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Commercial Catch Rate Data as an Index of Cod Abundance in NAFO Divisions. 2J3KL

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Introduction

Under certain assumptions commercial catch rate may provide an annual index of stock size. Methods for deriving an index vary. The most direct index is the ratio of total catch for the year to total effort for the year. This approach is most appropriate when there are no significant vessel, gear, area or season effects. When these effects exist, annual indices could be derived for homogenous categories, for example large stern trawlers in area A in spring. Gavaris (1980a) refined the approaches of Gulland (1956) and Robson (1966) to obtain a "standardized" annual index in which the different effects are removed using a multiplicative model. This approach is applied to individual ratios of catch and effort for sets, trips or some other definable unit of effort , e.g. $C_{i,j,k,l}/E_{i,j,k,l}$ where i = vessel type, j = gear type, k = area and il= season. Large (1992) considers the situation where interactions exist between the effects. Richards and Schnute (1992) develop a bivariate model in which E_i and C_i are recognized as correlated random variables and the index is determined from the central tendency of the bivariate distribution.

In this paper we review past used of catch rate indices in the assessment of 2J3KL cod. We then describe the contents of the historic DFO catch and effort database and develop catch rate indices for traps and gillnets from the available historic data. Lastly we consider the utility of inshore fixed gear and offshore mobile gear catch rates in 2J3KL cod stock assessments.

Past analyses of catch rates

Offshore mobile gear catch rate data from logbooks

The use of catch rate data in past assessments (Table 1) is taken from the narrative of cod assessments from extension of jurisdiction to moratorium by Bishop and Shelton (in prep.) and from the annual stock assessment research documents. Offshore mobile gear fishing effort was used to calibrate SPAs for 2J3KL cod in 1978 and 1979. For example, in the 1978 assessment of 2J3KL cod, effort from the USSR and Spanish commercial fisheries for the period 1963 to 1973 was used. This index was not standardized in any way and was not age disaggregated. From 1980 to 1985 a standardized CPUE index (Gavaris 1980a) was derived from offshore vessels using mobile gear (Gavaris 1980b) and used to calibrate the SPA. 4+ biomass was used in the calibration in assessments in 1980 and 1981, whereafter exploitable biomass obtained by accounting for partial recruitment was used. Partial recruitment was calculated by dividing the fishing mortality at age by total fishing mortality for ages 8-11.

In the 1982 NAFO assessment problems were experienced in using the extended catch rate series and in the September assessment it was decided to treat the data for the period 1962 to 1979 separately from the data for 1979 to 1982 and then to combine the two series by scaling by the 1979 value. This practice continued until the 1985 assessment. Thereafter both the 1978 and 1979 data were used to scale the two time series. In the 1982 assessment calibrations were attempted with both the catch rate against exploitable biomass and the RV index for 2J against the

4+ biomass. In 1983 only the catch rate calibration was used whereas in 1984 both the catch rate and RV calibrations were used. Concern was expressed in the 1985 assessment regarding using a catch rate series which spanned the period before and after extension of jurisdiction. Consequently only data for the period 1977 to 1984 was used in the calibration of the SPA. In the 1984 assessment a weighting factor was introduced into the multiplicative model analysis based on the observation that data with greater catch or effort were less variable. The weighting factor was ln(catch) x effort.

In 1986 both the RV index and the age-aggregated standardized catch rates for the post-extension of jurisdiction period were used to calibrate separate SPAs. They gave similar estimates of fully recruited terminal fishing mortality values. In November 1986 CAFSAC reviewed the results of the NAFO June 1986 assessment. One of the working papers tabled at this review (Winters 1986, cited in Hutchings and Myers 1994) was very critical of the use of commercial catch rates to calibrate the SPA in the assessments. The working paper by Winters suggested that biases were introduced into the catch rate index by violations in the assumptions of the multiplicative model. The working paper concluded that the stock had been consistently over-estimated as far back as the late 1970s and that the recent failures in the inshore fishery could be explained by accrued over-fishing as a result of persistently inappropriate advice on TAC levels.

The violation in the multiplicative model that Winters refers to is an alleged division-year interaction effect that was not accounted for. He claimed that the problem was further compounded by the weighting factor introduced in the analysis in 1984. He suggested that research vessel estimates of divisional biomasss be used as weighting factors. When he did this he found that the catch rate series was significantly different in that the index showed a decline for the period 1983-85 rather than an increase. Three observations should be made regarding the Winters working paper. Firstly, his revised index suggests that the stock was declining from 1983 to 1985 whereas current converged estimates for this period suggests the 3+ population grew by 1.6x from a low in 1980 to a peak in 1985 (Murphy et al. 1997). Secondly, the "recent failures" of the inshore fishery alluded to by Winters (1986) were a consequence of the weak 1976 and 1977 year classes and the inshore fishery increased quite dramatically after 1985 as the moderately strong 1978 and 1979 year classes and the very strong 1980-82 year classes entered the fishery. Thirdly, it makes little sense to take two independent indices of stock size (commercial catch rate index and research vessel trawl survey index) and destroy the independece by weighting the calculation of the one index by values for the other index, and then use both indices to calibrate the SPA.

In the 1987 assessment (Baird and Bishop 1987), weighting by ln(catch) x effort was used. In addition, indices were calculated separately for each division and then combined by weighting by average survey biomass in each division. This is a modification of the method suggested by Winters (1986). The two indices were in close agreement and did not reflect the decline found by Winters (1986) using annual divisional biomass. The ln(catch) x effort weighting continued to be used up to and including the 1992 assessment. The 1987 SPA was calibrated with the standardized catch rate calculated in the usual manner for the period 1978 to 1986, and a second SPA was calibrated with the RV index. The average of the terminal F values from the SPAs calibrated with catch rates and RV was considered most appropriate.

In the 1988 assessment the ADAPT framework (Gavaris 1988) was applied for the first time and standardized catch rates (1977-87) and the RV estimates were used simultaneously to calibrate an SPA. Because catch rates were not disaggregated by age, the RV index had considerably more weight (7x) in the calibration. The results of this SPA were not published in a research document. Two assessments were carried out in 1989 - one in January and one in May. In the January assessment the age aggregated catch rates were used in separate SPAs and the resulting terminal F values averaged. The May assessment used the same calibration results as the January assessment. In 1990, for the first time, age disaggregated catch rates for ages 5-8 (about 80% of the catch) for the period 1983-89 were used to calibrate the SPA together with the RV index in the same formulation. Age disaggregated catch rates were obtained by deriving the standardized effort from the standardized catch rates and dividing this into the offshore catch numbers at age. In 1991 age disaggregated catch rate data for ages 5-12 for the period 1983 to 1990 were used together with the RV index. The stock was assessed 3 times in 1992, January and May at CAFSAC and June at NAFO. The 1990 formulation of the ADAPT was used in the January assessment. In May and June the final version of the SPA accepted at the assessment used only the RV data for calibration. The moratorium has precluded further use of the offshore catch rate index in analytical assessments.

Criticisms

The use of the offshore mobile gear catch rate index in 2J3KL cod stock assessments has been severely criticised (Hilborn and Walters 1992, Hutchings and Myers 1994 and Walters and Maguire 1996). Hutchings and Myers (1994) suggest that reliance on commercial catch rate data as an index of stock size was one of the two prime factors contributing to the overexploitation of the stock from 1977 to 1991. Even those responsible for the assessments over much of the period after extension of jurisdiction are somewhat critical of the way in which they used the catch rate as an index (Baird et al. 1991a). It is worth looking at the suggested shortcomings in some detail to see to what extent these criticisms are justified and to determine the appropriate used of catch rate indices in future assessments.

Baird et al. (1991a) suggested that inappropriate weight was given to the commercial catch rate index in assessments in the calibration of SPAs in the mid-1980s. They felt that the increase in catch rates from 1978 to 1985 was partly due to changes in fleet efficiency during the early years of the catch-rate time series and that the exclusion of the 1978-82 data from the 1990 assessment onwards was justified. The age aggregated catch rate for the period 1978 to 1990 is given in the 1991 assessment (Baird et al. 1991b). There seems to be reasonable correspondence overall between the index up to 1987 and recent estimates of population biomass from an SPA calibrated with RV data only, as shown in Fig. 1. It is the 1988 to 1990 indices, showing an increasing trend at a time when the stock was declining which are of most concern. In a plot of the age aggregated index from the 1991 assessment against the estimated 4+ biomass (Fig. 2) it can be seen that from 1978 to 1984 the relationship is nearly linear, and therefore does not support the Baird et al. (1991a) observation. After 1984 catch rate does increase quite dramatically with almost no change in the 4+ biomass, however the 1987 point is closer to the line. The non-stationarity displayed after 1987 is a marked departure above the line. In the calibration of the SPA, 4+ biomass was only used up to 1982, after which exploitable biomass was used (Table 1). Exploitable biomass was calculated from partial recruitments obtained using the fishing mortalities from the current SPA. Following the standard practice for the time (e.g. Baird and Bishop 1986) age 8-11 was considered to be fully recruited to calculate exploitable biomass from the current estimates of population size. Using exploitable biomass in place of 4+ biomass (Fig. 2) does not substantially change the patterns observed in the 4+ biomass plot. The 1984-86 non stationarity is somewhat more serious in that catch rate increased over this period with declining exploitable biomass. Overall, the catch rate index would have provided a reasonable index up to 1984 but with the addition of the 1985 and 1986 data would have begun to overestimate stock size. This would have ameliorated somewhat with the addition of the 1987 data point. However after 1988 the serious non stationarity would have rendered the index much less useful.

Hilborn and Walters (1992) suggested that cod biologists have been misled by growing commercial CPUE due to increased search and harvesting efficiency, rather than by increased stock abundance. They refer to a plot of the age aggregated standardized catch rate index for the period 1962 to 1988 taken from Baird and Bishop (1989). Hutchings and Myers (1994) refer to a similar plot from Bishop and Gavaris (1982) for the period 1962 to 1981. Hutchings and Myers (1994) suggested that a power function between the standardized catch rate index and the exploitable biomass provided a significantly better fit to the data than the linear, zero intercept model usually used in the calibration. Neither models appear to explain the data very well (Fig. 3) - both pass between the data for the pre and post extension of jurisdiction periods. As noted above, the 1980 assessment used catch rate data for 1962 to 1977 and the 1981 assessment used catch rate data for the period 1962 to 1978 so that departures from linearity were not a major problem in these two assessments. In fact, the equivalent figure for a longer time period (1962 to 1988) in Baird and Bishop (1989) shows that the 1977-1979 index values were below the 1974 to 1976 values at equivalent levels of exploitable biomass (Fig. 4).

The decision made in the September 1982 assessment to treat the data for the period 1962 to 1979 separately from the data for 1979 to 1982 was, in hindsight, quite appropriate. Fig. 4 clearly shows that the relationships between the standardized catch rate index and the exploitable biomass was different before and after extension of jurisdiction, with the latter relationship having a relatively steeper slope. This is not a problem of increasing catchability with decreasing stock size and/or learning and gear improvements over time as suggested by Hilborn and Walters (1992), Hutchings and Myers (1994) and Walters and Maguire (1996). Rather, it reflects the change from one fishing fleet to another after extension of jurisdiction. Changes in catchability within a fishing fleet with time and/or stock size are of secondary and relatively minor importance. The combining of the two series by scaling by the 1979 value in each series, or later by the 1978 and 1979 values, was not, in hindsight, a good idea. This was realized in the 1985 assessment and from then on only the post extension of jurisdiction catch rate series was used in the SPA calibration. Therefore, it is only the 1982-84 assessments that were subject to the non-stationarity in the catch rate timeseries caused by the change in the composition of the fishing fleet after extension of jurisdiction.

Hutchings and Myers (1994) examined unstandardized catch rates from Canadian trawlers with GRT between 500 and 1000 tons plotted against 3+ biomass from SPA for the period 1984 to 1991 (Fig. 5). Again a power function is considered by Hutchings and Myers (1994) to provide a better fit to the data, particularly in that it provides smaller residuals from the 1990 and 1991 data points which are above the linear fit in their figure. This analysis does not in any way reflect what was done in the assessments at this time, or of the behaviour of the index. For example, the 1991 assessment (Baird et al. 1991) provides a thorough description of how the calibration of the SPA was carried out. This description is applicable, in general terms, to the 1990 to 1992 assessments as well. The standardized commercial catch rate index for 1978 to 1990 was obtained from a multiplicative model which accounted for country/gear, season and division effects. A catch rate at age index was derived from these data and the index for ages 5 to 12 for the period 1983 to 1990 were used, together with the RV index, in the calibration. The objective function included the minimization of the sum of the squared difference of the logarithm of the observed catch rate and the logarithm of the SPA predicted catch rate. This differs from the Hutchings and Myers (1994) analysis in 3 important ways. Hutchings and Myers used: (i) the unstandardized catch rates instead of standardized catch rate; (ii) the age aggregated index instead of the age disaggregated index, and they plotted this agains exploitable biomass rather than numbers at age; (iii) a fit in which the sums of squares was minimized rather than the objective function used in the caibration. Thus their view, that a power model fitted the data better than a linear model, is of no relevance whatsoever to the evaluation of past DFO assessments of this stock.

A more appropriate evaluation of whether the assessment was led astray by assuming a linear relationship, when actually a power relationship pertained, can be carried out by fitting both the linear and power models to the age disaggregated standardized index from Baird et al. (1991) and recent SPA estimates of numbers at age from a calibration using only the RV index and by minimizing the sums of squares of the difference of the logarithm of the observed and logarithm of the expected catch rates. The results of this analysis are shown in Fig. 6. Only the data for ages 5 and 6 show any difference at all with respect to the power and linear model fits and these differences are relatively minor. Overall, the linear relationship through the origin explains the data up to about 1988. The 1989 and 1990 data points tend to be above the line, as noted previously, indicating a recent non-stationarity in the catchability relationship, but not suggestive in any way of a power function.

In pursuing their argument that "Increased search and harvesting efficiency of Canadian trawlers contributed to the serious overestimates of northern cod abundance in the 1980s.", Hutchings and Myers (1994) observe that "abundance estimates based upon the commercial data indicated that the stock had increased threefold from 1978 to 1988, whereas those based upon the research surveys suggested that the stock had changed little in size". Comparison of the RV and catch rate indices for ages 6 to 8 from the 1991 assessment does show that the catch rate increased more than the RV index (excluding the 1986 anomalous RV data point) (Fig. 7). This is also reflected by the fact that the mean calibration parameter ("catchability") for ages 6 to 8 for the catch rate in the SPA is 2.2 times greater than the equivalent mean for the RV index (Table 49 in Baird et al. 1991). The difference in slope is, in itself, of no consequence - it merely indicates that one index changes relatively more with abundance than the other index. Current estimates of the converged population from SPA (Murphy et al. 1997) shows that the stock aged 3+ did increase quite substantially from extension of jurisdiction to 1985.

Hutchings and Myers (1994) state that "From 1978 to 1986, the abundance of northern cod was usually approximated by the midpoint of the VPA estimates derived from both commercial CPUE data and data from research vessel surveys". In actual fact, the average of the terminal fishing mortalities estimated from separate SPA calibrations with catch rates and RV values were only used in 1984, 1986 (most likely value from a range from various calibrations), 1987 and 1989.

SPA estimates of 4+ numbers at age from assessments carried out from 1982 to 1992, together with current estimates, are plotted in Fig. 8. The mid 1980s was a period of rapidly changing perception regarding population size. By far the major factor in this was the anomalous 1986 RV estimate which led to the inflated population estimate in the 1987 assessment. It should be noted that while the RV index indicated a sudden increase from 1985 to 1986, the catch rate index indicated little change. The current estimates of population size for this period also suggest little change from 1985 to 1986. Population size was revised down in both the September 1988 assessment and again in the January 1989 assessment with the availability of an additional year's data. In contrast to the 1988/89 revision of stock size, the dramatic 1983-1985 revision of 4+ population size can be attributed to the way in which the catch rate index was used in the assessments. The 1984 downward revision can be partly attributed to averaging the terminal fishing mortalities from SPAs calibrated separately with catch rate and RV indices rather compared with a calibration using only catch rates in the previous year. The big change in estimated 4+ population size from the 1984 to 1985 assessments is a consequence of higher terminal Fs resulting from calibration with only the more recent catch rate data (1977-1994).

The changes in estimated population sizes from the 1991 assessment to the 1992 assessment and from the 1992 assessment to the current perception regarding stock size can largely be attributed to the initially strong 1986 and particularly the 1987 year classes in the RV index which disappeared at ages 5 and 6 over the period 1991 to 1993. In subsequent SPAs the RV and catch rate at age for the younger ages of the 1986 and 1987 year classes are treated as large positive residuals and the estimated population size is much lower than in the 1991 and 1992 assessments. The high trawler catch rates that were maintained on spatially restricted but dense aggregations on the fishing grounds between 1989 and 1992 also contributed to the overestimation of stock size up until 1990, but then the index dropped quit steeply.

In the 1992 assessment, catch rate data for the period 1978 to 1982 were excluded from the calibration of the SPA because it was thought that "learning" occurred by the Canadian fleet over this period and because of the introduction of enterprise allocations and dockside grading during the early 1980s (Baird et al. 1992). The resulting index was much flatter over the period 1983 to 1990 and the extra year of data indicated a substantial decline in 1991. In hindsight , there does not appear to be a strong argument for leaving out the 1978-82 data.

Hutchings and Myers (1994) conclude from their review that the overestimation of stock size, caused in their opinion, by reliance of commercial data whose catch rates indicated that the stock was increasing in size, was probably a reflection of management's prediction of rapid growth of the stock in the late 1970s. This is a thinly veiled accusation that DFO assessment scientists compromised their integrity in the interpretation of the available data to fit government policy and political will. Our review of the analyses does not support their accusation. Unfortunately Walters and Maguire (1996) repeat many of the contentions of Hutchings and Myers (1994) regarding the use the commercial catch rate data in the assessment of 2J3KL cod without any critical review or new and objective analyses of their own. Their criticism is based almost entirely on the purported discovery by Hutchings and Myers (1994) that the calibration assumption of proportionality was wrong and that CPUE varied as the 0.4 to 0.5 power of stock size. We contend that there is no evidence of a significant power relationship in the CPUE index used in past assessments to calibrate 2J3KL cod SPAs and that the misleading perception of Hutchings and Myers (1994) is a consequence of superficial analysis of the available information. There is, however, evidence of non-stationarity in the relationship, particularly in the most recent years before the moratorium, compatible with either increased fishing power or the fact that cod became increasing concentrated in a restricted area in the offshore where commercial trawlers were able to maintain fairly substantial catches.

