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Eastern Scotian Shelf Shrimp (*Pandalus borealis*): 2018–2019

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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.

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ABSTRACT

The DFO-Industry survey stratified mean biomass estimate increased 1% to 23,449 mt (± 4,724 mt, 95% Confidence Interval [CI]) from the 2017 estimate of 23,382 mt (± 6,376 mt, 95% CI). The 2018 Spawning Stock Biomass (SSB, females) point estimate increased 2% to 12,599 mt, and remains below the Upper Stock Reference (USR, 14,558 mt). Based on the Precautionary Approach as it is applied to Eastern Scotian Shelf (ESS) Shrimp, the stock is considered to be in the Cautious Zone. An unchanged Total Allowable Catch (TAC) value in 2018 (2,600 mt) was applied to limit further reductions in total and spawning stock biomasses. This precautionary TAC helped to reduce both total and female exploitation to 10% and 12%, respectively. Commercial Catch Per Unit Effort (CPUE) indices declined by 16% and 4% for the Gulf and Maritimes (Standardized Nova Scotian) fleets, respectively. The trap fishery CPUE index declined by 1%, relative to 2017. The distribution of commercial catch was consistent with an increase in total biomass, with an increase in the number of areas with catch levels from <150 mt to >450 mt. Commercial and survey sample length frequency distributions, combined with modal analysis of survey data, suggest that the fishable stock is currently supported by the more abundant year-class originating between 2013 and 2014. Trends in shrimp size indices were consistent with expectations based on life history and growth rates for shrimp at moderate abundance (i.e., no evidence of slower growth or delayed sex transition that have occurred for this stock during periods with more abundant cohorts/high density). Unlike 2017, the 2018 belly-bag index of Age 1 abundance was found to be moderate. The 2013 year-class, which was first identified by a high belly-bag index in 2014 (second highest in the time series), was evident in the 2017 and 2018 main trawl survey and commercial samples, continuing to suggest good survival and growth of this cohort. Ecosystem characteristic indices suggest that present conditions on the ESS are favorable for shrimp. Bottom temperatures derived from the June shrimp survey are lower in 2018 compared to 2017. There is some stability in indices of abundance of sympatric species, which suggest that the environment is becoming more favorable for cold water species. The overall mean indicator, summarizing 24 indicators, is in the yellow for 2018 after 2 years in the red zone, largely due to positive changes in abundance, combined with increasing indices contributing to production and ecosystem characteristic categories. Small increases in the total and spawning stock biomass indices are consistent with the expectation that the 2013 year-class has recruited to the fishable component of the stock.

INTRODUCTION

The biology of Northern Shrimp, *Pandalus borealis*, is reviewed in Shumway et al. (1985) for various stocks world-wide, and by Koeller (1996, 2000, 2006) and Koeller et al. (2000a, 2003a) for the Eastern Scotian Shelf (ESS) stock. Shrimp on the ESS and in the Gulf of Maine are at the southern extreme of the species' range (concentrated north of 46°N), and, by inference, at the extreme of the species ecological and physiological limits (Koeller 1996). 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 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 (SFA) quotas were removed. Since 1994, the TAC has fluctuated between 2,600 and 5,500 mt. Although 24 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, and when large year-classes are known to be recruiting into 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 ESS Shrimp fishery and recent stock assessments are provided in Koeller et al. (2011), Hardie et al. (2011, 2013a, 2013b, 2015), and Broome et al. (2020).

The ESS Shrimp is assessed on a biennial assessment schedule, with stock assessments conducted every two years and stock status updates completed in the interim years. A stock framework was adopted in February 2015. The status of ESS Shrimp was last assessed in December 2016, followed by a stock status update in December 2017.

The organization of this report is based on a "Traffic Light" Analysis (TLA), 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 analyses and discusses individual indicators grouped under headings representing 4 summary "characteristics": Abundance, Production, Fishery Effects, and Ecosystem. In this document, the "Methods" section provides a description of the data sources, with reference to past documents for detailed indicator calculation methodology. The "Results and Discussion" section addresses the relevance/interpretation of each indicator to the characteristic that it represents. Note that indicators always represent summary data for the entire ESS 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 summarized graphically in Figure 18.

Where appropriate, the interpretation of the indicator time series is supplemented by additional figures and tables. For example, individual SFA data often corroborate the indicator trends and further substantiate them. Supporting data may be independent from the data used to derive the main indicator. For example, catch rates in the shrimp trap fishery supported the increased shrimp aggregation shown by the survey and Catch Per Unit Effort (CPUE) data (2015–2017); 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". 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 a tool for displaying, summarising, and synthesising a large number of relevant yet disparate data sources into a consensus opinion on the health of the stock.

A precautionary approach using reference points and harvest control rules within the context of the TLA (Figure 2) was last reviewed during the DFO Maritimes 2015 Regional Science Advisory Process (DFO 2016a, Hardie et al. 2018). The reference points for ESS Shrimp includes:

Limit Reference Point (LRP): which is 30% of the average female Spawning Stock Biomass (SSB), 5,459 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 ESS Shrimp population previously increased from a low level (approximately 4,300 mt) during the transition from low- to high-productivity, thus assuming that shrimp could recover from this level again given appropriate environmental conditions and fishing pressure (i.e., $B_{recover}$ proxy). Secondly, given the important role of shrimp in the ESS 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). The fishery is closed when SSB levels fall below the LRP.

Upper Stock Reference (USR): which is 80% of the average female SSB, 14,558 mt, maintained during the modern fishery (2000–2010[2]). The USR has been selected at the default value (80%) and serves 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 (RR) Point: The RR for ESS Shrimp is 20% female exploitation (actual female catch/SSB) when in the Healthy Zone (above the USR). This exploitation rate has been exceeded once during the modern fishery (2000–present), a period during which high CPUE and SSB have been maintained. Additionally, given that shrimp survive for approximately 3–4 years after their recruitment to the fishery, it can be approximated that 25–33% of the fishable biomass is subject to natural mortality in any given year. 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. The maximum RR of 20% for shrimp is on the conservative side of the simplistic approximate range of natural mortality (25–33%).

A suite of 24 indicators is used to characterize shrimp Abundance, Production, Fishing Effects, and Environmental Characteristics over time. An interpretation of these indicators provides additional context that informs the advice provided by Science on stock status relative to reference points.

The SFAs on the ESS are shown in Figure 3. Licensing information for the recent period covered under sharing agreements between the Gulf (midshore) and Maritimes (inshore, Nova Scotia) fleets, including the number of active vessels, is shown in Table 2. The fishery currently operates under an ‘evergreen’ Integrated Fisheries Management Plan.

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[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 where these reference points may no longer be suitable.

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 quota was set at 10% of the total TAC, e.g., 500 mt of a 5,000 mt TAC. In years where trap quota allocations were greater than what was possible for the trap fleet to catch, adjustments to the allocated quota were made, which provided the mobile fleet with an increase in their allocation. For example, in 2004, the initial 350 mt was reduced to 200 mt, which was closer to trap fleet catch capacity. The reallocation of the 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. The trap allocation was reduced to 8% in 2005, when trap fishing effort and catch were low during 2005–2010 due to poor market conditions. Market conditions for trap-caught shrimp remain variable. Total trap landings were 65 mt for 2017, and 62 mt (of 208 mt quota allocation) were landed as of November 15, 2018.

METHODS

TRAFFIC LIGHT INDICATORS

A suite of 24 indicators were considered in this analysis. Indicators were assigned a color for each year data were available according to their percentile value relative to the fixed high-productivity 2000–2010 period (Hardie et al. 2018). 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 of this high-productivity period, respectively (DFO 2016a, Hardie et al. 2018). Prior to the 2015 Framework, boundaries were determined relative to the mean of the entire time series for a given indicator (Hardie et al. 2018). If an increase was considered detrimental for stock health, the transition between boundaries was reversed. The “polarity” of the default boundary for the commercial CPUE series should be considered in the context of other indicators. For example, increased CPUE series coupled with increased aggregation and decreased survey abundance would be viewed as a negative development.

Data series vary in length from 17 to 36 years . A detailed description of the calculation of each indicator is described in Hardie et al. (2018). The methods used to calculate the 24 indicators that contribute to the Abundance, Production, Fishing Effects, and Ecosystem characteristics summarised in the TLA are presented annually in reference to the Framework. Indicators are not weighted in terms of their importance, and the group summary and overall indicators are an average of individual indicators. As suggested at the 2015 Framework Review, the Trap CPUE and Total Effort indices has been included since 2016 (DFO 2016a, Hardie et al. 2018). Alternatively, the Capelin abundance index and bottom temperature index derived from the DFO Summer Research Vessel *(*RV*)* Survey have been removed (DFO 2016a, Hardie et al. 2018).

DATA SOURCES

DFO-Industry Cooperative Trawl Survey

The 24th DFO-Industry trawl survey, incorporating a mixed stratified random - fixed station design, was conducted in June 2018. Survey design and station selection methods were similar to annual surveys completed since 1995 (Hardie et al. 2013b, Hardie et al. 2018): fishing depths >100 fathoms (identified using a Digital Elevation Model of the area; Greenlaw and McCurdy 2014), at 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 (updated to GIS shapefile in lieu of scanned chart in 2017 for improved accuracy). The fixed stations in Stratum 14 are assumed to be representative of shrimp abundance throughout the stratum and are, therefore, analyzed the same as the random stations in Strata 13, 15, and 17. The 2018 survey was completed by Marine Vessel *Cody & Kathryn*, which also conducted the survey in 1995, 1998, and 2009–2017. Since 1997, all surveys have used the standard trawl (Gourock #1126 2-bridle shrimp trawl and #9 Bison doors). Additionally, the trawl net is outfitted with a full complement of trawl mensuration sensors that record door spread, headline height, and temperature. biomass/population estimates (swept area method) and bootstrapped confidence intervals (Smith 1997) were calculated using the catch/standard tow (17.4 m × 1.25 nautical miles (nm)), i.e., the actual catch adjusted to the standard by the average measured wing spread (using NETMIND, and in later years eSonar sensors) of the survey trawl during each tow and the actual distance travelled (Halliday and Koeller 1981).

The co-operative DFO-Industry series, initiated in 1995, attempted several different vessel-trawl combinations requiring comparative fishing experiments in 1996–1997 (Koeller et al. 1997) and in 2013 (Hardie et al. 2018). To obtain a wider range of indicator values for this series, it was extended to include surveys conducted in 1982–1988, a period of low abundance, in contrast to the recent period of high abundance. There were 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. It is probable that the trawl used during the recent series was more efficient in catching shrimp than during the 1982–1988 series; thus, 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.

The Atlantic Canadian Mobile Shrimp Association (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 and 2000 hrs (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 summarized below.

- 1995: *Cody & Kathryn* – 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 Capt. Schrader)
- 2010: *Cody & Kathryn* – survey trawl (checked by Capt. 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)
- 2014–2018: *Cody & Kathryn* – survey trawl (new in 2018)

Commercial Catch Data

Data on catch rates were obtained from fishers' logs required from all participants and provided by 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 unstandardized mean catch/hour fished from all Gulf-based vessels in any given year. The shorter time series for the Maritimes fleet is used to estimate a standardised CPUE series from 1993 to 2018 derived from commercial catch data for the 28 (<65', Nova Scotia based) vessels that have fished for at least 7 of the 26 years. Standardised CPUE data were limited to April to July inclusive, the months when the bulk of the TAC is generally caught. A generalized linear model was used to standardize 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 Core Development Team 2005). The data fit best to a Gaussian distribution (lowest Akaike Information Criterion (AIC) value). Commercial counts (number of shrimp per pound) are also obtained from commercial logs.

Detailed Shrimp Analysis (Survey and Port Samples)

A random sample of approximately 10 lbs 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, and vessels >65' landing mainly in Arichat), and frozen for detailed analysis (i.e., carapace length, individual weight, sex, presence of parasite/diseases, spine condition, egg developmental stages, and presence of head roe). A total of 120 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. Because of the timing of the shrimp assessment relative to the collection and analysis of commercial samples, advice provided during past assessment processes (prior to 2012) may have been based on only a portion of the samples. Steps have been taken to expedite the analysis of samples. In 2018, all 120 survey samples and 29 commercial samples were included in this analysis.

Length Frequency Analysis

Survey population estimates were determined by the swept area method using individual set length frequencies, 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 a modal analysis ("*mixdist*" in R; Macdonald and Pitcher 1979). The data are initially assigned to 3 alternate age bin allocations (5, 6, and 7). The modal analysis for 2018 was assigned to 7 age bins, which are interpreted as corresponding to Ages 2–8. Age 1 is inferred through the belly bag analysis. Modes corresponding to older ages are binned together as 5+ because the assignment of ages would be highly subjective for Age 5 and older. Fitting the data to 7 ages provided a highly significant fit to the 2018 length frequency distribution (Chi-square, $p<0.001$).

Shrimp Size Indicators

There are 4 indicators considered for shrimp size: mean maximum size, mean size at sex transition, mean female size, and commercial counts (see details in Hardie et al. 2018). 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. (2018), and now includes 95% confidence intervals as a metric of uncertainty.

Ecosystem Data

Bottom temperature data are recorded in 2 ways during each shrimp survey over the last 4 years. First, a continuous temperature recorder (Minilog, Vemco Ltd.) is attached to the Port trawl door (previously attached to the trawl headline as the primary source of data). Secondly, the headline eSonar sensor is used. The data collected from eSonar sensors are optimized then averaged per tow. The Minilog data is saved as a backup in case tows have incomplete or no data available. Satellite data are used to estimate Sea Surface Temperatures (SST) within defined areas encompassing the shrimp holes for the last 2 weeks in February to the first 2 weeks in March (Figure 4). Predation, Cod, and Greenland Halibut (Turbot) recruitment indices are derived from the DFO Summer RV Survey strata encompassing the shrimp holes (Strata 443–445 and 459, details in Hardie et al. 2018). These indices could not be updated in 2018 due to operational limitations, creating a break in the 36-year time series. The Snow Crab recruitment index, as described in Hardie et al. (2018), is derived from the DFO-Industry Snow Crab survey. This index is shifted forward by one year in the TLA (e.g., 2017 value used for 2018) since the current-year value is typically unavailable for the shrimp assessment.

BYCATCH

Introduction of the Nordmøre separator grate in 1991 reduced bycatch and allowed the fishery to expand to its present size. Bycatch estimates are extrapolated from at-sea observer sampling during commercial fishing trips. Target coverage is 3 trips annually, which represents 3% coverage by trip. In 2018, sampling coverage was not met, as only 2 trips were collected. Low bycatch amounts (1.5 and <1%, 2017 and 2018, respectively) from observer coverage of 55 commercial sets from 2017 (2 trips) and 2018 (2 trips) suggest that the fleet's trawl configurations, including the use of the Nordmøre separator grate, continue to ensure low total bycatch by weight (Table 7). These bycatch values are likely over-estimated due to the minimum 1 kg weight recorded by the observers, per all observed species per set (e.g., a single Sand Lance would be recorded as 1 kg despite weighing only a few grams). Since 2015–16, reported total bycatch by weight from observed trips has been decreasing, while sampling frequency has remained consistent. The 2018 observed trips occurred during the spring/summer and covered portions of SFAs 13 (1 set only), 14 (28 sets), and 15 (3 sets). Observer coverage of SFA 13 has been minimal to nil for a number of years. Nonetheless, the ESS mobile shrimp fishery is considered to pose little risk in terms of bycatch amount or species-composition.

RESULTS AND DISCUSSION

PRECAUTIONARY APPROACH

The SSB (females) and female exploitation indices are reported in the TLA (below), but these indices also define stock and removal reference points for ESS Shrimp. The SSB is not a measure of reproductive capacity. Due to the relationship between fecundity and size, and the range of shrimp size in response to fluctuations in density, temperature, and growth rate, the

"Auxiliary Data" provided by the Traffic Light Indicators should be carefully considered when interpreting the reference points depicted in Figure 2.

Traffic Light Analysis

Input data for the TLA are provided in Table 3. Individual indicators are discussed in the sections below, grouped under the characteristics previously described. Individual indicators are shown in Figure 18, while summary characteristics and the overall mean summary indicator are shown in Figure 19.

ABUNDANCE

Survey Abundance Index

The DFO-Industry survey stratified mean biomass estimate for 2018 represents a total biomass of 23,449 mt (using the swept area method), which is relatively stable from the 2017 estimate of 23,382 mt. Total biomass estimates have been declining since 2015. A reduced decline was observed in 2017 and steadied in 2018. The distribution of survey catches during the last two years is shown in Figure 6. Biomass estimates declined by approximately 15% and 8% in Strata 14 and 15, respectively; however, the biomass estimates increased for Strata 13 (29%), and Strata 17 (2%) (Table 6). Relative to the available survey time series, Strata 13 and 17 remain at moderate biomass levels, while Strata 14 and 15 are currently at historic lows (Figures 5 and 7, Tables 4 and 6). An overall biomass increase was anticipated given that the 2013 year-class recruitment was expected to provide a higher contribution than the previously limited years (2009–2012) (DFO 2014, DFO 2015, DFO 2016b, Hardie et al. 2018, DFO 2018).

Interpretation*:* Less abundant Age 0 year-classes from 2009 to 2012 caused declining biomass from 2015–2017. In 2013, a stronger year-class was observed, and it is now entering the fishable component of the stock and has attenuated biomass decline. This abundant 2013–2014 year-class is expected to reach the end of its lifespan in 2020–2021 and no longer contribute to the fishable biomass. The decline in the 2017 survey abundance index corroborates the standardized CPUE index that has decreased since 2016; however, the marginal increase in 2018 is not yet supported by the CPUE index.

