Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2017/005

ASSESSMENT OF NORTHERN SHRIMP ON THE EASTERN SCOTIAN SHELF (SFAs 13-15)

(J. Domm 2006)

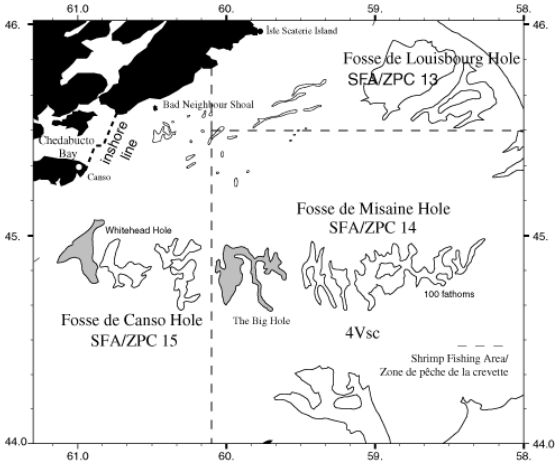

Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf.

Context:

Advice on the status of the Eastern Scotian Shelf Shrimp stock is requested by DFO Resource Management to help determine a Total Allowable Catch (TAC) that is consistent with the management plan. Annual assessments are required because of rapid changes in abundance, variable recruitment to the population and fishery, and changes in the size of Shrimp available for harvest. The resource is near the southern limit of the species' distribution where it is thought to be more vulnerable to significant and rapid declines, as has been observed in the adjacent Gulf of Maine stock. The current report provides information and advice for management of the 2017 fishery.

The trawl fishery on the Scotian Shelf occurs primarily during late spring and early summer with some fishing during fall, in the deep offshore Shrimp "holes", and on an inshore area near the Bad Neighbour Shoal. The main management tools are limits on the number of licenses and size of vessels used, minimum codend mesh size (40 mm), use of a Nordmøre separator grate, and a TAC. This fleet (about 16 active vessels) is divided into two sectors, a midshore sector consisting of vessels 65-100' Length Over All (LOA) based in New Brunswick in the Gulf Region, and an inshore sector consisting of vessels mainly <65' LOA based in the Maritimes Region. A trap fishery, currently consisting of 8 active vessels is restricted to Chedabucto Bay. All licenses except traps operate under Individual Transferable Quotas (ITQs). Annual stock assessments were conducted until 2012, until a biennial assessment schedule with interim year updates was initiated in 2013. Both assessment and update processes are based upon a full analysis of Shrimp stock indicators determined from the DFO-Industry survey, commercial landings, and environmental monitoring data.

This Science Advisory Report is from the December 7, 2016, Stock Assessment of Eastern Scotian Shelf Shrimp in Shrimp Fishing Areas (SFAs) 13-15. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- As of November 15, 2016, 3,026 mt of the 3,250 mt Total Allowable Catch (TAC) for 2016 had been landed.
- As predicted in recent assessments, the Eastern Scotian Shelf Shrimp stock has declined since 2014, as the 2007-2008 year-classes have now reached the end of their expected life span.
- The 2016 total biomass estimate declined 14% to 25,584 mt (± 5,079 mt, 95% Confidence Interval (CI)) from the 2015 estimate of 29,642 mt (± 7,324 mt, 95% CI).
- The 2016 Spawning Stock Biomass (SSB, females) point estimate declined 11% to 13,223 mt, and is now below the Upper Stock Reference (USR, 14,558 mt). Based on the precautionary approach as it is applied to Eastern Scotian Shelf Shrimp, this places the stock in the Cautious Zone.
- The 2016 TAC was reduced by 28% (from 4,500 mt in 2015 to 3,250 mt) to reflect declining fishable and spawning stock biomass resulting from the loss of the formerly abundant 2007-2008 year-classes. The precautionary TAC reduction helped to reduce both total and female exploitation to 12% and 16%, respectively.
- Belly-bag Age 1 abundance index values for 2015 and 2016 were the two lowest in the 15-year time-series, suggesting poor recruitment from the 2014 and 2015 year-classes.
- The abundance index for both Age 2 and Age 4 Shrimp decreased in 2016, which is consistent with the low belly-bag Age 1 abundance index values found in 2015 (i.e. 2014 year-class) and 2013 (i.e. 2012 year-class), respectively.
- The 2013 year-class increased the index of abundance for Age 3 male Shrimp to the second highest value in the time series in 2016.
- Ecosystem indicators, including sustained high bottom and sea surface temperatures and reductions in the abundance of sympatric species, suggest that conditions are currently unfavourable for coldwater species such as Shrimp.
- The overall mean summary indicator declined in 2016 and remains in the yellow zone due to declines in indicators representing abundance, productivity, and ecosystem characteristics.
- While Age 4+ males will increase in 2017, it is uncertain whether this will translate into an increase in the total biomass index in 2017. The 2013 year-class is not expected to recruit to the SSB until 2018. As a result, the SSB is not expected to begin to increase until 2018.
- Continuation of precautionary TAC reductions will help to maintain low exploitation rates and to protect more of the 2013 year-class until it can recruit to the SSB.

BACKGROUND

Species Biology

The Northern or Pink Shrimp, *Pandalus borealis*, is the only Shrimp species of commercial importance in the Maritimes Region. Shrimp are crustaceans that have a hard outer shell, which they must periodically shed (molt) in order to grow. Females generally produce eggs once a year (not more) in the late summer-fall and carry them, attached to their abdomen until the spring, when they hatch. Consequently, Shrimp bear eggs, (i.e., are "ovigerous") for about 8 months of the year. Newly hatched Shrimp spend 3 to 4 months as pelagic larvae, feeding

near the surface. At the end of this period they move to the bottom and take up the life style of the adults. On the Scotian Shelf, the Northern Shrimp first matures as a male at Age 2, and generally changes sex at Age 4, to spend another 1 to 2 years as a female. However, Shrimp may live up to 8 years, depending on environmental conditions and population dynamics. Shrimp concentrate in deep "holes" (>100 fathoms) on the Eastern Scotian Shelf (Figure 1), but nearshore concentrations along the coastline were discovered in 1995 by the DFO-Industry survey. In general, Northern Shrimp prefer temperatures of 2-6ºC, and a soft, muddy bottom with a high organic content.

The Fishery

The fishery currently consists of 28 inshore (Maritimes) licenses (11 active vessels during 2016), mostly <65' length overall (LOA), and 14 midshore (Gulf) licenses (5 active vessels during 2016) 65-100' LOA. All mobile licenses have been under Individual Transferable Quotas (ITQs) since 1998. A competitive trap fishery with 14 licenses (8 active during 2016) is largely restricted to Chedabucto Bay (Figure 1). The trap fishery allocation is currently 8% of the yearly Total Allowable Catch (TAC). The fishery operates under an "evergreen" management plan, which documents sharing agreements between fleet sectors.

Although there has been some Shrimp fishing on the Scotian Shelf since the 1960s, the Maritimes fishery began to expand toward its full potential only when groundfish bycatch restrictions were overcome with the introduction of the Nordmøre grate in 1991. The TAC was first reached in 1994 after individual Shrimp Fishing Area (SFA) quotas were combined into a single TAC (Table 1, Figure 2). Since that time there have been some minor shortfalls associated with re-allocations of uncaught trap quotas to the mobile fleet late in the season. The gap between the TAC and catch has narrowed steadily since 2005 as problems associated with market conditions and quota reallocations have been resolved. The mobile fleet continues to prefer open access to all areas (i.e., no individual SFA quotas) because of the flexibility this offers in obtaining favourable combinations of good catch rates and counts (Shrimp sizes).

As of November 15, 2016, 3,026 mt of the 3,250 mt TAC had been landed. The trap fleet landed 314 mt in 2015, and 106 mt had been landed as of November 15, 2016 (fishing is ongoing).

Table 1. Recent Eastern Scotian Shelf Shrimp Total Allowable Catches (TACs) and landings ('000s mt).

