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

Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2025/031

ASSESSMENT OF NEWFOUNDLAND AND LABRADOR (DIVISIONS 2HJ3KLNOP4R) SNOW CRAB IN 2023

*Snow Crab (*Chionoecetes opilio*)*

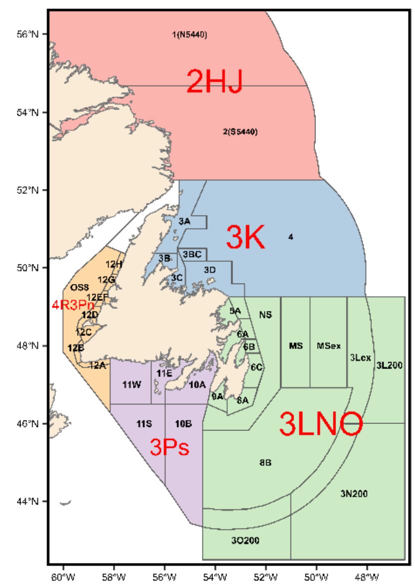

Figure 1. Map of Assessment Divisions (colours) and Newfoundland and Labrador Crab Management Areas (black).

CONTEXT

Snow Crab (*Chionoecetes opilio*) occupy a broad geographic range in the Northwest Atlantic from Greenland to southern Nova Scotia. Distribution in waters off Newfoundland and southern Labrador is widespread and continuous, with the genetic stock spanning throughout the region.

Snow crab harvesters use long-lines (“fleets”) of baited conical traps. The minimum legal size of Snow Crab is 95 mm carapace width (CW), which excludes females and a large proportion of adult males from the fishery; thereby, partially safeguarding stock reproductive capacity. Total Allowable Catch (TAC) management was initiated in the late-1980s, which led to the development of multiple TAC-controlled Crab Management Areas (CMAs; Figure 1), with approximately 2,200 license holders across numerous fleet sectors under enterprise allocation in 2023. All fleets have designated trap limits, quotas, trip limits, dedicated fishing areas within CMAs, and pre-determined fishing seasons.

Stock status is assessed annually within Assessment Divisions (ADs; Figure 1). Resource status is evaluated based on trends in exploitable biomass indices, recruitment prospects, and mortality indices, as well as fishery catch per unit of effort (CPUE). Data are derived from multispecies bottom trawl surveys in Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) 2HJ3KLNOP, collaborative trap surveys in NAFO Divs. 2HJ3KLNOP4R, Fisheries and Oceans Canada (DFO) inshore trap surveys in NAFO Divs. 3KLPs, fishery logbooks, at-sea observer measurements, as well as biological sampling from multiple sources.

This Science Advisory Report is from the February 19–22, 2024, regional peer review Stock Assessment of Snow Crab in 2HJ3KLNOP4R. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Assessment Divisions (ADs) 3L Inshore and 3LNO Offshore were combined into one AD (i.e., AD 3LNO) based on revised models for trap and trawl surveys.
- Conversion factors to calibrate DFO trawl survey catches for Snow Crab between new and outgoing vessels were estimated and applied across the survey area. In AD 3Ps, conversion factors could not be estimated for the *Canadian Coast Guard Ship (CCGS) Alfred Needler*; however, a different modelling approach showed comparability between vessels for exploitable and pre-recruit biomass.
- The overall exploitable biomass index has increased from historic lows in 2016–18. In 2023, the exploitable biomass index remained near the same level as 2022.
- Fishery Exploitation Rate Indices (ERIs) were moderate to low in most ADs in recent years. Status quo removals would maintain the moderate exploitation rates in most ADs in 2024. However, AD 3K has a projected exploitation rate of 42%.
- With status quo removals in 2024, all ADs are projected to be in the Healthy Zone of the Precautionary Approach (PA) Framework, except 2HJ, which is projected to be in the Cautious Zone.
- Recent and ongoing data deficiencies result in the exclusion of AD 4R3Pn from the PA Framework. The estimated exploitation rate index remains high in this AD.
- Pre-recruit and small crab indicators, as well as model predictions of exploitable biomass based on climate variables, indicate that resource growth may be limited in the short-term.
- The warming phase in the Newfoundland and Labrador (NL) ocean climate that started around 2018 continued in 2023. This warmer climate corresponded with improved conditions observed at the lower trophic levels, including increased concentrations of chlorophyll-*a*, earlier spring blooms, and increased zooplankton abundance and biomass.
- The NL bioregion continues to experience overall low productivity conditions, with total biomass measured in the DFO research vessel survey well below pre-collapse levels. The marine community has returned to a finfish dominated structure. Ecosystem trends in 2019–23 (e.g., biomass trends and stomach content weights) indicate improvements from the lows in the late-2010s, but overall biomass has yet to reach the early-2010s level.
- In recent years, the predation mortality index has been higher in 2J3K than 3LNO and 3Ps.

