Fisheries and Oceans Canada / Pêches et Océans Canada

Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2015/062

Maritimes Region

Scotian Shelf Shrimp 2014-2015

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December 2015

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Hardie, D., Covey, M., Nickerson, K. and King, M. 2015. Scotian Shelf Shrimp 2014-2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/062. v + 44 p.

Aussi disponible en français :

Hardie, D., Covey, M., Nickerson, K. et King, M. 2015. Crevette du plateau néo-écossais (2014-2015). Secr. can. de consult. sci. du MPO. Doc. de rech. 2015/062. v + 47 p.

TABLE OF CONTENTS

ABSTRACT

The Fisheries and Oceans Canada-industry survey stratified mean remained approximately stable, decreasing just 1.5% from 39,381 (32,435-46,328) metric tonnes (mt) in 2013 to 38,791 (31,469-46,555) mt in 2014. Similarly, the spawning stock biomass (SSB) decreased by 1.5%, and remains in the Healthy Zone for this stock. The 18% increase in the TAC for 2014 (to 4500 from 3800 mt in 2013) to capitalise on the high fishable biomass of the abundant 2007/08 year classes was sufficiently precautionary to maintain female exploitation at 15%, below the 20% removal reference for this stock. Both commercial catch per unit effort indices declined by 30%, which is inconsistent with the stability of the total, and SSB, relative to 2013. Difficult springtime fishing conditions (wind and ice) were reported to have contributed to low catch rates by the Gulf fleet. Overall, commercial and survey sample length frequency distributions, modal analysis of survey data and the stabilisation of total and SSB indices at a relatively high values suggest that the stock is currently supported primarily by the moderately abundant 2007 and 2008 year classes, supplemented by the less abundant year classes from the subsequent years of low recruitment. The belly-bag index of age 1 abundance was the second highest on record, suggesting very high juvenile recruitment from the 2013 year class. If survival conditions are favourable, the 2013 year class may be evident in survey belly bag and main trawl samples in the 2015 survey, and to begin to recruit to the fishable biomass in 2016. Trends in shrimp size indices are consistent with expectations based on life history and growth rates of moderately abundant shrimp (i.e. no evidence of slower growth or delayed sex transition that have occurred in these more abundant cohorts/high density periods in this stock). Spring sea surface temperatures cooled for the fourth consecutive year, which is thought to be positive for shrimp, while bottom temperatures on the shrimp grounds remained warm, which is negative. Similarly, indices of predation provided somewhat equivocal results; cod recruitment was extremely low while the general index of abundance of shrimp predators was high. Low or decreasing indices of abundance of sympatric coldwater species suggest that the environment on the Scotian Shelf is becoming less favourable for coldwater species such as shrimp. The stock is expected to continue to gradually decline in 2015 as the 2008 year class begins to reach the end of its life-expectancy and because succeeding year classes do not appear to be very abundant.

RÉSUMÉ

La moyenne stratifiée du relevé de Pêches et Océans Canada (MPO) et de l'industrie est restée à peu près stable, et a baissé d'à peine 1,5 %, à savoir de 39 381 tonnes métriques (tm) (32 435-46 328) en 2013 à 38 791 tm (31 469-46 555) en 2014. De plus, la biomasse du stock reproducteur (BSR) a diminué de 1,5 %, et demeure dans la zone saine pour ce stock. L'augmentation de 18 % du total autorisé des captures (TAC) pour 2014 (atteignant 4 500 tm par rapport à 3 800 tm en 2013) visant à tirer parti de la biomasse exploitable élevée des classes d'âge 2007-2008 abondantes était suffisamment préventive pour maintenir le taux d'exploitation des femelles à 15 %, ce qui est inférieur au taux d'exploitation de référence de 20 % pour ce stock. Les deux indices des captures par unité d'effort (CPUE) dans la pêche commerciale ont diminué de 30%, ce qui diffère des indices globaux, et de la BSR, par rapport à 2013. Il a été rapporté que les conditions de pêche difficiles en printemps (vent et glace) ont contribué aux faibles taux de capture par la flotte du Golfe. Dans l'ensemble, les indices de la répartition de la fréquence des longueurs dans la pêche commerciale et les relevés, l'analyse modale des données d'enquête et la stabilisation des indices totaux et de la BSR à des valeurs relativement élevées laissent entendre que, actuellement, le stock est soutenu principalement par les classes d'âge modérément abondantes de 2007 et 2008, suivi des classes d'âge moins abondantes des années suivantes de recrutement faible. L'indice de relevé avec sac ventral d'abondance des crevettes à l'âge 1 était le deuxième plus élevé jamais enregistré, ce qui indique un recrutement très important des juvéniles de la classe d'âge 2013. Lorsque les conditions de survie sont favorables, la classe d'âge 2013 peut être évidente dans les principaux échantillons de relevés avec sac ventral et au chalut de l'enquête 2015, ce qui devrait permettre d'entamer le recrutement de la biomasse exploitable en 2016. Les tendances dans les indices de taille des crevettes sont conformes aux attentes basées sur les caractéristiques biologiques et les taux de croissance des cohortes relativement abondantes; c'est-à-dire, il n'y a aucun signe de croissance ralentie ou de changement de sexe tardif dans les cohortes plus abondantes et les périodes de densité élevée de ce stock. Les températures de surface de la mer au printemps ont baissé pour la quatrième année consécutive, ce qui pourrait avoir un effet positif sur les crevettes, tandis que les températures au fond sur les bancs de crevettes sont restées chaudes, ce qui est négatif. De même, les indices de prédation ont fourni des résultats quelque peu équivoques; le recrutement de morue était extrêmement faible tandis que l'indice général de l'abondance des prédateurs de crevettes était élevé. Les indices faibles ou en déclin de l'abondance des espèces d'eau froide sympatriques laissent entendre que l'environnement sur le plateau néo-écossais devient de moins en moins favorable pour les espèces d'eau froide comme la crevette. Le stock devrait continuer à diminuer progressivement en 2015, car la classe d'âge 2008 commencera à atteindre la fin de sa durée de vie et les classes d'âge subséquentes ne semblent pas très abondantes.

INTRODUCTION

The biology of northern shrimp, *Pandalus borealis*, is reviewed in Shumway et al. (1985) for various stocks world-wide, and by Koeller (1996a, 2000, 2006) and Koeller et al. (2000a, 2003a) for the eastern Scotian Shelf stock. Shrimp on the Scotian Shelf and in the Gulf of Maine are at the southern extreme of the species' range (concentrated north of 46N), and by inference at the extreme of the species ecological and physiological limits (Koeller 1996a). The rationale for the assessment and management approach used is described in Koeller et al. (2000b). 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 Nordmøre grate in 1991 (Figure 1). The total allowable catch (TAC) was first reached in 1994, when individual Shrimp Fishing Area (SFAs) quotas were removed. Since 1994 the TAC has varied from 3000-5500 metric tonnes (mt). Although approximately 25 indicators are considered in the provision of science advice for this stock, the TAC has generally been higher during periods of high survey total and spawning stock biomass (SSB) and when large year classes are known to be recruiting to the fishery. The TAC has generally been reduced to maintain low exploitation rates when biomass indices and/or catch rates are decreasing, or are expected to decrease based on cohort tracking. Details of the history of the eastern Scotian Shelf shrimp fishery and recent stock assessments are given in Koeller (1996b), Koeller et al. (2011) and Hardie et al. (2011, 2013a, 2013b). Science advice was provided on an annual basis with full peer review and industry participation until 2012. Beginning in 2013 the fishery will be fully assessed on a biennial basis, with stock status updates provided in interim years. The first interim advice was provided in 2013 based on a complete analysis of the data (DFO 2014).

The organisation of this report is based on a "Traffic Light" analysis, which has been used in shrimp stock assessments since 1999 (Koeller et al. 2000b, Mohn et al. 2001, Halliday et al. 2001). This multiple indicator diagnostic approach analyzes and discusses individual indicators grouped under headings representing four "characteristics" presented in the summary. In this document, the "Methods" section is a description of the data sources, with reference to past documents for detailed indicator calculation methodology, except where new approaches have been taken. The discussion of the relevance/interpretation of each indicator to the characteristic that it represents is combined with the presentation of the 2014 results in the "Results and Discussion" section. 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 within the text of the document. Where appropriate, the interpretation of the indicator time series themselves are supplemented by other data which 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 quite independent from the data used to derive the main indicator. For example, catch rates in the shrimp trap fishery supported the apparent increasing shrimp aggregation shown by the survey and catch per unit effort (CPUE) data; anecdotal reports of large numbers of age 1 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 of indicator trends 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 intended to be translated directly into management action (e.g. in the form of rules linked to summary scores). The "Traffic Light" is currently seen simply as a tool for displaying, summarising, and synthesising a large number of relevant yet disparate data sources into consensus advice on the health of the stock.

A precautionary approach using reference points and control rules within the framework of the Traffic Light analysis was first reviewed during the Fisheries and Oceans Canada (DFO)

Maritimes 2009 Regional Science Advisory Process (Figure 2). That approach has since been modified and included in the new Integrated Fisheries Management Plan in 2011 and was reviewed at a Regional Science Advisory Process in 2012 (Smith et al. 2012). In general, the precautionary application of reference points for eastern Scotian Shelf shrimp includes:

Limit Reference Point (LRP): Which is 30% of the average SSB (5459 mt) maintained during the modern fishery (2000-2010[1]). The LRP is approximately equal to the average SSB during the low-productivity (pre-1990) period for this stock, characterised by low shrimp abundance, high groundfish abundance and relatively warm temperatures. The Scotian Shelf shrimp population previously increased from a low level (approximately 4300 mt) during the transition from low- to high-productivity, so the working assumption is that shrimp could once again recover from this level given appropriate environmental conditions and fishing pressure (i.e. $B_{recover}$ proxy). Secondly, given the important role of shrimp in the Scotian Shelf ecosystem, particularly as prey for groundfish, this LRP is set to avoid a decrease in shrimp abundance below the level at which it was previously able to fulfill its ecosystem roles under a situation of high groundfish abundance (i.e. to avoid a scenario in which low shrimp abundance could act as a limiting factor in groundfish non-recovery).

Upper Stock Reference (USR): Which is 80% of the average SSB (14558 mt) maintained during the modern fishery (2000-2010)[1]. The USR has been selected at the default value (80%) and to maintain a sufficient gap between the LRP and USR to account for uncertainty in the stock and removal reference values, and to provide sufficient time for biological changes in the population to be expressed, detected and acted upon.

Removal Reference Point: The removal reference for Scotian Shelf shrimp is 20% female exploitation (actual female catch/SSB) when above the USR. This exploitation rate has rarely been exceeded during the modern fishery (2000-present), a period during which high CPUE and SSB have been maintained. Additionally, given that shrimp survive for approximately three to four years after their recruitment to the fishery, it can be approximated that on the order of 25-33% of the fishable biomass would be subject to natural mortality in any given year. As a result, the removal reference of 20% for shrimp is on the conservative side of this simplistic estimation of natural mortality (25-33%). Although exploitation scenarios in which fishing mortality equals natural mortality may result in optimal yield (e.g. Gulland 1971) this may be an overly risky exploitation strategy. As a result, the maximum removal reference of 20% for shrimp is on the conservative side of the simplistic approximate range of natural mortality (25-33%).

At SSB levels below the LRP the fishery is closed. A suite of approximately 20 secondary indicators of shrimp abundance and production, fishing effects and environmental conditions, provide a scientific interpretation of holistic data to inform the way in which science advises and responds to stock status and removal relative to reference points.

The SFAs on the Scotian Shelf are shown in Figure 3 and Table 1. Table 2 gives licensing information for the recent period covered under sharing agreements between the Nova Scotia and Gulf fleets. It currently operates under an 'evergreen' Integrated Fisheries Management Plan.

The experimental trap fishery was not under quota management from 1995-1998, except for a 500 mt precautionary "cap". As a result, the total catch tended to exceed the TAC due to the trap fishery. When the trap fishery in Chedabucto Bay was made permanent in 1999, a trap

[1] The reference points are set based on data from 2000-2010 to avoid a scenario whereby reference points based on a moving average would become *less* conservative during a period of a biomass downturn. This action does not negate the need to be vigilant for signs of a shift away from the current high productivity regime towards a lower productivity regime in which these reference points may no longer be suitable.

quota was set at 10% of the total TAC: for example, 500 mt of the 5000 mt TAC. The reallocation of any uncaught portion of the trap quota late in the year resulted in some fishers being unable to take advantage of the additional quota. This often contributed to an overall catch lower than the TAC. In an attempt to avoid reallocations, in 2004, only 300 mt were allocated to this fishery, which was closer to its capacity. The trap allocation was reduced to 8% in 2005 and trap fishing effort and catch were very low during 2005-2010 due to poor market conditions. Market conditions improved in recent years. Total trap landings were 224 mt for 2013, and 122 mt (of 360 mt quota allocation) were landed as of November 17, 2014.

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 the “polarity” was reversed (i.e. the green-yellow transition was at 0.33 and the yellow-red boundary was at the 0.66 percentile, respectively, for negative indicators such as temperature, cod recruitment and predator abundance). Note that for commercial CPUE series, the “polarity” of the default boundary should be considered with other indicators for certain years. For example, increased CPUE series coupled with increased aggregation and decreased survey abundance would be viewed as a negative development. Traffic lights were not changed from the default (Koeller et al. 2002) in this document. Data series vary in length from 13-33 years depending on the availability of data for each indicator. In contrast to past documents, a detailed description of the calculation of each indicator is not repeated here. Instead, only the data sources and any methodological changes since 2012 are discussed in detail. Otherwise, the methods used to calculate the 24 indicators that contribute to the Abundance, Production, Fishing Effects and Ecosystem characteristics summarised in the Traffic Light analysis are given in Hardie et al. (2013a) and previous documents.

DATA SOURCES

DFO-Industry Cooperative Trawl Survey

The 20th DFO-industry trawl survey, incorporating a mixed stratified random-fixed station design, was conducted in June 2014. Survey design and station selection methods were similar to annual surveys completed since 1995 (Hardie et al. 2013b): 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 LaHave clay on Atlantic Geosciences Centre surficial geology maps. The fixed stations in stratum 14 are assumed to be representative of shrimp abundance throughout the stratum, and as such are not analysed differently from the random stations in strata 13, 15 and 17.

The 2014 survey was completed by motor vessel (MV) *Cody & Kathryn*, which had also conducted the survey in 1995, 1998, and 2009-2014. All surveys since 1997 were conducted using the standard trawl (Gourock #1126 2-bridle shrimp trawl and #9 Bison doors), which has been professionally maintained by the Atlantic Canadian Mobile Shrimp Association (ACMSA) since 2010. Biomass/population estimates (swept area method) and bootstrapped confidence intervals (Smith 1997) were calculated using the catch/standard tow (17.4 m x 1.25 nm); that is, the actual catch adjusted to the standard by the average measured wing spread (using NETMIND sensors) of the survey trawl during each tow and the actual distance travelled (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 1982-1988, a period of low abundance in contrast to the present period of high abundance. There was no comparative fishing experiments that allowed direct inter-calibration 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 1982-1988 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, selectivity of the two series were assumed to be the same. ACMSA oversees professional inspection and necessary maintenance of the survey trawl before (annually) and during (if necessary) the survey to ensure consistent catchability. Survey sets are carried out between 0500-2000 hours (daylight hours) when shrimp are concentrated on the bottom and catchability of the survey trawl is highest.

The chronology of survey vessels, gear changes and comparative fishing experiments are summarised below:

1995: Cody & Kathryn – used vessel's commercial net
1996: Lady Megan II – vessel's net, comparative fishing with Cody & Kathryn
1997: Miss Marie – survey trawl (built by Nordsea), comparative fishing with Cody & Kathryn
1998: Cody & Kathryn – survey trawl
1999-2001: Carmel VI (named Amelie Zoe in 1999) – survey trawl
2002-2003: All Seven – survey trawl (built by Pescatrawl)
2004-2008: All Seven – survey trawl (new in 2004)
2009: Cody & Kathryn – survey trawl (refurbished by Captain Schrader)
2010: Cody & Kathryn – survey trawl (checked by Captain Schrader and Morgan Snook)
2011: Cody & Kathryn – survey trawl (new in 2011)
2012: Cody & Kathryn – survey trawl (new in 2011)
2013: Cody & Kathryn – survey trawl (weight added to 2011 trawl, comparative fishing with unweighted trawl on 16 stations)
2014: Cody & Kathryn – survey trawl (weight added to 2011 trawl)

Commercial Catch Data

Data on catch rates were obtained from fishers' logs required from all participants and provided by the DFO Maritimes Region Commercial Data Division. Commercial catch data from Gulf-based vessels, which have the longest history in the fishery, provide a CPUE index as an unstandardised mean catch/hour fished from all Gulf-based vessels in any given year. The shorter time series for the Nova Scotian fleet (21 years) is used to estimate a standardised CPUE series 1993-2014 derived from commercial catch data for the 24 Nova Scotian (<65') vessels that have fished for at least 7 of the 21-year series. Standardised CPUE data were limited to April-July inclusive, the months when the bulk of the TAC is generally caught. A generalised linear model was used to standardise commercial CPUEs with year, month, area, and vessel as categorical components. Predicted standardised CPUE values and confidence limits for a reference vessel, month, and area were then calculated for each year using the package predict.glm (R Development Core Team 2005). The data fit best to a Gaussian distribution (lowest Akaike information criterion value). Commercial counts (number of shrimp per pound) are recorded in commercial logs.

Detailed Shrimp Analysis (Survey and Port Samples)

A random sample of approximately eight pounds of shrimp was collected from each survey set and from the last set of each commercial trip (collected during the fishery in all areas from all fleet components including vessels <65' landing mainly in Louisbourg, NS, and vessels >65' landing mainly in Arichat, NS), and frozen for detailed analysis (i.e. carapace length, individual weight, sex and egg developmental stage). One hundred and twenty survey samples (one each from the main survey trawl and belly bag at each station) and approximately 50 commercial samples (number of samples per month and area approximately allocated in proportion to temporal and spatial distribution of weight of landings) are analyzed annually. Due to the timing of the shrimp assessment relative to the collection and analysis of samples, the advice provided at the Regional Science Advisory Process meeting sometimes derives from only a portion of these samples (as few as half). Steps have been taken to expedite the analysis of samples such that for 2014 all 120 survey samples and 43 commercial samples were included in the analysis.

Length Frequency Analysis

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 ("mixdist" in R; Macdonald and Pitcher 1979). The data were assigned to seven age bins that are interpreted as corresponding to ages 1-7. Modes corresponding to older ages are binned together as 5+ because the assignment of ages would be highly subjective for ages 6 and older. Fitting the data to seven ages provided a highly significant fit to the length frequency distribution (Chi-square, $p<0.001$).

Shrimp Size Indicators

Four different indicators of shrimp size are used: mean maximum size; mean size at sex transition; mean female size; and commercial counts (see details in Hardie et al. 2013b). These indices had been presented as simple mean point estimates without any measure of uncertainly prior to 2013. Methods used to calculate size indicators remain unchanged from Hardie et al. (2013b).

