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An Assessment of the Eastern Scotian Shelf Shrimp Stock and Fishery for 2002.

Évaluation du stock et de la pêche en 2002 pour la crevette de l'est du plateau néo-écossais.

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Abstract

The DFO-industry survey index decreased in 2002 for the third consecutive year. The strong 1995 year class continued to support the fishery in 2002, however, subsequent years classes have been weaker and the total population is declining from the historic high levels of the late 1990s. Strata 13 (Louisbourg Hole), 15 (Canso Hole) and 17 (inshore) have all declined to the lowest levels since the DFO-industry survey series began in 1995. In contrast, Stratum 14 (Misaine holes) has continued to increase, with the last two years showing the highest abundances on record. The distribution of commercial effort reflects the changing distribution of biomass, with the highest proportion of the catch coming from SFA 14 for the first time since 1998. Survey and commercial catch rates again diverged in 2002 with commerial cpue continuing to increase due to the aggregation of the remaining biomass in dense concentrations. Spawning stock biomass remains high, and the area with the lowest exploitation rate (SFA 13) is experiencing declines similar to the more heavily fished areas. Conversely, Area 14, which has experienced among the highest exploitation rates during the last 8 years has continued to increase. Although the recent declines appear to be environmentally driven there are concerns that the combined negative effects of fishing and environmental influences could accelerate the observed biomass decreases in most areas and perhaps bring about a decline in SFA 14 prematurely, and prolong recovery. Increases in female exploitation, fewer larger females in the population due to removals by the fishery, increased fishing during the ovigerous period and decreases in the size at transition and maximum sizes may have been impacting negatively on the population's reproductive capacity in recent years, however the 40% decrease in TAC in 2002 appears to have had the desired effect and reversed or stabilized some of these trends. In addition, results from ‘belly bag’ samples suggest that the 2001 year class is strong. The Traffic Light analysis shows a marked improvement over previous years – 10 of the 23 indicators were green and only 3 were red in 2002 compared to 7 green and 10 red in 2001.

Résumé

En 2002, pour la troisième année consécutive, l'indice du relevé MPO-industrie a diminué. La forte classe d'âge de 1995 a continué de soutenir la pêche en 2002, mais les classes d'âge suivantes sont plus faibles, et la population totale baisse par rapport aux niveaux historiques de la fin des années 1990. Les strates 13 (fosse Louisbourg), 15 (fosse Canso) et 17 (eaux côtières) affichent les chiffres les plus bas atteints depuis que les relevés MPO-industrie ont été entrepris, en 1995. En revanche, les chiffres de la strate 14 (fosse Misaine) continuent d'être à la hausse, ceux des deux dernières années étant les plus élevés enregistrés. La répartition de l'effort commercial reflète le changement de la répartition de la biomasse : pour la première fois depuis 1998, la ZPC 14 a fourni la plus forte proportion des prises. Les chiffres du relevé et des prises commerciales divergent encore une fois en 2002, les PUE commerciales continuant d'augmenter en raison de la concentration de la biomasse résiduelle. La biomasse des géniteurs demeure élevée; la zone la moins exploitée (ZPC 13) montre des baisses similaires à celles des zones les plus exploitées, tandis que la zone 14, une des plus fortement exploitées au cours des huit dernières années, continue d'afficher une augmentation. Bien que les diminutions récentes semblent liées à des facteurs environnementaux, on craint que les effets négatifs combinés de la pêche et de l'environnement accélèrent les diminutions observées de la biomasse à la plupart des endroits et entraînent une diminution prématurée dans la ZPC 14 et retarde le rétablissement. L’exploitation accrue des femelles, la réduction résultante du nombre de femelles de grande taille, l’effort de pêche accru durant la période de ponte (femelles ovigères) et les réductions de la taille maximale et de la taille au moment de l'inversion sexuelle (transition) ont pu affecter la capacité de reproduction de la population ces dernières années; toutefois, la diminution de 40 % du TAC en 2002 semble avoir eu l'effet désiré et avoir inversé ou stabilisé certaines de ces tendances. En outre, d'après les échantillons prélevés à l'aide d'un sac attaché au ventre du chalut, la classe d'âge de 2001 serait forte. L'analyse suivant la méthode dite « des feux de circulation » indique une nette amélioration par rapport aux dernières années : 10 indicateurs verts et seulement 3 rouges (sur 23) en 2002, comparativement à 7 verts et 10 rouges en 2001.

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) and Koeller (2000) 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). 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. There has been evidence of reduced recruitment in recent years, but because of continued high spawning stock biomasses, and large year classes (1994, 1995) recruiting to the fishery, the TAC was increased to 5000mt for 1999 and to 5500mt for 2000. With the 1995 year class completing its 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 increasing harvest levels during the ovigerous period, the TAC was reduced to 5000 mt for 2001 and to 3000 mt for 2002.

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 of the Newfoundland, Gulf of St. Lawrence and eastern Scotian Shelf fisheries during the summer. There were no closures on the Scotian Shelf in 2002.

Beginning in 1999 the Newfoundland-Labrador, Gulf of St. Lawrence and Scotian Shelf shrimp stocks were assessed using the Traffic Light method of summarizing stock assessment results which was developed during several meetings of the Scientific Council of the North Atlantic Fisheries Organization (NAFO MS 1998, Koeller et al 2000). On the Scotian Shelf, a simple set of rules linking traffic light results to management action was also proposed (Koeller et al 1999), based on modelling results indicating that this would be more precautionary than the status quo (Koeller et al 2000). Although the Traffic Light approach has proved useful and was generally accepted by managers and industry, it has been criticised by the scientific community for lacking scientific rigor. This problem was addressed by the Fisheries Management Studies Working Group (FMSWG) of the Department of Fisheries and Ocean's Regional Advisory Process (Maritimes Region) beginning in 2000. Among the advances made by this group is the production of a computer program which summarises traffic light colours determined by pre-defined limits for individual indicators (Mohn et al 2001). In addition to an overall summary the program produces summaries for groups of indicators or "characteristics" such as biomass, production, fishing mortality and ecosystem. While the FMSWG has addressed other outstanding issues associated with the traffic light method, specifically, integration of the individual indicator scores including weighting of indicators, and linking traffic light results to harvest control rules, it has not resolved them to date.

The organisation of this report is based on the traffic light analysis itself, with methods and results for individual indicators grouped under headings representing "characteristics", in the order they are presented in the summary. The sections on each indicator in Methods and Materials 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. Although this additional information may be used in the interpretation associated with any change that is given in the Results and Discussion, 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 concensus 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 licencing 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. 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.

ABUNDANCE

Research Vessel Abundance Index

An eight industry funded trawl survey, incorporating a mixed stratified random - fixed station design, was conducted in June 2002. Survey design and station selection methods were similar to previous surveys completed in 1995-2001: 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 2002 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 all survey sets using SCANMAR sensors. The trawl was fitted with a 'belly bag' attached to the 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 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.

Commercial trawler Standardized Catch Per Unit Effort

The standardised CPUE series for 1993-2002 uses data from April-July inclusive, the months when the majority of the TAC was caught, for vessels that have fished for at least 4 of the 10 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 previous 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.

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.

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. 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.

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 therefor be prudent not to let the SSB decrease below 4,300, however, the stock increase at these SSB levels ocurred 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. It is nearly identical to the default 0.33 percentile used as the red limit for most 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) show that size at transition is related to growth rate. 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 hypothsised 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). Therefor 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 correllated with shrimp abundance on the Scotian Shelf and in most other shrimp fishing areas.

FISHING MORTALITY

Exploitation Index

An overal 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 and is 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 2001 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 overal 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 year 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 fshery 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 therefor 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 correllated 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 therefor 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. Restricting this indicator to juvenile halibut may 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

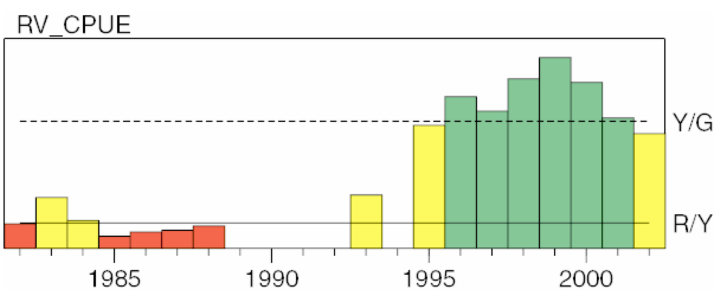
Individual traffic light indicators were summarised using the "direct" method. Each indicator is given a value according to its colour i.e. green = 3, yellow = 2 and red = 1, and a simple average is calculated. This average is assigned a "summary colour" according to limits determined by the probability 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 below.

ABUNDANCE

Research Vessel Abundance Index



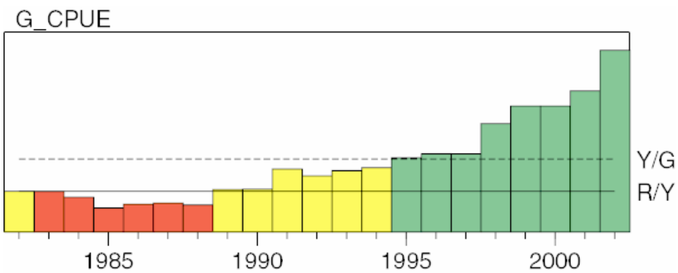
The stratified survey estimate decreased for the third year in a row. The estimates for 3 of the 4 strata also decreased to, or remained at, the lowest levels seen since the recent survey series began (Figure 2). Although Stratum 14 (Misaine Hole) also showed a slight decrease in 2002 it remained near the high level attained in 2001. The total biomass estimate decreased from 25,028 mt in 2001 to 20,773 mt in 2002.

It is noteworthy that Stratum 13 has generally registered the lowest estimates of all 4 areas and has decreased along with the others despite only relatively light fishing in this area. Conversely, Stratum 14 has increased 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 exagerated. Survey data for individual sets are presented in Table 4.

Interpretation: The decrease in the survey estimate for the third year in a row indicates that the stock is in decline, although it is still at a higher level compared to the low abundances of the 1980s. Fishing does not appear to be the main cause of these declines, or at least, it is not the only cause.

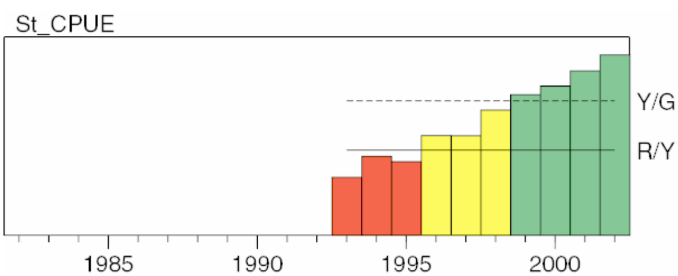
Gulf Vessels Catch Per Unit Effort



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

Interpetation: In light of changes in other indicators, i.e. the decrease in the survey estimate and evidence of increased aggregation from both survey and fishery indicators of dispersion, the increase in this indicator is apparently due to higher densities in these aggregations. Higher densities combined with decreasing abundance indicates that the population is under stress.

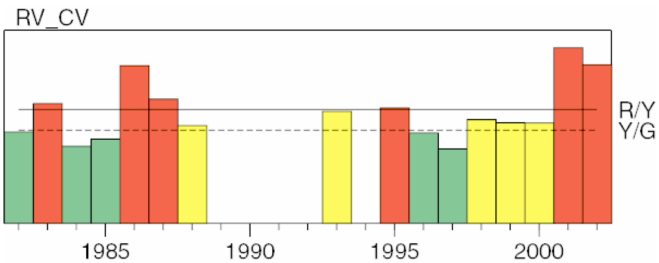
Commercial trawler standardized catch per unit effort



The standardized CPUE series has increased every year except for two of the 10 year series. The parallel trend in both survey and CPUE series broke down in 2000 with the survey showing decreases and CPUE showing increases in the last two years (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 2-3 years is probably due to better catches in denser and smaller shrimp aggregations and not to an increase in abundance. Higher densities combined with decreasing abundance as indicated by the survey index may be a signal that the population is under stress.

