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An Assessment of the Eastern Scotian Shelf Shrimp Stock and Fishery in 2005 and Outlook for 2006

Évaluation du stock et de la pêche de la crevette de l'est du plateau néo-écossais en 2005 et perspectives pour 2006

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ABSTRACT

The continued biomass increase projected last year did not materialise, due to the unforeseen density-induced slow growth and either inaccurate estimation or higher mortality of the strong 2001 year class. However, the 2005 DFO-industry survey total biomass index was still the second highest of the 11 year series, decreasing slightly from the record high of the previous year. The bulk of the biomass continues to concentrate in the offshore part of SFA 14 (i.e. survey stratum 14 or the Misaine Hole). The spawning stock biomass (females) also decreased from 2004 but was still the second highest on record. The 2001 year class in 2005 continues to be the largest on record at age 4 (~ 4 x average). Considering the exceptional continuing strength of this year class since its detection in 2002 belly bag samples, its slower growth is likely to continue, consequently not all of this year class is expected to become female for the 2006 fishery, or it may delay sex change entirely for a year. It should support the higher TAC effected in 2005 for several more years, however, concerns about growth overfishing continue and it is not advisable to increase the TAC above the 2005 level. The 2002-2004 year classes are weaker, consequently a biomass decrease is expected following the passage of the 2001 year class through the population. This is similar to what occurred during the last strong recruitment event (1994-1995), suggesting the establishment of a cyclical population dynamic often seen in established shrimp fisheries. Such a pattern may be indicative of decreased stability, re-enforcing the need for continued good monitoring information and a precautionary approach in managing this fishery.

Commercial counts in 2005 were the highest on record because of difficulty in avoiding the 2001 year-class. After shifting much of its effort and catch (60%) to the Louisbourg Hole (SFA 13) in 2004 where catch rates and counts were favourable, in 2005 the distribution of effort and catch was more evenly distributed between areas, including increased effort in SFA 14 and 15, while avoidance of the inshore area continued. There was also a temporal shift in effort that more fishing activity occurred during the fall months due to the increase in TAC, small\soft shrimp, and low prices, resulting in a larger percentage of ovigerous females in the catch. After a sustained increase of over a decade, commercial catch rates (standardized series) peaked in 2003. They have decreased slightly since but remain high. Spatial indicators suggest that the area with the highest commercial catch rates (>250 kg/hr^{-}) is expanding. Despite concerns of growth overfishing, the TAC for 2005 was increased substantially to take advantage of a projected biomass increase, and past performance of fishers in avoiding small shrimp due to flexibility in choosing fishing areas (i.e. no area quotas). The 2005 TAC was not caught, for a number of reasons, including poor market conditions, bad weather, difficulties in finding large shrimp and widespread distribution of the 2001 year class. A requested season extension into early 2006 was not recommended due to the lower-than-projected biomass, the resulting higher than projected exploitation rates, and large numbers of small shrimp in the catch. The trap fishery did not take place in 2005 due to poor market conditions.

RÉSUMÉ

L’augmentation continue de la biomasse prévue l’année dernière ne s’est pas concrétisée, à cause de la croissance lente imprévue, due à la densité, et soit à une estimation inexacte ou à un taux de mortalité plus élevé de la forte classe d’âge de 2001. Toutefois, l’indice de la biomasse totale du relevé MPO-industrie de 2005 demeure le deuxième plus élevé de la série chronologique de 11 ans, légèrement en baisse par rapport au sommet de l’année précédente. La biomasse continue d’être concentrée principalement dans la partie hauturière de la ZPC 14 (c.-à-d. la strate 14 du relevé ou la fosse de Misaine). La biomasse génitrice (femelles) a aussi diminué par rapport à 2004, mais elle n’en restait pas moins la deuxième plus élevée à ce jour. L’effectif de la classe d’âge de 2001, en 2005, continue d’être le plus fort jamais enregistrée à l’âge 4 (~ 4 fois la moyenne). Compte tenu de l’effectif exceptionnel continu de cette classe d’âge depuis son apparition en 2002 dans les échantillons prélevés à l’aide d’un sac attaché au ventre du chalut, son taux de croissance lent semble vouloir se maintenir; par conséquent, cette classe d’âge ne sera probablement pas entièrement recrutée au sein de la population de femelles pour la pêche de 2006, ou bien le changement de sexe pourrait être retardé d’un an. Elle devrait pouvoir soutenir le TAC élevé en vigueur en 2005 pendant plusieurs années encore. Cependant, les préoccupations relatives à la surpêche du potentiel de croissance subsistent, de sorte qu’il ne semble pas souhaitable de hausser le TAC au-delà de celui de 2005. Les classes d’âge de 2002 à 2004 sont plus faibles. On s’attend donc à une diminution de la biomasse après le recrutement de la classe d’âge de 2001 au sein de la population. Il s’est produit une situation semblable au moment de la pointe de recrutement de 1994-1995; on pourrait y voir l’établissement d’une dynamique cyclique de la population souvent observée dans les pêches de la crevette bien établies. Une telle tendance pourrait indiquer une baisse de la stabilité, soulignant d’autant la nécessité de continuer à bien surveiller l’information et d’adopter une approche prudente pour la gestion de cette pêche.

Les prises commerciales ont été les plus élevées jamais enregistrées, en 2005, à cause de la difficulté d’éviter la classe d’âge de 2001. Après avoir réorienté une grande partie de l’effort de pêche (60 %) vers la fosse de Louisbourg (ZPC 13) où la biomasse et le nombre étaient favorables, en 2005, l’effort et les prises ont été répartis plus uniformément entre les zones et il y a eu augmentation de l’effort dans les ZPC 14 et 15, pendant que l’on continuait d’éviter la zone côtière. On a aussi constaté une modification du régime temporel de l’effort de pêche, celui-ci ayant été accru au cours des mois d’automne en raison de l’augmentation du TAC, de la présence de petites crevettes « molles » et des prix faibles, de sorte que le pourcentage de femelles ovigères dans les prises était plus élevé. Après une augmentation soutenue pendant plus d’une décennie, les taux de prises commerciales (série chronologique normalisée) ont atteint un sommet en 2003. Ils ont diminué légèrement depuis, mais demeurent élevés. Les indicateurs du régime spatial semblent montrer que la zone ayant les plus fortes prises commerciales (>250 kg/h) s’étend. Malgré les préoccupations relatives à la surpêche du potentiel de croissance, le TAC de 2005 a été accru substantiellement, afin que l’on puisse tirer partir de l’augmentation prévue de la biomasse et de la capacité démontrée antérieurement des pêcheurs d’éviter les petites crevettes grâce à l’accès libre aux zones de pêche (au lieu des quotas de zone). Le TAC de 2005 n’a pas été atteint pour différentes raisons, notamment les mauvaises conditions du marché, le mauvais temps, la difficulté de trouver les grosses crevettes et la répartition étendue de la classe d’âge de 2001. La prolongation demandée de la saison jusqu’aux premiers mois de 2006 n’a pas été recommandée à cause de la biomasse plus faible que prévue, des taux d’exploitation plus élevés qu’anticipé et du grand nombre de petites crevettes parmi les prises. Il n’y a pas eu de pêche au casier en 2005, en raison des conditions défavorables du marché.

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. (2003a) 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, 2003b, 2004, 2005). 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 Area (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 2003, the survey index increased for the first time following three successive declines and the TAC was raised to 3500mt for 2004. Signs of improved recruitment in the form of a very strong 2001 year class suggested that the stock would continue to increase. The 2004 survey biomass was the highest on record and the TAC was raised to 5000mt for the 2005 fishery. Despite continuing good catch rates the TAC was not caught in 2005 for a number of reasons, including poor market conditions, bad weather, soft shrimp, gear conflicts (snow crab fishery) and other logistic problems.

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, 2004 and 2005 effort on the Scotian Shelf virtually stopped during the summer to avoid soft shrimp and crab traps. Prices for coldwater shrimp have remained low in recent years due to high inventories, small shrimp, and competition from warm water wild and aquacultured shrimp production. This has had serious and widespread economic consequences for the coldwater shrimp industry, ranging from the large offshore concerns (freezer trawlers) operating on both sides of the North Atlantic, to the small inshore trap fishery in Chedebucto Bay, Nova Scotia, which was virtually closed during 2005.

Since 1999 many shrimp stock assessments have included a “traffic light” analysis (Koeller et al. 2000b, Mohn et al. 2001, Halliday et al 2001, Caddy et al 2005). 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 were given to support the apparent increasing shrimp aggregation shown by the survey and catch per unit effort (CPUE) data; anecdotal reports of large numbers of 1-year old shrimp found on Cape Breton beaches in 2002 supported 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”. In any case, it should be noted that such scoring is not at this point intended to be translated directly into management action, for example, in the form of rules 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.

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 included provisions for temporary licences during favourable periods. Although this management plan expired in 2002 and negotiations for a renewed agreement were not successful, the 2003-2005 fisheries essentially operated under its provisions, which included removal of temporary licences when the quota dropped below an agreed threshold. Disagreement between temporary licence holders, who wanted permanency, and the permanent fleet component prevented the successful negotiation of a new multi-year plan. This stumbling block was removed when temporary licences were made permanent for the 2005 fishery – a draft Integrated Fisheries Management Plan (IFMP 2006-2010) is currently under review.

The experimental trap fishery was not under quota management from 1995-1997 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 overall catch has been lower than the TAC since 1998. Note also that the trap quota reallocation has been based on projected catches which were not achieved during some years. In an attempt to avoid reallocations, in 2004 only 300mt were allocated to this fishery which is closer to its capacity. With an increase in the TAC for 2005 this was increased to 382mt, but the fishery did not take place at all due to poor market conditions. The substantial projected TAC underrun for 2005 was considerably greater than this due to various logistic problems experienced by the mobile fleet, which requested a season extension. An expert opinion from science recommended against this because survey biomass for 2005 was lower than projected in the 2004 assessment, largely due to slow growth of the large 2001 year class.

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 arbitrarily 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 be viewed as a negative development. However, traffic lights were not changed from the default in this document. Similarly, the record high counts experienced by fishers in 2005 are negative in the context of the fishing impact characteristic because they are indicative of growth overfishing, but if considered within the production characteristic they are positive because they substantiate fishery independent (survey) results of exceptional 4-year old shrimp abundance.

ABUNDANCE

Research Vessel (RV) Abundance Index

An eleventh industry-funded trawl survey, incorporating a mixed stratified random - fixed station design, was conducted in June 2005. Survey design and station selection methods were similar to previous surveys completed in 1995-2004: 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; and 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 2005 survey was completed by MV *All Seven* (fourth year for this vessel/crew) fishing the new (in 2004) 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. Belly bag samples of *P. borealis* were 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 1993-2005 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 seven of the 11 year series. 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, a requirement of all participants and provided by DFO Maritimes Region Statistics Branch.

An increase in this and the preceding 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

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 computer program, 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. This is being addressed by using a small meshed belly-bag on the footrope and under the belly of the standard survey trawl during all regular June survey sets. Only four years of data are now available, however this gear correctly identified the 2001 year class as large one year before it recruited to the survey trawl, and appears to be useful in assessing year class strength 4-5 years before recruitment to the fishery.

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.

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 (2003a) 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.

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. 2003a). Consequently, maximum size attained in the population is another measure of growth rate.

Predation

A predation index is calculated as the mean catch/set for all groundfish species from the summer groundfish survey for strata that 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

Commercial Counts

Fishers determine the number of shrimp per pound (the "count") in their catches soon after they are brought aboard in order to determine the price they will obtain from buyers. This information is of economic importance and is often conveyed to other fishers or buyers before landing, so care is usually taken in obtaining and recording it. The methodology used is basic (number of shrimp in a fixed volume, often a tobacco can, that weighs about 1 pound) but generally agrees with more rigorous methods used by buyers. The index used here is the simple arithmetic average of all counts reported in log books for the year.

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). Moreover, an increase in this indicator can be considered good (increased recruitment) or bad (growth overfishing) depending on whether it is placed in the production or fishing effects characteristic. Consequently this indicator must be considered with others including abundance indices of the different age categories. Note that counts also change considerably during the fishing season, usually starting relatively high, decreasing to a minimum in July, and increasing thereafter, possibly due to size specific changes in vertical and\or geographic distribution associated with changes in day length.

Total 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). An industry-funded port sampling program began in 1995 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' Length Over All (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 4,300mt mentioned above would be considerably less in terms of effective reproductive capacity if most is taken before egg hatching.

ECOSYSTEM

RV (Groundfish Survey) Bottom Temperatures

This index is calculated from July groundfish survey data as the mean bottom temperatures at depths >100 m in sampling strata (443,444,445 and 459) on the eastern Scotian Shelf that encompass the shrimp grounds. 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 Sea Surface Temperatures (SST)

SSTs are calculated as average temperatures within defined rectangles encompassing the shrimp holes, using the Oceans Sciences Division 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 simple averaging. Each indicator is given a value according to its colour i.e. green = 3, yellow = 2 and red = 1, and an 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 Regional Advisory Process (RAP) review committee has emphasised that the summary is difficult to interpret and should not be the primary consideration in the advice, because issues such as weighting of indicators and harvest rules associated with any particular summary have not been resolved.

Projection

A "traditional" projection, for example, from a VPA population-at-age matrix using assumptions on recruitment, growth and natural mortality is not possible with this stock.

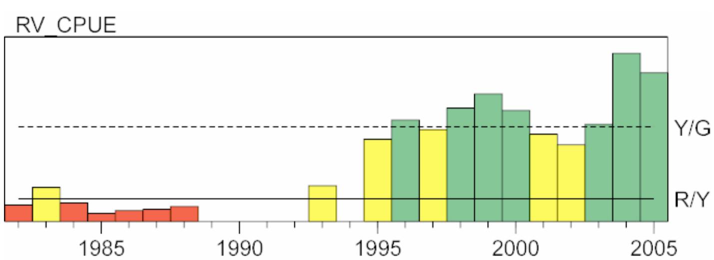
In general, the eastern Scotian Shelf shrimp stock appears as if it is never fully recruited to the survey e.g. the abundance of all year classes at age x+1 is often greater than at age x at all ages (see Koeller et al. 2004 and Table 5). However, regressions of population estimates at age x versus x+1 are often significant and were used in a simple projections to predict the 2005 population and biomass at age from the 2004 survey. Note that there are a number of problems with this method, including the fact that the regression projecting the female spawning stock biomass (age 5+) from age 4 abundance is not statistically significant (albeit only maginally so), although this is the most important component of the fishery (Fig. 15). The projection assumed current growth rates, constant mortality rates (natural and fishing) and accurate aging from modal analysis. As shown in the results, the projection was not accurate due largely to the unexpected slow growth of the 2001 year class and inaccurate estimation or higher mortality of this year class. Because of uncertainties associated with growth and sex change of this year class a projection to 2006 was not attempted.

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

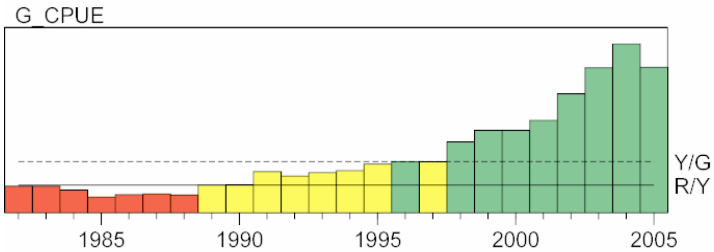
Research Vessel Abundance Index



The stratified survey estimate for 2005 (44, 433mt) decreased from the record high of 2004 (48,438mt), but was still the second highest of the series. (Fig. 2, Table 6). Most of the decrease ocurred in Strata 13 (Louisbourg Hole) which was heavily exploited last year, and Statum 17 (inshore area) which was heavily exploited in 2001 and 2002. The distribution of survey catches is shown in Figure 6.

