Fisheries and Oceans Canada | Pêches et Océans Canada
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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/062

ASSESSMENT OF SCOTIAN SHELF SNOW CRAB FROM 2023

*Snow Crab (*Chionoecetes opilio*, O. Fabricius)*

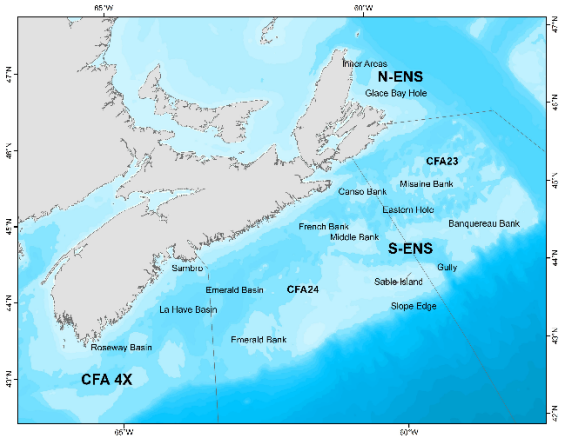

Figure 1. Map of the Scotian Shelf and Crab Fishing Areas (CFAs).

Context:

*Snow Crab (*Chionoecetes opilio*, O. Fabricius) are a dominant macroinvertebrate in the Scotian Shelf Ecosystem (SSE). The SSE Snow Crab are in the southernmost extreme of their spatial distribution in the northwest Atlantic. The fishery has existed since the early 1970s in Nova Scotia.*

In support of the Scotian Shelf Snow Crab fishery, Fisheries and Oceans Canada (DFO) Maritimes Fisheries Management requested from DFO Science an assessment of resource status. This Science Advisory Report is from the February 26–27, 2024, regional peer review on the Stock Assessment of Snow Crab in Maritimes Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Snow Crab landings from the Scotian Shelf in 2023 were 972 t in north-eastern Nova Scotia (N-ENS); 7,342 t in south-eastern Nova Scotia (S-ENS); and 7 t in crab fishing area (CFA) 4X (season was ongoing at the time of assessment), representing a decrease of 0.3%, an increase of 0.3% and a decrease of 84.2%, respectively, relative to 2022. Total allowable catches (TACs) for 2023 were 979 t, 7,345 t, and 55 t in N-ENS, S-ENS, and 4X, respectively.
- Bycatch of non-target species is low (<<1% of total catch) in all Snow Crab fishing areas; however, as sampling targets for at-sea observer coverage have not been met in recent years, there is uncertainty in the representativity of the data.
- In N-ENS, the modelled biomass (pre-fishery) of Snow Crab in 2023 was 3.27 kt, a decline of 10.9% relative to 3.67 kt in 2022. In S-ENS, the modelled biomass (pre-fishery) was 37.91 kt, a decline of 10.6% relative to 42.42 kt in 2022. In 4X, the 2023–2024 season's

modelled biomass (pre-fishery) was 0.08 kt, a decline of 46.7% relative to 0.15 t in the 2022–2023 season.

- Egg and larval production is expected to be high in 2024 in S-ENS and 4X.
- Based on length frequency data, little to no recruitment is expected for the next 1–3 years in N-ENS. Continued recruitment is expected for the upcoming years in S-ENS. Low levels of recruitment are expected in 4X; high mortality of adolescent crab makes recruitment into the fishable component uncertain.
- In 2023, bottom temperatures from the Snow Crab survey have returned to the historical mean in all three CFAs; however, a general warming trend has been observed in the Snow Crab survey since the early 1990s.
- The amount of viable Snow Crab habitat has consistently declined in all three areas since 2010, and does not show any strong evidence of increase.
- In 2023, the N-ENS mean estimated fishable biomass was above the upper stock reference (USR), placing the stock in the healthy zone; however, there is considerable model uncertainty around both the estimate and the reference point. In 2023, the harvest rate was 30.17%, slightly above the harvest control rule of 10–30%. A more conservative harvest strategy may support the stock in bridging the expected gap in recruitment.
- In 2023, the S-ENS mean estimated fishable biomass was above the USR, placing it in the healthy zone; however, there is considerable model uncertainty around both the estimate and the reference point. Harvest rates derived from the fishery model were 19.7% in 2023, and have remained between 10–20% since 2020. The stock status in S-ENS suggests that the current harvest strategy has not been detrimental to the stock.
- In 2023, the 4X mean estimated fishable biomass was below the limit reference point (LRP), placing the stock in the critical zone. The area is in the southernmost extent of Snow Crab distribution in the North Atlantic and experienced an extended period of unfavorable conditions for Snow Crab in the region.

INTRODUCTION

Snow Crab (*Chionoecetes opilio*, O. Fabricius) are a circumpolar, subarctic species. In the Scotian Shelf ecosystem (SSE; Figure 1), habitat preference is generally for soft mud and sandy bottoms, at depths from 60 to 300 m and temperatures from -1 to 6°C. Snow Crab have been a dominant macroinvertebrate in the SSE since the decline of groundfish. The SSE represents the southernmost part of Snow Crab distribution in the north Atlantic and, therefore, is most influenced by environmental variability.

The fishery has existed since the early 1970s in Nova Scotia. The management of the Snow Crab fisheries in the SSE was initially based on effort controls (season, license, trap limits) from 1982 to 1993 with harvesting during June–November of hard-shelled males larger than 95 mm carapace width. The following additional management measures were introduced between 1994 and 1999: individual boat quotas, total allowable catch (TAC), 100% dockside monitoring, mandatory logbooks, and at-sea monitoring by certified observers. In 2005, many crab fishing areas (CFAs) and subareas were merged with the resulting divisions being north-eastern Nova Scotia (N-ENS; CFAs 20–22), south-eastern Nova Scotia (S-ENS; CFAs 23, 24), and 4X (Figure 1). Spring fishing (started April 10, 2023 to avoid landing soft-shelled crab and reduce handling) efforts in N-ENS and S-ENS now represent a large portion of the overall landings. More detailed information with regards to Snow Crab life history, habitat requirements, and

spatiotemporal distributions of different life stages can be found in Zisserson et al. (2023) and Choi (2023a), and references therein.

ASSESSMENT

Fishery

Effort

Fishing effort in 2023 was 9,500 trap hauls in N-ENS, 62,100 trap hauls in S-ENS, and 200 trap hauls in 4X. Relative to the previous year, these represent an increase of 10.5% in N-ENS and a decrease of 9.9% in S-ENS (Tables 1–3, Figure 2). There was a delay to the start of the season for 2023 in S-ENS that may have contributed to changes in fishing effort. The 4X fishery is ongoing, but effort has declined by 91.3% in 2023 compared to 2022. Spatial distribution of effort has expanded in most areas, except 4X, from 2022 (Figure 3). The expansion is presumed to be, in part, related to the return of colder water into the area and will be expanded upon in the Ecosystem Considerations section.

Table 1: Fishery performance statistics in north-eastern Nova Scotia (N-ENS). Units are: total allowable catch (TAC; tons), landings (tons), effort (thousands of trap hauls), and catch per unit effort (CPUE; kg/trap haul).

Year	Licences	TAC	Landings	Effort	CPUE
2013	78	783	783	7.0	112
2014	78	783	781	6.9	114
2015	78	620	619	6.2	100
2016	78	286	290	2.7	109
2017	78	825	813	8.8	93
2018	78	784	742	12.2	61
2019	78	627	629	7.5	84
2020	78	847	836	7.7	108
2021	78	890	901	8.8	102
2022	78	980	975	8.6	113
2023	78	979	972	9.5	103

Table 2: Fishery performance statistics in south-eastern Nova Scotia (S-ENS). Units are: total allowable catch (TAC; tons), landings (tons), effort (thousands of trap hauls), and catch per unit effort (CPUE; kg/trap haul).

Year	Licences	TAC	Landings	Effort	CPUE
2013	116	11,311	11,341	105.5	107
2014	116	11,311	11,265	96.3	117
2015	116	11,311	11,295	103.9	109
2016	116	9,614	9,606	87.3	110
2017	116	6,730	6,718	69.9	96
2018	116	6,057	6,063	51.3	118
2019	116	6,663	6,632	61.9	107
2020	116	8,161	7,943	63.9	124
2021	116	8,161	8,332	80.8	103
2022	116	7,345	7,323	56.5	130
2023	116	7,345	7,342	62.1	118

Table 3: Fishery performance statistics in crab fishing area 4X. Units are: total allowable catch (TAC; tons), landings (tons), effort (thousands of trap hauls), and catch per unit effort (CPUE; kg/trap haul). NA indicates not available as season is ongoing.

Year	Licences	TAC	Landings	Effort	CPUE
2013	9	80	80	5.2	15
2014	9	80	82	2.5	33
2015	9	150	143	4.4	32
2016	9	80	79	2.9	27
2017	9	110	55	4.4	13
2018[a]	9	0	0	0.0	0
2019	9	55	59	1.1	51
2020	9	80	76	1.6	49
2021	9	110	110	3.1	36
2022	9	125	38	2.3	17
2023[b]	9	55	NA	0.2	33

[a] No fishery (0 TAC) due to low commercial biomass.
[b] As of January 23, 2024 season ongoing.