Gulf Vessels Catch Per Unit Effort

The Gulf vessels are the largest 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 important time series spans periods of both high and low abundance of the stock. 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 and high abundances should be interpreted cautiously. The unstandardized Gulf vessel CPUE showed an increasing trend through the 1990s, peaking in 2004, and has since been variable with an overall decreasing trend.

Interpretation: The 2018 value declined 16% from 2017 and has not been this low since the late 1990s (Figure 7A). The standardized CPUE of the Nova Scotian fleet, despite temporal and spatial variation in fishing activity, shows a similar overall trend to the Gulf CPUE index.

Commercial Trawler Standardised Catch Per Unit Effort

In general, the survey, Gulf, and standardized commercial CPUE-based indicators have followed similar trends over the time series. There have been four notable divergences between commercial CPUEs and the shrimp survey CPUE in the recent time series (i.e., high commercial

CPUEs despite declining survey CPUE in 2000–2003, 2006–2008, 2012, and 2015–2016; Figure 7A). For 2018, the slight divergence is characterized by an increase in survey CPUE, while the commercial CPUE is still decreasing. This can likely be attributed to distributional changes associated with the abundant 2013 year-class now contributing to the fishery. For the last three years, effort has also been decreasing and coincides with the onset of annual TAC decreases/maintenance.

Interpretation: The 2017 standardized CPUE indicator value decreased by 35% from 2016, while the 2018 value decreased by 4%. This reduced rate of decrease is likely attributable to the entry of the 2013 year-class into the fishery. The decrease in the standardized commercial CPUE, coupled with the increase in the survey CPUE, suggest lower catch rates due to increased stock dispersion, which coincides with a reduced TAC.

Trap Catch per Trap Hour

The trap Catch per Trap Hour (CPTH) index was incorporated following the 2015 framework review. The trap fishery CPTH, which provides an additional fishery-dependent abundance indicator, is derived from different gear and is spatially and temporally distinct from the trawl fishery catch indices. The trap fishery was made permanent in 1999 and, since 2005, the trap allocation has remained at 8% of the total TAC (Table 1). The trap fishery is competitive and consists of 14 licenses (7 active in 2018) that are restricted to Chedabucto Bay (Figure 3). Trap fishing effort and catch were very low during 2005–2010 due to poor market conditions. Market conditions have improved but remain variable year to year. The trap fleet landed 65 mt in 2017, and 62 mt has been landed as of November 15, 2018 (fishing is ongoing).

Interpretation: Based on preliminary catch results (mostly from spring), the 2018 trap CPTH index declined 1% relative to 2017. Reductions in the trap CPTH index may reflect reductions in large female shrimp from the introduction of the 2013 year-class into the fishery; however, the influence of external factors on this fleet should not be overlooked, as variation may be more closely linked to market conditions. The fall portion of catches is usually included the following year due to data inaccessibility and timing of the fishery when providing the annual updates.

Survey Coefficient of Variation

The survey measure of dispersion is calculated by quantifying the overall Coefficient of Variation (CV) and has generally remained high. An increase in this index describes a situation where the fishery may be maintaining high catch rates on high-density aggregations of a declining resource, while the survey indicates patchiness in the distribution of shrimp. Values in 2013 to 2015 were very consistent, followed by a slight decline in 2016 (Figure 8). The 2017 value was one of the highest since 2010, suggesting stock aggregation. In 2018, increases in CV were found in Strata 13–14, but the CV values for Strata 15 and 17 decreased. The CV value in Stratum 17 decreased by almost half from 2017 to 2018, while the CV value in Stratum 15 remained stable relative to the available time series (Figure 8). The number of stations used to calculate the survey CV have been consistent since 2006.

Interpretation: A reduction from relatively high CV of survey catches suggest dispersion of stock aggregations. This is supported by a slight increase in the total and spawning stock biomass indices described above. Further, temperatures have decreased in all survey strata since 2016 (Figure 17), providing an additional explanation for changes in stock distribution.

Commercial Fishing Area

This measure of dispersion is particularly important when survey indices are decreasing while commercial catch rates continue to increase. Currently, survey indices are stabilizing from declines since 2015 (+1% in 2018), while commercial catch rates are decreasing (Figure 7A). Increases in the commercial fishing area index indicate dispersal of stock biomass across a larger area.

Interpretation: Areas with commercial catch rates >250 kg/h forms the basis of the commercial fishing area index. These areas had been declining since 2015; however, the 2018 commercial catch rates values shows an increase in areas (Figure 9, top panel). The distribution of catch rates is consistent with an increase in the availability of the resource, where areas of very high to moderate catch rates have also increased (Figure 9). The maintenance of a lower TAC in 2018 is supported by an overall spatial distribution of effort that was similar in 2017 and 2018 (Figure 10). Effort was focused on SFA 14 in both years, with reduced effort in SFA 15 in 2018 (Figure 10).

PRODUCTION

Survey Belly-bag Abundance at Age 1

This index has exhibited a dynamic range over the 17-year time series. The index signalled the strength of the 2001, 2007–2008, and 2013 year-classes 2 years before they began to appeared in commercial catches, and as many as 5 years before they were fully recruited to the fishery (Figures 11 to 13, Table 5). These recruitment pulses indicate recruitment cycles that approximately equal the species' life-span. The appearance of recruitment cycles of different lengths suggest a stock recruitment relationship may exist (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, subsequently followed by very low values in 2015 to 2017 (Table 5, Figure 12).

Interpretation: Belly-bag index values for 2016 and 2017 were consistent and low, suggesting poor survival over the past two seasons; however, the value for 2018 shows an increase in Age 1 recruitment relative to the last few years (Table 5). The 2013 year-class, which was observed at approximately the same level as the 2001 year-class in the 2014 survey, has been monitored closely. This cohort has been tracked into the Age 2 indicator in 2015 and was evident within the 2015 and 2016 survey and commercial catch data (Table 5, Figures 11–13). Its continued growth was tracked into the Age 4 indicator in 2017 and is expected to recruit to the SSB over the 2018–2019 seasons. Various ecosystem factors are also understood to influence shrimp recruitment (e.g., spring sea-surface temperatures and predator abundance; see below).

Survey Abundance at Age 2

Although the length-frequency modal analysis tends to define the Age 2 mode, it is possible that this Shrimp size is under sampled by the main survey trawl. The index of Age 2 shrimp declined from 2015 to 2016, indicating that the 2013 year-class, as observed in the 2014 belly-bag Age 1 index, had now grown into the Age 5+ size class in 2018 (Table 5). In 2017, Age 2 shrimp increased from 2016 but decreased again in 2018.

Interpretation: Trends between indices of Age 1 and Age 2 abundance have traditionally been ambiguous (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). However, this was not the case for the 2015 indicator, which detected the abundant 2013 year-class. The low value of the 2016 Age 2 indicator was consistent with the low 2015 belly-bag Age 1 indicator. The 2016 belly-bag Age 1 indicator was nearly less than half of the 2015 value; however, the 2017 Age 2 indicator was higher than expected. The 2017 belly-bag Age 1 indicator was again low, followed by a low 2018 Age 2 indicator value.

Survey Abundance at Age 4

The 2017 Age 4 shrimp abundance was above the 20-year mean (Table 5); however, decreased in 2018. The 2017 Age 4 value increased due to the 2013 year-class though to a lesser magnitude given the previously qualified scale of this recruitment pulse. The decrease in the Age 4 indicator observed in 2018 is expected given the lower belly-bag index of the 2014 year-class.

Interpretation: The Age 4 modes for 2017 (representing the 2013 year-class) and 2018 (representing the 2014 year-class) were found at moderate levels that should contribute to the SSB over the 2018–2019 seasons.

Survey Spawning Stock Biomass (Females)

A clear stock-recruitment relationship has not yet been described for ESS Shrimp, although it has been for some other pandalid stocks (Hannah 1995, Boutillier and Bond 2000). Beginning in the late 1980s, SSB had increased from approximately 4,300 mt to values nearly 3-fold higher by the mid-1990s. These increases occurred under specific environmental conditions (cold water temperatures and decreasing natural mortality due to reduced predation) and negligible fishing mortalities. While stock abundance has increased from a low of 4,300 mt, a more conservative value (5,459 mt) is used as the LRP. Multiparous females typically do not spawn annually; thus, SSB is not considered a measure of reproductive capacity. Since fecundity is directly related to size, SSB should be considered in conjunction with the shrimp size indicators.

Interpretation: Spawning stock biomass estimates declined 7% in 2017 and increased 2% in 2018. The relatively high SSB observed in 2013 and 2014 is consistent with the completed recruitment of the abundant 2007–2008 year-classes. The subsequent declines in the SSB in 2015 and 2016 are indicative of the limited overall recruitment from 2009–2012 year-classes, and therefore low overall biomass of mature females. In 2018, the SSB increase suggests the 2013 year-class has begun contributing to the overall biomass of mature females. The SSB estimate for 2018 (12,599 mt) remains below the USR (14,558 mt), placing the stock within the Cautious Zone for the third consecutive year (Figures 2 and 14A).

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 has been declining since 2015. This decline slowed in 2018 and may indicate a positive change in population biomass/density (Figure 15D).

Interpretation: Declines in mean size at sex transition have averaged 1.6% from 2015 to 2017. The 2018 value has remained stable (declined by <0.5%) from 2017.

Average Maximum Size (L_{max})

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 *Pandalus borealis* (Charnov and Skúladóttir 2000). This rule was shown to apply to the ESS (Koeller et al. 2003b, Koeller 2006). Consequently, maximum size attained in the population is an indicator of growth (i.e. 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 2017 and 2018 index values were within the range of uncertainty for these data in recent years (Figure 15B).

Interpretation: The mean maximum size index has been relatively stable over the recent time period, which may signal moderate stock levels maintaining this mean size index.

Predation

Finfish abundance is negatively correlated with shrimp abundance on the ESS and in most other shrimp fishing areas. This index is used as a proxy of natural mortality and has varied considerably since 2002.

Interpretation: Following a decline in 2015, the index returned to a relatively high value in 2016 and increased again in 2017 by 15% (Figure 16). The 2018 value is not available; but, relative to the last 5 years (2013 onward), predation is expected to have remained high.

FISHING IMPACTS

Effort

The total trawl fleet effort was added as an index following the 2015 framework review and provides an additional indicator to the fishery impact characteristic. The total effort exerted by the ESS trawl fleet can serve (in concert with the Commercial Fishing Area index) to further support inferences regarding stock dispersion/aggregation and is relevant in reviewing and comparing commercial catch rate index values between successive years. The overall effort exerted in a season is influenced strongly by TAC level and can also be further affected by fleet dynamics and environmental factors. This index is expected to be most informative in years where there is little to no change in the TAC.

Interpretation: The total trawl effort declined approximately 3% from 2017 to 2018. This decline is consistent with the TAC remaining unchanged for the 2018 season (Table 3).

Commercial Counts

This indicator is a measure of the ease 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 is an abundance of small shrimp, or
- b) the population of larger shrimp is declining, or
- a combination of a) and b).

Moreover, an increase in this indicator can be considered positive (increased recruitment) or negative (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. Counts may 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: Following a decrease in 2014, to the lowest value in over a decade, commercial counts increased in 2015 and remained stable into 2016 (Figure 15A). In 2017, another decrease was observed, and the 2018 value is lower than what was described in 2014. The bulk of the tabulated counts are from data collected early in spring. With the contribution of the 2013 year-class of smaller size shrimp, the commercial count was expected to increase in 2018;

however, this was not observed in our analysis. The relatively low residual abundance from the 2009–2012 year-classes may have had a larger presence in the spring, which may have biased the count. Additionally, the counts come from few fishermen relative to fleet participation, and also from limited area coverage.

Exploitation Index

The survey total 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 likely 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 assumed to be similar to commercial gear. The biomass used to estimate exploitation can be considered a point estimate of “fishable biomass”. Assuming the entire TAC of 2,600 mt is caught in 2018 (2,410 mt (93%) caught as of November 15, 2018) the total exploitation index was approximately 10%, relatively stable since 2017 (Table 6, Figure 14).

Interpretation: The stability in total exploitation index for 2018 reflects the 2018 TAC (2,600 mt), to offset the 9% reduction in the 2017 biomass estimate. This precautionary measure was implemented with the expectation that the 2013 year-class would contribute to the fishable and spawning stock biomass in 2018.

Female Exploitation Rate

Since the shrimp fishery is selective for larger females, female exploitation can be considered one measure of fishing impact on the reproductive potential of the stock. Based on 2018 preliminary data, female exploitation (12%) decreased from 2017 and remains below the 20% RR (Figures 2 and 14B).

Interpretation: Like total exploitation, the reduction in female exploitation relative to 2017 reflects the unchanged precautionary 2018 TAC.

Mean Size of Females in Catch

A decrease in this indicator value can 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. The average size of females in the catch has generally declined from the early years of the fishery as the larger animals were selectively and continually removed from the population.

Interpretation: Increases in this index for 2017 and 2018 follow 2 years of a decreasing trend. This increase is likely attributable to the smaller bodied 2013-class females’ abundance relative to the declining abundance of the larger-bodied 2009–2012 year-classes (Figure 15C).

Proportion of Females in Catch

The proportion of females in the catch has been relatively stable at a high value since 2009 (Table 3). Following a decline in 2015, the index briefly rebounded in 2016 then continued to decline in 2017. In 2018, the index is stable relative to 2017 levels (Figure 10). The 2018 increase likely reflects the recruitment of the 2013 year-class to the female population with consistent fishery removals from 2017 to 2018.

Interpretation: The relative stability of this index at a high value in recent years reflects the fact that the population has been dominated by older, primarily female, shrimp with relatively poor succeeding year-classes (fewer males). This supposition is supported by the survey and commercial length-frequency distributions (Figures 11–13).

ECOSYSTEM

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 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 (Shumway et al. 1985). Recent work has indicated that colder bottom temperatures increase egg incubation times resulting in delayed hatching times, which align more favorably with optimum spring growing conditions (warmer surface water and the spring phytoplankton bloom) (Koeller et al. 2009). On the ESS, the large shrimp population increase that occurred from the mid-1980s to the mid-1990s was 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 to 1995, 2001, and 2007 to 2008 year-classes). Since 1995, bottom temperatures have an overall increasing trend (Figure 16).

Bottom temperatures on the shrimp grounds were relatively high during the 1980s, when the shrimp population was low, and temperatures were low during the population increase of the 1990s (Figures 16–17). Warmer temperatures in 2005, 2006, and 2009–2015 are consistent with the low belly-bag index results in 2006, 2007, and 2010–2016, respectively. However, despite warm bottom and spring sea-surface temperatures in 2013, the belly-bag index result from 2014 was found at the second highest value in the time series (Figure 17, Table 5). Bottom temperatures during the shrimp survey have shown a decreasing trend since 2016 and are at comparable lower levels observed in the recent time series (>1995) (Figures 16–17).

Interpretation: The reduced value of this index, since 2016, highlight the favorable overall conditions for ESS Shrimp and improves prospects for stronger recruitment from the 2017 and 2018 year-classes under these conditions.

Spring Sea Surface Temperatures

Negative correlations between Sea Surface Temperature (SSTs) and lagged population estimates (four to five years in Gulf of Maine) are common for the southern *P. borealis* stocks, including the ESS. This may be related to water-column stability and the match-mismatch of resulting phytoplankton bloom conditions with hatching times as hypothesized by Ouellet et al. (2007). Accordingly, SSTs used in this index were averages for a period encompassing average hatching times on the ESS (mid-February to mid-March).

Interpretation: Spring surface temperatures declined from 2010–2015 but increased in 2016 (Figure 16). In 2017–2018, SSTs have declined and combined with colder bottom temperatures indicate that conditions are currently favorable for shrimp.

Cod Recruitment

Cod abundance is generally negatively correlated with shrimp abundance for most North Atlantic stocks, including the ESS. This is 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) decreased to a very low level in 2014 but returned to values generally consistent with the recent time series in 2017. An update was not available for 2018.

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

Turbot (Greenland Halibut) Recruitment

Turbot, or Greenland Halibut, is a cold-water species whose abundance is often positively correlated with shrimp abundance. Turbot are also known predators of shrimp, so an increase in this indicator is both positive and negative. Restricting this indicator to juvenile Turbot may decrease the influence of predation and provide more predictive value for shrimp abundance. Turbot <30 cm peaked in abundance on the ESS in 2005–2006 and have since stabilized at relatively low levels.

Interpretation: The Turbot recruitment index decreased in 2017 and has remained relatively stable at low levels over the past decade. An update was not available for 2018, but similar to the other sympatric cold-water species, the recent/current environmental conditions are suggested to be favourable for Turbot recruitment.

Snow Crab Recruitment

As with Turbot, Snow Crab abundance tends 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 seen gradual declines since 2010.

Interpretation: The increasing trend in Snow Crab recruitment in the last 2 years adds further support to suggest that environmental conditions on the ESS may be gradually becoming favorable for the recruitment of sympatric cold-water species.

TRAFFIC LIGHT SUMMARY

Precautionary Note: The overall summary and characteristic summary values are derived by an averaging process that does not account for complex interactions that may be occurring between indicators. Consequently, the interpretation of individual indicators in relation to stock health must be approached cautiously.

