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EXECUTIVE SUMMARY

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This report addresses the objective of Project SPO2001/01, 'To find appropriate methods to monitor or assess the status of rig (*Mustelus lenticulatus*) Fishstocks'. This was done by describing the commercial and recreational fisheries in Fishstocks SPO 1 and SPO 8, and updating unstandardised CPUE analyses for the main fisheries (targeted setnetting).

Catch histories for regions approximating these Fishstocks were obtained from various published and unpublished sources. Catch and landing data for fishing years 1990–91 to 2000–01 were obtained from the Ministry of Fisheries database, and earlier landing data were compiled from published summaries.

Catches (by vessel, day, and statistical area) and landings (by vessel, trip and port) were compared. Two main categories of error were found: incorrect areas had been recorded, and a large number of catch values appeared to be processed weight instead of greenweight. The former were corrected where possible; the latter were retained with the assumption that the error rate had been similar over time. Corrections were made for the non-alignment of area and Fishstock boundaries.

CPUE indices were calculated for targeted setnet fisheries based on records where daily values of net length were 100–6000 m, and catch less than 10 t. The indices calculated (kg/km net) were close to those of an earlier study for overlapping years. Other indices gave similar trends through the 1990s.

The predominant fishing method is setnetting, and most of the setnet rig catch is targeted. A large number of setnet rig catches were reported with no bycatch, which appears anomalous.

In SPO 1, commercial catches and landings are centred on harbours and shallow bays. Geographic subsets show different trends, suggesting localised fisheries but not necessarily separate stocks. In most areas peak catches are made in October and November.

For the whole of SPO 1, CPUE indices trend slightly downwards. In SPO 1 East, east Northland, Hauraki Gulf, and Bay of Plenty fisheries showed a clearer decline when considered separately instead of in combination. In SPO 1 West, Ahipara, Kaipara, Manukau, and Raglan/Kawhia fisheries show a decline in CPUE, despite increased annual landings. The decline is greatest for vessels making highest catches, and is usually greatest in the main fishing season. Recent catch levels appear unsustainable in at least some regions of SPO 1. The fishery may be overcatching mature females during their inshore pupping migration. Some biological characterisation of the catch is required.

In SPO 8, catches are made along an open coastline. Annual catches rose and then fell slightly during the 1990s. Seasonality is less pronounced than in SPO 1; the main season is September to March, with a peak in October and November. In both Fishstocks, landings stayed below the TACC in the 1990s, and declined. Recreational catches of rig are low.

In SPO 8, catch and CPUE followed similar trends during the 1990s, moving slightly up and then down. It is not known whether recent catch levels in SPO 8 are sustainable, but the TACC remains under-caught, and CPUE indices declined in the late 1990s.

Recommendations are made for monitoring or assessing the status of rig Fishstocks. The main options are: CPUE indices, biological characterisation of catches, trawl surveys, tagging, and fixed-station setnet surveys.

1. INTRODUCTION

The small shark commonly known as rig (Figure 1) is present in New Zealand coastal waters and in some localities is quite common. It supports several target setnet fisheries and is a bycatch in many trawl, Danish seine, and line fisheries. A good understanding of these is necessary before detailed stock assessments can be made, or before CPUE studies can be generated for the target fisheries.

Until about 1960 there was only limited market demand for rig, and most bycatch was dumped at sea. Landings then rose slowly until about 1970 (Figure 2), mainly as a result of greater retention of the trawl bycatch. From the mid 1970s to the mid 1980s targeted setnet fisheries developed in many regions; landings increased rapidly, levelled off, and then dropped. This drop in the mid 1980s reflected overfishing, and/or a decrease in fishing effort once fishers had established a catch history before introduction of the Quota Management System (QMS). As a precaution, large reductions in the Total Allowable Commercial Catch (TACC) were made when the QMS was established in October 1986 (Figure 2). Stocks then appeared to rebuild, and in subsequent years rig Fishstocks were placed in the Adaptive Management Programme (AMP), in which quotas were increased and monitored for sustainability. Catch rates in the northern Fishstock (SPO 1) and the northwestern Fishstock (SPO 8) fell, and their TACCs reverted to their original level for fishing year 1997–98. The status of rig populations in these two Fishstocks was not subsequently investigated.

The specific objective of Project SPO2001/01 was 'to characterise the SPO 1 and SPO 8 fisheries by analysis of existing commercial catch and effort data, and data from other sources, and make recommendations on appropriate methods to monitor or assess the status of these Fishstocks.' This study first describes the component rig fisheries of these regions, and then presents raw CPUE trends in target setnet fisheries for the 11 fishing years 1990–91 to 2000–2001.

The possibility that the shortfall in landings (relative to TACCs) in these two Fishstocks is a consequence of suboptimal distribution and utilisation of quota lies outside the scope of this study.

2. LITERATURE REVIEW

Alternative common names for rig include gummy shark (small teeth), spotted dogfish (many small white spots), pioke (Maori), and lemonfish (when processed for sale). The rig was formerly classified as *Mustelus antarcticus*, which is also known in Australia, but it is now identified as a separate but very similar species, *M. lenticulatus*, endemic to New Zealand. Some 25–30 species of *Mustelus* occur in temperate seas throughout the world, many supporting small to modest fisheries. Sharks are more vulnerable to overfishing than most bony fishes, mainly because they have a low rate of reproduction. However, recent research has shown that rig mature earlier than most sharks, have a moderate growth rate, and are not particularly longlived. They are moderately productive, but care must still be taken in determining sustainable catch levels in commercial fisheries which either target them or take them in significant numbers as bycatch. Rig, in common with many sharks, are most vulnerable when they aggregate in shallow water during spring and summer for mating and pupping.

Biology

Although this study is not concerned with the biology of rig, some life history characteristics of the species should be considered when interpreting changes in catches and catch rates. Movements deduced from tagging studies (Francis 1988b) and some geographic variation in size at maturity (Francis & Mace 1980, Francis 1988c, Francis & Francis 1992b) imply several breeding stocks. Unfortunately, these studies cover only southern and central New Zealand populations. Fecundity is relatively low with a range of 2–24 (mean 11) embryos; it is strongly influenced by the length of the mother (Francis & Mace 1980, Massey & Francis 1989). Gestation is about 11 months, and most females breed every year; pupping, ovulation, and mating occur mainly in spring and early summer. Pupping occurs in or near shallow coastal areas such as sheltered bays and harbours, where the pups remain for 6 months. Adults migrate considerable distances along coastlines (Francis 1988b), as well as inshore during the breeding season (King 1984, Francis 1988b).

Francis & Francis (1992a, 1992b) and Francis & Ó Maolagáin (2000) considered growth and mortality rates. In general, females grow faster, particularly at larger sizes, than males, reaching greater size and probably ages. There are differences in size and age at maturity between sexes, and between regions. There are also regional differences in growth rate. Comparisons, however, are complex because of differences in sampling gear (e.g., mesh size), and because the species aggregates by sex, size, maturity, and probably age, making it difficult to obtain representative samples of regional populations. Rig probably reach an age of 15–20 years (Francis & Ó Maolagáin 2000), but the largest fish in exploited populations are now much younger (Francis & Francis 1992b).

Commercial fisheries

Most of the studies on New Zealand's commercial rig fisheries were directed at assessing potential yields before the establishment of the QMS (Francis 1985, 1986, 1988a, 1988c, Francis & Smith 1988), and in subsequent revisions of these yields (Francis & Francis 1992b, Vignaux 1997). These studies described broad trends in the fisheries, and developed some CPUE indices. Most of this work is summarised in annual plenary documents, e.g., Annala et al. (2002), which also contain details of AMP decisions. The size and sex composition of commercial catches in several South Island setnet fisheries has been described by Francis & Mace (1980), King (1984), Francis & Smith (1988), and Massey & Francis (1989). There is no comparable published information on fish size and sex ratios in North Island fisheries, although an industry-run logbook programme instituted under the AMP regime has collected some potentially useful data. Francis (1998a) provided an overview of New Zealand rig fisheries in the context of the country's total shark fisheries.

Setnet CPUE, SPO 1 and SPO 8

Francis & Smith (1988) reviewed regional New Zealand rig fisheries for the period 1974–85, defining their complexity, and developing CPUE indices. Their regions differ from the Fishstocks defined by the QMS and (in some details) the subdivisions of SPO 1 used in this study. The years covered by their study were those immediately following development of the setnet fishery, when gear technology was changing and fishers were moving into the fishery and acquiring skill. Nevertheless, they reached some conclusions which are applicable to the present work. CPUE indices were declining in most New Zealand regions, but at different rates, and there were some differences between 'the fleet' and 'the top five vessels'. Within SPO 1, Hauraki Gulf CPUE indices were relatively constant. Kaipara Harbour indices were relatively constant for the fleet, but may have risen for the top vessels. Manukau Harbour indices declined by 9% annually for the fleet, but rose and were then constant for the top vessels. Within SPO 8, New Plymouth indices declined by 17% annually for the fleet, 13% for the top vessels. South Taranaki (presumably centred on Wanganui) indices declined by 7% annually for the fleet, but were constant for the top vessels.

Vignaux (1997) calculated raw CPUE indices (kg/km net) for several rig fisheries, including SPO 1 and SPO 8 and subsets (by fishing statistical area) of these. Her analyses covered only five years (fishing years 1991–92 to 1995–96), spurious records were deleted from her dataset rather than corrected. Definitions of Fishstock boundaries differ slightly from those in the present work. Vignaux interpreted SPO 1 CPUE indices as showing a slight decline, both in total and when considered as East and West, but with considerable variation in some fishing areas. However, she considered that because targeted fishing was restricted to small parts of SPO 1, mainly harbours, CPUE may not be representative of the whole stock, and she did not use it as an index of abundance of the SPO 1 Fishstock. Vignaux interpreted SPO 8 CPUE indices as showing a slight increase, with most areas consistent. Area 037 gave erratic values in her study, and partly for this reason, data from this area have been treated differently in the present study.

Recreational fishing

Rig are not important in the recreational fishery, but some estimates have been made of catches (Bradford 1996, 1998, Teirney et al. 1997, Hartill et al. 1998, Fisher & Bradford 1999). These are discussed in Section 7.

3. DATA SOURCES AND METHODS

Most data used in this study were obtained directly from Ministry of Fisheries catch-effort databases via NIWA extract procedures. General information on landings, TACCs, etc., by Fishstock were derived from the most recent Working Group Report on rig (Annala et al. 2002). For historical (pre-1987) data on landings by Fishstock it was necessary to compile data from Annual Reports on Fisheries (Marine Department, Ministry of Agriculture and Fisheries) to 1973, from King (1985), and from various unpublished datasets; see table 2 in Francis (1998a) for information on these sources.

One issue that is not addressed in this report is the use of different conversion factors over time. Most rig are processed or dressed ('headed and gutted' or 'trunked') shortly after capture to avoid ammoniation of the flesh. In landing records, weight and landed state (which can be 'greenweight' instead of a processed state) should both be recorded. Before 1983, if the landed state was not reported the value defaulted to greenweight, which would have underestimated true landings (Francis 1998a). In 1980 the conversion factor for headed and gutted/trunked to greenweight was 2.00; earlier values are not recorded. From October 1992 this became 1.75, and from October 2000 1.55. If all landings were reported as processed weights, and all data were converted using the new factor, these changes would result in a considerable increase in the weight of rig actually caught relative to that recorded (by 14% from 1980 to fishing year 1992–93, or 29% from 1980 to fishing year 2000–01). It is not known what proportion of landings in any year were reported as processed, and were then converted to greenweight using the new conversion factor. In general terms, though, during the 1980s and 1990s true landings will have increased more rapidly than reported landings by up to 14%, and declined less rapidly than reported. The value of 29% applies to only the final year (2000–01) in this study.

3.1 Catch and landing extracts

For the fishing years (October–September) 1989–90 onwards, the most comprehensive and accessible data on estimated commercial catches, fishing effort, and landings are held in Ministry of Fisheries catch-effort databases. This study used data extracts to the fishing year 2000–01 inclusive. Separate extracts were obtained for each fishing year. NIWA has developed extract procedures using the 'niwa...fishing_event' table to obtain estimated catches from the catch-effort landing return (CELR) and trawl catch-effort processing return (TCEPR) subsets of the database. These summarise individual catch data by: vessel identifier (coded), date (year, month, day), fishing method, statistical fishing area, target fish species, catch by the required species code (SPO), and total catch (all species). Some associated daily effort values were also extracted: net length in metres (setnets only), number of fishing operations, and duration of fishing operations (other methods). A Ministry-generated 'trip code number' was also obtained for each line of catch and effort data, which could be used to link these data to separate extracts on the landings by each vessel. These extracts recorded landings by vessel identifier, date (year, month, day), required species code (SPO), fishing trip, and trip code number. CELR and TCEPR estimated catch data were obtained as daily summaries, and CELR and CLR recorded landings data were obtained as trip summaries, by vessel.

3.2 Linking effort, catches, and landings

Only the landings values represent 'total catches'. The estimated catch values are incomplete where rig do not come within the top five species that can be listed on catch forms, as often occurs in trawl catches, and in other fisheries when rig are not targeted. It is also possible that estimated catch values of rig which are processed (trimmed) at sea are recorded as processed weight instead of the greenweight value requested, as has been noted for school shark (Paul & Sanders 2001) and groper (Paul 2002). However, the landings values, though more complete, are not linked to effort information (fishing method, area, target species, etc.). In the present study, a relatively simple procedure was used to categorise landings by method. Estimated catch and landed catch extracts were integrated so that rows of catch and effort data, by vessel and trip, were followed by the landing row for that trip. The fishing method for each landing row could then be added. Most vessels used a single method, and blocks of sequentially coded vessels used the same method, which simplified this procedure. It may eventually be possible to automate this procedure using the trip code number, even though there are many trips for which either catch or landing data are missing. There was insufficient time to investigate this possibility during the present project. A moderate number of vessels (mainly trawlers) recorded landings, but no catches in a year, and thus a method could not be directly assigned to them. This was largely overcome by compiling a 'register' of vessels from the estimated catch extracts for all years (1989–90 to 2000–01), which gave their catch by method. Methods were assigned to vessels by referring to this list; exceptions were made for vessels which regularly used several methods, and their method was recorded as null. A null method was also recorded for the few vessels which made landings but no catches over the whole time period. Retaining these null records allowed vessel catch and landing sequences to be retained, although the total null landing values were negligible.

3.3 Statistical fishing areas and Fishstock boundaries

SPO 1 and SPO 8 Fishstock boundaries do not coincide with the boundaries of fishing areas (Figure 3). The southern boundary of SPO 8 subdivides statistical areas 037,0 39, and 040. Areas 039 and 040 are almost completely in SPO 8, and were assumed to be so. However, area 037 is divided about equally between SPO 8 and SPO 7. The northern boundary of SPO 8 subdivides statistical area 41; about two-thirds is in SPO 8, the remainder in SPO 1. Catches are recorded by statistical area, landings by Fishstock. The Ministry of Fisheries defines area 037 as being in QMA 7 (SPO 7), but moderate catches are made in this area by Wanganui vessels landing their catch as SPO 8. Vignaux (1997) incorporated area 037 in SPO 8, and her procedures are largely followed in this study. The Ministry of Fisheries defines area 041 as being QMA 8, i.e., SPO 8, and this definition was used for the present study. However, about one-third of it lies within QMA 9 (SPO 1), with moderate landings from it recorded in this Fishstock.

The issue of appropriately linking SPO 8 catches and landings was addressed by obtaining two additional extracts for each year:

(1) Landings by Fishstock from area 037. Using the trip code number, which links catches with landings, an extract was obtained of vessels which had fished area 037, and landed to SPO 8, SPO 7, or to other Fishstocks. This identified three groups of vessels. (a) Vessels fishing in area 037 and landing only to SPO 8; their records were retained in the extract of SPO 8 estimated catches. (b) Vessels fishing area 37 and landing to SPO 7 (or another Fishstock); their records for area 037 were removed from the extract of SPO 8 estimated catches. (c) Vessels fishing area 037 and landing into both SPO 7 and SPO 8; the records of estimated catches in area 037 were removed from the SPO 8 extract if there was not a matching SPO 8 landing.

(2) Landings by Fishstock from area 041. Using the trip code number, an extract was obtained of vessels which had fished area 041, and landed to SPO 8 or SPO 1, and/or any other Fishstock. This identified three groups of vessels. (a) Vessels fishing in area 041 and landing only to SPO 8; their records were retained in the extract of SPO 8 landings. (b) Vessels fishing area 041 and landing to SPO 1; their records for area 041 were removed from the extract of SPO 8 estimated catches and incorporated in the SPO 1 extract. (c) Vessels fishing area 041 and landing into both SPO 8 and SPO 1; the records of estimated catches in area 041 were removed if there was no corresponding SPO 8 landing and incorporated in the SPO 1 extract.

In summary, only a proportion of area 037 estimated catch records were retained in SPO 8, and estimated catch records from area 041 were allocated to SPO 8 or to SPO 1 according to landing records which identified the Fishstock.

3.4 Data grooming issues and procedures

3.4.1 Fishing area numbering systems

There is clearly some confusion in the use of the numbering systems for Fishing Statistical Areas, Fisheries Management Areas (FMAs), Quota Management Areas (QMAs), and Fishstocks. Most fishers record (correctly) the fishing area in the space provided in the top (estimated catch) part of the CELR form, which becomes one column in the estimated catch extract. Some fishers record either the FMA or QMA number, which can create confusion for numbers between 1 and 10 when they are written in this form and not 001 to 010. In this study, 'area' 1 is a minor problem; catches taken in '1' may not be from statistical area 001, but will still be from QMA 1. 'Areas' 2 to 9 are the main difficulty; they may be from statistical areas 002 to 009 in QMA 1, or they may be from QMAs 2–9. Some of the latter errors can be recognised by the nominated method and target species (e.g., setnetting for elephantfish in '3' will refer to QMA 3, not area 003). Where obvious errors of this kind were noticed during data grooming, the entries were deleted, but others will remain (e.g., setnetting for flatfish in '2' could refer either to statistical area 002 or QMA 2).

3.4.2 Landing points

A 'landing point' was selected in all relevant extracts, and used to identify potential errors; e.g. landings into southern South Island ports are unlikely to have been taken in SPO 1, and these entries were removed. The recorded landing point could not be used to locate all incorrect entries without more careful cross-checking than was possible in this study. Landings into Gisborne and Napier could have come from SPO 1, and landings into Manawatu coast, Cook Strait, and Marlborough/Nelson ports could have come from SPO 8.

The landing point listing, in conjunction with area, method, and target species, proved to be a useful component of the extracts. However, the names had not been standardised or checked, and were often of minor localities (e.g., boat-ramps), or names for which there were two possible localities. Some names were of unloading facilities rather than localities (e.g., 'ice-plant', 'fisherman's wharf', 'breakwater', or a company name). Most of these were eventually identified, although some errors may have resulted from misinterpretation of incorrectly spelled place names. This field is not checked by the Ministry, and the 200+ landing points each had up to five alternate spellings or misspellings. Many individual records had a 'null' entry, but after consolidating the catch and landing extracts and sorting by vessel and date, it was possible to infer the point of landing from information in adjacent entries. Some landing points were recorded as 'transhipped at sea'; where possible these were attributed to a vessel's usual port of landing, and others were listed as 'null'.

3.4.3 Catch and landing values discrepancies

After integrating and sorting the catch and landing extracts (by year, vessel, date), a variety of other discrepancies became apparent. These were dealt with as follows.

- Poor agreement between catches and landings. It is inevitable that small trawl bycatches of rig will not be recorded (when not one of the top five species caught), and appear only in trip landing records. There are many instances of poor agreement between catches and landings for setnet vessels which targeted rig and landed moderate to large quantities. Some vessels reported high catches but low (or no) landings, others the reverse. This could not be investigated further, although a significant part of this problem appears caused by incorrect recording of statistical fishing areas (other numbering systems being used). Unless the error was obvious and easily corrected, the data were used as recorded.

- Multiple landing records for the same trip. In most cases the landed values differed and their sum appeared appropriate for the trip, in others the values were equal but also seemed appropriate, and in some the landing row appeared to be duplicated. It was not possible to determine whether any were true duplicates, and all were retained.
- Unlikely method and target species combinations, e.g., ringnetting (RN) for flatfish and rig. When adjacent records were for setnetting (SN) an error was assumed and the entry changed.
- Suspected miscoding of target species. SCA (scallop) was corrected to the more probable SCH (school shark) taken by line and net. SPD (spiny dogfish) is a plausible target species, though not in SPO 8 where most spiny dogfish should be NSD, and this code was usually listed within sequences of 'SPO'. It may be a handwriting misinterpretation of SPO, but was not corrected in the data sets used; SPD values totalled less than 1 t annually, which made little difference to the analysis of catch by target species. However, it implies that some SPO catches and landings may have been miscoded as SPD, and these will have been omitted from the extracts obtained. SWA was judged an unlikely target species, and considered to be another handwriting problem (rather than an error for WAR); these target species entries were changed to SNA.
- 'Null' entries. These were not uncommon in almost all data fields. In the fields important to analyses (method, area, landing point, etc.) it was possible to correct most of these by examining the adjacent records for the same vessel. 'Null vessel' entries were removed; there were very few of these, and there would be negligible effect on results.
- High outlier catches and landings. Daily catches greater than 5 t, and trip landings greater than 10 t, were investigated. By comparing the catch with the landing pattern for the vessel involved, a judgement was made on which of these apparent outliers was erroneous; either a correction was then made (e.g., for a misplaced decimal point or a double-entered number) or an approximate value was substituted, based on adjacent records.
- Catches of rig recorded as '0'were retained, but these records were used only to confirm the fishing method, area, etc. of the vessel concerned, particularly when its adjacent records were sparse. There are many possible explanations for catches recorded as zero, most of them implying erroneous recording or data entry, rather than true zero catches when rig were targeted but not caught.

3.4.4 Data subset for CPUE analyses

After the grooming procedures described above, a separate set of files was created for all setnet catch and landing data, by Fishstock and year. Landings data (by trip) were not groomed further, but were separated from the catch and effort data (by day). Additional data grooming of the catch and effort records (one row per day) included the following.

- Net length (1). The recorded values for net length; in theory the length of net fished on the day in question, but from anecdotal information this may not be strictly true. Two possible misinterpretations by fishers are (i) length of a single net, and (ii) net(s) carried on the vessel but not necessarily used. The original net length values were retained. A duplicated column was inspected for outliers using range checks per vessel, and by scanning the chronological sequence of values for each vessel with apparent anomalies. There were many obvious and apparent errors, but most could be corrected by comparison with adjacent data. Most errors comprised additional or missing zeroes (e.g., 15000 or 150 for 1500), but there were also missing 'null' entries within a sequence of identical net lengths. For initial analyses which determined the effect of these modifications, this yielded two files for each Fishstock/year dataset; one with uncorrected net length values (following the procedure of Vignaux 1997), and one with corrected net length values.
- Net length (2). Following Vignaux (1997), high (over 6000 m) and low (under 100 m) outliers were removed from each dataset. The high values were removed, even though (by inspection)

most of these appeared to be valid, being recorded by a few vessels fishing many nets, e.g., with total lengths from 3000 m to 8000 m. In a few instances, most – sometimes all – of a vessel's net length values were clearly erroneous, and all records for these vessels were removed.

- Catch. Vignaux (1997) excluded daily catches greater than 10 t. After the earlier grooming of high outliers, no values of this size were found by range checks. Values of 1 kg were removed, on the grounds that they could have been fish counts rather than weights.
- CPUE. Daily CPUE values (kg/m) were calculated for each vessel. Vignaux (1997) excluded values greater than 10 kg/m. In the groomed datasets used in this study, there were no such values.
- Fishing statistical area outliers were re-checked. In some cases these could be corrected by referring to other entries by the same vessel, and to its port of landing. Records listing area 1 were removed; this is an open ocean area where rig would not be caught, and '1' probably referred to QMA 1 or to Fishstock SPO 1. Records of area 101 were changed to 010; the landings from this area were made into Tauranga, and '101' was assumed to be a transposition error.

3.4.5 Measures of CPUE

Several measures of CPUE were derived from the estimated catch values.

- All-vessel CPUE. The annual mean of total catch (kg) / total effort (km net length). This was the value calculated by Vignaux (1997); it minimises the influence of vessels which have unusually high or low daily and low annual catches.
- Vessel-day CPUE. The annual mean of the daily CPUE (kg/km) of all the vessels. This value was most influenced by the vessels fishing for the greatest number of days, i.e., the main vessels.
- Vessel CPUE. The annual mean of the annual CPUE (kg/km) of all the vessels. This value minimises the effect of vessels with some high and potentially erroneous daily catch or effort values, and it gives equal weight to all vessels regardless of their annual catch and effort.
- Vessel-day CPUE. The annual mean, in kg/day, of total catch / total number of days fished by all vessels.
- Median CPUE. The central CPUE value in a ranked sequence of the daily values.

These were derived from all setnet vessels which reported their target species as rig. Some CPUE indices were also calculated for the 'main' vessels, those which reported a catch of at least 5 t in one year of their time series. A CPUE trend was also determined for the single vessel which made consistent annual catches of more than 5 t through 10 of the 11 years under study.

Unless otherwise stated, the CPUE values used in this report are 'All-vessel CPUE', the measure employed by Vignaux (1997).

3.4.6 Rig catch in relation to total catch

Two additional features of the targeted setnet rig catch values required some clarification. (1) There was a high number of very small catches. (2) In many instances, the estimated rig catch was very similar or identical to the total estimated catch of all species (Figure 4).

The smallest rig catches (e.g., less than 9 kg) are generally a low percentage of the total catch in each fishing operation (usually a daily series of catches). This suggests that rig was either not the true target species – although it was nominated as such, or it was the true target and there was a large bycatch. As rig catch sizes increased, they became an increasingly large proportion of the total catch. Although some rig catches seemed surprisingly low – even if doubled under the assumption they were processed weights rather than greenweight – this general pattern seemed reasonable.

Rig catches equalled the total catch of a fishing operation (or day) in many instances at all catch levels. There are at least two explanations. (a) There was no bycatch, or alternatively no bycatch was recorded. The absence of bycatch is plausible at low catch levels, but seems surprising at high levels, where considerable lengths of net were deployed. A random check of a few vessels showed that where rig and total catch values were similar or identical, the landed weight of rig also equalled these. (b) There was some error in completing the CELR forms, such as entering the target species weight in the total catch weight space, as well as under its own entry. Further investigation lay outside the scope of this study, and it was assumed that the catch weights recorded as rig were correct even when they matched the total weight values.

3.4.7 Estimated catch in relation to landings

Estimated catch should be recorded as greenweight; there is no provision on the CELR form for recording the 'state' (gutted, trimmed, trunked, greenweight, etc.) of estimated catches. Landings can be initially recorded in any state, as there is provision for recording this, allowing conversion of a processed (partial) weight to full greenweight. In addition, the formal CELR landings panel requires 'Greenweight (kg) when advised by LFR [Licensed Fish Receiver]'. It was clear from many pairs of catches and landings, e.g., from days or trips, that there was a systematic error in the data. To examine this, the annual catch of each vessel was compared with its landing, for the years (1992–93 to 1999–2000) during which the conversion factor was 1.75 (Francis 1998a). If catches were reasonably well estimated, and both catches and landings correctly recorded, the values should centre on 100%, or slightly less, as some catches may not have been recorded. This is shown to be partly true in Figure 5, where there is a peak between 90% and 110%. A second peak occurs, however, between 50% and 60%, and the most likely explanation for this is that a large number of estimated catches were recorded in their processed form (probably trunked), which is slightly more than half their greenweight. That is, the catch data on which this study is based comprise a mixture of processed weights and greenweights. A less likely alternative is that both catches and landings were correctly recorded as greenweight, and the conversion factor of 1.75 incorrectly applied to the latter.

