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Research Document 2004/001

Document de recherche 2004/001

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An Assessment of the Eastern Scotian Shelf Shrimp Stock and Fishery for 2003 and Outlook to 2004

Évaluation du stock et de la pêche en 2003 pour la crevette de l'est du plateau néo écossais et perspectives pour 2004

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ISSN 1499-3848 (Printed / Imprimé)

Canada

ABSTRACT

The DFO-industry survey index increased in 2003 following 3 consecutive decreases. This suggests that the recent biomass decline attributed to the completion of the life cycle of a succession of strong year classes (1993-1995) followed by a series of weaker year classes (1996-1998) has stabilised. The year class which will recruit to the fishery in 2004 (1999) appears to be about average and should support the fishery at least at the 2003 level. The 2001 year class, which was characterised as strong from « belly bag » samples alone in the 2002 survey appears to be exceptional in both belly bag and survey trawl catches in 2003. Further biomass increases may occur as this year class grows and begins to recruit to the fishery in 2005, especially if this happens in all areas. At present the 2000 and 2002 year classes do not appear to be as strong, so it is not clear if the 2001 year class signals the beginning of another succession of good year classes such as those which led to the peak biomasses in all areas at the end of the 1990s. In 2003, however, survey biomass was still mainly concentrated in the offshore area of SFA 14. This was confirmed by the continued concentration of effort in this area by the commercial trawler fleet. Commercial catch rates again increased in 2003 and are at the highest levels recorded despite decreased survey estimates in most areas in recent years. This continues to be attributable to the maturation and aggregation of the strong year classes/sizes and the continuing ability of the fishery to find these concentrations. Spawning stock biomass remains high. Many traffic light indicators have reversed to green and the overall summary has been favourable for the last 2 years.

RÉSUMÉ

En 2003, après avoir diminué pendant trois années consécutives, l'indice du relevé MPO-industrie a augmenté. Ceci donne à penser que la récente baisse de la biomasse attribuée à l'achèvement du cycle vital d'une série de fortes classes d'âge (1993-1995), suivies d'une série de faibles classes d'âge (1996-1998), s'est stabilisée. La classe d'âge qui sera recrutée à la pêche en 2004 (1999) semble être de taille moyenne et devrait alimenter la pêche au moins au niveau de 2003. La classe d'âge 2001, caractérisée comme forte d'après des échantillons prélevés lors du relevé de 2002 à l'aide d'un sac attaché au ventre du cul-de-chalut, semble être de taille exceptionnelle d'après les prises de relevé au chalut et les échantillons prélevés de la même manière en 2003. La biomasse pourrait augmenter davantage à mesure que cette classe d'âge vieillit et commence à être recrutée à la pêche en 2005, surtout si cela se produit dans toutes les zones. À l'heure actuelle, les classes d'âge 2000 et 2002 ne semblent pas aussi fortes; il n'est donc pas clair si la classe d'âge 2001 signale le début d'une autre série de fortes classes d'âge, comme celles à l'origine des pics de biomasses dans toutes les zones à la fin des années 1990. En 2003, toutefois, la biomasse de relevé était encore concentrée principalement dans le secteur hauturier de la ZPC 14, ce qui a été confirmé par la concentration continue de l'effort déployé par la flottille de chalutiers commerciaux dans ce secteur. Les taux de capture commerciale ont augmenté à nouveau en 2003, atteignant les niveaux enregistrés les plus élevés, malgré la diminution des effectifs estimés par relevé dans la plupart des zones au cours des dernières années. Cela est encore attribuable à l'atteinte de la maturité et à l'agrégation des fortes classes d'âge et la capacité soutenue des pêcheurs de trouver ces concentrations. La biomasse du stock reproducteur demeure élevée. De nombreux feux de circulation sont passés à vert, l'ensemble de ceux-ci indiquant que le stock est en bon état depuis deux ans.

INTRODUCTION

The biology of northern shrimp, *Pandalus borealis*, is reviewed in Shumway *et al*. (1985) for various stocks world-wide, and by Koeller et al. (1996a), Koeller (2000), Koeller et al. (2000a) and Koeller et al. (in press) for the eastern Scotian Shelf stock. The history of the eastern Scotian Shelf shrimp fishery and recent stock assessments are given in Koeller et al (1996b, 1996d, 1997,1998, 1999, 2001,2002, 2003). Although there has been some shrimp fishing on the Scotian Shelf since the 1960s the Nova Scotia fishery began to expand toward its full potential only when groundfish bycatch restrictions were overcome with the introduction of the Nordmore grate in 1991. The Total Allowable Catch (TAC) has been caught every year since individual Shrimp Fishing Areas (SFAs) quotas were lifted in 1994. With biomass at historical highs and continued good recruitment, the TAC was raised from 3100mt to 3600mt for 1997 and to 3800mt for 1998. Despite evidence of reduced recruitment to the population, and because of continued high spawning stock biomasses and large year classes (1993-1995) recruiting to the fishery, the TAC was increased to 5000mt for 1999 and to 5500mt for 2000. With the strong year classes completing their life cycle; recruitment only average; a decreasing trend in the survey biomass; increasing exploitation rates; changes in the distribution of the resource, possibly due to increasing temperatures and\or size separation; and increasing harvest levels during the ovigerous period, the TAC was reduced to 5000 mt for 2001 and to 3000 mt for 2002 and 2003.

In 2001 shrimp prices dropped sharply due to large quantities of small shrimp in the Newfoundland and Labrador inshore fishery. This resulted in voluntary closures or greatly reduced fishing effort in the Newfoundland, Gulf of St. Lawrence and eastern Scotian Shelf fisheries during the summer. There were no closures on the Scotian Shelf in 2002. In 2003 effort on the Scotian Shelf decreased considerably during the summer to avoid soft shrimp.

Since 1999 the Newfoundland-Labrador, Gulf of St. Lawrence, Scotian Shelf shrimp stocks have been assessed using the “traffic light” method (Koeller et al. 2000b, Mohn et al. 2001). The organisation of this report is based on this multiple indicator diagnostic approach, with the “Methods” and “Results and Discussion” sections for individual indicators grouped under headings representing "characteristics", in the order they are presented in the summary. The sections on each indicator in “Methods” provide the methods used to calculate the indicators, and describe their relevance to the characteristic they represent. In Results and Discussion, the indicators always represent summary data for the entire area, i.e. all SFAs combined, according to the current practice of managing the fishery as one stock. The indicator series used in the analysis is given as an uncaptioned figure directly after the indicator heading. In addition to the indicator time series themselves, their sections in Results and Discussion include data which support trends seen in the summarized data. These data are given as numbered and captioned figures and tables at the end of the document. For example, individual SFA data often replicate the indicator trends and thus substantiate them. Supporting data may be entirely different from the main indicator, for example: catch rates in the shrimp trap fishery are given to support the apparent increasing shrimp aggregation shown by the survey and CPUE data; anecdotal reports of large numbers of 1-year old shrimp found on Cape Breton beaches in 2002 support survey data indicating a strong 2001 year class, etc. This additional information may be used in the interpretation associated with any change that is given in the Results and Discussion, but it is not used in the summary traffic light ‘scores’. It should be noted in any case that such scoring is not at this point intended to be translated directly into management action, for example in the form of rules directly linked to summary scores. The “traffic light” is currently seen simply as a tool for displaying, summarising and synthesizing a large number of relevant yet disparate data sources into a consensus opinion on the health of the stock and the management action required to achieve stated objectives.

The shrimp fishing areas on the Scotian Shelf are shown in Figure 1. Table 1 provides basic catch statistics for the fishery since 1980 and Table 2 gives licensing information for the recent period covered under sharing agreements between the Scotia Fundy and Gulf fleets and a multi-year (1998-2002) Integrated Management Plan which includes provisions for temporary licences during favourable periods. Although this management plan expired in 2002 and negotiations for a renewed agreement have not been successful to date, the 2003 fishery essentially operated under its provisions. Note that from 1995-1998 the experimental trap fishery was not under quota management except for a 500 mt precautionary ‘cap’, and so the total catch exceeded the TAC due to the trap fishery catch. When the trap fishery in Chedebucto Bay was made permanent in 1998 a trap quota was set at 10% of the total TAC e.g. 500 tons of the 5000 mt TAC was initially allocated to trappers in 1998. Any uncaught portion of the initial trap quota was reallocated to the mobile fleet. This reallocation has tended to be late in the year and some fishers were unable to take advantage of the additional quota, hence the catch has been lower than the TAC since 1998, including a shortfall of 232 mt in 2001. Note also that the trap quota reallocation has been based on projected catches which were not achieved during some years.

METHODS AND MATERIALS

Traffic light Indicators

Default boundaries between traffic lights for individual indicators i.e. transition from green to yellow and from yellow to red were taken as the 0.66 and 0.33 percentiles, respectively, of the data in the series unless an increase was considered bad for stock health, in which case these were reversed. Note that for commercial catch per unit effort series the « polarity » of the default boundary should be considered with other indicators for certain years. Clearly, the increase in the two commercial CPUE series, coupled with increased aggregation and decreased survey abundance, indicated that the increase in the two commercial CPUE series in the most recent years should now be viewed as a negative development. However, traffic lights were not changed from the default in this document.

ABUNDANCE

Research Vessel Abundance Index

A ninth industry-funded trawl survey, incorporating a mixed stratified random - fixed station design, was conducted in June 2003. Survey design and station selection methods were similar to previous surveys completed in 1995-2002: fishing depths >100 fathoms, randomly selected stations in strata 13 and 15; fixed stations in strata 14 due to the difficulty in finding trawlable bottom; 30 minute tow length; 2.5 knot vessel speed. Stations in Strata 17 (inshore) were selected randomly at all depths having a bottom type identified as La Have clay on Atlantic Geosciences Centre surficial geology maps. The 2003 survey was completed by MV *All Seven* fishing the standard survey trawl (Gourock #1126 2-bridle shrimp trawl and #9 Bison doors). Measurements of trawl wing spread and headline height were made throughout most survey sets using NETMINDER sensors. The trawl was fitted with a 'belly bag' attached to the footrope and belly between the two middle rollers. All O-group *P. borealis* were removed from the catch, frozen and returned to the laboratory for analysis.

Catches were standardised to the target distance travelled at 2.5 knots for 30 min (1.25 nm). Biomass/population estimates and bootstrapped confidence intervals (Smith 1997) were calculated using the product of the average measured wing spread (17.4 m) of the survey trawl and the distance travelled during a standard survey set (1.25nm) as the standard unit area swept by each set (Halliday and Koeller 1981).

The co-operative DFO-industry series begun in 1995 used several different vessel-trawl combinations requiring comparative fishing experiments in 1996 and 1997 (Koeller et al 1997). In order to obtain a wider range of indicator values for this series it was extended to include DFO surveys conducted in 1982-88, a period of low abundance in contrast to the present period of high abundance. There were no comparative fishing experiments which allowed direct intercalibration of the two survey series, consequently catch data were only adjusted by the difference in the wing spreads of the trawls used. Wing spreads were based on the performance specifications of the trawl used for the earlier series, and from actual measurements for the latter series. However, it is probable that the trawl used during the recent series was more efficient in catching shrimp than during the 1982-88 series, consequently the large differences in catch rates between the two series may be exaggerated and should be interpreted cautiously. Since the cod end mesh size in both series was the same (40 mm) size selectivities of the two series were assumed to be the same.

Gulf Vessels Catch Per Unit Effort

A CPUE index for Gulf based vessels, which have the longest history in the fishery, is calculated as a simple unstandardised mean catch/hour fished for all vessels fishing in any given year. These are the largest vessels in the fleet and although the participating vessels (and fishing gear) have changed considerably, they have always been >65 ft in length, compared to the <65ft Nova Scotia fleet. This is an important time series because it spans periods of both high and low abundance of the stock. However, since fishing methods and gear have probably improved over the years it is likely that the differences in CPUEs between the period of low abundance (pre-1993) and the recent high abundances are exaggerated and should be interpreted cautiously.

Commercial trawler Standardized Catch Per Unit Effort

The standardised CPUE series for 1993-2003 uses data from April-July inclusive, the months when the majority of the TAC was caught, for 17 vessels that have fished for at least 6 of the 11 yr series. A multiple regression analysis was conducted with year, month, area and vessel as categorical components. Predicted values and confidence limits for a reference vessel, month and area were then calculated for each year according to Gavaris (1980). Data on catch rates were obtained from fishers' logs required from all participants and provided by DFO Maritimes Region Statistics Branch.

An increase in this and the preceeding indicator does not necessarily indicate increasing stock abundance, especially when coupled with a decrease in the area fished (see commercial fishing area below) or a decrease in the dispersion of the stock (see research vessel coefficient of variation below).

Research Vessel Coefficient of Variation

A measure of dispersion was calculated from survey data as the simple coefficients of variation of all survey sets for each year i.e. the standard deviation of all catches divided by the overall average weight caught. An increase in this statistic indicates increased aggregation of shrimp on the grounds.

Commercial fishing area

A measure of dispersion was also calculated from commercial data as the number of area units (1 minute square rectangles) having an average catch of >250kg per hour. With catch rates continuing to increase but survey estimates decreasing, a decrease in this index would indicate a concentration of the remaining stock in smaller areas.

PRODUCTION

Commercial counts

Data on the count per pound by vessels landing in Canso, N.S. were collected by the main shrimp buyer in the area (Seafreeze Ltd.) who uses this information to determine landed value to fishers based on a pre-arranged pricing scale. Counts from each vessel's landings were made by taking a random sample of shrimp from 10 separate bags from each fishing day. An annual average count was calculated from all daily counts from all vessels. Counts were not available from the buyer in 2003 and were obtained using individual shrimp weights obtained from DFO commercial samples. Counts from both sources show similar trends for the period where comparable data are available (1994-2002).

This indicator is a measure of the ease or difficulty fishers are having in "making the count" i.e. getting the best price for their shrimp. An increase in the count could indicate that a) recruitment is good and there are so many small shrimp it is difficult to avoid them or b) the population of larger shrimp is declining, or a combination of a) and b). Consequently this indicator must be considered with others including abundance indices of the different age categories. Counts change considerably during the fishing season, usually starting relatively high, decreasing to a minimum in July, and increasing thereafter, probably due to size specific changes in vertical and\or geographic distribution associated with changes in day length.

RV Age 2 abundance

A random sample of 10 pounds of shrimp (approximately 500 individuals) was collected from the catch of each survey set and frozen for detailed analysis, i.e. carapace length, individual weight, sex and egg developmental stage. Survey population estimates (numbers) were determined by the swept area method using individual set length frequencies and weights caught, and a length-weight relationship. Survey population estimates by age group were then estimated by separating total population at length estimates from the swept area method into inferred age groups using modal analysis (MIX, MacDonald and Pitcher 1979).

The Age 2 abundance indicator is currently the only estimate of recruitment to the population with a longer time series. However, these shrimp are not caught efficiently by the standard survey trawl and research is being conducted on improving early recruitment estimates using a beam trawl during special juvenile surveys and by placing small-meshed bags on the standard survey trawl during the regular June survey. Some preliminary results from this special sampling gear are given as support for results obtained from the main survey trawl samples e.g. the apparent strength of the 2001 year class.

RV Age 4 abundance

Age 4 abundance is calculated as per Age 2 above, from survey population at length estimates (swept area) and modal analysis.

On the Scotian Shelf most Age 4 shrimp are in their final year as males. This group represents shrimp that will breed during the survey year and will change sex the following year. They also comprise the bulk of the catch for the next year, and so are a measure of recruitment to the fishery.

RV spawning stock biomass (Females)

The spawning stock biomass (SSB), or total weight of females in the population was calculated with the swept area method from the weight of females in each set, determined by identifying females and their lengths in the detailed sample, the total catch weight, and a length weight relationship. This estimate includes shrimp that were in the transition stage during the survey. On the Scotian Shelf transitional shrimp are seldom found during the fall i.e. all transitionals complete sex change during the summer and extrude eggs during the late summer.

A stock recruitment relationship has not been identified for the Scotian Shelf, although it has been for some other pandalid stocks, e.g. the Gulf of Maine, California-Oregon. On the Scotian Shelf a large population increase began during the late 1980s when SSBs were about 4,300mt, about 30% of those found in the late 1990s. It would therefore be prudent not to let the SSB decrease below 4,300, however, the stock increase at these SSB levels occurred at specific favourable environmental conditions and negligible fishing mortalities. Consequently, this SSB should be considered as the very lowest the stock should be allowed to decline. Coincidently, this is nearly identical to the default 0.33 percentile used as the red limit for all indicators, including SSB.

SSB by itself is not a measure of reproductive capacity. Since fecundity is directly related to size, it should be considered in conjunction with the average size at sex transition, maximum size and amount of fishing during the ovigerous period.

Average size at sex transition (L_t)

Shrimp in transition from the male to the female are identified by the pleopod development method and their average size is calculated as overall weighted average from all sets in the survey.

Koeller et al (in press 2003) show that size at transition is related to growth rate. It is hypothesised that an increase in growth rate, due to density dependant effects or temperature increases (Koeller et al 2000), results in decreases in the size at transition, maximum size and fecundity, followed by a population decline.

Average maximum size (L_{max})

Average annual maximum size is calculated as the average of the sample maximum sizes.

The ratio of size at sex transition to maximum size was hypothesized to be constant (invariant) at about 0.8-0.9 for all stocks of *P. borealis* (Charnov and Skulladotir 2000). This rule was shown to apply to the Scotian Shelf (Koeller et al., in press 2003). Therefore maximum size attained in the population is another measure of growth rate, however, because maximum potential size appears to be set at the time of sex transition L_{max} is probably more indicative of growth several years previously.

Predation

A predation index is calculated as the mean catch/set for all groundfish species from the summer groundfish survey for strata which encompass the shrimp holes i.e. 443-445 and 459.

This is considered an index of natural mortality. Groundfish abundance is negatively correlated with shrimp abundance on the Scotian Shelf and in most other shrimp fishing areas.

FISHING EFFECTS

Exploitation Index

An overall index of exploitation rate is calculated as the total catch weight divided by the RV biomass estimated using the swept area method.

The RV biomass estimate has been shown to be underestimated by as much as 25% because of lack of coverage in shallow areas surrounding the shrimp holes, consequently the exploitation rate is probably overestimated. This indicator is therefore considered an index of exploitation.