The overall mean of the characteristics in the summary Traffic Light indicator has increased to the yellow zone after hovering at the red zone threshold for the last 2 years (Figure 19). The Abundance characteristic indicator also increased and remains in the red zone due to several previous declines in total abundance, the Standardised CPUE index, and reductions in commercial catch rate area. The increase in Abundance is mainly driven by a decrease in CV and an increase in commercial catch rate areas for 2018 (Figure 18). The Production characteristic indicator increased, but remains in the red zone due to declines in the abundance of young shrimp associated with poor juvenile recruitment (declines in Age 2 and Age 4 abundance indices); however, increases in recruitment (belly-bag Age 1) and SSB provide positive signs for productivity in 2018. The Fishing Effects characteristic indicator increased and is in the green zone for 2018. The improvement can be attributed to declines in total and female exploitation due to the precautionary TAC measures implemented since 2016 and is reflected by increases in total and spawning stock biomass. The Ecosystem characteristic indicator increased and is just below the green zone threshold due to lower bottom and spring SSTs, and more favorable conditions indices for sympatric cold-water species (Turbot and Snow Crab).

SOURCES OF UNCERTAINTY

Interruptions in the collection of the data used in this assessment (the Snow Crab and DFO Summer RV surveys) prevents the annual update of some indicators. The 2018 DFO Summer RV Survey was incomplete due to mechanical issues with the vessel, resulting in a break in the

36-year time series that prevented the update of the predator indicator, Atlantic Cod recruitment, and Turbot abundance.

The DFO-Industry survey results are associated with high variances and biases associated with survey gear changes. 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 early June to try to mitigate this effect. In 2007–2008, problems with NETMIND distance sensors and data logging required the use of historical average instead of actual wing spread data to calculate swept areas and abundance.

Given the inability to accurately age Shrimp, modal groups are assigned to age classes a process that is subjective, particularly for larger individuals. Growth rates can change dramatically due to density dependence, as happened with the strong 2001 and 2007–2008 year-classes. Consequently, recruitment to the fishery can be delayed and spread over 2 to 3 years.

Commercial abundance indices are susceptible to logistic, economic, analytical, and other factors that influence index values in ways that may be unrelated to Shrimp abundance. For example, periods of bad weather or abundant sea ice or targeting large Shrimp for market reasons can cause low CPUEs. The standardised commercial CPUE index subsamples the data for vessels that meet certain criteria, which can also result in particularly successful or unsuccessful vessels influencing this index in ways that may be unrelated to Shrimp abundance in any given year.

Unforeseen changes in the ecosystem (specifically predator abundance) and the environment (specifically water temperature) increase the difficulty of making long-term projections for this stock. This is particularly challenging when increased predator abundance and water temperature co-occur.

Finally, because of the timing of the Shrimp assessment relative to the collection and analysis of commercial samples, advice provided during past assessments (prior to 2012) may have been based on only a portion of the samples. Steps have been taken to expedite the analysis of samples, and, in 2018, all 120 survey samples and 29 commercial samples were included in the assessment.

CONCLUSIONS AND ADVICE

The 2018 DFO-Industry survey stratified mean biomass estimate increased by <1% to 23,449 (± 4,724 95% CI). The point estimate of the 2018 SSB (12,599 mt) increased 2% and remains below the USR (14,558 mt), placing this stock within the Cautious Zone for the third consecutive year. These declines are consistent with the expectation of a lag between the mortality of the 2009–2012-year-classes, and the recruitment of the 2013 year-class.

Despite a marginal increase in the survey abundance index, commercial CPUEs remained at a low level (standardized CPUE decreased 4%, Gulf-based vessels declined by 16%). The distribution of areas representing various catch rate levels have all increased for 2018, which in combination with the increase in the survey abundance index, is consistent with a stabilizing resource.

Belly-bag Age 1 abundance indices in 2017 and 2018 highlight poor recruitment from the 2016 year-class and moderate recruitment for the 2017 year-classes, which is consistent with the expectation that lower temperature conditions are promoting favorable recruitment. The abundance of Age 2 and Age 4 shrimp also decreased in 2018, which is consistent with the low belly-bag index in 2017 (representing the 2016 year-class), and 2015 (representing the 2014 year-class). The abundant 2013 year-class increased the index of abundance of Age 4 male shrimp in 2017. Assuming continued growth and survival, the 2013 year-class has been recruiting to the spawning stock biomass during 2018–2019.

Size-based indicators (average maximum size and female size) demonstrate that the size of shrimp has been increasing in recent years, although the overall trend is declining. It is anticipated that the expected lifespan of the 2009-2012 year-classes has been reached since larger than average females are less abundant, and have been replaced by smaller size shrimp from the 2013 year-class recruiting to the fishing population.

Ecosystem indicators were primarily influenced by temperature trends as 2 of 3 sympatric species trends were not updated for 2018. The consistent decrease in temperatures and an increase in Snow Crab recruitment in the last few years, suggest that conditions are currently favourable for cold-water species such as shrimp.

The overall mean indicator, summarizing the 24 indicators, increased and is now in the yellow zone in 2018 after 2 years of being in the red zone. The fishing effects characteristic decreased for the third consecutive year in 2018. The unchanged precautionary 2018 TAC kept overall effort low and further decreased total and female exploitation indices relative to 2017.

Increases in abundance, production, and ecosystem indicators, in combination with decreases in exploitation indices in fishing effects, provides a favorable outlook for 2019. While Age 4+ males will increase in 2019, it is uncertain whether this will translate into an increase in the total biomass index. The 2013 year-class is expected to contribute to the SSB at least until 2020. Continuation of similar catch levels as in 2018 for 2019 would help maintain low exploitation rates and protect more of the 2013 year-class recruiting to the SSB.

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TABLES

Table 1. Total Allowable Catch (TAC) and catches for both (trawls and traps) from the Eastern Scotian Shelf Shrimp fishery (SFAs 13–15), 1980–2018. Cells with dashes indicate no data.

	TAC	TAC	Trawl Catch				Trap	Total
Year	Trawl	Trap	SFA 13	SFA 14	SFA 15	Total	Catch	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	4140	360	771	2265	1045	4081	250	4332
2015	4140	360	341	2069	1702	4112	314	4426
2016	2990	260	177	2094	721	2992	106	3098
2017	2392	208	277	1948	150	2375	65	2440
2018[4]	2392	208	293	1927	128	2349	62	2410
2018[5]	2392	208	276	1985	131	2992	208	2600

Notes:

[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 15, 2018).
[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.

	Trap	Trawl	
Year	Scotia-Fundy[1]	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	8(14)	10(28)	5(14)
2015	9(14)	10(28)	5(14)
2016	7(14)	10(28)	4(14)
2017	8(14)	9(28)	4(14)
2018	7(14)	9(28)	5(14)

Notes:

[1] All but one active trap licences are vessels <45'. They currently receive 8% of the Total Allowable Catch (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. Note: NAN = not a number.

Indicator	RV_CPUE	G_CPUE	St_CPUE	Trap_CPUE	RV_CPUE	Comm_area	RV_SSB	BB_1	RV_2	RV_4	sex_mm	max_mm	pred	effort	count	Exp_tot	Exp_fem	fem_prop	fem_size	RV_temp	Spring_SST	Cod_R	Turbot	Snow Crab
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	0.66	0.33	0.66	0.66	0.66	0.66	0.66	0.66	0.33	0.33	0.33	0.33	0.33	0.33	0.66	0.66	0.33	0.33	0.33	0.66	0.66
Level_RY	0.33	0.33	0.33	0.33	0.66	0.33	0.33	0.33	0.33	0.33	0.33	0.66	0.66	0.66	0.66	0.66	0.66	0.33	0.33	0.66	0.66	0.66	0.33	0.33
Characteristic	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	Trap_CPUE	RV_CV	Comm_area	RVSSB	BB_1	RV_2	RV_4	sex_mm	max_mm	pred	effort	count	Exp_tot	Exp_fem	fem_prop	fem_size	RV_temp	Spring SST	Cod_R	Turbot	snow_c
1982	34.50	128.00	NAN	NAN	89.06	NAN	5040.65	NAN	NAN	NAN	21.46	28.24	178.70	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	2.38	0.00	NAN
1983	71.50	127.70	NAN	NAN	78.52	NAN	7323.05	NAN	NAN	NAN	21.80	28.03	163.58	NAN	NAN	NAN	NAN	NAN	NAN	NAN	2.78	2.42	0.00	NAN
1984	39.00	109.50	NAN	NAN	75.84	NAN	4460.96	NAN	NAN	NAN	22.17	27.69	351.26	NAN	NAN	NAN	NAN	NAN	NAN	NAN	0.48	5.57	0.06	NAN
1985	17.00	75.40	NAN	NAN	83.09	NAN	2417.71	NAN	NAN	NAN	21.77	27.87	235.95	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-0.07	1.71	0.05	NAN
1986	23.00	87.30	NAN	NAN	106.13	NAN	3187.87	NAN	NAN	NAN	23.63	27.94	142.90	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-0.77	0.37	0.09	NAN
1987	25.50	90.70	NAN	NAN	67.53	NAN	3424.46	NAN	NAN	NAN	23.16	27.94	186.55	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.32	0.87	0.16	NAN
1988	31.50	85.10	NAN	NAN	60.14	NAN	4047.02	NAN	NAN	NAN	23.84	28.12	140.46	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-0.92	1.19	0.06	NAN
1989	NAN	133.40	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	65.53	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.07	1.75	0.00	NAN
1990	NAN	134.50	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	66.55	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.02	1.16	0.00	NAN
1991	NAN	197.90	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	46.36	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-0.77	0.17	0.46	NAN
1992	NAN	176.30	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	31.01	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.72	0.17	0.08	NAN
1993	75.00	187.89	142.20	NAN	80.33	94	NAN	NAN	NAN	NAN	23.78	30.45	65.57	1325.40	NAN	NAN	NAN	NAN	NAN	NAN	-2.07	0.29	1.86	NAN
1994	NAN	213.52	188.40	NAN	NAN	191	NAN	NAN	NAN	NAN	NAN	NAN	25.50	1680.90	NAN	NAN	NAN	0.89	26.05	NAN	-1.52	0.30	1.98	NAN
1995	173.02	187.02	181.17	NAN	82.84	277	10912.15	NAN	358.50	875.92	24.05	29.27	54.72	1728.50	55.92	13.44	21.04	0.72	26.03	1.59	-1.17	0.54	1.74	NAN
1996	213.92	244.58	224.35	2.21	64.88	410	13368.38	NAN	307.34	1247.63	24.73	29.99	30.51	1334.30	54.47	11.50	16.11	0.68	26.01	1.72	-0.92	0.16	4.78	NAN
1997	193.00	236.26	218.89	2.27	53.46	388	12100.80	NAN	128.85	1257.47	24.94	29.78	33.32	1538.60	56.35	14.41	19.08	0.64	26.44	2.74	-0.47	0.40	2.91	5651.68
1998	238.38	343.73	298.94	1.69	74.42	625	15707.48	NAN	39.89	1883.71	24.33	29.51	39.53	1321.20	53.22	12.08	14.73	0.60	25.68	1.97	-0.06	0.31	0.41	6096.40
1999	268.40	395.70	325.53	2.02	72.20	849	17607.48	NAN	165.63	3010.18	24.08	29.31	42.39	1483.20	55.30	13.24	16.90	0.63	25.46	3.24	-0.50	1.39	1.67	8068.38
2000	233.36	383.66	365.48	2.58	72.00	773	15893.36	NAN	280.34	0.00	24.74	29.74	46.42	1532.40	55.19	17.06	19.79	0.58	25.57	3.60	0.07	0.79	11.44	5324.63
2001	183.32	428.24	443.46	2.94	126.03	708	14475.58	NAN	174.90	1184.11	24.30	29.19	57.45	1302.66	55.12	19.05	19.56	0.63	25.15	2.36	-0.55	1.58	3.66	4348.11
2002	161.40	572.36	523.48	2.90	111.15	524	14133.20	959.56	134.00	399.17	24.45	29.02	32.14	659.48	52.88	14.17	13.43	0.70	25.61	2.77	-0.09	0.32	3.88	2227.76
2003	204.42	675.41	520.72	2.84	104.48	739	17048.27	184.05	576.74	1411.07	24.31	29.05	86.44	569.96	53.52	9.83	10.91	0.73	25.68	2.69	-1.23	1.03	6.69	1908.79
2004	353.70	793.14	549.32	3.42	78.00	783	26856.47	320.40	354.09	839.46	24.14	29.44	46.72	594.10	54.96	6.75	9.48	0.80	25.41	1.99	-0.43	0.64	3.44	1211.28
2005	312.90	683.25	496.53	2.99	83.01	1110	18587.50	179.96	187.02	4502.48	23.63	29.46	71.07	812.09	58.93	8.20	13.05	0.66	25.72	2.41	0.47	0.25	14.00	1511.64
2006	275.20	716.40	614.86	4.34	75.86	903	16288.53	56.99	121.30	0.00	23.39	29.35	65.20	817.33	63.23	10.55	13.57	0.55	25.96	3.62	1.03	0.80	18.92	3096.15
2007	281.20	696.62	507.79	3.60	66.34	1213	18345.54	188.70	39.00	0.00	23.67	29.07	46.29	882.82	65.30	11.92	12.28	0.45	25.70	2.30	-0.73	0.29	7.77	5604.78
2008	226.10	664.07	520.17	4.49	72.25	1243	12119.42	466.65	134.72	1046.18	23.84	28.57	81.09	838.41	61.52	13.98	20.50	0.52	24.98	1.96	0.03	1.24	6.51	5918.59
2009	333.10	648.76	628.16	5.15	91.70	963	24853.59	530.18	304.05	463.00	24.21	28.74	52.61	618.72	57.71	7.65	9.70	0.72	25.06	2.59	-0.61	0.57	5.42	4232.27

Year	RV_CPUE	G_CPUE	St_CPUE	Trap_CPUE	RV_CV	Comm_area	RVSSB	BB_1	RV_2	RV_4	sex_mm	max_mm	pred	effort	count	Exp_tot	Exp_fem	fem_prop	fem_size	RV_temp	Spring SST	Cod_R	Turbot	snow_c
2010	273.00	536.23	465.57	3.24	105.47	1214	21706.69	194.29	188.00	1036.00	24.53	28.87	63.67	997.31	57.77	12.31	15.45	0.74	25.20	2.35	1.54	0.16	2.55	6063.11
2011	223.60	671.18	456.36	3.75	78.89	1125	16823.67	85.60	57.82	1105.22	24.27	28.51	149.19	840.09	61.34	14.28	18.61	0.71	25.19	2.99	0.79	0.93	1.96	5134.39
2012	205.30	552.28	496.05	2.96	66.78	853	14103.79	86.26	42.69	1018.02	23.85	28.82	25.58	785.63	60.26	14.30	19.44	0.70	25.21	4.20	0.43	0.65	1.37	4560.81
2013	287.60	626.68	672.22	3.85	91.88	794	20679.52	20.11	211.18	1156.83	23.79	29.11	99.22	612.48	59.31	9.65	13.28	0.74	25.56	3.04	0.40	1.95	1.17	3641.20
2014	284.30	417.43	478.84	3.39	91.87	900	20358.62	786.86	26.44	613.17	24.30	28.97	105.00	912.00	55.93	11.17	15.28	0.70	25.62	3.64	-0.35	0.05	3.27	3230.39
2015	218.40	570.97	614.20	3.55	93.60	793	14939.03	276.39	495.00	690.42	24.46	29.28	63.34	874.80	60.93	15.16	16.95	0.57	25.36	4.72	-0.33	0.57	3.06	3518.22
2016	186.20	549.49	632.10	2.72	79.08	604	13223.48	107.85	16.69	1303.78	24.12	28.53	102.42	680.83	60.76	11.80	15.44	0.65	25.26	4.69	1.01	0.39	3.73	3361.51
2017	170.1	442.34	469.92	2.34	105.92	472	12312.04	82.34	166.34	1468.28	23.68	28.59	**120.82**	651.26	57.13	10.43	13.27	0.63	25.41	3.05	0.58	**0.19**	**0.12**	4767.81
2018	**172.3**	**371.32**	**453.14**	**2.32**	**78.37**	**556**	**12598.52**	**264.32**	**37.31**	**822.22**	**23.62**	**28.66**	**-**	**634.81**	**55.46**	**10.28**	**12.26**	**0.64**	**25.70**	**2.25**	**0.35**	**-**	**-**	**4566.42**

Table 4. Set statistics from DFO-Industry survey CK1801 conducted by MV Cody & Kathryn from June 1–12, 2018.

