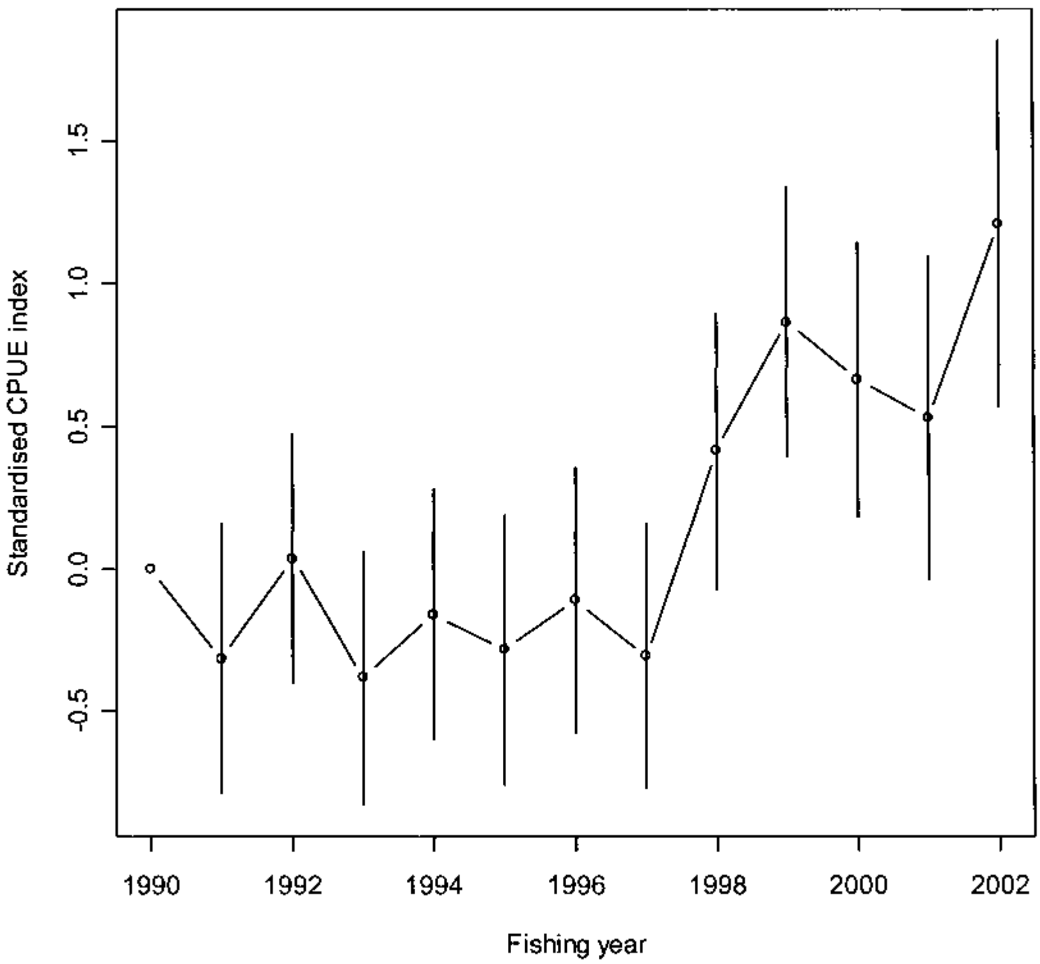

Figure 27: Binomial indices for school shark from the Cook Strait dropline fishery.

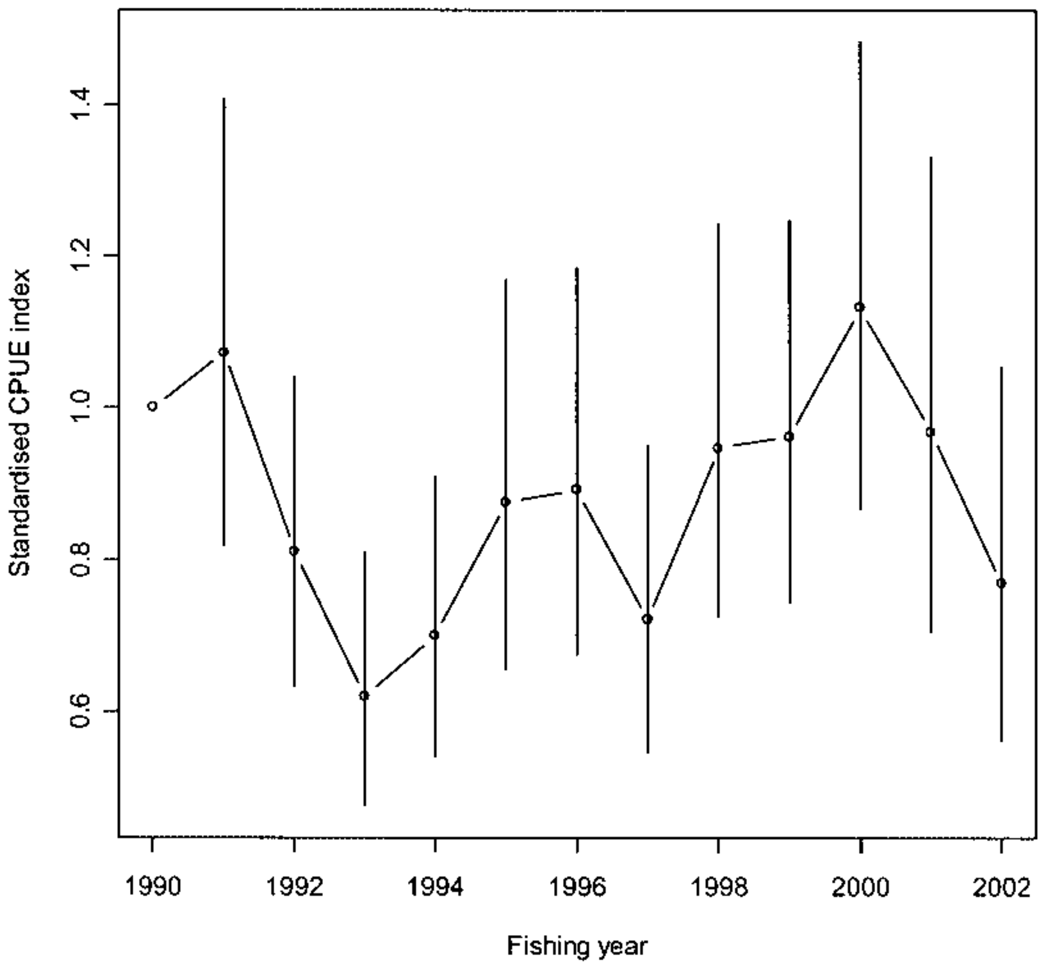

Figure 28: Standardised CPUE indices for school shark from the Cook Strait dropline fishery.

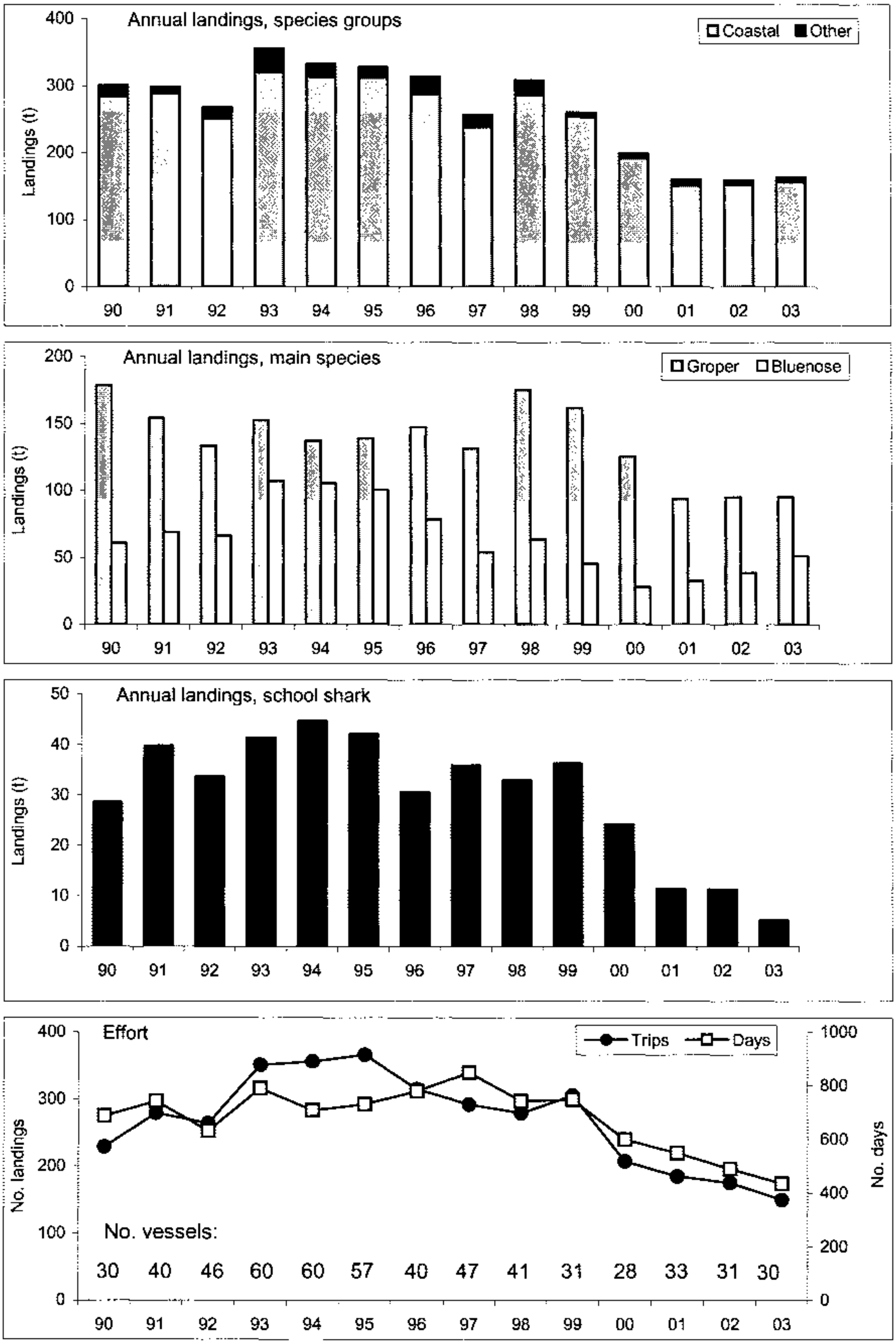

Figure 29a: Annual landings (t) and fishing effort for the northeast North Island dropline fishery, fishing years 1989–90 to 2002–03. Landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

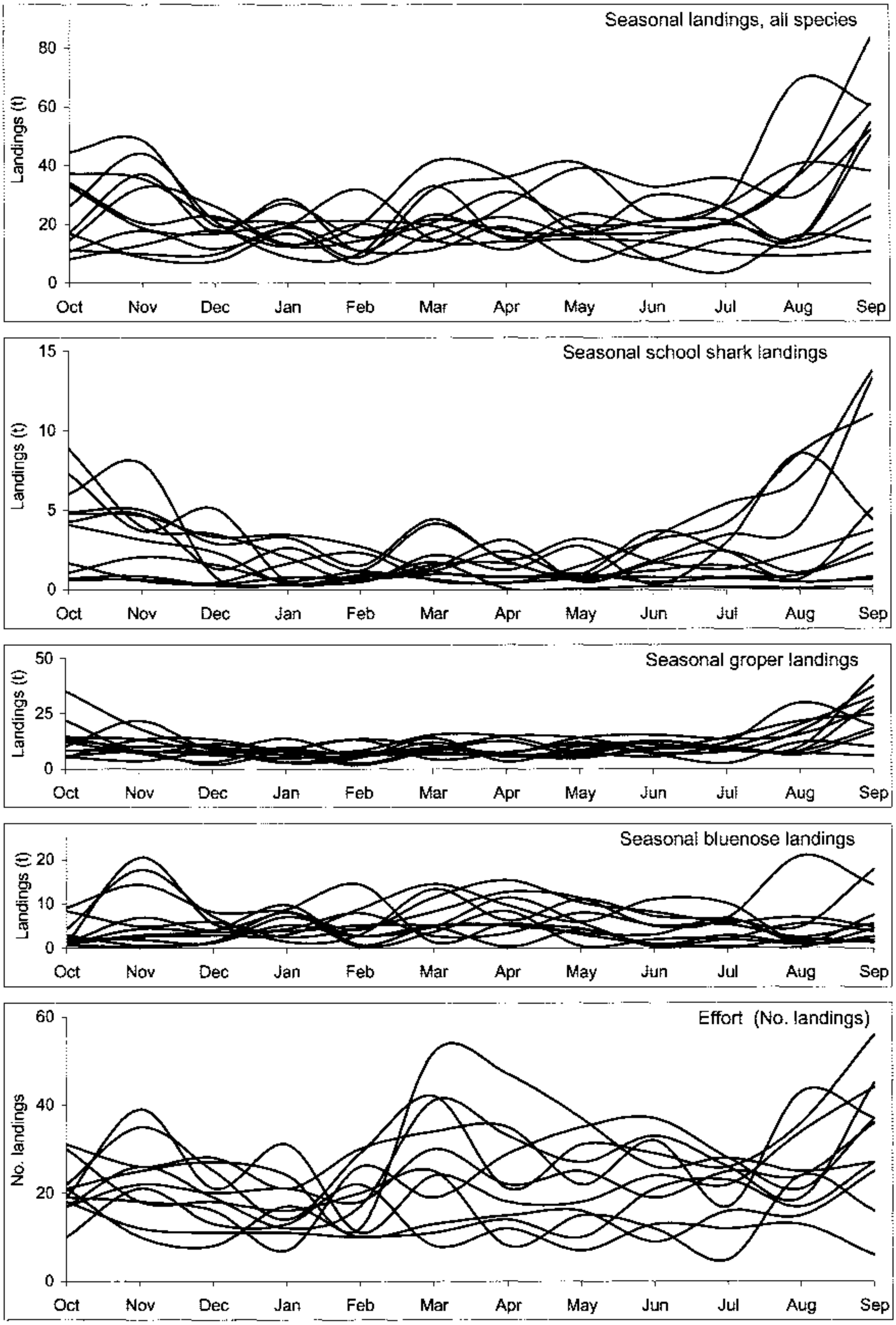

Figure 29b: Seasonal landings (t) and fishing effort for the northeast North Island dropline fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

