STOCK STATUS UPDATE OF EASTERN SCOTIAN SHELF SHRIMP (*PANDALUS BOREAL*IS) IN SHRIMP FISHING AREAS 13-15

Context

Advice on the status of the Eastern Scotian Shelf (ESS) Shrimp (*Pandalus borealis*) stock is requested annually by Fisheries and Oceans Canada (DFO) Fisheries and Aquaculture Management Branch and industry to help determine a Total Allowable Catch (TAC) that is consistent with the Integrated Fishery Management Plan (IFMP). Science advice for the management of the ESS Shrimp stock is provided as a fully peer-reviewed stock assessment at an inclusive Regional Advisory Process (RAP) meeting on a biennial basis. In interim years, science advice is provided as a stock status update and published as a Science Response. The most recent RAP took place in December 2016 (DFO 2017) and the most recent framework review took place in April 2015 (Hardie et al. 2018). The current report provides information on the stock status for 2017 and advice for management of the 2018 fishery.

This Science Response Report results from the Science Response Process of December 13, 2017, on the Stock Status Update of Eastern Scotian Shelf Shrimp in Shrimp Fishing Areas (SFAs) 13-15.

Background

As documented in recent assessments, the ESS Shrimp stock has been declining since 2014. The relatively abundant 2007-2008 year classes were expected to reach the end of their life expectancy in 2014-2016, while the less abundant 2009-2012 year classes were expected to provide limited replenishment to the fishing stock (DFO 2015, DFO 2017, Hardie et al. 2018). Due to very high adult biomass, the TAC was raised from 3,800 metric tons (mt) in 2013 to 4,500 mt in 2014 and held constant in 2015. As the stock began to show signs of decline, TAC reductions were put in place. In 2016, the TAC was reduced by 28% to 3,250 mt, and in 2017 there was a further TAC reduction of 20% to 2,600 mt. The most recent cohort for which there is evidence of high abundance is the 2013 year class (Hardie et al. 2018), which is anticipated to recruit to the spawning stock biomass in 2018.

Description of the Fishery

The trawl fishery on the Scotian Shelf occurs primarily during 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 (Figure 1). 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 (currently about 13 active licenses) 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 licenses is

restricted to Chedabucto Bay. The allocation of quota to the Chedabucto Bay trap fishery currently stands at 8% of the TAC.

Although there has been some Shrimp fishing on the Scotian Shelf since the 1960s, the Nova Scotia fishery began to expand toward its full potential only when groundfish bycatch restrictions were overcome with the introduction of the Nordmøre grate in 1991 (Figure 2). The TAC was first reached in 1994, when individual SFA quotas were removed. Since that time, the TAC has fluctuated between 3,100 – 5,500 mt, mostly in response to the influence of strong recruitment events (large year classes) on spawning stock and fishable biomass. In 2017, the TAC was decreased to the lowest level since 1992 (2,600 mt).

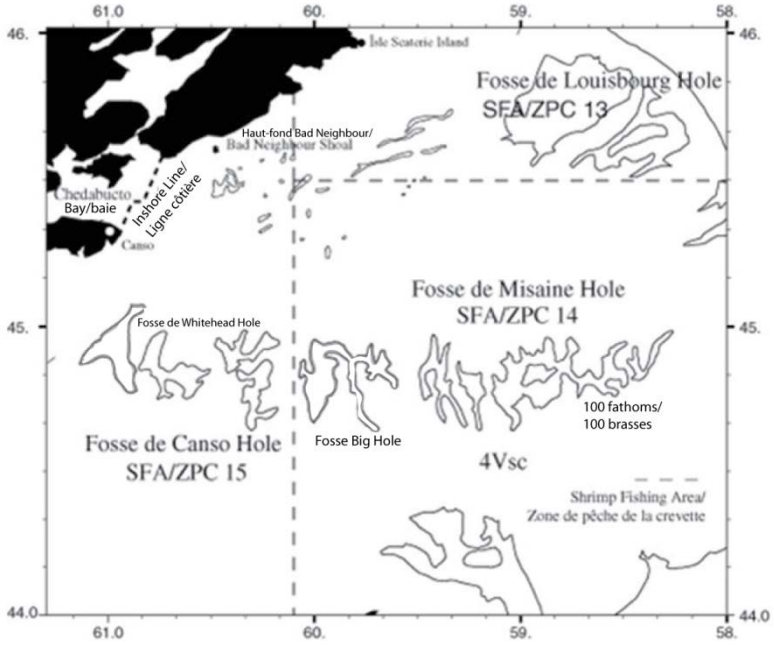

Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. The finely stippled line depicts survey Stratum 17, and survey strata 13-15 are the remaining portions of SFAs 13-15.