Female Exploitation Index

This is calculated as the estimated weight of females in the catch divided by the weight of females in the population from the survey i.e. the spawning stock biomass (SSB). The industry-funded port sampling program which began in 1995 continued in 2003 and allows determination of the catch composition by developmental stage and size from detailed analyses as per survey samples. Samples were collected throughout the fishery in all areas from all fleet components including vessels <65' LOA landing mainly in Canso and vessels >65' LOA landing mainly in Arichat. The number of samples per month and area was allocated in proportion to weight caught. Catch at length was determined from a weighted length frequency and a length-weight relationship.

Female exploitation is of interest because the shrimp fishery is selective for the larger females. It can be considered one measure of the impact of fishing on the reproductive potential of the stock.

Proportion of females in catch

The proportion of females in the catch by weight to the total catch weight is calculated from commercial samples which identify females, lengths and individual weights as per survey samples.

A decrease in this indicator could indicate a decrease in the number of larger shrimp in the population due to fishing removals and an increased reliance on smaller animals i.e. possible growth overfishing and/or recruitment overfishing. It should be interpreted cautiously and in combination with other indicators, since it could also indicate good recruitment conditions and difficulty in avoiding young shrimp.

Average size of females in catch

This indicator is calculated as the overall annual average size of females from port samples collected throughout the fishery.

A decrease in this indicator could indicate a decrease in the number of larger shrimp in the population due to fishing removals and an increased reliance on smaller animals i.e. possible growth overfishing and/or recruitment overfishing.

Fishing during ovigerous period

This is calculated as the percent of the total catch caught during August-March, the usual period when females are carrying eggs.

Since most eggs are laid by a single age class (i.e. age 5) enough females must escape the fishery to prevent recruitment overfishing. The fishery has generally concentrated in the non-ovigerous period with most of the catch taken during May-July, however as TACs increased an increasing amount of the catch has been taken during the ovigerous period. This indicator should be included with spawning stock biomass and size at transition when considering the population’s overall reproductive capacity, since their negative effects are probably cumulative. For example, the minimum SSB of 4,300 mentioned above would be considerably less in terms of effective reproductive capacity if most is taken before egg hatching.

ECOSYSTEM

RV bottom temperatures

This index is calculated from July groundfish survey data as the mean bottom temperatures at depths >100 m on the eastern Scotian Shelf. Temperatures were recorded with expendable bathythermographs (XBTs) or reversing thermometers. Beginning in 1995 near bottom temperatures were recorded throughout each shrimp survey set with a continuous temperature recorder (Vemco Ltd.) attached to the headline of the trawl. Trends in these data generally agree with groundfish survey data, however the latter is used in the analysis because of the longer time series.

It is hypothesized that warmer water temperatures have a negative influence on shrimp populations because of the decreased fecundity associated with increased growth rates, decreased size at transition and decreased maximum size as described above.

July SST

Sea surface temperatures are calculated as average temperatures within defined rectangles encompassing the shrimp holes, using the Oceans Sciences and Biological Oceanography Section SST databases.

Negative correlations between SSTs and lagged population estimates are common for the southern *P. borealis* stocks, including the Scotian Shelf, and are presumably also related to growth and fecundity, possibly because of diurnal migrations to near surface water.

RV Capelin abundance

This is calculated as the average catch/tow in numbers from the July groundfish survey in strata 443-445 and 459.

Capelin are the most common bycatch species both in the Scotian Shelf shrimp fishery and the June shrimp survey. Here they have been shown to increase in abundance during cold periods which are also favourable to shrimp and so can be considered a sympatric species (e.g. Frank 1994). It can therefore be considered an indicator of conditions favourable to the production of shrimp.

RV Cod recruitment

This is calculated as the average number of <30cm fish/tow from the July groundfish survey in strata 443-445 and 459.

Cod abundance is generally negatively correlated with shrimp abundance for most north Atlantic stocks, including the Scotian Shelf. This is probably partly due to large scale environmental influences such as temperature which appear to have opposite effects on cod and shrimp population dynamics, as well as a trophic effect of cod predation on shrimp. Restricting this indicator to juvenile cod may therefore decrease the influence of predation and have some predictive value for shrimp abundance.

RV Greenland halibut recruitment

This is calculated as the average number of <30cm fish/tow from the July groundfish survey in strata 443-445 and 459.

Greenland halibut is a cold water species whose abundance is often positively correlated to shrimp abundance. However, it should be noted that Greenland halibut are also known predators of shrimp, and so an increase in this indicator is both positive and negative. Restricting this indicator to juvenile halibut may decrease the influence of predation and have some predictive value for shrimp abundance.

RV Snow crab recruitment

This is the stratified random abundance index for pre-recruits calculated for the snow crab assessment from annual crab surveys in southeastern Nova Scotia. Like Greenland halibut and capelin, snow crab is a cold water species that is often positively correlated with shrimp abundance.

Traffic Light Summary

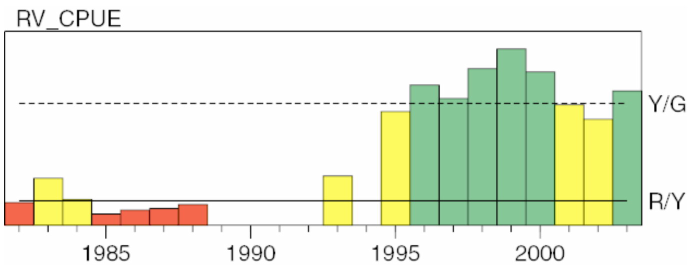
Individual traffic light indicators were summarised using the "direct" method. Each indicator is given a value according to its colour i.e. green = 3, yellow = 2 and red = 1, and a simple average is calculated. This average is assigned a "summary colour" according to limits determined by the probability distribution of possible outcomes i.e. the limits between red, yellow and green are set so that each of the three summary colours has an equal probability of being assigned in a random set of individual indicator colours/values. The RAP review committee has emphasised that the summary is difficult to interpret and should not be a consideration in the advice, because issues such as weighting of indicators and harvest rules associated with any particular summary have not been resolved.

RESULTS AND DISCUSSION

Input data for the traffic light analysis are given in Table 3. These data are graphed in the uncaptioned figures immediately following the indicator headings in the section below.

ABUNDANCE

Research Vessel Abundance Index



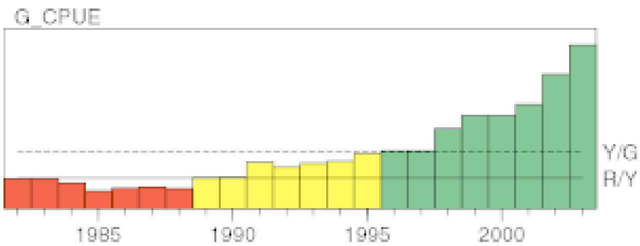
The stratified survey estimate for 2003 increased for the first time after three consecutive decreases beginning in 1999. The estimates for 3 of the 4 strata also improved from the low values of 2002 (Figure 2). Stratum 14 (Misaine Hole) remained near the high level attained in 2001. The total biomass estimate increased from 20,773 mt in 2002 to 28,130 mt in 2003

It is noteworthy that Stratum 13 has often registered the lowest estimates of all 4 areas throughout the series and has decreased along with the others despite only relatively light fishing in this area. Conversely, abundance in Stratum 14 has increased or remained high throughout the recent survey period despite relatively heavy fishing there (Figure 2, Table 1,6).

The earlier survey period (1982-1988) used a different trawl than the more recent period and there were no direct intercalibrations (comparative fishing experiments) between the two series. The series were intercalibrated using a factor which only incorporated the difference in trawl wing spreads. Shrimp trawl efficiencies can vary significantly even between shrimp trawls with nearly identical wing spreads (Koeller et al 1997). In addition to being significantly smaller, the trawl used during the earlier series did not use a sorting grate to exclude bycatch and had a much lower headline height compared to the modern shrimp trawls used in the more recent series. It is therefore likely that the trawl used during the 1982-1988 surveys was less efficient at catching shrimp than the trawl used since 1993. It follows that the differences in catch rates between the two series are probably exaggerated. Individual set data for the 2003 survey are presented in Table 4.

Interpretation: The stock decline observed from 1999 to 2002 in 3 of the 4 areas appears to have stabilized, apparently at a higher level than the low abundances of the 1980s. Abundance in the fourth area (Misaine Hole, Stratum 14) has stabilized at a high level despite relatively heavy fishing here.

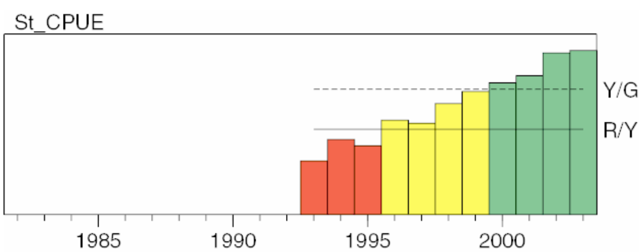
Gulf Vessels Catch Per Unit Effort



The un-standardised Gulf Vessel CPUE has continued to show an increasing trend since the 1980s.

Interpretation: In light of changes in other indicators, i.e. the recent decrease in the survey estimate and evidence of increased aggregation from both survey and fishery indicators of dispersion, the increase in this indicator is probably due to higher densities in these aggregations, not to overall increased abundance.

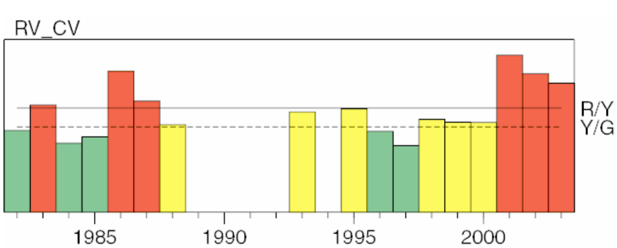
Commercial trawler standardized catch per unit effort



The standardized CPUE series has increased every year except for two of the 11 year series. The parallel trend in both survey and CPUE series broke down from 1999-2002 with the survey showing decreases and CPUE showing increases (Figure 3A). Unstandardized CPUEs are shown in Figure 3B by area.

Interpretation: As with the Gulf CPUE series the increase in this indicator during the last few years is probably due to better catches in denser but geographically smaller shrimp aggregations and not to an increase in abundance.

Research vessel coefficient of variation

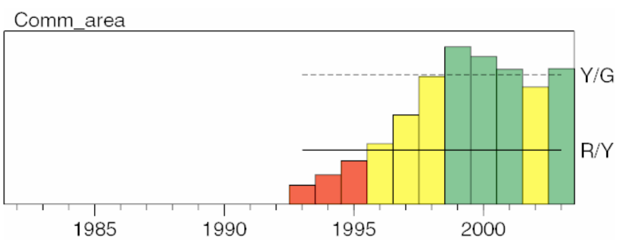


The overall measure of dispersion has been relatively high for the last few years. However, CVs in Stratum 14 have remained low due to uniformly high catches and abundance in this area

(Figure 4A). Except for 2003, CVs in Stratum 15 have also remained relatively low due to uniform low abundance. However, one previous assessment (2001) showed that relatively small but dense concentrations were missed by the random selection in this area, consequently CVs in this area would have been higher had more stations been allocated to it, at least in that year. Consequently, the overall impression is of increased aggregation in all areas except Area 14. The overall index is in agreement with the dispersion index from fishery data and indicates increased aggregation of shrimp (Figure 4B, 6). The distribution of catches from all surveys shown in Figure 5 in relation to bottom temperatures also shows a greater variation in catches during 2001-2003 compared to earlier years. Note that 1999 and 2000 were particularly warm over much of the shrimp grounds, although large incursions of warm water from the Scotian Slope and the Laurentian Channel also occurred in 2001-2003. Such incursions could be responsible for the increased aggregation observed in some areas and years. Whatever the cause, increased aggregation would make the population more vulnerable to fishing and so is considered a negative development.

Interpretation: shrimp aggregated more than usual during 2001-2003 in all areas except Stratum 14, and in part this may account for the increases in the CPUE indicators and the discrepancy between commercial and survey indices in recent years.

Commercial fishing area

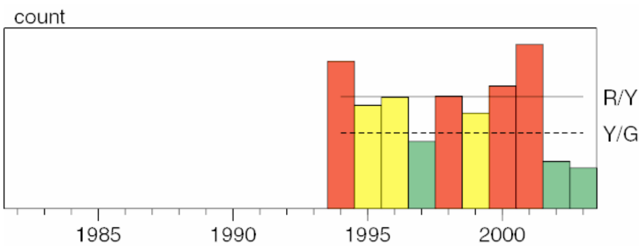


The area with commercial catch rates >250kg/hour increased since the beginning of the series until 1999, when it began to decrease. The area with catch rates >150kg began to decrease in 1997, while the interval with the highest catch rates (>450) has continued to increase (Figure 6). There is some suggestion that this may be reversing in the last year or two. This pattern is consistent with a concentration of the resource in a smaller area and appears to be a longer term phenomenon. The pattern is broadly similar in each of the areas. Increased aggregation was noted by fishers in formal interviews conducted in 2000 and 2001 (Koeller et al 2002) and in anecdotal information for 2002 and 2003. Figure 7 shows changes in the distribution of effort since 1995, including a concentration of effort in SFA 14, (particularly the « 107 », « Big » and « H » holes) and decreasing effort in other SFAs and the inshore during 2001-2003. This is consistent with the change in catch distribution by SFA (Table 1), survey abundances by area (Figure2) , and survey dispersion (Figure 4A). Overall CVs from commercial catches (Figure 4B) generally agree with the survey CVs in Figure 4A although there are discrepancies at the area level, which may be attributed to the non-random distribution of fishing effort. For example, Area 13 shows consistently low CVs in commercial data. This area is fished mainly by the Gulf fleet which may be more experienced in fishing dense concentrations consistently, resulting in lower CVs. Increases in trap catch rates directly off Canso (Figure 8) in recent years imply increased movement of the large, mainly female shrimp which constitute most of the catch into shallow nearshore areas within the inshore area, consistent with increased aggregation of shrimp shown by survey and commercial data, fisher interviews, and the shallower distribution of offshore fishing effort (Koeller et al 2002).

Interpretation: Scotian Shelf shrimp have been aggregating in smaller areas of higher density possibly in response to unfavourable environmental conditions (temperature distribution) and\or the aggregation of similar sized animals as the population accumulates in the larger sizes. There are indications that this pattern may be reversing.

PRODUCTION

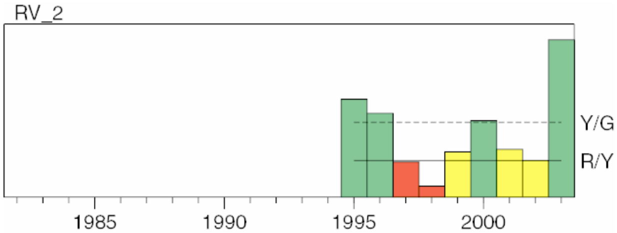
Commercial counts



Note that the polarity of this indicator is ambiguous unless it is considered in relation to other indicators, especially recruitment and catch composition by size i.e. a higher count could be « bad » or « good » depending on whether it is primarily caused by decreasing abundance of larger shrimp or increasing recruitment, respectively. Also, the variation around this parameter is large (Figure 9) despite large sample sizes (>1000) and there is a seasonal component, with counts decreasing to a minimum in July and increasing thereafter (Koeller et al 2002). Since recruitment has been lower in recent years, the increase in counts (numbers/pound) since 1997 are probably due to removal of accumulated large animals in the population. In 2002 and 2003 this trend was reversed, due partly to continued maturation of several strong year classes followed by poorer recruitment, but also probably to the concentration of the larger animals targeted by the fishery. The carapace length composition of the catch (Figure 10) has changed considerably over the last few years and indicates that there were proportionally fewer shrimp caught at the largest sizes in recent years, in agreement with fisher's observations. The decreased counts are reflected in the catch composition by the relatively large numbers of shrimp between 23-27 mm (mostly females) caught in 2003-2003.

Interpretation: Commercial counts increased from 1997-2001 for the last few years due to a decrease in the number of very larger shrimp in the population. This indicator decreased in 2002-2003 due to continued lower recruitment, growth of the remaining shrimp from several large year classes, and aggregation of females on the fishing grounds.

RV abundance at age 2

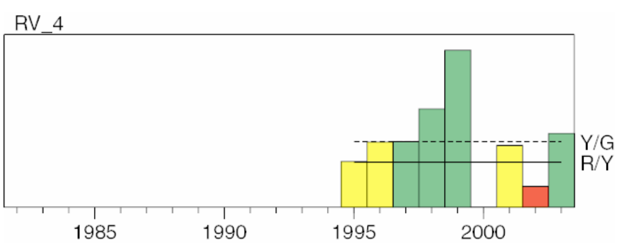


Age 2 abundance must be interpreted cautiously because these shrimp are not fully recruited to the survey gear and correlations between abundance at this age and later ages are not good (Figure 12b). Age 2 abundance (i.e. 2001 year-class in 2003) was the highest of the 9-year series. This substantiates observations on O-group shrimp made in 2002 from beam trawl (February) and « belly bag » (June 2002) samples that the 2001 year class is strong (Figure 11 and Koeller et al 2003). In addition, anecdotal information indicates large numbers of very small shrimp, probably from this year class, on southern Cape Breton beaches in 2002, a phenomenon not reported previously.

Survey population estimates at length are given in Figure 12. The year classes are identified in this figure as are the length frequencies for transitional + primiparous and the multiparous shrimp which usually represent separate year classes within the last "blended" mode. This clearly shows the shift toward larger and older shrimp in recent years due to lower recruitment and the maturation of the large 1993-95 year classes. Population estimates at length for each of the four survey strata given in Figure 13 for 2001-2002 show that relative year class strength varies considerably between areas but that the 2001 year class is relatively strong in all areas.

Interpretation: The 2001 year class appears to be strong. This suggests that recruitment is improving after a period of average or below average recruitment. If so, this could result in high biomasses when this year class changes sex in 2005.

