Fisheries and Oceans Canada | Pêches et Océans Canada
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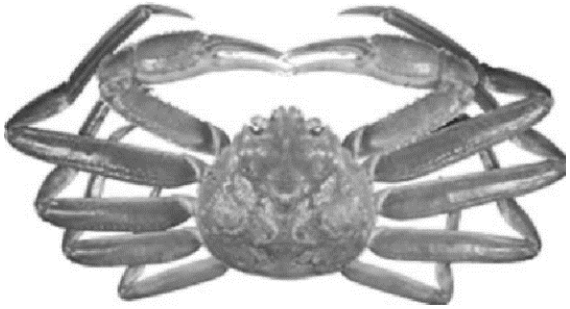
Maritimes Region

Canadian Science Advisory Secretariat
Science Response 2022/036

STOCK STATUS UPDATE OF SCOTIAN SHELF SNOW CRAB (*CHIONOECETES OPILIO*, O. FABRICIUS)



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

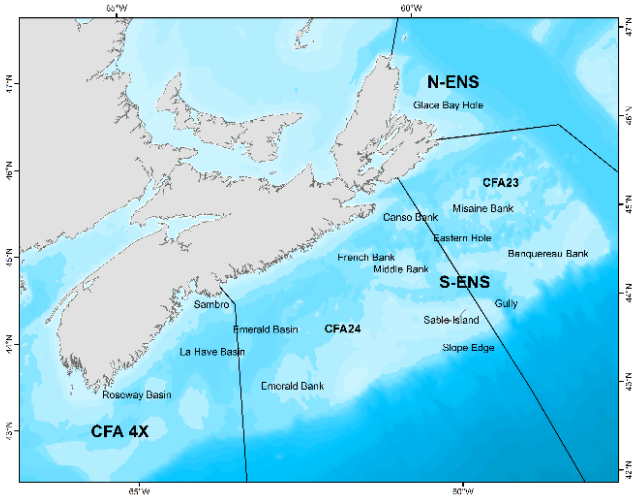


Figure 1. Map of the Scotian Shelf and Crab Fishing Areas (CFAs).

Context

In support of the fishery, Fisheries and Oceans Canada (DFO) Maritimes Fisheries Management requests from DFO Science annual advice on the status of Scotian Shelf Snow Crab. The last assessment of the status of the Scotian Shelf Snow Crab, conducted in February 2020, was based on fishery independent surveys using indicators of abundance, reproductive potential, recruitment, and exploitation rates. Ecosystem and environmental indicators are also incorporated into the assessment (DFO 2020). Commercial catch rates and other fishery statistics were reported as well. There was no survey conducted in 2020 due to COVID-19 restrictions, as well as reduced at-sea observer coverage in 2020 and 2021.

This Science Response Report is from the regional Science Response Process on the Stock Status Update of Scotian Shelf Snow Crab, held on February 24th and March 15th, 2022.

Background

Species Biology

Snow Crab (*Chionoecetes opilio*, O. Fabricius) is a subarctic species with a distribution from northern Labrador to near the Gulf of Maine. Habitat preference is for deep, soft bottom

substrates. Smaller Crabs are found in more complex habitats with shelter. Commercial sized Crab (males ≥ 95 mm carapace width [CW]) in large numbers are found at depths from 60 to 280 m and temperatures from −1 to 6 °C in the Scotian Shelf. Temperatures greater than 7 °C are known to be detrimental to Snow Crab. The primary food items of Snow Crab are shrimp, fish (Capelin and Lumpfish), starfish, sea urchins, worms, detritus, large zooplankton, other crabs, molluscs, sea snails, and sea anemones. Predators of Snow Crab are Atlantic Halibut, skates (especially Thorny Skate), Atlantic Cod, seals, American Plaice, squids, and other crabs. Crab in the size range of 3 to 30 mm CW are particularly vulnerable to predation, as are soft-shelled crab during the spring moulting season. Snow Crab have been a dominant macro-invertebrate in the Scotian Shelf since the decline of groundfish abundance during the late 1980s and early 1990s. The Scotian Shelf Snow Crab are in the southern-most extreme of their spatial distribution in the northwest Atlantic and, as such, are one of the most susceptible to increasing ocean temperatures.

Fishery

The Snow Crab fishery in eastern Canada began in 1960 with incidental bycatches by groundfish draggers near Gaspé, Quebec. Its development was slow until the 1980s, when it began expanding rapidly to become one of the largest fisheries in Canada in terms of landings and landed value. On the Scotian Shelf, the fishery has been in existence since the early 1970s. The management of the Snow Crab fisheries in the Scotian Shelf 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 or equal to 95 mm CW. Additional management measures were introduced from 1994 to 1999: individual boat quotas, Total Allowable Catches (TACs), 100% dockside monitoring, mandatory logbooks, and at-sea monitoring by certified observers. There is also a concerted effort to avoid areas of newly moulted (soft-shelled) crab, and to discard immature males.

The North-Eastern Nova Scotia (N-ENS) and South-Eastern Nova Scotia (S-ENS) fisheries are conducted within a calendar year. The 4X fishery is conducted over a fall-to-spring fishing season spanning calendar years, and this is why seasons are considered ongoing. Total landings increased to record-levels of approximately 10,000 tonnes (t) each year in the early 2000s and increased further to approximately 14,000 t in 2010 (Figure 2). In 2005, many Crab Fishing Areas (CFAs) and subareas were merged, with the resulting divisions being N-ENS (formerly CFAs 20–22), S-ENS (CFAs 23 and 24), and 4X (Figure 1).

Fishery Performance

Landings in 2021 were 901 t in N-ENS, 8,326 t in S-ENS and 103 t in CFA 4X, representing an increase of 8%, 5% and 36% (4X fishing season ongoing), respectively, relative to 2020 (Figure 2, Tables 1–3). Total Allowable Catches (TAC) for 2021 were 890 t, 8,161 t, and 110 t in N-ENS, S-ENS, and 4X, respectively (Tables 1–3). The quota limits vary from the TAC as they account for any carry-forward quota. In response to concerns about the ability to safely conduct fishing activities in light of the COVID-19 pandemic, DFO Fisheries Management approved a carry-forward of up to 25% of the 2020 quota to the 2021 season for all licence holders in the N-ENS and S-ENS Snow Crab fishery. Most of the TAC was successfully landed in the 2020 season, so the resulting carry-forward amount was considerably below the maximum potential

allowance. The carry-forward amounts were 11.2 t in N-ENS, 203.6 t in CFA 23, and 13.8 t in CFA 24 (a combined total of 217.4 t in S-ENS). This permitted fishing in excess of the TAC that was otherwise allocated for the 2021 season. As such, landings beyond the TAC are likely reflective of this additional allowance, rather than over-fishing.

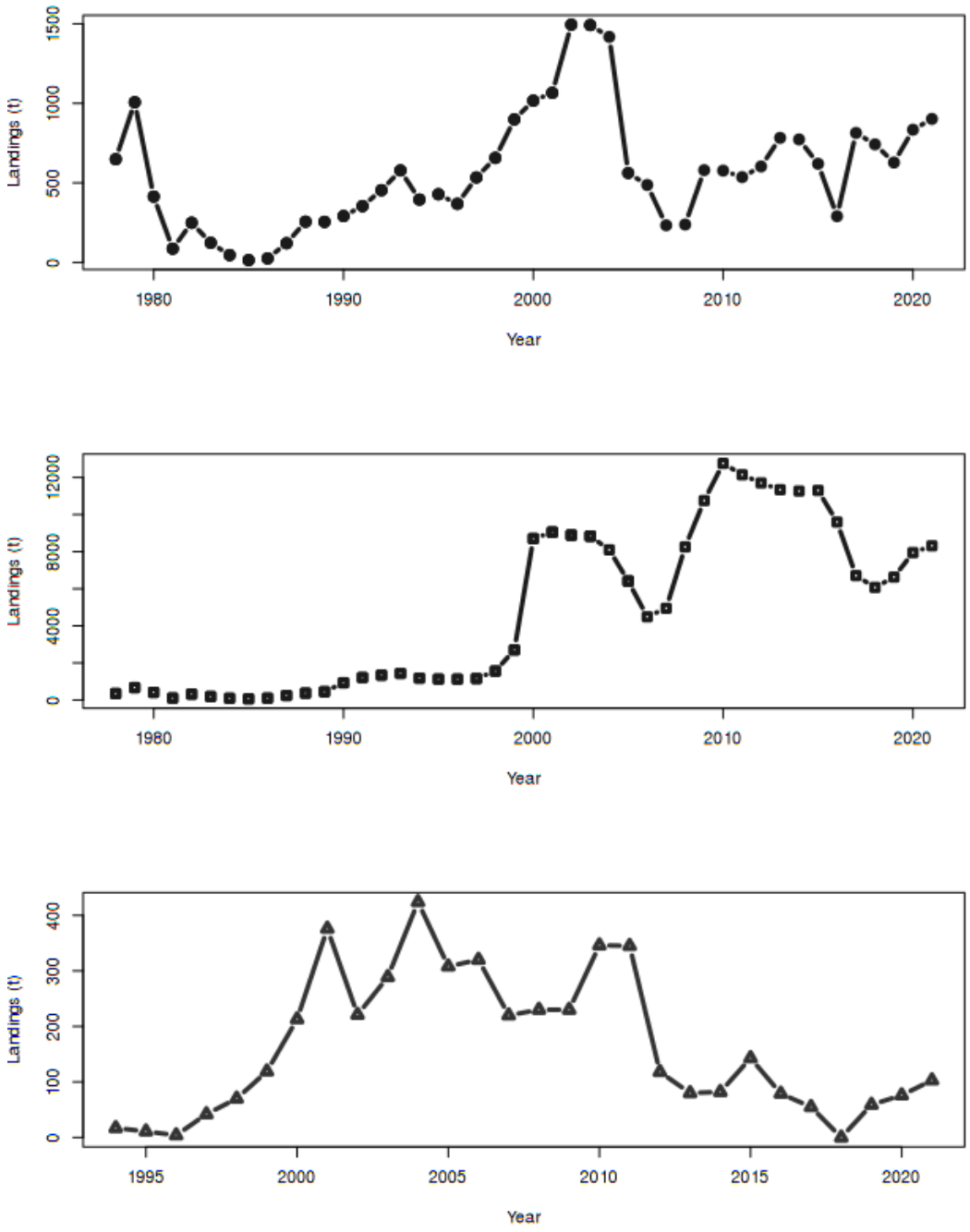


Figure 2. Temporal variations in the landings (t) of Snow Crab on the Scotian Shelf. The landings follow the Total Allowable Catches (TACs) with little deviation, so the TACs are not shown. For 4X, the year refers to the starting year of the season. Top panel: N-ENS; middle panel: S-ENS; bottom panel: 4X. Note: the scale of the y-axis is different in each panel.

Table 1. Summary of the Snow Crab fishery in North-Eastern Nova Scotia. (TAC = total allowable catch, CPUE = Catch Per Unit Effort).

Year	Number of Licenses	TAC (t)	Quota Limit (t)	Landings (t)	Effort (x1000 trap hauls)	CPUE (kg/trap haul)
2011	78	534	534	536	4.7	114
2012	78	603	603	603	4.9	123
2013	78	783	783	783	7.0	112
2014	78	783	783	781	6.9	113
2015	78	620	624	619	6.2	100
2016	78	286	286	290	2.7	107
2017	78	825	825	813	8.8	92
2018	78	784	786	742	12.2	61
2019	78	627	631	629	7.5	84
2020	78	847	848	836	7.8	107
2021	78	890	901	901	8.8	102

Table 2. Summary of the Snow Crab fishery in South-Eastern Nova Scotia. (TAC = total allowable catch, CPUE = Catch Per Unit Effort).

Year	Number of Licenses	TAC (t)	Quota Limit (t)	Landings (t)	Effort (x1000 trap hauls)	CPUE (kg/trap haul)
2011	116	12,120	12,120	12,146	111.2	109
2012	116	11,707	11,733	11,707	114.2	103
2013	116	11,311	11,311	11,341	105.5	107
2014	116	11,311	11,311	11,265	96.3	117
2015	116	11,311	11,311	11,295	103.9	109
2016	116	9,614	9,614	9,606	87.3	110
2017	116	6,730	6,730	6,718	69.9	96
2018	116	6,057	6,057	6,063	51.3	118
2019	116	6,663	6,663	6,632	61.9	107
2020	116	8,161	8,161	7,943	63.9	124
2021	116	8,161	8,379	8,326	80.5	103

Table 3. Summary of the Snow Crab fishery in CFA 4X. Year refers to the starting year of the season. (TAC = total allowable catch, CPUE = Catch Per Unit Effort). There were no landings or TACs in 2018–2019 due to multiple indications of low abundance. The 2021–2022 season is still ongoing.