BACKGROUND

Species Biology

The Snow Crab life cycle features a planktonic larval period after spring hatching, involving several stages before settlement. Benthic juveniles of both sexes molt frequently and may become sexually mature at approximately 40 mm CW (or at approximately four years of age).

Snow Crab grow by molting in late-winter or spring. Females cease molting after sexual maturity is achieved at 35–75 mm CW and do not contribute to the exploitable biomass. Sexually mature (adolescent) males generally molt annually until their terminal molt, when they develop enlarged claws (adults) that likely enhance their competitiveness for mating. Males molt to adulthood at any size larger than approximately 40 mm CW. Only a portion of any cohort will recruit to the fishery at 95 mm CW.

Age cannot be determined, but Snow Crab are believed to recruit to the exploitable biomass (fishery) at 9–13 years of age across the stock range, with the majority of crab 9–11 years of age (Mullowney et al. 2023b). Skip-molting, leading to delays, is most common in cold temperatures, (Dawe et al. 2012; Mullowney and Baker 2021); however, population density also affects molt frequency, with more frequent molting (lower incidence of terminal molt at small size) under high density conditions, at least in males (Mullowney and Baker 2021). After recruiting to the exploitable biomass as soft-shelled crab, it takes almost a full year for shells to become filled with meat and the crab to be of commercial quality.

Snow Crab is a stenothermal species and temperature and associated climatic mechanisms affect production, early survival, and subsequent recruitment to fisheries (Foyle et al. 1989; Dawe et al. 2008; Marcello et al. 2012). Cold conditions during early-mid life stages are associated with increased survey biomass indices and fishery CPUE several years later.

Adult legal-sized males remain soft-shelled or new-shelled throughout the remainder of the year of their terminal molt. They are considered to be immediate pre-recruits until the following fishery, when as hard-shelled crab they begin to contribute to the exploitable biomass as recruits. Males may live a maximum of approximately six to eight years as adults after the terminal molt (Fonseca et al. 2008), but such longevity is not thought to be common, particularly in heavily exploited areas.

Snow Crab undertake an ontogenetic migration from shallow cold areas with hard substrates to warmer deeper areas with soft substrates (Mullowney et al. 2018a). Large males are most common on mud or mud/sand in deep areas, while smaller Snow Crab are common on harder substrates typically associated with shallow areas. Some Snow Crab also undertake a migration in the winter or spring for mating and/or molting. Although the dynamics of winter and spring migrations are not fully understood, they are known to be associated with different mating periods for first-time spawning (primiparous) and multiple-time spawning (multiparous) females, and are generally from deep to shallow areas.

Snow Crab are opportunistic feeders, with their diet including fish, clams, polychaete worms, brittle stars, shrimp, Snow Crab, and other crustaceans. Predators include various groundfish, other Snow Crab, and seals.

The Fishery

The fishery began in Trinity Bay in 1967 (CMA 6A; Figure 1). Initially, Snow Crab were taken as gillnet bycatch, but within several years a directed trap fishery developed in inshore areas along the northeast coast of Div. 3KL. The minimum legal mesh size of traps is 135 mm (5 ¼”) to allow small crab to escape. Under-sized and soft-shelled males that are retained in the traps are returned to the sea, but the post-release mortality rate is unknown.

