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An Assessment of the Eastern Scotian Shelf Shrimp Stock and Fishery in 2004 and Outlook for 2005

Évaluation du stock et de la pêche de la crevette de l'est du plateau néo-écossais en 2004, et perspectives pour 2005

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ABSTRACT

The 2004 DFO-industry survey total biomass index was the highest of the 10 year series. While the bulk of the biomass (42%) continues to concentrate in the offshore part of SFA 14 (i.e. survey stratum 14 or the Misaine Hole), the biomass in the other areas has also increased substantially - all except the Canso Hole showed record estimates in 2004. The commercial fleet shifted much of its effort to the Louisbourg Hole (SFA 13), where both counts and biomass were favourable during most of the season. The spawning stock biomass (females) in 2004 was also by far the highest on record. This large increase in SSB was unexpected - in the 2003 survey the year class (~1999) recruiting to the 2004 female population only appeared about average. Biomass increases are expected to continue over the next several years as the exceptionally strong 2001 year class enters its last year as males in 2005 and recruits to the female population in 2006. In 2005 as much as 60% of this biomass could be comprised of this year class, consequently, it is expected that the difficulties predicted and experienced by fishers in avoiding small shrimp in 2004 will continue into the 2005 fishery. The 2001 year class, first characterised as strong from “belly bag” samples alone in the 2002 survey continues to appear exceptional in both belly bag and survey trawl catches in 2004. In belly bag samples the 2001 year class is about three times larger than the two succeeding year classes (i.e. 2002 and 2003). The 2003 year class appears stronger than the 2002 year class in belly bag samples, and the latter appears above average in the main survey trawl estimate, consequently, current recruitment appears to be good. It is possible that the 2001 year class will experience slower growth due to density dependence as was observed with the 1995 year class. Commercial catch rates (standardized series) appear to have levelled off at a high level in 2004. Spatial indicators suggest that the biomass is again beginning to expand in area, after a contraction associated with the concentration of the previous round of strong year classes (1993-1995) which allowed for continuing high commercial catch rates despite decreasing survey biomasses from 1999-2002. It should be noted that a new survey trawl was used for the 2004 survey which may account for some of the large biomass increase observed (increased trawl efficiency). However, the trawl was built to the same plans and specifications as the old trawl and NETMINDER mensuration showed that it performed in a similar manner. Traffic light indicators have improved during the last 3 years. A substantial increase is indicated in 2005 to take advantage of the accumulated and growing fishable biomass. There are two main concerns 1. although an increase in TAC appears warranted the large number of males from the 2001 year class may result in growth overfishing – the increase is based on the observation that in the past fishers have been able to avoid small shrimp due to the flexibility they have in fishing throughout the areas without major restrictions. 2. at the same time, this flexibility and the absence of area quotas tends to results in overexploitation in some areas and underexploitation in others.

RÉSUMÉ

L'indice de la biomasse totale du relevé MPO-industrie de 2004 était le plus élevé de la série chronologique de dix ans. Tandis que la biomasse continue d'être concentrée principalement (42 %) dans la partie hauturière de la ZPC 14 (c.-à-d. la strate 14 du relevé ou la fosse de Misaine), la biomasse a aussi augmenté substantiellement dans les autres zones – toutes les zones, sauf la fosse de Canso, ont affiché une estimation record en 2004. La flottille commerciale a réorienté une grande partie de l'effort de pêche vers la fosse de Louisbourg (ZPC 13) où la biomasse et le nombre étaient favorables durant une bonne partie de la saison. La biomasse génitrice (femelles) en 2004 était aussi, et de loin, la plus élevée jamais enregistrée. Cette forte hausse de la biomasse génitrice était imprévue – au cours du relevé de 2003, la classe d'âge (~1999) qui était recrutée au sein de la population de femelles de 2004 semblait seulement moyenne. On s'attend à ce que cet accroissement de la biomasse se poursuive pendant plusieurs années, tandis que la classe d'âge exceptionnellement forte de 2001 entreprend sa dernière année au sein des mâles en 2005 et sera recrutée au sein de la population femelle en 2006. En 2005, jusqu'à 60 % de cette biomasse pourrait être composée de cette classe d'âge; par conséquent, on s'attend à ce que la difficulté d'éviter les petites crevettes qui avait été prévue et qu'ont connue les pêcheurs en 2004 se poursuive au cours de la pêche de 2005. La classe d'âge de 2001, d'abord caractérisée comme une classe forte d'après les seuls échantillons prélevés à l'aide d'un sac attaché au ventre du chalut au cours du relevé de 2002, continue de sembler exceptionnelle aussi bien selon les échantillons prélevés à l'aide du sac du ventre du chalut et les prises du relevé au chalut de 2004. D'après les prises du sac, la classe d'âge de 2001 est environ trois fois plus grande que les deux classes d'âge subséquentes (2002 et 2003). Celle de 2003 semble plus forte que celle de 2002 dans l'échantillonnage du sac du chalut, la seconde paraissant supérieure à la moyenne selon l'estimation réalisée à partir du chalut principal du relevé. Ainsi, le recrutement actuel semble bon. Il est possible que la classe d'âge de 2001 connaisse une croissance lente à cause de la dépendance à l'égard de la densité, comme ce fut le cas de la classe d'âge de 1995. Les taux de prises commerciales (série standardisée) paraissent avoir marqué un palier élevé en 2004. Les indicateurs du régime spatial semblent montrer que la biomasse recommence à s'étendre après une contraction associée à la concentration de la série de classes d'âge précédentes (1993-1995), qui a permis des taux de prise commerciales élevés et soutenus, malgré la diminution de la biomasse selon les relevés, de 1999 à 2002. Il convient de noter qu'un nouveau chalut a été utilisé pour le relevé de 2004, ce qui pourrait expliquer une partie des grandes augmentations de biomasse observées (efficacité accrue du chalut). Toutefois, le chalut était fabriqué suivant les mêmes devis et dimensions que l'ancien et les mesures réalisées à l'aide de capteurs NETMINDER montrent que son efficacité a été comparable. Les indicateurs fournis par la méthode des feux de circulation se sont améliorés au cours des trois dernières années. Une hausse substantielle est indiquée en 2005 pour tirer parti de la biomasse exploitable accumulée et croissante. On note toutefois deux grandes préoccupations : 1. même si l'augmentation du TAC semble justifiée, le grand nombre de mâles de la classe d'âge de 2001 pourrait entraîner une surpêche du potentiel de croissance – l'augmentation étant basée sur l'observation de la capacité des pêcheurs, dans le passé, d'éviter les petites crevettes grâce à la flexibilité qu'ils ont de pêcher dans toutes les zones sans restriction. 2. Par ailleurs, cette flexibilité et l'absence de quotas de zone tendent à entraîner une surexploitation dans certaines zones et une sous-exploitation dans d'autres.

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. (2003) for the eastern Scotian Shelf stock. The history of the eastern Scotian Shelf shrimp fishery and recent stock assessments are given in Koeller et al (1996b, 1996d, 1997,1998, 1999, 2001,2002, 2003, 2004). 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 (SFA) 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 3 successive declines and the TAC was raised to 3500mt. Signs of improved recruitment in the form of a very strong 2001 year class suggested that the stock would continue to increase.

In 2001 shrimp prices dropped sharply due to large quantities of small shrimp in the Newfoundland and Labrador inshore fishery and other economic factors. 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 and 2004 effort on the Scotian Shelf virtually stopped during the summer to avoid soft shrimp and other logistic factors.

Since 1999 many shrimp stock assessments have included a “traffic light” analysis (Koeller et al. 2000b, Mohn et al. 2001). The organisation of this report is based on this multiple indicator diagnostic approach, with the “Methods” and “Results and Discussion” sections for individual indicators grouped under headings representing "characteristics", in the order they are presented in the summary. The sections on each indicator in “Methods” provide the methods used to calculate the indicators, and describe their relevance to the characteristic they represent. In Results and Discussion, the indicators always represent summary data for the entire area, i.e. all SFAs combined, according to the current practice of managing the fishery as one stock. The indicator series used in the analysis is given as an uncaptioned figure directly after the indicator heading. In addition to the indicator time series themselves, their sections in Results and Discussion include data which support trends seen in the summarized data. These data are given as numbered and captioned figures and tables at the end of the document. For example, individual SFA data often replicate the indicator trends and thus substantiate them. Supporting data may be entirely different from the main indicator, for example: catch rates in the shrimp trap fishery have been previously used to support the apparent increasing shrimp aggregation shown by the survey and CPUE data; anecdotal reports of large numbers of 1-year old shrimp found on

Cape Breton beaches in 2002 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 have not been successful to date, the 2003 and 2004 fishery 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 wish to become permanent, and the permanent fleet component has been one of the main stumbling blocks preventing the successful negotiation of a new multi-year plan. 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. In 2004 only 300mt were allocated to the fishery despite the 3500mt TAC. This is closer to the trap fishery's capacity and was intended to avoid reallocations.

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.

ABUNDANCE

Research Vessel Abundance Index

A tenth industry-funded trawl survey, incorporating a mixed stratified random - fixed station design, was conducted in June 2004. Survey design and station selection methods were similar to previous surveys completed in 1995-2002: fishing depths >100 fathoms, randomly selected stations in strata 13 and 15; fixed stations in strata 14 due to the difficulty in finding trawlable bottom; 30 minute tow length; 2.5 knot vessel speed. Stations in Strata 17 (inshore) were selected randomly at all depths having a bottom type identified as La Have clay on Atlantic Geosciences Centre surficial geology maps. The 2004 survey was completed by MV *All Seven* (third year for this vessel/crew) fishing the standard survey trawl (Gourock #1126 2-bridle shrimp trawl and #9 Bison doors. Measurements of trawl wing spread and headline height were made throughout most survey sets using NETMINDER sensors. The trawl was fitted with a 'belly bag' attached to the footrope and belly between the two middle rollers. All *P. borealis*, including 1-year olds, 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.

The trawl used in 2004 was newly constructed, as the old survey trawl had been used for 7 years and was showing its age. The new trawl was built by *Pesca Trawl Ltd.* using the original specifications and net drawings. The builder was given the old trawl and instructed to use it as the model should there be discrepancies between the original plan and the net itself. In addition, the old footrope gear and headline floats were used in the new trawl. Netminder results taken throughout the 2004 survey were compared to Netminder and Scanmar measurements taken on the old trawl during previous surveys (see results).

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 improved over the years it is likely that the differences in CPUEs between the period of low abundance (pre-1993) and the recent high abundances are exaggerated and should be interpreted cautiously.

Commercial trawler Standardized Catch Per Unit Effort

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

An increase in this and the 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, MacDonald and Pitcher 1979).

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

RV Age 4 abundance

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

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

RV spawning stock biomass (Females)

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

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

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

Average size at sex transition (L_t)

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

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

Average maximum size (L_{max})

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

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

Predation

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

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

FISHING EFFECTS

Commercial counts

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

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

Exploitation Index

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

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

Female Exploitation Index

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

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

Proportion of females in catch

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

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

Average size of females in catch

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

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

Fishing during ovigerous period

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

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

ECOSYSTEM

RV bottom temperatures

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

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

July SST

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

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

RV Capelin abundance

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

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

RV Cod recruitment

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

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

RV Greenland halibut recruitment

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

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

RV Snow crab recruitment

This is the stratified random abundance index for pre-recruits calculated for the snow crab assessment from annual crab surveys in south-eastern 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 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

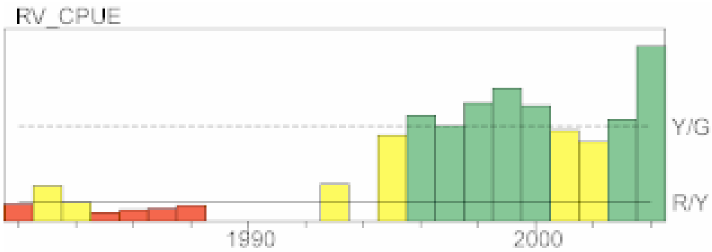
A « traditional » projection, for example, from a VPA population-at-age matrix using assumptions on recruitment, growth and natural mortality is not possible with this stock. In general, the eastern Scotian Shelf shrimp stock appears as if it is never fully recruited to the survey e.g. the abundance 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 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 marginally so), although this is the most important component of the fishery (Figure 18). The projection assumes current growth rates, constant mortality rates (natural and fishing) and accurate aging from modal analysis. It is not intended as an accurate prediction for management purposes but as an approximation of the likely population trends over the next year.

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



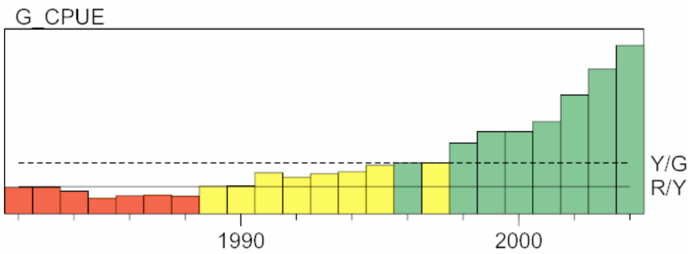
The stratified survey estimate for 2004 increased for the second time after three consecutive decreases beginning in 1999. The stratified estimate was the highest of the 10 year series, as were 3 of the four survey areas. The total biomass estimate increased from 28,130 mt in 2003 to 48,438mt in 2004 (Table 6).

Although it increased again in 2004, Stratum 15 gave the lowest estimate of the 4 areas. Stratum 14 has generally shown the largest estimate throughout the series and the largest increase in 2004. This stratum did not experience a decrease in abundance from 1999-2002 as did the other areas. (Figure 2, Table 6).

Figure 3 gives a schematic of the new Gourock #1126 trawl used in the 2004 survey, redrawn by *Pescatrawl Ltd*, for comparison with the original Gourock #1126 used during the 1997-2003 surveys and shown in Koeller et al (1997). Note that the trawls were manufactured to the same specifications and that every effort was made to ensure that the new trawl was identical to the old one, including having the old trawl on hand for comparison during manufacture and using the old footrope bobbins, footrope discs and floats. In addition, the new trawl was fitted with the old codend and grate to insure continuity of net selectivity. Headline height and wingspread readings (Figure 4A) taken with Netminder from the old trawl in 2003 are quite similar to those taken with the new trawl in 2004 (averages given in upper part of figure), indicating that the two trawls were performing similarly and should have comparable fishing powers. Headline heights in 2003 (old trawl) and 2004 (new trawl) were much higher (nearly 2 m) than readings taken in 1998. The higher headline heights of 2003 and 2004 should have resulted in much lower compensatory wingspreads, however these were similar for all surveys. We conclude that the higher headline heights observed both with the old trawl in 2003 and new trawl in 2004 were due to improper sensor placement. This happens if the sensor is allowed to hang at an angle to the top belly and results in an overestimate of the headline height except when trawl movement occasionally bounces the sensor to a vertical position as shown in Figure 5. This was confirmed from inspection of mensuration data from 2003 and 2004 surveys both of which showed occasional readings of headline height near the expected 6m (Figure 4B). While we conclude that the new net was fishing properly and similarly to the old trawl we cannot account for any increased efficiency that may be due to new materials used (e.g. new footrope wire, twine).

Interpretation: Stock biomass is at an all time high. However, it cannot be ruled out that some of the large increase observed in 2004 was due to improved trawl efficiency from the new net materials used.

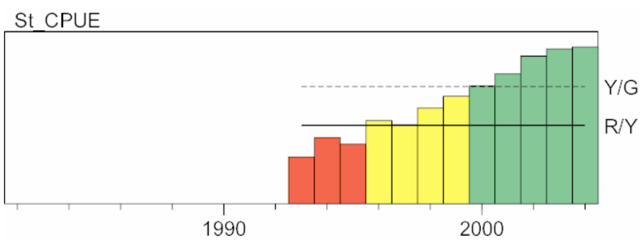
Gulf Vessels Catch Per Unit Effort



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

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

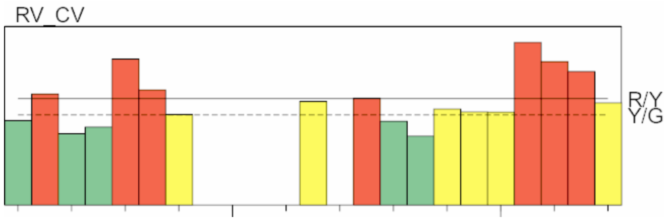
Commercial trawler standardized catch per unit effort



The standardized CPUE series has increased every year except for two of the 12 year series. The parallel trend in both survey and CPUE series broke down from 1999-2002 with the survey showing decreases and CPUE showing increases (Figure 6A). With recent survey increases and renewed expansion of the population area the standardized CPUE and survey index may have realigned themselves, however we continue to use the survey index as the indicator which most accurately shows population and biomass trends. The increases in this indicator appear to have levelled off during the last 2 years.

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.