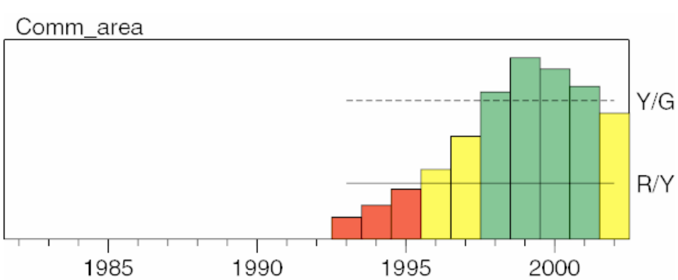
Research vessel coefficient of variation



This measure of dispersion has been high for the last 2 years. This is mainly due to increases in strata 13 and 17 (Figure 4). Stratum 14 and 15 CVs have remained relatively low due to uniform high and low abundances throughout these areas, respectively. The overal index is in agreement with the dispersion index from fishery data and indicates increased aggregation of shrimp, possibly because the population is under some environmental stress The distribution of catches from all surveys shown in Figure 5 in relation to bottom temperatures also shows a greater variation in catches during 2001-2002 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 ocurred in 2001 and 2002. Such incursions could be responsible for the increased aggregation observed in some areas. 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 2001-2002 in some areas, and in part this may account for the increases in the CPUE indicators and the discrepancy between commercial and survey indices.

Commercial fishing area

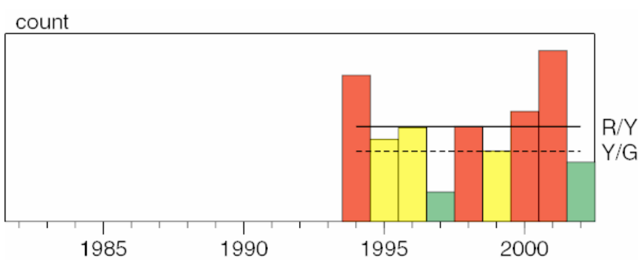


The area with commercial catch rates >250kg/hour increased since the beginning of the series until 1999, when it began to decrease. The area with catch rates >150kg began to decrease in 1997, while the interval with the highest catch rates (>450) has continued to increase (Figure 6). This pattern is consistent with a concentration of the resource in a smaller area and appears to be a longer term phenomenon. Increased aggregation was noted by fishers in interviews conducted in 2000 and 2001 (Koeller et al 2002). Figure 7 shows changes in the distribution of effort since 1995, particularly the shift toward the eastern holes of SFA 14 and decreasing effort in other SFAs and the inshore in 2002. This is consistent with the change in catch distribution by SFA (Table 1), survey abundances by area (Figure2) ,survey dispersion (Figure 4) and commercial catch rates (Figure 3B). i.e. fishers are shifting their effort to the area with the best and most consistent catch rates. 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). After the initial decrease in trap catch rates in 1997 attributed to removal of accumulated large animals in the small trapping area off Canso average trap catch rates have increased annually since 1998, with 2001 showing the largest catches and catch rates in the short history of the fishery (Table 1, Figure 8). Although 2002 trap catch rates decreased somewhat, preliminary results from the 2002-2003 season indicate average catch rates > 6 lbs per trap haul

Intrepretation: Scotian Shelf shrimp are aggregating in smaller areas of higher density possibly in response to unfavourable environmental conditions i.e. increasing temperatures.

PRODUCTION

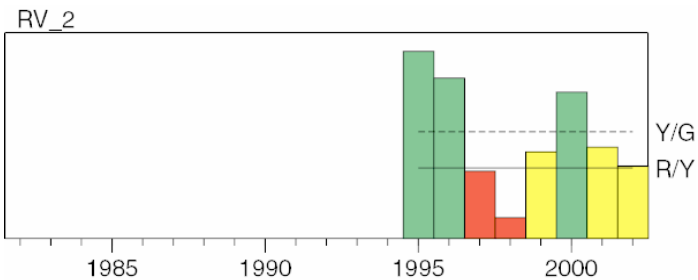
Commercial counts



Note that the polarity of this indicator is ambiguous unless it is considered in relation to other indicators, espcially 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 9A) despite large sample sizes (>1000) and there is a seasonal component, with counts decreasing to a minimum in July and increasing thereafter (Figure 9B). 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 this trend was reversed, due partly to continued maturation of the 1994-95 year classes and poor recruitment, but also probably due to the concentration of the larger animals targetted by the fishery. The 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 2002.

Interpretation: Commercial counts have increased for the last few years due to a decrease in the number of larger shrimp in the population. This indicator decreased in 2002 due to continued poor recruitment, growth of the remaining shrimp from the large 94-95 year classes and aggregation of females on the fishing grounds.

RV abundance at age 2



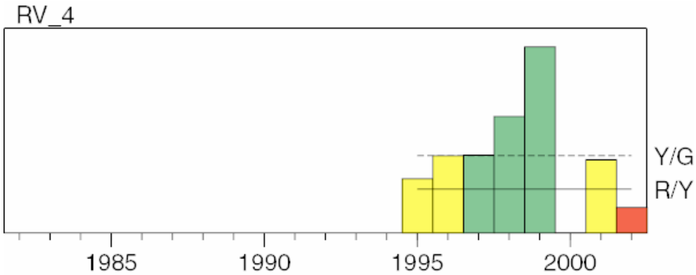
Age 2 abundance (i.e. 2000 year-class in 2002) was below average for the 8 year survey period, however this is not a reliable estimator of recruitment to the population. For example, the strong 1995 year class has one of the lowest estimates at Age 2 but one of the highest at age 4 (Table 5), while the 1998 year class was among the largest at Age 2 in 2000 but is below average at Age 3 and 4. On the other hand, the 1996 year class has been poor in all years and had the lowest estimate at Age 2, consequently this indicator may be of some value in detecting very poor year classes. The apparent failure of the 1996 year class has been attributed to the high incidence of egg disease that year.

Juvenile surveys using special small meshed gear were conducted in February 2000-2002, and in June 2002 in order to improve recruitment prediction. Beam trawl catches of 0-group shrimp in February 2000-2001 (1999 and 2000 year classes) were relatively small and patchy, with an average catch of about 27 shrimp per tow (Figure 11). However, 0-group shrimp distribution was widespread and abundance was significantly higher in February 2002 (2001 year class). This was confirmed in June 2002 using a 'belly-bag' attached to the footrope of the standard trawl. The belly bag caught over three times the number of the 2001 year classs than the beam trawl 3 months earlier. Since the belly bag's effective opening is only 17% of the beam trawl the former appears to be much more efficient at catching 0-group shrimp and will be used for future surveys.

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 1994-95 year classes. Population estimates at length for each of the four survey strata are shown in Figure 13 for 2001-2002. This shows that relative year class strength varies considerably between areas.

Interpretation: recruitment to the population has been below average for 5 of the last 6 years and is resulting in a declining population of larger shrimp. This may not be reversed until the apparently strong 2001 year class changes sex in 2005.

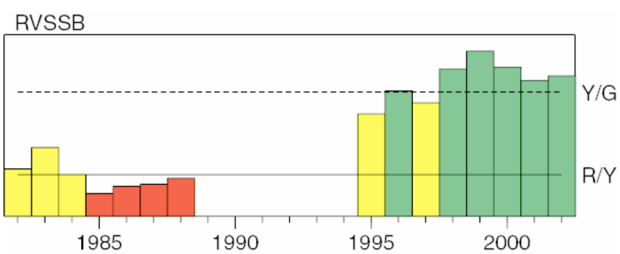
RV abundance at age 4



The abundance of age 4 shrimp in 2002 was the lowest of the 8 year series. The abundance of age 3 shrimp was also well below average (Table 5), consequently recruitment to the fishery during the next few years does not appear to be good. Age 5+ abundance was also below average as the large 1995 year class began to die off.

Interpretation: The abundance of year classes that will be recruiting to the fishery in the next 2 years is below average, especially 4 year old shrimp that will provide the bulk of the catch in 2003. The large 1995 year class continued to support the 2002 fishery as expected, however its abundace is decreasing as its natural mortality inceases. Consequently the population of older and larger shrimp targetted by the fishery will continue to decrease for the next few years. Unless the aggregation of the resource in smaller areas seen in the last two years continues, decreases in catch rates should be expected.

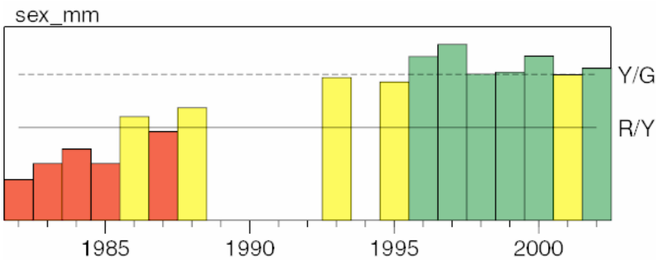
RV spawning stock biomass (Females)



Research vessel spawning stock biomass increased slightly in 2002 and at 14,965 mt it remains well above the low SSBs of the 1980s (average 4,272) when the population was increasing. It is therefore unlikely that the decreased recruitment seen in recent years is due to overfishing of spawners. It should be noted that the earlier survey time 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. Decreased spawing stock biomass and recruitment overfishing does not appear to be the cause of the recent decline in recruitment.

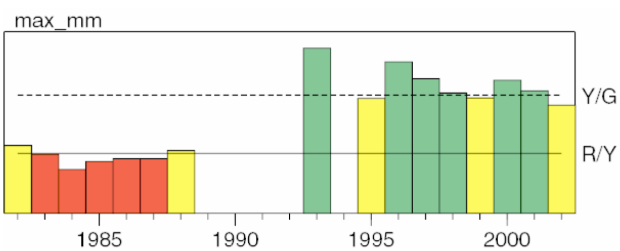
Average size at sex transition (L_t)



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.

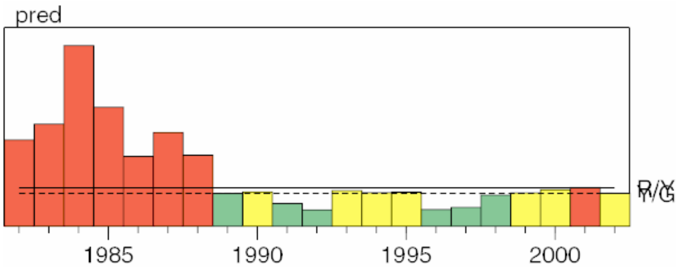
Average maximum size (L_{max})



Average maximum size in the population decreased in 2002. This indicator appears to have a decreasing trend since 1996 but 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 therefor be due to lower fecundities of the smaller animals.

Interpretation: There has been no major change in growth rates but a decreasing trend in maximum size during the last few years suggest that growth rates are increasing and may eventually lead to decreased population fecundities.

Predation

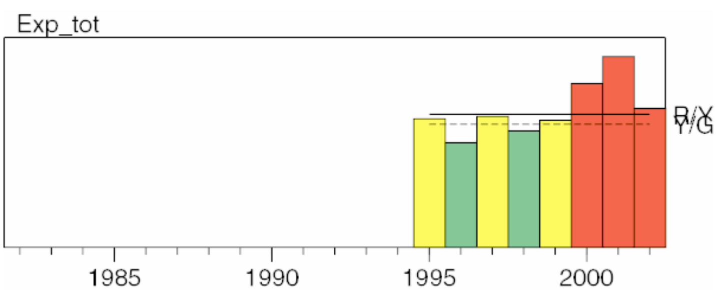


There has been a slight increasing trend in groundfish abundance in recent years, however, groundfish abundance remains well below the high levels during the 1980s when the shrimp population was low.

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 MORTALITY AND IMPACT

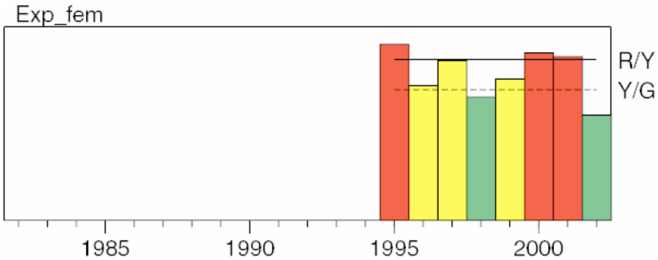
Exploitation Rate



Overall exploitation increased annually since 1998 due mainly to increasing TACs. Increases in 2000 and 2001 were particularly large due to decreases in the survey biomass estimates during those years. Exploitation decreased in 2002 due to the decrease in TAC but was still the third highest recorded. Exploitation rates by SFA are given in Table 6. Exploitation during 2002 was relatively low in all areas except the inshore which had the highest index recorded.

Interpretation: The decrease in TAC imposed in 2002 appears to have stabilised exploitation rates, as intended.

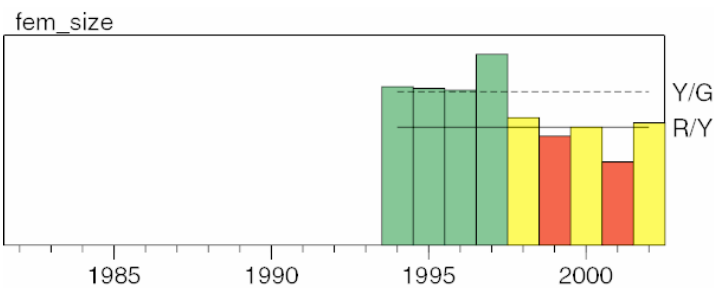
Female Exploitation Rate



Female exploitation rates increased from1998-2000 as TACs were increased, and remained high in 2001. In combination with other factors (fishing during the ovigerous period, decrease in proportion of females in catch, size at sex change and maximum size) this could affect the population's reproductive capacity. Female exploitation decreased significantly in 2002 due to the decrease in TAC.