Ecosystem Data

Shrimp survey bottom temperatures are determined throughout each shrimp survey set with a continuous temperature recorder (Vemco Ltd.) attached to the headline of the trawl. Satellite data are used to estimate sea surface temperatures within defined rectangles encompassing the shrimp holes for February-March. The predation, capelin abundance, cod recruitment and Greenland halibut abundance indices derive from the summer groundfish survey that encompasses the shrimp holes (i.e. strata 443-445 and 459, details in Hardie et al. 2013b). The snow crab recruitment index, as described in Hardie et al. (2013b), is now shifted forward by one year in the Traffic Light Analysis (e.g. 2013 value used for 2014 Traffic Light Value) to solve the problem that the current-year value is generally not available in time for the shrimp assessment.

TRAFFIC LIGHT SUMMARY

Individual traffic light indicators were summarised using simple averaging. Each indicator is given a value according to its colour; that is green = 3, yellow = 2, and red = 1, and an average is calculated. The average is assigned a "summary colour" according to limits determined by the probability distribution of possible outcomes. 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 DFO Maritimes Regional Science Advisory Process 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. As a result, the Traffic Light summary is interpreted only to guide the discussion of the trends in individual Traffic Light indicators, which form the basis of the science advice itself.

RESULTS AND DISCUSSION

BYCATCH

The introduction of the Nordmøre grate in 1991 reduced bycatch and allowed the fishery to expand to its present size. Bycatch information from Observer coverage of 21 commercial sets from 2014 (two trips) suggests that the fleet's trawl configurations, including the use of the Nordmøre grate, continue to ensure low total bycatch (2.86%) by weight. It is noteworthy that this value is very likely over-estimated due to the minimum 1 kg weight recorded by the observers (e.g. a single sand lance would be recorded as 1 kg despite weighing only a few grams). It should also be noted that 92% of the herring bycatch was reported in two sets, increasing the total estimated bycatch from 0.57%. Both observed trips took place during the spring/summer and covered portions of SFA 14 and inshore of SFA 15. There was no Observer coverage in SFA 13 during 2014. Nonetheless, the Eastern Scotian Shelf mobile shrimp fishery currently poses little risk in terms of bycatch amount or species-composition.

PRECAUTIONARY APPROACH

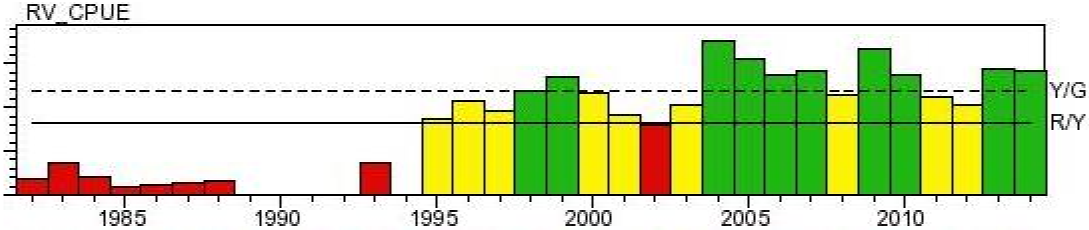
Spawning stock biomass and female exploitation indices are reported in the Traffic Light (below), but these indices also define stock and removal reference points for Eastern Scotian Shelf shrimp. In this context, it is worth reiterating that SSB by itself is not a measure of reproductive capacity. Because the relationship between fecundity and size, and the dynamic range of shrimp size in response to fluctuations in density, temperature and growth rate, it is important to carefully consider the "Auxiliary Data" provided by the Traffic Light Indicators when interpreting the reference points depicted in Figure 2.

Traffic Light Analysis

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 within the section below.

ABUNDANCE

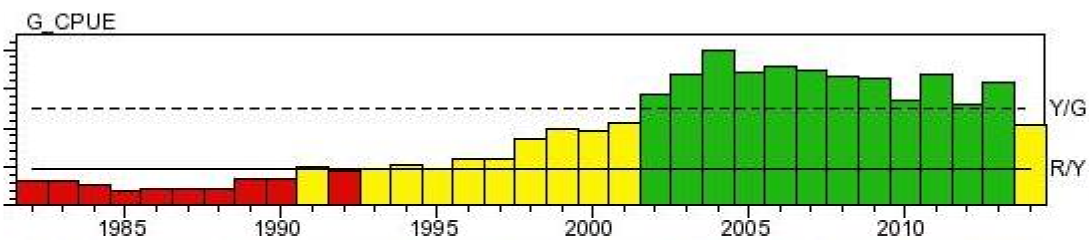
Research Vessel Survey Abundance Index



The stratified survey estimate for 2014, representing a biomass of 38,791 mt using the swept area method, decreased very slightly from the 2013 estimate of 39,381 mt. After three consecutive years of decline (2010-2012) from the near-record high of 2009, biomass increased in 2013 and remained stable at this level in 2014. The biomass estimates for strata 13 and 17 continued to increase in 2014 and are at the high-end of the historical range of abundance for these strata. Biomass estimates for strata 14 and 15 are nearer the lower end of the historical range (Figures 4-5; Tables 4 and 6).

Interpretation: The increase in the biomass estimate for 2013/2014 is consistent with the complete recruitment of the abundant 2007 and 2008 year classes to the fishable biomass, supplemented by the less abundant subsequent cohorts. The high estimate of the 2014 survey abundance index is inconsistent with downturns in both Gulf and Standardised CPUE indices (Figure 6).

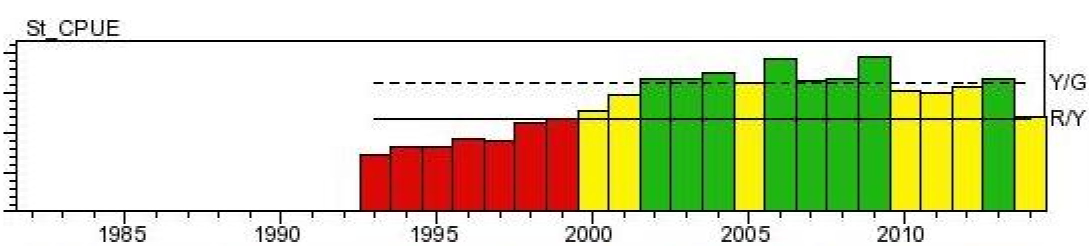
Gulf Vessels Catch per Unit Effort



These are the largest vessels in the fleet and although the participating vessels (and fishing gear) have changed considerably since the beginning of the time series, they have always been >65’ in length, compared to the <65’ 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 (i.e. introduction of Nordmøre grate in 1991), the differences in Gulf CPUEs between the period of low abundance (pre-1993) and the recent high abundances should be interpreted cautiously. The unstandardised Gulf vessel CPUE showed an increasing trend during the late-1980s to 2004 before stabilising at a relatively high level through to 2013.

Interpretation: The 2014 value decreased substantially to the lowest value since 2000 (Figure 6A). Gulf vessels reported very difficult fishing conditions in the early season (when they do nearly all of their fishing), which resulted in some very low catches. However, it is notable that the Standardised CPUE of the Nova Scotian fleet (which fishes throughout the season) shows a nearly identical trend.

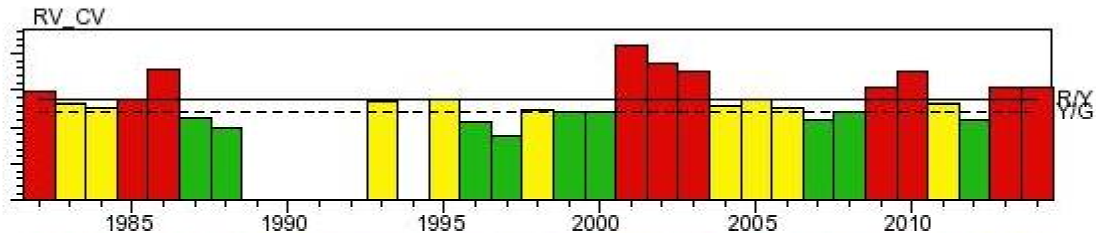
Commercial Trawler Standardised Catch per Unit Effort



In general, the three CPUE-based indicators follow similar trends. There have been two other notable divergences between commercial CPUEs and the shrimp survey (i.e. high commercial CPUEs in the face of declining survey CPUE in 2000-2003 and 2005-2008; Figure 6A). The first divergence was attributed to distributional changes associated with the demise of the large 1995 year class. The second divergence appears to be, at least in part, due to problems with the survey trawl (Koeller et al. 2011).

Interpretation: Similarly to the Gulf CPUE indictator, the 2014 standardised CPUE indicator declined to the lowest value since 2000. The 2014 divergence differs from previous divergences of survey and commercial CPUE in that the survey CPUE stayed higher while both commercial CPUE indices decreased sharply (i.e. does not suggest a fishery maintaining high catch rates on a declining resource due to clumping of the stock).

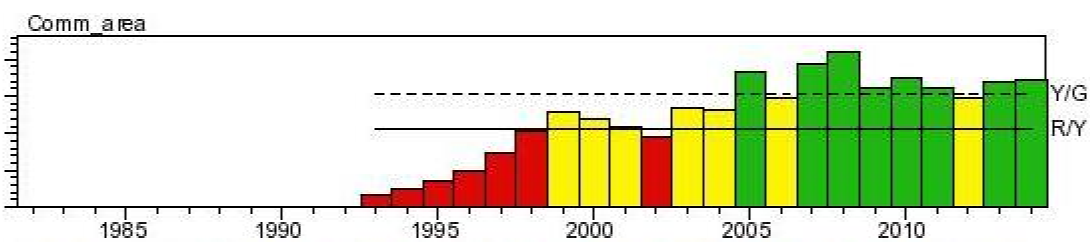
Research Vessel Survey Coefficient of Variation



The survey measure of dispersion (overall Coefficient of Variation, CV) remained high for the second consecutive year (Figure 7).

Interpretation: Although the relatively high CV of survey catches could indicate that the fishery may be targeting aggregations of a declining resource, the fact that total and SSB indices remain high suggests that this is not the case. Temperature changes in the survey area, particularly warming in stratum 14 and cooling in stratum 15 (Figure 8) may provide a more plausible explanation for changes in stock distribution. The dominance of old female shrimp from the 2007-2008 year classes relative to the less abundant subsequent year classes (Figure 9; Table 5) may also result in increased stock aggregation.

Commercial Fishing Area

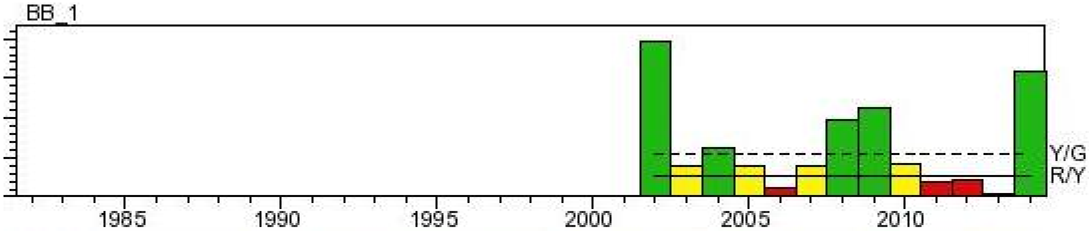


This measure of dispersion is particularly important when survey indices are decreasing while commercial catch rates continue to increase (in which case, a decrease in this index could indicate a concentration of the remaining stock in a smaller area). This is not currently the case, given that survey and commercial catch rates have been quite consistent in recent years, and the divergence of commercial from survey CPUEs in 2014 is in the opposite direction (high in survey, declining in commercial indices).

Interpretation: The area with commercial catch rates >250 kg/h remained relatively stable, increasing only slightly from the 2013 value and remaining within the range of data from the past decade (Figure 10, upper panel). Overall, the trends in areas of various ranges of catch rates have been stable for the past five years (Figure 10, lower panel). However, the area of highest catch rates (>450 kg/h) declined after the passage of the 2001 year class, increased as the 2007-2008 year classes recruited to the fishery and has now declined then in 2014. The spatial distribution of effort changed slightly between 2013 and 2014, with more effort taking place in the inshore and to the north in Louisbourg Hole (Figure 11).

PRODUCTION

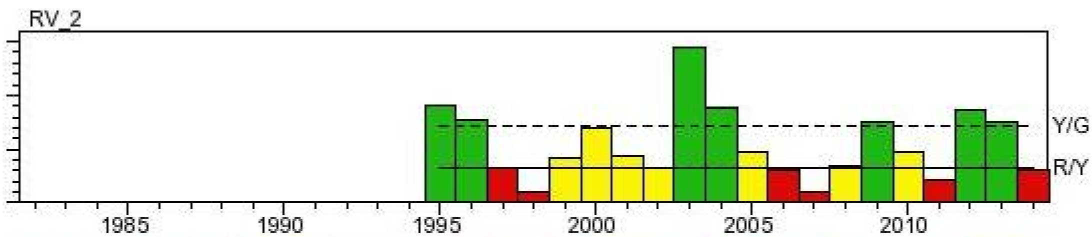
Research Vessel Survey Belly-bag Abundance at Age 1



This index shows considerable dynamic range despite only 13 years of data. It correctly predicted the strength of the 2001, 2007 and 2008 year classes, two years before these began to show up in commercial catches, and as many as five years before they were fully recruited to the fishery (Figures 10-12, Table 5). These three recruitment pulses since the modern fishery began (i.e. associated with the 1994-1995, 2001, and 2007-2008 year classes) provide evidence of recruitment cycles that approximately equal the species' life-span. The appearance of recruitment cycles of different lengths provides evidence that some form of a stock recruitment relationship exists (i.e. strong year classes result in large spawning stocks), resulting in strong year classes. The belly-bag index of age 1 abundance was the second highest on record in 2014 (Figure 13; Table 5).

Interpretation: The very high value of the belly-bag age 1 abundance index suggests that juvenile recruitment was good in 2014 (of the 2013 year-class as one-year olds). Based on past results of strong year-classes, the 2013 year class is expected to begin to be detectable in the commercial catch in 2016, and to fully recruit to the fishery in 2017-2019. However, it is important to consider that various environmental influences are also understood to strongly influence shrimp recruitment (e.g. spring sea surface temperatures and predator abundance, see below).

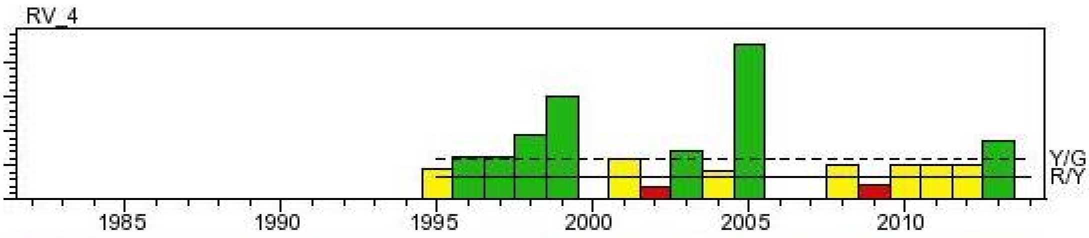
Research Vessel Survey Abundance at Age 2



Although the length frequency modal analysis tends to clearly define the age 2 mode, it is possible that this size of shrimp is not well (quantitatively) sampled by the main survey trawl. The index of age 2 shrimp decreased substantially in 2014 (Table 5).

Interpretation: Although trends between indices of age 1 and age 2 abundance have been somewhat equivocal (i.e. changes in the age 1 index are not always followed by concomitant changes in the age 2 indicator the following year, Table 5), this is not the case for the 2014 indicator. The very low age 2 indicator for 2014 is consistent with the fact that the 2013 belly-bag age 1 indicator was the lowest on record.

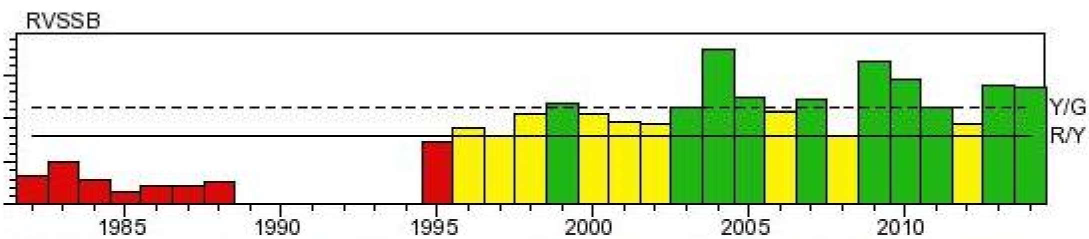
Research Vessel Survey Abundance at Age 4



The abundance of age 4 shrimp in 2014 was indistinguishable from the large mode associated with the 2007-2008 year classes. This has occurred in the past (2000, 2006 and 2007) when the mode representing age 4 shrimp could not be distinguished from the large 1995 and 2001 year classes (Figure 9; Table 5). In several cases, this index has reflected recruitment pulses first seen in the belly-bag 4 years before (e.g. 1995 year class in 1999 age 4 index, 2001 year class in 2002 belly bag and 2005 age 4 index, and 2007-08 year classes in 2008-09 belly bag and 2011-12 age 4 index; Table 5).

Interpretation: The age 4 mode (2010 year class) being indistinguishable from the large mode representing the 2007 and 2008 year classes is consistent with the fact that the 2011 belly-bag age 1 index was very low and further supports that the 2010 year class is small relative to the 2007 and 2008 year classes. The 2010 year class is not expected to recruit strongly to the female or total biomass.

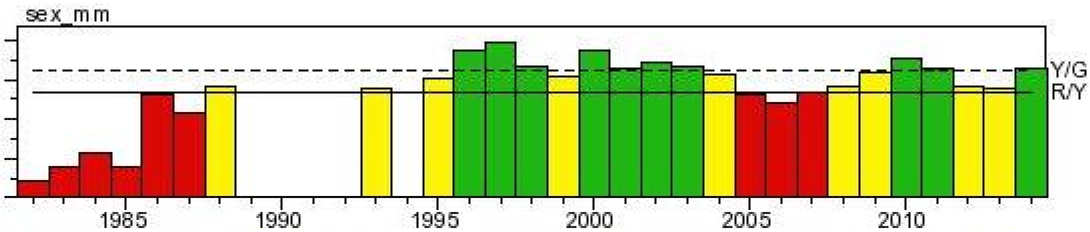
Research Vessel Survey Spawning Stock Biomass (Females)



A clear stock-recruitment relationship has not yet been described for Scotian Shelf shrimp, although it has been for some other pandalid stocks (Hannah 1995, Boutillier and Bond 2000). Beginning in the late-1980s, SSBs increased from approximately 4300 mt to values nearly three-fold higher by the mid-1990s. However, these increases occurred under specific environmental conditions (cold water temperatures and decreasing natural mortality due to predation) and negligible fishing mortalities, so 4300 mt should be considered the very lowest that the stock should be allowed to decline, and a more conservative value (5459 mt) is used as the LRP for this stock. 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 shrimp size indicators. In addition, multiparous females tend not to spawn every year. Spawning stock biomass decreased very slightly from the 2013 value, but remains at a high value in the healthy zone (20,359 mt: Figure 2 and Figure 14 – upper panel).

Interpretation: The high SSB for 2013 and 2014 is consistent with the complete recruitment of the strong 2007-2008 year classes to the SSB.