Interpretation: Stock biomass continues to be high. It is unlikely that the small decrease in overall biomass in 2005 is the beginning of a multi-year trend as experienced between 1999 and 2002 because recruitment of the exceptional 2001 year class to the female population should begin in 2006, and is likely to continue for several years.

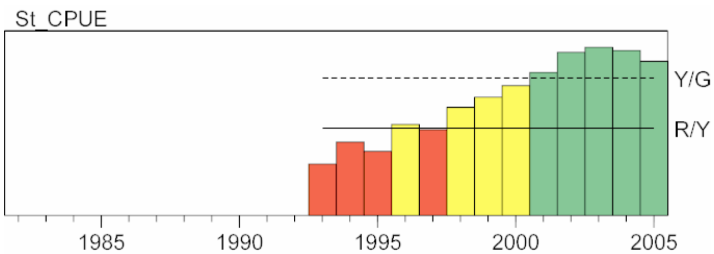
Gulf Vessels Catch Per Unit Effort



The unstandardised Gulf Vessel CPUE has shown an increasing trend since the 1980s. In 2005 it decreased for the first time in 13 years.

Interpretation: The small decrease in CPUE experienced by Gulf boats in 2005 may be due to the similar decrease in survey biomass (but see below).

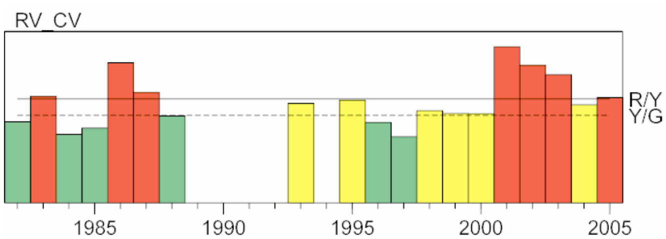
Commercial Trawler Standardized Catch Per Unit Effort



The standardized CPUE series has decreased slightly since its peak in 2003, but it remains high. (Fig. 3A). Divergence of CPUE and survey indicators and spatial analyses have previously shown that CPUEs are not always representative of abundance, but are strongly influenced by changes in distribution and densities of shrimp concentrations. The spatial distribution of effort is shown in Figure 7 and the seasonal (monthly) distribution of catch, effort and CPUEs in Figure 8.

Interpretation: As with the Gulf CPUE series changes in this indicator are probably more related to changes in the distribution of the resource and fishing effort than to abundance and must be interpreted cautiously. The relative stability of these indicators in recent years together with an increasing spatial indicator (see below) may be considered positive.

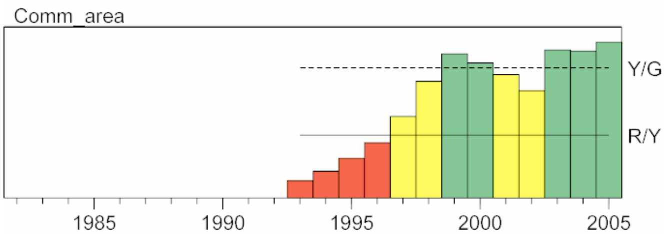
Research Vessel Coefficient of Variation



The overall measure of dispersion decreased over the last few years, but increased slightly in 2005 (Figs. 4, 6).

Interpretation: The decrease in the survey dispersion index is due to the recent biomass increases and wider distribution of the resource over the survey area. 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 during those years. The slight increase in 2005 is not statistically insignificant.

Commercial Fishing Area

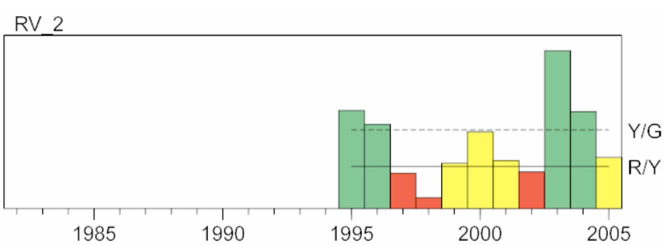


The area with commercial catch rates >250kg/hour increased since the beginning of the series until 1999, when it began to decrease due to a concentration of larger shrimp in a smaller area during the biomass decrease. Consistent with this interpretation, the area with catch rates >150 kg/hr began to decrease in 1997, while the interval with the highest catch rates (>450 kg/hr) continued to increase (Fig. 5). This trend appears to have reversed in the last three years as the biomass began to increase again and expand in area. Note that the distribution of effort changed significantly over the years (Fig. 7), especially in 2004, when much of the effort and catch was taken out of SFA 13 (Louisbourg Hole).

Interpretation: Scotian Shelf shrimp aggregated in smaller areas of higher densities as similar sized animals from several strong year classes accumulated from 1999 to 2002. This pattern appears to be reversing as the population increases again and begins to expand spatially.

PRODUCTION

RV abundance at age 2

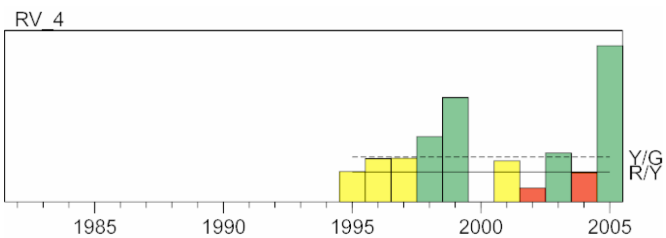


In 2005 the 2003 year-class at age 2 was below average. The 2002 year-class at age 2 was above average in the 2004 survey, however in 2005 at age 3 it appears below average (Table 5). It appears that the good recruitment associated mainly with the 2001 year class is being followed by lower recruitment, similar to what followed the good 1994-1995 year classes. This cycle of good followed by lower recruitment is a familiar pattern in established shrimp fisheries. Population modelling suggests that this may be a fishing effect. It also suggests lower population stability and the continued need for good monitoring and precaution.

Belly bag samples indicate that the the 2004 year class at age 1 is the lowest of the 4 year series (Table 5, Fig. 10), and that the 2002 and 2003 year classes at ages 3 and 2, respectively, are weaker still (Fig. 10). The 2001 year class continued to dominate belly bag samples in 2005. Belly bag samples generally substantiate results from the main trawl (Fig. 11) and indicate several weaker year classes following the strong 2001 year class.

Interpretation: Recruitment is decreasing following the recent recruitment pulse in what may be an unavoidable cyclical phenomenon associated with fishing.

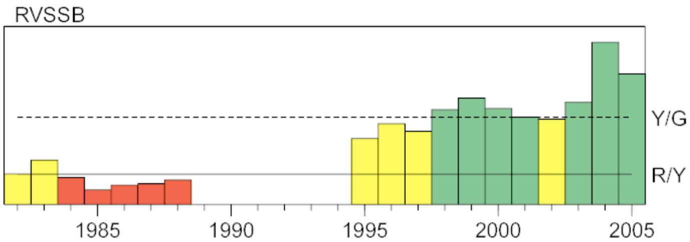
RV Abundance at Age 4



The abundance of age 4 shrimp increased from below average in 2004 to the highest on record, reflecting the recruitment of the strong 2001 year class to what usually is the oldest male age group in the population. The abundance of this age group is considerably greater than the previous group of strong year classes at the same age (Table 5, Fig. 11), consequently its recruitment to the female population is likely to be exceptional. The bimodal pattern of age 4 shrimp abundance mirrors (with a 2-3 year lag) the same pattern in age 2 shrimp (above), re-inforcing the hypothesis that a cyclical recruitment pattern has been established. Although the abundance of age 3 shrimp is below average and subsequent year classes appear weak, it is likely that the 2001 year class will recruit to the female population and contribute to the fishery over several years. A portion of the previous round of strong year classes delayed sex change for a year, and experienced slower growth, a phenomenon generally seen in shrimp fisheries. The amount of the decrease in growth and proportion of the population changing sex is currently not predictable, consequently a quantitative projection for 2006 is not feasible. It is possible this year class will delay sex change entirely until 2007.

Interpretation: The abundance of 4 year old shrimp that will provide the bulk of the catch in the next few years is well above average but it is not possible to project biomass.

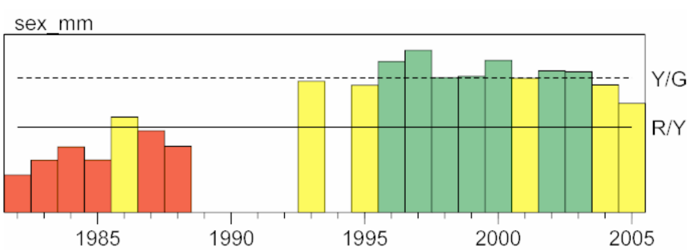
RV Spawning Stock Biomass (Females)



Research vessel spawning stock biomass decreased in 2005, reflecting the relatively low age 4 male population the previous year. Considering the record high age 4 population this year it is unlikley that SSB will decrease again for 2006, and it is likley to increase, but this is dependant on growth and sex change of the 2001 year class.

Interpretation: Spawning stock biomass is currently the second highest on record and remains well above the low levels of the 1980s when the population was increasing. It may increase next year, certainly the year following. There is no concern at present for recruitment overfishing.

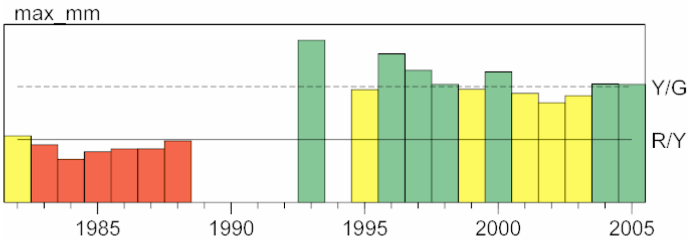
Average Size at Sex Transition (L_t)



This indicator has been decreasing for several years and is now significantly lower than the large sizes at sex change recorded in the mid to late 1990s, but not as low as the period of low abundance during the 1980s. In view of the increasing biomasses and densities of recent years this could be an indication that growth rates are decreasing due to density dependence. This is problematic in that fecundity is directly related to size, and may be one of the factors driving the recruitment cycle described above. Note, however, that the large numbers of males in the oldest age class has probably biased this calculation to the smaller sizes. This is supported by the fact that maximum size, which usually changes concurrently with L_t when growth rates change, has not decreased at this time. Annual changes in this indicator are often reflected in all regions (Figure 13A), as in 2005.

Interpretation: Growth rates may be decreasing in response to increasing densities, but the decrease in size at sex transition in 2005 may also be due, at least in part, to strong recruitment into the oldest male age class.

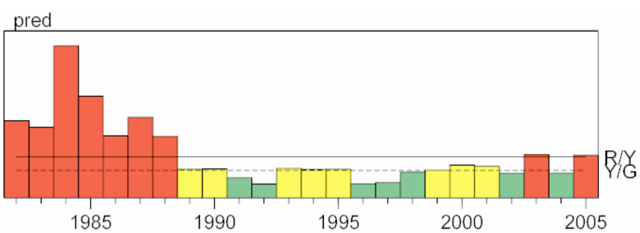
Average Maximum Size (L_{max})



Although smaller than the maximum sizes of the mid to late 1990s, maximum size remains substantially higher than the period of faster growth during the 1980s. As with size at transition, annual changes are often reflected in all regions although this is not the case for 2005 (Fig. 13B). The generally smaller maximum sizes in area 13 may be due to faster growth rates and smaller size at sex change caused by higher temperatures in this area, i.e. greater metabolic demand under food limitation (see temperature distributions and trends in Figures 6 and 14). The consistently lower abundances in this area may therefore be due to lower fecundities of the smaller animals.

Interpretation: There has been no decrease in maximum size similar to that seen for size at sex transition, however, changes in maximum size often lag changes in size at sex transition. Maximum size may decrease in the next few years.

Predation

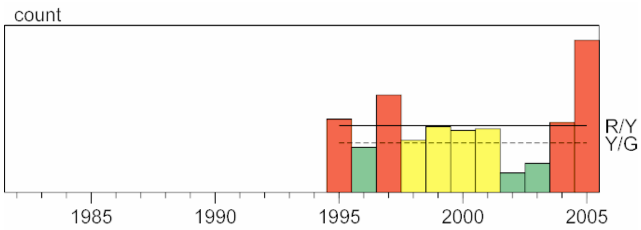


Groundfish abundance remains well below the high levels during the 1980s when the shrimp population was low. There have been two red indicators during the last 3 years including 2005, and there appears to have been a slight increasing trend since 1995.

Interpretation: Natural mortality due to predation remains well below the high values of the 1980s that probably contributed to the low shrimp abundances during that period. Natural mortality may have been increasing slightly since the mid 1990s.

FISHING IMPACTS

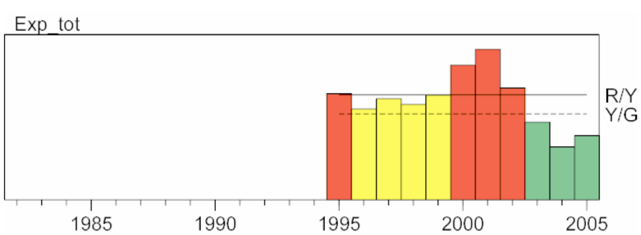
Commercial counts



These fishery-derived data reflect the strong recruitment events evident in survey data (compare with age 2 and 4 recruitment). Counts increased significantly in 2004, and especially in 2005 as the 2001 year class became more catchable. Considering the slow growth of the 2001 year class, higher counts are also likely in 2006. In addition to being significantly higher in 2005 regardless of experience, counts reported by boats that have been in the fishery for over 10 years were significantly lower statistically than those that had been in the fishery for only one to three years. This indicates that the count obtained is related to crew experience and skill. The catch at length shown in Figure 9 shows the relatively large numbers of small shrimp from the 2001 year-class caught in 2004 and 2005, and survey results show that it continues to be widespread throughout the stock area (Fig. 12). Note that the interpretation of this indicator is ambiguous. An increase can reflect both an increase in recruitment (good) as indicated by the similar trend of the age 4 recruitment indicator, or a sign of recruitment overfishing (bad), the latter being more appropriate in the context of the fishing impact characteristic.

Interpretation: Some fishers had difficulty, or did not attempt to remain below the counts which command the best prices from buyers. There is some concern for growth overfishing. Abundance of four year old shrimp is at an all time high.

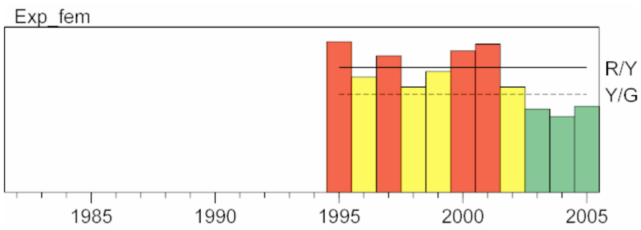
Exploitation Rate



Total exploitation increased slightly in 2005 due mainly to the increase in the catch and decrease in survey abundance, but remained below the long-term average. Effort, catch and exploitation rates were more evenly distributed throughout the stock area in 2005, notably with less fishing pressure put on SFA 13, and more in SFA 14 where most of the stock is concentrated (Table 6).

Interpretation: Overall exploitation remains relatively low and exploitation was more evenly distributed throughtout the stock area.

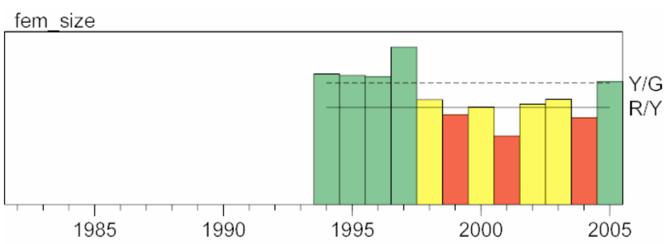
Female Exploitation Rate



Female exploitation increased slightly in 2005 but remained below the long-term average. Length specific exploitations from 1995-2005 is shown in Figure 16. This also shows that the exploitation of 4 year old shrimp i.e. the 2001 year class, is below average.

Interpretation: Female exploitation rates remain below average.