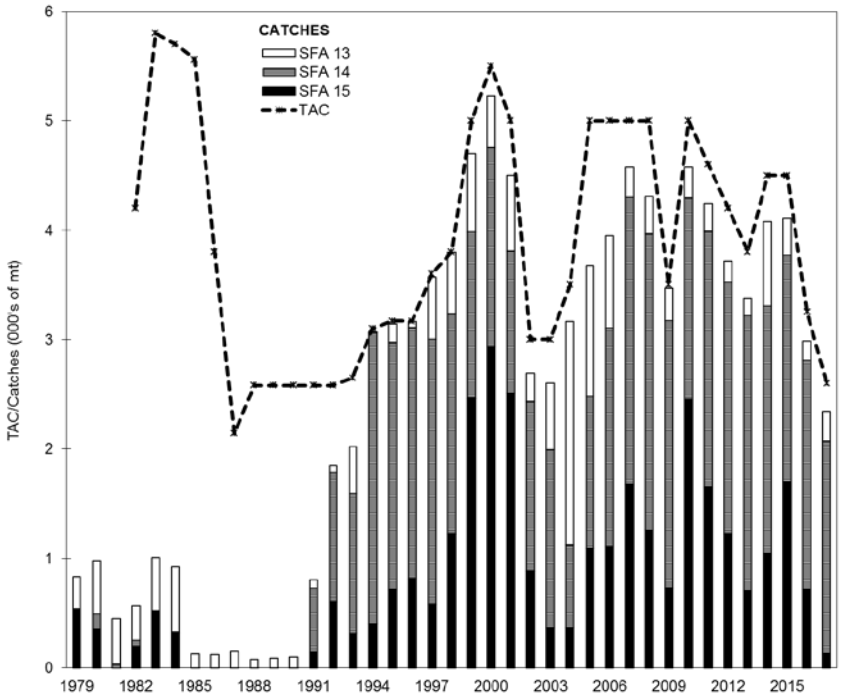

Figure 2. History of Eastern Scotian Shelf Shrimp fishery showing catches per Shrimp Fishing Areas, and Total Allowable Catch up to November 17, 2017.

Analysis and Response

The stock assessment for ESS Shrimp is based on a "Traffic Light" analysis (Koeller et al. 2000, Mohn et al. 2001, Halliday et al. 2001) that uses a multiple indicator diagnostic approach, with discussion of individual indicators grouped under headings representing four characteristics: Abundance, Productivity, Fishing Effects, and Ecosystem (see DFO 2017).

A precautionary approach using reference points and control rules within the framework of the Traffic Light analysis has been used in recent assessments for this stock. The precautionary application of reference points for ESS Shrimp includes a Limit Reference Point (LRP) and Upper Stock Reference (USR), which are 30% and 80%, respectively, of the average Spawning Stock Biomass (SSB) maintained during the high productivity period of the modern fishery (2000-2010). A maximum removal reference point of 20% female exploitation is used to help guide management decisions (Hardie et al. 2018).

Data used in this assessment include commercial catch data, survey Catch Per Unit Effort (CPUE) data (expanded to total biomass using the swept area method), detailed Shrimp biological data (commercial and survey samples), survey data for other marine species, and various environmental data (Hardie et al. 2018).

Indicators of the Stock Status

The swept area survey biomass index declined by 8.6% from 25,584 +/- 7,542 mt (95% confidence interval) in 2016 to 23,382 +/- 6,376 mt (95% confidence interval) in 2017. Biomass estimates declined in all strata except for Stratum 14 (Figure 3). In 2017, CPUE trends from the Gulf and the standardized commercial fishery data also show a decrease (Figure 4). The trap CPUE is not currently available for 2017, as fishing is ongoing, but is anticipated to show a

similar trend. Overall, the mean normalized commercial CPUE and the survey CPUE both corroborate a decline in 2017.

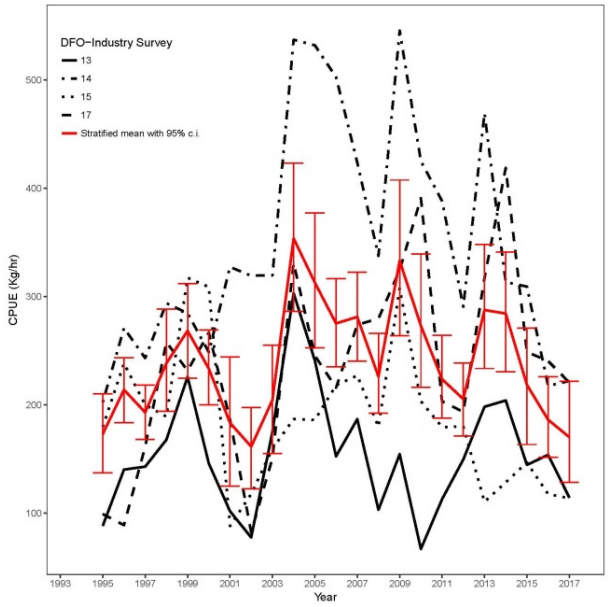

Figure 3. Overall stratified mean survey Catch Per Unit Effort (solid red line with 95% confidence intervals) and Catch per Unit Effort by survey stratum, solid black line is Stratum 13 (Louisbourg Hole), dash-dot line is Stratum 14 (Misaine Hole), dot line is Stratum 15 (Canso Hole), and dash line is Stratum 17 (Inshore).