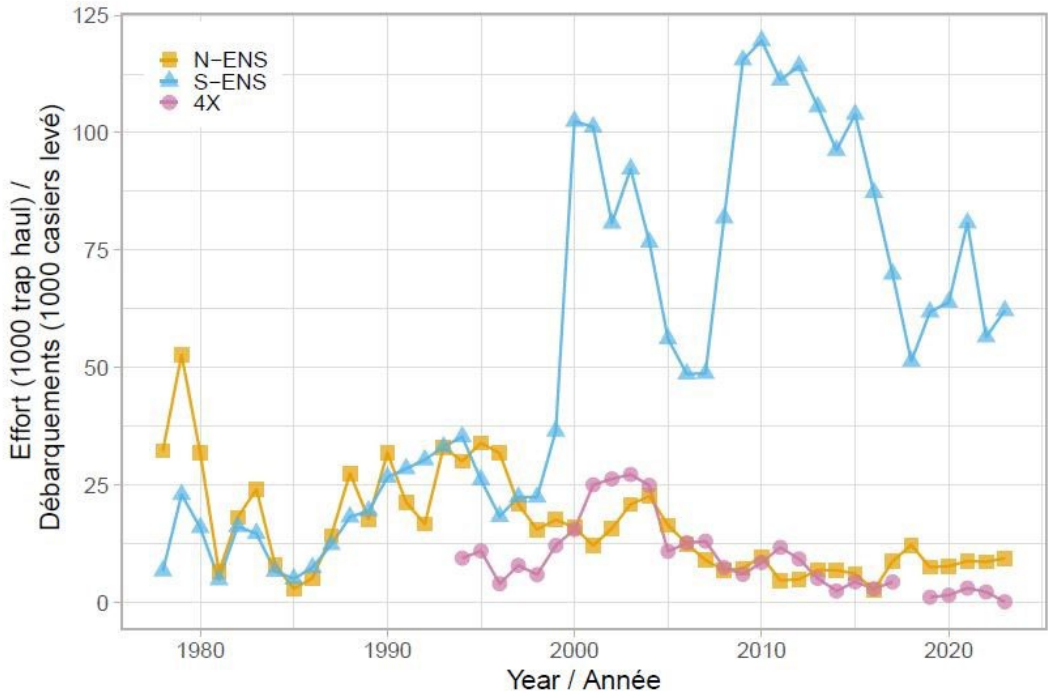

Figure 2. Temporal variations in the fishing effort for Snow Crab for north-eastern Nova Scotia (N-ENS), south-eastern Nova Scotia (S-ENS, and crab fishing area 4X, expressed as the number of trap hauls ($\times 10^3$). Year in 4X refers to the year at the start of the fishing season and is still ongoing for 2023. No fishery occurred in 4X for the 2018 season.

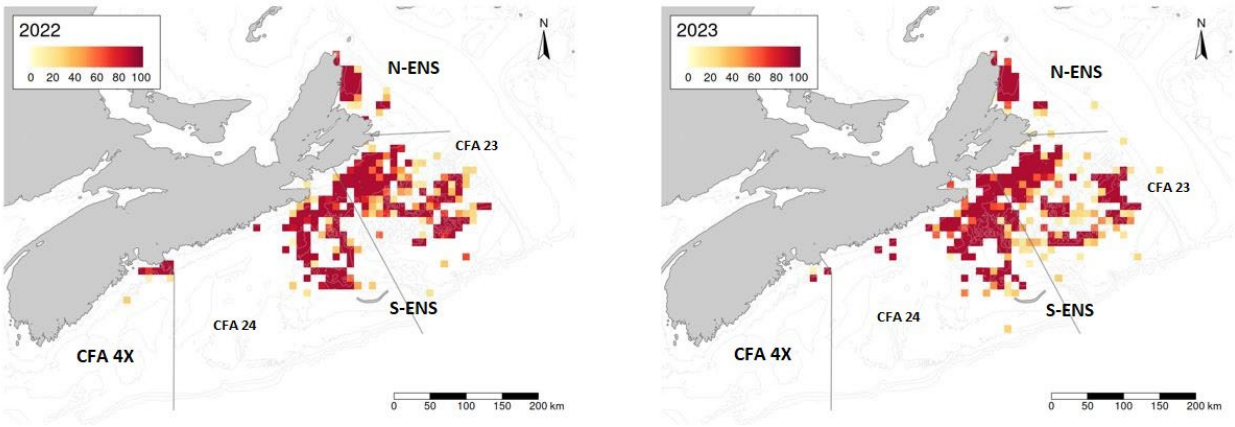

Figure 3. Snow Crab fishing effort (number of trap hauls × 10^3 per 10 km × 10 km grid) from fisheries logbook data for 2022 (left) and 2023 (right). The fishery is still ongoing in crab fishing area 4X for 2023.

Landings

Landings across time are shown in Figure 4. In 2023, landings were 972 t, 7,342 t, and 7 t, in N-ENS, S-ENS, and 4X (season ongoing), respectively. Relative to 2022, they represent a decrease of 0.3% in N-ENS, an increase of 0.3% in S-ENS, and a decrease of 84.2% in 4X (Tables 1–3). Total allowable catches (TACs) for 2023 were 979 t, 7,345 t, and 55 t in N-ENS, S-ENS, and 4X, respectively.

In 2023, landings in all areas were below respective TACs (Tables 1–3), though the season in area 4X was ongoing at the time of assessment.

The landings in N-ENS for 2023 and 2022 were similar in their spatial patterns (Figure 5). In S-ENS, landings, as with fishing effort, were slightly more expanded (Figure 5). There were no landings on the continental slope areas of S-ENS in 2023; it continues to serve as a “reserve” for Snow Crab from fishing. The landings in 4X for 2023, as with 2022, were primarily in the area just south of Sambro NS, bordering onto CFA 24 (Figure 5). In N-ENS, the majority (91%) of landings occurred in the spring, likely reducing the softshell mortality.

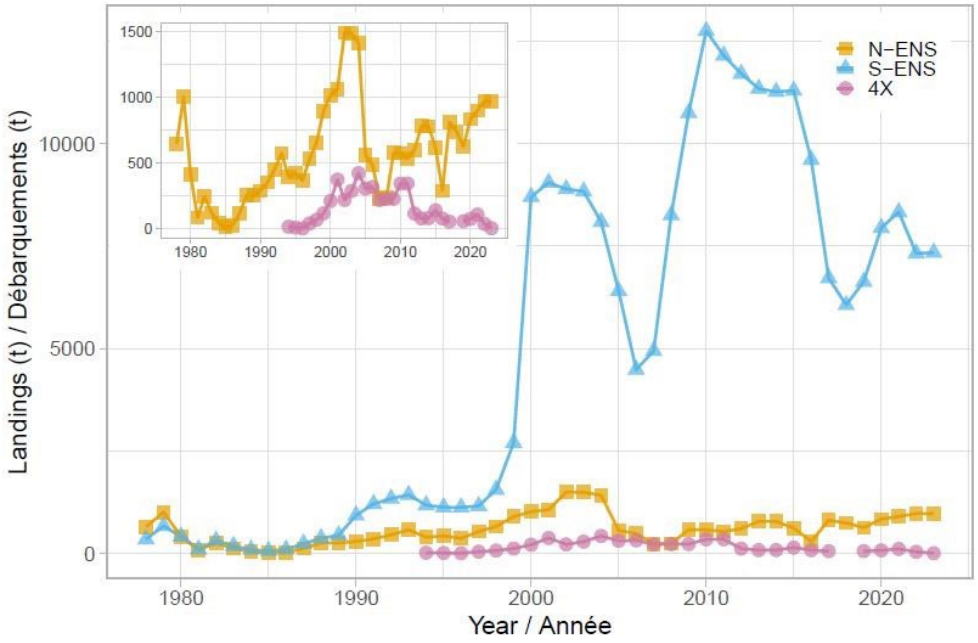

Figure 4. Landings (t) of Snow Crab for north-eastern Nova Scotia (N-ENS), south-eastern Nova Scotia (S-ENS), and crab fishing area 4X. For 4X, the year refers to the starting year of the season. The season is still ongoing in 4X for 2023. Inset is a closeup view of the timeseries of N-ENS and 4X. Note the total allowable catch was zero in 2018 for the 4X fishery.

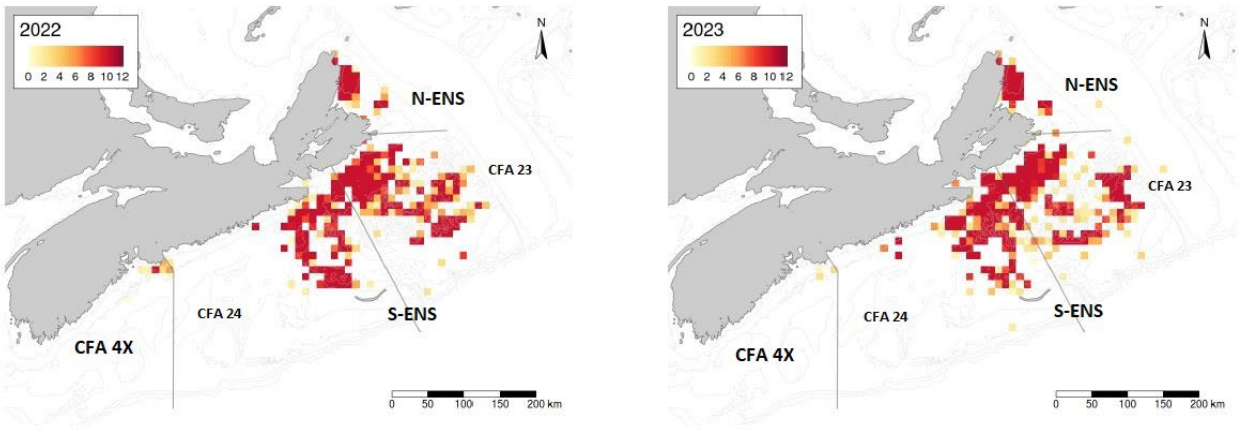

Figure 5. Snow Crab landings (tons per 10 km × 10 km grid) from fisheries logbook data for 2022 (left) and 2023 (right) from north-eastern Nova Scotia (N-ENS), south-eastern Nova Scotia (S-ENS), and crab fishing areas (CFAs) as noted. The fishery is still ongoing in 4X for 2023.