In theory, the estimated catch weights could be corrected by determining the annual error factor for each vessel, and multiplying by this. This was considered to be too large a task, and to involve too many assumptions, particularly when the catches were less than 40%, and more than 120%, of landings. Catch values were retained as recorded (apart from the outliers previously corrected or removed), and the assumption made that the mixture of processed weights and greenweight remained constant during the years of this study.

3.4.8 Consequences of grooming the effort values

The effect of grooming the effort (net length) data by correcting obvious errors and interpolating missing values was examined in the smaller of the two Fishstock datasets (SPO 8). CPUE indices derived from the uncorrected (but with outliers removed) series of net lengths, were compared with those derived from the corrected series (see Section 3.5.1). In most years 1–5% of net length values (for SPO 8) were corrected; very few records were removed because corrections were not possible. CPUE indices (all setnet vessels, targeting rig and other species) changed little, whether calculated as all-vessel CPUE or vessel-day CPUE (Table 1). However, the corrections were often made to records from vessels reporting moderate to large catches. It was considered desirable to keep the records of these vessels as complete as possible in the subsample of vessels targeting rig, and the CPUE indices used subsequently in this report for both Fishstocks were calculated using the corrected series of effort (net length) values.

Table 1: Comparison of CPUE values (all-vessel, kg/km) for Fishstock SPO 8 obtained using effort (net length) values after outliers were simply removed 'groomed', with effort values where most outliers were corrected by inspection ('corrected').

Fishing	All-vessel CPUE		Vessel-day CPUE	
year	Groomed	Corrected	Groomed	Corrected
1990–91	88	88	76	76
1991–92	59	60	52	53
1992–93	78	76	66	60
1993–94	89	89	67	64
1994–95	100	96	89	79
1995–96	109	117	107	111
1996–97	96	95	112	110
1997–98	113	111	156	153
1998–99	90	88	128	122
1999–00	90	89	127	119
2000–01	88	87	96	95

3.4.9 Selection of fishing years

Extracts were obtained for fishing years 1989–90 to 2000–2001. The first of these years is not included in CPUE analyses because these data are considered incomplete (see Tables 3 and 13). For example, in SPO 1, CELR+CLR landing totals were 85–108% of the landings reported directly into the QMS (QMR landings) for fishing years 1990–91 onwards, but only 62% for the 1989–90 fishing year. Vignaux (1997) started her time series at 1991–92, one year later; the reason why she omitted 1990–91 is not stated, but may have been because the objective of her study was to monitor the effect of AMPs introduced in 1991–92.

4. THE COMMERCIAL FISHERY

4.1 General

Reported annual rig landings in New Zealand in the 1930s were generally less than 50 t, and increased only slowly, reaching a few hundred tonnes in the 1950s. Annual landings reached 500 t in 1960, 900 t in 1970, and then rose rapidly in the late 1970s to average about 3200 t per year in the late 1970s and early 1980s (Figure 6). Catches peaked at over 3800 t in 1983, but declined to 2900 t in 1986, before falling to 1100 t in 1987 (fishing year 1986–87) when the QMS was introduced. The introduction of a reduced catch limit was in response to declining CPUE. In subsequent years total catches have risen steadily and from 1991–92 have remained at 1600–1700 t, a little under the total TACC.

Landings in SPO 1 and SPO 8 have followed this general pattern, but both have declined during the late 1990s.

4.2 The Adaptive Management Programme

In response to anecdotal information that rig stocks were rebuilding in some regions, quotas (Total Allowable Commercial Catches, TACCs) were raised during the 1990s via the Adaptive Management Programme (AMP). This seemed reasonable, as there was accumulating biological evidence that rig were moderately productive small sharks (Francis & Francis 1992a, 1992b). The AMP carried an obligation on the fishing industry to monitor the stock status to determine that the higher catch levels were sustainable. Some Fishstocks, including SPO 1 and SPO 8, were removed from the AMP in the 1997–98 fishing year because initial catch rates were not maintained, and because monitoring was considered inadequate. TACC changes under the AMP are summarised in Table 2.

Table 2: TACC movements for rig Fishstocks, as a consequence of Adaptive Management Plan decisions.

Fishstock	1986–87[1] TAC	1990–91[2] TAC	Revision up[3]	Revision down[4]	Revision up
SPO 1	540	688	825 (1992)	692 (1998)	–
SPO 2	60	71	85 (1992)	72 (1998)	–
SPO 3	330	364	430 (1992)	–	600 (2001)
SPO 7	240	294	350 (1992)	–	–
SPO 8	240	310	370 (1992)	310 (1998)	–

Notes:
1. The TACs set for the first (1986–87) fishing year of the QMS.
2. Revised TACs following successful quota appeals and administrative increases.
3. Revised TACCs for the 1991–92 fishing year, the first year of AMP increases.
4. Revised TACCs for the 1997–98 fishing year, when three Fishstocks were removed from the AMP.
5. Revised TACC for the 2000–01 fishing year for SPO 3, increased further under the AMP.

5. THE NORTHERN FISHERY, SPO 1

Fishstock SPO 1 includes FMAs 1 and 9, and extends from Tirua Point on the west coast to Cape Runaway on the east coast, covering approximately half of the North Island coastline. By Ministry of Fisheries definition it includes fishing statistical areas 001 to 010 on the northeast coast, and areas 042 to 048 on the northwest coast (see Figure 3), plus their adjacent offshore areas (which are not relevant to the rig fishery). The boundary extending northwest from Tirua Point passes through area 041, and some catches from this area are recorded as SPO 1 landings, not SPO 8 (see Section 3.3.)

5.1 Catch history

SPO 1 landings increased rapidly in the late 1980s, reaching and exceeding the TACC (Figure 6). In the 1991–92 fishing year the TACC was increased from 688 to 825 t (829 t in 1993–94). This was exceeded in the first year (by landings of 878 t), but in subsequent years landings of only 600–700 t were achieved. SPO 1 was removed from the AMP in 1996–97, the TACC dropping to 692 t in 1997–98. Landings also dropped, to 550–600 t. The status of this northern stock was not adequately monitored under the AMP, and it was not known whether either the TACC or the level of catches was sustainable.

5.2 Quotas, landings, and estimated catches

The relationships between catches, landings, and TACCs since 1989–90 are given in Table 3. Landing values used in this study were close to the landings recorded in the QMS, particularly from 1992–93 onwards. Estimated catches were two-thirds to three-quarters of the landings, the discrepancy presumably arising (a) from many catches being recorded as processed weight, and (b) some rig catches falling outside the top five species recorded in a fishing event.

In the remainder of this study, 'estimated catches' refer to groomed CELR + TCEPR data, and 'landings' to groomed CELR + CLR data.

Table 3: TACCs, reported landings, and estimated catches (t) of rig, SPO 1.

Year	TACC	QMR total[1]	Landing[2]	Landing %[3]	Est. catch[4]	Catch as % landing[5]
1989–90[6]	687	689	425	62	330	79
1990–91	688	656	561	86	371	66
1991–92	825	878	745	85	520	70
1992–93	825	719	692	96	476	69
1993–94	829	631	681	108	523	77
1994–95	829	666	658	99	517	79
1995–96	829	603	624	103	459	76
1996–97	829	681	681	100	483	71
1997–98	692	621	576	93	383	66
1998–99	692	553	585	106	332	57
1999–00	692	608	614	101	409	67
2000–01	692	554	573	103	381	66

Notes:

1. Landings from Quota Management Reports (QMRs).
2. Landings (landed catch) from Catch Effort Landing Returns (CELRs) and Catch Landing Returns (CLRs). Groomed values.
3. CELR + CLR landings as a percentage of QMR landings.
4. Estimated catches from CELRs and TCEPRs. Groomed values.
5. Estimated catches as a percentage of CELR + CLR landings.
6. Data for the 1989–90 fishing year are considered incomplete, and not used in subsequent analyses.

5.3 Landings by port

When landings by port are examined, three trends are apparent, both in total landings of rig and in landings of rig taken by setnet (Tables 4 and 5). At west coast ports, particularly Kaipara and Manukau Harbours, there have been increased landings in recent years. At east coast ports, particularly the main ports of Auckland and Thames, there has been a decrease in landings. At the smaller ports on both coasts, landings have remained relatively steady.

Table 4: Landings (t) of rig by port, SPO 1, taken by all methods. Ports are based on point of landing records which include some landings at moderate distances away from the actual port.

Fishing year	Ahipara	Kaipara Hbr	Manukau Hbr	Raglan Hbr	Kawhia Hbr	Other NW coast	Whangarei	Other NE coast	Auckland	Thames	Coromandel	Whitianga	Tauranga	Other Bay of Plenty	Other	Total
1990–91	30	33	66	28	8	4	14	10	198	97	48	7	13	5	2	561
1991–92	21	57	63	33	7	6	39	19	307	123	33	15	14	4	3	745
1992–93	25	34	76	37	5	11	14	33	250	102	37	35	20	13	1	692
1993–94	19	42	111	33	15	10	12	25	228	58	15	20	73	20	2	681
1994–95	25	79	103	53	18	11	14	18	214	54	14	12	26	13	6	658
1995–96	52	73	72	37	35	19	14	16	124	52	26	18	56	8	5	606
1996–97	60	85	141	62	22	24	35	28	108	37	30	12	19	14	3	681
1997–98	72	57	119	57	23	14	23	19	74	45	26	14	15	9	9	576
1998–99	61	82	128	23	36	14	20	13	91	43	26	13	23	9	5	585
1999–00	36	114	149	27	12	20	13	17	79	54	36	27	20	6	4	614
2000–01	40	116	122	33	32	20	13	19	62	39	44	9	12	5	6	573

Notes:

1. 'Other NW coast' includes landing points centred on Hokianga, Port Waikato, and New Plymouth.
2. 'Other NE coast' includes landing points centred on the Bay of Islands, Whangaroa, Mangonui, Houhora, and Parengarenga.
3. Auckland includes landing points in the southwestern Hauraki Gulf from Leigh to Kawakawa Bay, plus Great Barrier Island and Waiheke Island.
4. 'Other Bay of Plenty' includes landing points centred on Whangamata, Whakatane, and Opotiki.
5. 'Other' represents minor landing points not identifiable to port, plus ports outside SPO 1

Table 5: Landings (t) of rig by port, SPO 1, taken by setnet. Ports are based on point of landing records, which include some landings at moderate distances away from the actual port.

Fishing year	Ahipara	Kaipara Hbr	Manukau Hbr	Raglan Hbr	Kawhia Hbr	Other NW coast	Whangarei	Other NE coast	Auckland	Thames	Coromandel	Whitianga	Tauranga	Other Bay of Plenty	Other	Total
1990–91	30	32	46	18	8	4	7	3	124	97	39	6	6	4	0	423
1991–92	21	55	51	21	7	6	26	12	204	123	23	13	4	4	< 1	569
1992–93	24	34	42	19	4	10	5	19	174	102	31	33	10	11	0	520
1993–94	19	42	69	23	15	9	6	13	166	58	11	18	8	17	< 1	477
1994–95	25	78	83	36	18	11	8	12	150	54	11	11	3	11	4	517
1995–96	52	73	46	20	35	19	10	9	48	51	24	16	8	7	2	420
1996–97	60	85	117	52	22	23	32	16	54	37	29	11	11	14	< 1	563
1997–98	72	55	93	45	22	13	21	13	27	45	25	12	6	9	4	464
1998–99	61	81	80	7	35	13	15	7	39	41	25	12	14	9	2	441
1999–00	36	113	111	17	12	20	8	5	26	54	34	26	8	6	< 1	476
2000–01	40	116	83	28	32	19	10	10	17	39	43	8	5	4	1	455

Notes:

1. It is possible to estimate landings of rig by port by method, but it was considered unrealistic and too time-consuming to make a further subdivision by target species. Landed values are not directly linked to catch by target species; it is theoretically possible to make a pro-rata estimate, but this was not attempted.

6. See also notes 1–5, Table 4.

5.4 Catch by statistical area

Only the estimated catch can be categorised by statistical fishing area. (Landings are not linked to area; pro-rata estimates can be made but they involve several assumptions, and were not attempted in this study.) Setnet catches by area are shown in Table 6. In SPO 1 East, the largest catches have been in area 007, the inner Hauraki Gulf. Together with the catches in area 006 (central/outer Gulf), they show a similar decline to that seen in Auckland and Thames landings. In SPO 1 West, the largest catches have been in areas 041 and 042 (probably representing Raglan and Kawhia Harbours), 043 (Manukau Harbour), 044 (Kaipara Harbour), and 047 (Ninety-mile Beach). They show an increase over the time period comparable to the rise in port landings.

Table 6: Estimated setnet catches (t) of rig by statistical area in SPO 1, all target species.

Fishing	SPO 1 West							SPO 1 East									Total
year	047	046	045	044	043	042	041	002	003	004/005	006	007	008	009	010	
1990–91	29	1	2	23	44	17	7	2	5	2	18	125	12	7	1	298
1991–92	20	3	6	38	44	22	14	7	22	9	33	191	2	8	1	427
1992–93	30	1	6	31	29	22	2	14	6	7	27	163	34	10	6	387
1993–94	23	1	3	32	62	20	9	9	16	46	26	84	38	8	7	383
1994–95	36	2	10	56	78	52	16	14	31	68	23	80	27	14	11	517
1995–96	42	< 1	1	45	38	45	24	5	9	8	< 1	90	12	5	4	328
1996–97	50	< 1	39	40	50	56	34	7	23	7	2	84	10	9	5	415
1997–98	58	< 1	10	38	33	58	19	5	11	12	< 1	68	9	4	4	330
1998–99	50	6	6	56	42	20	27	6	13	19	7	62	7	6	5	332
1999–00	26	3	10	95	74	15	19	2	6	2	10	66	8	6	2	348
2000–01	33	3	14	88	56	19	5	5	8	1	< 1	62	15	6	2	317

Notes:

1. The relatively small catches listed for statistical area '1' (probably QMA '1') are not listed here.
2. Catches from areas 004/005 are predominantly from area 005, outer Hauraki Gulf; area 004 catches are assumed to have been made by vessels working from Great Barrier Island.

Targeted setnet catches by area are shown in Table 7. They show the same pattern as the setnet catches of rig taken both as a target and a bycatch, reflecting the fact that a high proportion of the setnet catches were targeted.

Table 7: Estimated setnet catches (t) of rig by statistical area in SPO 1, target species rig.

Fishing	SPO 1 West							SPO 1 East									Total
year	047	046	045	044	043	042	041	002	003	004/005	006	007	008	009	010	
1990–91	24	1	< 1	18	43	13	7	1	3	2	16	106	4	3	1	245
1991–92	19	3	< 1	30	41	20	13	3	5	7	26	169	< 1	5	0	346
1992–93	25	< 1	4	26	26	21	< 1	8	4	7	22	138	27	3	< 1	311
1993–94	18	< 1	2	29	58	18	7	4	14	45	25	75	36	3	4	338
1994–95	12	< 1	4	53	76	37	10	8	23	58	15	70	22	3	3	392
1995–96	24	< 1	1	44	37	44	19	3	7	7	< 1	85	12	2	< 1	285
1996–97	27	< 1	39	38	49	50	32	4	20	6	2	81	9	3	1	362
1997–98	22	< 1	10	33	30	52	15	1	10	11	< 1	62	9	2	1	258
1998–99	10	3	< 1	52	38	11	22	4	7	7	1	58	4	2	1	217
1999–00	12	3	9	88	70	15	12	2	4	2	10	63	8	3	< 1	304
2000–01	14	3	14	84	54	19	5	2	7	1	< 1	58	15	< 1	1	278

5.5 Landing by method

Landings of rig by fishing method are shown in Table 8. Setnetting, contributing 70–80% of landings, is the main method. Trawling took 10–20% of landings, declining slightly through the 1990s. Low landings by Danish seiners (2–4%) also declined.

Table 8: Landings (t) of rig by method in SPO 1.

Fishing					Method	
year	Setnet	Trawl	Danish seine	Longline	Other	Total
1990–91	423	111	18	10	< 1	561
1991–92	569	132	23	20	< 1	745
1992–93	520	123	25	23	1	692
1993–94	477	107	25	71	< 1	681
1994–95	517	83	23	30	5	658
1995–96	420	95	21	68	2	606
1996–97	563	73	22	22	2	681
1997–98	464	75	12	23	3	576
1998–99	441	102	13	25	5	585
1999–00	476	93	11	31	4	614
2000–01	455	82	11	24	2	573

Notes:
1. 'Other' includes a few small landings for which the method could not be determined.

5.6 Catch by target species

Only the estimated catch can be categorised by target species. Catches of rig (all methods) by target species are shown in Table 9. Most (65–77%) of the catch is targeted. About 10% is taken as a bycatch when snapper were targeted, and 2–5% in gurnard, trevally, or flatfish fisheries.

Table 9: Estimated catch (t) of rig by target species in SPO 1, all methods.

Fishing									Target species	
year	Rig	Snapper	Gurnard	Trevally	Flatfish	School shark	Tarakihi	Kahawai	Other species	Total
1990–91	246	70	11	21	7	5	2	2	8	371
1991–92	351	105	18	19	8	4	4	4	7	520
1992–93	311	73	27	23	12	6	4	6	13	476
1993–94	402	54	15	14	11	4	7	4	11	523
1994–95	400	48	20	12	7	6	4	5	14	517
1995–96	335	43	19	23	5	10	4	2	18	459
1996–97	364	31	28	28	8	7	5	1	13	483
1997–98	258	30	28	28	12	8	3	2	12	383
1998–99	221	29	34	20	9	3	5	< 1	11	332
1999–00	305	31	32	10	10	7	3	< 1	10	409
2000–01	278	32	27	20	9	3	3	< 1	10	381

Setnet catches of rig by target species are shown in Table 10. Most (80–90%) of the setnet catch is targeted. The remainder is a bycatch of several other species. The declining bycatch in the snapper fishery matches the decline in Hauraki Gulf catches, and probably reflects less effort in the snapper fishery in this area.

Table 10: Estimated catch (t) of rig by target species, SPO 1, by setnet.

Fishing year	Target species								Total
	Rig	Gurnard	Trevally	Flatfish	School shark	Kahawai	Snapper	Other	
1990–91	245	4	13	6	4	2	21	4	298
1991–92	346	7	15	7	4	4	43	2	427
1992–93	311	8	16	11	5	6	23	7	387
1993–94	339	5	11	7	4	4	10	3	383
1994–95	392	15	9	5	6	5	4	1	437
1995–96	288	15	10	4	9	2	5	2	335
1996–97	362	17	16	6	6	1	3	4	415
1997–98	258	24	19	10	8	2	5	5	330
1998–99	217	23	11	7	3	< 1	2	3	264
1999–00	304	16	6	9	7	< 1	2	4	348
2000–01	278	18	6	8	2	< 1	2	3	317

5.7 Landing by season

Recorded total landings of rig show a strong seasonal pattern (Table 11). Highest landings occur from September to December, with a peak usually in October, sometimes November. Over 40% of annual landings are made in these two months.

Table 11: Landings (t) of rig by month, SPO 1, fishing years 1990–91 to 2000–01, all methods.

Fishing year	Month												Annual
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1990–91	141	107	42	50	48	29	17	29	11	21	21	46	561
1991–92	160	183	75	33	50	67	44	28	23	17	24	41	745
1992–93	125	154	60	45	37	45	28	26	28	64	34	46	692
1993–94	146	110	54	58	59	46	27	24	41	25	39	53	681
1994–95	134	133	70	48	44	32	57	27	12	10	21	68	658
1995–96	125	146	57	38	37	26	28	27	12	14	21	76	624
1996–97	186	127	60	48	48	28	20	19	19	29	18	79	681
1997–98	146	103	39	38	33	39	27	16	17	18	21	78	576
1998–99	115	103	67	37	33	31	14	21	14	14	21	114	585
1999–00	194	67	51	43	31	34	21	22	19	24	23	85	614
2000–01	164	81	40	34	41	23	19	15	14	16	16	110	573

Seasonal trends in the targeted setnet fishery for rig can also be seen in the estimated catch data (Table 12). (Landings can be categorised by method but not target species.) The pattern is similar to that for total landings; highest catches occur from September to December, with a peak usually in October, sometimes November, with over 50% of annual catches made in these two months.

Table 12: Targeted setnet catches (t) of rig by month, SPO 1, fishing years 1990–91 to 2000–01.

Fishing year	Month												Annual
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1990–91	89	61	23	20	17	4	1	6	5	3	6	11	245
1991–92	108	132	41	13	15	16	6	5	2	1	1	8	346
1992–93	80	94	33	14	10	13	7	6	4	18	8	24	311
1993–94	93	58	33	33	31	16	15	11	13	3	11	21	339
1994–95	92	87	46	27	20	15	32	10	4	5	11	44	392
1995–96	77	89	25	13	9	5	6	8	5	4	3	45	288
1996–97	121	67	37	24	20	10	4	9	8	12	7	42	362
1997–98	89	52	18	15	8	13	7	7	4	6	6	33	258
1998–99	55	44	31	13	5	3	2	3	3	4	4	50	217
1999–00	115	34	32	19	8	10	4	6	7	11	8	51	304
2000–01	102	48	25	11	11	4	2	4	4	5	4	54	278

5.8. Summary of the main rig fisheries in SPO 1

Rig landings are made into all ports around the coastline of SPO 1, with highest landings centred on shallow harbours or adjacent sheltered embayments. Auckland and Thames are the main east coast ports, Kaipara Harbour and Manukau Harbour the main west coast ports. The main east coast fishing ground is the Hauraki Gulf (probably its shallow harbours and bays, and the Firth of Thames), and the main west coast grounds are Kaipara and Manukau Harbours, probably the sheltered southern end of Ninety Mile Beach, and (by inference only) Raglan and Kawhia Harbours. Catches and landings have increased in some regions of SPO 1, decreased in some regions, and remained relatively steady in others. This is consistent with the assumption that there are localised fisheries, but does not necessarily indicate separate biological stocks within this large geographical Fishstock. In general, there was a decline on the east coast and a rise on the west coast, but whether this results from a change or a shift in effort (i.e., fisheries starting or ceasing fishing, or shifting between coasts) is not known.

About three-quarters of the SPO 1 rig landings are taken by setnetting. Most of the rest is taken (as bycatch) by trawling and Danish seining. Bycatch from these fisheries declined from about 20% of the total in the early 1990s to about 16% in the late 1990s.

Most (80–90%) of the setnet catch is targeted, the remainder taken as bycatch in snapper, gurnard, trevally, or flatfish fisheries. This targeted catch is strongly seasonal, with over 50% of the annual total being taken in October and November.

5.9 SPO 1 CPUE analyses

5.9.1 General

Data were selected and CPUE indices calculated essentially following the criteria used by Vignaux (1997) (see Section 3.4.4). They are summarised in Table 13 and Figure 7.

Table 13: Summary of catch data and raw CPUE (kg/km) for target rig in SPO 1.

Year	Vessels[1]	Records[2]	Catch (kg)	Net (km)	CPUE (kg/km)[3]	Vignaux (1997) CPUE
1990–91	140	1 460	243 128	1 727	140.73	
1991–92	108	1 785	342 153	2 211	154.74	145.12
1992–93	113	2 021	302 176	2 953	102.33	92.40
1993–94	110	1 880	253 273	3 142	80.60	80.57
1994–95	115	1 830	303 216	2 664	113.80	107.09
1995–96	107	1 616	249 500	2 091	119.30	104.14
1996–97	119	2 216	358 621	2 786	128.68	
1997–98	99	1 849	256 491	2 381	107.71	
1998–99	94	1 885	217 148	2 435	89.16	
1999–00	110	2 414	304 269	3 026	100.54	
2000–01	100	2 335	277 645	2 757	100.67	

Notes:
1. Number of vessels reporting a catch.
2. Number of records will usually represent the number of days fished, but some records may represent sets of more than one day.
3. CPUE is total catch / total effort (net length).

The overall trend during the 1990s is slightly downwards, but this is due to relatively high values in the first two fishing years (1990–91 and 1991–92). From the 1992–93 fishing year onwards the values fluctuate around 100 kg/km, and change little. CPUE indices generally follows the pattern of estimated catches, which during the 1990s show moderate variability around a slight downward trend.

Comparison with previous study

The CPUE values from Vignaux (1997) for fishing years 1991–92 to 1995–96 agree closely with those determined in this study (Figure 7). The difference is greatest in 1995–96; possibly the dataset for this year was updated after Vignaux's study.

Comparison of different CPUE indices

These CPUE values are ratios of means (total catch/total effort, kg per km), following Vignaux (1997). Other series of CPUE indices were calculated and compared to determine whether they showed a similar pattern (Figure 8).

All indices show similar trends, a decline from fishing year 1991–92 to 1992–93 and 1993–94, a rise to the mid 1990s, followed by either no decline (particularly in the median values) or a slight and fluctuating decline. It is not known whether the relatively high 1991–92 catch rates are real, or a result of poorer data quality in this early year of the series. If the first two fishing years are disregarded, the CPUE indices essentially show no trend.

5.9.2 CPUE indices for the main fishing season

The main fishing season in SPO 1, based on the estimated catch of rig targeted and taken by setnet, extends from September to December in most years. The peak is usually in October, sometimes in November (Figure 9). However, Fishstock SPO 1 comprises several relatively independent fisheries, and it is more appropriate to consider each of these separately.

The five main regional fisheries are Hauraki Gulf, Bay of Plenty, 'Ahipara' (southern Ninety Mile Beach), Kaipara Harbour, and Manukau Harbour (Figure 9).

Hauraki Gulf catches are strongly seasonal, peaking mainly in October, sometimes November, with minimal targeted catches during the rest of the year. Bay of Plenty targeted catches are small, less than 5 t per month, with no seasonal peak; bycatches are generally larger, but also have no seasonal pattern. Ahipara targeted catches are usually low through the winter, and have one or more seasonal peaks in spring and summer (September to March). The targeted Kaipara Harbour fishery has a season from September to March, with peak catches usually in October, and essentially no catch from April to August. The Manukau Harbour fishery is similar to that of Kaipara, but the peak is usually bimodal, in October and December.

The relationship between seasonal catch, effort, and CPUE was examined in the largest (Hauraki Gulf) fishery (Figure 10). Catch and effort (days fished, and total net length recorded per month) show the same pattern, low (often negligible) values through most of the year, with a strong peak in November and December. CPUE has a less clearly defined seasonal signal. However, there is a small rise from September to December, and values are more uniform at this time than during the rest of the year.

Because the seasonal peak in catches varies by one or more months (or is absent) in the different fisheries comprising SPO 1, and CPUE is not greatly different during the Hauraki Gulf seasonal peak, annual (fishing year) CPUE values are used to describe trends in the entire SPO 1 Fishstock, and in large subsets of it, e.g. 'East' and 'West'. In the localised fisheries within East and West, both annual and seasonal indices are used, definitions of the latter differing a little between fisheries.

5.9.3 CPUE indices by SPO 1 East and SPO 1 West

The broadest subdivision of SPO 1 is into 'East' (FMA 1) and 'West' (FMA 9), each comprising several statistical fishing areas. Vignaux (1997) presented data by these categories, and this study repeats her analysis across a longer sequence of years, using the same measure of CPUE (total catch divided by total effort, i.e., catch per vessel-day). The data are summarised in Table 14.

Table 14: Summary of catch data and raw CPUE (kg/km) for target rig in SPO 1 East and SPO 1 West.