SET	SFA	STRATUM	DATE	LAT.	LONG.	SPEED (kts.)	DIST. (nm)	DUR. (min.)	WING (m)	DEPTH (fth)	TEMP (°C)	RAW CATCH (kg)	STAND. CATCH (kg)	DENSITY gm/m^2 or mt/km^2)
1	15	15	1/June/18	445704	604613	2.15	1.09	30	16.76	119.70	3.16	154.40	183.34	5.42
2	15	15	1/June/18	444636	604366	2.24	1.51	30	16.51	141.78	2.22	50.35	46.63	0.95
3	15	15	1/June/18	444631	603586	2.19	1.13	30	16.43	127.50	2.26	199.58	234.26	6.81
4	15	15	1/June/18	445741	602260	2.36	1.42	30	15.83	117.78	2.58	99.61	96.73	2.32
5	15	15	1/June/18	445158	601644	2.36	1.17	30	16.99	145.39	2.44	112.31	122.54	3.33
6	15	15	1/June/18	444813	602028	2.43	1.18	30	17.08	178.46	2.64	48.53	52.89	1.42
7	15	15	1/June/18	444283	601224	2.41	1.17	30	16.37	116.46	3.69	25.40	23.38	0.80
8	15	15	1/June/18	443886	601344	2.45	1.28	30	16.41	119.87	3.69	47.63	49.70	1.28
9	14	17	2/June/18	451994	594636	2.37	1.17	30	15.81	56.13	1.66	70.31	82.30	2.40
10	14	17	2/June/18	451748	595659	2.58	1.13	30	15.76	75.93	1.67	201.67	246.63	7.48
11	14	17	2/June/18	451837	600162	2.40	1.27	30	16.20	71.43	1.62	140.39	148.00	3.88
12	14	17	2/June/18	452193	600183	2.36	1.22	30	16.00	109.69	1.72	104.42	115.85	3.20
13	14	17	2/June/18	452522	595767	2.28	1.11	30	15.92	78.20	1.80	93.44	114.43	3.50
14	13	17	2/June/18	453770	595455	2.48	1.25	30	16.29	79.26	1.74	38.10	40.58	1.08
15	13	17	2/June/18	453310	600488	2.49	1.32	30	15.93	82.65	1.67	63.50	66.22	1.70
16	15	17	2/June/18	453375	601026	2.22	1.13	30	16.47	101.31	1.62	350.54	410.12	11.90
17	15	17	2/June/18	453265	601308	2.36	1.21	30	16.51	113.71	1.75	305.18	332.16	8.98
18	15	17	3/June/18	453035	602848	2.39	1.15	30	16.64	71.12	1.56	433.18	492.16	13.89
19	15	17	3/June/18	452919	603399	2.50	1.31	30	16.25	76.82	1.57	451.60	461.83	11.71
20	15	17	3/June/18	452622	604412	2.52	1.26	30	15.95	51.03	1.52	238.95	258.74	6.95
21	15	17	3/June/18	452664	605035	2.13	1.06	30	16.10	45.43	1.48	199.94	254.83	8.06
22	14	14	4/June/18	444229	600140	2.28	1.11	30	16.98	109.64	3.32	19.05	21.93	0.63
23	14	14	4/June/18	444700	595879	2.08	1.20	30	16.91	126.44	3.30	83.91	90.02	2.39
24	14	14	4/June/18	445339	595864	2.11	1.06	30	16.53	100.05	2.99	36.29	44.70	1.38

SET	SFA	STRATUM	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)
25	14	14	4/June/18	445194	594353	2.29	1.16	30	17.18	122.17	2.88	203.21	221.54	6.00
26	14	14	4/June/18	444146	593426	2.45	1.25	30	16.53	113.71	3.04	135.62	144.62	3.82
27	14	14	4/June/18	444266	594689	2.19	1.10	30	17.18	145.14	3.25	125.19	151.93	4.58
28	15	15	5/June/18	450327	605419	2.32	1.14	30	16.36	107.39	1.49	109.04	124.42	3.53
30	15	15	5/June/18	445991	605913	2.35	1.18	30	16.27	100.05	1.51	93.44	102.51	2.80
31	13	13	8/June/18	454036	590797	2.42	1.23	30	16.71	117.72	2.31	23.89	26.94	0.75
32	13	13	8/June/18	453945	585897	2.55	1.32	30	16.72	133.09	2.34	117.21	119.10	3.01
33	13	13	8/June/18	454243	590126	2.26	1.15	30	15.75	150.66	2.47	115.94	128.73	3.55
34	13	13	8/June/18	454981	585490	2.47	0.96	30	16.19	122.59	2.41	158.39	218.86	7.53
35	13	13	8/June/18	454796	585042	3.39	1.27	30	17.04	148.79	2.58	556.47	566.86	14.35
36	13	13	8/June/18	454063	584961	2.45	1.68	30	16.36	130.37	2.43	139.34	109.97	2.16
37	13	13	8/June/18	454120	584410	2.42	1.26	30	16.67	127.56	2.36	120.29	124.25	3.19
38	13	13	8/June/18	454687	583713	2.61	1.37	30	16.81	171.17	2.58	126.19	118.97	2.79
39	13	13	8/June/18	455013	583596	2.47	1.49	30	16.78	156.42	2.54	415.49	361.02	7.80
40	13	13	8/June/18	455321	583691	2.46	1.33	30	16.72	128.09	2.42	28.58	28.36	0.69
41	13	13	9/June/18	454959	582983	2.16	1.12	30	17.28	188.09	2.52	67.13	75.28	2.10
42	13	13	9/June/18	453354	582179	2.31	1.22	30	17.06	193.14	2.07	75.30	78.39	2.03
43	13	13	9/June/18	453091	582026	2.34	1.19	30	17.06	223.76	2.03	74.39	79.29	2.11
44	13	13	9/June/18	453054	582764	2.44	1.18	30	16.83	143.32	2.03	122.65	134.73	3.66
45	13	13	9/June/18	453235	583577	2.18	1.42	30	16.85	159.14	2.22	45.36	40.90	0.92
46	14	14	10/June/18	445575	582014	2.30	1.20	30	16.96	143.77	2.24	267.44	285.29	7.57
47	14	14	10/June/18	445068	583168	2.42	1.65	30	15.55	143.72	2.03.	119.93	101.72	2.14
48	14	14	10/June/18	444786	583814	2.29	1.49	30	16.72	144.25	2.05	140.61	123.13	2.67
49	14	14	10/June/18	445491	584383	2.24	1.18	30	16.03	154.96	1.88	437.72	503.61	14.38
50	14	14	10/June/18	444793	585259	2.37	1.45	30	17.55	152.57	1.91	244.58	209.36	4.44
51	14	14	10/June/18	443995	590182	2.29	1.29	30	17.28	121.05	1.78	273.15	266.34	6.45

SET	SFA	STRATUM	DATE	LAT.	LONG.	SPEED (kts.)	DIST. (nm)	DUR. (min.)	WING (m)	DEPTH (fth)	TEMP (°C)	RAW CATCH (kg)	STAND. CATCH (kg)	DENSITY gm/m^2 or mt/km^2)
52	14	14	10/June/18	444699	591106	2.40	1.19	30	16.22	127.04	1.77	217.72	245.61	6.87
53	14	14	10/June/18	445061	590371	2.40	1.21	30	15.05	126.43	1.82	71.21	84.79	2.51
54	14	14	11/June/18	445099	592802	2.28	1.16	30	16.92	140.04	2.74	315.52	350.13	9.63
55	15	15	11/June/18	444660	600616	2.07	1.04	30	16.21	115.14	3.13	48.99	63.23	2.03
56	15	17	11/June/18	452853	600838	2.49	1.37	30	14.87	96.25	1.73	237.68	254.05	6.73
57	15	17	12/June/18	452335	610197	2.47	1.24	30	14.28	34.23	1.41	84.37	103.15	3.14
58	15	15	12/June/18	445344	604973	2.45	1.28	30	16.42	106.01	2.08	106.87	110.72	2.84
59	15	15	12/June/18	444948	605682	2.32	1.19	30	16.95	135.70	2.65	138.80	149.88	4.01
60	15	15	12/June/18	445478	610134	2.30	1.20	30	16.53	111.66	1.61	57.15	62.49	1.70
61	15	15	12/June/18	445207	611048	2.05	1.05	30	15.93	97.39	3.23	110.95	144.33	4.66

Table 5. Minimum survey population numbers-at-age from modal analysis. Numbers × 106. Cells with dashed lines indicate no data. Shaded portion of the table represents numbers updated to include all Shrimp Fishing Areas (SFAs).

Age	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Avg.
1[1]	-	-	-	957	205	311	198	61	191	479	541	197	88	94	22	796	288	112	83	267	288
2	166	280	175	134	616	354	187	121	39	114	304	188	58	43	211	26	495	17	166	37	181
3	27	757	362	383	312	3118	652	880	506	396	267	1020	513	348	302	119	501	193	581	361	608
4	3010	0[4]	1184	399	1506	839	4502	0[4]	0[4]	1190	463	1036	1105	1018	1157	613	690	1304	1468	822	1349
5+	1952	3374	2110	1847	1727	3324	2224	5106	5506	3017	6020	4109	2694	2688	4091	4673	2956	3076	1734	2231	2830
TOTAL	5155	4412	3831	2763	4161	7636	7763	6169	6244	5201	7622	6616	4458	4191	5783	6227	4930	4702	4032	3718	5054
Age 4+ males[2]	3235	1784	1771	938	1526	1549	4956	3916	2804	3317	4263	3454	2003	2241	2960	3831	2270	2931	1859	1966	2530
Primiparous[3]	736	728	817	678	551	870	786	771	1739	892	1492	1324	947	371	699	706	521	664	453	433	797
Multiparous	991	863	706	630	1188	1698	1183	480	1157	482	1295	630	937	1188	1611	1545	1143	897	973	921	932
Total females	1727	1591	1523	1308	1739	2568	1969	1251	2896	1374	2787	1954	1884	1559	2310	2251	1664	1561	1426	1354	1729

Notes:

[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 (4) year olds of the 2000, 2006, and 2007 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 total biomasses, commercial shrimp catches, and exploitation rates (catch/biomass) by survey stratum (13–15, offshore part), and the inshore area (17), 2000–2018.

Parameter	Strata	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
Biomass (mt)	13	5866	4089	3114	7047	12184	9687	6129	7507	4144	6208	2688	4537	6011	7970	8204	5809	6184	4593	5928	6205
	14	9364	12325	12020	12035	20228	20035	18929	15957	12710	20544	16009	14614	10941	17682	11801	11641	8190	8361	7141	13712
	15	7268	2073	2766	3751	4399	4378	5130	5345	4227	7235	4784	4223	4232	2594	3022	3451	2765	2677	2462	4041
	17	9365	6541	2872	5296	11627	10333	7581	9622	9823	11438	13731	7136	6793	11136	15765	8741	8445	7751	7918	9048
Total		**31863**	**25028**	**20773**	**28130**	**48438**	**44433**	**37769**	**38431**	**30904**	**45424**	**37212**	**30510**	**27978**	**39381**	**38791**	**29642**	**25584**	**23382**	**23449**	**33006**
Catch (mt)	13	233	432	253	585	2011	1145	630	85	212	11	125	4	0	0	438	101	88	269	252	370
	14	1750	1206	1552	1621	752	1372	1998	2640	2696	2026	1844	2342	2526	2259	2283	2060	2096	1947	1927	1947
	15	915	965	264	226	338	613	444	612	534	540	1123	986	805	924	192	40	2	1	44	506
	17	2538	2165	874	333	168	515	915	1245	879	900	1490	1026	827	688	1002	2210	912	222	187	952
Total		**5436**	**4768**	**2943**	**2765**	**3268**	**3645**	**3986**	**4582**	**4321**	**3477**	**4581**	**4358**	**4158**	**3871**	**3915**	**4411**	**3100**	**2439**	**2410**	**3776**
Expltn. (%)	13	4.0	10.6	8.1	8.3	16.5	11.8	10.3	1.1	5.1	0.2	4.6	0.1	0.0	0.0	5.3	1.7	1.4	5.9	4.3	5.2
	14	18.7	9.8	12.9	13.5	3.7	6.8	10.6	16.5	21.2	9.9	11.5	16.0	23.1	12.8	19.3	17.7	25.6	23.3	27.0	15.8
	15	12.6	46.6	9.6	6.0	7.7	14.0	8.6	11.5	12.6	7.5	23.5	23.3	19.0	35.6	6.4	1.2	0.1	0.0	1.8	13.0
	17	27.1	33.1	30.4	6.3	1.4	5.0	12.1	12.9	8.9	7.9	10.9	14.4	12.2	6.2	6.4	25.3	10.8	2.9	2.4	12.4
Total		**17.1**	**19.1**	**14.2**	**9.8**	**6.7**	**8.2**	**10.6**	**11.9**	**14.0**	**7.7**	**12.3**	**14.3**	**14.9**	**9.8**	**10.1**	**14.9**	**12.1**	**10.4**	**10.3**	**12.0**

Table 7. Bycatch of the commercial shrimp fishery from observer data of 23 sets in 2017, and 32 sets in 2018.

Species	% Catch (# of Sets)		Total Observed Weight (2017–2018)		Combined 2017–2018 Mobile TAC (Kgs)
	2017 (23 sets)	2018 (32 sets)	Est. Weight (Kgs)	%	
Shrimp	98.51%	99.75%	108,551	99.31%	4,784,000
American Plaice	0.50%	0.03%	221	0.20%	9,672
Capelin	0.01%	0.01%	12	0.01%	525
Atlantic Herring	0.26%	0.08%	158	0.14%	6,915
Unseparated Redfish	0.15%	0.01%	69	0.06%	3,020
Unid. Rockling	-	0.03%	21	0.02%	919
Unid. Shanny	-	0.03%	19	0.02%	832
Short-Fin Squid	-	<0.01%	2	<0.01%	88
Silver Hake	0.01%	<0.01%	5	<0.01%	219
Striped Atlantic Wolffish	-	<0.01%	1	<0.01%	44
Greenland Halibut (Turbot)	0.07%	0.01%	35	0.03%	1,532
Witch Flounder	-	0.03%	24	0.02%	1,050
Winter Flounder	0.15%	-	57	0.05%	2,495
Eelpouts (NS)	0.11%	-	43	0.04%	1,882
Squid (NS)	0.09%	-	37	0.03%	1,619
Alligatorfish	0.07%	-	27	0.02%	1,182
Sand Lance (NS)	0.04%	-	14	0.01%	613
Squirrel or Red Hake	0.02%	-	6	0.01%	263
Longnose Lancetfish	0.01%	-	5	<0.01%	219
Thorny Skate	<0.01%	-	1	<0.01%	44
Atlantic Cod	<0.01%	-	1	<0.01%	44
% Bycatch	**1.49%**	**0.25%**	**-**	**0.69%**	-

Note: Shrimp includes *P. borealis*; *P. montagui* & *Crangon*. Estimated weights may be overestimated due to observer data collection restrictions (i.e. minimum recorded weight is 1 kg). Hyphens (-) indicate the species was not observed.

FIGURES

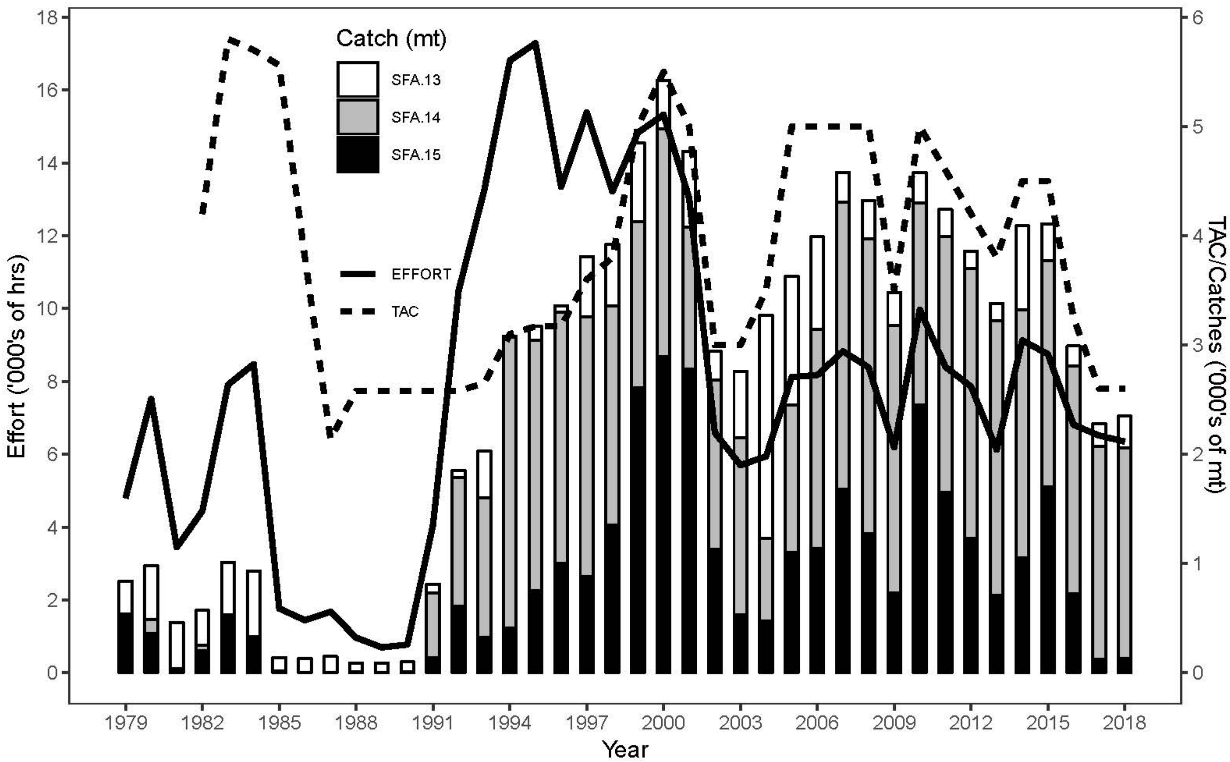


Figure 1. History of Eastern Scotian Shelf Shrimp fishery catches per Shrimp Fishing Area (SFA) (13, 14 and 15), Total Allowable Catch (TAC) (thousands of mt) and effort (thousands of hours) from 1979–2018. Effort and catches for 2018 represent preliminary data as of November 15, 2018.