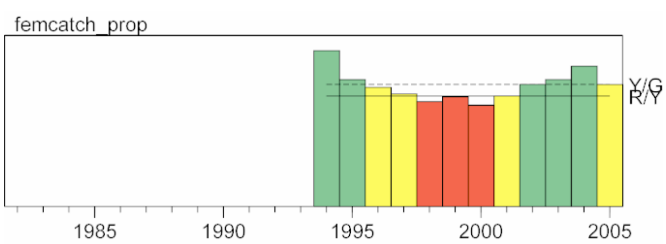
Mean Size of Females in Catch



The average size of females in the catch increased in 2005 above the relatively low values seen since the late 1990s.

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 slightly in 2002-2003, as recruitment to the female fraction decreased and the remaining population grew. It is likely to decrease in the next year or two as the large 2001 class begins to change sex.

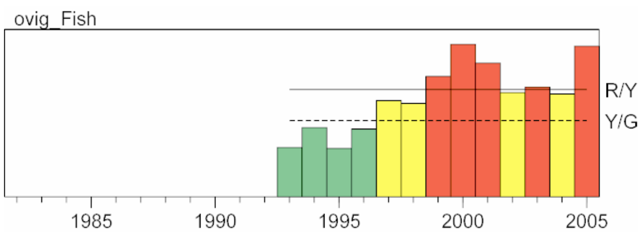
Proportion of Females in Catch



The proportion of females in the catch showed a decreasing trend from 1994 to 2000 but has increased to 2004. It decreased in 2005.

Interpretation: The proportion of females in the catch decreased as a group of strong year classes (1993-1995) recruited to the fishery and more shrimp were caught as males. This indicator has been increasing since 2000 as recruitment decreased and the remaining population accumulated in the female fraction. It decreased in 2005 as more males were caught from the 2001 year class. It will decrease further if this year class delays sex change for a year.

Fishing During Ovigerous Period

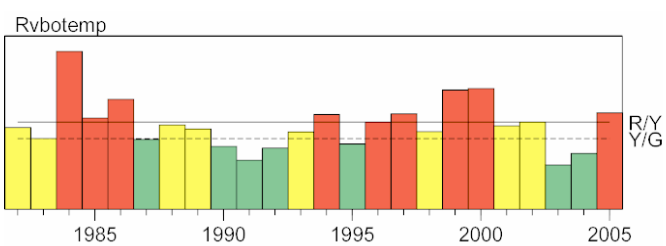


Fishing during the ovigerous period increased significantly from the early 1990s to a maximum in 2000 due to the longer time required to catch increasing TACs by a relatively small fleet of vessels. In addition, quota transfers have occurred and many vessels fished several individual quotas, further extending the length of the season. This indicator decreased in 2001-2002 as the lower TAC was again caught mainly during the non-ovigerous summer period. It increased sharply in 2005 because of the TAC increase and curtailed effort during the summer months to avoid soft shrimp. The monthly distribution of catches, effort and catch rates are shown in Figure 8.

Interpretation: Fishing during the ovigerous period may be impacting population reproductive potential in 2005 by removing ovigerous females before their eggs have hatched. The degree to which this is a problem has not been established.

ECOSYSTEM

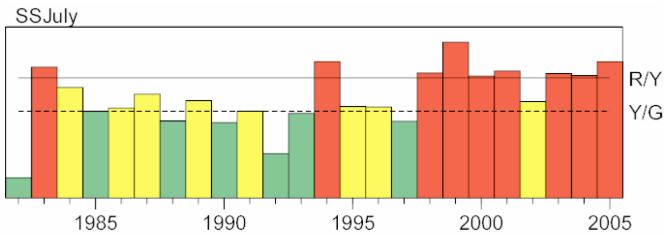
RV (Groundfish Survey) Bottom Temperatures



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, with cooler conditions during the last few years. Temperatures from shrimp surveys by SFA (Fig. 14) generally show the same trends as data from groundfish surveys . Cooling during the most recent years appears to be a widespread phenomenon and has been noticed as far away as the Grand Banks, however, bottom temperatures jumped sharply in 2005.

Interpretation: Decreasing bottom temperatures during the 1980s may have resulted in decreasing growth rates, and corresponding increases in size at transition, maximum size and fecundity. Increasing bottom temperatures during the 1990s did not appear to have resulted in significant increases in growth rates, perhaps due to density dependant effects. Colder temperatures during more recent years are more favourable for shrimp, however the increase in 2005 may be of concern if a trend of increasing temperatures develops.

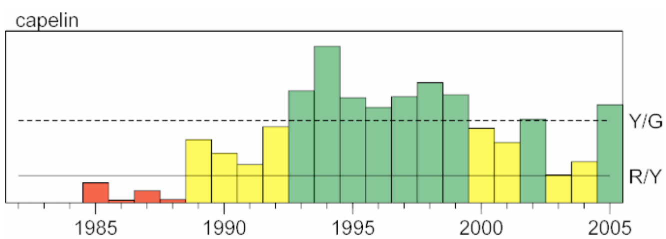
July SST



Surface temperatures are inversely related to shrimp abundance with a lag of four to five years. The below average temperatures prevalent during the late 1980s and early 1990s may have led to the high abundances in the mid to late 1990s. Surface temperatures have been relatively high during the late1990s.

Interpretation: The above average temperatures during the late 1990s could have lead to decreased abundances in the early part of the 2000s. However, continued high temperatures in recent years does not appear to explain the improved recruitment seen.

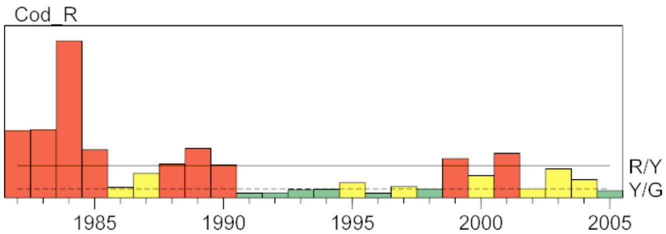
RV Capelin Abundance



During the last six years capelin abundance has been lower on average than the relatively high values between 1993 to 1999. However, they remain considerably higher than tduring the period of low shrimp abundance during the 1980s.

Interpretation: Environmental/ecological conditions that result in high production of capelin and shrimp have not been as favourable since 2000, but they are better than during periods of poor shrimp and capelin production.

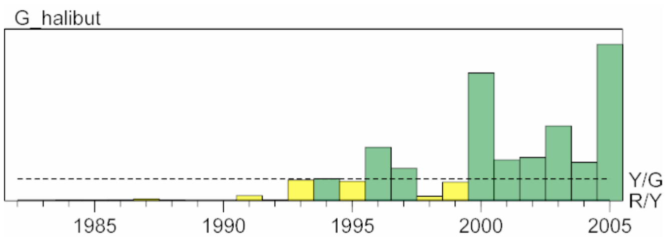
Cod Recruitment



Cod recruitment remains well below values seen in the 1980s.

Interpretation: Environmental conditions continue to be less favourable for cod and more favourable for shrimp.

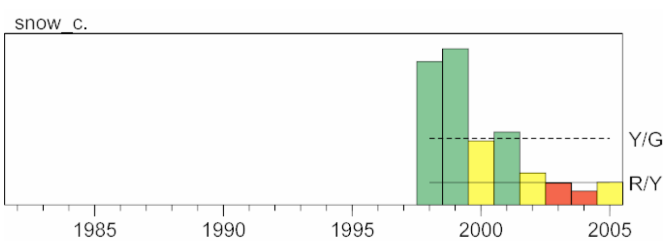
Greenland Halibut Recruitment



Greenland halibut <30cm continue to be abundant on the eastern Scotian Shelf. This species was rarely found during the warmer period of the 1980s when shrimp and capelin were also low in abundance.

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

Snow Crab Recruitment



The pre-recruit index from the Cape Breton snow crab survey has been decreasing in recent years and is of concern to this fishery. Snow crab abundance, as with Greenland halibut and capelin, tend to track shrimp abundance, consequently this observation is not in accord with observations and interpretation of trends for the latter two species i.e. that environmental conditions remain favourable for shrimp. Since snow crab is the only one of the three ecological indicator species that is fished commercially on the Scotian Shelf, it is possible that fishing effects have masked environmental influences.

Interpretation: Due to fishery effects snow crab recruitment may not currently be an indicator of environmental conditions favourable for shrimp.

Projections

Population, biomass and catch projections based on ages x versus x+1 regressions (Fig. 15) were conducted last year to determine what catch levels could be expected under average length-specific exploitation (Fig. 16) and growth rates rates. The projection indicated that the 2001 year class will be an important component of the 2005 biomass and catch, and could affect counts detrimentally. While this did occur, and the projection for the older ages and sizes (5+ and >23mm) was quite accurate (Fig. 17), the total biomass projected for 2006 was overestimated by 29% (57,543mt projected versus 44,439mt 2005 survey estimate). This was partly due to a) the slower than average growth of the 2001 year class and b) an overestimate of population numbers using the age 3 vs 4 relationship in Figure 18 without the point for 2001. The latter may be due to larger than expected mortality of the 2001 year class and/or underestimate of the 2005 survey and/or overestimate in the 2004 survey. Considering these sources of error in addition to the uncertainty associated with the growth/sex change of the 2001 year class, a population/biomass projection to 2006 was not attempted.

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.

The overall summary has been green for the last three years, following four red or yellow years. Abundance indicators are all favourable (green) except for the research vessel coefficient of variation, indicating a larger variance in the data and a greater patchiness in shrimp distribution during the 2005 survey. Note that this indicator has been red or yellow during the past 8 years and its interpretation relative to stock health is problematic i.e. greater patchiness can occur during population downturns when the remaining larger shrimp concentrate in denser shoals, or during increases when exceptionally large catches increase such dispersion indices. Considering the relatively good abundance indicators the latter case seems more likely. Note also that the CPUE series should be interpreted more cautiously and weighted lower than survey results because the former are not always good indicators of abundance due to spatial changes in the distribution of the resource and fishing effort, something that is not reflected in this characteristic or overall summary. The production characteristic remained yellow in 2005 although there was a considerable change in the distribution of colours among indicators. Most notably, the two recruitment indictors reversed colours, although the change of RV Age 4 abundance (RV_4) from red to green is the more significant for next year's fishery. Age 2 will not be recruiting to the fishery as females for three years and should not be a concern for the 2006-2007 fisheries. These fisheries should be sustained by the 2001 year class represented by the high RV_4 indicator, however the apparent slow growth of this year class is a concern for the 2006 fishery if these shrimp remain small for their age, and only part of the populations changes sex, or transition is completely delayed by one year. A small, probably insignificant increase in the predation indicator changed it from green to red. The fishing impact characteristic remained yellow, with the same number of green (3) yellow (1) and red (2) indicators as the previous year, the latter reflecting the high proportion of females taken during the ovigerous period and high counts. Note that the count indicator is ambiguous in that increases can be interpreted as good or bad depending on whether one is considering recruitment or growth overfishing. The ecosystem characteristic remained yellow despite improvements with indicator species, primarily because of increased surface and bottom temperatures, however there seems to be no clear increasing temperature trend, as yet. At this time there is no indication that the regime may be changing to one less favourable for shrimp and the decreased recruitment following the large 2001 year class may be a cyclical phenomenon often observed in developed shrimp fisheries.

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Table 1. TACs (trawls) and catches (trawls and traps) from the eastern Scotian Shelf shrimp fishery 1980-2005.

	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	3797
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
2003	2700	300	612	1623	373	2608	157	2765
2004	3300	200	2041	755	376	3172	96	3268
[4]**2005**	4390	383	1175	1346	1089	3610	6	3616

[1] Nordmore separator grate introduced.
[2] overall 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)
2004	6(14)	14(23)	6(23)
2005	1(14)	20(28)[8]	7(24)[9]

[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.

[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

[8] five (5) temporary licences made permanent.

[9] one (1) temporary licence made permanent

Table 3. Input data for traffic light analysis.

Indicators	RV_CPUE	G_CPUE	St_CPUE	RV_CV	Comm_area	RVSSB	RV_2	RV_4	sex_mm	max_mm	pred	count	Exp_tot	Exp_fem	femcatch_	fem_size	ovig_Fish	Rvbotemp	SSJuly	capelin	Cod_R	G_halibut	snow_c.
Action	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile
Indirect																							
Rule	abundance	(production	==	red)	+																		
Direct																							
Overwts	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maxwts	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Level_YG	0.66	0.66	0.66	0.33	0.66	0.66	0.66	0.66	0.66	0.66	0.33	0.33	0.33	0.33	0.66	0.66	0.33	0.33	0.33	0.66	0.33	0.66	0.66
Level_RY	0.33	0.33	0.33	0.66	0.33	0.33	0.33	0.33	0.33	0.33	0.66	0.66	0.66	0.66	0.33	0.33	0.66	0.66	0.66	0.33	0.66	0.33	0.33
Characteristics	Polarity																						
Abundance	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Production	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
FishingM	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Ecosystem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Year																							
1982	34.5	128	NAN	65.5423	NAN	5040.65	NAN	NAN	21.7157	28.2356	179	NAN	NAN	NAN	NAN	NAN	NAN	2.569091	9.6667	0	2.3846	0	NAN
1983	71.5	127.7	NAN	86.0137	NAN	7323.05	NAN	NAN	22.1074	28.0317	164	NAN	NAN	NAN	NAN	NAN	NAN	2.220909	15.15	0	2.4151	0	NAN
1984	39	109.5	NAN	55.3514	NAN	4460.96	NAN	NAN	22.4624	27.6918	353	NAN	NAN	NAN	NAN	NAN	NAN	4.954444	14.14	0	5.569	0.060764	NAN
1985	17	75.4	NAN	60.4767	NAN	2417.71	NAN	NAN	22.113	27.8709	236	NAN	NAN	NAN	NAN	NAN	NAN	2.864444	12.96	1.5542	1.7091	0.051471	NAN
1986	23	87.3	NAN	113.141	NAN	3187.87	NAN	NAN	23.261	27.9352	144	NAN	NAN	NAN	NAN	NAN	NAN	3.451176	13.118	0.1344	0.3683	0.085784	NAN
1987	25.5	90.7	NAN	89.2028	NAN	3424.46	NAN	NAN	22.8922	27.9364	187	NAN	NAN	NAN	NAN	NAN	NAN	2.192857	13.808	0.7652	0.8659	0.162037	NAN
1988	31.5	85.1	NAN	70.1921	NAN	4047.02	NAN	NAN	23.4806	28.119	143	NAN	NAN	NAN	NAN	NAN	NAN	2.645455	12.483	0.1727	1.1947	0.057566	NAN
1989	NAN	133.4	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	66.6	NAN	NAN	NAN	NAN	NAN	NAN	2.517273	13.488	18.377	1.7535	0	NAN
1990	NAN	134.5	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	67.3	NAN	NAN	NAN	NAN	NAN	NAN	1.973043	12.4	9.2281	1.1632	0	NAN
1991	NAN	197.9	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	46.9	NAN	NAN	NAN	NAN	NAN	NAN	1.5375	12.965	5.0715	0.1659	0.463853	NAN
1992	NAN	176.3	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	32.1	NAN	NAN	NAN	NAN	NAN	NAN	1.92069	10.863	34.878	0.1691	0.084541	NAN
1993	75	193	191.6215	80.32	31	NAN	NAN	NAN	24.216	30.4525	68.5	NAN	NAN	NAN	NAN	NAN	11.91123	2.4245	12.858	193.36	0.2868	1.860152	NAN
1994	NAN	202.4	273.7544	NAN	48	NAN	NAN	NAN	NAN	NAN	66.2	NAN	NAN	NAN	0.889797	26.04963	16.70647	2.976	15.42	1563.9	0.2999	1.978313	NAN
1995	173	233.8	239.5697	82.8449	71	10912.1	358.5	875.9	24.1096	29.3083	66.5	55.92	13.4414	21.03512	0.724603	26.02959	11.69146	2.048214	13.195	138.62	0.5358	1.735172	NAN
1996	213.5	245.9	339.5787	64.8785	99	13368.4	307.3	1248	24.7413	30.1393	32.6	54.47	11.498	16.10622	0.680097	26.00976	16.37874	2.738148	13.17	87.534	0.1611	4.784847	NAN
1997	193	245.5	319.7801	53.4554	146	12100.8	128.9	1257	25.0403	29.7576	35.9	57.16	12.8003	19.08014	0.642841	26.44078	23.23438	2.996296	12.468	146.64	0.396	2.906094	NAN
1998	238.5	341	403.2289	74.4176	209	15707.5	39.89	1884	24.3125	29.4323	59.9	54.83	12.0783	14.72796	0.599315	25.67582	22.58156	2.437083	14.858	284.31	0.3068	0.41271	107998
1999	268.5	396	441.4621	72.1962	258	17607.5	165.6	3010	24.3478	29.3182	64.1	55.54	13.2447	16.89573	0.625535	25.4562	29.09086	3.743571	16.38	159.96	1.3907	1.672614	117617
2000	233.5	396	484.5721	71.9952	242	15893.4	280.3	0	24.7718	29.7214	76.3	55.34	17.0605	19.78618	0.578256	25.56624	36.8085	3.79	14.705	32.375	0.7869	11.43957	48199
2001	183.5	444	533.6877	126.032	221	14475.6	174.9	1184	24.2945	29.2234	73.3	55.42	19.0507	20.72329	0.631052	25.14556	32.29507	2.618125	14.957	15.994	1.5792	3.659454	54900
2002	161.4	572	609.0531	111.149	192	14133.2	134.00	399.2	24.4954	29.0036	57.3	53.15	14.1673	14.71785	0.697372	25.60901	25.1521	2.737778	13.441	49.85	0.316	3.875452	23999
2003	204.4155	697.085	627.3475	103.505	265	16916.2	576.74	1411	24.469	29.1661	101	53.65	9.82933	11.62761	0.725179	25.68051	26.48311	1.39	14.829	2.698	1.0255	6.690889	16459
2004	353.7	810.906	615.4312	79.1939	263	26856.5	354.1	839.5	24.1182	29.4417	57.5	55.75	6.68748	10.59507	0.801358	25.41152	24.8154	1.751176	14.726	5.9286	0.6415	3.436608	10438
2005	312.9	699	575.2593	85.0236	279	21633.2	187	4502	23.6272	29.431	99	59.98	8.13811	12.00869	0.696471	25.93896	36.38035	3.027	15.414	99.407	0.2488	13.99674	17086