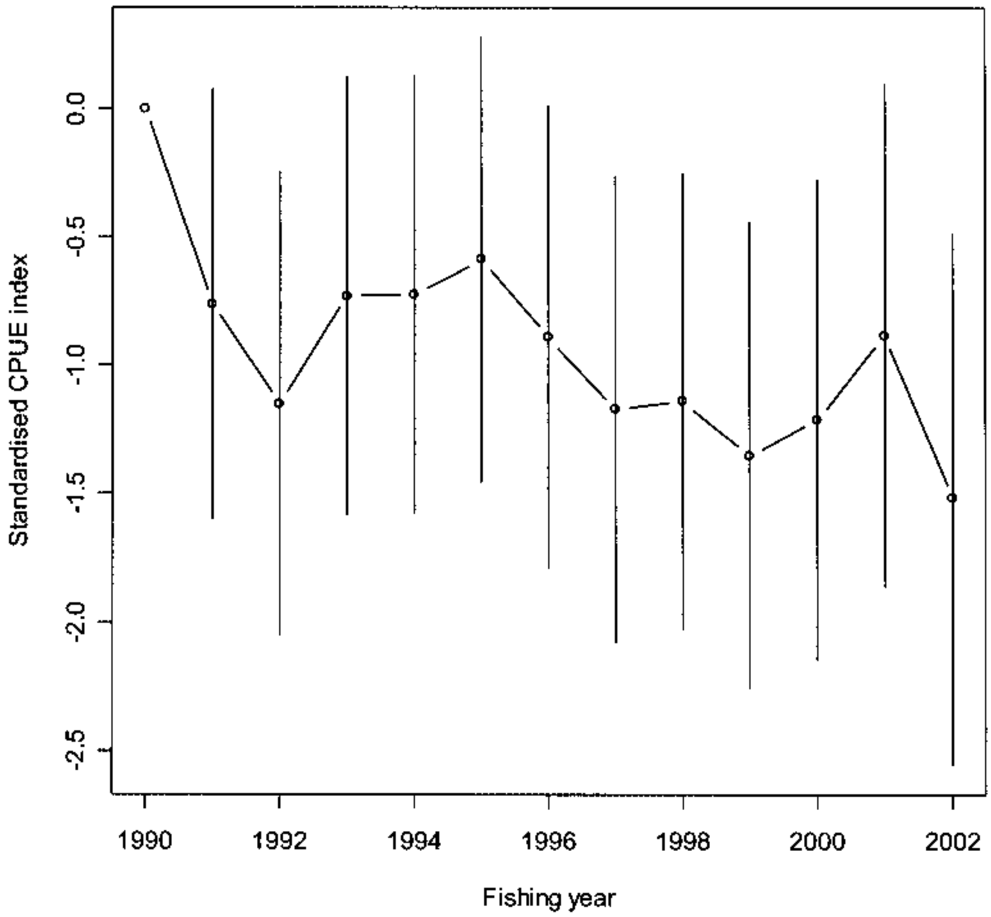

Figure 30: Binomial index for school shark from the northeast North Island dropline fishery.

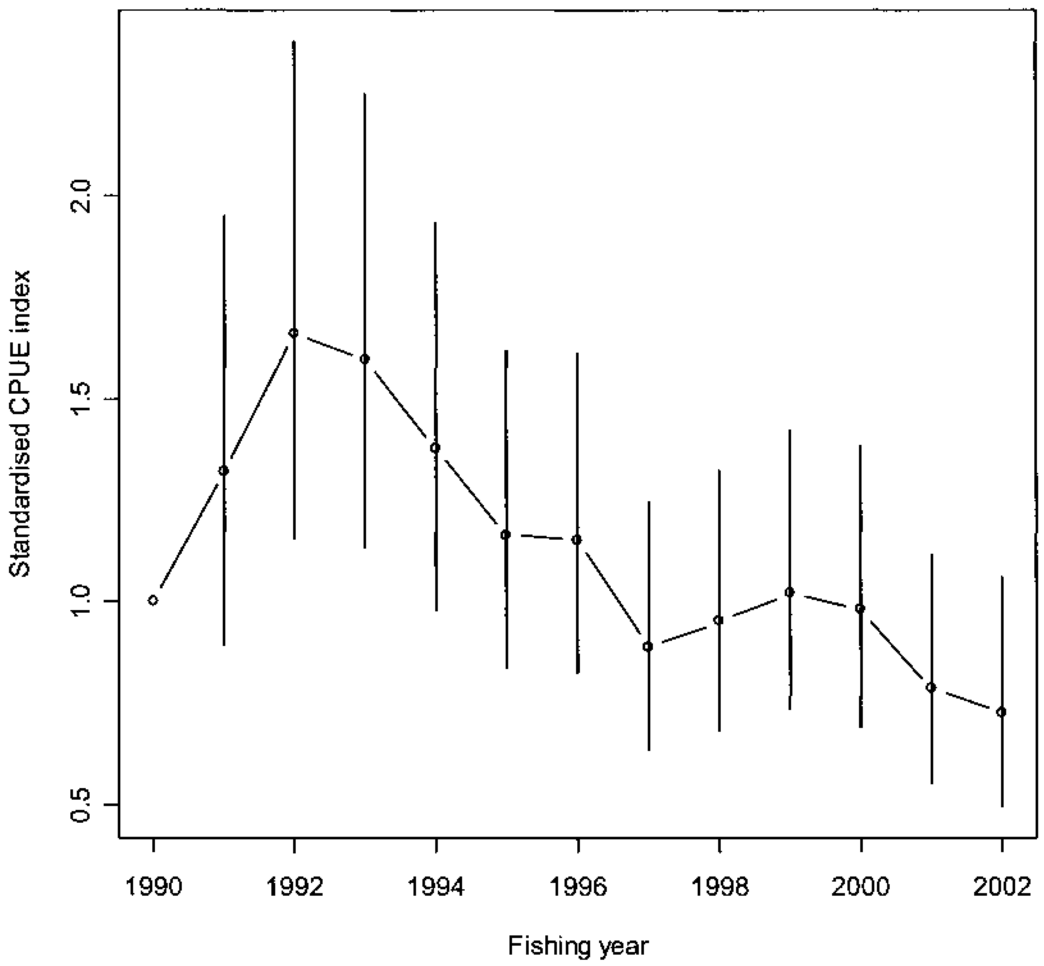

Figure 31: Standardised non-zero CPUE indices for school shark from the northeast North Island dropline fishery.

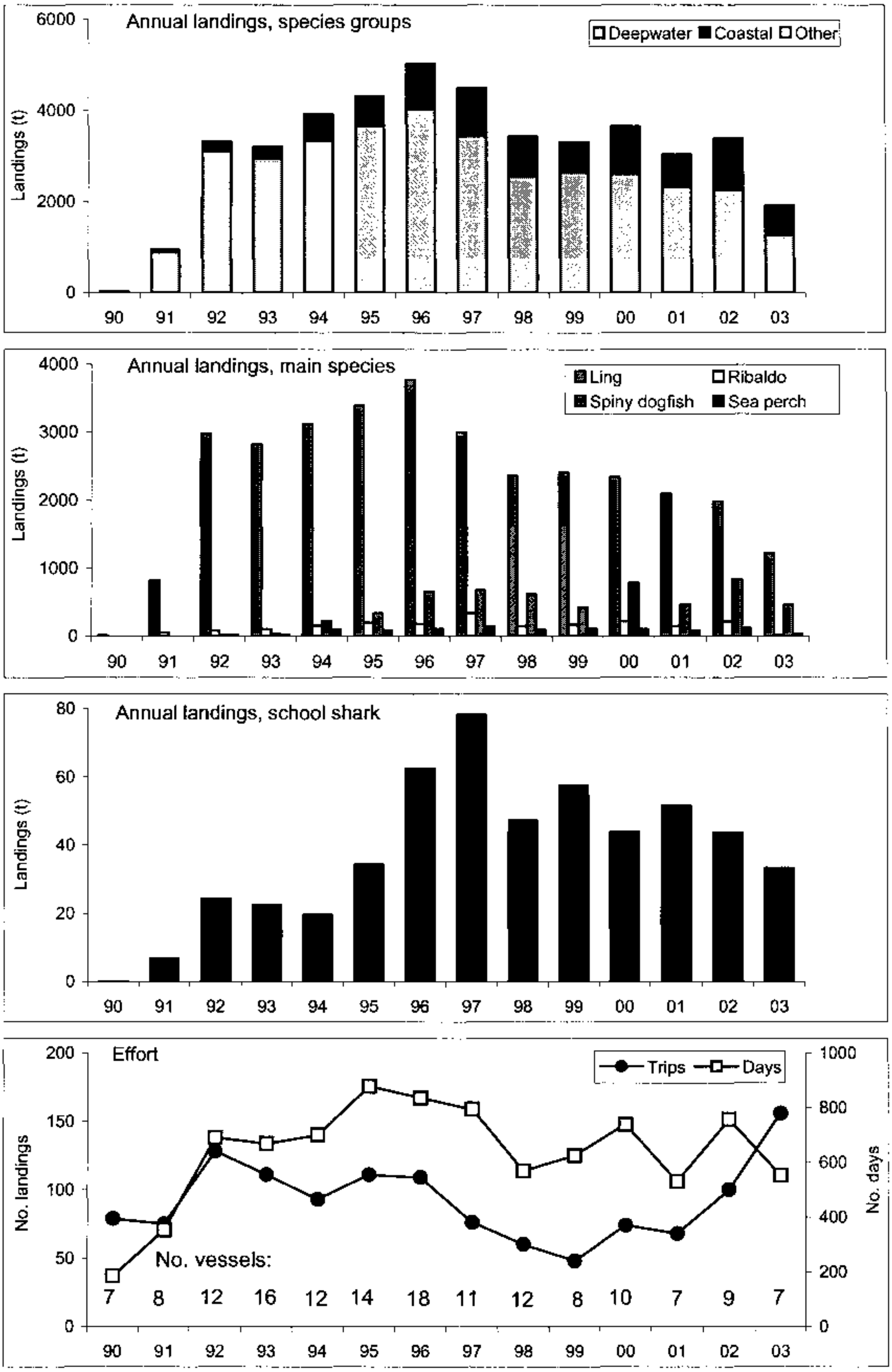

Figure 32a: Annual landings (t) and fishing effort for the Chatham Rise longline fishery, fishing years 1989–90 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort.

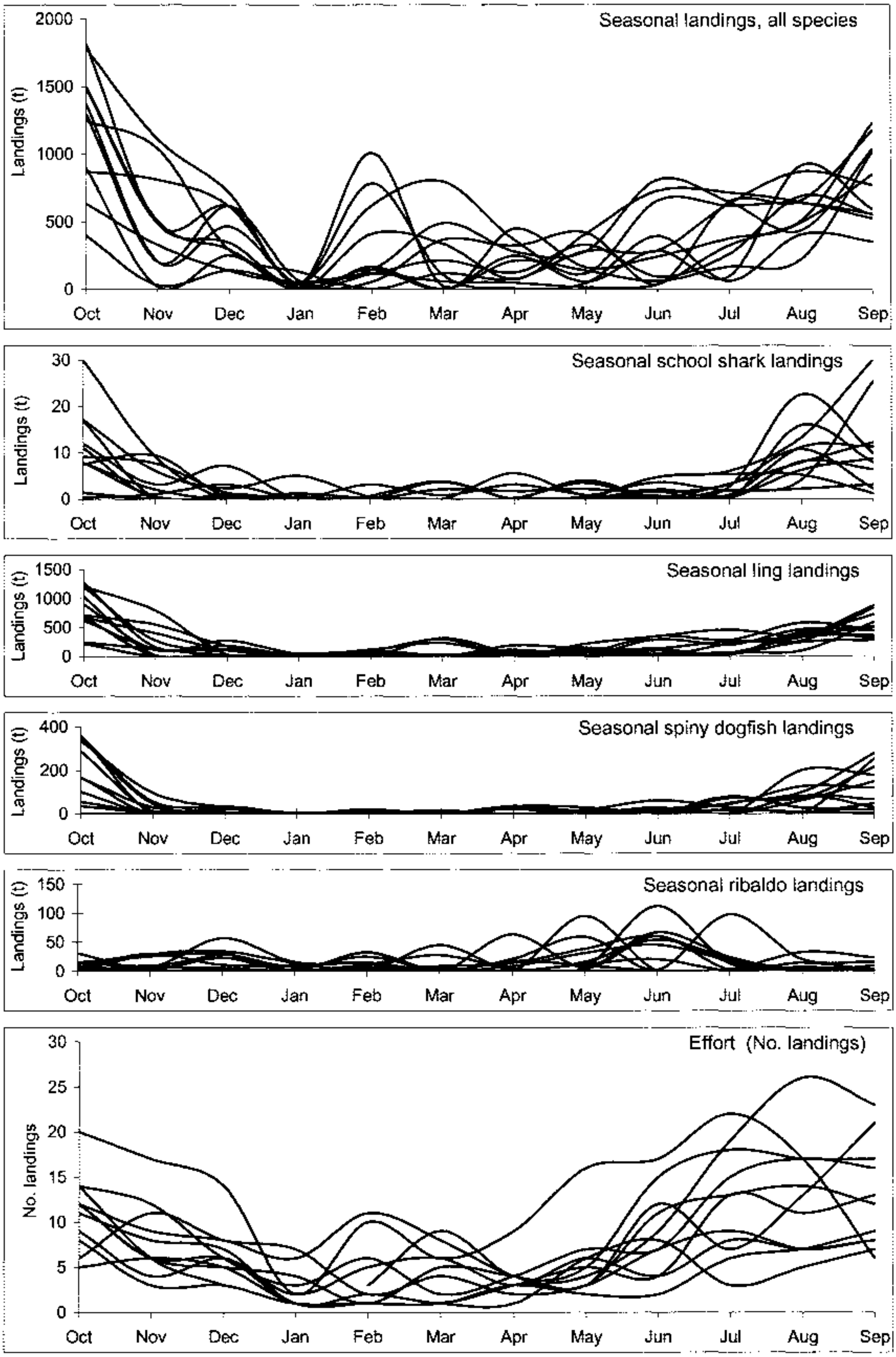

Figure 32b: Seasonal landings (t) and fishing effort for the Chatham Rise longline fishery, fishing years 1992–93 to 2002–03. Panels from top: landings of all species taken in the selected trips in the fishery; landings of the main (targeted or bycatch) species, including school shark; fishing effort. Each line represents smoothed monthly data from one fishing year.