Until the early-1980s, the fishery was prosecuted by approximately 50 vessels limited to 800 traps each. In 1981, fishing was restricted to the NAFO Division adjacent to where the license holder resided. During 1982–87, there were major declines in the resource in traditional areas in Div. 3K and 3L, and new fisheries started in Div. 2J, Subdiv. 3Ps, and offshore Div. 3K. A Snow Crab fishery began in Div. 4R in 1993.

Licenses supplemental to groundfish fisheries were issued in Div. 3K and Subdiv. 3Ps in 1985, in Div. 3L in 1987, and in Div. 2J in the early-1990s. Since 1989, there has been a further expansion in the offshore fishery. Temporary permits for inshore vessels less than 35 feet (less than 10.7 m) were introduced in 1995 and subsequently converted to permanent licenses in 2003. There are now several fleet sectors and approximately 2,200 license holders in 2023.

In the late-1980s, quota control was initiated in all management areas of each Division. Current management measures include trap limits, individual quotas, trip limits, dedicated fishing areas within CMAs, and differing seasons. The fishery has started earlier during the past decade and is now prosecuted predominately in spring, where possible, with the intent to reduce catch of soft-shelled crab. A protocol was initiated in 2004 that resulted in closure of localized areas when soft-shelled crab exceeded 20% of the legal-sized catch. In Div. 3LNO, the closure threshold was reduced to 15% in 2009. Mandatory use of the electronic Vessel Monitoring System (VMS) was fully implemented in offshore fleets in 2004 to ensure compliance with regulations regarding area fished.

Landings for Divs. 2HJ3KLNOP4R increased steadily from 1989 to a peak of 69,100 t in 1999, largely due to expansion of the fishery to offshore areas (Figure 2). Landings decreased by 20% to 55,400 t in 2000 and changed little until they decreased to 44,000 t in 2005, primarily due to a sharp decrease in landings in Div. 3K. Landings remained near 50,000 t from 2007–15, but steadily declined to a 25-year low of 26,400 t in 2019. Landings have continued to increase since then and were over 51,000 t in 2023.