Year	Vessels[1]	Records[2]	Catch (kg)	Net (km)	CPUE (kg/km)[3]	Vignaux (1997) CPUE
SPO 1 East[4]						
1990–91	126	874	135 754	1 176	115.45	
1991–92	73	1 148	217 058	1 575	137.78	128.92
1992–93	77	1 429	199 308	2 371	84.06	75.35
1993–94	63	1 079	121 957	2 392	50.98	55.23
1994–95	62	830	111 502	1 605	69.46	71.59
1995–96	55	703	107 652	1 190	90.48	79.41
1996–97	70	883	122 948	1 345	91.44	
1997–98	55	807	94 894	1 268	74.81	
1998–99	50	839	82 615	1 330	62.14	
1999–00	52	941	96 322	1 582	60.89	
2000–01	40	755	84 978	1 267	67.08	
SPO 1 West[5]						
1990–91	102	586	107 374	552	194.64	
1991–92	46	637	125 095	636	196.80	191.24
1992–93	46	592	102 868	582	176.76	164.75
1993–94	57	801	131 316	750	175.02	173.36
1994–95	65	1 000	191 714	1 059	181.01	173.95
1995–96	61	913	141 848	902	157.33	142.62
1996–97	65	1 333	235 673	1 442	163.39	
1997–98	54	1 042	161 597	1 113	145.20	
1998–99	54	1 046	134 533	1 106	121.65	
1999–00	68	1 473	207 947	1 444	143.96	
2000–01	70	1 580	192 667	1 491	129.20	

Notes:

1. Number of vessels reporting a catch.
2. Number of records will usually represent the number of days fished, but some records may represent sets of more than one day.
3. CPUE is total catch / total effort (net length).
4. Comprises Fishing Statistical Areas 001 to 010.
5. Comprises Fishing Statistical Areas 041 (part) to 048.

A moderate number of setnet vessels report targeting rig, but most spend relatively little time in the fishery. In SPO 1 East, 309 vessels recorded targeting rig during the period 1990–91 to 2000–01. An average of 66 vessels (range 40–126) fished in any one year, and the average length of time a vessel spent in the fishery was 2.3 years. In SPO 1 West, 263 vessels recorded targeting rig during the same period. An average of 63 vessels (range 46–102) fished in any one year, and the average length of time a vessel spent in the fishery was 2.6 years.

Because rig fisheries are relatively localised within SPO 1 East and SPO 1 West, it is appropriate to examine CPUE trends for each of these. Vignaux (1997) used two areas in SPO 1 East, and four areas in SPO 1 West. The longer time series of data now available allows a slightly different set and arrangement of areas to be used.

5.9.4 SPO 1 East

Vignaux (1997) used two areas: 003 (southern east Northland) and 007 (inner Hauraki Gulf). Her 'area 3' CPUE indices varied considerably, which may have resulted from erroneous area values (from FMA/QMA/Fishstock 3) being included in some years. The dataset used in the present study is not free from all such errors, but catches from vessels landing into South Island ports were removed during grooming. Two analyses were made, the first of relatively small regions (one to three statistical areas), the second of larger regions (three areas) and incorporating a seasonal component where appropriate.

The first analysis used five areas or area groupings of annual (fishing year) data: 002+003+004 (east Northland), 005+006 (outer and central Hauraki Gulf), 007 (inner Hauraki Gulf), 008 (western Bay of Plenty), and 009+010 (eastern Bay of Plenty). They were chosen and grouped mainly for reasons of geography, i.e., the likelihood they comprised separate fisheries. CPUE indices for SPO 1 East in total, and for its component fisheries, show broadly similar trends to about 1998; there is a decline followed by a recovery, and then after 1998 there is variability between areas but the overall trend is essentially flat (Figure 11). CPUE indices for the largest fishery (inner Hauraki Gulf) show this pattern; from fishing year 1993–94 onwards they rise and fall a little but the trend is level.

The second analysis was of three regions: east Northland (areas 002+003+004 again), Hauraki Gulf (005+006+007), and Bay of Plenty (008+009+010). More detail is presented, i.e., catch, effort, and CPUE (Figures 12, 13, and 14). Hauraki Gulf catch data are strongly seasonal (see Figure 10), and CPUE indices were determined for the main season (October and November) as well as the complete year.

For the small east Northland fishery (Figure 12), catches rise to 1996–97 and then decline, but effort continues rising a year or two longer. CPUE indices show an overall trend downwards, but with three apparent 'recoveries', 1991–92, 1997–97, and 2000–2001.

For the relatively large Hauraki Gulf fishery (Figure 13), trends are similar in the annual and main season data. Catch and effort for both data sets peaked in different years in the early 1990s; effort then dropped to a relatively constant level from about 1996 onwards, but the catch continued to decline. CPUE indices trended downwards, with an accentuated but short-term fall in the early to mid 1990s.

For the small Bay of Plenty fishery (Figure 14), the catch peaked in 1992–93, then declined to remain about level from 1994–95 onwards. Effort continued to rise, with fluctuations. As a consequence, CPUE declined during the 1990s. The high value in 1992–93 (resulting from a single vessel) makes the decline appear large; without it, however, the decline is still in the order of 50% from 1990–91 to 2000–01. However, the CPUE indices can also be interpreted as remaining reasonably stable from 1994–95 onwards.

5.9.5 SPO 1 West

Vignaux (1997) used four statistical areas: 047 (Ahipara/Ninety Mile Beach), 044 (Kaipara Harbour), 043 (Manukau Harbour), and part-041+042 (Raglan and Kawhia Harbours and adjacent coast). This study used the same areas, but differed in that catches from area 041 landed as SPO 1 were added to area 042 catches (Figure 15). CPUE indices for SPO 1 West (total) show a decline from about 200 kg/km in the early 1990s to about 140 kg/km at the end of the decade. The four areas show declines in annual CPUE indices of between 35% and 55% over the decade.

Because of this decline, the relationship between reported landings, estimated catches, and CPUE (total catch/total effort, kg/km) was examined further for the four SPO 1 West areas (Figure 16). In each area, the CPUE values determined in this study for fishing years 1991–92 to 1994–95 are very similar to those of Vignaux (1997). The values for 1995–96 show the greatest difference, possibly because the data for that year were incomplete at the time of Vignaux's study. Catches and landings generally trend together, with the exception of Ahipara and Manukau from 1995–96 onwards, where landings become considerably greater than catches. This discrepancy appears to result from unreliable data; of the eight main vessels which landed at Ahipara, seven had a very poor relationship between reported catch and landing values from the mid 1990s onwards. The possibility that these vessels moved to fish on east coast grounds (areas 001 to 005) was investigated and discounted. It is more likely that catch records were miscoded in some way; there is a strong possibility that the statistical areas were reported incorrectly, but this is difficult to verify.

In general, catches and landings increased from west coast harbours and bays during the 1990s, while CPUE decreased.

Because the west coast harbour catches are strongly seasonal, CPUE indices were calculated for the main fishing season (September to January) and compared with the annual indices (Figure 17). The decline in the CPUE indices from the main season is similar (which is not unexpected given that most data come from this season), possibly a little greater in three of the four areas.

5.9.6 CPUE indices from the major vessels

The catch and effort dataset is dominated numerically by vessels making only small catches. To determine whether data from the relatively more important vessels show a different trend, a subset was chosen of vessels fishing the Hauraki Gulf in SPO 1 East (areas 005 to 007), and the harbours and adjacent coasts in SPO 1 West (areas 041 to 044, 047) which had caught more than 5 t in any one year. The CPUE trends were essentially similar (Figure 18). The subset of major Hauraki Gulf vessels showed a similar fluctuating decline to that of all vessels. The subset of major SPO 1 West vessels showed a slightly greater rate of decline to that of all vessels.

No vessel fished consistently through the 1990s, with catches of 5 t or more in all, or even most, years. Consequently, it was not possible to follow the CPUE trend of an even smaller subset of high catch vessels which fished through the decade.

5.9.7 Relationship between catch, effort, and CPUE

The relationship between catch, effort, and CPUE in the eastern and western subdivisions of Fishstock SPO 1 is shown in Figure 19. In SPO 1 East there is moderate agreement between trends in catch and CPUE. They peaked in fishing year 1991–92, declined to 1993–94, and have fluctuated around a slight decline since then. Effort peaked in 1992–93 and 1993–94, declined to 1995–96, and has since remained about level. In SPO 1 West catch and effort have fluctuated upwards over the whole decade, while CPUE has steadily declined.

The decline in CPUE indices for SPO 1 West was examined further by plotting the median values of kilograms of catch per kilometre of net (kg/km), by fishing year and by the main season (September to January) of each fishing year (Figure 20). The decline is also apparent in these median values; annual values declined by about 20%, and main season values by about 30%, from 1990–91 to 2000–01.

5.9.8 Distribution of CPUE values

In SPO 1 East most daily CPUE values from the targeted rig catch are low, being less than 100 kg per km of net (Figure 21). Fewer catches in the range 100–200 kg/km are made, and there is a very small number of catches from 200 kg to more than 1 t. The variability in the frequency distribution of CPUE values between clarifies the trends in mean CPUE indices plotted in other Figures. From 1990–91 to 1991–92 the mean increased slightly to its highest level. The distribution of values shows relatively more daily catches in the 100–200 kg/km range, plus the highest number of catches in categories above 200 kg/km. The mean then declines to a low in 1993–94; the distribution shows a rise in catches less than 100 kg and a decline in the number of high catch days. CPUE indices (means) in following years are reasonably stable, increasing a little in 1995–96 and 1996–97, then declining slightly; this is reflected in the size distribution of daily catches, particularly in the decline in the number of catches of more than 200 kg/km per day.

In SPO 1 West most daily catches are also low, less than 100 kg per km of net, but in comparison with the east coast there are more catches of 100–200 kg/km (Figure 22). CPUE indices (means) decline steadily until 1998–99, and are then stable. The distribution of CPUE values shows a steady rise in the proportion of daily catches less than 100 kg/km during the period of decline, accompanied by a fall in the number of catches greater than 200 kg/km. Minor variations, such as small rises in mean CPUE values in 1996–97 and 1999–2000, appear to be caused by a few more large daily catches made in these years.

6. THE NORTHWESTERN FISHERY, SPO 8

Fishstock SPO 8 comprises FMA 8, extending from Tirua Point on the northwest coast south to Mana Island just north of Cook Strait (see Figure 3). It comprises approximately the southwestern half of the North Island. By Ministry of Fisheries definition it includes fishing statistical areas 039 to 041, plus their adjacent offshore areas (which are not relevant to the rig fishery). However, there are problems with both the northern and southern boundaries which complicate stock analyses based on catches from areas and landings into Fishstocks. The northern boundary extending northwest from Tirua Point passes through area 041, and some catches from this area are recorded as SPO 1 landings, not SPO 8. The southern boundary approximately bisects area 037; some catches from this area are recorded as SPO 7 landings (see Section 3.3 for an explanation of how these problems were resolved).

6.1 Catch history

SPO 8 landings fell to 125 t following introduction of the QMS, but increased to about 200 t in the early 1990s, with a TACC of 310 t (see Figure 6). Although the TACC was not being reached, it was increased to 370 t in 1991–92 (see Table 2). Landings did rise to 250–300 t in the mid 1990s, still well under the TACC, and then declined fairly steadily from their high of 330 t in 1995–96 to 174 t in 2000–01. It was considered that the status of this stock was not being monitored, that the TACC and landings were unsustainable, and in 1997–98 the TACC reverted to 310 t.

6.2 Quotas, landings, and estimated catches

The relationships between catches, landings, and TACCs for the period covered in this study are given in Table 15. Landing values used in this study were close to the landings recorded in the QMS. Estimated catches were 69–83% of the landings, the discrepancy presumably arising (a) from many catches being recorded as processed weight, and (b) some rig catches falling outside the top five species recorded in a fishing event.

Table 15: TACCs, reported landings, and estimated catches (t) of rig, SPO 8.

Year	TACC	Landing[1]	Landing[2]	Landing %[3]	Est. catch[4]	Catch as % landing[5]
1989–90[6]	310	206	175	85	133	76
1990–91	310	196	176	90	141	80
1991–92	370	145	135	93	101	75
1992–93	370	239	223	93	176	79
1993–94	370	255	241	95	196	81
1994–95	370	273	279	102	232	83
1995–96	370	330	320	97	249	78
1996–97	370	277	252	91	175	69
1997–98	310	287	271	94	209	77
1998–99	310	235	225	96	156	69
1999–00	310	219	209	95	145	69
2000–01	310	174	168	97	134	80

Notes:
1. Landings from Quota Management Reports (QMRs).
2. Landings (landed catch) from Catch Effort Landing Returns (CELRs) and Catch Landing Returns (CLRs). Groomed values.
3. CELR + CLR landings as a percentage of QMR landings.
4. Estimated catches from CELRs and TCEPRs. Groomed values.
5. Estimated catches as a percentage of CELR + CLR landings.
6. Data for the 1989–90 fishing year are considered incomplete, and not used in subsequent analyses.

6.3 Landing by port

Reported landings by port are shown in Tables 16 and 17. The main ports within the geographic limits of the Fishstock are New Plymouth and Wanganui; small landings are made at landing points along the Manawatu coast, and at Raglan and Kawhia Harbours just north of the boundary. Small landings were recorded as coming from Fishstock SPO 8 into east Northland ports, Wellington, and northern South Island ports. These landings are probably valid records, but some landings of SPO 8 rig into southern South Island ports are probably not and have been disregarded. Landings into New Plymouth, Wanganui, and along the Manawatu coast rose to the mid 1990s and then declined; the much smaller landings into ports outside the region are variable but show no trend.

Table 16: Landings (t) of rig by port, SPO 8, all methods.

Fishing year	Manukau Hbr	Raglan	Kawhia	New Plymouth	Wanganui	Manawatu coast	Wellington	Picton	Nelson	Golden Bay	NE Coast	Total
1990–91	1	1	0	52	45	9	2	4	43	16	< 1	176
1991–92	1	1	0	47	50	7	8	< 1	17	2	0	135
1992–93	0	1	< 1	105	76	5	3	< 1	27	6	0	223
1993–94	< 1	1	< 1	96	110	12	4	< 1	17	< 1	0	241
1994–95	9	< 1	2	105	112	20	4	4	3	16	4	279
1995–96	< 1	1	21	113	87	14	3	23	43	8	1	320
1996–97	< 1	1	18	92	74	14	1	2	42	7	1	252
1997–98	3	1	6	118	63	8	2	25	44	2	< 1	271
1998–99	1	1	2	72	76	7	1	24	39	2	< 1	225
1999–00	3	4	1	75	54	11	7	7	46	< 1	< 1	209
2000–01	3	< 1	1	51	37	9	4	17	27	16	< 1	168

Note: Small (<1 t to 6 t) 'SPO 8' landings were reported at other ports, but these are considered erroneous, perhaps because of confusion between statistical area and Fishstock numbers.

Table 17: Landings (t) of rig by port, SPO 8, taken by setnet.

Fishing year	Manukau Hbr	Raglan	Kawhia	New Plymouth	Wanganui	Manawatu coast	Wellington	Picton	Nelson	Golden Bay	NE Coast	Total
1990–91	0	0	0	39	42	8	0	3	42	16	0	153
1991–92	0	0	0	38	48	6	5	< 1	13	0	0	111
1992–93	0	0	< 1	93	75	4	0	< 1	25	6	0	202
1993–94	0	0	< 1	86	109	10	0	< 1	13	< 1	1	220
1994–95	0	0	2	92	112	16	0	2	0	16	0	240
1995–96	0	0	21	105	87	12	0	20	28	8	0	287
1996–97	< 1	1	18	82	71	10	0	1	19	7	0	207
1997–98	< 1	1	6	106	63	6	0	24	30	2	0	237
1998–99	0	0	2	67	76	5	0	23	20	2	0	194
1999–00	0	3	< 1	67	53	10	1	7	34	< 1	0	176
2000–01	0	0	< 1	47	37	9	0	17	22	16	0	150

Note: Small (<1 t to 5 t) SPO 8 landings were reported at other ports, but these are considered erroneous.

6.4 Catch by statistical area

Only the estimated catch can be categorised by statistical fishing area. Setnet catches by area are shown in Table 18. Reasonably consistent catches were made in the main areas 039 to 041, all rising in the mid 1990s, and smaller catches in area 037, only half of which occurs in SPO 8.

Table 18: Estimated catch (t) of rig by statistical area, SPO 8, taken by setnet, all target species.

Fishing	SPO 8				
year	037	039	040	041	Total
1990–91	38	58	20	14	130
1991–92	4	27	37	22	90
1992–93	18	26	72	46	163
1993–94	26	47	78	36	186
1994–95	15	65	67	64	217
1995–96	25	55	84	64	229
1996–97	13	23	61	58	154
1997–98	13	48	50	82	192
1998–99	20	34	56	31	140
1999–00	23	35	61	14	133
2000–01	11	45	57	15	128

Targeted setnet catches by area are shown in Table 19. They show the same pattern as the setnet catches of rig taken both as a target and a bycatch.

Table 19: Estimated catch (t) of rig by statistical area, SPO 8, taken by setnet, target species rig.

Fishing	SPO 8				
year	037	039	040	041	Total
1990–91	37	46	12	8	103
1991–92	4	23	37	22	90
1992–93	17	24	58	41	140
1993–94	26	45	65	31	166
1994–95	14	58	58	48	178
1995–96	20	51	73	55	199
1996–97	13	22	54	44	133
1997–98	11	46	31	71	159
1998–99	19	32	48	23	122
1999–00	21	34	49	12	116
2000–01	11	40	45	10	105

6.5 Landing by method

Landings of rig by fishing method are shown in Table 20. Setnetting, contributing 80–90% of landings, is the main method. Trawling took most of the remainder.

Table 20: Landings (t) of rig by method, SPO 8.

Fishing	Method				
year	Setnet	Trawl	Longline	Other	Total
1990–91	153	21	1	1	176
1991–92	111	20	1	3	135
1992–93	202	20	1	< 1	223
1993–94	220	20	1	1	241
1994–95	240	38	1	1	279
1995–96	287	30	2	1	320
1996–97	207	41	4	1	252
1997–98	237	32	2	< 1	271
1998–99	194	31	0	< 1	225
1999–00	176	33	< 1	< 1	209
2000–01	150	17	1	< 1	168

6.6 Catch by target species

Only the estimated catch can be categorised by target species. Catches of rig (all methods) by target species are shown in Table 21. Most (70–85%) of the catch is targeted. About 6% is taken as a bycatch when school shark were targeted, and small quantities with other species.

Table 21: Estimated catch (t) of rig by target species, SPO 8, all methods.

Fishing year	Rig	School shark	Gurnard	Warehou	Trevally	Snapper	Other	Total
						Target species		
1990–91	103	15	3	1	5	7	7	141
1991–92	72	11	3	3	3	4	4	101
1992–93	140	12	2	5	8	3	4	173
1993–94	166	8	5	4	4	4	6	196
1994–95	178	9	6	3	4	12	5	217
1995–96	199	13	6	5	6	3	16	249
1996–97	133	10	17	4	4	1	5	175
1997–98	160	17	14	5	3	4	6	209
1998–99	123	7	13	3	3	1	5	156
1999–00	116	5	7	8	5	1	3	145
2000–01	105	7	7	8	3	1	5	134

Setnet catches of rig by target species are shown in Table 22. Most (80–90%) of the setnet catch is targeted. The remainder is a bycatch of school shark and several other species.

Table 22: Estimated catch (t) of rig by target species, SPO 8, by setnet.

Fishing year	Rig	School shark	Gurnard	Warehou	Trevally	Snapper	Other	Total
							Target	
1990–91	103	15	2	1	2	2	4	130
1991–92	70	11	2	3	1	< 1	2	90
1992–93	140	12	1	5	3	1	2	163
1993–94	166	8	1	4	3	1	3	186
1994–95	178	9	2	3	3	1	1	196
1995–96	199	13	< 1	5	4	< 1	7	229
1996–97	133	10	5	4	2	< 1	< 1	154
1997–98	159	17	6	5	2	< 1	3	192
1998–99	122	7	4	3	2	1	1	140
1999–00	116	5	2	8	2	< 1	< 1	133
2000–01	105	6	5	8	1	< 1	4	128

6.7 Landing by season

Recorded total landings of rig show a moderate seasonal pattern (Table 23). Highest landings occur from September to March, with the main months usually being October and November. Seasonality is not as strong as in SPO 1; only 22% of annual landings are made in the latter two months.

Table 23: Landings (t) of rig by month, SPO 8 fishing years 1990–91 to 2000–01, all methods.

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
												Month	
1990–91	10	20	18	19	34	24	7	14	6	6	7	12	176
1991–92	8	7	12	13	19	17	22	8	5	3	3	18	135
1992–93	21	21	21	16	27	28	21	7	5	16	11	9	223
1993–94	17	40	38	37	29	20	17	7	9	7	8	11	241
1994–95	29	33	22	29	23	26	22	11	14	8	24	40	279
1995–96	61	44	39	33	23	34	23	11	9	6	7	31	320
1996–97	50	12	20	32	25	22	14	22	12	11	10	22	252
1997–98	33	29	27	34	16	33	14	12	9	5	7	42	271
1998–99	17	38	20	38	34	17	11	10	11	4	11	14	225
1999–00	29	20	15	34	39	27	9	13	5	5	4	10	209
2000–01	11	14	17	30	28	16	7	8	7	8	6	16	168

Seasonal trends in the targeted setnet fishery for rig can be seen in the estimated catch data (Table 24). (Landings can be categorised by method but not target species.) There are increased catches from September to April, but, as with landings, seasonality is not as strong as in SPO 1. Although peak catches do sometimes occur in October and November, they are just as likely to occur in January and/or February.

Table 24: Targeted setnet catch (t) of rig by month, SPO 8 fishing years 1990–91 to 2000–01.

Fishing											Months		
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990–91	2	17	7	9	26	12	4	12	2	3	4	5	103
1991–92	4	3	4	6	12	12	14	3	1	1	1	8	70
1992–93	13	20	11	9	18	20	13	3	2	11	10	19	140
1993–94	11	31	25	27	21	12	11	9	5	5	5	4	166
1994–95	17	17	19	21	10	16	14	5	8	6	11	34	178
1995–96	47	35	27	19	11	16	9	5	2	3	4	20	199
1996–97	36	6	9	16	11	14	4	8	5	6	3	15	133
1997–98	25	22	15	12	9	12	13	4	5	3	4	35	159
1998–99	8	18	14	20	15	12	8	6	6	2	6	8	122
1999–00	19	13	9	22	25	14	3	3	1	2	1	3	116
2000–01	5	6	11	22	20	9	3	4	3	5	4	13	105

6.8. Summary of the main rig fisheries in SPO 8

Rig landings are made into all ports along the coastline of SPO 8, with highest landings into New Plymouth and Wanganui. Moderate landings from this Fishstock are also made into ports outside its geographic limits. Catches are taken from all statistical areas; these are too large to reveal any localised fisheries.

A high proportion (80–90%) of the SPO 8 rig landings are taken by setnetting, the remainder as a trawl bycatch.

Most (80–90%) of the setnet catch is targeted, the remainder taken as bycatch in school shark, warehou, trevally, gurnard, and other fisheries. This targeted catch is only moderately seasonal; the main months are October and November (as in SPO 1), but only 22% of the annual total is taken in these months; the season of reasonably high catches extends from September to April, and highest catches sometimes occur in January or February.

6.9 SPO 8 CPUE ANALYSES

6.9.1 General

Data were selected and CPUE indices calculated essentially following the criteria used by Vignaux (1997) (see Section 3.4.4). They are summarised in Table 25 and Figure 23.

Table 25: Summary of catch data and raw CPUE (kg/km) for target rig in SPO 8.

Year	Vessels[1]	Records[2]	Catch (kg)	Net (km)	CPUE (kg/km)[3]	Vignaux (1997) CPUE
1990–91	30	390	90 547	619	147.8	
1991–92	24	506	70 068	790	88.7	90.43
1992–93	33	716	138 315	1 222	113.2	114.50
1993–94	32	659	159 709	1 360	117.4	110.26
1994–95	27	583	177 759	1 390	127.9	140.22
1995–96	28	472	190 281	1 215	156.7	143.59
1996–97	25	479	129 437	995	130.1	
1997–98	24	467	149 555	939	159.4	
1998–99	25	529	122 292	1 067	114.6	
1999–00	22	435	115 807	1 000	115.8	
2000–01	21	410	105 879	841	125.9	

Notes:
1. Number of vessels reporting a catch.
2. Number of records will usually represent the number of days fished, but some records may represent sets of more than one day.
3. CPUE is total catch / total effort (net length).

A moderate number of setnet vessels report targeting rig, but most spend relatively little time in the fishery. In SPO 8, 93 different vessels recorded targeting rig from 1990–91 to 2000–01. An average of 26 vessels (range 21–33) fished in any one year, and the average length of time a vessel spent in the fishery was 3.1 years.

Comparison with previous study

A comparison between the CPUE indices from this study and those from Vignaux (1997) is shown in Figure 23. The trends are very similar, and generally follow the rising catches between fishing years 1991–92 and 1995–96. After 1995–96, the CPUE indices from the present study trend slightly downwards, again closely following the pattern of catches.

Comparison of different CPUE indices

These CPUE values are ratios of means (total catch / total effort) It is possible to calculate other series of CPUE indices, and these were compared to determine whether they showed a similar pattern (Figure 24). All indices show similar trends, a rise to the mid to late 1990s, followed by a slight and fluctuating decline. It is not known whether the relatively higher 1990–91 values are real, or a result of poorer data quality in this year. The three mean kilogram of catch to kilometre of net (kg/km) indices (total catch/total effort, mean of vessel CPUE, and mean of vessel-day CPUE) are similar from 1990–91 to 1996–97, but more variable in subsequent years; the reason for this variation is unknown.

6.9.2 CPUE indices for the main fishing season

The main fishing season, based on estimated catch of rig taken by setnet, extends from September to April in most years (Figure 25). The peak is usually in October, sometimes in September or November, and catches are generally higher during the first half of this season. However, effort – as net length fished or number of days fished – is higher in the second half of the season (February to April). A similar pattern is shown by landings (Figure 26), which can be defined as caught by setnet but not by target species, although the targeted rig catch predominates. The tonnage landed is highest from September to December, but the number of landings (assumed to be a proxy for effort) is highest from October right through until April.

The resulting CPUE (estimated catch) values by month, both as catch by kilometre of net, and as catch per day, are essentially flat through most of the year, with higher but variable values from September to November (see Figure 25).

In summary, catches and landings are highest from September through to March, sometimes April, but because effort is highest from February to April CPUE values peak earlier, usually from September to November. The main season can thus be defined either as the longer period of moderate to high catches, or the shorter period of high CPUE.

If the longer (September–March) period is chosen as the main season, 'annual' CPUE indices are little changed from the values from the whole year (Figure 27). The main difference is that the increase to 1995–96 is slightly steeper, and the subsequent decline more evident.

6.9.3 CPUE indices by area

SPO 8 CPUE (total catch/total effort) is shown by statistical area in Figure 28. No clear inferences can be drawn. Area 037 shows the greatest variability, but the indices are based on relatively small and variable catches. The two main areas, 040 and 041, both show the general rise to the mid 1990s, followed by a slight decline. The data for 1991–92 to 1995–96 approximate those of Vignaux (1997) but are not directly comparable. Vignaux's analysis excluded some outliers which were corrected in the dataset used for this study, and her values for areas 037 and 041 are based on all catches from those areas, whereas this dataset includes only the catches from these two areas which were landed as Fishstock SPO 8.

6.9.4 CPUE indices from the major vessels

The catch and effort dataset is dominated numerically by vessels making only small catches. To determine whether data from the relatively more important vessels show a different trend, a subset was chosen of the vessels which had caught more than 5 t in any one year The trends were essentially similar, an increase to the mid 1990s, followed by a very slight decline (Figure 29). The two CPUE measures chosen, all-vessel CPUE and all-vessel-day CPUE, were generally similar, but diverged in fishing year 1997–98; the reason for this is not known.