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
TAC	5.0	5.0	5.0	5.0	3.5	5.0	4.6	4.2	3.8	4.5	4.5	3.2
Landings	3.6	4.0	4.6	4.3	3.5	4.6	4.4	4.1	3.6	4.3	4.4	3.0[1]

[1]Landings to November 15, 2016.

The spatial pattern of the fishery has changed significantly over the years (Figure 2), reflecting changing distributions of biomass and size frequencies. In general, the bulk of the catch has been taken from SFAs 14 and 15, although 57% of the TAC was landed in SFA 13 in 2004. As of November 15th, 69% of the 2016 TAC has been landed from SFA 14.

Historically (up to 2009), the fishing began in April and a large proportion of the catch was taken by June, at which time fishing generally stops to avoid the moulting period. Fishing has generally resumed in September-October and may continue into December if catch rates and Shrimp condition are suitable. In recent years, fishing has been starting earlier in the calendar year.

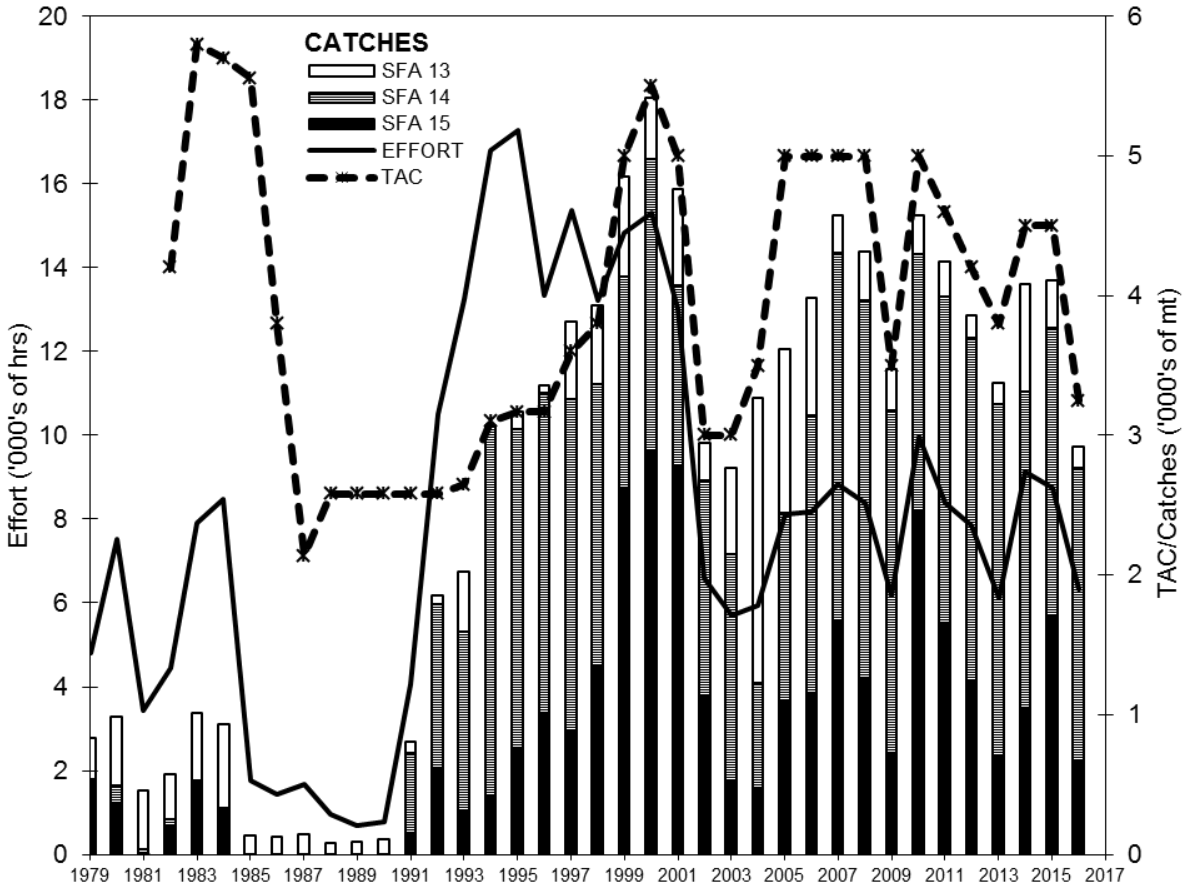

Figure 2. History of Eastern Scotian Shelf Shrimp catches per Shrimp Fishing Area (SFA) (13, 14, and 15), Total Allowable Catch (TAC) (thousands of mt), and effort (thousands of hours), from 1979-2016. Effort and catches for 2016 represent data up to November 15, 2016.

ASSESSMENT

Stock Trends and Current Status

A Traffic Light Analysis (TLA) has been used to assess the status of the Eastern Scotian Shelf Shrimp stock for the provision of science advice since 1999 (Koeller et al. 2000). This holistic multiple indicator approach considers the current value of each indicator relative to its time series and summarises individual indicators into four “characteristics”, as well as in an overall mean summary indicator. 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 TLA is used to display, summarise, and synthesise a large number of relevant yet disparate data sources into a consensus opinion on the state of the Shrimp stock.

As predicted in recent assessments, the Eastern Scotian Shelf Shrimp stock has declined since 2014, as the 2007-2008 year-classes have now reached the end of their expected life span. In 2016, the 3 Catch Per Unit Effort (CPUE) based indicators provided diverging results. The DFO-Industry survey CPUE decreased 14%, while the standardized CPUE increased 3%, and the Gulf vessel CPUE decreased by 4% (Figure 3A). As of November 15, 2016, the trap catch index had declined 22% relative to 2015. The 2016 total biomass estimate declined 14% to 25,584 mt

(± 5,079 mt, 95% Confidence Interval (CI)) from the 2015 estimate of 29,642 mt (± 7,324 mt, 95% CI).

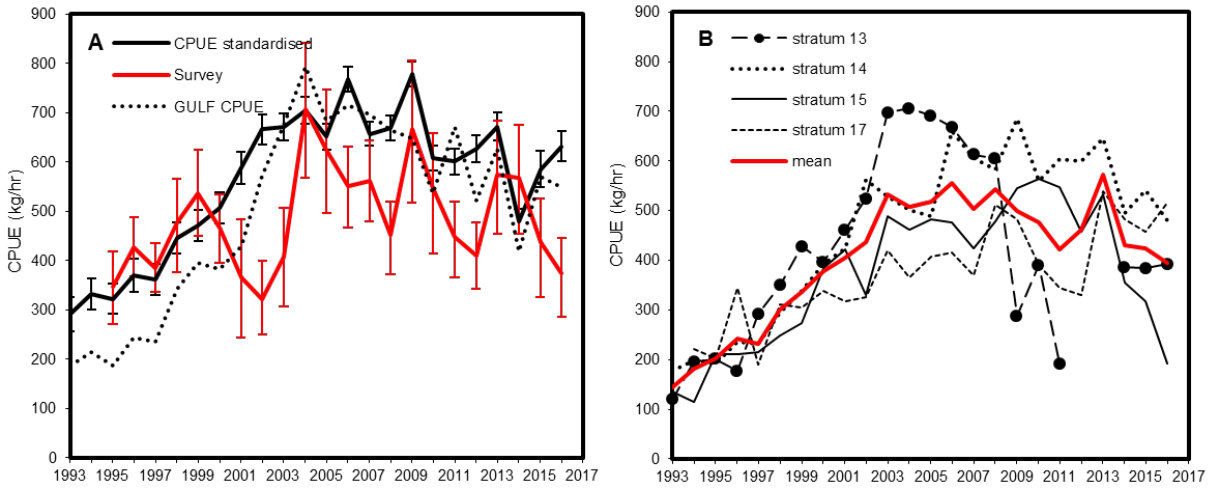

Figure 3. A – DFO-Industry survey stratified Catch Per Unit Effort (CPUE), standardised commercial CPUE with 95% confidence intervals, and unstandardised Gulf vessel CPUE, and B - unstandardised commercial CPUE for each fishing area, from 1993-2016.

