



2022 STOCK STATUS UPDATE OF EASTERN SCOTIAN SHELF NORTHERN SHRIMP (SFAS 13–15)

Context

Advice on the status of the Eastern Scotian Shelf (ESS) Northern Shrimp stock is requested annually by Fisheries and Oceans Canada (DFO) Resource Management to help determine a Total Allowable Catch (TAC) that is consistent with its management plan (DFO 2011). The science advice is required because of rapid changes in abundance, variable recruitment to the population and fishery, and changes in the size of Northern Shrimp available for harvest. This stock is also near the southern limit of the species' distribution where it is thought to be more vulnerable to significant and rapid declines, as observed in the adjacent Gulf of Maine (GoM) stock (ASMFC 2018). The current report provides information and advice for management of the 2023 fishery.

This Science Response Report results from the regional peer review on December 08, 2022, entitled Stock Status Update of Shrimp on the Eastern Scotian Shelf.

Background

The ESS Northern Shrimp, *Pandalus borealis*, stock status indicators have provided mixed signals in recent assessments. Following a 4-year decline (2014–2017), positive changes to biomass were observed in 2018. A steady biomass increase was then observed up until 2020. In 2021, the biomass decreased to 21,167 t, and a subsequent decrease in 2022 to 15,610 t was observed. Currently, the less abundant year-classes from 2015 and 2016 are contributing limited recruitment to the fishable biomass until the end of their expected lifespan in 2022 and 2023 (DFO 2021, DFO 2022). Since 2017, recruitment has been at a consistent level near the time series mean (273 million, 1999–2022), and has begun contributing to the fishable biomass in 2022.

In 2016, after two years of biomass declines, TAC reductions were put in place. The TAC was reduced by 28% to 3,250 t in 2016, with a further TAC reduction of 20% to 2,600 t in 2017. From 2018 until 2021, a status quo TAC was implemented. Then in 2022, in response to a decrease in both total and spawning stock biomass, TAC was further reduced by 11.5% to 2,300 t.

Stock assessments are conducted bi-annually with interim year updates on stock health. Both assessment and update processes are based upon a full analysis of Northern Shrimp stock indicators determined from the DFO-Industry collaborative survey, commercial catch, a port sampling program, and environmental monitoring data.

Description of the 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 Northern Shrimp “holes”, and in the inshore area of Bad Neighbour Shoal (Figure 1). The main management tools include 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. The mobile sector¹ (16 active vessels in 2022) is divided into two fleets, a Gulf Region fleet consisting of vessels 65–100' Length Over All (LOA) based in New Brunswick, and a Maritimes Region fleet consisting of vessels mainly < 65' LOA. The trap sector¹ fleet (7 active vessels) is restricted to the Chedabucto Bay area, and their activity has dramatically decreased in the last two years (2 active vessels in 2022). All mobile sector licenses operate under an Individual Transferable Quota (ITQ) system, while all trap sector licenses operate under a Competitive Quota (CQ). The quota allocated to the trap fishery is currently 8% of the TAC. As described in the ESS Northern Shrimp Integrated Fisheries Management Plan (IFMP), sectors negotiate annually on transfers of uncaught trap quota to the mobile fleet (DFO 2011).

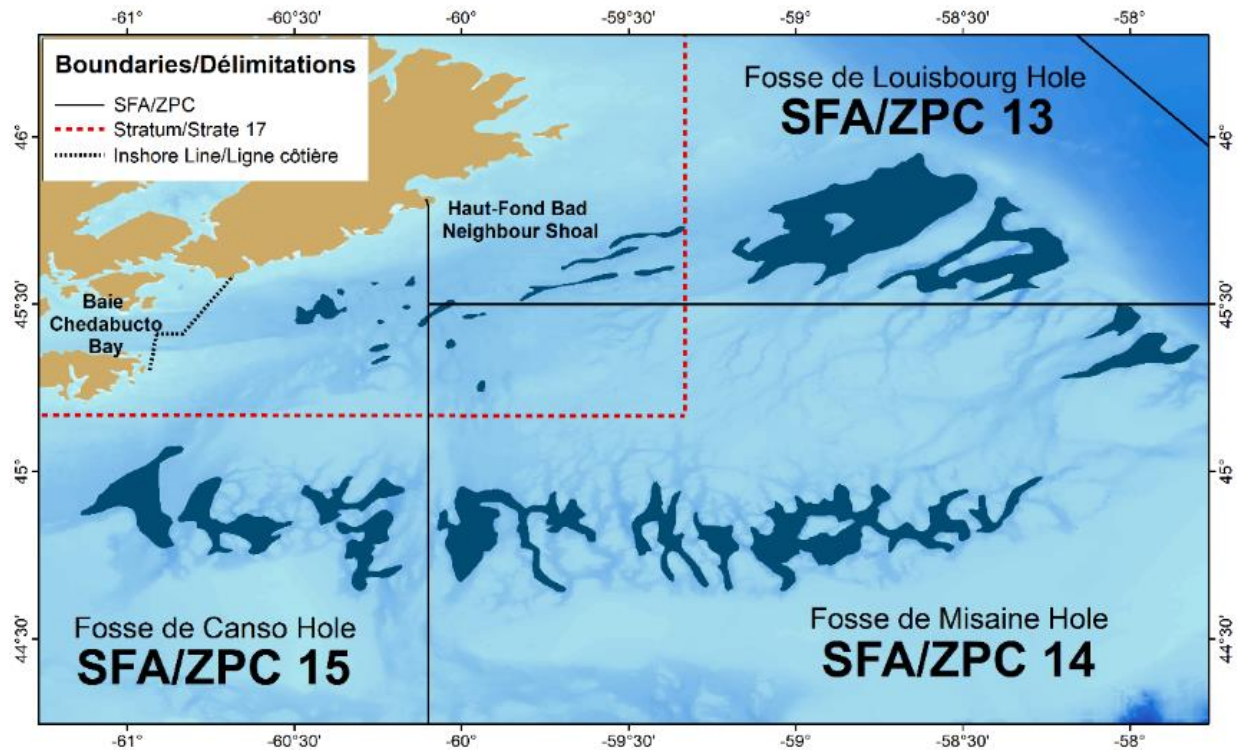


Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. The area within the dashed red line depicts survey stratum 17 (inshore area); survey strata 13–15 are the remaining portions of SFAs 13–15.