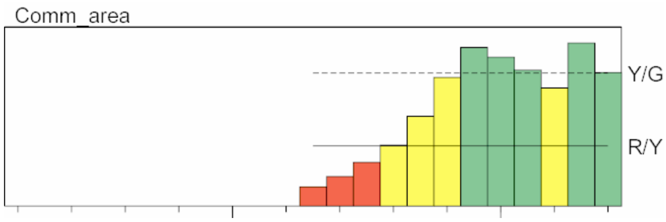
Research vessel coefficient of variation



The overall measure of dispersion has been decreasing over the last few years (Figure 7).

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.

Commercial fishing area

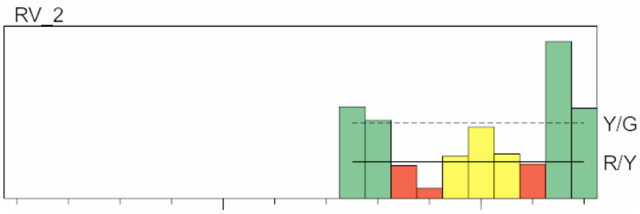


The area with commercial catch rates >250kg/hour increased since the beginning of the series until 1999, when it began to decrease. The area with catch rates >150kg began to decrease in 1997, while the interval with the highest catch rates (>450) continued to increase (Figure 9). This pattern is consistent with a concentration of the resource in a smaller area during the biomass decrease. There is some suggestion that this may be reversing in the last two years. It should be noted that the distribution of effort changed significantly over the years (Figure 10), 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. There are indications that this pattern is reversing as the population increases again and begins to expand spatially.

PRODUCTION

RV abundance at age 2

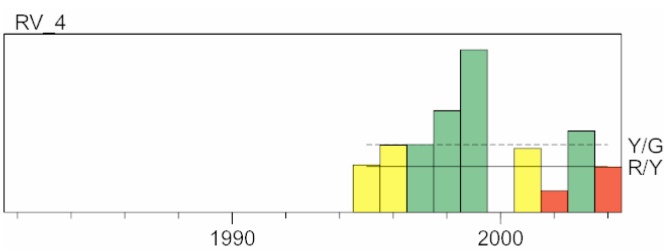


Age 2 abundance in 2003 was the highest of the 9-year series due to the strength of the 2001 year class which was first seen in belly-bag samples in 2002 (Figure 13). Age 2 abundance in the 2004 survey was not as strong but still above average (Table 5).

The 2001 year class is prominent in all belly bag catches from 2002-2004 (Figure 13), and it is the strongest year class by far at three years old in the 2004 main trawl catch (Figure 13,14). This year class is widely distributed and is prominent in all areas (Figure 15). The 2003 year class appears stronger than the 2002 year class in belly bag samples, and the latter appears above average in the main survey trawl estimate (Table 5, Figure 13,14)

Interpretation: Although the 2002 and 2003 year classes are not as strong as the 2001 year class, they still appear to be above average. Recruitment may be improving after a period of average or below average recruitment and does not appear to be confined to the exceptional 2001 year class.

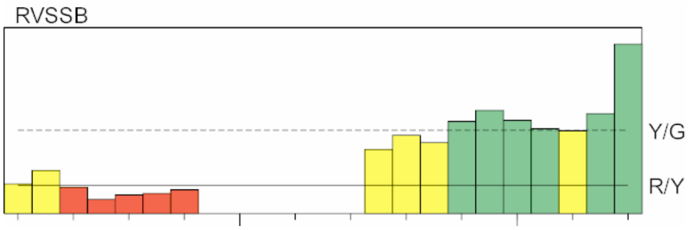
RV abundance at age 4



The abundance of age 4 shrimp (1999 year class) increased from the second lowest value in 2002 to about average in 2003, suggesting that recruitment to the female population should be reasonably good in 2004 (Table 5). However, the abundance of females 5+ was exceptional in 2004, so this indicator does not appear to currently reflect female abundance the following year. The estimate for 4 year olds in the 2004 survey was below average, suggesting that the high abundance of females seen in 2004 may decrease.

Interpretation: The abundance of 4 year old shrimp that will provide the bulk of the catch in 2005 appears to be below average in 2004 but this has not always been a reliable predictor, particularly in 2003 when an average population estimate at age 4 was followed by a record population estimate of age 5+ females.

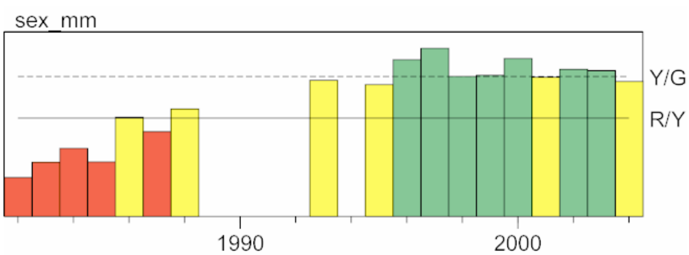
RV spawning stock biomass (Females)



Research vessel spawning stock biomass increased in 2004 to the highest of the series, almost double the previous high. SSB has remained well above the low SSBs of the 1980s (about 6,000mt) when the population was increasing. It seems unlikely that the recent lower recruitments were due to overfishing of spawners.

Interpretation: Spawning stock biomass is currently the highest on record and remains well above the low levels of the 1980s when the population was increasing. There is no concern at present for recruitment overfishing

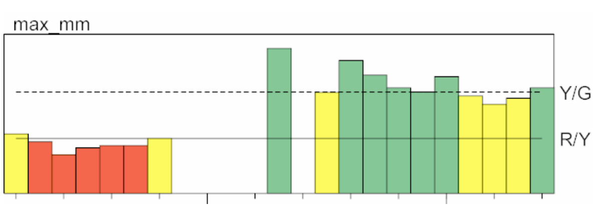
Average size at sex transition (L_t)



There has been no clear trend in this indicator that would suggest a change in growth rate, and size at transition remains substantially higher than the period of faster growth during the 1980s. There has been a slight decrease during the last three years which may be associated with density dependant effects as the population increases. Annual changes are generally reflected in all regions (Figure 16A).

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

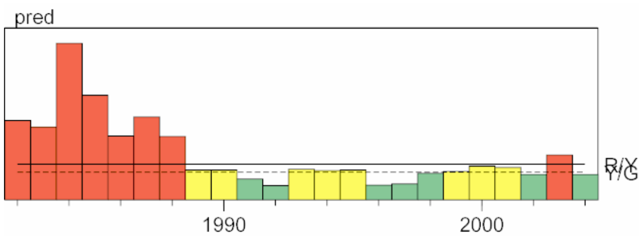
Average maximum size (L_{max})



There was a decreasing trend since 1996 which appears to have reversed in 2002. Despite these changes 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 16B). The generally smaller maximum sizes in area 13 are attributed to faster growth rates caused by higher temperatures in this area (see temperature distributions and trends in Figure 8 and 17). The consistently lower abundances in this area may therefore be due to lower fecundities of the smaller animals.

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

Predation

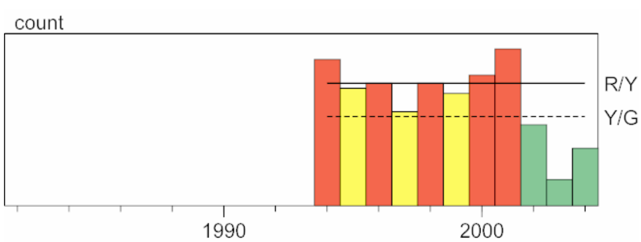


Groundfish abundance remains well below the high levels during the 1980s when the shrimp population was low.

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.

FISHING IMPACTS

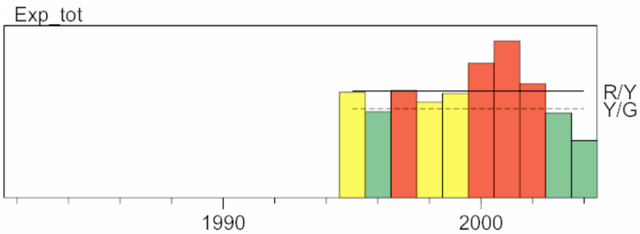
Commercial counts



The variation around this parameter is large and there is a seasonal component, with counts decreasing to a minimum in July and increasing thereafter (Koeller et al 2002). Counts appear to have decreased recently.

Interpretation: Fishers continue to have no difficulty staying below the counts which command the best prices from buyers (<65). There are no immediate concerns regarding growth overfishing.

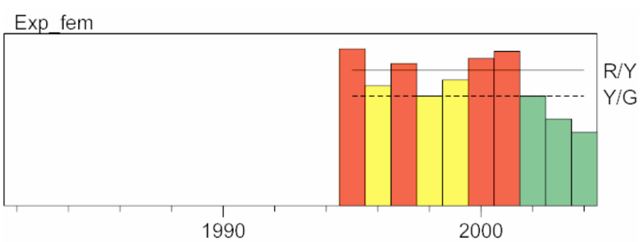
Exploitation Rate



Total exploitation decreased again in 2004 to the lowest value on record due mainly to the increases in survey abundance. Exploitation decreased significantly in strata14 and 17(inshore) but it increased in 13 and 15, with a very large increase in the former (Table 6). This has resulted in an unbalanced situation in which stratum 14 now has the highest biomass but lowest exploitation it has experienced historically. Stratum 13 showed both the largest biomass and exploitation rate in that area.

Interpretation: Overall exploitation has decreased to very low levels due to biomass increases. Exploitation is very low (Strata 14,17) or acceptable (Stratum 15) in most strata, but it has increased significantly in 13 where the fleet concentrated most of its effort in 2004. Catch rates in SFA 13 have been exceptional during the last 2 years (Figure 6B), and fishers had less difficulty avoiding small shrimp in this area.

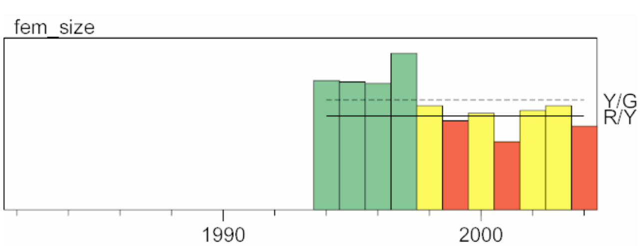
Female Exploitation Rate



Female exploitation decreased to the lowest value of the series due mainly to the large increase in SSB.

Interpretation: The large increase in SSB in 2004 has resulted in a decrease in the female exploitation rate.

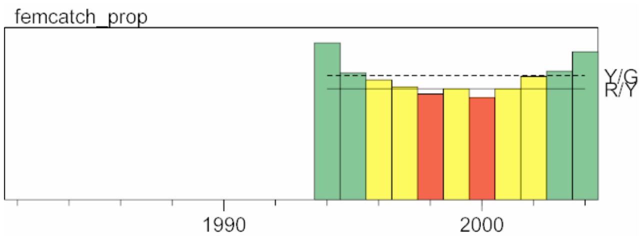
Mean size of females in catch



The average size of females in the catch decreased from the mid 1990s to 2001, and it has remained relatively low since.

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 appears to parallel the decreasing size at transition and maximum size seen in the survey.

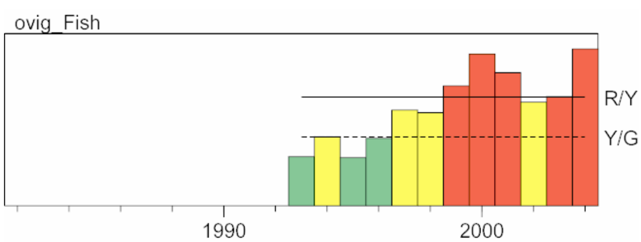
Proportion of females in catch



The proportion of females in the catch showed a decreasing trend from 1994 to 2000 but has increased since then.

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. Under this interpretation this indicator would be expected to decrease again as the 2001 year class recruits to the fishery as the oldest age class of males in 2005.

Fishing during ovigerous period

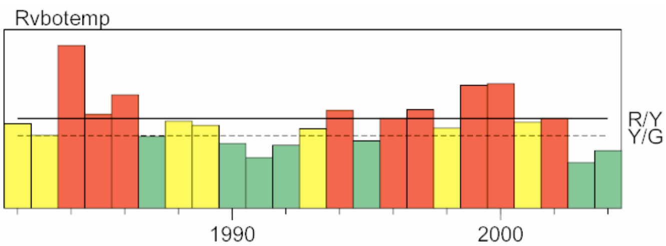


Fishing during the ovigerous period increased significantly from the early 1990s to a maximum in 2000 due to the longer time required to catch increasing TACs by a relatively small fleet of vessels, many of which are also engaged in other fisheries. In addition, quota transfers have occurred and many vessels fished several individual quotas, further extending the length of the season. This indicator decreased in 2001-2002 as the lower TAC was again caught mainly during the non-ovigerous summer period. It increased in 2003-2004 because of greatly decreased effort during the summer months to avoid soft shrimp. The monthly distribution of catches and catch rates are shown in Figure 11 and the catch at length is shown in Figure 12.

Interpretation: Fishing during the ovigerous period may have impacted population reproductive potential in recent years by removing ovigerous females before their eggs have hatched. This does not appear to be a problem at this time considering the relatively low female exploitation rate and high spawning stock biomass.

ECOSYSTEM

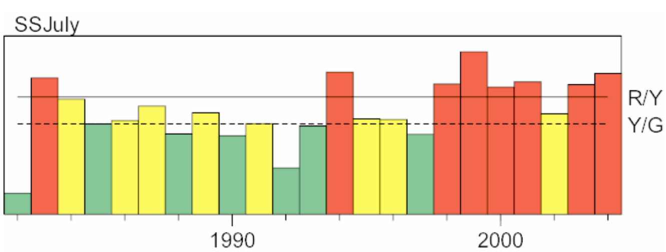
RV (groundfish survey) bottom temperatures



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 (Figure 17) 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.

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.

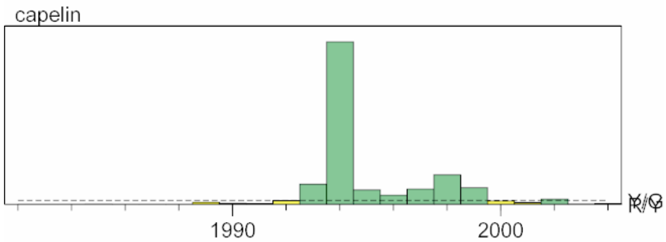
July SST



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 late 1990s.

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.

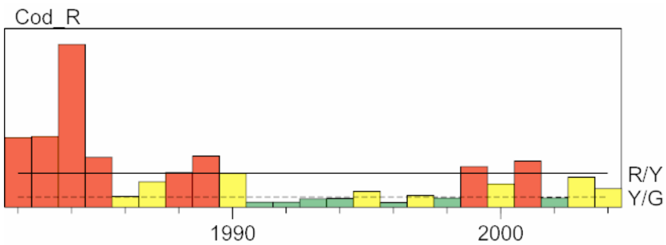
RV Capelin abundance



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

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

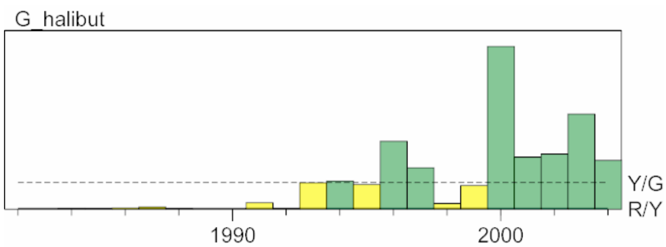
Cod recruitment



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

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

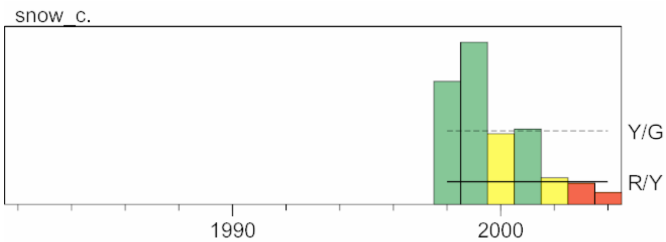
Greenland halibut recruitment



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 for Greenland halibut and probably also to shrimp.