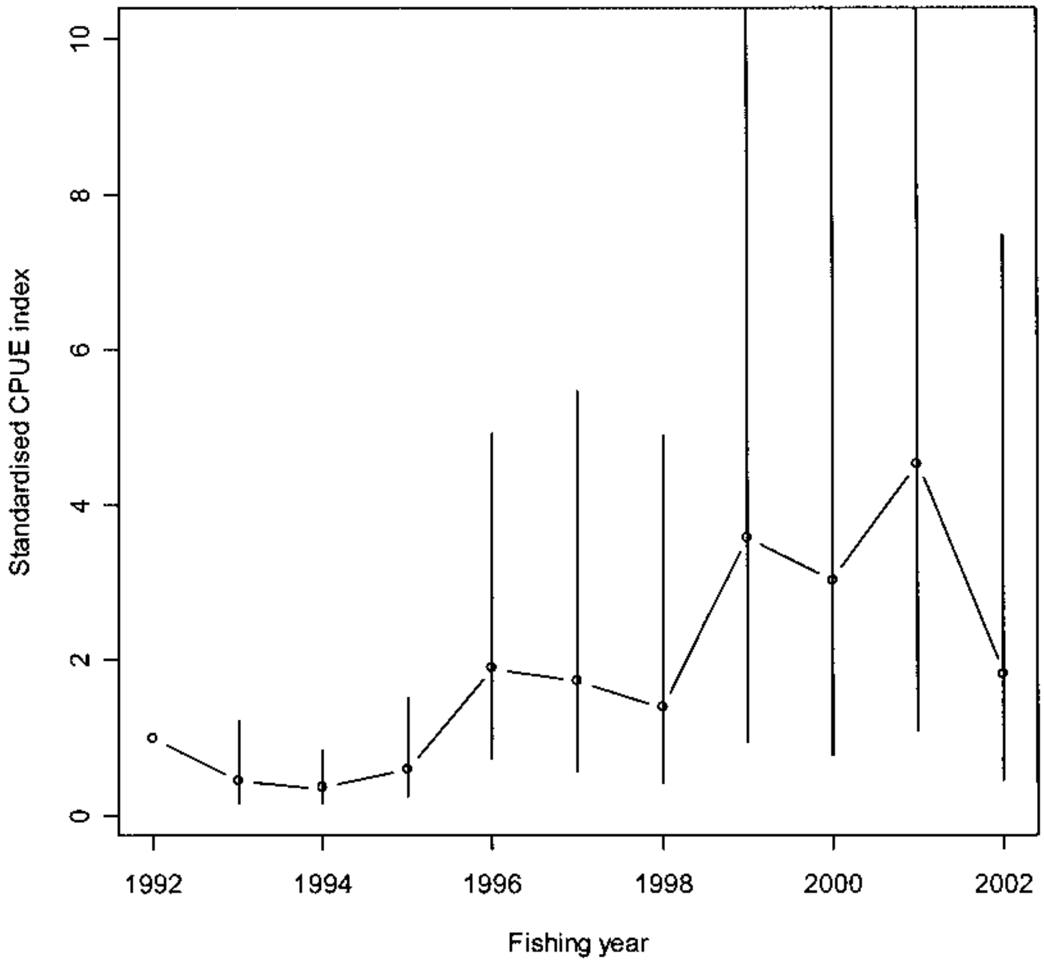

Figure 33: Non-zero indices for school shark from the Chatham Rise longline fishery. Note: the three confidence intervals that extend out of the chart area have endpoints at 13.8, 12.1, and 18.8.

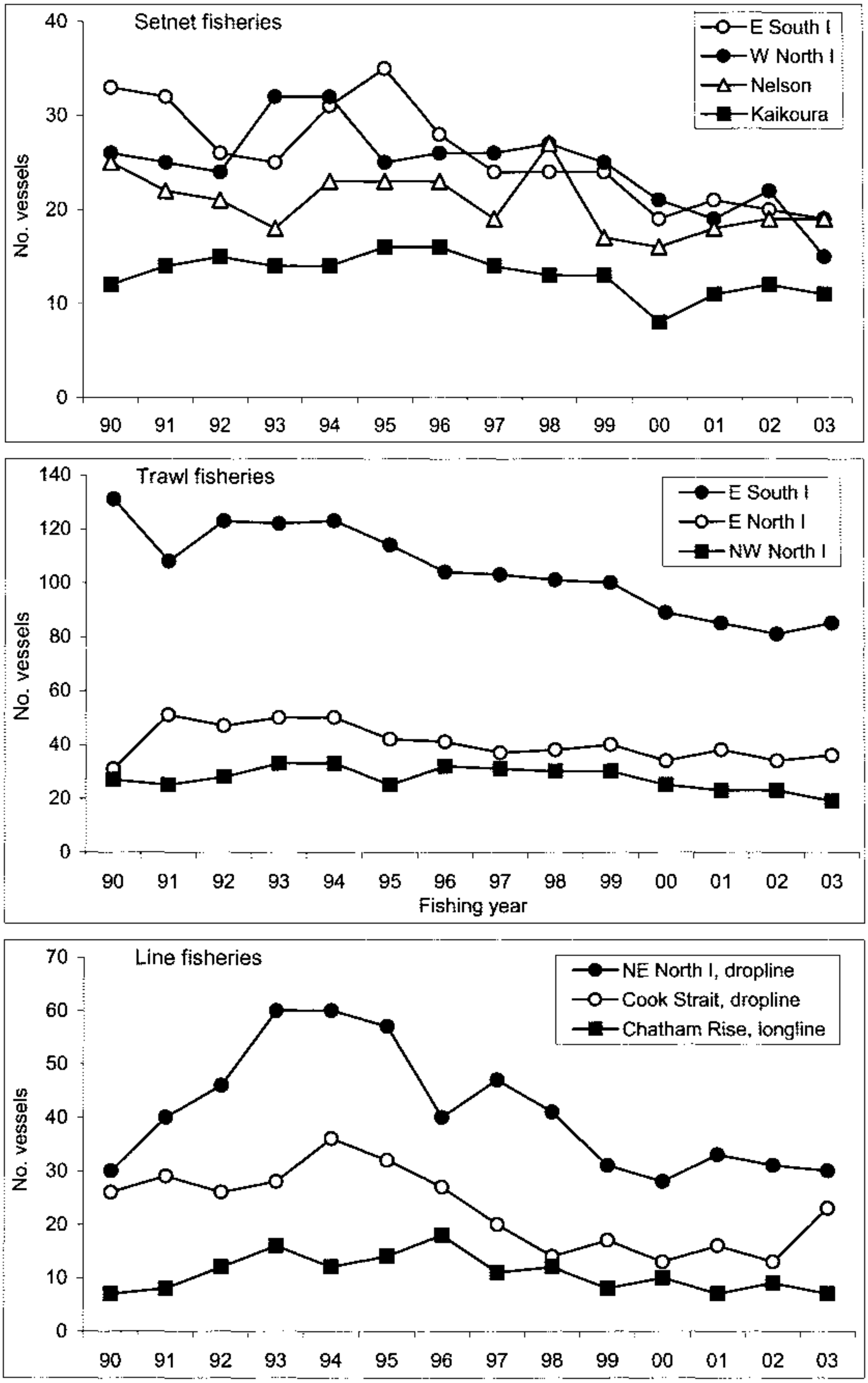

Figure 34: Annual changes in the number of vessels fishing in each regional fishery, grouped by method, fishing years 1989–90 to 2002–03.

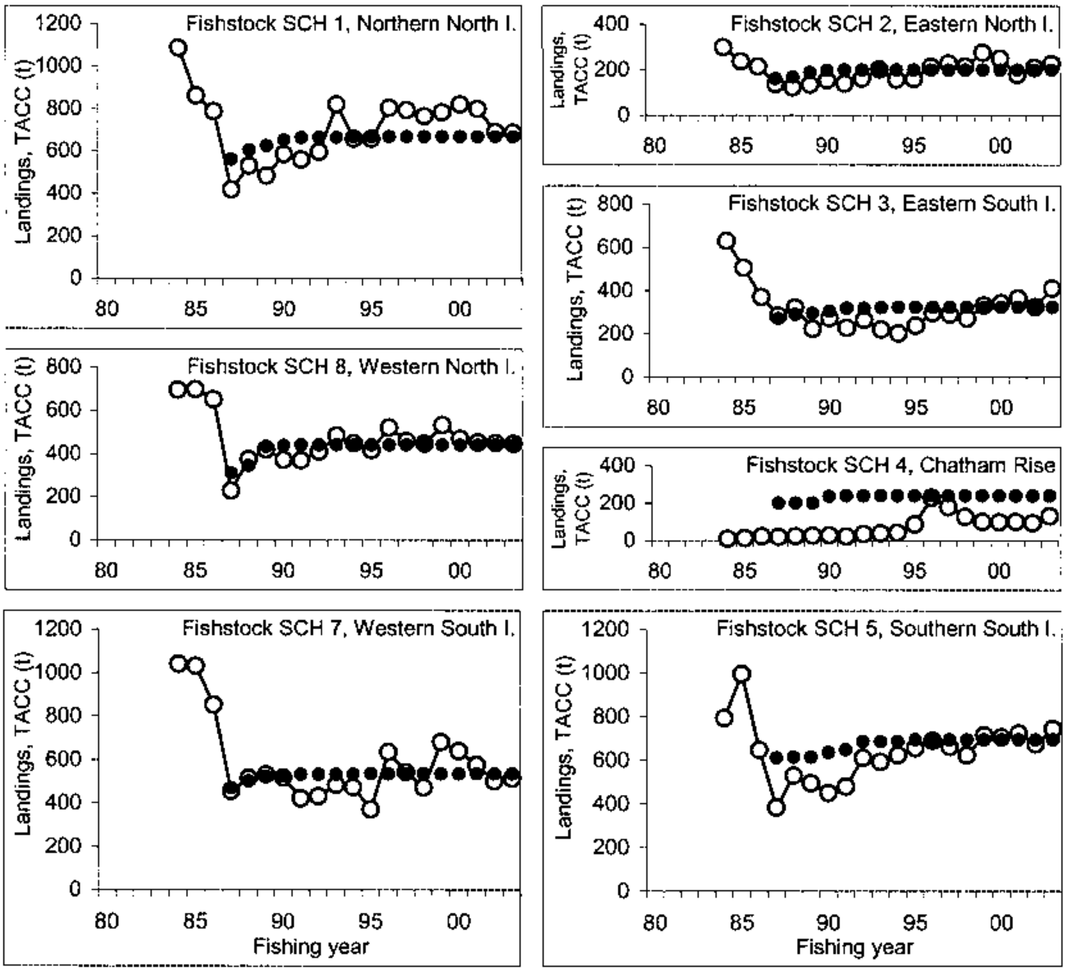

Figure 35: Landings and TACCs (t) of school shark by Fishstock, fishing years 1983–84 (plotted as 1984) to 2002–03. Data from Ministry of Fisheries Plenary Report documents. Landings, linked open circles; TACCs, closed circles.

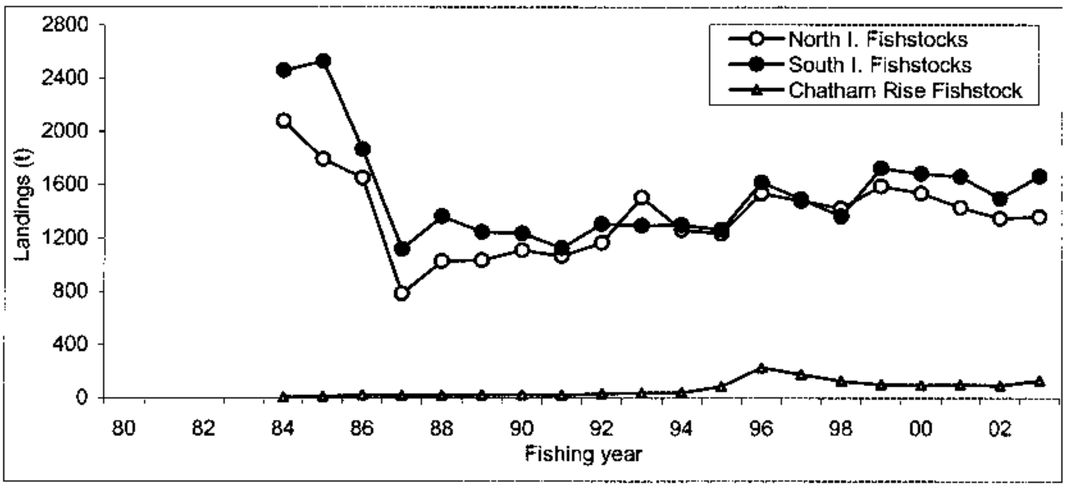

Figure 36: Landings (t) of school shark by Fishstocks grouped into "North Island" (1, 2, 8) and "South Island" (3, 5, 7), with the Chatham Fishstock shown separately.