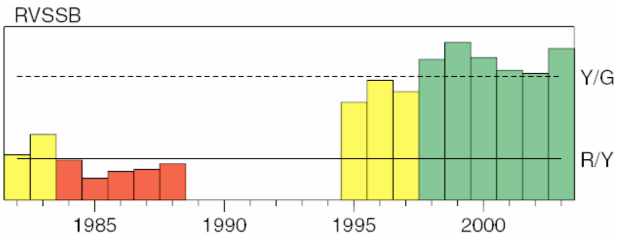
RV abundance at age 4



The abundance of age 4 shrimp (1999 year class) increased from the second lowest value of the 9 year series in 2002 to about average in 2003, suggesting that recruitment to the fishery should be reasonably good in 2004 (Table 5). Note that the abundance of the 1999 year class was below average at age 3 in 2002, but is above average in 2003. This indicates the unreliability of year class strength assessment at age 3 and younger from standard survey data alone. Note also that the regression between age 4 and 5+ abundance is dependant mainly on one point (1995 year class, Figure 12b).

Interpretation: The abundance of 4 year old shrimp that will provide the bulk of the catch in 2004 appears to be about average.

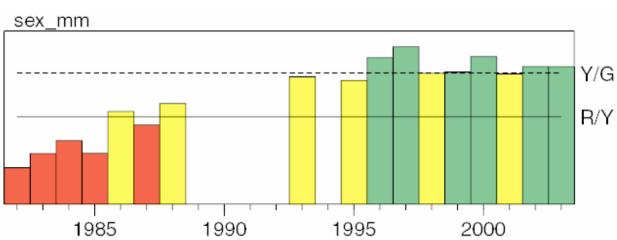
RV spawning stock biomass (Females)



Research vessel spawning stock biomass increased in 2003 to the second highest of the series. It continues to remain well above the low SSBs of the 1980s (average 4,272) when the population was increasing. It seems unlikely that the recent lower recruitments were due to overfishing of spawners. It should be noted that the earlier survey series did not include inshore sampling. Assuming that shrimp were as abundant inshore during the earlier period as they were during the latter, i.e. they contributed about 25% of the total biomass, this would increase the average SSB in the earlier period to about 5600 mt.

Interpretation: Spawning stock biomass remains well above the low levels of the 1980s when the population was increasing.

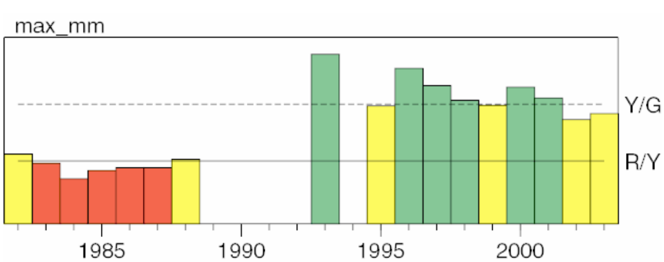
Average size at sex transition (L_t)



There has been no clear trend that would suggest increasing growth rates, and size at transition remains substantially higher than the period of faster growth during the 1980s. Annual changes are generally reflected in all regions (Figure 14A).

Interpretation: There has been no major change in growth rates in recent years.

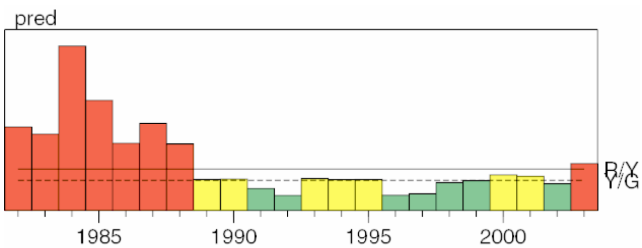
Average maximum size (L_{max})



Despite a suggestion of a decreasing trend since 1996 maximum size remains substantially higher than the period of faster growth during the 1980s. As with size at transition, annual changes are generally reflected in all regions (Figure 14B). The consistently smaller maximum sizes in area 13 are attributed to faster growth rates caused by higher temperatures in this area. The consistently lower abundances in this area may therefore be due to lower fecundities of the smaller animals.

Interpretation: Despite a slight increasing trend there has been no major change in growth rates in recent years.

Predation

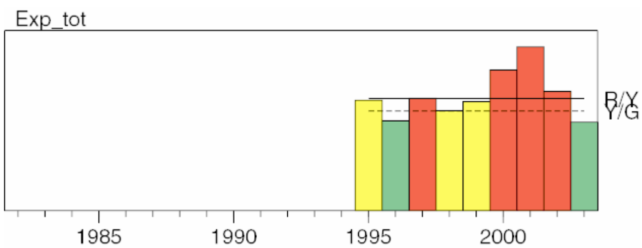


There has been a slight increasing trend in groundfish abundance in recent years, however, groundfish abundance remains well below the high levels during the 1980s when the shrimp population was low.

Interpretation: natural mortality due to predation may be increasing slightly but remains well below the high values of the 1980s that probably contributed to the low shrimp abundances during that period.

FISHING IMPACTS

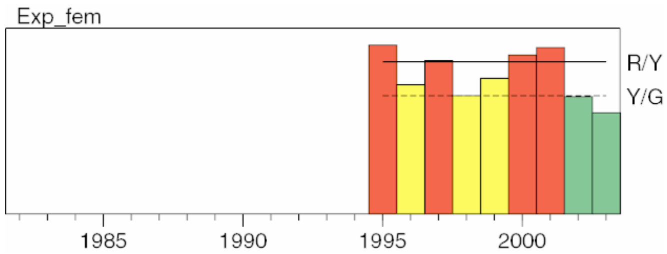
Exploitation Rate



Exploitation decreased again in 2003 to the lowest value in the series due mainly to the increase in survey abundance. Exploitation decreased in all areas except SFA 14 (Table 6). Despite concentration of effort in this area exploitation remained low relative to the high levels of the late 1990s. Exploitation in 2003 was lower in all size categories (Figure 10b).

Interpretation: The large decrease in TAC imposed in 2002 and maintained in 2003 appears to have stabilized exploitation rate well within acceptable levels.

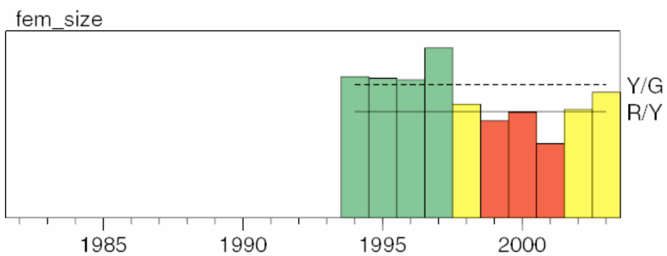
Female Exploitation Rate



Female exploitation decreased significantly in 2002 due to the decrease in TAC, and again in 2003 to the lowest value of the series. This is also reflected in the exploitation rate by size category (Figure 10b)

Interpretation: The decrease in TAC in 2002 has resulted in a decrease in the female exploitation rate.

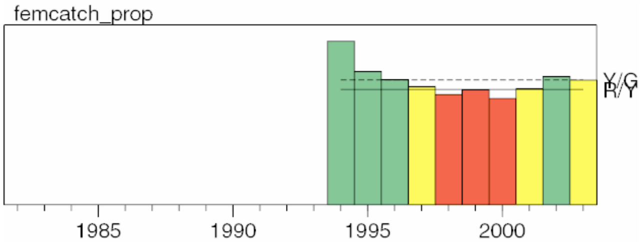
Mean size of females in catch



The average size of females in the catch decreased from the mid 1990s to 2001, but it has increased during the last two years.

Interpretation: The average size of females in the catch has decreased as the larger animals were selectively removed from the population by the fishery. Since fecundity is directly related to size this, in combination with other factors (fishing during the ovigerous period, increased female exploitation, size at sex change and maximum size), may have impacted the reproductive capacity of the population. This indicator increased in 2002-2003, as recruitment to the female fraction decreased and the remaining population grew.

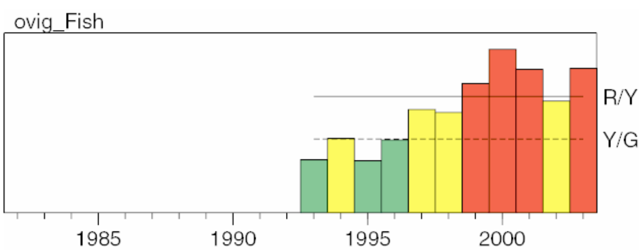
Proportion of females in catch



The proportion of females in the catch showed a decreasing trend from 1994 to 2000 but this indicator has increased in the last few years. The catch at length (Figure 10) has also showed a decrease in the proportion of the largest shrimp in the catch since sampling began in 1995.

Interpretation: the proportion of females in the catch decreased as the larger animals were selectively removed from the population by the fishery. Since fecundity is directly related to size this, in combination with other factors (fishing during the ovigerous period, increased female exploitation, size at sex change and maximum size), may have impacted the reproductive capacity of the population. Also, increasing exploitation of the smaller, non-female part of the population could have resulted in growth overfishing. This indicator has been increasing since 2000 as recruitment has been decreasing and the remaining population accumulates in the female fraction.

Fishing during ovigerous period

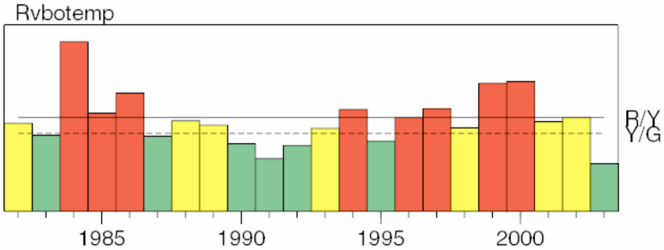


Fishing during the ovigerous period increased significantly from the early 1990s to a maximum in 2000 due to the longer time required to catch increasing TACs by a relatively small fleet of vessels, many of which are also engaged in other fisheries. In addition, quota transfers have occurred and many vessels fished several individual quotas, further extending the length of the season. This indicator decreased in 2002 as the lower TAC was again caught mainly during the non-ovigerous summer period. It increased in 2003 because of greatly decreased effort during the summer months to avoid soft shrimp.

Interpretation: Fishing during the ovigerous period may have impacted population reproductive potential in recent years by removing ovigerous females before their eggs have hatched. The decrease in the TAC appeared to have reduced this potential problem in 2002, but it resurfaced in 2003 due to unforeseen events in the fishery. This does not appear to be a problem at this time considering the relatively low female exploitation rate and high spawning stock biomass. It does not appear to be a longer term trend in fishing patterns.

ECOSYSTEM

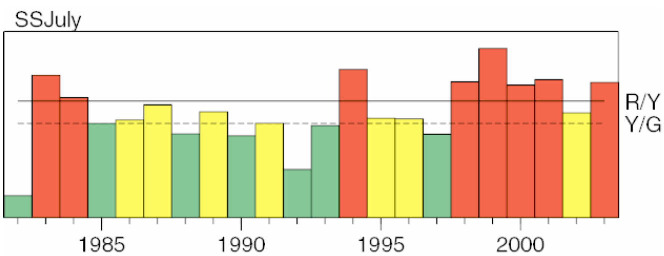
RV (groundfish survey) bottom temperatures



Bottom temperatures on the shrimp grounds have fluctuated during the groundfish survey time series but in general they decreased during the 1980s and increased during the 1990s, but with cooler conditions during the last three years. Temperatures from shrimp surveys by SFA generally show the same trends as data from groundfish surveys (Figure 15). Cooling during the most recent years appears to be a widespread phenomenon and has been noticed as far away as the Grand Banks.

Interpretation: decreasing bottom temperatures during the 1980s resulted in decreasing growth rates, and corresponding increases in size at transition, maximum size and fecundity. Increasing bottom temperatures during the 1990s have not yet resulted in significant increases in growth rates, probably due to density dependant effects.

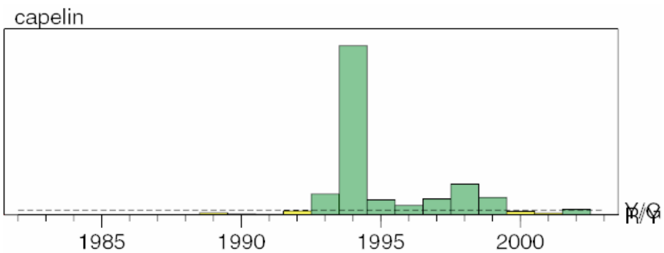
July SST



Surface temperatures are inversely related to shrimp abundance with a lag of 4-5 years. The below average temperatures prevalent during the late 1980s and early 1990s appear to have led to the high abundances in the mid to late 1990s. Surface temperatures have been relatively high during the 1990s.

Interpretation: the above average temperatures during the late 1990s could have lead to decreased abundances in the early part of the 2000s and may be associated with the decline observed since 2000.

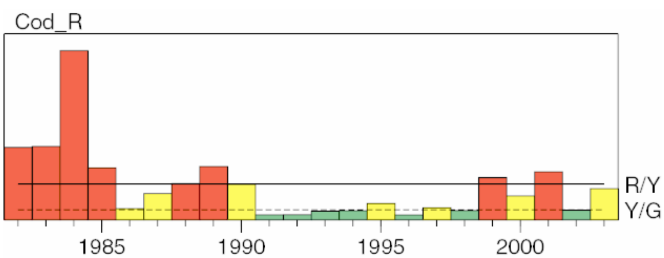
RV Capelin abundance



The capelin abundance index in the last three years has been lower than the relatively high values between 1993 to 1999.

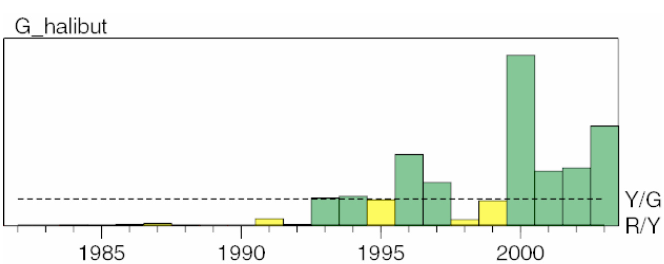
Interpretation: Conditions which resulted in high production of capelin and shrimp in the mid to late1990s may be changing to ones less favourable to these species.

Cod recruitment



Cod recruitment appears to have increased in recent years, but is still well below values seen in the 1980s.

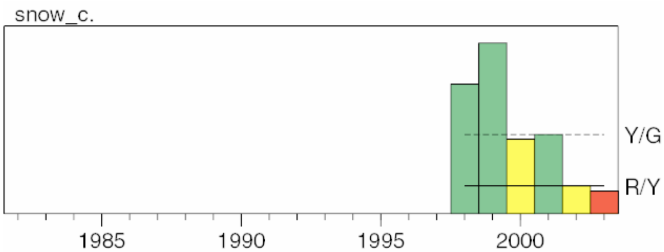
Interpretation: Environmental conditions may be marginally more favourable for cod (and less unfavourable for shrimp) during recent years.



Greenland halibut <30cm continue to be relatively abundant on the eastern Scotian Shelf although it was rarely found during the warmer period of the 1980s.

Interpretation: Conditions still appear to be favourable to Greenland halibut and probably also to shrimp.

Snow crab recruitment



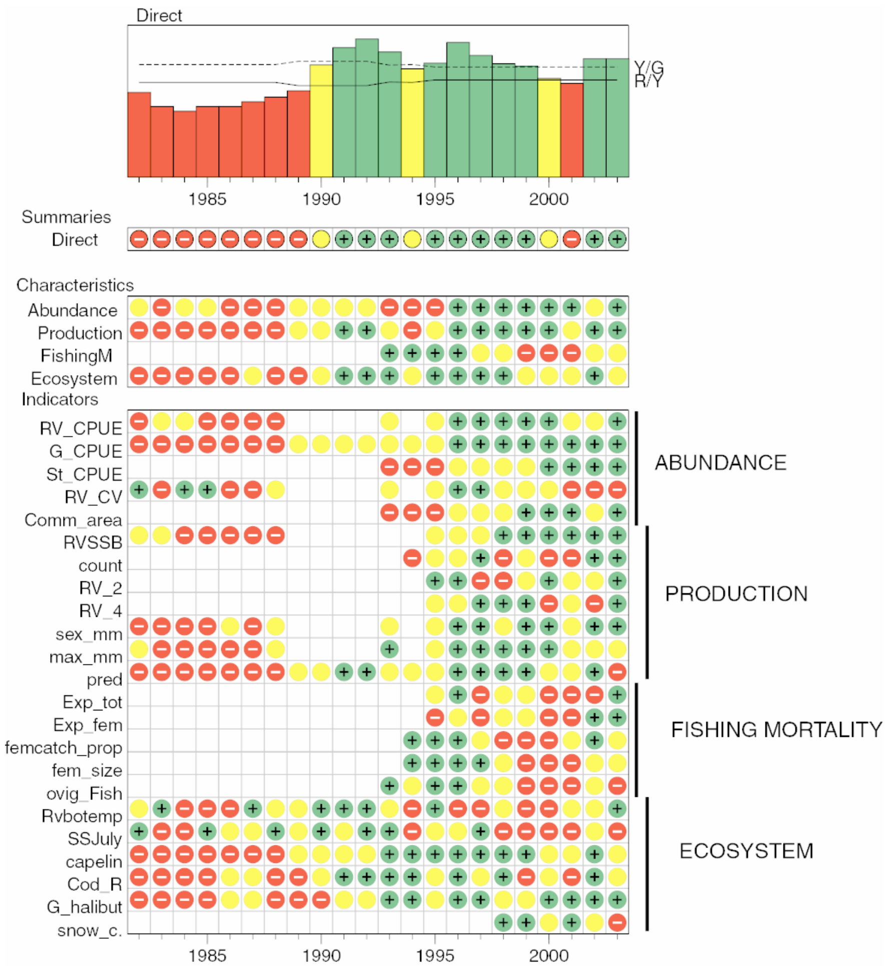
The pre-recruit index from the Cape Breton snow crab survey has been decreasing in recent years.

Interpretation: Environmental conditions favourable to snow crab and shrimp may be deteriorating.

Traffic Light summary

Note : the overall summary value is derived by a simple averaging process which does not account for complex interactions between indicators which may be occurring. Consequently, even the interpretation of individual indicators must be approached cautiously with regard to their relationship to stock health. Their placement within characteristics is also open to interpretation.