Table 4. Set statistics from DFO-industry survey AS0501 conducted by MV All Seven June 1 - 11 2005.

SET	SFA	DATE	LAT.	LONG.	SPEED	DIST.	DUR.	WING.	DEPTH	TEMP	RAW	stand.	DENSITY
					(kts)	(nm)	(min)	(m)	(fth)	(^{o}C)	CATCH	catch	(gm/m^2 or
											(kg)		mt/km2)
1	15	01-Jun-05	44°57.07	61°06.56	2.4	1.23	30	17.8	106	1.6	107	106.5	2.6
2	15	01-Jun-05	44°54.90	61°05.79	2.5	1.20	30	16.6	106	1.8	142	155.4	3.9
3	15	01-Jun-05	44°56.67	60°57.52	2.5	1.24	30	16.2	107	1.9	77	82.7	2.1
4	15	01-Jun-05	44°47.97	60°54.35	2.4	1.18	30	18.0	136	1.9	295	303.5	7.5
5	15	01-Jun-05	44°53.51	60°46.82	2.5	1.20	30	17.1	122	2.1	216	228.5	5.7
6	15	01-Jun-05	44°57.75	60°47.98	2.5	1.20	30	17.5	106	1.9	85	88.3	2.2
7	15	01-Jun-05	44°57.47	60°44.79	2.4	1.22	30	16.5	124	1.9	150	161.5	4.0
8	15	02-Jun-05	44°49.97	60°40.21	2.5	1.24	30	17.2	158	2.2	78	79.8	2.0
9	15	02-Jun-05	44°47.86	60°36.39	2.6	1.28	30	16.6	144	2.2	114	116.5	2.9
10	15	02-Jun-05	44°52.97	60°36.24	2.5	1.25	30	17.4	130	2.2	187	187.0	4.6
11	15	02-Jun-05	44°54.06	60°25.72	2.5	1.26	30	16.6	139	1.9	430	447.5	11.1
12	15	02-Jun-05	44°49.00	60°15.88	2.4	1.24	30	16.1	175	2.0	178	193.3	4.8
13	15	02-Jun-05	44°45.55	60°20.76	2.4	1.23	30	17.8	119	1.9	169	167.7	4.2
14	15	02-Jun-05	44°42.03	60°18.65	2.3	1.24	30	17.1	147	2.0	263	267.8	6.6
15	15	02-Jun-05	44°42.48	60°12.31	2.4	1.22	30	17.6	118	3.1	201	204.3	5.1
16	14	02-Jun-05	44°41.66	60°00.40	2.4	1.19	30	17.2	121	2.7	416	440.9	10.9
17	14	02-Jun-05	44°47.06	59°58.70	2.5	1.22	30	16.9	135	2.3	248	262.5	6.5
18	14	03-Jun-05	44°53.61	59°58.97	2.4	1.19	30	17.3	106	2.0	360	379.7	9.4
19	14	03-Jun-05	44°51.78	59°43.20	2.3	1.16	30	18.2	120	2.1	390	402.6	10.0
20	14	03-Jun-05	44°42.16	59°46.44	2.4	1.22	30	17.9	137	2.3	389	388.9	9.7
21	14	03-Jun-05	44°43.67	59°32.50	2.3	1.13	30	17.7	122	2.1	1281	1390.0	34.5
22	14	03-Jun-05	44°49.23	59°28.95	2.3	1.14	30	17.7	138	2.1	810	876.9	21.8
23	14	03-Jun-05	44°48.74	59°12.32	2.2	1.08	30	17.6	129	1.7	585	672.7	16.7
24	14	03-Jun-05	44°48.99	59°07.11	2.3	1.15	30	18.0	124	1.7	407	428.1	10.6
25	14	03-Jun-05	44°41.84	59°02.42	2.2	1.09	30	17.8	148	1.8	51	57.0	1.4
26	14	04-Jun-05	44°46.07	58°55.38	2.3	1.16	30	17.6	150	1.8	309	329.2	8.2
27	14	04-Jun-05	44°54.78	58°43.92	2.3	1.14	30	18.0	146	1.9	243	258.1	6.4
28	14	04-Jun-05	44°47.96	58°39.89	2.5	1.23	30	17.8	141	1.9	678	674.6	16.7
29	14	04-Jun-05	44°50.33	58°32.79	2.4	1.22	30	17.6	139	1.9	392	396.7	9.8
30	14	04-Jun-05	44°54.66	58°20.80	2.4	1.18	30	17.2	134	2.2	960	1023.6	25.4
31	17	08-Jun-05	45°22.41	61°00.73	2.5	1.23	30	15.0	60	0.9	398	472.7	11.7
32	17	08-Jun-05	45°26.12	60°56.09	2.3	1.16	30	13.5	61	1.2	172	239.3	5.9
33	17	09-Jun-05	45°29.89	60°31.51	2.3	1.13	30	16.4	95	1.7	337	394.5	9.8
34	17	09-Jun-05	45°27.95	60°25.86	2.3	1.12	30	16.8	111	1.8	489	568.2	14.1
35	17	09-Jun-05	45°20.75	60°17.17	2.3	1.15	30	17.2	105	1.8	195	213.8	5.3
36	17	09-Jun-05	45°13.42	59°56.71	2.4	1.16	30	17.7	94	1.9	339	358.8	8.9
37	17	09-Jun-05	45°17.83	59°56.09	2.3	1.14	30	16.9	84	1.9	68	76.4	1.9
38	17	09-Jun-05	45°18.32	59°52.21	2.3	1.12	30	17.7	87	1.9	38	41.6	1.0
39	17	09-Jun-05	45°24.99	59°59.02	2.4	1.18	30	17.3	97	2.3	155	165.0	4.1
40	17	09-Jun-05	45°28.25	60°10.01	2.5	1.24	30	17.1	91	1.9	221	226.2	5.6
41	17	09-Jun-05	45°31.11	60°09.77	2.4	1.19	30	17.6	93	2.0	125	130.0	3.2

42	17	10-Jun-05	45°34.05	60°14.97	2.4	1.21	30	17.2	88	1.8	461	483.6	12.0
43	17	10-Jun-05	45°35.58	60°08.06	2.4	1.19	30	16.9	83	1.8	191	206.5	5.1
44	17	10-Jun-05	45°36.37	60°01.68	2.3	1.13	30	15.9	99	2.1	68	82.4	2.0
45	17	10-Jun-05	45°38.87	59°52.20	2.4	1.19	30	15.7	87	2.1	20	23.8	0.6
46	13	10-Jun-05	45°36.35	59°06.05	2.5	1.29	30	17.3	139	3.5	389	380.4	9.4
47	13	10-Jun-05	45°40.33	59°03.06	2.5	1.27	30	16.5	151	3.7	384	399.9	9.9
48	13	10-Jun-05	45°40.90	58°55.95	2.4	1.19	26	18.3	134	3.7	165	165.8	4.1
49	13	10-Jun-05	45°39.54	58°51.00	2.5	1.24	30	17.4	119	3.5	55	55.8	1.4
50	13	10-Jun-05	45°42.00	58°47.63	2.4	1.13	30	17.0	138	3.9	255	288.0	7.2
51	13	11-Jun-05	45°43.68	58°54.89	2.4	1.17	30	17.7	147	3.7	50	52.8	1.3
52	13	11-Jun-05	45°46.16	58°46.11	2.2	1.13	30	17.0	150	4.1	228	258.2	6.4
53	13	11-Jun-05	45°50.50	58°45.27	2.4	1.16	*30*	16.9	144	4.2	343	380.2	9.4
54	13	11-Jun-05	45°51.12	58°37.01	2.5	1.19	*30*	17.2	148	4.1	395	418.2	10.4
55	13	11-Jun-05	45°47.79	58°32.24	2.2	1.06	*28*	17.2	160	4.1	46	55.2	1.4
56	13	11-Jun-05	45°43.85	58°36.76	2.3	1.09	*30*	17.3	134	3.8	459	530.1	13.2
57	13	11-Jun-05	45°39.72	58°30.30	2.3	1.12	30	16.4	208	3.5	81	95.9	2.4
58	13	11-Jun-05	45°37.11	58°37.84	2.3	1.13	30	17.1	164	3.3	46	51.4	1.3

Table 5. Minimum survey population numbers at age from modal analysis. Numbers x 10^{-6}. Age 1 estimates are from catches in the belly-bag attached to the main trawl.

		95	96	97	98	99	00	01	02	03	04	05	Ave.
	1								980	196	316	155	497
	2	359	307	129	40	166	280	175	134	616	354	187	256
	3	1046	276	1159	785	27	757	362	383	312	3118	652	823
	4	876	1248	1257	1884	3010	0	1184	399	1506	839	4502	1220
	5+	1702	2162	1539	2047	1952	3374	2110	1847	1727	3324	2224	2178
	TOTAL	3983	3993	4084	4755	5155	4412	3831	2763	4161	7636	7565	4477.33
4+ males		1369	1971	1578	2243	3235	1784	1771	938	1526	1549	4758	1796.35
primiparous		649	777	709	889	736	728	817	678	533	847	786	736.22
multiparous		560	661	509	647	991	863	706	630	1175	1768	1183	851.03
total females		1209	1438	1218	1535	1727	1591	1523	1308	1708	2615	1969	1587.24

Table 6. Survey biomasses, commercial shrimp catches and exploitation rates (catch/biomass) by survey strata (13-15, offshore part), and the inshore area (17), 1995-2005.

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	13	4837	6838	5920	7187	9517	5919	4089	3114	7047	12184	9686
	14	9067	12094	9471	11278	11039	9544	12325	12020	12035	20228	20035
BIOMASS(mt)	15	5299	6610	4736	4548	7806	7213	2073	2766	3751	4399	4378
	17	4415	3663	6220	9530	8262	9183	6541	2872	5296	11627	10333
	total	**23620**	**29206**	**26349**	**32545**	**36625**	**31860**	**25038**	**20773**	**28130**	**48438**	**44433**
	13	169	58	538	514	615	302	565	254	582	2003	1186
	14	2284	2435	2285	2012	1511	2016	1552	1552	1626	754	1441
CATCH(mt)	15	721	865	550	618	592	1615	1087	265	226	339	600
	17	0	0	0	787	2132	1503	1564	872	331	143	389
	total	**3175**	**3358**	**3373**	**3931**	**4851**	**5436**	**4768**	**2943**	**2765**	**3239**	**3616**
	13	3.5	0.9	9.1	7.2	6.5	5.1	13.8	8.2	8.3	17.6	12.2
	14	25.2	20.1	24.1	17.8	13.7	21.5	12.6	12.9	13.5	3.6	7.2
EXPLOITATION(%)	15	13.6	13.1	11.6	13.6	7.6	22.2	52.4	9.6	6.0	9.6	13.7
	17	0.0	0.0	0.0	8.3	25.8	16.1	23.9	30.4	6.2	1.7	3.8
	total	**13.4**	**10.9**	**13.6**	**12.1**	**13.2**	**17.1**	**19.1**	**14.2**	**9.8**	**7.2**	**8.1**

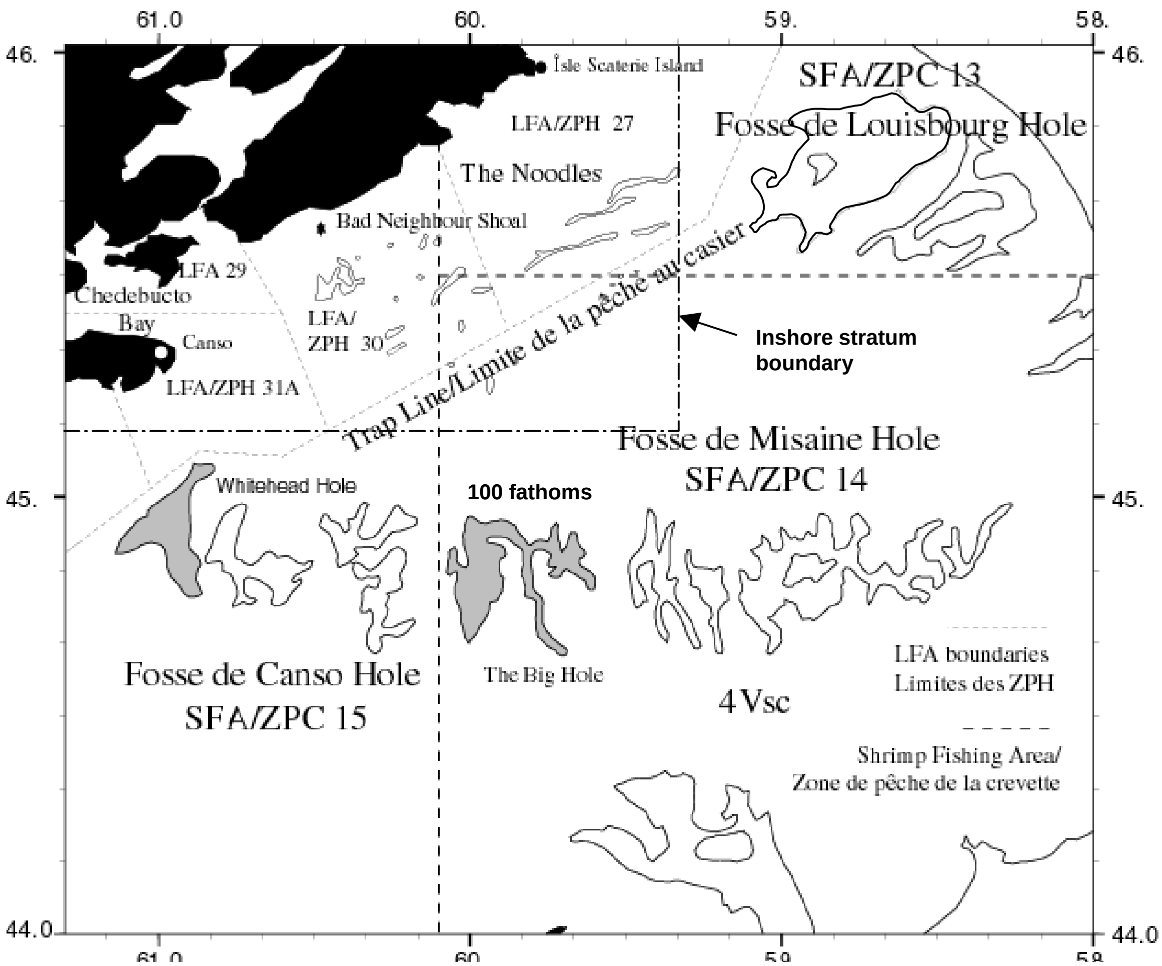


Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. The lobster Fishing Areas (LFAs) used to allocate shrimp trap licences, and the shrimp trap line are also shown. Trappers are prohibited from fishing seaward of this line. Another line (not shown) prohibits trawlers from fishing inside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