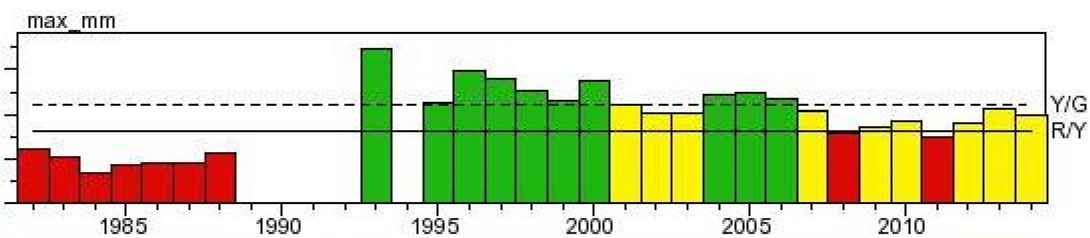
Average Size at Sex Transition (L_t)



Delayed sex-transition occurs during periods of high population density, and results in extra years of growth, which in turn results in the production of larger females. This indicator increased slightly in 2014 (Figure 15D).

Interpretation: This is consistent with increases in this value throughout the high-density period associated with the recruitment and passage of the 2001 year class through the fishery, and now once again with the 2007-2008 year classes.

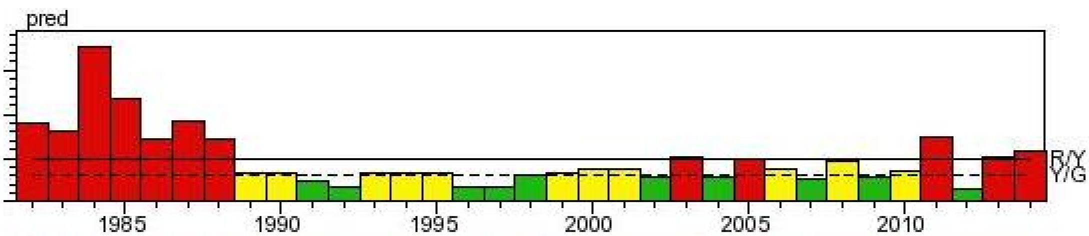
Average Maximum Size (L_{max})



The ratio of size at sex transition to maximum size was hypothesised to be constant (invariant) at about 0.8-0.9 for all stocks of *P. borealis* (Charnov and Skúladóttir 2000). This rule was shown to apply to the Scotian Shelf (Koeller et al. 2003b, Koeller 2006). Consequently, maximum size attained in the population is an indicator of growth; that is, change in maximum size is probably indicative of a change in growth rate. The relationship between L_t or L_{max} to changes in growth rate is complex due to the influence of other factors including concurrent changes in longevity and natural mortality (e.g. slower growing shrimp tend to live longer). The current value is within the range of uncertainty in these data in recent years (Figure 15B).

Interpretation: The relative stability of the mean maximum size index in recent years is consistent with other indicators that suggest the stock is moderately abundant and stable.

Predation

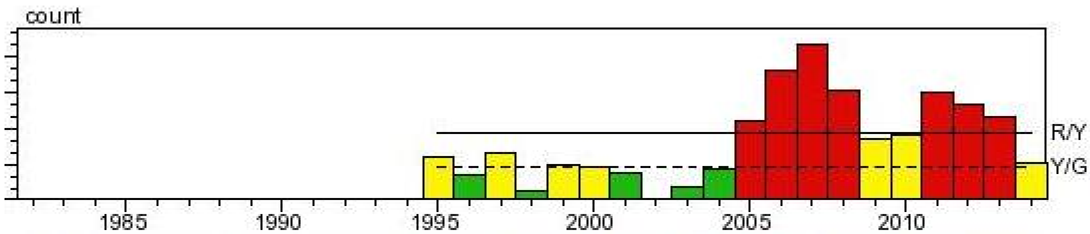


Groundfish abundance is negatively correlated with shrimp abundance on the Scotian Shelf and in most other shrimp fishing areas. This index of predation on shrimp rose slightly in 2014 (Figure 8).

Interpretation: Based on the 2014 value, natural mortality due to predation is expected to be relatively high, unlike most years in the past two decades.

FISHING IMPACTS

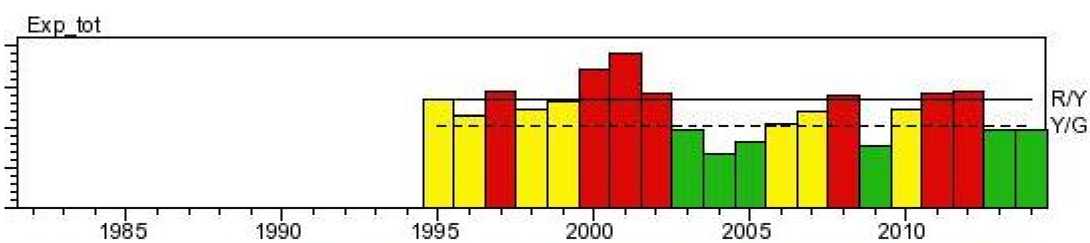
Commercial Counts



This indicator is a measure of the ease or difficulty fishers are having in "making the count"; that is, getting the best price for their shrimp. An increase in the count could indicate: a) recruitment is good and there are so many small shrimp it is difficult to avoid them; b) the population of larger shrimp is declining; or c) 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, probably due to size specific changes in vertical and\or geographic distribution associated with changes in day length.

Interpretation: The commercial count decreased substantially in 2014 (Figure 15A), to the lowest value in over a decade. This is consistent with the commercial catch being dominated by the 2007 and 2008 year classes with very little representation of the less abundant subsequent year classes.

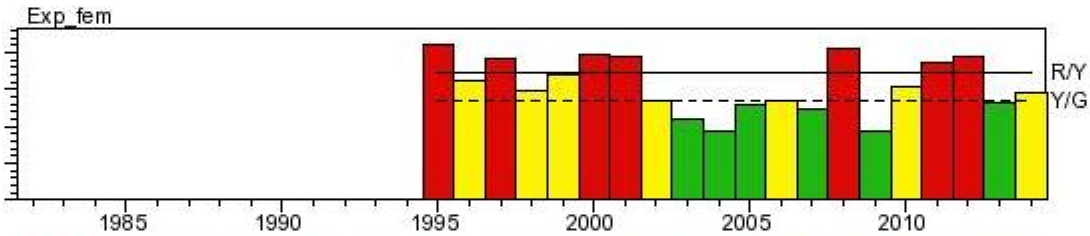
Exploitation Index



The research vessel 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. Since the survey uses a common commercial trawl with a Nordmøre grate, its selectivity is similar to commercial gear. The biomass used to estimate exploitation can be considered a point estimate of “fishable biomass”. Assuming that the entire TAC (4500 mt) is caught in 2014 (4041 mt caught as of November 17), the total exploitation index will be 11%, a slight increase relative to 2013 (Figure 14).

Interpretation: This slight increase in the 2014 exploitation index reflects the increase in the TAC, as well as the approximately stable biomass estimate relative to 2013.

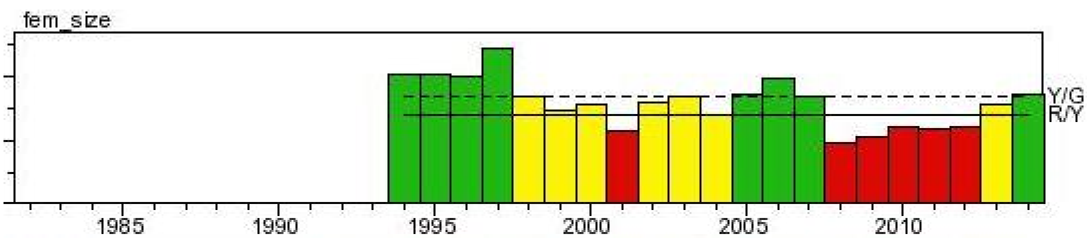
Female Exploitation Rate



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. Based on preliminary data for 2014, female exploitation (14.6%) remains well below the removal reference (Figure 2 and Figure 14 – lower panel).

Interpretation: As was the case for total exploitation, the minor increase in female exploitation relative to 2013 reflects the higher TAC and slightly decreased spawning stock biomass.

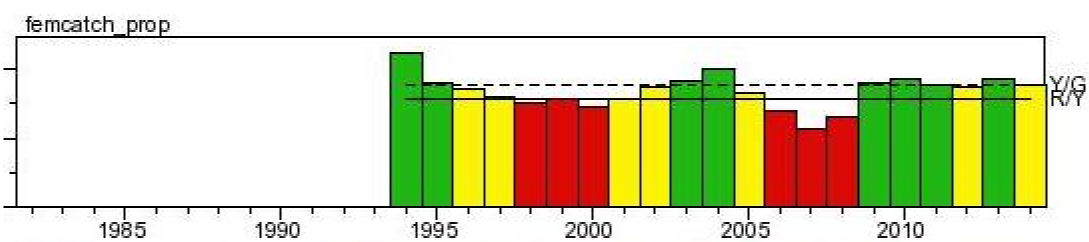
Mean Size of Females in Catch



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; that is, possible growth overfishing and/or recruitment overfishing. The average size of females in the catch has decreased from the early years of the fishery as the larger animals were selectively and continually removed from the population.

Interpretation: The sharp decrease in 2008 was due to the sex transition of the slow growing 2001 year class as small females. Female size has been steadily increasing since that time, as faster-growing shrimp from the less abundant succeeding year classes recruit to the female population (Figure 15C).

Proportion of Females in Catch

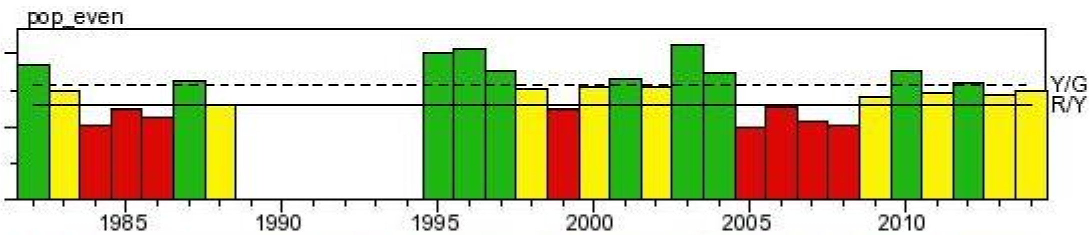


The proportion of females in the catch decreased between 2004 and 2006 due to the increase in the proportion of 2001 year class males. The increase in 2007-2010 was due to the sex change and recruitment to the female population of this year class and the delayed sex-transition of abundant age 4+ males observed in 2009. The proportion of females in the catch has been relatively stable at a high value since 2009 (Table 3).

Interpretation: The relative stability of this index at a high value in recent years reflects the fact that the population is currently dominated by older shrimp, mostly female, with relatively poor succeeding year classes (fewer males), which is also apparent in survey and commercial length frequency distributions (Figures 10-12).

ECOSYSTEM

Population Age-length Evenness



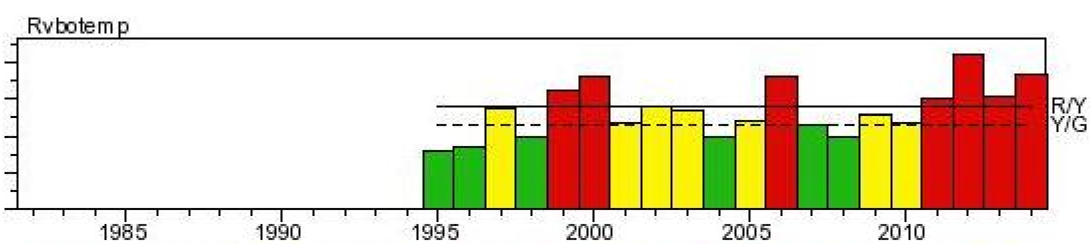
This indicator is placed under the ecosystem characteristic assuming that evenness is related to the population's robustness or resiliency to various perturbations within the ecosystem. However, it could also have been placed under fishing effects since fishing will remove the largest/oldest length/age classes, or production since an even length/age distribution implies stable recruitment. On the other hand, this index will also respond to the passage of an exceptional year class through the population, which may not be a negative development if the abundance of other year classes remains relatively stable.

Population evenness was high at the beginning of the survey series in 1995 when the fishery was relatively new (it first attained the TAC only in 1994). It declined in the late-1990s as the large 1994-1995 year classes dominated the population, and was very low once again in 2003-2006 as the 2001 year class dominated. Since the end of the long-lived 2001 year class in 2009, the index has been fluctuating around a relatively high value.

Interpretation:

The 2014 value and relative stability of this index is consistent with a population composed of several year classes, most notably the relatively abundant 2007 and 2008 year classes that make up the bulk of the fishable biomass as 6-7 year old female shrimp. However, the paucity of the succeeding year classes since 2008 (Figures 10-12; Table 5) should not be overlooked.

Research Vessel Survey Bottom Temperatures



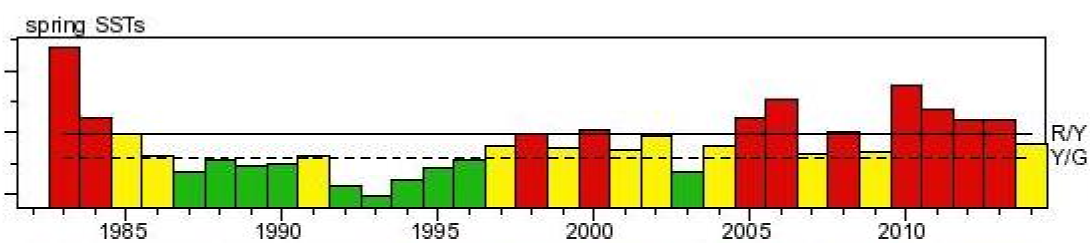
For some Northern shrimp stocks near the southern limits of the species' range, abundance is negatively correlated with water temperatures. It is hypothesised that warmer water temperatures have a negative influence on shrimp populations because of the decreased fecundity associated with increased growth rates, decreased size at transition, and decreased maximum size as described above. Recent work also indicates that colder bottom temperatures increase egg incubation times resulting in later hatching times, which are closer to favourable spring growing conditions (warmer surface water and the spring phytoplankton bloom) (Koeller et al. 2009). On the eastern Scotian Shelf, the large population increase that occurred from the mid-1980s to the mid-1990s is associated with colder surface and bottom water temperatures. Large fluctuations in bottom water temperatures may also be associated with the cyclical recruitment pattern experienced since the early-1990s (i.e. 1993-1995, 2001 and 2007-2008 year classes).

Bottom temperatures on the shrimp grounds were relatively high during the 1980s, when the shrimp population was low. It was also low during the population increase of the 1990s (Figures 15-16). Higher temperatures preceded the population downturn in 2001-2003 and the low belly bag index values for 2006-2007. Bottom temperatures during the shrimp survey have been high for the past four years, and increased in 2014 relative to 2013 (Figures 15-16).

Colder temperatures in 2007-2008 may have helped larval survival, as measured by belly bag results, by increasing the incubation period, bringing hatching times closer to the spring bloom and vernal warming of surface waters, conditions favourable for larval growth and survival. Similarly, the warmer temperatures in 2005, 2006 and 2009 are consistent with the low belly bag index results in 2006, 2007 and 2010, respectively. However, despite warm bottom and spring sea surface temperatures in 2013, the belly bag index result from 2014 was very high (Figure 8; Table 5).

Interpretation: The high value of this index for 2014, and for the past four years, is likely to be unfavourable for the Scotian Shelf shrimp overall and for the prospects of strong recruitment from the 2014 year class. However, the spring sea surface temperature index was positive (cooler) for 2014 (see following indicator).

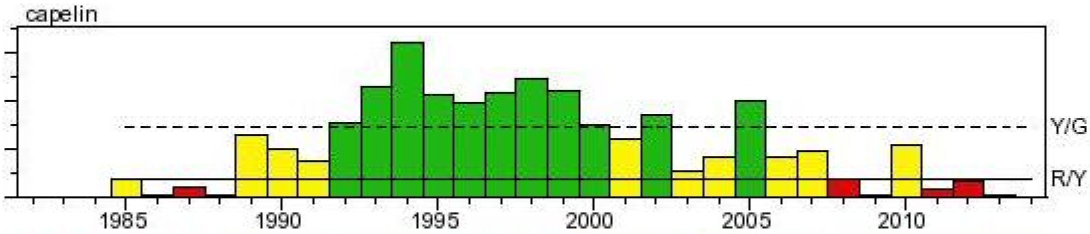
Spring Sea Surface Temperatures



Negative correlations between sea surface temperature (SST) and lagged population estimates (four to five years in Gulf of Maine) are common for the southern *P. borealis* stocks, including the Scotian Shelf. This may be related to water column stability and the match-mismatch of resulting phytoplankton bloom conditions with hatching times, as hypothesised by Ouellet et al. (2007). Accordingly, SSTs used were averages for a period encompassing average hatching times on the Scotian Shelf (mid-February to mid-March). On the Scotian Shelf, the below average temperatures prevalent during the late-1980s and early-1990s may have facilitated the high abundances in the mid- to late-1990s associated with the strong 1994-1995 year classes. However, at least one exceptional recruitment event occurred recently (2001) despite relatively high SSTs, and the same appears to be true for the 2013 year class. The 2014 spring SST index decreased for the fourth consecutive year, since the record high value in 2010, to a value in the range of the long-term average of the data (Figure 16).

Interpretation: Spring surface temperatures decreased in 2014, which given the high SSB, may have provided favourable conditions for the 2014 year class. However, bottom temperatures were very warm, suggesting that conditions are unfavourable for shrimp (see previous indicator).

Research Vessel Survey Capelin Abundance

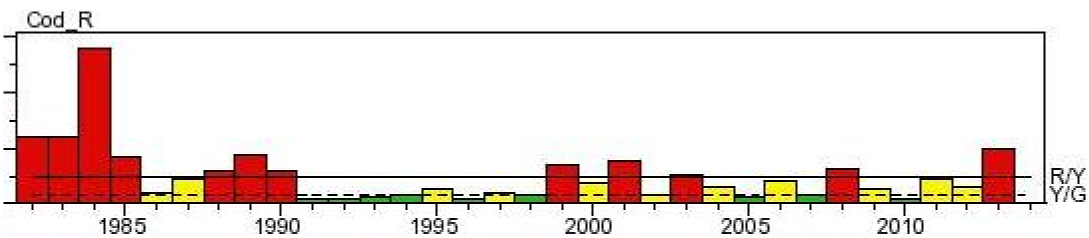


Capelin is among the most common bycatch species, both in the Scotian Shelf shrimp fishery and the June shrimp survey. They have been shown to increase in abundance during cold periods, which are also favourable for shrimp recruitment, so can be considered a sympatric species (e.g. Frank et al. 1994). Their presence can, therefore, be considered an indicator of conditions favourable to the production of shrimp.

During the last 10 years, capelin abundance has been lower on average than the relatively high values between 1993 and 1999, and was especially low (near those of the 1980s when shrimp abundance was low) in 2008-2009. Capelin abundance in 2014 was the lowest on record.

Interpretation: The low index for 2014 for this species suggests that recent/current environmental conditions are not favourable for recruitment of sympatric cold water species such as capelin and shrimp.