Although there has been some Northern 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 after individual Shrimp Fishing Area (SFA) quotas were combined into a single TAC. 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 favorable combinations of good catch rates and counts (shrimp sizes). The

¹ Number of active vessels for mobile and trap fleets is reported as of November 22, 2022.

fishing season is from January 1st to December 31st. As of November 22, 2022, 2,128 t of the 2,300 t TAC had been landed (of the total landings, less than 1 t was landed by the trap fleet).

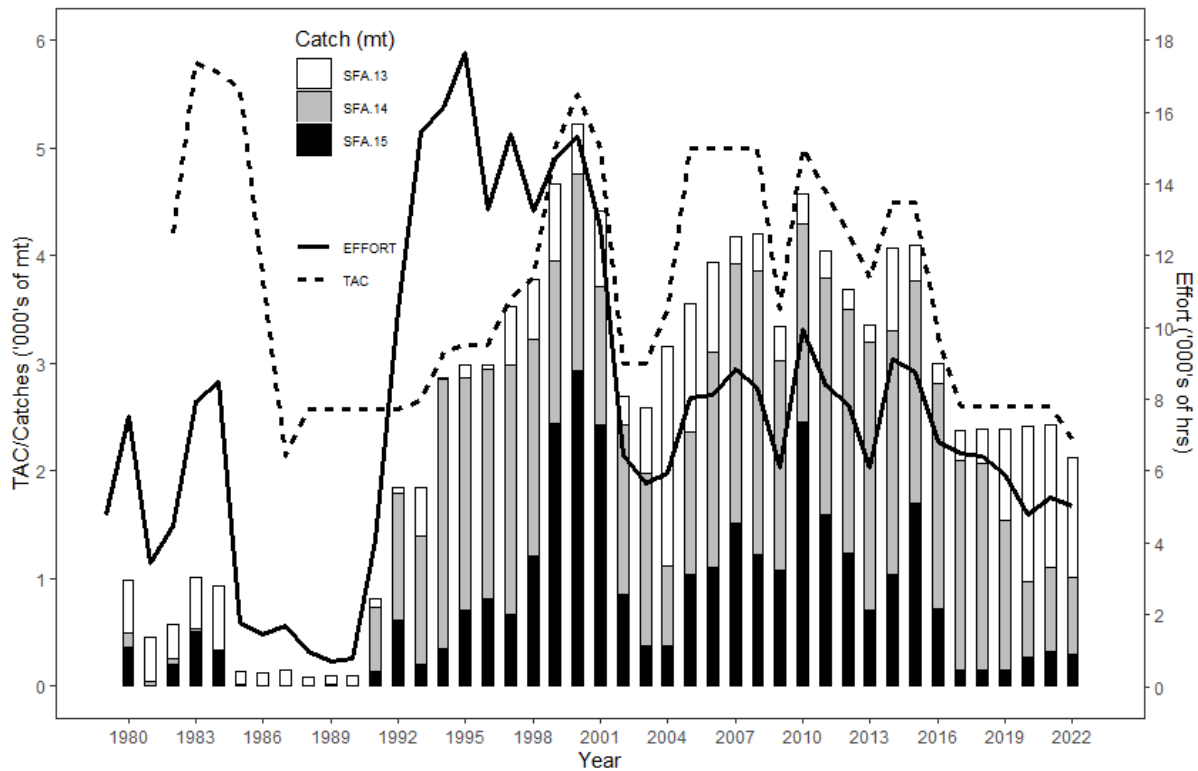


Figure 2. History of Eastern Scotian Shelf Northern Shrimp catches per Shrimp Fishing Area (SFA; 13, 14, and 15), Total Allowable Catch (TAC) (thousands of t), and effort (thousands of hours), from 1979–2022. Effort and catches for 2022 represent data available as of November 22, 2022.

The spatial pattern of the fishery has not significantly changed since 2005, with the bulk of the catch taken from SFAs 14 and 15. However, since 2017 fishing activity has decreased in SFA 15 and increased in SFA 13. COVID-19 restrictions in 2020–2021 affected spatial (fishing increase in SFA 13) and temporal (fishing later in the season) fishing patterns in the ESS Northern Shrimp fishery. These changes to fishing patterns have remained similar in 2022, and as of November 22nd, 53% of the 2022 landings were harvested in SFA 13.

Analysis and Response

A Traffic Light Analysis (TLA) has been used to assess the status of the ESS Northern 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 summarizes individual indicators into four characteristic groupings focusing on Abundance, Production, Fishing Effects, and the Ecosystem, as well as in an overall mean summary indicator. The TLA is used to display, summarize, and synthesize many relevant yet disparate data sources into a consensus opinion on the state of the Northern Shrimp stock.

A Precautionary Approach (PA) Framework using reference points and harvest control rules has been implemented within the Sustainable Fisheries Framework using the TLA to inform on ESS Northern Shrimp stock status through its assessments. The Limit Reference Point (LRP; 5,459 t) and Upper Stock Reference (USR; 14,558 t) for the ESS Northern Shrimp stock are 30% and

80%, respectively, of the average Spawning Stock Biomass (SSB) maintained during the high productivity period of the modern fishery (2000–2010). When the stock is within the healthy zone, a maximum removal reference point of 20% female exploitation rate is used to help guide management decisions (Hardie et al. 2018).

Data used in this assessment include commercial catch data, survey catch data (expanded to total biomass using the swept area method), detailed Northern 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 decreased by 26% from 21,167 +/- 4,109 t (95% confidence interval) in 2021 to 15,610 +/- 4,055 t (95% confidence interval) in 2022. The Maritimes mobile fleet standardized Catch Per Unit Effort (CPUE) and the Gulf fleet unstandardized CPUE decreased by 10% and 9%, respectively (Figure 3A). The Maritimes mobile fleet unstandardized commercial CPUE decreased in all strata (Figure 3B). Since 2021, the trap catch index has not been an informative proxy as it is biased against only a few vessels and with reduced fishing activity, and is only reported in the summary TLA in Figure 9. Monitoring 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. However, in 2022, both the survey biomass and commercial catch indices corroborate on stock abundance.