A second favourable overall summary occurred in 2003, following a 5 year declining trend that began in 1996. The improved values for the last 2 years include improvements to indicators in all 4 characteristics. With regard. to abundance, the green rating of this characteristic in recent years has been overly optimistic because the two commercial CPUE indices have not been considered indicative of abundance due to concentration of larger shrimp in denser patches, which the fishery continues to be able to access. Nevertheless, survey abundance, which is less subject to such complications, did increase in 2003 for the first time in three years. In addition, there are initial indications from both survey and commercial dispersion indices that the « bunching up » seen in the last few years is relaxing.



Production indicators are generally favourable, due to the continuing high spawning stock biomass and improvements in recruitment, both to the population (age 2) and the fishery (age 4). The decrease in counts (considered « good ») from industry data is primarily due to the recent decreased recruitment to the population and accumulation of the biomass of a number of relatively good year classes (increased recruitment to the fishable biomass) in the larger size categories. Fishing impact indicators improved dramatically after the TAC decrease in 2002. The proportion of the catch taken during the ovigerous period is the only indicator in this characteristic which is still red, but this is less of a concern under a lower TAC. In any case, it may be an isolated occurrence caused by decreased summer effort to avoid « soft shrimp » rather than a changing trend in fishing patterns. Ecosystem indicators have been ambivalent recently. Bottom temperatures decreased, while surface temperatures increased in 2003 although lower values for both these indicators are considered favourable for shrimp. The capelin abundance, cod recruitment and snow crab recruitment indicators were less favourable in 2003 while the Greenland halibut recruitment indicator continued to show a favourable value.

ACKNOWLEDGEMENTS

We thank the captain and crew of MV *All Seven* for conducting the 2003 survey. We also thank Mary Richardson, Mike Newell, Tony DeRoche, Calvin Pitcher, Buzz Roberts, Susan Blagdon and Hector Baldwin for obtaining count and/or commercial samples for analysis. Steve Smith provided statistical advice on bootstrap confidence intervals for survey data, and standardization of CPUEs.

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Table 1. TACs (trawls) and catches (trawls and traps) from the eastern Scotian Shelf shrimp fishery 1980-2002

	TAC		**Catch**					
	Trawl	**Trap**	**Trawl**				**Trap**	
			SFA					
			13	**14**	**15**	**Total**		**Total**
1980	5021		491	133	360	984		984
1981	-		418	26	10	454		454
1982	4200		316	52	201	569		569
1983	5800		483	15	512	1010		1010
1984	5700		600	10	318	928		928
1985	5560		118	-	15	133		133
1986	3800		126	-	-	126		126
1987	2140		148	4	-	152		152
1988	2580		75	6	1	82		82
1989	2580		91	2	-	93		93
1990	2580		90	14	-	104		104
[1]**1991**	2580		81	586	140	804		804
1992	2580		63	1181	606	1850		1850
[2]**1993**	2650		431	1279	317	2044		2044
[3]**1994**	3100		8	2656	410	3074		3074
1995	3170		168	2265	715	3148	27	3175
1996	3170		55	2299	817	3171	187	3358
1997	3600		570	2422	583	3574	222	3773
1998	3800		562	2014	1223	3800	131	3931
1999	4800	200	717	1521	2464	4702	149	4851
2000	5300	200	473	1822	2940	5235	201	5436
2001	4700	300	692	1298	2515	4505	263	4768
2002	2700	300	261	1553	885	2699	244	2943
[4]**2003**	2700	300	484	1912	604	2750	250	3000

[1] Nordmore separator grate introduced.

[2] overal TAC not caught because TAC for SFA 14 and 15 was exceeded.

[3]individual SFA TACs combined

[4] preliminary

Table 2. Number of active vessels and total licences (in brackets) for the eastern Scotian Shelf shrimp fishery.

	Trap	Trawl	
Year	**S-F[1]**	**S-F[2]**	**Gulf[3]**
1995	4	24(23)	6(23)
1996	9(17)	21(24)	6(23)
1997	10(17)	18(23)	6(23)
1998	15(26)	17(28)[4]	10(23)[5]
1999	15(22)	19(28)[4]	10(23)[5]
2000	12(21)	18(32)[6]	10(23)[5]
2001	10(28)	18(28)[4]	10(23)[5]
2002	10(14)[7]	15(23)	6(23)
2003	9(14)	14(23)	5(23)

[1] All but one active trap licences are vessels < 45'. These vessels are allocated 10% of the TAC, with the uncaught portion reallocated to the trawl fleet

[2] These vessels receive 75% of the trawl quota according to a Federal-Provincial agreement that expires December 31, 2002. Inactive NAFO 4X licences (15) not included in total ( ).

[3] All licences 65-100' LOA. Eligibility to fish in Scotia-Fundy for 25% of the trawl quota split under the Federal-Provincial agreement that expires December 31, 2002.

[4] temporary allocation divided among 5 vessels.

[5] temporary allocation divided among 4 vessels.

[6] temporary allocation divided among 9 licences.

[7] nine (9) licences were made permanent for 2002. The reduction in the total number of trap licences is due to cancellation of some non-active exploratory licences.

Table 3. Input data for traffic light analysis.

	RV_CPUE	G_CPUE	St_CPUE	RV_CV	Comm_area	RVSSB	count	RV_2	RV_4	sex_mm	Max_mm
1982	68.78	128.00	NAN	65.50	NAN	5040.65	NAN	NAN	NAN	21.72	28.24
1983	142.50	127.70	NAN	86.00	NAN	7323.05	NAN	NAN	NAN	22.11	28.03
1984	78.07	109.50	NAN	55.30	NAN	4460.96	NAN	NAN	NAN	22.46	27.69
1985	33.61	75.40	NAN	60.40	NAN	2417.71	NAN	NAN	NAN	22.11	27.87
1986	46.02	87.30	NAN	113.10	NAN	3187.87	NAN	NAN	NAN	23.26	27.94
1987	50.84	90.70	NAN	89.20	NAN	3424.46	NAN	NAN	NAN	22.89	27.94
1988	62.76	85.10	NAN	70.10	NAN	4047.02	NAN	NAN	NAN	23.48	28.12
1989	NAN	133.40	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
1990	NAN	134.50	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
1991	NAN	197.90	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
1992	NAN	176.30	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
1993	149.70	193.00	214.37	80.32	31.00	NAN	NAN	NAN	NAN	24.22	30.45
1994	NAN	202.40	300.89	NAN	48.00	NAN	58.79	NAN	NAN	NAN	NAN
1995	346.04	233.80	275.53	82.80	71.00	10912.15	57.71	358.5	875.92	24.11	29.31
1996	427.84	245.90	377.89	64.87	99.00	13368.38	57.91	307.3	1247.63	24.74	30.14
1997	386.00	245.50	365.34	53.45	146.00	12100.80	56.82	128.8	1257.47	25.04	29.76
1998	476.76	341.00	444.49	74.41	209.00	15707.48	57.93	39.89	1883.71	24.31	29.43
1999	536.80	396.00	493.11	72.19	258.00	17607.48	57.51	165.6	3010.18	24.35	29.32
2000	466.72	396.00	527.96	71.995	242.00	15893.36	58.18	280.3	0.0	24.77	29.72
2001	366.64	444.00	556.48	126.03	221.00	14475.58	59.21	174.9	1184.11	24.29	29.22
2002	322.8	572.00	647.19	111.15	192.00	14965.21	56.33	134.0	399.17	24.50	29.00
2003	408.83	697.09	657.52	103.51	222.00	16916.16	56.17	576.7	1411.07	24.49	29.14

	pred	Exp_tot	Exp_fem	F_prop	ovig_Fish	RVbtemp	SST July	capelin	Cod_R	G_Hal_R	Snow_R
1982	165.89	NAN	NAN	NAN	NAN	2.57	9.67	0	2.385	0	
1983	196.36	NAN	NAN	NAN	NAN	2.22	15.15	0	2.415	0	
1984	347.25	NAN	NAN	NAN	NAN	4.95	14.14	0	5.569	0.06	
1985	228.63	NAN	NAN	NAN	NAN	2.86	12.96	1.55	1.709	0.05	
1986	133.96	NAN	NAN	NAN	NAN	3.45	13.12	0.13	0.368	0.09	
1987	179.76	NAN	NAN	NAN	NAN	2.19	13.81	0.77	0.866	0.16	
1988	136.44	NAN	NAN	NAN	NAN	2.65	12.48	0.17	1.195	0.06	
1989	62.94	NAN	NAN	NAN	NAN	2.52	13.49	18.38	1.753	0	
1990	65.55	NAN	NAN	NAN	NAN	1.97	12.40	9.23	1.163	0	
1991	43.42	NAN	NAN	NAN	NAN	1.54	12.97	5.07	0.166	0.46	
1992	31.00	NAN	NAN	NAN	NAN	1.92	10.86	34.87	0.169	0.08	
1993	68.33	NAN	NAN	NAN	11.91	2.42	12.86	193.36	0.287	1.86	
1994	64.36	NAN	NAN	0.89	16.71	2.98	15.42	1563.8	0.30	1.98	
1995	65.45	13.33	21.04	0.72	11.69	2.05	13.20	138.61	0.536	1.74	
1996	32.04	10.86	16.11	0.68	16.37	2.74	13.17	87.53	0.161	4.78	
1997	36.21	13.57	19.08	0.64	23.23	3.00	12.47	146.6	0.396	2.91	
1998	59.61	12.08	14.73	0.60	22.58	2.44	14.89	284.30	0.307	0.41	267.8
1999	64.02	13.17	16.90	0.63	29.09	3.74	16.38	159.95	1.391	1.67	353.1
2000	69.96	17.00	19.79	0.58	36.81	3.79	14.70	32.38	0.787	11.44	153.9
2001	74.18	19.80	20.72	0.63	32.30	2.62	14.96	15.99	1.579	3.66	163.7
2002	63.25	14.41	14.62	0.70	25.15	2.74	13.44	49.85	0.316	3.88	57.52
2003	100.65	10.70	12.59	0.68	39.71	1.39	14.83	2.70	1.025	6.69	46.33

Table 4. Set statistics from DFO-idustry survey AS0301 conducted by MV All Seven June 4 - 18 2003. Bold set numbers indicate exploratory fishing sets, while Italics under wingspread indicate sets with poor or no readings from the trawl mensuration equipment and the use of survey averages in swept area estimates .

SET	SFA	DATE	LAT.	LONG.	SPEED (kts)	DIST. (n. m.)	WING. (m)	DEPTH (fth)	TEMP (°C)	RAW CATCH (kg)	stand. catch	DENSITY (gm/m^2 or m.t./km2)
1	15	4-Jun-03	45°05.22'	60°51.82'	2.5	1.27	*17.4*	107	2.0	2	2.2	0.1
2	15	4-Jun-03	45°00.57'	60°59.67'	2.5	1.27	*17.4*	106	3.8	1	1.3	0.0
3	15	4-Jun-03	44°55.14'	61°06.01'	2.5	1.27	*17.4*	105	3.7	1	0.7	0.0
4	15	4-Jun-03	44°53.14'	61°08.40'	2.5	1.27	*17.4*	105	3.8	11	11.2	0.3
5	15	5-Jun-03	44°54.99'	60°58.97'	2.5	1.27	*17.4*	119	4.0	18	17.4	0.4
6	15	5-Jun-03	44°47.25'	60°52.68'	2.4	1.27	*17.4*	134	4.5	797	784.9	19.5
7	15	5-Jun-03	44°49.06'	60°45.18'	2.6	1.27	*17.4*	144	3.5	170	167.0	4.1
8	15	5-Jun-03	44°45.67'	60°38.11'	2.3	1.27	*17.4*	129	2.9	103	100.9	2.5
9	15	5-Jun-03	44°48.24'	60°33.86'	2.3	1.27	*17.4*	147	3.0	134	132.2	3.3
10	15	5-Jun-03	44°55.37'	60°26.76'	2.4	1.27	*17.4*	135	1.4	165	162.5	4.0
11	15	5-Jun-03	44°52.12'	60°24.29'	2.4	1.27	*17.4*	125	1.5	244	240.6	6.0
12	15	5-Jun-03	44°49.02'	60°16.16'	2.4	1.27	*17.4*	165	1.5	175	171.9	4.3
13	15	5-Jun-03	44°41.93'	60°18.42'	2.5	1.27	*17.4*	149	1.5	15	14.3	0.4
14	17	6-Jun-03	45°22.59'	61°00.00'	2.3	1.27	*17.4*	58	0.7	117	115.6	2.9
15	17	7-Jun-03	45°30.69'	60°38.10'	2.5	1.27	*17.4*	74	1.3	356	350.5	8.7
16	17	7-Jun-03	45°29.91'	60°31.50'	2.4	1.27	*17.4*	94	1.6	675	664.3	16.5
17	17	7-Jun-03	45°27.08'	60°34.55'	2.6	1.27	17.0	99	1.6	328	330.4	8.2
18	17	7-Jun-03	45°27.62'	60°17.05'	2.5	1.27	17.3	96	2.0	148	146.4	3.6
19	17	7-Jun-03	45°32.68'	60°10.70'	2.5	1.27	16.6	231	2.2	48	49.1	1.2
20	17	7-Jun-03	45°35.91'	60°09.86'	2.5	1.27	17.0	79	1.5	0	0.0	0.0
21	17	8-Jun-03	45°19.03'	60°14.50'	2.5	1.27	17.6	111	2.1	334	324.9	8.1
22	17	8-Jun-03	45°21.94'	60°00.95'	2.4	1.27	16.6	102	2.5	201	207.8	5.2
23	17	8-Jun-03	45°23.50'	59°44.74'	2.5	1.27	16.4	80	2.2	5	4.7	0.1
24	17	8-Jun-03	45°29.01'	59°42.56'	2.4	1.27	16.1	78	2.7	3	3.4	0.1
25	17	8-Jun-03	45°27.39'	59°57.31'	2.4	1.27	17.6	96	2.6	60	58.7	1.5
26	17	8-Jun-03	45°30.07'	60°04.83'	2.4	1.27	16.2	94	2.3	5	4.8	0.1
27	17	8-Jun-03	45°33.84'	59°56.90'	2.4	1.27	17.1	91	2.5	1	0.9	0.0
28	17	8-Jun-03	45°39.11'	59°58.35'	2.4	1.27	17.3	86	1.8	0	0.0	0.0
29	15	9-Jun-03	44°42.90'	60°11.63'	2.5	1.27	18.1	116	2.3	283	267.4	6.6
30	14	9-Jun-03	44°41.89'	59°59.99'	2.5	1.27	17.6	123	2.0	364	354.0	8.8
31	14	9-Jun-03	44°47.30'	59°58.65'	2.6	1.27	17.7	137	1.9	575	556.5	13.8
32	14	9-Jun-03	44°53.72'	59°58.73'	2.6	1.27	18.1	105	2.1	44	41.2	1.0
33	14	9-Jun-03	44°51.99'	59°43.32'	2.4	1.27	18.0	123	1.6	323	307.3	7.6
34	14	9-Jun-03	44°42.16'	59°46.68'	2.6	1.27	17.6	142	1.9	123	120.1	3.0
35	14	10-Jun-03	44°43.99'	59°32.23'	2.6	1.27	18.1	117	1.6	240	227.5	5.6
36	14	10-Jun-03	44°49.26'	59°29.15'	2.6	1.27	17.8	135	1.3	752	723.1	18.0
37	14	10-Jun-03	44°47.78'	59°23.52'	2.5	1.27	17.6	150	1.2	587	570.7	14.2
38	14	10-Jun-03	44°48.77'	59°12.50'	2.6	1.27	17.9	126	0.4	577	552.0	13.7
39	14	10-Jun-03	44°48.55'	59°07.36'	2.4	1.27	17.8	131	0.4	376	361.4	9.0
40	14	10-Jun-03	44°41.57'	59°01.96'	2.5	1.27	17.8	138	0.4	127	121.8	3.0
41	14	10-Jun-03	44°46.68'	58°54.55'	2.5	1.27	17.8	149	0.5	250	240.9	6.0

42	14	10-Jun-03	44°47.76'	58°39.32'	2.6	1.27	17.4	142	0.8	321	316.1	7.8
43	14	10-Jun-03	44°51.11'	58°34.86'	2.4	1.27	18.0	125	0.8	262	249.4	6.2
44	14	10-Jun-03	44°54.67'	58°43.70'	2.5	1.27	18.3	153	1.1	56	52.6	1.3
45	13	14-Jun-03	45°35.72'	58°24.04'	2.5	1.27	17.4	153	2.9	163	160.7	4.0
46	13	14-Jun-03	45°38.27'	58°18.72'	2.4	1.27	16.9	205	3.0	33	33.6	0.8
47	13	14-Jun-03	45°38.36'	58°12.10'	2.6	1.27	18.0	124	2.9	55	52.2	1.3
48	13	14-Jun-03	45°41.72'	58°26.76'	2.5	1.27	16.2	212	3.3	46	48.9	1.2
49	13	14-Jun-03	45°41.16'	58°41.36'	2.5	1.27	16.4	124	3.8	122	127.9	3.2
50	13	14-Jun-03	45°45.18'	58°38.82'	2.5	1.27	16.3	148	4.3	133	139.6	3.5
51	13	14-Jun-03	45°44.61'	58°42.86'	2.4	1.27	16.6	146	4.2	280	288.7	7.2
52	13	14-Jun-03	45°43.01'	58°54.84'	2.5	1.27	16.9	125	4.0	5	4.6	0.1
53	13	14-Jun-03	45°39.15'	58°59.44'	2.6	1.27	17.0	137	3.8	98	99.2	2.5
54	13	14-Jun-03	45°40.33'	59°03.43'	2.5	1.27	17.3	150	4.0	269	266.7	6.6
55	13	14-Jun-03	45°40.29'	59°06.54'	2.4	1.27	17.1	125	3.5	203	203.5	5.1
56	13	17-Jun-03	45°48.89'	59°01.81'	2.5	1.27	17.9	109	3.4	38	36.0	0.9
57	13	17-Jun-03	45°47.87'	58°46.91'	2.3	1.27	18.1	148	4.3	498	470.8	11.7
58	13	17-Jun-03	45°51.81'	58°46.49'	2.4	1.27	17.4	122	4.0	7	6.7	0.2
59	13	17-Jun-03	45°51.46'	58°36.57'	2.5	1.27	18.3	146	4.3	737	689.8	17.1
60	13	17-Jun-03	46°05.49'	58°41.88'	2.3	1.27	17.4	121	5.4	0	0.0	0.0
61	13	17-Jun-03	46°12.54'	58°48.89'	2.3	1.27	17.6	155	6.0	8	7.9	0.2
62	13	17-Jun-03	46°21.52'	58°56.74'	2.5	1.27	17.3	178	5.9	8	8.1	0.2
63	13	17-Jun-03	46°25.50'	58°58.28'	2.4	1.27	16.6	194	5.7	11	11.2	0.3
64	13	17-Jun-03	46°26.19'	59°05.35'	2.5	1.27	18.5	157	6.0	19	17.6	0.4
65	13	18-Jun-03	46°31.95'	59°11.52'	2.3	1.27	18.1	184	5.8	20	19.3	0.5
66	13	18-Jun-03	46°31.80'	59°18.57'	2.5	1.27	18.2	146	6.0	26	24.3	0.6
67	13	18-Jun-03	46°30.37'	59°21.83'	2.7	1.27	18.2	97	3.6	0	0.0	0.0
68	13	18-Jun-03	46°29.99'	59°18.71'	2.7	1.27	17.5	141	6.0	10	9.8	0.2
69	13	18-Jun-03	46°28.65'	59°16.16'	2.6	1.27	18.1	127	5.1	3	3.0	0.1

Table 5. Minimum survey population numbers at age with proportions at each age from the population at length estimates determined with MIX. Numbers x 10-6.