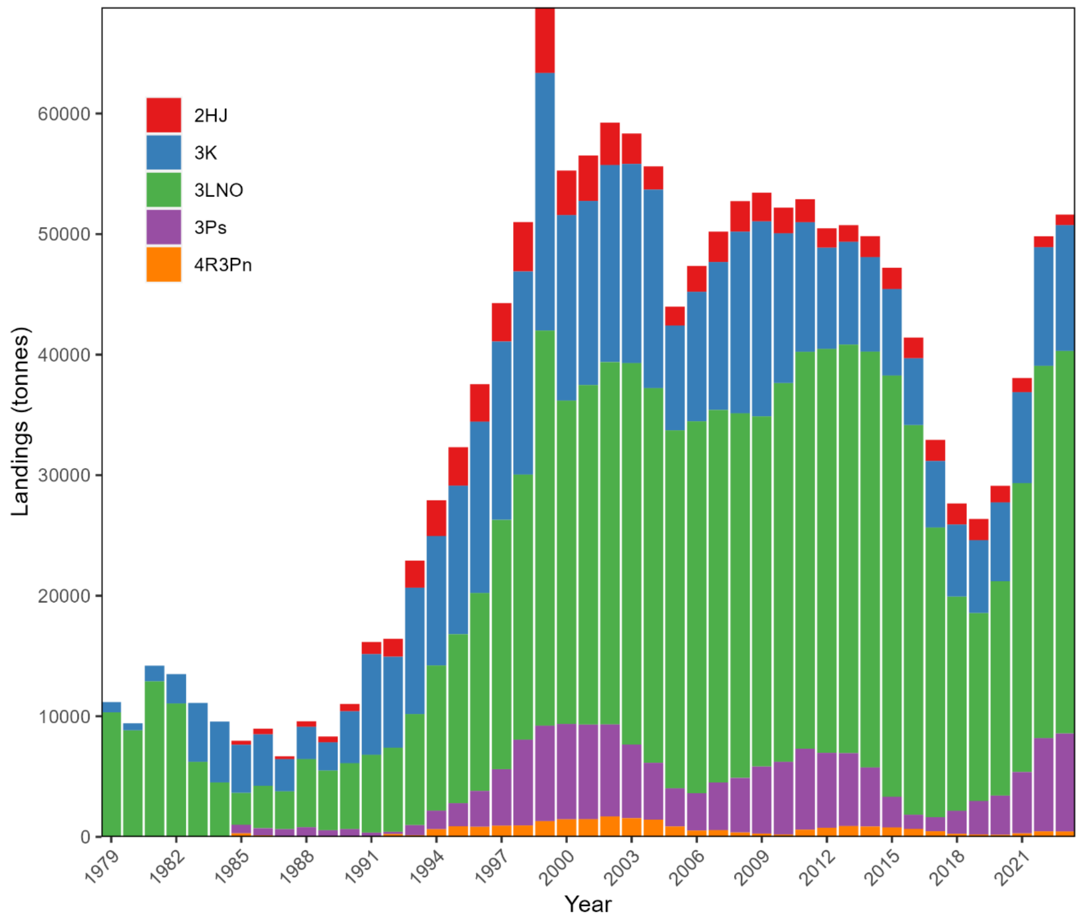

Figure 2. Annual landings (tonnes) of Snow Crab by AD (1979–2023).

The spatial distribution of the fishery grew as licences and landings increased throughout the 1980–90s. The resource is now deemed fully-exploited, with fishing effort typically spanning from the fringes of the Makkovik Bank off central Labrador in the north to the far offshore slope edges of the Grand Bank in Div. 3LNO in the south, to near the border of Quebec in the westernmost portions of Div. 4R (Figure 3). Fishery CPUE is typically highest in Div. 3L; however, in recent years Div. 3K and Subdiv. 3Ps have also had high levels of fishery CPUE (Figure 3).