6.9.5 CPUE indices from a major vessel

Only one vessel fished consistently and recorded estimated catches and landings of at least 5 t in each of 10 years of the 11 year period under review. In very general terms, its catches and landings follow the pattern of the whole fleet and the major vessels; a rise to the mid 1990s, followed by a decline, although the rates of change and the peak years differ (Figure 30). In the early 1990s catches, landings, effort, and CPUE trended together. In the late 1990s effort remained high, but catches, landings, and CPUE declined.

6.9.6 Relationship between catch, effort, and CPUE

The relationship between catch, effort, and CPUE is shown in Figure 31. Catches rose until 1995–96, and then declined slightly. Fishing effort measured as total net length peaked earlier in 1994–95, so that CPUE continued rising with catches until 1995–96, before levelling and declining. Fishing effort measured as number of days fishing peaked in 1992–93. It is not known which of 'number of days fishing' or 'net length' is the most appropriate measure of effort, but they give essentially similar results.

6.9.7 Distribution of CPUE values

In SPO 8 most CPUE values from the targeted rig catch are low, being less than 100 kg per km of net (Figure 32), with a relatively low number of catches in 100 kg/km categories up to 1 t per km. The increase in mean CPUE from 1991–92 to 1995–96 corresponds to a decline in the number of small catches and an increase in the relatively low number of catches greater than 200 km/kg. The slight decline in mean CPUE in subsequent years corresponds to a reversal of this pattern.

7. THE RECREATIONAL FISHERY

7.1 General

Rig are caught by recreational fishers throughout New Zealand, but they are seldom targeted, are sometimes released alive, or dumped dead as unwanted (and incorrectly) 'inedible shark'. Discarded rig carcases are commonly seen on beaches where drag-netting and surfcasting has taken place. Many fishers do not identify and distinguish rig from other small sharks, and in fishing diaries they are often recorded only as 'dogfish' (which confuses them with species of *Squalus*), or 'shark' (which may also include school shark, sevengill shark, etc.). In addition, there may have been some inadvertent confusion of codes for rig (SPO) and the frequently caught spotty (a wrasse, STY, or SPT) during entry of field data into recreational catch databases. It is unclear whether these problems have under- or over-estimated the recorded rig catches. Consequently, recreational catch estimates extrapolated from the relatively small datasets currently available are extremely unreliable.

There are two difficulties in evaluating the catch of rig by recreational fishers. (1) The species is caught in low numbers, and because it is difficult to extrapolate from small sample sizes, studies on recreational fisheries either provide minimal data on such species or ignore them completely. (2) Rig are poorly identified by fishers, and there may also be database coding errors. In future studies of recreational fisheries, it would be advantageous to provide fishers with good identification material (illustrations and correct names) on rig and other small species of shark, as well as any other fish species which may be unfamiliar and/or cause confusion in the resulting data.

7.2 SPO 1

In 1993–94 a survey of recreational fishers in the North fisheries region (QMAs 1 and 9), using telephone polls plus diaries from selected anglers, gave an estimated catch of 11 000 rig in SPO 1 (c.v. 21%), or a catch of 5–25 t (Teirney et al. 1997). In this region an estimated 22 000 'other shark' were taken, and some of these could well have been rig (Bradford 1996, and pers. comm.). Of the 82 fish recorded by diarists, almost all were taken in summer; the main methods were handline from boat (35), handline from shore (12), and setnet (28). The regional distribution of this catch was Northwest Coast (35), Bay of Plenty (24), Hauraki Gulf (15), and East Northland (8), (Bradford 1996).

In 1996 a national diary survey of recreational fishers provided catch estimates of 28 000 rig (c.v. 31%), or 25–45 t (Bradford 1998) in SPO 1. Rig was a very minor species, rarely targeted; catches were not analysed in detail, but most were made in the Waikato/Raglan/Kawhia area (Fisher & Bradford 1999). Curiously, few catches were reported from Kaipara Harbour and none from Manukau Harbour, where there are large recreational (and commercial) fisheries.

In 1996 a nationwide boat ramp survey of recreational catches, undertaken in conjunction with the diary survey, recorded 150 rig, 0.16% of the total recreational catch. Of the 64 rig measured, most (36) were caught on the west coast of the North Island in SPO 1 West, although most sampling sites were on the northeast coast (Hartill et al. 1998 and pers. comm.).

7.3 SPO 8

Fishstock SPO 8 is fished by recreational fishers resident in the Central and North fisheries regions. Recreational fishers in these regions were surveyed in 1992–93 and 1993–94 respectively by telephone polls plus diaries from selected anglers, giving an estimated catch of 19 000 rig (c.v. 43% for the 18 000 fish from the Central region), equivalent to a catch of 20–60 t (Teirney et al. 1997).

In 1996 a national diary survey of recreational fishers provided catch estimates of 7000 rig, but the sample size was too small to provide a reliable estimate of the c.v. or tonnage (Bradford 1998). The meagre data available suggest that they were taken along the whole coastline of this Fishstock (Fisher & Bradford 1999).

7.4 Tag returns

Of 2234 rig tagged around the South Island and along the Manawatu coasts in 1982–84, 381 were recaptured, of which only 3% (11) were caught by recreational fishers (Francis 1988b, Annala et al. 2002). However, this proportion cannot be extrapolated to the northern half of the North Island (Fishstocks SPO 1 and SPO 8) where there are probably a relatively higher number of recreational fishers. Some of the rig tagged around the South Island did migrate northwards into this region, but not in sufficient numbers to provide useful data.

7.5 Summary of recreational fisheries

Rig are seldom targeted by recreational fishers, and their reported take as bycatch is not large. The fisheries in which they are taken is not recorded, but in SPO 1 and SPO 8 almost certainly include setnetting for flatfish, snapper, and trevally, and handlining for snapper and gurnard. For New Zealand in total, it has been estimated that less than 15% of the total rig harvest is taken by recreational fishers (Annala et al. 2002). For SPO 1, the 1996 recreational catch estimates of 25 and 45 t represent 4% and 7% of the total catch. Because it is suspected that rig are under-reported by recreational fishers, their true catch might be in the order of 10%. The limited data suggest that the recreational catch may be relatively higher in SPO 1 West. There are no reliable values on which to base an estimate of the recreational catch in SPO 8.

8. DISCUSSION

An undesirable number of errors and ambiguities were found in the data used to compile this account. They result from badly chosen Fishstock boundaries (subdividing the statistical fishing areas used to report catches), complexities in the CELR form that appear to be misunderstood or misread by fishers, and inadequate error checking of the catch-effort database. Many of the errors are not apparent in aggregated data, and some become obvious only when direct vessel-by-vessel comparisons are made between catches and landings.

However, the broad findings of this study – that rig landings in both Fishstocks have remained below the TACCs, and only briefly increased when the latter were raised in the Adaptive Management Programme – are considered good justification for updating the previous CPUE indices.

The CPUE indices determined in this study agree closely with those presented by Vignaux (1997). Vignaux's five-year time series was too short to identify any trend during fishing years 1991–92 to 1995–96. Her measure of CPUE was the total estimated catch by the setnet vessels which recorded rig as the target species, divided by the total length of net reported as set by these vessels (kg/km). This procedure was followed in most of the analyses reported in this study. Additional CPUE indices were calculated, using the mean of vessel-day values, the mean of vessel (annual) values, and the mean catch per day when rig were caught (total catch divided by total days). All indices showed similar trends.

The data were initially groomed using the criteria set by Vignaux (1997) for maximum and minimum net length values, maximum and minimum daily catches, and maximum daily CPUE. However, it was found to be relatively straightforward, though time-consuming, to correct net lengths, or interpolate missing values, using adjacent values for the same vessel. The corrected values had little influence on the CPUE indices, but the procedure was considered useful in retaining more complete records for each vessel, particularly when the datasets were subsequently subdivided by area and season.

During grooming, some obvious errors in records were corrected where possible (e.g., it was possible to modify very high catch or landing values by inspection of adjacent values), or were removed. Catches and landings made by vessels obviously based well outside the two Fishstocks in question (e.g., landings to southern South Island ports) were also removed. These almost certainly resulted from confusion between Fishstock, QMA/FMA, and Statistical Area numbering systems. Errors of lower magnitude clearly remain within the datasets (e.g., small catch or landing values could be wrong by a factor of 10 or 100 but undetectable as outliers, and some listed statistical areas could be wrong but plausible). There were often inexplicable large differences between catches and landings, even by vessels supposedly targeting rig, and these could not be resolved. Some vessels periodically listed SPD (spiny dogfish) as their target species, and it is possible that these were misinterpretations of 'SPO' by code-punch operators (the northern spiny dogfish should be coded NSD). In a few cases where the context strongly suggested this was the case, the entry was changed and retained, but most were left as SPD and the records omitted from the targeted catch. The inference must also be drawn that catches listed as SPD in error for SPO were not included in the data extracts. The assumption has to be made that the number and effects of such errors are reasonably constant between years.

In many cases, catches, landings, and CPUE indices were reasonably well correlated. Trends in effort (net length, or days) were less well correlated. The simplest explanation for the agreement between catch and CPUE is that when rig abundance (either seasonal or annual) increased, catches and catch rate both increased for little or no increase in effort. If this is so, the declining CPUE in SPO 1 West must be regarded with some concern, as it is doing so while catches and effort are increasing.

CPUE indices for the SPO 1 Fishstock (considered in total) are reasonably stable. There is a drop from the first two years, when data may perhaps have been less reliable, through to an essentially flat trend in the late 1990s. Vignaux (1997) examined only the first part of this time series and could reach no conclusions, but speculated that because 'rig fishing is restricted to small parts of SPO 1, mainly in harbours' it was likely 'that CPUE data may be unrepresentative of the whole stock.' And 'therefore, CPUE has not been used as an index of abundance for this Fishstock.'

Vignaux's (1997) study separated SPO 1 data into east and west coast data sets. Her time series was too short to detect any clear trend in the fluctuating values, but they appeared to be declining slightly in both regions. This study examined eastern and western data in more detail, and over a longer period. The CPUE indices for SPO 1 East declined until the mid 1990s, and then the trend was essentially flat. The CPUE indices for SPO 1 West continued the slowly declining trend presented by Vignaux (1997) across the longer time period.

In SPO 1 East, annual CPUE indices for individual statistical areas broadly follow the same pattern. When areas are grouped, however, regional differences become apparent. Vignaux suggested that separate harbours and their adjacent bays had fisheries that were to some extent independent (though not separate stocks). While this is likely to be true, it seems reasonable to make a broad grouping of SPO 1 East data into east Northland, Hauraki Gulf, and Bay of Plenty regions. In each of these, CPUE declined during the 1990s. These declines were greater than the decline for SPO 1 East as a whole, possibly because in the latter there was an averaging effect of high and low regional values which occurred in different years.

In SPO 1 West, CPUE indices declined more steadily than in SPO 1 East, and they declined about equally in all four main regions. In these regions, the broad agreement between catch trends and CPUE indices observed elsewhere does not hold. Catch and effort have both increased during the 1990s, while CPUE has decreased. In the three west coast regions centred on harbours (Kaipara, Manukau, and Raglan/Kawhia) catches were strongly seasonal, while catches centred on the more coastal Ahipara locality showed little seasonal variation. Although CPUE values were usually a little higher in the main season, the rate of decline was not particularly different (perhaps a little faster in three of the four areas). However, it was found that the decline in annual CPUE was somewhat greater for the main vessels (those making higher catches) than for the whole fleet. These CPUE indices are mean values from highly skewed data. When median values are used, there is a slightly different pattern. The rate of decline during the decade is somewhat lower than that shown by means, but there is a clear difference between the decline in annual indices (c. 26%), and the decline in main seasonal indices (c. 36%).

The results of the present study support and extend the comments by Vignaux (1997). In SPO 1 East there are separate regional fisheries with different patterns of CPUE decline, although the decline generally appears to be relatively faster in the early 1990s. It is not known whether regional differences result from the way each fishery operates (e.g., the relative number of skilled and unskilled fishers in different years, given the short time most vessels spend in the fishery), or from some subdivision of the northeastern rig 'stock' into discrete units. In SPO 1 West the CPUE decline is similar in four regions. Three of these are harbours, the fourth is a bay (Ahipara) some distance to the north. Despite the similarities in catch history, it is not known whether these fisheries, which have some geographical separation, are based on one or several northwestern stock units.

In SPO 8, a coastal fishery extending along the Taranaki, Wanganui, and Manawatu coastline, reported catches, landings, CPUE (and to a lesser extent effort) have trended together. These rose until the mid 1990s, and then returned to a similar level. The only real sign of declining CPUE is in the main season in the late 1990s. This must be regarded as a preliminary finding, however, as there is a consistent and unexplained difference in timing between the peak of targeted fishing, and the peak of targeted catch.

Other issues remain unresolved for both Fishstocks.

- In some regional fisheries, catch and CPUE trend together. This seems intuitively reasonable; both may be tracking abundance. But if this is so, is the declining CPUE in the SPO 1 West regions more serious than it appears, given the continued increase in annual landings?
- Why was the TACC not met, either when it was raised in the AMP, or even when it returned to its former level? Does the pattern of quota-holding, either by companies or individuals, restrict catching opportunities?
- How reliably is the parameter 'net length' recorded? Is it a good measure of effort? Have mesh sizes varied through the 1990s, and have fishing practices (localities, soak time, targeting preferences) changed during the same period?
- Almost half the daily records of targeted setnet rig catches are less than 100 kg per 1 km of net. Because many catches are recorded as processed weight, catches as greenweight will be somewhat higher, but still seem low for a targeted species. Are these catches of just a few kilograms of fish (per kilometre of net, or per day) a reliable record of targeted fishing?
- Are the present Fishstock boundaries appropriate?

Several features of the CPUE trends determined from the present analyses, in combination, cause some concern. The decline in SPO 1, where there are coastal and harbour fisheries, is greater than in SPO 8, where the fishery is almost entirely coastal. The decline in SPO 1 West catch rates is greater than in SPO 1 East; it is likely that the former is based more heavily on harbour fisheries. The decline is greater in the main fishing season than for the whole year, and a decline in the main season has occurred in SPO 8 from fishing year 1996–97 onwards. These features might result from the harbour and some inshore fisheries overharvesting the pregnant females during their inshore migration in spring to release their pups. It is unfortunate that there is no information on the size and sex distribution of rig in the commercial catch in SPO 1 and SPO 8.

Rig are relatively productive sharks. They have a moderate growth rate, and with a life-span of 15–20 years are not particularly long lived (Francis & Francis 1992a, 1992b). Females are reported to breed annually, but with a mean of 11 embryos their fecundity is quite low (Francis & Mace 1980, Massey & Francis 1989). Perhaps unusually for sharks, rig are believed to be capable of recovering relatively quickly from an overfished state, and consequently they were considered suitable for the Adaptive Management Programme where quotas were raised (and catches monitored) to determine whether increased Fishstock yields were sustainable.

In SPO 1, landings only briefly reached the raised TACC, and steadily declined both before and after the TACC was lowered. Recent catches of 550–600 t (the TACC is 692 t) appear unsustainable, based on falling catches and a declining CPUE. The declining CPUE is probably most serious in SPO 1 West, where catches are still rising.

In SPO 8, landings did not reach either the raised TACC or the subsequently lowered TACC, and have declined by about one-third since the mid 1990s. Based only on the catch history, recent catches of about 200 t (the TACC is 310 t) may be unsustainable. CPUE indices have risen and fallen during the 1990s in close parallel with catches, and the most recent decline may also be an indication that recent catch levels are unsustainable. At the very least, the TACC is probably too high.

In addition to these findings on sustainability, this study suggests that information on the size and sex composition of the rig catch would be highly desirable. If the catch taken from the northwestern harbours, in particular, contains a large proportion of pregnant females, some consideration should be given to reducing exploitation of this important component of the population. Coupled with this, consideration could also be given to subdividing the geographically large SPO 1 Fishstock to allow more flexibility in setting sustainable quotas. For example, it may be necessary to have lower quotas in areas where pregnant females predominate, and conversely higher quotas where the exploited population comprises sub-mature adults of both sexes.

Two further issues are not addressed by this study, but are relevant to management of the northern, largely harbour-based, rig 'stocks'. First, targeting and bycatch. Most of the setnet catch of rig is nominally targeted, but a large proportion of these catches are so small that the reality of the target species listing must be questioned. Consequently, would a reduction in rig TACC have implications for any other harbour setnet fisheries? Second, is there any mortality of juvenile rig taken in setnets fished for other species, such as flatfish, mullet, and trevally?

9. CONCLUSIONS

In previous years, rig Fishstocks have been monitored by following CPUE indices. One requirement of the present study was to reassess this approach.

CPUE

This study suggests that CPUE indices are a useful procedure for monitoring rig fisheries (some trends in unstandardised CPUE, or 'catch rate', do became apparent), although this is difficult to assess because no other analyses have been undertaken to either support or refute the information in the CPUE indices. However, this study showed quite clearly that a better understanding of the fishery is necessary before selecting the datasets to use for CPUE.

The SPO 1 Fishstock is too large to use as a whole, and even a subdivision into eastern and western sectors is probably too large. The fishery is based mainly on rig resident in, or seasonally entering, shallow bays and harbours, and it appears possible to recognise these 'unit fisheries' by the pattern of catch by area, and landing by port (clusters of landing points). The different CPUE trends suggest that a stratified stock assessment would be more useful than one based only on the Fishstock, although the issue of effort (fishers) moving between harbours would have to be addressed. Raw CPUE indices for SPO 1 in total only undulated; the slight downward trend was unconvincing. Indices from harbour-based subdivisions of SPO 1 trended downwards. Most, but not all, fisheries within SPO 1 proved to be strongly seasonal, and greater declines were observed in data from the main season.

The SPO 8 Fishstock is smaller, coastal rather than centred on harbours and shallow bays, and both effort and catch appeared likely (from recorded landing points) to be fairly evenly distributed along the coastline. It seems appropriate to treat SPO 8 as a unit fishery.

Both catch and CPUE values (kg/km, or kg/day) are very strongly skewed towards low values. Medians may be more appropriate than means, and the choice of a measure of spread (c.v., etc.) needs careful consideration.

CPUE indices are usually determined for target fisheries. This study selected catch data when rig was the nominated target species. The large number of low catches, relative to the total catch reported for the fishing record, cast some doubt on whether the nominated target was the true target. An alternative extract procedure would be to select rig catches when rig was the main species (or among the top x species) caught.

This study took no account of mesh size. This would certainly have an effect on catch and CPUE if (for whatever reason – regulatory, or market requirements) there was either a sudden change in mesh size, or a slower shift in dominant mesh size over time. It would probably be difficult to correct for this, and there are so few vessels catching moderate quantities of rig in any one year that it would be impractical to subdivide the fleet into vessels using similar mesh. Mesh size information could provide only qualitative information which might explain CPUE trends.

This study made some progress in identifying the components of the SPO 1 and SPO 8 fisheries which should be monitored for CPUE. There is a high turnover of fishers in the rig fishery, and relatively few fishers make moderate to high catches. It should be possible, however, to identify a core group of fishers (either those with moderate catches, or those with a certain number of years in the fishery), and develop standardised CPUE indices. Standardised indices remove or at least identify variation due to vessel, season, statistical area, east/west, etc. Once a suitable series of indices was identified (or perhaps more than one series, given the highly skewed pattern of catches), annual updates should be relatively straightforward and inexpensive. It is too early to select these indices based on existing information; all unstandardised indices used showed similar trends, and standardisation may reveal some differences, but (following Vignaux 1997) total catch / total effort seems appropriate, and using median values as well as means may be useful.

Some further work is required, however, to determine the true level of errors in the catch-effort dataset, determine whether there is a better way of identifying targeted rig catches, and clarify some ambiguities (e.g., high rig catches with apparently no bycatch). However, data grooming is time-consuming. It is appropriate during the initial study of a fishery to gain some understanding of the data, but only minimal grooming may be needed for annual updates. It would be informative to compare the results obtained from progressively groomed data sets, to determine the minimum requirement. Additionally, present analyses use 'vessel-code' as a proxy for 'fisher'. It is possible that in this small-vessel fishery there may be more movement of fishers between vessels, and use of the same vessel by several fishers, confounding the 'vessel = fisher experience and fishing pattern' variable. It may be more desirable to identify fishers, rather than vessels, in the fishery.

A final point to consider is the probability that CELR setnet forms will be redesigned. While this will almost certainly reduce the number of errors known to be present in the catch-effort database, it may alter the pattern of catch and effort reporting so radically that a new time series of CPUE indices may need to be started after its introduction.

Monitoring the catch composition

An important component of characterising a fishery is a description of the catch; in particular, its size distribution, sex ratio, and (most importantly for a shark fishery) the proportion of mature females caught. For the latter, information on the relative numbers carrying well developed or full-term young is also important.

For most fish, this information can be obtained quite easily by market sampling. For rig, and other species which are processed (headed and gutted, or trunked) at sea, there may be logistic difficulties. The vessels in the rig fishery tend to be small, work opportunistically from a variety of landing points, and the fish are brought aboard and processed rapidly. The necessary data would need to be recorded by an observer working closely with, and perhaps part of, the fishing operation. The data could alternatively be recorded by the fisher (and an industry logbook scheme does cover parts of southern and central New Zealand), but it is an onerous task, and it may also be considered unreasonable to require a fisher to record information that may subsequently lead to restrictions on his fishing or reduce his quota.

Very limited information exists on the nature of the rig catch in SPO 1 and SPO 8. It is highly desirable that the fishery be characterised in this way. In particular, the proportion of large pregnant females caught in or near harbours during the peak season (October and November) needs to be determined, as this is the vulnerable part of the population.

Data on fish sizes and sex ratios are unlikely to be useful, on their own, for monitoring the fishery. They also suffer from the disadvantage of not having an existing time series. However, they will almost certainly provide information on undesirable characteristics of the existing fishery (e.g., too many large females being caught in certain areas), and they will be essential for any length- or age-structured model of the fishery that may subsequently be developed.

Moderate cost would be involved in collecting such data. After an initial programme covering several areas at different times of the year, it may be possible to reduce the sampling regime to cover only the most important catches (e.g., main season, certain harbours or bays).

Trawl surveys

Rig are poorly monitored by trawl surveys. They are caught in low numbers, the largest fish may be able to out-swim trawls, and (depending on survey timing) their seasonal inshore migration may remove part of the population from the grounds covered by the survey. However, immature fish in the size range 50–100 cm are regularly caught, and it may be possible to monitor their relative numbers and determine whether the abundance of pre-recruit fish was declining. Data exist for several time series of trawl surveys, but are not routinely reported on. Little cost is involved in ensuring that suitable data continue to be collected, but the continuation of some trawl survey series is not assured.

Tagging

A well designed tagging programme can provide an estimate of current biomass, as well as information on movements between Fishstocks, within Fishstocks (i.e., between the harbours in SPO 1), growth rate, and exploitation rate (Francis 1998b). It is useful in supplying parameters to a model of the fishery, but is not immediately useful in monitoring the status of the fishery. The experimental design must include such elements as method of capture, tag type, estimation of tag shedding, tagging-induced mortality, timing of release and recapture periods (relative to the rig's life history), catch-sampling during the recovery phase, correction of the tagged/untagged ratio for natural recruitment over the time period, detection of measurement errors, and correction for growth during the period at liberty.

There are two further particularly important considerations: (1) The requirement to tag the fish randomly throughout the distribution of the stock; this is more likely to be achieved for the coastal rig populations of central and southern New Zealand, than for the harbour populations of northern New Zealand, which are more likely to be seasonally and geographically segregated by size and sex.

(2) The need to assess whether the rate of reporting tagged fish will be influenced by fishers' perceptions of the outcome of such reporting. Hidden tags detected by scanners can overcome this potential bias, but these require that a substantial proportion of landings pass through a few centralised locations; this condition is not met in the northern rig fishery, where dispersed landings go to many small wholesalers and are often sold directly to retailers.

Because of their complexity and intensive nature, tagging programmes are relatively high cost, even when specialised tags are not used.

Fixed-station surveys

Randomised sampling is usually a major consideration when surveying fish populations, but there are some situations where sampling the population on a regular basis at fixed sites has advantages. The most comparable fishery to that for New Zealand rig is the Australian 'southern shark fishery' which targets both school shark and gummy shark, the latter being a species closely related to rig. This Australian fishery has been extensively studied for decades, and although the school shark component became severely overfished before the danger was recognised and management action taken, the gummy shark component appears stable and the present catch sustainable. Monitoring has been primarily through tracking CPUE indices, undertaking specific tagging programmes, and obtaining biological information (size, age, and sex ratios). The southern shark fishery is scheduled to move to output controls (ITQs), a change considered likely to affect the reliability (or at least the continuing comparability) of catch rates recorded in fishing logbooks. This has prompted a consideration of alternative monitoring procedures, and the one currently favoured – although not yet in operation – is a fixed station gillnetting survey. A series of nets would be deployed at regular intervals in appropriate localities for both school shark and gummy shark. The gear and locations would remain unchanged over time, and observers would record biological characteristics of the retained and discarded catch and bycatch (number, size, sex, maturity for the target species), collect vertebrae for ageing, and any other information or material that was required from time to time. Commercial fishers would be trained to undertake much of this survey work, a major consideration being to develop a cost-effective programme.

Some form of fixed-station survey could be considered for the northern New Zealand rig fisheries. The sites (sampling localities) would be chosen to represent the geographically separate and sometimes different regional components. As in Australia, it would be both necessary and appropriate to involve commercial fishers. Strict guidelines would have to be developed, and adhered to, to ensure comparability between different geographic sites in the fishery, and comparability over time as different fishers undertook the work.

If such a survey was established, there would be considerable advantage in making it comparable with the Australian scheme. Knowledge gained in designing and undertaking both surveys could be shared, as could the analysis of data, development of models, and formulation of management advice.

As for tagging, this method would not provide good information on population trends until after it had been in operation for several years.

10. ACKNOWLEDGMENTS

Much credit is due to Brian Sanders, who designed and obtained all the extracts from the Ministry of Fisheries database, and who discovered a solution to the mismatch of statistical fishing area and Fishstock data. I thank Malcolm Francis for his advice on rig fisheries in general, and for assistance with this study. Also Bruce Hartill, whose careful review of an earlier draft of the manuscript was very helpful. This study was funded through Ministry of Fisheries contract SPO2001/01.

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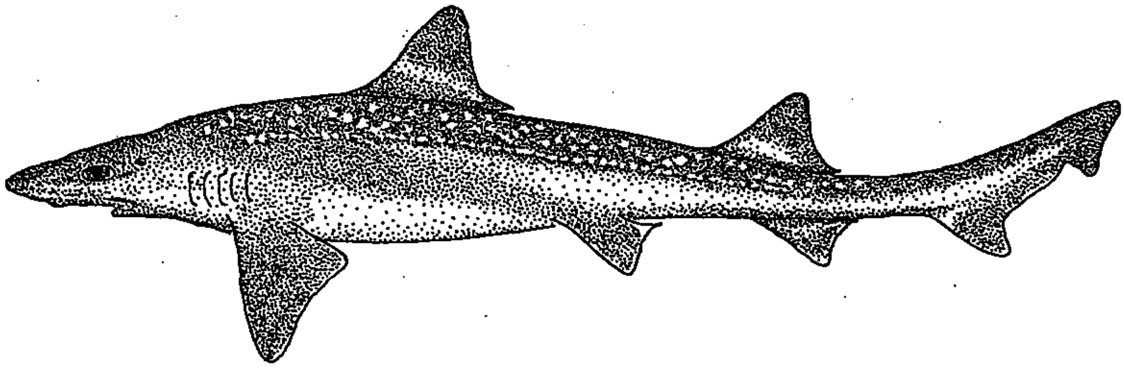


Figure 1: Adult female rig (*Mustelus lenticulatus*). Also known as spotted dogfish, gummy (shark), spotted smoothhound, and pioke, and sold as lemonfish. Closely related to the gummy shark (*M. antarcticus*) of southern Australia, and formerly considered to be that species.