Divergences in commercial and DFO-Industry survey CPUE trends have occurred previously (Figure 3A). The first, between 2000-2003, was attributed to changing spatial distribution patterns of the relatively large 1994-1995 year-classes as these moved through the population and died off. The second, 2005-2008, was at least partly due to a problem with the attack angle of the Nordmøre grate in the DFO-Industry survey trawl. The direction of the 2014-2016 divergence, with commercial CPUE remaining at a high level while the DFO-Industry survey CPUE declines, is similar to that experienced in 2000-2003. Commercial CPUE indices may not always reflect overall abundance changes in the short term, due to changes in the spatial distribution of the resource and fishing effort. The current divergence is likely indicative of changing spatial distribution patterns associated with the decline of the 2007-2008 year-classes at the end of their lifespan. The declines in the DFO-Industry survey CPUE are corroborated by the distribution of commercial catch areas, where, since 2014, declines have occurred in all catch rate categories. Commercial trawl CPUE indices remaining at a relatively high level is likely a reflection of the reduced 2016 TAC, which has served to limit the fishing effort and reduce overall pressure on a declining resource.

The 2016 Spawning Stock Biomass (SSB, females) point estimate declined 11% to 13,223 mt, and is now below the Upper Stock Reference (USR, 14,558 mt). Based on the precautionary approach as it is applied to Eastern Scotian Shelf Shrimp, this places the stock in the Cautious Zone (Figure 4A and Figure 5). The 2016 TAC was reduced by 28% (from 4,500 mt in 2015 to 3,250 mt) to reflect declining fishable and spawning stock biomass resulting from the loss of the formerly abundant 2007-2008 year-classes. The precautionary TAC reduction helped to reduce total and female exploitation to 12% and 16%, respectively (Figure 4B and Figure 5). A decreasing trend in the areas of all catch rate categories, coupled with the decrease in the point estimates of both total and spawning stock biomass, suggest continuation of the population downturn into 2017.

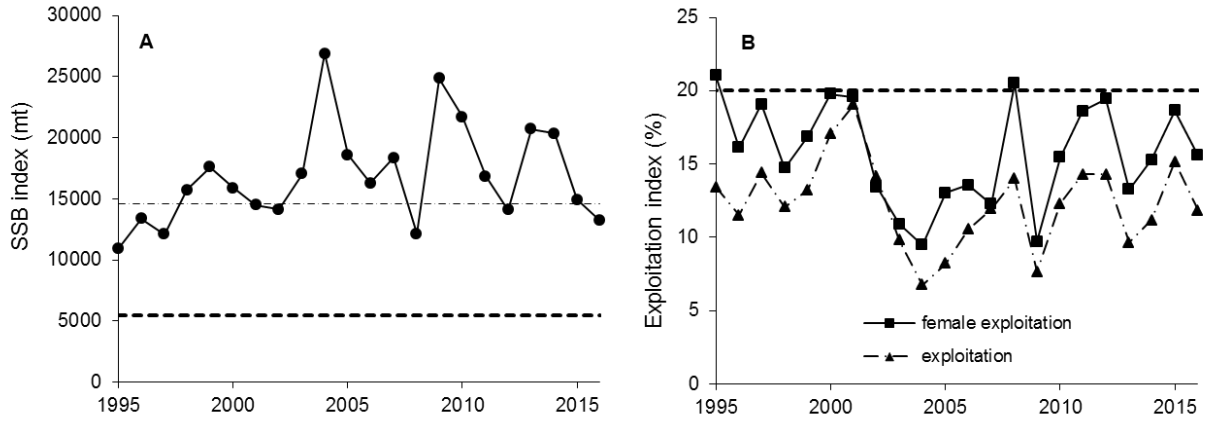

Figure 4. A - Changes in the Spawning Stock Biomass (SSB) index for the Eastern Scotian Shelf Shrimp population. The dashed lines show the Lower Reference Point (LRP) at 30% and Upper Stock Reference (USR) at 80% of the mean SSB during the 2000-2010 high-productivity period. B - Changes in the exploitation indices for the Eastern Scotian Shelf Shrimp fishery. The dashed line shows the removal reference of 20% for the female exploitation index when in the Healthy Zone.

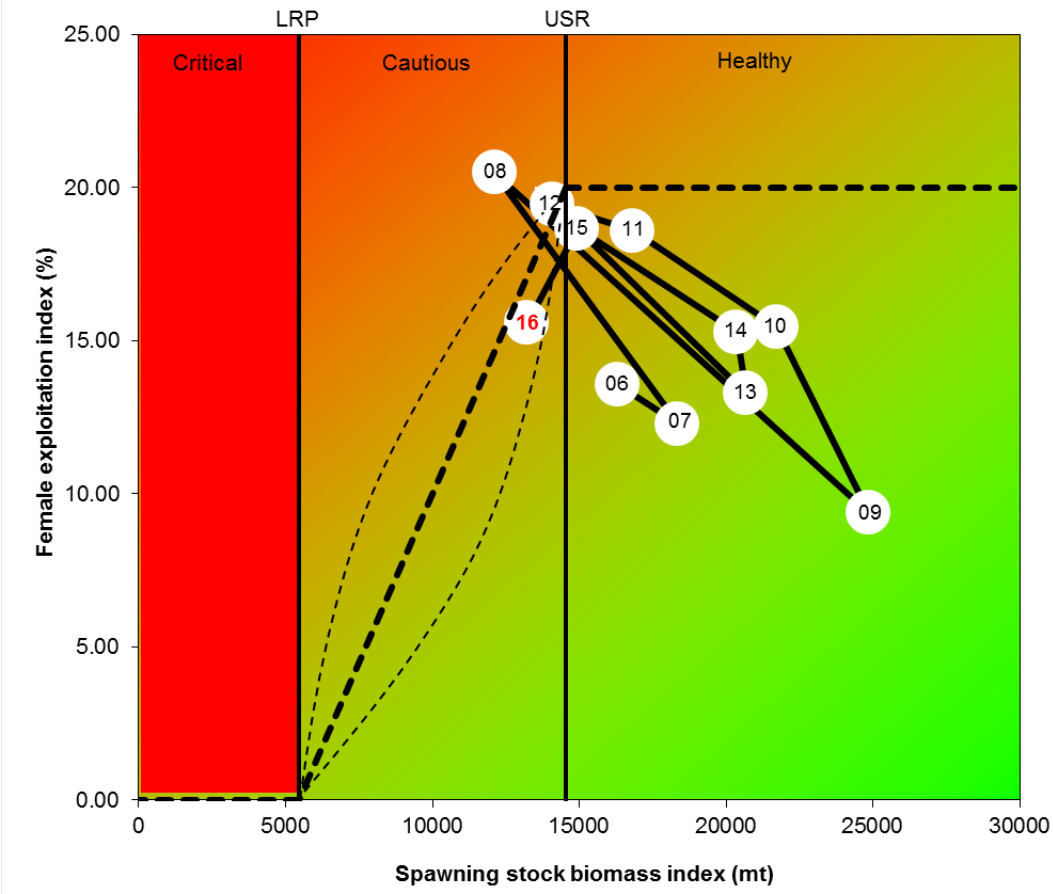

Figure 5. Graphical representation of the precautionary approach for Eastern Scotian Shelf Shrimp. The dotted lines in the Cautious Zone represent a range of management actions possible, depending on whether the stock is stable, increasing or decreasing, or on trends in other indicators of stock or ecosystem health.

The interpretation of year-class strength and longevity can be complicated by a number of factors, including: the low catchability of Shrimp younger than Age 4; the strong influence of growth rate on the catchability of Age 4 Shrimp; difficulty in distinguishing and assessing year-classes after Age 3; and changing longevities and natural mortalities associated with environmental or density dependent influences. The tendency of a single year-class, especially relatively large ones such as 2001 and 2007-2008, to change sex over a number of years, makes it difficult to distinguish them from adjacent year-classes. Nonetheless, the recruitment pulses of 2001, 2007-2008, and most recently 2013, have coincided with the maturation of strong year-classes, i.e., 1993-1995, 2001, and 2007-2008, respectively, providing evidence that strong year-classes have produced large spawning stock biomasses.