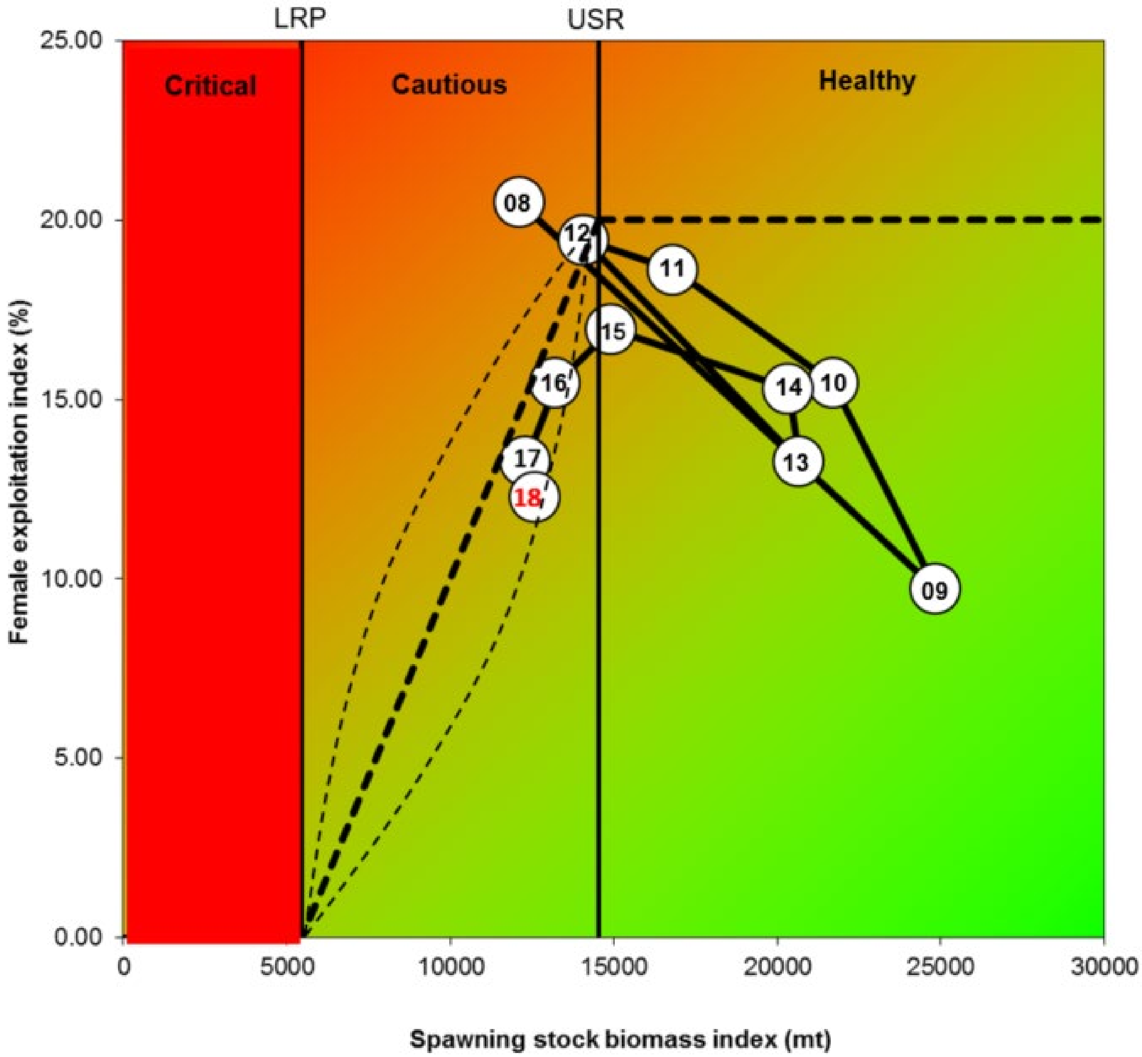


Figure 2. The Precautionary Approach (PA) for Eastern Scotian Shelf Shrimp showing spawning stock biomass index (PA Abundance Index) and female exploitation index (PA Removal Reference 20%, when in the Healthy Zone) point estimates from 2008–2018 relative to lower (LRP, 5,459 mt) and upper stock reference points (USR, 14,558 mt).

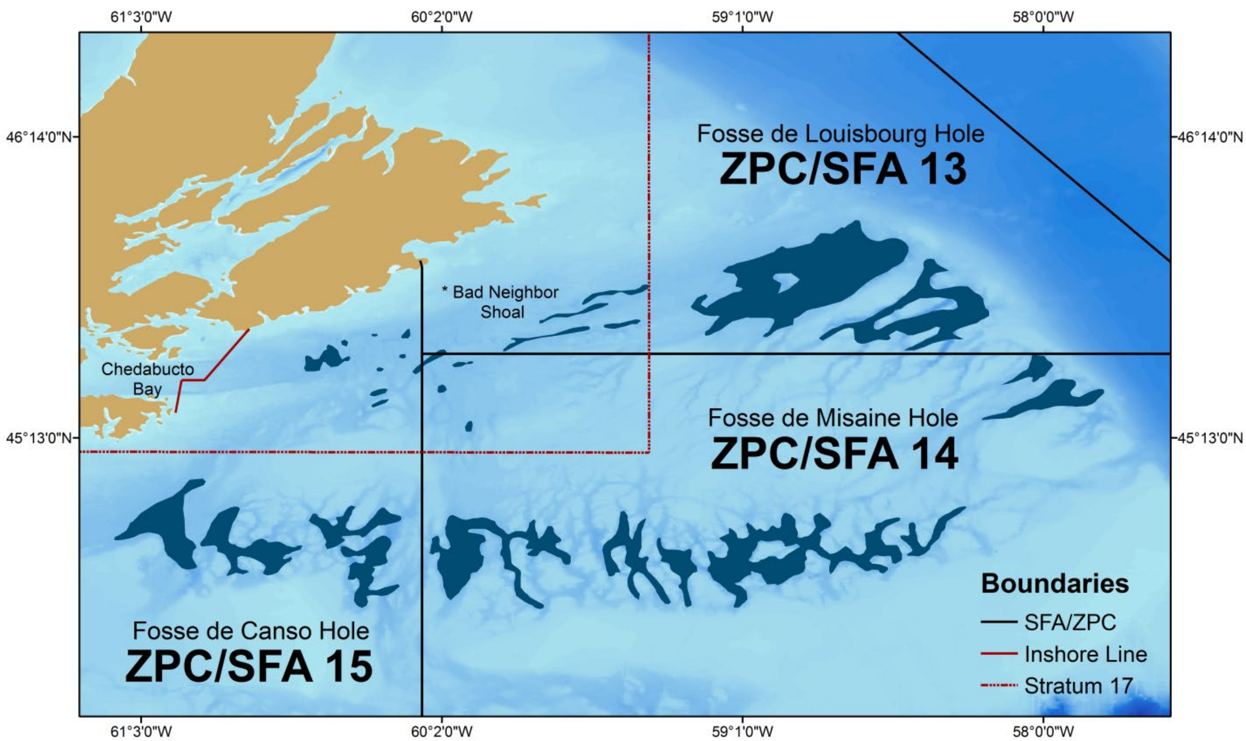


Figure 3. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. Survey strata approximately correspond to the main shrimp holes and SFAs. Stratum 13 – Louisbourg Hole and SFA 13; Stratum 14 – Misaine Holes and SFA 14; Stratum 15 – Canso Holes and the offshore part of SFA 15. Stratum 17, or the 'Inshore', is comprised of inshore parts of SFA 13–15 denoted by the finely stippled line. Bathymetric data provided by Greenlaw and McCurdy (2014).

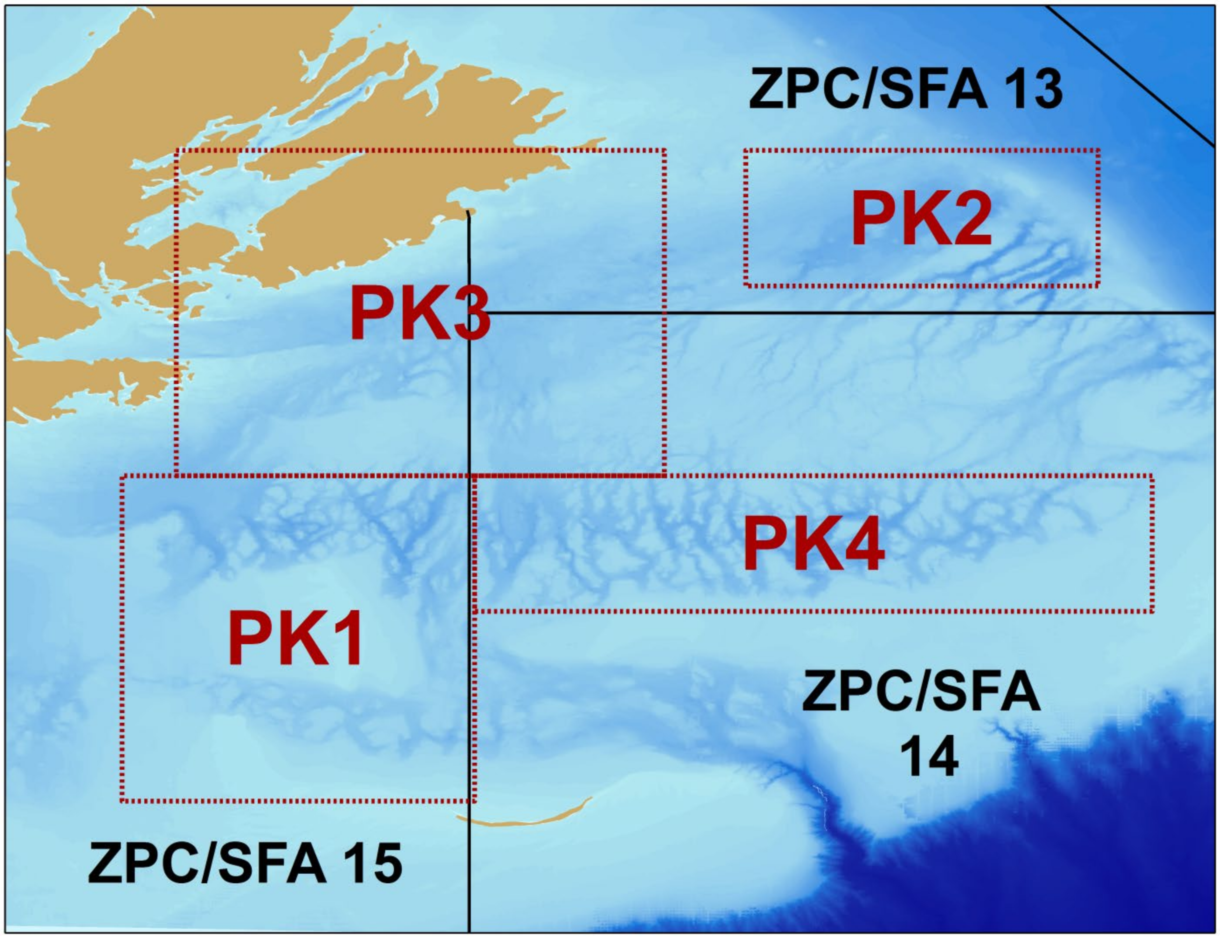


Figure 4. Eastern Scotian Shelf area boxes from which satellite sea surface temperature data for the last 2 weeks of February and the first 2 weeks of March are analysed.

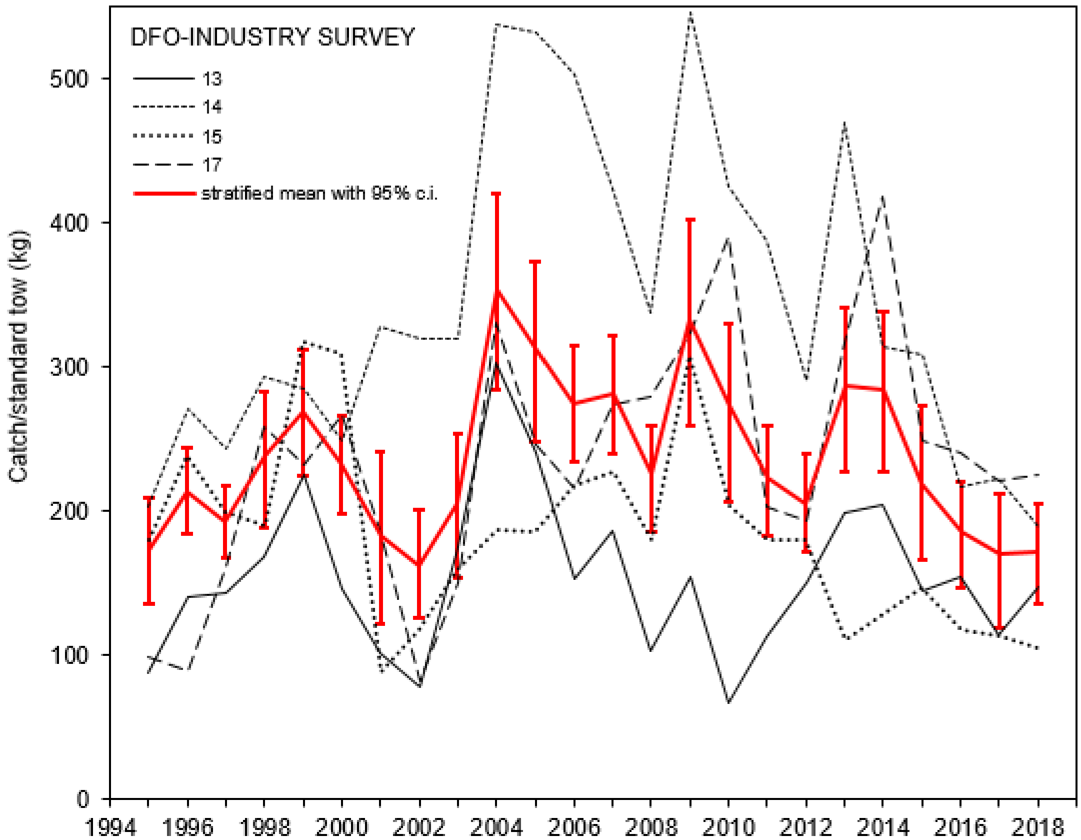
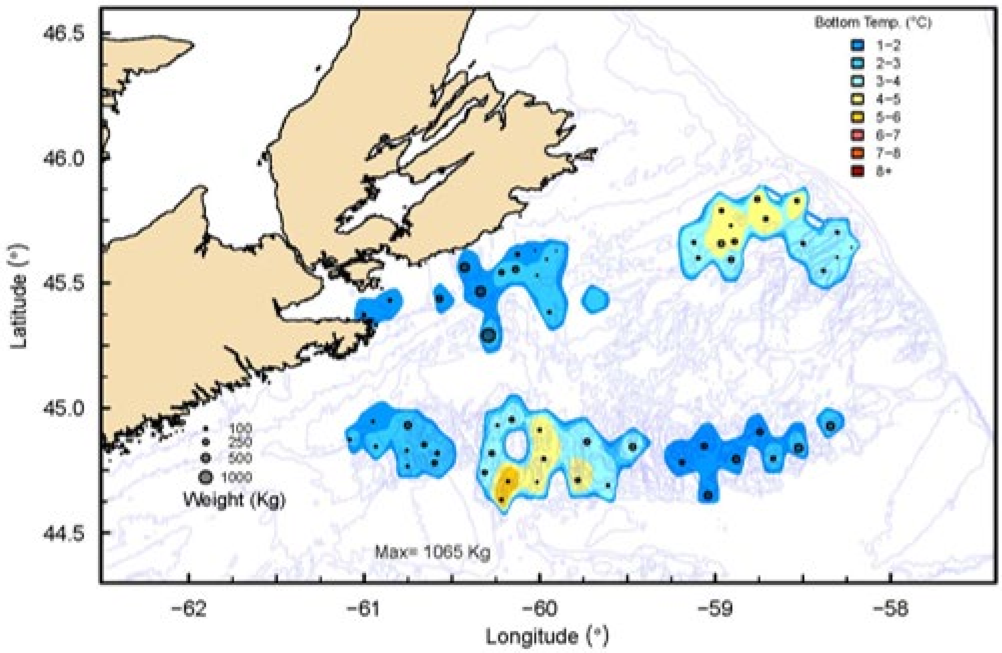


Figure 5. Stratified catch/standard tow for DFO-Industry co-operative surveys from 1995–2018 and estimates for the individual survey strata.



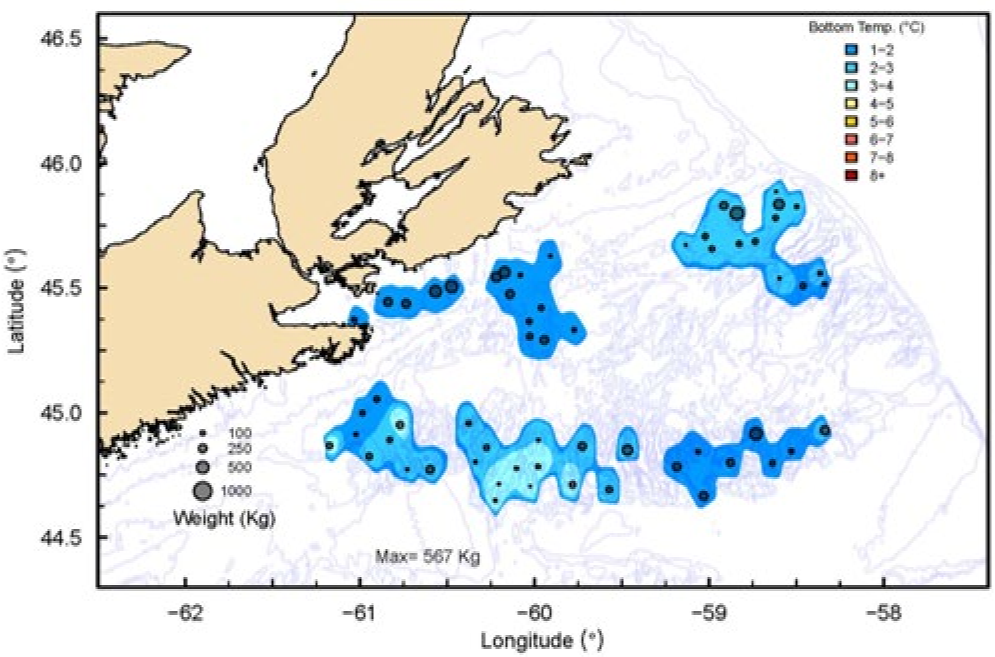


Figure 6. Distribution of catches (kg/standard 30-minute tow) and bottom temperatures from the 2017 (upper panel) and 2018 (lower panel) DFO-Industry surveys. See previous research documents for distributions prior to 2017 (Hardie et al. 2013b; 2018).