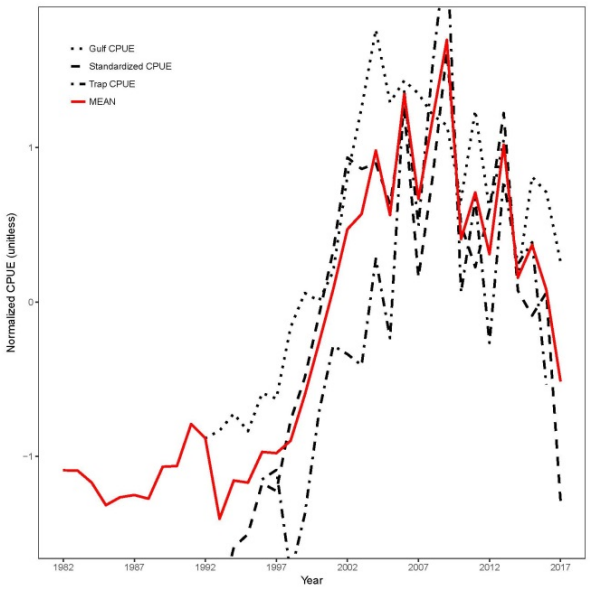

Figure 4. Overall mean-normalized commercial Catch per Unit Effort (solid red line), and normalized Catch per Unit Effort by fleet association, dot line is Gulf portion of mobile fleet, dash line is all mobile fleet, and dash-dot line is trap fleet.

Spawning stock biomass is the biomass indicator. The lower and upper stock reference points are defined as the 30% and 80% of the average SSB from 2000-2010. As depicted in Figure 5, the point estimate of the SSB decreased 6.9% from 13,223 mt in 2016 to 12,312 mt in 2017, placing these last two years below the USR (14,558 mt). The precautionary TAC reductions

have helped to reduce female exploitation since 2015 to 12.9% in 2017, close to the halfway mark from the maximum removal reference of 20% (Figure 5).

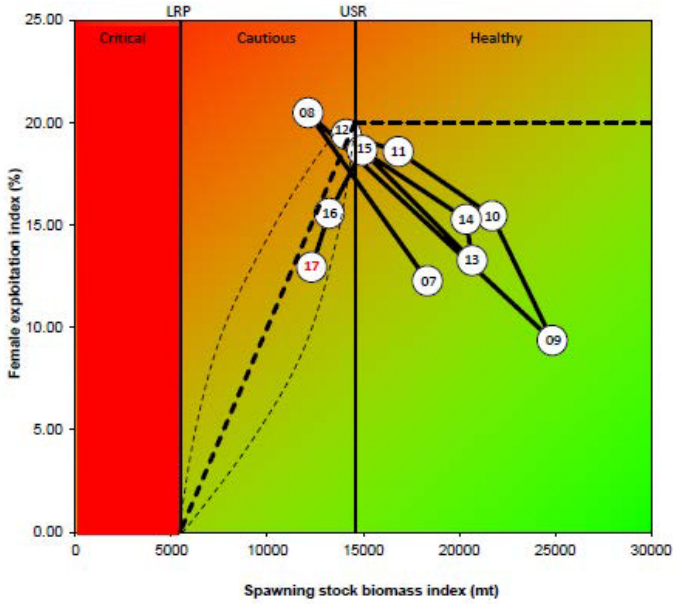

Figure 5. Graphical representation of the precautionary approach for Eastern Scotian Shelf Shrimp. The dotted lines in the Cautious Zone represent a range of management actions possible, depending on whether the stock is stable, increasing or decreasing, or on trends in other indicators of stock or ecosystem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

Table 1. Survey population numbers at age from modal analysis. Numbers X 10^6.