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

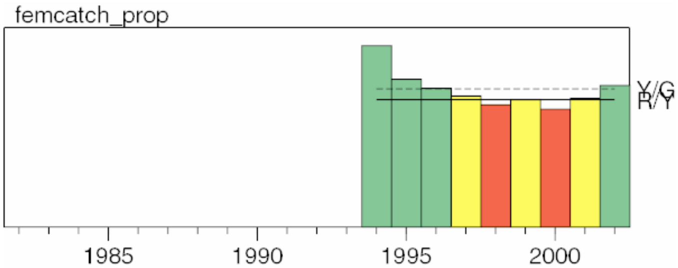
Mean size of females in catch



The average size of females in the catch has decreased since the mid 1990s, although there was an increase in 2002.

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 be impacting on the reproductive capacity of the population. This indicator increased in 2002, as recruitment to the female fraction decreases and the remaining population grew.

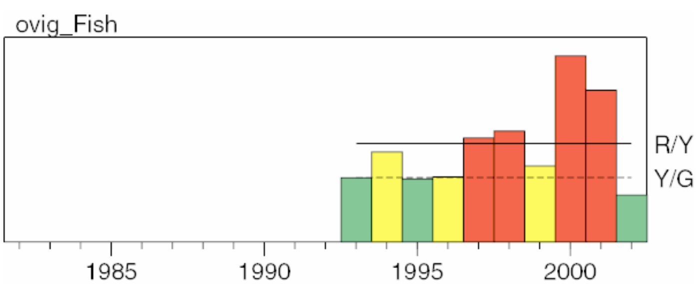
Proportion of females in catch



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

Interpretation: the proportion 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 be impacting on the reproductive capacity of the population. Also, increasing exploitation of the smaller, non-female part of the population could result 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

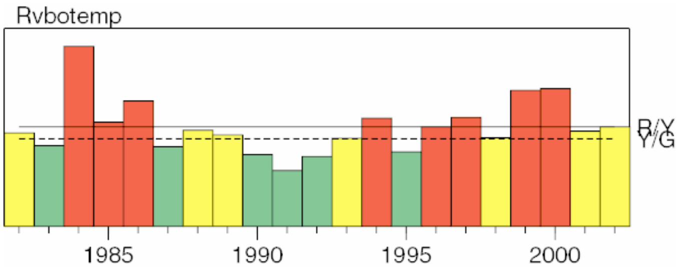


Fishing during the ovigerous period increased significantly in 2000-2001 due to the longer time required to catch larger TACs by a relatively small fleet of vessels, many of which are also engaged in other fisheries. In addition, quota transfers have ocurred and many vessels fished several individual quotas, further extending the length of the season. This trend was reversed in 2002 as the smaller TAC was again caught mainly during the non-ovigerous period.

Interpretation: Fishing during the ovigerous period may have impacted population reproductive potential in recent years by removing ovigerous females before their eggs have hatched. However, the decrease in the TAC appears to have reduced this potential problem in 2002.

ECOSYSTEM

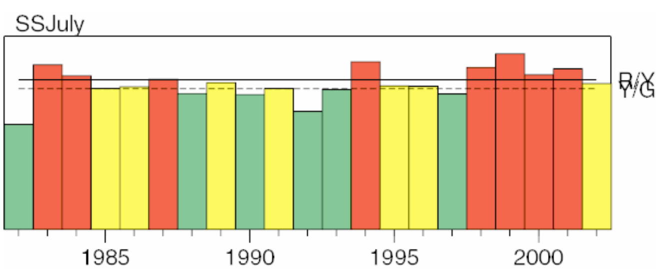
RV (groundfish survey) bottom temperatures



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. Temperatures from shrimp surveys by SFA generally show the same trends as data from groundfish surveys (Figure 15).

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.

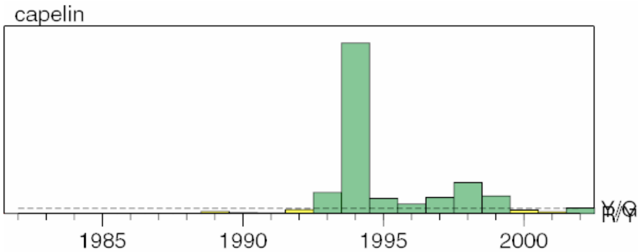
July SST



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.

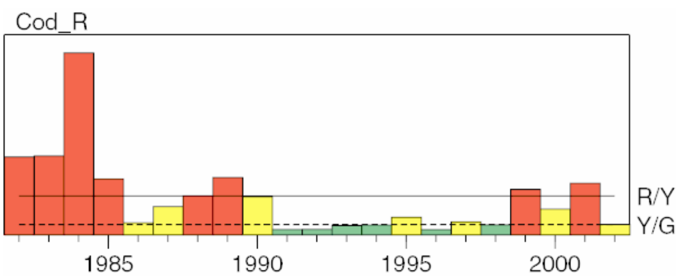
RV Capelin abundance



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

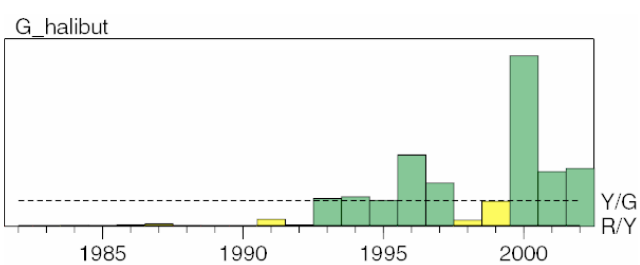
Interpretation: Conditions which resulted in high production of capelin and shrimp in the mid to late1990s may be changing to ones less favourable to these species.

Cod recruitment



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

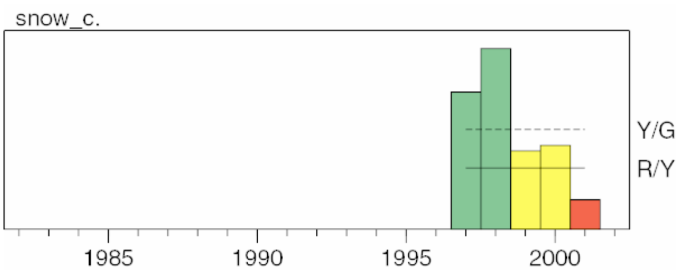
Interpretation: Environmental conditions which favour cod (and are unfavourable for shrimp) may be improving.



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.

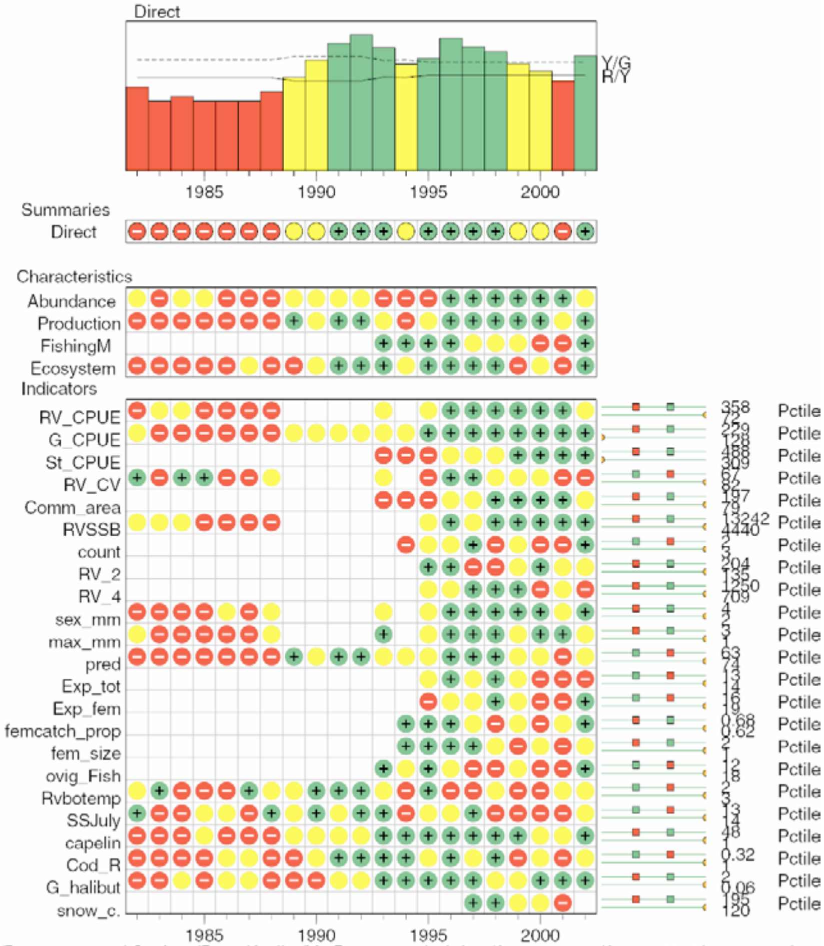
Snow crab recruitment



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



C:/Documents and Settings/Peter Koeller/My Documents/_shrimp/Assessments/Assess2002/summary.ai

The figure above shows the first increase in the overal summary since1996. This is primarily due to improvements in indicators associated with the fishing mortality, production and ecosystem characteristics. Fishing mortality indicators improved primarily due to the decrease in the TAC imposed in 2002. Note that overal exploitation was still 'red' despite a substantial decrease. Some production indicators must be interpreted cautiously in relation to their being 'good' and 'bad' because of changes in the population size structure. For example, the decrease in counts from industry data is primarily due to decreased recruitment and accumulation of the biomass in larger sizes. In addition, the more important indicators in this characteristic i.e. age 2 and 4 abundance, are not favourable. The yellow rating of the abundance characteristic is overly optimistic because the two commercial CPUE indices are no longer considered indicative of abundance. In summary, the decrease in the TAC in 2002 has had a favourable effect, however, the abundance trends observed last year which prompted the decrease have continued and will largely determine management action.

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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
[4]2002	2700	300	270	1601	829	2700	294	2994

[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)

[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	1.00	1.54
1983	142.50	127.70	NAN	86.00	NAN	7323.05	NAN	NAN	NAN	1.40	1.34
1984	78.07	109.50	NAN	55.30	NAN	4460.96	NAN	NAN	NAN	1.75	1.00
1985	33.61	75.40	NAN	60.40	NAN	2417.71	NAN	NAN	NAN	1.40	1.18
1986	46.02	87.30	NAN	113.10	NAN	3187.87	NAN	NAN	NAN	2.55	1.24
1987	50.84	90.70	NAN	89.20	NAN	3424.46	NAN	NAN	NAN	2.18	1.24
1988	62.76	85.10	NAN	70.10	NAN	4047.02	NAN	NAN	NAN	2.77	1.43
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	210.599	80.32	31.00	NAN	NAN	NAN	NAN	3.51	3.76
1994	NAN	202.40	286.641	NAN	48.00	NAN	3.46	NAN	NAN	NAN	NAN
1995	346.04	233.80	267.243	82.80	71.00	10912.15	2.38	358.5	875.92	3.40	2.62
1996	427.84	245.90	361.716	64.87	99.00	13368.38	2.58	307.3	1247.63	4.03	3.45
1997	386.00	245.50	361.318	53.45	146.00	12100.80	1.49	128.8	1257.47	4.33	3.07
1998	476.76	341.00	454.319	74.41	209.00	15707.48	2.60	39.89	1883.71	3.60	2.74
1999	536.80	396.00	510.423	72.19	258.00	17607.48	2.18	165.6	3010.18	3.64	2.63
2000	466.72	396.00	541.41	71.995	242.00	15893.36	2.85	280.3	0.0	4.04	3.03
2001	366.64	444.00	596.585	126.03	217.00	14475.58	3.88	174.9	1184.11	3.58	2.79
2002	322.8	572.00	654.872	113.79	179.00	14965.21	1	138.4	412.54	3.74	2.46