Year	Number of Licenses	TAC (t)	Quota Limit (t)	Landings (t)	Effort (x1000 trap hauls)	CPUE (kg/trap haul)
2011	9	346	346	346	11.6	30
2012	9	263	263	118	9.3	13
2013	9	80	80	80	5.2	15
2014	9	80	80	82	2.5	33
2015	9	150	150	143	4.4	33
2016	9	80	80	79	2.9	27
2017	9	110	110	55	4.3	13
2018[1]	9	0	0	-	-	-
2019	9	55	55	59	1.1	54
2020	9	80	80	76	1.6	48
2021[2]	9	110	110	103	2.9	36

[1] No fishery (0 TAC) due to low commercial biomass. Dash (-) represents no data.
[2] Season ongoing.

In 2020 and 2021, the majority of N-ENS landings came almost exclusively from the inner grounds, not the Glace Bay Hole (Figures 1 and 3). In S-ENS, there was a slight shift to more inshore fishing (Figure 3). There were no landings on the continental slope areas of S-ENS in 2020 or 2021. In 4X, the majority of the fishing occurred on the 4X/S-ENS boundary and remained constant between 2020 and 2021.

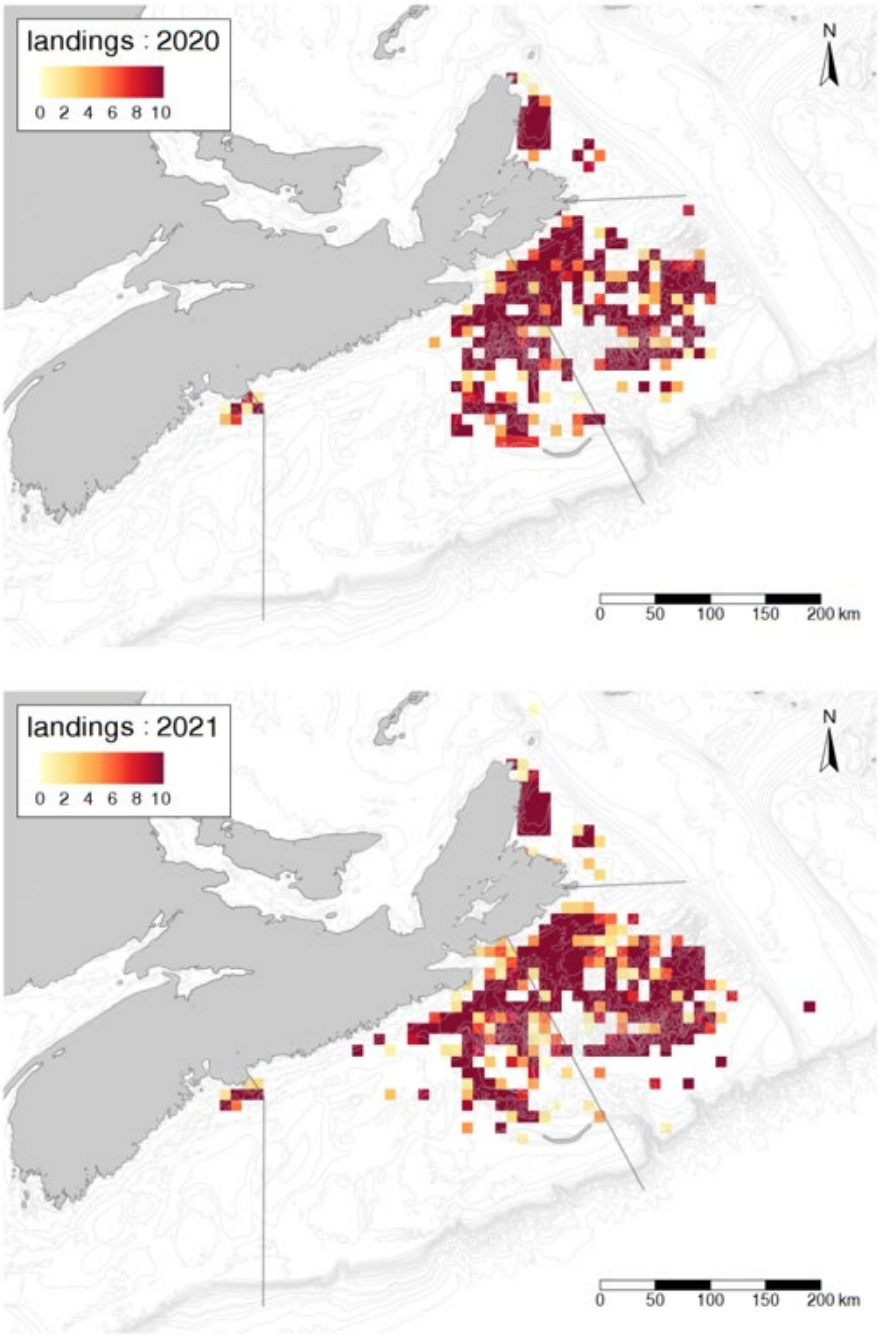


Figure 3. Snow Crab landings (tonnes/10km^2 grid) from fisheries logbook data for 2020 (top) and 2021 (bottom). For 4X, year refers to the starting year.

Fishery catch rates are biased indicators of Snow Crab abundance. This is because spatial and temporal distribution of Snow Crab and fishing effort are not the same. Catch rates depend upon seasonality, bottom temperatures, food availability, reproductive behaviour, substrate/shelter availability, relative occurrence of soft and immature Crab, species composition, fisher experience, bait type, soak time, and ambient currents. Catch rates have not

been adjusted for these influences. As such, catch rates are used primarily as a measure of fishery performance.

Non-standardized catch rates in 2021 were 102 kg/th in N-ENS, 103 kg/th in S-ENS and 36 kg/th in CFA 4X. This represents a decrease of 6%, 17%, and 27% respectively, relative to the previous year (Tables 1–3, Figures 4–5). The effect of TACs on catch rates can confound direct comparison over time and between management areas.

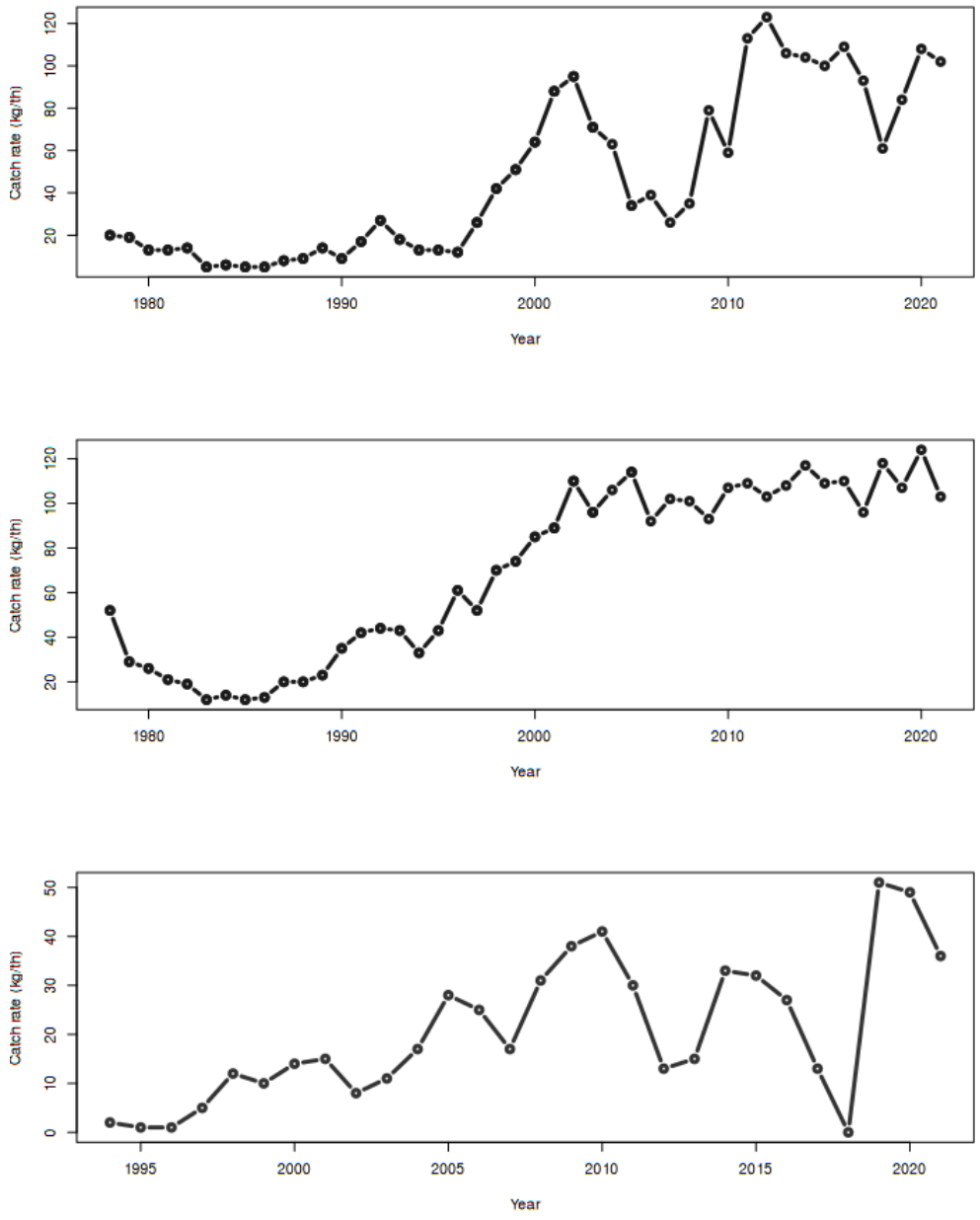


Figure 4. Temporal variations in catch rates of Snow Crab on the Scotian Shelf, expressed as kg per trap haul (th). Trap design and size have changed over time. No corrections have been made for variation in trap-types, soak time, or bait-type. Top panel: N-ENS; middle panel: S-ENS; bottom panel: 4X. Note: the scale of the y-axis is different in each panel.

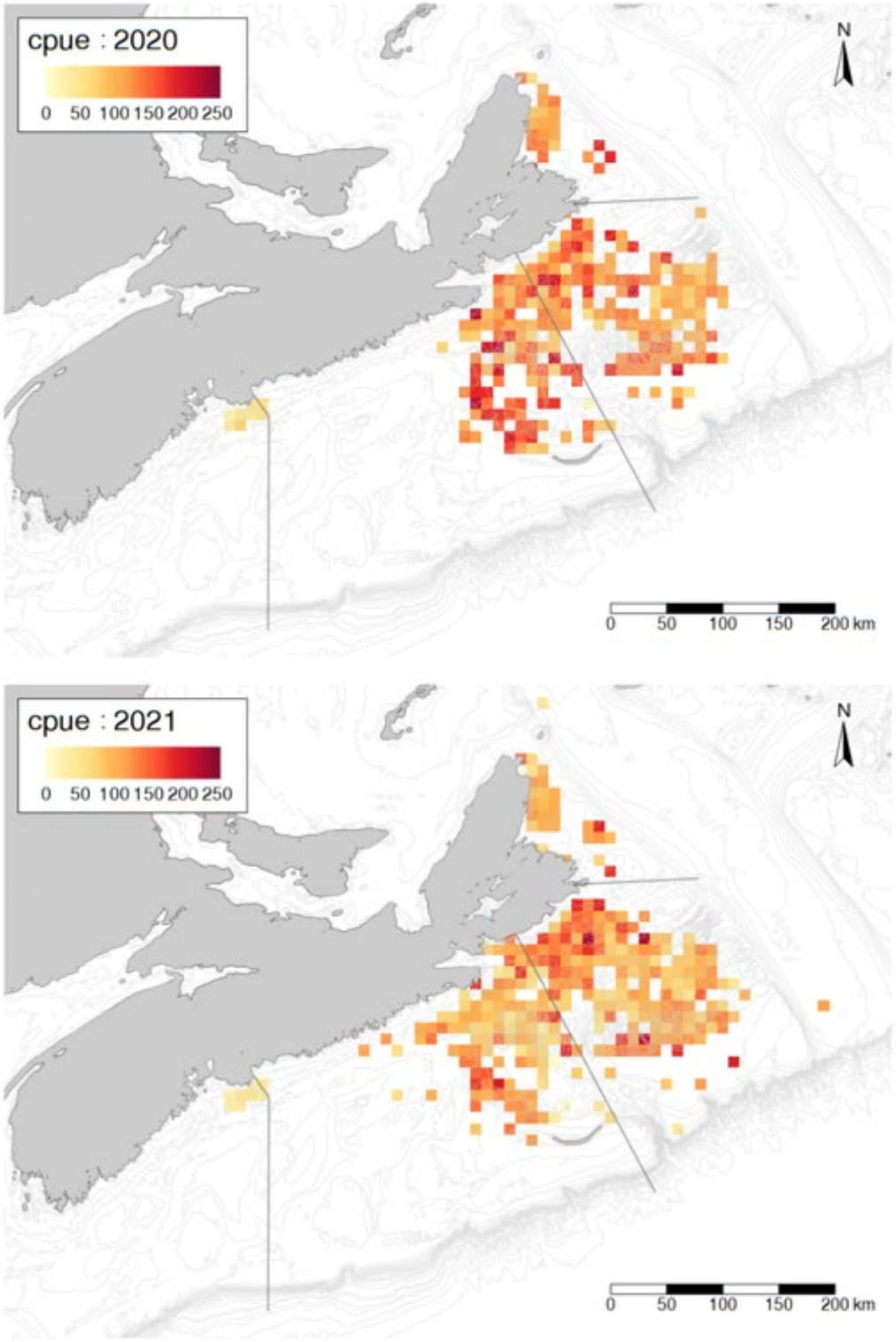


Figure 5. Catch rates per 10km^2 grid (CPUE in kg/trap haul) of Snow Crab on the Scotian Shelf in 2020 (top) and 2021 (bottom).