	04	05	06	07	08	09	10	11	12	13	14	15	16	17	Avg.
1[4]	316	198	61	194	484	567	263	97	113	25	789	24	23	88	276
2	354	187	121	39	114	304	188	85	348	302	110	504	1042	581	282
3	3118	652	880	506	396	267	1020	752	1018	1157	552	756	1225	1468	821
4	839	4502	0[3]	0[3]	1190	463	1036	1044	1022	1693	0[3]	922	583	448	1321
5+	3324	2224	5106	5506	3017	6020	4109	2488	1666	2398	4375	1956	1591	1286	2762
TOTAL	7636	7763	6169	6244	5201	7622	6616	4467	4167	5574	5826	4162	4464	3871	5083
4+ males[1]	1549	4956	3916	2804	3317	4263	3454	1755	1211	1032	2670	427	533	204	2109
Primiparous[2]	870	786	771	1739	892	1492	1324	930	281	860	659	399	555	491	808
Multiparous	1698	1183	480	1157	482	1295	630	945	1309	2224	1835	2076	1109	1127	1057
Total Females	2568	1969	1251	2896	1374	2787	1954	1875	1590	3084	2494	2475	1664	1618	1865

[1] Total population less ages 2, 3 males, transitionals, and females; i.e. males that will potentially change to females the following year
[2] Includes transitionals.
[3] Shrimp 4 year olds of the 1996 and 2002, 2003 year classes were not distinguishable in the modal analysis. These year classes appear to be small and are contained in the Age 3 or 5+ categories.
[4] Bellybag.

The declines in the total and spawning stock biomass indices are consistent with the expectation that the 2007-2008 year classes are reaching, or have reached, the end of their lifespan, and that the succeeding year classes (2009-2012) are not abundant. Transitional/primiparous Shrimp are the group of females entering the SSB, and multiparous identifies the group of females that are already contributing to the SSB. The decreased survey length frequencies of transitional/primiparous Shrimp in 2017 (Figure 6) support the declines observed in the biomass indices, although the abundance of multiparous Shrimp remained fairly

stable (Figure 6-8, Table 1). The estimated abundance of Age 4 and older male Shrimp, the age at which Shrimp are expected to recruit to the female biomass the following year, is the lowest on record (Figure 8, Table 1). However, the abundant 2013 year class is evident in the survey and commercial length frequencies (Figure 6 and 7). The estimation from the modal analysis quantifies that the most abundant cohort in 2017 is Age 3 Shrimp, but this is likely a statistical artefact created by the analysis's inability to consistently differentiate the Age 4 cohort. The bellybag index (an indicator of Age 1 Shrimp) values for the 2014 and 2015 year classes were the lowest on record, but in the 2017 survey, the 2016 year class shows an increase from the last two years.

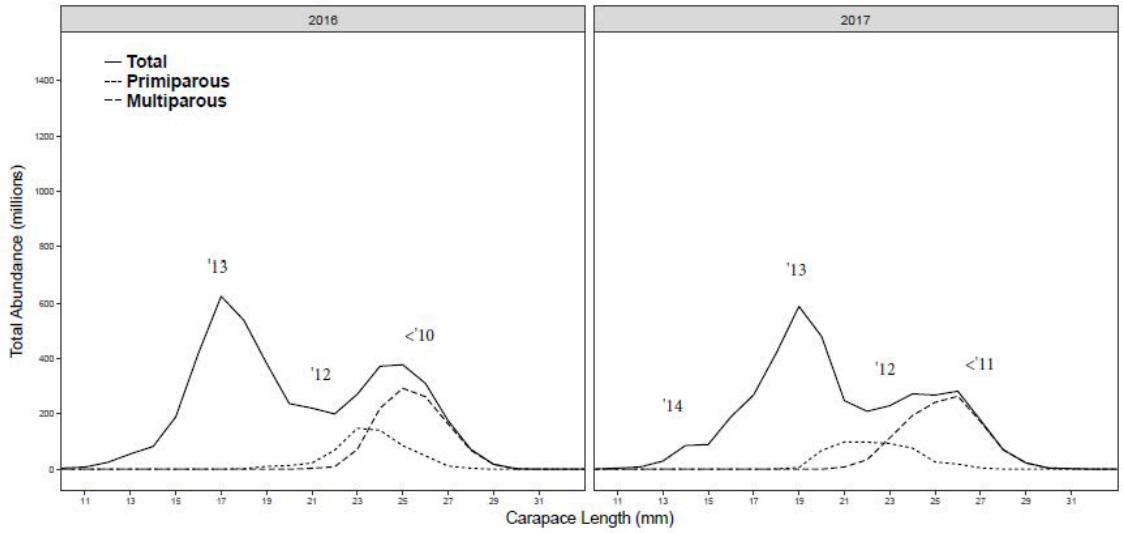

Figure 6. Population estimates of number of Shrimp at length from the 2016 and 2017 DFO-Industry surveys (solid line). The dotted line in each figure represents transitional and primiparous Shrimp, and the dash line represents multiparous Shrimp. Year classes associated with Shrimp at given carapace lengths are indicated. See Hardie et al. 2018 for complete time-series of survey length-frequencies.