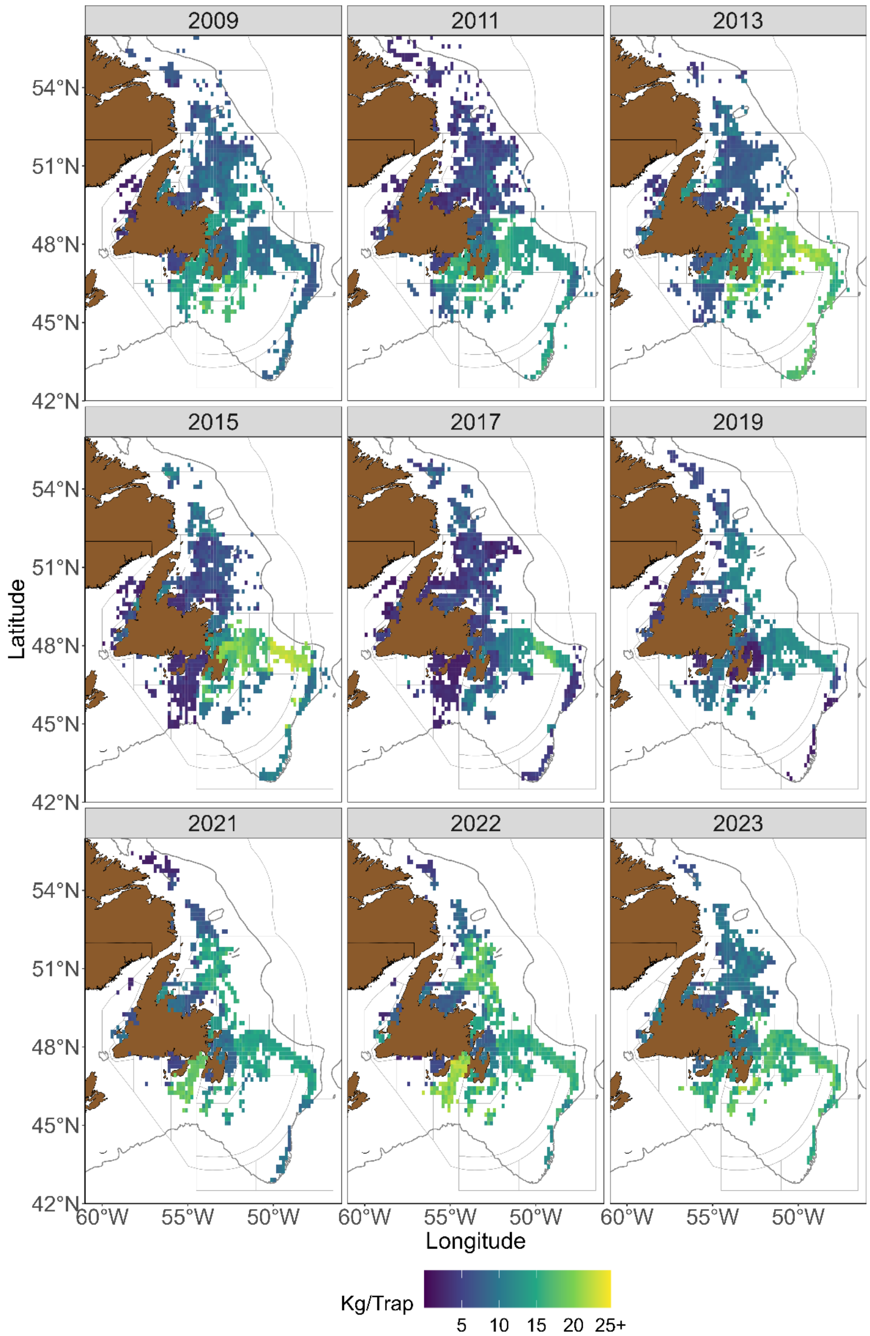

Figure 3. Locations of fishery sets and catch rates (kg/trap) from fishery logbooks (2009, 2011, 2013, 2015, 2017, 2019, and 2021–23). Data in the most recent year is considered preliminary due to delays in logbook returns and data entry.

Overall effort increased to near 3.8 million trap hauls in 2023 (Figure 4). Overall standardized fishery CPUE was at a time-series low in 2018, but has greatly increased since then to near the time-series high in 2022 (Figure 4). Standardized fishery CPUE decreased slightly in 2023.