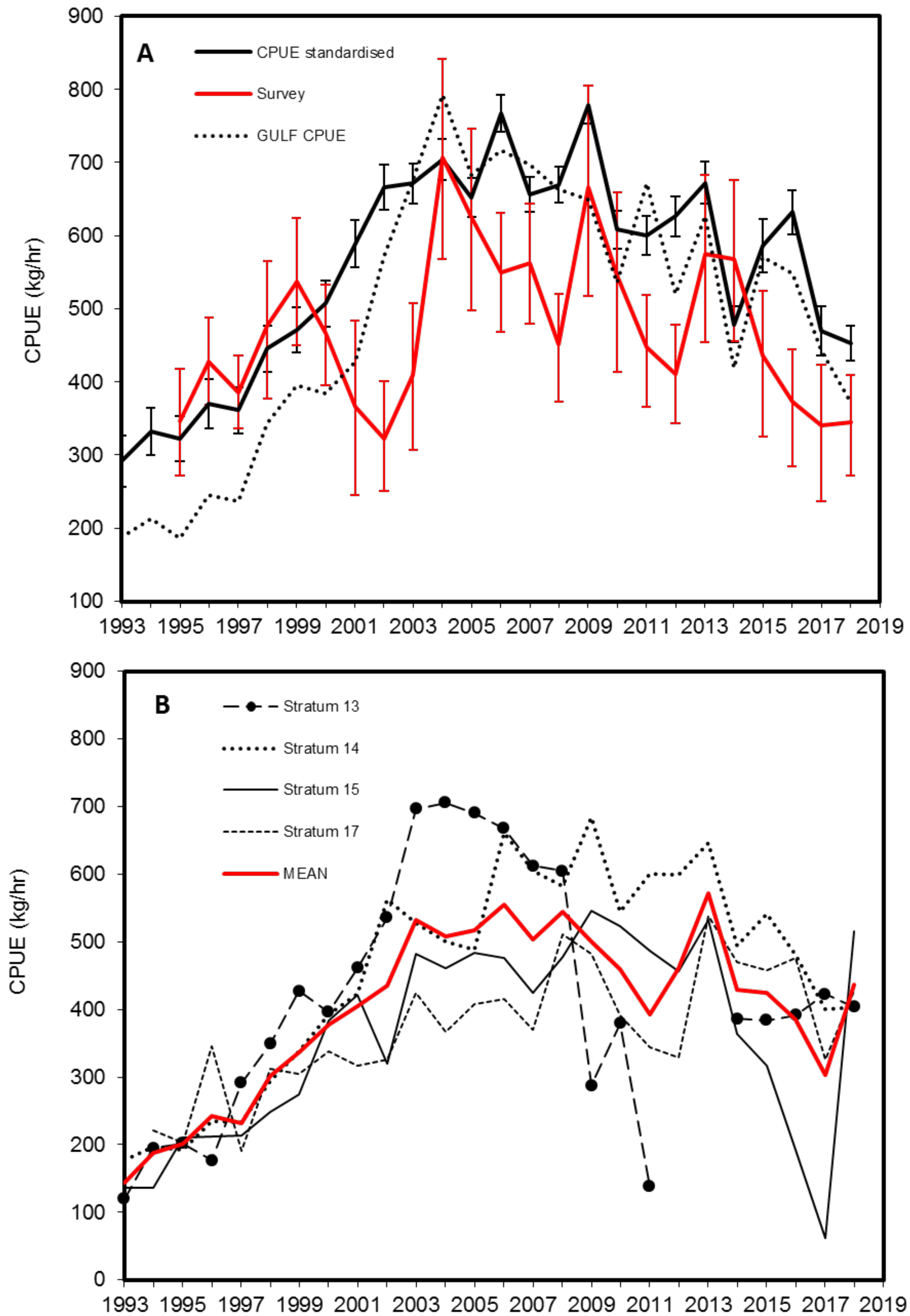


Figure 7. A (upper panel) – Survey stratified Catch Per Unit Effort (CPUE) and, standardised commercial CPUE with 95% confidence intervals, and unstandardized Gulf vessel CPUE; B (lower panel) – unstandardized commercial CPUE for each fishing area, from 1993–2018.

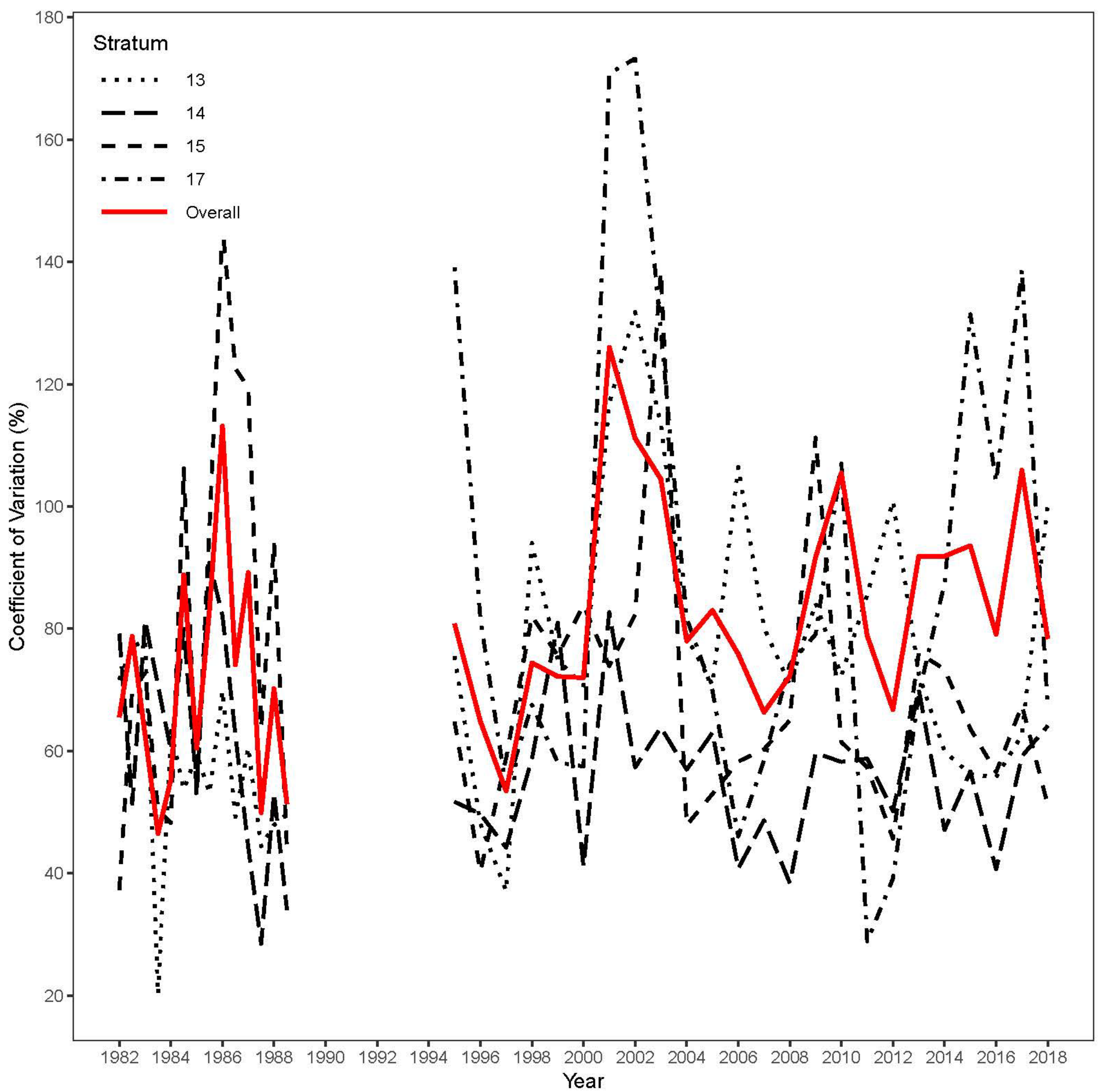
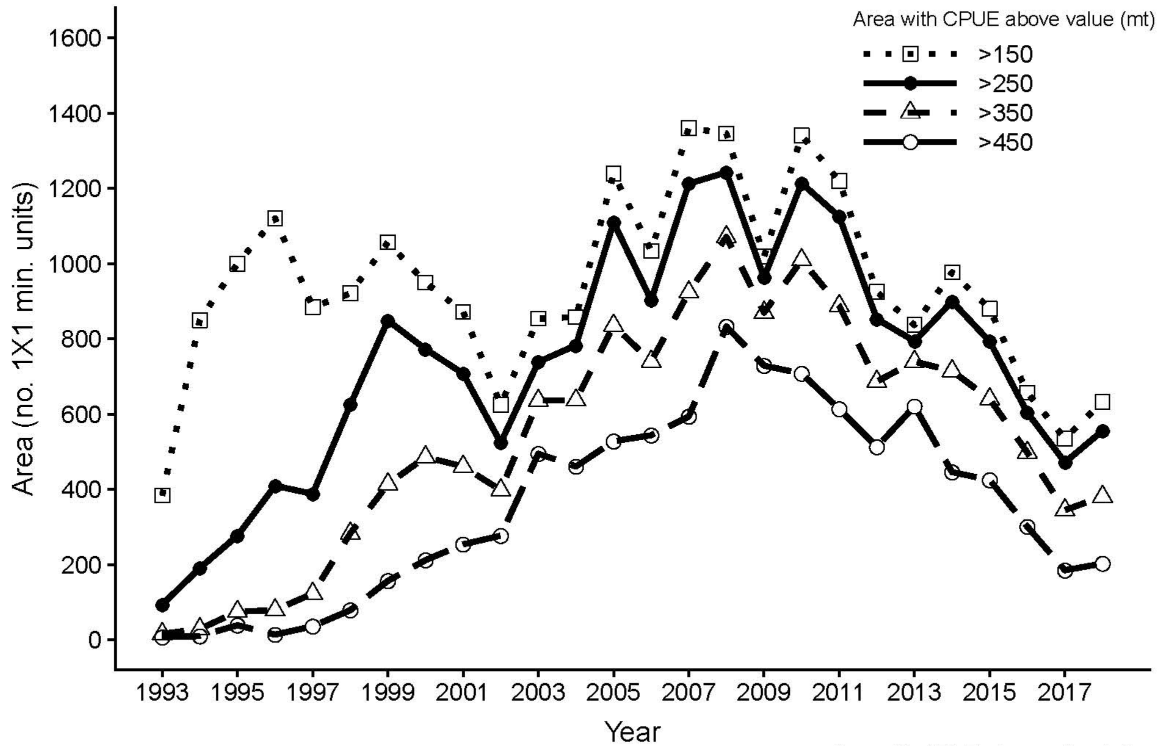


Figure 8. Coefficients of variation (CV) for Shrimp survey strata 13, 14, 15, and 17, from 1982–2018. Note that use of fixed stations in stratum 14 likely acts to constrain inter-annual changes in CV relative to other areas with randomized stations.



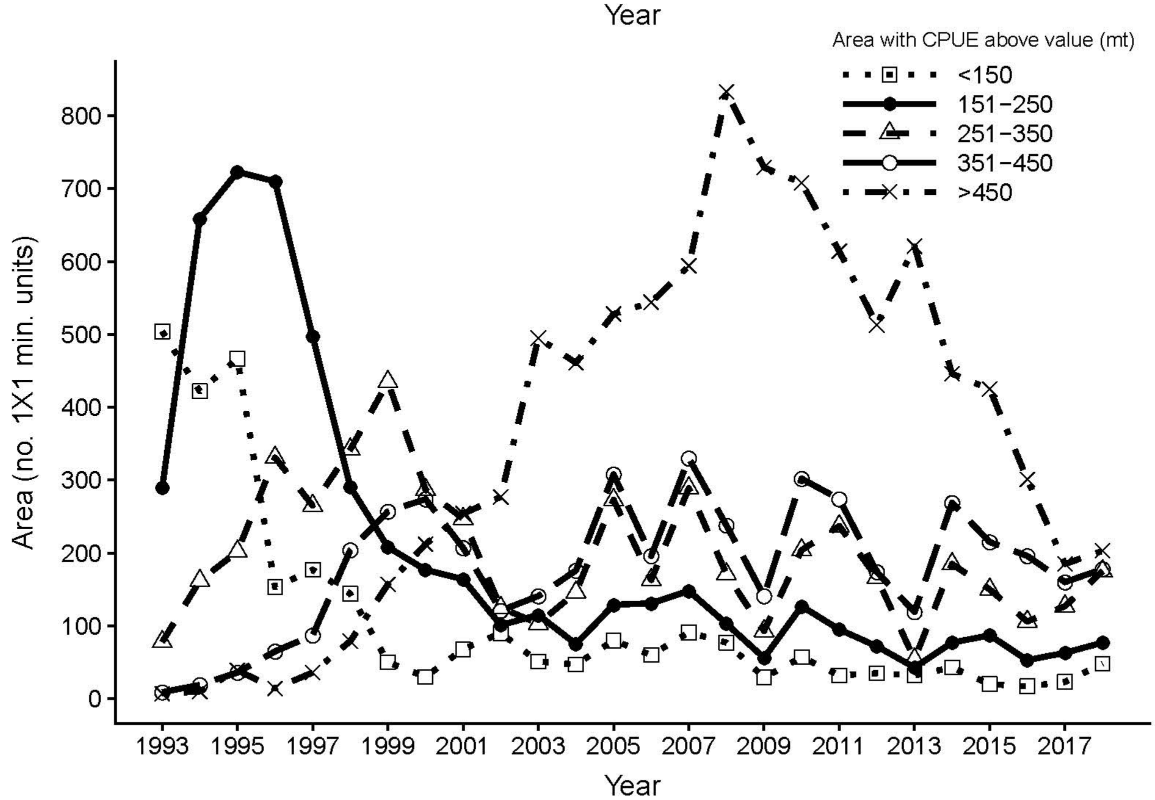


Figure 9. Number of 1-minute square unit areas fished by the Eastern Scotian Shelf Shrimp fleet with mean catch rates above (top) and within (bottom) the values or ranges specified in the legend, from 1993 to 2018 count.

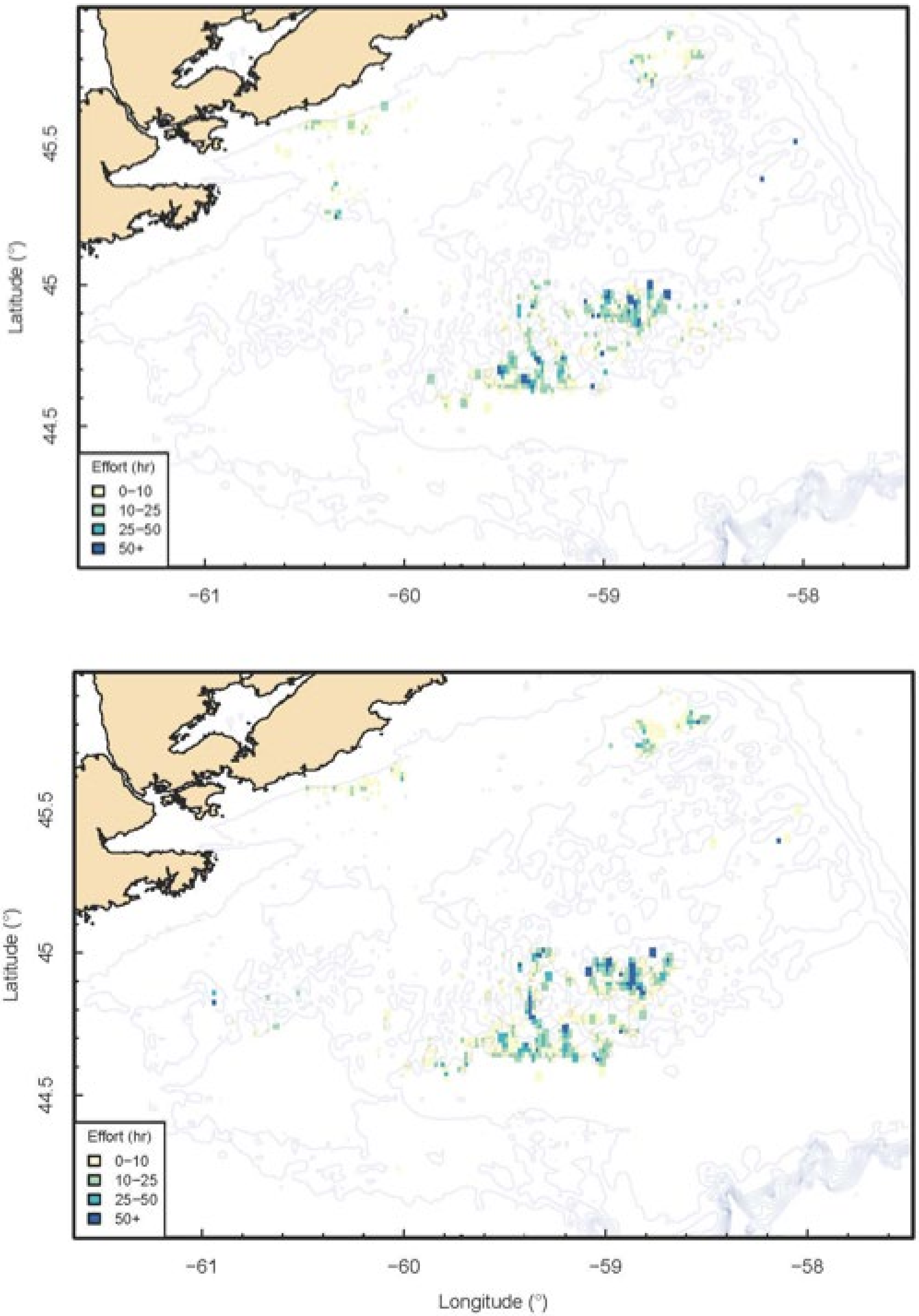


Figure 10. Annual Eastern Scotian Shelf trawl fleet effort (hours) in 2017 (upper panel) and 2018 (lower panel), cumulative by 1-minute squares.