Carapace condition (CC) defines the approximate age of the Crab since its terminal moult based on the relative development and subsequent decay of its carapace. CC1 signifies a newly moulted Crab, soft-shelled, with no epibiont growth (e.g., barnacles). CC2 has begun to harden but is still considered to be soft and of no commercial value. CC3 and CC4 represent ideal commercial Crab. The oldest carapace condition (CC5) signifies extensive shell decay with no expectation of survival into the next year.

In N-ENS, there were no at-sea observations in 2021, while in 2020, CC1 and CC2 made up 2.5% and 30% of the size frequency distribution by at-sea observers respectively while CC5 levels were low at 3% (Figure 6). In S-ENS the occurrence of CC1 and CC2 was 0.8% and 13.2% respectively in 2021 compared to 0.1% and 44.8% respectively in 2020 (Figure 6). There were no at-sea-observations in 4X in 2021 although soft-shelled discards are generally negligible in this area due to season timing (Figure 6).

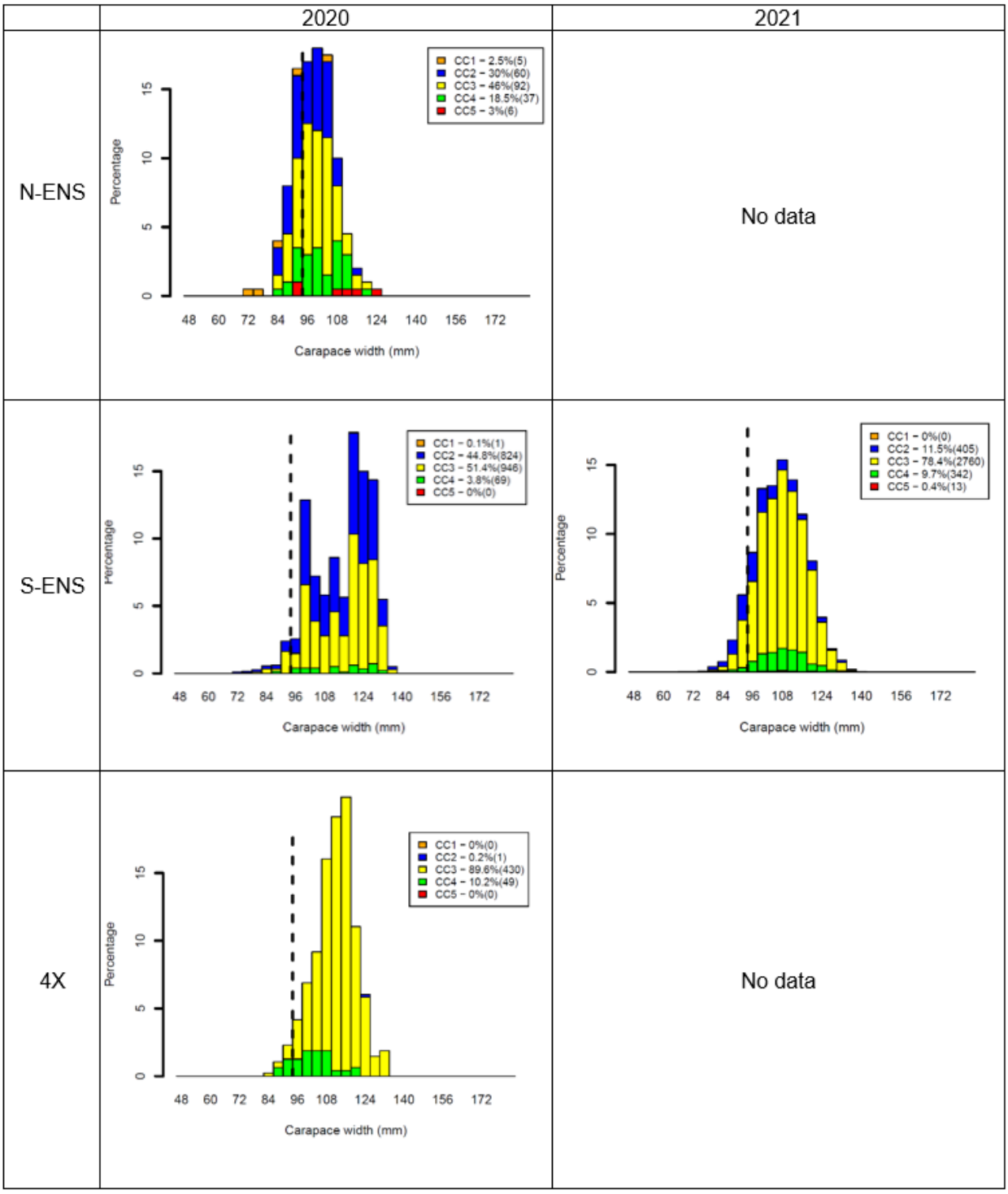


Figure 6. Size frequency distribution of Snow Crab sampled by at-sea observers, broken down by carapace condition (CC). For 4X, the year refers to the starting year of the season; the current season is ongoing. Vertical lines indicate 95 mm carapace width, the minimum legal commercial size. In N-ENS and 4X there were no at-sea observations in 2021 and, therefore, no data.

Analysis and Response

Applying the 2020 peer reviewed assessment framework, a predicted fishable biomass index is estimated using conditional auto-regressive spatio-temporal models (CARSTM; Choi In press[1]). This approach models Snow Crab numerical abundance and mean size, with environmental (depth, substrate, temperature) and biological factors (species composition) as covariates to estimate biomass. This index is coupled with a logistic population dynamics model (fishery model) to determine fishable biomass and relevant biological reference points (i.e., carrying capacity and fishing mortality at maximum sustainable yield, or F_{MSY}) associated with the harvest control rules of the Snow Crab fishery.

In the application of the 2020 assessment framework for this 2022 stock status update, biomass estimates were found to be potentially overestimated and hyperstable. A proposed, more precautionary, modification to the model to address these issues did not pass peer review. For this reason, estimates of fishable biomass and reference points are not presented in this Science Response Report.

Stock Trends

Fishable Biomass

The crude geometric mean fishable biomass areal density (Figure 7) shows what was captured by the Snow Crab survey. In 2021, values were higher than average in N-ENS, while in S-ENS and CFA 4X they were lower than their respective averages. Figure 8 shows a map of the predicted biomass density estimates from the 2021 Scotian Shelf Snow Crab survey.

[1] Choi, J. S. (In press). A Framework for the Assessment of Snow Crab (*Chionoecetes opilio*) in Maritimes Region (NAFO Div 4VWX). DFO Can. Sci. Advis. Sec. Res. Doc. Presented and reviewed in February 2020 at the Framework Review meeting.

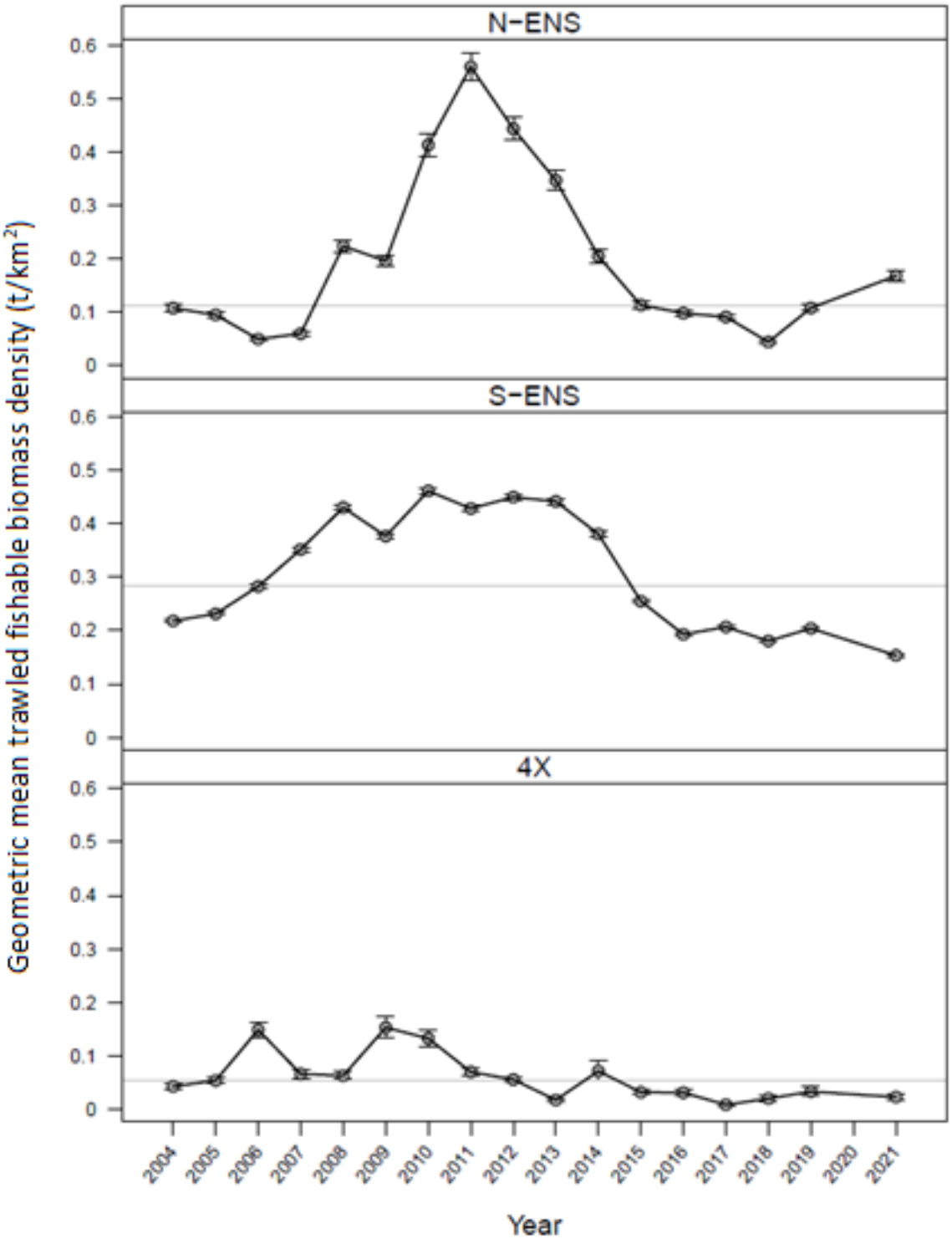


Figure 7. The crude geometric mean fishable biomass density (t/km²) from the Snow Crab survey in 2021. Error bars represent 95% Confidence Intervals around the geometric mean. The horizontal grey line represents each area's respective averages.