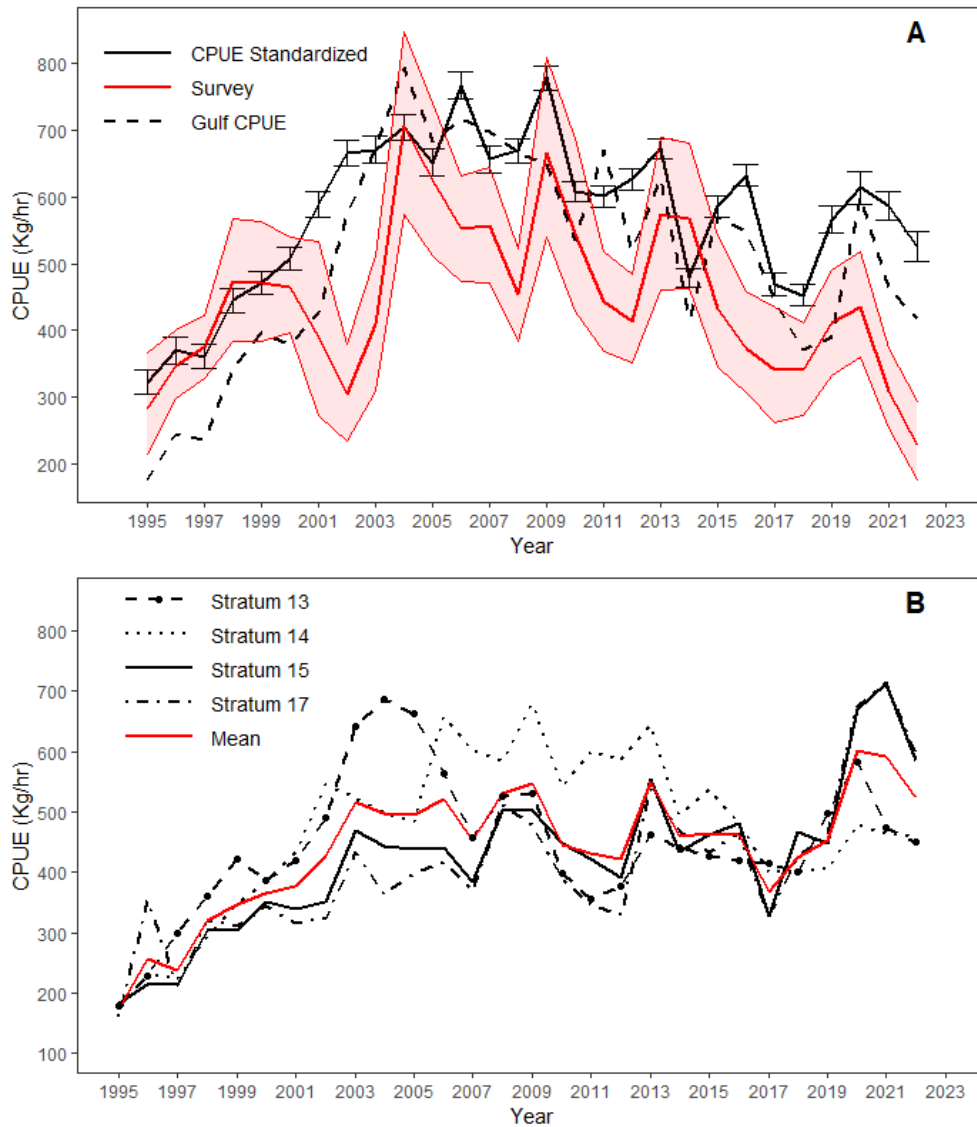


Figure 3. (A) DFO-Industry survey stratified Catch Per Unit Effort (CPUE) with 95% confidence intervals (red), standardized commercial CPUE with 95% confidence intervals (solid black line), and unstandardized Gulf vessel CPUE black, dash line; and (B) Unstandardized commercial CPUE for each stratum from 1995–2022.

The PA framework for the ESS Northern Shrimp stock uses SSB (a Production characteristic) as the unit for stock status and female exploitation rate (a Fishing Effects characteristic) as the unit for the removal rate (Figure 4). The 2022 SSB point estimate decreased by 22% to 10,165 t ($\pm 4,914$ t, 95% CI) and is below the Upper Stock Reference (USR, 14,558 t). Based on this framework, the ESS Northern Shrimp stock remains in the Cautious Zone for 2022 (Figure 4). The TAC has helped to maintain lower total and female exploitation rates since 2017; however, both rates have been increasing since 2021, and in 2022 are 14% and 13%, respectively.