With the 2007-2008 year-classes having now reached the end of their expected lifespan, less abundant year-classes (2009-2012) currently support the remaining fishable and spawning stock biomass; as evidenced in the 2016 DFO-Industry survey (Figure 6 and Figure 7) and commercial catches (Figure 8). Cohort tracking through length frequency distributions from the DFO-Industry survey and commercial samples corroborate the low belly-bag (Age 1 abundance) index from 2010-2013 in predicting low contributions to fishable and spawning stock biomass from the 2009-2012 year-classes (Table 2). Belly-bag Age 1 abundance index values for 2015 and 2016 were the 2 lowest in the 15-year time-series, suggesting poor recruitment from the 2014 and 2015 year-classes. The abundance indices for Age 2 and Age 4 Shrimp decreased in 2016, which is consistent with the low belly-bag index values found in 2015 (i.e. 2014 year-class) and 2013 (i.e. 2012 year-class), respectively (Table 2). The low overall abundance of Age 1 and Age 2 Shrimp observed in the 2016 DFO-Industry survey is consistent the reductions in spawning stock biomass and elevated temperature indices observed since 2014.

The 2013 year-class, first observed in 2014 as the second highest belly-bag index in the time series (Table 2), has been closely monitored and continues to provide a strong signal in the DFO-Industry survey (Table 2; Figure 6 and Figure 7) and commercial fishery data (Figure 8). The 2013 year-class increased the index of abundance for Age 3 male Shrimp to the second highest value in the time series in 2016. Assuming continued growth and survival of the 2013 year-class, the abundance of Age 4 males should increase significantly in 2017. While Age 4+ males will increase in 2017, it is uncertain whether this will translate into an increase in the total biomass index in 2017. The 2013 year-class is not expected to recruit to the SSB until 2018. As a result, the SSB is not expected to begin to increase until 2018.

Table 2. Minimum survey population numbers-at-age from modal analysis. Numbers x 10^6.

Age	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
1[1]	-	-	-	980	196	316	198	61	194	484	567	263	97	113	25	790	24	23	289
2	166	280	175	134	616	354	187	121	39	114	304	188	85	348	302	125	504	193	230
3	27	757	362	383	312	3118	652	880	506	396	267	1020	752	1018	1157	628	756	2296	840
4	3010	0[4]	1184	399	1506	839	4502	0[4]	0[4]	1190	463	1036	1044	1022	1693	0[4]	922	550	1368
5+	1952	3374	2110	1847	1727	3324	2224	5106	5506	3017	6020	4109	2488	1666	2398	4980	1956	1534	2827
TOTAL	5155	4412	3831	2763	4161	7636	7763	6169	6244	5201	7622	6616	4467	4167	5574	6523	4162	4596	5145
Age 4+ Males[2]	3235	1784	1771	938	1526	1549	4956	3916	2804	3317	4263	3454	1755	1211	1032	3276	427	773	2206
Primiparous[3]	736	728	817	678	551	870	786	771	1739	892	1492	1324	930	281	860	659	399	663	827
Multiparous	991	863	706	630	1188	1698	1183	480	1157	482	1295	630	945	1309	2224	1835	2076	898	1044
Total Females	1727	1591	1523	1308	1739	2568	1969	1251	2896	1374	2787	1954	1875	1590	3084	2494	2475	1561	1871

Notes:
[1] Belly-bag. Time series began in 2002.
[2] Total population less ages 2 and 3 males, transitionals (i.e. males that will potentially change to females the following year), and females.
[3] Includes transitionals.
[4] Four year olds of the 2002, 2003, and 2010 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.

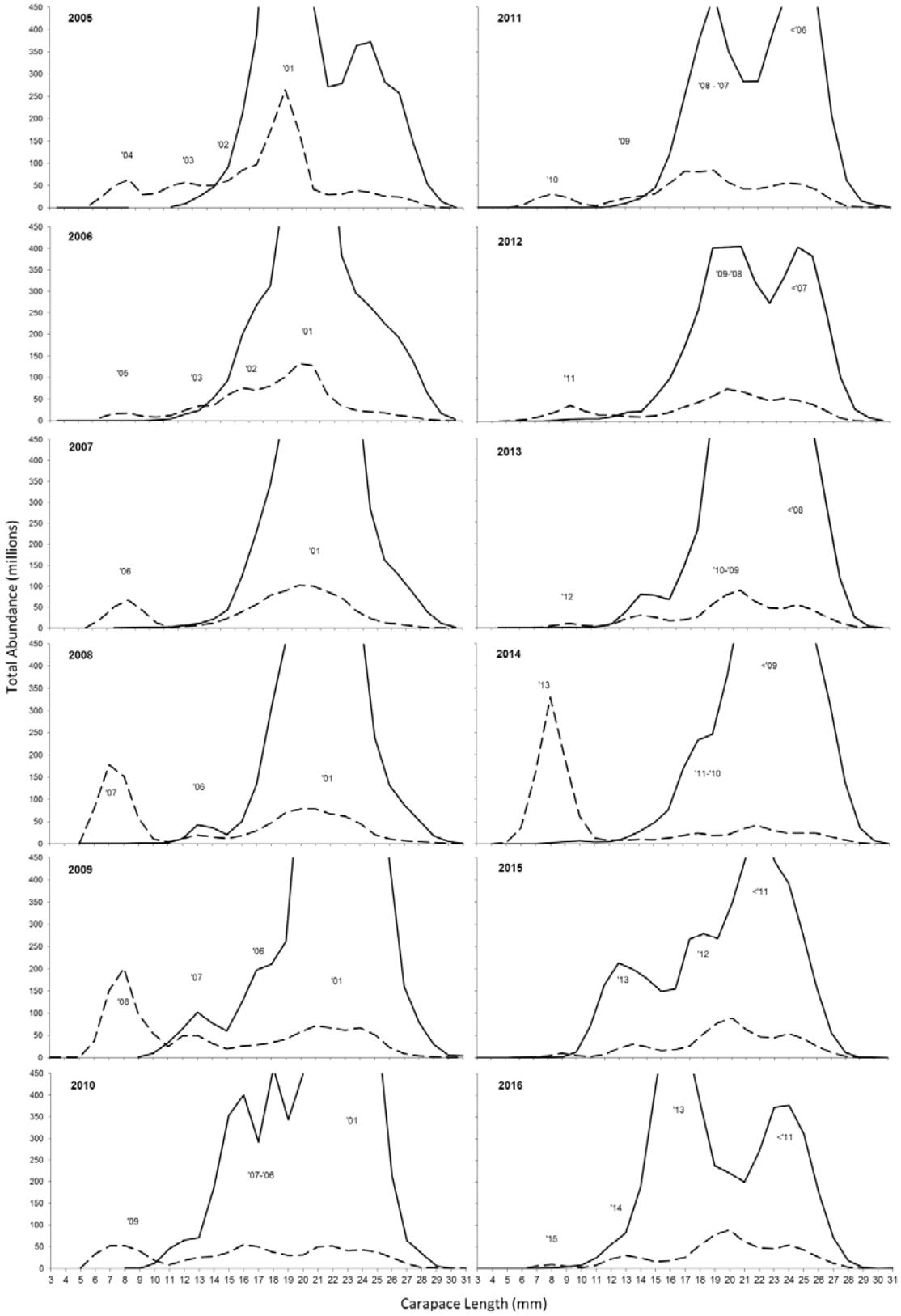

Figure 6. Population estimates from belly-bag and main trawl catches for 2005-2016 DFO-Industry surveys.