	95	96	97	98	99	00	01	02	03	Ave.
2	359	307	129	40	166	280	175	134	577	241
3	1,046	276	1,159	785	27	757	362	383	292	565
4	876	1,248	1,257	1,884	3,010	0	1184	399	1,411	1,252
5+	1,702	2,162	1,539	2,047	1,952	3,374	2,110	1,847	1,618	2,039
	3,983	3,993	4,084	4,755	5,155	4,412	3831	2,763	3,897	4,097

Table 6. Survey biomasses, commercial shrimp catches and exploitation rates (catch/biomass) by SFA (13-15, offshore part), and the inshore area (17), 1995-2003.

		1995	1996	1997	1998	1999	2000	2001	2002	2003
	13	4837	6838	5920	7187	9517	5919	4089	3114	7047
	14	9067	12094	9471	11278	11039	9544	12325	12020	12035
BIOMASS(mt)	**15**	5299	6610	4736	4548	7806	7213	2073	2766	3751
	17	4415	3663	6220	9530	8262	9183	6541	2872	5296
	total	**23620**	**29206**	**26349**	**32545**	**36625**	**31860**	**25038**	**20773**	**28130**
	13	168	55	570	514	612	301	588	254	406
	14	2265	2299	2422	2012	1503	2009	1616	1553	1810
CATCH(mt)	**15**	715	817	583	618	589	1609	1132	265	242
	17	0	0	0	787	2121	1498	1629	873	542
	total	**3148**	**3171**	**3575**	**3930**	**4825**	**5417**	**4965**	**2945**	**3000**
	13	3.5	0.8	9.6	7.1	6.4	5.1	14.4	8.2	5.8
	14	25.0	19.0	25.6	17.8	13.6	21.0	13.1	12.9	15.0
EXPLOITATION(%)	**15**	13.5	12.4	12.3	13.6	7.5	22.3	54.6	9.6	6.5
	17	0.0	0.0	0.0	8.3	25.7	16.3	24.9	30.4	10.2
	total	**13.3**	**10.9**	**13.6**	**12.1**	**13.2**	**17.0**	**19.8**	**14.2**	**10.7**

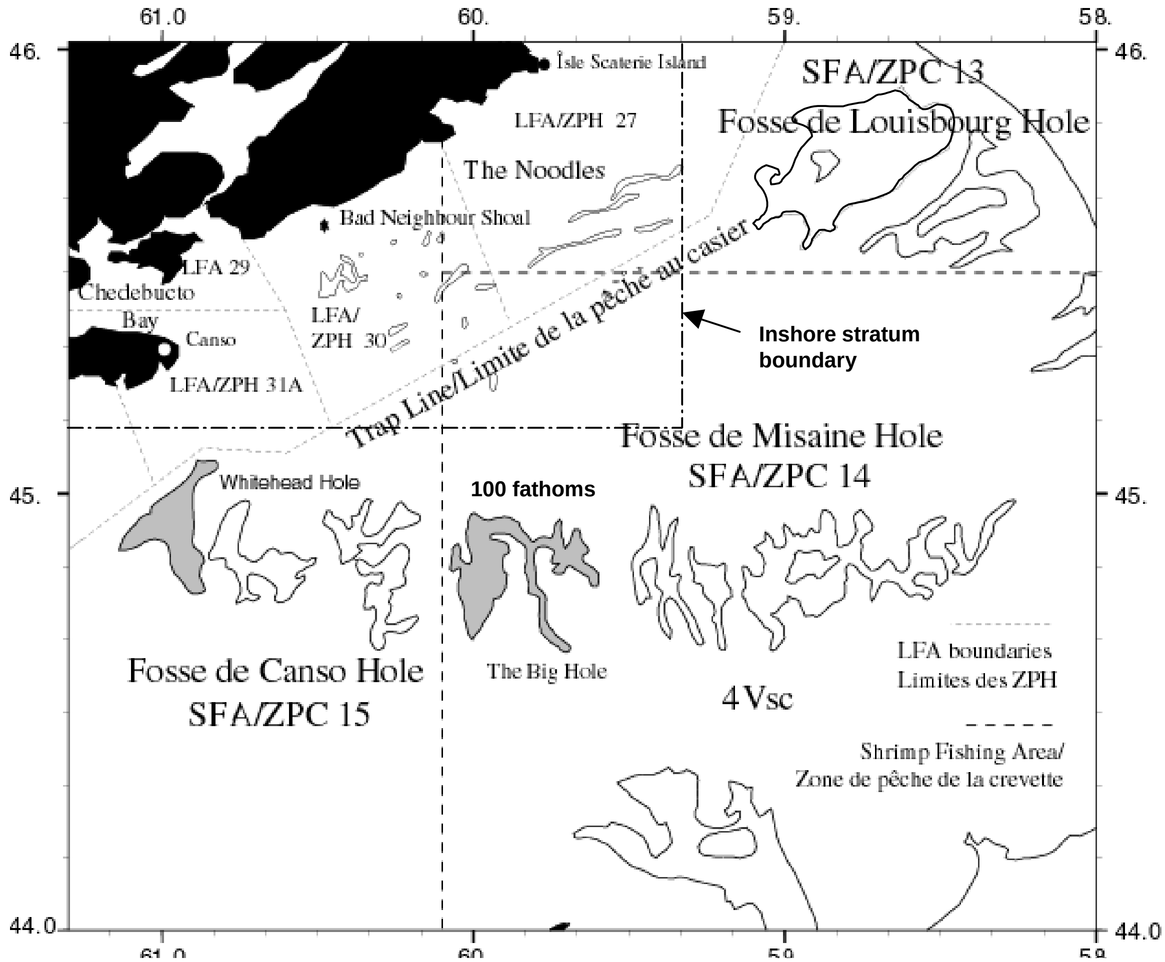


Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. The lobster Fishing Areas (LFAs) used to allocate shrimp trap licences, and the shrimp trap line are also shown. Trappers are prohibited from fishing seaward of this line. Another line (not shown) prohibits trawlers from fishing inside Chedebucto Bay during the trapping season (fall to spring). Note the distinction between SFAs used to report catches and survey strata defined by the 100 fathom contour (except the inshore stratum)

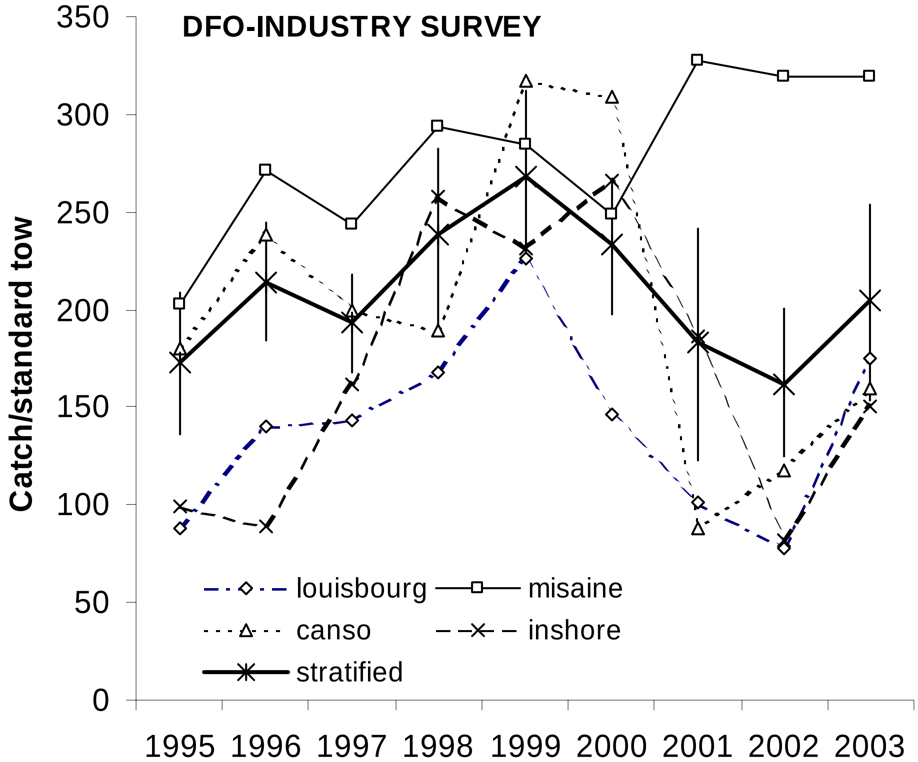


Figure 2. Stratified catch/standard tow for DFO-industry co-operative surveys 1995-2003 and unstratified estimates for the individual strata, which approximately correspond to the main shrimp holes and SFAs. Stratum 13 is Louisbourg Hole and SFA 13; Stratum 14 - Misaine Holes and SFA 14; Stratum 15 - Canso Holes and the offshore part of SFA 15. The Inshore, or Stratum 17, is comprised of inshore parts of SFA 13-15.

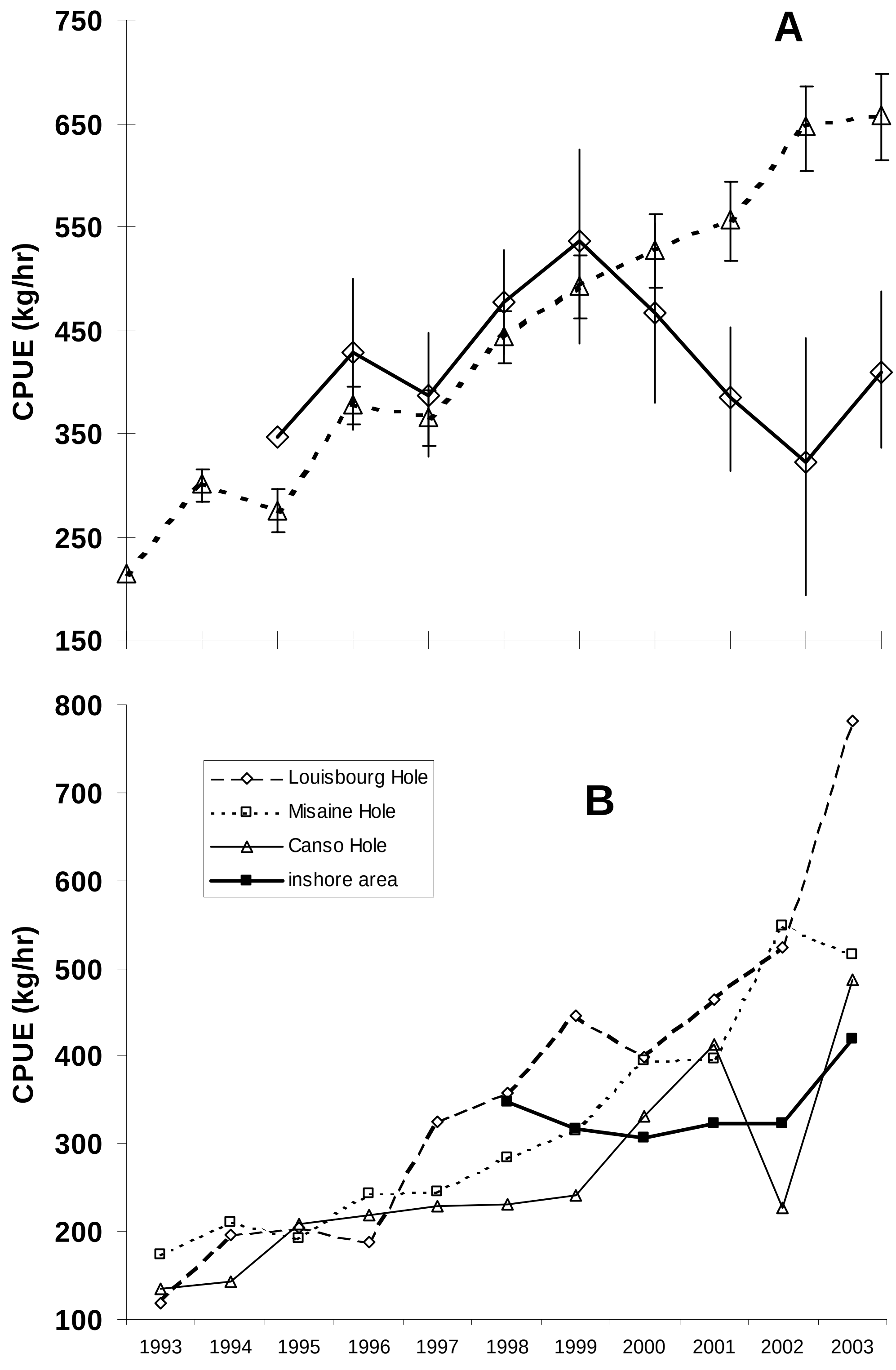


Figure 3. A - Survey stratified estimate and standardised CPUE with 95% confidence intervals, and B - unstandardised commercial CPUE for each fishing area. Note that SFA15 includes the inshore, but the latter is also shown separately since fishing began there in 1998.

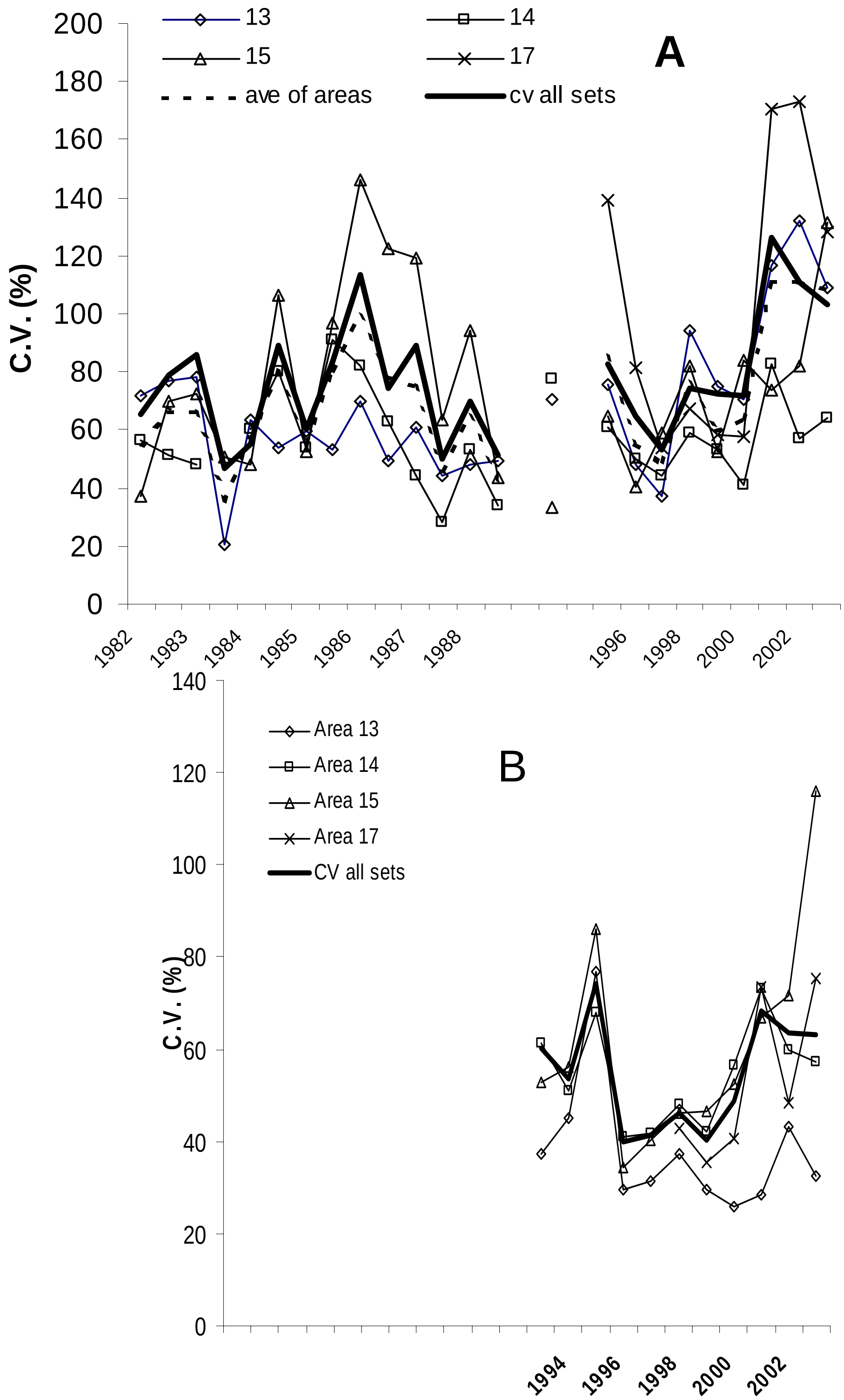


Figure 4. A. Coefficients of variation (C.V.) for individual shrimp fishing areas from shrimp surveys. Note that the earlier survey series has two values per year, one for the spring and one for the fall survey. B. CVs from the commercial trawl fishery