Commercial catches as an indicator

The inshore fixed gear catches have always been accounted for as accurately as possible in the SPA, but have not been used as a calibration index. Nevertheless, fixed gear catches are what fisherman respond to and have often been given considerable weight in forming public and political perceptions regarding stock status. For example, the Task Group on Newfoundland Inshore Fisheries (TGNIF) chaired by D.L. Alverson was formed in 1987 "in order to provide and independent analysis of the factors which have influenced the recent (1982-1987) declines in the catches of certain inshore fisheries." (TGNIF, 1997). Winters (1986) also suggested that "recent failures" in the inshore fishery were a result of overfishing brought about through inappropriate use of catch rate data in the assessments. It is therefore not uncommon to hear that "fisherman were saying that the stock was declining in the early 1980s and, as it turns out, they were quite correct". This is quite misleading. The inshore fishery has, to a large part, responded, with a lag related to the selectivity of the different gear, to the strong and weak year classes that have passed through the population. The top panel in Fig. 9 includes various "looks" at year class strength from the survey data, all appropriately lagged to line up with the year in which the year class arose, and standardized by dividing by the mean: ADAPT estimates of numbers at age 3, multiplicative model estimates of relative year class strength from models fitted to age 1-13, 1-3, 1-5, 3-13, 3-5 and mean numbers per tow in the survey at age 2, 3, 4, 5, and 6. When averaged out it is apparent that there have been three strong pulses of recruitment over the twenty year period 1970-90: 1973-74, 1980-83 and 1986-87. The last pulse is still somewhat controversial because it was visible in the younger ages but not in the older ages (see top panel). These pulses were separated by very poor year classes in 1976-77 and 1983-85.

The annual catches by gear type in the inshore fishery (Fig. 10) suggest these pulses and troughs had a big impact on the catches in many cases. The gillnet catch in 2J has a peak starting in 1979 as a consequence of the 1973-74 pulse in year class strength, a trough in 1983-85 as a consequence of the weak 1976-77 year classes, a further peak in 1986-90 as a consequence of the 1980-83 pulse in year class strength, followed by a rapid decline as a consequence of the poor year classes in 1983-85. Similar peaks and troughs are reflected in the gillnet catches in 3K and very clearly in the trap and gillnet catches in 3L. Reasons for the north to south offset in the peaks and troughs require further investigation. What is obvious from these data, however, is that the declines in the catches from 1982-87 which resulted in the Alverson committee was a consequence of the poor year classes centred around 1976-77 and that the gillnet fishery in 2J and the gillnet and trap fishery in 3L increased rapidly from the mid-1980s with the entry of the strong 1980-83 year classes into the fishery. The response for traps and gillnets in 3K was more variable and trap catches in 2J were increasing throughout this time.

Observer index

In the 1990 assessment Baird et al. (1990) analysed a data comprising 29,864 fishing sets for the period 1980-89 recorded by observers on Canadian trawlers. About 71% of the data were for the period 1987-89. Catch and effort data were summed to give one value for each available year-division-country/gear/tonnage class-month cell. Only data for stern trawlers in the tonnage class 4-6 were used (included most of the data). A mulipicative model was used to standardize the data. Results from this subset of the trawler catch and effort data were very similar to that obtained from logbook data.

Trap catch index

In the 1992 assessment, Baird et al. (1992a) examined the catch at age in cod traps as potential abundance index. This was prompted by the analysis of Rose (1992) which suggested that the exploitation rate in the inshore fishery may not increase linearly with increasing effort because good fishing locations are limited in number, well known, and used seasonally on a regular basis, while new fishing locations maybe less effective. Therefore effective fishing effort may have remained relatively constant, and catches may reflect stock abundance alone and not changes in effective effort. Several inconsistencies were noted in the index derived in the 1992 assessment and these analyses were not pursued further.

Catch per purchase slips

In the 1986 assessment, Baird and Bishop (1986) attempted to use purchase slip data as a proxy for catch and effort data for the inshore. Before moratorium, purchase slips were completed at fish plants and returned to DFO Statistics Branch for processing. Vessels for which catch is only recorded by purchase slips comprise mostly vessels less than 35' - the bulk of the inshore fishing effort. Larger vessels are required to complete logbooks. A major problem with purchase slips is the lack of any effort data. At some point an effort field was added to the purchase slip, but data were seldom entered in the field, and if entered, were not punched into the database by Statistics Branch. Catch per purchase slip was therefore analysed in place of catch per unit effort, under the assumption that effort remained fairly constant for the catch recorded on a purchase slip for a particular gear type. The purchase slip was assumed to approximate one day of effort. In the 1986 assessment data were only available for 1984 and 1985. In the 1987 assessment (Baird and Bishop 1987) data for trap, gillnet, linetrawl and handline were analysed for the period 1981 to 1986 by division and separately for vessels less than 35' and between 35' and 64' in length. In general no trends in catch per purchase slip were observed for the large vessels, whereas for the smaller vessels the catch in Div. 3L declined as effort declined, while the catch in 2J and 3K declined as effort remained stable. It was noted that the procedure for purchase slips changed in 1986 such that landings could be distributed among several purchase slips. In the 1988 assessment catch per purchase slip for the period 1981-87 for 2J, 3K and 3L were analysed using a multiplicative model (Baird and Bishop 1988). Gear type, vessel size and division effects were modelled. Results suggested that catch per purchase slip was highest in 1982, but declined thereafter. When considered by division, the indices suggested a declining trend in 2J since 1983, a declining trend in 3K since 1982 and relative stability in 3L since 1982. Purchase slips were not used in subsequent assessments, presumably because of the increased problem of splitting of catches across several purchase slips and other concerns regarding the reliability of the data.

Analysis of trap and gillnet catch rates

Hutchings and Myers (1994) examined trap and gillnet data summarized on a trip by trip basis for the period 1985-91 for selected areas. Based on their analyses, they claimed that catch rates in the 3K and 3L trap fisheries decreased from 1986 to 1991 with the decline clearly evident by 1989. They note that a tripling of trap catches in 3L between 1987 and 1990 was associated with a 70% reduction in catch rate. They suggest that significant reductions in gillnet catch rate were evident in Trinity Bay by 1988, Bonavista and Conception bays by 1989 and between St. Mary's Bay and Southern Shore by 1990. They also note that stable or declining gillnet catches were associated with declines in catch rate of 80%, 60% and 76% in Bonavista Bay ((1986-89), Conception Bay (1987-89) and Trinity Bay (1985-89) respectively and that catches from St Mary's Bay and along the Southern Shore declined by 21% whereas catch rate declined 30%. Hutchings and Myers (1994) suggest that increasing inshore catches combined with declining catch rates were indicative of dramatic increases in effort in the mid to late 1980s. They also suggest that the ability of fishers to catch fish increased dramatically with time, particularly during the 1980s, as a consequence of the introduction of echo sounders, increased use of Japanese traps, advanced navigation aids, etc.

We examined the fixed gear catch rate analyses by Hutchings and Myers (1994) in some detail and discovered a number of problems with their treatment of the data. Firstly, they present analyses for various spatial aggregations (division, unit area, group of unit areas) without an explanation for why these particular aggregations were chosen rather than others. Secondly, they appear unaware that the data they are analysing include a variety of trap and gillnet gear that were purposefully set to catch species other than cod, such as herring, capelin, blackbacked flounder, etc. Thirdly, they appear unaware that their analysis is restricted to vessels greater than 35' only and that these vessels are responsible for a relatively small portion of fixed gear landings of cod (Table 5). Fourthly, they do not apply the same analysis to both trap and gillnet data. For traps they calculate an index by taking the mean of the catch rates for the individual purchase slips. For gilllnets they have summed the catch and effort across purchase slips and then taken the ratio of the total catch and total effort. The index differs, in some cases substantially, depending on which method is used. In theory the different treatments can even give completely different trends in the index. Fifthly, they ignore an implied decimal in the effort field, so that their calculated catch rates are an order of magnitude too low.

Reanalysis of fixed gear catch rate data

We reanlysed the same summarised data set as Hutchings and Myers (1994), but corrected the second, fourth, and fifth problems associated with their analysis. First however, we describe the content of the raw catch and effort data base (STACAC/ZIF) in some detail. Records in this data base may constitute portions of a trip - i.e. individual sets for the larger vessels and more than one purchase slip for a trip for the smaller vessels. In Table 2 we examine the percentage of all data records which contain information in the fields that are of potential use for examining catch and effort data. There are close to 2 million records in the raw database for all NAFO divisions in the Newfoundland Region. Around 80% have CFV numbers associated with them - this constitutes mostly the set by set trawler data and, after the moratorium, the sentinel fishery data. The date landed, unit area caught, gear used and port landed are generally available. The amount caught (live weight equivalence) is generally available but data appear to be poor in 1991. Main species sought, an important field in determining only cod directed fishing, is filled in only between 31% and 74% of the time (excluding post moratorium period) whereas the main species caught field is more reliable. Hours fished is only filled in between 28% and 69% of the time. Date caught has similar percentages. Overall, this analysis of the database suggests that a poor record has been kept of information related to the catches that could be useful in providing an index of cod abundance based on catch rate.

With respect to the subset of the data which includes only those vessels with CFV numbers (vessels larger than 35'), the data are better in some respects (Table 3). However, there are major problems with the main species sought field, the days and hours fished fields, the amount of gear field and the date caught field. With respect to the subset of data for those vessels without CFV numbers (vessels less than 35') there are no data that can be used to derive fishing effort (Table 4). However, information on amount of fish caught and area caught seem to be consistently filled in. The analyses that follow are restricted to only that portion of the data which is from vessels which have CFV numbers (i.e. greater than 35' in length) and include only those records in which cod was the main species caught. The percentage of the reported cod catch by main unit areas of gillnets and traps for which there are effort data (i.e. from vessels greater than 35') is given in Table 5. It is clear that in most cases the percentages are quite low. The problems associated with the quality and representitiveness of these data must be taken into account in drawing any inferences regarding indications of changes in fish abundance.

We applied both methods of calculating catch rate used by Hutchings and Myers (1994) - the average of the ratios (mean index) and the ratio of the sums (sum index). We use the same scale throughout for a gear type so that comparisons can be made under the assumption that catchabilities do not vary substantially from one area to another. We examine the trap and gillnet indices for each division separately and then we examine the index for the 6 unit areas which had the highest mean catch over the period 1985-91 for each gear type.

With respect to trap catch rate by division (Fig. 11) the only indication of a decline at this level of aggregation is in 3L from 1986 to 1990 using the mean index. In contrast the sum index for 3L does not reflect this trend and is rather constant for the 1988 to 1991 period. This differs from the results of Hutchings and Myers (1994) which found that in both 3K and 3L trap catch rates (mean index) decreased from 1986 to 1991 with the decline clearly evident by 1989. With regard to gillnet catch rates calculated using the two methods for each of the three divisions (Fig. 12), the mean index for 3L shows a fairly steady decrease from 1987 to 1991. The decrease is similar for the sum index, but with a high catch rate value in 1989. Note that the 3L data includes offshore catch rates for the Virgin Rocks fishery which reached a peak in 1990 and then collapsed. There are no clear trends for the other divisions from either of the two indices.

On a unit area basis, increasing trap catches between 1987 and 1990 in 3Lb (Trinity Bay), 3Lf (Conception Bay) and 3Lj (Southern Shore) correspond to little or no change in the catch rate (Fig. 13) and therefore imply (if the rate for vessels greater than 35' can be extrapolated) that trap fishing effort was increasing over this period. Effort is calculated for each of the unit areas from the product of the reported catch and the ratio of effort to catch from the catch rate for greater than 35' vessels (Fig. 14). From this calculation there is an indication that effort increased by a factor of about 6 from 1987 to 1990 in Trinity Bay (3Lb) using the mean catch rate or a factor of about 4 using the sum catch rate. Effort also appears to have increased in Conception Bay (3Lf) over the same period, but to a lesser extent. The 1990 and 1991 mean index for Trinity Bay is lower than that for the preceding 3 years (Fig. 13) whereas there is little change in the sum index for the more recent years. Catches and catch rates in 3Ki (Fogo-Twillingate area) and 3Kd (White Bay) showed no clear trend. In 2Jm (Mary's Harbour area) catches increased to 1989 and then decreased while catch rates do not show any strong trend.

With regard to gillnet catch rates (Fig. 15), there was no trend in 2Jm (Mary's Harbour area), 3Kh (Notre Dame Bay, unusually high catch rate in 1989) and in 3Ki (Fogo-Twillingate area). There is a general trend of declining gillnet catch rates in 3La (Bonavista Bay), 3Lb (Trinity Bay) and 3Lq (St. Mary's Bay). The trends do not appear to differ substantially between the mean and the sum methods when applied to gillnets. The declines are in agreement with those found for 3L unit areas by Hutchings and Myers (1994). The changes in effort derived from the catch rates (Fig. 16) Suggest increasing gillnet effort in 2Jm and possibly in 3La (mean catch rates) but nowhere else.

In summary, the analysis of fixed gear catch rates from the mean method for both traps and gillnets indicates a decline in 3L commencing in the mid to late 1980s. The sum method only indicates a decline for gillnets. For traps, this decline was not universal at smaller spatial scales, there being little or no change in Trinity Bay and the Southern Shore, two areas of high trap catches. Thus the conclusion by Hutchings and Myers (1994) that "Catch rates in the 3K and 3L trap fisheries decreased from 1986 to 1991 with the decline clearly evident by 1989" is not upheld in this study - the outcome depends strongly on the area examined and method used for calculating catch rate. Recall that Hutchings and Myers (1994) used the mean method for traps, combining areas within divisions, but examined the gillnet catch rates for separate areas within divisions using the sum method. For gillnets, all three unit areas examined in 3L showed a general decline over the time period examined using either method. Thus this conclusion from Hutchings and Myers (1994) is upheld in the present study.

Analysis of catches

Although catch rate data are only available for vessels greater than 35', monthly catches can be examined for all vessels fishing fixed gear. In Fig. 17 the monthly trap catches are plotted for the period 1975 to 1992 for the same areas examined for trap catch rates. In area 2Jm, catches increased steadily over the time period to a peak in 1990 and then declined. In 3Kd trap catches were quite variable, but no lower in the late 1980s and early 1990s than in the rest of the period. In 3Ki catches were high in 1982-85 period and generally lower thereafter, except for 1988. In 3Lb catches were high in the 1982-84 period and very high in 1990 and 1991. There was some elevation in catches in 1982-85 in 3Lf, but more noticeable is an increasing trend from a low in 1987 to a peak in 1990. In 3Lj catches were low in 1980 and 1981, high from 1982 to 1985, low in 1986 and 1987 and then increasing to a peak in 1990. The elevated catches in the late 1980s - early 1990s coincides with the entry of the strong 1986 and 1987 year classes into the trap fishery.

Gillnet catches for all vessels (Fig. 18) were high in 2Jm in 1980 and 1981, low from 1982 to 1985, then high again from 1986 to 1990 with a peak in 1989. In 3Kh gillnet catches were generally low except for 1983. In 3Ki gillnet catches were generally high, but quite variable. Peak catches were in 1987 and 1988. Gillnet catches were generally lower in the unit areas examined in 3L, but in 3La and 3Lb the fishery appeared to last longer and sometimes had more than one modal month with a year.

For less than 35' vessels, monthly trap and gillnet catches show considerable variability (Fig. 19). In 3L trap catches rose to a peak in 1990 and in 3Lb and 3Lj 1991 catches were also high. In comparison, gillnet catches were generally low in 3L compared to 2J and 3K (Fig. 20). In 3Ki gillnet catches reached a peak in 1988 and then decline steadily. Both trap and gillnet catches peaked in 2Jm in 1988 and were at a quite a low level in 1991.

For vessels greater than 35' monthly trap catches were relatively high in 1990 and 1991 in 3Kd, 3Ki, 3Lb, 3Lf and 3Lj, but low in 2Jm (Fig. 21). Gillnet catches were high in 2Jm in 1989 and remained high in 1990 (Fig. 22). Catches were low throughout the time period in 3Kh, declined from 1987 in 3Ki, wee low, but with prolonged seasons in 3La and 3Lb throughout the period, and low in 3Lq, particularly in the last two years.

Summary and conclusions

Under the appropriate conditions, catch rates can provide an index of stock abundance. The use of the offshore trawl catch rates to tune SPAs from extension of jurisdiction to moratorium has been criticised. From our review, the use of offshore catch rates did not bias the assessments to the extent that has been suggested, except in the early

1980s prior to the use of RV data when both the pre and post extension of jurisdiction data were being used. The first big downward revision occurred in 1984 when two separate calibrations were used for RV and catch rate and the estimated terminal F's averaged. The second and more substantial revision occurred in 1985 when only the 1977 to 1984 catch rate data were used in the calibration. From then on the calibrations resulted in SPAs that reasonably followed what is now thought to have been the trend in population size from the converged SPA, but with the ever-present "retrospective problem". The more recent departure in the estimated population size occurred in the 1991 and 1992 assessments. This mostly reflects the entry of the 1996 and 1997 year classes into the survey and the catches. However these year classes were estimated to be considerably weakened in subsequent assessments. The SPA is unable to reconcile the conflicting information regarding the strength of these year classes, and subsequent SPAs have large positive residuals for the younger ages of these year classes. The offshore catch rate remained high when the stock was declining in the late 1980s and early 1990s and this contributed to some extent to the overestimation of stock size in the assessments just prior to moratorium.

There is considerable non-stationarity in the catch rate versus 4+ population or exploitable population size. The main non stationarity is between the pre and post extension of jurisdiction data. Clearly these data reflect two very different catchability relationships and no single model should be fitted through the data. In hindsight it was a mistake to attempt to join the two series, but quite understandable that it took a couple of years to realize this at the time. The second non-stationarity is the departure above the post-extension relationship from 1989 onwards. Between 1978 and 1988 the data fall reasonable close to a catchability relationship through the origin. Although non-stationarity has been observed in the catch rate - population relationship, there is no evidence of a power relationship in either the age-aggregated or age disaggregated indices.

Interpretation of relative stock size using fixed gear catch rate data is restricted to the greater than 35' fleet for the period 1985 onwards. The strongest signal from these data is that trap catches in 3L increased quite steeply in the late 1980s and early 1990s partly as a consequence of a rapid increase in effort and partly as a consequence of the entry of strong year classes into the fishable population relative to trap selectivities. Gillnet catch rates, on the other hand, declined quite steadily in 3L over the same time period, reflecting the decline in the abunance of older ages in the population. From the analysis of catches for vessels less than 35', it is clear that the cod trap fishery was booming in much of the 2J3KL region right up to just prior to moratorium. In contrast, 1991 was a poor year for the gillnet fishery over the whole region.

Based on this review, there would seem to be good reason to continue to obtain a catch rate index from the offshore mobile gear in any reopened fishery. With regard to the inshore, the fixed gear catch rate data that are available are not adequate to evaluate their suitability as an index of population size. Trap catch rates may be indicative of the abundance of immature cod under some conditions, and gillnet catch rates, at least in unit areas in 3L, appeared to track the decline in the age 3+ stock size after the peak in the mid 1980s. Further work and a review of other studies (including work by C. Jones, Old Dominion University and her co-workers) is required to determine under what conditions the sum index or the mean index is the more robust of the two indices.

The inability to conclude whether or not past fixed gear catch rate data are useful as an index of stock size should not preclude a high priority being given to the capture of accurate catch and effort data on a set by set basis for all gear types and vessel sizes in any reopened cod-directed fishery. These data constitute by far the biggest contribution of information that fishers can make to the stock assessment process. In this regard it should be noted that the reopening of the Subdiv. 3Ps cod fishery in 1997 has coincided with the introduction of a new log book for vessels less than 35'.