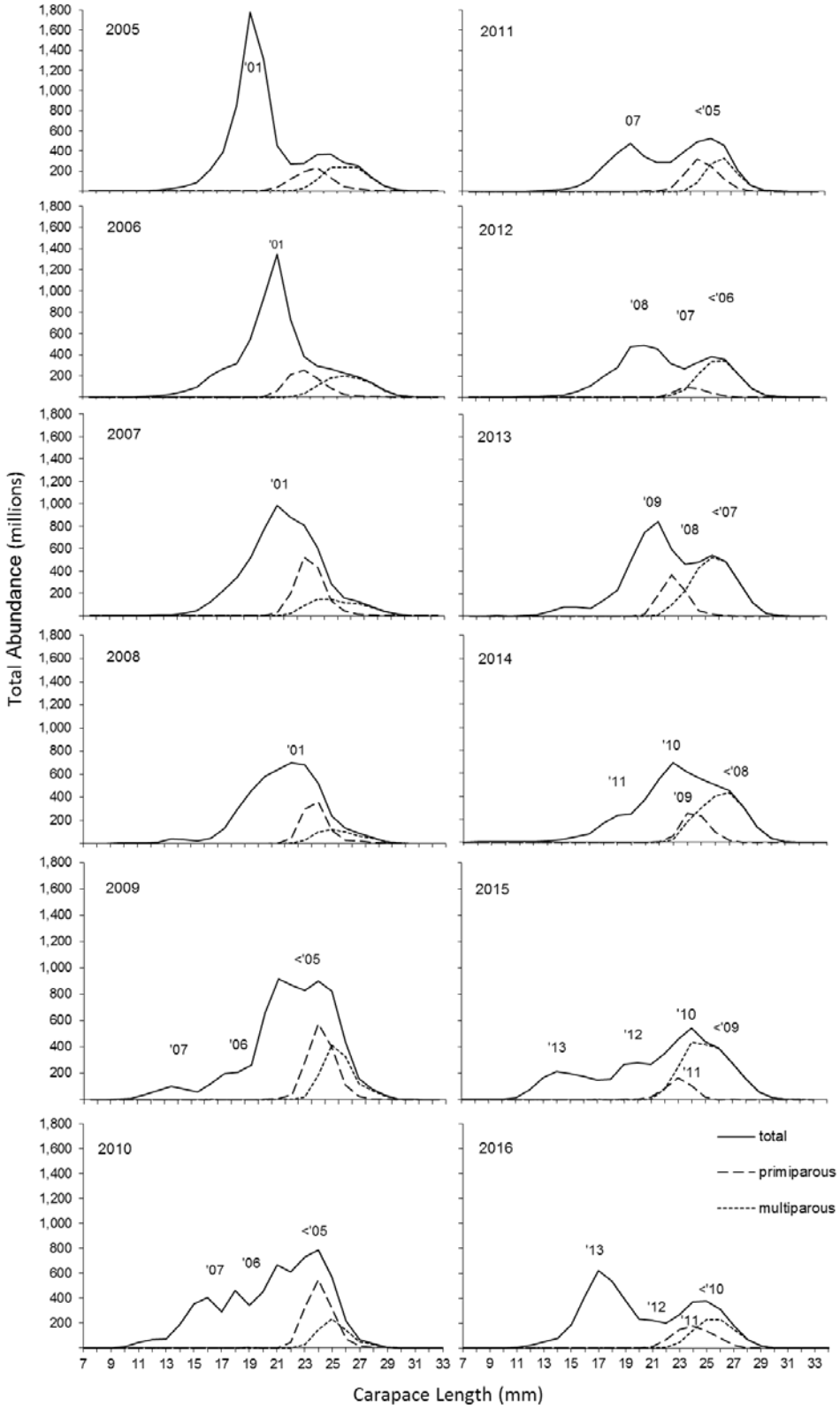

Figure 7. Population estimates- at- length from DFO-Industry surveys 2005-2016 (solid line). The heavy dotted line in each figure represents transitional and primiparous Shrimp, and the stippled line represents multiparous Shrimp.

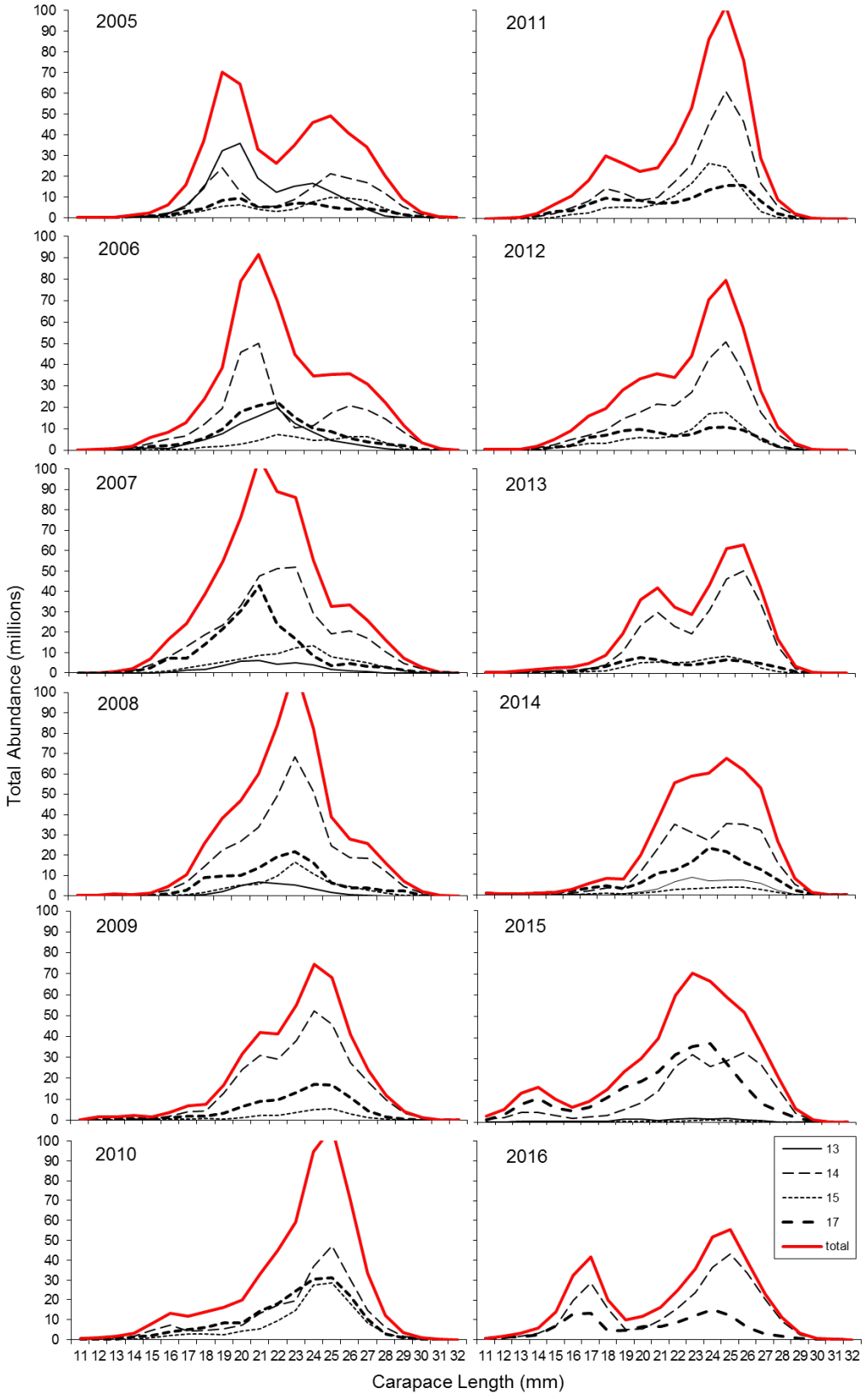

Figure 8. Catch- at- length from commercial sampling by stratum, 2005-2016.