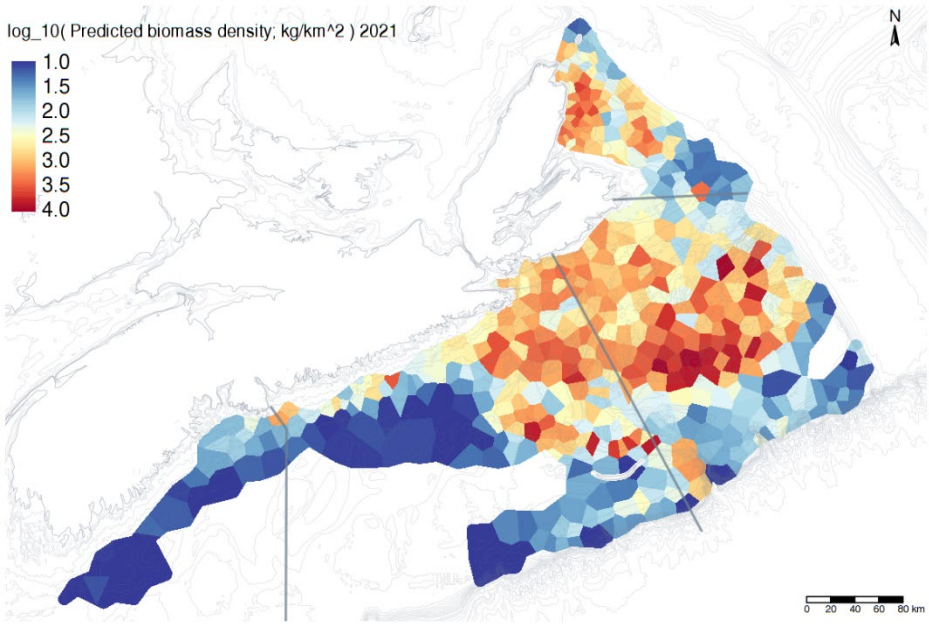


Figure 8. Estimation of predicted fishable biomass index log10 (t/km^2) predictions using CARSTM from the Snow Crab survey in 2021. Dark blue areas represent low biomass densities and red is high biomass densities.

Recruitment

Quantitative determination of recruitment levels into the fishable biomass is confounded by several factors. These include terminal moult (the timing offset of moulting in spring and the survey in the fall), the inability to age crab, and the inability to predict the age that male crab will terminally moult. Based on size-frequency histograms of the male Snow Crab population, minimal to moderate internal recruitment (from within the same fishing area) to the fishery is expected for 2022 in N-ENS, followed by a gap of about 4 years before the onset of the year-class centered near 30 mm CW (Figure 9). Internal recruitment in S-ENS is expected to be moderate, having peaked in 2019. Steady recruitment in S-ENS is expected to continue without any gaps. In 4X, recruitment is not expected for the next two years at a minimum. The current pulse is centered near 50 mm CW, and that will take another three years to enter the 4X fishery. Immigration of crab into 4X from the adjoining S-ENS is possible; however, erratic temperature fields in 4X create strong uncertainties for future recruitment.

Reproduction

In all areas, there was substantial recruitment of female crab into the mature (egg-bearing) segment of the population from 2016–2018 (Figure 10) and egg/larval production is expected to continue decreasing, as the numerical densities of adolescent and mature female crab are now declining. This decline in mature females, coupled with increased male maturation, produces a declining mature sex ratio (proportion of mature female to male crab; Figure 11) since 2017 in N-ENS and S-ENS. In 4X, mature sex ratios are more stable in the same time frame. The Scotian Shelf Snow Crab fishery is traditionally male dominated, although there seems to be a higher ratio of mature females in Area 4X (Figure 12). Most of N-ENS and S-ENS see much

higher proportions of males than females especially in Middle Bank, Eastern Hole, and off Banquereau (Figure 12).

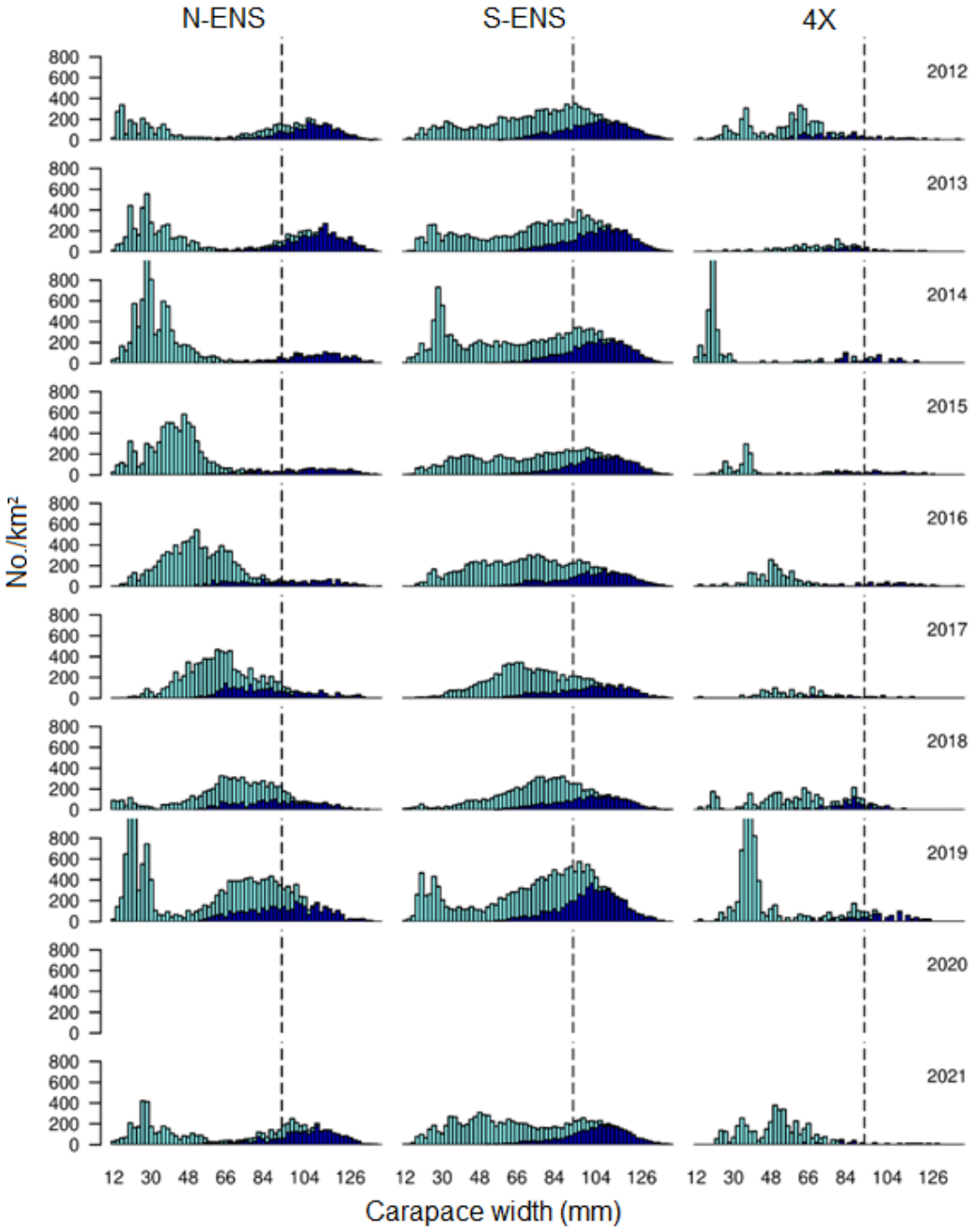


Figure 9. Size-frequency histograms of carapace width of male Snow Crab from the Snow Crab survey. This figure provides information about the relative densities within a given year. The vertical line represents the legal size (95 mm). Immature animals are shown with light coloured bars, mature with dark. The year 2020 is left blank as there was no survey.

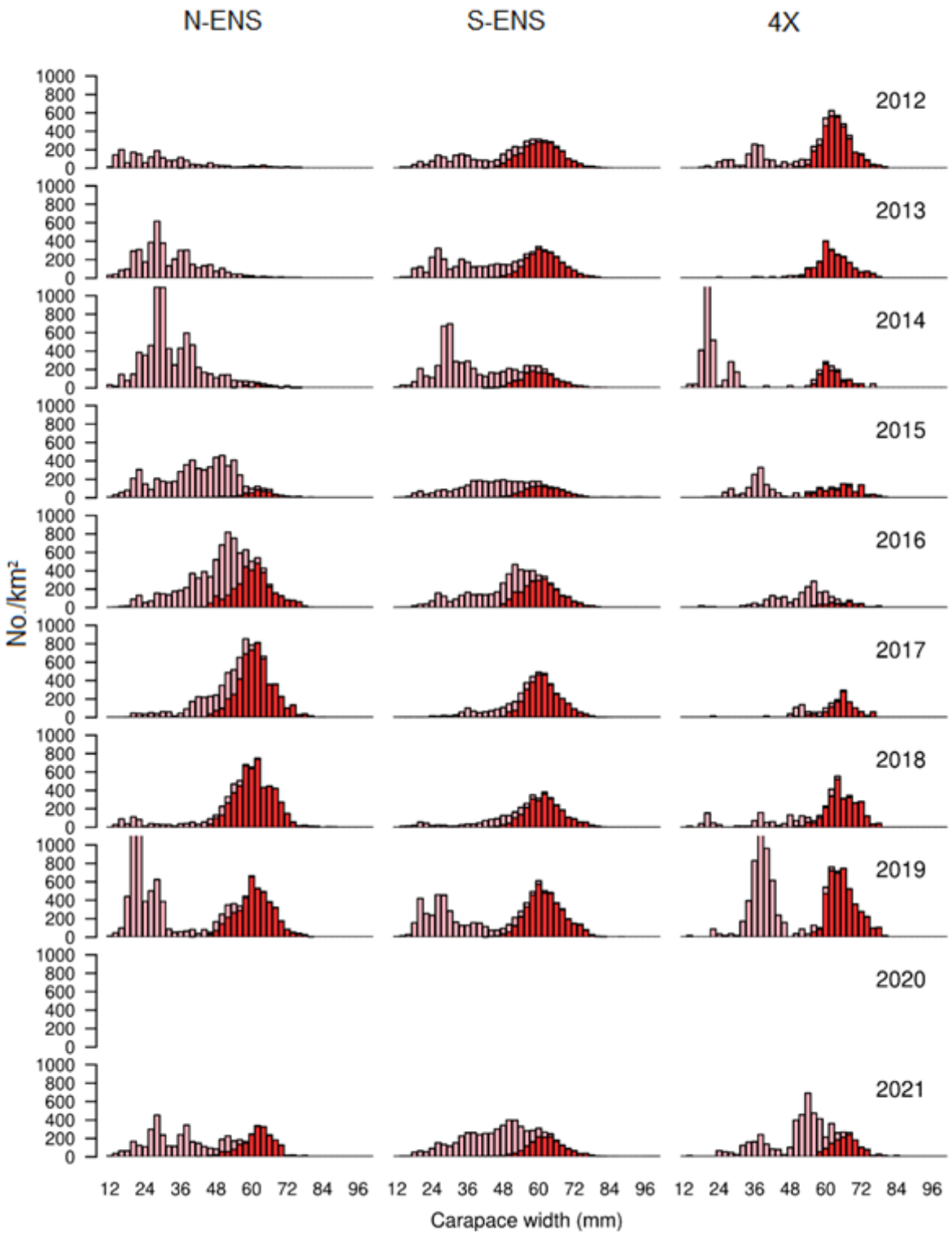


Figure 10. Size-frequency histograms of carapace width of female Snow Crab from the Snow Crab survey. This figure provides information about the relative densities within a given year. Immature animals are shown with light coloured bars, mature with dark. The year 2020 was left blank as there was no survey.