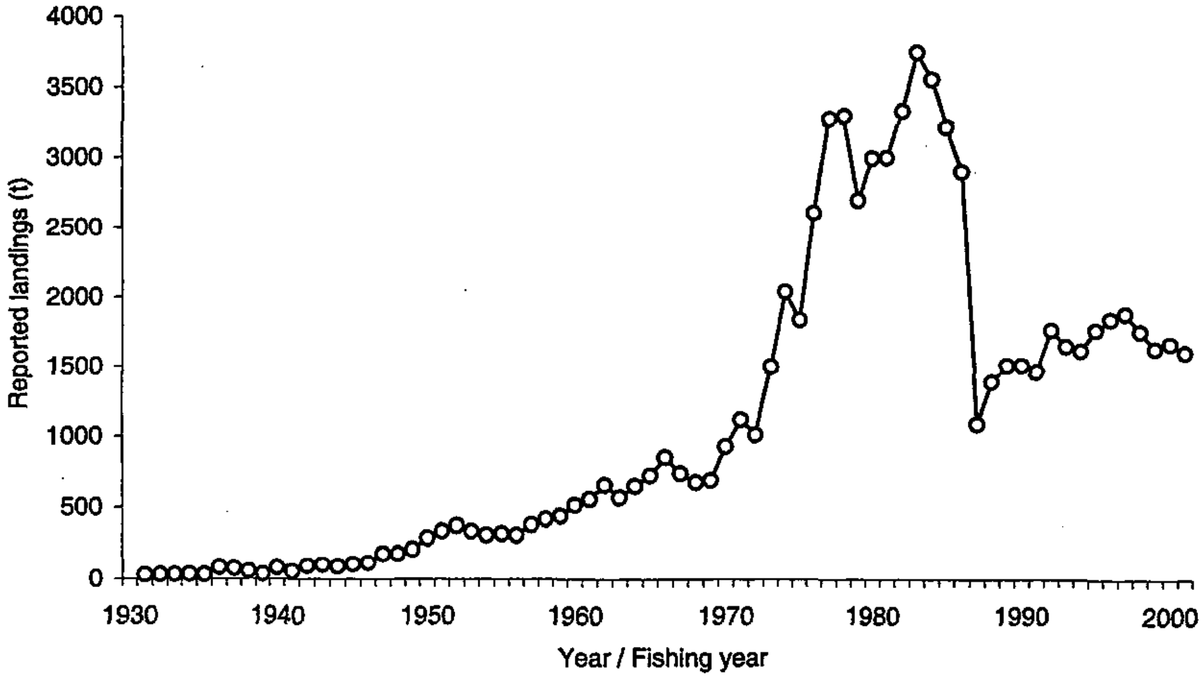


Figure 2: New Zealand landings (t) of rig, 1931 to 2001. Data to 1973 are for calendar years, data from 1987 are for fishing years (Oct-Sep). Intervening values are from various sources and with different definitions of a year. Value for 1973 not available, plotted as the mean of adjacent years.

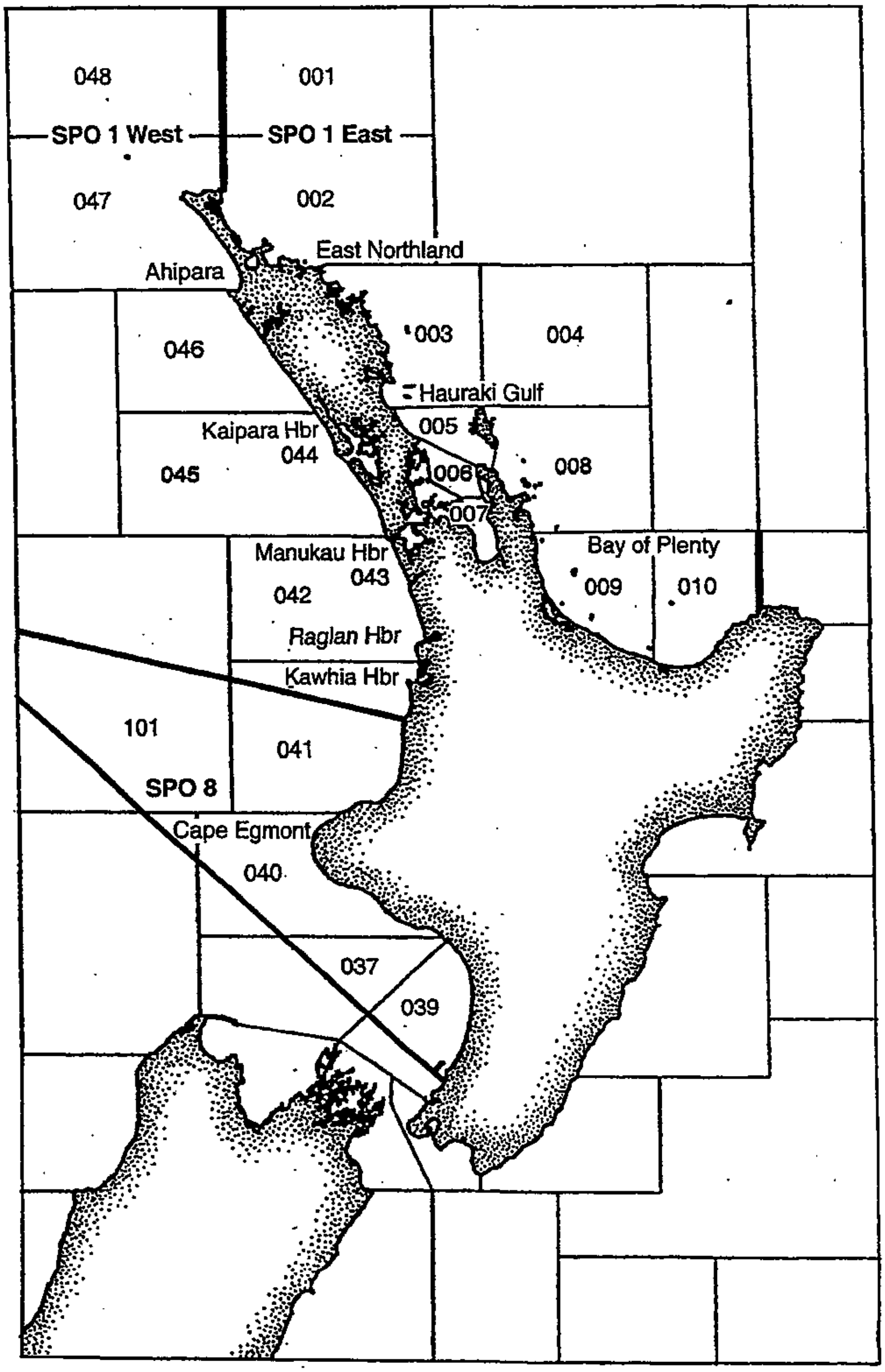


Figure 3: ***SPO 1 and SPO 8 boundaries, statistical fishing areas, and locations. SPO 1 is subdivided*** **(nominally) at North Cape into East and West. Some of the catch taken in statistical area 041 is landed into SPO 1, some into SPO 8. The catch taken in area 040 is considered to be SPO 8. Some of the catch in area 037 is landed into SPO 8, some into SPO 7. See text for explanation of how the estimated catch data from areas 037 and 041 were allocated to Fishstocks.**

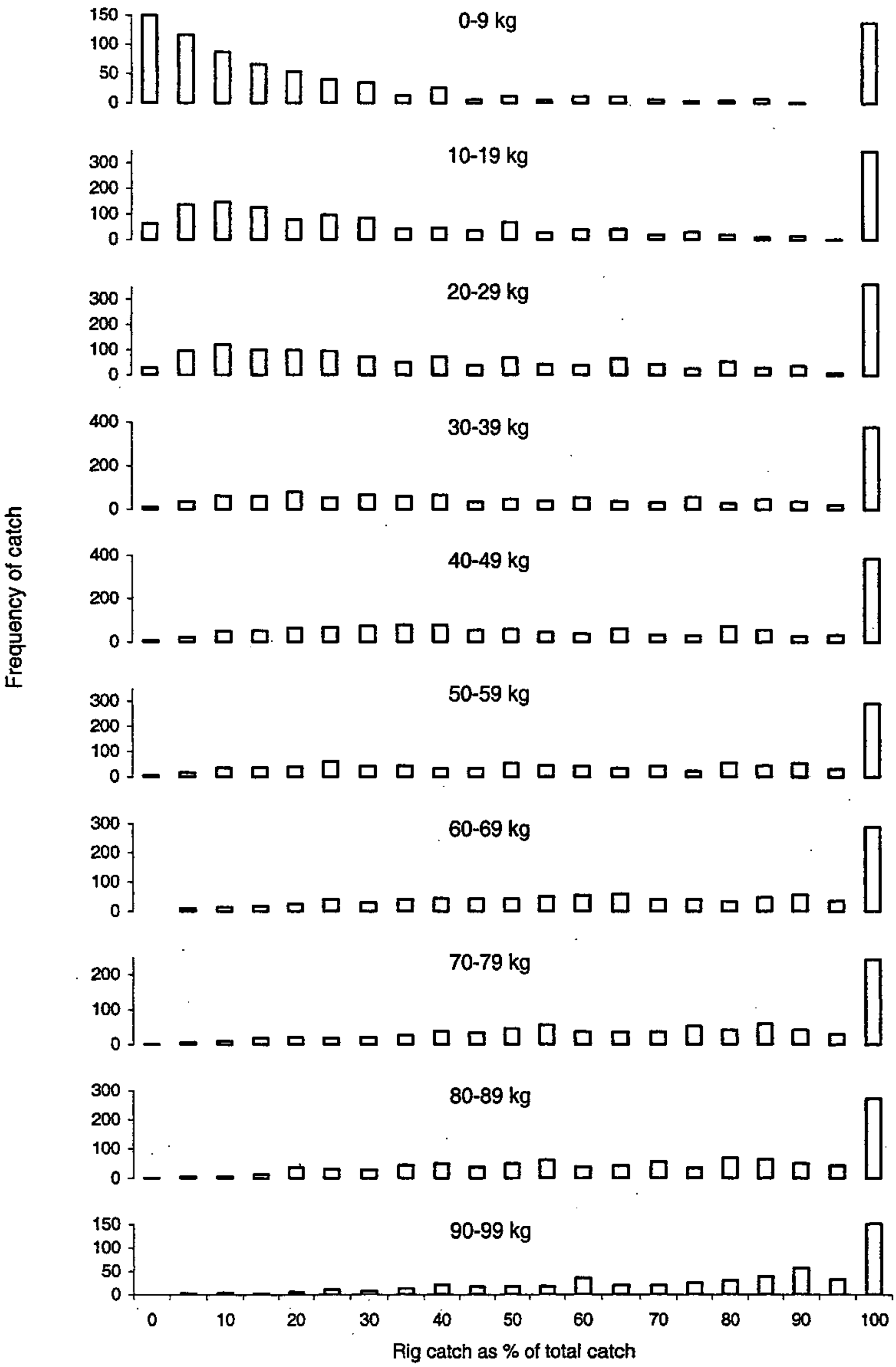


Figure 4: Rig catch as a percentage of total (daily) catch, by rig catch size groupings. Percentage units grouped as < 1 to 4 (labelled as 0), 5 to 9, 10 to 14, etc. Based on all targeted rig setnet catches in SPO 1, fishing years 1990–91 to 2000–01 combined.

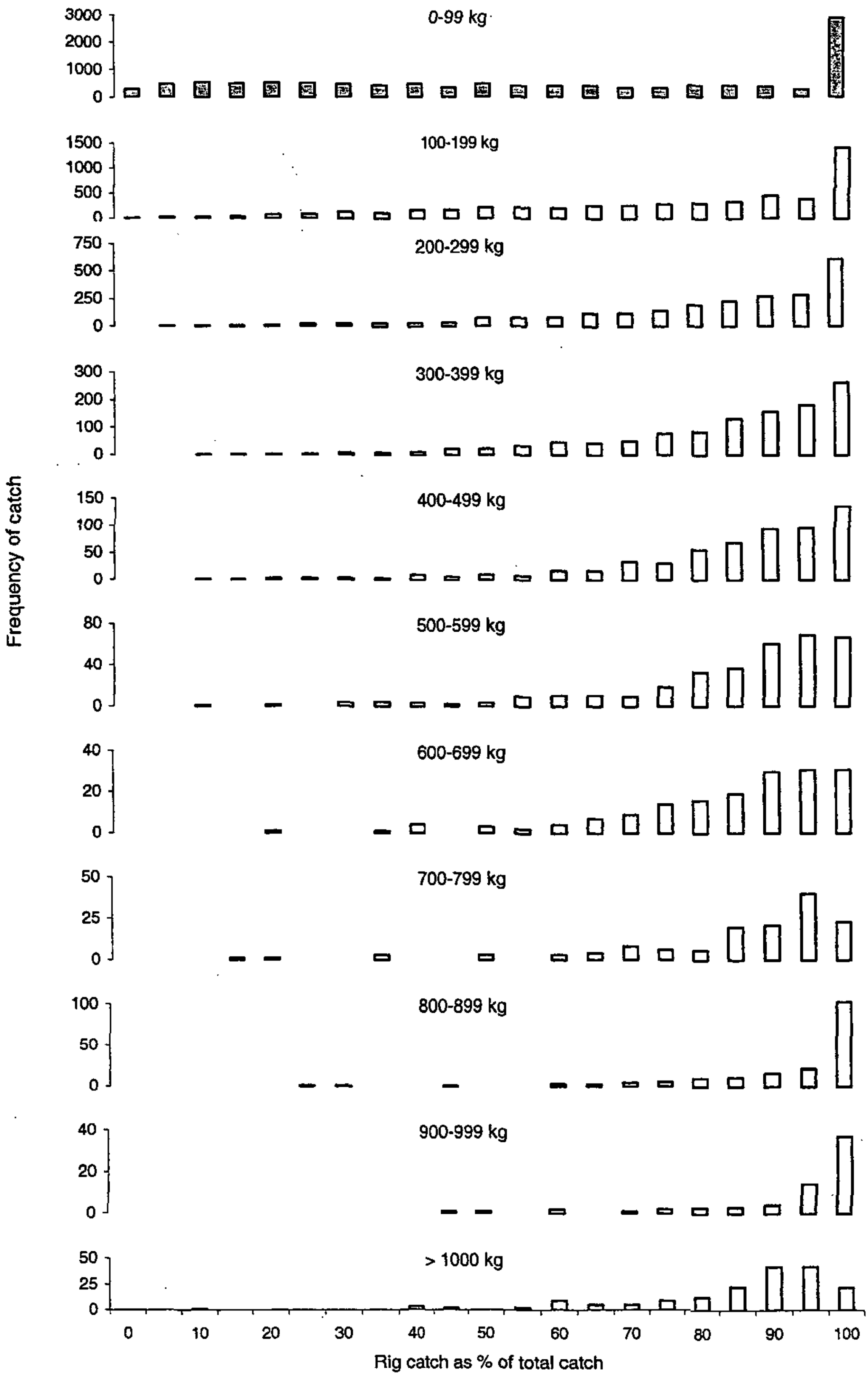


Figure 4 (contd): Rig catch as a percentage of total (daily) catch, by rig catch size groupings. Catches less than 100 kg (from previous page) are grouped in the top panel.

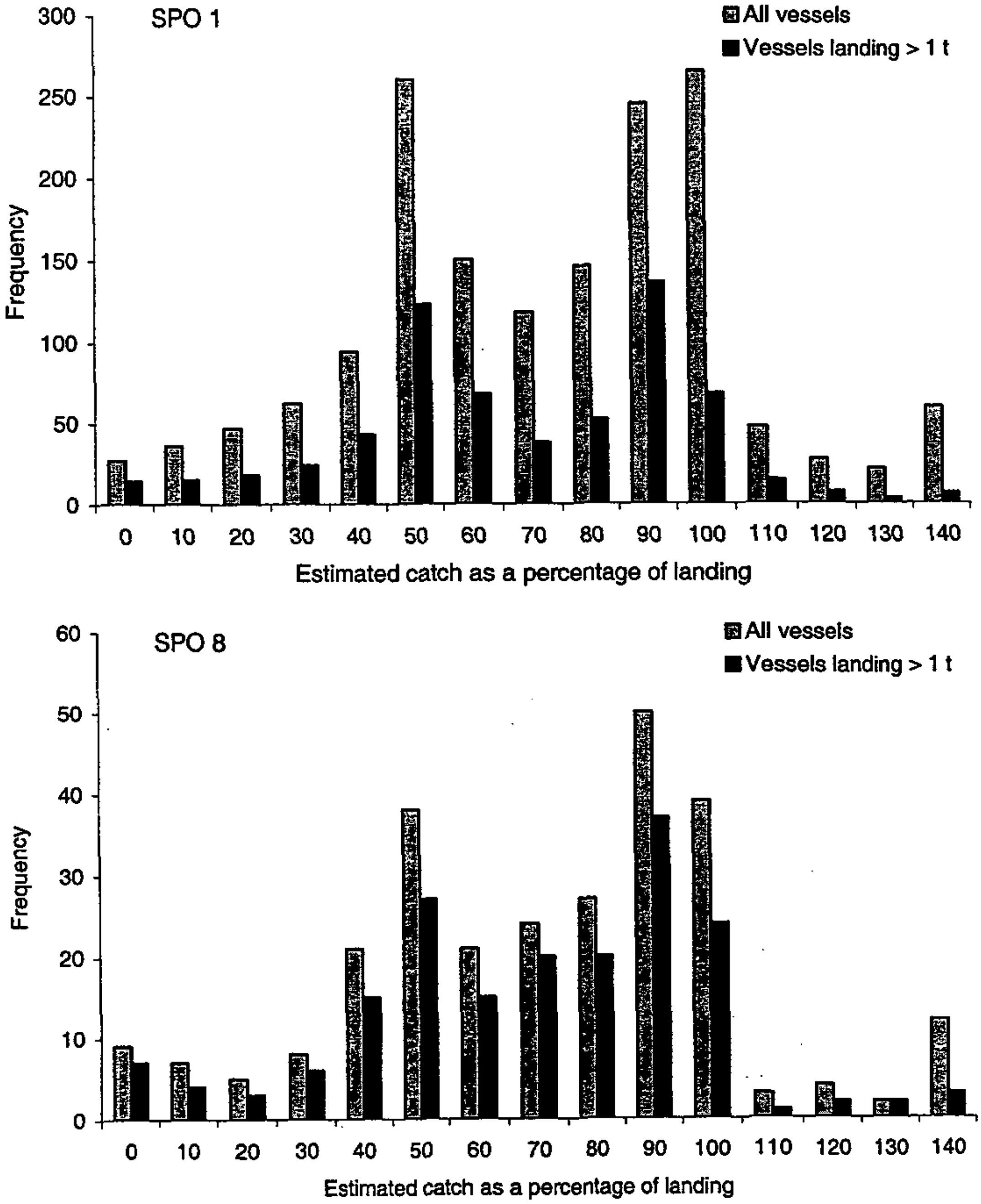


Figure 5: Relationship between estimated catches and recorded landings of rig, setnet vessels, SPO 1 and SPO 8. Each vessel's catch for a fishing year was calculated as a percentage of its landing for that year. Data cover the fishing years 1992–93 to 2000–01, when the conversion factor was 1.75. Each vessel contributed a data point for each year it fished. Data are shown for all setnet vessels, and for setnet vessels with an annual landing of at least 1 t. 0 comprises values between 0.1% and 9.9%, 140 comprises values of 140% and greater.

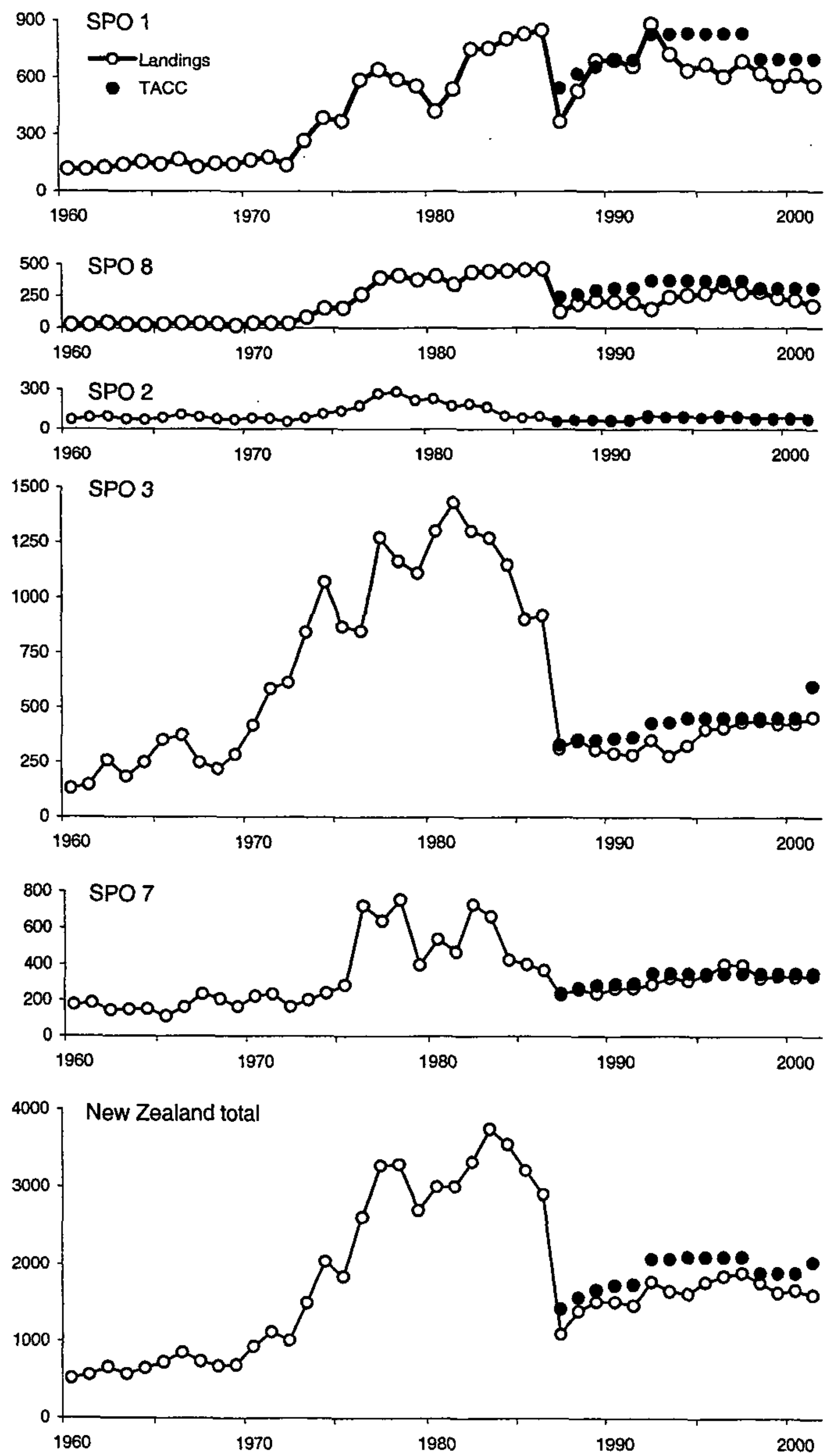


Figure 6: Landings (t) of rig from SPO 1 and SPO 8 (top panels), in relation to landings at other Fishstocks (centre panels) and total New Zealand (bottom panel). Data to 1973 are calendar years (from Annual Reports on Fisheries), data from 1987 are Oct-Sep fishing years (Plenary Reports); intervening values are from various less reliable sources and for different definitions of a year. *1973* values not available, plotted as means of adjacent years.

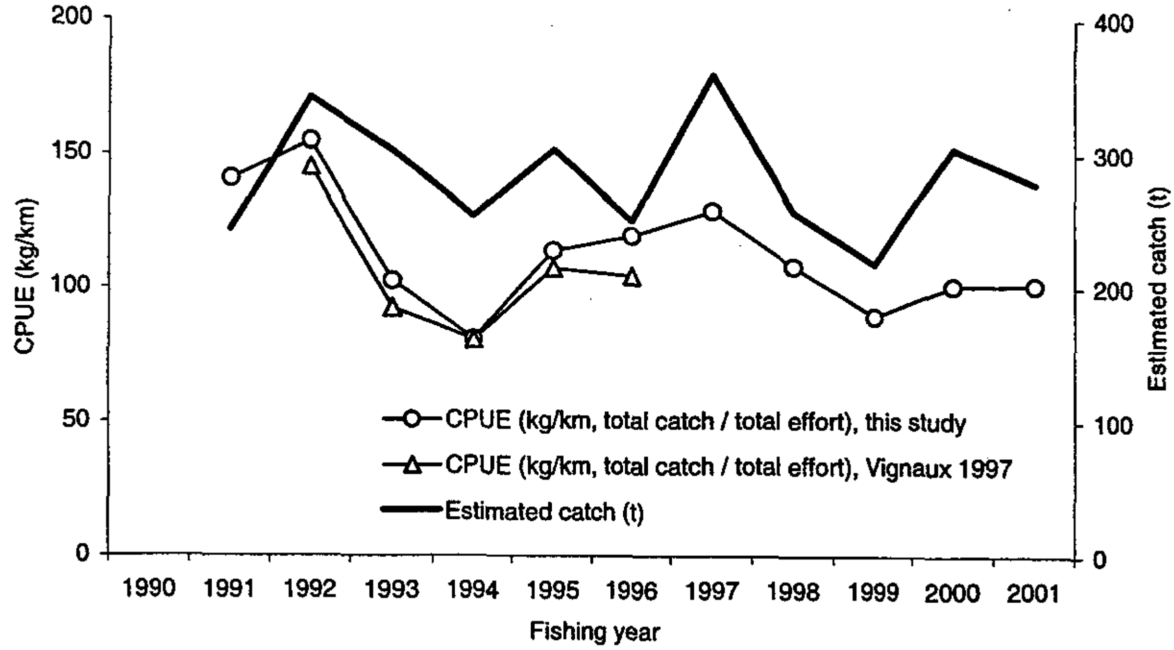


Figure 7: Comparison of CPUE indices for SPO 1 obtained in this study with those of Vignaux (1997), and their relationship to the trend in estimated catch.