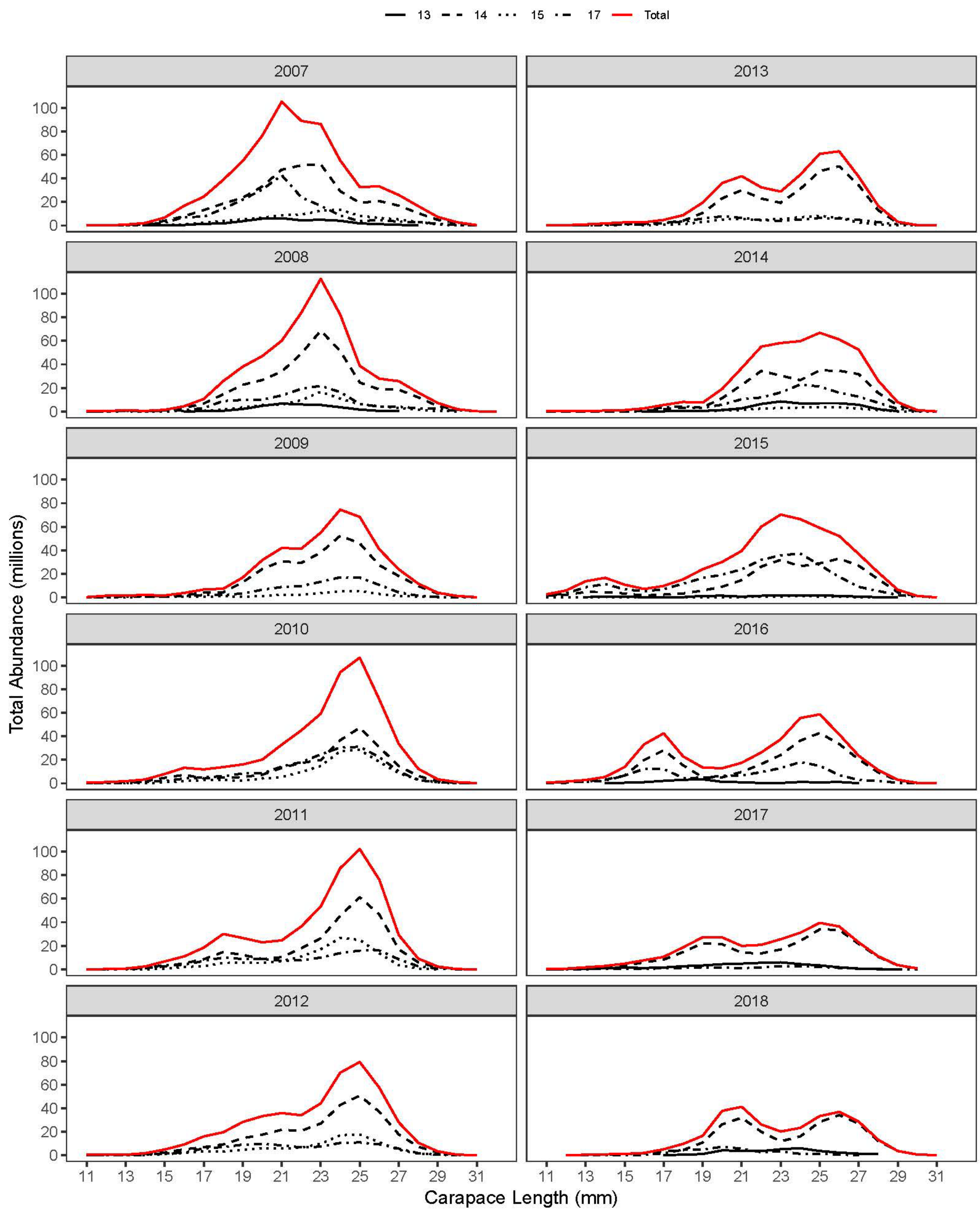


Figure 11. Catch at length from commercial sampling by stratum, 2007–2018.

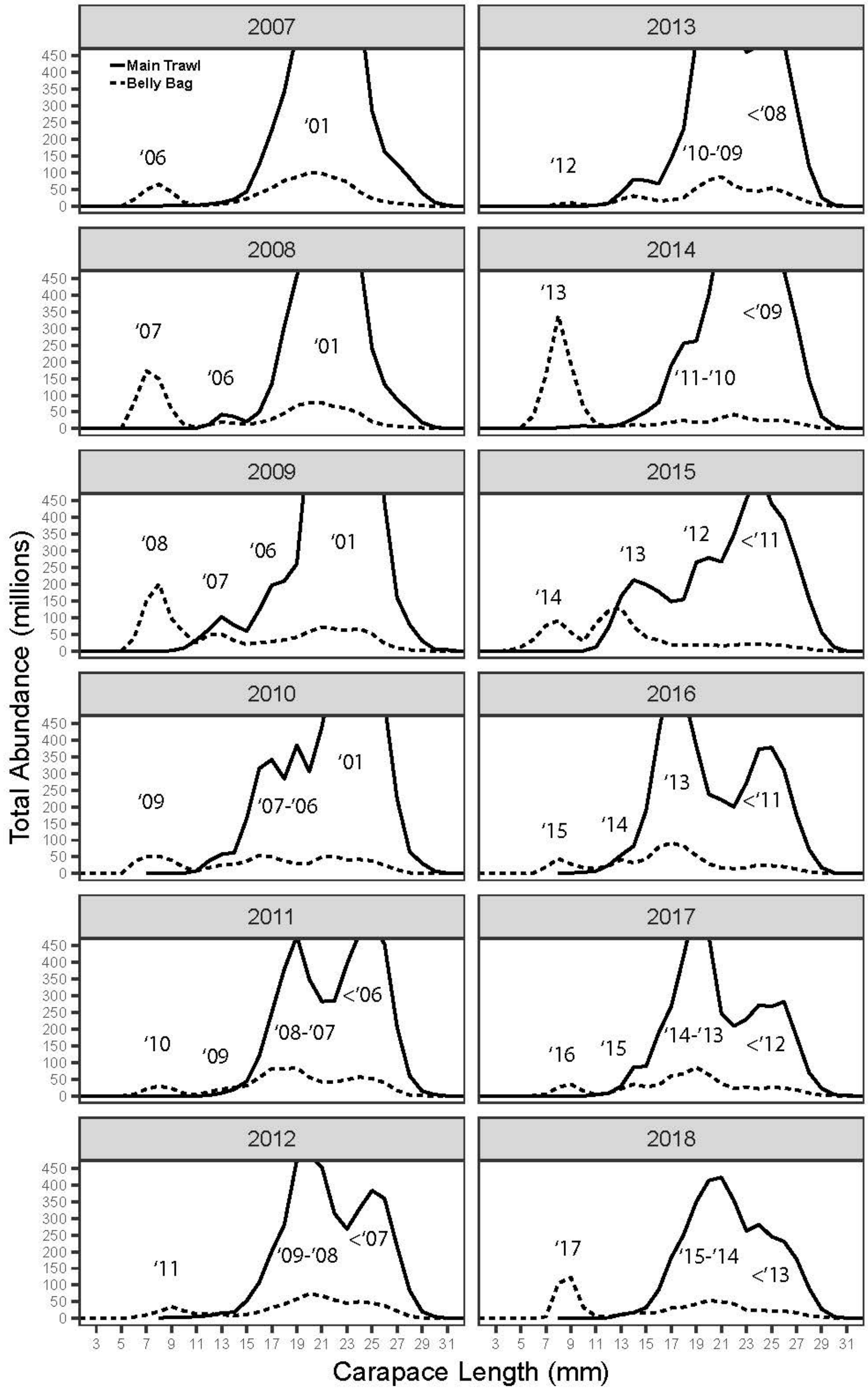


Figure 12. Population estimates from belly-bag (dashed line) and main trawl (solid line) catches for the 2007–2018 surveys.

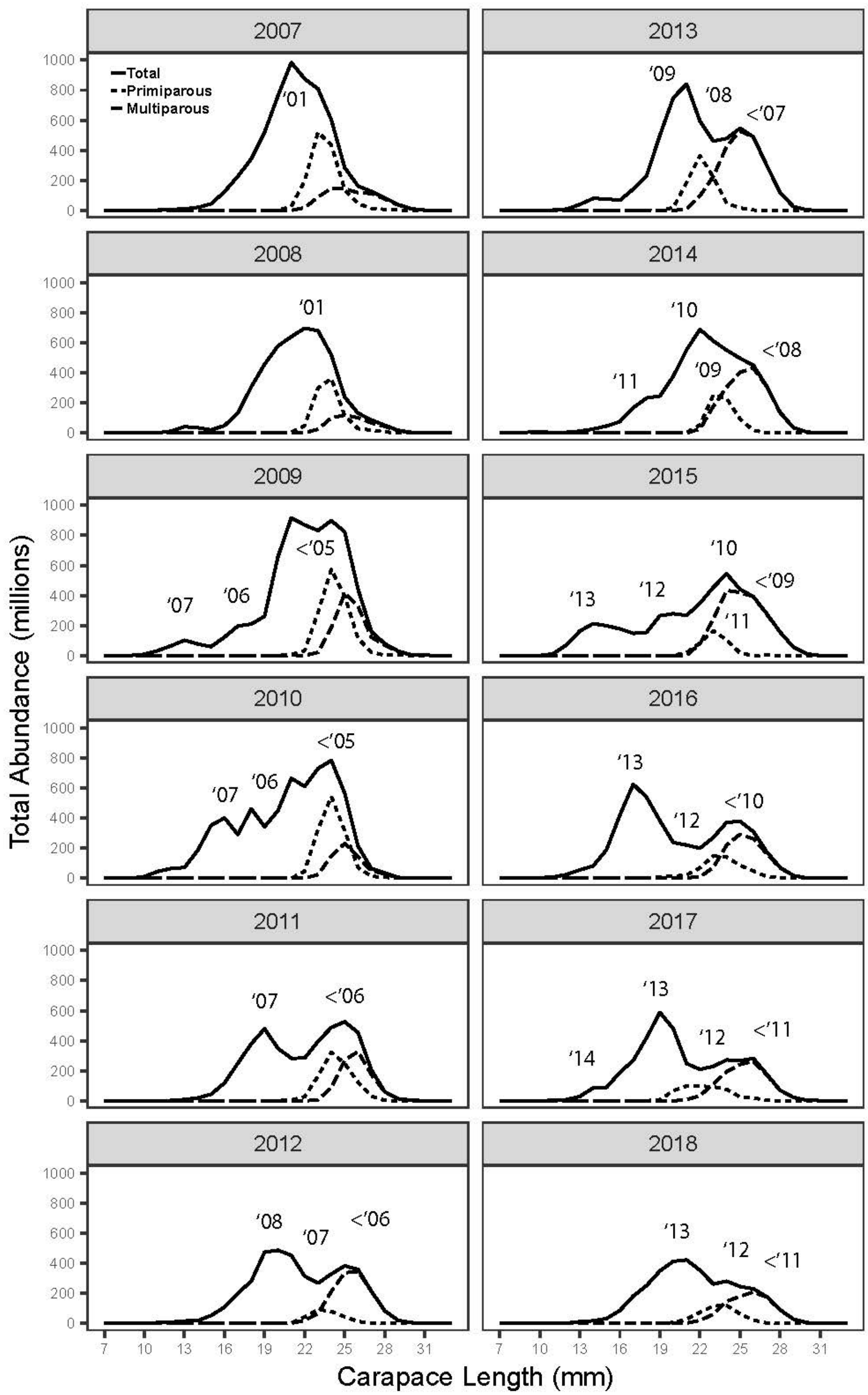


Figure 13. Population estimates at length from DFO-Industry surveys 2007–2018 (solid line). The heavy dotted line in each figure represents transitional and primiparous shrimp, and the long dash line represents multiparous shrimp.

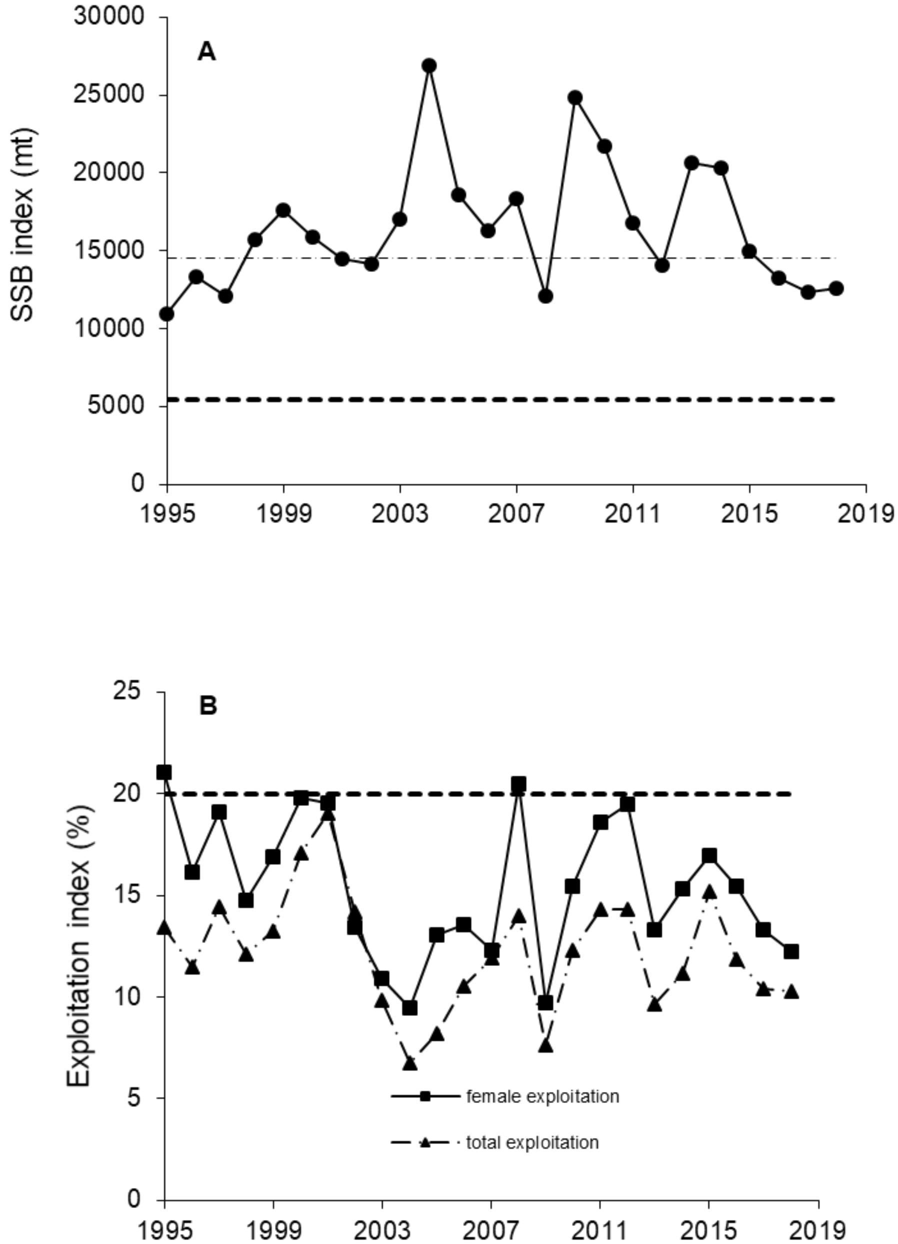


Figure 14. A – Changes in the Spawning Stock Biomass (SSB) index for the Eastern Scotian Shelf (ESS) Shrimp population. The dashed lines show the Lower Reference Point (LRP) at 30% and Upper Stock Reference (USR) at 80% of the mean SSB during the 2000–2010 high-productivity period. B – Changes in the exploitation indices for the ESS Shrimp fishery. The dashed line shows the removal reference of 20% for the female exploitation index when in the Healthy Zone.