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Table 1. Summary of the use of catch and effort data in 2J3KL cod assessments from 1978 to 1992.

Year	Source of catch and effort data	Period	Treatment	Calibration	Determination of final values	Term. F	4+ population ('000)	Reference
1978	USSR, USSR research by division, Spain	1963-76	Annual aggregate effort	Separate regressions of effort against fishing mortality	Average of the F values from regressions	0.400	603,500	Wells, R. ICNAF Res. Doc. 78/VI/66
1979	USSR, USSR research by division, Spain	1953-78	Annual aggreage effort	Used 1978 regressions to predict F based on effort for USSR and Spanish data	Took the lower of the two F values	0.270	994,800	Wells, R. ICNAF Working Paper 79/IV/102
1980	Spain, Portugal, USSR, Canada, Iceland	1962-77	Multiplicative model to remove country-gear, month and division effects to get standardized series; data for 1974-76 excluded	Separate regressions of standardized effort against F and standardized catch rate against 4+ SPA biomass	Vague	0.200	1,206,400	Wells, R. and C.A. Bishop NAFO SCR Doc. 80/VI/101
1981	Can, USSR, Spain, Portugal, GDR, FRG,UK	1972-78	Multiplicative model to remove country-gear, month and division effects to get standardized series; data for 1974-76 included and excluded	Regressions of 4+ biomass against standardized catch rate for a range of terminal Fs	Vague	0.170	1,024,400	Wells, R. NAFO SCR Doc. 81/VI/66
1982	Canada, Soviet Union, Spain, Portugal, Poland, German Democratic Repub., Fed. Rep. Germany, Great Britain,	1962-82	Separate analyses for country-gear type; multiplicative model used to remove month and division effects; indices combined by scaling to the 1979 value; data for 1974-76 excluded	Separate regressions of catch rate against exploitable biomass obtained from partial recruitments, and research survey against 4+ biomass	Terminal fishing moratality chosen equal to that from catch rate regression and lower range for survey regression	0.150	1,368,400	Bishop, C.A. and S. Gavaris NAFO SCR Doc. 82/IX/111
1983	Canada, Portugal, Spain	1962-82	Separate application of the multiplicative model to 1962-79 and 1979-82 periods; indices combined by scaling to the 1979 value; data for 1974-76 not used	Regression of standardized catch rate against exploitable biomass	Regression result	0.225	1,473,100	Gavaris, S. and C.A. Bishop NAFO SCR Doc. 83/VI/54
1984	Canada, Portugal, Spain	1962-83	Separate application of the multiplicative model to 1962-79 and 1979-83 periods; indices combined by scaling to the 1979 value; data for 1974-76 included in the analysis	Separate regressions of standardized catch rate against exploitable biomass and survey biomass agains 4+ biomass	Estimates of F from the two regressions were averaged	0.225	1,553,100	Gavaris, S., C.A. Bishop and J.W. Baird NAFO SCR Doc. 84/VI/73
1985	Canada, Portugal, Spain	1962-84	Separate application of the multiplicative model to 1962-79 and 1979-84 periods; indices combined by scaling to the1978 and1979 values;	Standardized catch rate for 1977 to 1984 regressed against offshore exploitable biomass and survey biomass index regressed against 4+ biomass in separate analyses	Vague	0.230	976,900	Baird, J.W. and C.A. Bishop NAFO SCR Doc. 85/37
1986	Canada, Portugal, Spain	1962-85	Separate application of the multiplicative model to 1962-79 and 1979-85 periods; indices combined by scaling to the1978 and1979 values;	Standardized catch rate for 1979 to 1985 regressed against offshore exploitable biomass and two RV indices, one from Canadian surveys regressed against 7+ population numbers and one from German surveys regressed against 4+ population numbers; all in separate analyses	Most likely value from a range from the various calibrations	0.250	1,103,000	Baird, J.W. and C.A. Bishop NAFO SCR Doc. 86/47
1987	Canada, Portugal, Spain	1962-86	Separate application of the multiplicative model to 1962-79 and 1979-86 periods; indices combined by scaling to the1978 and1979 values;	Standardized catch rate for 1978-86 regressed against offshore exploitable biomass and Canadian survey 6+ numbers regressed against 7+ numbers from the SPA at the beginning of the next year in separate analyses	Estimates of F from the two regressions were averaged	0.210	1,409,500	Baird, J.W and C.A. Bishop CAFSAC Res. Doc. 87/42
1988	Canada, Portugal, Spain (Canada unde one third rule)	1978-87	Standardization using multiplicative model Jan and Feb data for 2J omitted	ADAPT forumulation with age disaggregated survey index for ages 3-9 and age aggregated standardized catch rate	F estimated from ADAPT formulation calibrated with two indices	0.400		Baird, J.W and C.A. Bishop CAFSAC Working Paper 88/129.
1989	Canada, Portugal, Spain (Canada under one third rule)	1962-88	Separate application of the multiplicative model to 1962-79 and 1979-88 periods; indices combined by scaling to the1978 and1979 values: Jan and Feb data for 2J omitted	Research vessel survey and age aggregated catch rate data analysed in separate ADAPT formulations; in the catch rate formulation only data for 1978-88 were used;	Terminal fishing mortalities from the two ADAPT formulations were averaged	0.436	835,971	Baird, J.W. and C.A. Bishop CAFSAC Res. Doc. 89/6
1990	Canada, Portugal, Spain	1962-89	Separate application of the multiplicative model to 1962-79 and 1979-89 periods; indices combined by scaling to the1978 and1979 values;	ADAPT forumulation including both the RV index and the standardized catch rate disaggregated by age for ages 5 to 8 for the period 1983 to 1989	Terminal fishing mortality from the ADAPT formulation using the two indices combined	0.560	563,872	Baird, J.W., C.A. Bishop and W.B. Brodie CAFSAC Res. Doc. 90/18
1991	Canada, Portugal, Spain	1962-90	Multiplicative model applied to standardize catch rates for period 1983-90; data for 1978-82 considered influenced by enterprize allocatn and dockside grading	ADAPT forumulation including both the RV index and the standardized catch rate disaggregated by age for ages 5 to 12 for the period 1983 to 1990	Terminal fishing mortality from the ADAPT formulation using the two indices combined	0.520	768,280	Baird, J.W., C.A. Bishop and E.F. Murphy CAFSAC Res. Doc. 91/53
1992	Canada	1983-91	Multiplicative model applied to standardize catch rates for period 1983-91	Several ADAPT calibrations attempted with various indices; calibration with RV together with catch rate for ages 5-12 for period 1983-91 had poor residual pattern; recommendation made that the catch rate index be excluded from future calibrations	Terminal F from several calibrations	0.700	0	Baird, J.W., C.A. Bishop, W.B. Brodie and E.F. Murphy NAFO SCR Doc. 92/18

Table 1. Summary of the use of catch and effort data in Divisions 2J3KL cod assessments from 1978 to 1992.

Table 2. Percentage of all data records by year for which the various data fields have information in DFO catch rate data base.

	Results from proc freq run on all data values are % of data which have valid entries (not necessarily correct).											
records	170652	120824	207347	187015	165602	177108	159548	99950	246176	221373	205544	243653
CODE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
commercial fishing vessel number	82.3	70.1	82.5	82.1	80.5	83.9	82.8	80.7	91.8	94.2	94.1	97.8
gross tonnage	74.3	70	78.3	78	75.2	76.5	73.6	71.3	32.7	26.9	19.4	26
vessel length in feet	82.3	70	82.5	82.1	80.6	83.9	82.7	80.7	91.8	93.9	94	98.1
Brake horsepower	52.2	70	58.5	57.7	54.8	56.5	59.4	60.1	50.8	48.7	44.7	45.1
home port	82.3	70	82.5	82.1	80.6	83.9	82.5	80.1	91.9	94.4	94.3	98.1
home port electral district	79.9	67.8	69.3	78.9	73.3	0	0	0	0	0	0	0
Gulf based vessel	100	100	100	99.9	99.9	99.9	98.6	98.7	100	100	100	100
vessel company	0	0	0	0	0	0	0	0	0	0	0	0
quota report	79.2	79.7	83.2	87.4	87.9	80.8	85.8	81	70.4	26.8	17.2	23.1
trip number	82.3	70	82.5	82.1	80.6	83.9	82.7	80.7	85.8	95.7	96.9	99.9
date landed	82.3	74.8	82.1	81.9	80.5	83.9	82.5	80.6	95	99.8	100	100
unit area	100	100	99.9	96.2	97.1	96.7	96.2	94.5	91.5	90.5	92.4	90
Division	100	100	99.9	99.7	98.8	98.7	98.6	96.8	99.3	95	97.1	96.5
gear	100	100	100	100	100	100	100	100	100	100	99.9	99
gear class	100	100	100	100	100	100	100	100	100	100	99.9	99
port landed	100	100	100	100	100	100	100	100	100	100	100	100
port landed electral district	100	99.9	99.4	99.3	99.3	0	0	0	0	0	0	0
buyer company	0	0	0	0	0	0	0	0	0	0	0	0
buyer	100	100	100	100	100	100	100	100	100	100	100	100
species group	100	100	100	100	100	100	100	100	100	100	100	100
species	100	100	100	100	100	100	100	100	99.9	100	100	100
species size code	100	100	100	100	100	100	100	100	99.9	100	100	100
species landed form	100	100	100	100	100	100	100	100	99.9	100	100	100
species quality	0	0	0	0	0	0	0	0	0	0	0	0
unit of measure	100	87.6	92.3	92.3	90.9	91.7	91.3	88.5	100	99.9	99	100
landed quantity	81.8	86	88.4	86.8	88.9	99	47.2	100	100	100	100	100
landed value	81.8	86	88.4	86.8	88.9	99	47.2	100	100	100	100	100
live weight equivalance (kg)	91.3	86	88.4	86.9	88.9	99	47.2	100	100	100	100	100
effort flag	100	100	100	100	100	100	100	100	100	100	100	100
main species caught	82.3	70	82.5	82.1	80.5	83.9	75.4	80.5	36.2	24.5	18.5	28.5
main species sought	44.1	69.8	58.7	62.2	60.7	73.8	63.7	64.6	31	24.5	18.5	28.5
200 mile limit	100	100	100	100	100	100	100	100	100	100	100	100
trip fraction	0	0	0	0	0	0	0	0	0	0	0	0
days at sea	44.9	69.2	57	59.8	58.2	71.1	67.6	64.6	30.2	24.5	18.4	27.7
days on ground	44.9	69.2	57	59.8	58.2	71.1	67.6	64.6	30.2	24.5	18.4	27.7
days fished	44.9	69.2	57	59.8	58.2	71.1	67.6	64.6	30.2	24.5	18.4	27.7
hours fished	44	69.2	54	58.3	56.2	68.3	55.9	60.7	27.9	24.5	18.4	27.7
amount of gear	1.1	0.2	7.4	11.6	14.6	26.2	15.3	6.6	2.7	4.7	4.8	14
date caught	44.6	70	57.2	61.4	56.2	70.6	65.5	64.6	29.4	24.5	18.5	31.5
depth zone	81.2	69.3	80.3	79.4	78.2	78.6	69.1	72.5	34.4	20	17.2	21.6
region	100	100	100	100	100	100	100	100	100	100	100	100
latitude	0	0	0	0	0	0	0	0	0	3.9	14.3	24.3
longitude	0	0	0	0	0	0	0	0	0	3.9	14.3	24.3

Table 3. Percentage of records by year from vessels with registration numbers (generally □ 35 foot) for which the various data fields have information in DFO catch rate data base.

	Results from proc freq run data with valid CFV's fishing INSHORE GEARS (GEAR =41 51 53 58 61),.											
	values are % of data which have valid entries (not necessarily correct)											
CODE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
commercial fishing vessel number	100	100	100	100	100	100	100	100	100	100	100	100
gross tonnage	77.5	100	88.4	88.8	88.1	85.1	80.4	82.9	15.5	13.2	9.5	14.3
vessel lenght in feet	100	100	100	100	100	100	100	100	99.9	100	99.8	99.8
brake horsepower	21.7	91.3	26.9	28	31.4	35.8	37.3	33.4	48.2	50.1	43	39.2
home port	100	100	99.9	100	99.9	100	100	100	99.9	100	100	98
quota report	87.2	94.4	83.7	89.3	93.1	93.2	89.9	81.6	72.6	20.2	25	34.4
trip number	100	100	100	100	100	100	100	100	95.7	100	100	100
date landed	100	100	99.9	99.9	99.9	99.9	99.9	99.8	100	100	100	100
unit area	100	100	100	99	99.9	99.5	98	96.1	88.5	95.1	87.9	95.4
division	100	100	100	99	99.9	99.9	100	100	99.9	100	100	99.5
gear	100	100	100	100	100	100	100	100	100	100	100	100
gear class	100	100	100	100	100	100	100	100	100	100	100	100
port landed	100	100	100	100	100	100	100	100	100	100	100	100
buyer	100	100	100	100	100	100	100	100	100	100	100	100
species group	100	100	99.9	100	100	100	100	100	99.9	100	100	100
species	100	100	100	100	100	100	100	100	99.9	100	100	100
species size	100	100	100	100	100	100	100	100	99.9	100	100	100
species form	100	100	100	100	100	100	100	100	99.9	100	100	100
unit of measure	100	100	100	100	100	100	100	100	100	100	100	100
landed quantity	100	100	100	100	100	100	100	100	100	100	100	100
landed value	100	100	100	100	100	100	100	100	100	100	100	100
live weight equivalance (kg)	100	100	100	100	100	100	100	100	100	100	100	100
effort flag	100	100	100	100	100	100	100	100	100	100	100	100
main species caught code	100	100	99.9	99.9	99.9	99.9	73	98.9	11.3	100	2.6	13.3
main species sought code	1.6	5.3	24.9	35.2	42.8	73.6	36.8	24.1	3.3	2.8	2.6	13.3
days at sea	1.6	96	21.5	31.1	39.4	68.7	51.2	26.6	2.6	2.8	2.6	12.6
days on ground	1.6	96	21.5	31.1	39.4	68.7	51.2	26.6	2.6	2.8	2.6	12.6
days fished	1.6	96	21.5	31.1	39.4	68.7	51.2	26.6	2.6	2.8	2.6	12.6
hours fished	1.6	85.4	11.5	26.4	33.7	61.3	11.6	11.8	0.7	2.8	2.6	12.6
amount of gear	1.4	91.1	22.8	33.1	39.1	65	49.8	25.5	3	2.8	2.5	12.1
date caught	1.6	94.4	18.3	33.3	32.4	64.8	72.9	26.4	1.8	2.8	2.6	13.3
depth zone	100	98.1	99.3	99.7	99.3	97.3	70.7	95.7	10.3	1.6	1.6	7.5
latitude	0	0	0	0	0	0	0	0	0	0.1	2.6	10.3
longitude	0	0	0	0	0	0	0	0	0	0.1	2.6	10.3

Table 4. Percentage of records by year from vessels without registration numbers (generally < 35 foot) for which the various data fields have information in DFO catch rate data base.

	Results from proc freq run data without CFV's),. values are % of data which have valid entries (not necessarily correct)											
CODE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
commercial fishing vessel number	0	0	0	0	0	0	0	0	0	0	0	0
gross tonnage	0	0	0	0	0	0	0	0	0.5	1.3	0.4	11.4
vessel lenght in feet	0	0	0	0	0	0	0	0	0.7	2.5	0.6	21
brake horsepower	0	0	0	0	0	0	0	0	0.6	1.1	0.3	10.9
home port	0	0	0	0	0	0	0	0	0.7	2.5	0.6	21
quota report	65.6	65.7	62.7	70.6	71.7	76.8	69.3	59.4	47.8	29.2	17.1	10.4
trip number	0	0	0	0	0	0	0	0	17.9	26.4	47.7	96.2
date landed	0	0	0	0	0	0	0	0	41.3	92	100	100
unit area	100	100	100	100	100	99.9	99.3	99	98.3	99	98.2	99.7
division	100	100	100	100	100	100	100	100	100	100	100	100
gear	100	100	100	100	100	100	100	100	100	100	100	99.9
gear class	100	100	100	100	100	100	100	100	100	100	100	100
port landed	100	100	100	100	100	100	100	100	100	100	100	100
buyer	100	100	100	100	100	100	100	100	100	100	100	100
species group	100	100	100	100	100	100	100	100	100	100	100	100
species	100	100	100	100	100	100	100	100	100	100	100	100
species size	100	100	100	100	100	100	100	100	100	100	100	100
species form	100	100	100	100	100	100	100	100	100	100	100	100
unit of measure	100	41.4	44.1	43	46.7	48.6	49.2	40.4	100	95.5	90.1	100
landed quantity	100	100	100	100	100	100	100	100	100	100	100	100
landed value	100	100	100	100	100	100	100	100	100	100	100	100
live weight equivalance (kg)	100	100	100	100	100	100	100	100	100	100	100	100
effort flag	100	100	100	100	100	100	100	100	100	100	100	100
main species caught code	0	0	0	0	0	0	0	0	0.7	0.7	0.4	20.2
main species sought code	0	0	0	0	0	0	0	0	0.6	0.7	0.4	20.2
days at sea	0	0	0	0	0	0	0	0	0.3	0.7	0.3	18.6
days on ground	0	0	0	0	0	0	0	0	0.3	0.7	0.3	18.6
days fished	0	0	0	0	0	0	0	0	0.3	0.7	0.3	18.6
hours fished	0	0	0	0	0	0	0	0	0.1	0.6	0.3	18.6
amount of gear	0	0	0	0	0	0	0	0	0.3	0.6	0.3	11.5
date caught	0	0	0	0	0	0	0	0	0.7	0.7	0.4	20.2
depth zone	0	0	0	0	0	0	0	0	0.7	0.6	0.4	17.3
latitude	0	0	0	0	0	0	0	0	0	0.6	0.3	14.1
longitude	0	0	0	0	0	0	0	0	0	0.6	0.3	14.1

Table 5. The percentage of the reported cod catch by NAFO unit areas in Divisions 2J3KL by gillnets and traps for which there are effort data (i.e. from vessels □ than 35').