Bycatch of Other Species in the Snow Crab Fishery

Bycatch in the Snow Crab fishery is monitored by at-sea observer sampling. Bycatch of non-target species is low (<<1% of total catch) in all Snow Crab fishing areas; however, as sampling targets for at-sea observer coverage have not been met in recent years, there is uncertainty in the representativity of the data. Historically, bycatch in the Snow Crab fishery has been minimal (Zisserson et al. 2023), with increasing levels as a function of increasing water temperature. Bycatch is higher in warmer conditions, primarily other Crustacea (crab and lobster). Low bycatch has been attributed to trap design (top entry conical traps), the large mesh size (5.25 inches, knot to knot), and the passive nature of the gear (Hebert et al. 2001).

Stock Status

All planned stations (384) for the 2023 Snow Crab survey were completed; due to mechanical issues, 302 stations were completed in 2022. See Figure 6 for a comparison of the stations completed in 2023 compared to 2022.

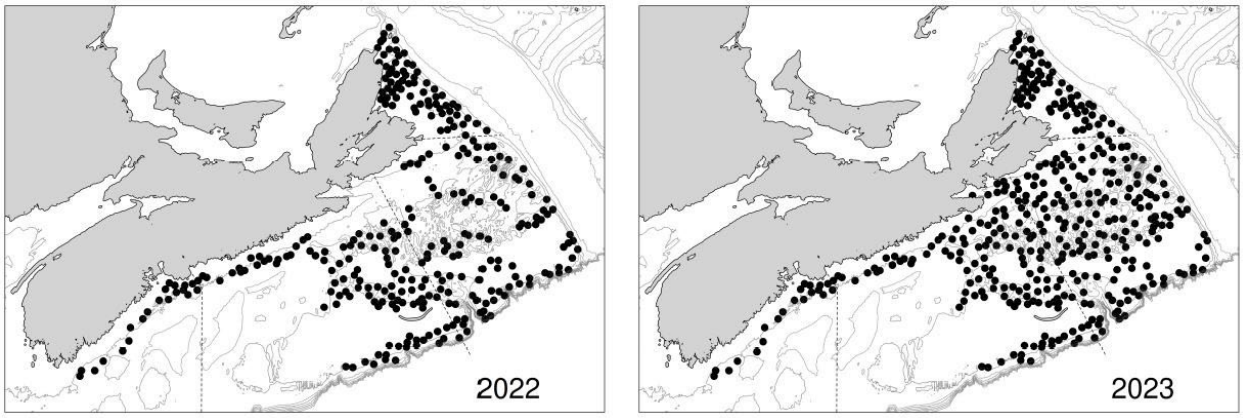

Figure 6. Snow Crab survey station locations from 2022 (left) and 2023 (right). In 2022, 83 stations were not completed due to mechanical issues with the survey vessel. A total of 384 stations were completed in the 2023 survey.

Male Size Distribution

There are many factors that make quantitative determination of recruitment levels into the fishable component of the fishery difficult, such as: terminal molt (timing of offset of molting in spring and the survey in fall); inability to accurately age crab; and, inability to predict the age that male crabs will terminally molt. The preferred habitat and habitat requirements differ significantly amongst adolescent, larval, and mature male crabs, which makes estimating their recruitment level difficult.

In N-ENS, based on the size-frequency histograms of the male Snow Crab population, there will be little to no recruitment for the next 1–3 years (Figure 7). In S-ENS, recruitment is expected to continue for the upcoming years (Figure 7). In 4X, there is continued erratic interannual patterns with low levels of recruitment expected (Figure 7).

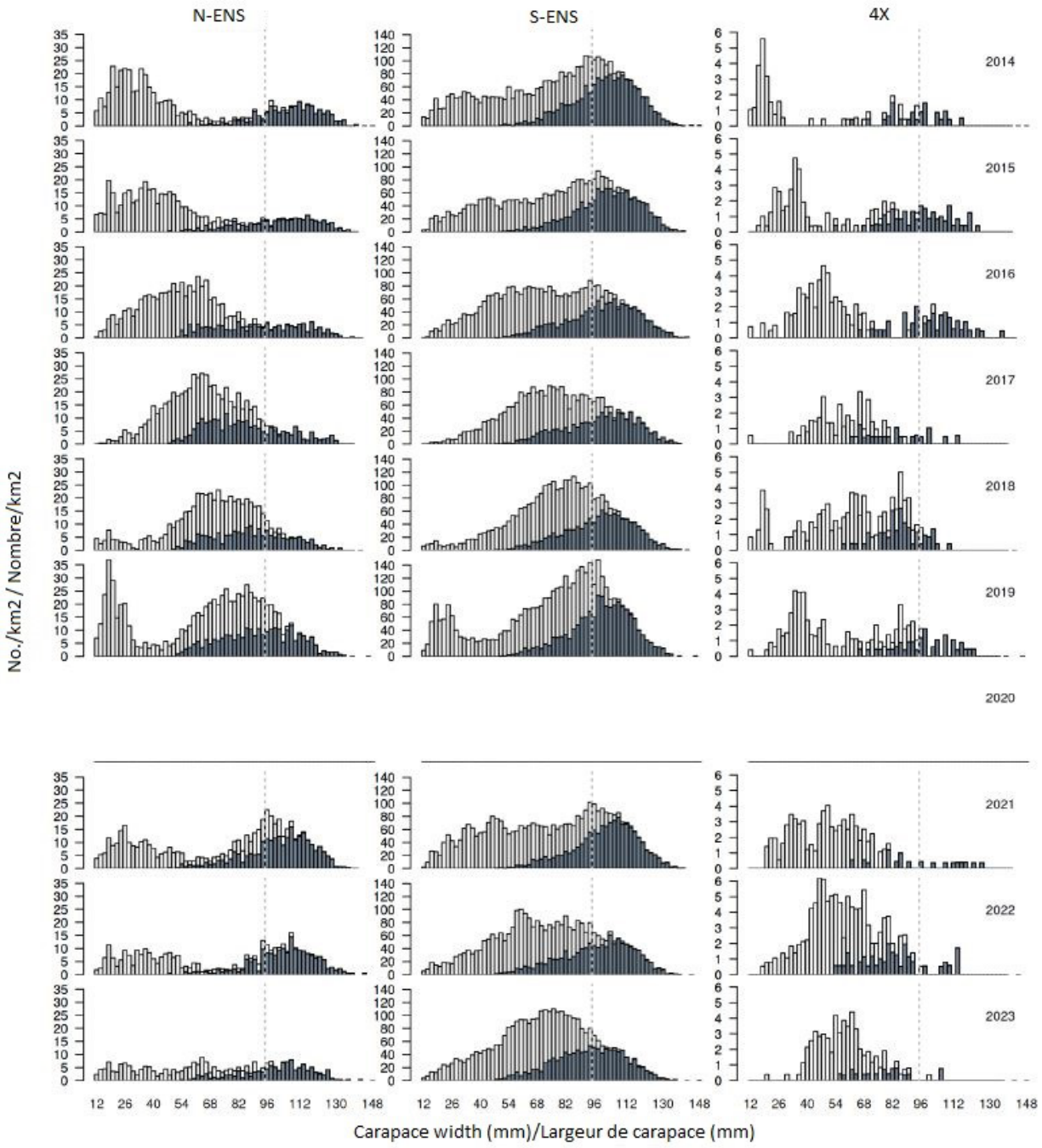

Figure 7. Size-frequency (areal density, No./km^2) histograms of carapace width of male Snow Crab from the Snow Crab survey for north-eastern Nova Scotia (N-ENS; left column), south-eastern Nova Scotia (S-ENS; middle column), and crab fishing area 4X (right column). This figure provides information about the relative densities within a given year. The vertical dashed lines represent the legal size (95 mm). Immature animals are shown with the lighter bars and mature with darker. The year 2020 is blank as there was no survey.

Female Size Distribution

In all areas there was continued recruitment of female crab into the mature (egg-bearing) stage of the population from 2016 to 2023 (Figure 8). However, in N-ENS and 4X there has been a

general decline in numerical densities of both the mature and adolescent components since 2017. In S-ENS there has been a general increase since 2021. Egg and larval production is expected to be moderate to high in the next year in all areas except N-ENS (Figure 8). Female crabs tend to be found in shallower water. The 83 survey stations that were not completed in 2022, due to mechanical issues with the survey vessel, resulted in a gap in sampling in an area where females would likely be found. A decrease in the number of mature females sampled in 2022 may be due to the sampling gap rather than a decrease in mature female density.