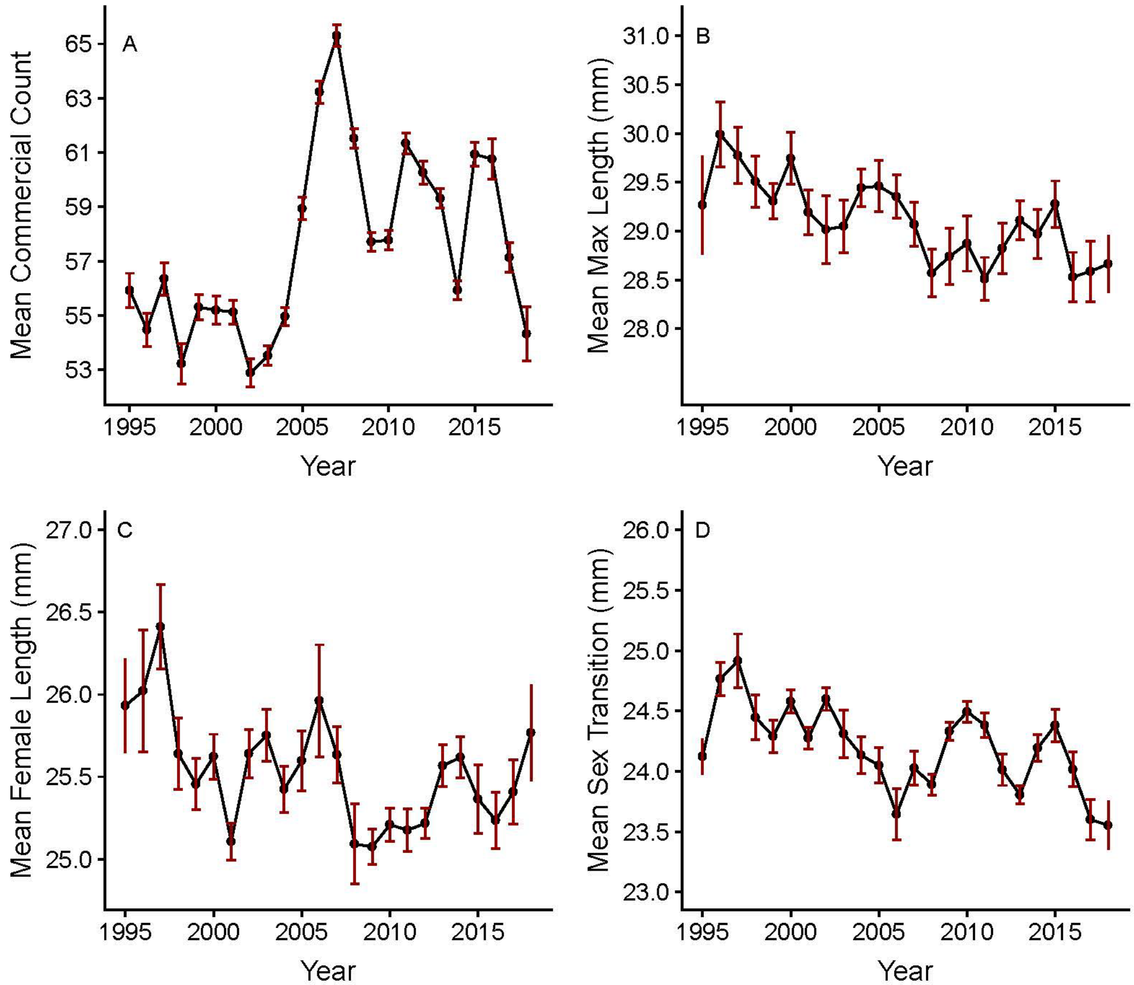


Figure 15. Mean: A – commercial count, B – maximum length., C – female size and D – size at sex transition for all Shrimp Fishing Areas (SFAs) combined for 1995–2018 with 95% confidence intervals.

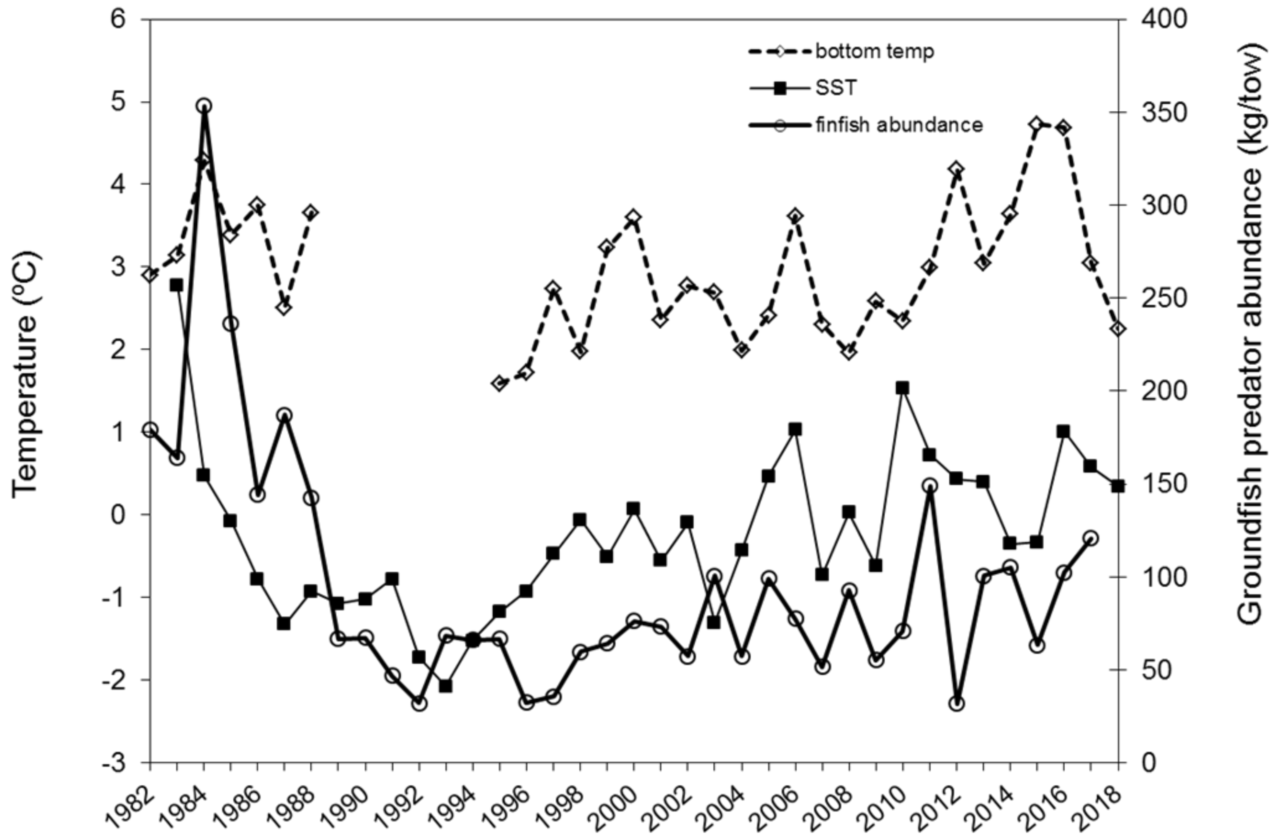


Figure 16. Bottom and spring Sea Surface Temperatures (SSTs) and predator abundance on the Eastern Scotian Shelf Shrimp grounds.

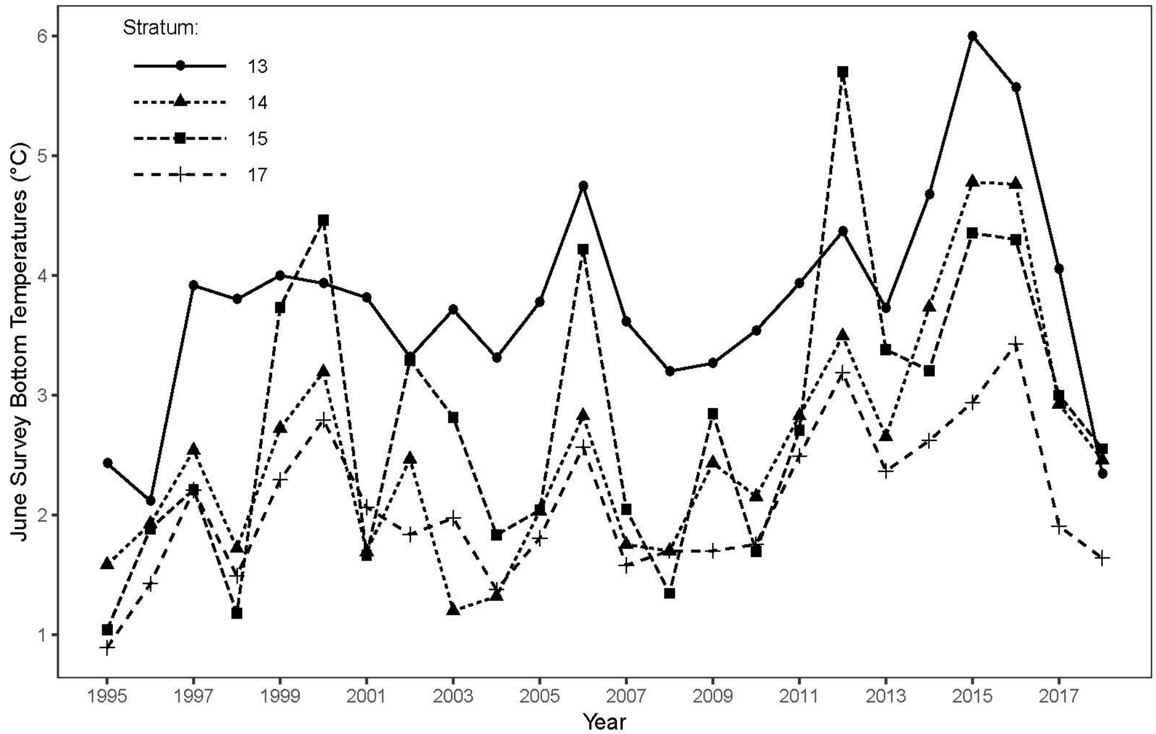


Figure 17. Mean bottom temperatures from Shrimp surveys by stratum (13, 14, 15, and 17). Note June surveys started in 1995 and are conducted annually.

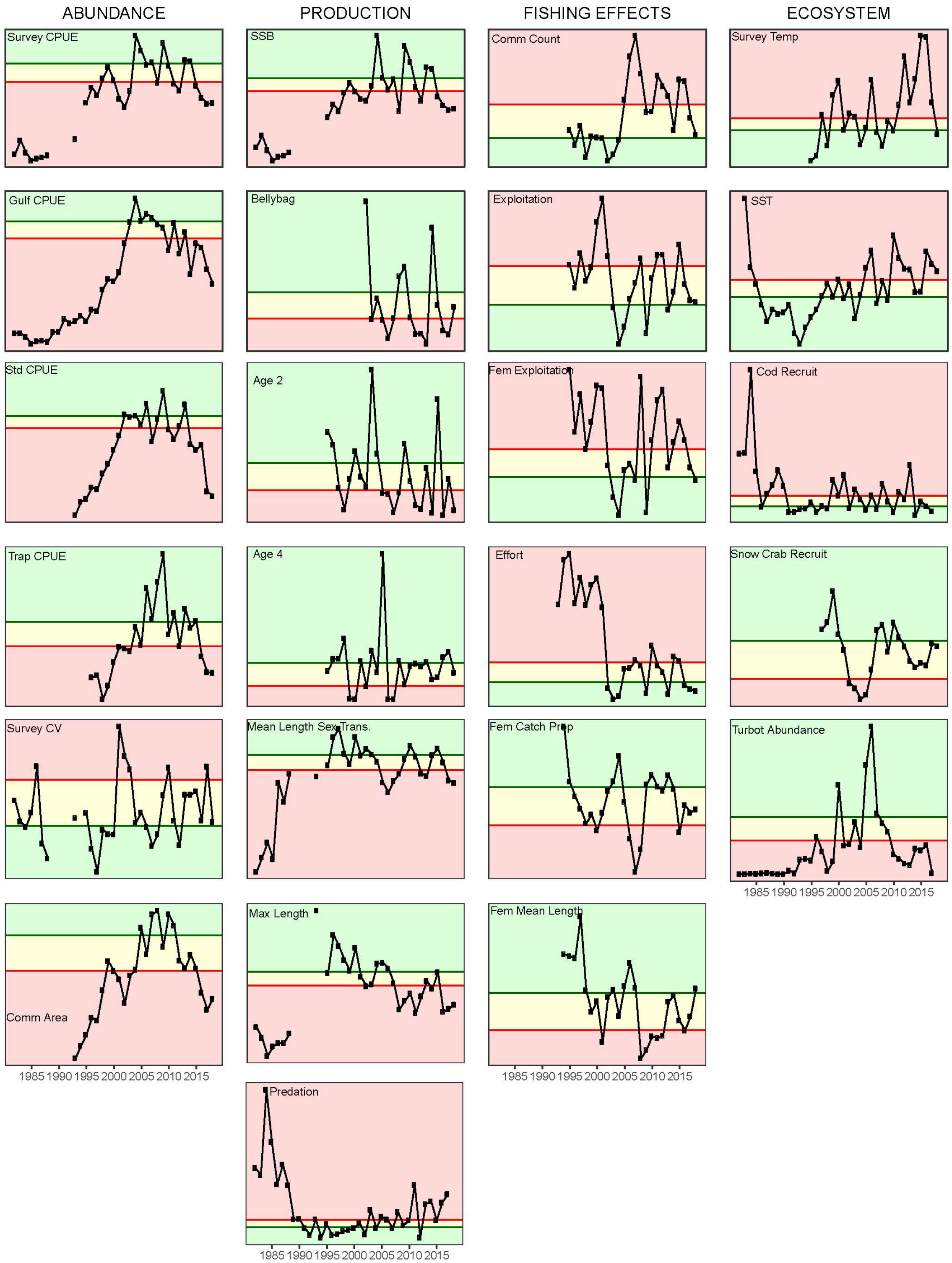


Figure 18. Time series of all available indicators from 1982–2018. Thresholds between red, yellow, and green are at the 33rd and 66th percentile of the fixed 2000–2010 data series for each indicator. Not all indicators in the summary above are discussed in the text. See Hardie et al. (2018) for detailed description of indicators. Note that the Predation indicator (Production), the Cod Recruitment (Ecosystem), and the Turbot Abundance (Ecosystem) could not be updated for 2018.

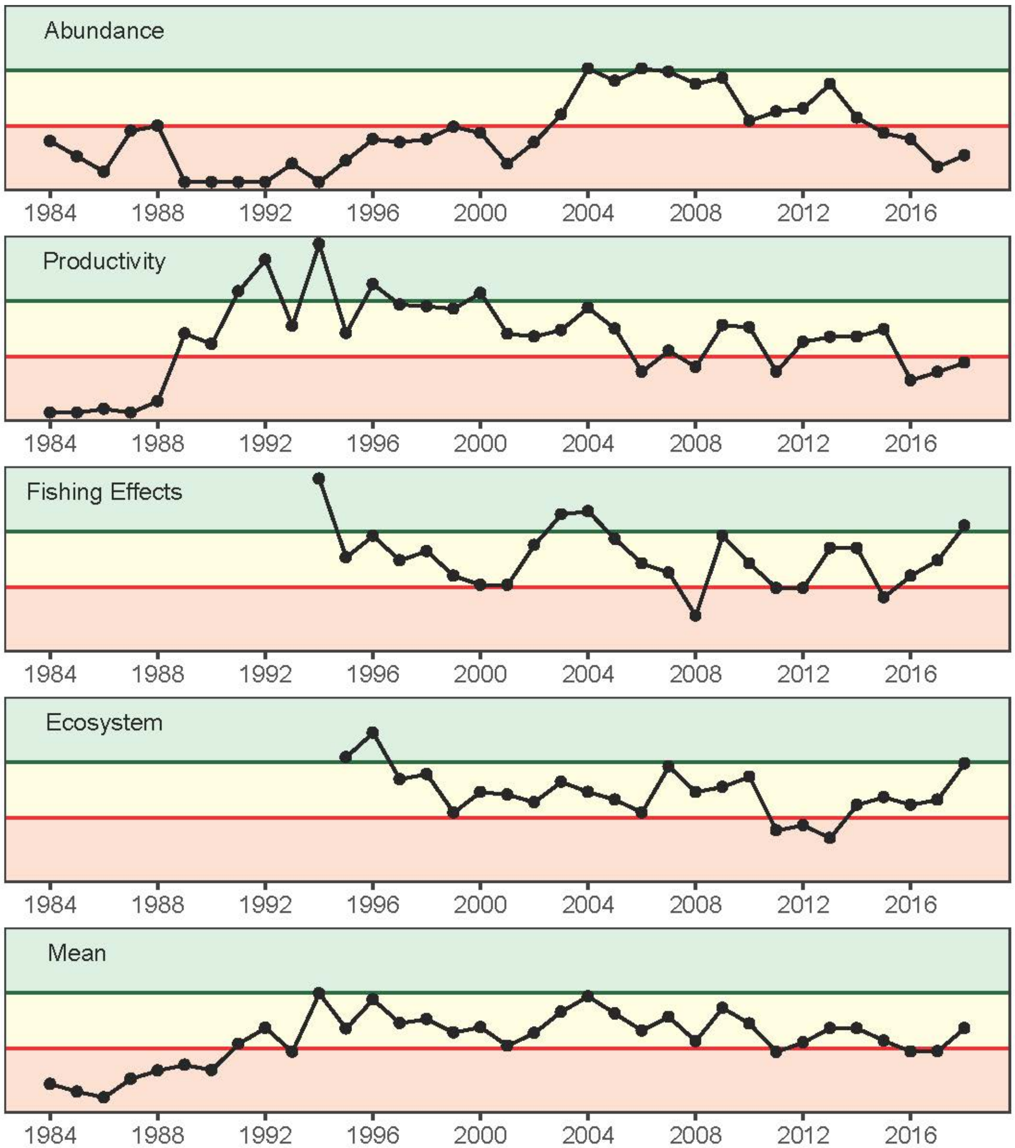


Figure 19. Time series of characteristics and mean (overall) indicator from 1984–2018. Thresholds between red, yellow, and green are at the 33rd and 66th percentile of the fixed 2000–2010 data series for each indicator. Not all indicators in the summary above are discussed in the text. See Hardie et al. (2018) for detailed description of summary characteristics. Note that the Productivity (-1) and Ecosystem (-2) summary characteristic have missing indicators in 2018, and will affect their overall mean differently than in previous years. (2018 Ecosystem Plot is weighted differently than previous year)