Snow crab recruitment



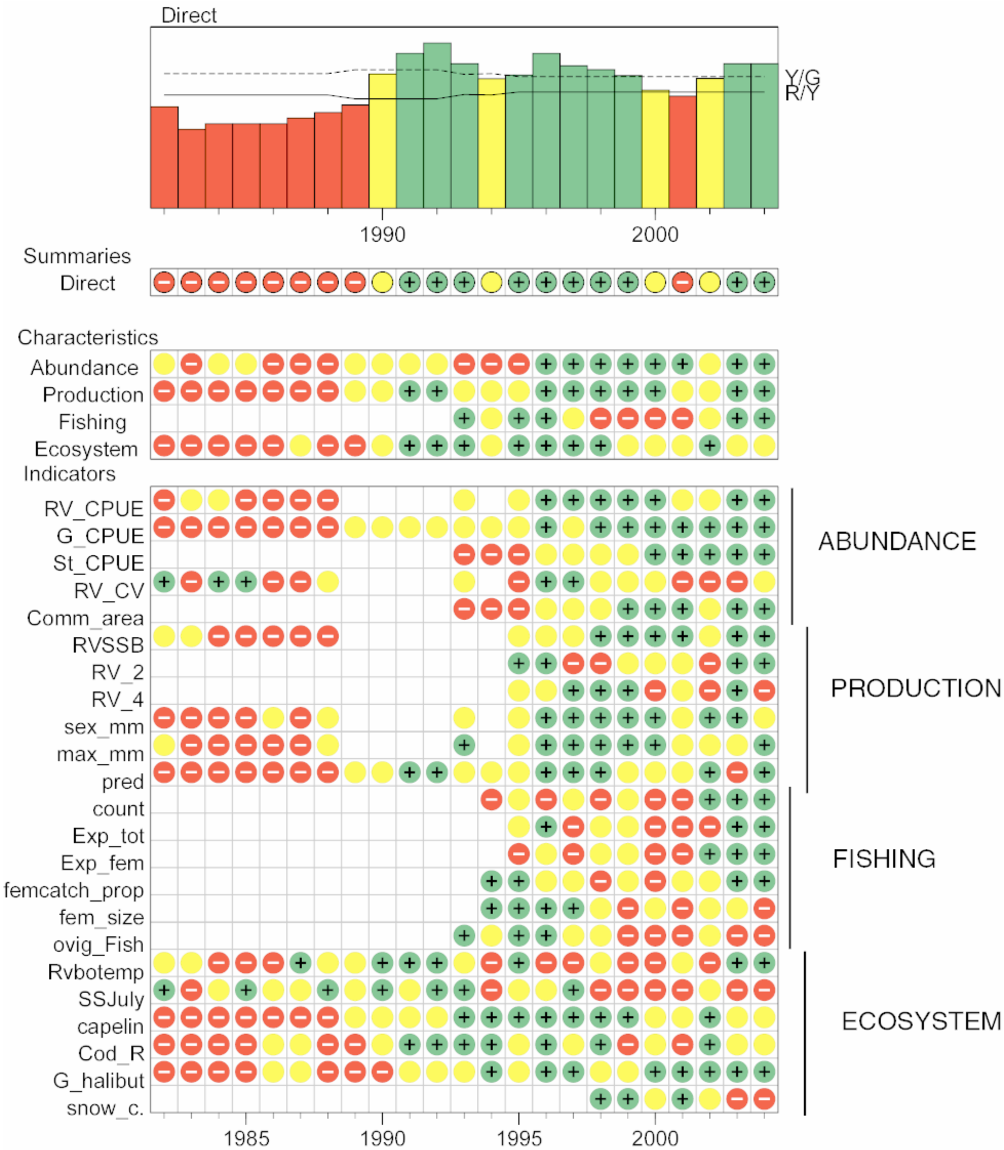
The pre-recruit index from the Cape Breton snow crab survey has been decreasing in recent years.

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

Projection

Population, biomass and catch projections based on ages x versus x+1 regressions (Figure 18) and average length specific exploitation from 1995-2003 (Figure 19) are shown in Figure 20. The projection suggests that the 2001 year class will be an important component of the 2005 biomass and catch, and may affect counts detrimentally. For example, a projected catch of 6800 mt based on an average (1995-2004) exploitation rate would have a count of 67 shrimp per pound, marginally above the buyer's limit which have recently commanded the best prices. Nearly 60% of this catch would comprise shrimp <23mm carapace length having a count above 80.

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 increased since 2000, following a 5 year declining trend. Improvements have been seen in all 4 characteristics except ecosystem, which appear to be ambivalent relative to shrimp production.

Abundance indicators are mostly favourable, however the CPUE series must be interpreted more cautiously and weighted lower than survey results in this regard due to changing spatial resource and effort distribution. Production indicators are generally favourable, due to the increasing spawning stock biomass and improved recruitment to the population. Although the low RV_4 indicator is a concern for the 2005 fishery, this has not always been a reliable indicator for recruitment to the fishery. Fishing impact indicators have improved significantly during the last few years but the size of females in the catch has decreased and the proportion of the catch taken during the ovigerous period remains high. In view of the high spawning stock biomass this is not a concern relative to population reproductive capacity. Despite increased recruitment to the population and decreasing female sizes count data from industry data indicates that fishermen have experienced no difficulties in obtaining sizes which command the best prices from buyers. Ecosystem indicators have been ambivalent recently. Bottom temperatures have decreased, but surface temperatures have remained relatively high. The capelin abundance, cod recruitment and snow crab recruitment indicators were less favourable in 2003-2004 while the Greenland halibut recruitment indicator continued to show a favourable value. There is no clear indication that the regime may be changing to one less favourable for shrimp.

ACKNOWLEDGEMENTS

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Table 1. TACs (trawls) and catches (trawls and traps) from the eastern Scotian Shelf shrimp fishery 1980-2004.

	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
[4]**2004**	3300	200	2111	748	441	3300	200	3500

[1] Nordmore separator grate introduced.

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

[3]individual SFA TACs combined

[4] preliminary

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

	Trap	**Trawl**	
Year	**S-F[1]**	**S-F[2]**	**Gulf[3]**
1995	4	24(23)	6(23)
1996	9(17)	21(24)	6(23)
1997	10(17)	18(23)	6(23)
1998	15(26)	17(28)[4]	10(23)[5]
1999	15(22)	19(28)[4]	10(23)[5]
2000	12(21)	18(32)[6]	10(23)[5]
2001	10(28)	18(28)[4]	10(23)[5]
2002	10(14)[7]	15(23)	6(23)
2003	9(14)	14(23)	5(23)
2004	6(14)	14(23)[8]	6(23)[8]

[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 200 2. The reduction in the total number of trap licences is due to cancellation of some non-active exploratory licences

[8] small temporary allocation to be determined.

Table 3. Input data for traffic light analysis.

	RV_CPUE	G_CPUE	St_CPUE	RV_CV	Comm_ar	RVSSB	count	RV_2	RV_4	sex_mm	max_mm	
1982.00	34.50	128.00	NAN	65.54	NAN	5040.65	NAN	NAN	NAN	21.72	28.24	
1983.00	71.50	127.70	NAN	86.01	NAN	7323.05	NAN	NAN	NAN	22.11	28.03	
1984.00	39.00	109.50	NAN	55.35	NAN	4460.96	NAN	NAN	NAN	22.46	27.69	
1985.00	17.00	75.40	NAN	60.48	NAN	2417.71	NAN	NAN	NAN	22.11	27.87	
1986.00	23.00	87.30	NAN	113.14	NAN	3187.87	NAN	NAN	NAN	23.26	27.94	
1987.00	25.50	90.70	NAN	89.20	NAN	3424.46	NAN	NAN	NAN	22.89	27.94	
1988.00	31.50	85.10	NAN	70.19	NAN	4047.02	NAN	NAN	NAN	23.48	28.12	
1989.00	NAN	133.40	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	
1990.00	NAN	134.50	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	
1991.00	NAN	197.90	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	
1992.00	NAN	176.30	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	
1993.00	75.00	193.00	196.94	80.32	31.00	NAN	NAN	NAN	NAN	24.22	30.45	
1994.00	NAN	202.40	278.93	NAN	48.00	NAN	58.79	NAN	NAN	NAN	NAN	
1995.00	173.00	233.80	251.68	82.84	71.00	10912.15	57.71	358.50	875.92	24.11	29.31	
1996.00	213.50	245.90	350.62	64.88	99.00	13368.38	57.91	307.34	1247.63	24.74	30.14	
1997.00	193.00	245.50	333.02	53.46	146.00	12100.80	56.82	128.85	1257.47	25.04	29.76	
1998.00	238.50	341.00	403.23	74.42	209.00	15707.48	57.93	39.89	1883.71	24.31	29.43	
1999.00	268.50	396.00	453.27	72.20	258.00	17607.48	57.51	165.63	3010.18	24.35	29.32	
2000.00	233.50	396.00	497.22	72.00	242.00	15893.36	58.18	280.34	0.00	24.77	29.72	
2001.00	183.50	444.00	547.55	126.03	221.00	14475.58	59.21	174.90	1184.11	24.29	29.22	
2002.00	161.40	572.00	622.52	111.15	192.00	14133.20	56.33	134.00	399.17	24.50	29.00	
2003.00	204.42	697.09	652.57	103.51	265.00	16916.16	54.23	576.74	1411.07	24.47	29.17	
2004.00	353.70	810.91	660.68	79.19	217.00	28897.65	55.43	354.09	839.46	24.19	29.61	

	pred	Exp_tot	Exp_fem	femcatch_	fem_size	ovig_Fish	Rvbotemp	SSJuly	capelin	Cod_R	G_halibut	snow_c.
1982.00	179.29	NAN	NAN	NAN	NAN	NAN	2.57	9.67	0.00	2.38	0.00	NAN
1983.00	164.05	NAN	NAN	NAN	NAN	NAN	2.22	15.15	0.00	2.42	0.00	NAN
1984.00	353.25	NAN	NAN	NAN	NAN	NAN	4.95	14.14	0.00	5.57	0.06	NAN
1985.00	236.37	NAN	NAN	NAN	NAN	NAN	2.86	12.96	1.55	1.71	0.05	NAN
1986.00	144.33	NAN	NAN	NAN	NAN	NAN	3.45	13.12	0.13	0.37	0.09	NAN
1987.00	187.04	NAN	NAN	NAN	NAN	NAN	2.19	13.81	0.77	0.87	0.16	NAN
1988.00	142.81	NAN	NAN	NAN	NAN	NAN	2.65	12.48	0.17	1.19	0.06	NAN
1989.00	66.58	NAN	NAN	NAN	NAN	NAN	2.52	13.49	18.38	1.75	0.00	NAN
1990.00	67.33	NAN	NAN	NAN	NAN	NAN	1.97	12.40	9.23	1.16	0.00	NAN
1991.00	46.91	NAN	NAN	NAN	NAN	NAN	1.54	12.97	5.07	0.17	0.46	NAN
1992.00	32.10	NAN	NAN	NAN	NAN	NAN	1.92	10.86	34.88	0.17	0.08	NAN
1993.00	68.53	NAN	NAN	NAN	NAN	11.91	2.42	12.86	193.36	0.29	1.86	NAN
1994.00	66.17	NAN	NAN	0.89	26.05	16.71	2.98	15.42	1563.89	0.30	1.98	NAN
1995.00	66.52	13.33	21.04	0.72	26.03	11.69	2.05	13.20	138.62	0.54	1.74	NAN
1996.00	32.56	10.86	16.11	0.68	26.01	16.38	2.74	13.17	87.53	0.16	4.78	NAN
1997.00	35.85	13.57	19.08	0.64	26.44	23.23	3.00	12.47	146.64	0.40	2.91	NAN
1998.00	59.87	12.08	14.73	0.60	25.68	22.58	2.44	14.86	284.31	0.31	0.41	267.80
1999.00	64.13	13.17	16.90	0.63	25.46	29.09	3.74	16.38	159.96	1.39	1.67	353.10
2000.00	76.29	17.00	19.79	0.58	25.57	36.81	3.79	14.70	32.38	0.79	11.44	153.90
2001.00	73.28	19.80	20.72	0.63	25.15	32.30	2.62	14.96	15.99	1.58	3.66	163.70
2002.00	57.30	14.41	14.72	0.70	25.61	25.15	2.74	13.44	49.85	0.32	3.88	57.52
2003.00	100.65	10.70	11.63	0.73	25.68	32.49	1.39	14.83	2.70	1.03	6.69	46.33
2004.00	57.46	7.23	9.85	0.84	25.38	38.03	1.75	15.36	5.93	0.64	3.44	26.10

Table 4. Set statistics from DFO-idustry survey AS0401 conducted by MV All Seven June 1 - 10 2004.

SET	SFA	DATE	LAT.	LONG.	SPEED (kts)	DIST. (n. m.)	DUR. (min)	WING. (m)	DEPTH (fth)	TEMP (^{o}C)	RAW CATCH	stand. catch (kg)	DENSITY (gm/m^2 or m.t./km2)
1	15	01-Jun-04	45°04.59	60°53.27	2.5	0.44	15	17.2	110	0.8	30	85.9	2.1
2	15	01-Jun-04	44°56.79	61°06.92	2.4	0.99	29	16.9	106	3.0	81	106.3	2.6
3	15	01-Jun-04	44°53.32	60°57.30	2.5	1.23	29	16.9	132	3.5	149	157.0	3.9
4	15	01-Jun-04	44°46.83	60°53.10	2.4	1.20	28	16.6	149	3.6	196	212.4	5.3
5	15	01-Jun-04	44°52.22	60°46.55	2.6	1.37	29	16.4	128	2.7	251	242.1	6.0
6	15	01-Jun-04	44°58.39	60°44.42	2.5	1.26	28	16.2	112	2.3	122	129.7	3.2
7	15	01-Jun-04	44°49.59	60°34.86	2.5	1.22	29	16.6	140	1.9	345	371.3	9.2
8	15	01-Jun-04	44°57.40	60°28.20	2.4	1.19	28	16.5	128	1.0	252	280.1	7.0
9	15	01-Jun-04	44°55.29	60°22.88	2.4	1.21	29	18.9	123	1.0	179	170.3	4.2
10	15	02-Jun-04	44°59.86	60°07.66	2.5	1.28	29	20.5	114	1.3	256	212.0	5.3
11	15	02-Jun-04	44°57.46	60°14.02	2.7	1.36	29	17.1	110	1.1	187	174.6	4.3
12	15	02-Jun-04	44°50.92	60°14.21	2.5	1.27	28	17.0	162	1.2	85	85.9	2.1
13	15	02-Jun-04	44°45.47	60°18.84	2.7	1.27	21	16.1	177	1.3	91	96.1	2.4
14	15	02-Jun-04	44°39.64	60°18.75	2.7	1.31	29	17.7	124	1.1	247	232.0	5.8
15	15	02-Jun-04	44°36.65	60°11.88	2.4	1.23	27	16.0	118	1.7	225	248.3	6.2
16	14	02-Jun-04	44°41.71	60°00.24	2.6	1.23	28	16.6	123	1.6	555	589.2	14.6
17	14	02-Jun-04	44°47.01	59°58.79	2.5	1.26	26	16.3	133	1.6	359	379.5	9.4
18	14	02-Jun-04	44°53.42	59°58.73	2.6	1.31	28	16.7	105	1.6	346	345.4	8.6
19	14	02-Jun-04	44°52.01	59°43.55	2.7	1.21	23	16.6	121	1.5	418	453.4	11.3
20	14	03-Jun-04	44°42.24	59°46.56	2.4	1.18	26	16.1	143	1.6	766	873.4	21.7
21	14	03-Jun-04	44°43.56	59°32.41	2.6	1.33	27	16.9	126	1.6	557	541.5	13.4
22	14	03-Jun-04	44°49.25	59°29.17	2.4	1.22	26	17.0	140	1.3	851	894.5	22.2
23	14	03-Jun-04	44°48.75	59°12.29	2.2	1.12	30	17.5	126	1.0	483	533.6	13.2
24	14	03-Jun-04	44°48.88	59°07.14	2.4	1.16	28	17.4	129	1.0	356	383.8	9.5
25	14	03-Jun-04	44°41.83	59°02.20	2.4	1.14	30	17.8	143	1.0	222	237.4	5.9
26	14	03-Jun-04	44°46.40	58°55.09	2.6	1.25	26	16.9	156	1.1	261	267.7	6.6
27	14	04-Jun-04	44°54.51	58°44.27	2.4	1.17	24	16.9	151	1.1	148	163.5	4.1
28	14	04-Jun-04	44°47.88	58°40.18	2.4	1.19	27	16.6	140	1.2	545	601.2	14.9
29	14	04-Jun-04	44°50.26	58°32.90	2.4	1.19	23	16.8	139	1.2	368	402.3	10.0
30	14	04-Jun-04	44°54.80	58°20.71	2.4	1.19	26	16.6	136	1.4	1266	1391.6	34.5
31	13	06-Jun-04	45°47.30	58°58.39	2.5	1.21	28	16.8	128	3.7	139	149.4	3.7
32	13	06-Jun-04	45°50.56	58°54.09	2.5	1.21	25	16.3	117	3.2	88	97.6	2.4
33	13	06-Jun-04	45°48.01	58°50.70	2.6	1.26	25	17.4	144	3.8	271	269.9	6.7
34	13	06-Jun-04	45°46.44	58°44.05	2.5	1.24	26	16.7	153	3.9	567	595.2	14.8
35	13	06-Jun-04	45°49.52	58°32.68	2.6	1.28	27	17.3	163	3.8	452	444.8	11.0
36	13	06-Jun-04	45°46.64	58°33.54	2.5	1.22	20	16.3	151	3.8	377	413.8	10.3
37	13	06-Jun-04	45°42.98	58°14.26	2.5	1.23	29	18.1	116	2.6	148	144.5	3.6
38	13	06-Jun-04	45°39.71	58°13.41	2.4	1.21	21	16.6	147	2.7	49	53.5	1.3
39	13	06-Jun-04	45°36.06	58°22.93	2.6	1.27	26	16.2	154	2.7	177	185.9	4.6
40	13	07-Jun-04	45°36.96	58°38.41	2.6	1.21	23	15.9	162	3.1	37	41.9	1.0
41	13	07-Jun-04	45°36.08	58°54.20	2.6	1.24	28	16.8	124	3.1	845	877.4	21.8
42	13	07-Jun-04	45°41.41	58°47.31	2.5	1.24	27	16.6	124	3.4	447	473.0	11.7
43	13	07-Jun-04	45°40.06	58°57.24	2.5	1.23	27	17.1	136	3.4	320	331.3	8.2
44	13	07-Jun-04	45°36.69	59°05.48	2.4	1.14	27	17.5	132	3.3	379	414.6	10.3

Table 4. (continued).