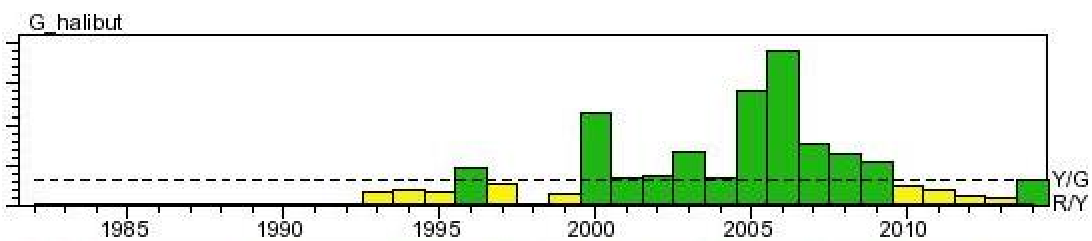
Cod Recruitment



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. Cod recruitment (<30 cm in length) decreased in 2014 to the lowest value on record.

Interpretation: Natural mortality of shrimp due to cod predation is likely to remain low.

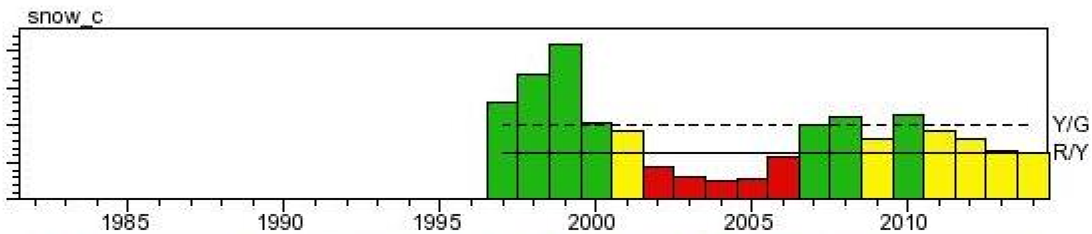
Greenland Halibut Recruitment



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. Greenland halibut <30 cm in length have been abundant on the eastern Scotian Shelf in the past decade, but have been decreasing steadily during the last six years. This species was rarely found during the warmer period of the 1980s when shrimp and capelin were also low in abundance.

Interpretation: Although the Greenland halibut recruitment index increased in 2014, it has remained relatively low for the past decade. Overall, this is consistent with the low value for capelin and suggests that recent/current environmental conditions are not favourable for recruitment of sympatric cold water species such as Greenland halibut, capelin and shrimp.

Snow Crab Recruitment

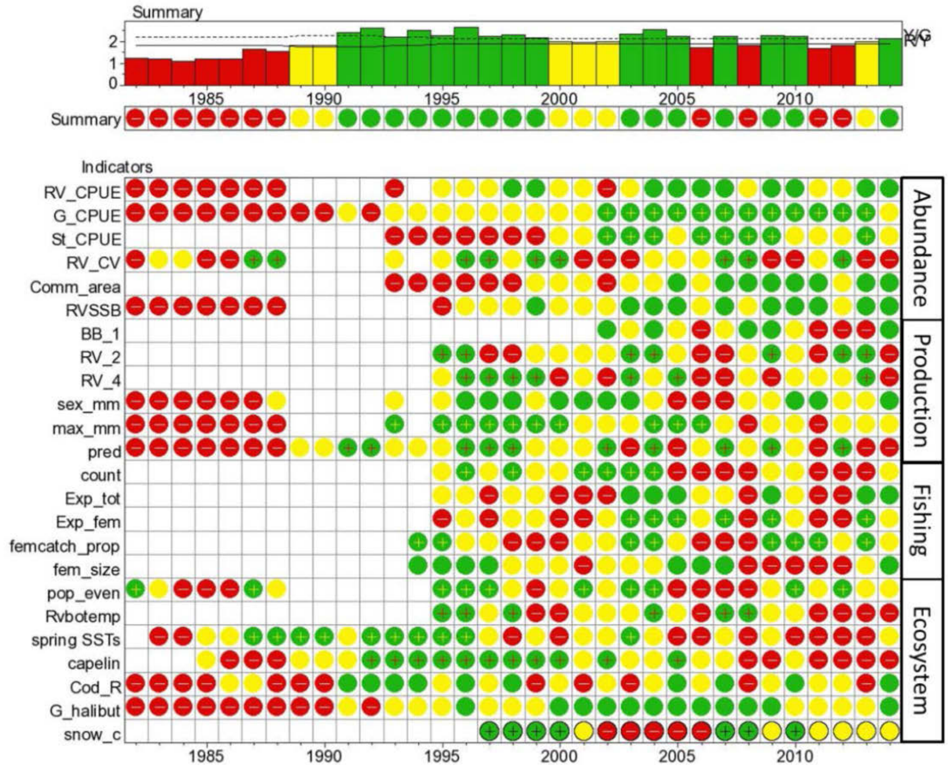


Snow crab abundance, as with Greenland halibut and capelin, tend to track shrimp abundance in the long-term; however, snow crab have considerably longer longevities and population cycles. The male pre-recruit index from the snow crab survey off southern Cape Breton has been gradually declining since 2010.

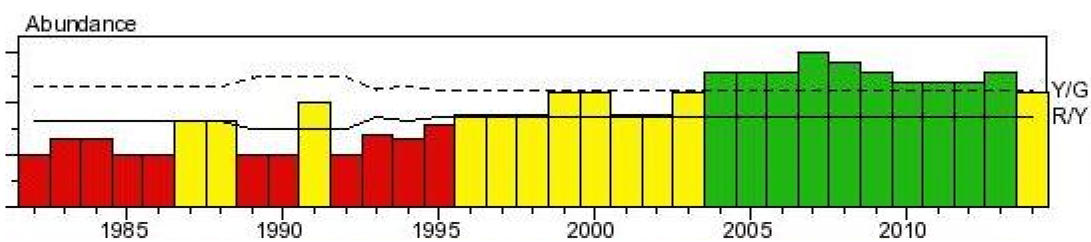
Interpretation: The decreasing trend in snow crab recruitment in recent years, coupled with low index values for other sympatric species (see indicators above), suggests that environmental conditions on the Scotian Shelf may be gradually becoming less favourable for the recruitment of sympatric cold water species such as shrimp and snow crab.

TRAFFIC LIGHT SUMMARY

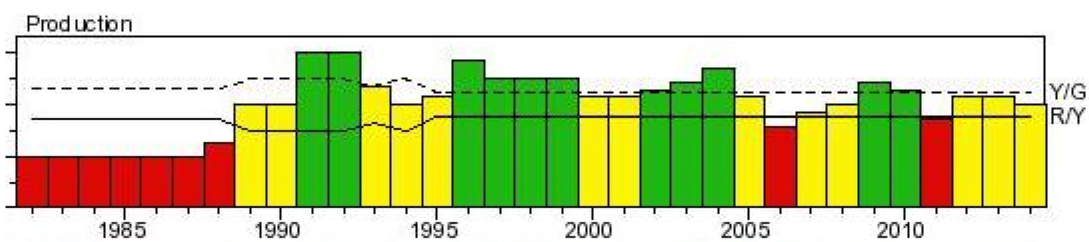
The summary Traffic Light indicator for 2014 improved to green for the first time in four years. In general, while indices of Abundance declined, Ecosystem indices improved, and Fishing Effects and Production indices remained relatively stable.



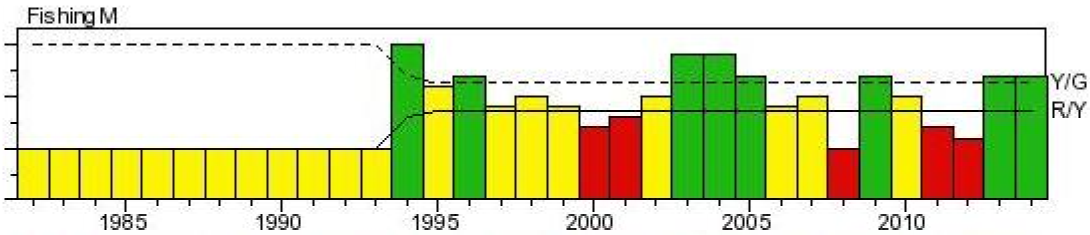
Precautionary Note: The overall summary and characteristic summary values are derived by a simple averaging process, which does not account for complex interactions between indicators that may be occurring. Consequently, even the interpretation of individual indicators must be approached cautiously with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



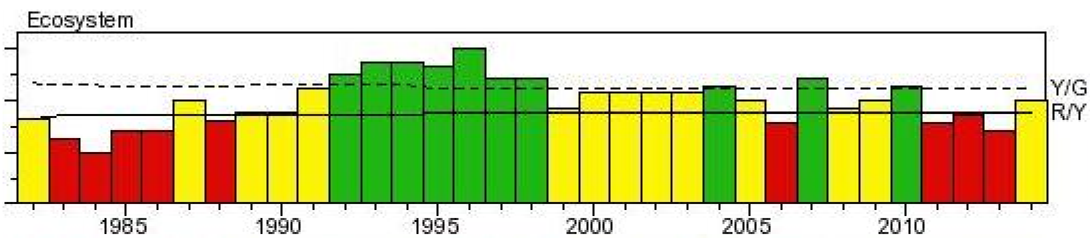
The Abundance characteristic declined to yellow for the first time in a decade due to declines in the Gulf and Standardised CPUE indices.



The Production characteristic remained yellow in 2014. The negative influence of declines in the abundance of young shrimp associated with poor juvenile recruitment over the past four years were offset by the positive influence of a very strong recruitment signal of the 2013 year class in the 2014 belly bag and the maintenance of high SSB.



The Fishing Effects characteristic remained green for 2014 after having improved greatly from red values for 2011 and 2012. This is due mostly to relatively low total and female exploitation indices and a high proportion of large females in the catch.



The 2014 Ecosystem characteristic improved to yellow after three years as red. This improvement is accounted for by a decrease in spring SST (good juvenile recruitment conditions), a very low cod recruitment index (expectation of low predation by cod) and an increase in Greenland halibut recruitment (sympatric coldwater species).

SOURCES OF UNCERTAINTY

Spatial and temporal variability in the distribution of shrimp is a source of uncertainty with regard to the accuracy of survey estimates; the survey is conducted consistently during the first ten days of June to try to mitigate this effect. In 2007-2008, problems with NETMIND distance sensors and data logging required use of historical average instead of actual wing spread data to calculate swept areas and abundance. The trend in commercial catch rate has not always been consistent with the trend in the shrimp survey index; the possible reasons for these divergences have been discussed previously and have been less problematic in recent years. The assignment of modal (length) groups of shrimp to age classes is somewhat subjective, particularly for larger individuals. Further, growth rates can decrease dramatically due to density dependence, as happened with the strong 2001 year class. Consequently, recruitment to the fishery can be delayed and spread over a longer time period. Last, unforeseen changes in the ecosystem (e.g. predators) and environment (e.g. temperature) together increase the difficulty of making long-term projections.

ACKNOWLEDGEMENTS

The authors thank Captain Bob Schrader for his excellent co-operation and expert advice on the survey gear, and the entire crew of MV *Cody & Kathryn* for successfully conducting the 2014 survey. Thanks to Scott Bates and Tony DeRoche for their conscientious collection, handling and storage of the shrimp samples for laboratory analysis. Thanks again also to the many fishers and buyers who provided fishery data such as counts, catch and effort data and shrimp samples over the years. Last, the authors also thank reviewer Jessica Sameoto and a second reviewer for their constructive comments.

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TABLES

Table 1. Total allowable catches (TACs; trawls) and catches (trawls and traps) from the eastern Scotian Shelf shrimp fishery (SFAs 13-15), 1980-2014. Cells with dashes (-) indicate no data.

Year	TAC Trawl	TAC Trap	Trawl Catch SFA 13	Trawl Catch SFA 14	Trawl Catch SFA 15	Trawl Catch Total	Trap Catch	Total Catch
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
2005	4608	392	1190	1392	1054	3636	9	3645
2006	4608	392	846	1997	1111	3954	32	3986
2007	4820	200	267	2633	1678	4578	4	4582
2008	4912	100	349	2703	1265	4317	4	4321
2009	3475	25	298	2450	727	3475	2	3477
2010	4900	100	280	1846	2454	4580	1	4581
2011	4432	168	254	2340	1653	4247	111	4358
2012	3954	246	197	2296	1227	3693	199	3892
2013	3496	304	158	2514	708	3380	224	3604
2014[4]	4140	360	644	2259	996	3919	122	4041
2014[5]	4140	360	697	2444	999	4140	360	4500

1. Nordmøre separator grate introduced.
2. Overall TAC not caught because TAC for SFAs 14 and 15 was exceeded.
3. Individual SFA TACs combined.
4. Current year to date (November 27, 2014).
5. Current year prorated to total TAC.

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

Year	Trap Scotia-Fundy[1]	Trawl	
		Scotia-Fundy[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	2(14)	20(28)[8]	7(24)[9]
2006	5(14)	18(28)	7(24)
2007	2(14)	20(28)	7(24)
2008	1(14)	18(28)	7(24)
2009	1(14)	17(28)	6(14)[10]
2010	3(14)	18(28)	7(14)
2011	7(14)	15(28)	5(14)
2012	8(14)	12(28)	5(14)
2013	11(14)	13(28)	6(14)
2014	7(14)	9(28)	5(14)

1 All but one active trap licences are vessels <45'. They receive about 8% of the TAC.
2 These vessels receive about 70% of the TAC according to the management plan. Inactive NAFO 4X licences (15) not included in total.
3 All licences 65-100' length over all (LOA). Eligibility to fish in Scotia-Fundy for about 23% of the TAC.
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.
10 The previously reported number of licenses included (10) that were invalid for a number of reasons. The number of valid licenses was updated in 2009.

Table 3. Input data for traffic light analysis. 'NAN' refers to not-a-number.

Action	Pctile	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	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	1
Level_YG	0.66	0.66	0.66	0.33	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.33	0.33	0.33	0.33	0.66	0.66	0.66	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	0.33	0.66	0.66	0.66	0.66	0.33	0.33	0.33	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	0
Production	0	0	0	0	0	1	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	0	1	1	1	1	1	0	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	1

Year	RV_CPUE	G_CPUE	St_CPUE	RV_CV	Comm_ area	RVSSB	BB_1	RV_2	RV_4	sex_mm	max_mm	pred	count	Exp_tot	Exp_fem	fem_prop	fem_size	pop_even	Rvtemp	Spring SST	capelin	Cod_R	G_halibut	snow_c
1982	34.50	128.00	NAN	89.06	NAN	5040.65	NAN	NAN	NAN	21.46	28.24	179.29	NAN	NAN	NAN	NAN	NAN	0.81	NAN	NAN	NAN	2.38	0.00	NAN
1983	71.50	127.70	NAN	78.52	NAN	7323.05	NAN	NAN	NAN	21.80	28.03	164.05	NAN	NAN	NAN	NAN	NAN	0.77	NAN	2.78	NAN	2.42	0.00	NAN
1984	39.00	109.50	NAN	75.84	NAN	4460.96	NAN	NAN	NAN	22.17	27.69	353.25	NAN	NAN	NAN	NAN	NAN	0.73	NAN	0.48	NAN	5.57	0.06	NAN
1985	17.00	75.40	NAN	83.09	NAN	2417.71	NAN	NAN	NAN	21.77	27.87	236.37	NAN	NAN	NAN	NAN	NAN	0.75	NAN	-0.07	1.55	1.71	0.05	NAN
1986	23.00	87.30	NAN	106.13	NAN	3187.87	NAN	NAN	NAN	23.63	27.94	144.33	NAN	NAN	NAN	NAN	NAN	0.74	NAN	-0.77	0.13	0.37	0.09	NAN
1987	25.50	90.70	NAN	67.53	NAN	3424.46	NAN	NAN	NAN	23.16	27.94	187.04	NAN	NAN	NAN	NAN	NAN	0.79	NAN	-1.32	0.77	0.87	0.16	NAN
1988	31.50	85.10	NAN	60.14	NAN	4047.02	NAN	NAN	NAN	23.84	28.12	142.81	NAN	NAN	NAN	NAN	NAN	0.76	NAN	-0.92	0.17	1.19	0.06	NAN
1989	NAN	133.40	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	66.58	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.07	18.38	1.75	0.00	NAN
1990	NAN	134.50	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	67.33	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.02	9.23	1.16	0.00	NAN
1991	NAN	197.90	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	46.91	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-0.77	5.07	0.17	0.46	NAN
1992	NAN	176.30	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	32.10	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.72	34.88	0.17	0.08	NAN
1993	75.00	187.89	142.20	80.33	31.00	NAN	NAN	NAN	NAN	23.78	30.45	68.53	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-2.07	193.36	0.29	1.86	NAN
1994	NAN	213.52	188.40	NAN	48.00	NAN	NAN	NAN	NAN	NAN	NAN	66.17	NAN	NAN	NAN	0.89	26.05	NAN	NAN	-1.52	1563.89	0.30	1.98	NAN
1995	173.02	187.02	181.17	82.84	71.00	10912.15	NAN	358.50	875.92	24.05	29.27	66.52	55.92	13.44	21.04	0.72	26.03	0.83	1.59	-1.17	138.62	0.54	1.74	NAN
1996	213.92	244.58	224.35	64.88	99.00	13368.38	NAN	307.34	1247.63	24.73	29.99	32.56	54.47	11.50	16.11	0.68	26.01	0.83	1.72	-0.92	87.53	0.16	4.78	NAN
1997	193.00	236.26	218.89	53.46	146.00	12100.80	NAN	128.85	1257.47	24.94	29.78	35.85	56.35	14.41	19.08	0.64	26.44	0.80	2.74	-0.47	146.64	0.40	2.91	6588.78
1998	238.38	343.73	298.94	74.42	209.00	15707.48	NAN	39.89	1883.71	24.33	29.51	59.87	53.22	12.08	14.73	0.60	25.68	0.78	1.97	-0.06	284.31	0.31	0.41	8446.24
1999	268.40	395.70	325.53	72.20	258.00	17607.48	NAN	165.63	3010.18	24.08	29.31	64.13	55.30	13.24	16.90	0.63	25.46	0.75	3.24	-0.50	159.96	1.39	1.67	10482.22
2000	233.36	383.66	365.48	72.00	242.00	15893.36	NAN	280.34	0.00	24.74	29.74	76.29	55.19	17.06	19.79	0.58	25.57	0.78	3.60	0.07	32.38	0.79	11.44	5128.69
2001	183.32	428.24	443.46	126.03	221.00	14475.58	NAN	174.90	1184.11	24.29	29.19	73.28	54.70	19.05	19.56	0.63	25.15	0.79	2.36	-0.55	15.99	1.58	3.66	4664.29
2002	161.40	572.36	523.48	111.15	192.00	14133.20	980.00	134.00	399.17	24.45	29.02	57.30	52.53	14.17	13.43	0.70	25.61	0.78	2.77	-0.09	49.85	0.32	3.88	2212.31
2003	204.42	675.41	520.72	104.48	265.00	16916.16	196.00	576.74	1411.07	24.31	29.05	100.65	53.48	9.83	10.91	0.73	25.68	0.84	2.69	-1.30	2.70	1.03	6.69	1656.46
2004	353.70	793.14	549.32	78.00	263.00	26856.47	316.00	354.09	839.46	24.13	29.44	57.46	54.96	6.75	9.48	0.80	25.41	0.80	1.99	-0.43	5.93	0.64	3.44	1248.30
2005	312.90	683.25	496.53	83.01	364.00	18587.50	198.00	187.02	4502.48	23.63	29.46	99.05	58.93	8.20	13.05	0.66	25.72	0.73	2.41	0.47	99.41	0.25	14.00	1500.56
2006	275.20	716.40	614.86	75.86	296.00	16288.53	61.00	121.30	0.00	23.39	29.35	77.47	63.23	10.55	13.57	0.55	25.96	0.75	3.62	1.03	5.78	0.80	18.92	3012.34
2007	281.20	696.62	507.79	66.34	389.00	18345.54	194.00	39.00	0.00	23.67	29.07	51.64	65.30	11.92	12.28	0.45	25.70	0.73	2.30	-0.73	8.45	0.29	7.77	5482.42
2008	226.10	664.07	520.17	72.25	423.00	12119.42	484.11	134.72	1046.18	23.84	28.57	92.82	61.52	13.98	20.50	0.52	24.98	0.73	1.96	0.03	1.36	1.24	6.51	6145.07
2009	333.10	648.76	628.16	91.70	324.00	24853.59	566.52	304.05	463.00	24.21	28.74	55.35	57.56	7.65	9.37	0.72	25.06	0.77	2.59	-0.61	0.21	0.57	5.42	4424.86
2010	273.00	536.23	465.57	105.47	350.00	21706.69	205.08	188.00	1036.00	24.53	28.87	70.88	57.77	12.31	15.45	0.74	25.20	0.80	2.35	1.54	11.06	0.16	2.55	6264.81
2011	223.60	671.18	456.36	78.89	320.00	16823.67	97.34	85.22	1044.08	24.27	28.51	149.12	61.34	14.28	18.61	0.71	25.19	0.77	2.99	0.72	0.57	0.93	1.96	4912.83
2012	205.30	552.28	496.05	66.78	294.00	14762.95	124.76	273.22	1022.00	23.88	29.01	31.80	59.61	15.01	18.93	0.72	25.22	0.79	4.20	0.43	1.25	0.65	1.37	4436.99
2013	287.60	626.68	672.22	91.88	337.00	20679.51	24.92	302.00	1693.00	23.79	29.11	101.00	59.30	9.64	13.27	0.74	25.56	0.76	3.04	0.40	0.17	1.94	1.17	3363.25
2014	**284.30**	**417.43**	**478.84**	**91.86**	**342.00**	**20358.62**	**789.32**	**125.00**	**0.00**	**24.29**	**28.97**	**115.00**	**55.54**	**9.80**	**14.56**	**0.70**	**25.72**	**0.77**	**3.64**	**-0.35**	**0.10**	**0.04**	**3.27**	**3214.33**

Table 4. Set statistics from DFO-industry survey CK1401 conducted by MV Cody & Kathryn from June, 1-12, 2014.