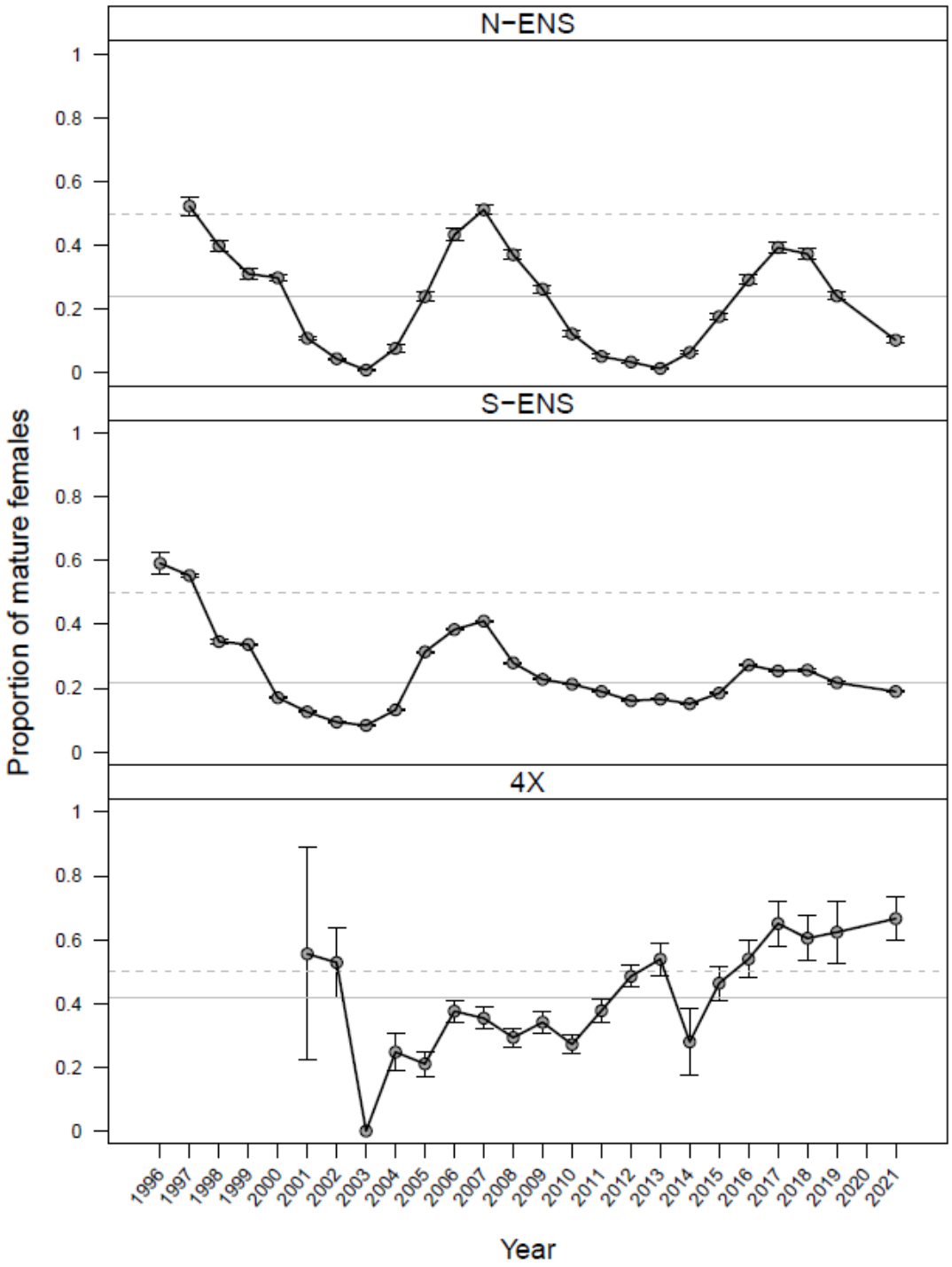


Figure 11. Sex ratios (proportion female) of mature Snow Crab. The Scotian Shelf is generally male dominated. Dashed line shows equal proportions. Solid grey line represents the long-term mean.

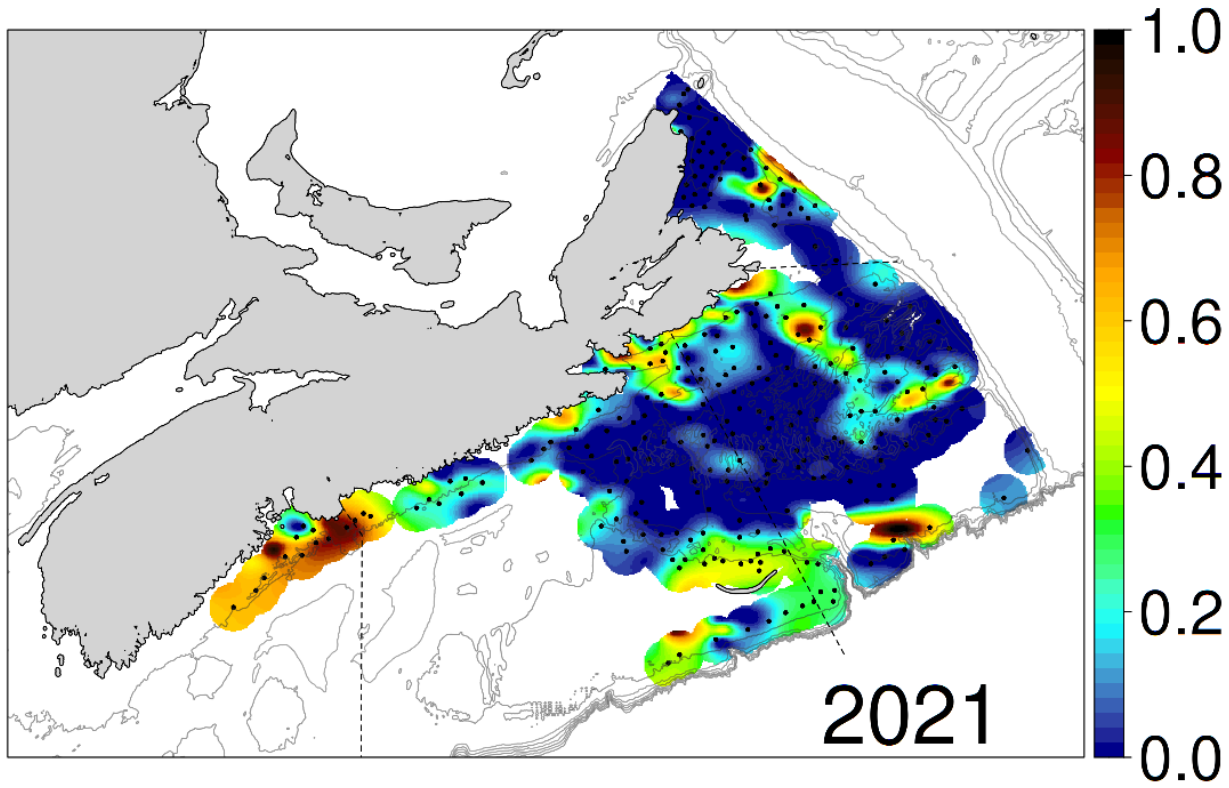


Figure 12. Proportion of females in the mature population. Note the heterogeneous distribution of sexes in all areas. The black dots represent the Snow Crab survey stations.

Ecosystem Considerations

Environmental Variability

Average bottom temperatures in the 2021 Snow Crab survey were higher than the long-term median in all areas and the highest observed in the time series (Figure 13 and 14). A general warming trend has been observed since 2010 on the Scotian Shelf. Temperatures are more stable in N-ENS than S-ENS; 4X exhibits the most erratic annual mean bottom temperatures. In 4X, bottom temperatures over the last ten years (2011 and 2021 in Figure 14) have significantly exceeded 6 °C and are generally over the 7 °C upper tolerance limit for Snow Crab, S-ENS has seen an exceptionally warm past two years (Figure 13). In N-ENS, there has been a general warming trend as well in the last two years. Warming temperatures are not ideal habitat for Snow Crab because of added pressures from predators that prefer warmer conditions, higher spread of diseases (bitter crab disease), and their metabolic preference for colder waters. Warming temperatures could lead to higher mortality rates and, therefore, negatively impact the Scotian Shelf Snow Crab biomass.

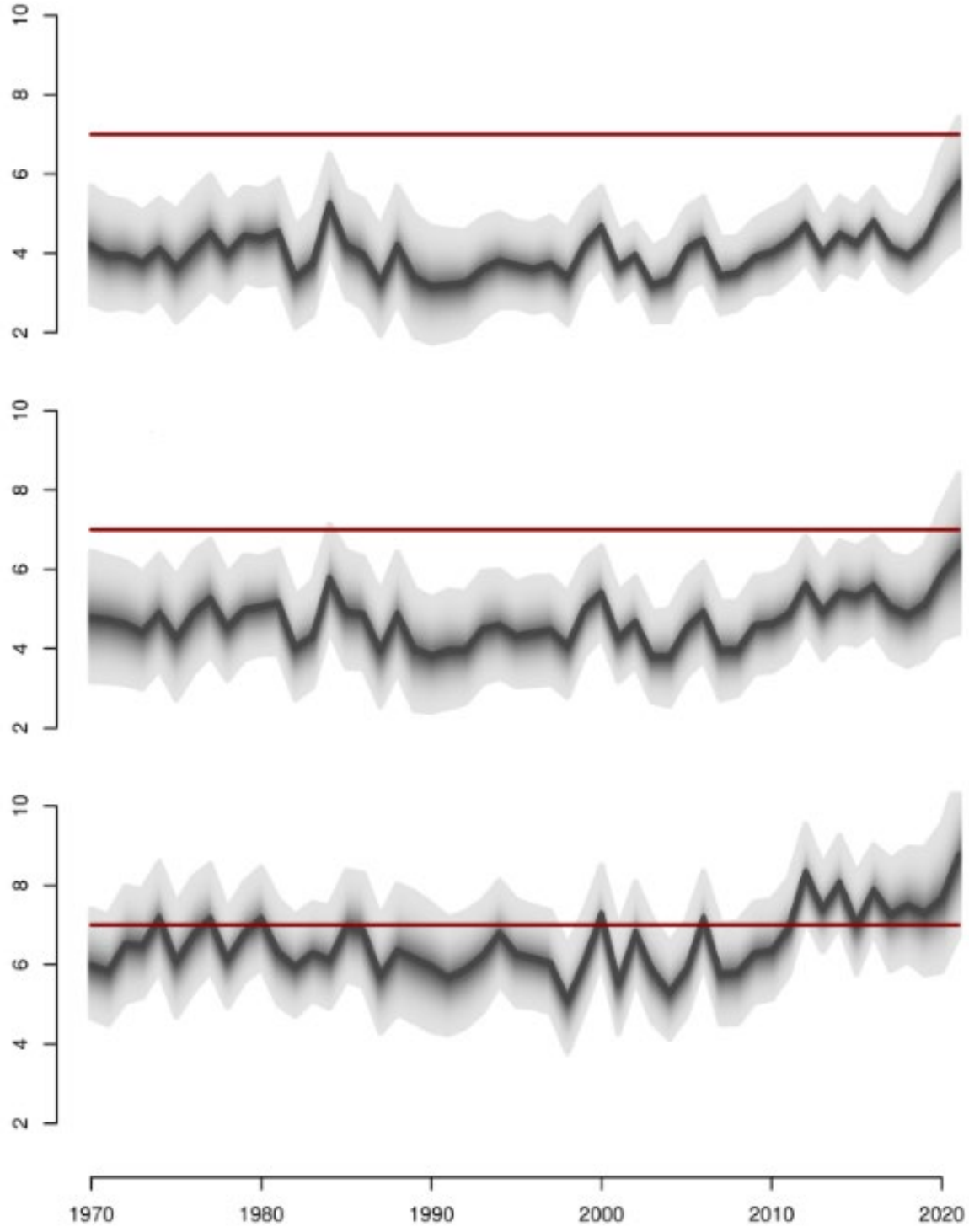


Figure 13. Annual variations in bottom temperature observed in September from the annual Snow Crab survey. The red line is 7 °C for reference as the Snow Crabs upper temperature threshold. The light grey shading represents the 95% Credible Intervals (spatial variation) shown as a colour intensity. Top panel: N-ENS; middle panel: S-ENS; bottom panel: 4X.