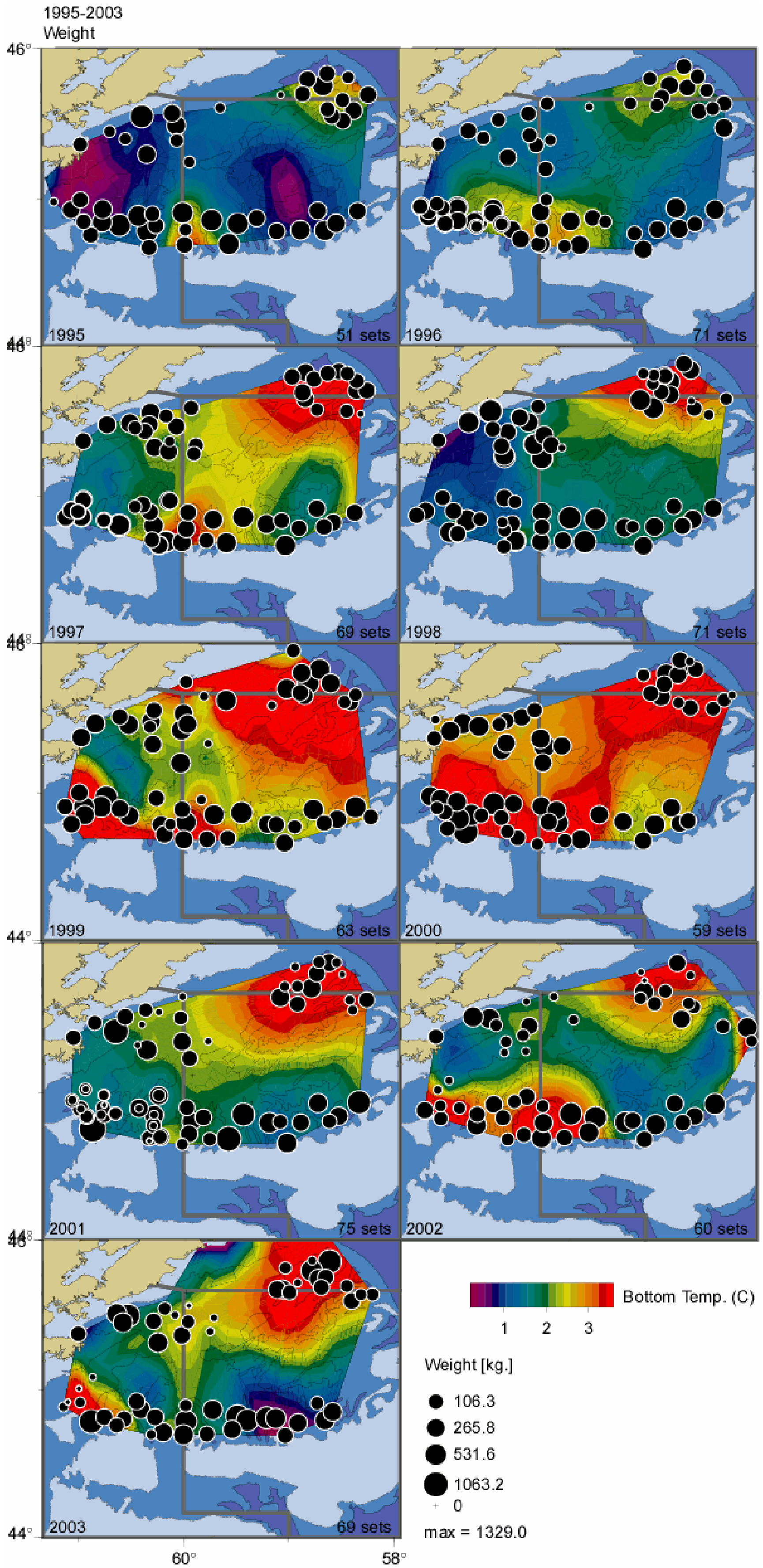
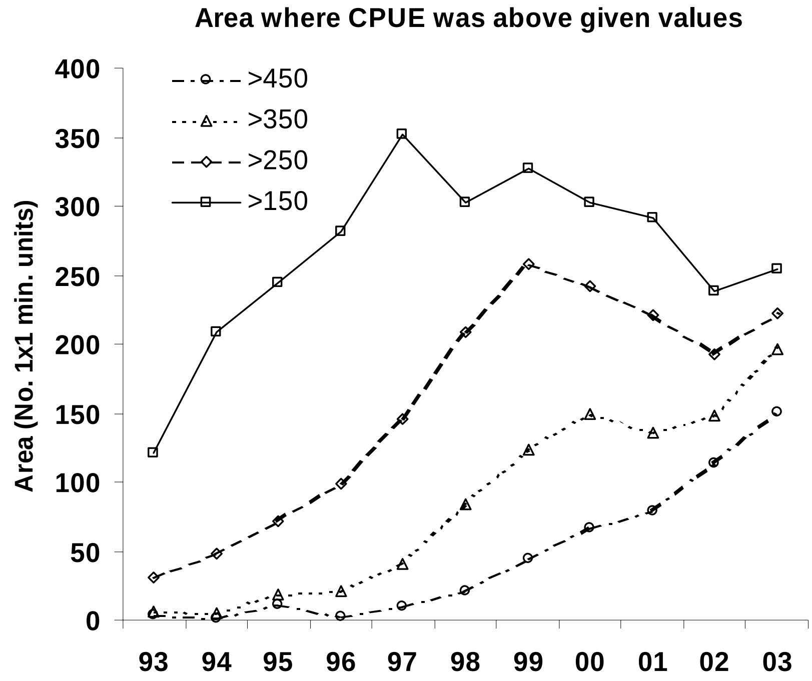


Figure 5. Distribution of catches and bottom temperatures from DFO-industry surveys 1995-01.



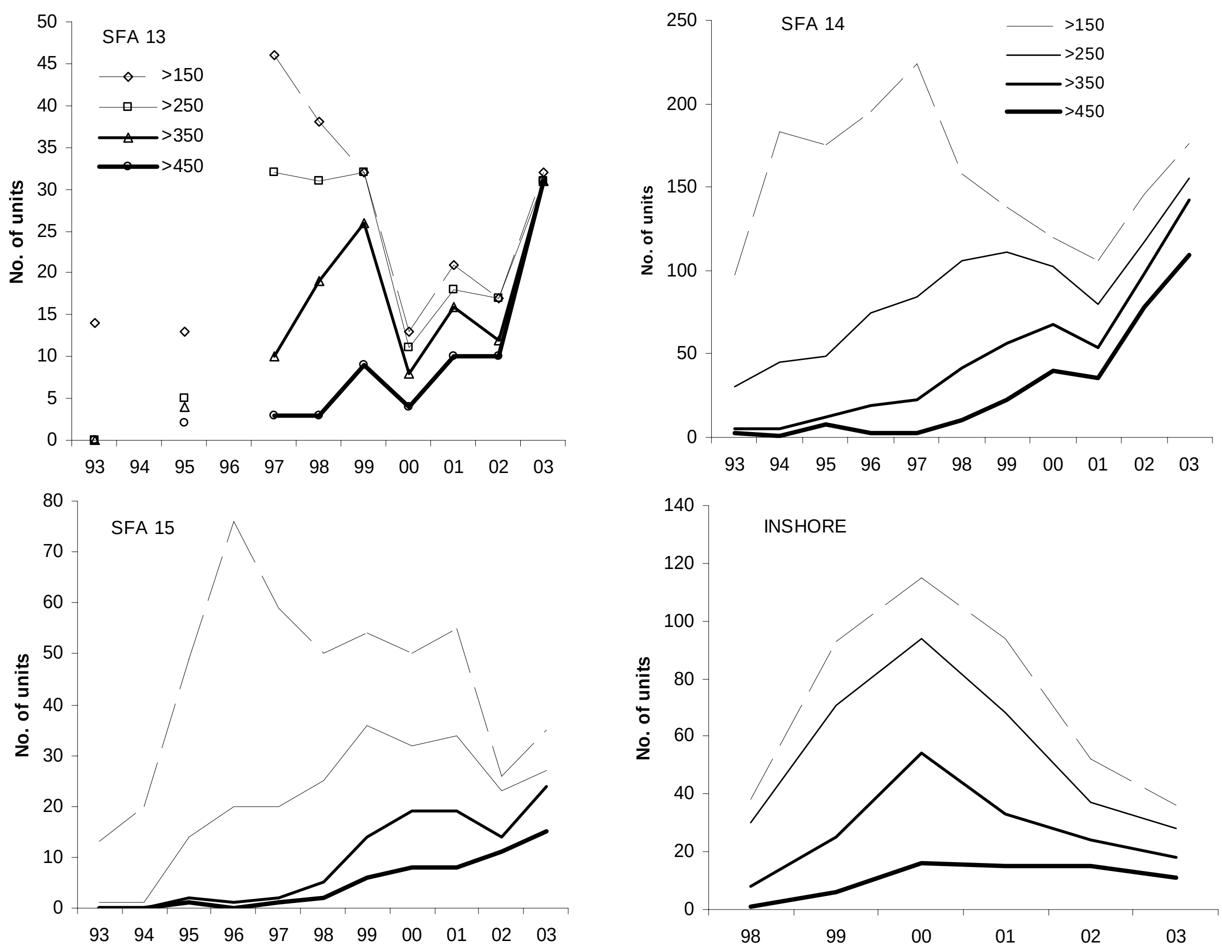


Figure 6. Number of 1 minute square unit areas fished by the shrimp fleet with mean catch rates above the values specified in the legend. Top figure is all areas combined.

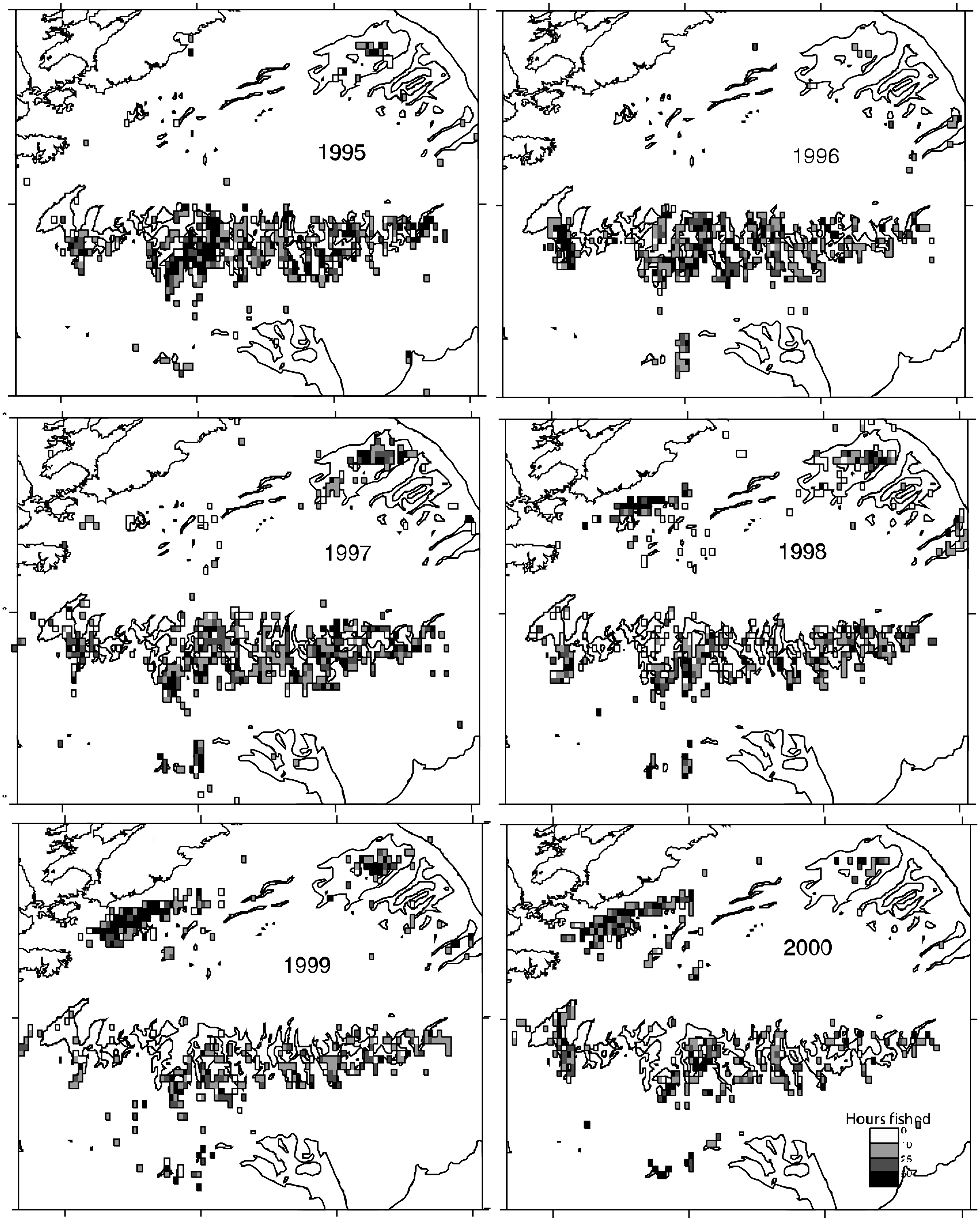


Figure 7. Annual effort by trawlers 1995-2003, cumulative by one minute squares.

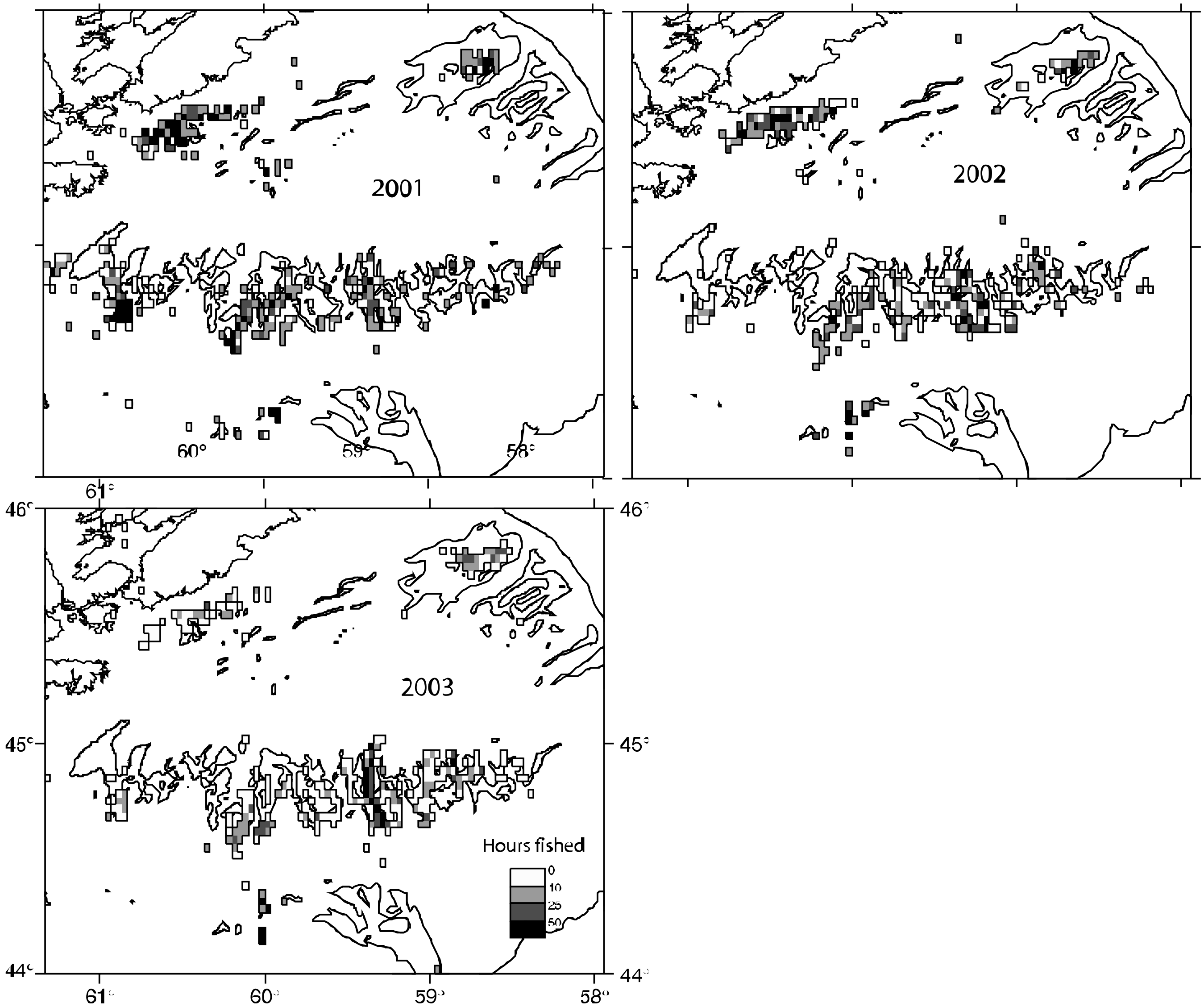


Figure 7. Annual effort by trawlers 1995-2003, cumulative by one minute squares.