Set	SFA	Date	Lat.	Long.	Speed (kts)	Dist. (nm)	Dur. (min.)	Wing. (m)	Depth (fth)	Temp (°C)	Raw Catch (kg)	Stand. Catch (kg)	Density (gm/m² or mt/km²)
1	15	01-Jun-14	445940	605870	2.67	1.22	30	17.17	104.57	2.37	22.68	23.53	0.58
2	15	01-Jun-14	445652	610178	2.72	1.31	30	16.72	105.57	2.25	48.99	48.78	1.21
3	15	01-Jun-14	445417	610375	2.67	1.31	30	16.99	110.29	2.28	82.55	80.59	2.00
4	15	01-Jun-14	445340	605812	2.62	1.19	30	17.92	134.29	2.26	175.45	179.55	4.46
5	15	02-Jun-14	444817	605615	2.53	1.06	30	16.36	136.14	2.33	53.52	66.90	1.66
6	15	02-Jun-14	445603	604637	2.50	1.18	30	17.51	120.57	2.62	151.05	158.82	3.94
7	15	02-Jun-14	445035	604076	2.25	1.16	30	17.37	156.14	3.23	112.72	121.28	3.01
8	15	02-Jun-14	444683	603692	2.44	1.18	30	17.67	127.00	3.30	37.56	39.10	0.97
9	15	02-Jun-14	445676	602762	2.67	1.31	30	17.67	133.43	3.76	80.74	75.95	1.89
10	15	02-Jun-14	445478	602344	2.56	1.16	30	17.51	129.43	3.87	231.70	247.86	6.15
11	15	02-Jun-14	445009	602189	2.55	1.18	30	17.58	164.43	3.98	69.85	73.12	1.82
12	15	02-Jun-14	444928	601633	2.41	1.21	30	17.09	163.43	3.88	35.38	37.17	0.92
13	15	03-Jun-14	445518	601166	2.37	1.18	30	17.59	142.86	3.81	281.23	294.46	7.31
14	15	03-Jun-14	445786	600828	2.40	1.22	30	17.08	118.43	3.64	220.45	229.62	5.70
15	15	03-Jun-14	445470	595846	2.48	1.19	30	16.86	105.71	4.02	230.43	249.12	6.18
16	14	03-Jun-14	444831	595825	2.57	1.20	30	16.59	133.00	4.23	91.99	100.48	2.49
17	14	03-Jun-14	444062	600737	2.38	1.16	30	16.54	103.00	4.43	60.78	68.84	1.71
18	14	03-Jun-14	444154	600079	2.24	1.09	30	16.98	116.43	4.70	93.89	109.96	2.73
19	14	03-Jun-14	444320	594712	2.62	1.28	30	18.27	139.29	4.47	256.74	238.91	5.93
20	14	03-Jun-14	444153	593595	2.29	1.14	30	17.11	115.57	4.17	184.39	205.63	5.10
21	14	04-Jun-14	445610	581975	2.48	1.16	30	17.35	139.00	3.76	464.48	502.89	12.48
22	14	04-Jun-14	445055	583181	2.54	1.23	30	17.47	138.17	3.47	258.82	263.05	6.53
23	14	04-Jun-14	444768	583798	2.60	1.26	30	17.40	139.43	3.57	223.17	221.73	5.50
24	14	04-Jun-14	445608	584304	2.52	1.20	30	17.69	142.29	3.17	541.50	556.64	13.82
25	14	04-Jun-14	444768	585328	2.50	1.20	30	17.57	144.86	3.30	396.90	409.01	10.15
26	14	04-Jun-14	445145	590318	2.43	1.17	30	17.29	128.57	3.06	415.04	445.70	11.06
27	14	04-Jun-14	444755	591130	2.43	1.21	30	17.08	124.71	3.07	279.42	293.31	7.28
28	14	05-Jun-14	443858	590260	2.51	1.25	30	17.31	117.29	2.96	279.51	281.56	6.99
29	14	05-Jun-14	445107	592792	2.54	1.19	30	17.57	141.71	3.72	381.02	395.01	9.81
30	14	05-Jun-14	445120	594204	2.39	1.18	30	17.24	122.71	4.11	571.17	608.51	15.11
31	17	09-Jun-14	451530	595534	2.51	1.18	30	17.03	105.86	2.95	917.54	996.54	24.74
32	17	09-Jun-14	451827	594767	2.46	1.24	30	16.55	74.14	2.44	3.63	3.85	0.10
33	17	09-Jun-14	452126	595370	2.41	1.22	30	16.55	82.00	2.69	166.20	179.48	4.46
34	17	09-Jun-14	452743	594376	2.61	1.19	30	16.55	71.57	2.48	0.00	0.00	0.00
35	17	09-Jun-14	452465	595780	2.34	1.15	30	16.33	91.43	3.18	119.21	137.74	3.42
36	17	09-Jun-14	452831	600317	2.31	1.35	30	16.92	97.29	3.12	95.26	90.53	2.25
37	17	09-Jun-14	453417	600517	2.37	1.25	30	17.28	97.57	2.75	1242.86	1247.02	30.96
38	17	09-Jun-14	453683	595958	2.40	1.21	30	17.65	94.29	2.76	542.32	552.88	13.73
39	13	10-Jun-14	453651	584011	2.36	1.20	30	17.99	161.14	4.33	103.42	104.23	2.59
40	13	10-Jun-14	453507	583505	2.43	1.19	30	17.47	138.14	4.11	163.02	169.84	4.22
41	13	10-Jun-14	453233	582894	2.20	1.06	30	17.21	139.00	4.26	251.66	299.21	7.43
42	13	10-Jun-14	453397	582090	2.30	1.16	30	15.83	203.14	4.60	82.10	96.85	2.40
43	13	10-Jun-14	454047	581950	2.21	1.14	30	16.49	201.50	4.48	53.52	62.16	1.54
44	13	10-Jun-14	454079	582818	2.51	1.23	30	16.30	205.57	4.70	65.32	71.09	1.76
45	13	10-Jun-14	454778	583130	2.30	1.21	30	17.49	163.00	4.98	403.25	416.00	10.33
46	13	10-Jun-14	454705	583537	2.32	1.17	30	17.94	163.57	5.01	241.31	250.79	6.23
47	13	11-Jun-14	454645	583988	2.29	1.15	30	17.44	154.71	4.99	122.47	132.37	3.29
48	13	11-Jun-14	455074	584991	2.37	1.21	30	17.37	134.29	4.83	270.34	279.15	6.93
49	13	11-Jun-14	454771	585745	2.45	1.20	30	17.35	129.29	4.78	305.00	318.10	7.90
50	13	11-Jun-14	454440	590030	2.57	1.26	30	17.45	138.71	4.75	414.86	411.36	10.21
51	13	11-Jun-14	454298	585611	2.37	1.13	30	17.48	138.71	4.79	160.57	176.12	4.37
52	13	11-Jun-14	454213	585126	2.78	1.23	30	17.55	132.43	4.76	143.79	145.17	3.60
53	13	11-Jun-14	453709	590463	2.67	1.16	30	17.67	142.14	4.68	120.66	128.04	3.18
54	17	12-Jun-14	452878	602425	2.13	1.15	30	16.71	118.57	2.87	271.34	308.25	7.65
55	17	12-Jun-14	453321	602851	2.31	1.33	30	16.43	84.86	2.62	616.26	613.13	15.22
56	17	12-Jun-14	452977	603177	2.58	1.20	30	17.24	95.86	2.86	922.07	971.05	24.11
57	17	12-Jun-14	452925	603731	2.59	1.26	30	15.93	81.00	2.50	384.56	416.34	10.34
58	17	12-Jun-14	452634	603460	2.50	1.27	30	15.81	88.57	2.72	500.41	540.39	13.42
59	17	12-Jun-14	452552	604165	2.46	1.24	30	15.56	76.29	2.36	458.50	517.32	12.84
60	17	12-Jun-14	452259	605979	2.42	1.26	30	16.73	58.71	0.92	151.54	156.82	3.89

Table 5. Minimum survey population numbers at age from modal analysis, 1998-2014. Numbers x 10^6. Cells with dashes (-) indicate no data.

Age	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
1[1]	-	-	-	-	980	196	316	198	61	194	484	567	263	97	113	25	790	316
2	40	166	280	175	134	616	354	187	121	39	114	304	188	85	348	302	125	215
3	785	27	757	362	383	312	3118	652	880	506	396	267	1020	752	1018	1157	628	754
4	1884	3010	0[4]	1184	399	1506	839	4502	0[4]	0[4]	1190	463	1036	1044	1022	1693	0[4]	1428
5+	2047	1952	3374	2110	1847	1727	3324	2224	5106	5506	3017	6020	4109	2488	1666	2398	4980	2891
TOTAL	4755	5155	4412	3831	2763	4161	7636	7763	6169	6244	5201	7622	6616	4467	4167	5574	6523	5161
Age 4+ males[2]	2243	3235	1784	1771	938	1526	1549	4956	3916	2804	3317	4263	3454	1755	1211	1032	3276	2424
Primiparous[3]	889	736	728	817	678	551	870	786	771	1739	892	1492	1324	930	281	860	659	868
Multiparous	647	991	863	706	630	1188	1698	1183	480	1157	482	1295	630	945	1309	2224	1835	885
Total females	1535	1727	1591	1523	1308	1739	2568	1969	1251	2896	1374	2787	1954	1875	1590	3084	2494	1753

1 Belly-bag.
2 Total population less ages 2,3 males, transitionals and females, i.e. males that will potentially change to females the following year.
3 Includes transitionals.
4 Four year olds of the 1996 and 2002, 2003 year classes were not distinguishable in the MIX analysis. These year classes appear to be small and are contained in the ages 3 or 5+ categories.

Table 6. Survey biomasses, commercial shrimp catches and exploitation rates (catch/biomass) by offshore survey strata areas (13-15) and the inshore survey strata area (17), 1998-2014.

Parameters	stratum	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Biomass (mt)	**13**	7188	9517	5866	4089	3114	7047	12184	9687	6129	7507	4144	6208	2688	4537	6011	7970	8204	6324
	14	11279	11040	9364	12325	12020	12035	20228	20035	18929	15957	12710	20544	16009	14614	10941	17682	11801	13984
	15	4549	7807	7268	2073	2766	3751	4399	4378	5130	5345	4227	7235	4784	4223	4232	2594	3022	4975
	17	9530	8262	9365	6541	2872	5296	11627	10333	7581	9622	9823	11438	13731	7136	6793	11136	15765	8086
Total		**32546**	**36626**	**31863**	**25028**	**20773**	**28130**	**48438**	**44433**	**37769**	**38431**	**30904**	**45424**	**37212**	**30510**	**27978**	**39381**	**38791**	**33401**
Catch (mt)	**13**	517	616	233	432	270	585	2011	1145	630	85	212	11	125	4	0	0	438	445
	14	2029	1516	1750	1206	1552	1621	752	1372	1998	2640	2696	2026	1844	2309	2126	2509	2283	1897
	15	486	442	915	965	247	226	338	613	444	612	534	540	1123	982	694	407	192	631
	17	899	2276	2538	2165	874	333	168	515	915	1245	879	900	1490	1062	827	688	1002	983
Total		**3931**	**4851**	**5436**	**4768**	**2943**	**2765**	**3268**	**3645**	**3986**	**4582**	**4321**	**3477**	**4581**	**4358**	**3647**	**3604**	**3916**	**3955**
Exploitation (%)	**13**	7.2	6.5	4.0	10.6	8.7	8.3	16.5	11.8	10.3	1.1	5.1	0.2	4.6	0.1	0.0	0.0	5.3	6.8
	14	18.0	13.7	18.7	9.8	12.9	13.5	3.7	6.8	10.6	16.5	21.2	9.9	11.5	15.8	19.4	14.2	19.3	15.0
	15	10.7	5.7	12.6	46.6	8.9	6.0	7.7	14.0	8.6	11.5	12.6	7.5	23.5	23.3	16.4	15.7	6.4	12.9
	17	9.4	27.5	27.1	33.1	30.4	6.3	1.4	5.0	12.1	12.9	8.9	7.9	10.9	14.9	12.2	6.2	6.4	12.8
Total		**12.1**	**13.2**	**17.1**	**19.1**	**14.2**	**9.8**	**6.7**	**8.2**	**10.6**	**11.9**	**14.0**	**7.7**	**12.3**	**14.3**	**13.0**	**9.2**	**10.1**	**12.4**

Table 7. Fish bycatch of the commercial shrimp fishery from observer data of 22 sets from 2014. Weights may be overestimated due to data collection restrictions (minimum recorded weight is 1 kg).

Species	Total Catch	
	Est. Weight (kg)	**Total (%)**
Pandalus Borealis	37981	97.14%
Silver Hake	3	0.01%
Herring (Atlantic)	9751	2.49%
Witch Flounder	7	0.02%
Capelin	4	0.01%
American Plaice	5	0.01%
Eelpouts (NS)	5	0.01%
Thorny Skate	1	0.00%
Sand Lances (NS)	3	0.01%
Redfish (Unseparated)	4	0.01%
Turbot, Greenland Halibut	5	0.01%
Alewife	104	0.27%
Pollock	2	0.01%
Haddock	1	0.00%
Bycatch (%)		2.86%

[1] 900 kg of herring were caught in 2 sets.

FIGURES

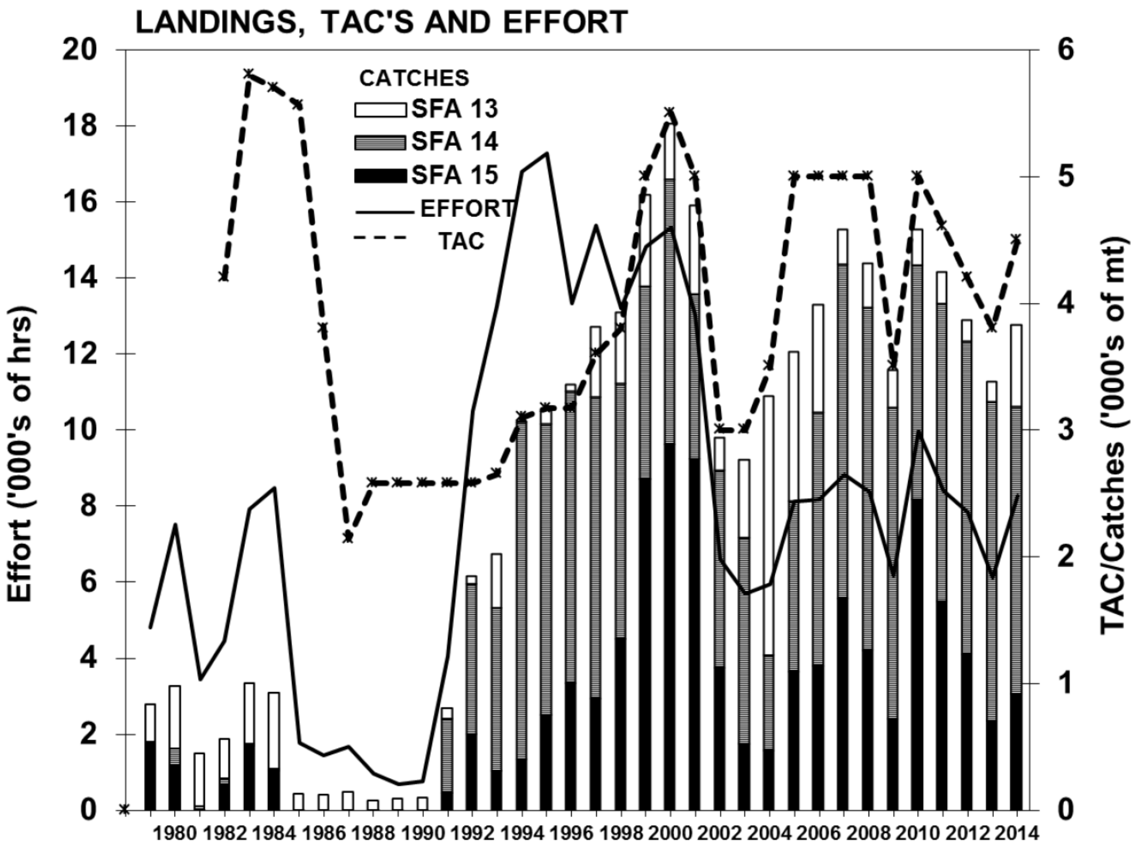


Figure 1. History of eastern Scotian Shelf shrimp fishery catches per SFA (13, 14 and 15), TAC (thousands of mt) and effort (thousands of hours), from 1980-2014.