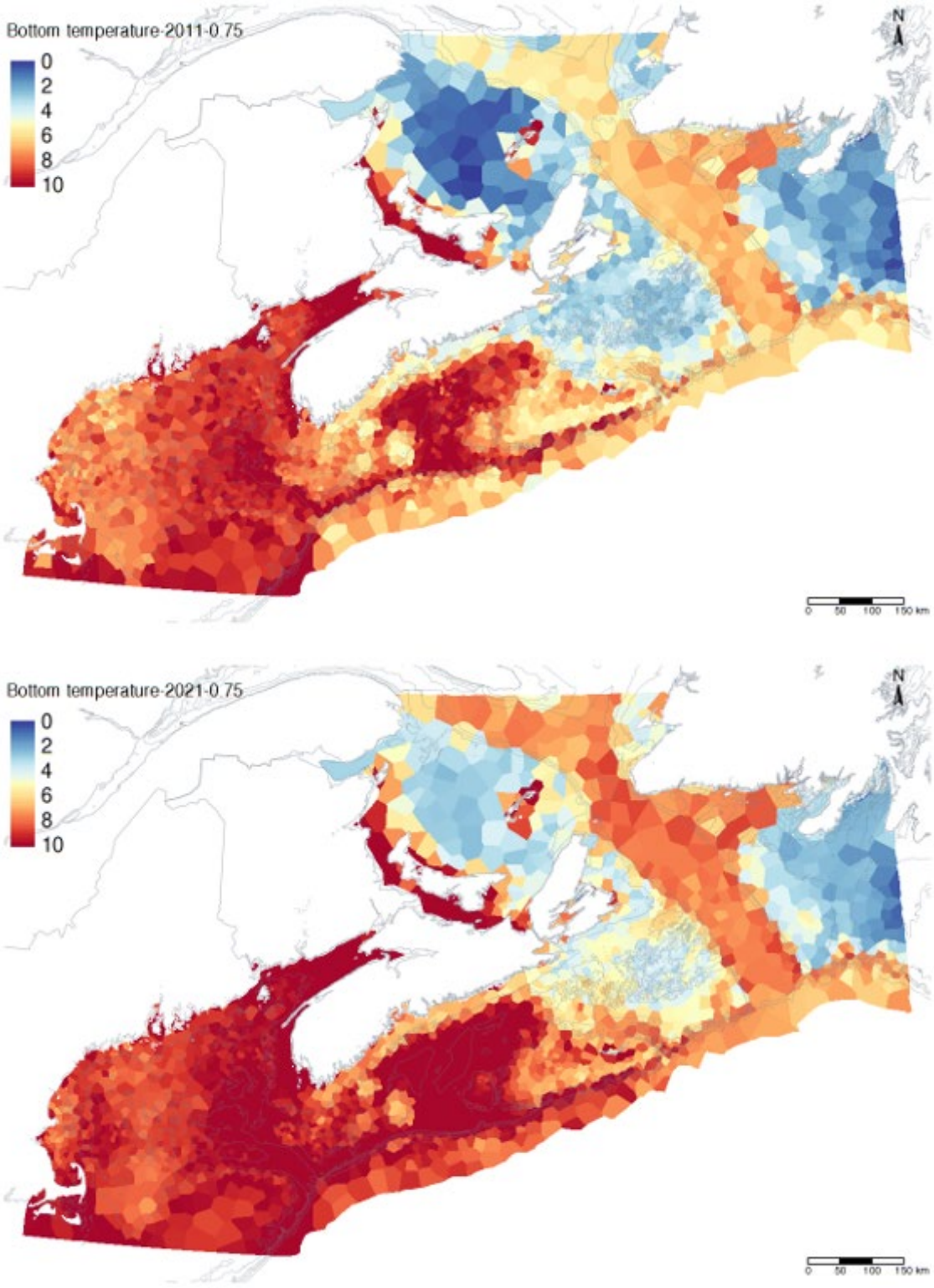


Figure 14. Variations in posterior predicted bottom temperature observed in September of 2011 and 2021 during the Snow Crab survey. 2011 is shown for reference as the temperature trends start increasing from the historical means, especially in 4X (Figure 13).

Habitat

The habitat of Snow Crab is expressed in terms of the probability of observation. This probability has a strong relationship with depth and temperature (Figure 15). Mature males have a stronger preference for colder and deeper habitats. Males potentially recruiting into the fishery in the next year and immature crabs also have preferences for colder and deeper habitats; however, they were marginally less selective (Figure 15). This information is used to estimate the spatial pattern of good habitat in 2021 for each of the demographic groups (Figures 16–18) and also the spatially persistent locations (core habitat) using the CARSTM approach. Relative to the core habitat, the habitat in 2021 for mature males and potential recruits were highly constrained. Immature (juvenile) Snow Crab, however, experienced a better than normal habitat throughout the area.

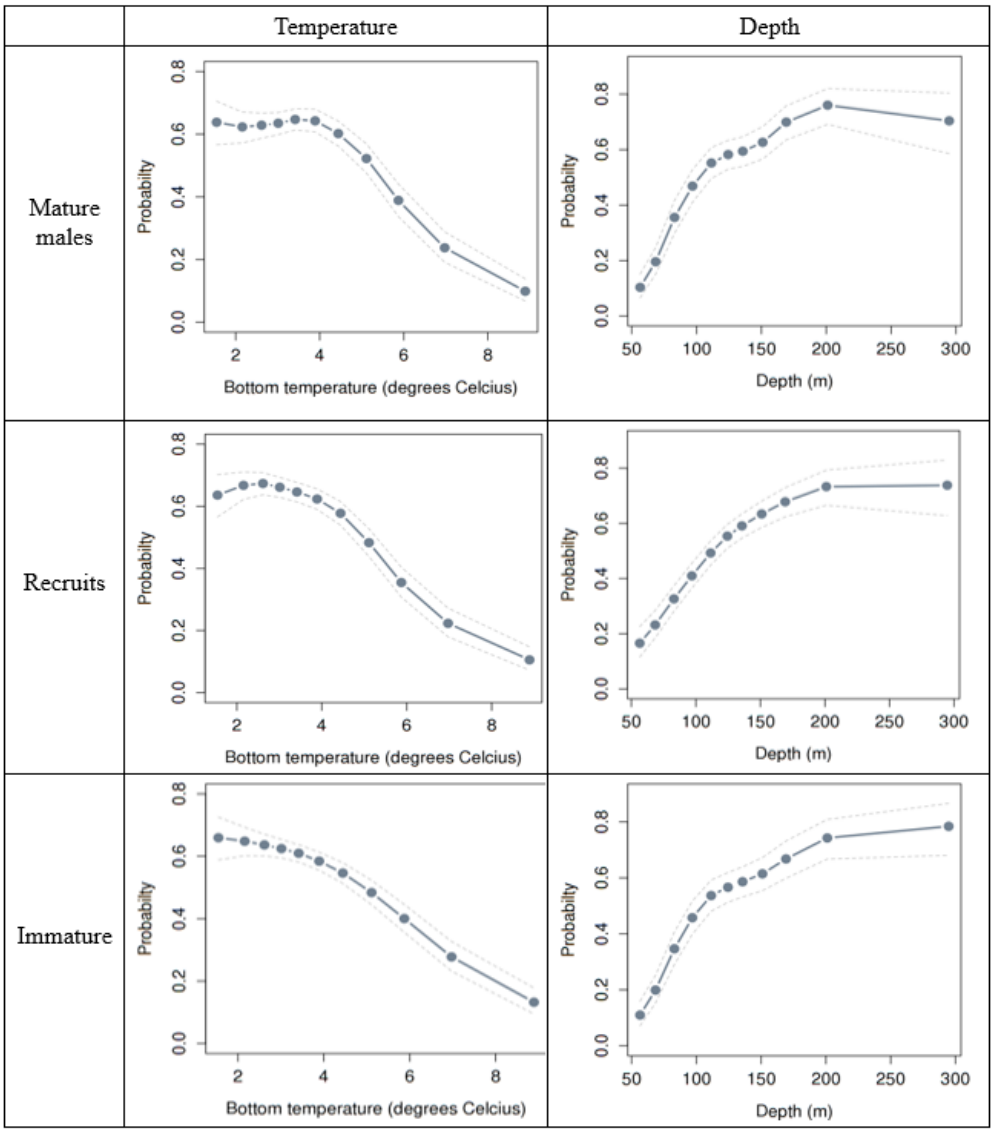


Figure 15. Temperature and depth preference of Snow Crab for various demographic groups. 95% Credible Intervals are represented by the dotted lines.

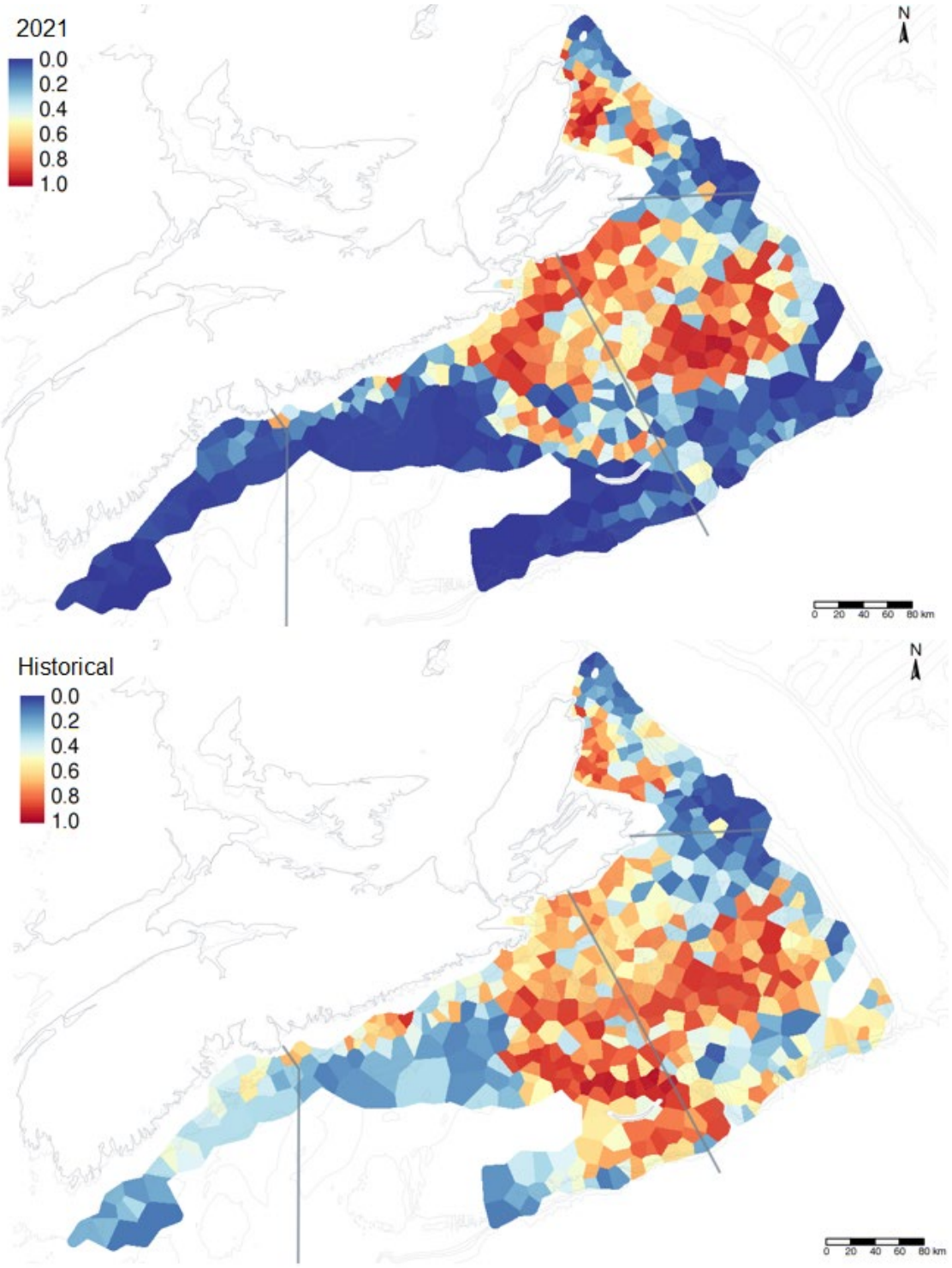


Figure 16. Probability of observing the demographic group of mature male Snow Crab in 2021 (top) and the persistent spatial effects in the historical record, independent of depth, temperature effects other covariate effects (bottom). The latter identifies core areas.