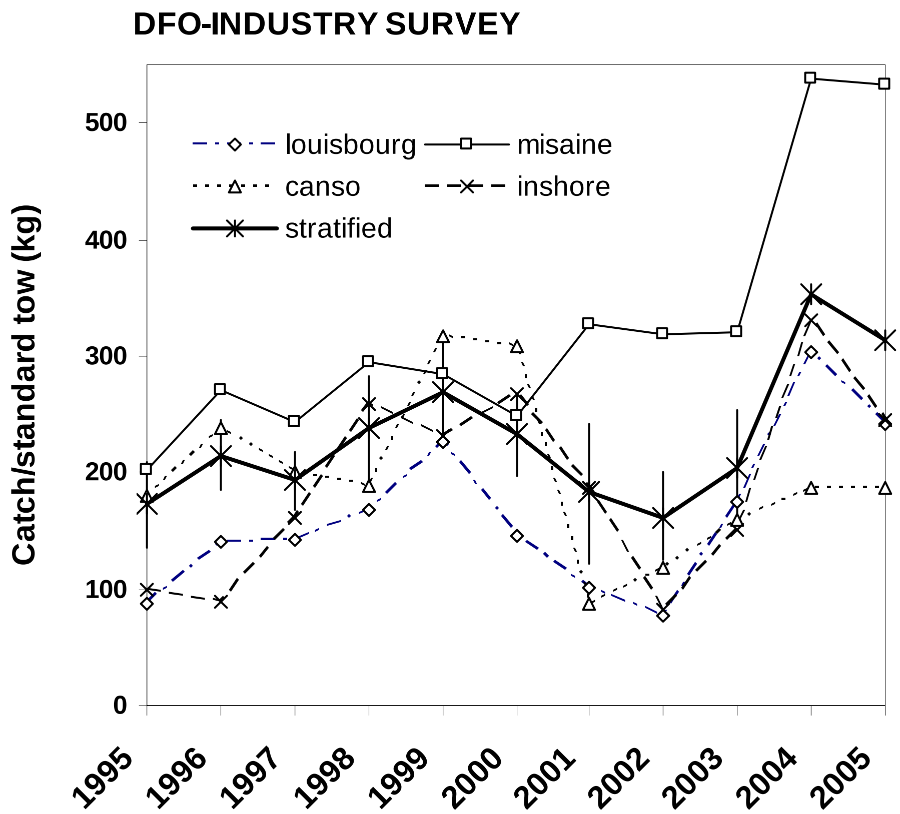


Figure 2. Stratified catch/standard tow for DFO-Industry co-operative surveys 1995-2005 and estimates for the individual strata, which approximately correspond to the main shrimp holes and SFAs. Stratum 13 is Louisbourg Hole and SFA 13; Stratum 14 - Misaine Holes and SFA 14; Stratum 15 - Canso Holes and the offshore part of SFA 15. The Inshore, or Stratum 17, is comprised of inshore parts of SFA 13-15.

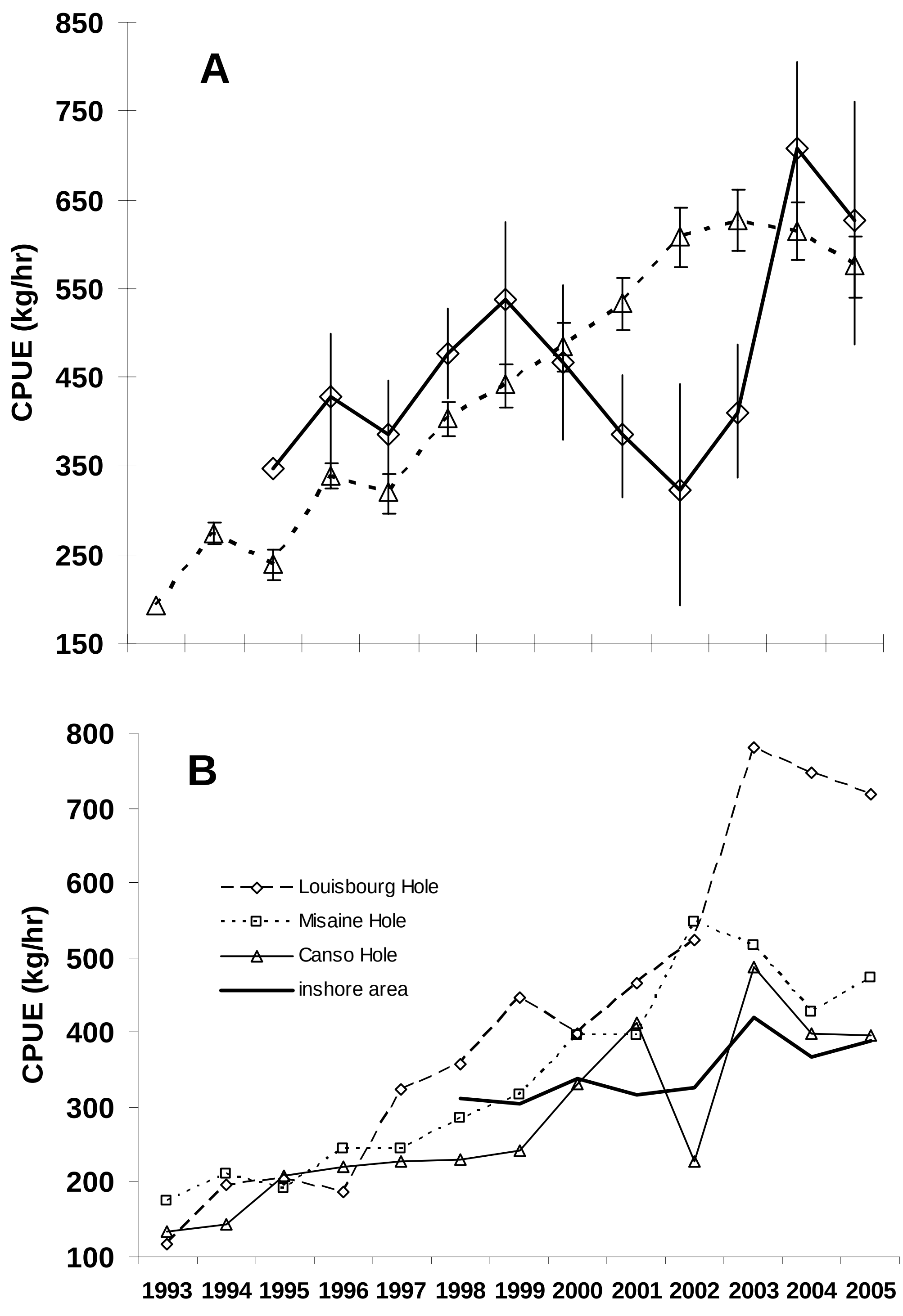


Figure 3. A - Survey stratified estimate and standardised CPUE with 95% confidence intervals, and B - unstandardised commercial CPUE for each fishing area. Note that SFA15 includes the inshore, but the latter is also shown separately since fishing began there in 1998.

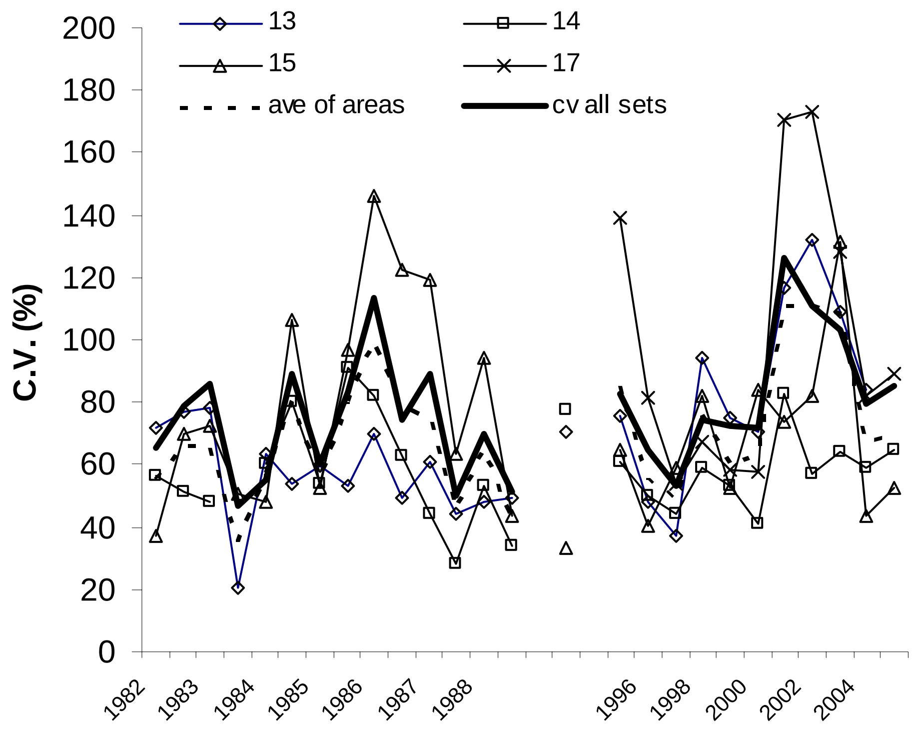
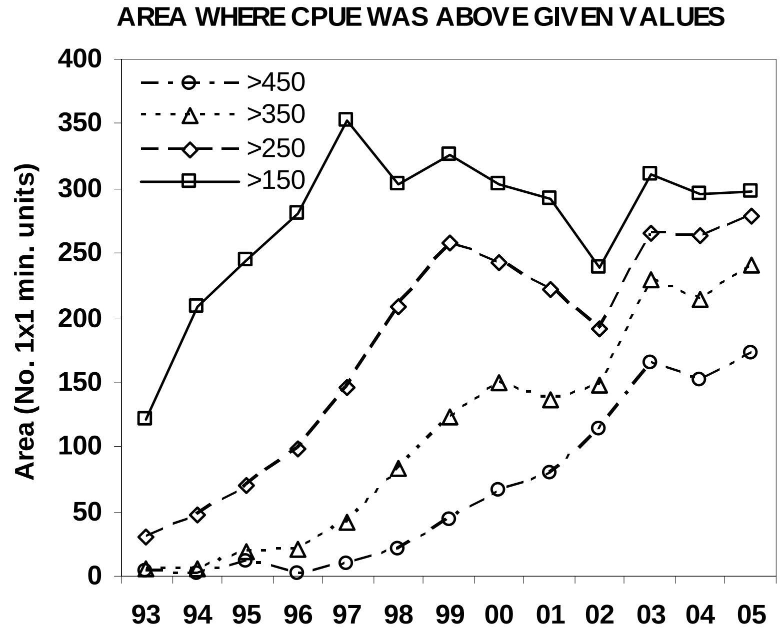


Figure 4. Coefficients of variation (C.V.) for individual shrimp fishing areas from shrimp surveys. Note that the earlier survey series has two values per year, one for the spring and one for the fall survey.



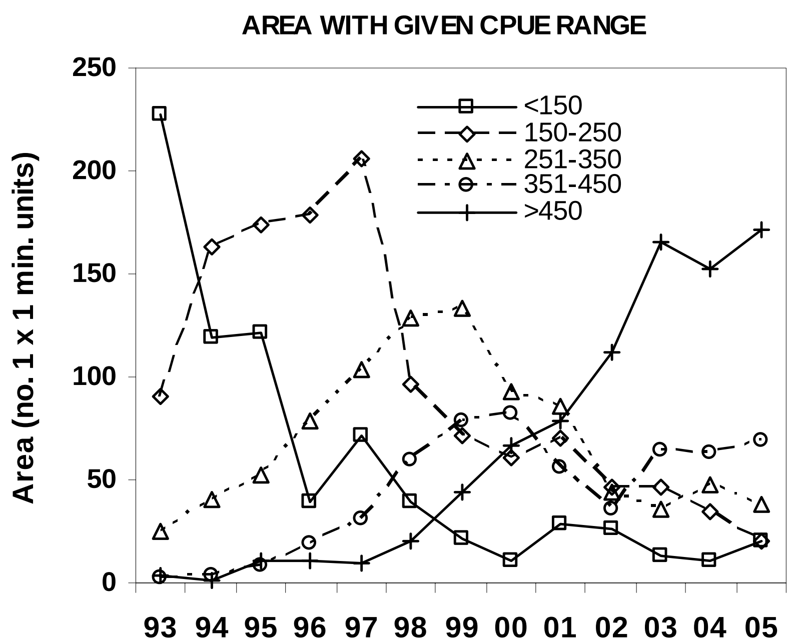


Figure 5. Number of one minute square unit areas fished by the shrimp fleet with mean catch rates (kg/hour) above (top) and within (bottom) the values or ranges

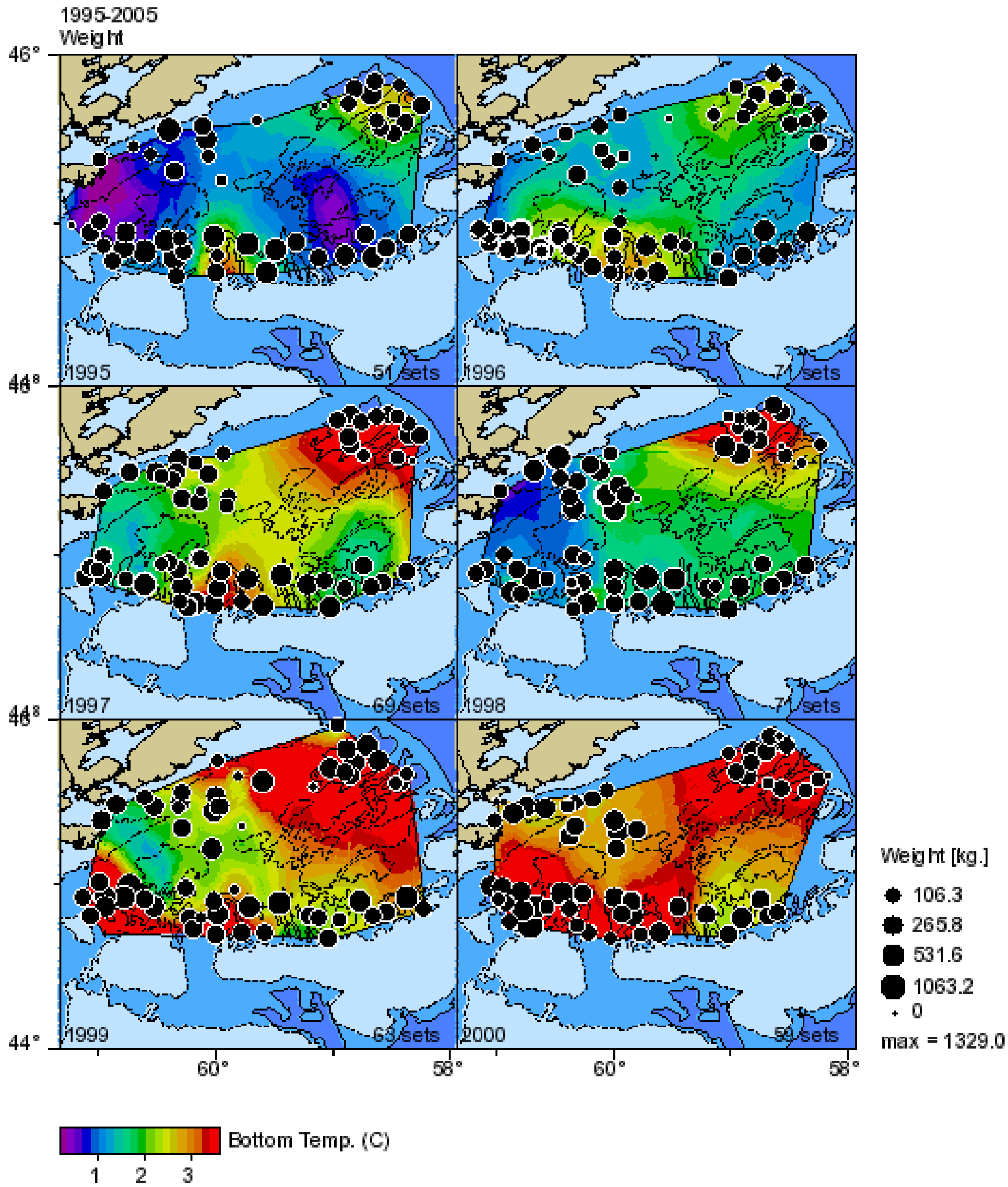


Figure 6. Distribution of catches and bottom temperatures from DFO-Industry surveys 1995-2005.