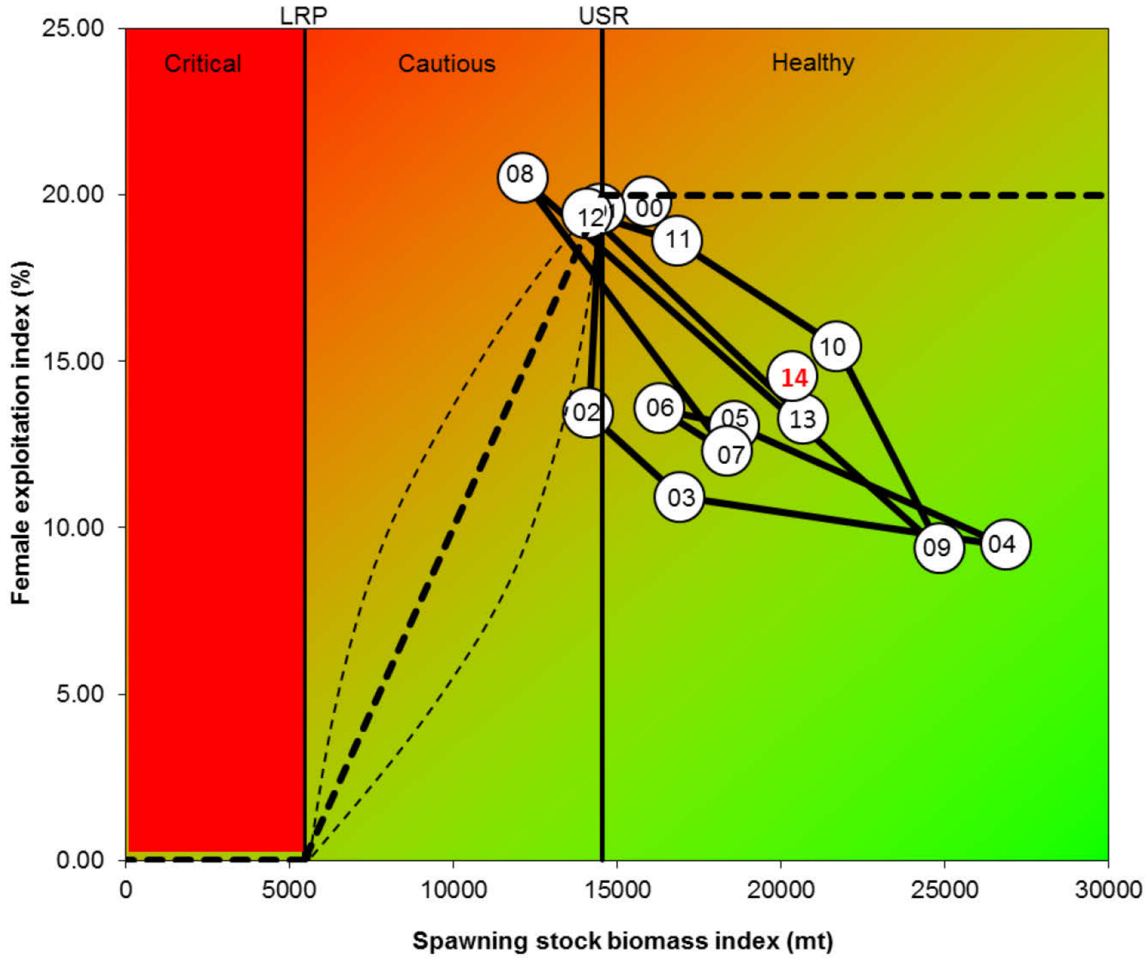


Figure 2. Graphical representation of the Precautionary Approach for Scotian Shelf shrimp. The dotted lines in the cautious zone represent a range of management actions possible, depending on whether the stock is stable, increasing or decreasing, or on trends in other indicators of stock or ecosystem health.

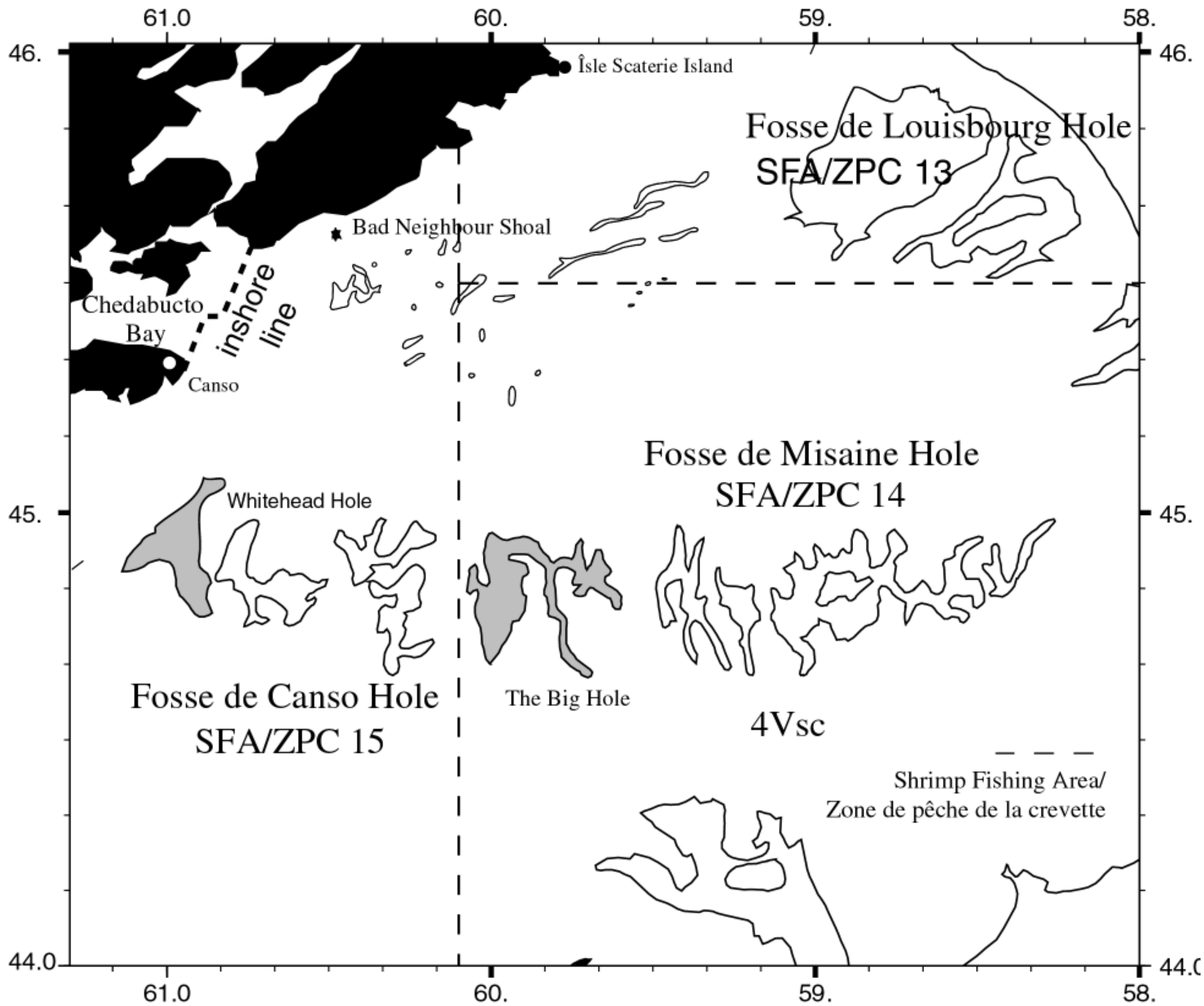


Figure 3. Shrimp Fishing Areas (SFAs) on the eastern Scotian Shelf. The inshore line prohibits trawlers from fishing inside Chedabucto Bay during the trapping season (fall to spring). Note the distinction between SFAs used to report catches and survey strata defined offshore (strata 13, 14, 15) by the 100 fathom contour (solid lines) and inshore (stratum 17) by the extent of LaHave clay north of 45°10' and west of 59°20' on surficial geology maps.

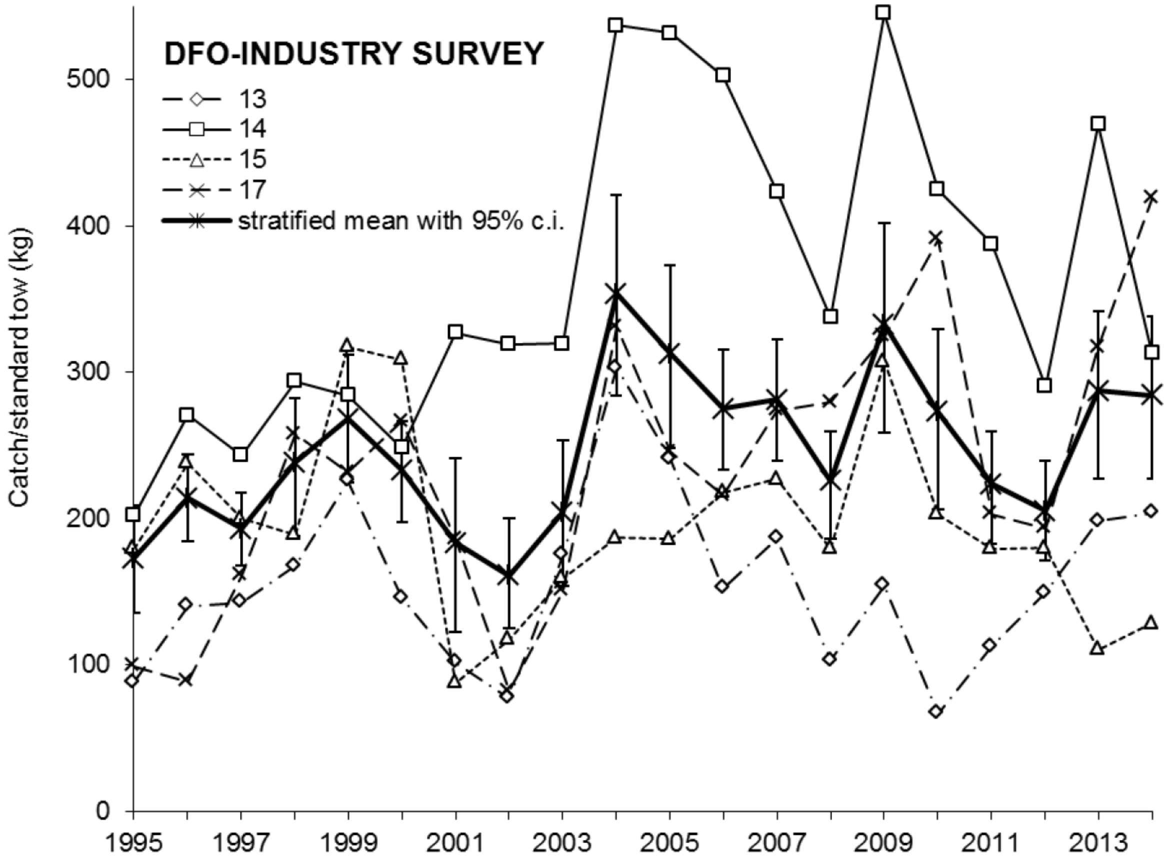


Figure 4. Stratified catch/standard tow for DFO-industry co-operative surveys from 1995-2014, and estimates for the individual strata, which approximately correspond to the main shrimp holes and SFAs. Stratum 13 - Louisbourg Hole and SFA 13; Stratum 14 - Misaine Holes and SFA 14; Stratum 15 - Canso Holes and the offshore part of SFA 15. The 'Inshore', or Stratum 17, is comprised of inshore parts of SFA 13-15.

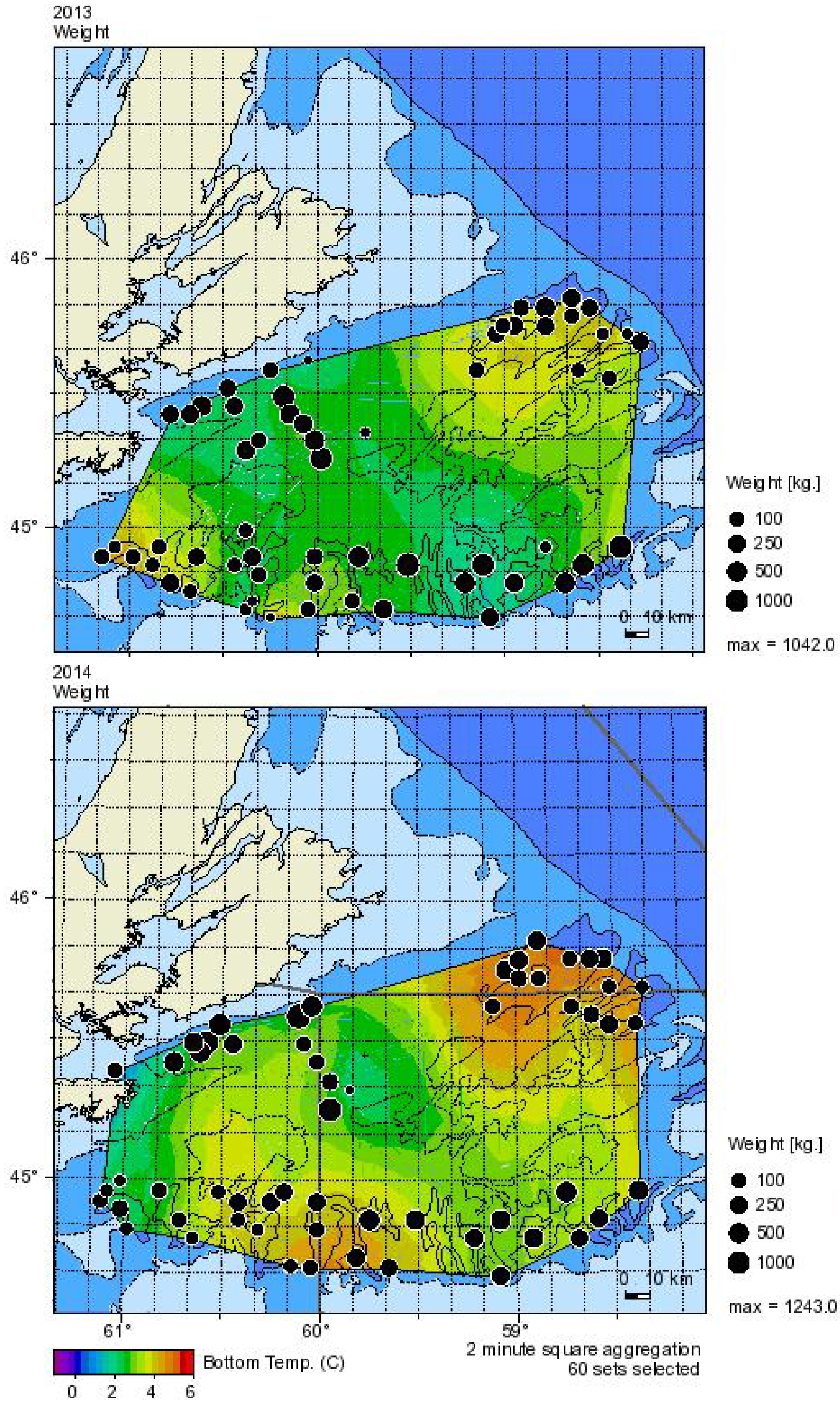


Figure 5. Distribution of catches (kg/standard 30 minute tow) and bottom temperatures from DFO-industry surveys 2013 and 2014. See previous research documents for distributions prior to 2013 (Hardie et al. 2011, 2013a, 2103b).

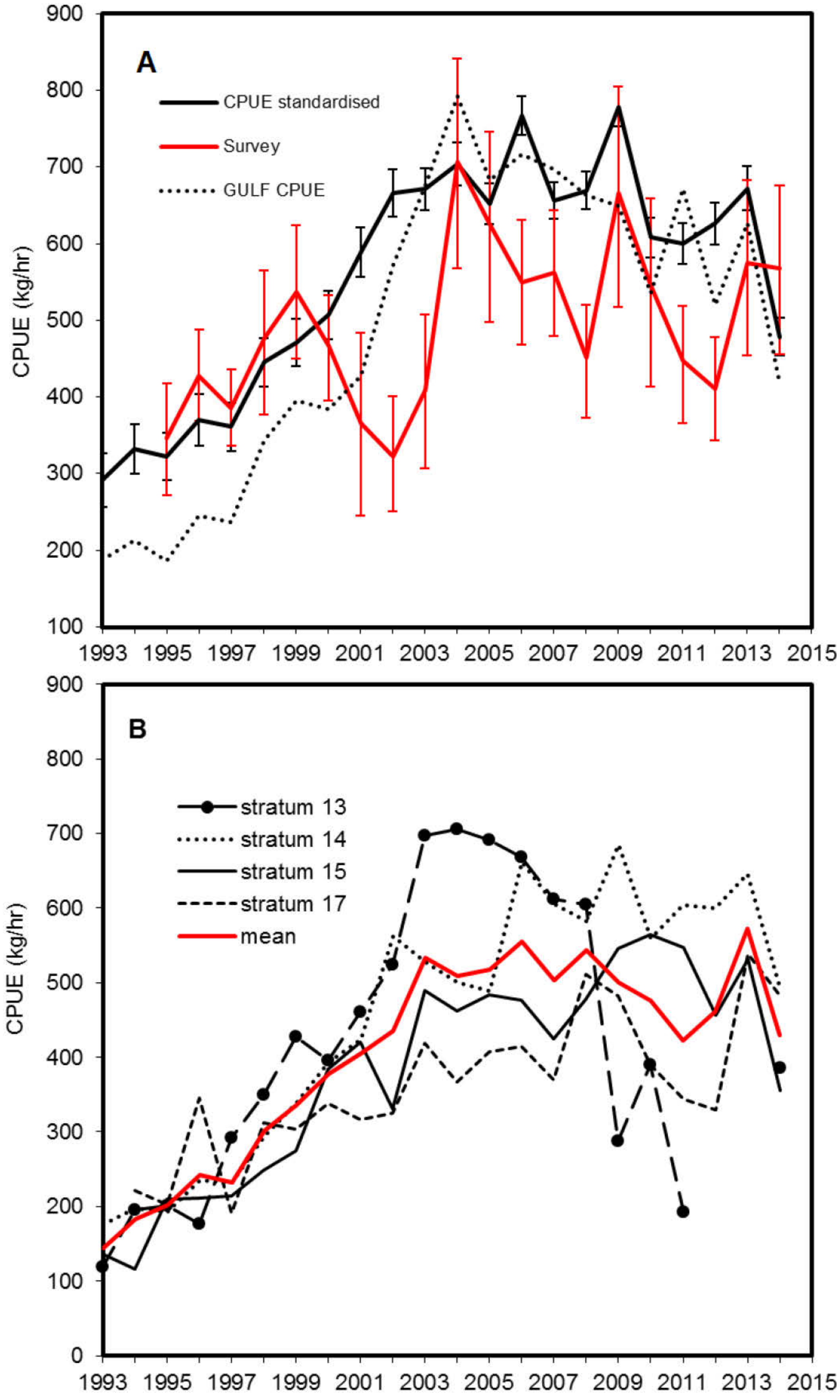


Figure 6. A) Survey stratified catch per unit effort (CPUE) and standardised commercial CPUE with 95% confidence intervals, as well as the unstandardised Gulf vessel CPUE; and B) unstandardised commercial CPUE for each fishing area from 1993-2014. Note that SFA 15 includes the inshore (stratum 17), but stratum 17 is also shown separately, since fishing began there in 1998.