GILLNETS PERCENT OF CATCH WIT EFFORT

	2JM	3KH	3KI	3LA	3LB	3LQ
1985	13.5	0	0	0	0.4	0
1986	4.8	1.2	2	3.3	4.7	1.3
1987	1.9	12.2	3.8	2.8	5.4	11.3
1988	0.5	4.9	4.1	7.4	5	9.5
1989	2.9	7.3	9	1.1	4.4	53.5
1990	6.3	11.3	28.2	5.4	19.7	12.6
1991	0	2.5	7	2.2	4.7	8.3

TRAP PERCENT OF CATCH WITH EFFORT

	2JM	3KD	3KI	3LB	3LF	3LJ
1985	0.6	0	0	0	0	0
1986	0.3	0	0.4	0	0.7	0.6
1987	0	2.8	0.3	0.5	0.8	0
1988	0.5	0.2	6.5	1.4	0.7	2.3
1989	0.6	8.8	9.8	1.4	2.3	2.1
1990	2.1	33.5	18.7	8.5	8.6	6.8
1991	0	12.8	19.6	4.3	5.3	7.5

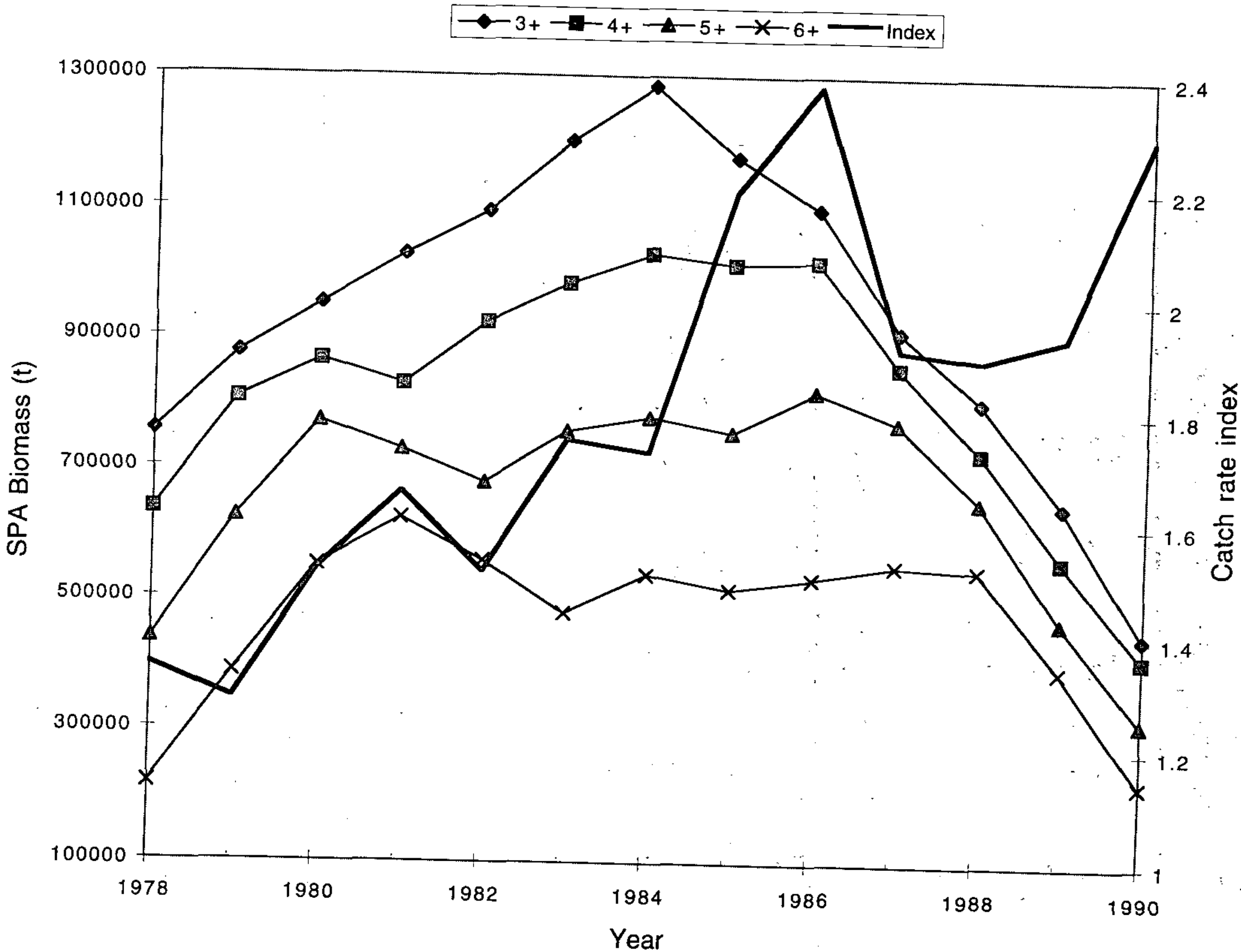


Fig. 1. The age aggregated standardized catch rate index derived from commercial catch and effort data and estimates of population biomass at age for ages 3+, 4+, 5+ and 6+ for the period 1978 to 1990.

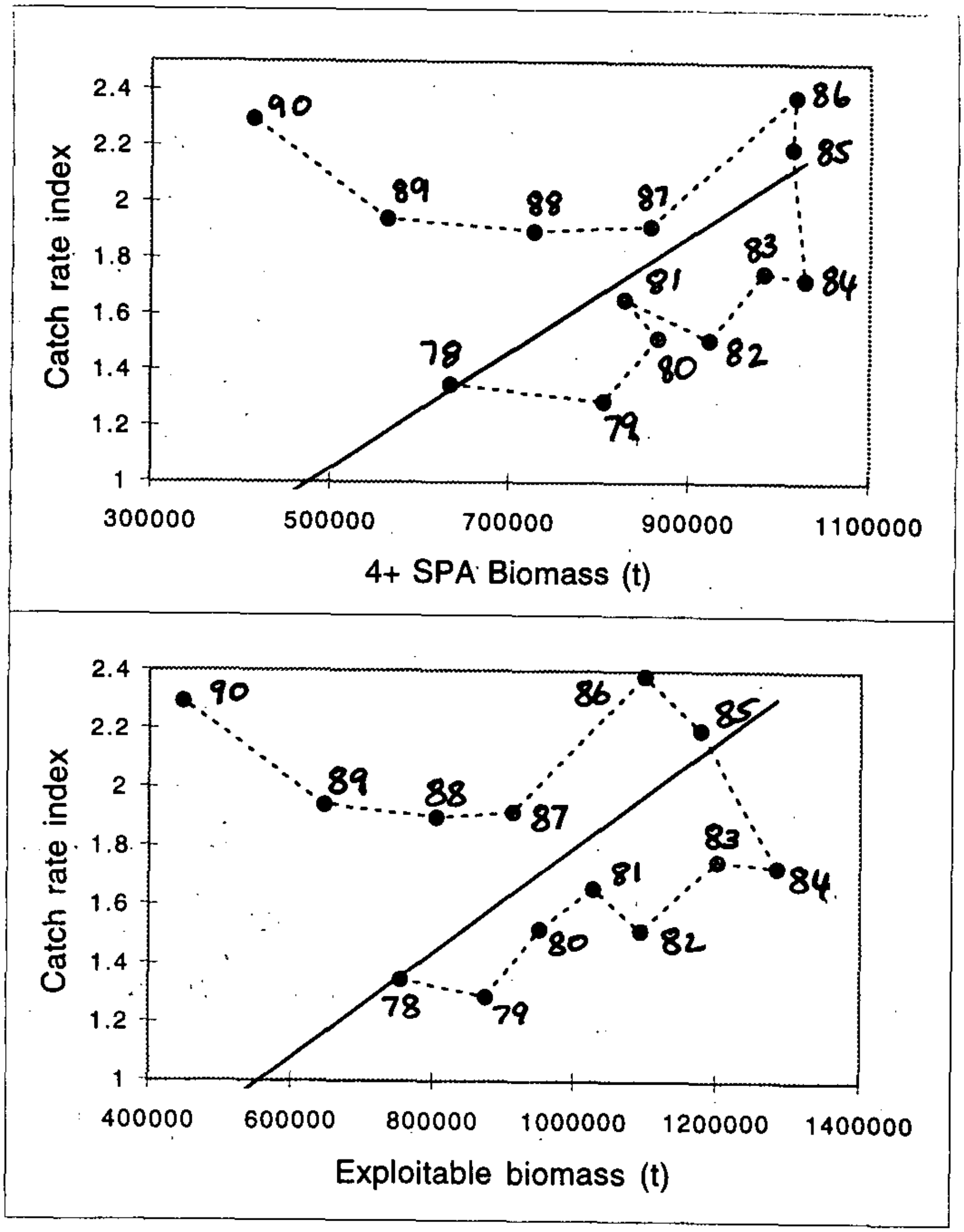


Fig. 2. Age aggregated standardized catch rate index from the 1991 assessment plotted against the estimated 4+ biomass and the exploitable biomass for the period 1978 to 1990.

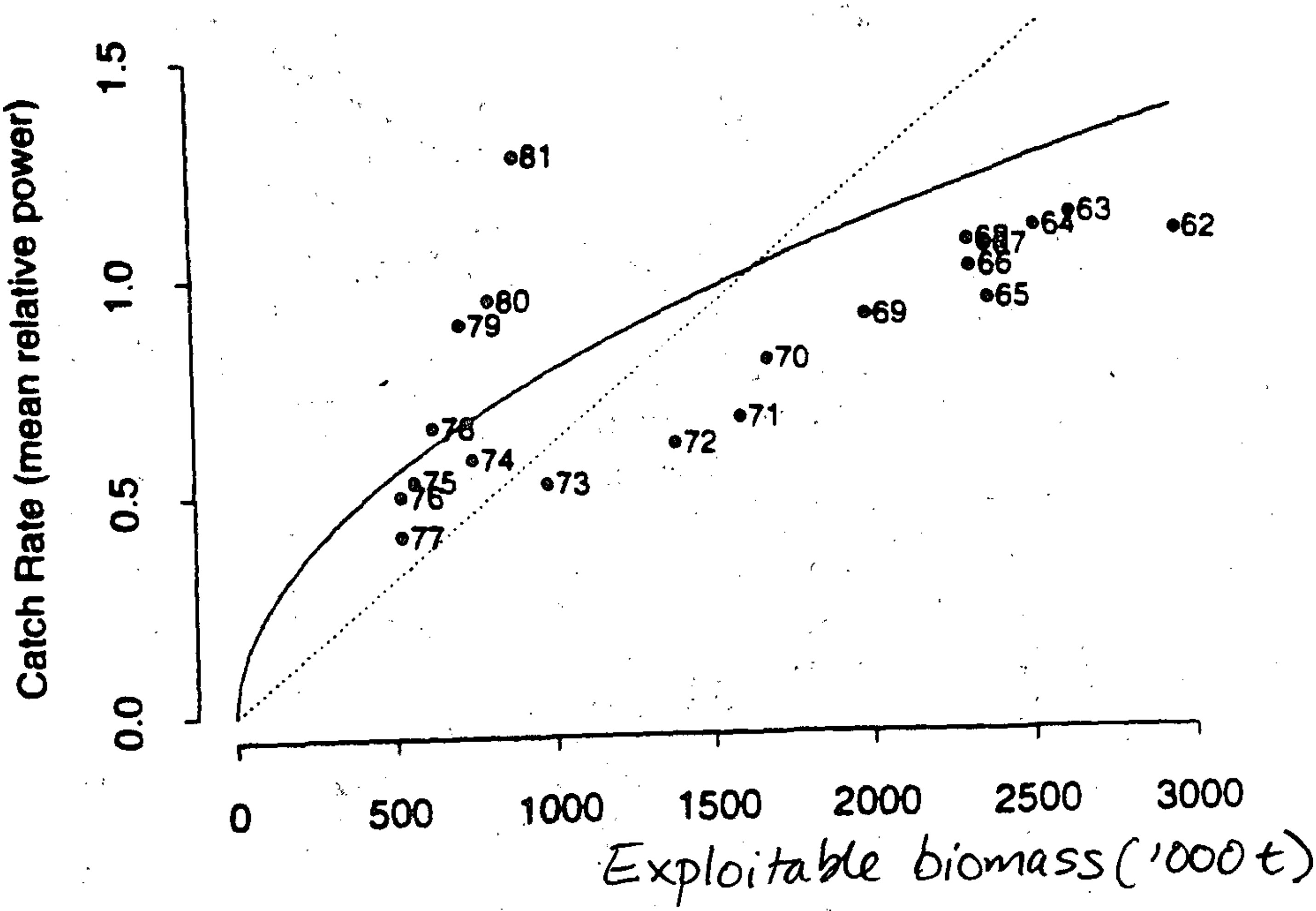


Fig. 3. Relationship between the standardized catch rate index and harvestable biomasss (age 3 and older) for the period 1962 to 1981 with linear and power relationships fitted through the origin (from Huthings and Myers 1994).

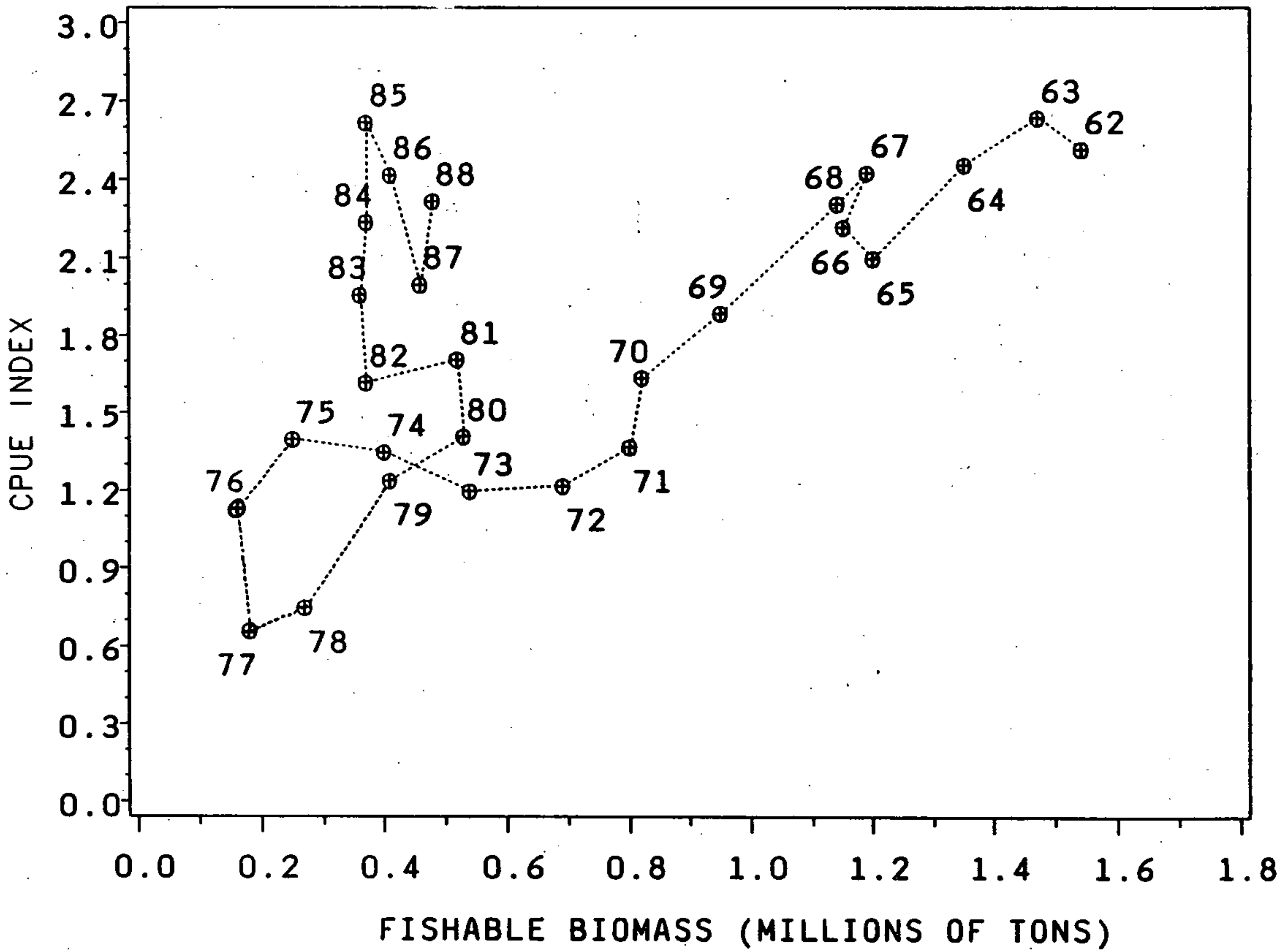


Fig. 4. Age aggregated standardized catch rate index plotted against fishable biomass fo the period 1962 to 1988 (from Baird and Bishop 1989).

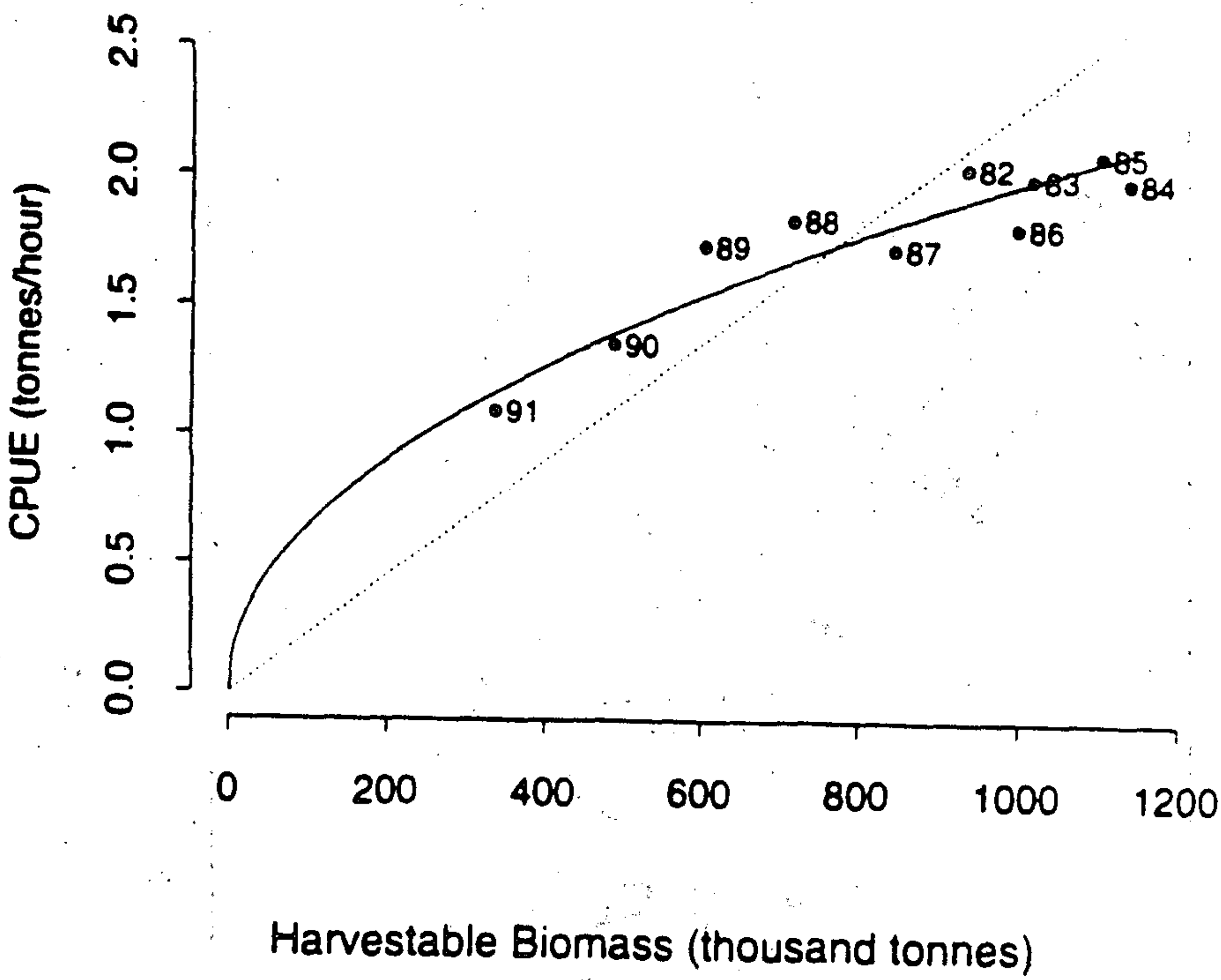


Fig. 5. Unstandardized catch rates from Canadian trawlers with GRT between 500 and 100 tons plotted against 3+ biomass from SPA for the period 1984 to 1991 with a power function fitted through the origin (from Hutchings and Myers 1994).