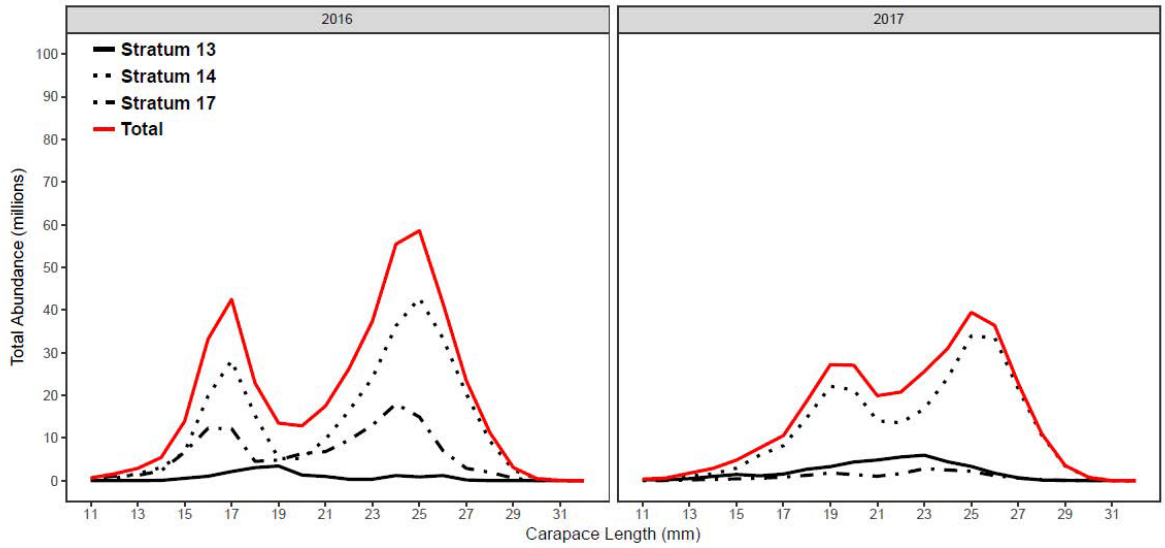

Figure 7. Catch-at-length from commercial sampling by stratum, 2016-2017.

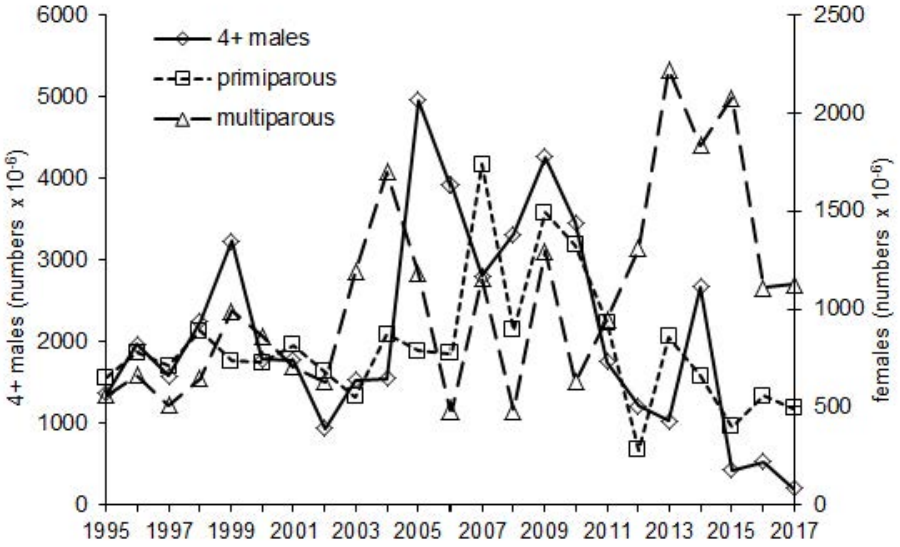

Figure 8. Modal analysis population estimates of Age 4 and older male, primiparous female, and multiparous female Shrimp from the survey.

The suite of available indicators is grouped into four characteristics (Figure 9). The Abundance characteristics show an expected further decline in the red zone from 2016, as all CPUE indicators in 2017 have declined. The Productivity characteristics are also in the red zone but seem to stabilize for 2017. Fishing Effects and Ecosystem characteristics are in the yellow zone, and indicate an improvement from the 2016 values. The most important changes in ecosystem indicators in 2017 are a reduction of bottom temperatures derived from the June Shrimp survey and also the Sea Surface Temperatures (SST) (Figure 10). These temperature decreases are believed to be beneficial as Shrimp prefer cooler temperatures (approximately 0-5°C) and tend to be more abundant and productive during periods and in areas of cooler bottom temperatures (Shumway et al. 1985); however, the general temperature trend shows an increase and, therefore, caution should be taken in the interpretation of the annual variability of temperatures. The overall mean of all four characteristics also shows a slight increase in value, but nonetheless is still in the red zone.