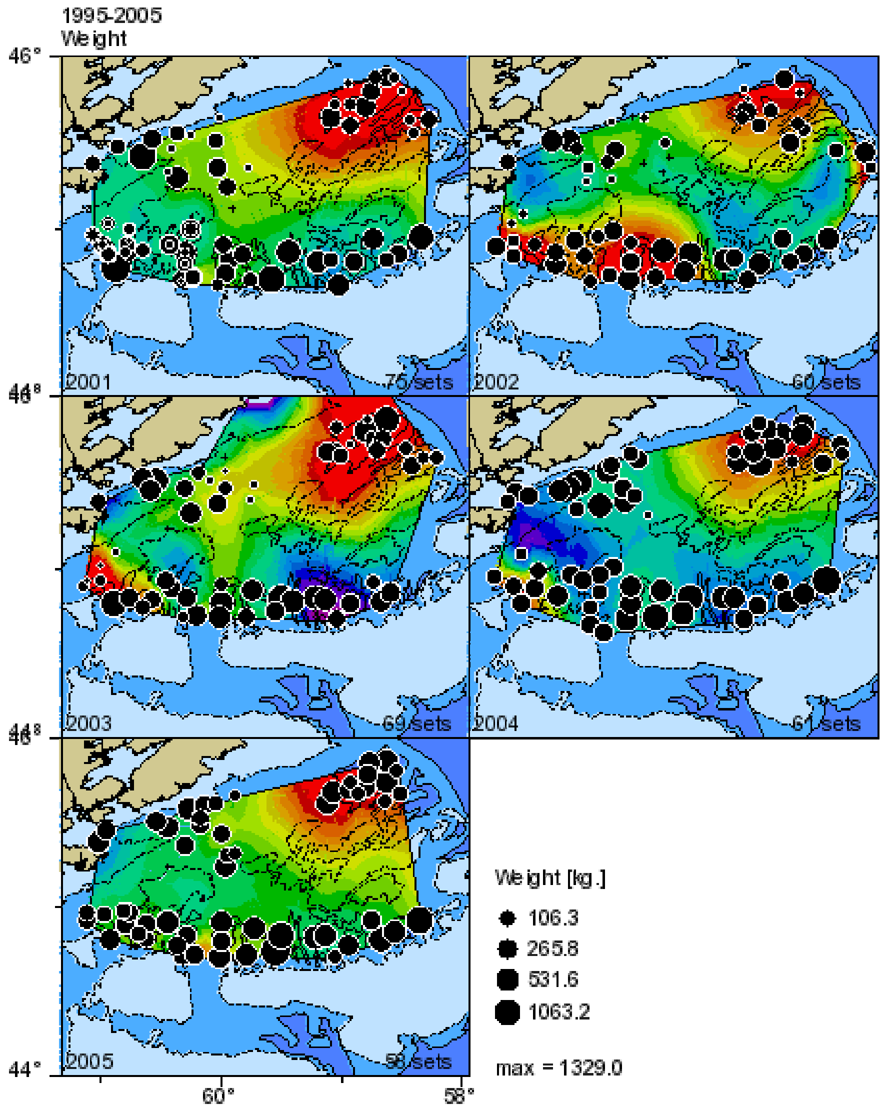


Figure 6. Continued

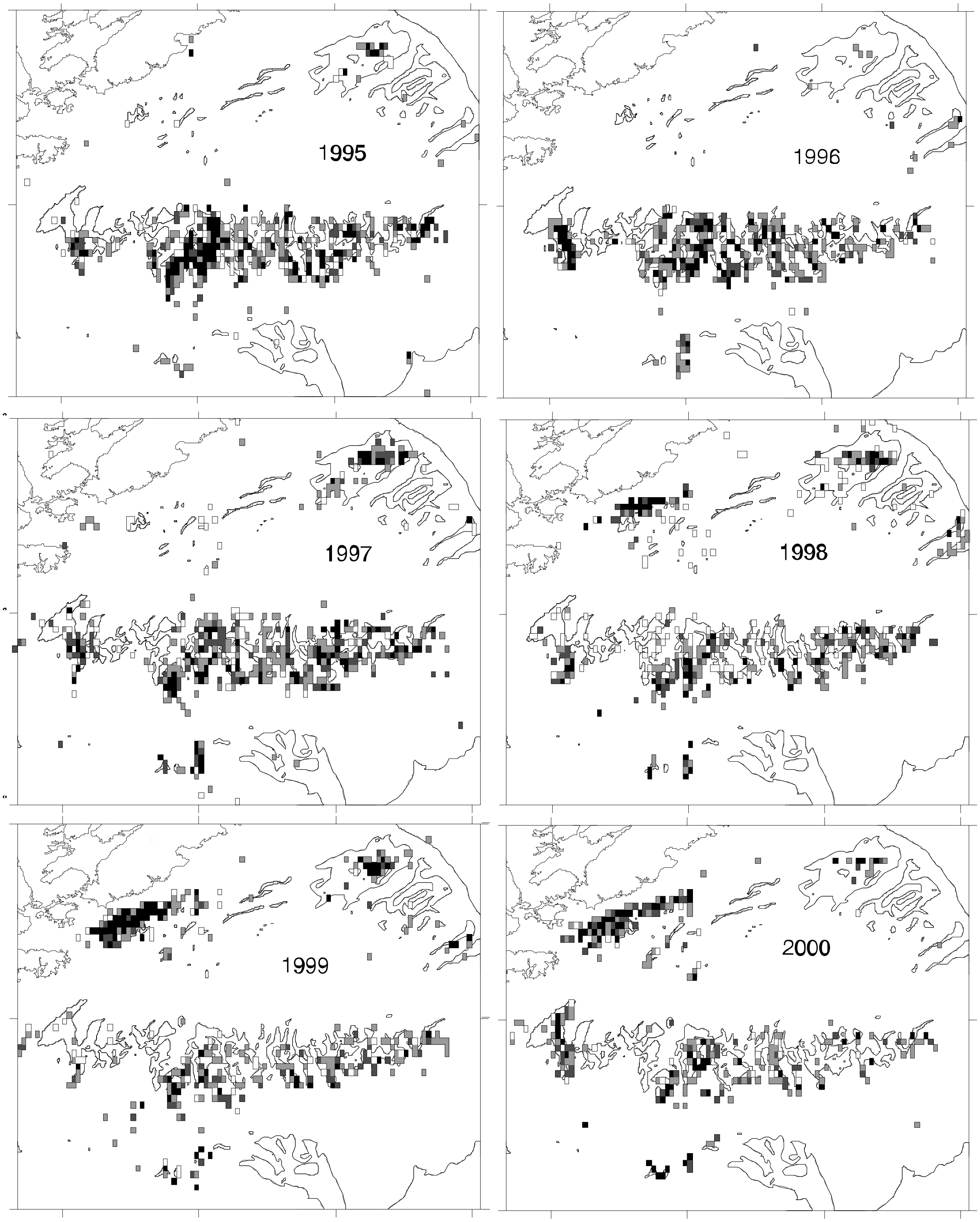


Figure 7. Annual effort by trawlers 1995-2005, cumulative by one minute squares.

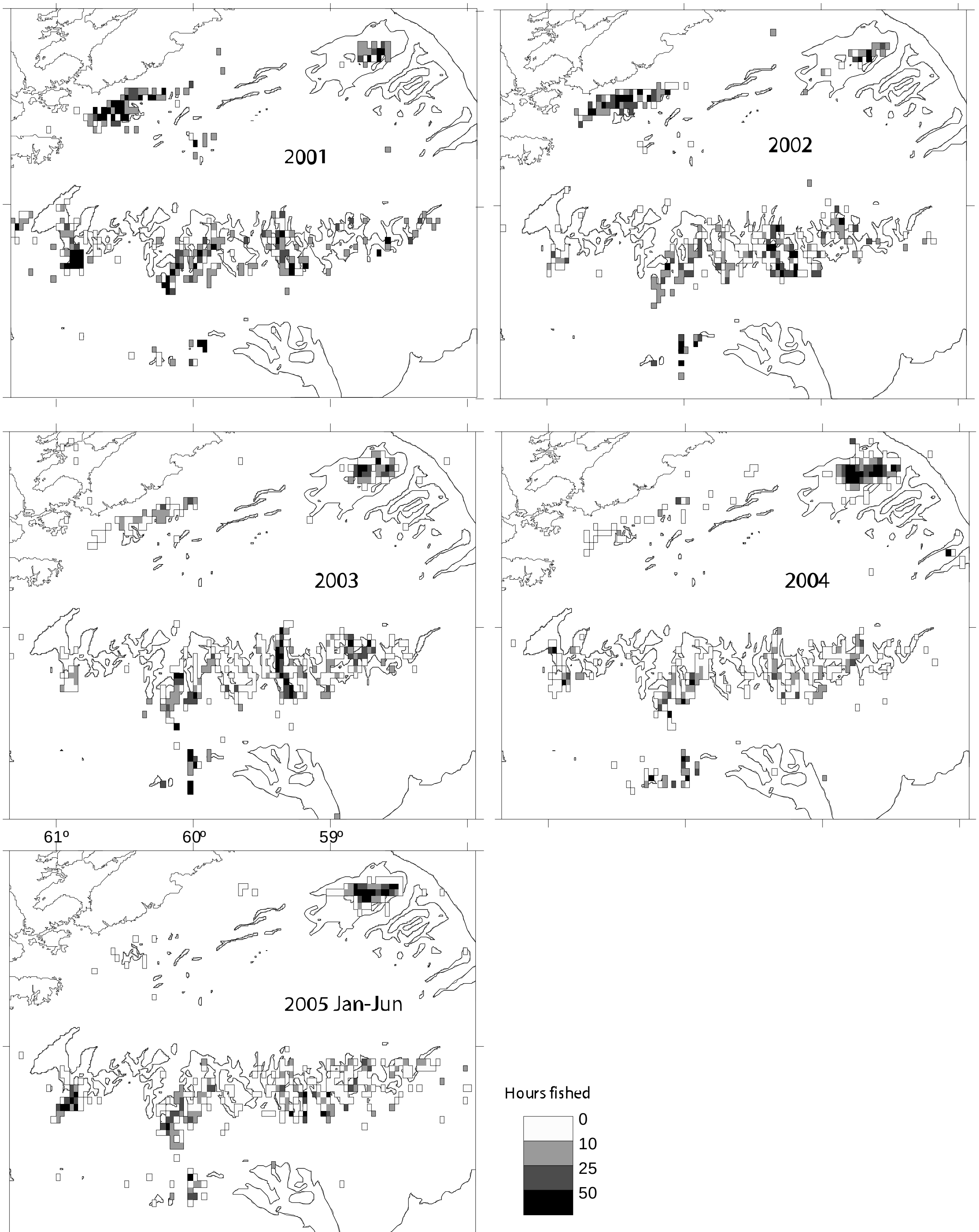


Figure 7 continued.

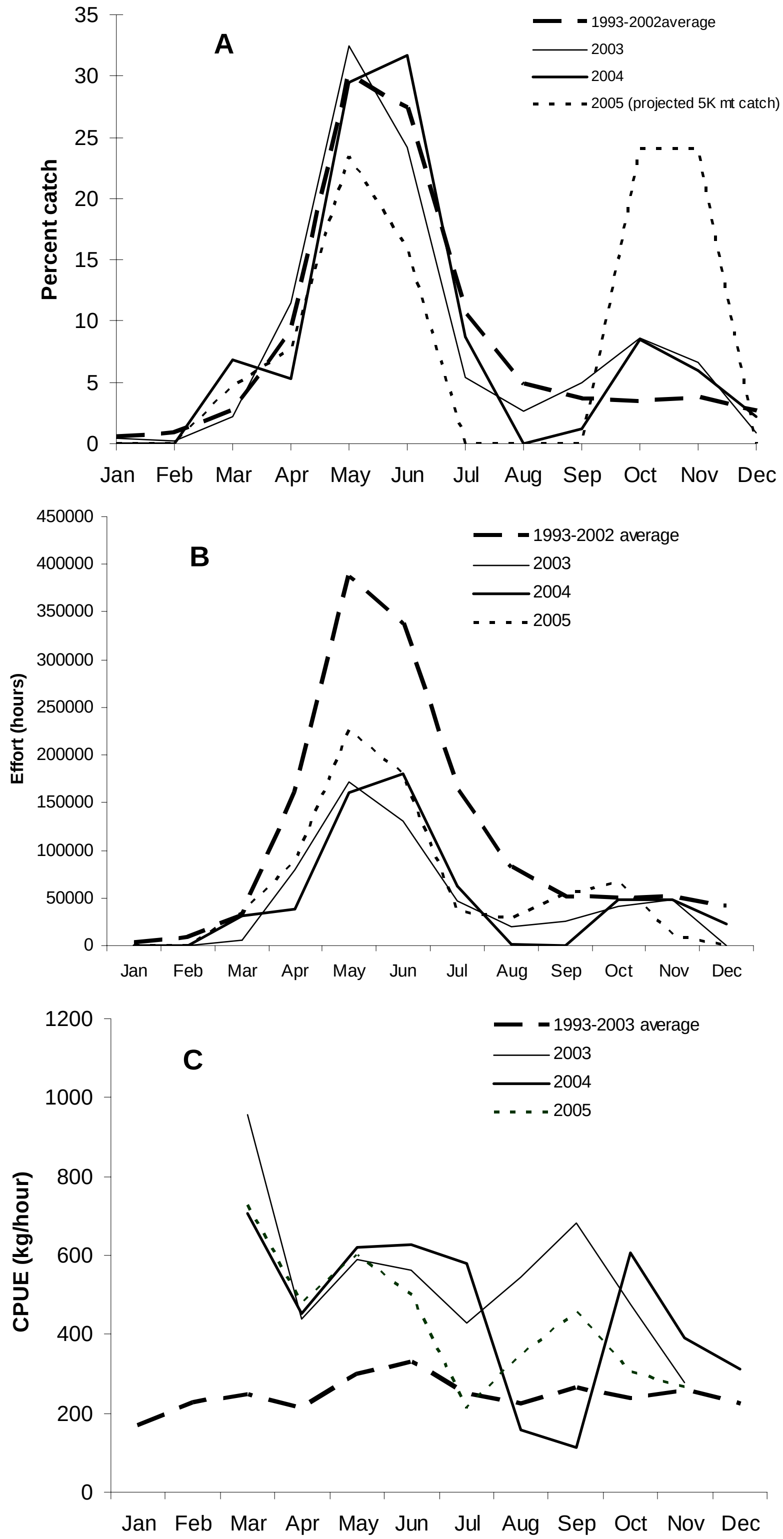


Figure 8. A. Catches from the shrimp fishery as a percentage of the total catch, B. average CPUEs and C. total effort, by month.