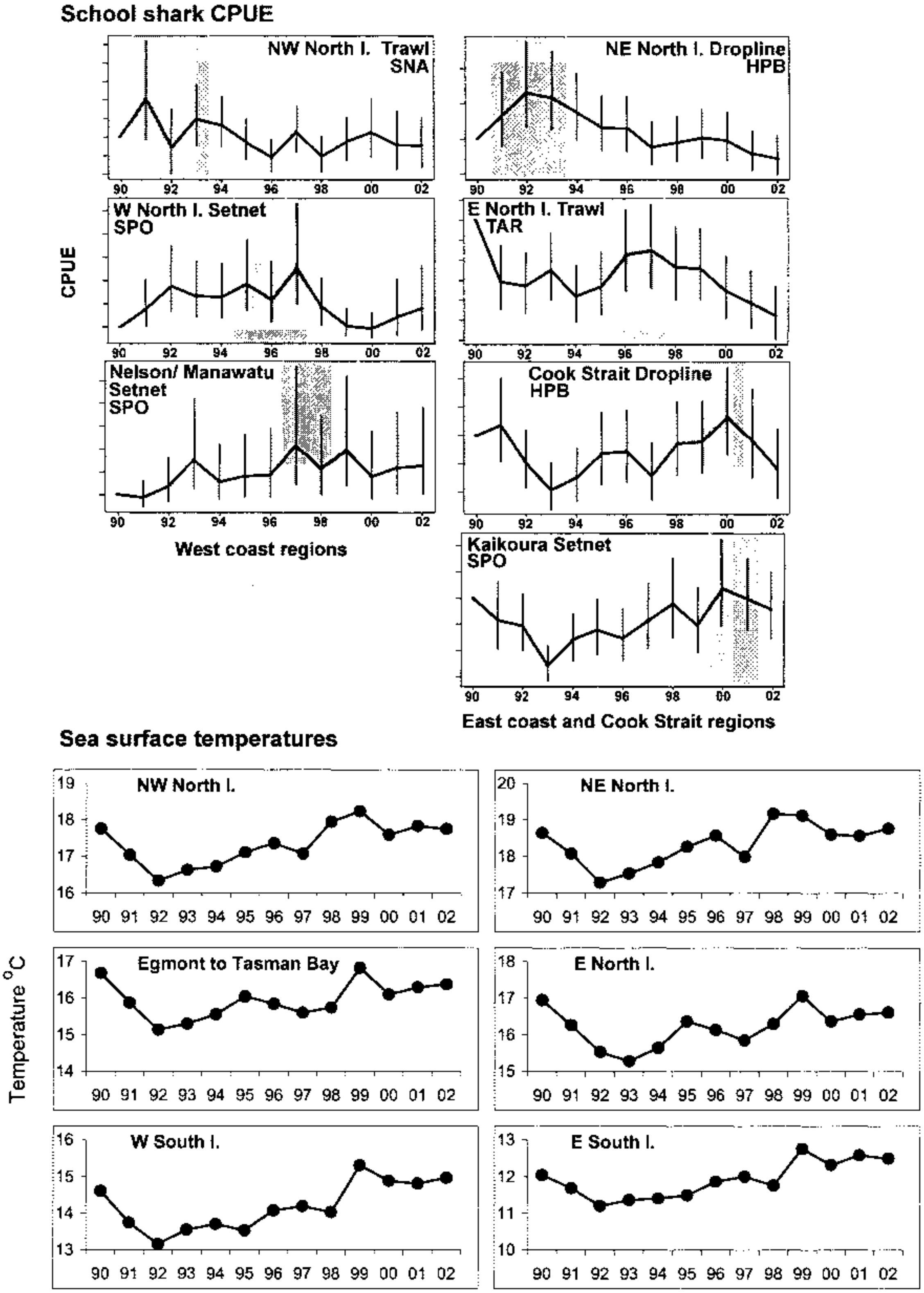

Figure 37: Upper panel: Comparison of standardised CPUE trends in the main regional fisheries analysed in this study, arranged north/south and west/east. High points in each CPUE series (estimated by eye) are shaded. Region, method, and target species are listed in each panel. Lower panel: mean annual (fishing year) sea surface temperatures for approximately the same coastal areas, calculated from monthly 1x1 degree resolution global sea surface temperature fields supplied by the NOAA Climate Diagnostics Center (Reynolds et al., 2002).

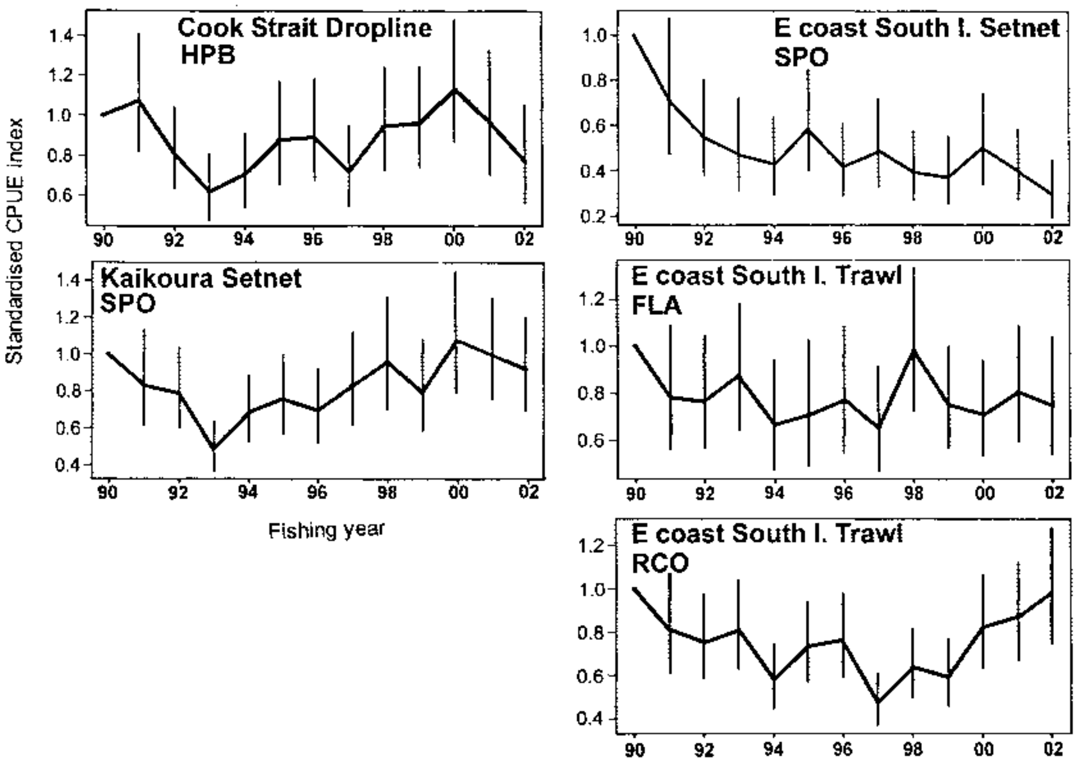

Figure 38: Comparison of standardised CPUE trends from Cook Strait and east coast South Island fisheries, by region, method, and target species. There is some similarity in trends from adjacent regions, but differences in trends between fisheries (method and target species subsets of data) within the same region.

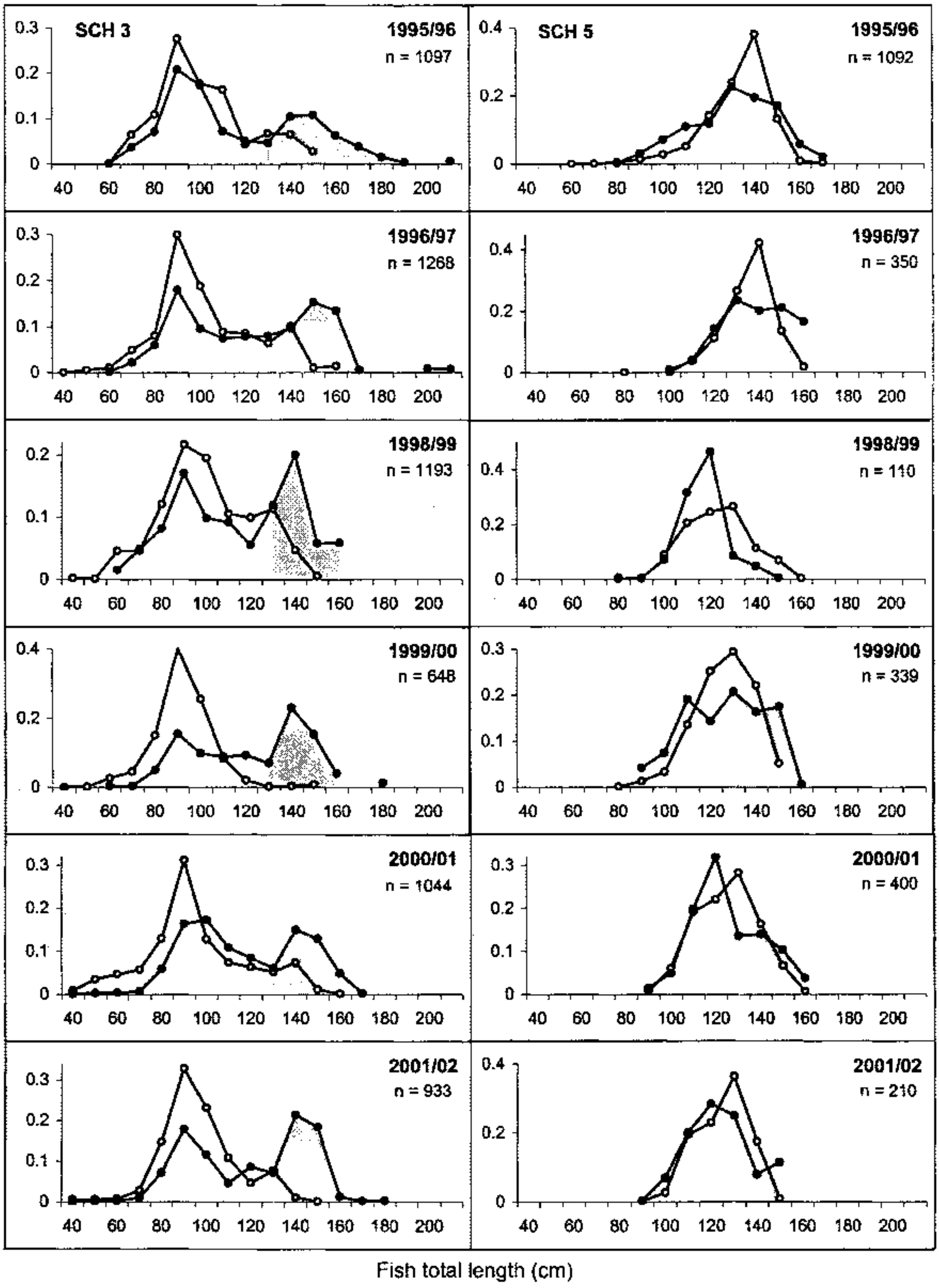

Figure 39: Scaled size distribution of school shark landed in the SCH 3 and SCH 5 setnet fisheries. Males, open circles; females, closed circles, mature females (from mean size at maturity of 130 cm) shaded. Length measurements grouped in 10 cm units, plotted as the lower end of the range. Source, SeaFIC shark logbook programme, unpublished data.

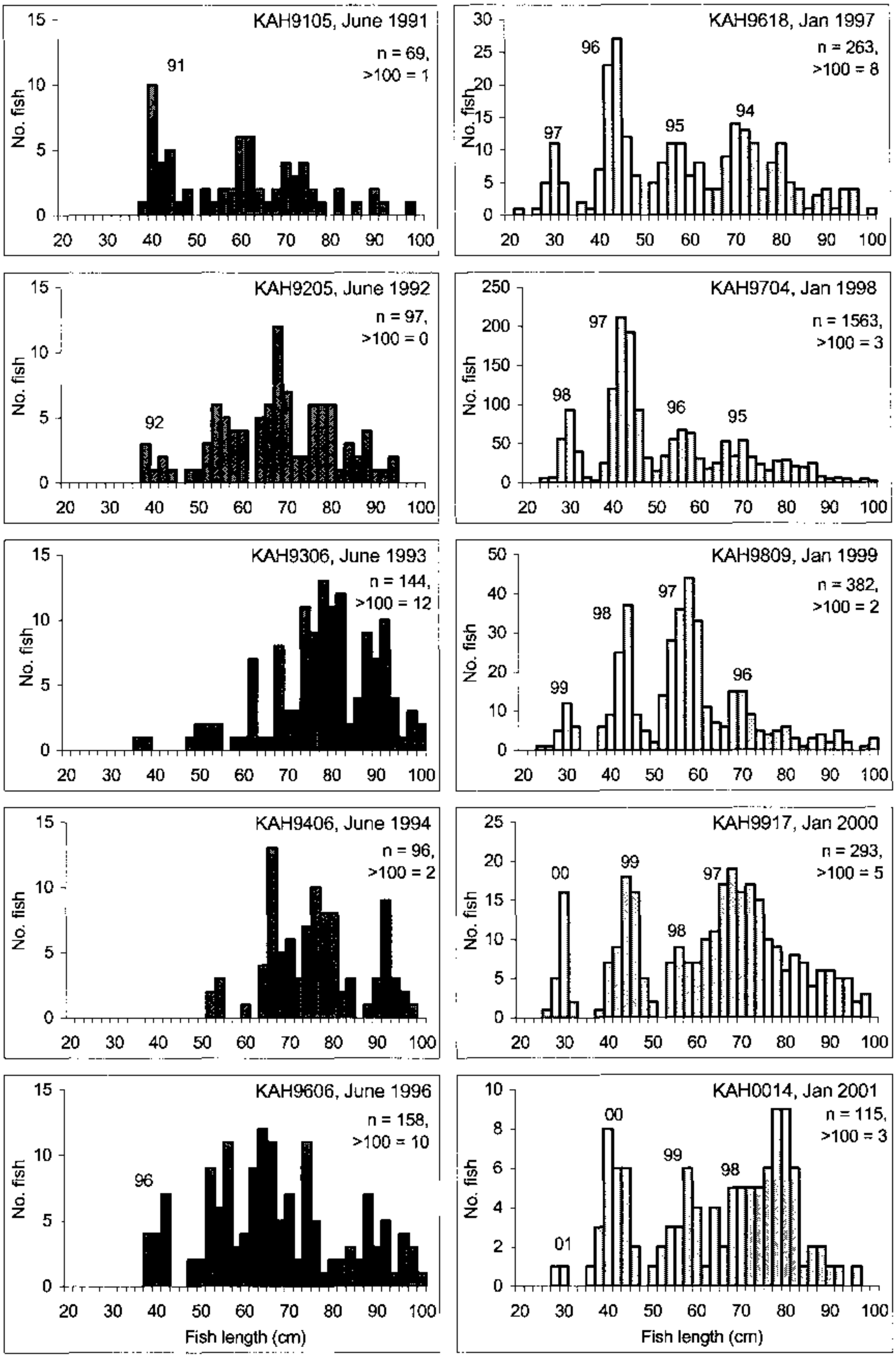

Figure 40: Unscaled size distribution of school shark caught in the two series of east coast South Island research trawl surveys, 1991 to 2001. (Winter, June; summer, December/January.) Sample sizes are listed, and the number of fish larger than 100 cm. The labelled year classes were identified by their modal size.

Appendix 1: Summary account of fisheries for *Galeorhinus galeus*

This widely distributed coastal shark is taken in targeted fisheries and as bycatch throughout most of its geographic range in the northern and southern hemispheres (Figure A1).