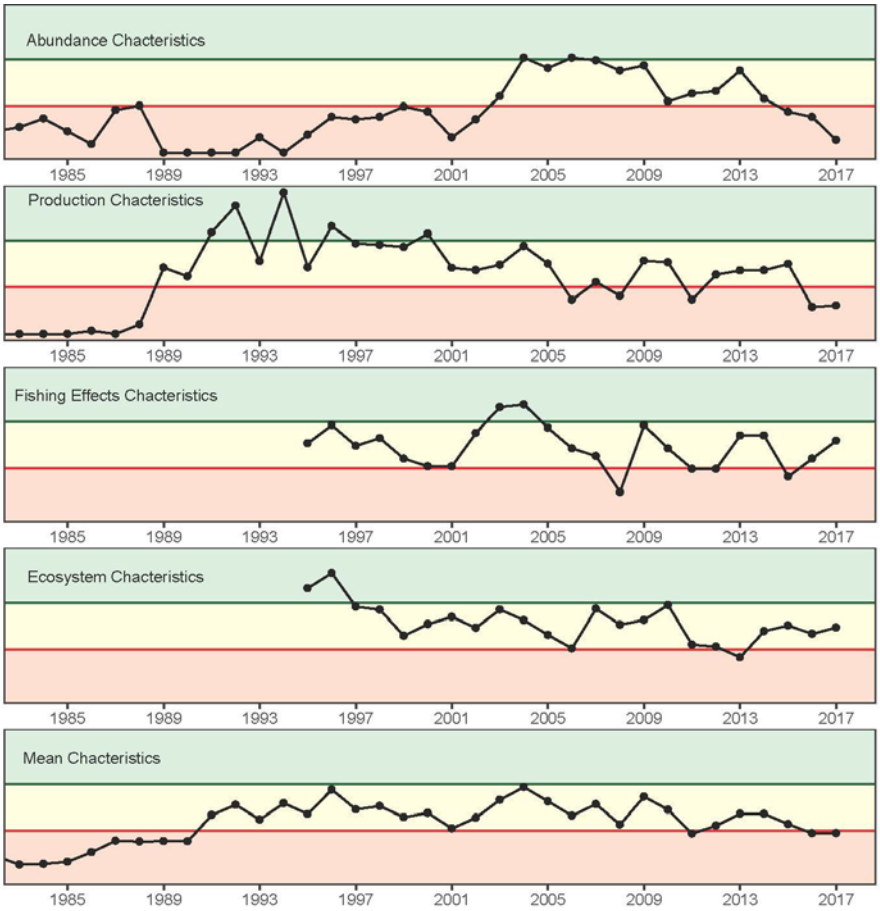

Figure 9. Time series of all available indicators grouped into four characteristics (top four panels) and the mean (overall) indicator (bottom panel) from 1983-2017. Thresholds between red, yellow and green are at the 33rd and 66th percentile of the 2000-2010 data series for each indicator. Not all indicators in the summary above are discussed in the text. See Hardie et al. 2018 for a detailed description of indicators.