SET	SFA	DATE	LAT.	LONG.	SPEED (kts)	DIST. (n. m.)	DUR. (min)	WING. (m)	DEPTH (fth)	TEMP (°C)	RAW CATCH	stand. catch (kg)	DENSITY (gm/m^2 or m.t./km2)
45	13	07-Jun-04	45°40.18	59°07.34	2.5	1.25	28	17.1	128	3.2	52	52.7	1.3
46	17	07-Jun-04	45°37.54	59°55.34	2.5	1.25	30	17.1	90	1.5	207	211.2	5.2
47	17	08-Jun-04	45°39.34	59°58.29	2.4	1.13	30	17.6	85	1.4	89	97.2	2.4
48	17	08-Jun-04	45°35.69	60°07.90	2.5	1.04	27	17.5	87	1.6	155	185.1	4.6
49	17	08-Jun-04	45°33.87	60°09.98	2.5	1.19	32	16.9	105	1.6	576	622.8	15.5
50	17	08-Jun-04	45°27.32	60°02.36	2.5	1.20	29	17.4	95	1.5	231	240.8	6.0
51	17	08-Jun-04	45°24.84	59°56.43	2.3	1.13	30	17.2	86	1.5	75	83.4	2.1
52	17	08-Jun-04	45°18.37	59°50.39	2.4	1.14	30	14.4	81	1.5	2	3.0	0.1
53	17	09-Jun-04	45°22.97	60°02.04	2.2	1.11	*30*	17.0	112	n/d	374	430.1	10.7
54	17	09-Jun-04	45°21.54	60°14.17	2.3	1.17	*30*	17.3	120	n/d	627	674.4	16.7
55	17	09-Jun-04	45°20.33	60°25.14	2.4	1.06	*30*	17.5	81	n/d	102	119.3	3.0
56	17	10-Jun-04	45°22.59	61°00.26	2.5	1.20	*30*	16.3	57	n/d	75	83.3	2.1
57	17	10-Jun-04	45°26.15	60°56.64	2.4	1.16	28	15.5	63	0.7	245	295.9	7.3
58	17	10-Jun-04	45°25.07	60°49.39	2.6	1.21	27	15.6	67	1.0	191	219.9	5.5
59	17	10-Jun-04	45°26.94	60°34.22	2.4	1.21	28	17.1	99	1.3	374	393.1	9.8
60	17	10-Jun-04	45°27.25	60°29.31	2.4	1.16	28	16.8	112	1.4	625	699.0	17.4
61	17	10-Jun-04	45°29.42	60°24.40	2.3	1.12	27	16.9	119	1.5	815	937.3	23.3

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	Average
1								980	196	316	
2	359	307	129	40	166	280	175	134	616	354	255.93
3	1046	276	1159	785	27	757	362	383	312	3118	822.61
4	876	1248	1257	1884	3010	0	1184	399	1506	839	1220.41
5+	1702	2162	1539	2047	1952	3374	2110	1847	1727	3324	2178.38
TOTAL	3983	3993	4084	4755	5155	4412	3831	2763	4161	7636	4477.33
4+ males	1369	1971	1578	2243	3235	1784	1771	938	1526	1549	1796.35
primiparous	649	777	709	889	736	728	817	678	533	847	736.22
multiparous	560	661	509	647	991	863	706	630	1175	1768	851.03
total females	1209	1438	1218	1535	1727	1591	1523	1308	1708	2615	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), 1995-2004.

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	13	4837	6838	5920	7187	9517	5919	4089	3114	7047	12184
	14	9067	12094	9471	11278	11039	9544	12325	12020	12035	20228
BIOMASS(mt)	**15**	5299	6610	4736	4548	7806	7213	2073	2766	3751	4399
	17	4415	3663	6220	9530	8262	9183	6541	2872	5296	11627
	total	**23620**	**29206**	**26349**	**32545**	**36625**	**31860**	**25038**	**20773**	**28130**	**48438**
	13	169	58	538	514	615	302	565	254	582	2146
	14	2284	2435	2285	2012	1511	2016	1552	1552	1626	730
CATCH(mt)	**15**	721	865	550	618	592	1615	1087	265	226	421
	17	0	0	0	787	2132	1503	1564	872	331	203
	total	**3175**	**3358**	**3373**	**3931**	**4851**	**5436**	**4768**	**2943**	**2765**	**3500**
	13	3.5	0.9	9.1	7.2	6.5	5.1	13.8	8.2	8.3	17.6
	14	25.2	20.1	24.1	17.8	13.7	21.5	12.6	12.9	13.5	3.6
EXPLOITATION(%)	**15**	13.6	13.1	11.6	13.6	7.6	22.2	52.4	9.6	6.0	9.6
	17	0.0	0.0	0.0	8.3	25.8	16.1	23.9	30.4	6.2	1.7
	total	**13.4**	**10.9**	**13.6**	**12.1**	**13.2**	**17.1**	**19.1**	**14.2**	**9.8**	**7.2**

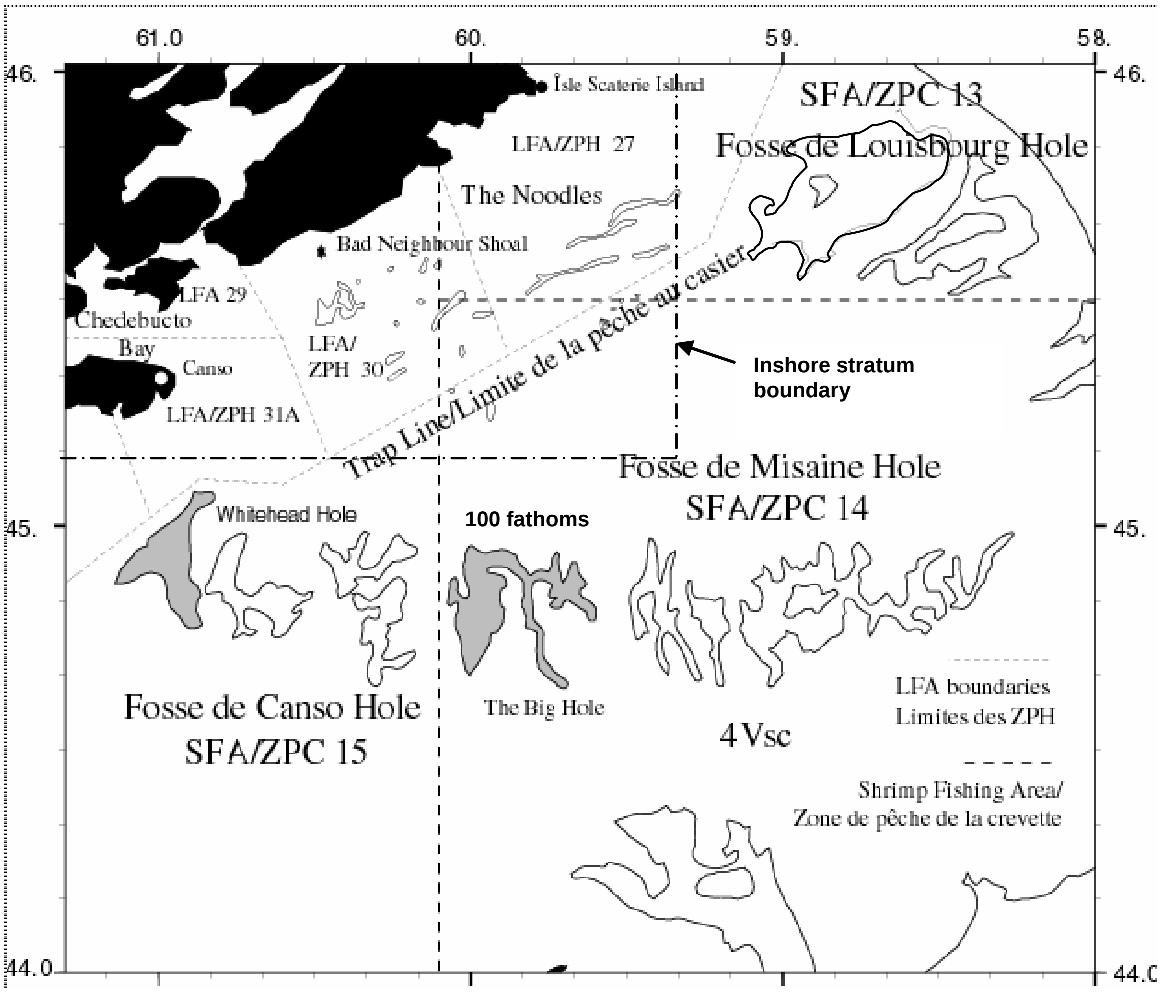


Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. The lobster Fishing Areas (LFAs) used to allocate shrimp trap licences, and the shrimp trap line are also shown. Trappers are prohibited from fishing seaward of this line. Another line (not shown) prohibits trawlers from fishing inside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

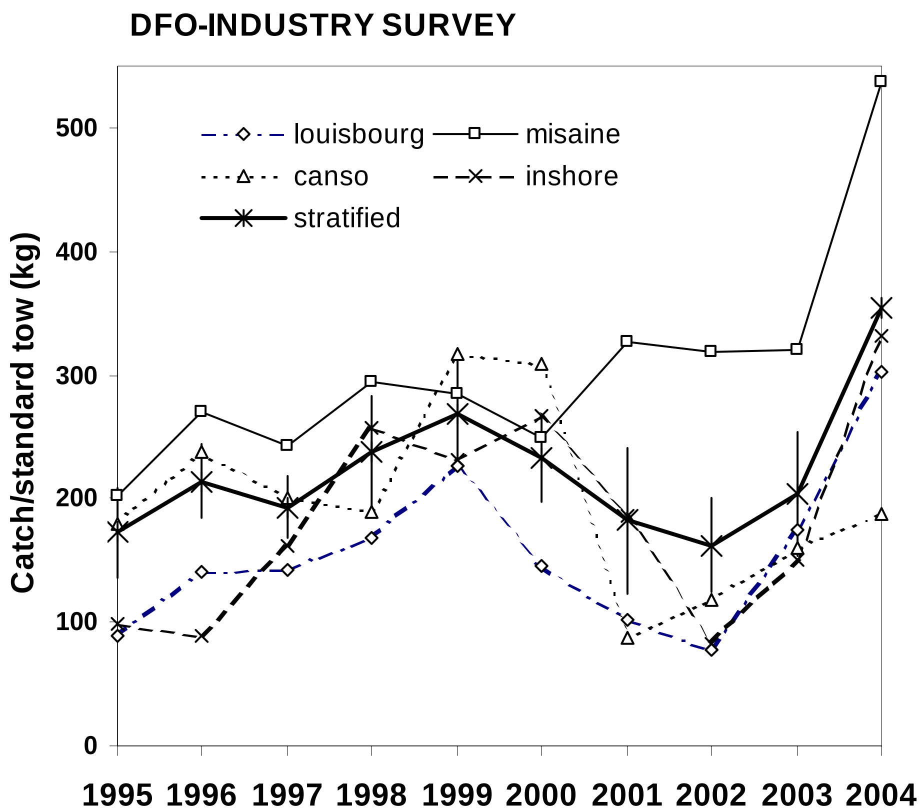


Figure 2. Stratified catch/standard tow for DFO-industry co-operative surveys 1995-2004 and unstratified estimates for the individual strata, which approximately correspond to the main shrimp holes and SFAs. Stratum 13 is Louisbourg Hole and SFA 13; Stratum 14 - Misaine Holes and SFA 14; Stratum 15 - Canso Holes and the offshore part of SFA 15. The Inshore, or Stratum 17, is comprised of inshore parts of SFA 13-15.

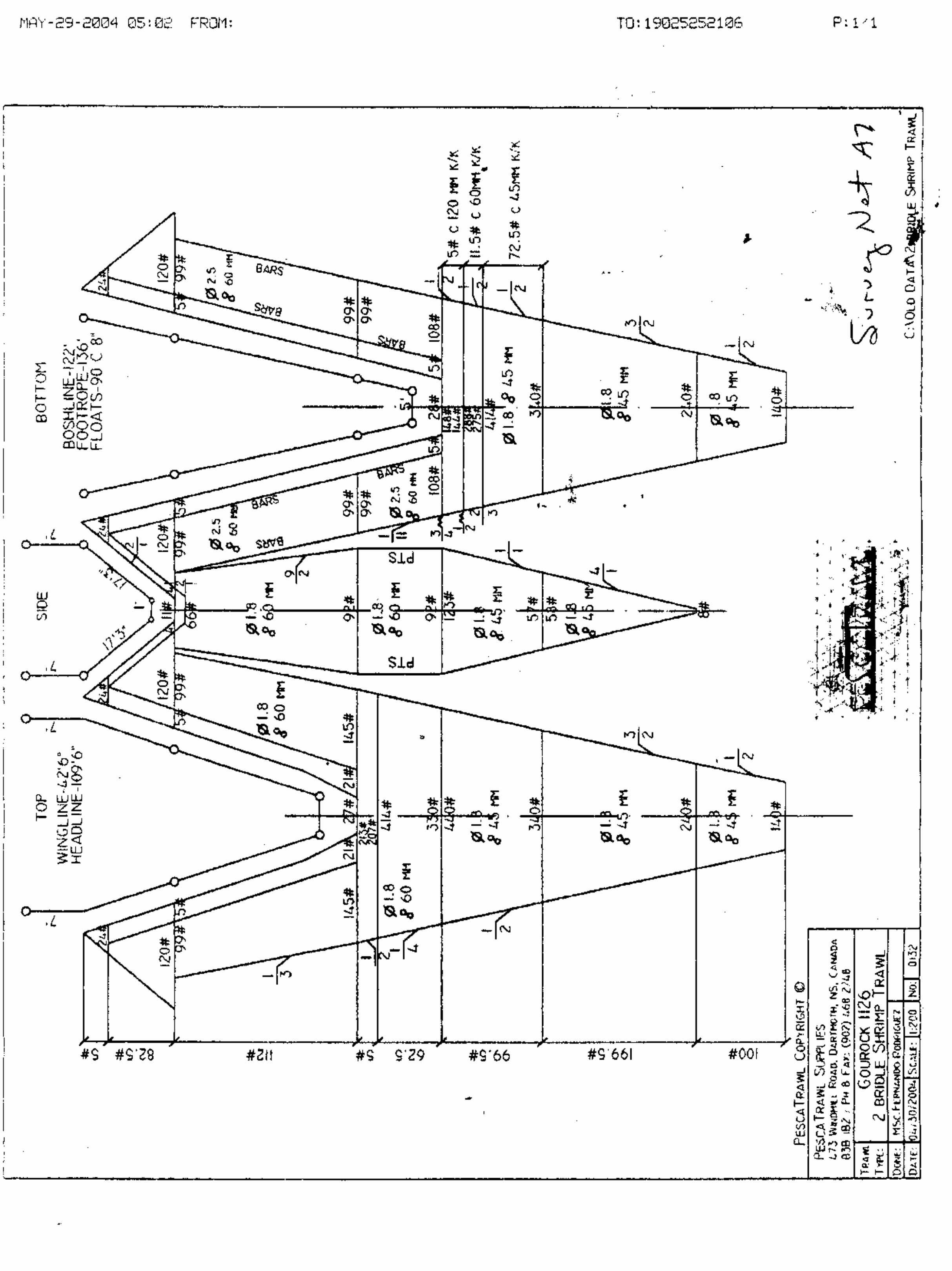


Figure 3. Net plans for the new Gourock #1126 Survey trawl manufactured by Pescatrawl Ltd. and used in the 2004 survey.