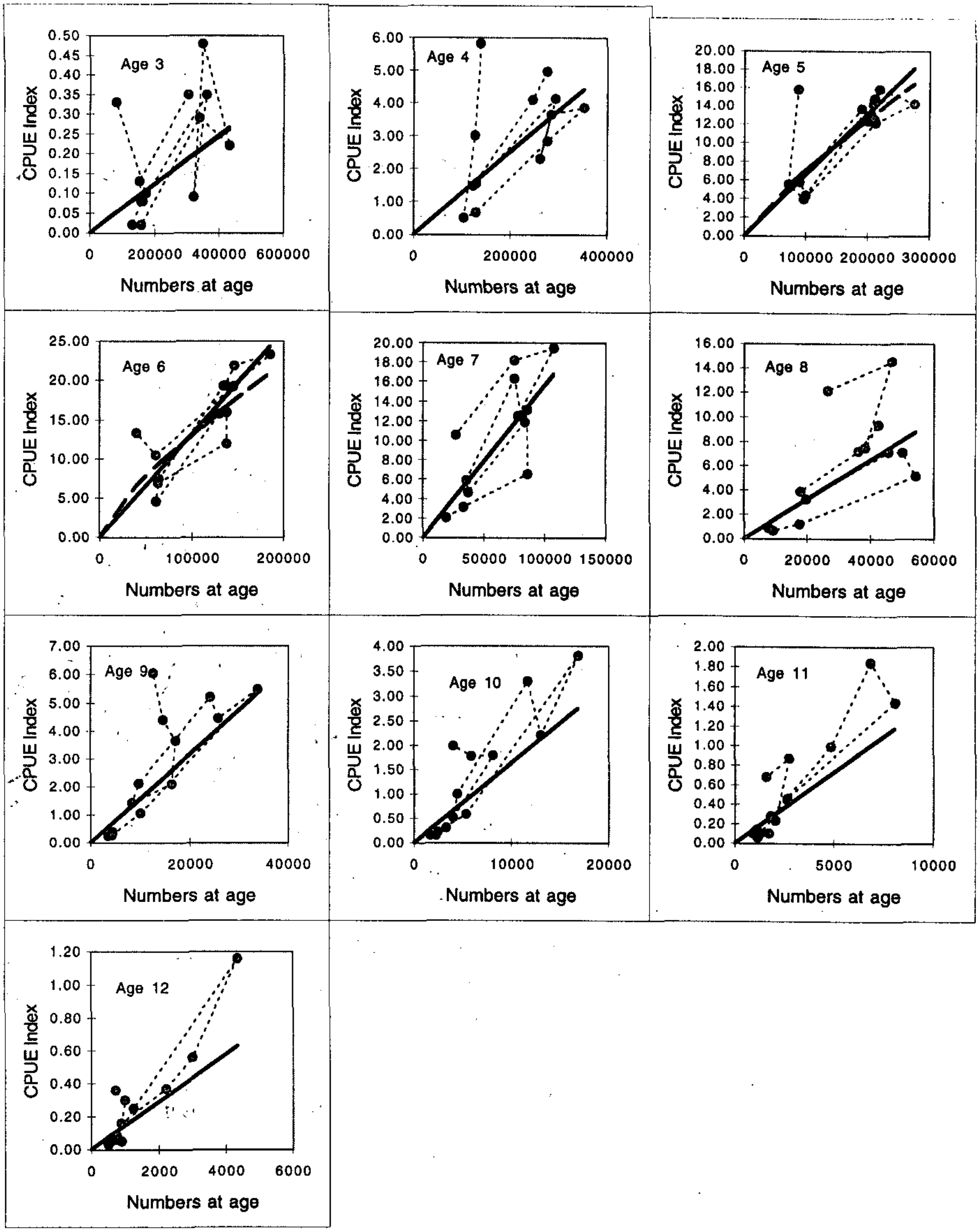


Fig. 6. Age disaggregated standardized catch rate index from Baird et al. (1991) plotted against recent SPA estimates of numbers at age from a calibration using only the RV index for the period 1978 to 1990. Both linear (solid line) and power models (broken line) are fit to the data by minimizing the sums of squares of the difference of the logarithm of the observed and logarithm of the expected catch rates (the objective function used in the SPA minimization).

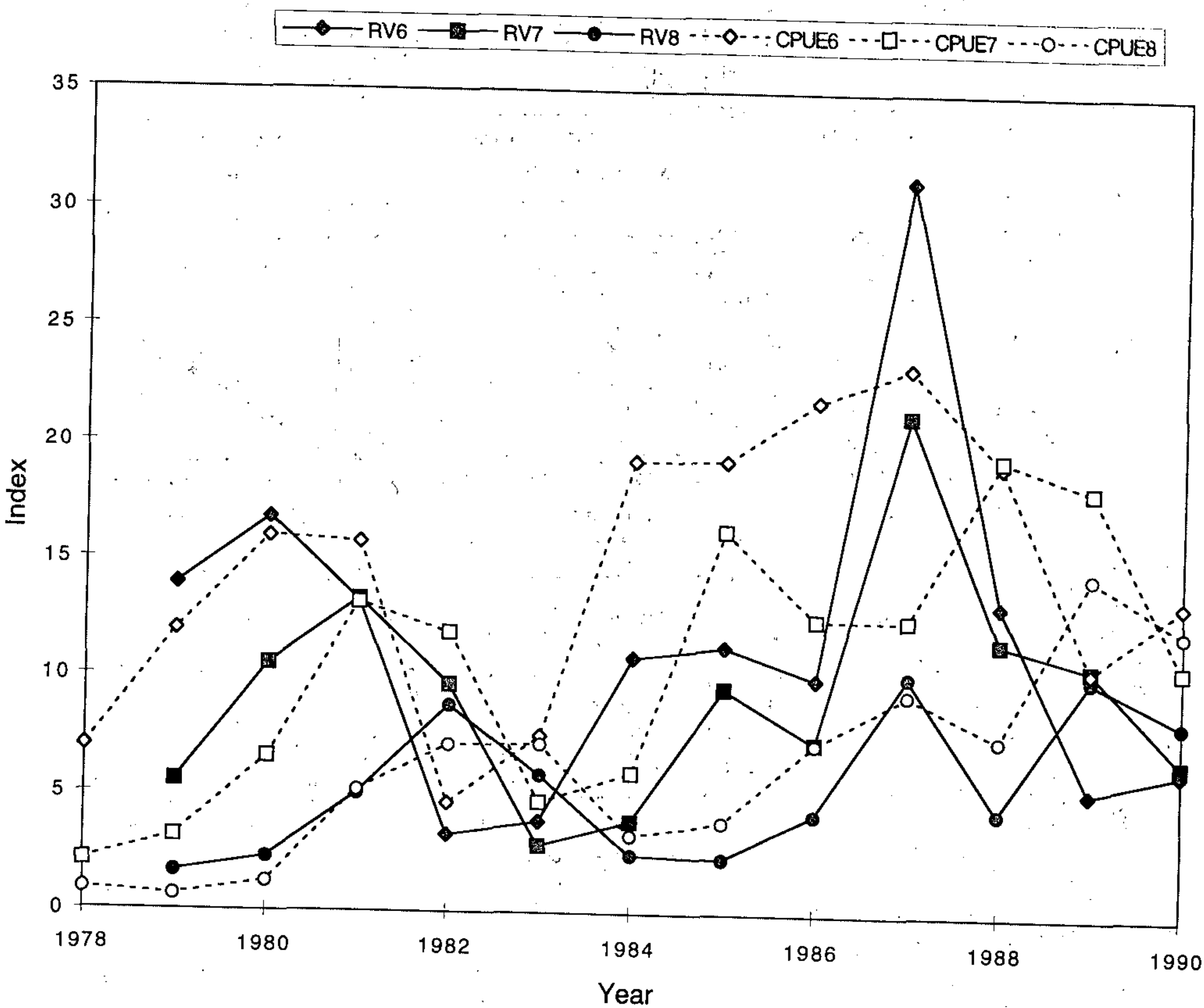


Fig. 7. Comparison of the RV and catch rate indices for ages 6 to 8 from the 1991 assessment (Baird et al. 1991) for the period 1978 to 1990.

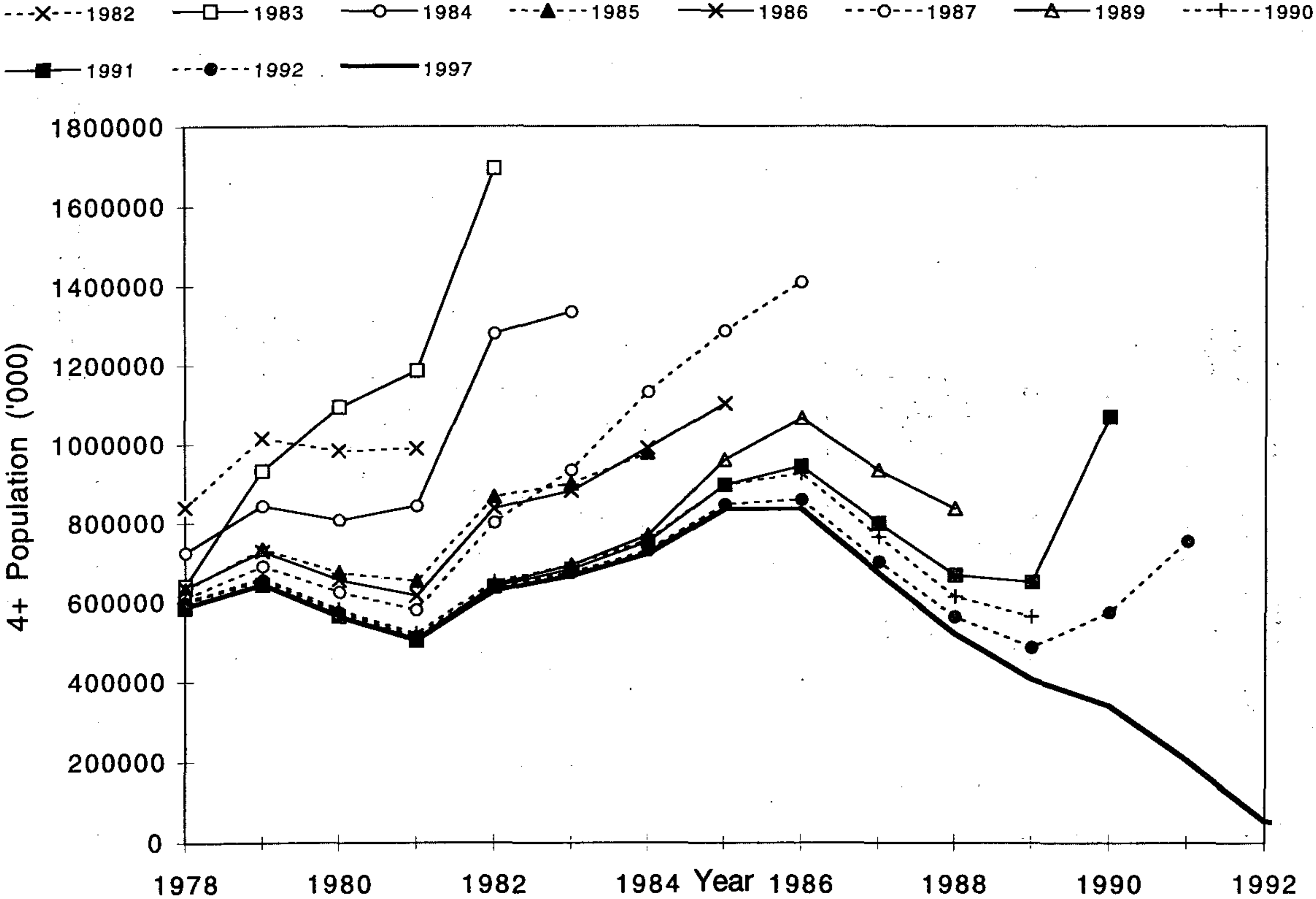


Fig. 8. SPA estimates of 4+ numbers at age from assessments carried out from 1982 to 1992, together with current (i.e retrospective) estimates for the same time period.

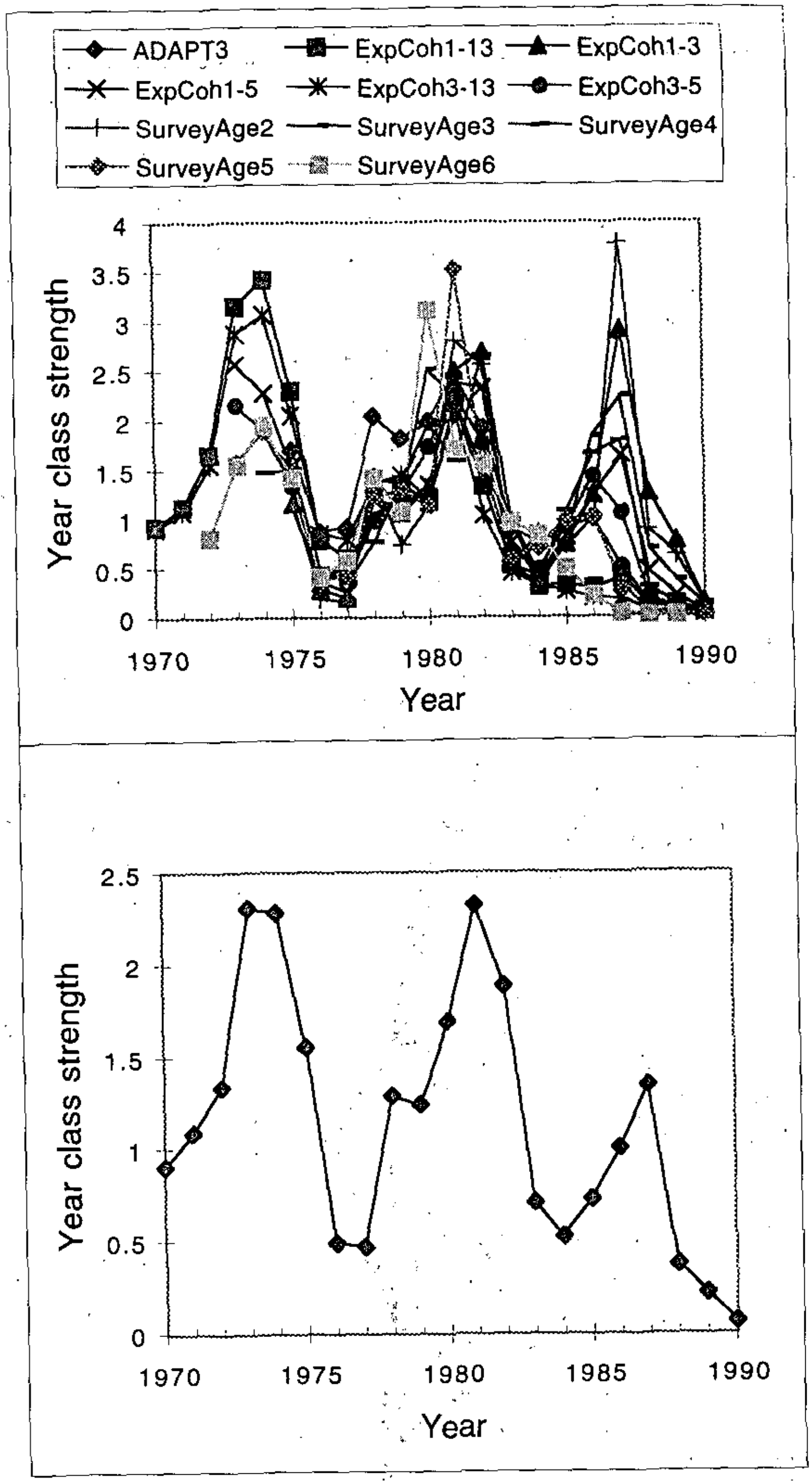


Fig. 9. Top panel - plot of various "looks" at year class strength from the survey data, from a multiplicative model fitted to various combinations of survey data and the survey data itself (see text for details). Bottom panel - Annual averages derived from the indices in the top panel.

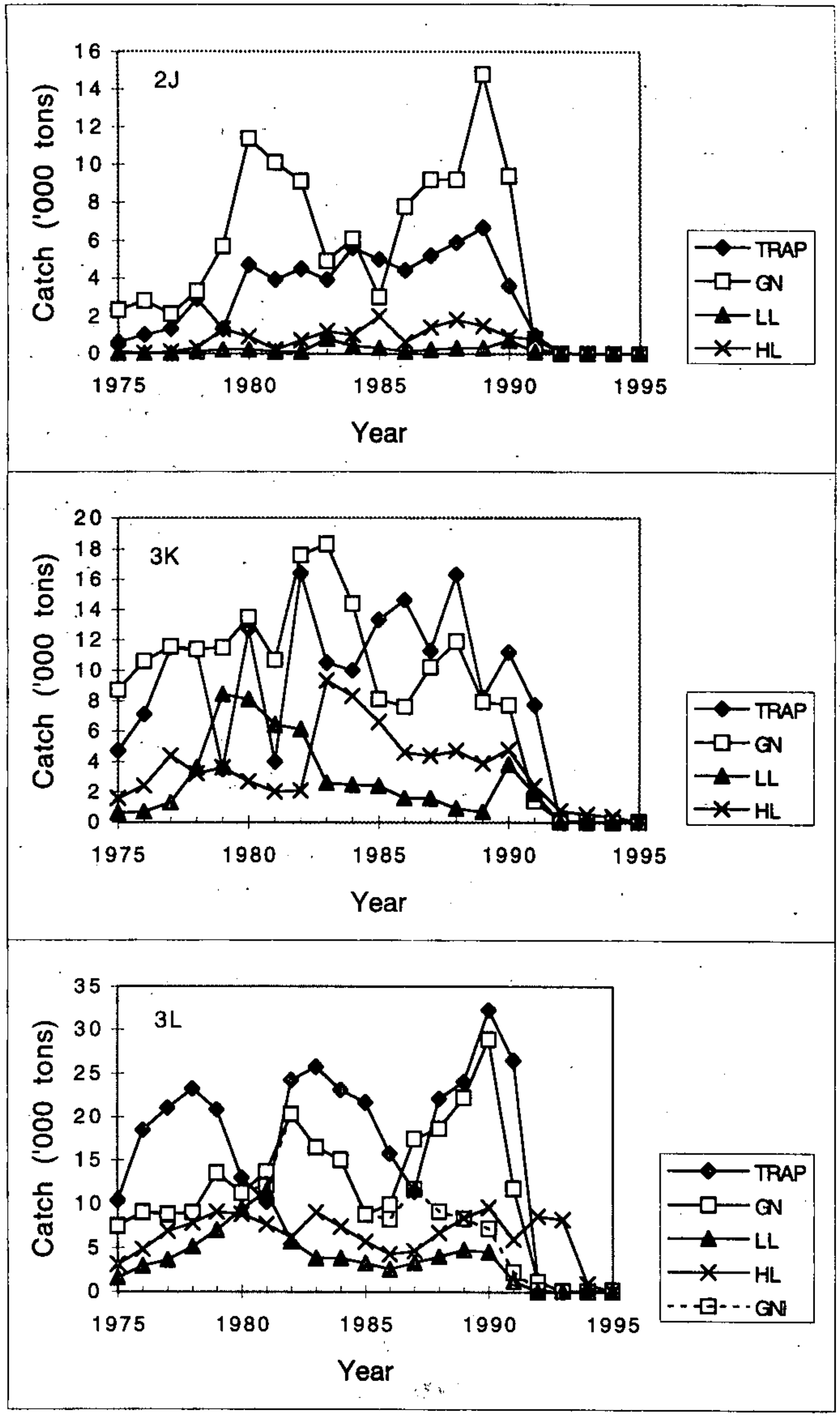


Fig. 10. Annual catches by gear type in the inshore fishery in Divisions 2J3KL for theperiod 1975 to 1995.