	pred	Exp_tot	Exp_fem	F_prop	ovig_Fish	RVbtemp	SST June	capelin	Cod_R	G_Hal_R	Snow_R
1982	165.89	NAN	NAN	NAN	NAN	1.98	9.67	0	2.385		
1983	196.36	NAN	NAN	NAN	NAN	2.20	15.15	0	2.415		
1984	347.25	NAN	NAN	NAN	NAN	4.46	14.14	0	5.569	0.06	
1985	228.63	NAN	NAN	NAN	NAN	2.58	12.96	1.55	1.709	0.05	
1986	133.96	NAN	NAN	NAN	NAN	2.87	13.12	0.13	0.368	0.09	
1987	179.76	NAN	NAN	NAN	NAN	1.85	13.81	0.77	0.866	0.16	
1988	136.44	NAN	NAN	NAN	NAN	2.68	12.48	0.17	1.195	0.06	
1989	62.94	NAN	NAN	NAN	NAN	1.85	13.49	18.38	1.753	0	
1990	65.55	NAN	NAN	NAN	NAN	1.38	12.40	9.23	1.163	0	
1991	43.42	NAN	NAN	NAN	NAN	1.62	12.97	5.07	0.166	0.46	
1992	31.00	NAN	NAN	NAN	NAN	2.02	10.86	34.87	0.169	0.08	
1993	68.33	NAN	NAN	NAN	11.91	2.60	12.86	193.36	0.287	1.86	
1994	64.36	NAN	NAN	0.89	16.71	2.41	15.42	1563.8	0.30	1.98	
1995	65.45	13.33	21.04	0.72	11.69	1.51	13.20	138.61	0.536	1.74	
1996	32.04	10.86	16.11	0.68	12.07	2.32	13.17	87.53	0.161	4.78	
1997	36.21	13.57	19.08	0.64	19.32	2.38	12.47	146.6	0.396	2.91	267.8
1998	59.61	12.08	14.73	0.60	20.60	2.63	14.89	284.30	0.307	0.41	353.1
1999	64.02	13.17	16.90	0.63	14.11	3.01	16.16	159.95	1.391	1.67	153.9
2000	69.96	17.00	20.00	0.58	34.57	3.74	14.23	32.38	0.787	11.44	163.7
2001	74.18	19.01	19.56	0.63	28.18	2.62	14.79	15.99	1.579	3.66	52.52
2002	63.25	14.41	12.57	0.69	8.71	2.74	--	49.85	0.316	3.88	---

Table 4. Set statistics from DFO-idustry survey AS0201 conducted by MV All Seven June 1 - 10 2002. 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/m² or m.t./km2)**
1	13	1-Jun-02	4520°75.00'	5759°42.00'	2.5	1.30	14.6	149	4.3	29	33.8	0.8
2	13	1-Jun-02	4526°20.00'	5801°91.00'	2.4	1.20	16.2	150	4.1	344	384.7	9.5
3	13	1-Jun-02	4526°59.00'	5815°77.00'	2.3	1.20	16.5	142	1.6	80	88.1	2.2
4	13	1-Jun-02	4529°54.00	5839°48.00'	2.4	1.20	15.8	130	2.7	231	265.8	6.6
5	13	1-Jun-02	4534°43.00'	5832°47.00'	2.4	1.26	17.0	149	2.9	60	61.4	1.5
6	13	1-Jun-02	4535°85.00'	5835°43.00'	2.4	1.22	*16.6*	130	3.0	39	41.4	1.0
7	13	1-Jun-02	4535°69.00'	5854°77.00'	2.5	1.20	16.2	123	3.0	78	87.2	2.2
8	13	2-Jun-02	4551°56.00'	5831°03.00'	2.4	1.22	16.7	118	3.5	0	0.0	0.0
9	13	2-Jun-02	4551°86.00'	5841°83.00'	2.4	1.24	16.8	151	3.7	178	185.3	4.6
10	13	2-Jun-02	4547°00.00'	5834°43.00'	2.5	1.25	16.6	138	3.5	7	7.6	0.2
11	13	2-Jun-02	4548°31.00'	5902°55.00'	2.5	1.30	17.0	107	3.5	2	1.8	0.0
12	13	2-Jun-02	4544°94.00'	5900°54.00'	2.4	1.13	17.7	133	3.5	1	1.0	0.0
13	13	2-Jun-02	4540°69.00'	5848°61.00'	2.3	1.22	16.5	117	3.2	65	70.1	1.7
14	13	2-Jun-02	4540°45.00'	5900°83.00'	2.4	1.05	17.5	152	3.5	300	354.9	8.8
15	13	2-Jun-02	4537°87.00'	5902°87.00'	2.4	1.20	16.9	120	3.2	39	41.5	1.0
16	17	3-Jun-02	4529°25.00'	5941°06.00'	2.4	1.33	15.8	85	1.9	15	15.0	0.4
17	17	3-Jun-02	4525°02.00'	5940°38.00'	2.5	1.13	15.9	77	1.9	0	0.3	0.0
18	17	3-Jun-02	4519°75.00'	5943°71.00'	2.4	1.12	16.4	70	1.6	0	0.0	0.0
19	17	3-Jun-02	4522°83.00'	5953°09.00'	2.4	1.26	15.9	84	1.9	0	0.1	0.0
20	17	3-Jun-02	4526°83.00'	6006°26.00'	2.5	1.22	16.0	91	2.2	179	199.8	4.8
21	17	3-Jun-02	4523°04.00'	6009°95.00'	2.5	1.20	16.6	96	2.2	41	45.0	1.1
22	17	3-Jun-02	4520°48.00'	6019°59.00'	2.4	1.20	16.9	90	1.6	28	29.7	0.8
23	17	3-Jun-02	4516°15.00'	6020°50.00'	2.3	1.23	16.0	100	1.6	5	5.0	0.1
24	17	3-Jun-02	4516°64.00'	6008°32.00'	2.4	1.18	16.6	87	1.9	5	6.0	0.1
25	17	4-Jun-02	4538°47.00'	5952°28.00'	2.4	1.12	16.7	85	2.1	6	7.4	0.2
26	17	4-Jun-02	4539°24.00'	5958°30.00'	2.4	1.10	16.3	73	1.8	0	0.0	0.0
27	17	4-Jun-02	4536°55.00'	6007°97.00'	2.5	1.20	*16.6*	86	1.9	3	3.0	0.1
28	17	4-Jun-02	4527°10.00'	6025°28.00'	2.4	1.00	15.8	114	1.9	42	58.1	1.4
29	17	4-Jun-02	4529°81.00'	6029°07.00'	2.4	1.20	16.6	85	1.9	383	418.8	10.4
30	17	4-Jun-02	4530°41.00'	6038°41.00'	2.5	1.20	16.9	70	1.6	380	407.2	10.1
31	17	7-Jun-02	4522°55.00'	6059°62.00'	2.5	1.30	14.6	60	1.4	105	120.3	3.0
32	14	7-Jun-02	4455°40.00'	5820°37.00'	2.4	1.12	16.1	128	2.1	466	562.4	14.0
33	14	7-Jun-02	4450°44.00'	5832°01.00'	2.3	1.12	*16.6*	147	1.7	205	240.3	6.0
34	14	7-Jun-02	4447°85.00'	5838°81.00'	2.4	1.20	16.4	131	1.6	150	165.9	4.1
35	14	7-Jun-02	4455°62.00'	5843°32.00'	2.4	1.30	17.0	151	1.5	186	183.1	4.5
36	14	7-Jun-02	4447°05.00'	5854°14.00'	2.4	2.20	*16.6*	146	1.5	386	229.5	5.7
37	14	7-Jun-02	4441°09.00'	5900°61.00'	2.5	1.20	17.4	149	1.4	163	170.1	4.2
38	14	7-Jun-02	4448°68.00'	5907°27.00'	2.4	1.14	17.4	118	1.4	176	192.5	4.8
39	14	7-Jun-02	4447°98.00'	5911°57.00'	2.4	1.21	17.9	116	1.4	499	501.5	12.5
40	14	8-Jun-02	4449°95.00'	5928°54.00'	2.5	1.28	*16.6*	136	2.8	586	599.7	14.9
41	14	8-Jun-02	4443°89.00'	5932°31.00'	2.5	1.23	*16.6*	115	3.4	356	379.2	9.4
42	14	8-Jun-02	4441°82.00'	5946°27.00'	2.4	1.20	*16.6*	139	3.7	147	160.9	4.0
42	14	8-Jun-02	4441°82.00'	5946°27.00'	2.4	1.20	*16.6*	139	3.7	147	160.9	4.0

43	14	8-Jun-02	4451°44.00'	5942°63.00'	2.3	1.20	*16.6*	134	3.4	623	679.8	16.9
44	14	8-Jun-02	4454°53.00'	5958°64.00'	2.4	1.20	*16.6*	104	3.5	49	53.5	1.3
45	14	8-Jun-02	4447°81.00'	5958°28.00'	2.4	1.20	*16.6*	118	3.8	257	280.2	7.0
46	14	8-Jun-02	4441°63.00'	5959°40.00'	2.4	1.19	*16.6*	113	3.8	354	389.9	9.7
47	15	8-Jun-02	4442°89.00'	6009°43.00'	2.5	1.18	*16.6*	108	4.1	101	112.3	2.8
48	15	9-Jun-02	4441°08.00'	6018°64.00'	2.4	1.21	16.7	143	3.0	50	54.4	1.3
49	15	9-Jun-02	4449°84.00'	6021°39.00'	2.4	1.20	16.7	169	3.0	128	139.3	3.5
50	15	9-Jun-02	4456°37.00'	6014°80.00'	2.5	1.19	16.8	106	2.9	63	68.3	1.7
51	15	9-Jun-02	4458°37.00'	6007°75.00'	2.5	1.22	17.4	123	3.0	175	179.4	4.5
52	15	9-Jun-02	4455°25.00'	6026°58.00'	2.4	1.22	16.6	133	2.9	212	227.4	5.6
53	15	9-Jun-02	4451°26.00'	6035°97.00'	2.3	1.21	16.5	143	3.0	131	142.6	3.5
54	15	9-Jun-02	4446°85.00'	6036°38.00'	2.4	1.20	17.2	131	3.2	323	339.1	8.4
55	15	9-Jun-02	4453°76.00'	6046°14.00'	2.4	1.22	17.0	122	3.8	41	42.9	1.1
56	15	10-Jun-02	4449°54.00'	6056°78.00'	2.4	1.20	16.6	132	4.4	85	92.4	2.3
57	15	10-Jun-02	4452°83.00'	6106°01.00'	2.5	1.24	17.3	103	4.4	200	203.1	5.0
58	15	10-Jun-02	4454°69.00'	6057°01.00'	2.4	1.22	17.0	105	4.1	29	30.5	0.8
59	15	10-Jun-02	4501°04.00'	6058°54.00'	2.4	1.20	17.0	104	2.7	7	7.3	0.2
60	15	10-Jun-02	4504°82.00	6052°11.00	2.5	1.23	17.1	103	1.6	6	6.6	0.2
Average					**2.4**	**1.2**	**16.6**	**117.2**	**2.7**	**146.7**	**156.2**	**3.9**

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	Ave.
2	359	307	129	40	166	280	175	138	199
3	1,046	276	1,159	785	27	757	362	396	601
4	876	1,248	1,257	1,884	3,010	0	1184	413	1,234
5+	1,702	2,162	1,539	2,047	1,952	3,374	2110	1909	2,099
	3,983	3,993	4,084	4,755	5,155	4,412	3831	2856	4,134

Table 6. Survey biomasses, commercial shrimp catches and exploitation rates (catch/biomass) by SFA (13-15, offshore part), and the inshore area (17), 1995-2001.