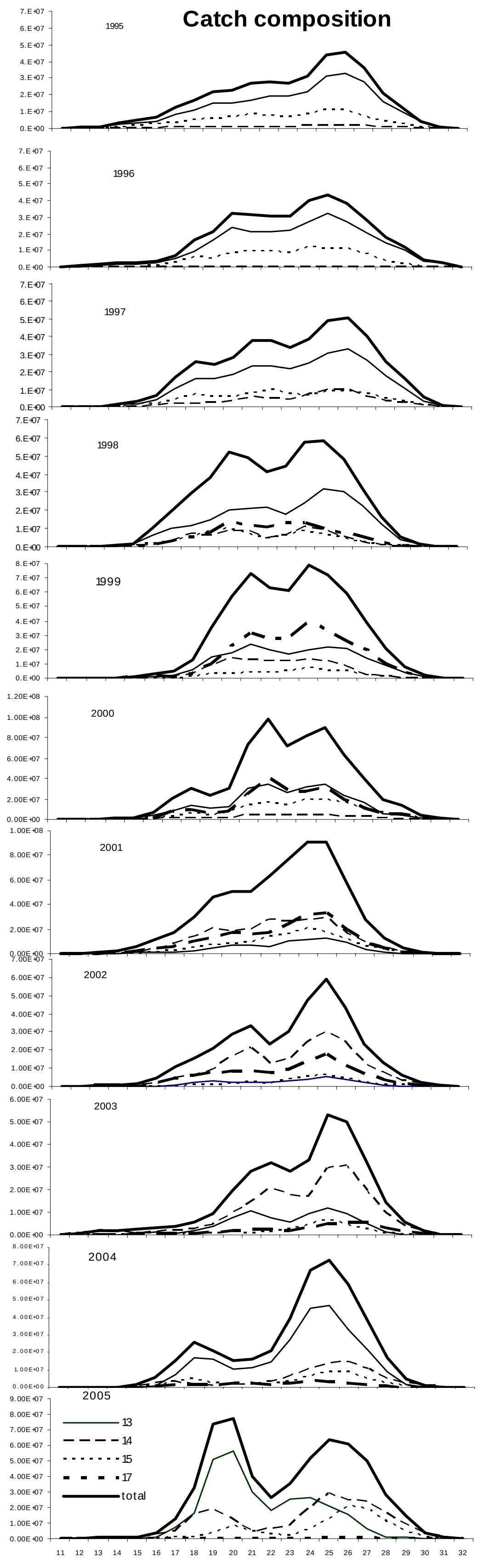


Figure 9. Catch at length from commercial sampling, 1995-2005.

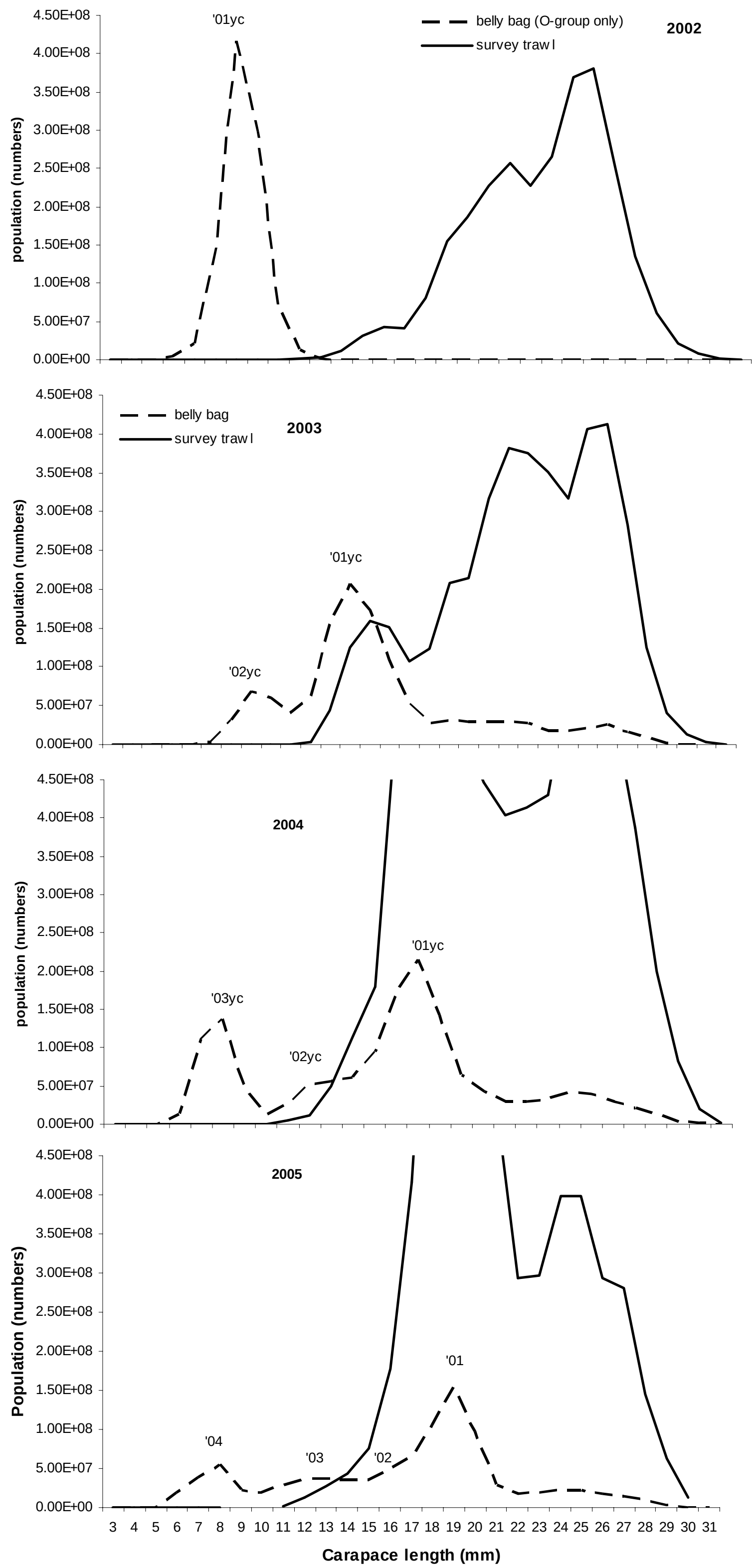


Figure 10. Population estimates from belly bag and main trawl catches for the 2002-2005 survey. Note that the 2002 belly bag estimate was made only for 1-year olds.

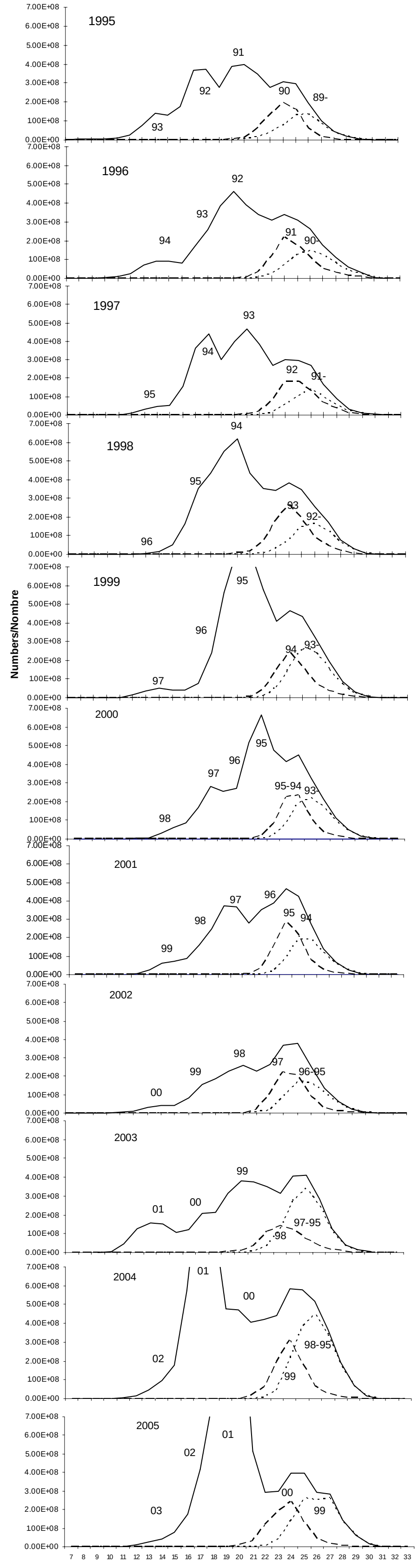


Figure 11. Population estimates at length from DFO-Industry surveys. The heavy dotted line in each figure represents transitional and primiparous shrimp, and the stippled line represents multiparous shrimp.

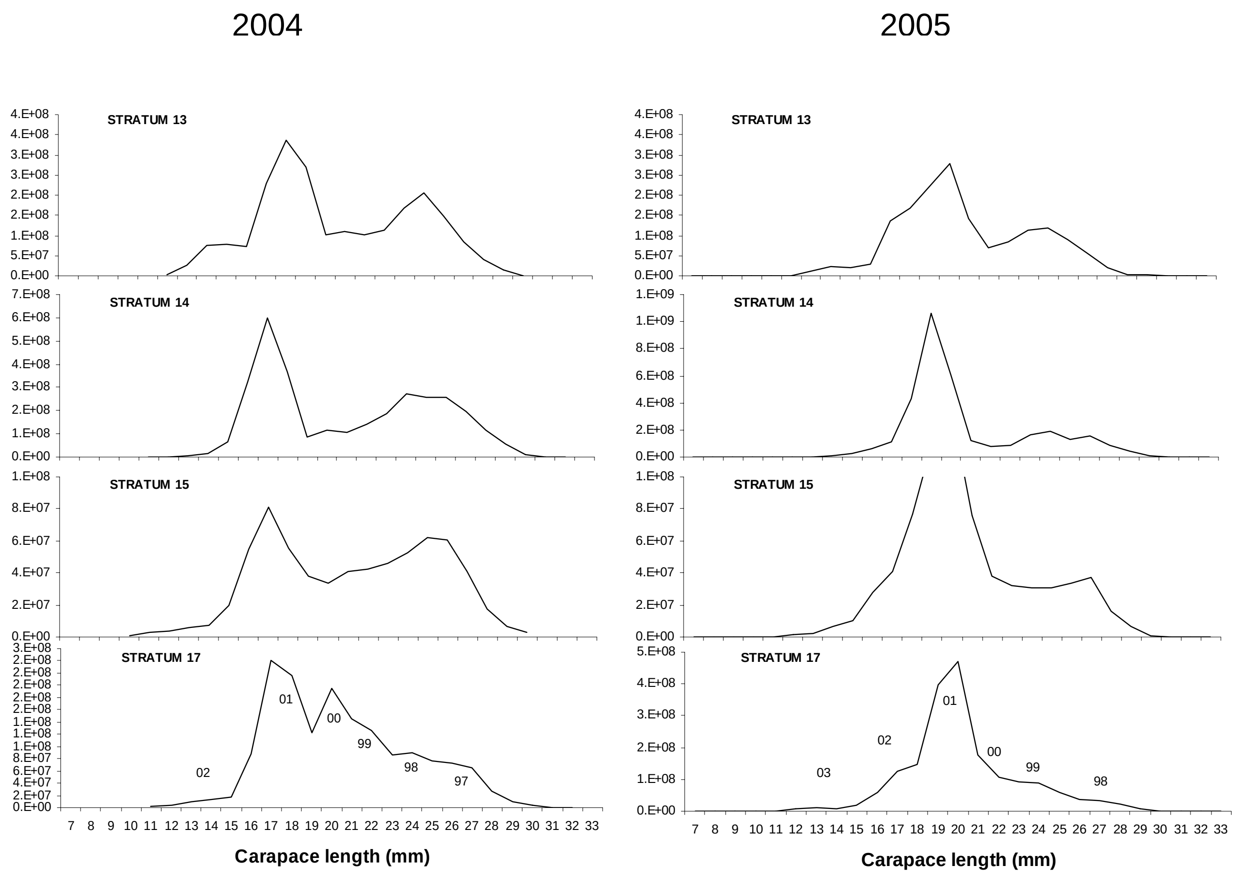


Figure 12. Population at length estimates by Shrimp Fishing Area from the DFO-Industry survey conducted in June, 2004 and 2005.

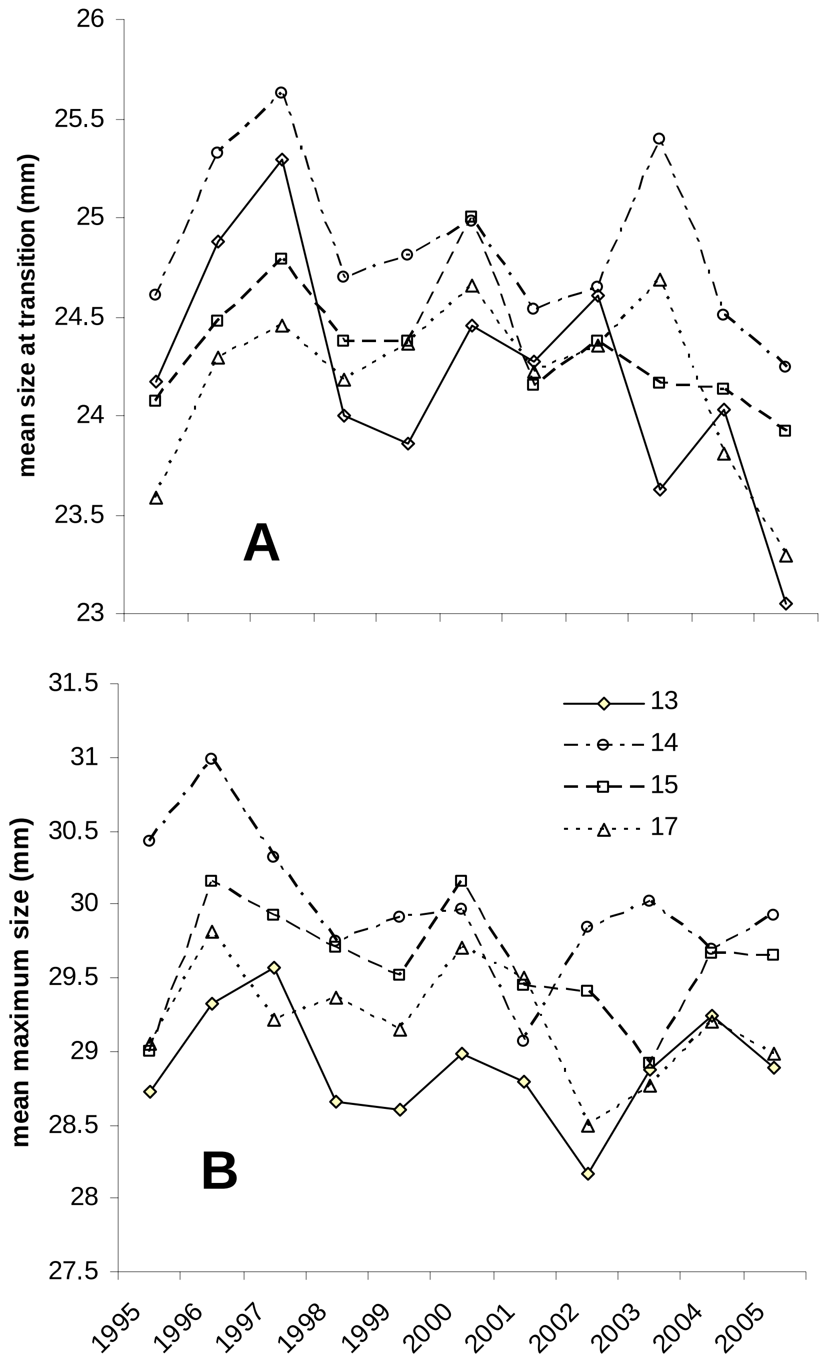


Figure 13. Average size at A. sex transition and B. maximum size by shrimp fishing area for the DFO-Industry surveys 1995-2005.