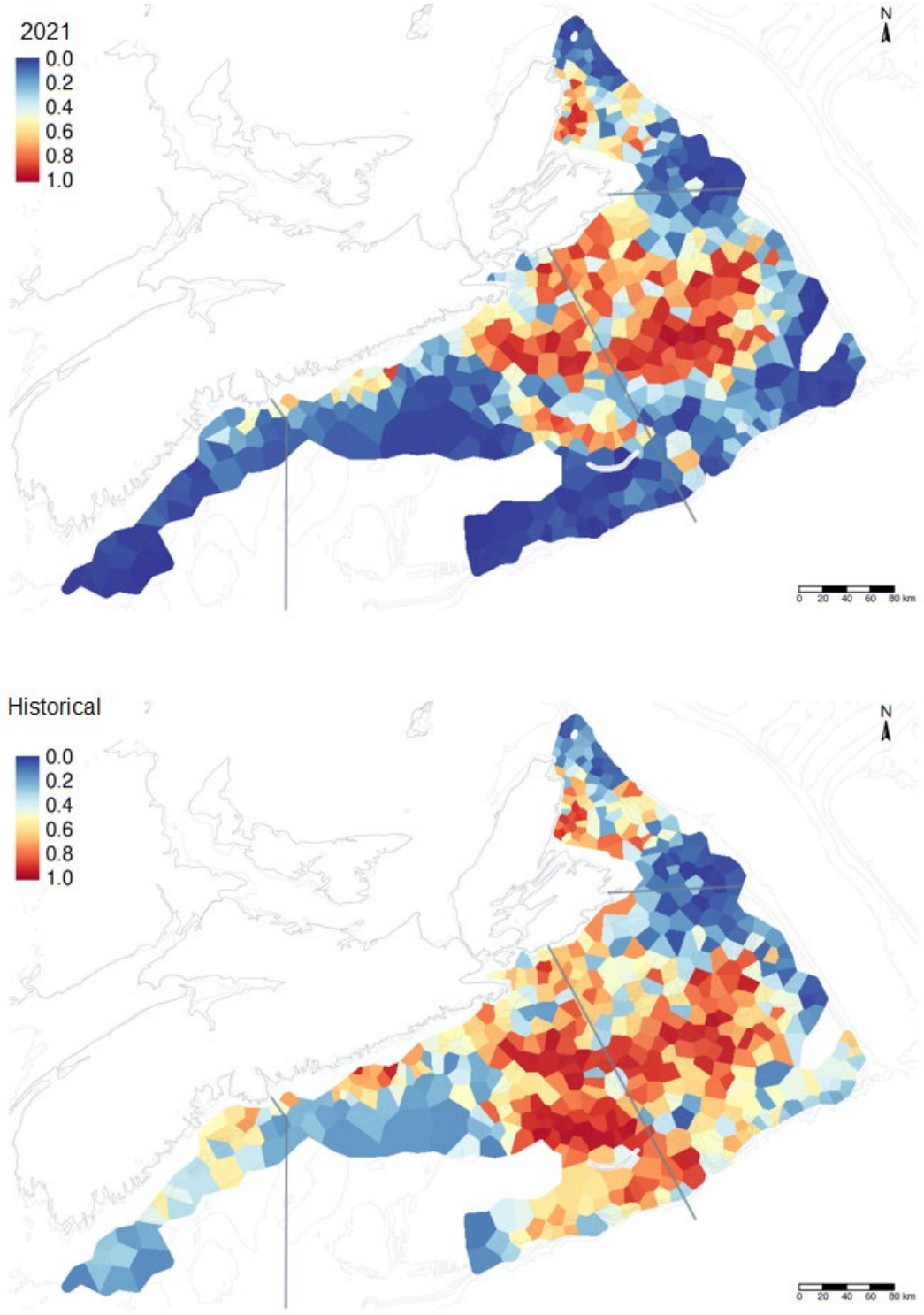


Figure 17. Probability of observing the demographic group of recruit Snow Crab in 2021 (top) and the persistent spatial effects in the historical record, independent of depth, temperature effects other covariate effects (bottom). The latter identifies core areas.

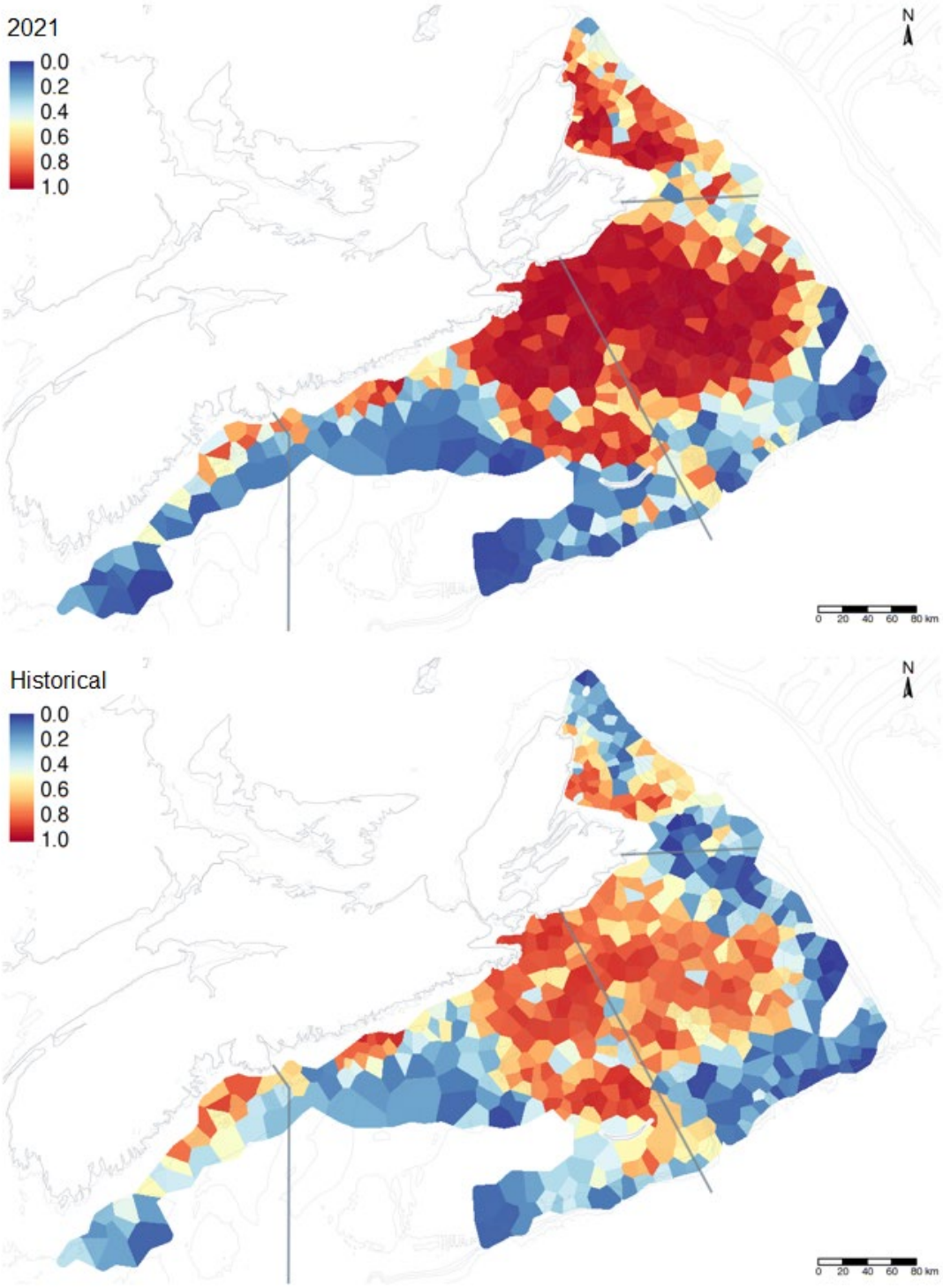


Figure 18. Probability of observing the demographic group of immature male Snow Crab in 2021 (top) and the persistent spatial effects in the historical record, independent of depth, temperature effects other covariate effects (bottom). The latter identifies core areas.

The overall spatial average probability of observing Snow Crab as a function of time suggests a decline in mature males since highs in 2012 (Figure 19). Though the declines were weaker for recruits (adolescent males) and pre-adolescent immature crab, 2021 was still a poor year for them. There has been a decline in mature males since the highs of 2012 to a historical low in 2021.

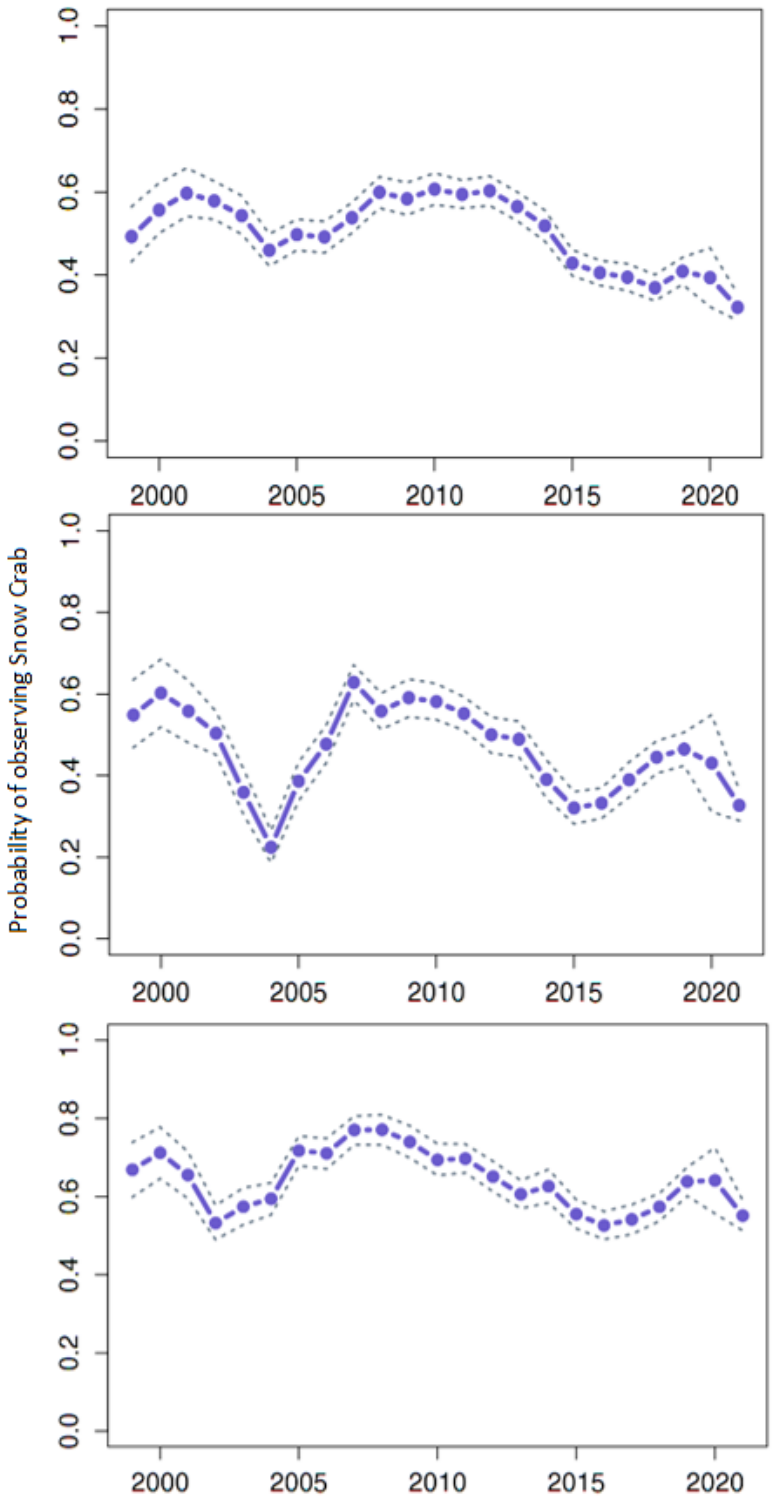


Figure 19. Posterior probability of observing Snow Crab and 95% Credible Intervals by demographic group. Top panel: mature males, middle panel: recruits, bottom panel: immature crab.

Predation

Based on stomach sampling, Atlantic Halibut (Figure 20; DFO 2018), Atlantic Wolffish, Thorny Skate (Figure 21), and other skate species are predators of Snow Crab. Localized predation rates may be much higher due to relative local abundance and encounter rates.

Atlantic Halibut biomass has increased rapidly since 2010 (DFO 2018); consequently, the total number of Snow Crab consumed by Halibut is expected to increase. This is especially the case for N-ENS and CFA 4X where historical highs are observed in the 2021 Snow Crab survey. Large Atlantic Halibut with mature female Snow Crab in their stomachs have been reported. As bottom temperatures continue to rise in all areas, higher levels of predation from Halibut may be observed (due to their habitat preferences). Increasing predation lowers both the abundance and reproductive potential of Snow Crab on the Scotian Shelf.