Commercial count estimates (numbers of Shrimp per pound) increased in 2015 and remained stable at a high level in 2016 (Figure 9A). The increased count index in 2015-2016 relative to 2014 is likely indicative of declines in female Shrimp from the 2007-2008 year-classes reaching the end of their lifespan (Table 2). With the loss of these large mature females from the population, smaller females and males, contributed by the less abundant 2009-2012 year-classes, now comprise a greater portion of the catch (Figure 8). Mean female size and mean maximum size indices have been variable, but overall have shown a decreasing trend since the mid-1990s (Figure 9B-C). The stability of the mean female size indicator between 2013 and 2016 can be attributed to the sustained abundance of large females from the 2007-2008 year-classes relative to less abundant, smaller females from succeeding year-classes. Decreases in mean length at sex transition in Shrimp stocks may contribute to population downturns through decreased female fecundity (i.e. smaller Shrimp produce fewer eggs). Length at sex transition can be influenced by large year-classes, which can delay the timing of sex transition, allowing additional year(s) of growth potential. Size at sex transition has been trending in a slow decline toward an average level (for the high-productivity period, 2000-present) for this stock, and continues to fluctuate around 24 mm (Figure 9D). The observed long-term decreasing trend in mean maximum size, mean female size, and mean size at sex transition indicators may represent a cumulative fishing effect that could negatively impact on the population's reproductive capacity.

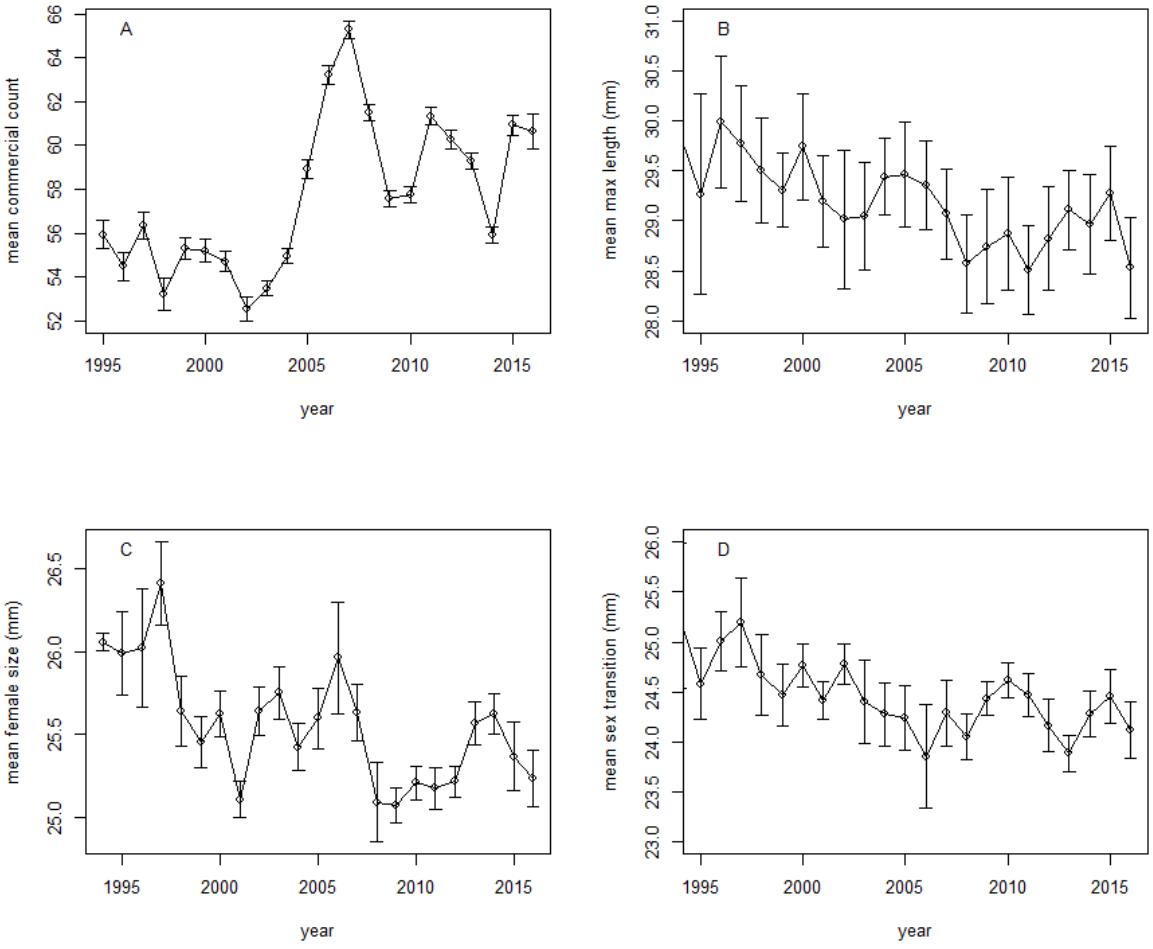

Figure 9. Mean: commercial count (A), maximum length (B), female size (C) and size at sex transition (D) for all Shrimp Fishing Areas (SFAs) combined for 1995-2016 with 95% confidence intervals.

Predator feeding studies have shown that Shrimp are important prey for many finfish species. Significant negative correlations between Shrimp and finfish abundance have been demonstrated from the Gulf of Maine to Greenland (Parsons 2005). Over the recent high-productivity period the predation index has been variable, but remains at a low level relative to the early 1980s, when Shrimp abundance was low. Cod recruitment remained low in 2016. The general index of Shrimp predator abundance increased from 2015 to 2016, but remains within the range of the recent time series (Figure 10). Despite the increased overall predator abundance from 2015 to 2016, it is expected that natural mortality of Shrimp due to predation will continue to be low relative to the available time series.

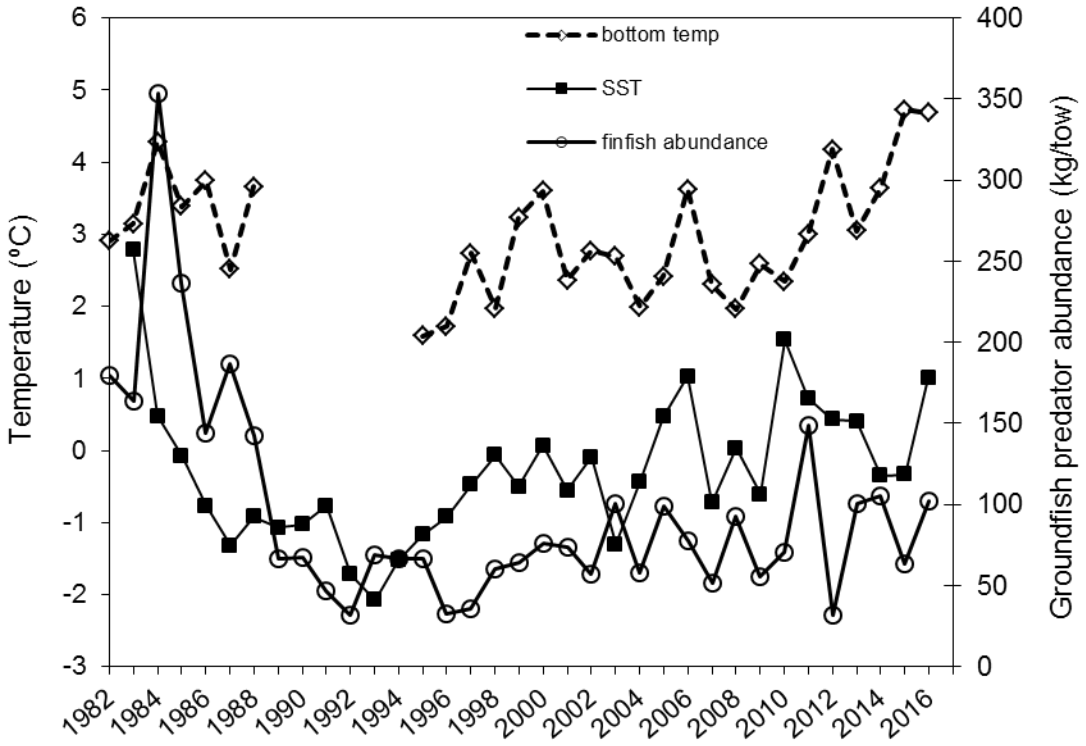

Figure 10. Bottom and spring sea surface temperatures (SSTs) and predator abundance on the Eastern Scotian Shelf Shrimp grounds.