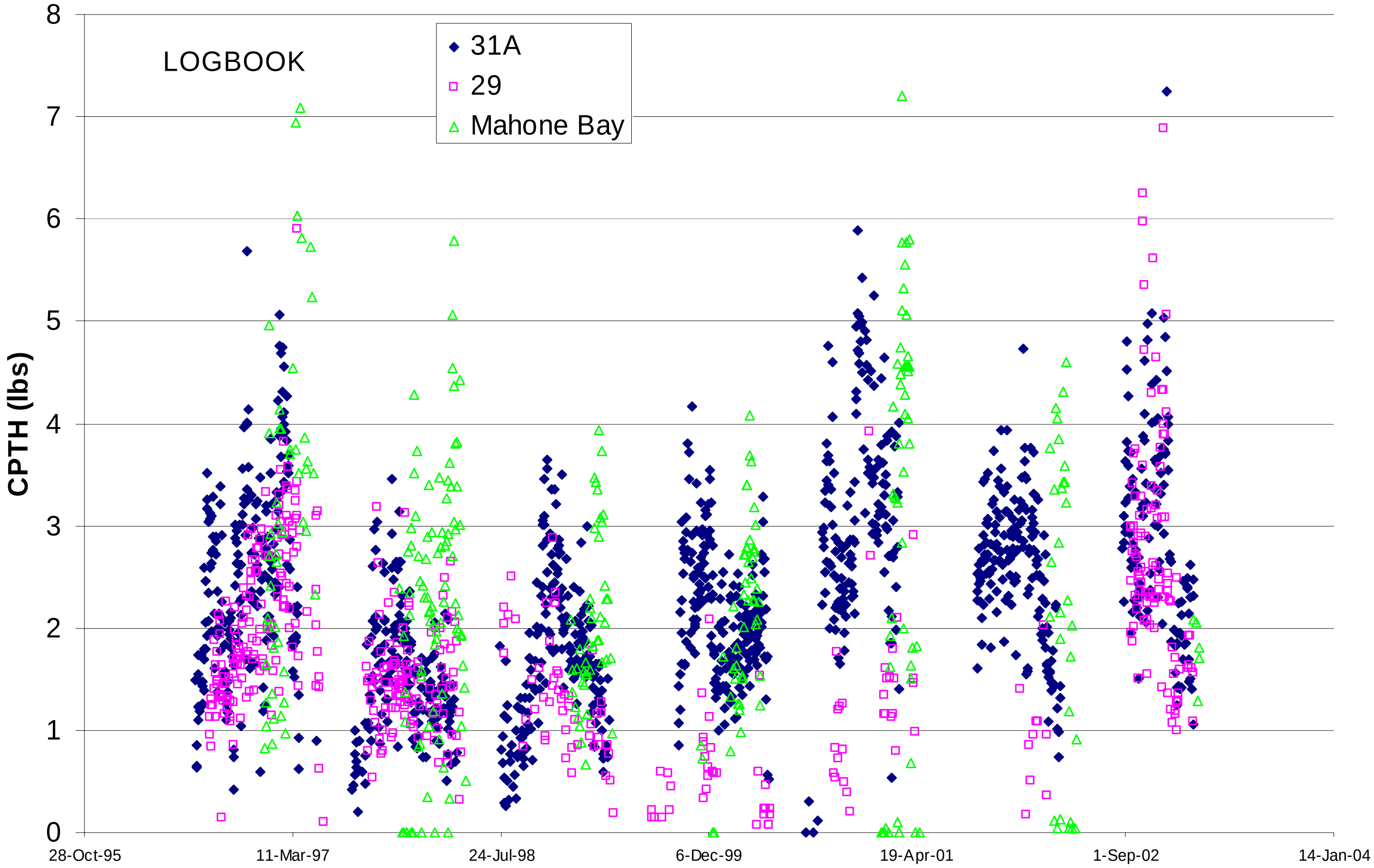


Figure 8. Mean daily catches per trap haul for the shrimp trap fishery including the north (31A) and the south (29) shores of Chedebucto Bay.

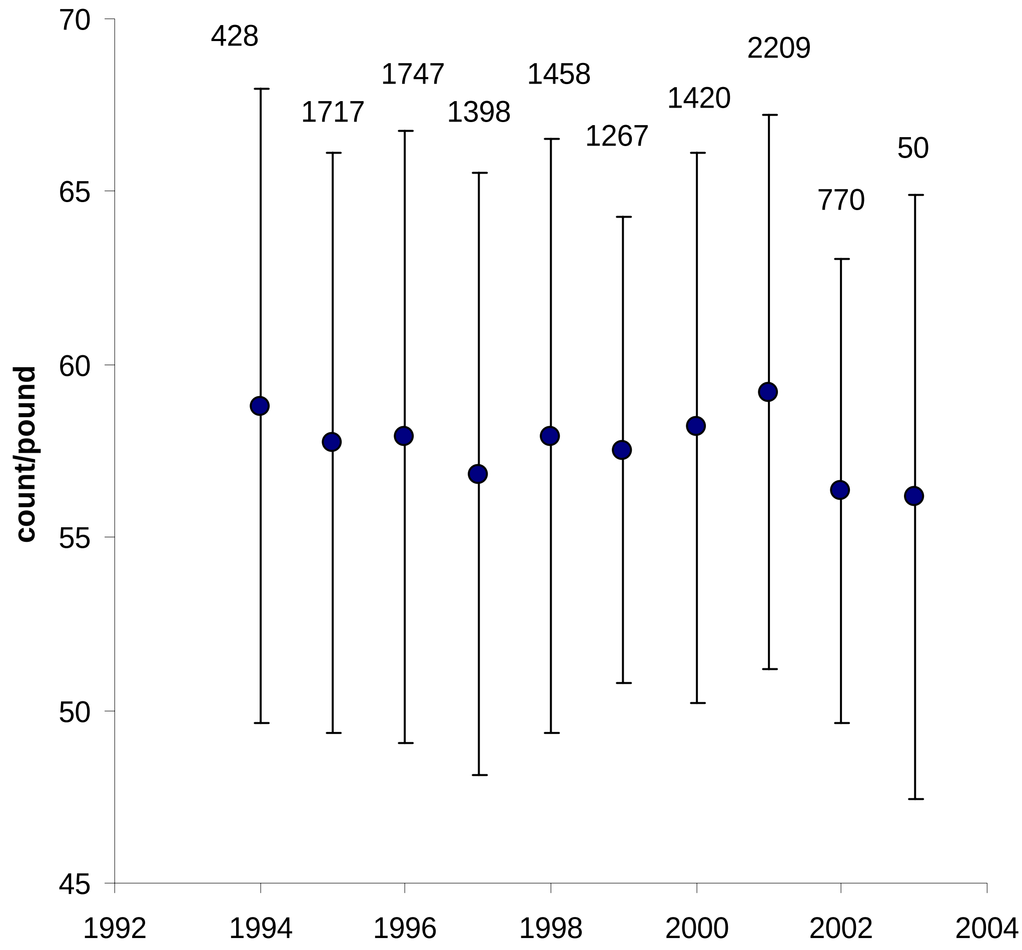


Figure 9. Annual mean commercial shrimp counts per pound for vessels landing in Canso. The bars represent 1 standard deviation and the numbers above each bar are the number of observations. Data are from Seafreeze Ltd. Except 2003, which were obtained from individual shrimp weights from DFO commercial samples.

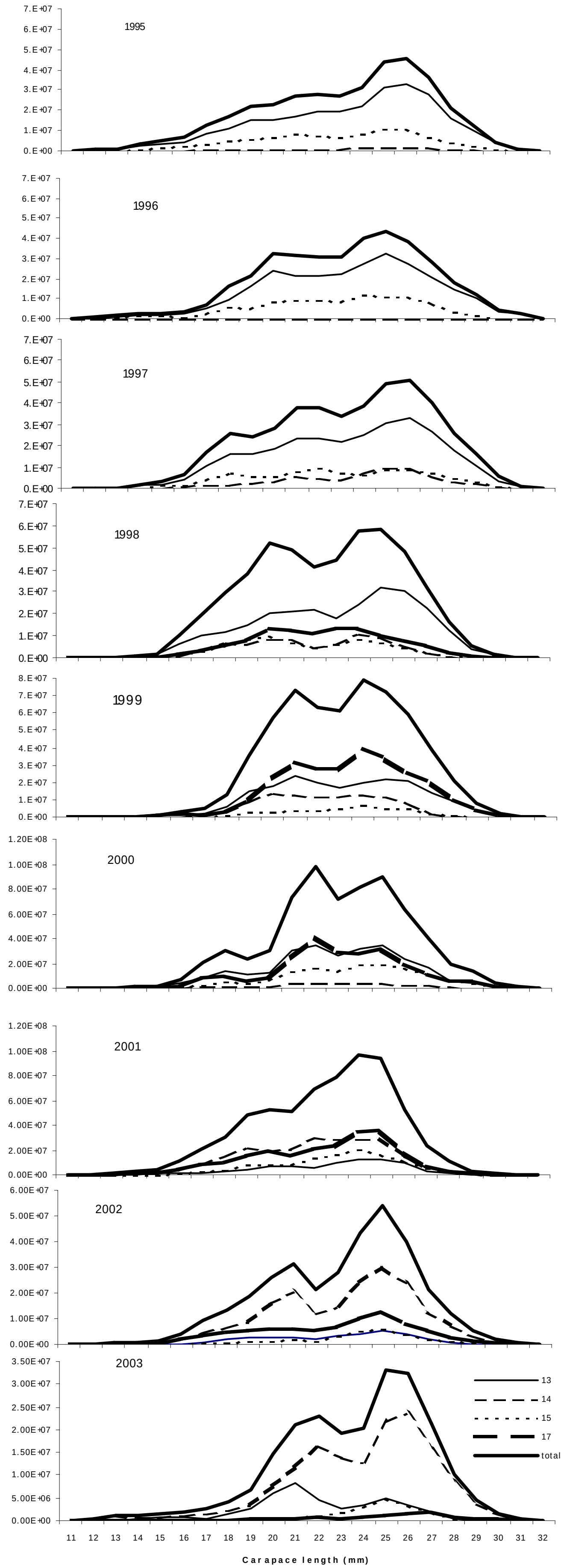


Figure 10. a. Catch at length from commercial sampling, 1995-2003.

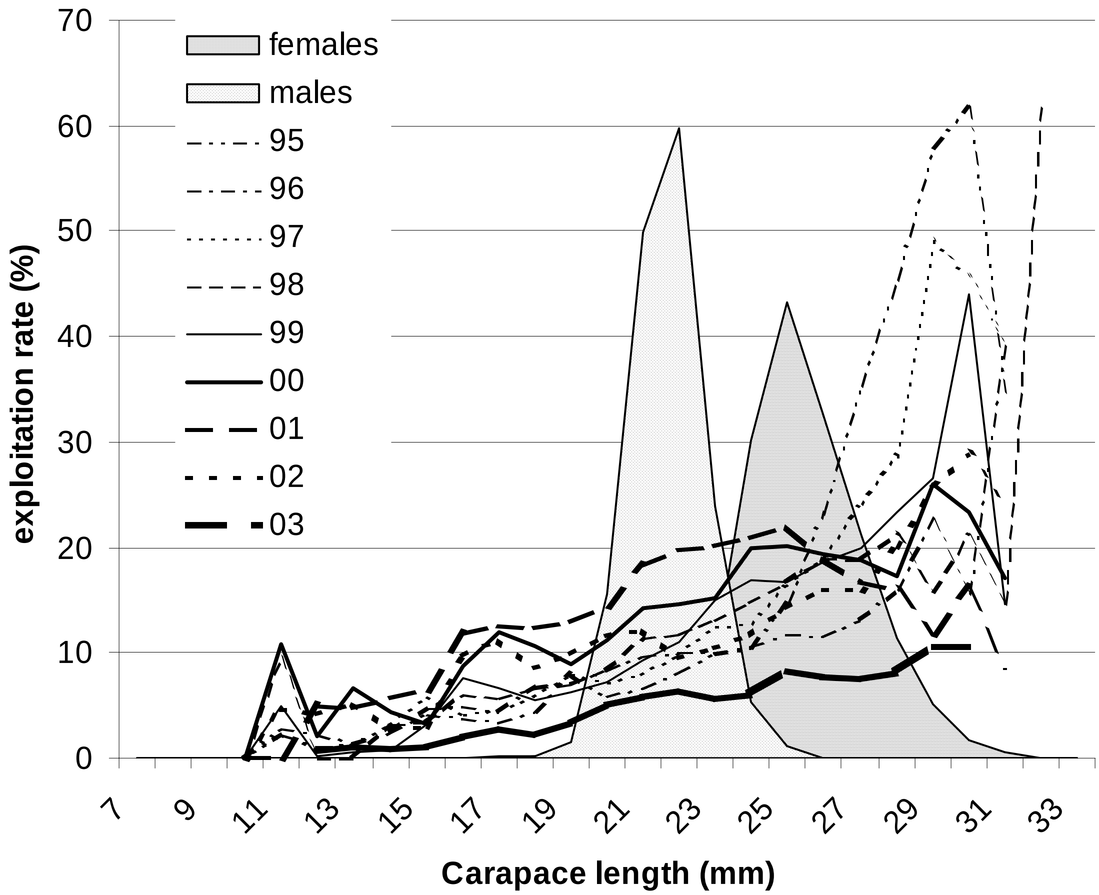


Figure 10 con’t b. Exploitation at length from commercial sampling and DFO-industry surveys.

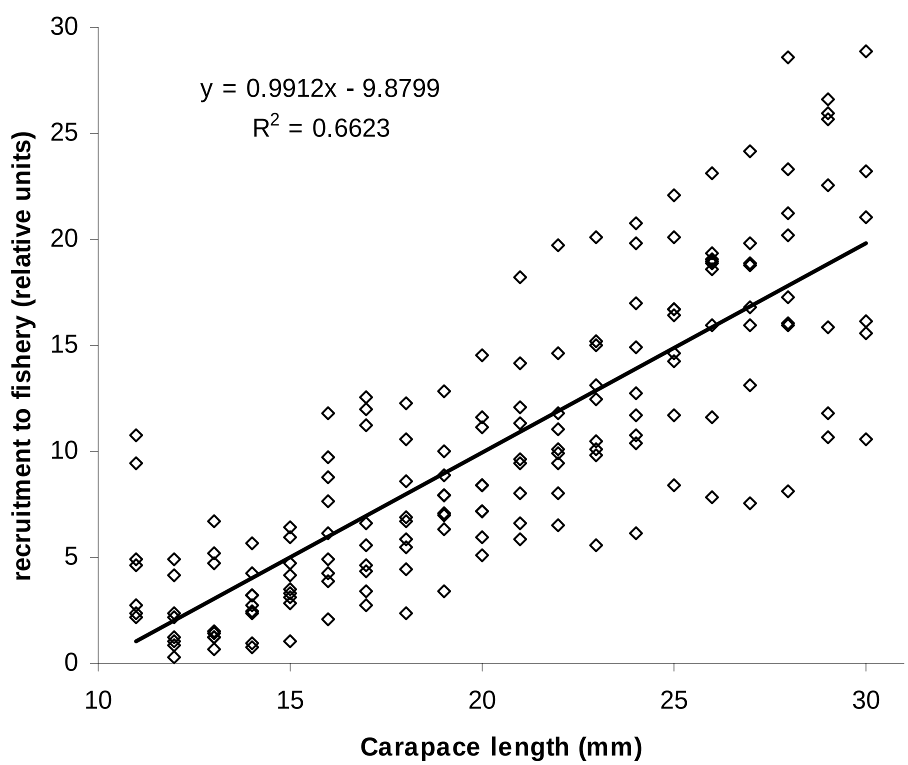


Figure 10 con’t c. derived from data in b. for lengths and exploitations <30. The slope could be considered as the minimum relative partial recruitment to the fishery by size.

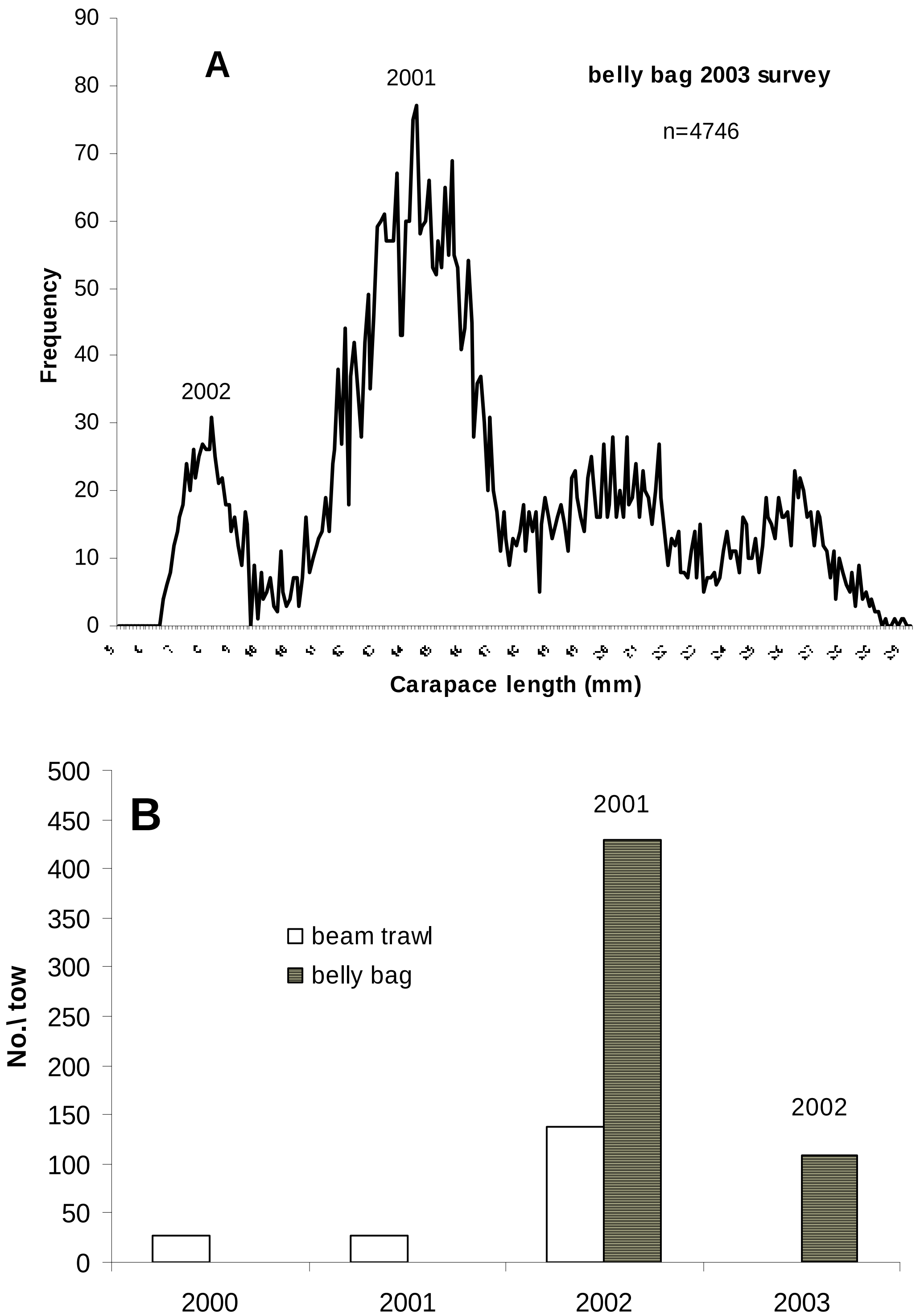


Figure 11. A. weighted length frequency from belly bag catches in the 2003 DFO-industry survey, B. Abundance of approx. 1 year old shrimp from juvenile beam trawl surveys conducted on RV Alfred Needler (February 2000-2002) and belly bag samples taken during the standard DFO-industry survey (June 2002-2003). The 2001 and 2002 year classes are identified in both figures.