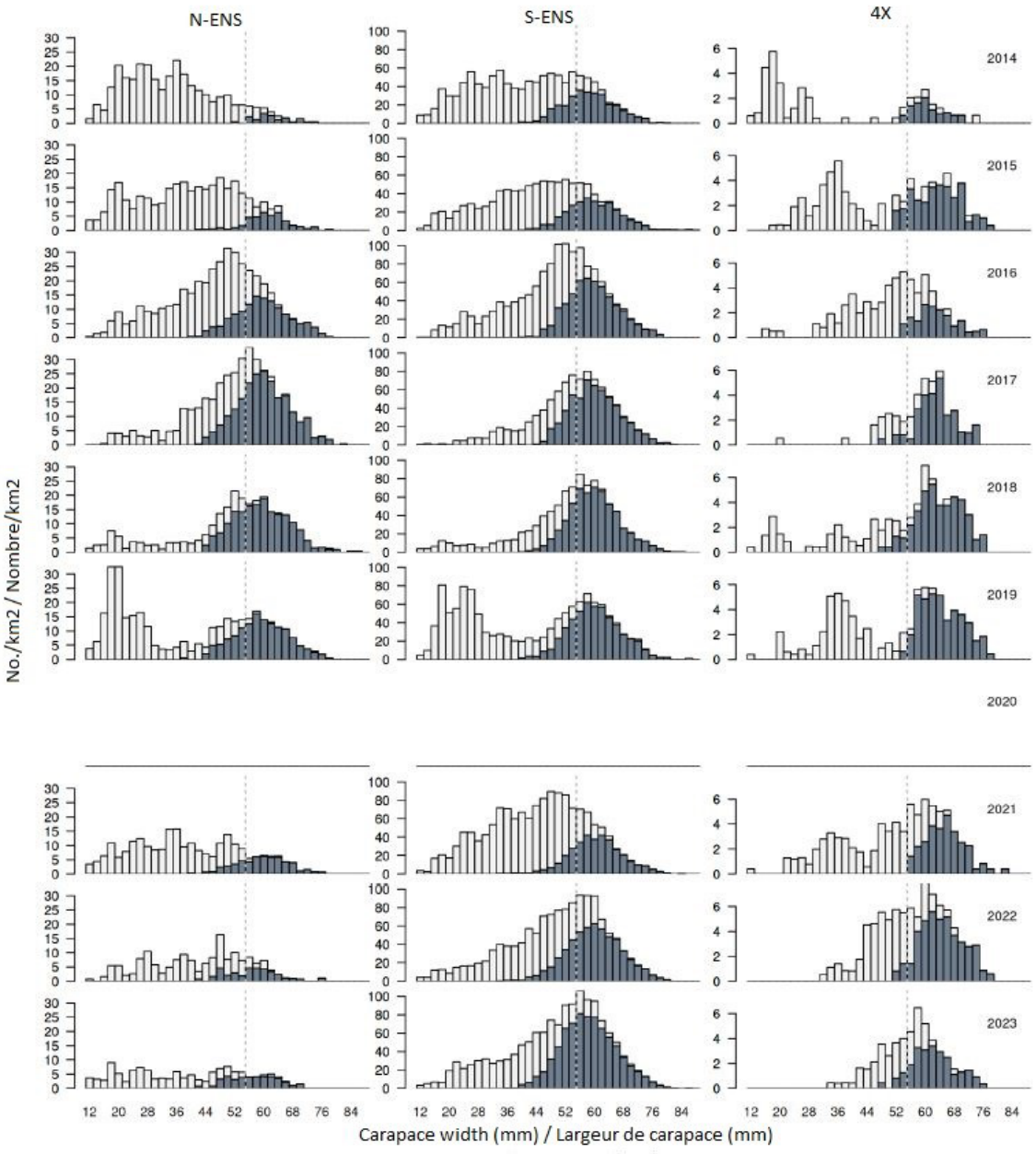

Figure 8. Size-frequency histograms of carapace width of female Snow Crab from the Snow Crab survey for north-eastern Nova Scotia (N-ENS; left column), south-eastern Nova Scotia (S-ENS; middle column), and crab fishing area 4X (right column). The vertical dashed line is at 54mm, the approximate size at 50% maturity. This figure provides information about the relative densities within a given year. Immature animals are shown with the lighter bars and mature with darker. The year 2020 is blank as there was no survey.

Biomass density

The fishable component is defined as Snow Crab that are male, mature, and larger than 95 mm carapace width. The crude, unadjusted, geometric mean fishable biomass density (per unit swept area by the Snow Crab survey trawl) is shown in Figure 9. A peak in crude biomass densities was observed from 2009 to 2014 and had been declining in all areas until 2018 for N-ENS and 2022 for S-ENS. The biomass density in 2023 is increasing. Note that high and low biomass density areas fluctuate with time. Biomass density, however, does not equate to total biomass as the areas occupied by crab can contract, expand, and shift with environmental conditions and ecosystem changes.

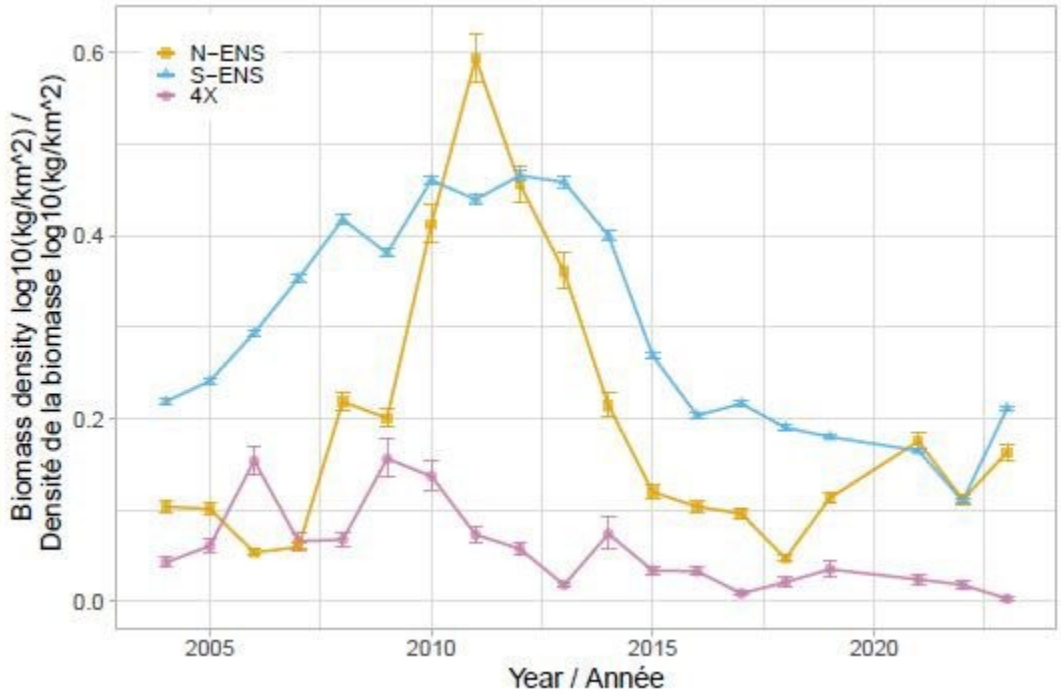

Figure 9. The unstandardized, unadjusted geometric mean fishable biomass density $log_{10}(kg/km^2)$ of Snow Crab from the Snow Crab survey for north-eastern Nova Scotia (N-ENS), south-eastern Nova Scotia (S-ENS), and crab fishing area 4X. Error bars represent 95% confidence intervals. Note the absence of data in 2020 due to no survey being conducted. Prior to 2004, surveys were conducted in the spring.

Biomass index

The fishable biomass index (statistically adjusted for covariates and autocorrelation; Figures 10–11), was computed using conditional autoregressive spatiotemporal models (CARSTM; Choi 2023a). This approach models Snow Crab numerical abundance and mean size with environmental (depth, substrate, temperature) and biological factors (species composition) as covariates in a spatiotemporal context with a Hurdle distributional assumption. Upon aggregation we see that the overall biomass has had several cycles (Figure 10). Further, the biomass index model infers the spatiotemporal distribution of the biomass density of the fishable component from the covariates measured in that year (Figure 10; note also the aggregate timeseries with elevated uncertainty for the 2020 estimate due to no survey).

The magnitudes of the biomass index are optimistically high as the spatial expansion uses areal units with large surface areas, on average, much larger than the patchiness of Snow Crab

distributions (Choi 2023a). As such, it should only be seen as a spatially and temporally consistent relative index of abundance. The spatial distribution of the biomass index has been consistent over the past six years; S-ENS and 4X had a peak in 2019 and N-ENS peaked in 2021 (Figure 10). Since then, a reduction in the biomass index was observed throughout the region. Contraction of spatial range in 4X and the western parts of S-ENS were evident from 2022 to 2023 (Figure 11). Upon aggregation, the predicted biomass index declined marginally in all areas from 2022 to 2023 (Figure 11).

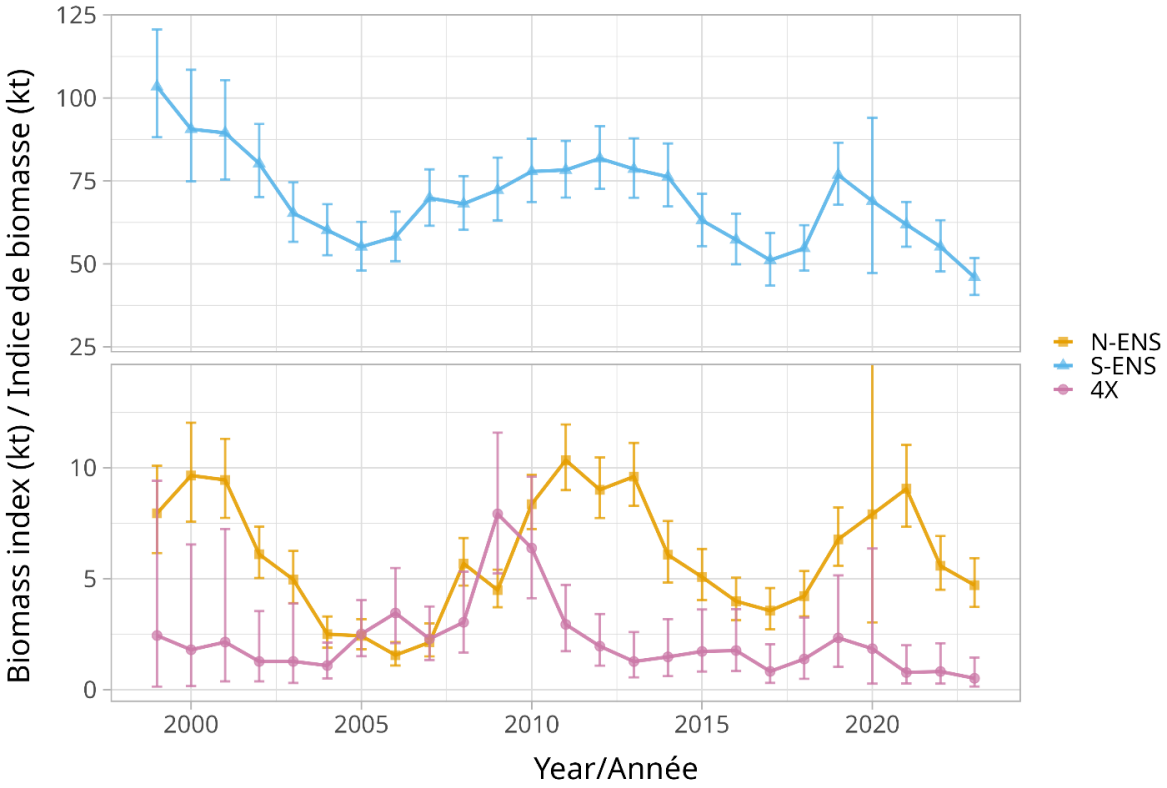

Figure 10. The fishable biomass index (kt) predicted from the Snow Crab survey for north-eastern Nova Scotia (N-ENS), south-eastern Nova Scotia (S-ENS), and crab fishing area 4X. Error bars represent Bayesian 95% credible intervals. Note large errors in 2020 when there was no survey completed.