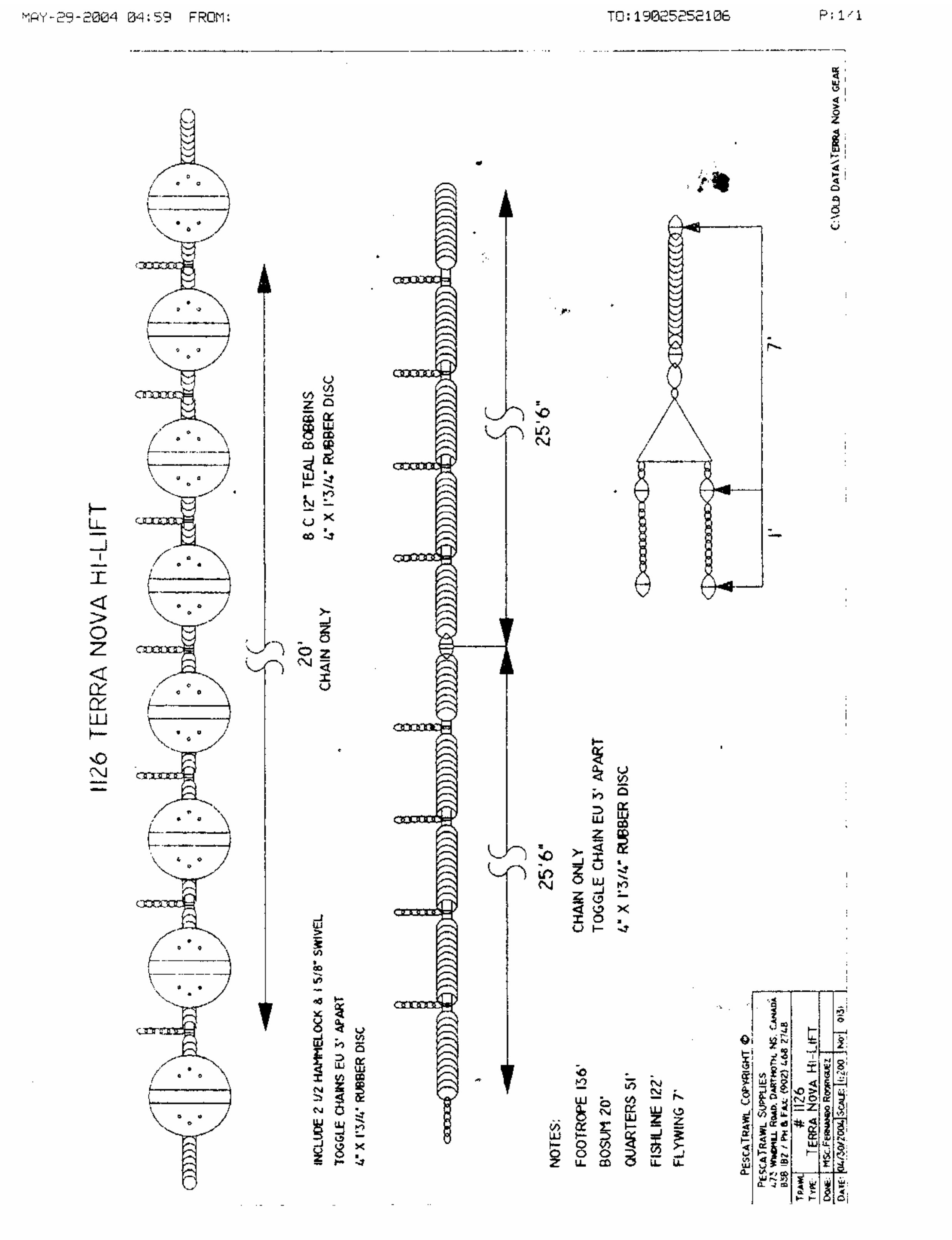


Figure 3. (continued).

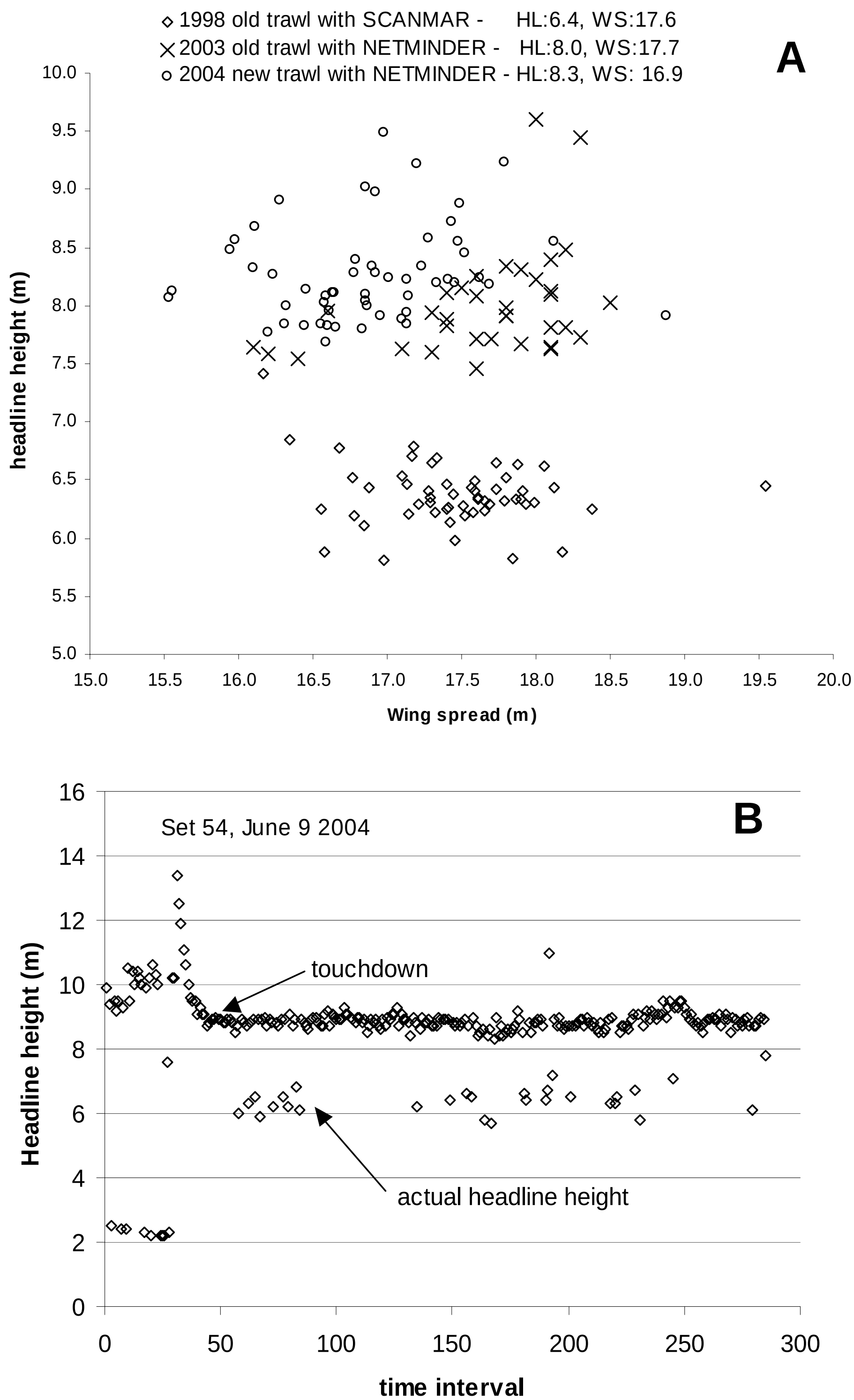


Figure 4. A – headline height and wingspread for 2 surveys using the old Gourock #1126 trawl (1998, 2003) and the new Gourock #1126 trawl used in 2004 and B – example headline height readings taken with Netminder during 2004 showing actual lower headline height readings occasionally when the sensor was in the horizontal position.

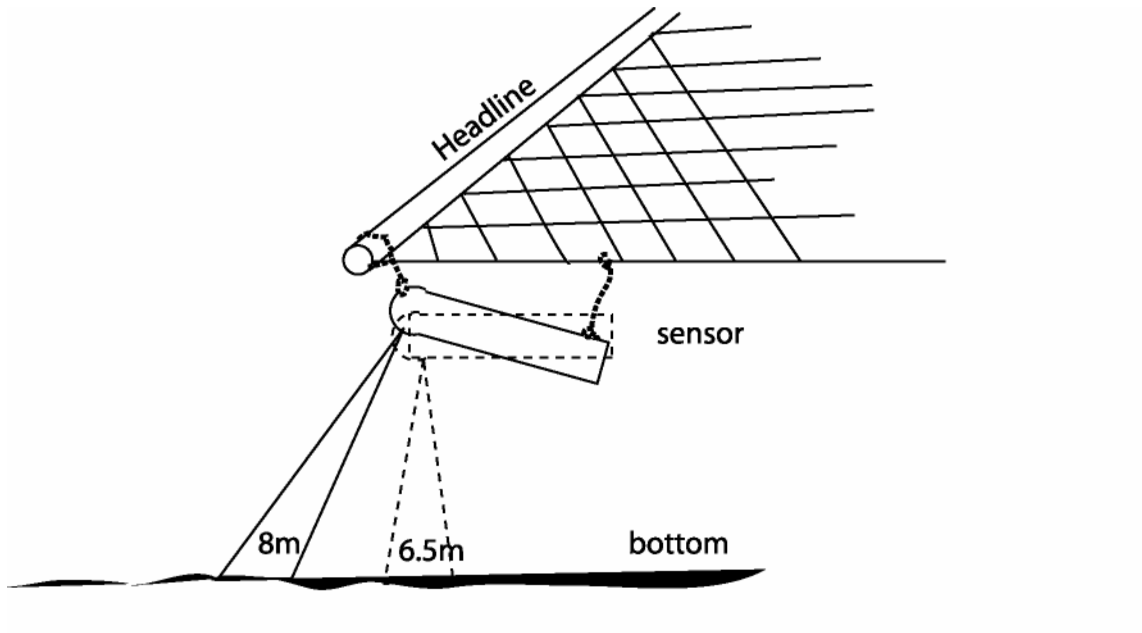


Figure 5. Schematic showing how improper sensor placement can result in overestimates of headline and the pattern of readings observed during the 2003 and 2004 surveys as exampled in Figure 4B.

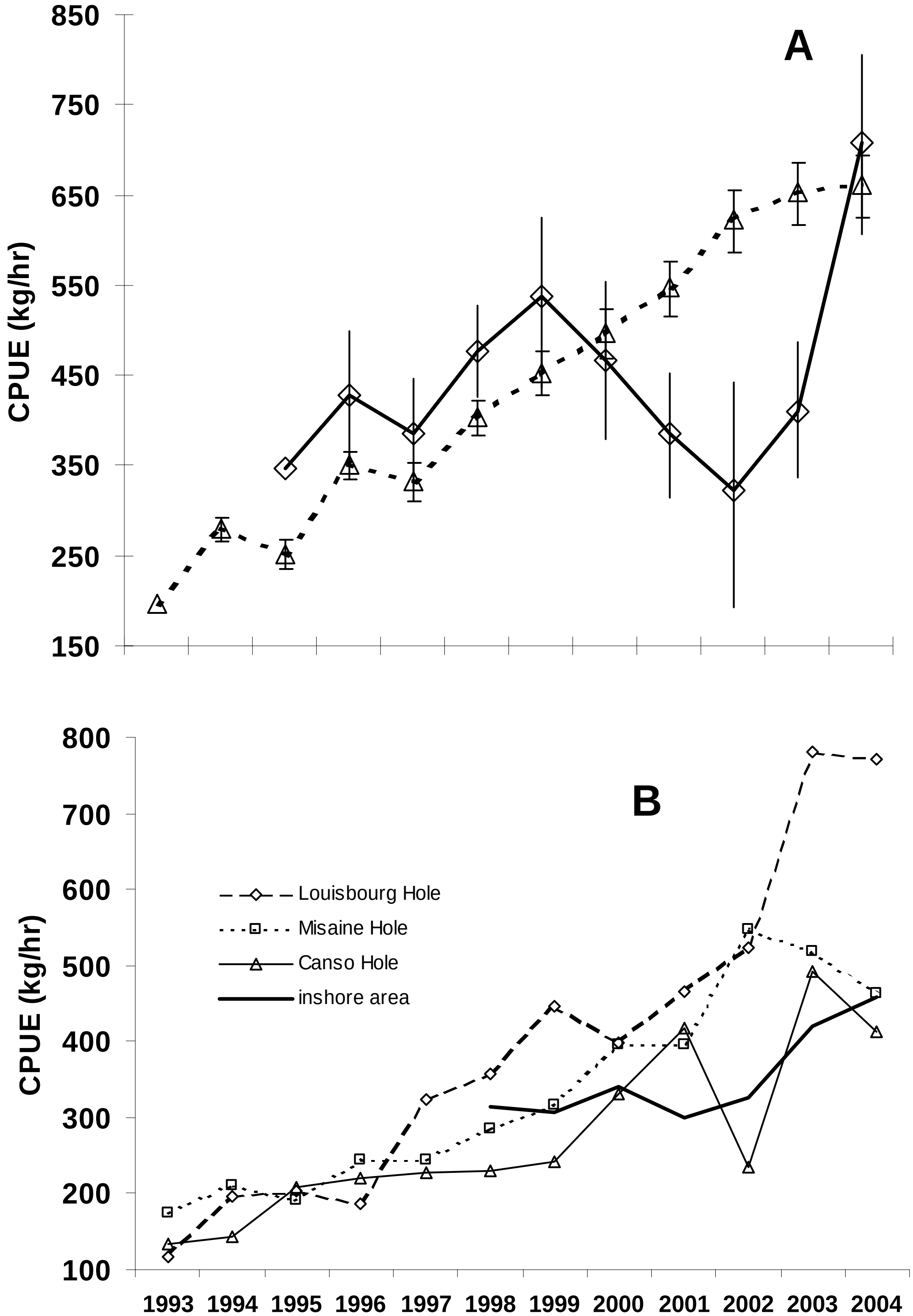


Figure 6. A - Survey stratified estimate and standardised CPUE with 95% confidence intervals, and B - unstandardised commercial CPUE for each fishing area. Note that SFA15 includes the inshore, but the latter is also shown separately since fishing began there in 1998.

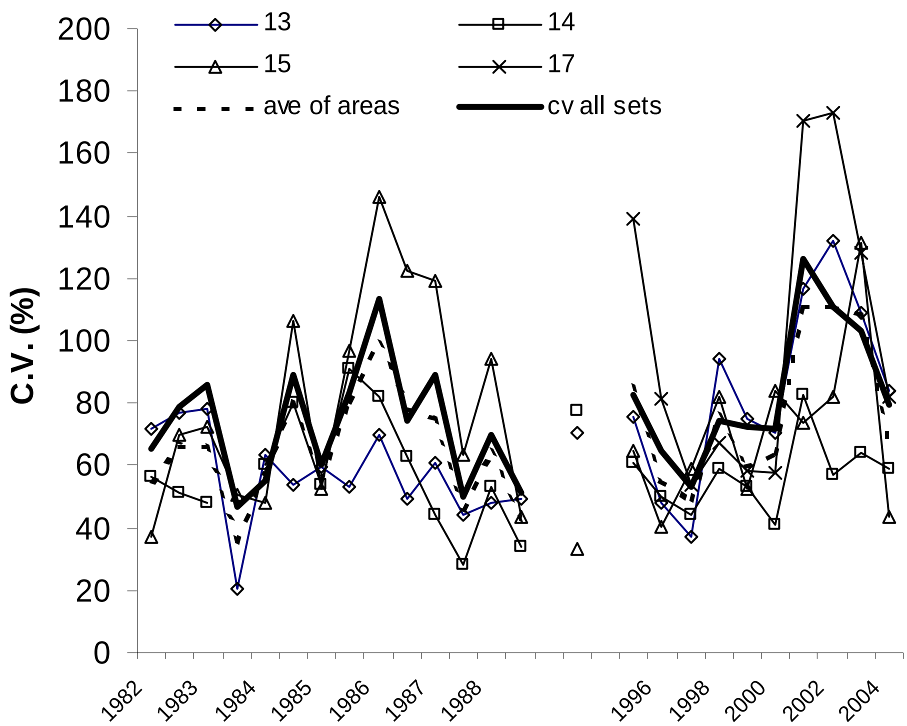


Figure 7. Coefficients of variation (C.V.) for individual shrimp fishing areas from shrimp surveys. Note that the earlier survey series has two values per year, one for the spring and one for the fall survey.