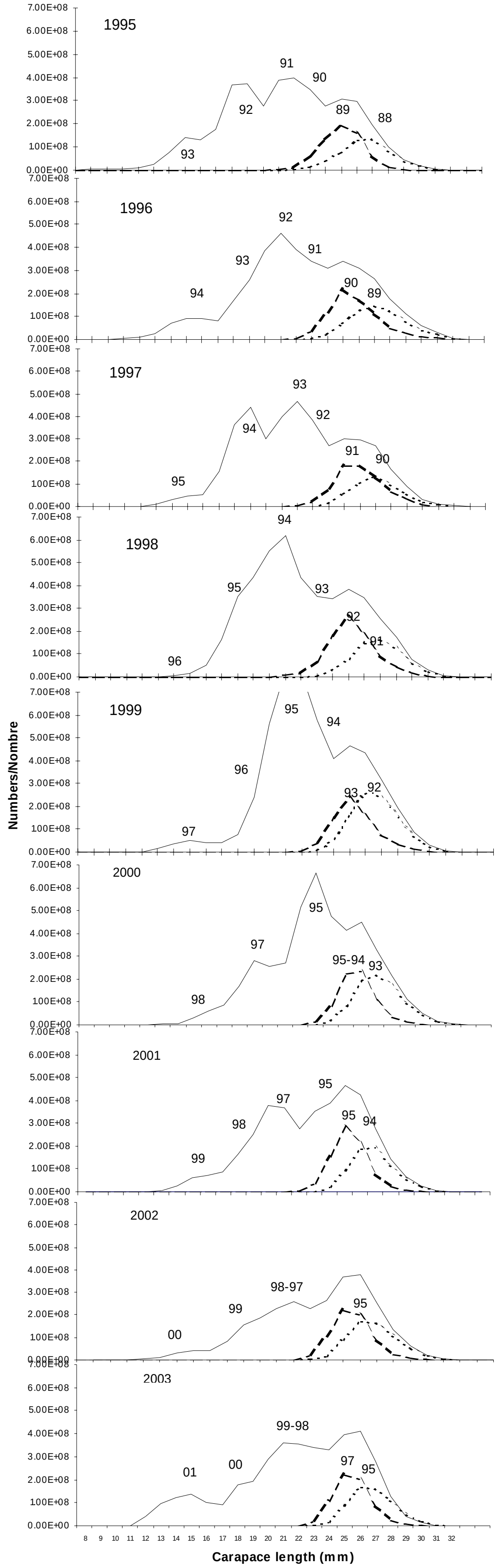


Figure 12a. Population estimates at length from DFO-industry surveys. The heavy dotted line in each figure represents transitional and primiparous shrimp, and the stippled line represents multiparous shrimp.

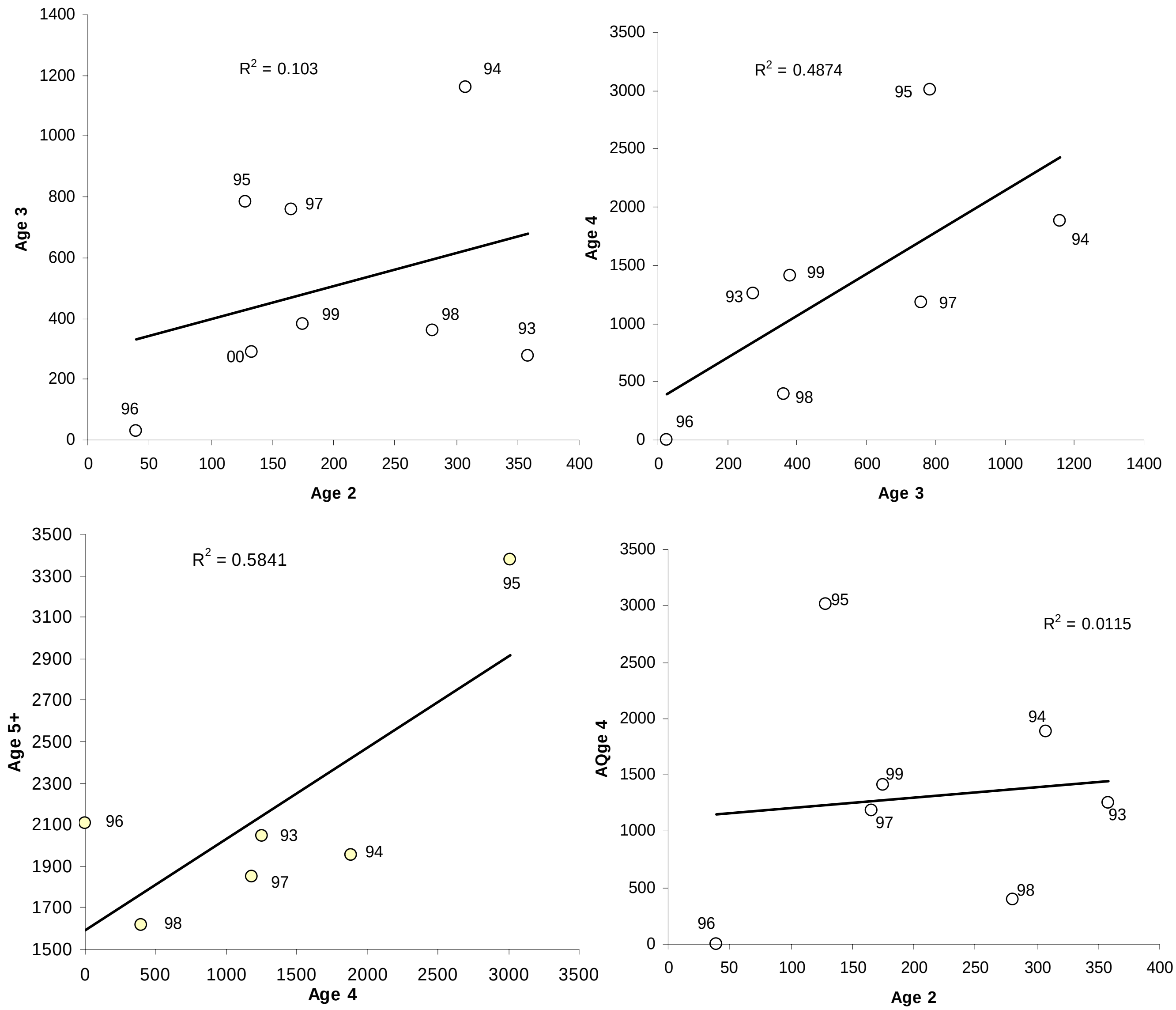


Figure 12b regressions of age classes from MIX analyses.

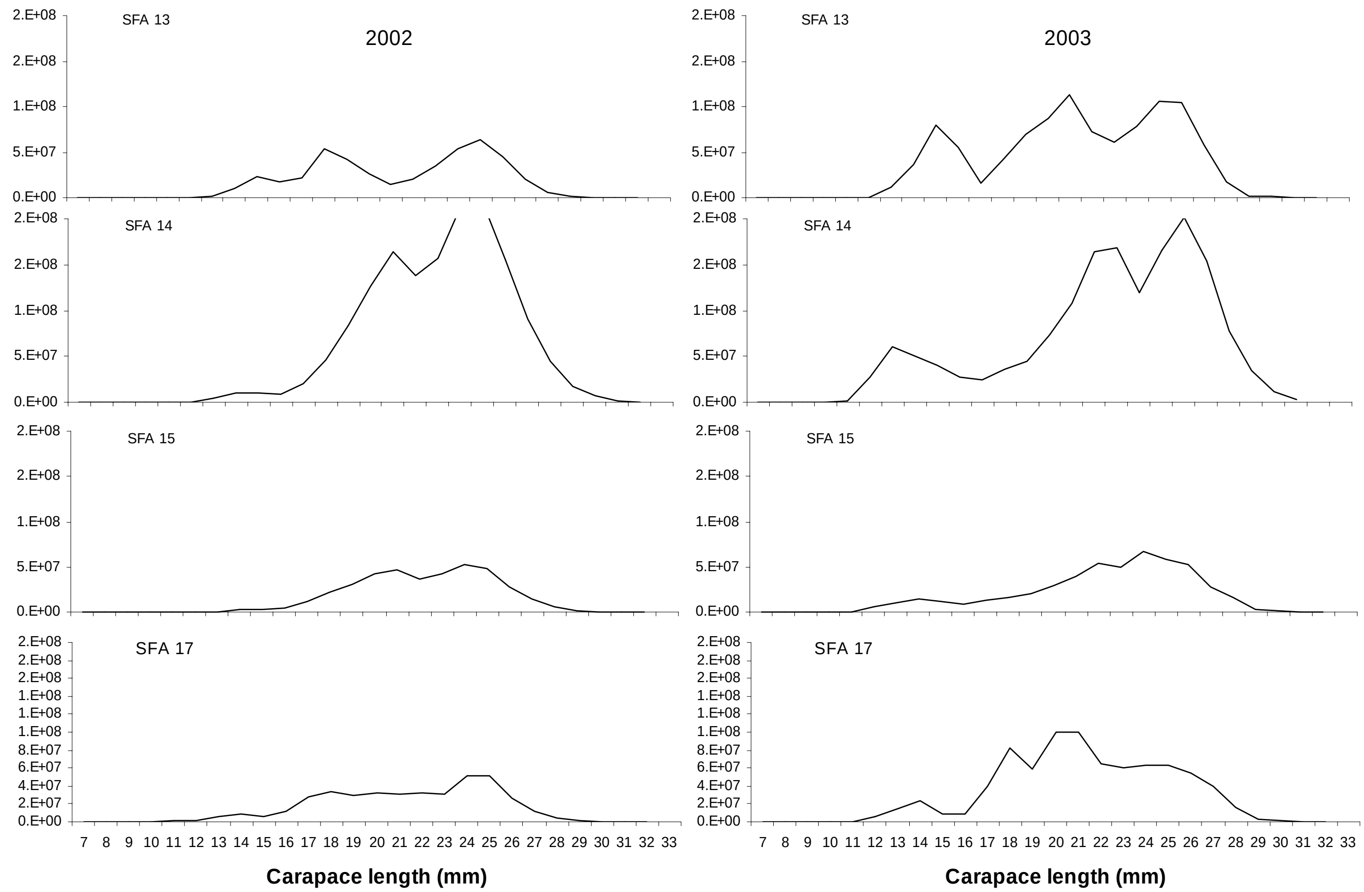


Figure 13. Population at length estimates by Shrimp Fishing Area from the DFO-Industry survey conducted in June, 2002-2003.

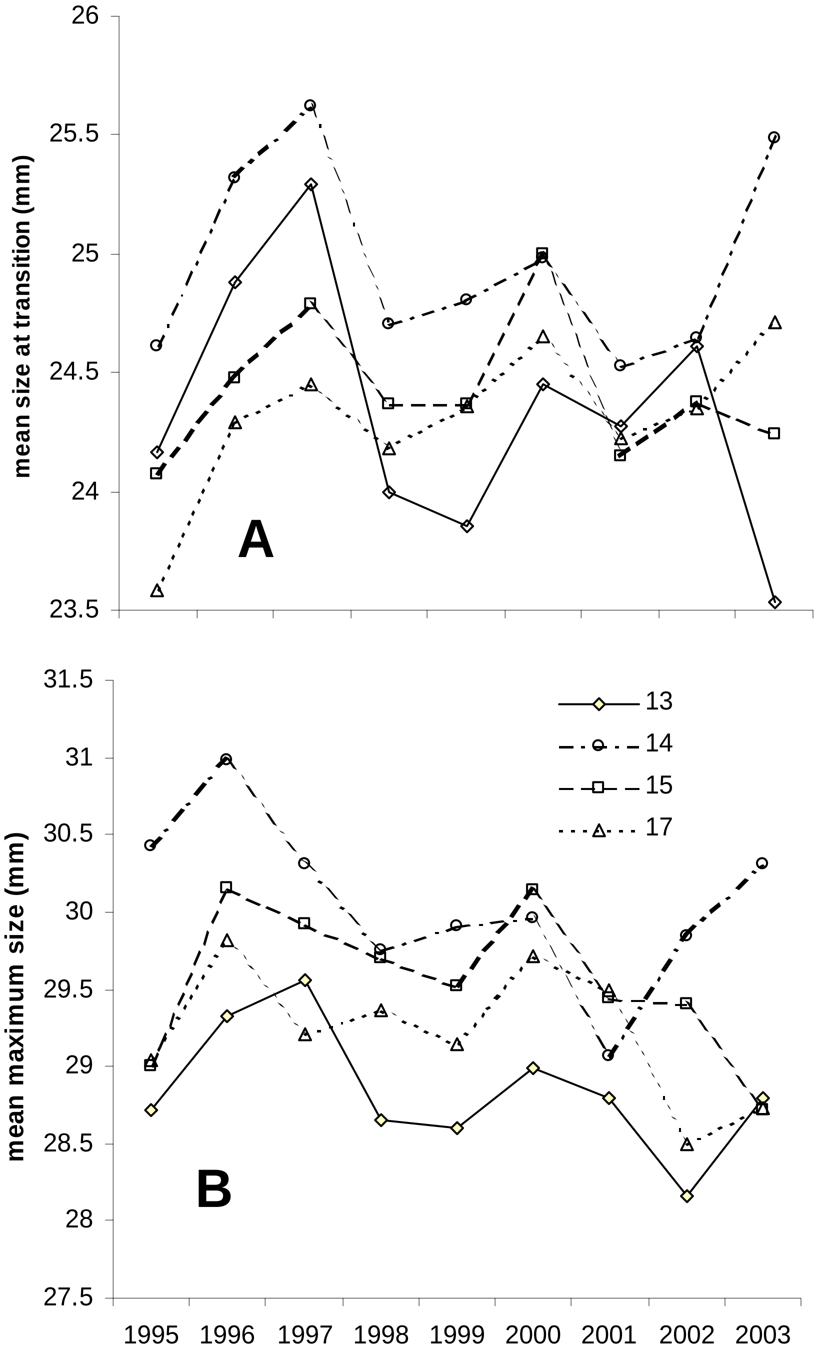


Figure 14. Average size at A. sex transition and B. maximum size by shrimp fishing area for the DFO-industry surveys 1995-2001.

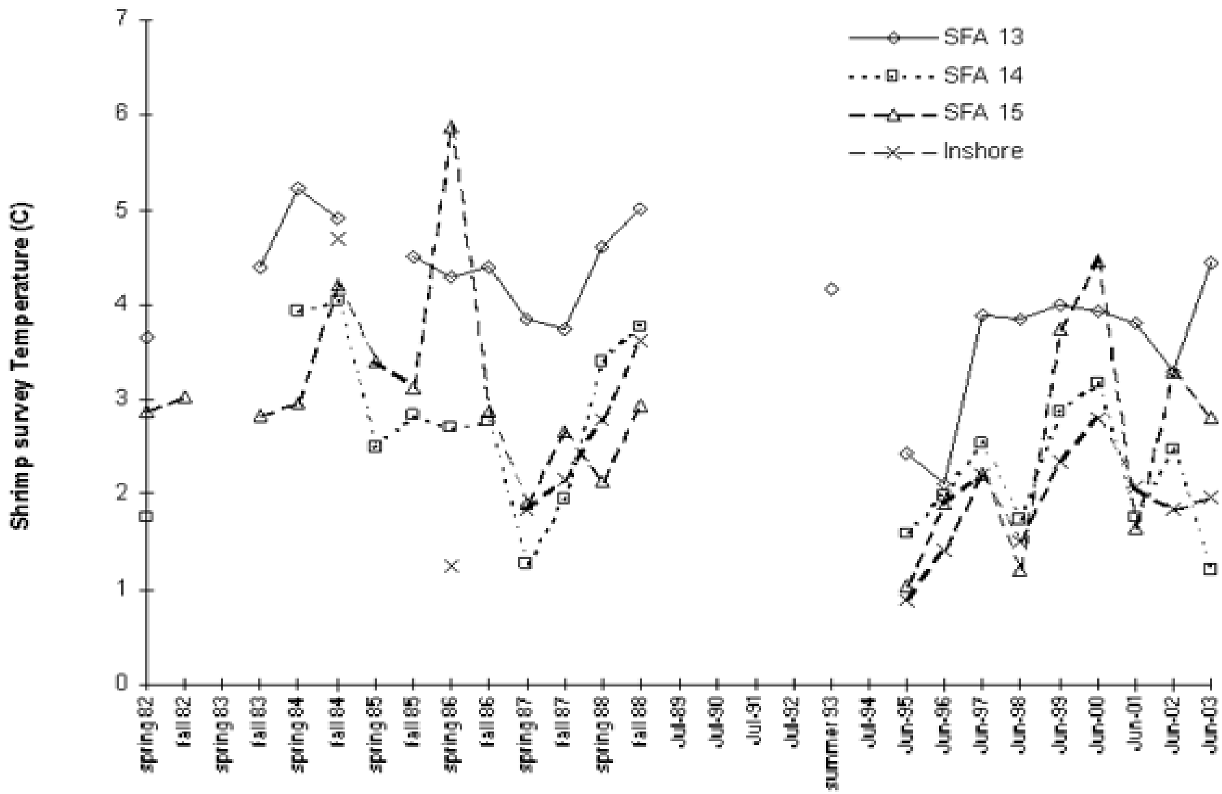


Figure 15. Mean bottom temperatures from shrimp surveys by SFA. Note that both spring and fall values were available from the earlier series (1982-88), but only one survey (June) was conducted annually in the recent series.