		1995	1996	1997	1998	1999	2000	2001	2002
	13	4837	6838	5920	7187	9517	5919	4089	3114
	14	9067	12094	9471	11278	11039	9544	12325	12020
BIOMASS(mt)	**15**	5299	6610	4736	4548	7806	7213	2073	2766
	17	4415	3663	6220	9530	8262	9183	6541	2872
	total	**23620**	**29206**	**26349**	**32545**	**36625**	**31860**	**25038**	**20773**
	13	168	55	570	514	612	301	588	270
	14	2265	2299	2422	2012	1503	2009	1616	1601
CATCH(mt)	**15**	715	817	583	618	589	1609	1132	347.2
	17	0	0	0	787	2121	1498	1629	775
	total	**3148**	**3171**	**3575**	**3930**	**4825**	**5417**	**4965**	**2994**
	13	3.5	0.8	9.6	7.1	6.4	5.1	14.4	8.7
	14	25.0	19.0	25.6	17.8	13.6	21.0	13.1	13.3
EXPLOITATION(%)	**15**	13.5	12.4	12.3	13.6	7.5	22.3	54.6	12.6
	17	0.0	0.0	0.0	8.3	25.7	16.3	24.9	27.0
	total	**13.3**	**10.9**	**13.6**	**12.1**	**13.2**	**17.0**	**19.8**	**14.4**

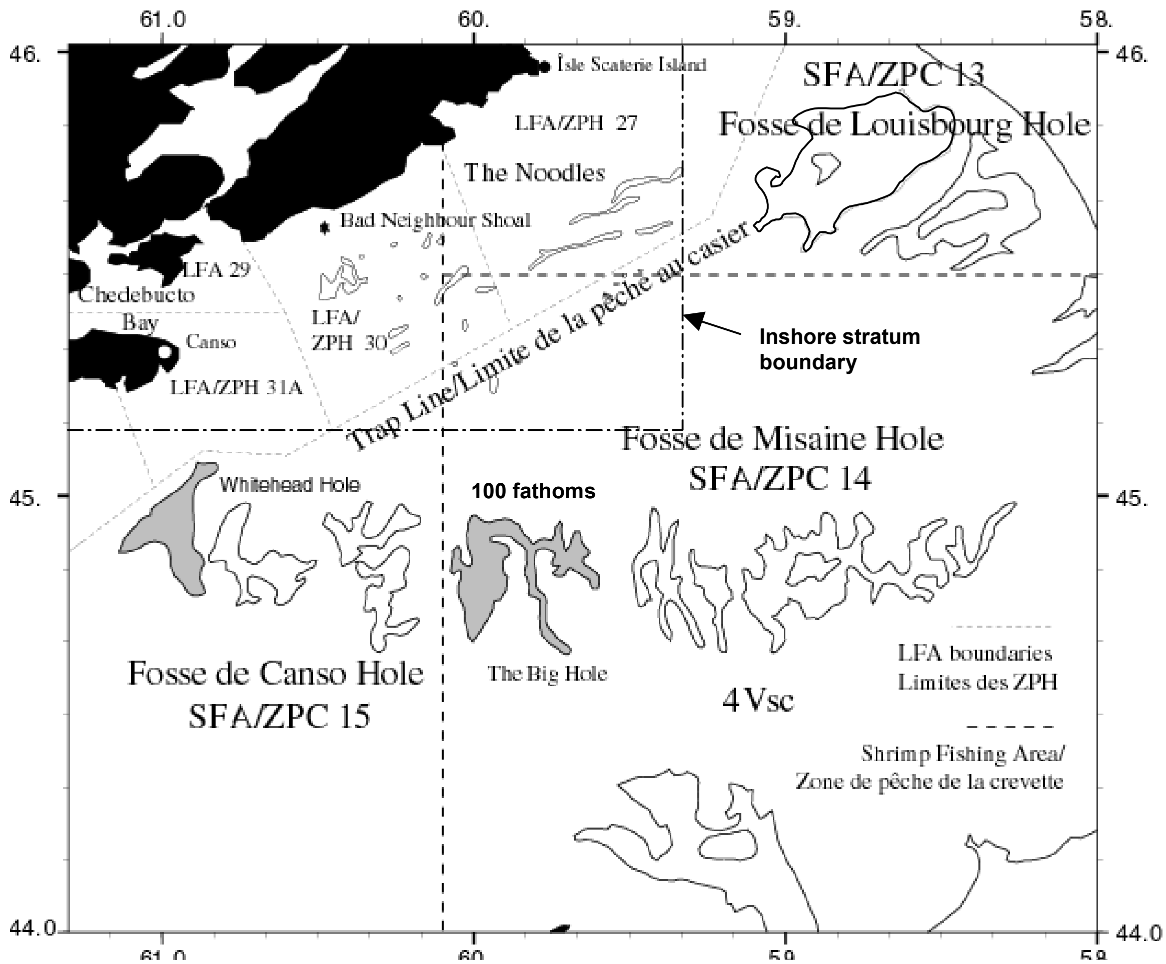

Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. The lobster Fishing Areas (LFAs) used to allocate shrimp trap licences, and the shrimp trap line are also shown. Trappers are prohibited from fishing seaward of this line. Another line (not shown) prohibits trawlers from fishing inside 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)

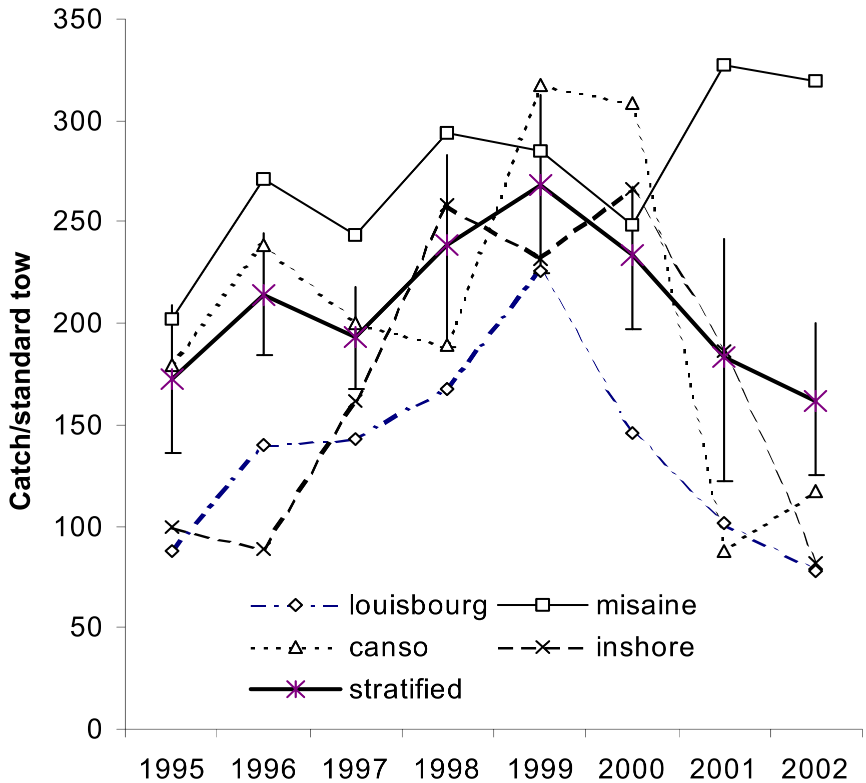

Figure 2. Stratified catch/standard tow for DFO-industry co-operative surveys 1995-2002 and unstratified estimates for the individual strata, which approximately correspond to the main shrimp holes and SFAs. Stratum 13 is Louisbourg Hole and SFA 13; Stratum 14 - Misaine Holes and SFA 14; Stratum 15 - Canso Holes and the offshore part of SFA 15. The Inshore, or Stratum 17, is comprised of inshore parts of SFA 13-15.

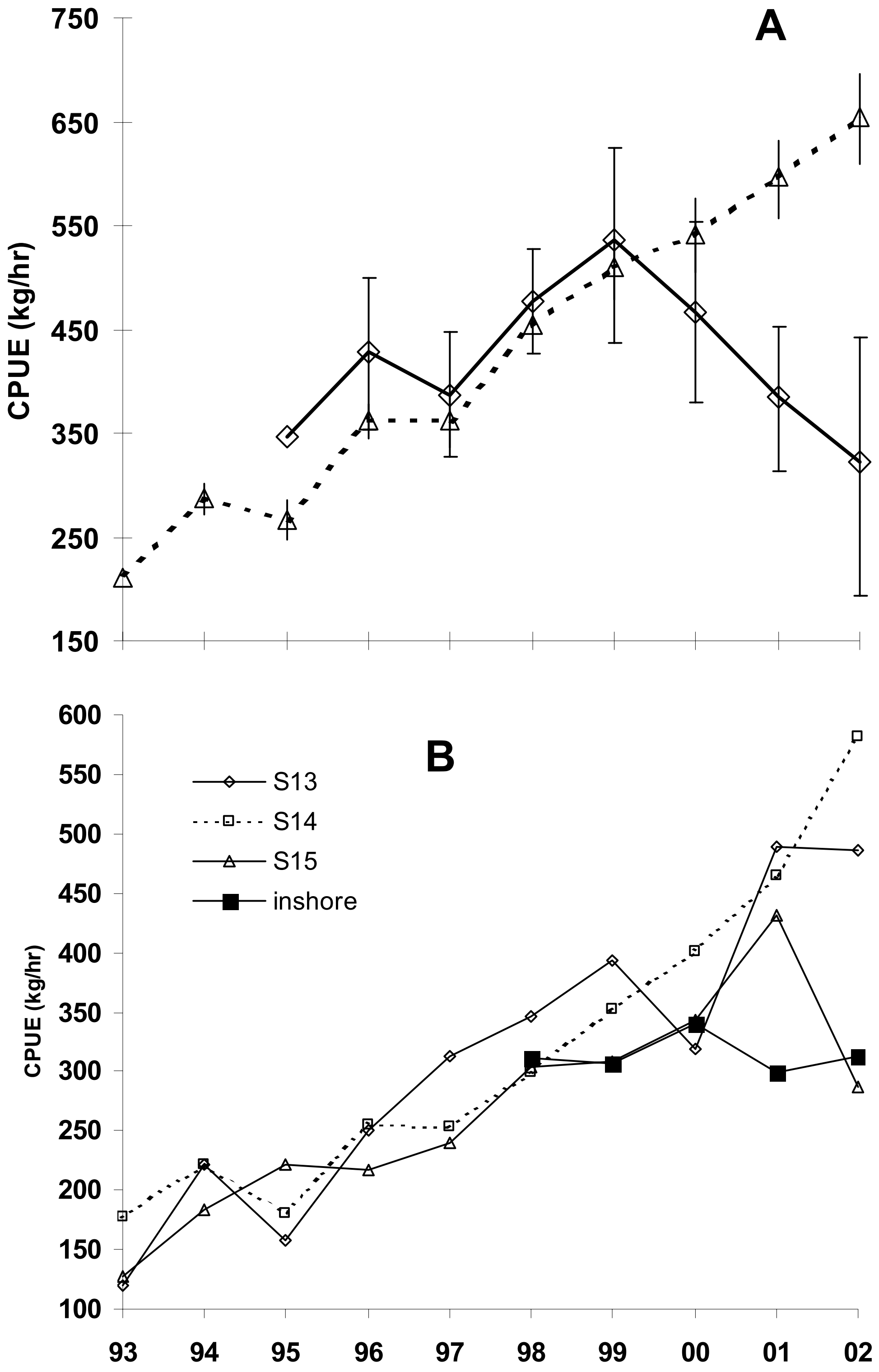

Figure 3. A - Survey stratified estimate and standardised CPUE with 95% confidence intervals, and B - unstandardised commercial CPUE for each fishing area. Note that SFA15 includes the inshore, but the latter is also shown separately since fishing began there in 1998.

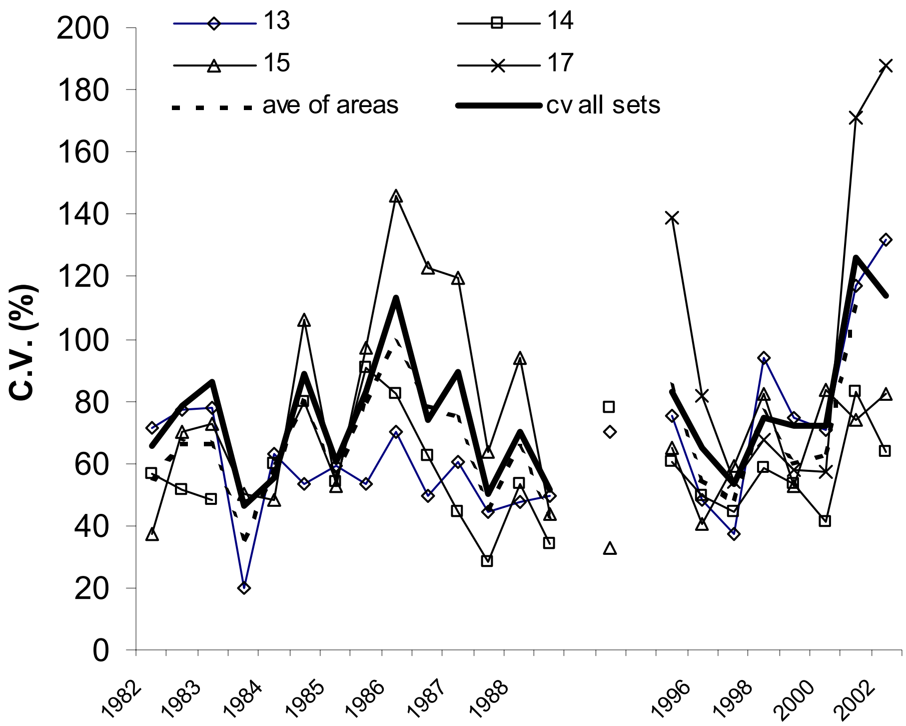

Figure 4. Coefficients of variation (C.V.) for individual shrimp fishing areas from shrimp surveys. Note that the earlier survey series has two values per year, one for the spring and one for the fall survey.