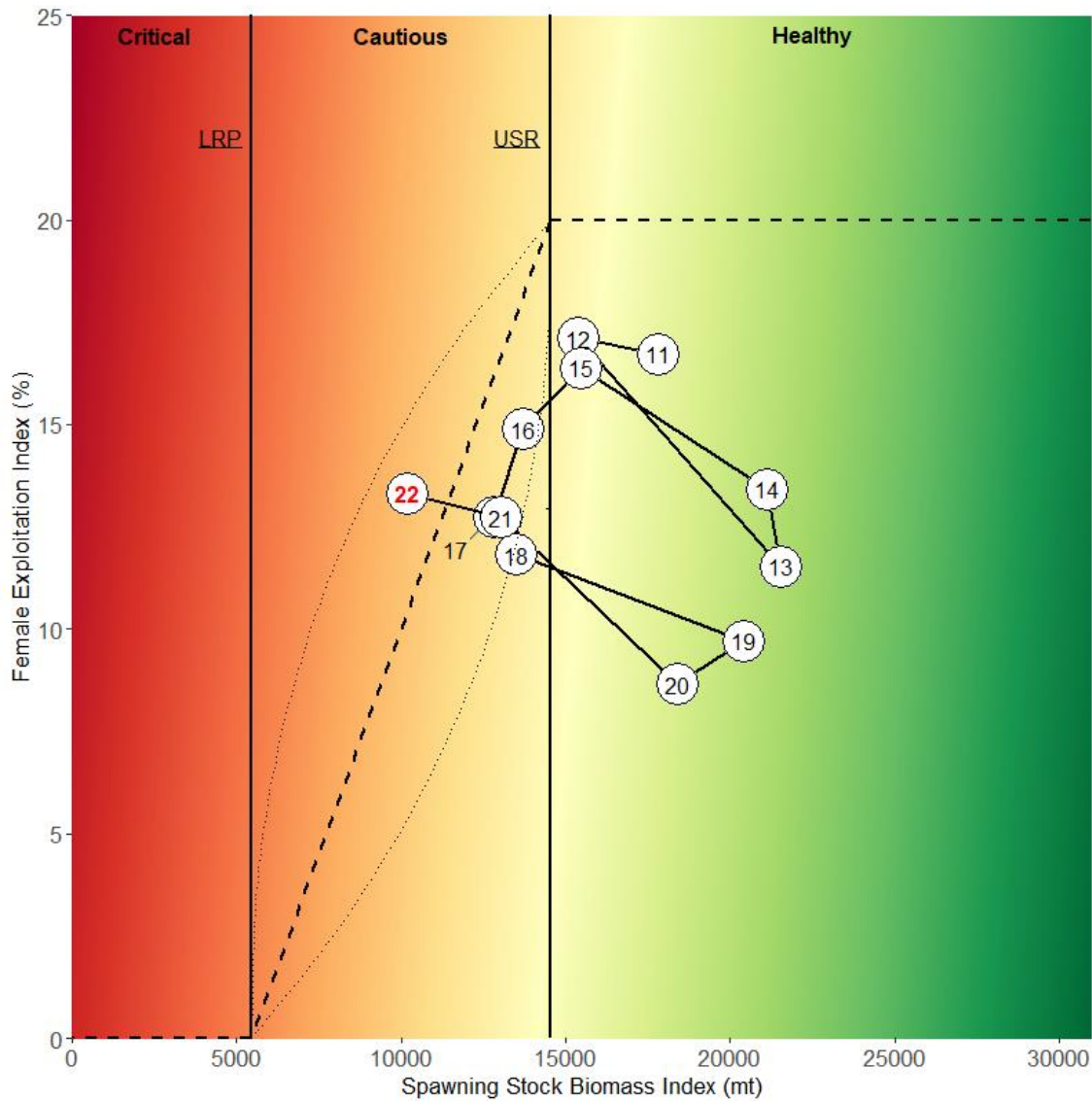


Figure 4. Graphical representation of the precautionary approach framework for Eastern Scotian Shelf Northern Shrimp. The black vertical lines represent the Limit Reference Point (LRP; 5,459 t) and the Upper Stock Reference (USR; 14,558 t). The dotted lines in the Cautious Zone represent a range of possible management actions.

The interpretation of year-class strength and longevity can be complicated by several factors, including: the low catchability of Northern Shrimp younger than Age 4; the strong influence of growth rate on the catchability of Age 4 Northern Shrimp; difficulty in distinguishing and assessing year-classes after Age 3; and changing longevities and natural mortalities associated with environmental and/or density-dependent influences. The tendency of a single year-class to change sex over a few years, especially relatively large year-classes such as 2001, 2007–2008, and 2013 (represented by year+1 in Table 1), makes it difficult to distinguish them from adjacent year-classes. Nonetheless, these recruitment pulses have coincided with the maturation of strong year-classes, providing evidence that strong year-classes have produced large spawning stock biomass estimates.

Cohort tracking through length-frequency distributions from the DFO-Industry survey and commercial samples help predict upcoming contributions to fishable and spawning biomass. Since 2020, decreases in the fishable and spawning biomass coincide with the low belly-bag index from 2016 (112 million) and 2017 (83 million), and demonstrate that fewer individuals contributed at commercial sizes and are now reaching the end of their expected lifespan in 2022 (Table 1). Belly-bag index values from 2018–2021 show an increase in recruitment relative to 2016 and 2017 and suggest better contributions in the next four years. The 2022 estimate was 52 million, a decrease compared to the last four years, and is the lowest value since the 2012 year-class as evidenced in the 2013 belly-bag index (Table 1). In 2022 the abundance index for Age 2 decreased and for Age 4 increased, which is consistent with the belly-bag index values found in 2021 (i.e., 2020 year-class) and 2019 (i.e., 2018 year-class) (Table 1). The low overall abundance of Age 1 and Age 2 Northern Shrimp observed in the 2022 DFO-Industry survey is consistent with the decreasing SSB.

Table 1. Minimum survey population numbers-at-age of Northern Shrimp (millions of individuals) from modal analysis.. Average and median are based on data from 1999–2022. The shaded portion of the table represents numbers updated to include all SFAs.

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Avg.	Median
1*	61	191	479	541	197	88	94	22	796	288	112	83	267	272	279	244	52	273	205
2	121	39	114	304	188	58	43	211	26	495	17	166	37	68	72	154	106	163	123
3	880	506	396	267	1,020	513	348	302	119	501	193	581	361	195	368	462	309	528	365
4	0****	0****	1,190	463	1,036	1,105	1,018	1,157	613	690	1,304	1,468	822	392	522	583	687	1215	1,083
5+	5,106	5,506	3,017	6,020	4,109	2,694	2,688	4,091	4,673	2,956	3,076	1,734	2,231	3,155	3,000	2,109	1,341	2,919	2,978
TOTAL	6,169	6,244	5,201	7,622	6,616	4,458	4,191	5,783	6,227	4,930	4,702	4,032	3,718	4,082	4,241	3,552	2,495	4,952	4,580
Age 4+ males**	3,916	2,804	3,317	4,263	3,454	2,003	2,241	2,960	3,831	2,270	2,931	1,859	1,966	2,273	2,137	1,611	1,046	2,526	2,272
Primiparous***	771	1,739	892	1,492	1,324	947	371	699	706	521	664	453	433	435	573	398	388	745	703
Multiparous	480	1,157	482	1,295	630	937	1,188	1,611	1,545	1,143	897	973	921	1,111	1,091	927	646	991	982
Total females	1,251	2,896	1,374	2,787	1,954	1,884	1,559	2,310	2,251	1,664	1,561	1,426	1,354	1,546	1,664	1,325	1,034	1,736	1,627

Notes:

* Belly-bag. Time series began in 2002.

**Total population less Ages 2 and 3 males, transitionals (i.e., males that will potentially change to females the following year), and females.