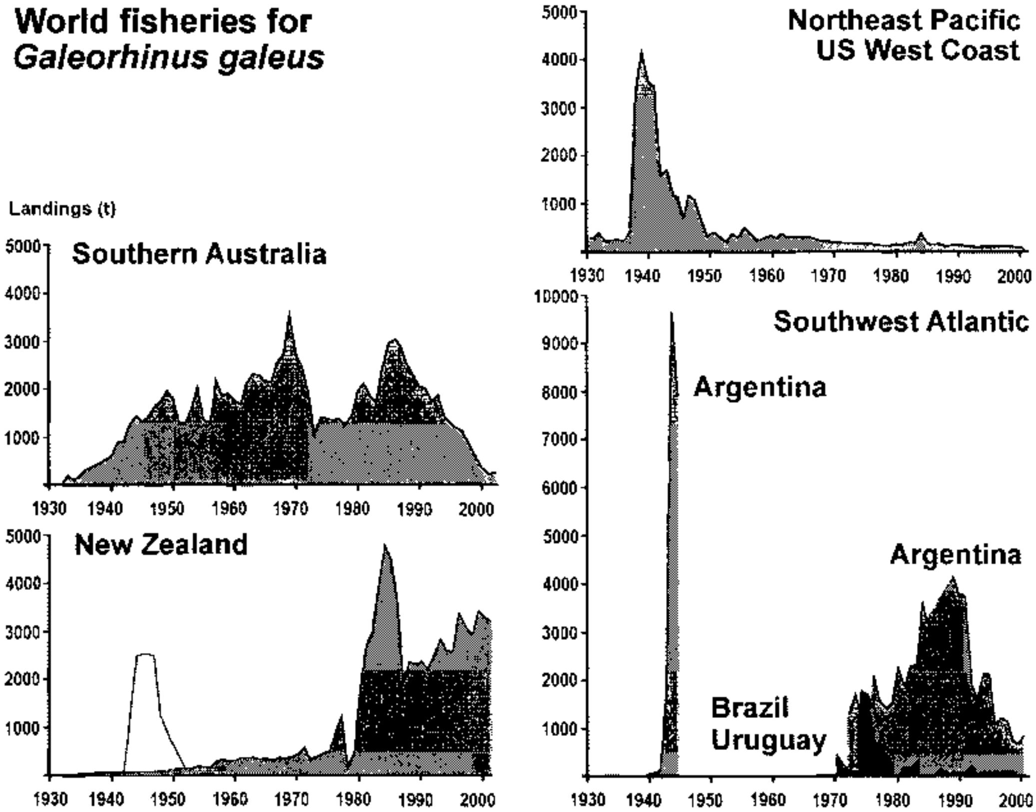

Figure A1: Trends in reported landings of *Galeorhinus galeus* in its main fisheries throughout the world, to place the New Zealand fishery in a broader context. Catch and landing data for shark fisheries are generally poorly reported. In some cases approximations can be made, in others gaps must be left. Some landings are "over-reported" because other shark species are included, others are under-reported because of missing data, or because an unknown proportion of the landings are reported as processed weights (half to two-thirds of total weight). However, the broad trends are considered to be valid. The New Zealand values for the 1940s are estimates of catch based on liver weights landed. Adapted and updated from Walker (1999).

New Zealand

School shark have been caught for well over a century. Before 1940 they were an unwanted bycatch and an unknown but relatively small quantity was discarded at sea. From then until about 1950 a target fishery for their liver oil occurred (as it did in several regions elsewhere). Although also unrecorded, the weight of sharks caught in this fishery can be estimated from processed liver weights to have reached 2500 t for a few years. From 1950 to the mid 1970s a modest fishery for fillets developed and reported landings rose slowly to about 500 t, of which a moderate proportion was exported. Landings then increased sharply when monofilament gillnets were adopted, and as the availability of other coastal fish species declined. They reached over 1200 t in 1977, dropped in 1978 and 1979 from controls on high mercury levels, then rose again to 5000 t in the mid 1980s. The Quota Management System (QMS) and quotas reduced landings to 2000 t in 1987, but they have since risen steadily to about 3000 t. Landings are now constrained by regional TACCs to about this level. The New Zealand school shark fishery is unique among the world's fisheries for the species, and remarkable among shark fisheries in general, in maintaining such high productivity. It has supported landings of more

than 2000 t for two decades, and more than 3000 t for several years on two occasions – the mid 1980s and in 1996–2001 – with no sign of collapse.
References: Francis (1998), Paul & Sanders (2001).

Australia
The fishery began in the 1920s, increased rapidly through the 1940s to supply the liver-oil market, fluctuated around 2000 t through the 1950s as the demand for livers dropped and the shark meat market slowly developed. Catches rose rapidly from the mid 1960s as gillnets were introduced, landings peaking at over 3500 t in 1969. A 1972 ban on taking large sharks because of high mercury levels reduced reported landings to about 1000 t, they remained a little above this until the late 1970s, then with the relaxation of the ban rose again to over 3000 t in 1986. Since then, landings steadily declined to less than 200 t in 2002, both as a consequence of declining stock size, and regulatory moves (gear restrictions, quotas) to limit the fishery. In recent years landings have been below the quota, and the species has become only a bycatch in the fishery for the more productive gummy shark (*Mustelus antarcticus*). At current catch rates the stock is not rebuilding to its scheduled 2011 target level, and may take at least two decades to recover. In summary, the Australian fishery supported landings of 2000 t for several decades, and briefly reached 3000 t on two occasions, but from 1986 it has declined to less than 200 t despite restrictive management measures.
References: Punt & Walker (1998), Walker (1999), Walker et al. (2003), Anon. (2003).

Northeast Pacific (U.S. West Coast)
A Californian fishery developed rapidly in the late 1930s, mainly to supply liver oil. Estimated catches reached a peak of over 4000 t in 1940, but then dropped rapidly to about 1000 t in 1944. Subsequent catches and landings are not recorded, but the fishery largely disappeared through a combination of overfishing and loss of the liver oil market when synthetic vitamin A became available. Around 1980 landings rose to about 200 t, but then declined to 50 t or less. Similar low landings are taken from Oregon and Washington coastal waters. The status of this regional stock is unknown.
References: Ripley (1946), Holts (1988), Cailliet et al. (1993), Ebert (2001).

Southwest Atlantic (Brazil, Uruguay, Argentina)
There have been intermittent fisheries along the southeast coast of South America. There was a fishery (for liver-oil) in Uruguay and Argentina in the 1940s, estimated catches in the latter briefly reaching 10 000 t. The species would have been an unrecorded catch component in several artisanal coastal fisheries. In Uruguay, a partly targeted fishery gradually developed, estimated landings probably reached a few hundred tons but diminished rapidly during the 1990s. In southern Brazil, catches of "demersal sharks" (mainly *Galeorhinus galeus* combined with the more productive *Mustelus schmitti*) taken by several methods rose through the 1970s and 80s; the trawl catch and CPUE peaked in the mid 1980s, then CPUE declined by 85% in subsequent years. In Argentina there was intensive fishing with landings of about 4000 t for five years centred on 1990, then a very rapid decline. The species is now scarce in this region, taken mainly as bycatch. Fisheries have been unregulated, but controls are now recommended.
References: Chiaramonte (1998, 2001), Miranda & Vooren (2003).

South Africa
There have also been variably intensive targeted or bycatch fisheries for this species off South Africa since the 1930s, in association with other sharks; records are incomplete, but suggest landings of 3000–4000 t in the 1940s liver oil fishery, and 1000–2000 t in the subsequent fishery for flesh. Landings from the longline fishery dropped from 250 t to 70 t during the 1990s, but it is unclear whether this represents a decline in abundance.
References: Kroese & Sauer (1998), Freer (1992).

Northeast Atlantic and Mediterranean
The species is taken as bycatch in a variety of net and line fisheries. It was reportedly never abundant, and has steadily declined to become rare in most areas. Reference: IUCN Redlist documentation, draft report (unpublished 2004).

Appendix 2: Summary of the biology of *Galeorhinus galeus*

Although numerous studies have been carried out on specific aspects of the biology of *Galeorhinus galeus* throughout its range, it is still difficult to generalise on its overall life history. Studies are difficult because school shark, in common with most other sharks, segregates by size and sex. The adults are migratory. The two important measures of the species "productivity" – age and growth, and reproductive parameters – are not well understood.

Distribution

Widespread in temperate waters of both hemispheres, but absent from the Northwest Atlantic and Northwest Pacific (Figure A2). Usually coastal and demersal to semi-pelagic, but also present in near-surface offshore waters.

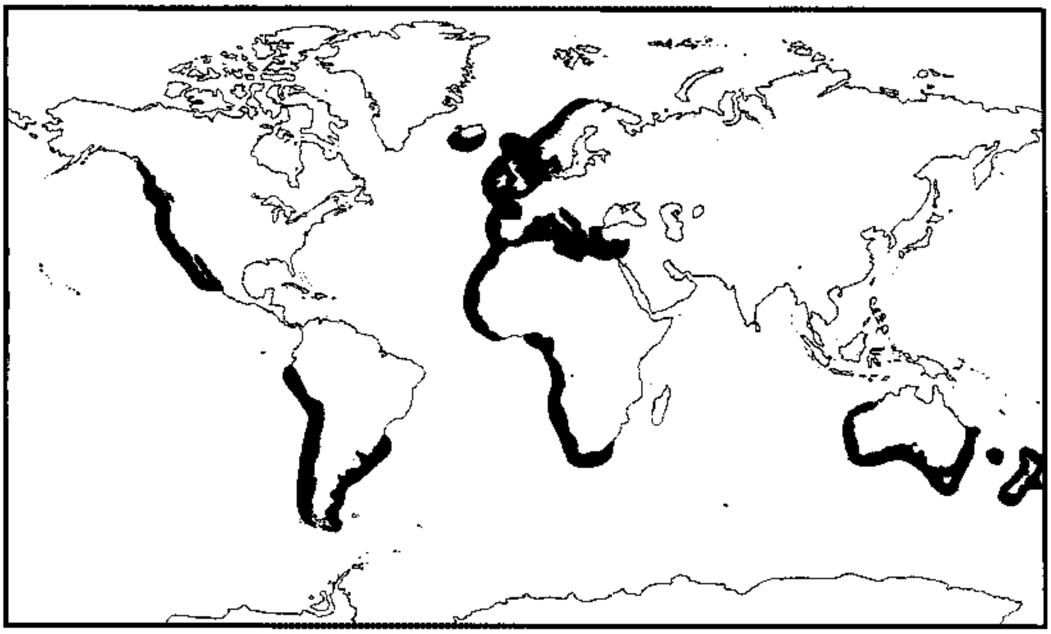

Figure A2: Known distribution of *Galeorhinus galeus*. Based on Compagno (1984).

Migrations

Some moderately long-distance migrations have been recorded: Britain to Iceland, Canary Islands, and the Azores; southern Brazil to Argentina; New Zealand to Australia; southeast Australia to western Australia. These and shorter movements are assumed to be associated with the reproduction cycle.

Size at maturity, and maximum size

All sizes are total lengths. Females, 130 cm in some areas, larger elsewhere. Males, 120 cm in some areas, larger elsewhere. Maximum length about 200 cm, apparently varying between regions (the largest fish – mature females – usually occur in separate schools and are not taken in some fisheries).

Age at maturity

Females, ~10 years. Males, ~8–9 years.

Longevity

Estimated at 60 years, from the recapture of a few tagged fish in Australia.

Gestation period, and reproductive periodicity

Estimates of the gestation period range from 6 months to (more commonly) one year. Reproductive periodicity of the females has been estimated at one year in the Northeast Atlantic Ocean, two years in Australia (neither is confirmed), and three years off Brazil (based on the occurrence of three reproductive stages in the population at any one time). As a generalisation, there is a one year gestation, followed by one or two resting/recovery years. In New Zealand gestation is about one year (with pupping centred on November), but periodicity is unknown.

Size at birth

Pups are born at ~30 cm, with some apparent regional variation.

Fecundity (litter size)

Reported to be from 8 to 35, depending on maternal size, and possibly region.

Natural mortality (M)

Poorly known, but the value of 0.113 was used by Smith et al. (1998).

Appendix 3. Diagnostic plots from the generalised linear models.

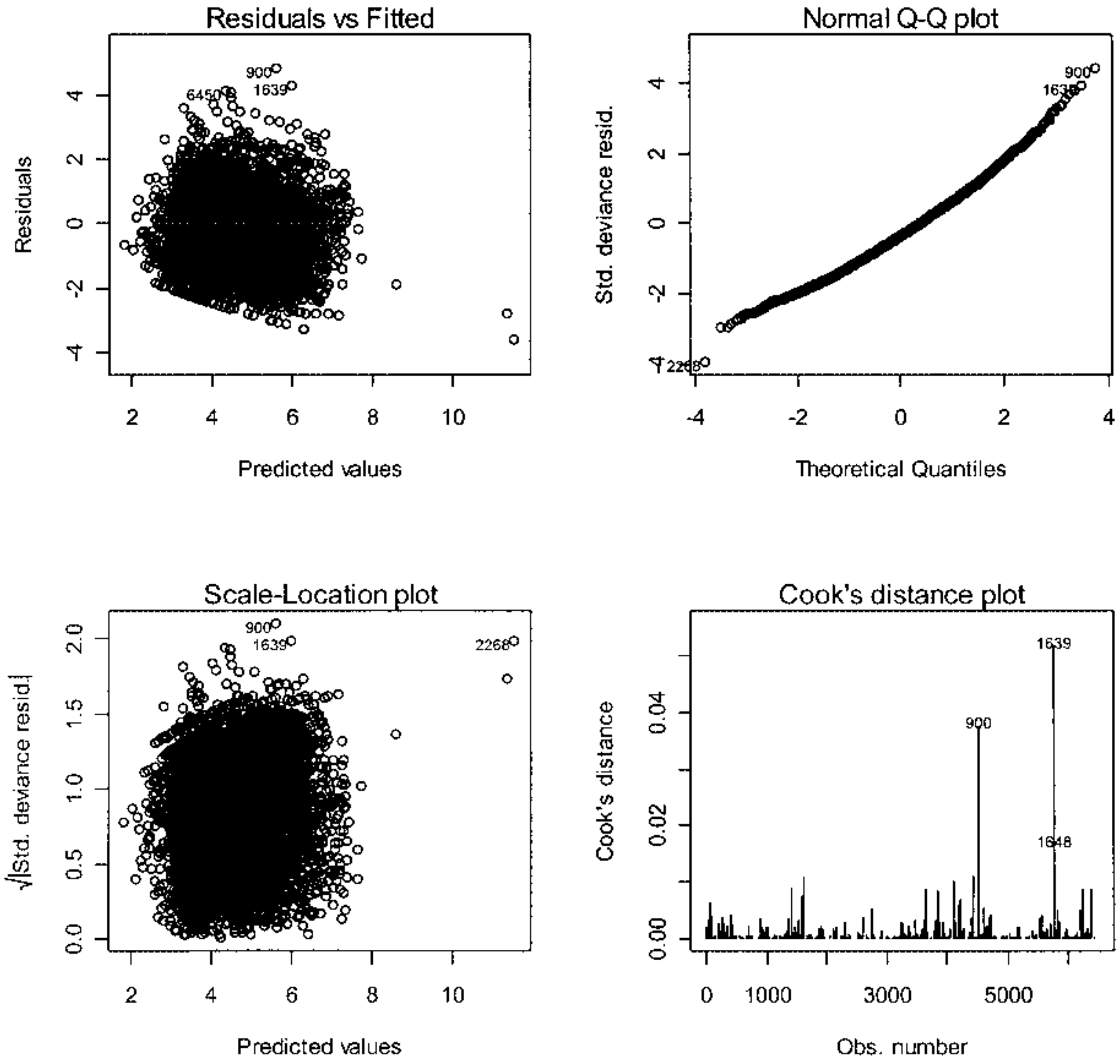

Figure A3-1: Diagnostic plots from the east coast South Island setnet fishery.