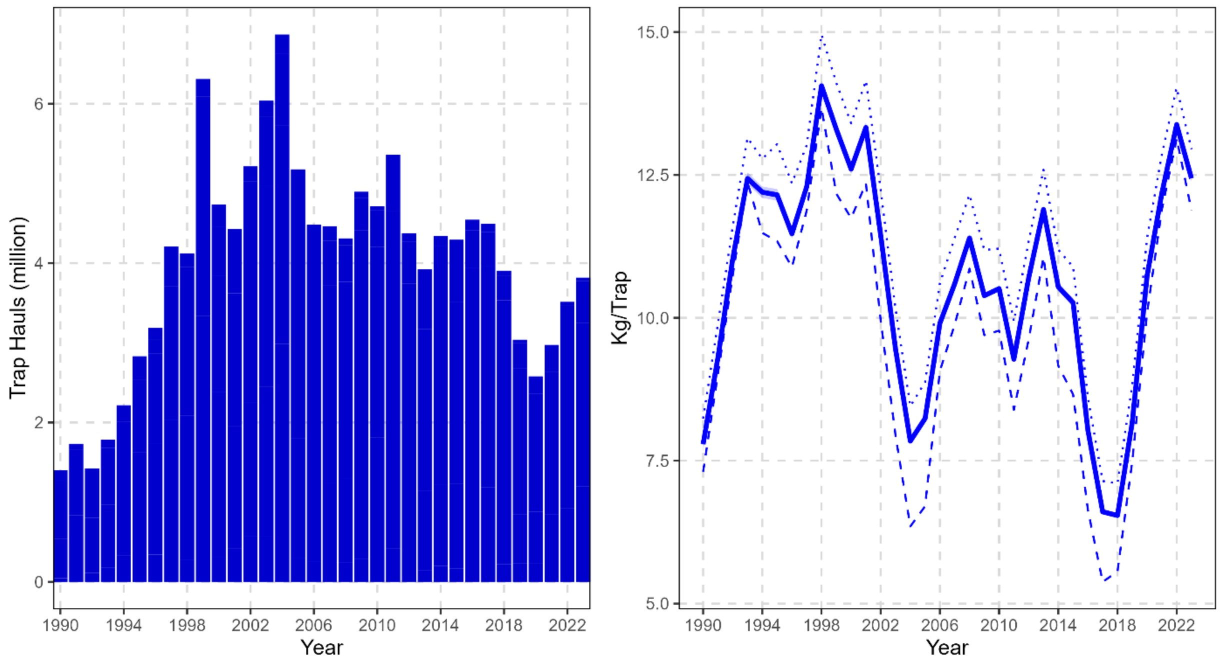

Figure 4. Left panel: Estimated number of trap hauls per year for the fishery in Divs. 2HJ3KLNOP4R (1990–2023). Right panel: Standardized fishery CPUE (kg/trap) for Divs. 2HJ3KLNOP4R (1990–2023), where: solid line = standardized CPUE, dotted line = raw mean CPUE, dashed line = raw median CPUE, and shaded band = 95% confidence intervals (CIs). Data in the most recent year is considered preliminary due to delays in logbook returns and data entry.

ASSESSMENT

The boundaries of the CMAs have no biological basis and the resource is assessed at larger-scale ADs, which are either NAFO Divs./Subdivs. or combinations of NAFO Divs. (Figure 1). Div. 2H is combined with Div. 2J (AD 2HJ) as the resource extends only into the southern portion of Div. 2H, and is managed at a spatial scale that extends over the divisional boundary line. Divs. 3LNO are assessed as a unit (AD 3LNO), essentially encompassing the Grand Bank and associated inshore areas. Subdiv. 3Pn is combined with Div. 4R (AD 4R3Pn) to conform to management boundaries. Div. 3K (AD 3K) and Subdiv. 3Ps (AD 3Ps) are assessed at the NAFO Div. and Subdiv. level, respectively. Prior to the present assessment, the inshore areas of Div. 3L were assessed separately from the offshore areas of Divs. 3LNO. Recent improvements in trap survey coverage in the offshore and new spatiotemporal modelling of both trap and trawl survey data has allowed for the combination of these two areas into one AD (AD 3LNO).

Resource status was evaluated based on trends in survey exploitable biomass indices, fishery CPUE, fishery recruitment prospects, and mortality indices. Information was derived from multiple sources: multispecies bottom trawl surveys conducted during fall in ADs 2HJ, 3K, and 3LNO and spring in AD 3Ps; two collaborative trap surveys covering all ADs; DFO inshore trap surveys in ADs 3K, 3LNO, and 3Ps; fishery data from logbooks; and at-sea observer (ASO) catch-effort data.

The spring and fall bottom trawl surveys are based on a depth-stratified random sampling scheme. The surveys are used to provide an index of exploitable biomass that is expected to be available for the upcoming fishery in the same year (spring survey in AD 3Ps) or the following year (fall survey in ADs 2HJ, 3K, and 3LNO). Fisheries have begun earlier since the mid-2000s and now overlap with the timing of the spring trawl survey in AD 3Ps. The trawl surveys were conducted aboard the *CCGS Teleost* and *CCGS Alfred Needler* (or its sister ship the *CCGS Wilfred Templeman*) since 1995 using a Campelen 1800 shrimp trawl. These vessels were replaced by the new Offshore Fishery Science Vessels (OFSVs), the *CCGS John Cabot* and *CCGS Captain Jacques Cartier* for use in 2022 and going forward. Comparative fishing (i.e., direct side-by-side comparison between the old and new vessels; DFO 2024) occurred from 2021–23 to determine differences in relative catchability between the outgoing vessels with the standard Campelen trawl and the new vessels with a modified Campelen trawl (Wheeland et al. 2024). For Snow Crab, conversion factors were estimated for the *CCGS Teleost* across the spring and fall survey areas, and for the *CCGS Alfred Needler* in Divs. 3KL in fall. Consistency in habitat, distribution, and biological characteristics of Snow Crab supported the application of conversion factors estimated for the *CCGS Alfred Needler* in Div. 3KL across the fall survey area for this vessel. Conversion factors were applied to the previous time series (1995–2023) to rescale indices to units equivalent to the new vessels going forward.