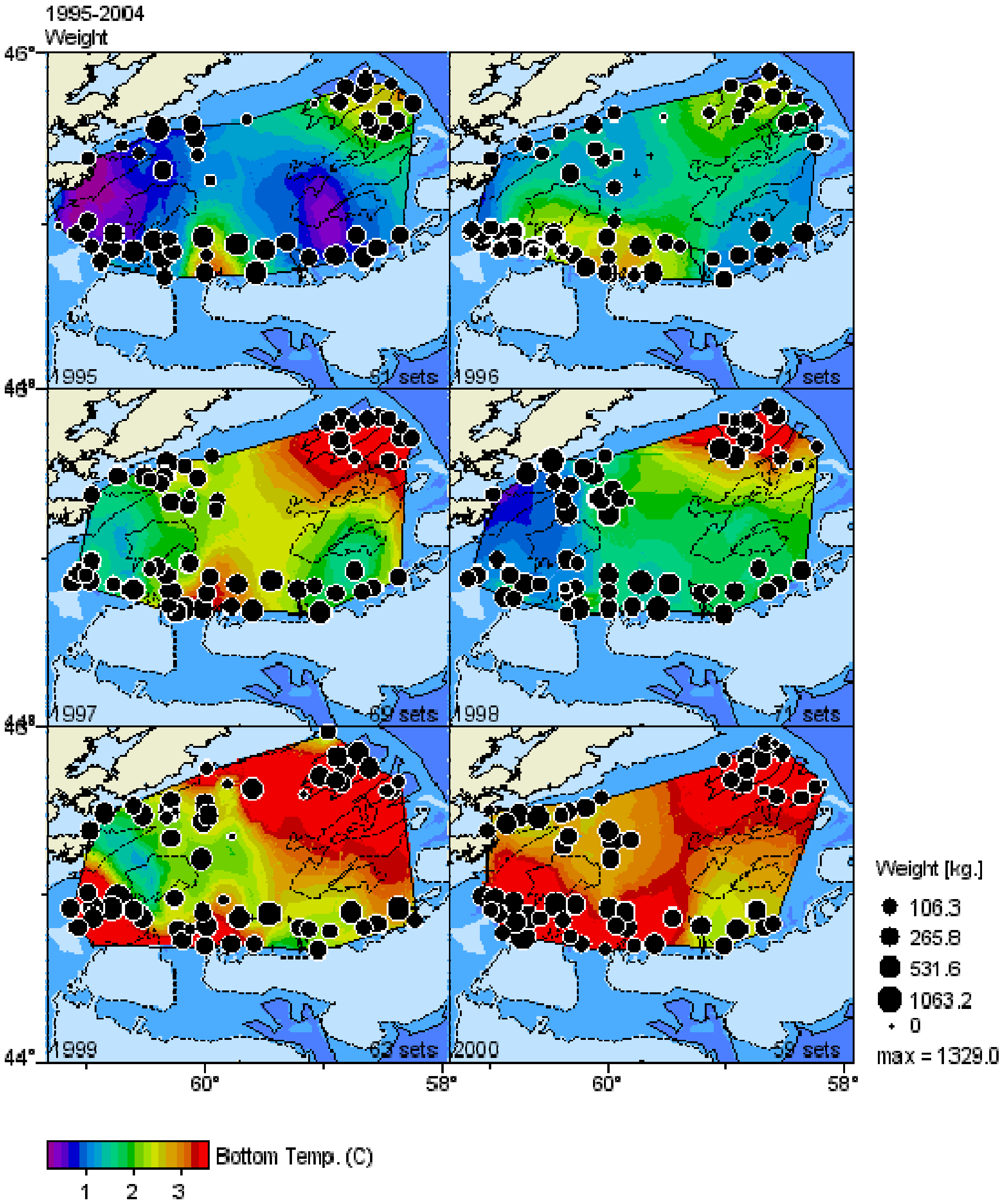


Figure 8. Distribution of catches and bottom temperatures from DFO-industry surveys 1995-2004.

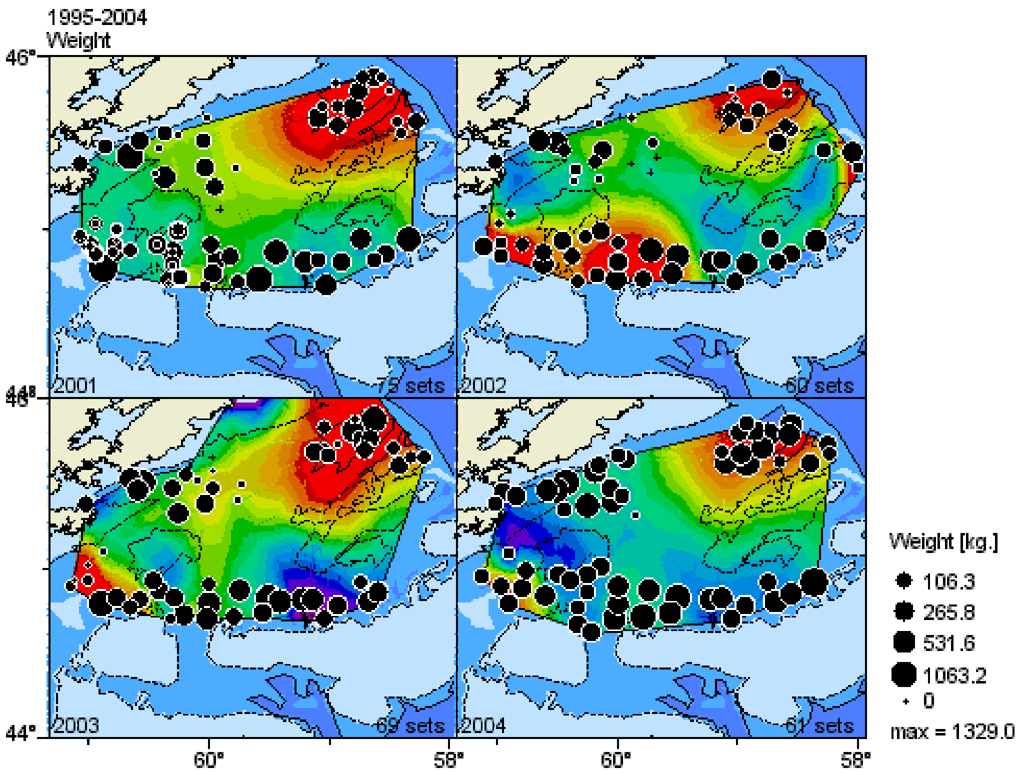


Figure 8. (continued).

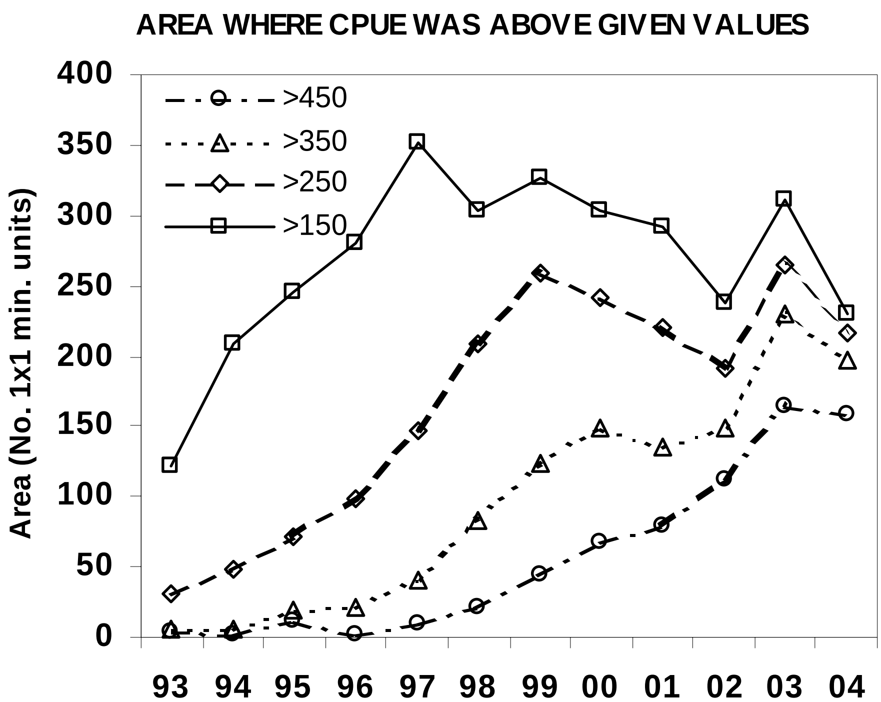


Figure 9. Number of 1 minute square unit areas fished by the shrimp fleet with mean catch rates above the values specified in the legend.

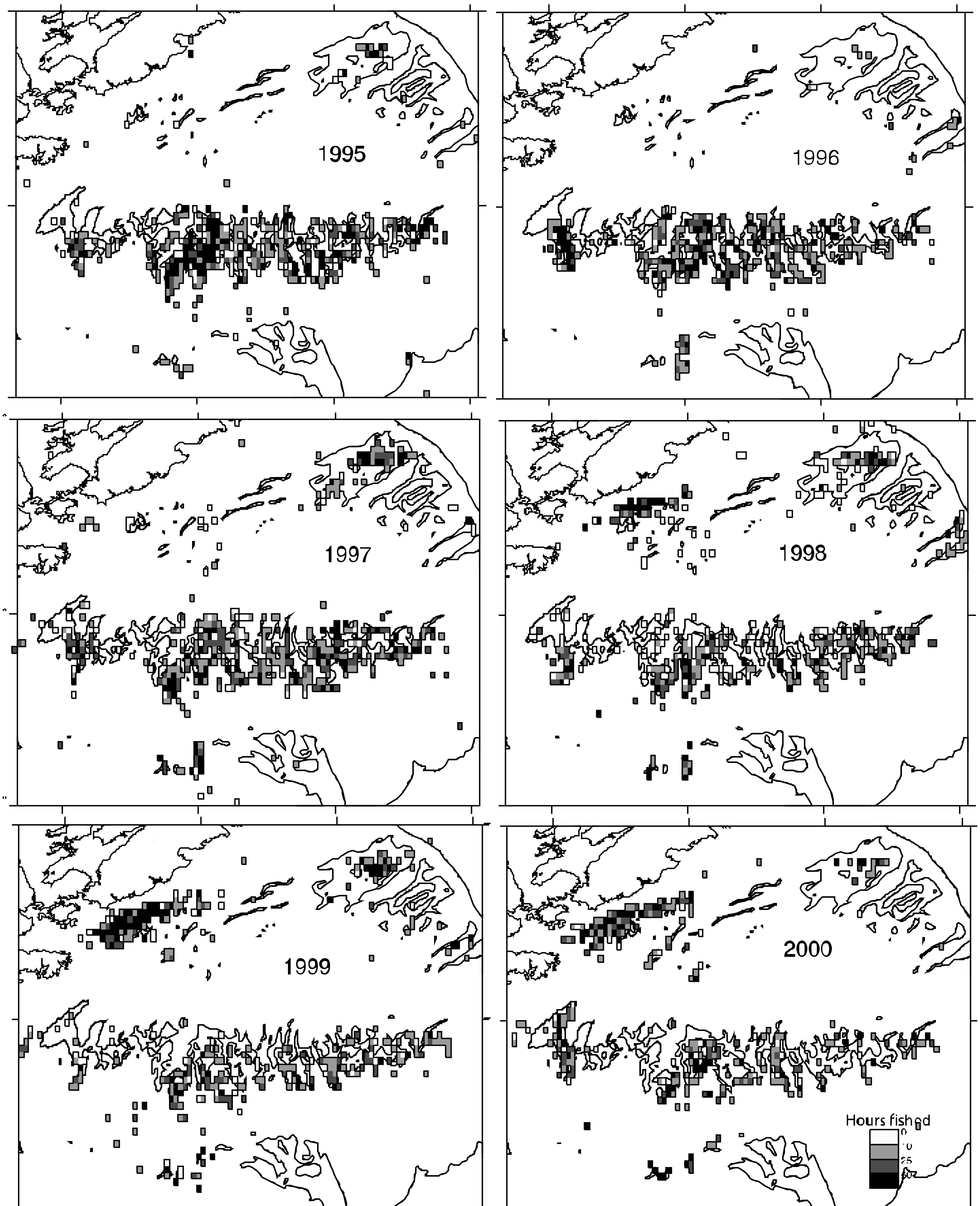


Figure 10. Annual effort by trawlers 1995-2004, cumulative by one minute squares.

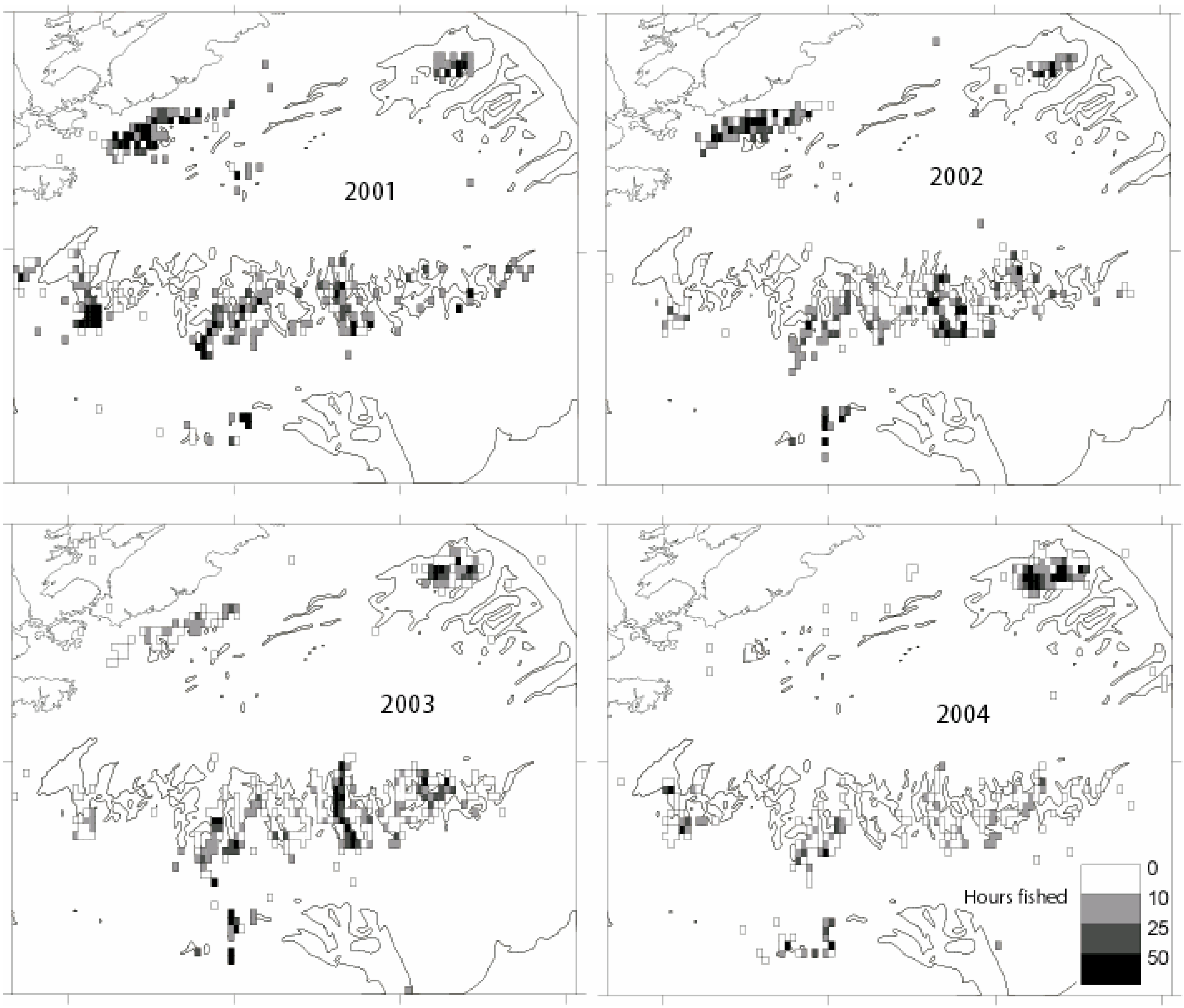
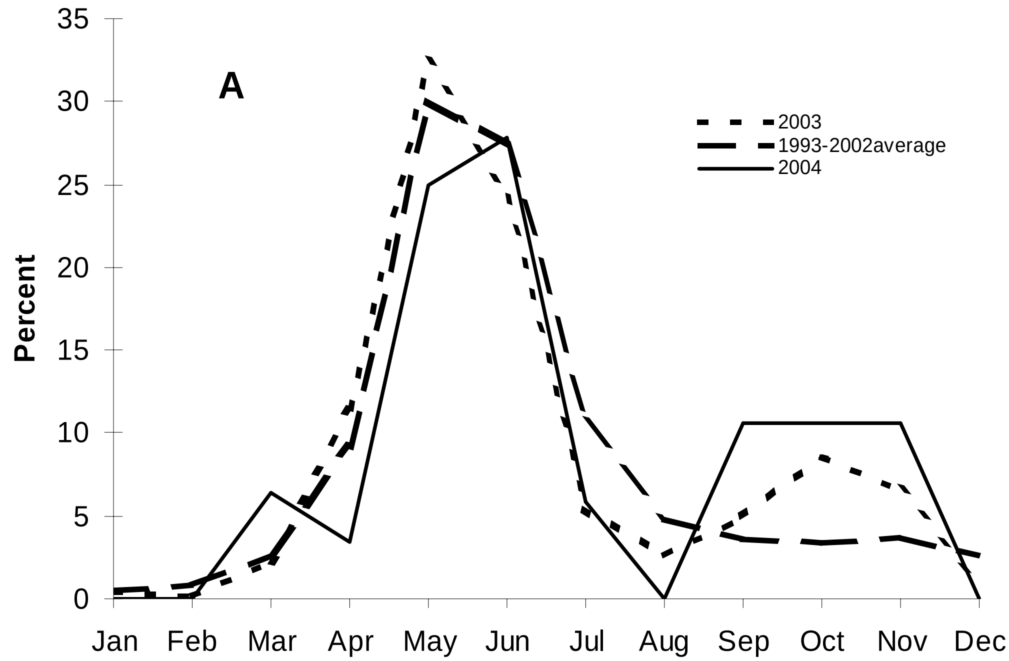


Figure 10. (continued).