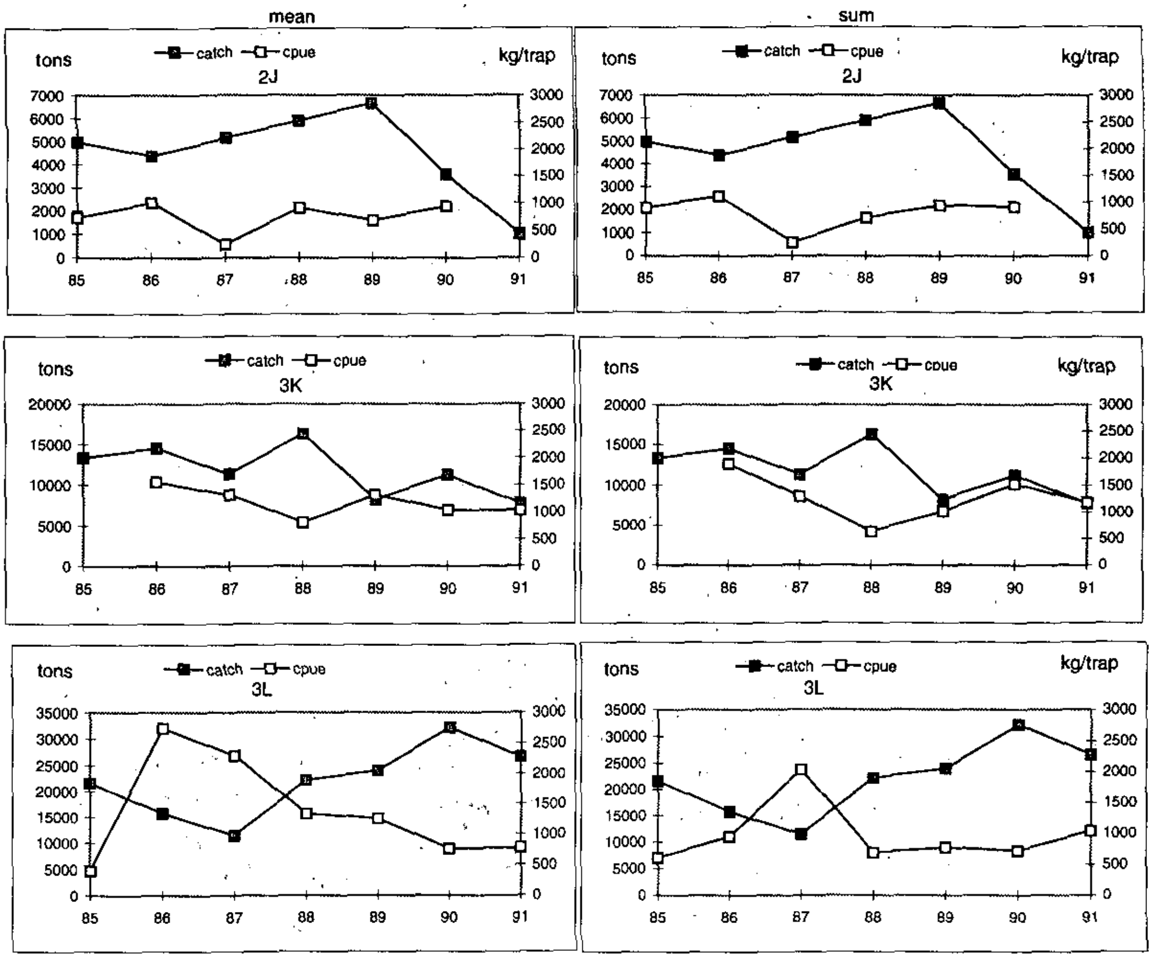


Fig. 11. Calculations of the mean catch rate index and the sum catch rate index for cod traps by NAFO division for the period 1985 to 1991 (see text for details of calculation).

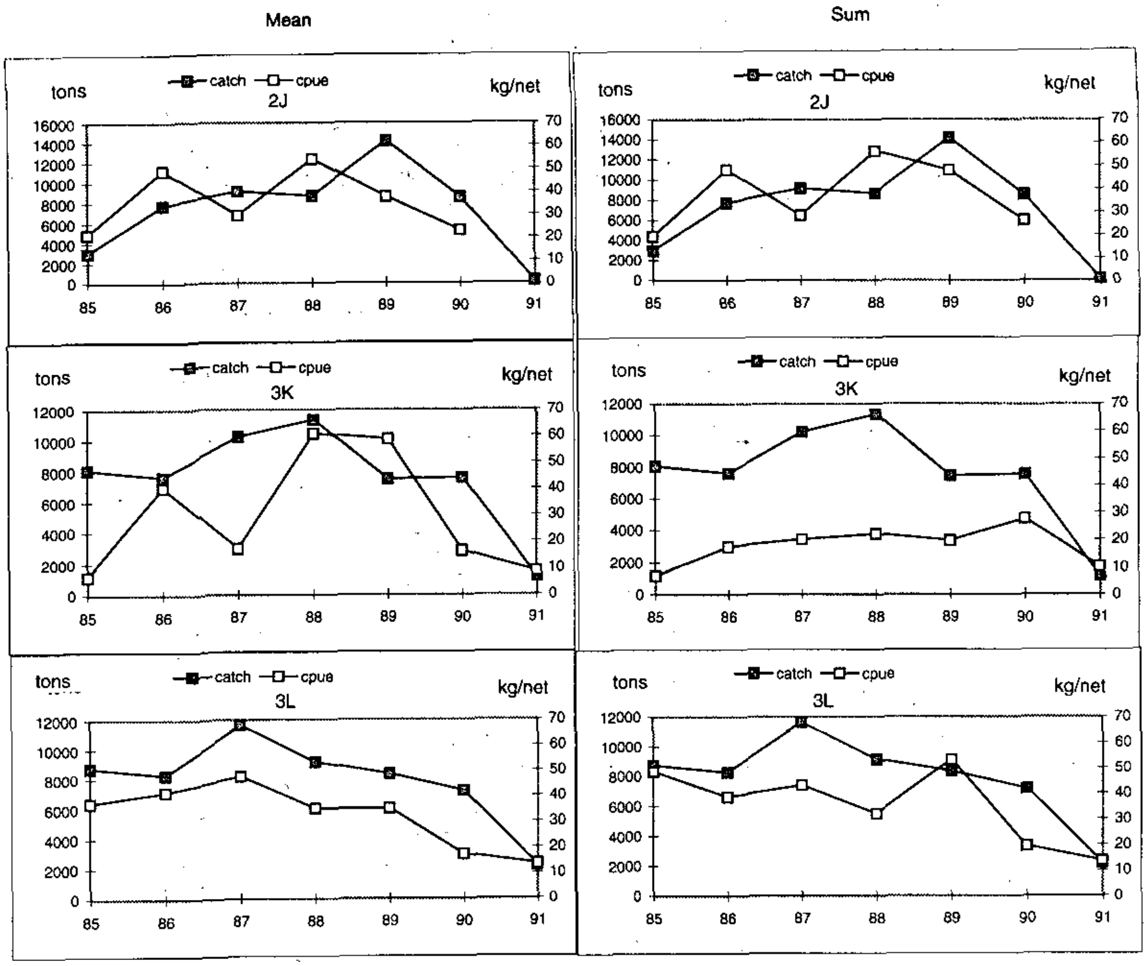


Fig. 12. Calculations of the mean catch rate index and the sum catch rate index for gillnets by NAFO division for the period 1985 to 1991 (see text for details of calculation).

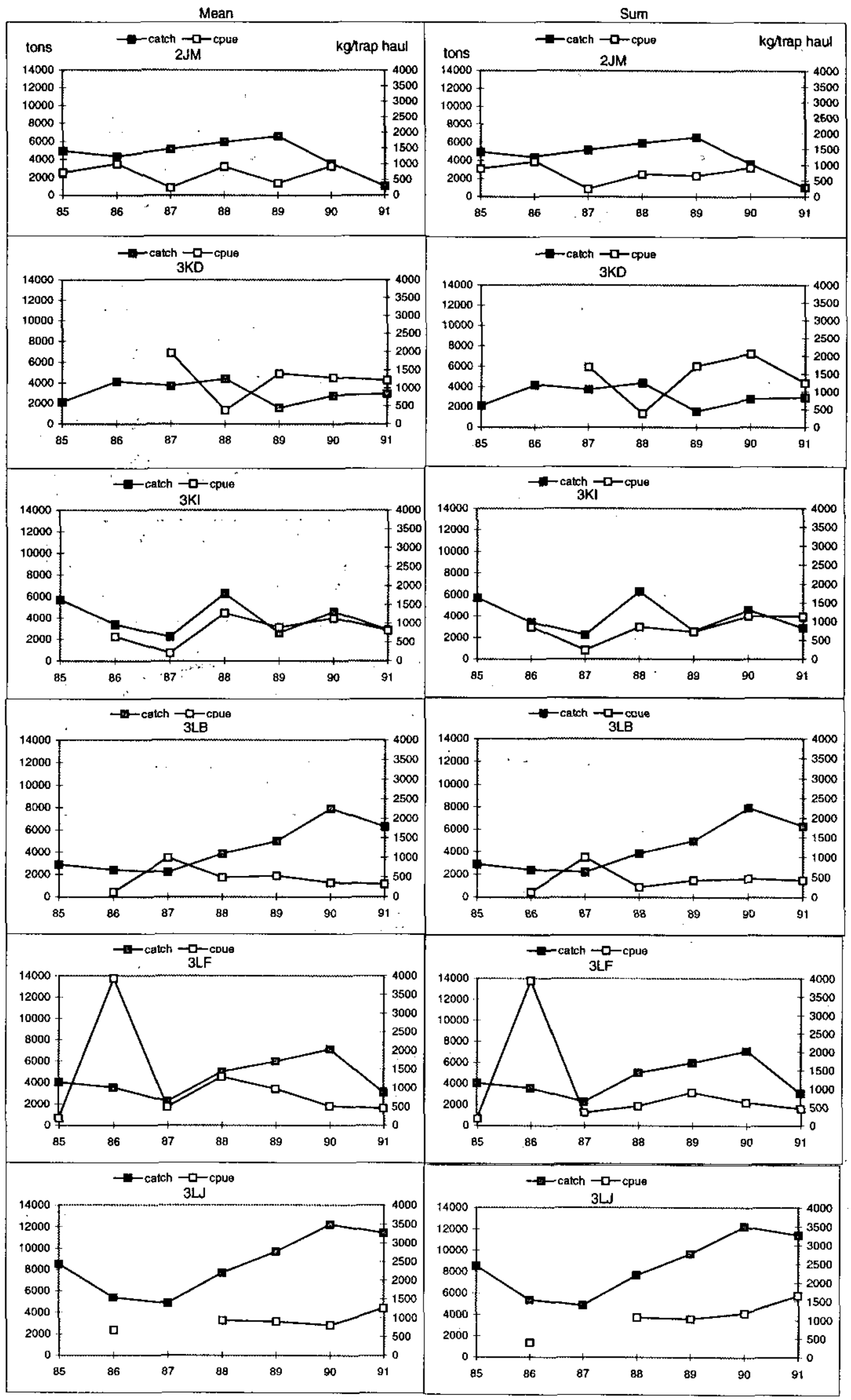


Fig. 13. Calculations of the mean catch rate index and the sum catch rate index for cod traps for the 6 NAFO unit areas with the highest average catch for the period 1985 to 1991.

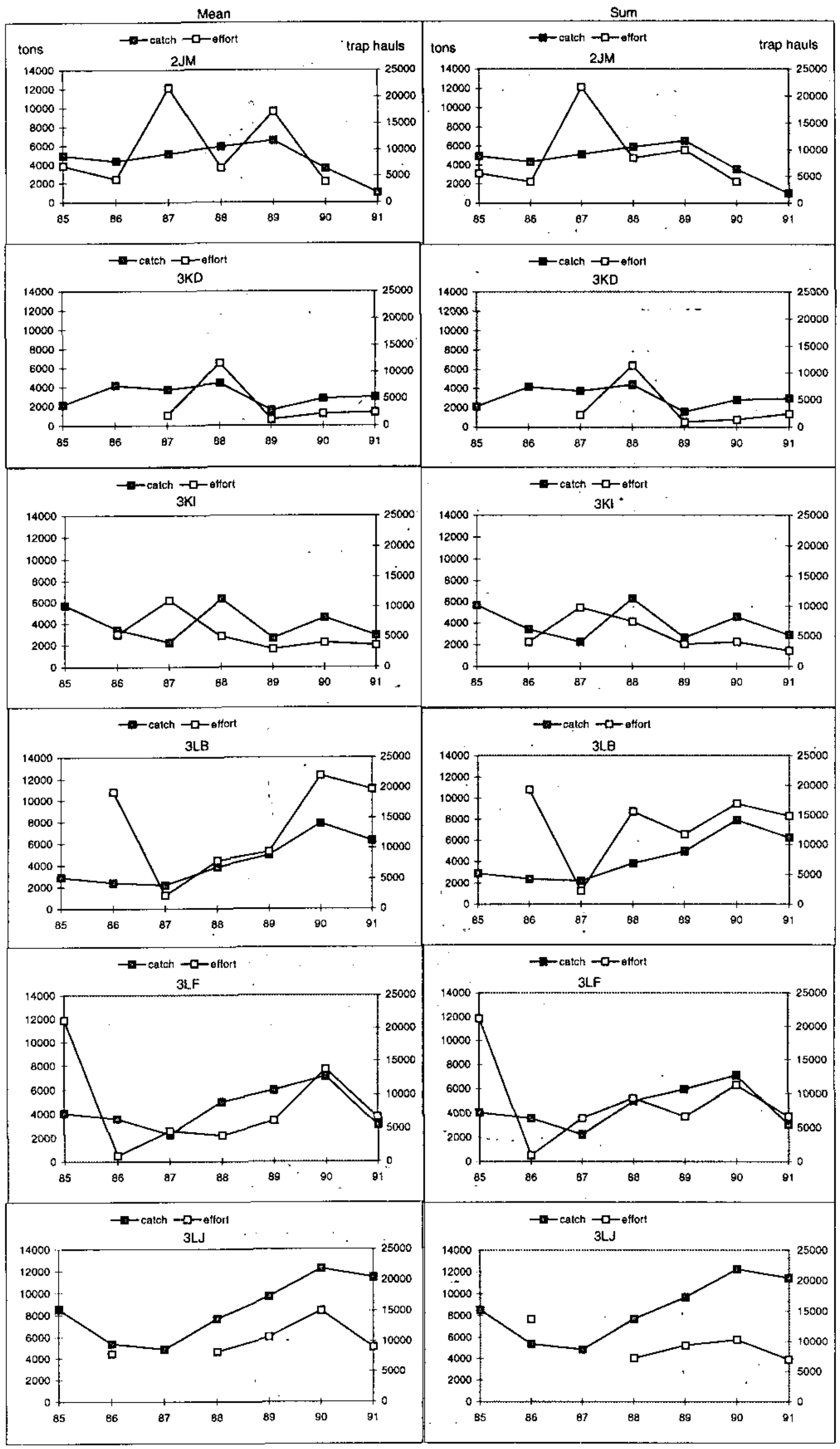


Fig. 14. Calculations of the mean catch and effort and the sum catch and effort for cod traps for the 6 NAFO unit areas with the highest average catch for the period 1985 to 1991.

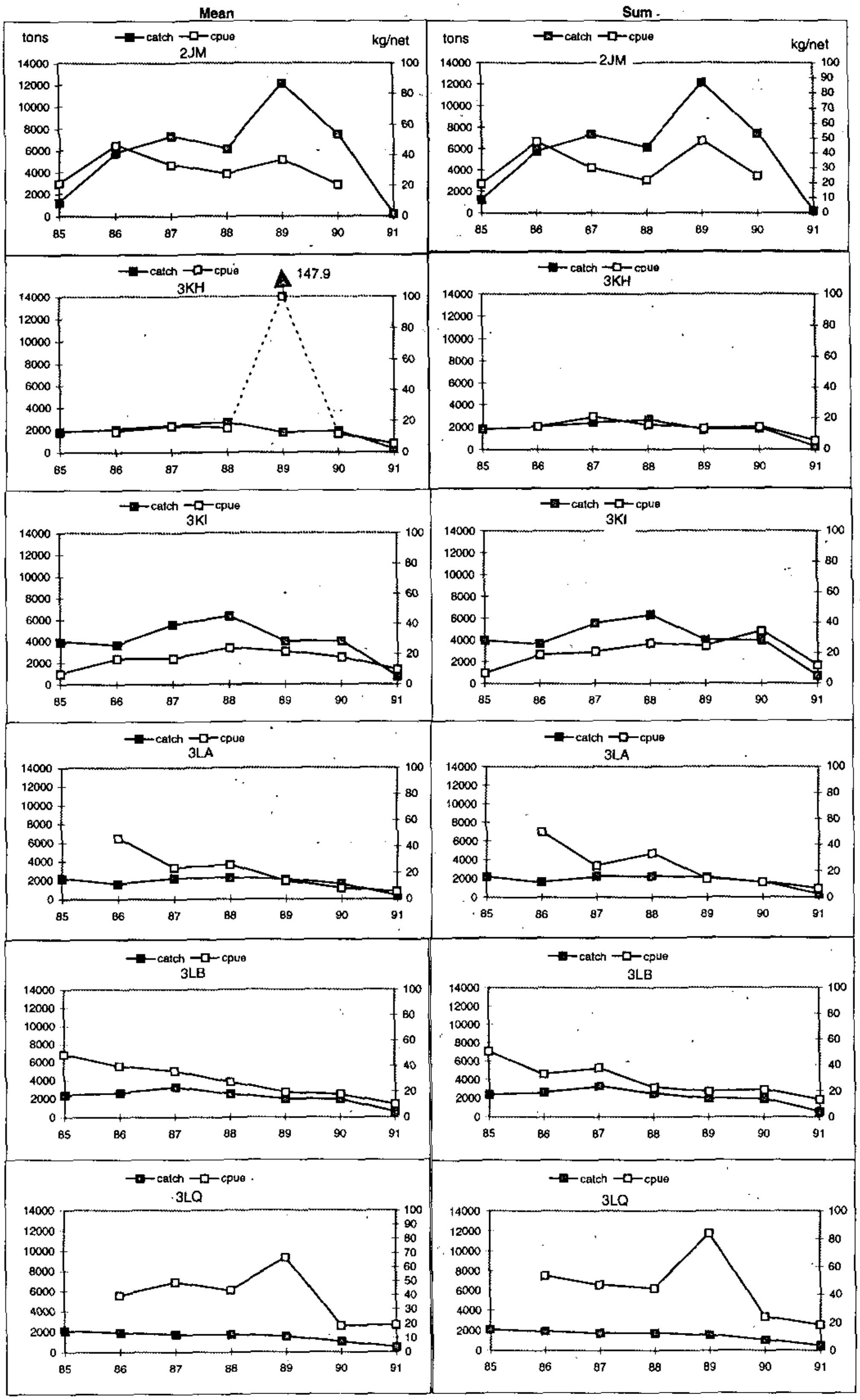


Fig. 15. Calculations of the mean catch rate index and the sum catch rate index for gillnets for the 6 NAFO unit areas with the highest average catch for the period 1985 to 1991.