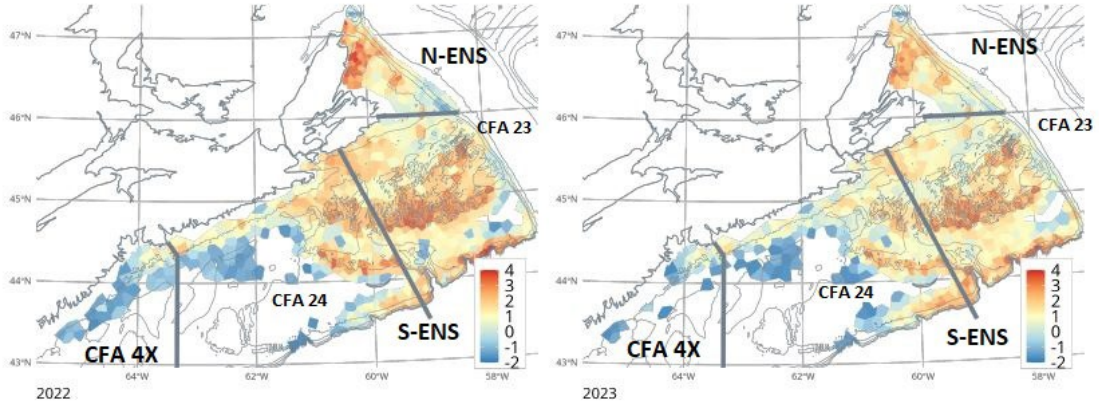

Figure 11. Snow Crab biomass index log_{10} (t/km^2) predicted from the Snow Crab survey in 2022 (left) and 2023 (right) in north-eastern Nova Scotia (N-ENS), south-eastern Nova Scotia (S-ENS), and crab fishing areas (CFA) as indicated.

Modelled Biomass

The fishable biomass index along with fishery removals are used to fit a logistic biomass dynamics model (Choi 2023a and 2023b) to determine fishable modelled biomass ("summer" or "pre-fishery" biomass estimated from the fisheries model; Figure 12) and relevant biological reference points (i.e., carrying capacity and fishing mortality at maximum sustainable yield, FMSY).

In N-ENS, the modelled biomass (pre-fishery) of Snow Crab in 2023 was 3.27 kt, a decline of 10.9% relative to 3.67 kt in 2022. In S-ENS, the modelled biomass (pre-fishery) was 37.91 kt, a decline of 10.6 % relative to 42.42 kt in 2022. In 4X, the 2023–2024 season's modelled biomass (pre-fishery) was 0.08 kt, a decline of 46.7% relative to 0.15 kt in the 2022–2023 season. There is a continuing decrease in modelled biomass in N-ENS since 2021, and since 2019 in S-ENS and 4X.

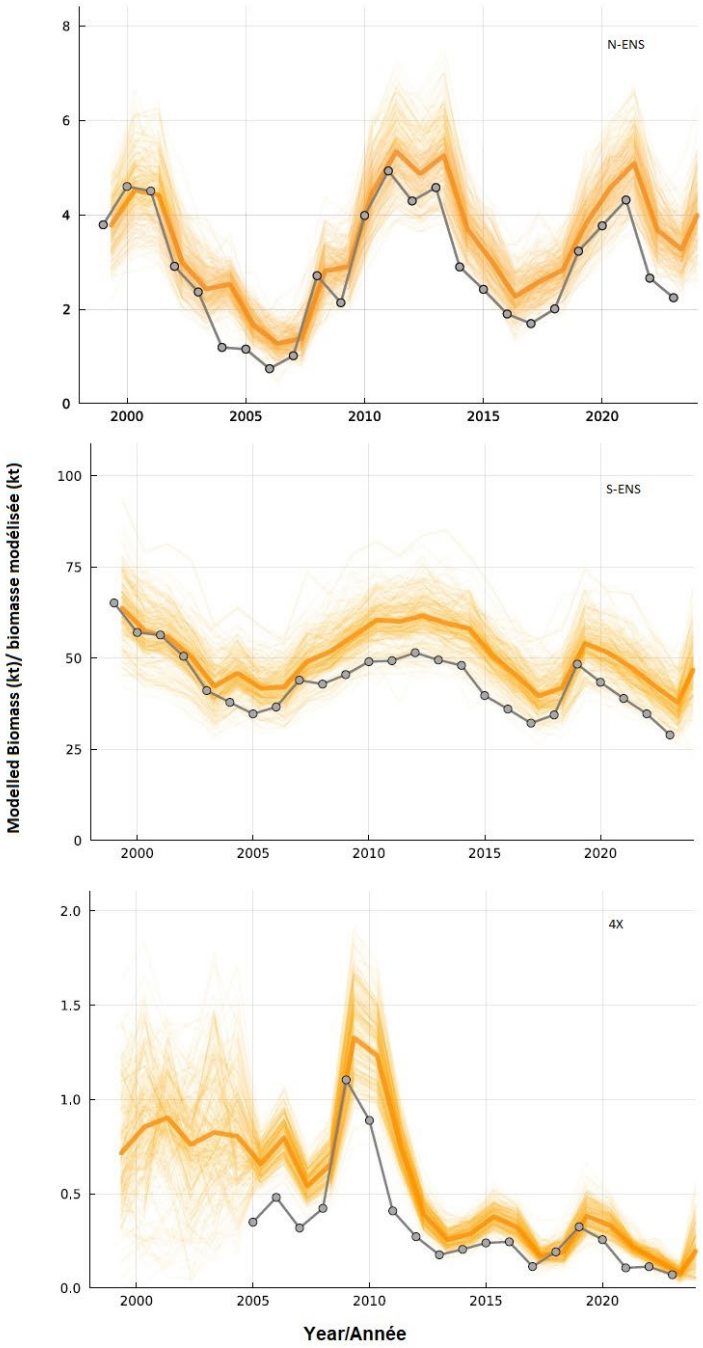

Figure 12. Fishable posterior mean modelled biomass (pre-fishery; kt) are shown in dark orange for north-eastern Nova Scotia (N-ENS; top), south-eastern Nova Scotia (S-ENS; middle), and crab fishing area 4X (bottom). Light orange are posterior samples of modelled biomass (pre-fishery; kt) to illustrate the variability of the predictions. The biomass index (post-fishery; kt) after model adjustment by the model catchability coefficient is in grey.

Fishing Mortality

In N-ENS, the 2023 fishing mortality (F) is estimated to have been 0.264 (annual exploitation rate of 30.17%), while in 2022 it was 0.239 (annual exploitation rate of 26.9%; Figure 13).

In S-ENS, F is estimated to have been 0.18 (annual exploitation rate of 19.7%) for 2023, while in 2022 it was 0.161 (annual exploitation rate of 17.5%; Figure 13). Localized exploitation rates are likely higher, as not all areas for which biomass is estimated are fished (e.g., continental slope areas and western).

In 4X, for the 2023–2024 season (ongoing), F is estimated to be 0.077 (annual exploitation rate of 8%), while in the 2022–2023 season it was 0.236 (annual exploitation rate of 26.6%; Figure 13). Localized exploitation rates are likely higher, as not all areas for which biomass is estimated are fished.

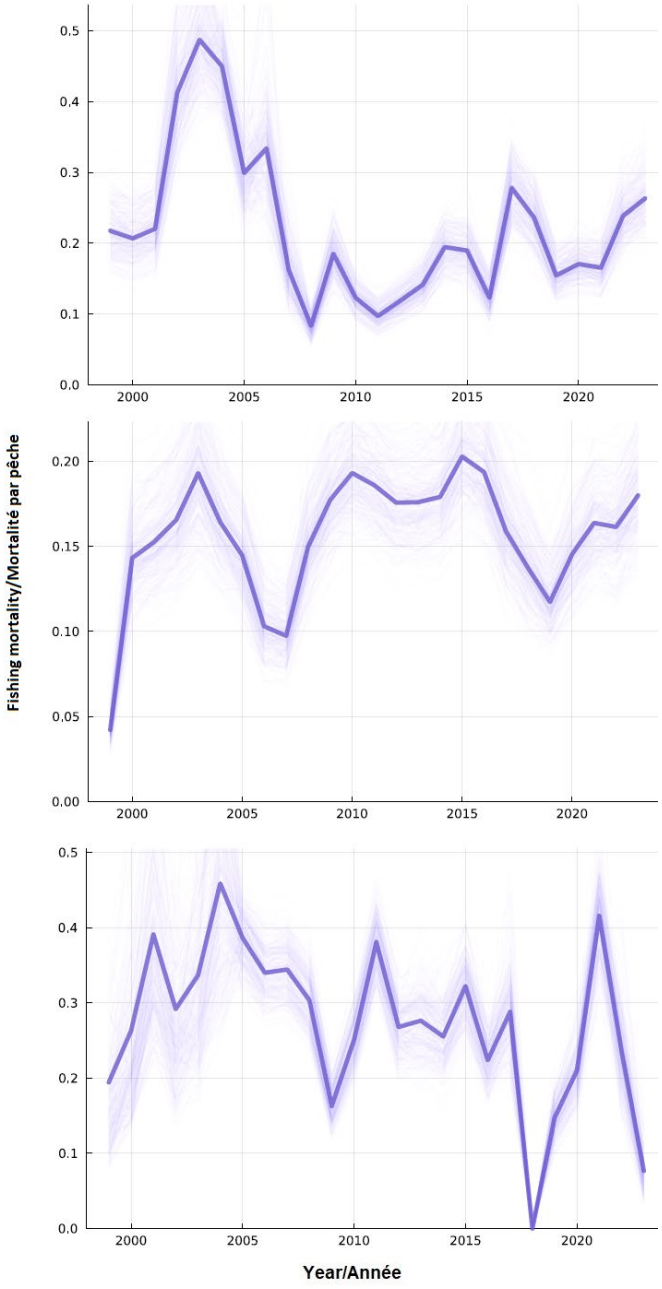

Figure 13. Time-series of modelled instantaneous fishing mortality for north-eastern Nova Scotia (N-ENS; top), south-eastern Nova Scotia (S-ENS; middle), and crab fishing area 4X (bottom). Samples of the posterior densities are presented, with the darkest line being the mean.