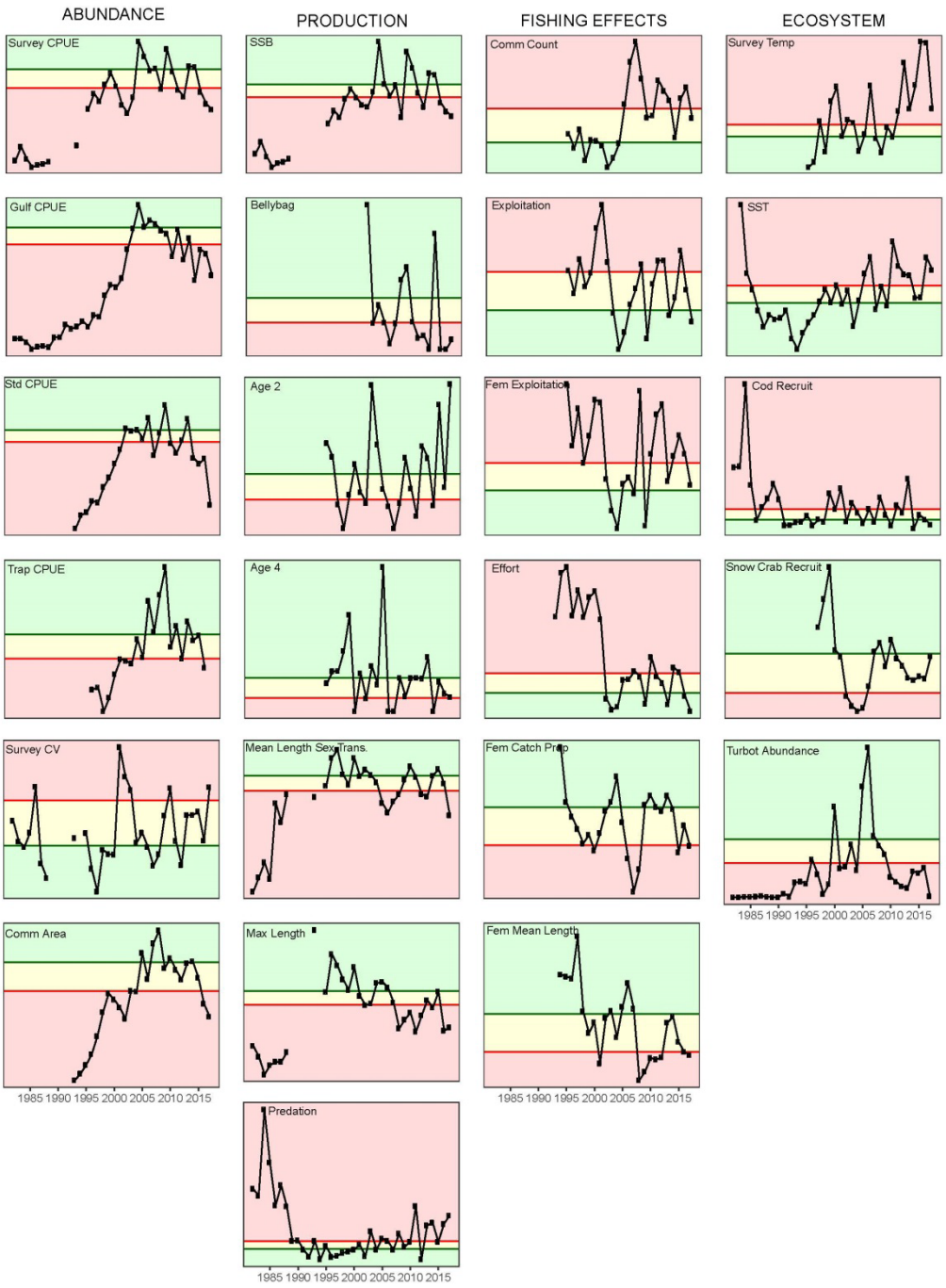

Figure 10. Time series of all available indicators (1982-2017). Thresholds between red, yellow and green are at the 33rd and 66th percentile of the 2000-2010 data series for each indicator. Not all indicators in the summary above are discussed in the text. See Hardie et al. 2018 for a detailed description of indicators.

Bycatch

Of the total catch on observed Shrimp trips in 2017, 1.49% of the weight was bycatch and is based on 23 sets. This is a decrease from the 2016 value of 3.93% (14 sets). The main bycatch species in 2017 are American Plaice (0.50%), Atlantic Herring (0.25%), Winter Flounder

(0.15%), and redfish (0.15%). Table 2 summarizes the bycatch of the commercial Shrimp fishery from observer data for 2016 and 2017.

Table 2. Bycatch of the commercial Shrimp fishery from observer data of 14 sets in 2016, and 23 sets in 2017.

Species	% Bycatch (# of Sets)		Total Observed Weight (2016-2017)		Combined 2016-2017 Mobile TAC (Kgs)
	2016 (14 Sets)	2017 (23 Sets)	Weight (Estimated Kgs)	%	
Shrimp	96.07%	98.51%	69,495	97.45%	5,382,000
Silver Hake	1.95%	0.01%	627	0.88%	47,317
Alewife	0.92%	-	294	0.41%	22,187
Greenland Halibut (Turbot)	0.61%	0.07%	224	0.31%	16,904
Redfish, Unseperated	0.41%	0.15%	193	0.27%	14,565
Atlantic Herring	-	0.26%	102	0.14%	7,698
Winter Flounder	-	0.15%	57	0.08%	4,302
American Plaice	-	0.50%	198	0.28%	14,942
Snow Crab (Queen)	0.01%	-	3	<0.01%	226
Eelpouts, Unseparated)	-	0.11%	43	0.06%	3,245
Sand Lance	-	0.04%	14	0.02%	1,057
Atlantic Cod	0.02%	<0.01%	9	0.01%	679
Squid	-	0.09%	37	0.05%	2,792
Thorny Skate	-	<0.01%	1	<0.01%	75
Alligator Fish	-	0.01%	4	0.01%	302
Capelin	-	0.01%	4	0.01%	302
Squirrel or Red Hake	-	0.02%	6	0.01%	453
Longnose Lancefish	-	0.01%	5	0.01%	377
Striped Atlantic Wolffish	<0.01%	-	1	<0.01%	75
% Bycatch	**3.93%**	**1.49%**		**2.55%**	

Note: Shrimp includes *Pandalus borealis*; *P. montagui* and Genus 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

Conclusions

As documented in the 2015 (DFO 2015, Hardie et al. 2018) and 2016 (DFO 2017) assessments, the ESS Shrimp stock is declining. This decline is consistent with the expectation that the abundant 2007-2008 year classes are reaching or have reached the end of their lifespan (6-8 years). The commercial and survey length frequency data provide evidence that the 2013 year class is identifiable and, therefore, able to contribute the fishable biomass; however, this fishable stock is still predominantly composed of the less abundant 2009-2012 year classes and remnants of the 2007-2008 cohorts.