For some Northern Shrimp stocks near the southern limit of the species' range, abundance is negatively correlated with water temperatures. 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. Colder temperatures can increase the length of the egg incubation period, resulting in later egg hatchings that are closer to the spring phytoplankton bloom and warming of the surface layers where larvae feed and grow. Large fluctuations in bottom water temperatures (Figure 10) may also be associated with the cyclical recruitment pattern experienced since the early 1990s (i.e., 1993-1995, 2001 and 2007-2008 year-classes). Spring sea surface temperatures increased in 2016, and June survey bottom temperatures increased considerably since 2013 and were consistent from 2015 to 2016. These indices highlight the increased temperature conditions currently found on the Eastern Scotian Shelf. Warm water conditions, which are approaching the upper level of thermal preference for Shrimp, are thought to have a negative influence on juvenile recruitment. This is substantiated by the very low recruitment observed in the belly-bag Age 1 abundance index for both 2015 and 2016. Further, the abundance of cold water indicator species (Snow Crab and Turbot (Greenland Halibut)) have declined or remained low. Ecosystem indicators, including sustained

high bottom and sea surface temperatures and reductions in the abundance of sympatric species, suggest that conditions are currently unfavourable for coldwater species such as Shrimp.

The 24 indicators relating to the health of the Eastern Scotian Shelf Shrimp stock are summarized in Figure 11. Each indicator was assigned a color for every year data was available according to its percentile value relative to the fixed high-productivity 2000-2010 period. 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 (i.e., >0.66 percentile = green; 0.66-0.33 percentile = yellow; and <0.33 percentile = red). However, if an increase in the indicator was considered bad for stock health the transition between boundaries was reversed. Individual indicators were then grouped into categories of abundance, production, fishing effects and ecosystem characteristics, as well as an overall mean summary indicator (Figure 12). Note that indicators are not weighted in terms of their importance, and abundance, production, fishing effects and ecosystem categories and overall mean summary indicator are determined as a simple average of individual contributing indicators.

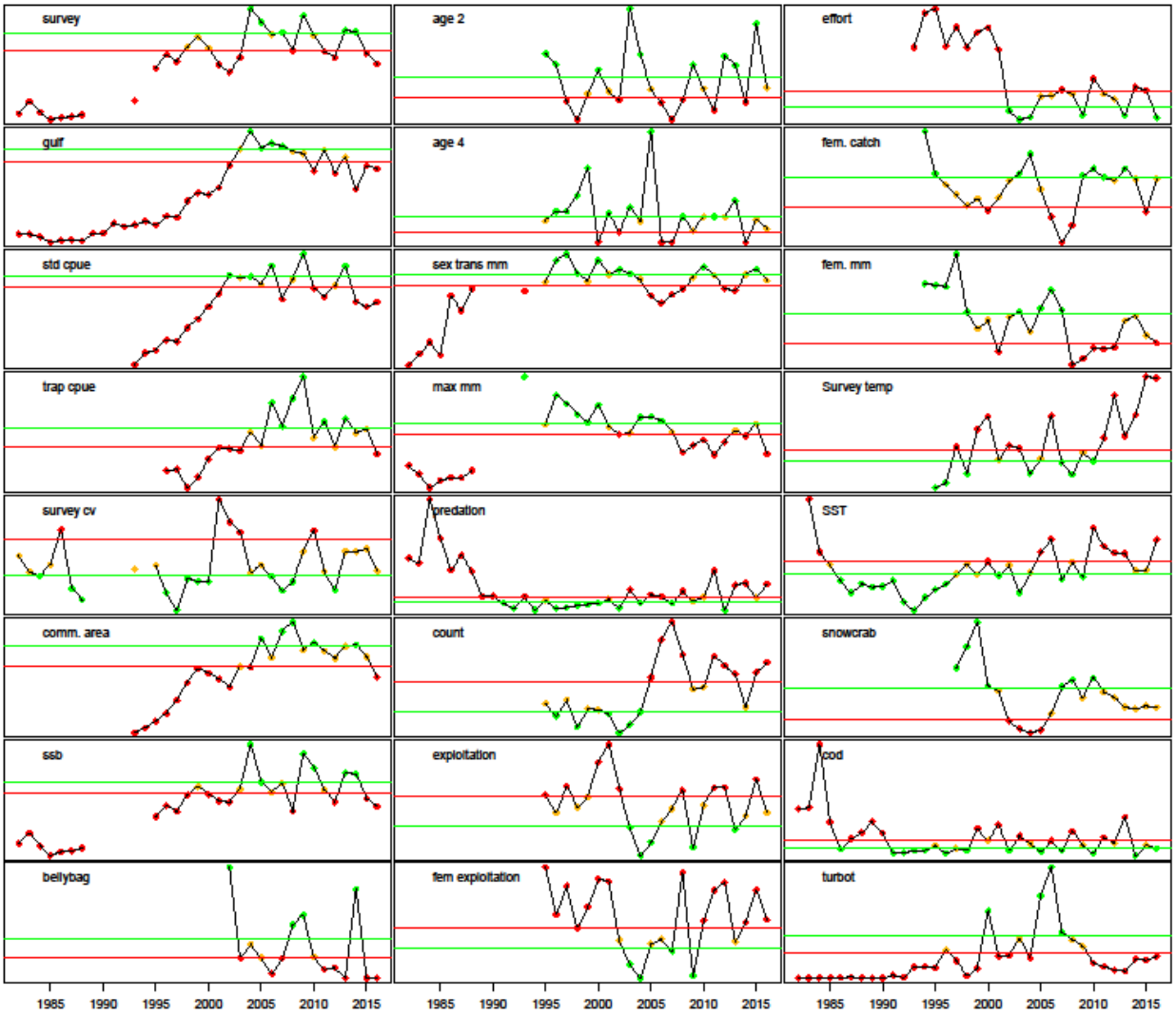

Figure 11. Time series of individual Shrimp indicators. Note: Not all indicators are discussed in the text. Please consult past CSAS Research Documents for detailed description of indicators (e.g. Hardie et al. 2013).

The abundance characteristic declined and remains in the yellow zone due to declines in total abundance, declines in both Gulf and trap CPUE indices, and reductions in commercial catch rate area (Figure 12). The production characteristic also declined and remains in the yellow zone. This is a result of declines in the abundance of young Shrimp associated with poor juvenile recruitment (low belly-bag Age 1), declines in Age 2 and Age 4 abundance indices, reduced SSB, and increased predatory finfish abundance. The fishing effects characteristic improved, but remains in the yellow zone. The improvement can be attributed to declines in total and female exploitation due to the precautionary reduction in the 2016 TAC and fishing effort that was adopted in response to predicted declines in total and spawning stock biomass. The ecosystem characteristic declined and remains in the yellow zone due to high bottom and spring sea surface temperatures, and low/declining indices for sympatric coldwater species (Turbot and Snow Crab). The overall mean summary indicator declined in 2016 and remains in the yellow zone due to declines in indicators representing abundance, productivity, and ecosystem characteristics described above.