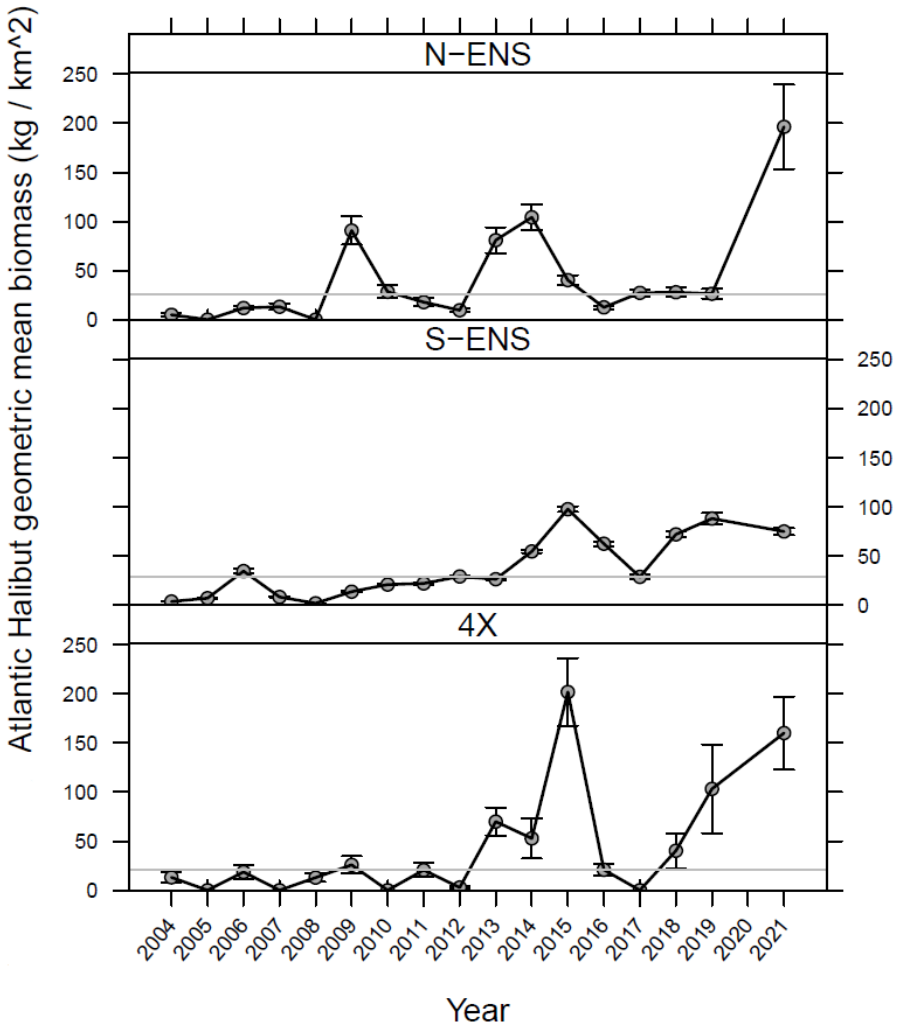


Figure 20. Geometric mean Atlantic Halibut biomass density in kg per square km from the annual Snow Crab surveys. Error bars are 95% Confidence Intervals estimated by bootstrapping.

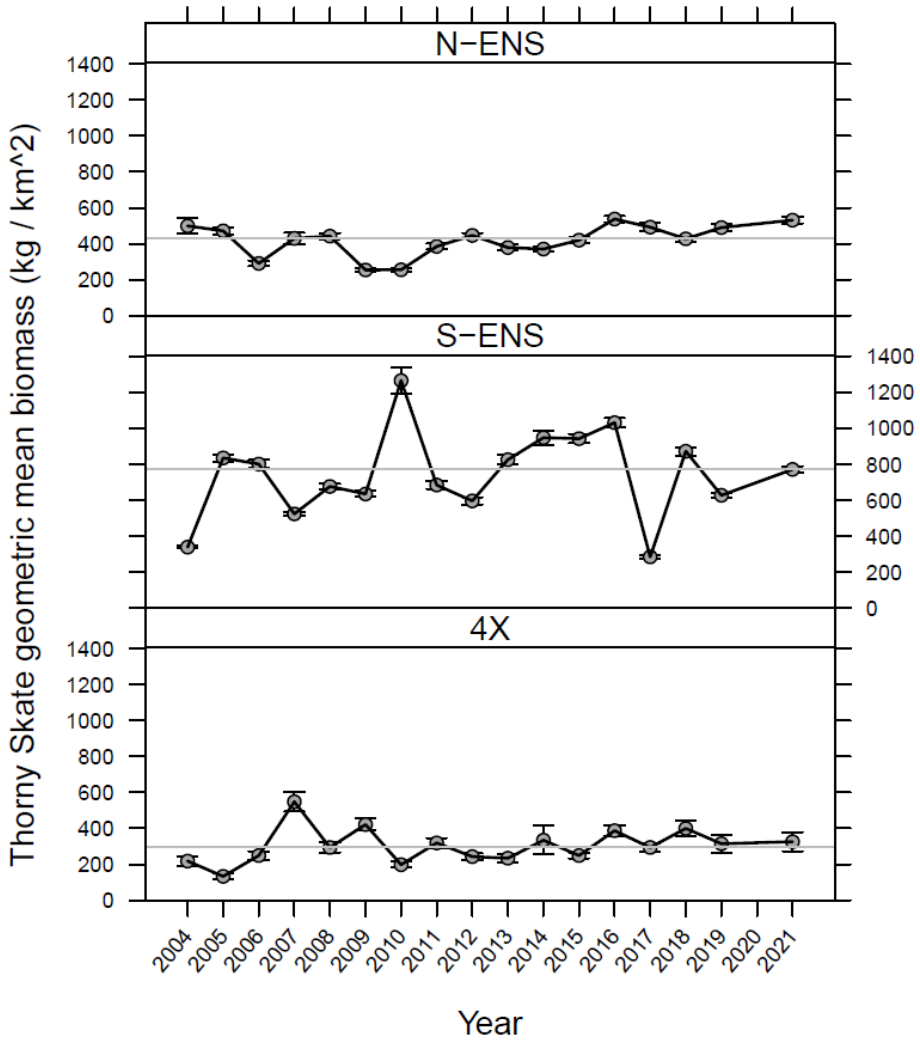


Figure 21. Thorny Skate biomass density trends from annual Snow Crab surveys. Horizontal lines indicate the long-term median within each subarea. Error bars are 95% Confidence Intervals estimated by bootstrapping.

Bycatch and Incidental Catch

Bycatch levels in the Scotian Shelf Snow Crab fishery have been extremely low over the long term (DFO 2020). Estimates of bycatch in this fishery are extrapolated from at-sea observer estimates. There has been minimal at-sea observer coverage in 2020 and 2021 due to COVID-19 restrictions. As such, there is uncertainty around these bycatch estimates. The majority of bycatch for all areas are generally composed of other invertebrate species (e.g., Northern Stone Crab, Jonah Crab, and American Lobster) for which higher survival rates can be expected after being released as compared to finfish discards (DFO 2020). Multiple entanglements of North Atlantic Right Whales in a neighbouring Snow Crab area (CFA 12 in the Gulf of St. Lawrence) during the summers of 2017 and 2019 has increased vigilance and modified management

measures within the Scotian Shelf Snow Crab fisheries to minimize the potential for marine mammal interactions with Snow Crab fishing gear.

Sources of Uncertainty

Snow Crab are cold water stenotherms, which renders the environmental variability experienced in the Maritimes as a source of concern for the population. The warm bottom temperatures in 2021 likely caused very clustered spatial distributions. As such, the fixed station design of the Snow Crab survey may have missed these aggregations. Though the assessment methodology attempts to account for these dynamic factors, the unprecedented nature of warming still adds uncertainty to the assessment.

Being long-lived, the influence of predators can be significant. Especially important are predators of females and smaller immature Snow Crabs. Some of these predators (Halibut in particular [Figure 20]) have increased in abundance in the Region, especially as temperatures keep rising.

The capture of soft-shelled Snow Crab is a concern, as handling them represents a source of mortality to the fraction of a population that is on the verge of recruitment in the fishable biomass; mortality that can be avoided. This depends upon annual variations in recruitment and time of year they are fished. An earlier season in N-ENS and S-ENS has significantly reduced soft-shell handling and, presumably, the associated mortality. Prompt and careful return of immature (small-clawed, non-terminally moulted) crab to the water is an important conservation measure that will enhance the two to three year productivity.

Illegal, unreported, and unregulated fishing activities are known to occur. Such activities hinder the application of a precautionary approach to the management of this resource.

Undersea cables have been identified by fishers as another source of concern, in particular, the Emera Maritime Link subsea electricity cables spanning approximately 180 km from Cape Ray, Newfoundland to Point Aconi, Nova Scotia. At present, there is no information that can be presented to definitively describe their effects upon Snow Crab.

St. Anns Bank was designated as a Marine Protected Area (MPA) in 2017 (Canada Gazette 2016). The presence of a refuge from fishing activities is potentially positive as it could serve as a fallow area. However, if the reserve is disproportionately beneficial to other organisms, either predators or prey of Snow Crab, the effects upon Snow Crab could be mixed. The long-term effects of the MPA cannot be determined at this point.

Mortality of Snow Crab from other fisheries is still not quantified. Trawls can increase mortality, especially upon the soft-shelled phases of Snow Crab. The lack of trawl fisheries (other than shrimp trawling), in the majority of Snow Crab habitat on the Scotian Shelf, limits this potential damage. Additional effort of high bottom contact fisheries (such as dredging) could negatively impact Snow Crab habitat. The temporal and spatial overlap of Snow Crab and Lobster populations in 4X introduce a potential source of increased mortality or animal stress. The Lobster fishery in 4X (Lobster Fishing Areas 33–34) is active for 6 months of the year with hundreds of participants. Bottom damage from the placement of Snow Crab traps is thought to be minimal.

Conclusions

A reference points-based Precautionary Approach has been implemented in the Scotian Shelf Snow Crab fishery. The calculation of the biological reference points and fishable biomass relies on the biomass dynamics fishery model from the assessment framework. A proposed more precautionary modification to the model that addresses potential overestimation did not pass peer review, these estimates are not reported; therefore, an update of the stock status for the Scotian Shelf Snow Crab is not available. In the medium term, continuation of a conservative harvest strategy is advised to protect the Snow Crab population in all fishing areas. As secondary indicators (population and ecosystem) have been used to further inform harvest strategies, summaries of these indicators are provided for the Scotian Shelf fishing areas.

Average bottom temperatures in the 2021 Snow Crab survey were higher than the long-term median in all areas and the highest observed in the time series. Warming temperatures are not ideal habitat for Snow Crab because of added pressures from predators that prefer warmer conditions, higher spread of diseases (bitter crab disease) in warm water conditions, and the metabolic preference of Snow Crab for colder waters. Through these mechanisms, warming temperatures could lead to higher mortality rates, negatively impacting the Scotian Shelf Snow Crab biomass.

Mature males have a particularly stronger preference for colder and deeper habitats. Relative to the core habitat for Snow Crab on the Scotian Shelf, the habitat in 2021 for mature males and potential recruits was highly constrained. The overall spatial average probability of observing Snow Crab over time suggests a decline in mature males since highs in 2012 to an historical low in 2021.

North-Eastern Nova Scotia

The geometric mean fishable biomass density from the 2021 Snow Crab survey was higher than average in N-ENS. A gap in future recruitment to the fishery is expected for about four years based on the size structure of the N-ENS Snow Crab population. This gap will impact the future of the commercial biomass. It is also important to highlight the general warming trend that has been observed in N-ENS over the last two years.

South-Eastern Nova Scotia

The geometric mean fishable biomass density from the 2021 Snow Crab survey was lower than the average for S-ENS. In the medium-term, steady and moderate recruitment is expected in S-ENS without any gaps. It is important to protect this incoming recruitment to support the commercial biomass. The exceptionally warm temperatures of the past two years in S-ENS are concerning given the potential for higher mortality rates under these conditions due to pressures described above.

CFA 4X

The geometric mean fishable biomass density from the 2021 Snow Crab survey was lower than the average for CFA 4X. In the medium-term, recruitment into the fishery is expected to be low and will continue to be so for at least another three years, impacting the future commercial biomass. It is important to note that the erratic temperature fields in 4X add uncertainty to the

future recruitment in this area. In the past year, a significant decrease in mature males was observed.

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Sources of Information

Canada Gazette. 2016. St. Anns Bank Marine Protected Area Regulations. Canada Gazette, Part I, Vol 150, Issue 51: 4143-4149.

DFO. 2018. Stock Status Update of Atlantic Halibut (*Hippoglossus hippoglossus*) on the Scotian Shelf and Southern Grand Banks in NAFO Divisions 3NOPs4VWX5Zc. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/022.

DFO. 2020. Assessment of Scotian Shelf Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/042.

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