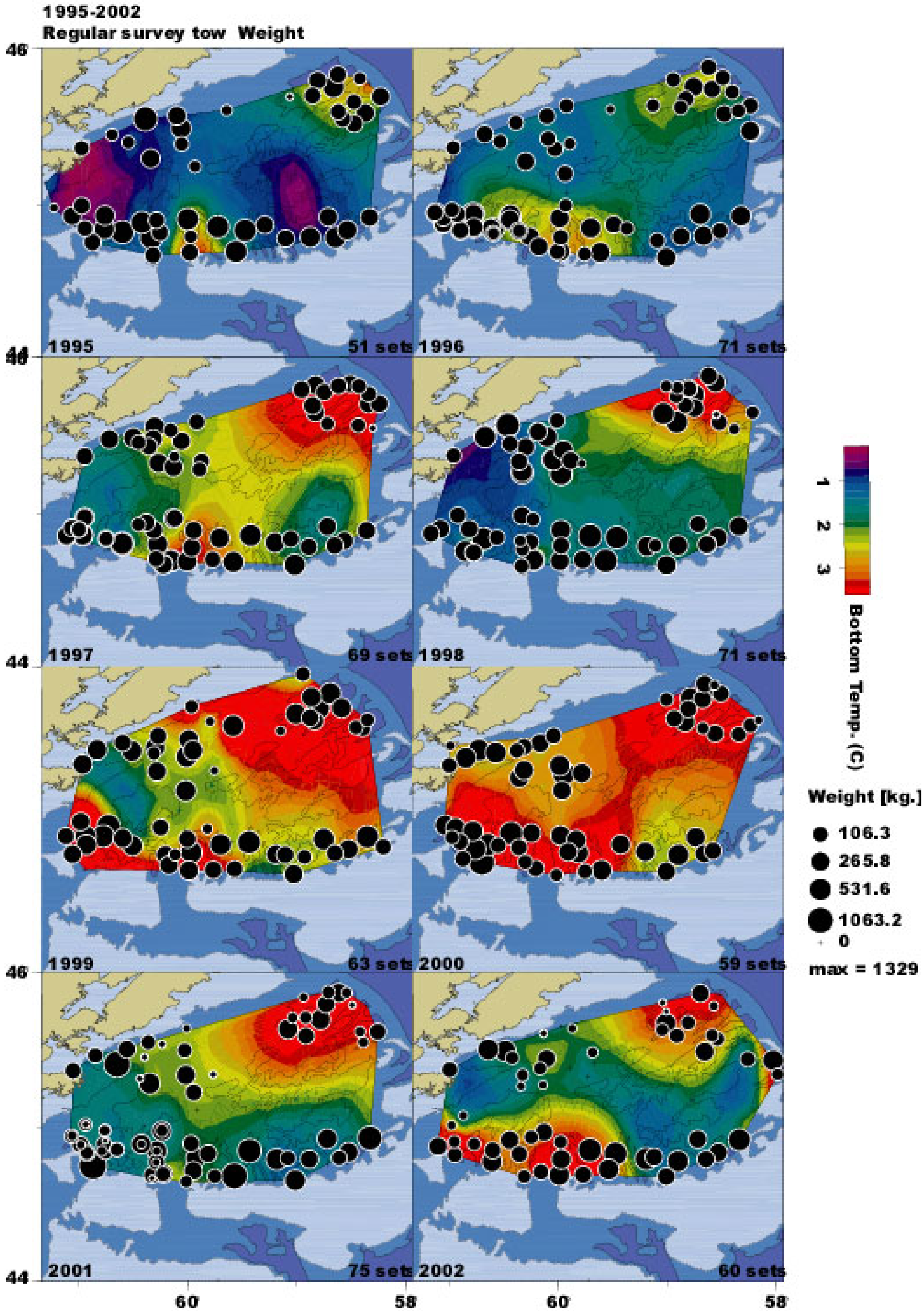

Figure 5. Distribution of catches and bottom temperatures from DFO-industry surveys 1995-01.

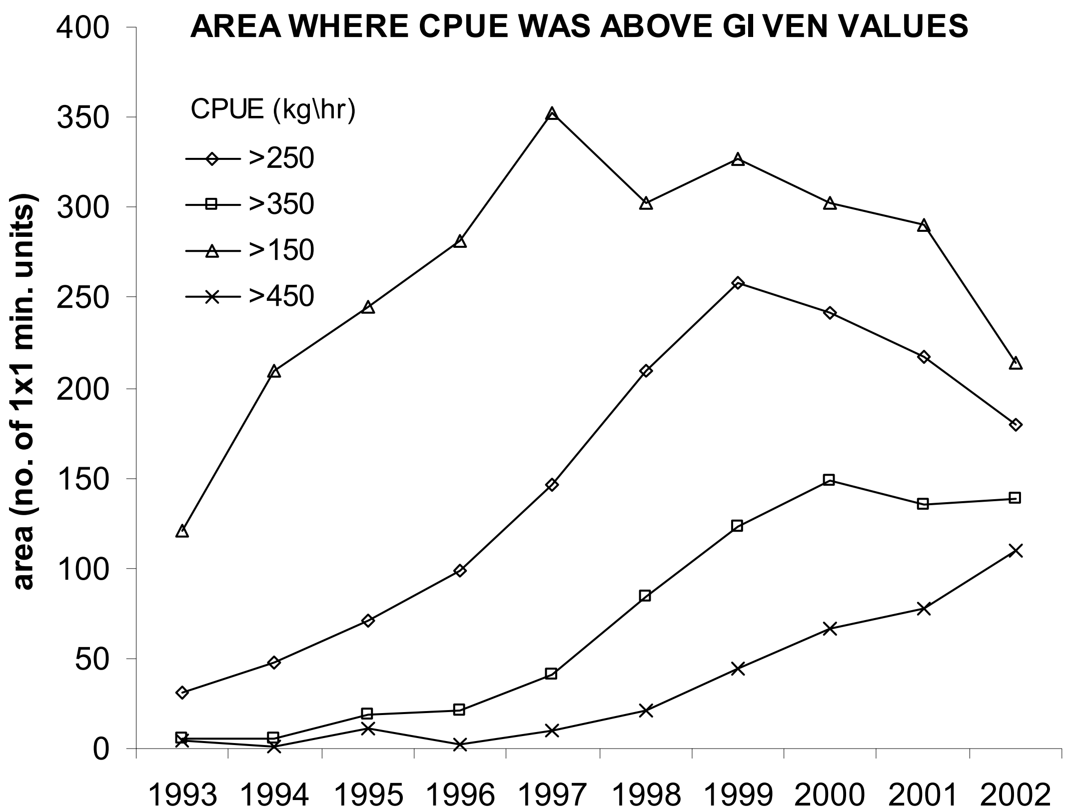

Figure 6. Number of 1 minute square unit areas fished by the shrimp fleet with mean catch rates above the values specified in the legend.

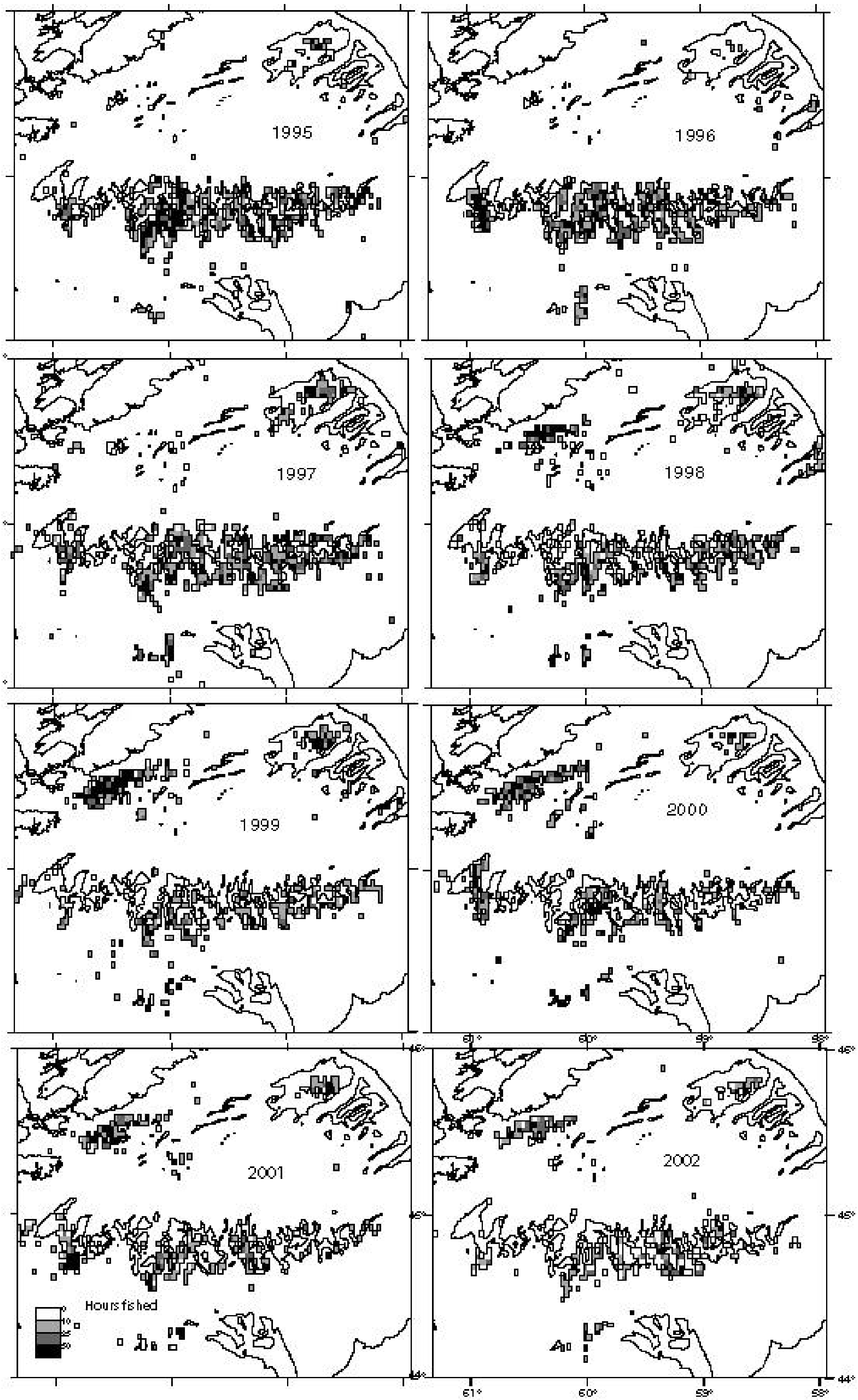

Figure 7. Annual effort by trawlers 1995-2002, cumulative by one minute squares.

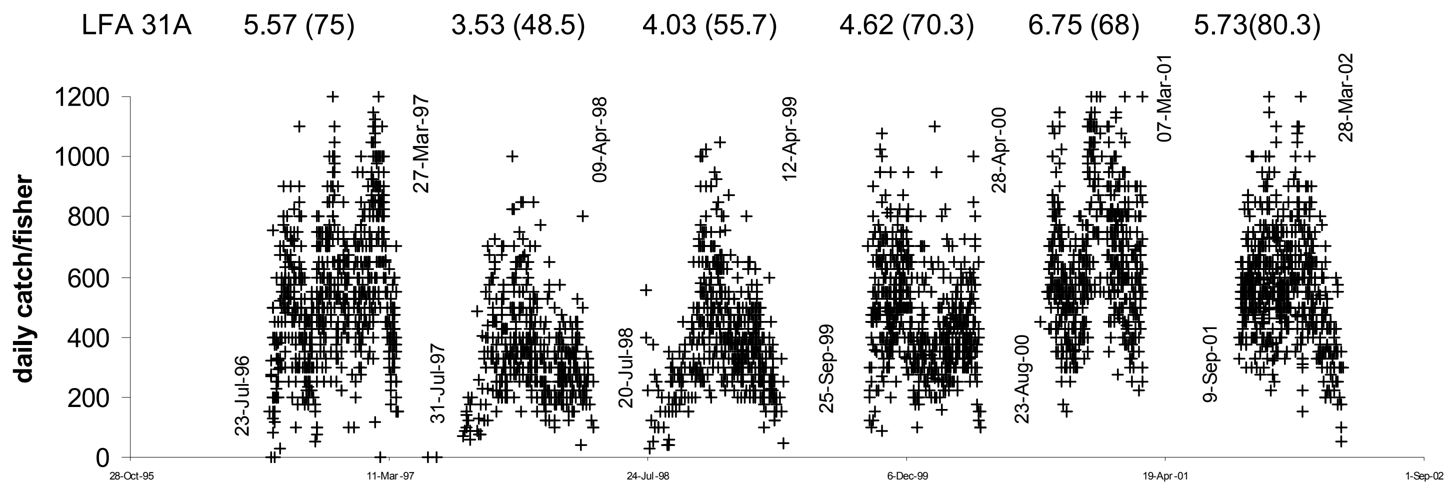

Figure 8. Mean daily catches per trap haul for the Canso trap fishery. The dates indicate the beginning and end of the fishery each year (there is no season restriction) and the values at the top indicate annual mean catches per trap haul and total effort in parentheses (trap hauls x 10^{-3}).