The age estimates from the modal analysis could not confidently quantify the anticipated increase in Age 4+ male Shrimp for 2017. This low estimate of Age 4^{+} male Shrimp (pre-

recruits) coupled with the low abundance of 2009-2012 year classes suggests that the SSB is unlikely to increase notably until the 2013 year class begins to undergo sex transition. Based on the length frequencies and associated modal analysis, the 2013 year class appears to be surviving well but recruiting to the population at a slower rate than expected. This transition is expected to occur in 2018 and result in an increase in Age 5^+ female Shrimp. Although the 2013 year class has not yet contributed to the SSB, Shrimp in this cohort are expected to increase their contribution to the total biomass as they continue to grow and to spawn as males in 2017-2018.

The record-low bellybag index values in 2015 and 2016 (2014 and 2015 year classes, respectively) suggest that the recovery of the stock from the current decline will be mostly dependent on the 2013 year class recruiting to the fishery. However, in 2017 a slight increase in the bellybag index (2016 year class) was observed and indicates a positive response from the current SSB. The slight increase in the bellybag index and in Age 2 Shrimp have both contributed to the Production characteristics grouping value, which has increased from 2016 but remains in the red zone for 2017.

Abundance and favorable survival of the 2013 year class is supported by the 2017 length frequency data. This year class will also contribute to the fishable biomass in 2018 if it continues to have a high survival rate; however, the 2013 year class has not yet contributed significantly to the SSB. The stock declined into the Cautious Zone in 2016, and remains in this zone in 2017. The stock seems to be responding favorably to the last TAC decrease, which has allowed some of the remaining SSB to be conserved. This is supported by the Productivity characteristic and the overall mean of all the indicator characteristics, which have not declined further in the red zone and show a slight increase from 2016. Maintaining the TAC at a similar level would likely conserve more of the remaining SSB until the 2013 year class begins to undergo sex transition in 2018. Evidence that the 2013 year class is currently the only abundant year class expected to provide strong recruitment to the stock in the coming years, coupled with variability in temperature in the stock area during the last few years, highlight the need for a conservative harvest approach.

Contributors

Name	**Affiliation**
Manon Cassista-Da Ros (Lead)	DFO Science, Maritimes Region
Michele Covey	DFO Science, Maritimes Region
Jessica Cosham	DFO Science, Maritimes Region
Lottie Bennett	DFO Science, Maritimes Region
Leslie Nasmith (Reviewer)	DFO Science, Maritimes Region
Daphne Themelis (Reviewer)	DFO Science, Maritimes Region
Irene Andrushchenko	DFO Science Maritimes Region
Claire MacDonald	DFO Resource Management, Maritimes Region

Approved by

Alain Vézina
Regional Director of Science
DFO Maritimes Region
Dartmouth, Nova Scotia
Ph. 902-426-3490

Date: February 6, 2018

Sources of Information

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

DFO. 2015. Assessment of Northern Shrimp on the Eastern Scotian Shelf (SFAs 13-15). DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/004.

Halliday, R.G., Fanning, L.P., and Mohn, R.K. 2001. Use of the Traffic Light Method in Fishery Management Planning. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/10.

Hardie, D., Covey, M., and Cook, A. 2018 Eastern Scotian Shelf Shrimp Framework. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/005.

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

Mohn, R., Black, J., and Koeller, P. 2001. Traffic Light Indicators. BIO Review 2000: 88 p.

Shumway, S.E., Perkins, H.C., Schick, D.F., and Stickney, A.P. 1985. Synopsis of Biological Data on the Pink Shrimp, *Pandalus borealis* Krøyer, 1838. NOAA Tech. Rept. NMFS 30.

This Report is Available from the :

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

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

ISSN 1919-3769

Correct Citation for this Publication:

DFO. 2018. Stock Status Update of Eastern Scotian Shelf Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 13-15. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/014.

Aussi disponible en français :

MPO. 2018. Mise à jour de l'état du stock de crevettes (Pandalus borealis) dans les zones de pêche à la crevette 13 à 15 de l'est du plateau néo-écossais. Secr. can. de consult. sci. du MPO, Rép. des Sci. 2018/014.