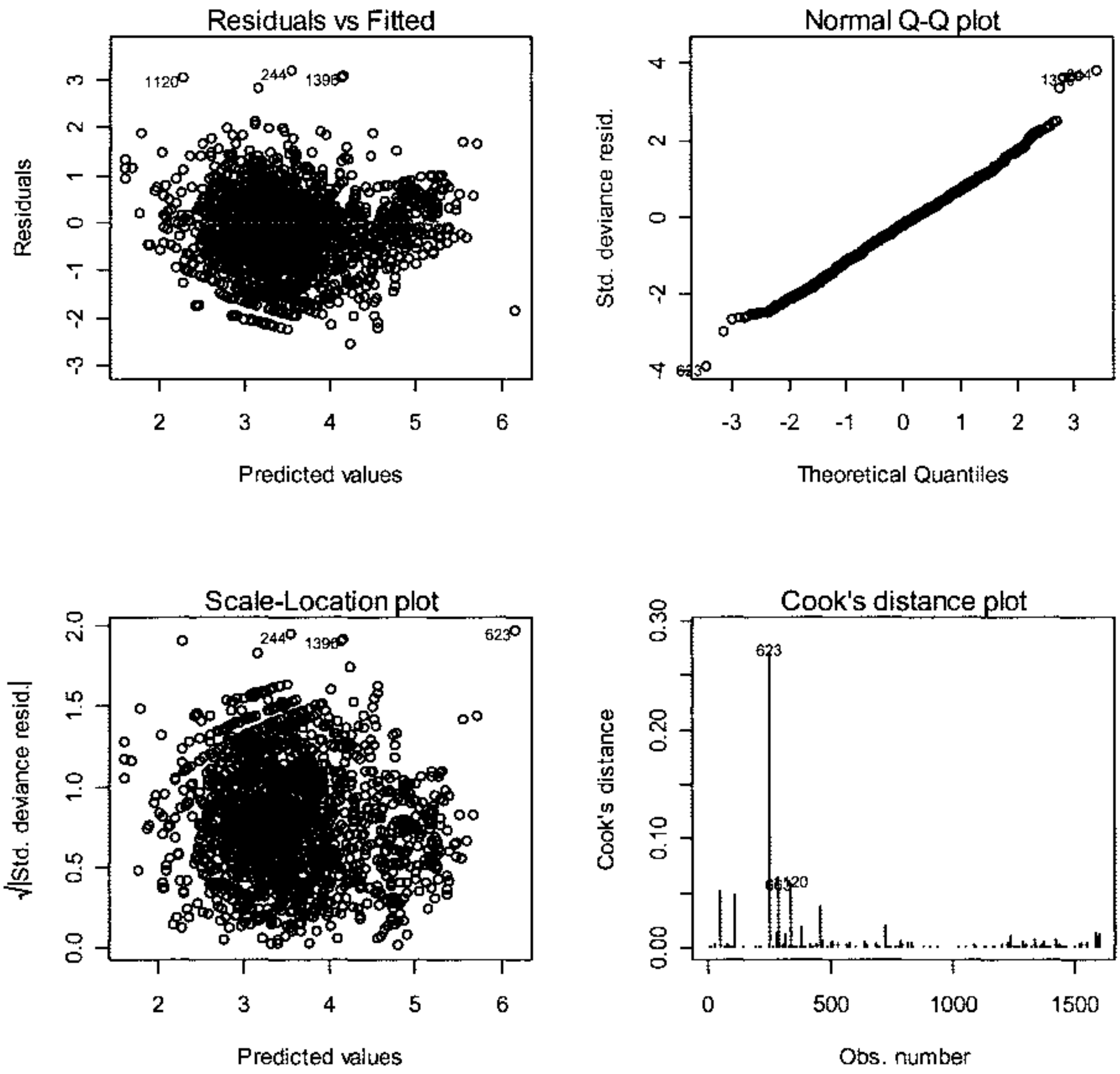

Figure A3-2: Diagnostic plots from the Kaikoura fishery.

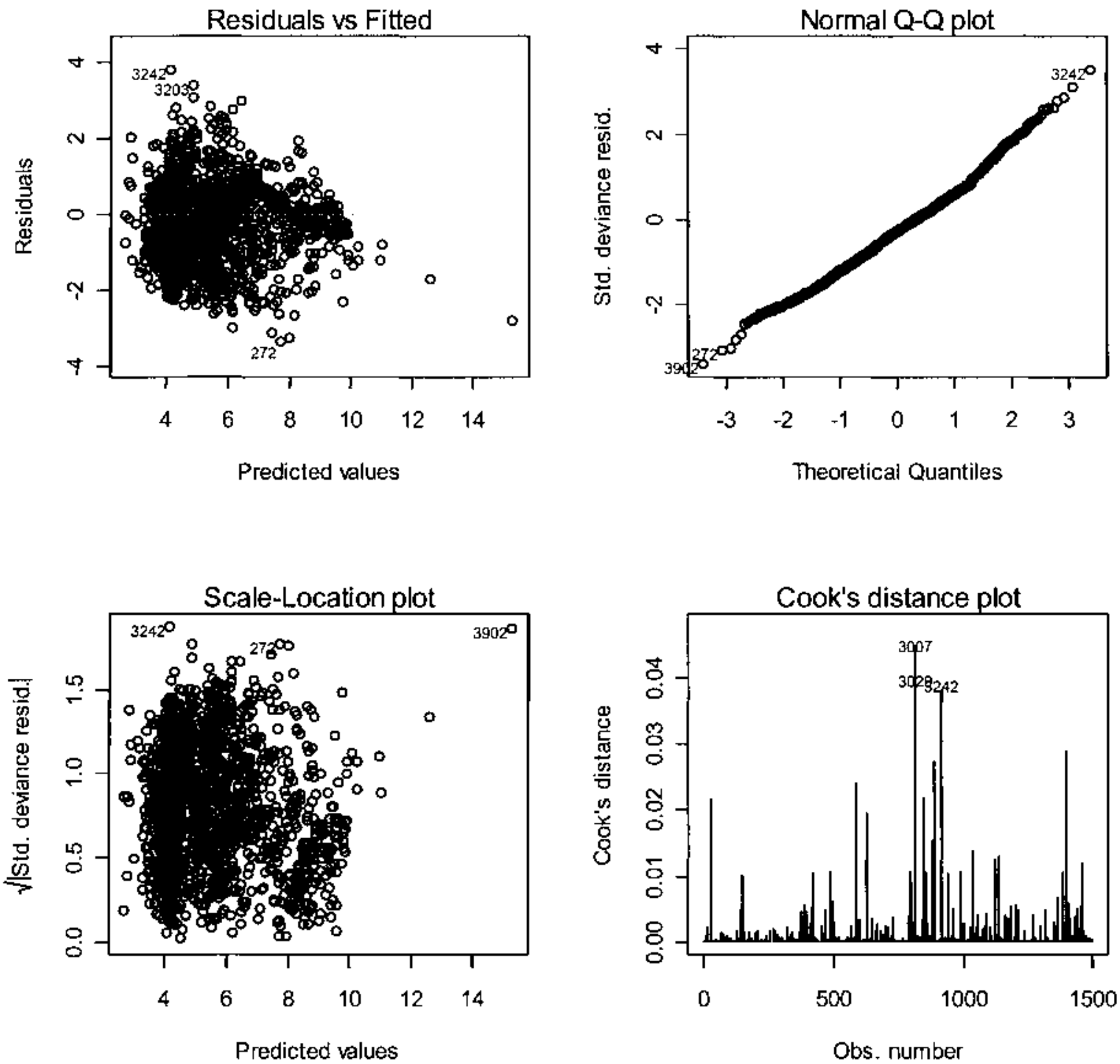

Figure A3-3: Diagnostic plots from Nelson Bays/Manawatu all targets.

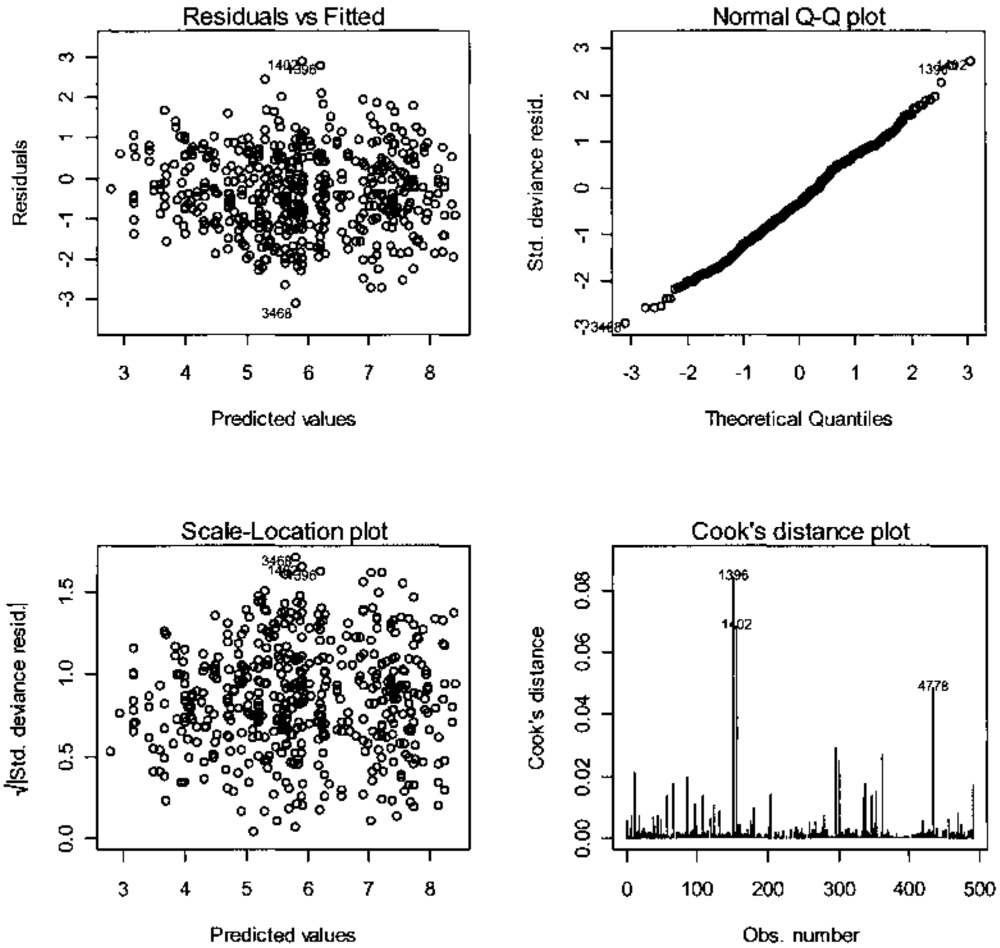

Figure A3-4a: Diagnostic plots from the west coast North Island school shark target setnet fishery.

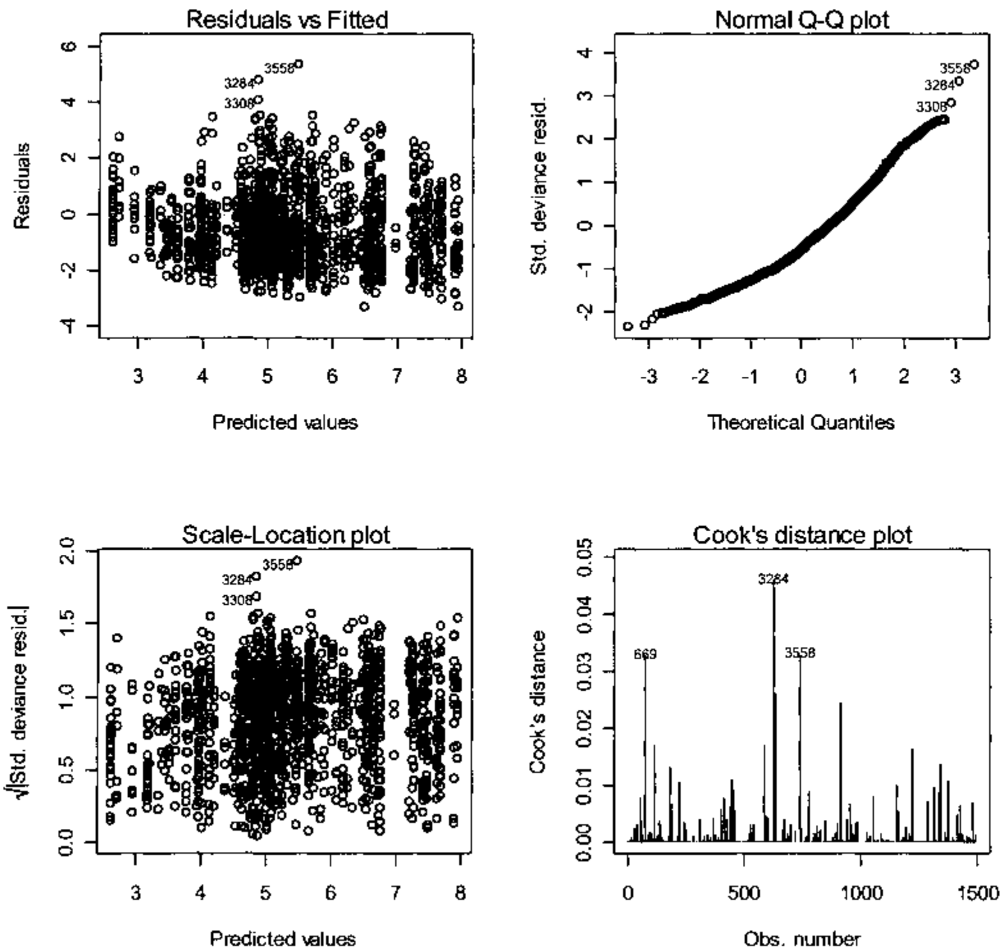

Figure A3-4b: Diagnostic plots from the west coast North Island rig target setnet fishery.