Ecosystem Considerations

Bottom temperature

A general warming trend has been observed in the Snow Crab survey since the early 1990s on the Scotian Shelf until 2022 (Choi et al. 2022, Figure 14). Temperatures are more stable in N-ENS than S-ENS, and 4X exhibits the most erratic and highest annual mean bottom temperatures (Figure 14). The average temperature is found to have increased well beyond the 7 °C threshold (Foyle et al. 1989) in 4X since 2010. N-ENS and S-ENS also continued to experience historical highs in bottom temperature and elevated spatial variability of bottom temperatures up to 2022. In 2023, bottom temperatures collected on the survey have returned to the historical range in all three CFAs (Figure 14).

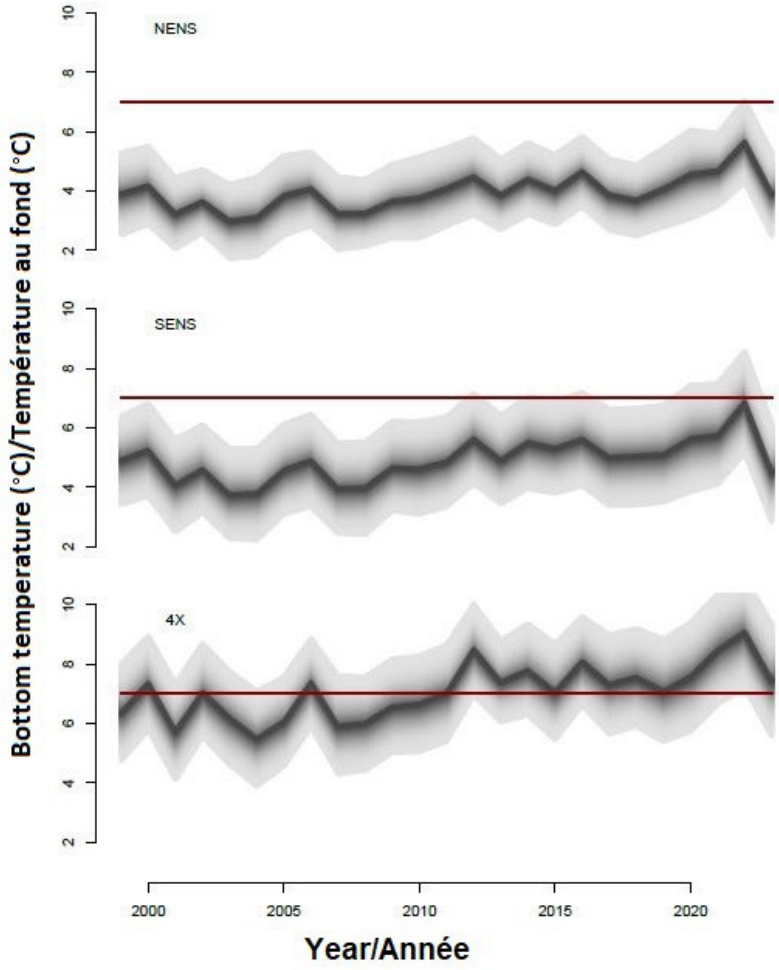

Figure 14. Temporal variations in bottom temperature estimated from a historical analysis of temperature data for north-eastern Nova Scotia (N-ENS; top), south-eastern Nova Scotia (S-ENS; middle), and crab fishing area 4X (bottom). Red horizontal line is at the 7 °C threshold. Presented are 95% credible intervals of spatial variability in temperature at each time slice, after adjustment for spatiotemporal autocorrelation.

Viable habitat

Viable habitat is defined as the probability of observing a demographic group in a given time and location based on the influence of temperature, depth, species assemblages, and spatiotemporal autocorrelation (Choi 2011). Snow Crab being cold water stenotherms, stability

of environmental conditions is critical for their survival. The Maritimes Region being at the confluence of many oceanic currents renders the area highly variable. Rapid climate change and uncertainty exacerbates this situation. The viable habitat estimated for each area across time has shown some variations (Figures 15 & 16) in the historical record. 4X showed significantly lower average viable habitat levels relative to the N-ENS and S-ENS levels. A peak in average probability of observing fishable Snow Crab ("viable habitat") was observed in 2010 for 4X, 2011 for N-ENS, and 2012 for S-ENS. Since 2015, the average viable habitat has declined and remained low in 2021 and 2022 for all three areas. In 2023, there has been a marginal increase in N-ENS and S-ENS, while 4X decreased again and is at one of its lowest points (Figure 15).

Figure 15. Habitat viability (probability of observing fishable Snow Crab) for north-eastern Nova Scotia (N-ENS), south-eastern Nova Scotia (S-ENS), and crab fishing area 4X. Annual means and 95% credible intervals are presented.

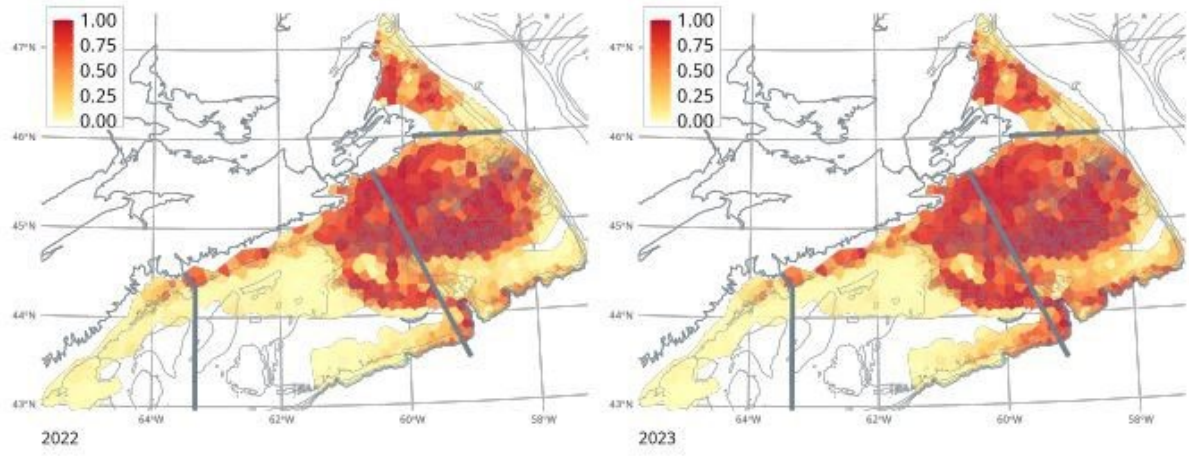

Figure 16. Habitat viability (probability of observing fishable Snow Crab) for 2022 (left) and 2023 (right).

Reference points

The operational and current estimates of reference points associated with the Snow Crab fishery are as follows (Table 4 and Figures 17–19):

- Lower Stock Reference (LSR) defined as 25% of estimated carrying capacity and delineates the critical and cautious zones - K/4
- Upper Stock Reference (USR) defined as 50% of estimated carrying capacity and delineates the cautious and healthy zones - K/2

Removal Reference (RR): not to exceed FMSY (where F is the fishing mortality of the legal sized mature male population, MSY is the theoretical maximum sustainable yield, and r is the intrinsic rate of increase) - r/2:

- In the logistic model, FMSY=r/2. As r≈1 for Snow Crab, FMSY≈0.5 is expected.

Harvest Control Rules

The operational target exploitation changes depending upon the zone in which a population lands.

- When in the healthy zone, the rule of thumb has been to keep annual exploitation rates between 10% and 30% of the available biomass (F = 0.11, 0.36, respectively).
- In the cautious zone, the rule of thumb has been to keep annual exploitation rates between 0% and 20% (F = 0, 0.22, respectively).
- In the critical zone, fishery closure is considered until recovery is observed, where recovery indicates at a minimum, modelled biomass greater than the LSR.

Other biological and ecosystem considerations, such as, recruitment, spawning stock (female) biomass, size structure, sex ratios, and environmental and ecosystem conditions provide additional guidance within each range.

The current state of the fishable components and the above landmarks (Figures 17–19) suggest that:

- N-ENS is in the healthy zone
- S-ENS is in the healthy zone

- 4X is in the critical zone

It should be noted that using these parameters assumes that the population dynamics are well-described by the fishery model. This is, of course, not true. The Scotian Shelf Snow Crab population is not at, nor near, any equilibrium state. As a result, the parameter estimates derived from the logistic model provide, at best, first order estimates of the true biological reference points (Choi 2023a, 2023b). Further, the observation of fisheries landings is assumed to be known without error. This is not true, as unauthorized and unreported exploitation is not quantified. These, and other unaccounted factors, can easily bias parameter estimates. As such, caution is advised in using these reference points. Other contextual indicators should be used in conjunction, such as:

- Strength of recruitment (short-term, and long-term)
- Strength of spawning stock (females)
- Ecosystem variability (predator and prey trends and distributions) within norms
- Habitat viability within norms
- Availability of spatial and temporal refugia within norms

Table 4. Reference points from the logistic biomass dynamics fishery model: K is carrying capacity (units are kt) and r is intrinsic rate of increase (non-dimensional). Note that FMSY (fishing mortality associated with maximum sustainable yield) is r/2. Similarly, BMSY (biomass associated with maximum sustainable yield) is K/2. SD is posterior standard deviation.