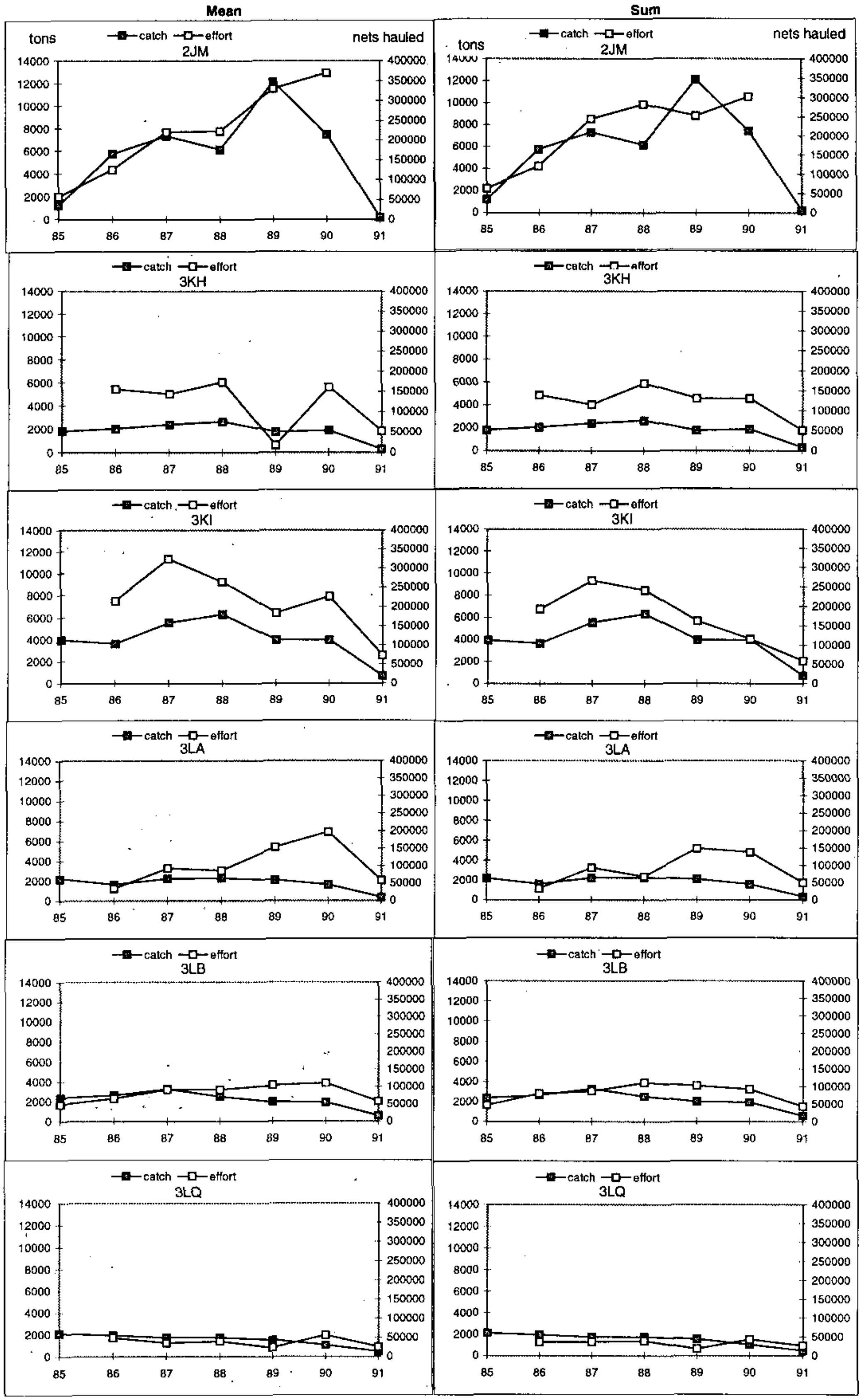
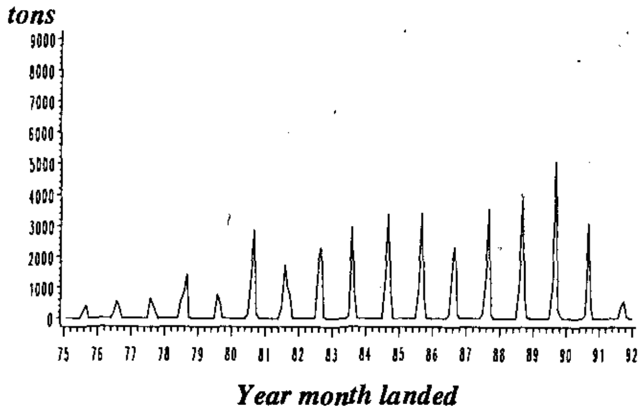


Fig. 16. Calculations of the mean catch and effort and the sum catch and effort for gillnets for the 6 NAFO unit areas with the highest average catch for the period 1985 to 1991.

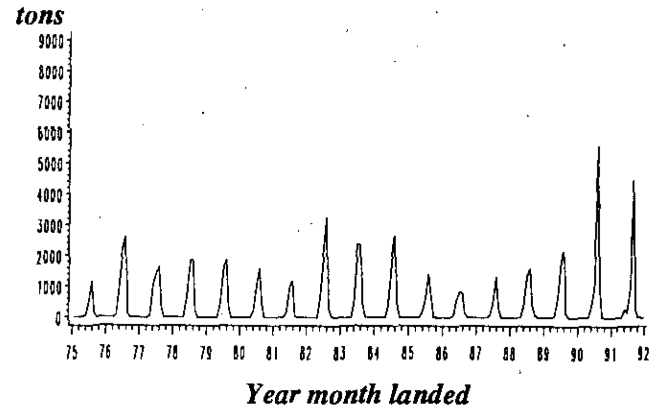
Cod catches all vessels.

AREA=' 2JM Fox Harbour to Cartwright' GEAR=Trap



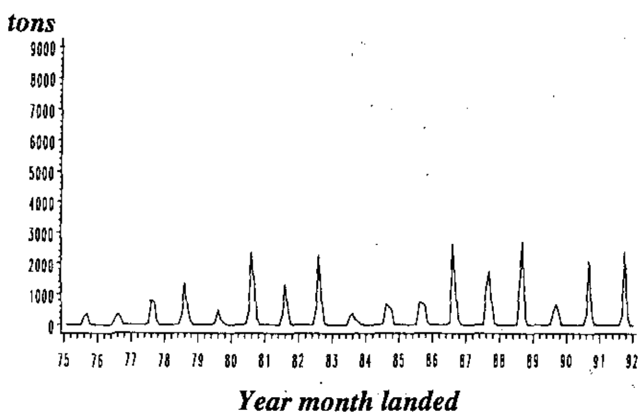
Cod catches all vessels.

AREA=' 3LB Trinity Bay' GEAR=Trap



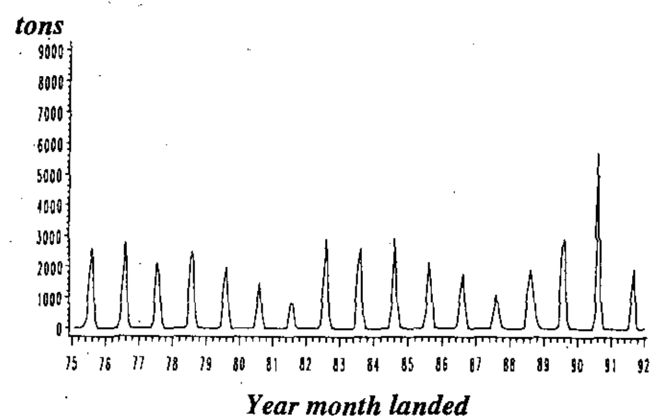
Cod catches all vessels.

AREA=' 3KD White Bay' GEAR=Trap



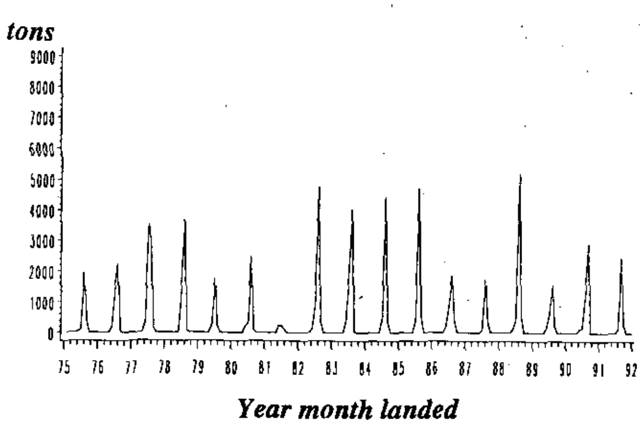
Cod catches all vessels.

AREA=' 3LF Conception Bay' GEAR=Trap



Cod catches all vessels.

AREA=' 3KI Twillingate to Cape Freel' GEAR=Trap



Cod catches all vessels.

AREA=' 3LJ Southern Shore' GEAR=Trap

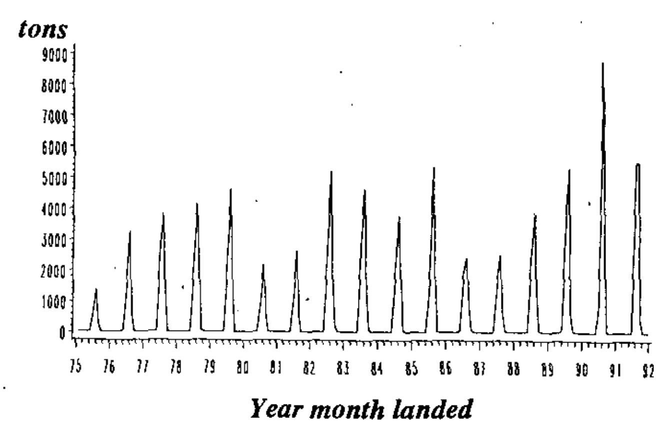
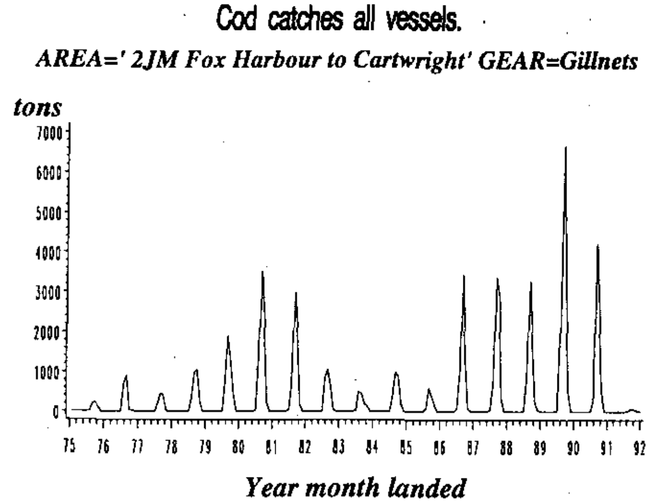
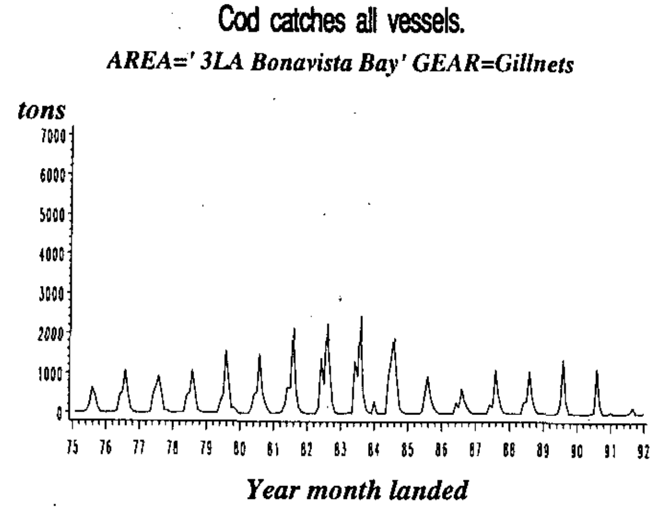
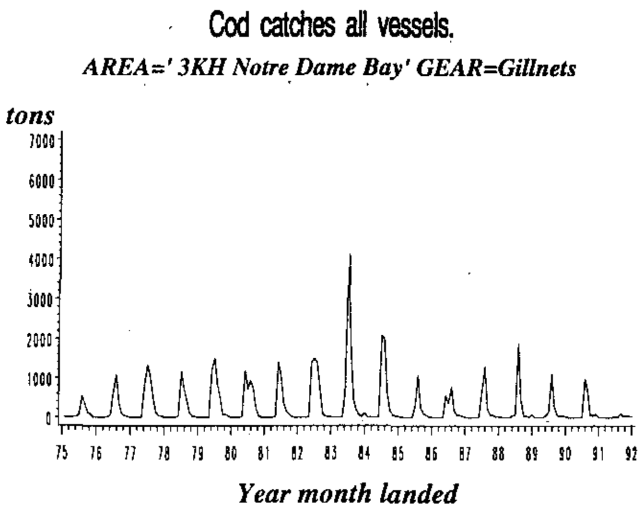
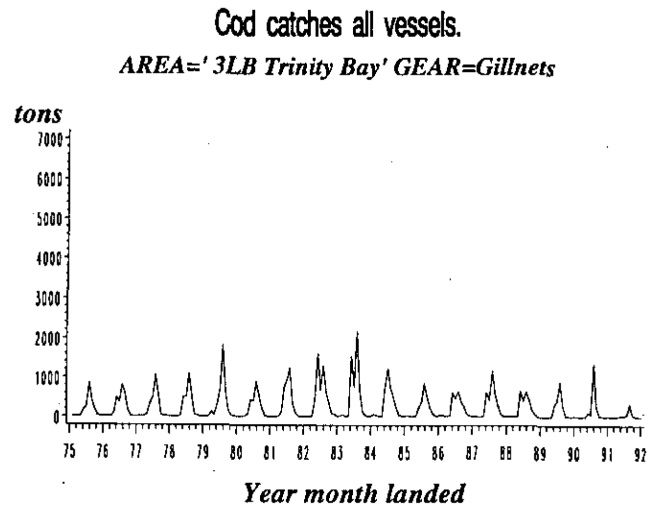


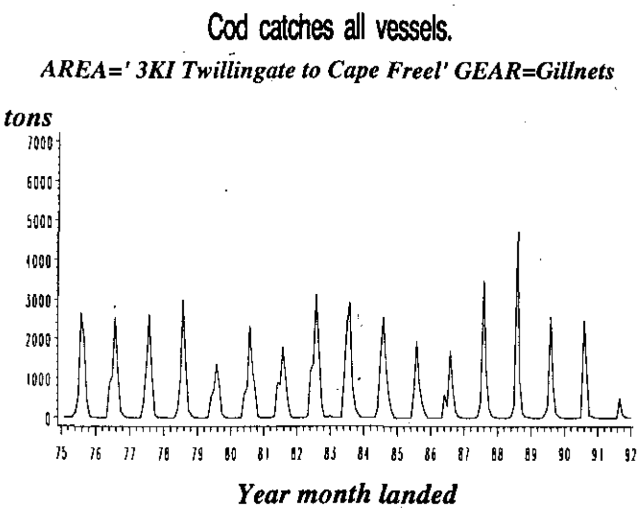
Fig. 17. Monthly trap catches plotted for the period 1975 to 1992 for the same NAFO unit areas examined for trap catch rates (6 highest average catches) for all vessels.











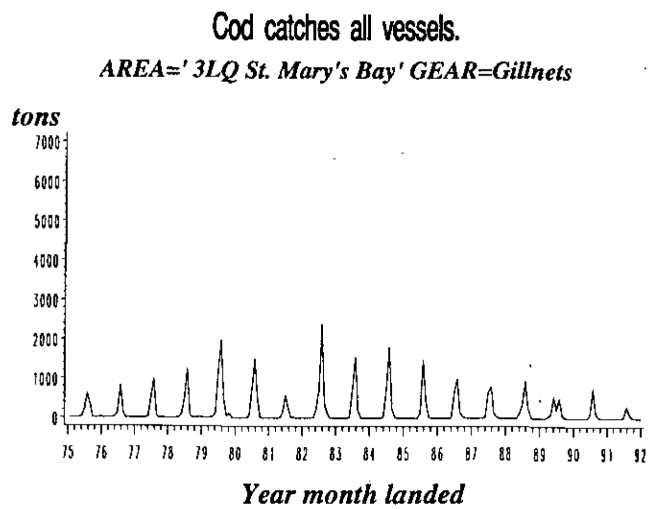
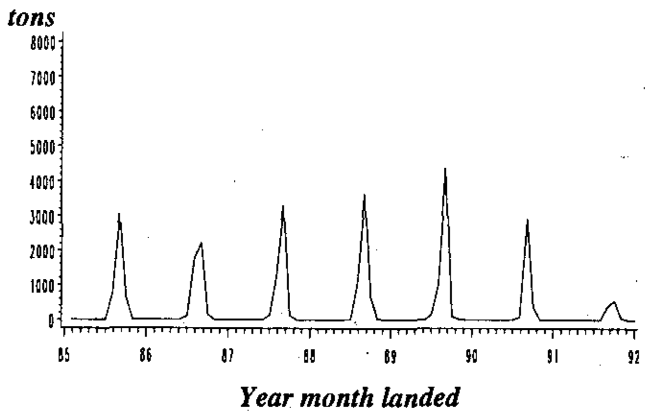
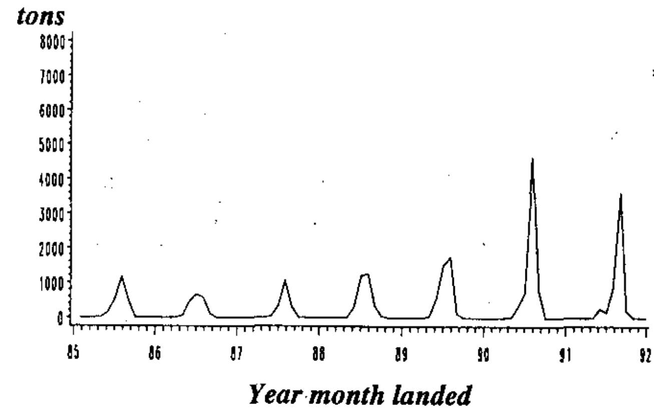


Fig. 18. Monthly gillnet catches plotted for the period 1975 to 1992 for the same NAFO unit areas examined for gillnet catch rates (6 highest average catches) for all vessels.