***Includes transitionals.

****Four-year olds from 2006 and 2007 were not distinguishable in the MIX analysis. These year-classes appear to be small and are contained in the Ages 3 or 5+ categories.

The 2013 year-class, first observed in 2014 as the second highest belly-bag index in the time series (1999–2022), has been closely monitored and has provided a strong signal in the DFO-Industry survey (Table 1) and commercial fishery data until 2022. The abundance of Age 5+ females and the Age 4+ males has declined since 2019, coinciding with lower overall recruitment from the 2015 and 2016 year-classes. The survey length frequency of transitional and primiparous (first-time spawner) Northern Shrimp has decreased in 2022. The abundance of multiparous (multi-year spawner) Northern Shrimp has also decreased and supports the decrease observed in the SSB index noted in Figure 4. Furthermore, the total female estimate for 2022 in Table 1 is at an all-time low for the time series (1999–2022). The 2017 year-class is expected to recruit to the SSB in 2022; however, a low belly-bag index for this year-class and a small primiparous contribution was observed (Figures 5 and 7B).

The port sampling program provides a length distribution of commercial catches across SFAs throughout the year. Figure 6 suggests that smaller size Northern Shrimp are being retained commercially, and at sizes prior to female transition as a primiparous (Figure 5). This is not a novel practice as there is no minimum size of capture for this fishery; however, in 2022 the relative proportion of smaller Northern Shrimp in commercial catch was higher as observed in Figure 6. Given the decreasing numbers for 2022 (males, primiparous, multiparous, and total females), combined with the compromised ability of recruitment to survive to maturity, the total abundance is reaching an unprecedented low.

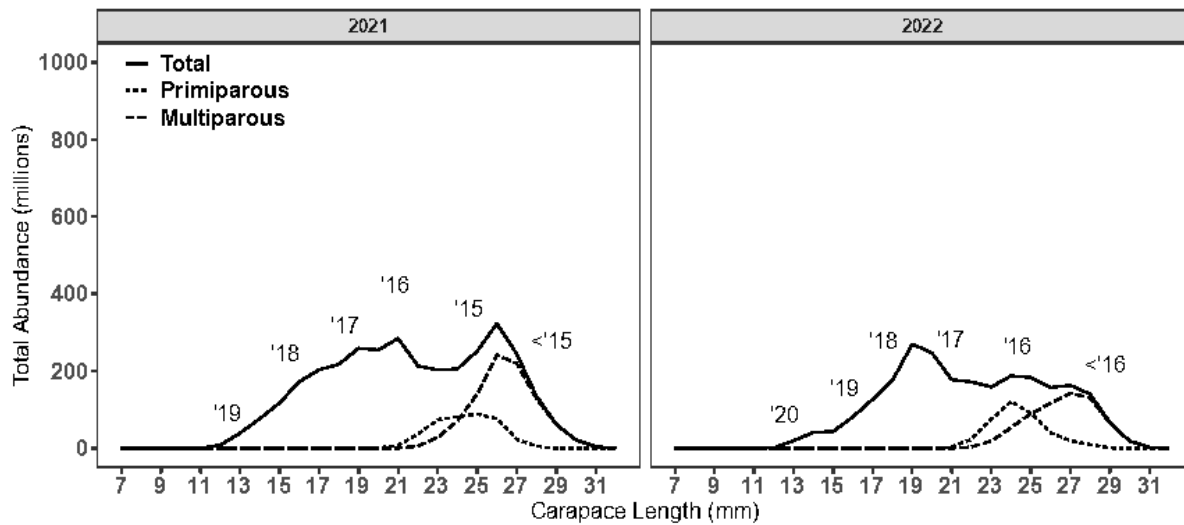


Figure 5. Population estimates of number of shrimp-at-length from the 2021 and 2022 DFO-Industry surveys (solid line). The dot line in each figure represents transitional and primiparous Northern Shrimp, and the dash line represents multiparous Northern Shrimp. Year-classes associated with Northern Shrimp at given carapace lengths are indicated. See DFO 2022 for a complete time-series of survey length-frequencies.

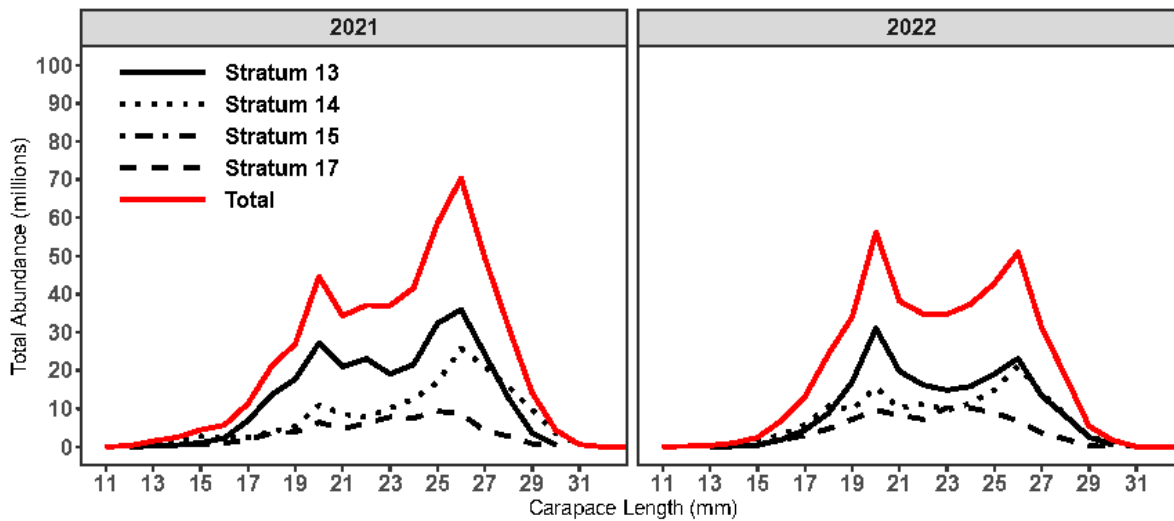


Figure 6. Catch-at-length from commercial sampling by stratum for 2021 and 2022.