Area	K [SD]	r [SD]
North-eastern Nova Scotia	5.15 [0.44]	0.95 [0.44]
South-eastern Nova Scotia	64.41 [5.04]	0.89 [5.04]
4X	1.28 [0.11]	0.94 [0.11]

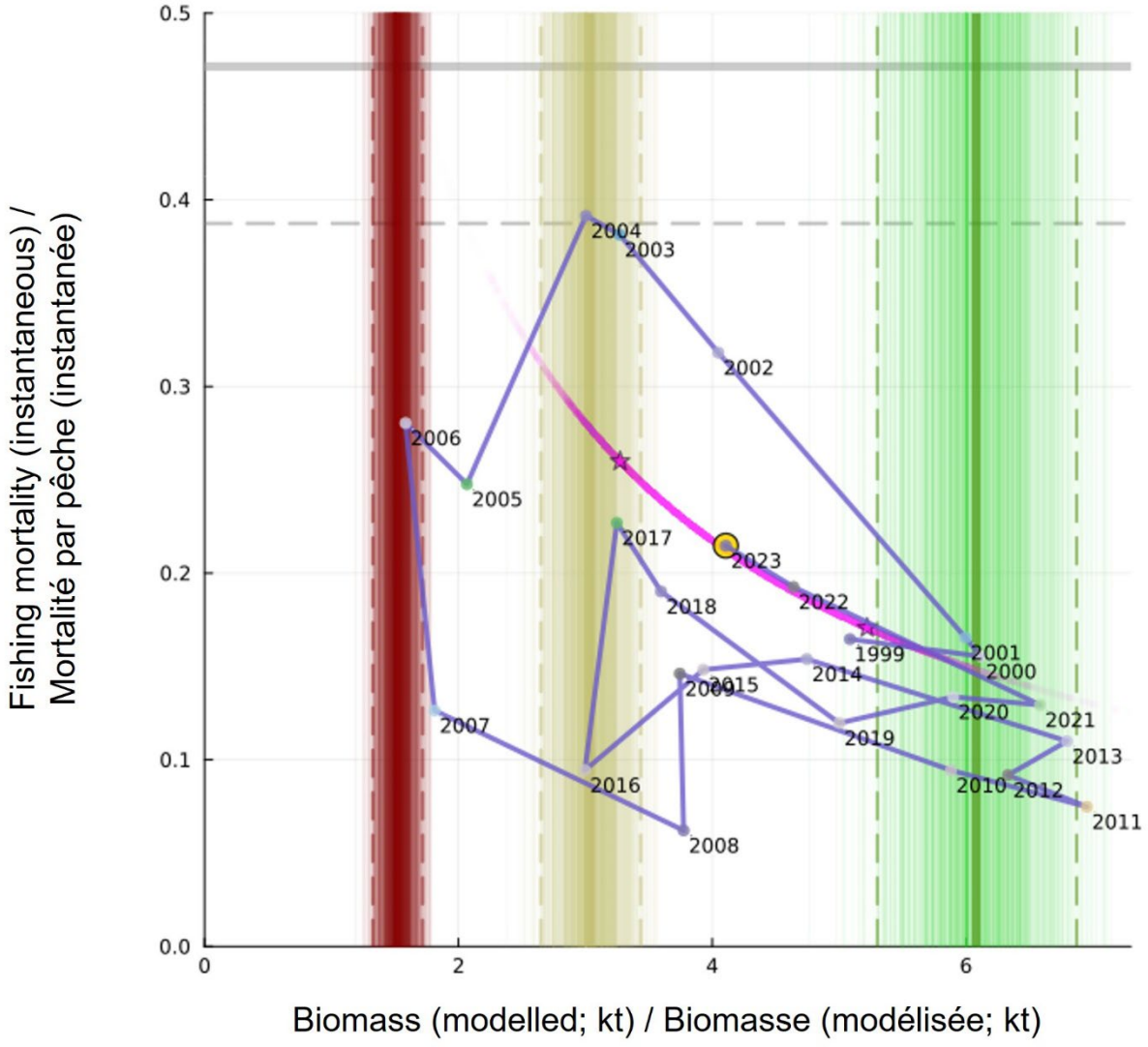

Figure 17. Reference points (F: instantaneous fishing mortality versus modelled biomass [kt]) for north-eastern Nova Scotia. The circular points represent posterior mean estimates of stock biomass and instantaneous fishing mortality (harvest rate). The most recent year is indicated with a large yellow dot and the 95% credible intervals are presented by pink stars. The posterior distribution of fishable biomass and fishing mortality is shown as the thick pink line and falls upon a line as fishing mortality is computed from fishable biomass with no error assumed in catch. The grey solid horizontal line identifies the FMSY estimated for each area and the stippled horizontal lines identify the 95% credible intervals. The solid coloured vertical lines identify the estimates of the 25% (red), 50% (yellow) and 100% (green) carrying capacity for each region and the stippled lines delimit the 95% credible intervals for each threshold. The lighter coloured vertical lines are posterior samples to demonstrate the variability associated with each parameter.

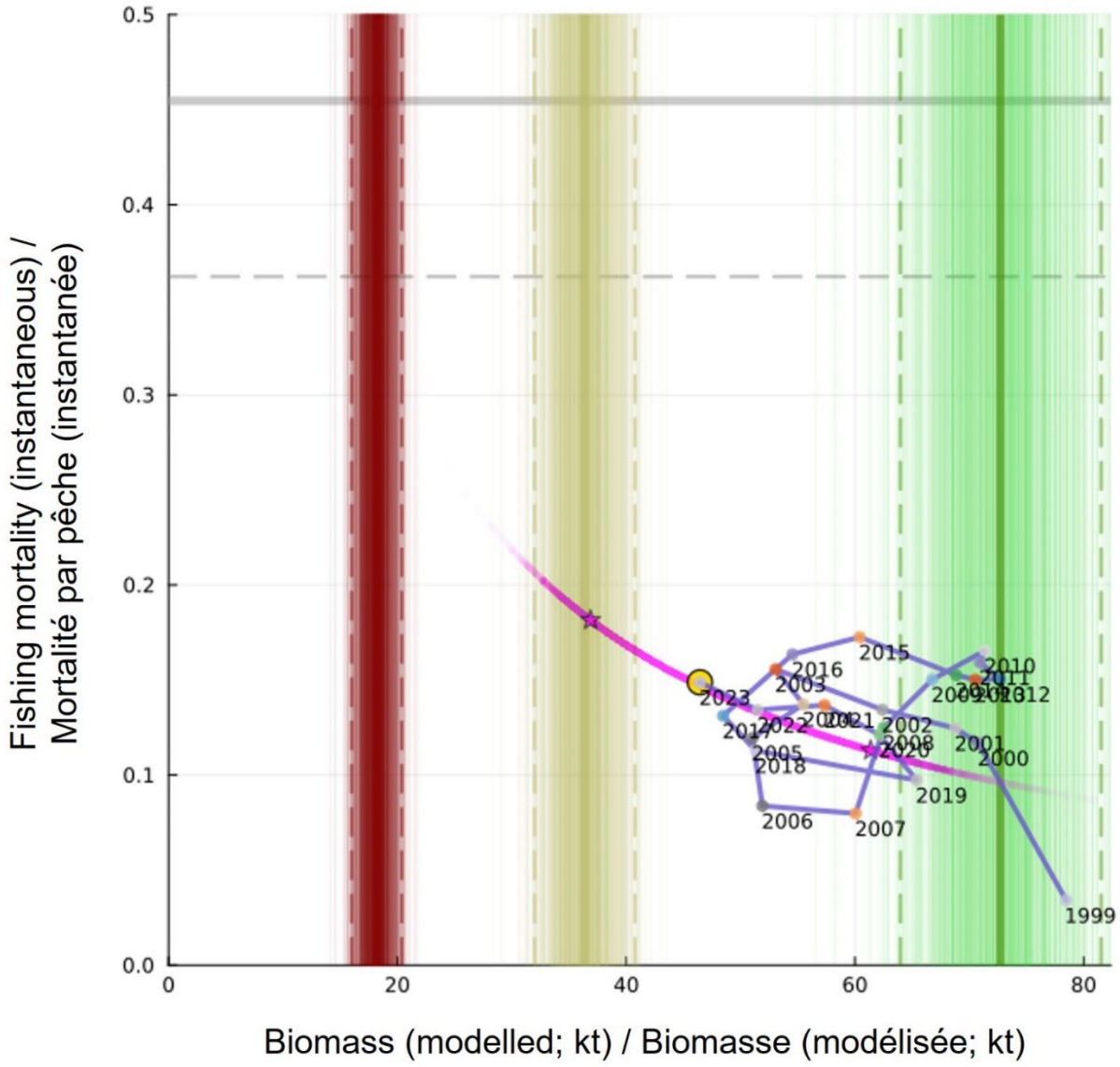

Figure 18. Reference points (F: instantaneous fishing mortality versus modelled biomass [kt]) for south-eastern Nova Scotia. The circular points represent posterior mean estimates of stock biomass and instantaneous fishing mortality (harvest rate). The most recent year is indicated with a large yellow dot and the 95% credible intervals are presented by pink stars. The posterior distribution of fishable biomass and fishing mortality is shown as the thick pink lines and fall upon a line as fishing mortality is computed from fishable biomass with no error assumed in catch. The grey solid horizontal line identifies the FMSY estimated for each area and the stippled horizontal lines identify the 95% credible intervals. The solid coloured vertical lines identify the estimates of the 25% (red), 50% (yellow) and 100% (green) carrying capacity for each region and the stippled lines delimit the 95% credible intervals for each threshold. The lighter coloured vertical lines are posterior samples to demonstrate the variability associated with each parameter.