Comparative fishing coverage was insufficient to estimate conversion factors for the *CCGS Alfred Needler* in AD 3Ps and therefore direct estimates of potential differences in relative catchability to the new OFSVs was not possible. However, spatiotemporal modelling in this area indicated no significant vessel effect for indices of pre-recruit and exploitable biomass, therefore the various vessel series have been used as equivalent in AD 3Ps in this assessment.

In recent years, standard depth-stratified multispecies bottom trawl surveys were not conducted in Subdiv. 3Ps in 2020 and 2023, Divs. 2HJ3K in 2022, and Divs. 3LNO in 2021 and 2022. However there was comparative fishing survey data available for some areas and years during 2021–23 where standard Snow Crab sampling was conducted, but the station allocation was not random depth-stratified.

DFO inshore trap surveys are conducted in ADs 3K, 3LNO, and 3Ps from May to October. The survey takes place in Fortune Bay and St. Mary's Bay in late-spring and early-summer, Bonavista Bay and Trinity Bay in mid-summer, and White Bay, Notre Dame Bay and Conception Bay in late-summer and fall. These surveys follow a depth-stratified random survey design and utilize large-mesh and small-mesh traps alternating within each fleet of gear.

The industry-DFO Collaborative Post-Season (CPS) trap survey occurs late-summer to early-fall each year and covers all areas except CMA 1 (N5440 or 2JN) and Div. 2H. It was historically based on a fixed station grid design and was more spatially limited than the trawl survey as it targeted only portions of commercial fishing grounds. To improve its representativeness for the stock assessment, the CPS survey has transitioned to a more random stratified spatial design since 2018, and is now a 50% fixed and 50% random station design, covering both a horizontally and vertically broader area of the continental shelf than the historic design. Historically, a set of core stations was selected from this survey for calculating catch rates (kg/trap) of legal-sized adults; however, a comparative index from all stations is now also calculated and used in the assessment instead of the core stations. Only the core stations have been consistently surveyed in AD 4R3Pn; therefore, only the time series for core stations is presented for that AD. The CPS survey also includes small-mesh traps to provide data on recruitment prospects. Historically, small-mesh traps were deployed on select stations, but expanded to include most stations in recent years; therefore, only data from 2018 onward are used in this assessment. There have been consistent issues with coverage in the CPS trap survey that affect the interpretation of stock status trends, including spatial bias and abandonment of survey areas in times of poor fishery performance. Most recently, this survey was notably not completed in CMA Nearshore (CMA NS) in AD 3LNO in 2022 and CMAs NS and 8B in AD 3LNO in 2023, as well as CMA 10B in AD 3Ps in 2023. While there were other areas where not all stations were completed, the large parts of ADs 3LNO and 3Ps not surveyed in 2023 resulted in some results not presented for these ADs.

A third trap survey series used in the assessment is the Torngat Joint Fisheries Board-DFO collaborative trap survey. This is a fixed-station survey, covering the northern portion of Div. 2J and a portion of Div. 2H, chosen to target sampling within the deep channels where the fishery occurs, as well as in the shallow peripheries around the fishing grounds. This survey also includes small-mesh traps at every station to provide data on recruitment prospects. In 2023, two stations were not surveyed in the same location as in the rest of the time series.

Spatiotemporal models were developed to predict exploitable crab biomass for both the trawl and trap time series using available trap and converted trawl survey data in the R package 'sdmTMB' (Anderson et al. 2022). This program fits generalized linear mixed models across spatial and temporal domains for geostatistical time series data. These models replaced the previous spatial expansion program 'Ogmap' (Evans et al. 2000). Separate models were developed for the Divs. 2HJ3KLNO fall trawl time series, the Subdiv. 3Ps spring trawl time series, and the Divs. 2HJ3KLNOP4R trap time series, and multiple iterations of models including various combinations of covariates were explored. The best models for predicting exploitable crab biomass from Divs. 2HJ3KLNO and Subdiv. 3Ps trawl data incorporated additional co-variates beyond spatial co-ordinates. Specifically, depth was included as a spatially-varying coefficient and year was included as a factor covariate. This modelling approach also enabled inclusion of all set types in a given survey series, not only those from random depth stratified set allocation, and set type was included as a factor covariate. The best model for predicting exploitable crab biomass from Divs. 2HJ3KLNOP4R trap data incorporated depth as a spatially-varying coefficient, year and survey type (Inshore DFO, CPS, or Torngat) as factor covariates, and calendar day as a scaled covariate.