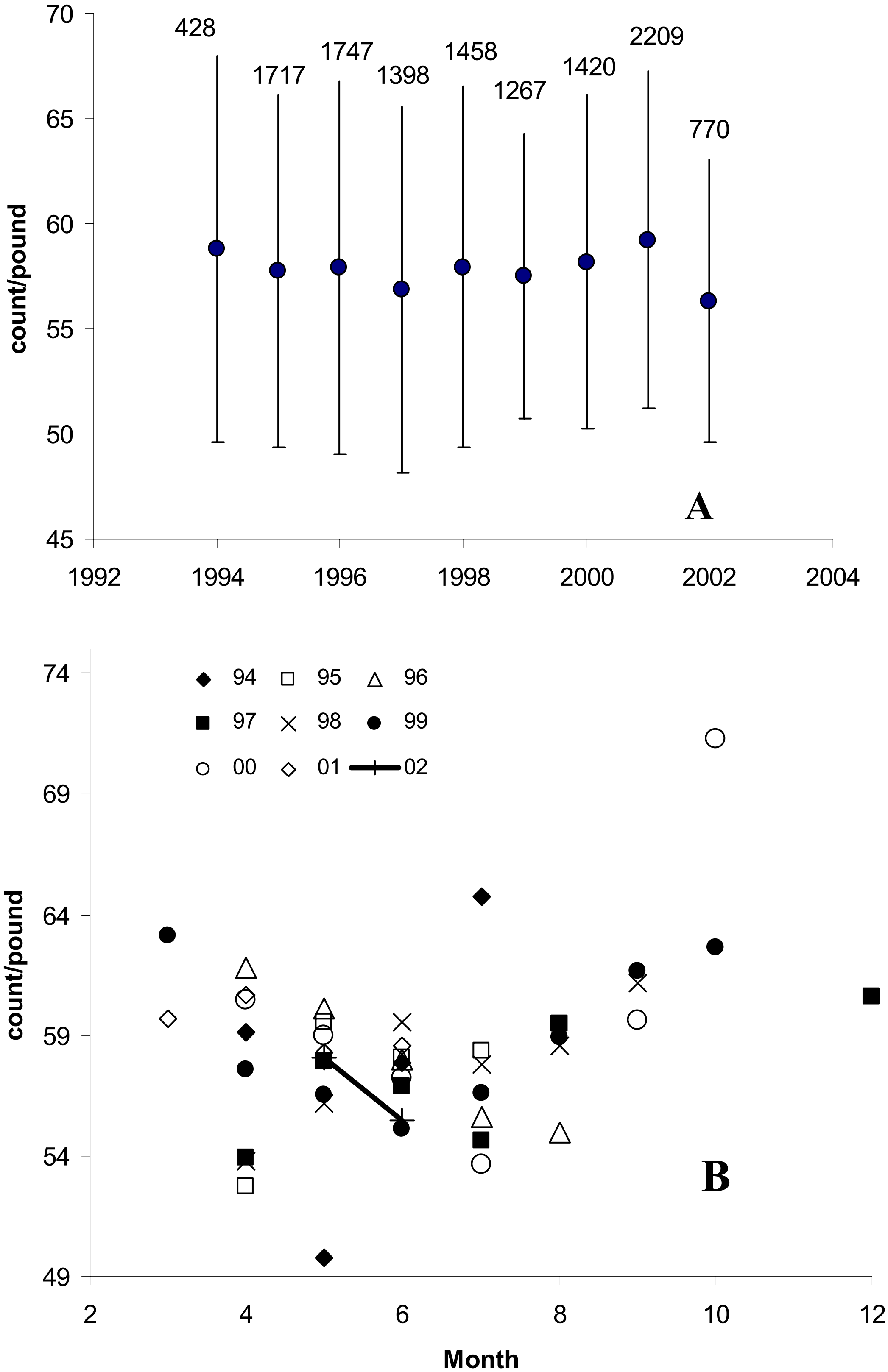

Figure 9. Annual (A) and monthly (B) mean commercial shrimp counts per pound for vessels landing in Canso. The bars in the upper figure represent 1 standard deviation and the numbers above each bar are the number of observations.

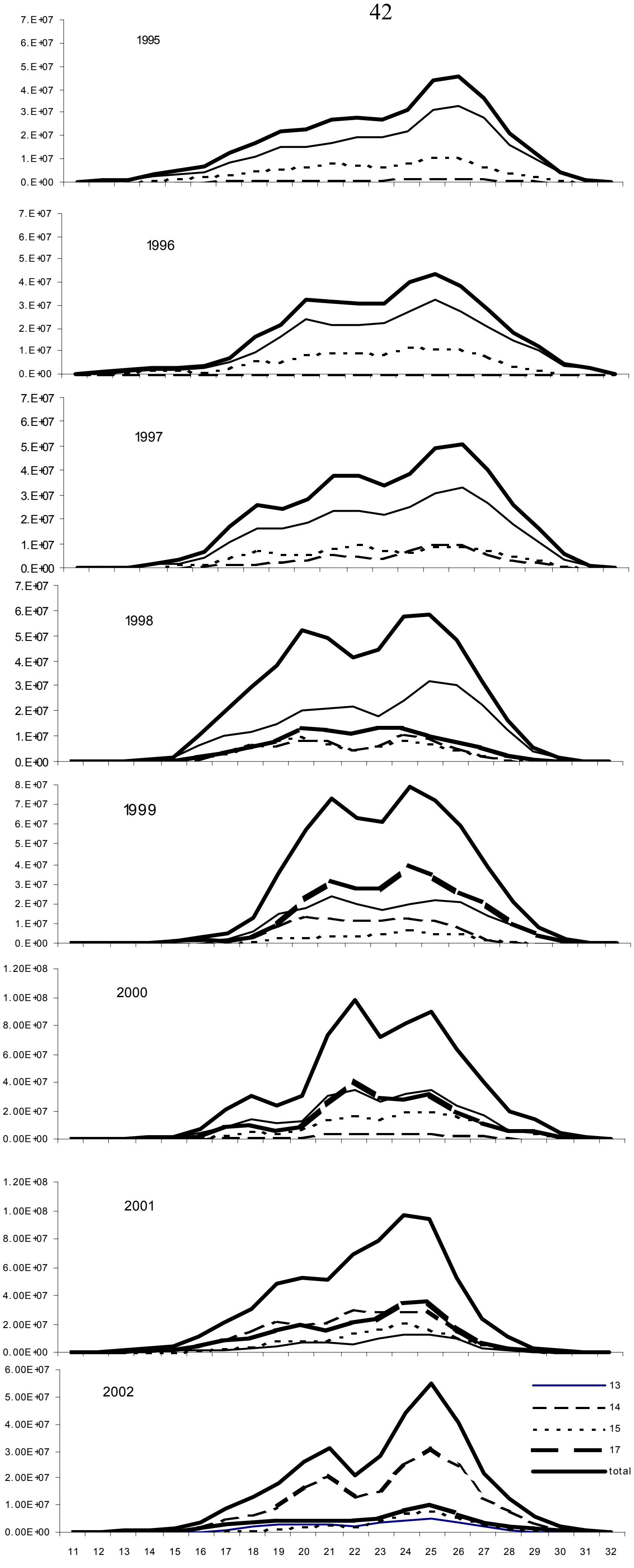

Figure 10. Catch at length from commercial sampling, 1995-2002

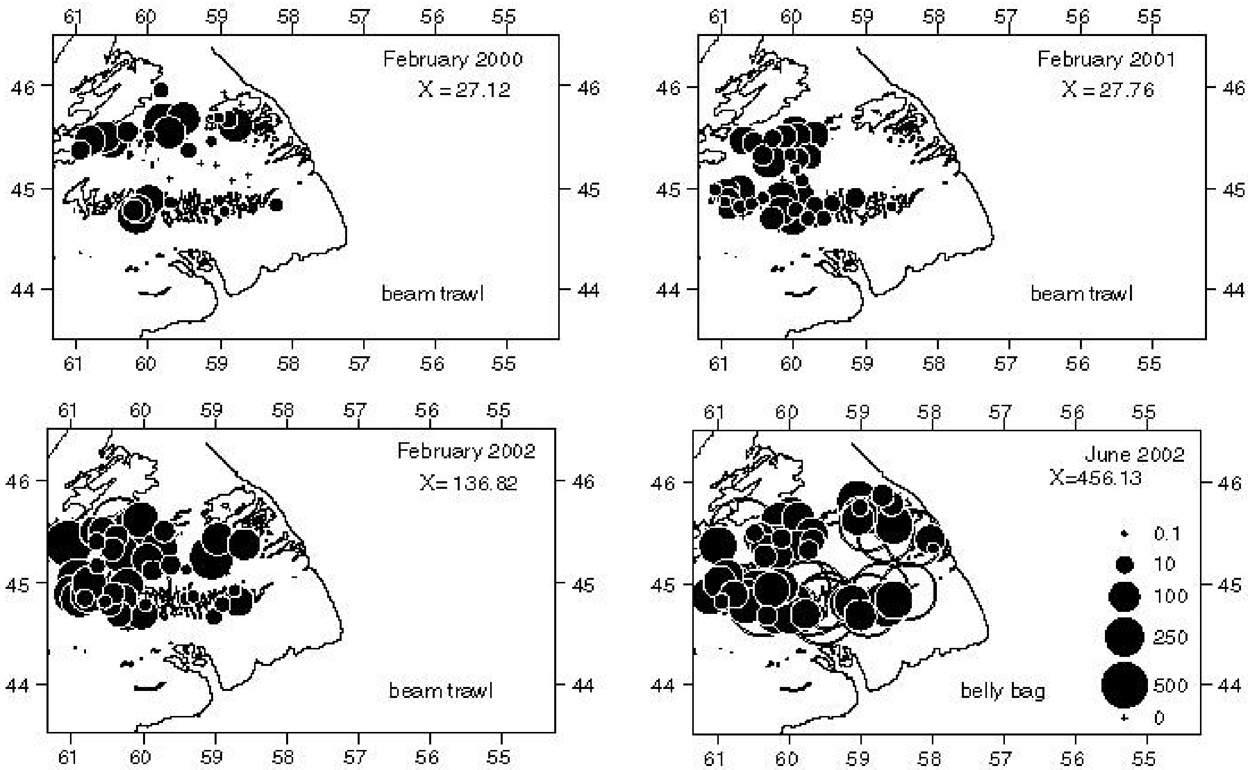

Figure 11. Distribution and abundance (X=average catch per tow) from juvenile beam trawl and "belly bag" surveys.