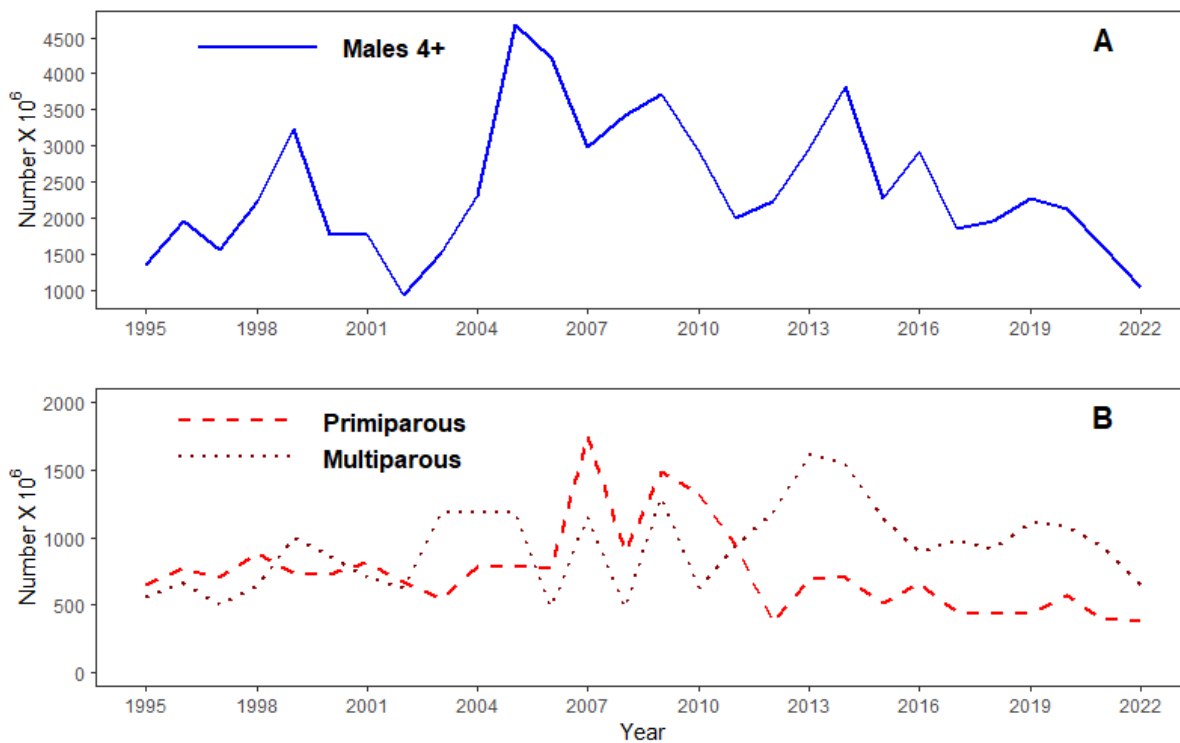


Figure 7. (A) Modal analysis population estimates of Age 4 and older male, and (B) Primiparous female and Multiparous female, Northern Shrimp from the DFO-Industry survey.

The 24 indicators relating to the health of the ESS Northern Shrimp stock (Figure 9) are summarized in Figure 8. These indicators are grouped into categories of Abundance, Production, Fishing Effects, and Ecosystem characteristics, as well as an overall mean summary indicator. The Abundance characteristic decreased in 2022 after four years of steady increases. The Abundance characteristic remains in the red zone for 2022, mainly due to declines in the commercial mobile and survey CPUE indices. Indicators of productivity have

experienced a sharp decline in 2022. Annual contributions of recruitment have been consistent in the last four years; however, they have been lower in magnitude and are only starting to supplement the SSB portion of the stock. The Fishing Effects characteristic was steadily improving up until 2019, after which it began to decline. It now sits near the lower end of its range in the time series. Despite the precautionary reductions/maintenance of the TAC since 2016, stock exploitation and female exploitation have both been increasing since 2021. The average commercial count of Northern Shrimp per pound has increased to 58 in 2022, a notable increase from 2021 when the count was 54. This indicates the presence of smaller Northern Shrimp in the fishable population, and that the proportion of females, particularly large females, has decreased.

In 2021, the Ecosystem characteristic was primarily influenced by temperature indices, since the Snow Crab, Greenland Halibut, and Atlantic Cod recruitment trends were not included in the 2021 update (DFO 2022). The Ecosystem characteristic has slightly improved in 2022 with the addition of the Snow Crab recruitment index, even though the value has decreased since 2020. The inclusion of the Snow Crab recruitment index provides a better weighted perspective across indicators; however, the overall trend remains in the red zone.

Three out of four characteristic summaries in 2022 show decreases from the 2021 values, resulting in an overall mean decrease into the red zone and suggesting that the ESS Northern Shrimp stock health is negatively affected. The fact that 17 out of 24 indicators (3 indicators outstanding) describe adverse outcomes also supports the PA framework that the stock is in the Cautious Zone.