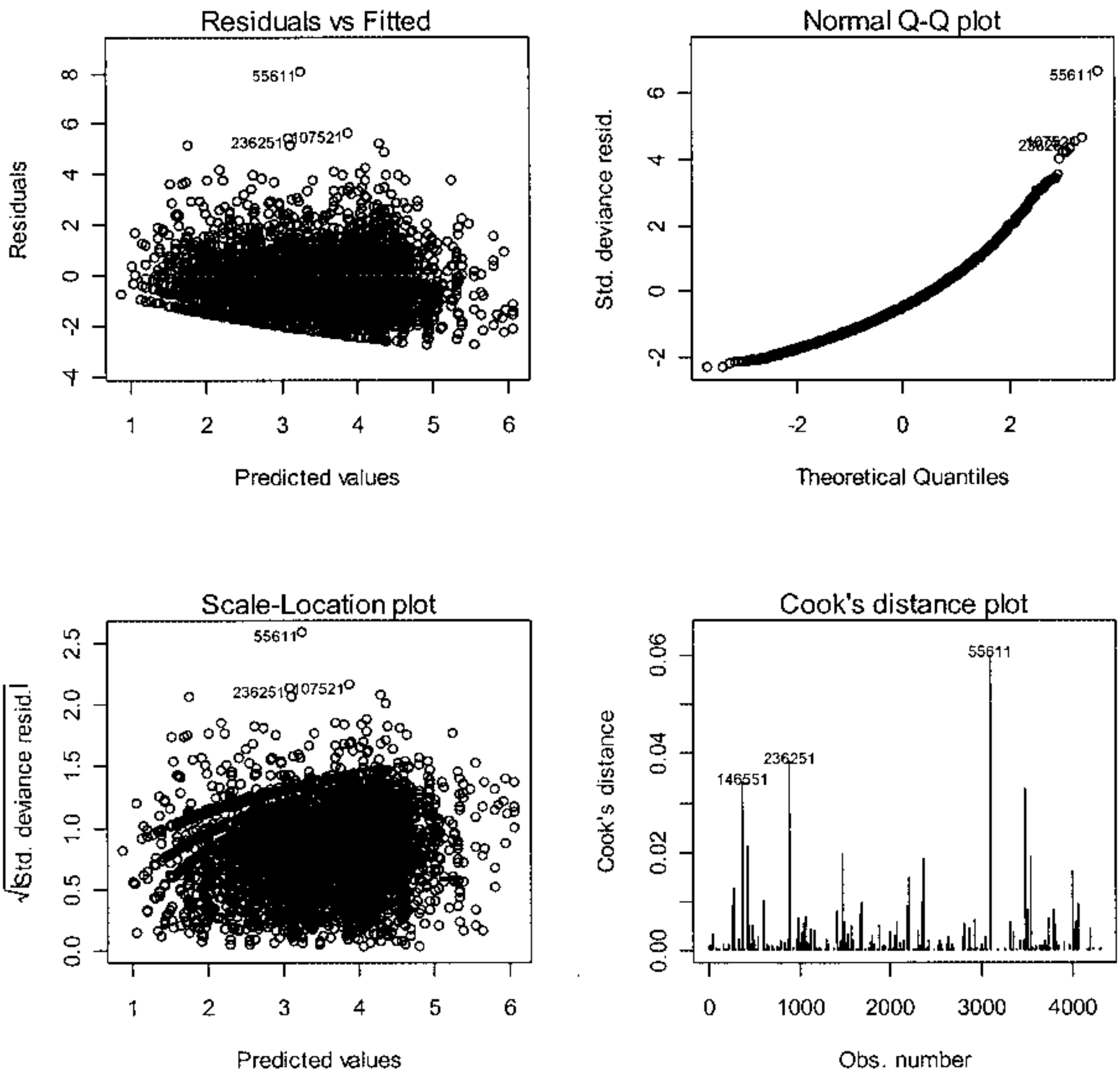

Figure A3-5: Diagnostic plots from the east coast South Island bottom trawl fishery. Trips targeting flatfish.

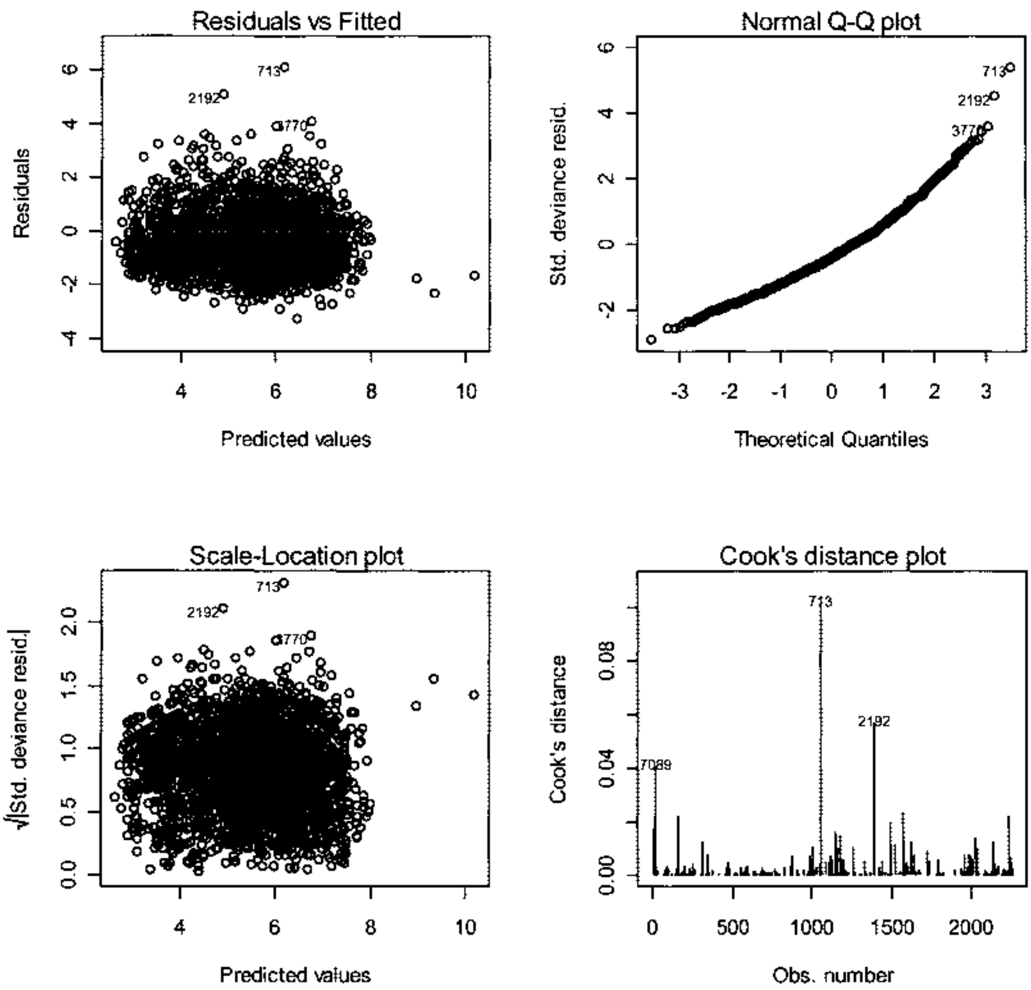

Figure A3-6a: Diagnostic plots from the northwest North Island bottom trawl fishery. SNA

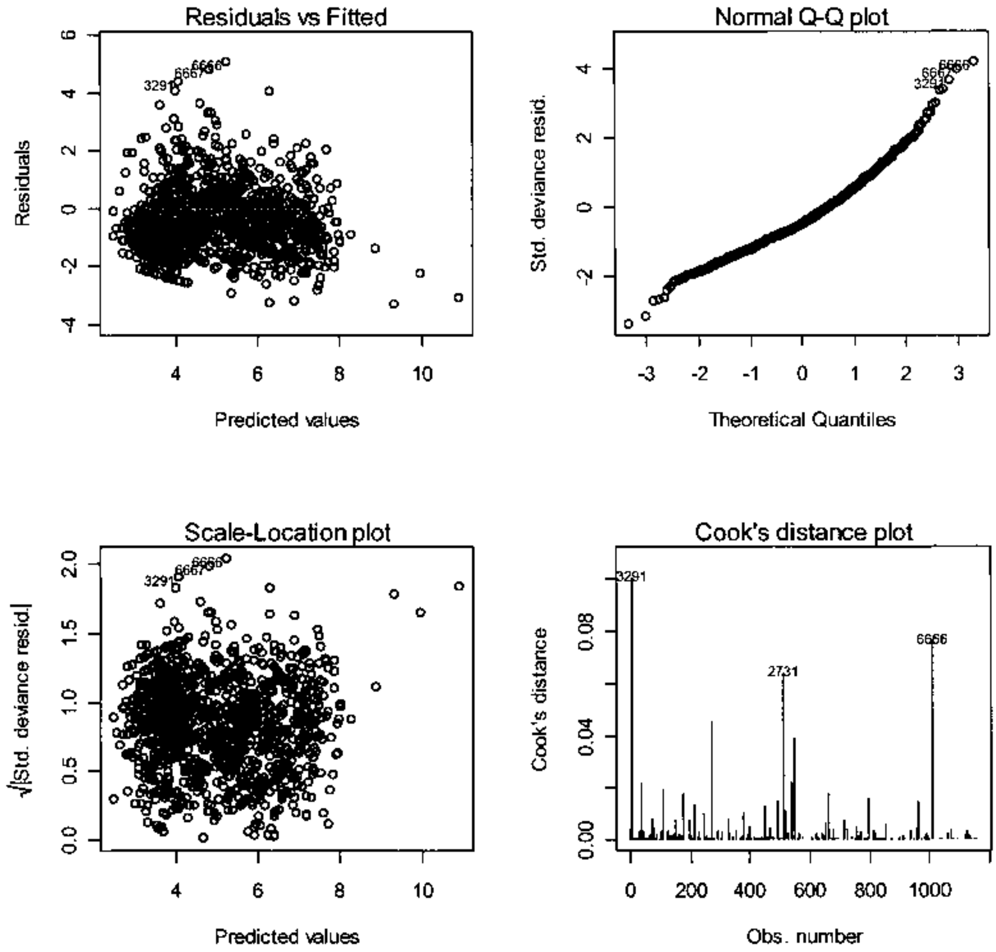

Figure A3-6b: Diagnostic plots from the northwest North Island bottom trawl fishery. TRE

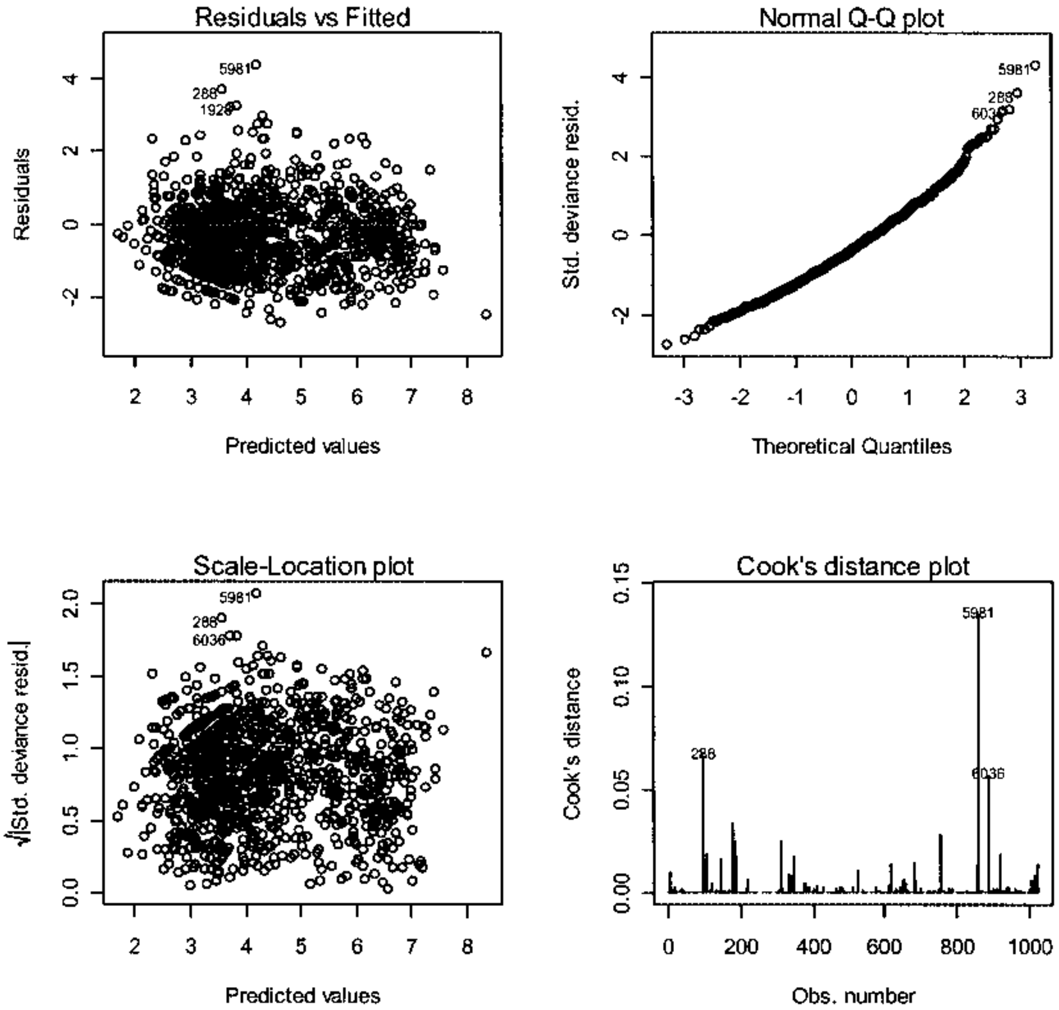

Figure A3-6c: Diagnostic plots from the northwest North Island bottom trawl fishery. GUR