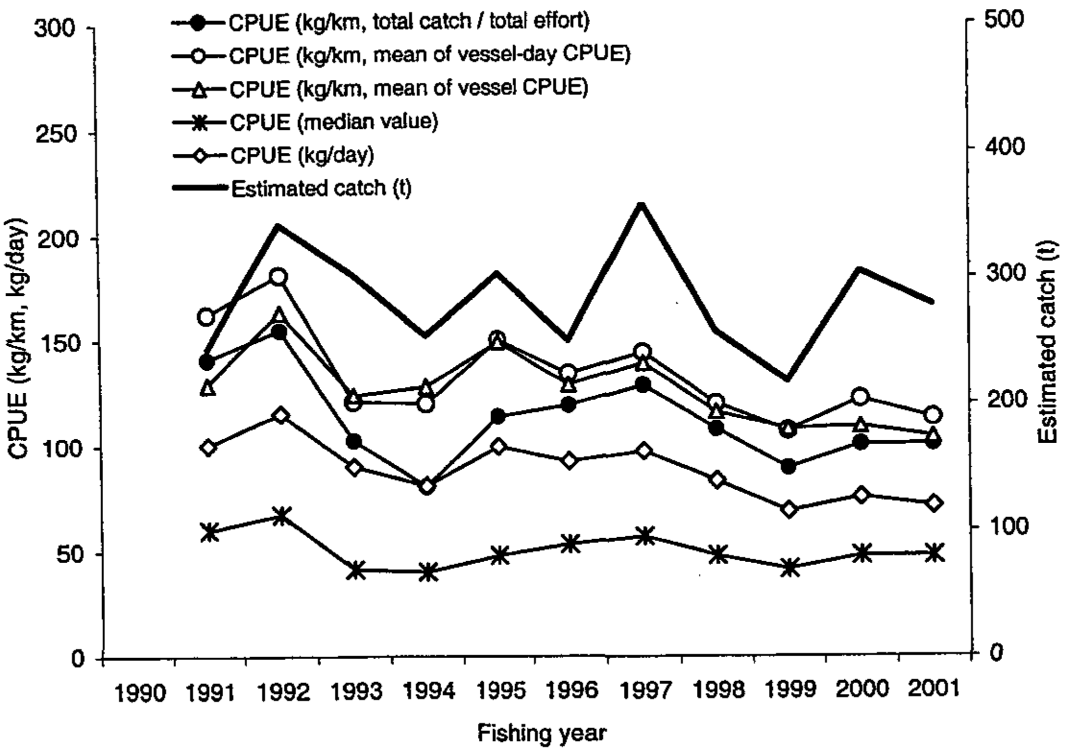


Figure 8: Comparison of several CPUE indices for SPO 1. Total catch/total effort is the sum of all estimated catches divided by the sum of all daily net lengths. Mean of vessel-day is the mean of all daily CPUE values. Mean of vessel CPUE is the mean of the annual CPUE values of all vessels. Median value is the central daily CPUE value of each year's ranked dataset.

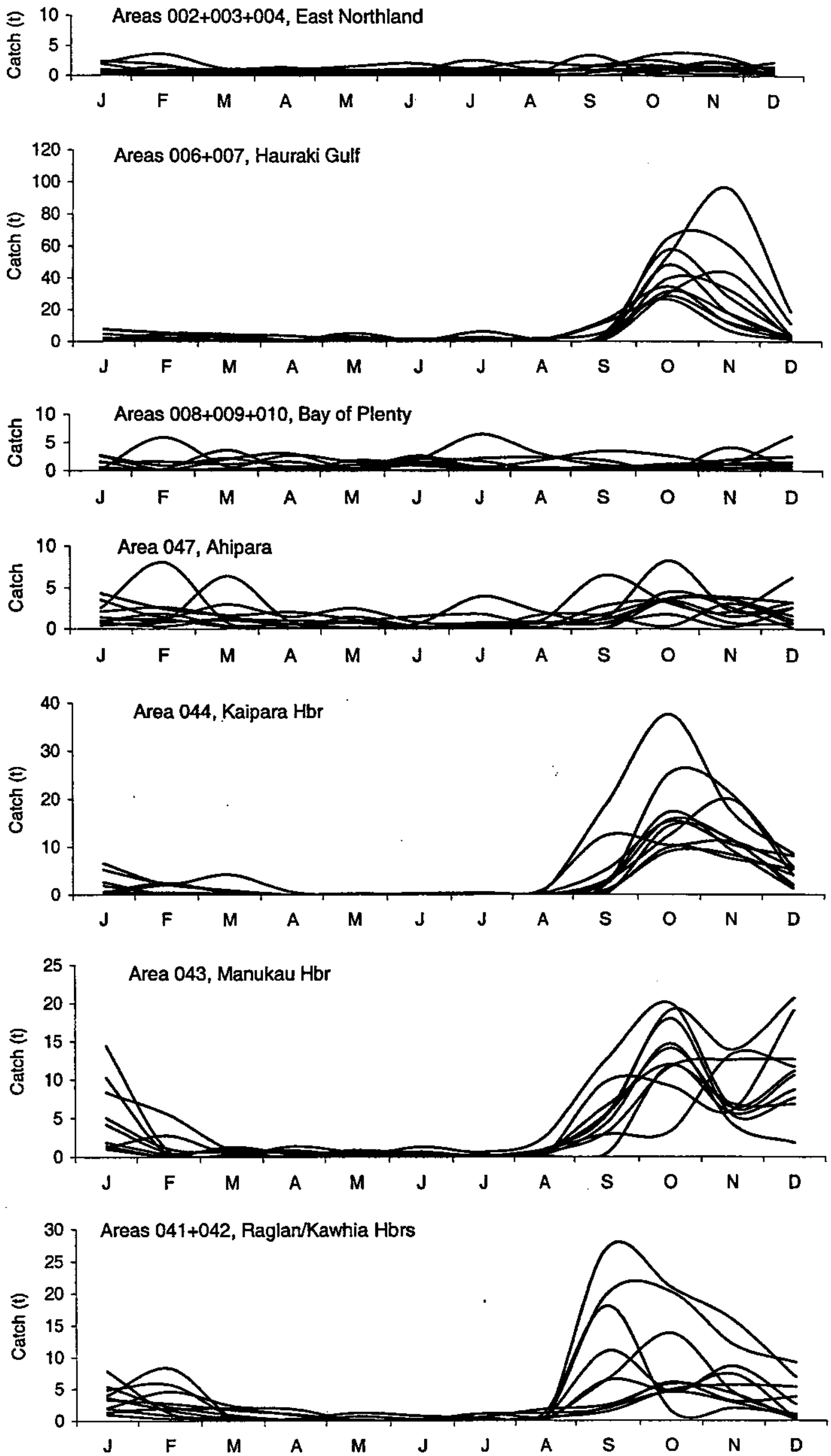


Figure 9: Seasonality of targeted setnet rig catches in the main regions of SPO 1. Monthly values (smoothed) for calendar years 1991 to 2000.

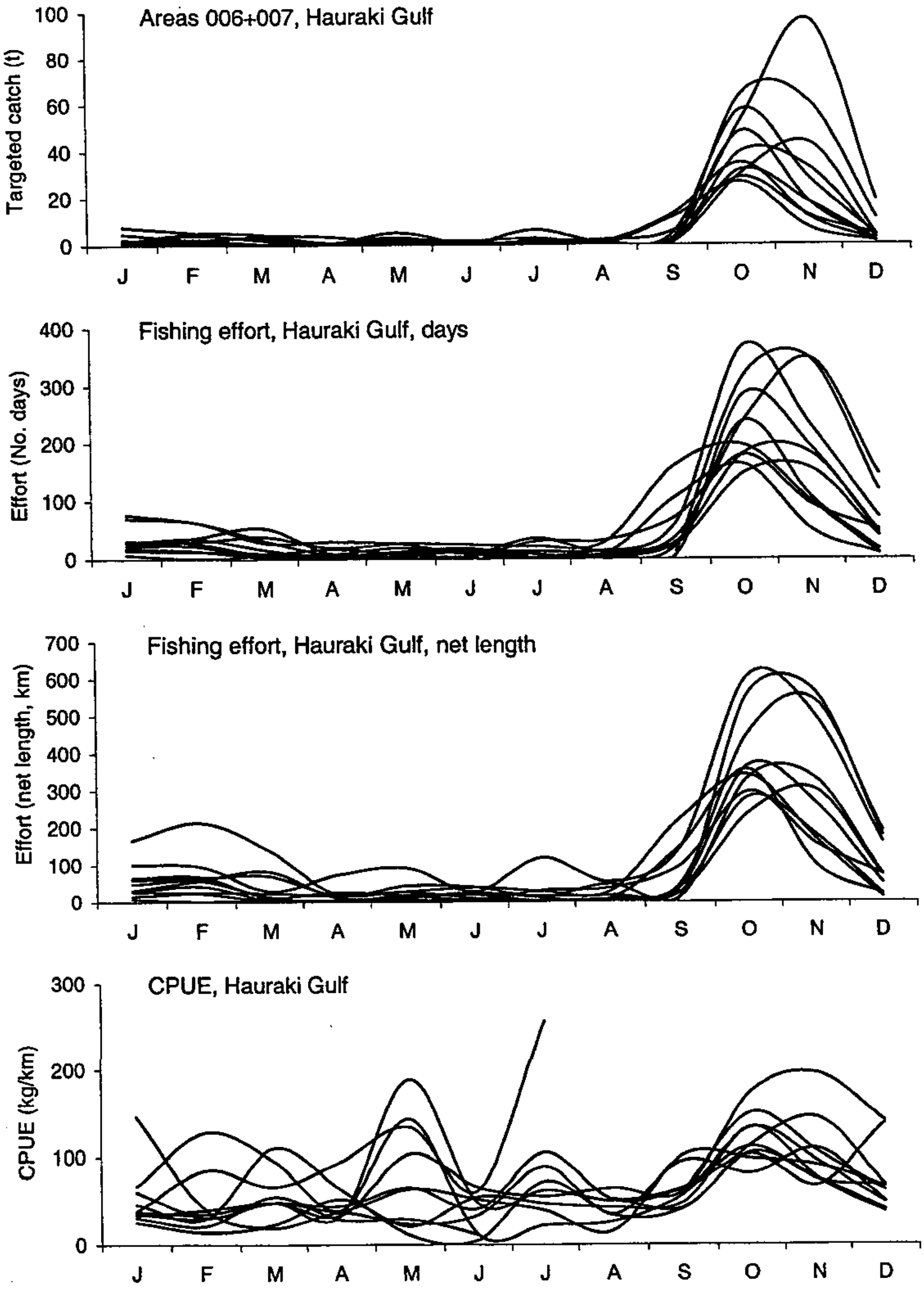


Figure 10: Seasonality of targeted rig setnet catch, effort, and CPUE in the Hauraki Gulf fishery.

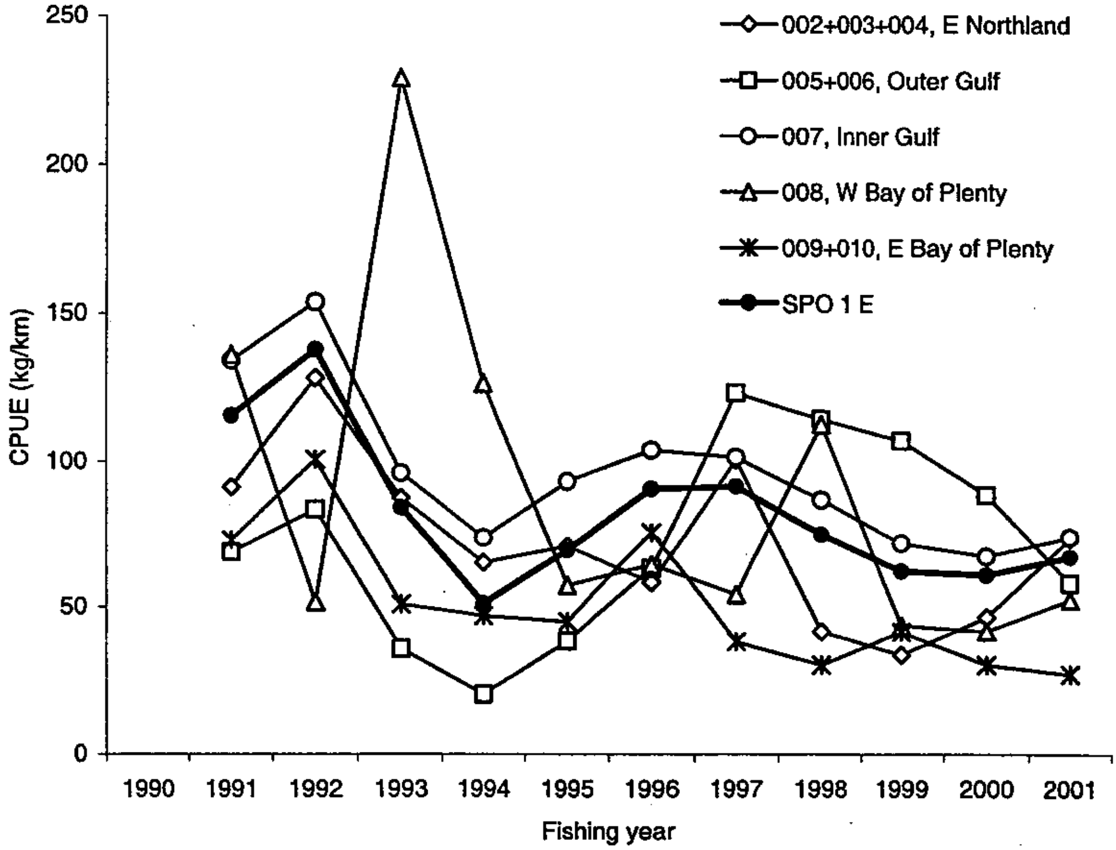


Figure 11: CPUE (kg/km) for target rig setnet fisheries in SPO 1 E, defined by statistical area.

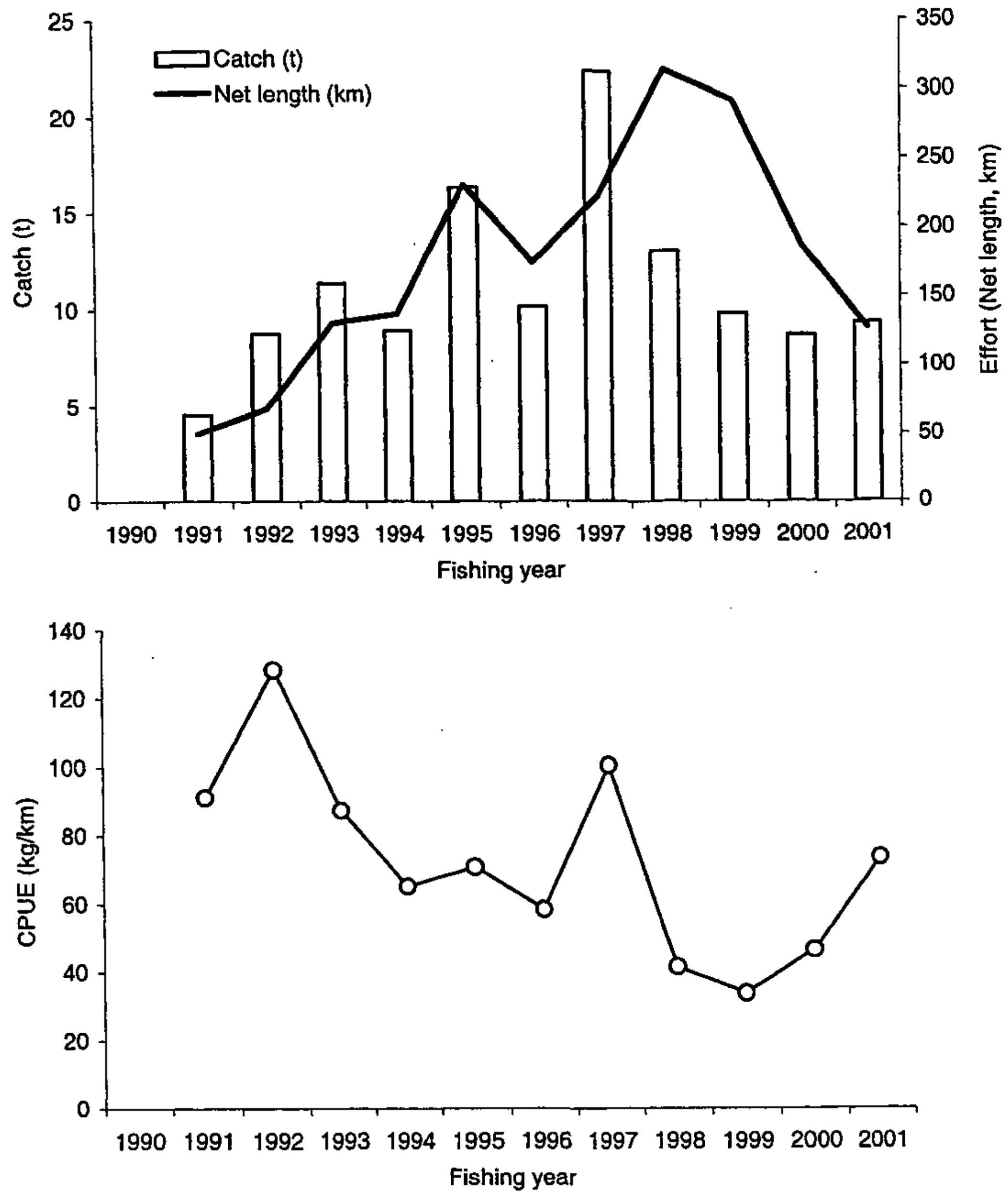
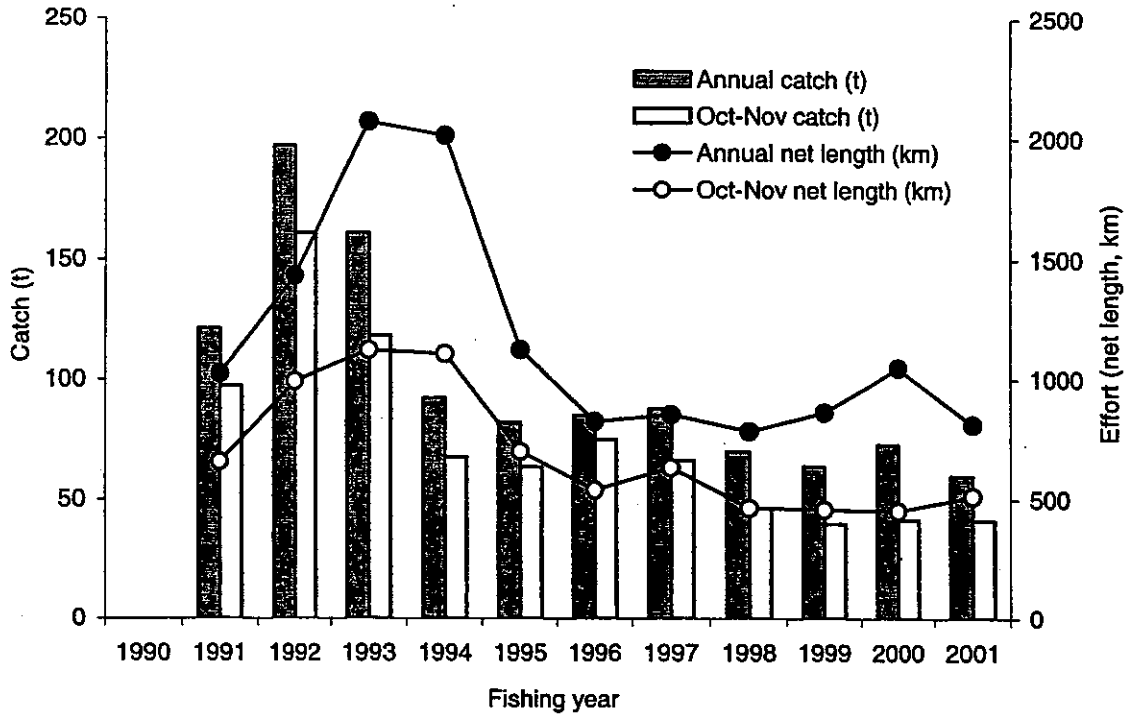


Figure 12: Catch, effort, and CPUE indices, as total catch / total effort (kg/km), for annual catches in the east Northland fishery (areas 002+003+004) of SPO 1.



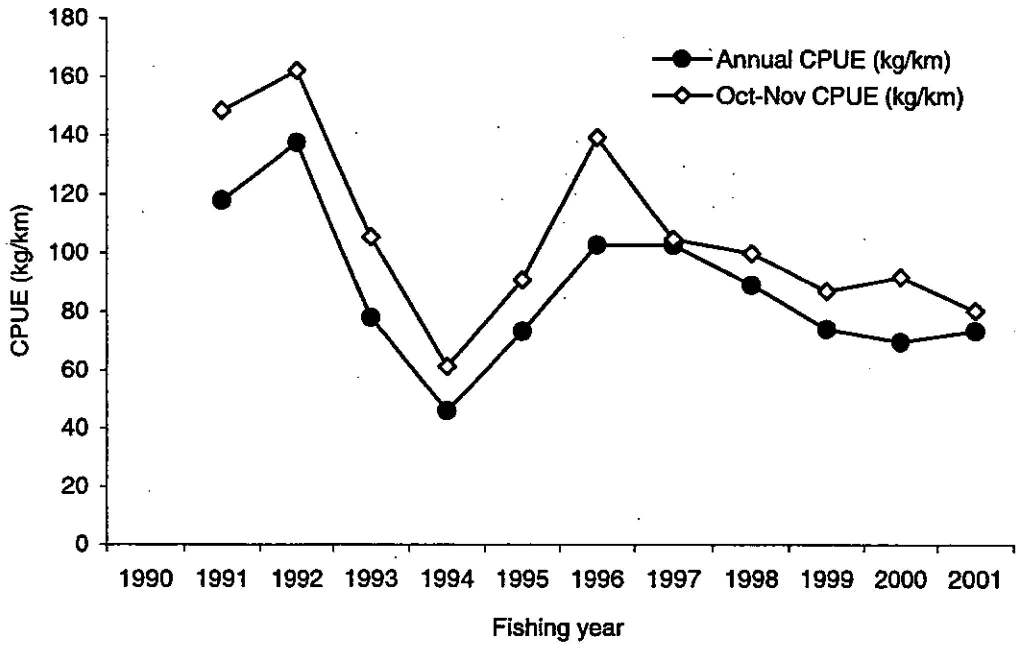
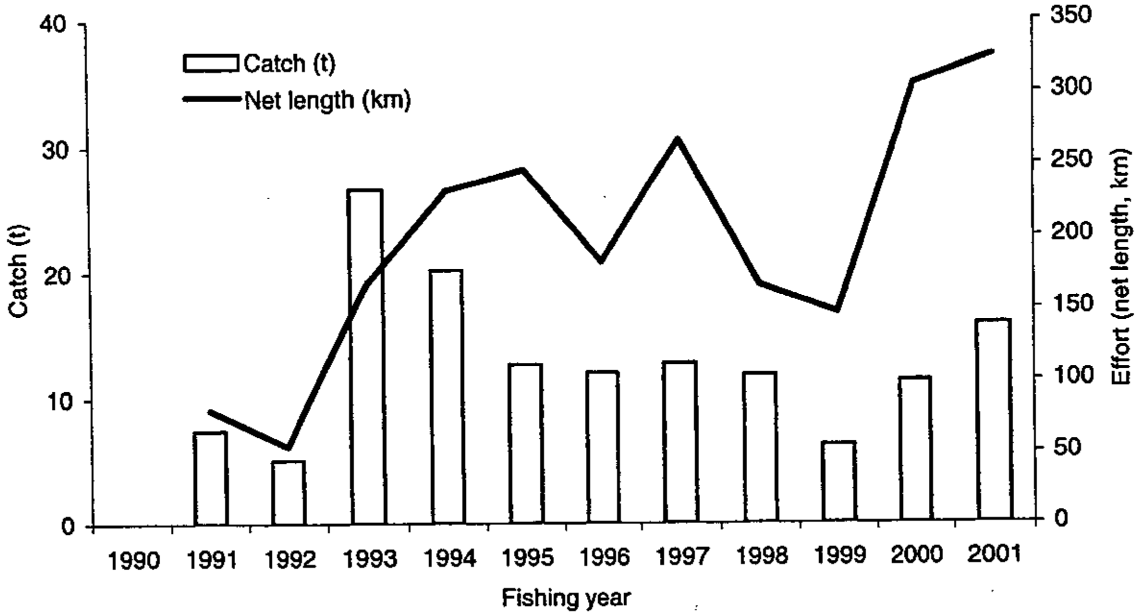


Figure 13: Catch, effort, and CPUE indices, as total catch / total effort (kg/km) for annual and peak season (October and November) data from Hauraki Gulf (areas 005+006+007), the main fishery in SPO 1 East.



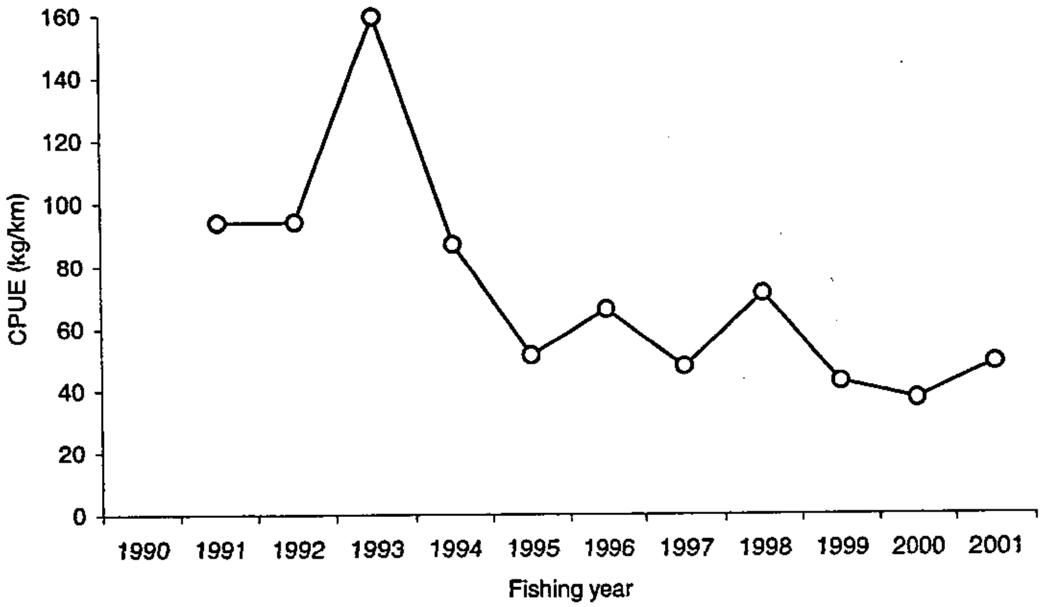


Figure 14: Catch, effort, and CPUE indices, as total catch / total effort (kg/km), for annual catches in the Bay of Plenty fishery (areas 008+009+010) of SPO 1 East.

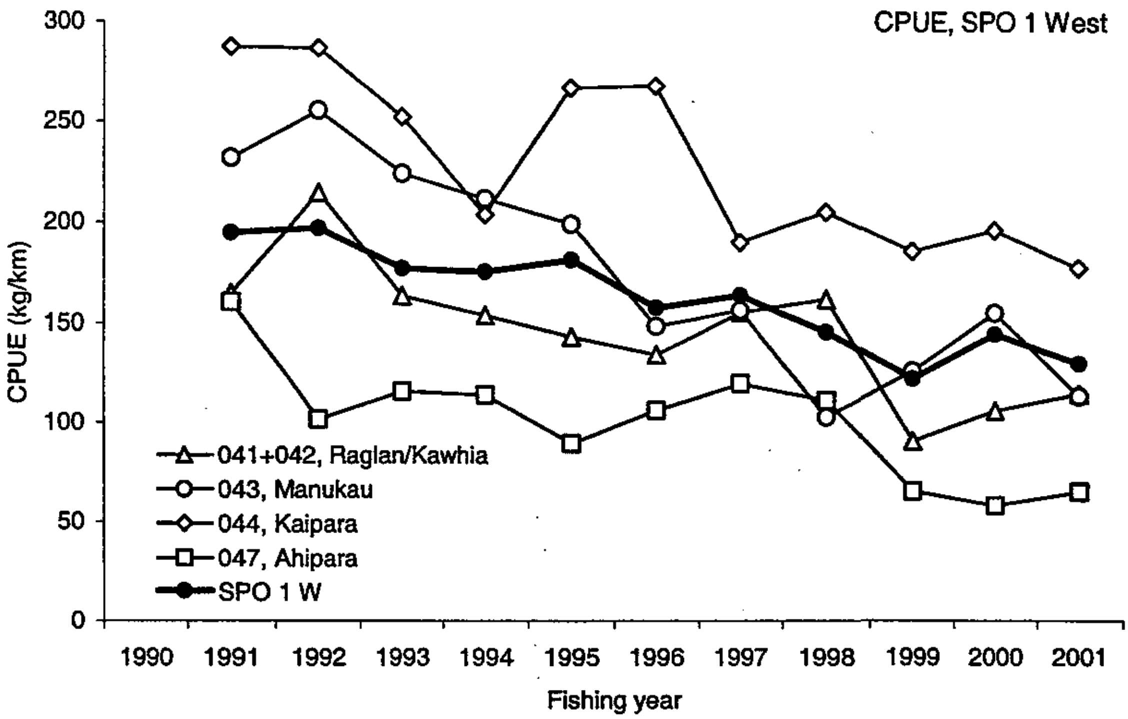


Figure 15: CPUE indices, as total catch / total effort (kg/km) for SPO 1 W, and area (mainly harbour) fisheries, from annual catches.