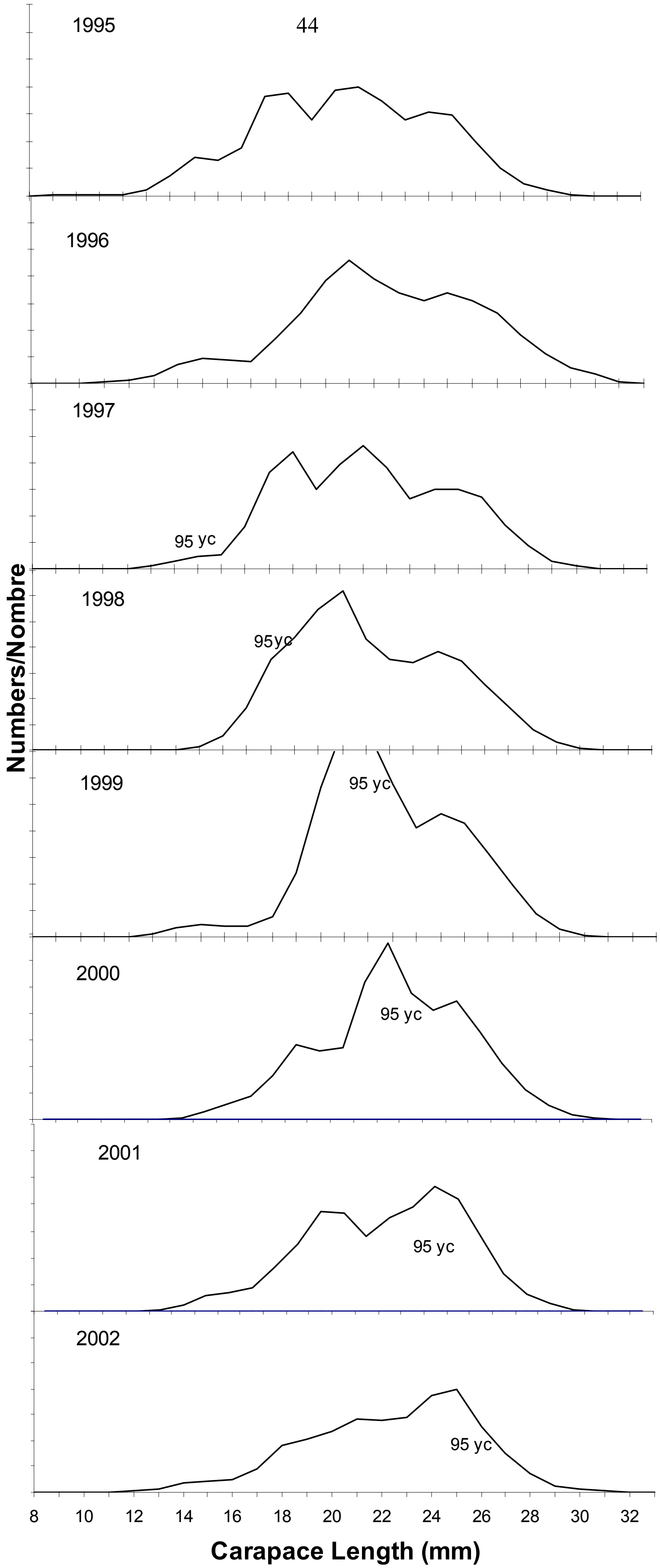

Figure 12. Population estimates at length from DFO-industry surveys. The heavy dotted line in each figure represents transitional and primiparous shrimp, and the stippled line represents multiparous shrimp.

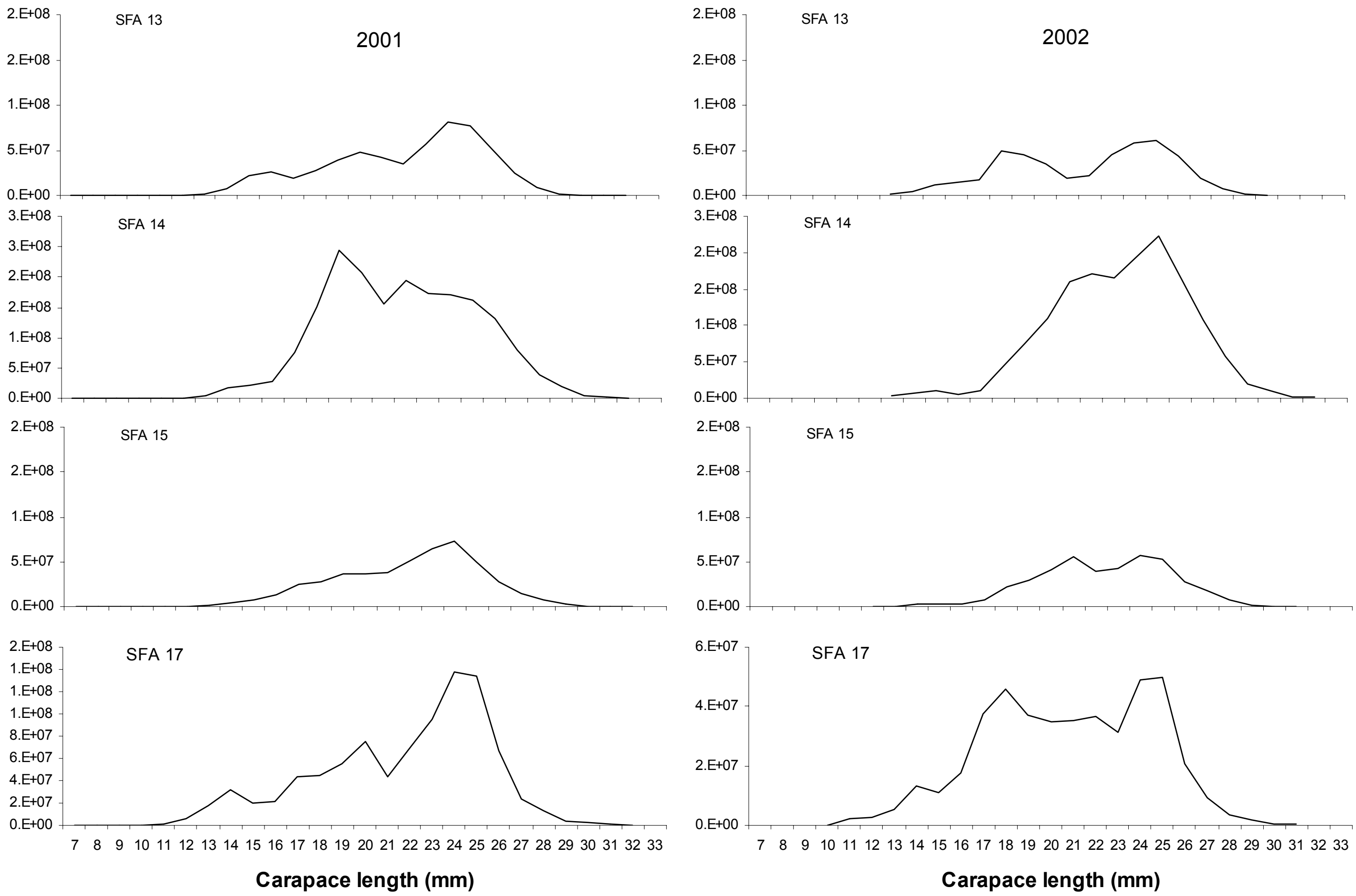

Figure 13. Population at length estimates by Shrimp Fishing Area from the DFO-Industry survey conducted in June, 2001-2002.

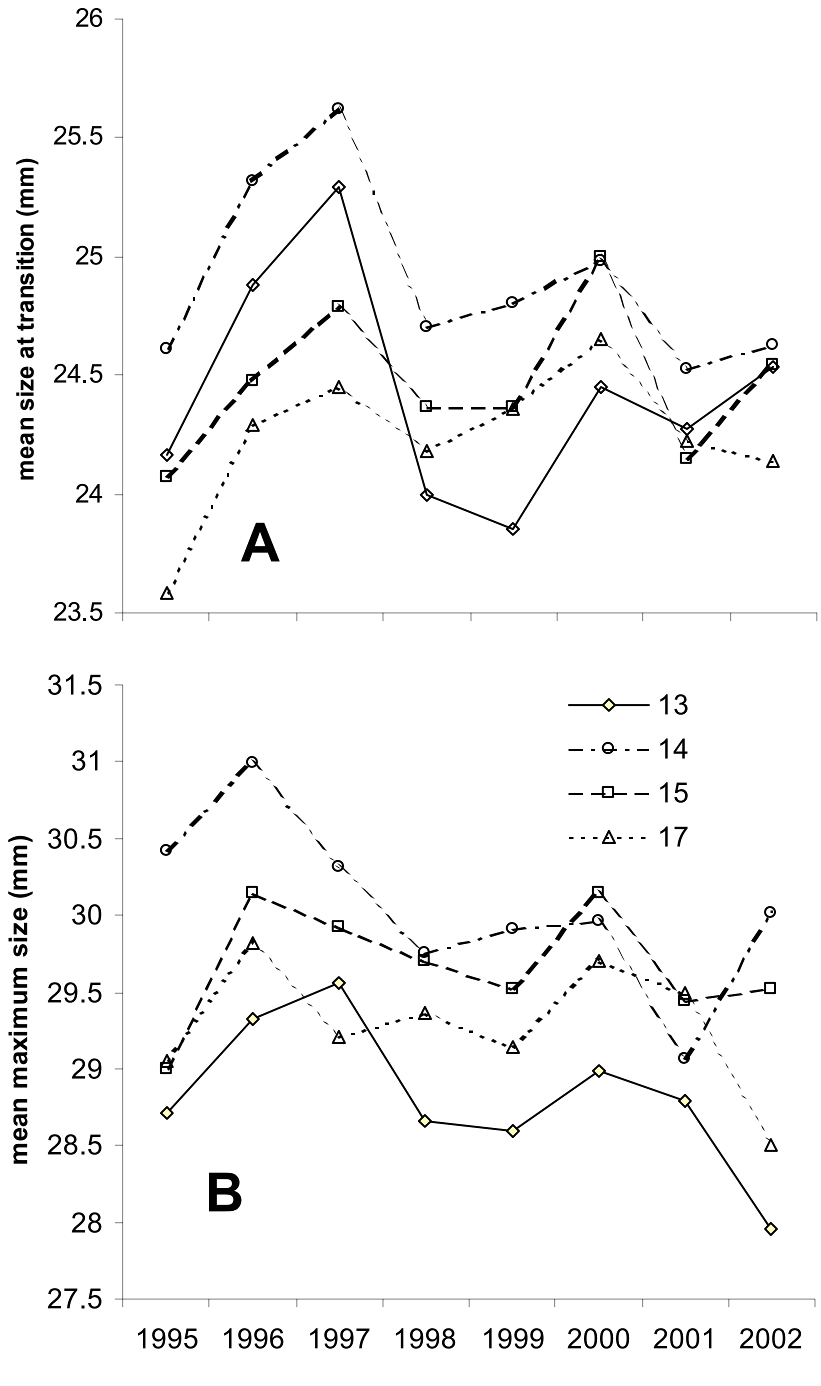

Figure 14. Average size at A. sex transition and B. maximum size by shrimp fishing area for the DFO-industry surveys 1995-2001.

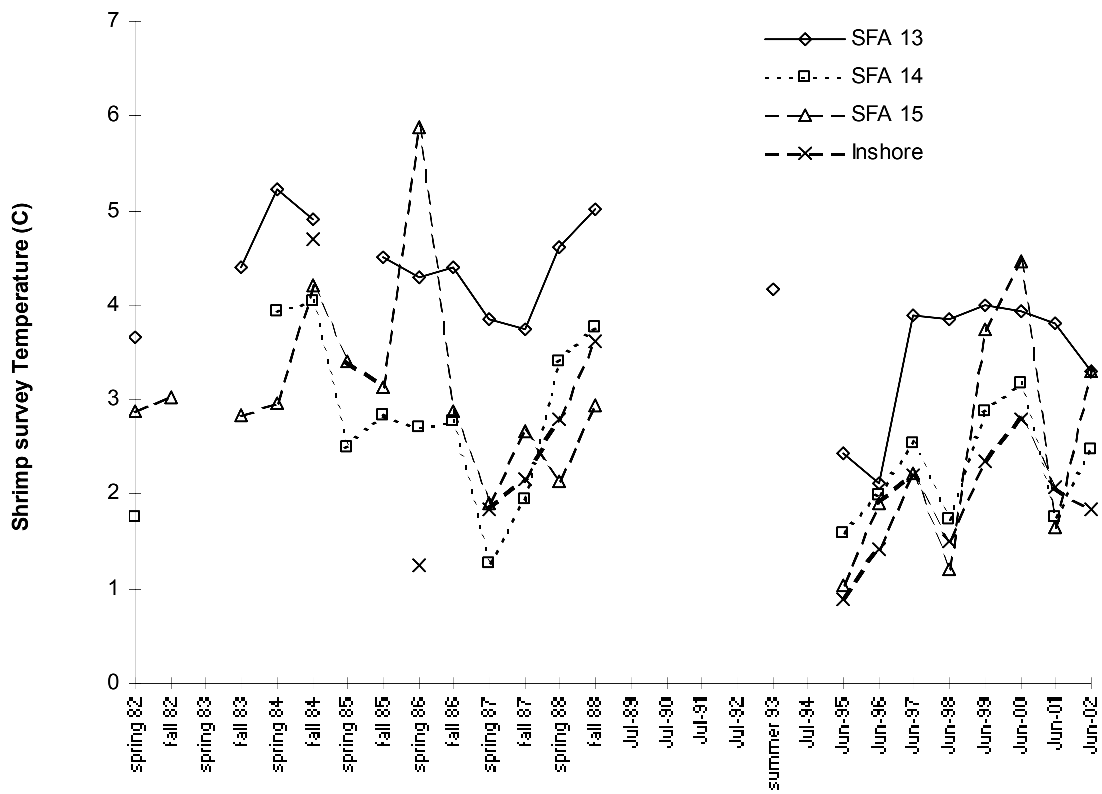

Figure 15. Mean bottom temperatures from shrimp surveys by SFA. Note that both spring and fall values were available from the earlier series (1982-88), but only one survey (June) was conducted annually in the recent series.