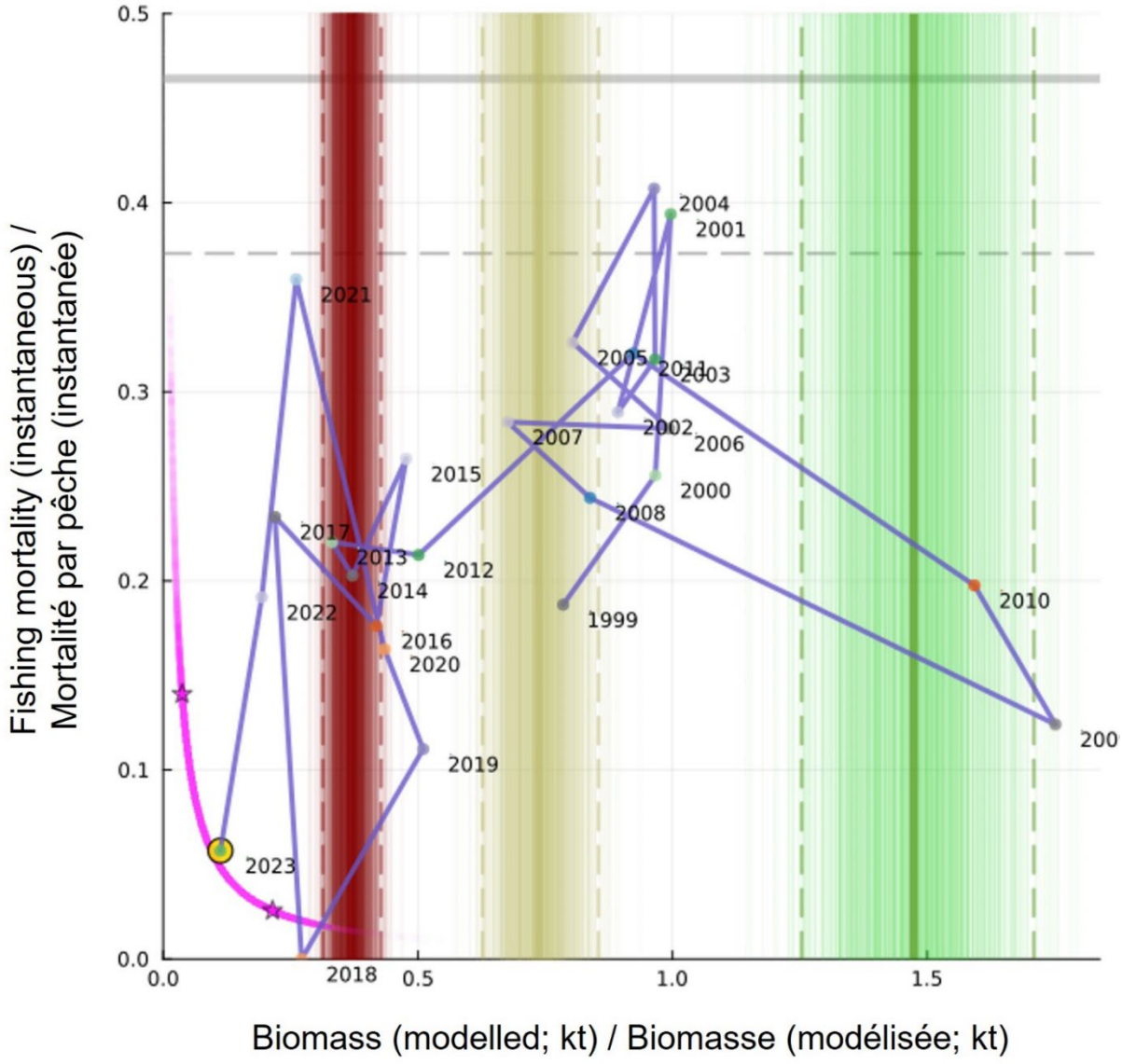

Figure 19. Reference points (F: instantaneous fishing mortality versus modelled biomass [kt]) for crab fishing area 4X. The circular points represent posterior mean estimates of stock biomass and instantaneous fishing mortality (harvest rate). The most recent year is indicated with a large yellow dot and the 95% credible intervals are presented by pink stars. The posterior distribution of fishable biomass and fishing mortality is shown as the thick pink lines and fall upon a line as fishing mortality is computed from fishable biomass with no error assumed in catch. The grey solid horizontal line identifies the FMSY estimated for each area and the stippled horizontal lines identify the 95% credible intervals. The solid coloured vertical lines identify the estimates of the 25% (red), 50% (yellow) and 100% (green) carrying capacity for each region and the stippled lines delimit the 95% credible intervals for each threshold. The lighter coloured vertical lines are posterior samples to demonstrate the variability associated with each parameter. For fishing area 4X, the year refers to the starting year of the fishing season.

Sources of Uncertainty

- Bycatch of non-target species in the Snow Crab fishery cannot currently be reliably computed as sampling targets for at-sea observer coverage have not been met in recent years.

- Bycatch of Snow Crab in other fisheries remains as a source of uncertainty. In recent years, fisheries violations have been dealt with for cases involving unauthorized retention of sublegal and female Snow Crab as bycatch and the use of these as bait.
- Marine Protected Areas (MPAs) continue to be developed (e.g., Canada Gazette 2016). The presence of a refuge from fishing activities is potentially positive for Snow Crab. However, positive effects upon other organisms (predators or prey) can have counter-balancing effects. The overall long-term effects of the MPAs upon Snow Crab are unknown.
- Limited electronic tagging and spaghetti tagging suggests movement of male crabs between fishing zones, and there is concern that immigration and emigration may not be reflected in our estimates of stock productivity for N-ENS specifically. N-ENS can act as a corridor for crab moving to and from the southern Gulf of St. Lawrence to S-ENS.
- Capture of soft-shell Snow Crab is always a concern. Prompt and careful return of immature (small-clawed, non-terminally molted) crab to the water is an important conservation measure that will enhance the 2–3 year productivity of the fishable component. It is not possible to quantify the impact of improper handling stress on the growth and mortality of captured soft-shell Snow Crab which also leads to uncertainty in the fishery model parameters.
- Unauthorized harvesting has the potential to have an impact on stock assessment and application of precautionary approach towards management of this resource by introducing bias and uncertainty in the estimation of reference points.

CONCLUSIONS AND ADVICE

The SSE is still experiencing instability driven by rapid ecosystem and climatic variations. The overall indications of population status suggest that Snow Crab are still able to persist under extreme conditions, with some shifts in spatial distribution towards cooler and deeper waters, if the conditions are episodic.

North-eastern Nova Scotia (N-ENS)

In 2023, the N-ENS mean estimated fishable biomass was above the USR, placing the stock in the healthy zone; however, there is considerable model uncertainty around both the estimate and the reference point. Though recruitment continues at low levels, a gap in future recruitment to the fishery is expected for the next 1–3 years, potentially limiting stock growth in the short-term. In 2023, fishing mortality was 30.17%, slightly above the HCR of 10–30%. A more conservative harvest strategy may support the stock in bridging the expected gap in recruitment.

South-eastern Nova Scotia (S-ENS)

In 2023, the S-ENS fishable biomass was above the USR, placing it in the healthy zone; however, there is considerable model uncertainty around both the estimate and the reference point. A moderate level of recruitment to the fishery is likely to continue for the upcoming season (the next 1–3 years, or continuing). Exploitation rates derived from the fishery model were 19.7% in 2023, and have remained between 10–20% since 2020. The stock status in S-ENS suggests that the current harvest strategy has not been detrimental to the stock. The recent return of more favorable environmental conditions could be beneficial to the stock in the short-term; however, the warming trends since 2015 are predicted to continue into the medium and long-term.

Area 4X

In 2023, the 4X fishable biomass was below the LRP, placing the stock in the critical zone. In 4X, low to moderate levels of recruitment are expected for four years (40 mm carapace width), but high mortality of the adolescent crab makes recruitment into the fishable component uncertain. The area is also in the southernmost extent of Snow Crab distribution in the North Atlantic and experienced an extended period of unfavorable conditions for Snow Crab in the region. Viable habitat has been depressed for many years.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Anderson, Bob	CFA 24 – South-eastern Nova Scotia Industry Representative
Cameron, Brent	DFO Science – Maritimes Region
Cassista-DaRos, Manon	DFO Science – Maritimes Region
Choi, Jae	DFO Science – Maritimes Region
Christie, Kate	DFO Science – Maritimes Region
Clancey, Lewis	Nova Scotia Department Fisheries & Aquaculture
Couture, John	Oceans North
Ganapathiraju, Pramod	DFO Resource Management – Maritimes Region
Glass, Amy	DFO Science – Maritimes Region
Gould, Bobby	Waycobah First Nation Fisheries
Greenlaw, Michelle	DFO Science – Maritimes Region
Kehoe, Andrew	CFA 24 – South-eastern Nova Scotia Industry Representative
Langille, Janet	DFO Resource Management – Maritimes Region
Licandeo, Roberto	Institute for the Oceans and Fisheries, University of British Columbia
MacDonald, Gordon	CFA 23 – South-eastern Nova Scotia Industry Representative
MacMullin, Neil	N-ENS – Crab Fishermen's Association Representative
McIntyre, Tara	DFO Science – Maritimes Region
Olmstead, Melissa	DFO Science – National Capital Region
Organ, Greg	N-ENS Snow Crab Industry Representative
Paul, Tyson	Unama'ki Institute of Natural Resources
Pedersen, Eric	Concordia University
Pomerleau, Corinne	DFO Science – Maritimes Region
Townsend, Kathryn	Maritime Aboriginal Peoples Council
Whynot, Larry	Native Council of Nova Scotia

SOURCES OF INFORMATION

This Science Advisory Report is from the February 26–27, 2024, regional peer review on the Stock Assessment of Snow Crab in Maritimes Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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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.MaritimesCSA-CASMaritimes.MPO@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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