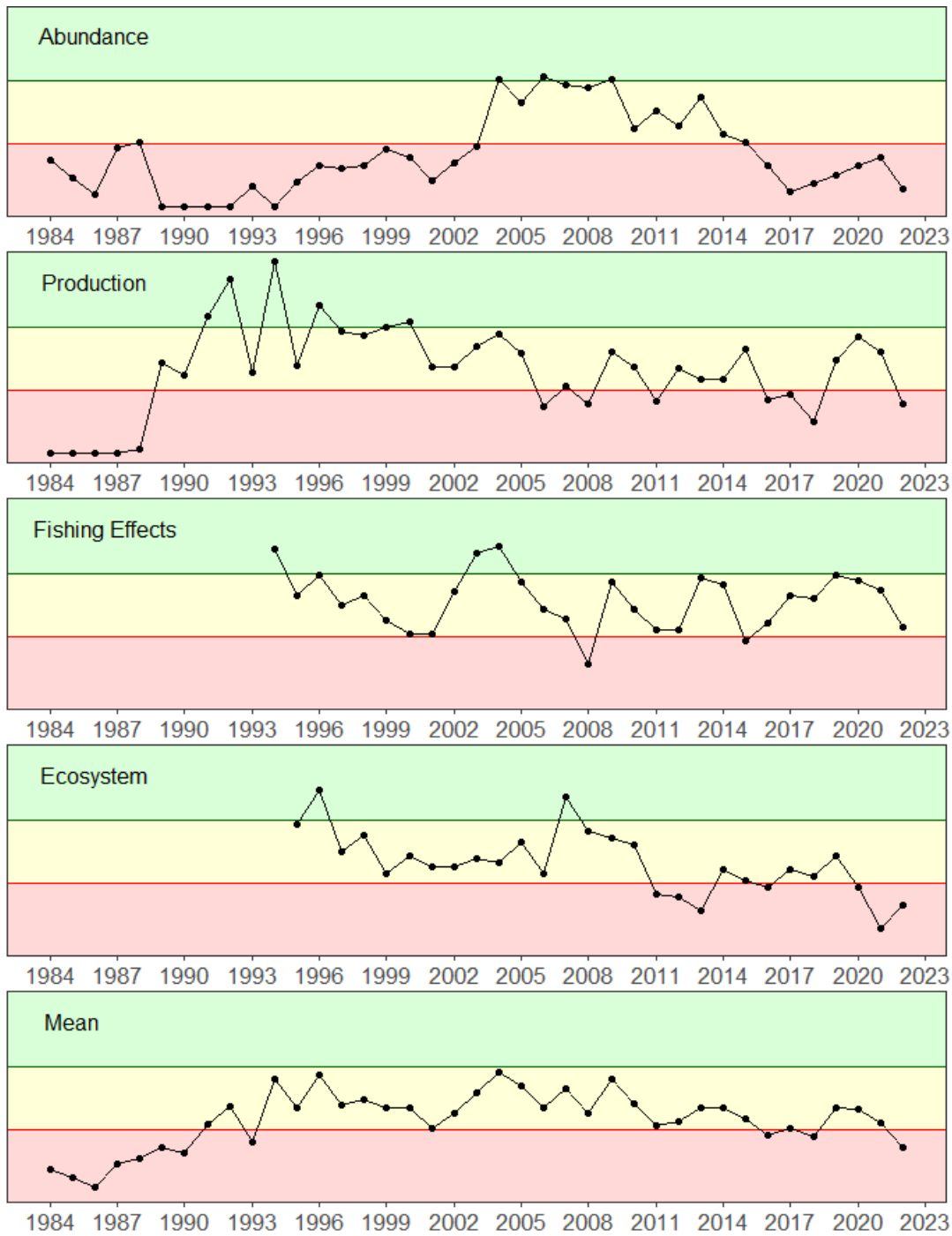


Figure 8. Time series of all available indicators grouped into four characteristics (top four panels) and the mean (overall) indicator (bottom panel) from 1984–2022. Thresholds between red, yellow, and green are at the 33rd and 66th percentile of the 2000–2010 data series for each indicator. Not all indicators in the summary above are discussed in the text. See Hardie et al. (2018) for a detailed description of indicators.

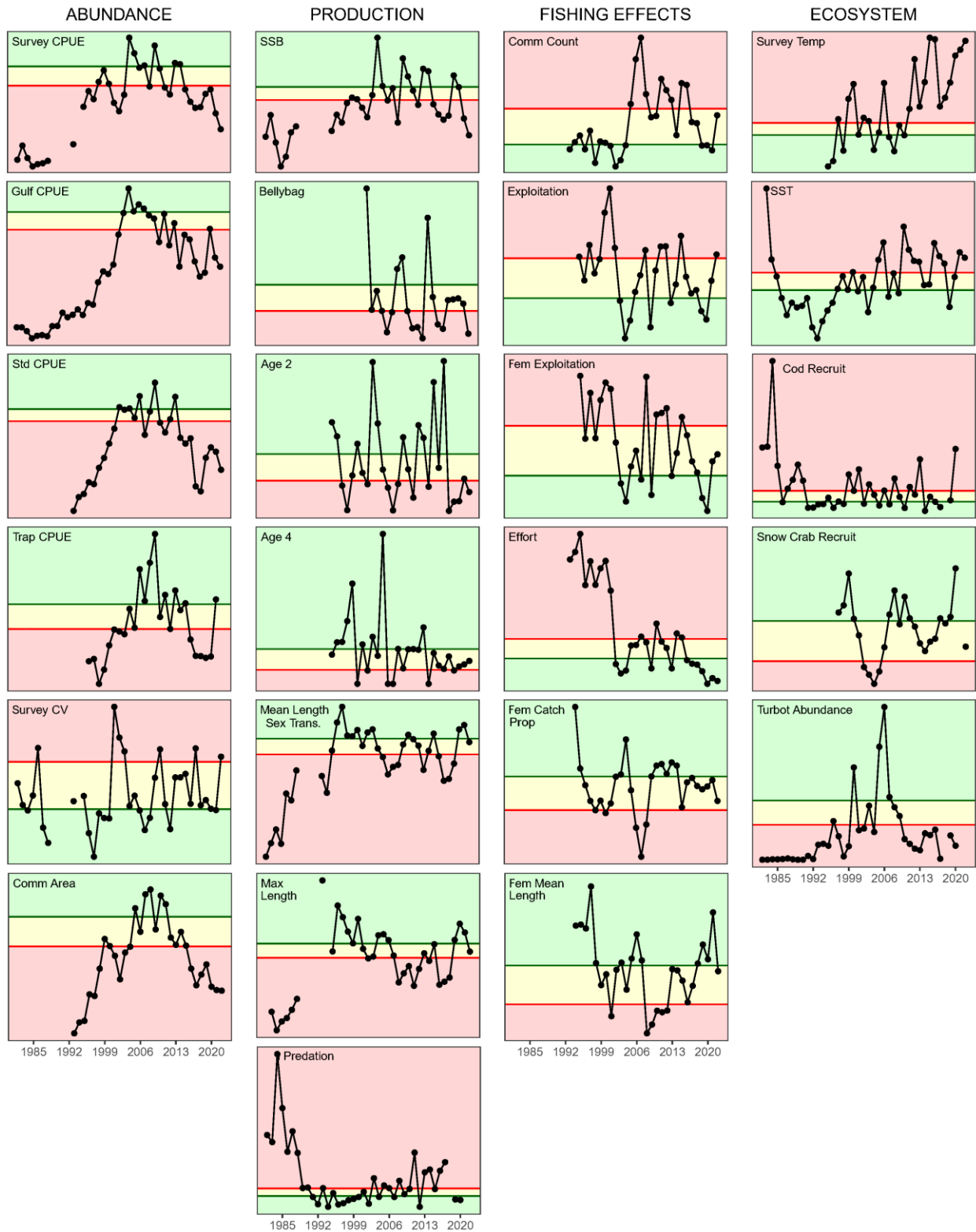


Figure 9. Time series of individual Northern Shrimp indicators. Note: not all indicators are discussed in the text. Refer to past Canadian Science Advisory Secretariat Research Documents for detailed description of indicators (e.g., Hardie et al. 2018).