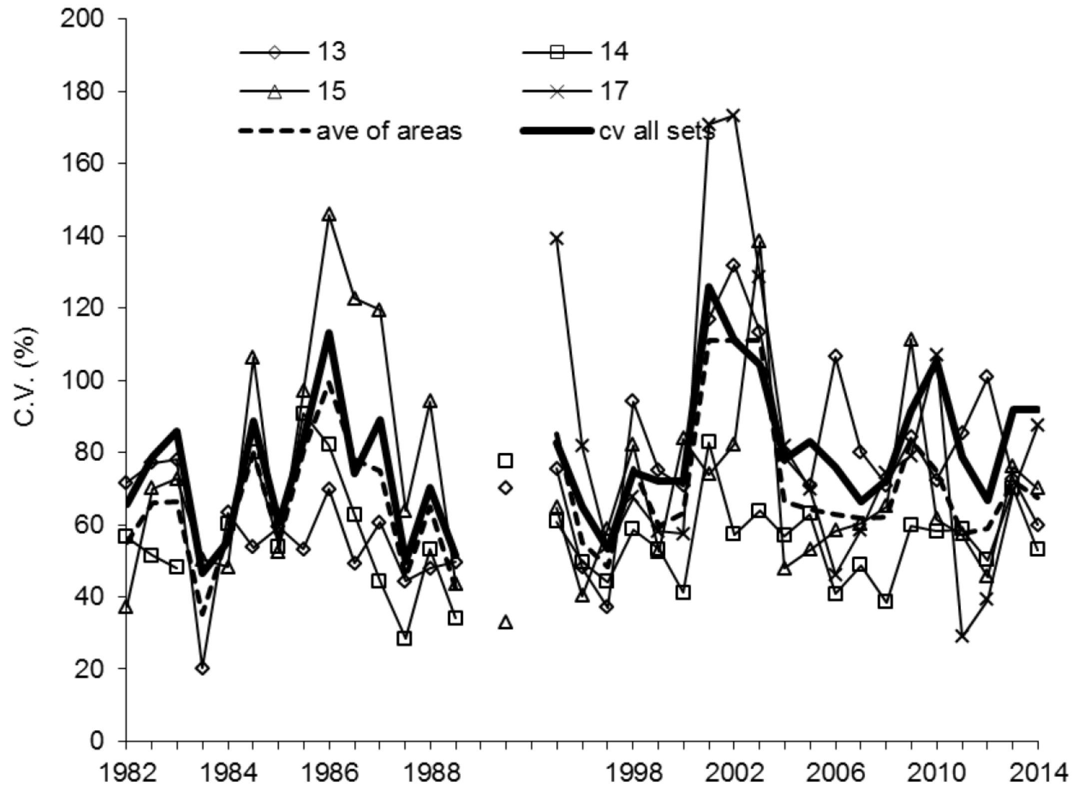


Figure 7. Coefficients of variation (CV) for shrimp survey strata 13, 14, 15, and 17 from 1992-2014. Note that the earlier survey series has two values per year; one for the spring and one for the fall survey. The use of fixed stations in stratum 14 likely acts to constrain interannual changes in CV relative to other areas with random stations.

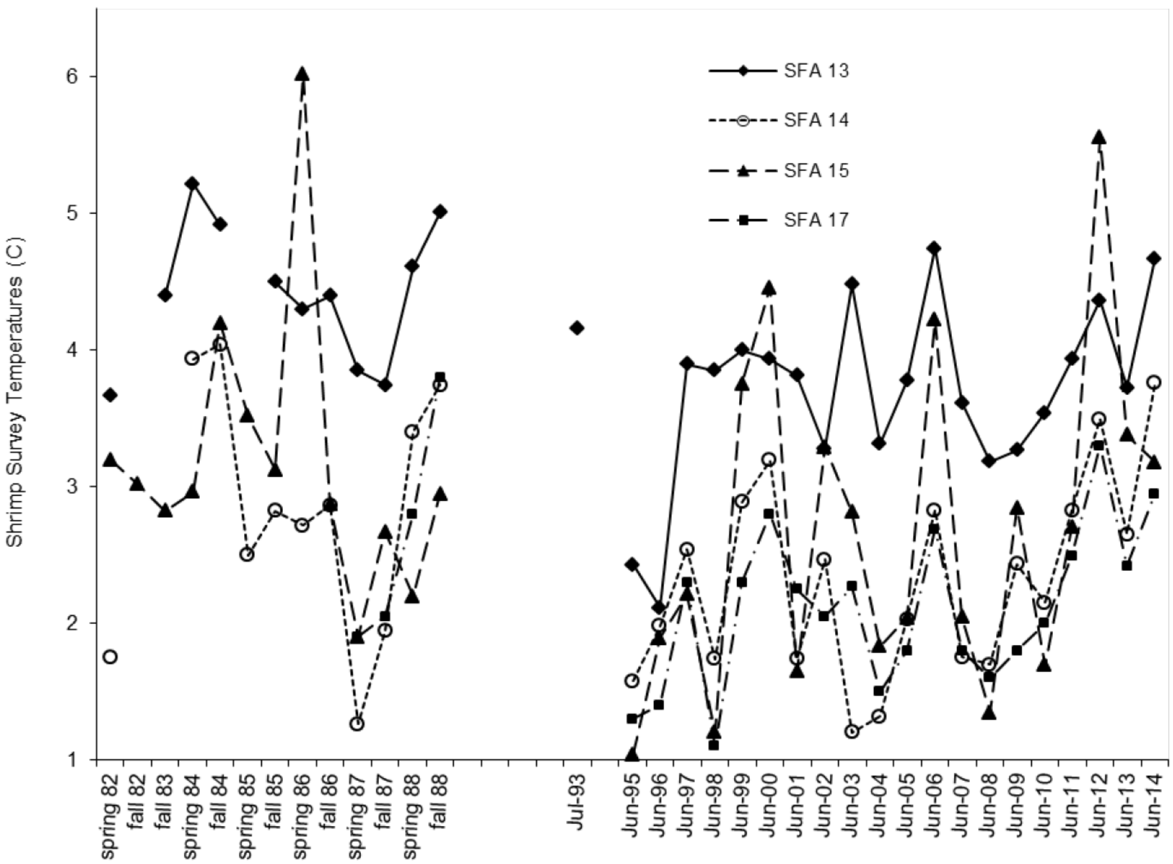


Figure 8. Mean bottom temperatures (°C) from shrimp surveys for strata 13, 14, 15 and 17. Both spring and fall values were available from the earlier series (1982-1988), but only one survey (June) was conducted annually in the recent series.

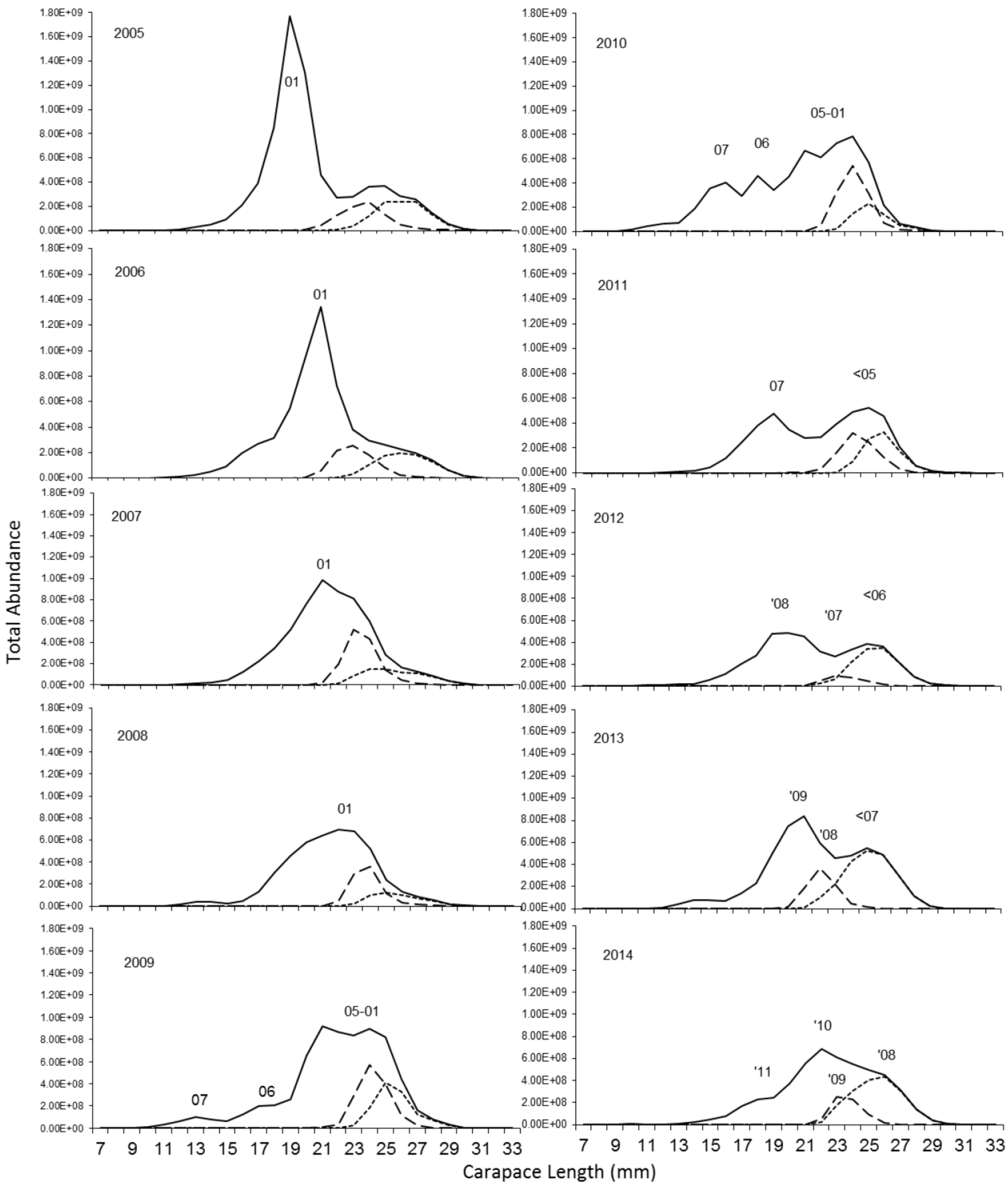


Figure 9. Population estimates at length from DFO-industry surveys for 2005-2014 (solid line). The heavy dotted line in each figure represents transitional and primiparous shrimp. The stippled line represents multiparous shrimp.

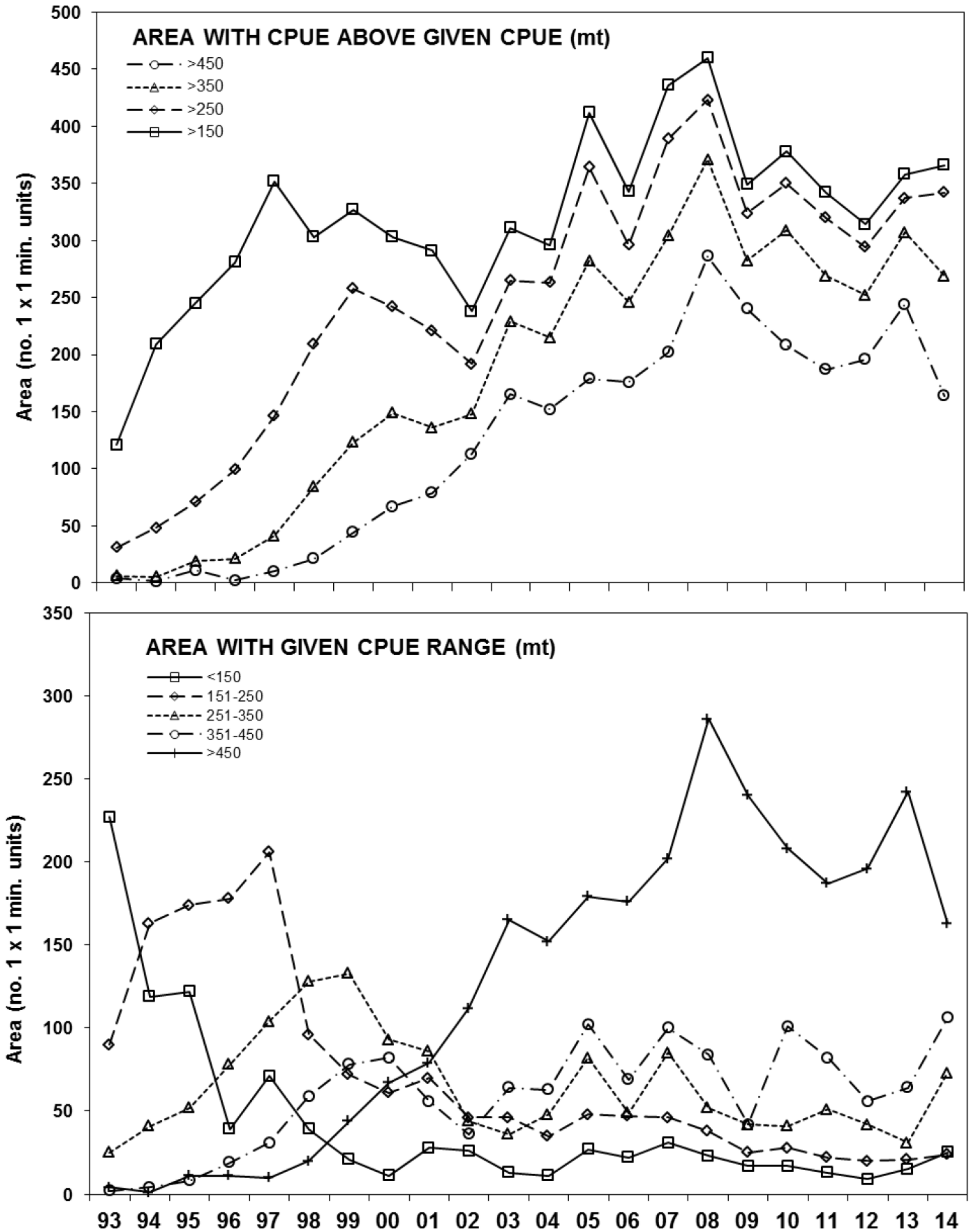
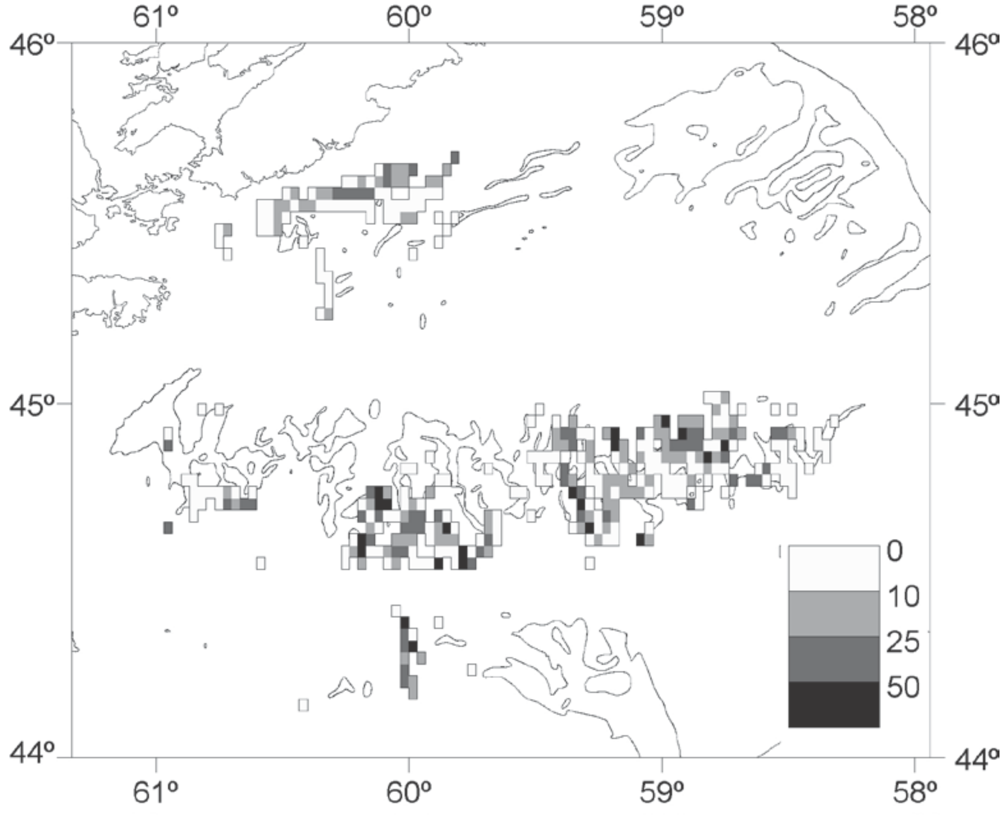


Figure 10. Number of 1-minute square unit areas fished by the shrimp fleet with mean catch rates above (upper panel) and within (lower panel) the values or ranges specified in the figure legend, 1993-2014.



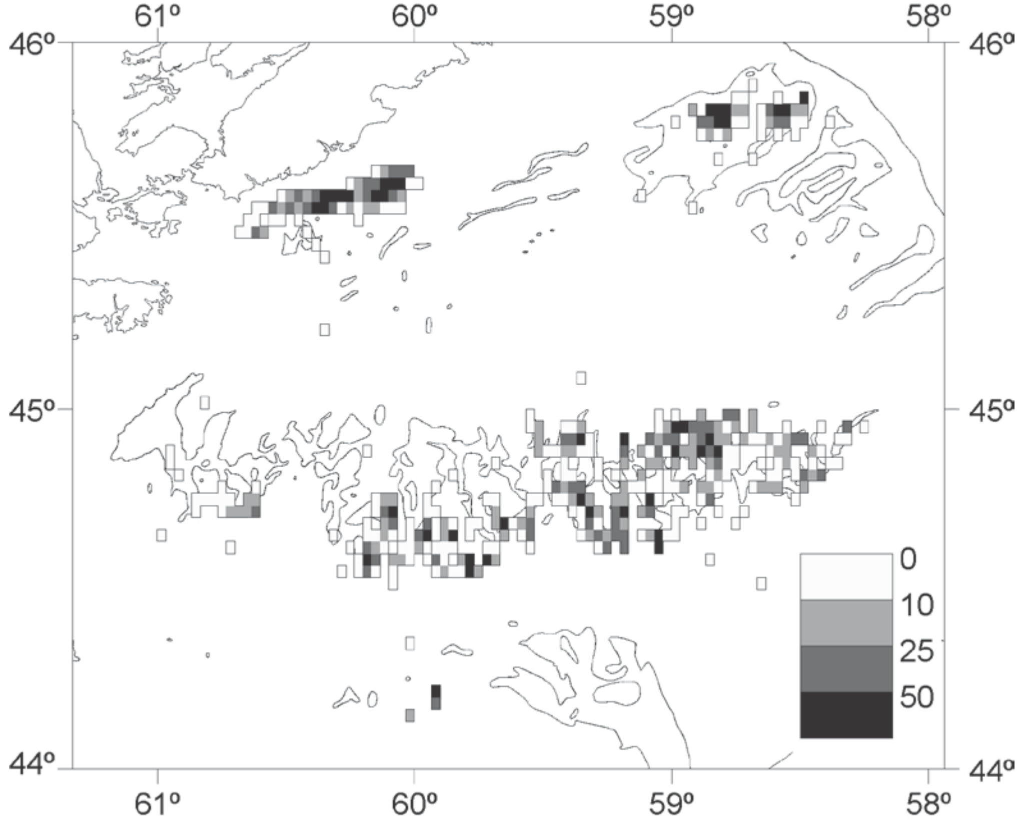


Figure 11. Annual cumulative effort by trawlers in 2013 (upper panel) and in 2014 (lower panel) by 1-minute squares.