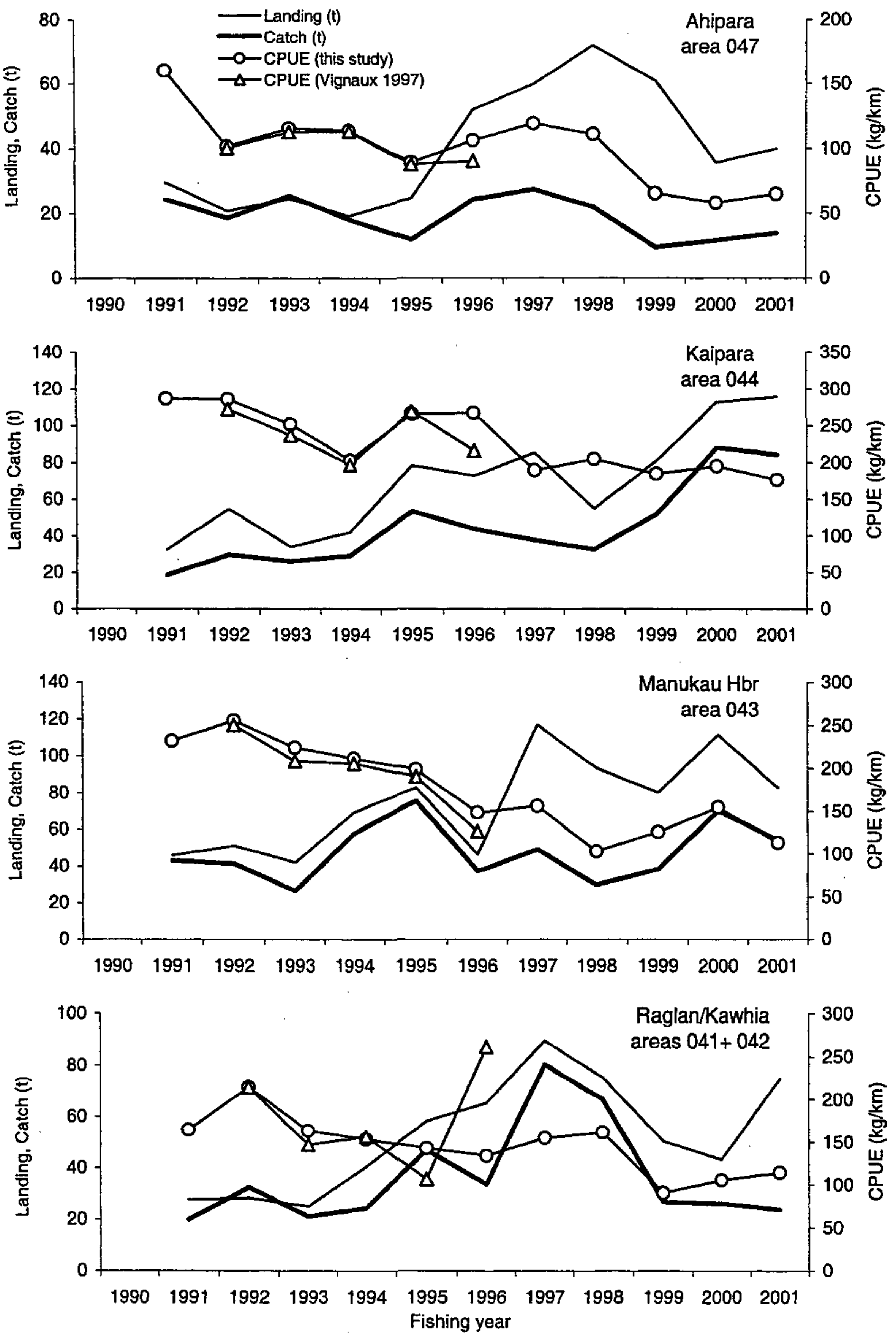


Figure 16: Reported landings, estimated catches, and CPUE indices (total catch / total effort, kg/km) for the four main target rig fisheries in SPO 1 West.

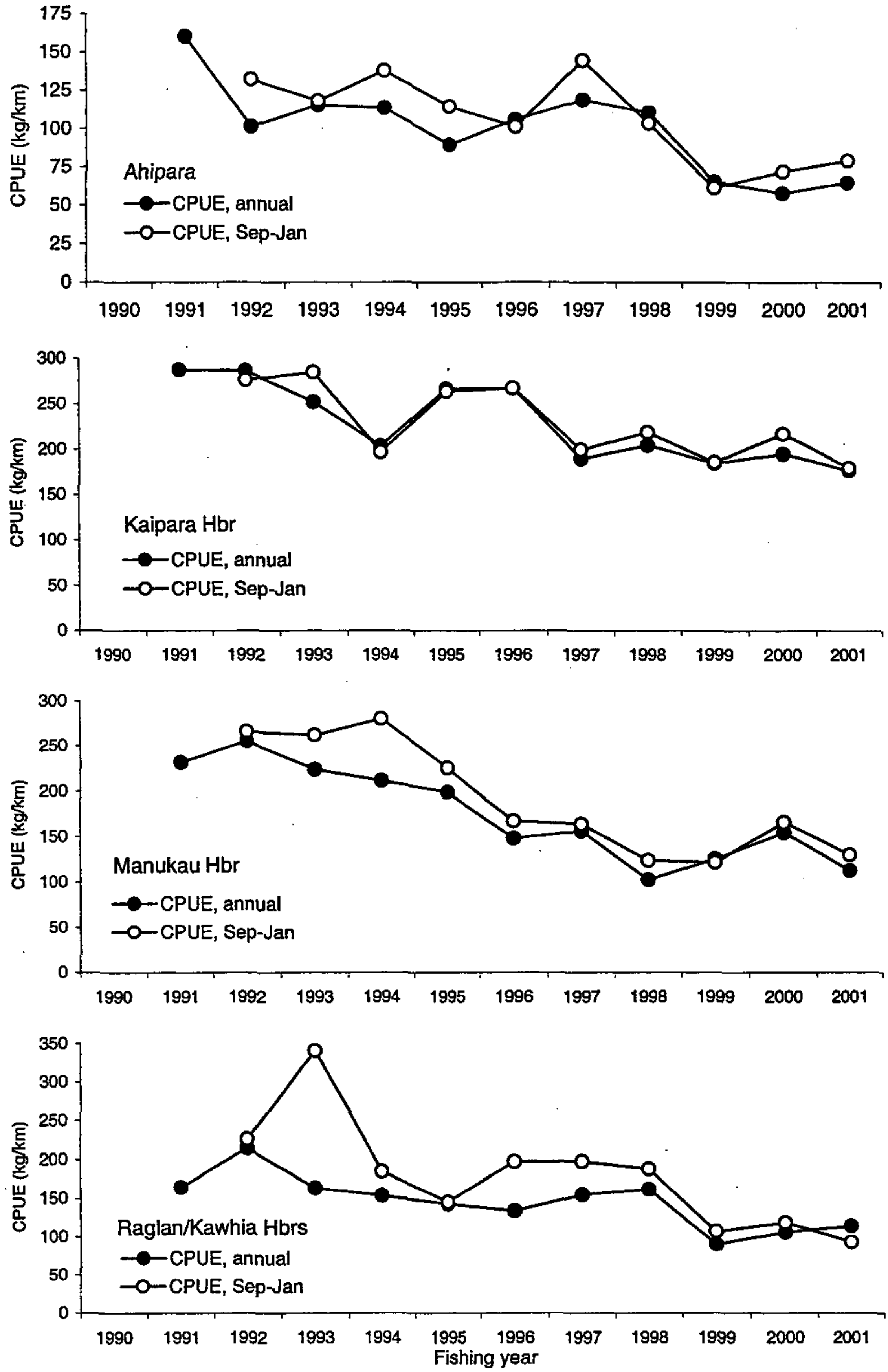


Figure 17: CPUE indices, as total catch/total effort (kg/km) for the four main SPO 1 West regions. Annual values, and main season (September to January) values. September values are added to the fishing year ahead, i.e. September 1991 is included in the 1992 fishing year.

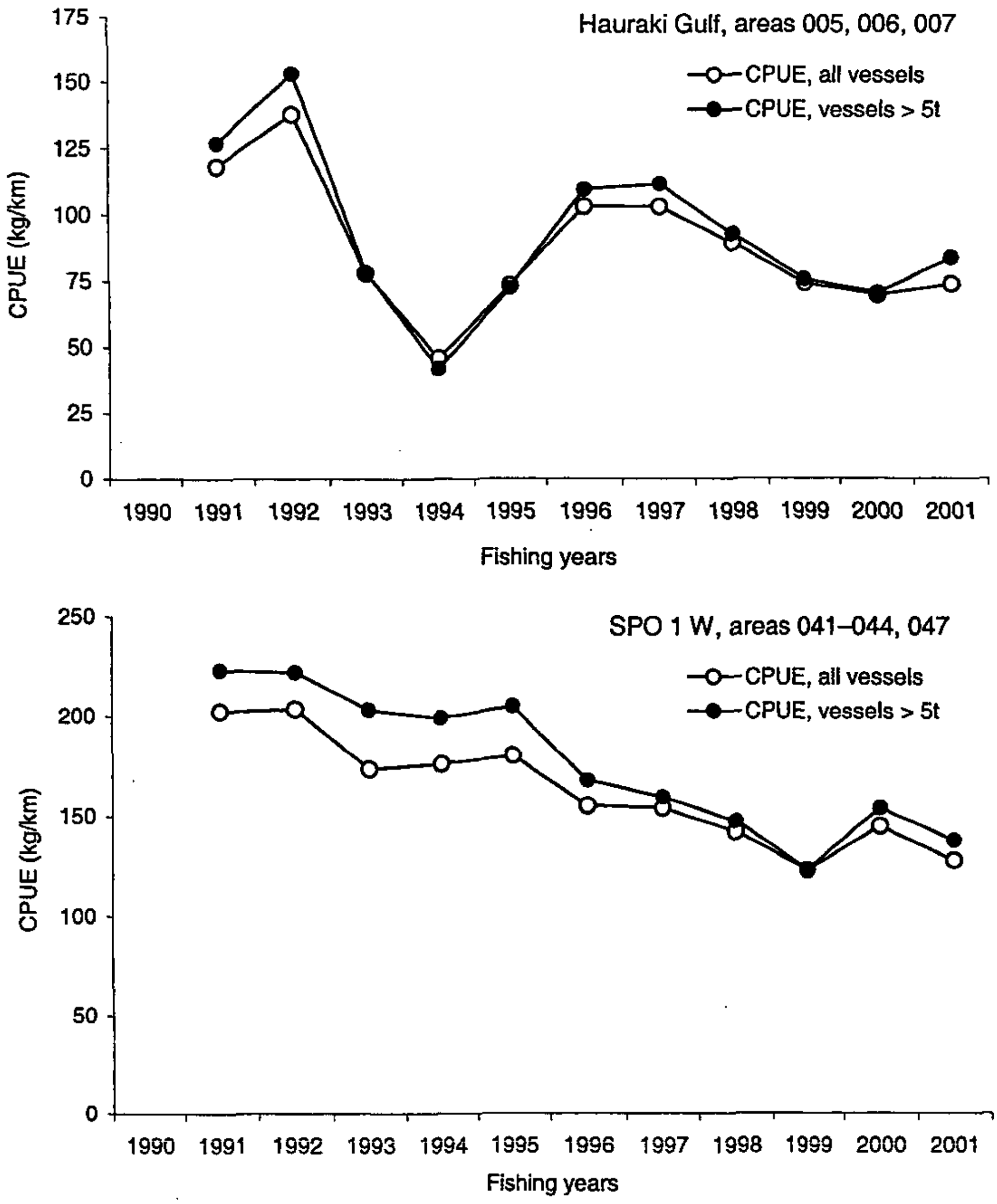


Figure 18: CPUE indices, as total catch / total effort (kg/km) for the main fisheries in SPO 1. CPUE indices for the main vessels, those defined as catching at least 5 t in any one year, are shown separately from those for all vessels.

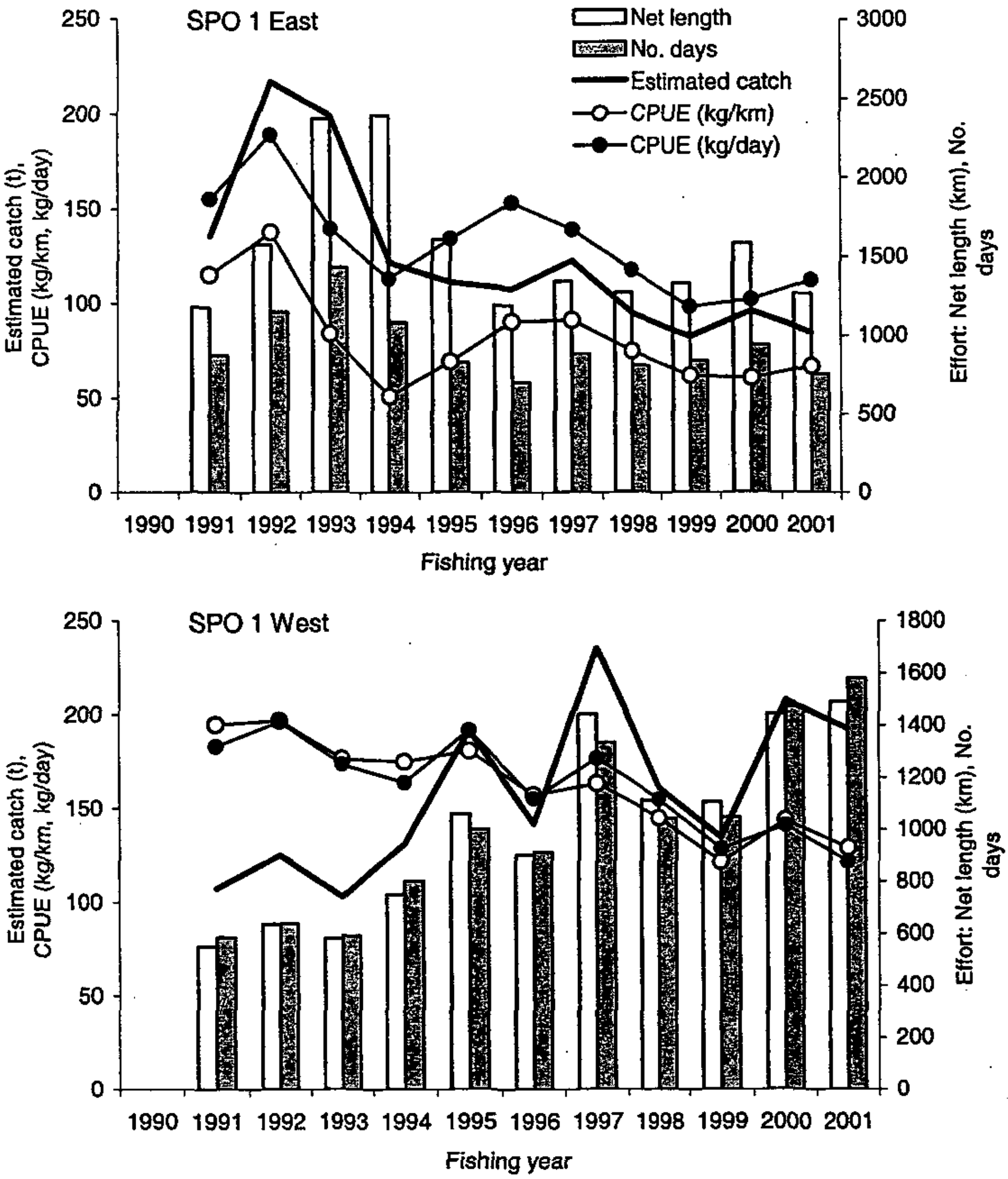


Figure 19: Relationship between catch, effort, and CPUE (total catch / total effort) in SPO 1 East and SPO 1 West.

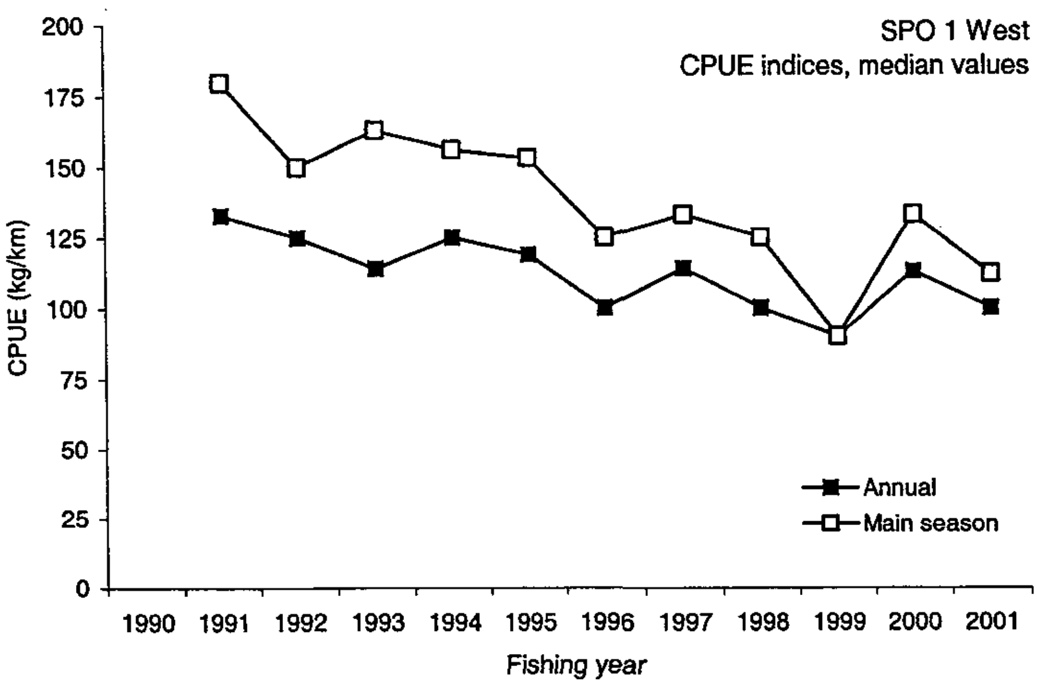


Figure 20: CPUE indices for targeted setnet catches of rig, SPO 1 West, medians of ranked daily kg/km values. Annual (fishing year) and main season (September to January) values.

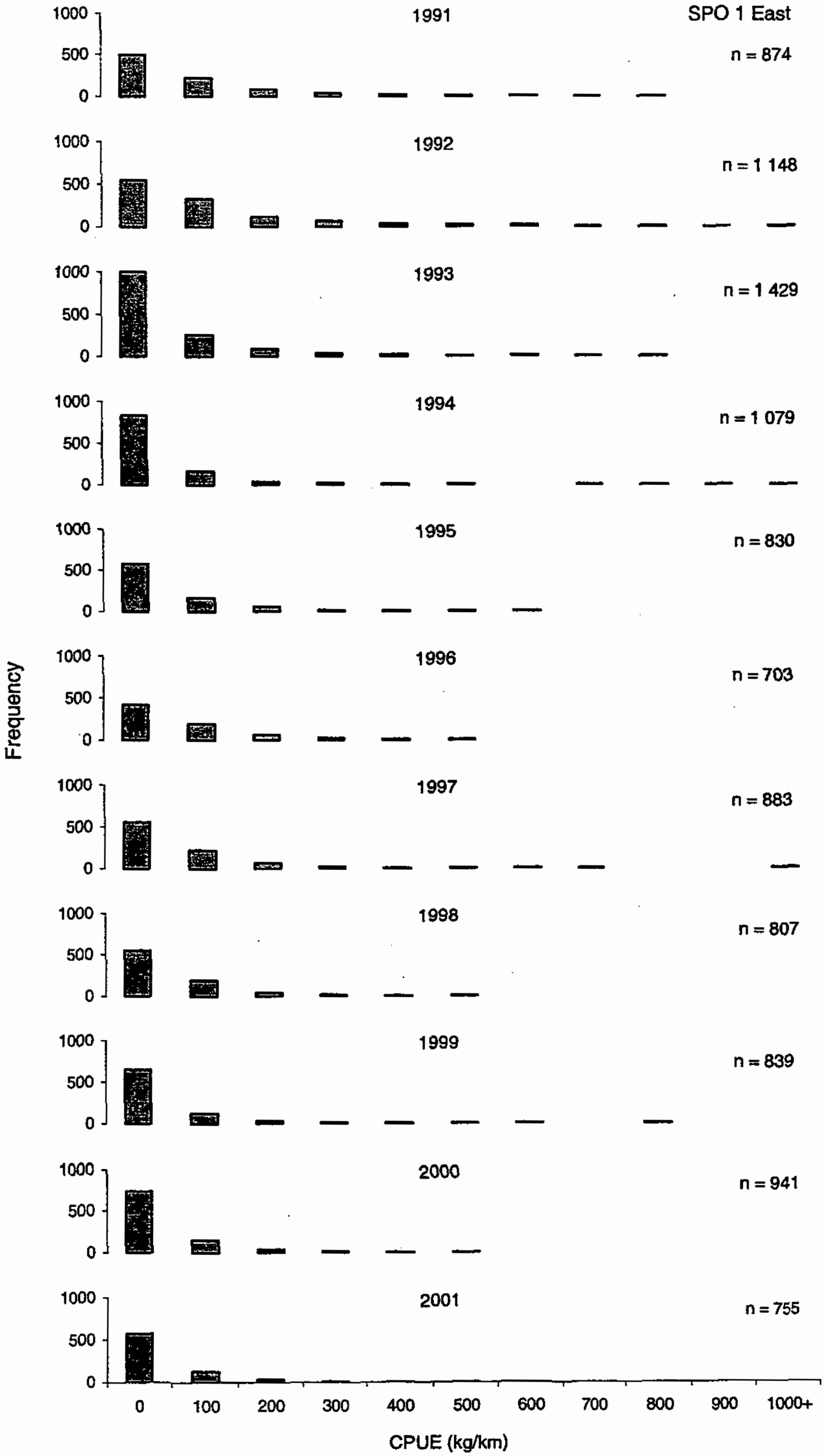


Figure 21: Frequency distribution of CPUE (kg/km) values for SPO 1 East, by fishing year.

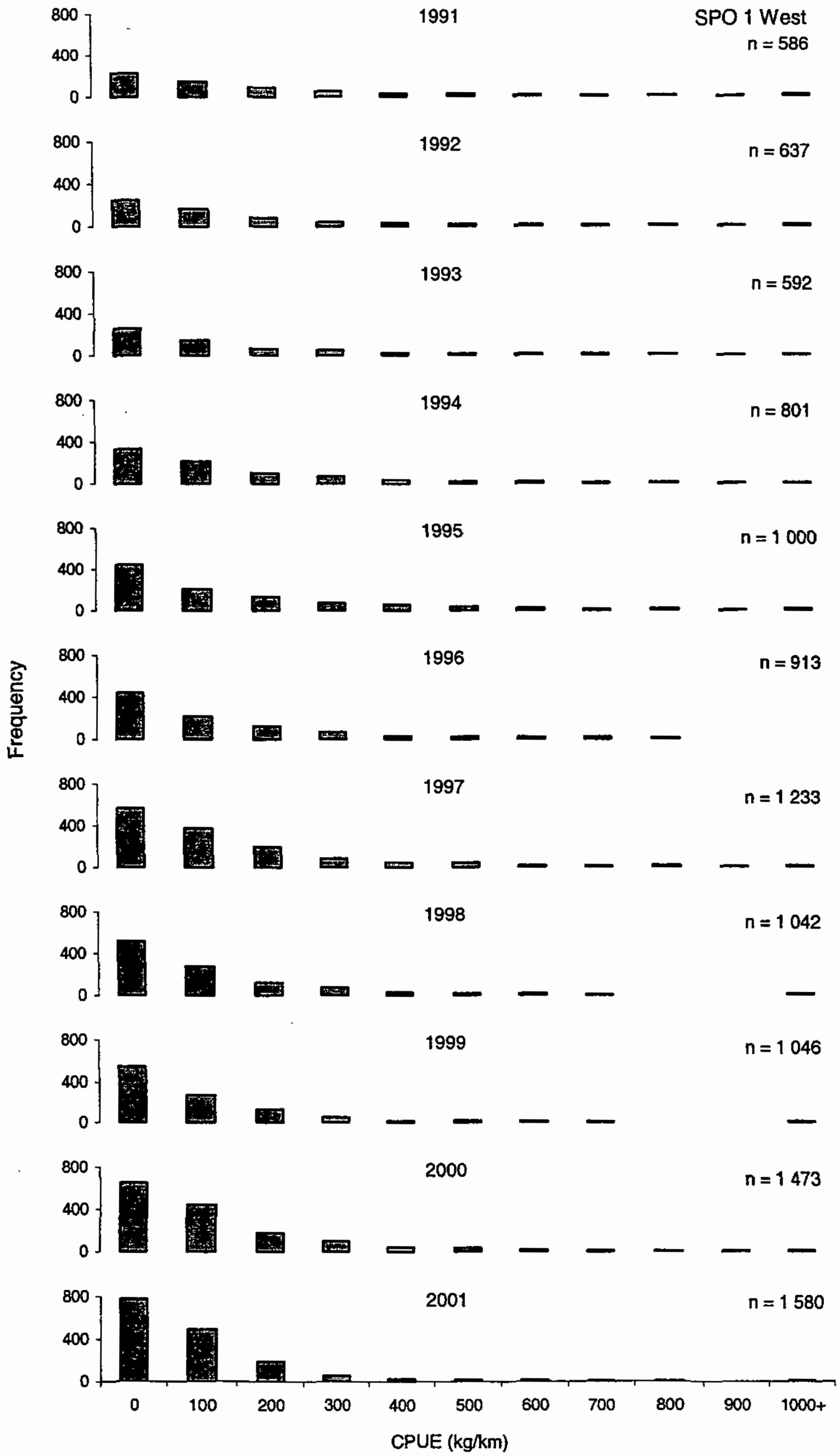


Figure 22: Frequency distribution of CPUE (kg/km) values for SPO 1 West, by fishing year.