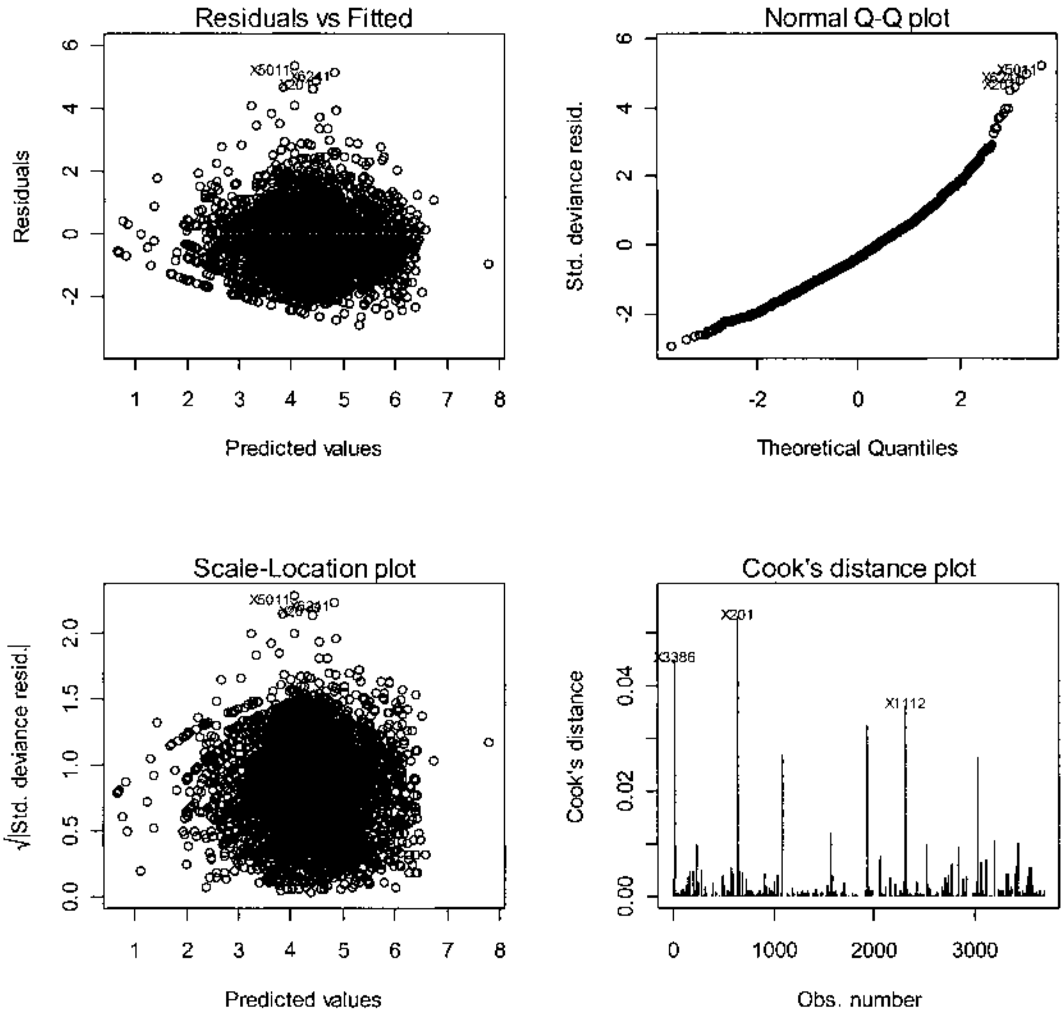

Figure A3-7. Diagnostic plots from the east North Island bottom trawl fishery.

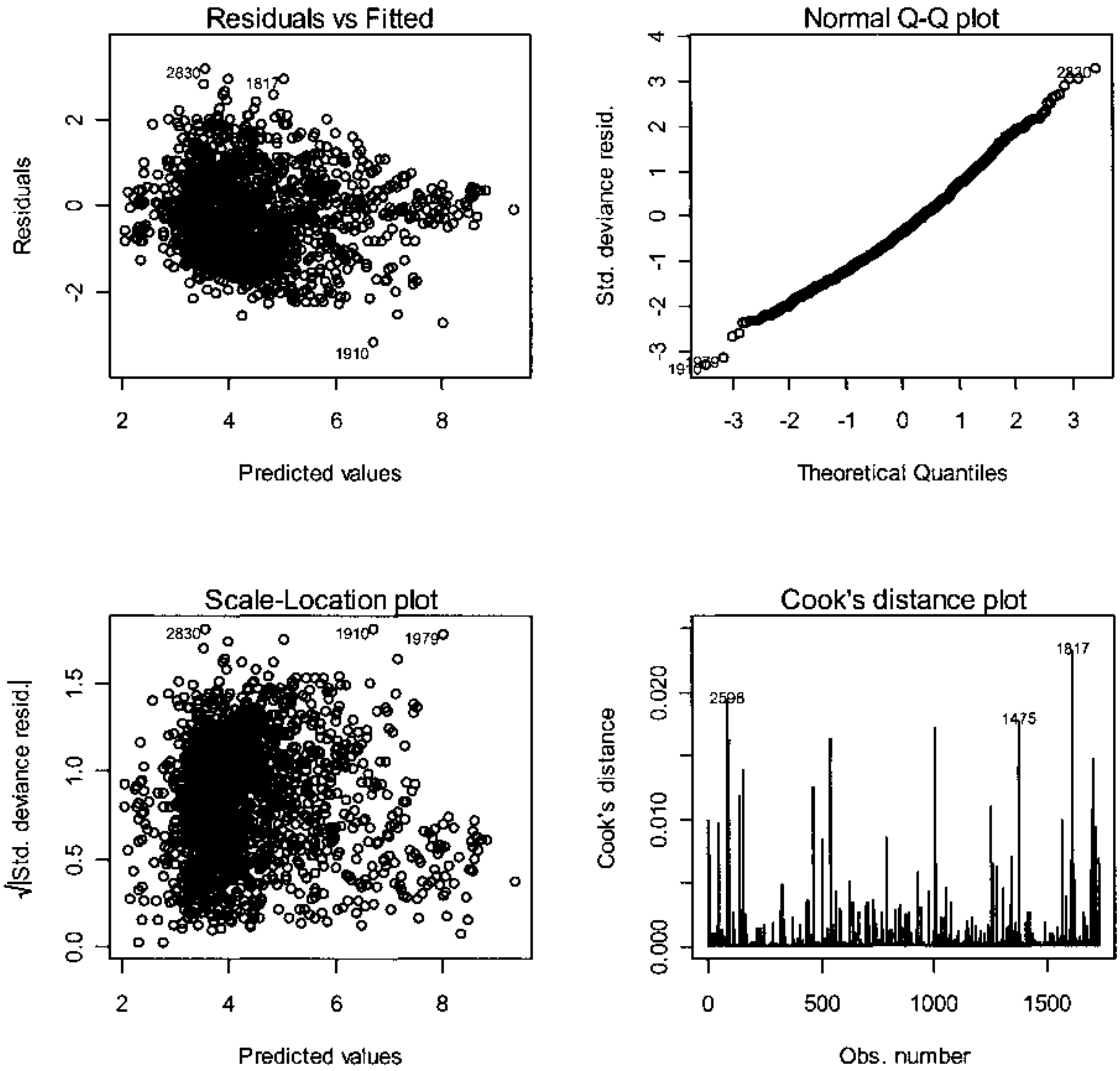

Figure A3-8: Diagnostics from the Cook Strait groper line fishery.

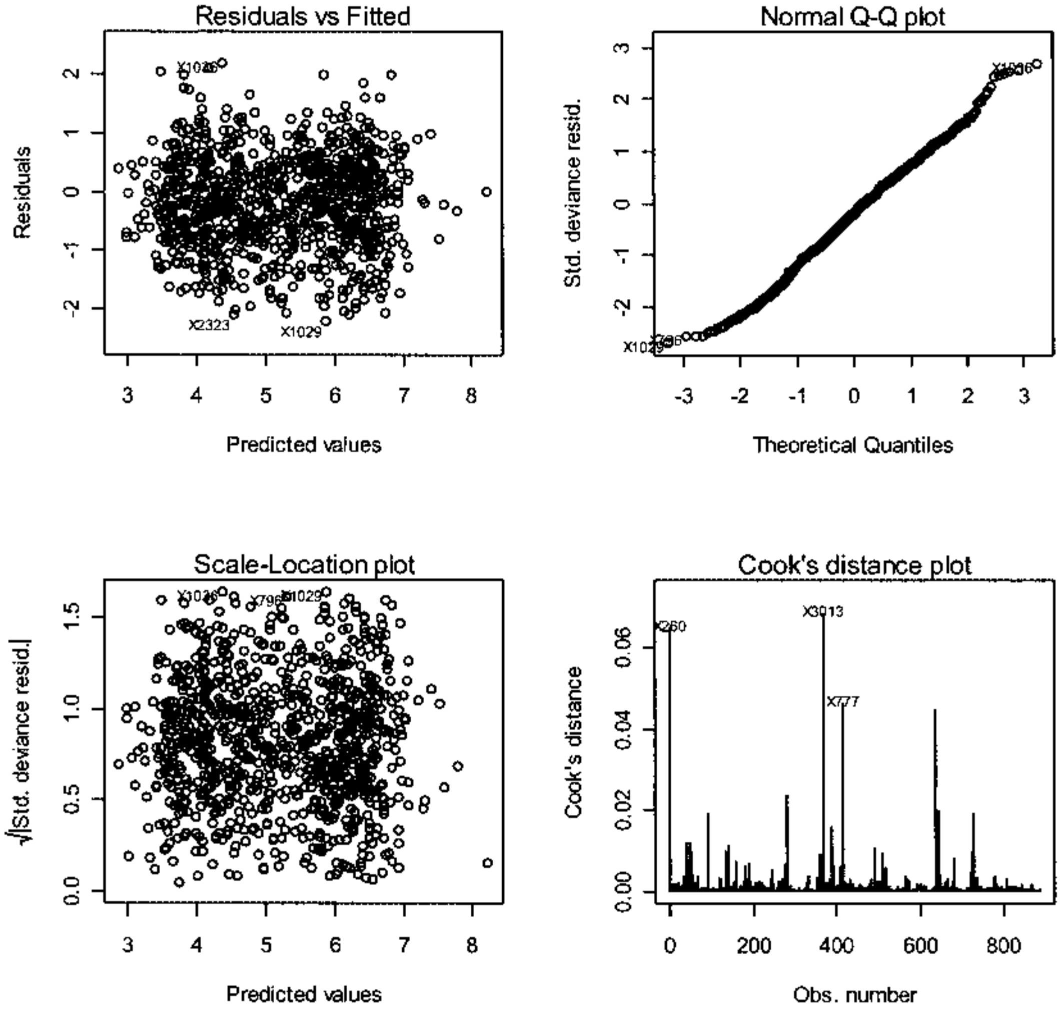

Figure A3-9: Diagnostic plots from the northeast North Island line fishery.

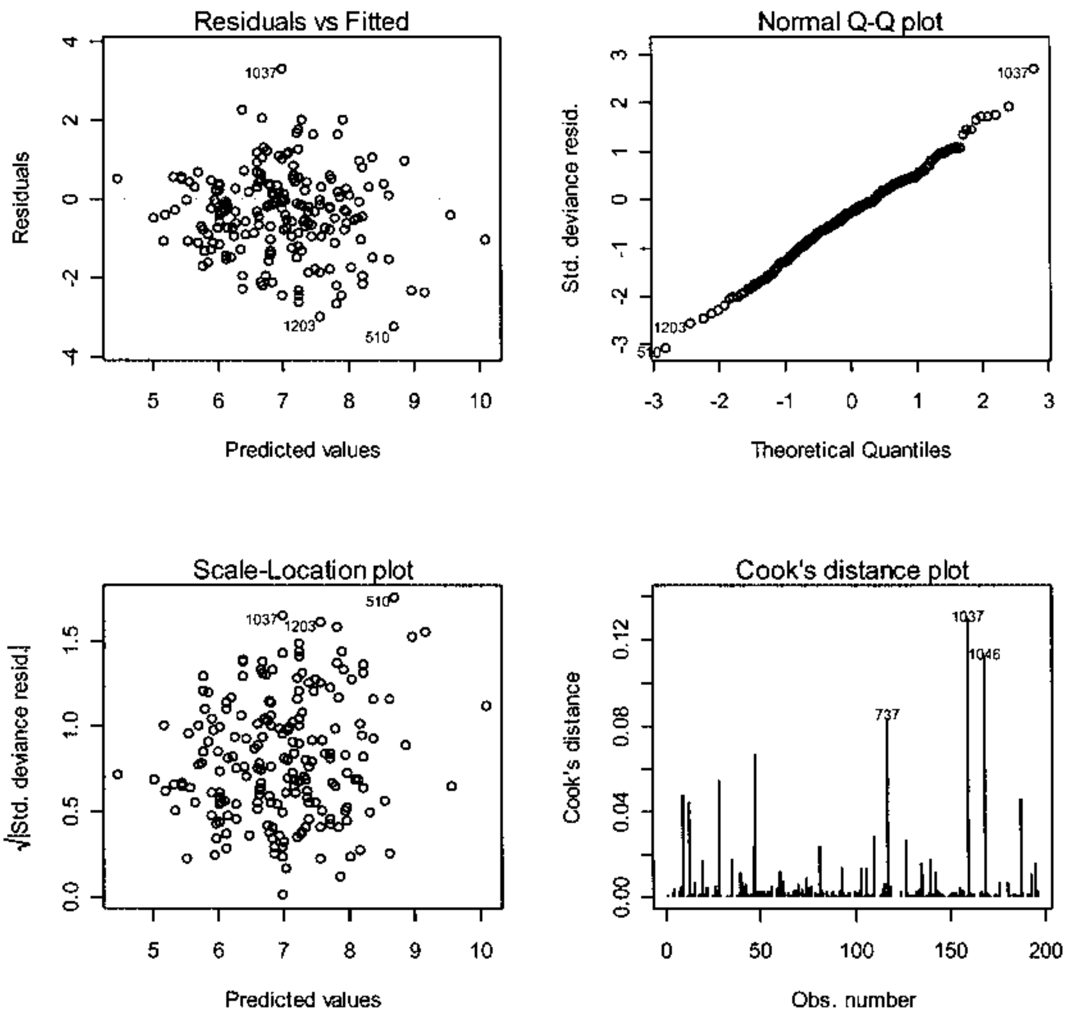

Figure A3-10: Diagnostics from the Chatham Rise bottom longline ling fishery.