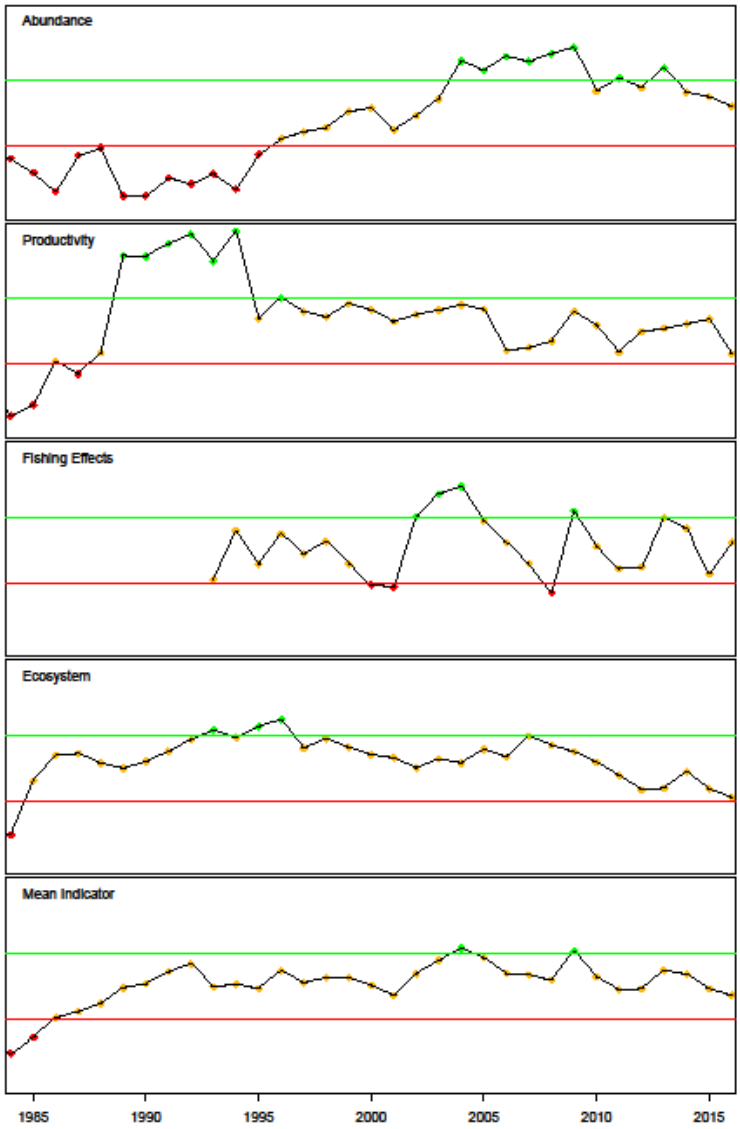

Figure 12. Time series of the characteristic summaries and overall mean summary Eastern Scotian Shelf Shrimp indicator.

Bycatch

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 41 commercial sets from 2015 (2 trips) and 2016 (1 trip) suggests that the fleet's trawl configurations, including the use of the Nordmøre grate, continue to ensure low total bycatch (2.01%) by weight. This value is likely over-estimated due to the minimum 1 kg weight recorded by the observers (e.g. a single fish would be recorded as 1 kg despite weighing only a few grams). Total bycatch by weight from observed trips in 2015-16 is similar to that reported in past assessments. Two of the observed trips took place during the spring/summer and covered portions of SFA 14. The other trip took place in the fall covering the inshore of SFA 15. There was no observer coverage of SFA 13 during 2015 or 2016. Nonetheless, the Eastern Scotian Shelf mobile Shrimp fishery currently poses little risk in terms of bycatch amount or species composition.

Sources of Uncertainty

The DFO-Industry Shrimp 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 can cause low CPUEs, as can fishing areas targeting large Shrimp for market reasons. The standardised commercial CPUE index subsamples the data for vessels that meet certain criteria, which can also result in particularly successful or particularly 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 assessment processes (prior to 2012) may have been based on only a portion of the samples. However, steps have been taken to expedite the analysis of samples such that for 2016, all 120 survey samples and 45 commercial samples were included.

CONCLUSIONS AND ADVICE

The 2016 DFO-Industry survey stratified mean biomass estimate decreased by 14%, to 25,584 mt (± 5,079 mt, 95% CI). The point estimate of the 2016 spawning stock biomass (13,223 mt) decreased 11%, falling below the USR point of 14,558 mt, placing this stock within the Cautious Zone. As predicted by recent assessments, these declines are consistent with the expectation of a lag between the complete mortality of the long-lived 2007-2008 year-classes, and poor recruitment of 2009-2012 year-classes.

Despite declines in the survey abundance index, commercial CPUEs remained at a high level (standardized CPUE increased 3%, Gulf-based vessels declined by 4%). The distribution of areas representing various catch rate levels have all declined since 2014, which in combination with declines in the survey abundance index, is consistent with a declining resource.

Belly-bag Age 1 abundance indices in 2015 and 2016 highlight poor recruitment from the 2014 and 2015 year-classes, respectively, which is consistent with the expectation that high temperature conditions lead to poor recruitment. The abundance of Age 2 and Age 4 Shrimp also decreased in 2016, which is consistent with the low belly-bag index in 2015 (representing the 2014 year-class), and 2013 (representing the 2012 year-class). The abundant 2013 year-class increased the index of abundance of Age 3 male Shrimp in 2016. Assuming continued growth and survival, this age class is expected to recruit to the spawning stock biomass in 2018.

Size-based indicators (mean size at sex transition, mean maximum size, mean female size, mean count) demonstrate that the size of Shrimp has been decreasing in recent years This is consistent with the end of the expected lifespan of the 2007-2008 year-classes that matured as larger than average females and were replaced by smaller, less abundant Shrimp.

Ecosystem indicators, including sustained high temperatures and reductions in the abundance of sympatric species, suggest that conditions are currently unfavourable for coldwater species such as Shrimp.

The overall mean summary indicator, summarizing the 24 indicators, declined and remained in the yellow zone in 2016 due to all four summary characteristics falling within that zone. Despite remaining in the yellow zone, the fishing effects characteristic saw an increase in 2016 based on the precautionary TAC reduction, which in turn reduced overall effort and induced declines in both total and female exploitation indices relative to 2015.

Declines in abundance, production, and ecosystem characteristics, in combination with the SSB biomass declining below the USR in 2016, provides an unfavourable outlook for 2017. While Age 4+ males will increase in 2017, it is uncertain whether this will translate into an increase in the total biomass index in 2017. The 2013 year-class is not expected to recruit to the SSB until 2018. Continuation of precautionary TAC reductions will help to maintain low exploitation rates and to protect more of the 2013 year-class until it can recruit to the SSB.

SOURCES OF INFORMATION

This Science Advisory Report is from the December 7, 2016, Stock Assessment of Eastern Scotian Shelf Shrimp in Shrimp Fishing Areas (SFAs) 13-15. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2016. Stock Status Update of Northern Shrimp on the Eastern Scotian Shelf (SFAs 13-15). DFO Can. Sci. Advis. Sec. Sci. Resp. 2016/001.

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

Hardie, D., M. Covey, M. King, and B. Zisserson. 2013. Scotian Shelf Shrimp 2012-2013. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/034.

Koeller, P. 2000. Relative Importance of Environmental and Ecological Factors to the Management of the Northern Shrimp (*Pandalus borealis*) Fishery on the Scotian Shelf. J. Northw. Atl. Fish. Sci. 27: 21-33.

Koeller, P. 2006. Inferring Shrimp (*Pandalus borealis*) Growth Characteristics from Life History Stage Structure Analysis. J. Shellf. Res. 25: 595-608.

Koeller, P., L. Savard, D. Parsons, and C. Fu. 2000. A Precautionary Approach to Assessment and Management of Shrimp Stocks in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 27: 235-247.

Koeller, P., C. Fuentes-Yaco, M. Covey, M. King, and B. Zisserson. 2010. The Last Traffic Light on the Scotian Shelf: Shrimp 2009-2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/061.

Parsons, D.G. 2005. Predators of Northern Shrimp, *Pandalus borealis* (Pandalidae), Throughout the North Atlantic. Mar. Bio. Res. 1:1, 48-59.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
1 Challenger Drive, PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2

Telephone: 902-426-7070
E-Mail: XMARMRAR@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2017. Assessment of Northern Shrimp on the Eastern Scotian Shelf (SFAs 13-15). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/005.

Aussi disponible en français :

MPO. 2017. Évaluation de la crevette nordique de l'est du plateau néo-écossais (ZPC 13-15). Secr. de consult. sci. du MPO. Avis sci. 2017/005.