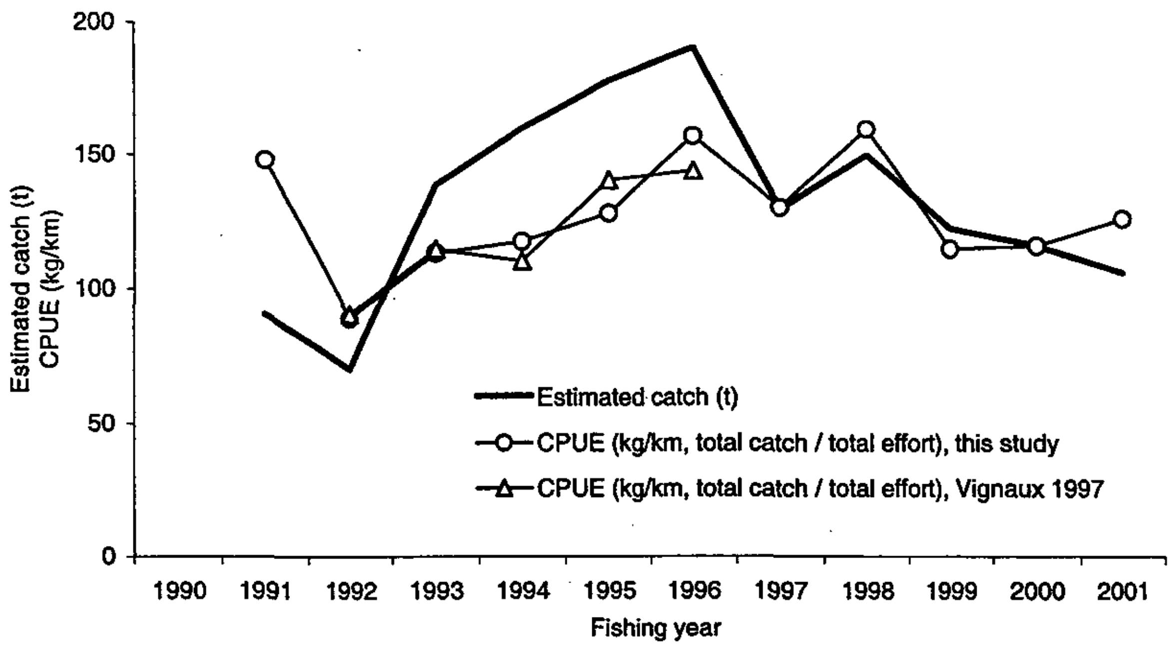


Figure 23: Comparison of CPUE indices for SPO 8 obtained in this study with those of Vignaux (1997), and their relationship to the trend in estimated catch.

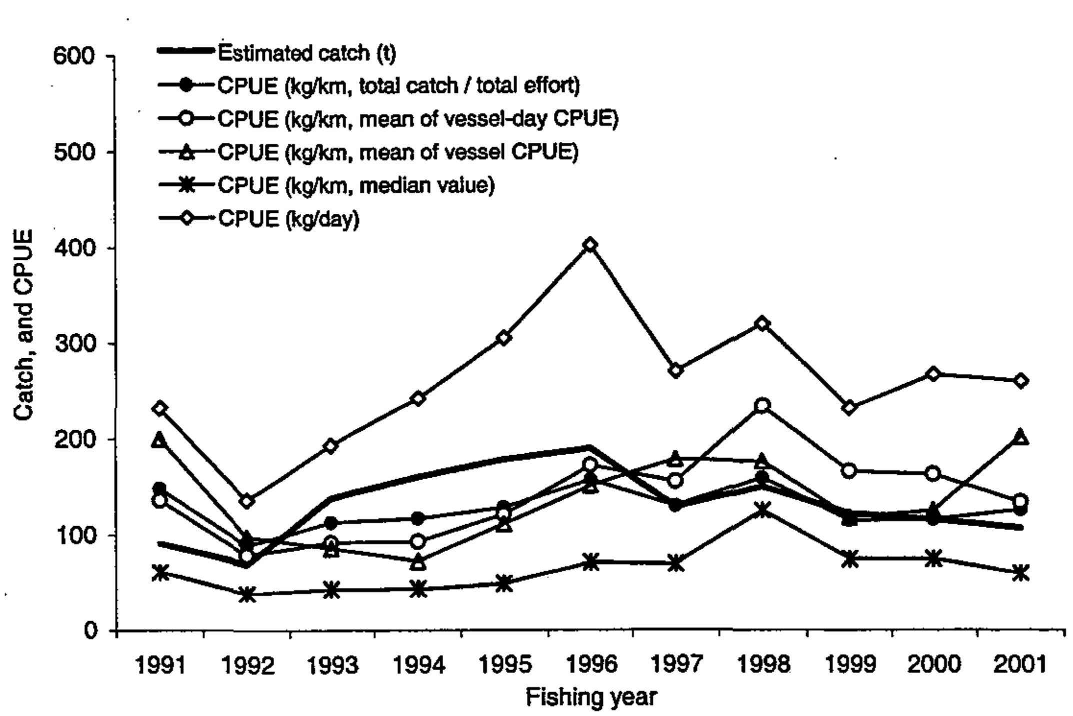


Figure 24: Comparison of several CPUE indices for SPO 8. Total catch/total effort is the sum of all estimated catches divided by the sum of all daily net lengths. Mean of vessel-day is the mean of all daily CPUE values. Mean of vessel CPUE is the mean of the annual CPUE values of all vessels. Median value is the central daily CPUE value of each year's ranked dataset.

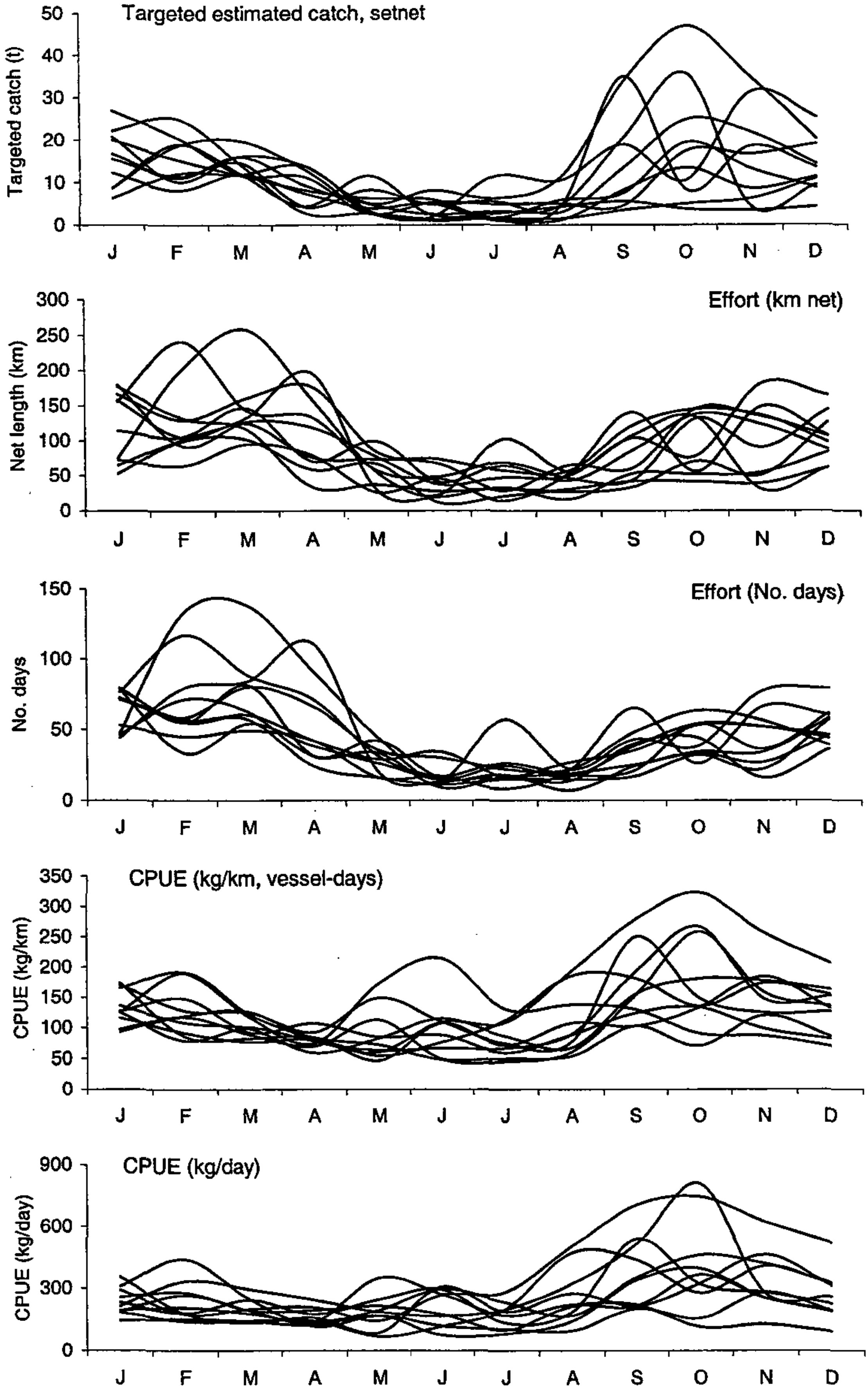


Figure 25: Seasonality of targeted setnet rig catches in SPO 8. Monthly values (smoothed) for calendar years 1991 to 2000.

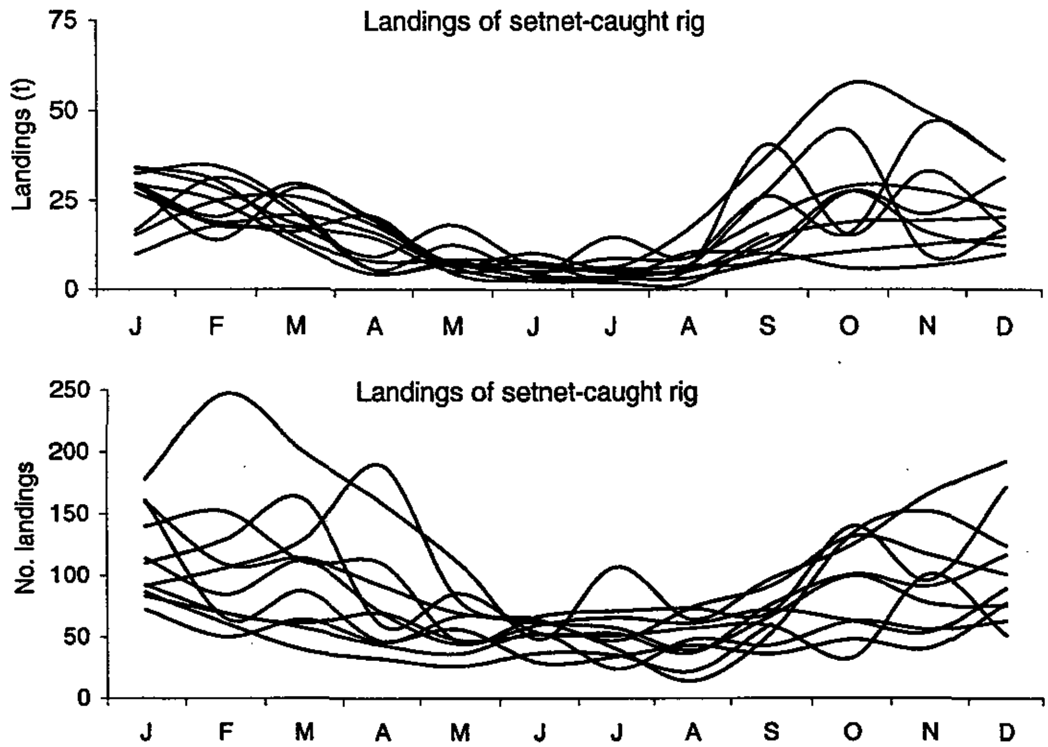


Figure 26: Seasonality of setnet-caught rig landings in SPO 8. Landings recorded as tonnes (upper) and by number (lower). Monthly values (smoothed) for calendar years 1991 to 2000.

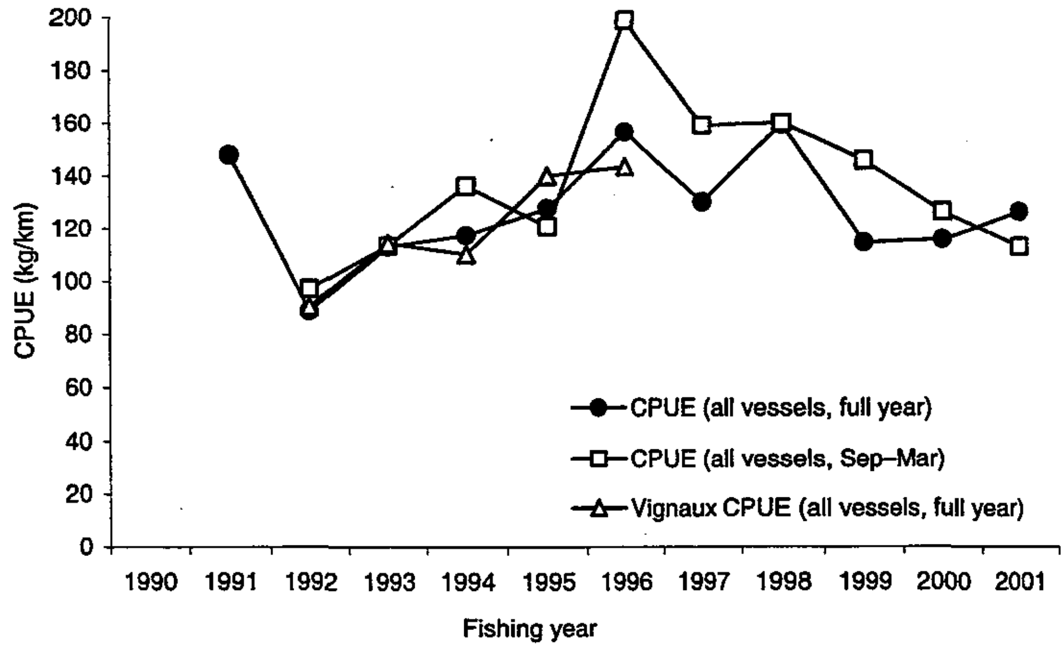


Figure 27: Comparison of annual and main season CPUE indices. Annual indices are for the October to September fishing year. Main season is September to March, September values being added to the following fishing year; thus a value is not available for 1991. Also shown are the annual indices from Vignaux (1997).

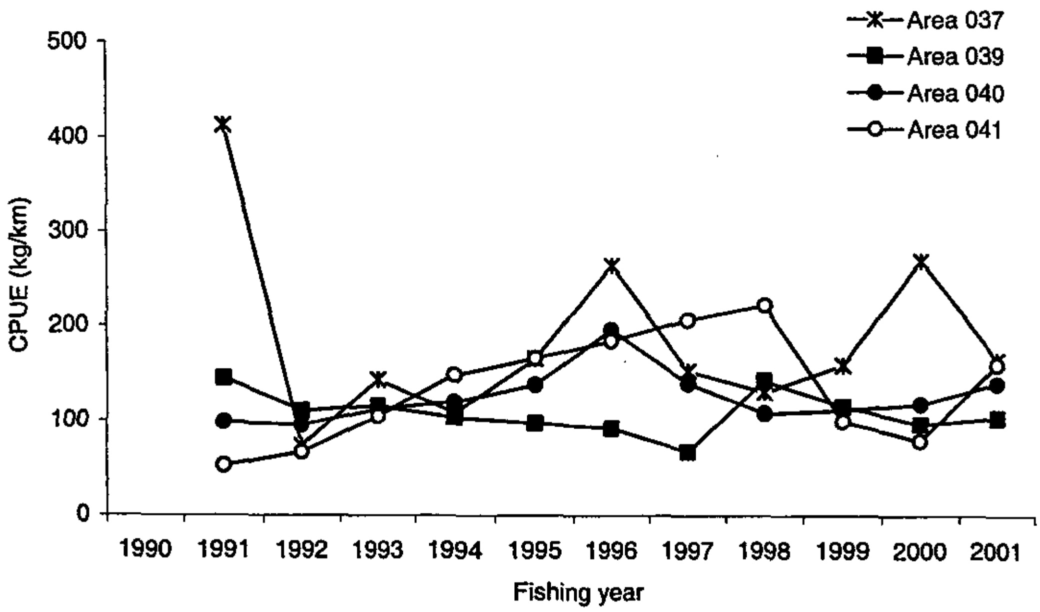


Figure 28: CPUE indices (total catch/total effort, kg/km) for targeted rig setnet catches in SPO 8, defined by statistical area.

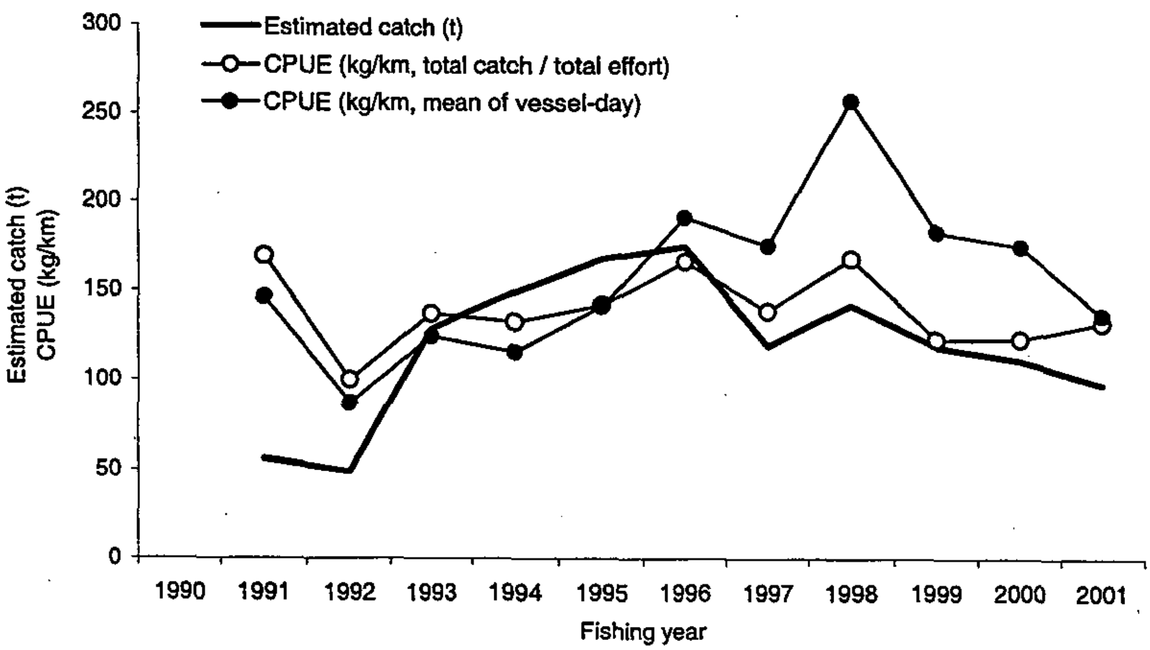


Figure 29: Catch and CPUE indices of setnet vessels which targeted rig in SPO 8, and caught at least 5 t in any one year.

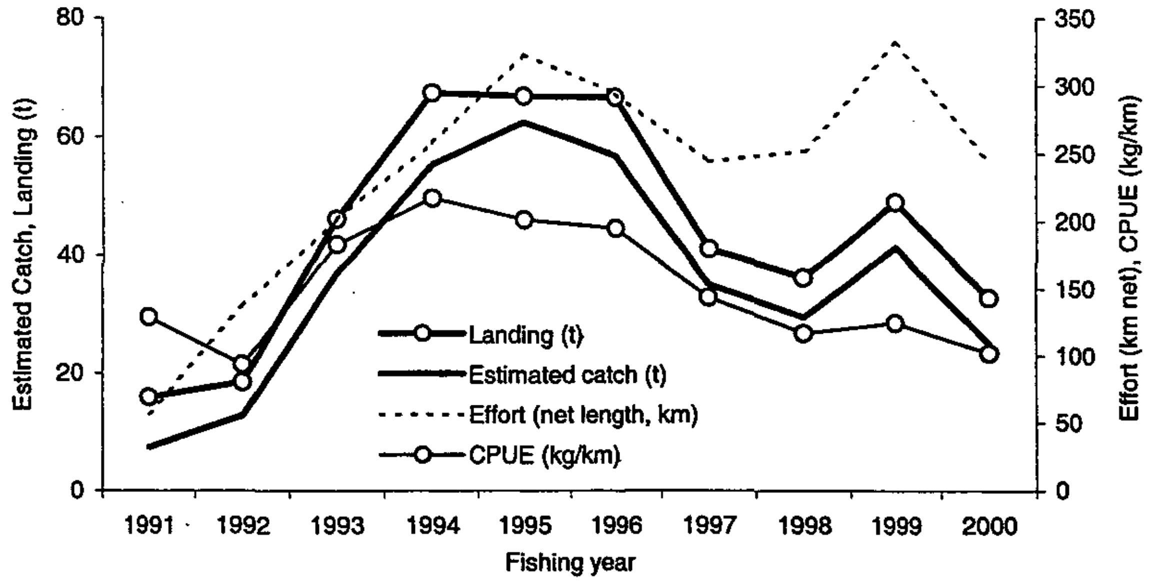


Figure 30: Estimated catch, landing, effort (net length, and days), and CPUE of a vessel which fished in SPO 8 through the 1990s.

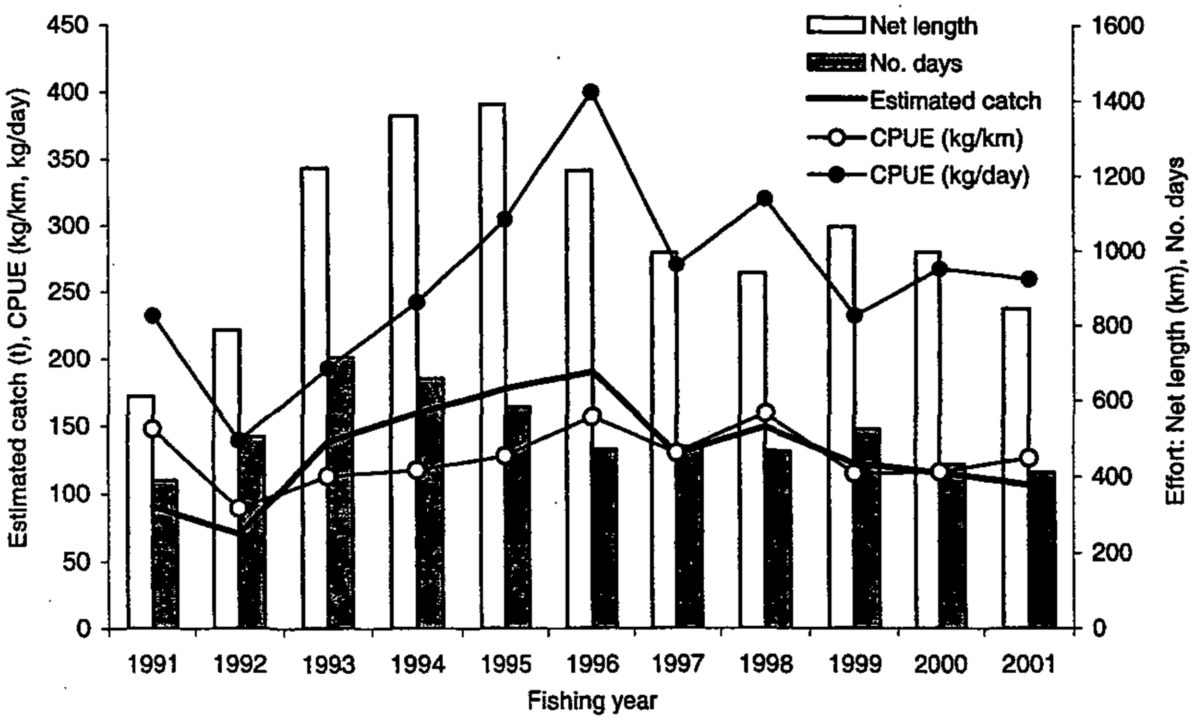


Figure 31: Relationship between catch, effort, and CPUE (total catch / total effort) in SPO 8.

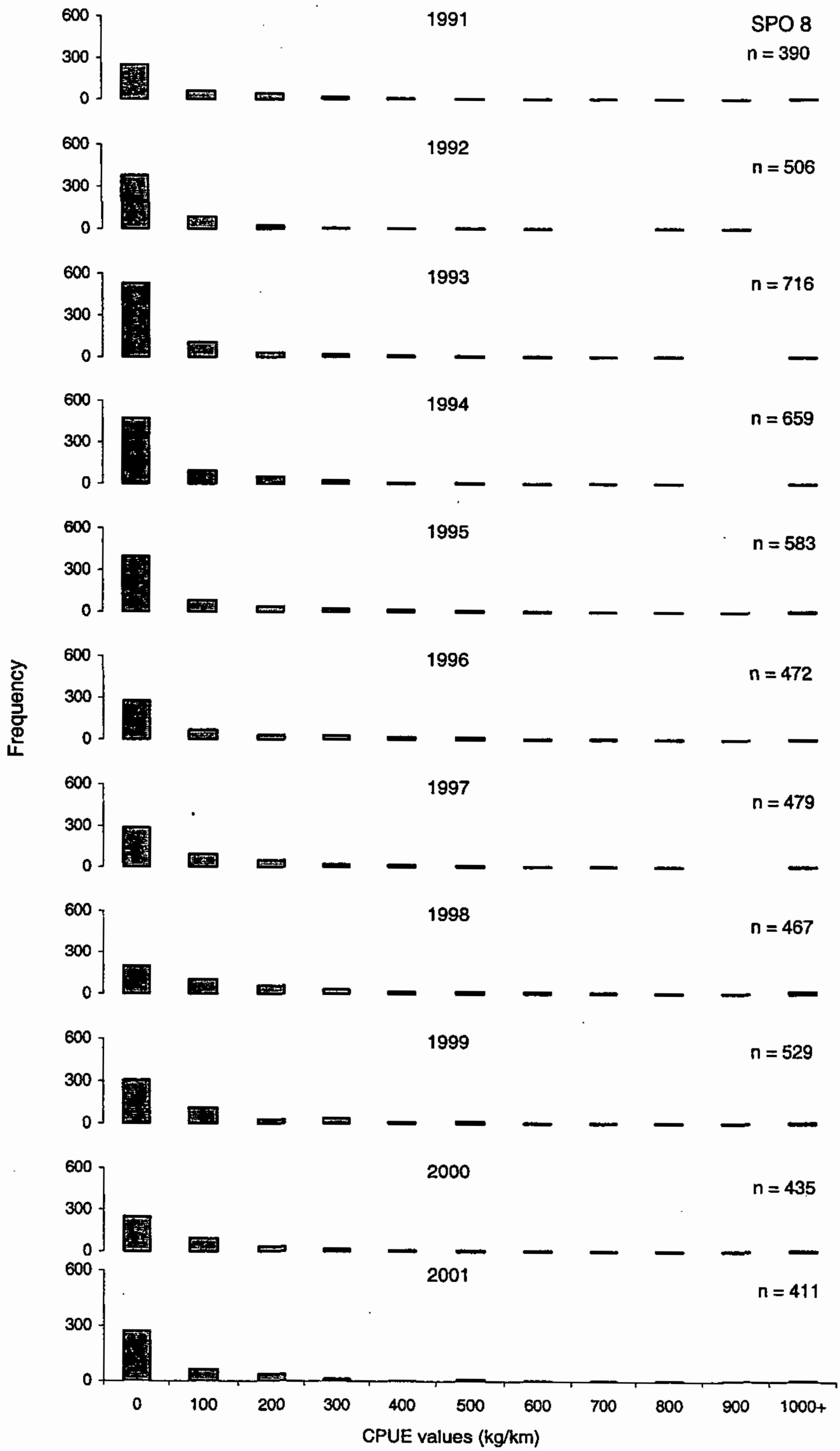


Figure 32: Frequency distribution of CPUE (kg/km) values for SPO 8, by fishing year.