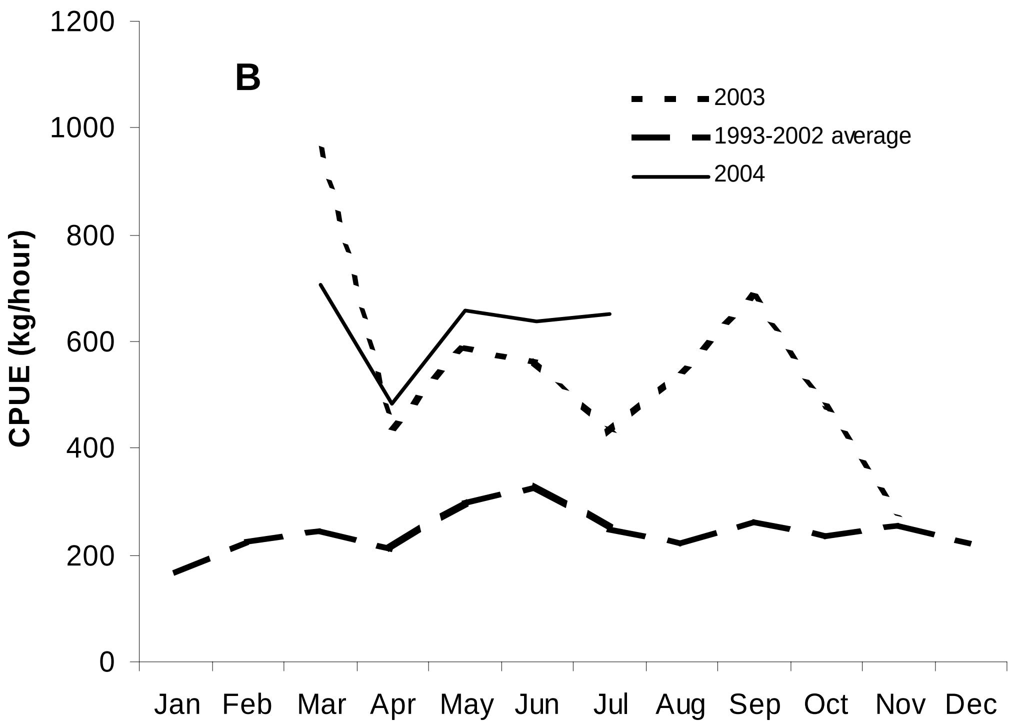


Figure 11. Monthly catches (A) and catch per unit effort (B) from the shrimp fishery.

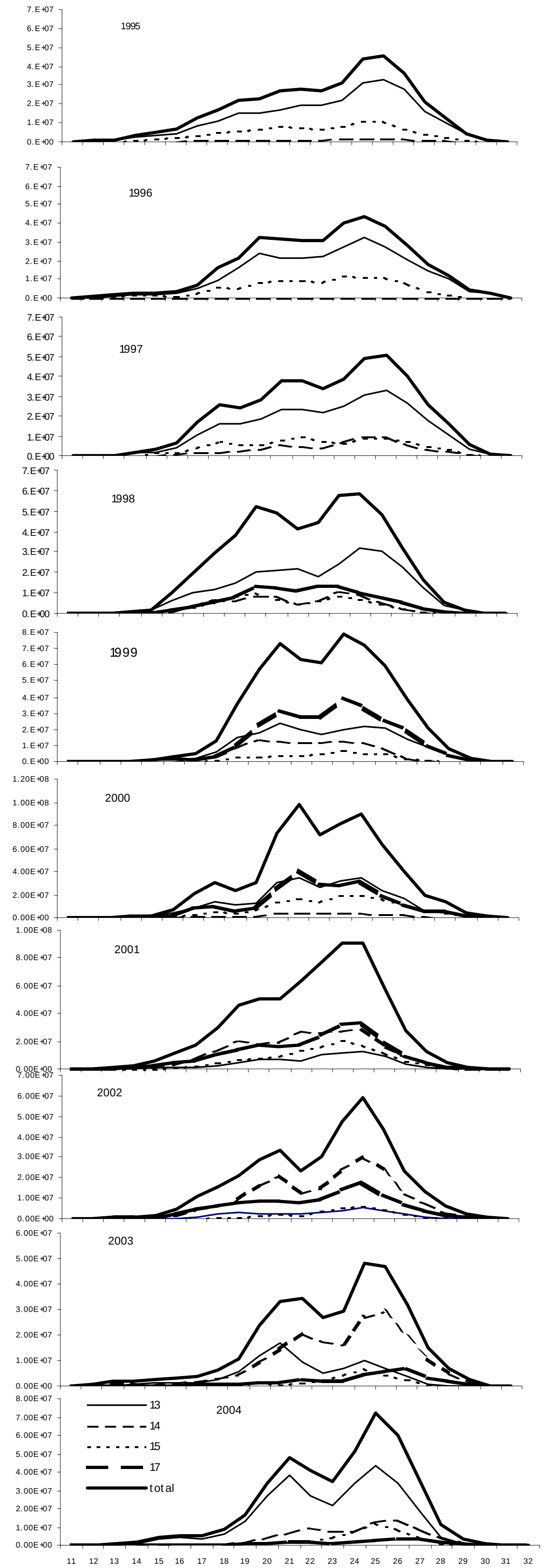


Figure 12. Catch at length from commercial sampling, 1995-2004.

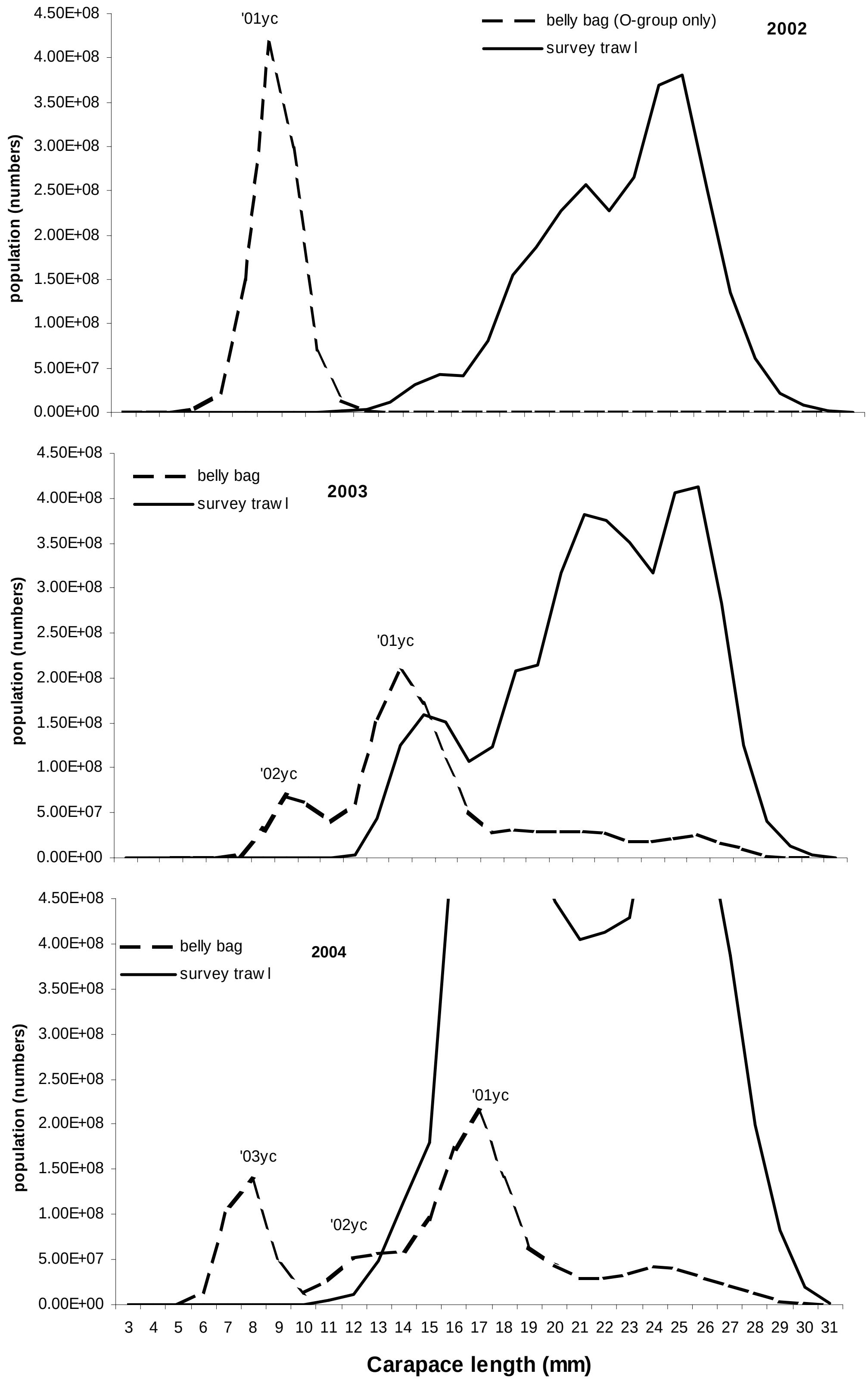


Figure 13. Population estimates from belly bag and main trawl catches for the 2002-2004 survey. Note that the 2002 belly bag estimate was made only for 1year olds.

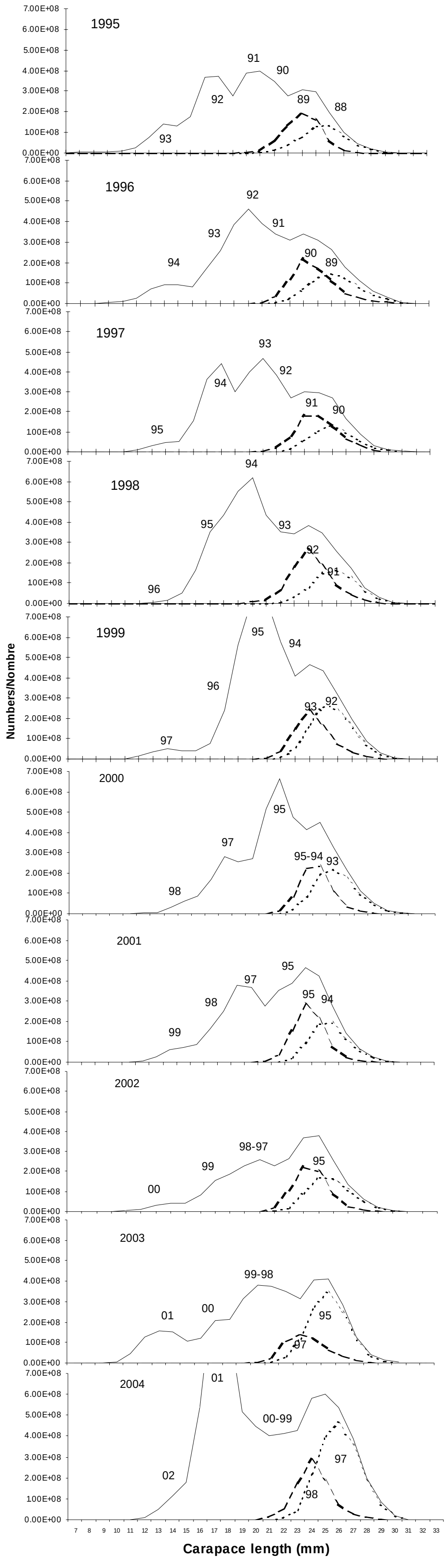


Figure 14. Population estimates at length from DFO-industry surveys. The heavy dotted line in each figure represents transitional and primiparous shrimp, and the stippled line represents multiparous shrimp.

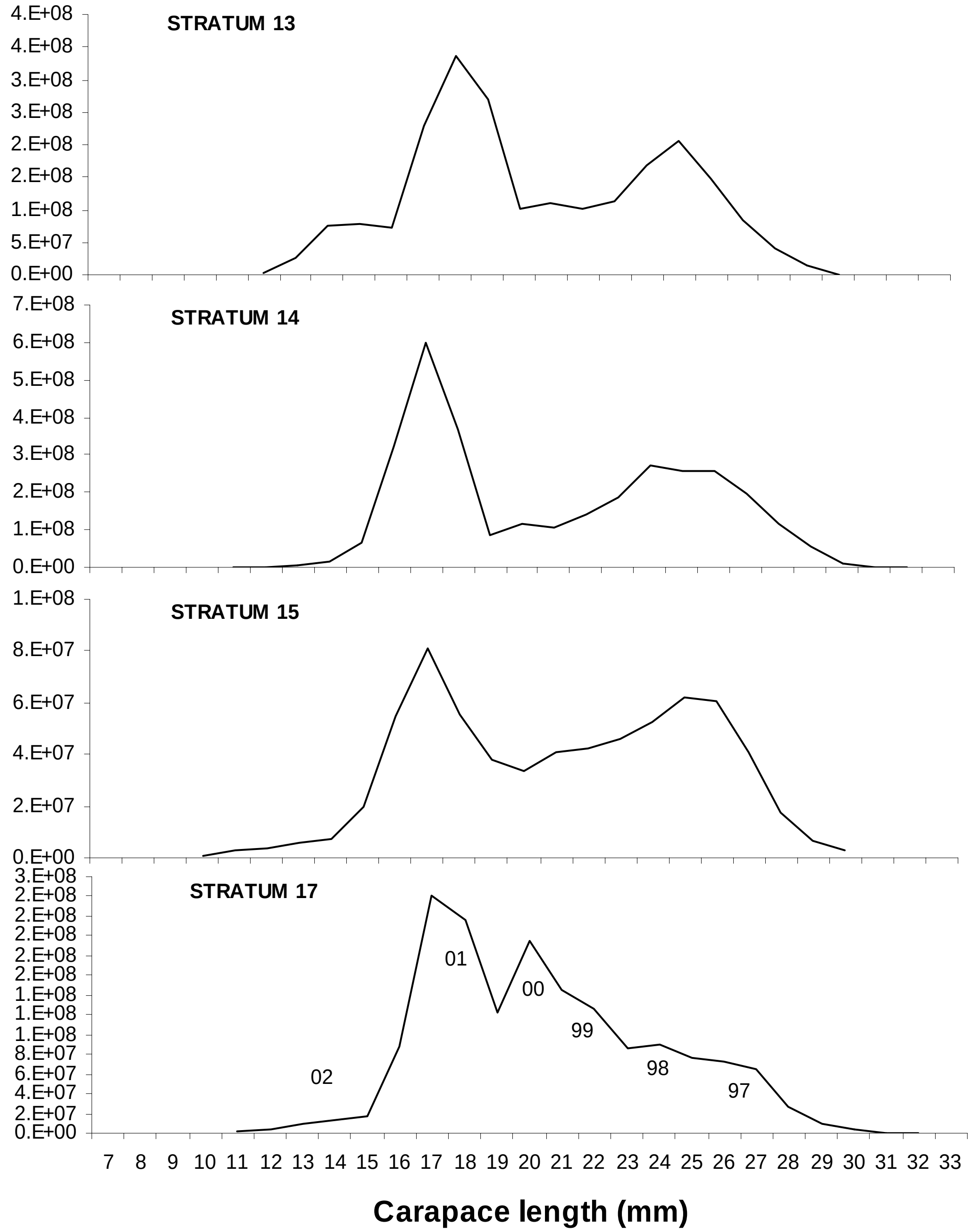


Figure 15. Population at length estimates by Shrimp Fishing Area from the DFO-Industry survey conducted in June, 2004.