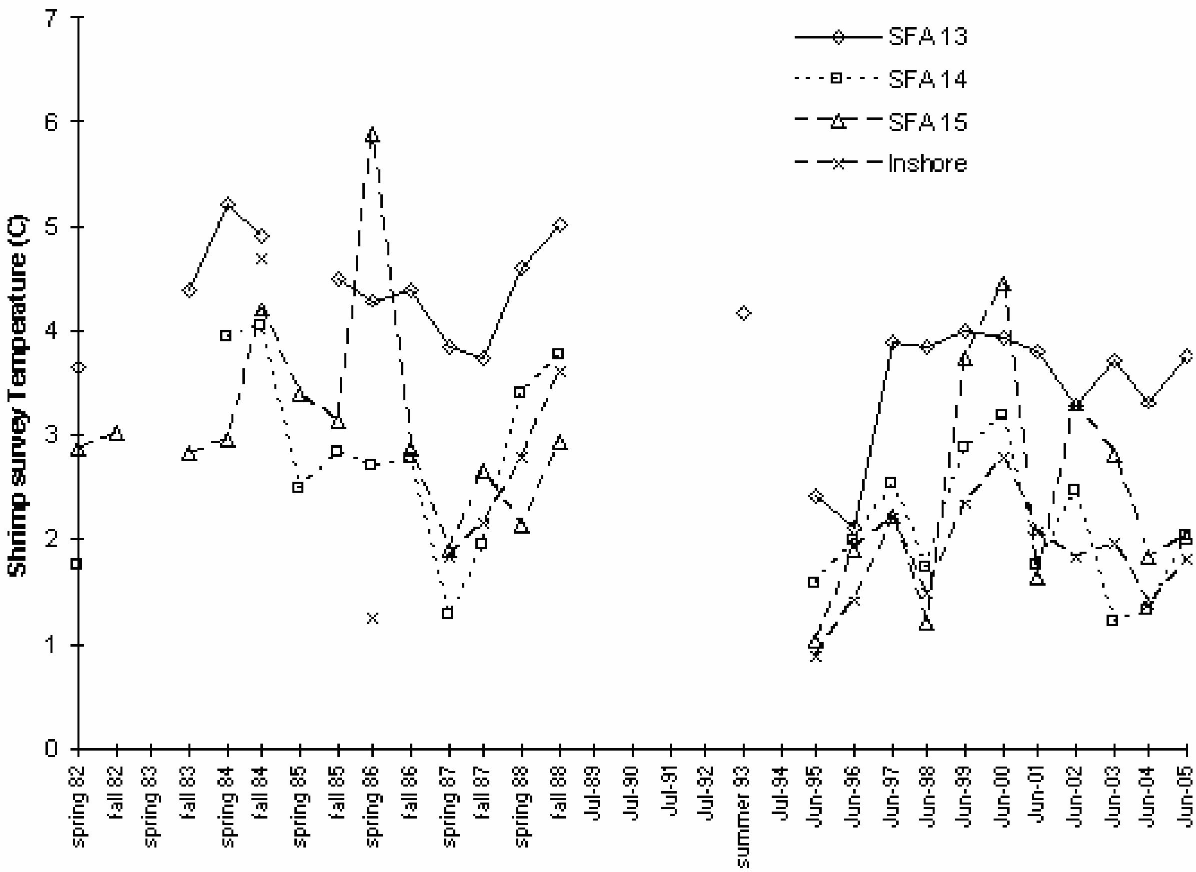


Figure 14. Mean bottom temperatures from shrimp surveys by SFA. Note that both spring and fall values were available from the earlier series (1982-88), but only one survey (June) was conducted annually in the recent series.

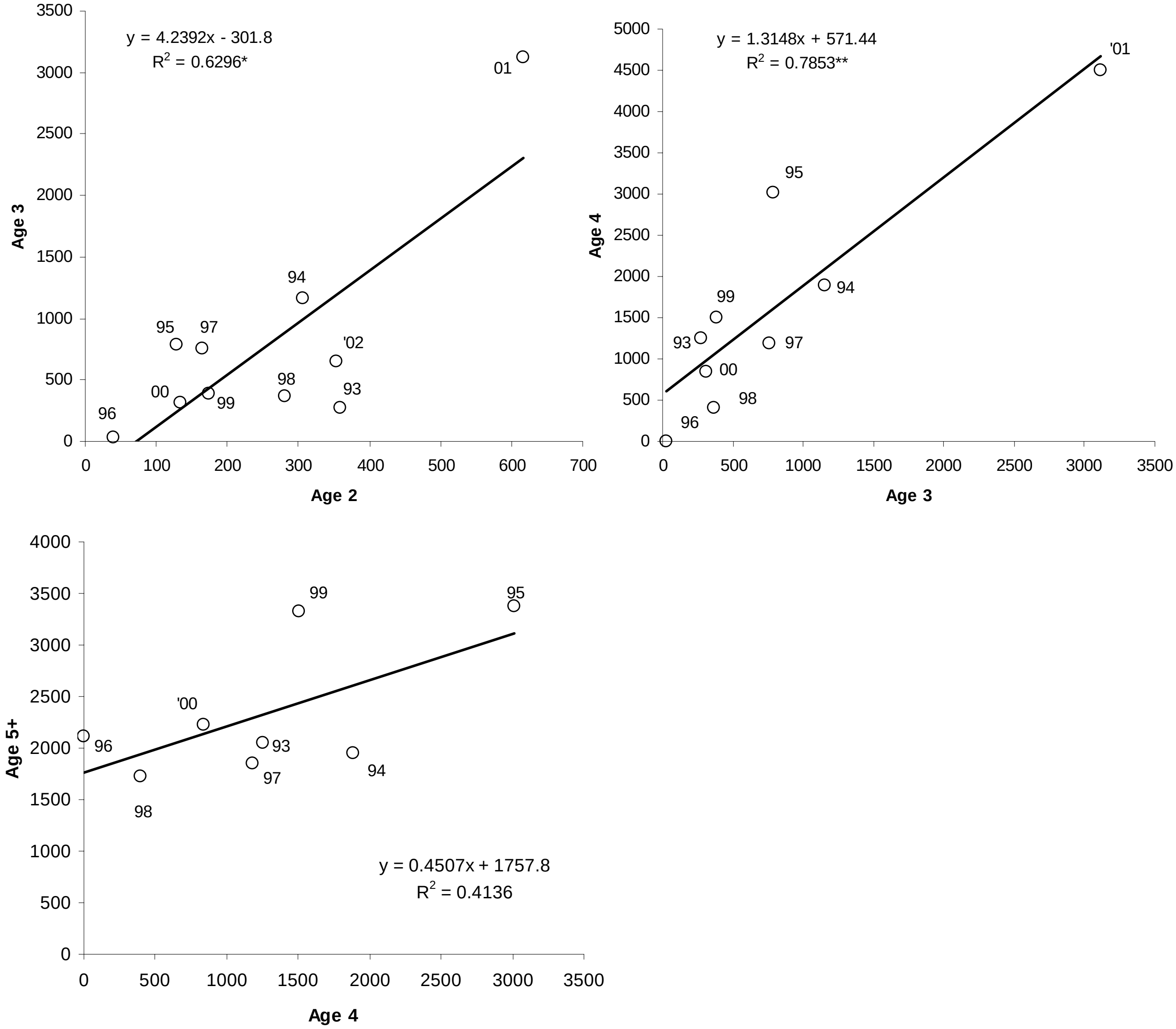


Figure 15. Regressions of age x versus x+1 survey population estimates from MIX analyses. These regressions were used to project the 2004 survey population at age to 2005 using current growth rates. Projection for 2006 was not attempted.

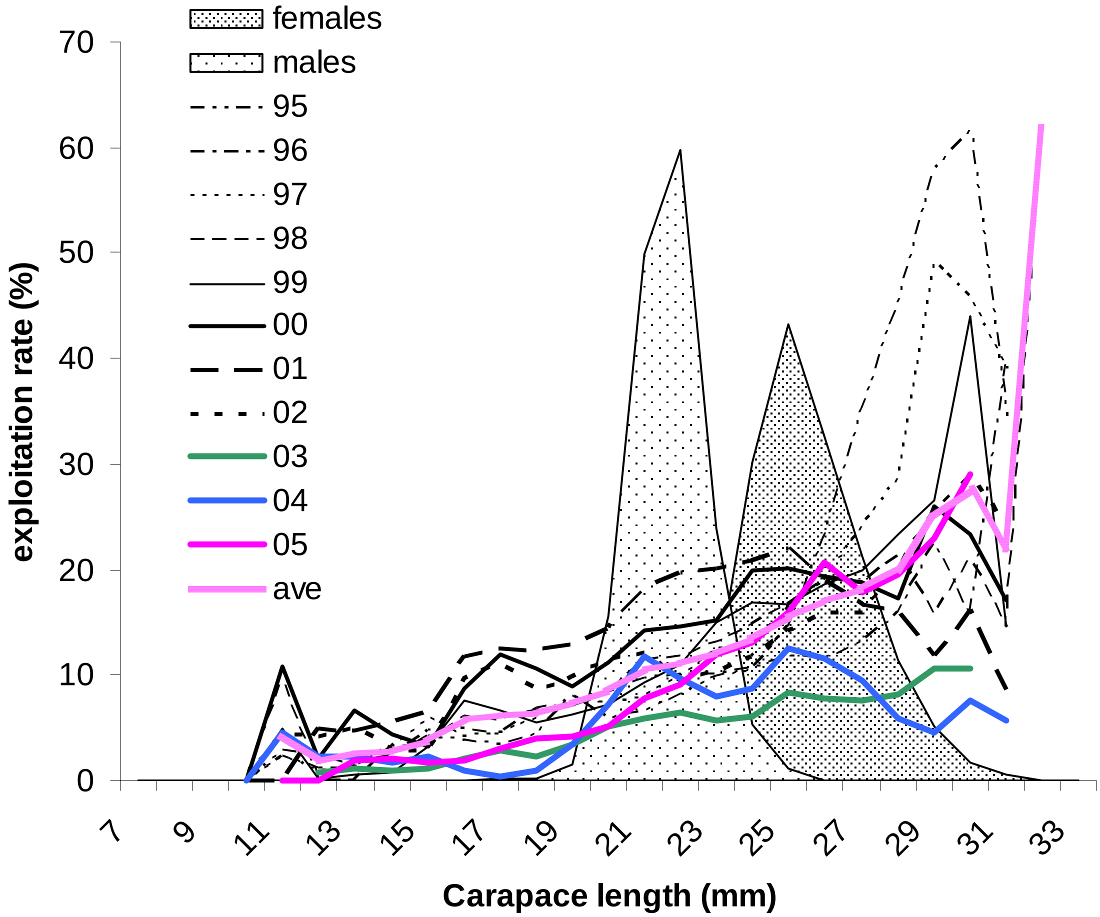


Figure 16. Exploitation at length from commercial sampling and DFO-industry surveys (1995-2005). The average exploitation rates were applied to the total projected population at length to determine a projected catch (Figure 17). The graph also shows the average size of age 4+ males and age 5+ females in the population.

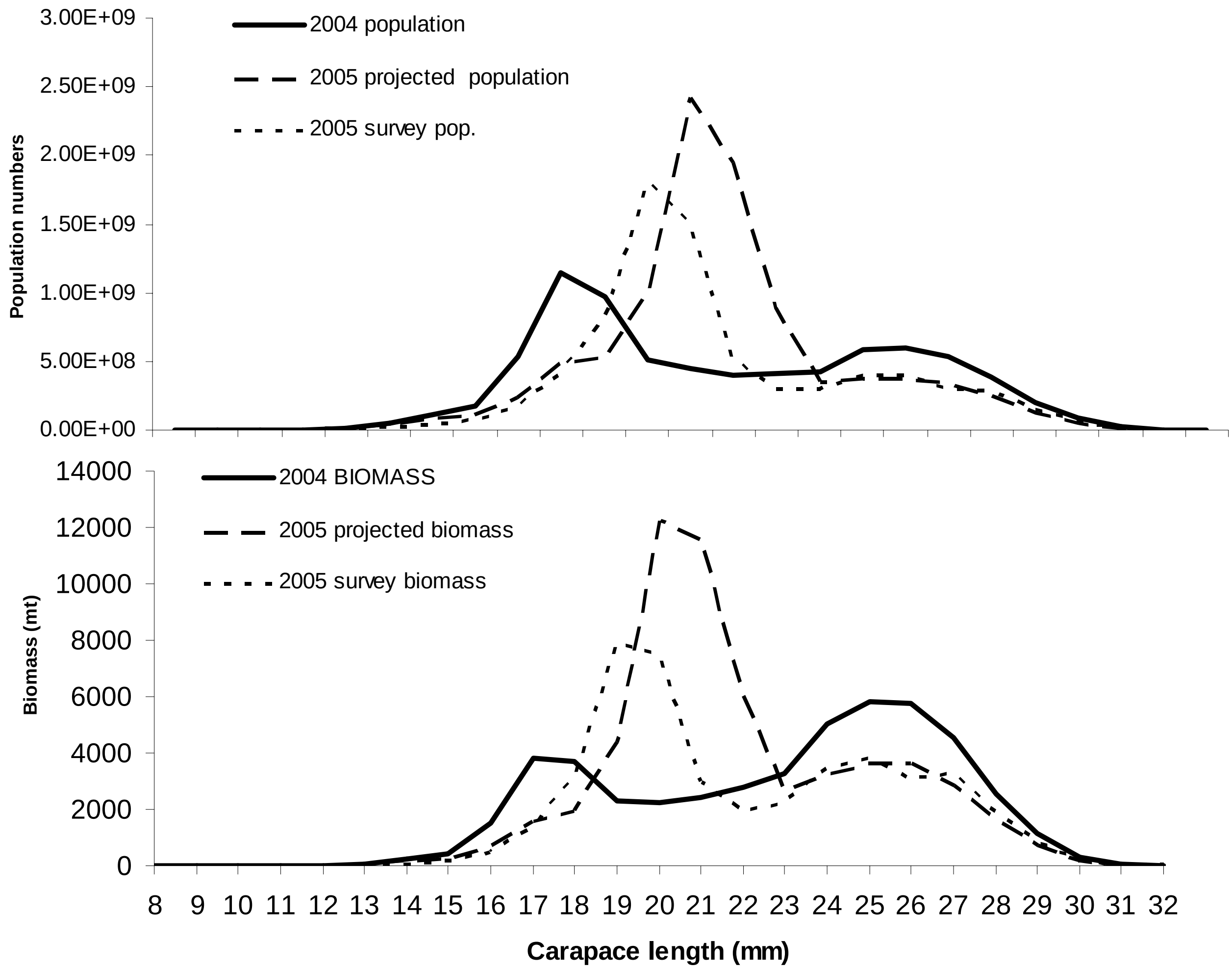


Figure 17. 2004 population (upper) and biomass (lower) estimates at length from the DFO-Industry survey, 2005 projected population and biomass estimates at length calculated from the 2004 survey estimate and the regressions in Figure 15, and 2005 projected catch in numbers and weight