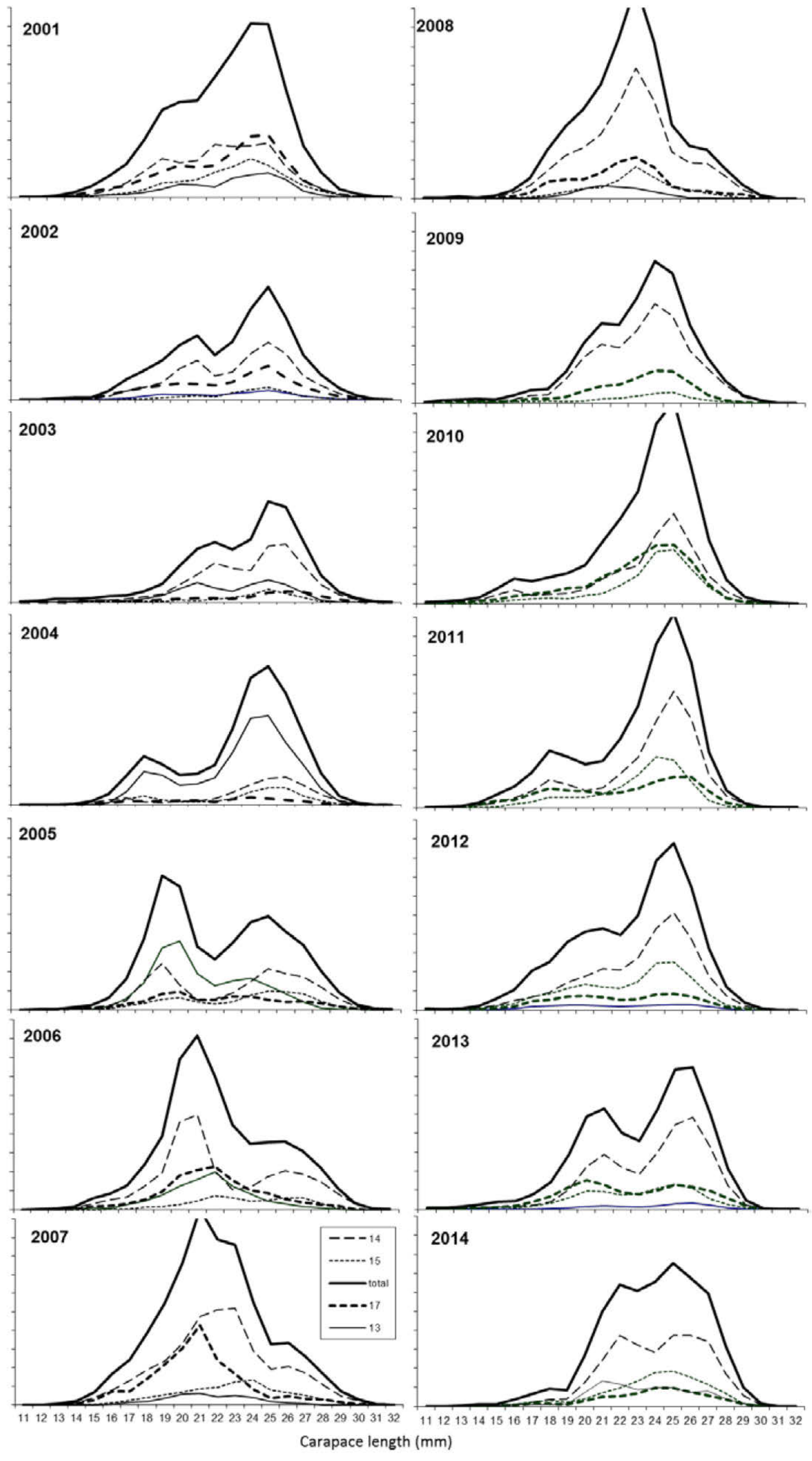


Figure 12. Catch at length from commercial sampling by stratum for 2001-2014.

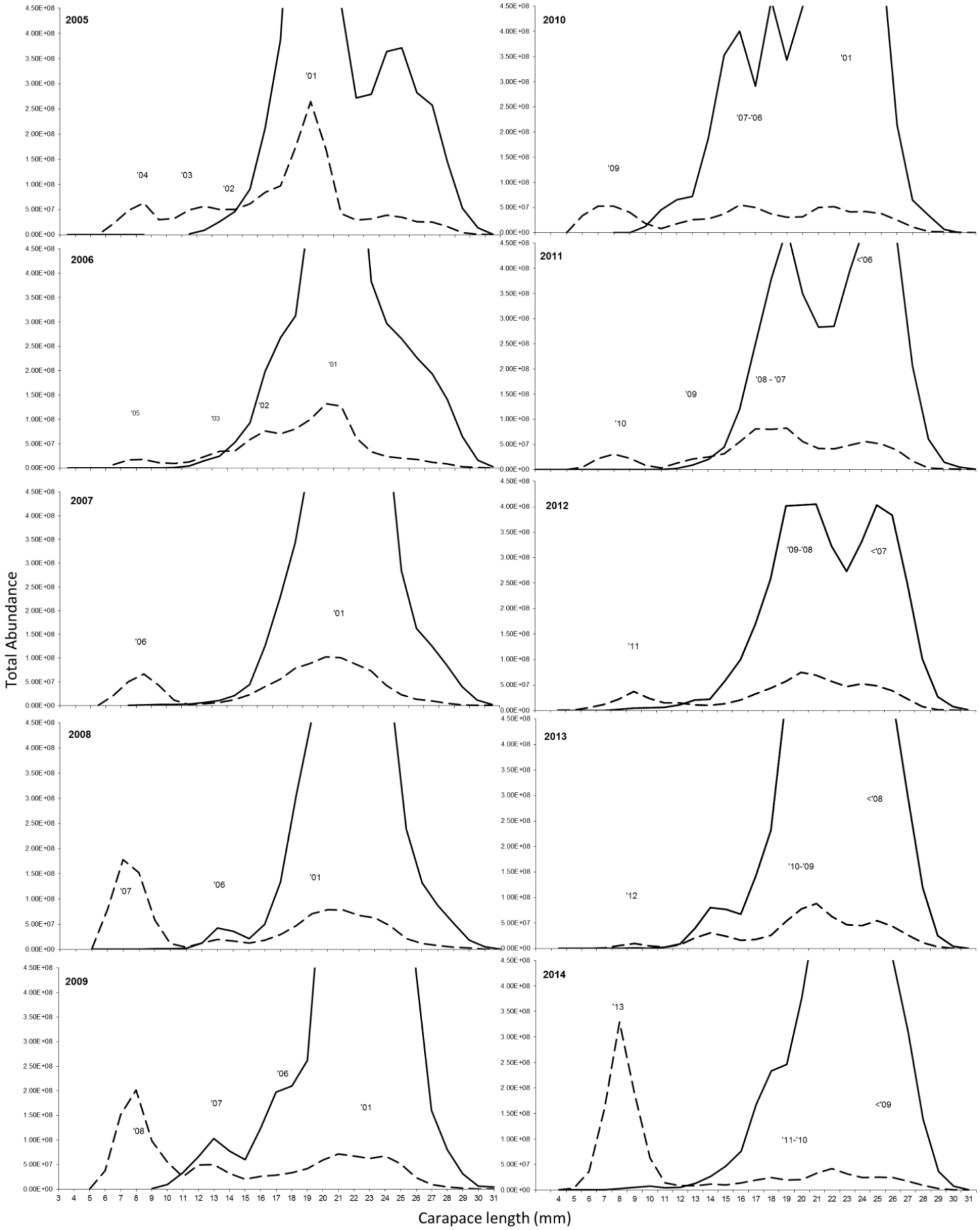


Figure 13. Population estimates from belly-bag (dashed line) and main trawl (solid line) catches for the 2005-2014 surveys.

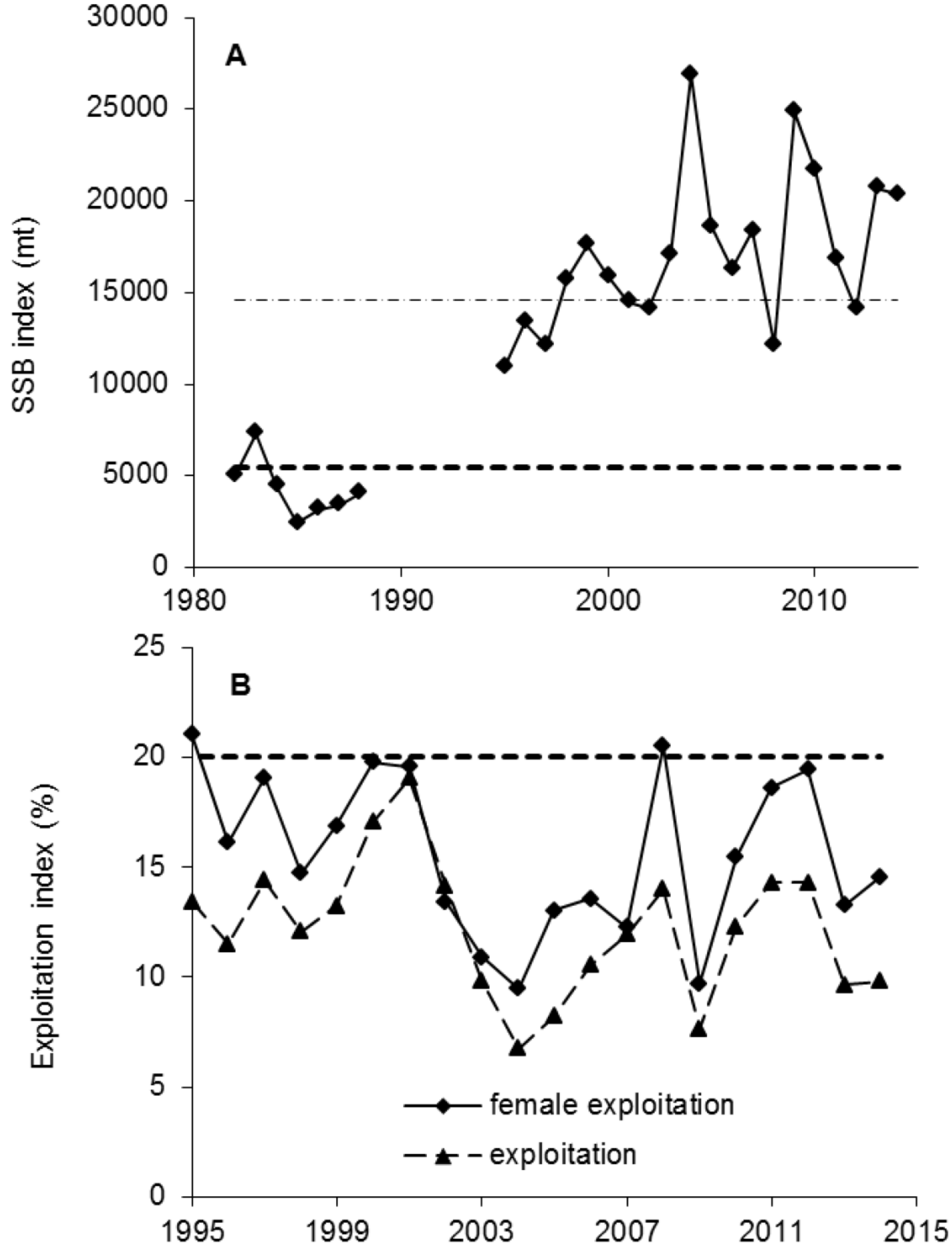


Figure 14. A) Changes in the SSB index (upper panel); and B) the total and female exploitation indices (top panel) for the eastern Scotian Shelf shrimp population. The dashed lines shows the LRP at 30% and URP at 80% of the mean SSB value during the 2000-2010 high-productivity period (upper panel) and the removal reference of 20% for the exploitation index (bottom panel).

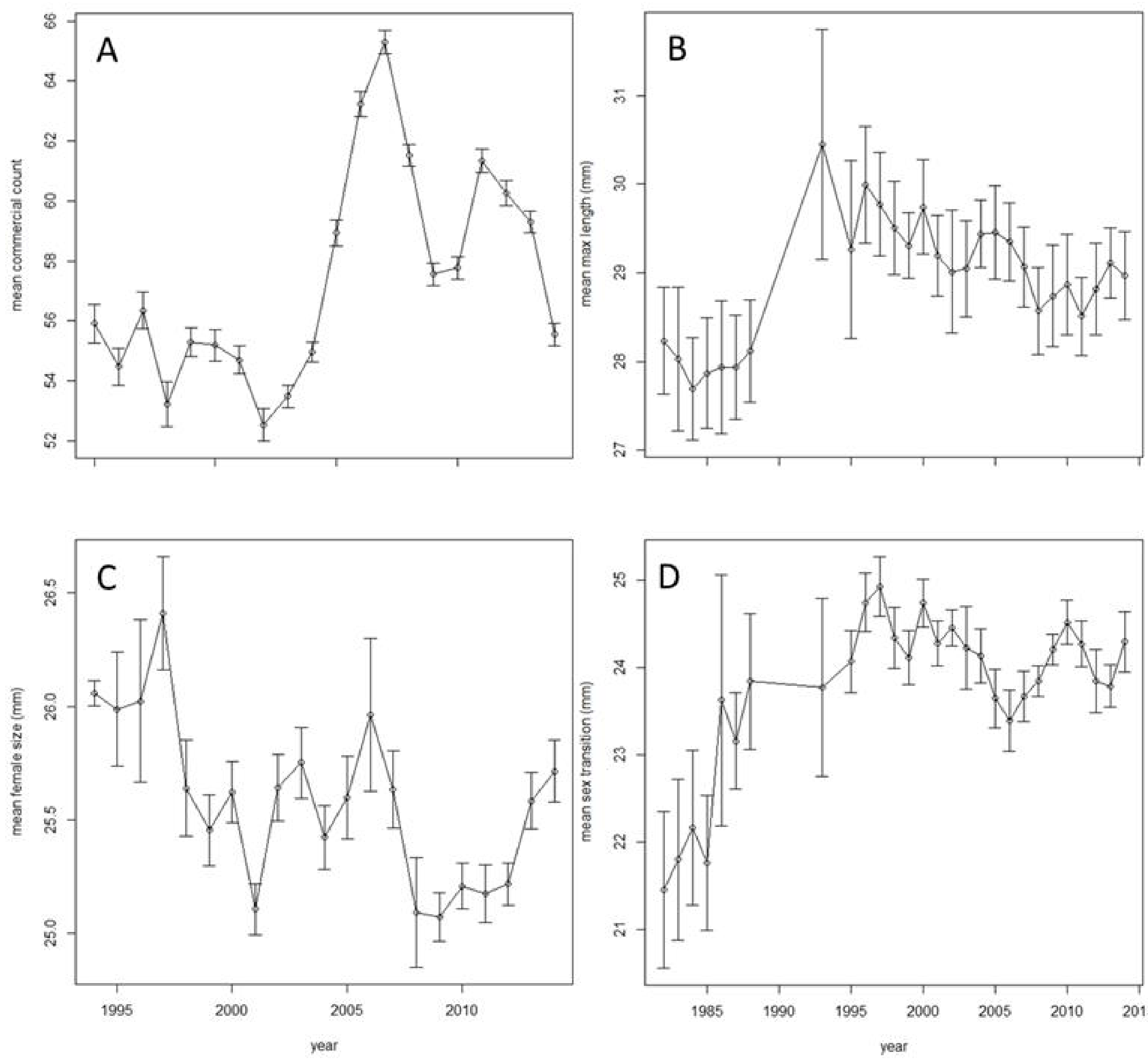


Figure 15. Averages for: A) commercial count (upper left panel); B) maximum length (upper right panel); C) female size (lower left panel); and D) size at sex transition (lower right panel) for all SFAs combined for 1995-2014, with 95% confidence intervals.

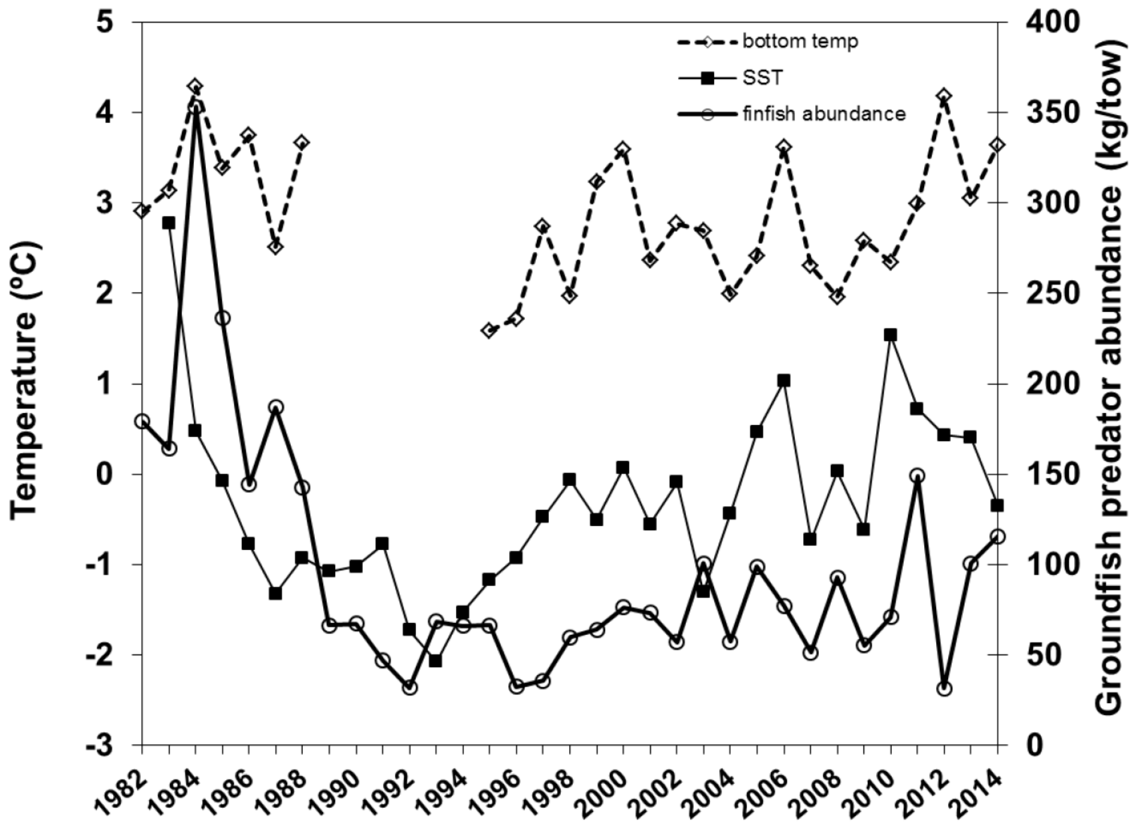


Figure 16. June bottom temperatures (°C) and finfish predator abundance (kg/tow) on the eastern Scotian Shelf shrimp grounds.