Bycatch

The introduction of the Nordmøre separator grate in 1991 led to a reduction in bycatch and allowed the fishery to expand to its present size. Bycatch estimates are extrapolated from at-sea observer sampling during commercial trips. Target coverage is 6 trips annually (6% coverage based on trips). There were no trips observed for 2021 or 2022; however, low bycatch amounts (less than 1% in 2019 and 2020) from the mobile fleet are expected. With minimal bycatch interactions from both commercial fleets, the Northern Shrimp fishery currently poses little risk in terms of bycatch amount or species composition.

Conclusions

The 2022 DFO-Industry survey stratified mean biomass estimate shows a decrease to 15,610 +/- 4,055 t. The point estimate of the 2022 SSB (10,165 t ± 4,914 t, 95% CI) decreased by 22%, and is below the USR point of 14,558 t, placing this stock within the Cautious Zone for 2022.

The Belly-bag Age 1 abundance index from 2018 to 2021 highlights consistent recruitment and is within the time series mean of 273 million individuals despite increasing water temperatures. The abundance of Age 4 Northern Shrimp increased in 2022 and is consistent with the increase observed in the Age 3 value of 2021. Theoretically, with continued growth and survival of recruitment to mature females, the 2017–2018 year-classes will be contributing to the SSB during 2022–2023. However, for 2022, the abundance estimates for 4+ males, primiparous, multiparous and total females have decreased. In addition, the 2022 total female abundance estimate is the lowest observed in the 1999 to 2022 time series.

Three of the size-based indicators (size at sex-transition, female size, count) demonstrate that the average size of Northern Shrimp, that was increasing in recent years, is now decreasing. This is consistent with a decrease in the number of existing larger size females and an increase in the number of smaller size females. The lower recruitment index estimate from 2016 and 2017 suggests that there will be fewer, smaller Northern Shrimp contributing to the stock. These recruitment years are now contributing to the Age 5+ group where decreases have been observed in 2021 and 2022. The growth and sustained survival of the Northern Shrimp recruitment from 2018–2021 has a greater potential of contributing positively to the stock.

Recent observations have shown an increase in the retention of smaller immature shrimp by the fishery, declines in both total biomass and SSB estimates, and declining abundance estimates across mature female sizes. If these trends continue, there is a possibility of sustained reductions in smaller sizes prior to their contribution as mature females. If the SSB continues to decrease and the anticipated replenishment is harvested prior to its reproductive contribution, the stock's long-term sustainability could be at risk.

Ecosystem indicators were primarily influenced by temperature trends as Greenland Halibut and Atlantic Cod recruitment trends were not updated for 2022. The increases in temperature in the last few years also coincide with a decrease in Snow Crab recruitment for 2022 (known sympatric species), suggesting that conditions are currently unfavorable for cold-water species such as Northern Shrimp.

The overall mean summary from Figure 8, encompassing the 24 stock health indicators, decreased in 2022 and is in the red zone for the first time since 2018. This is due to decreases in three of the four summaries representing Abundance, Production, Fishing Effects, and Ecosystem characteristics. There are 17 out of 24 TLA indicators (3 not updated in 2022)

describing adverse results for Northern Shrimp stock health. According to DFO's PA policy, the stock remains in the Cautious Zone.

Contributors

Name	Affiliation
Manon Cassista-Da Ros (Lead)	DFO Science, Maritimes Region
Jessica Cosham	DFO Science, Maritimes Region
Tara McIntyre	DFO Science, Maritimes Region
Jeremy Broome	DFO Science, Maritimes Region
Mark Billard	DFO Science, Maritimes Region
Suzette Soomai	DFO Resource Management, Maritimes Region
Lorne Penny	DFO Resource Management, Maritimes Region
Bronwen Hughes	DFO Resource Management, Maritimes Region

Approved by

Francine Desharnais
Regional Director of Science
DFO Maritimes Region
Dartmouth, Nova Scotia

Date: 13 January 2023

Sources of Information

- Atlantic States Marine Fisheries Commission. 2018. [Northern Shrimp Benchmark Stock Assessment and Peer Review Report](#). 356pp.
- DFO. 2022. [2021 Assessment of Northern Shrimp on the Eastern Scotian Shelf \(SFAs 13–15\)](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/033.
- DFO. 2021. [2020 Stock Status Update of the Eastern Scotian Shelf Northern Shrimp \(SFAs 13–15\)](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/014.
- DFO. 2011. Scotian Shelf Shrimp (*Pandalus borealis*) Integrated Fisheries Management Plan.
- Hardie, D., M. Covey, and A. Cook. 2018. [Eastern Scotian Shelf Shrimp \(*Pandalus borealis*\) Framework](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2018/005.
- 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: 235–246.

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

E-Mail: DFO.MARCSA-CASMAR.MPO@dfo-mpo.gc.ca

Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-3769

ISBN 978-0-660-48433-4 Cat. No. Fs70-7/2023-023E-PDF

© His Majesty the King in Right of Canada, as represented by the Minister of the
Department of Fisheries and Oceans, 2023



Correct Citation for this Publication:

DFO. 2023. 2022 Stock Status Update of Eastern Scotian Shelf Northern Shrimp (SFAs 13–15).
DFO Can. Sci. Advis. Sec. Sci. Resp. 2023/023.

Aussi disponible en français :

*MPO. 2023. Mise à jour de 2022 sur l'état du stock de crevettes nordiques de l'est du plateau
néo-écossais (ZPC 13 à 15). Secr. can. des avis sci. du MPO. Rép. des Sci. 2023/023.*