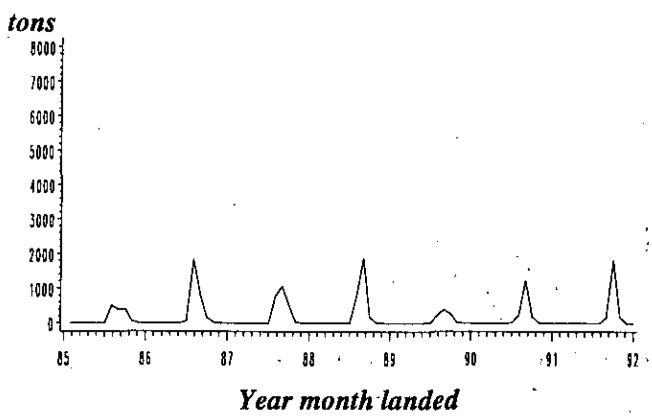
Cod catches by vessels less than 35 ft in length.
AREA=' 2JM Fox Harbour to Cartwright' GEAR=Trap



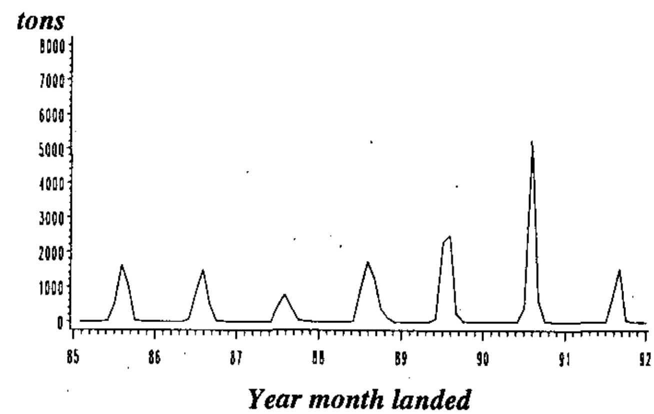
Cod catches by vessels less than 35 ft in length.
AREA=' 3LB Trinity Bay' GEAR=Trap



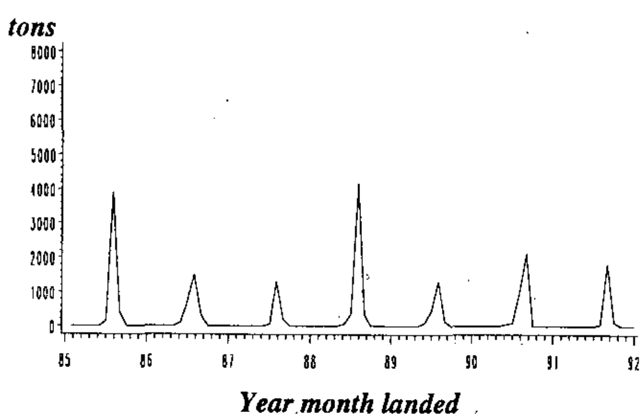
Cod catches by vessels less than 35 ft in length.
AREA=' 3KD White Bay' GEAR=Trap



Cod catches by vessels less than 35 ft in length.
AREA=' 3LF Conception Bay' GEAR=Trap



Cod catches by vessels less than 35 ft in length.
AREA=' 3KI Twillingate to Cape Freel' GEAR=Trap



Cod catches by vessels less than 35 ft in length.
AREA=' 3LJ Southern Shore' GEAR=Trap

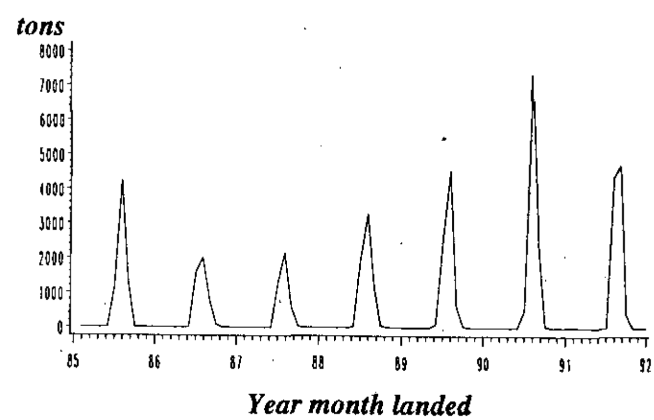


Fig. 19. Monthly trap catches plotted for the period 1975 to 1992 for the same NAFO unit areas examined for trap catch rates (6 highest average catches) for vessels less than 35 ft in length.

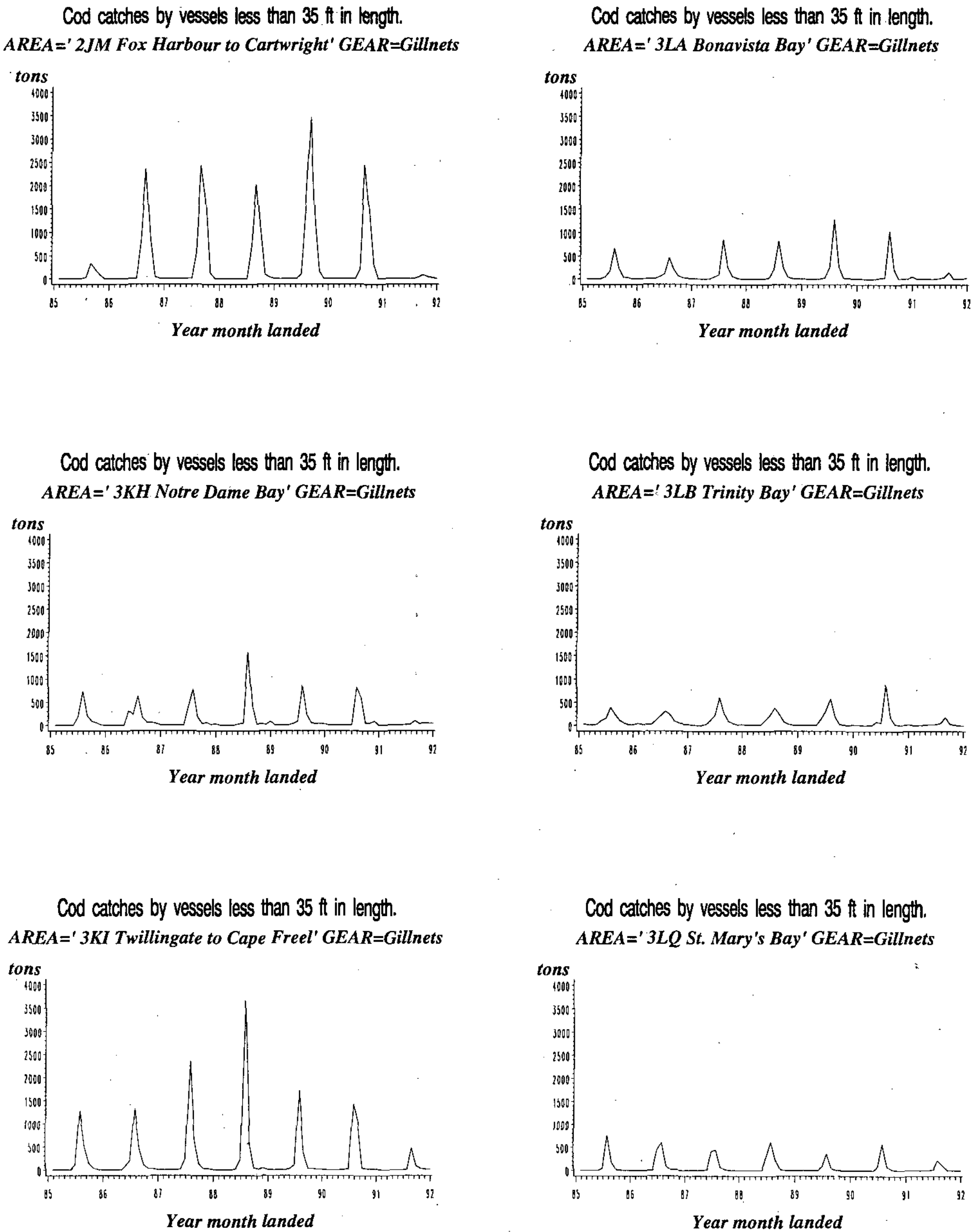


Fig. 20. Monthly gillnet catches plotted for the period 1975 to 1992 for the same NAFO unit areas examined for gillnet catch rates (6 highest average catches) for vessels less than 35 ft in length.

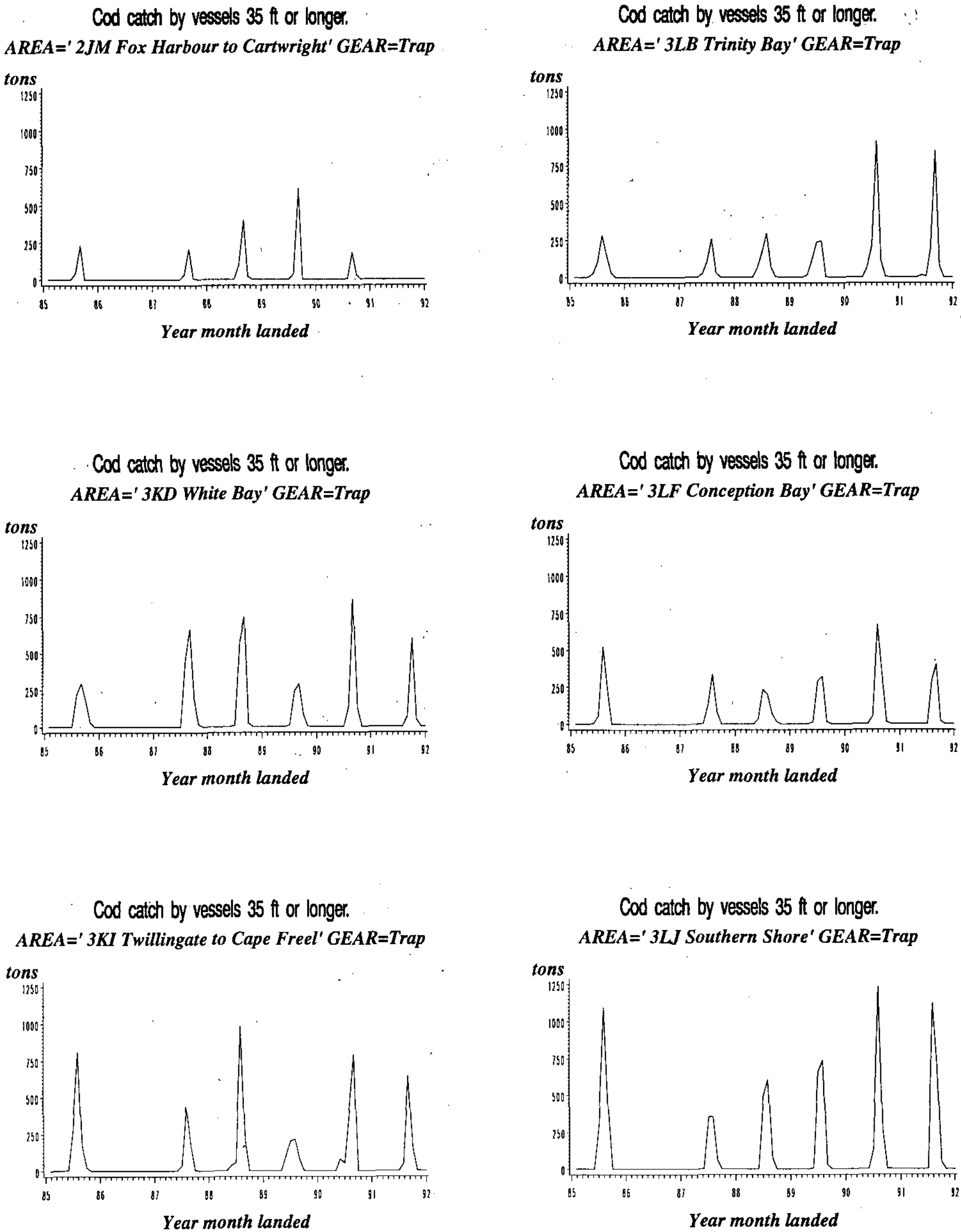
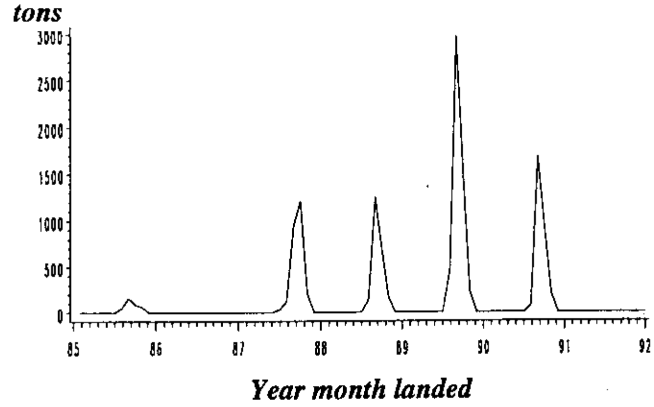
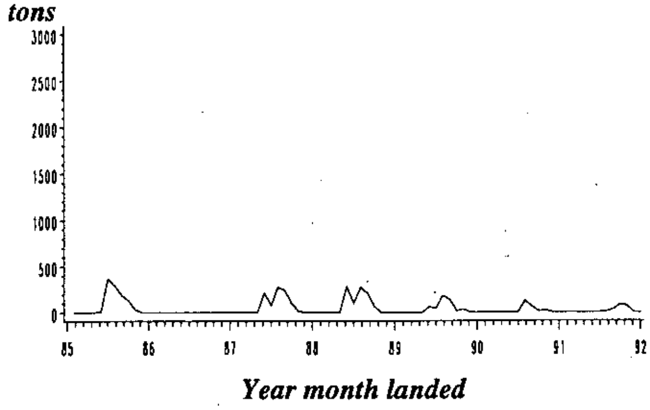


Fig. 21. Monthly trap catches plotted for the period 1975 to 1992 for the same NAFO unit areas examined for trap catch rates (6 highest average catches) for vessels □ 35 ft in length.

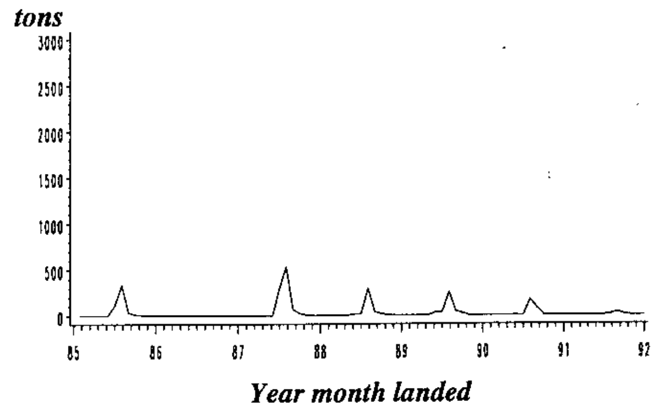
Cod catch by vessels 35 ft or longer.
AREA=' 2JM Fox Harbour to Cartwright' GEAR=Gillnets



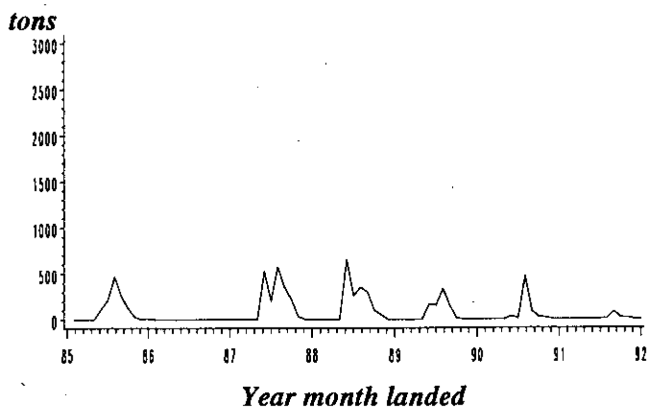
Cod catch by vessels 35 ft or longer.
AREA=' 3LA Bonavista Bay' GEAR=Gillnets



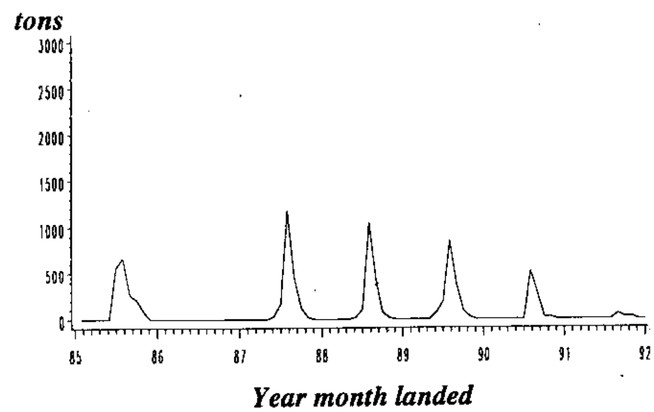
Cod catch by vessels 35 ft or longer.
AREA=' 3KH Notre Dame Bay' GEAR=Gillnets



Cod catch by vessels 35 ft or longer.
AREA=' 3LB Trinity Bay' GEAR=Gillnets



Cod catch by vessels 35 ft or longer.
AREA=' 3KI Twillingate to Cape Freel' GEAR=Gillnets



Cod catch by vessels 35 ft or longer.
AREA=' 3LQ St. Mary's Bay' GEAR=Gillnets

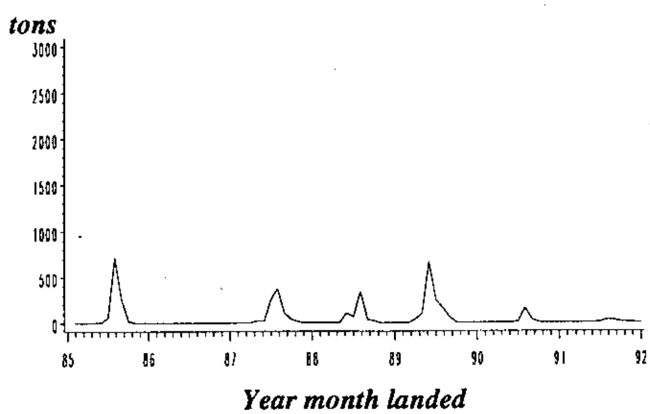


Fig. 22. Monthly gillnet catches plotted for the period 1975 to 1992 for the same NAFO unit areas examined for gillnet catch rates (6 highest average catches) for vessels □ 35 ft in length.