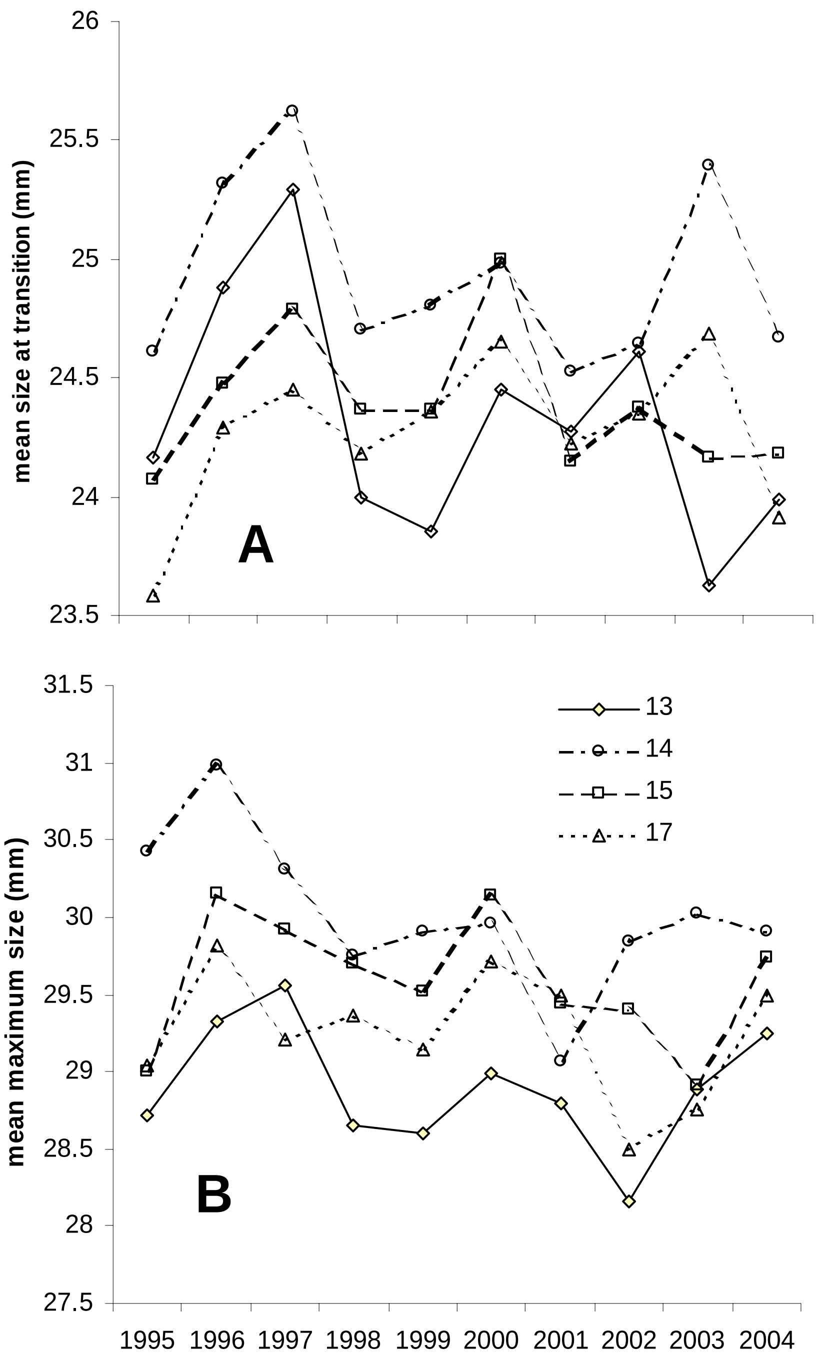


Figure 16. Average size at A. sex transition and B. maximum size by shrimp fishing area for the DFO-industry surveys 1995-2001.

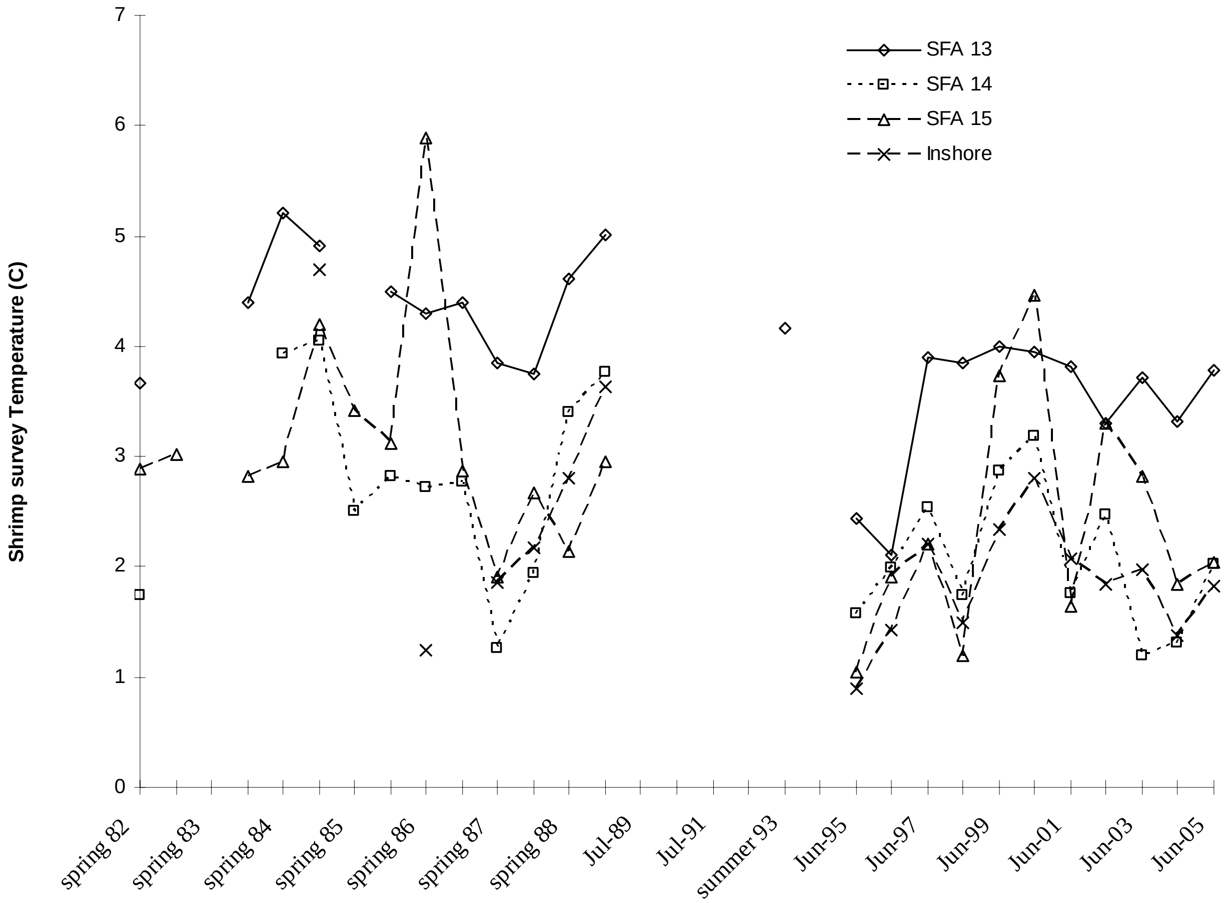


Figure 17. Mean bottom temperatures from shrimp surveys by SFA. Note that both spring and fall values were available from the earlier series (1982-88), but only one survey (June) was conducted annually in the recent series.

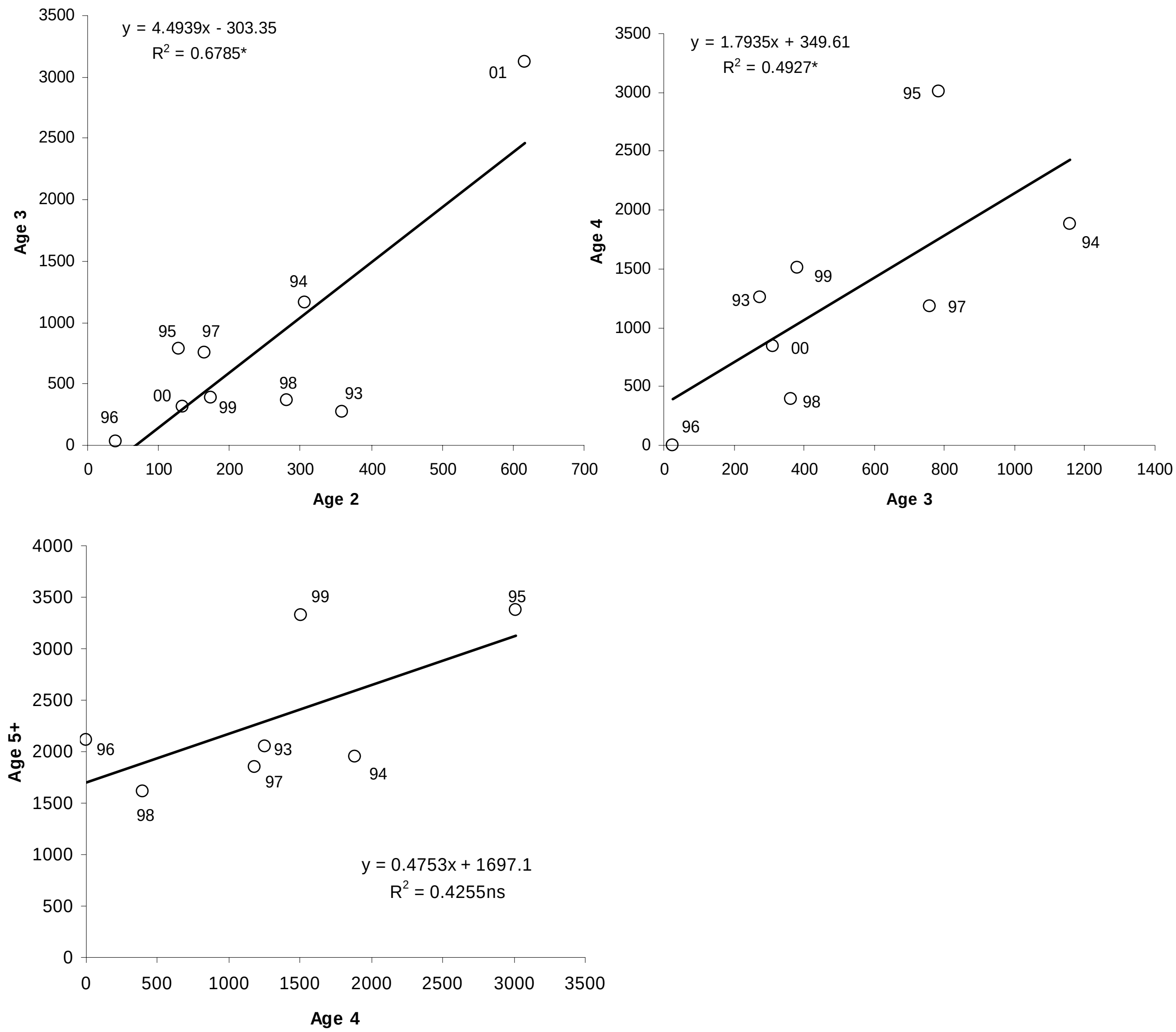


Figure 18. Regressions of age x versus x+1 survey population estimates from MIX analyses. These regressions were used to project the 2004 survey population at age to 2005 using current growth rates.

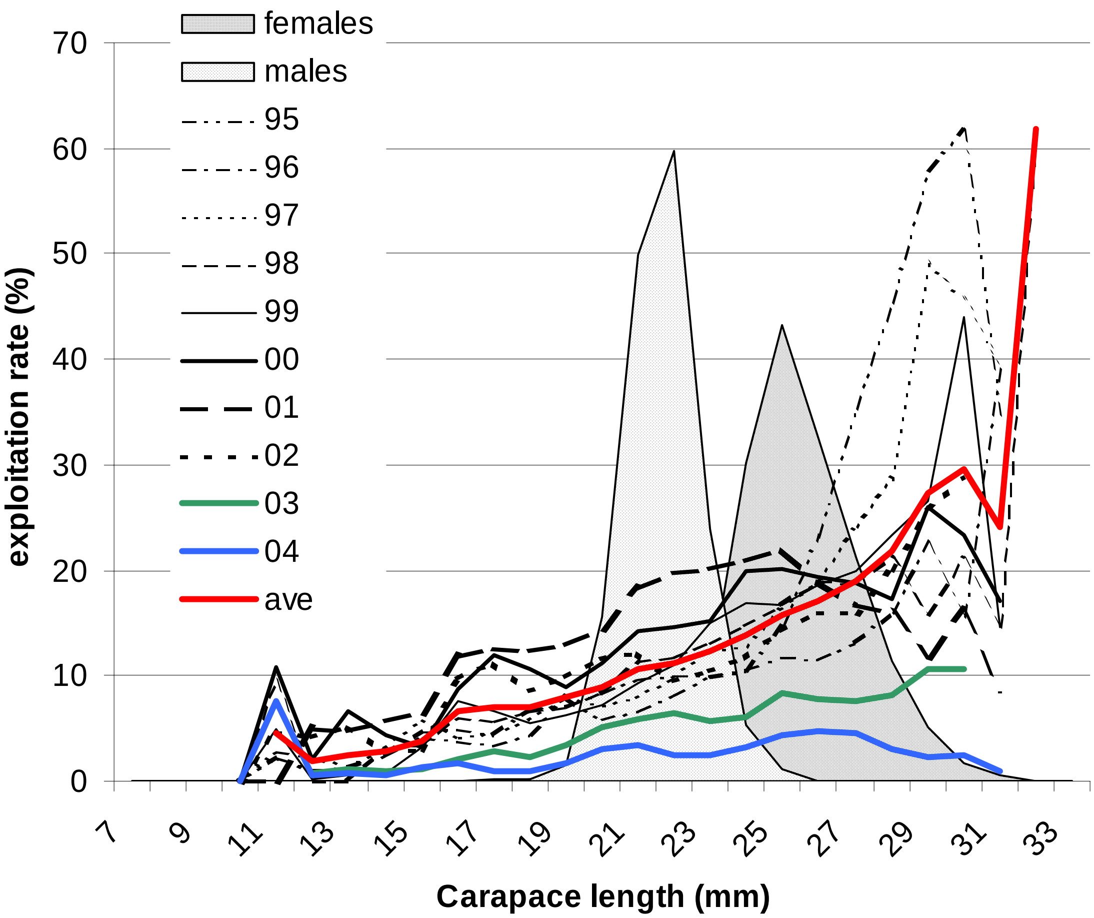


Figure 19. Exploitation at length from commercial sampling and DFO-industry surveys. The average exploitation rates (1995-2003) were applied to the total projected population at length to determine a projected catch. The graph also shows the average size of age 4+ males and age 5+ females in the population.

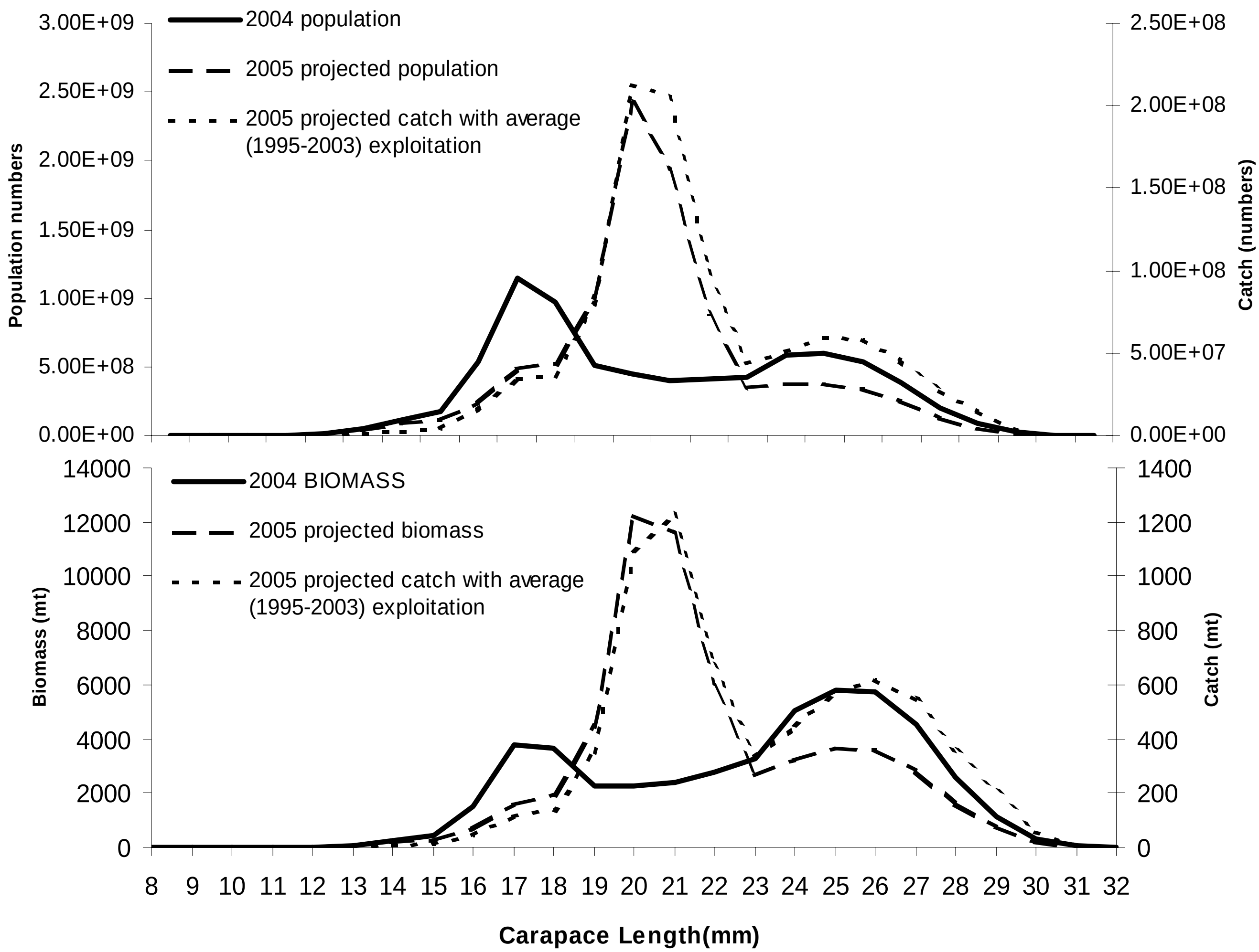


Figure 20. 2004 population and biomass estimates at length from the DFO-industry survey, 2005 projected population and biomass estimates at length calculated from the 2004 survey estimate and the regressions in Figure 18, and 2005 projected catch in numbers and weight calculated from the projected population and the average exploitation at length given in Figure 19.