Biomass estimates from sdmTMB are not deemed absolute because the capture efficiency of Snow Crab by the survey gears is not known. For the trawl, the gear efficiency is known to be low, particularly for the smallest crab sizes, but retention efficiency is below 100% ($q<1$) even at the largest sizes. Besides crab size, trawl efficiency is also affected by substrate type and depth (Dawe et al. 2010a), and therefore varies considerably spatially. Efficiency is lower and more variable on hard (typically shallow) substrates than on soft (typically deep) substrates. Trawl survey catch rates also appear affected by the diurnal cycle, being higher during dark periods when crab appear most active. Other potential factors affecting trawl catchability include vessel and gear set ups. For traps, capture efficiencies are unknown and vary between individual set ups. Effective Fishing Areas (EFAs) of survey traps could potentially be affected by numerous factors including: bait type, quantity, and quality; soak times; gear spacing; ocean currents; and crab density. For trap survey biomass estimation, the EFA parameter, analogous to the swept area parameter for survey trawls, was estimated at 0.01 km^2 to enable biomass estimation in the models.

For the trawl and trap surveys, raw model-based exploitable biomass estimates were adjusted by a catchability scalar (*S*) in each AD. This scalar was determined through a common baseline source, logbook catch rate DeLury depletion models, with a scalar determined each year in the respective survey time series when depletion estimates were deemed valid. The DeLury fisheries depletion biomass estimates are applicable to the beginning of the season (spring); therefore, a one-year lag was applied to most survey estimates in calculating the annual scalar, as most surveys occur in late-summer or fall (2HJ3KLNO trawl surveys, CPS survey, Torngat survey). For the trawl surveys, *S* was calculated as the median ratio of annual survey biomass to DeLury logbook biomass in each AD, with the one-year temporal lags applied where necessary. Due to considerable time-series length, little change occurs in the time-series *S* for the trawl surveys from year-to-year, as an additional year has little influence on the time-series median. Standardized biomass indices were calculated as raw exploitable biomass estimates divided by *S*. For the shorter trap surveys, there has been variability in the catchability scalars that have been influenced by a contracting fishery in some ADs in recent years. Consequently, for ADs with trawl surveys the trap survey biomass estimates were scaled to the trawl survey estimates based on average ratios over the 2017–22 period. For AD 4R3Pn, where there is no trawl survey, the depletion scalar was determined from a linear regression over the time series.

Trawl and trap surveys also provide data on recruitment (i.e., crab just entering into the exploitable biomass), pre-recruitment, and mature females. Recruitment prospects for the upcoming fishery are inferred from catch rates of new-shelled legal-sized Snow Crab (immediate recruits) and pre-recruitment is based on adolescent (non-terminally-molted) males 70–94 mm CW. Pre-recruits would be expected to be recruited into the exploitable biomass in approximately two to three years.

Trends in exploitation rate were inferred from changes in the ERI, defined as landings divided by the exploitable biomass index from the most recent survey, with exploitable biomass indices smoothed as a two-year moving average to account for year effects in survey performance. Natural mortality rates are unknown, but predation is highest on smaller crab (e.g., less than 50 mm CW) (Chabot et al. 2008).

Fishery CPUE is used as an index of fishery performance. Annual CPUE (kg/trap) is based on logbook information on catch and effort for individual or daily set hauls and is standardized using a linear mixed model incorporating main and random effects of time (calendar day and year) and space (CMA nested in AD), as well as trap soak time. The CPUE model also includes a weighting factor accounting for the importance of the grid cell (10’ x 10’ nautical mile) where the set occurred, defined as the number of years the cell has been fished. The logbook dataset is normally most incomplete in the current assessment year, resulting from a time lag associated with compiling data from the most recent fishery; thus, the terminal points are considered preliminary.

Resource Status

Landings & Effort

In AD 2HJ, landings remained near 1,700 t from 2014–19, but have since declined due to TAC reductions. Landings were around 880 t in 2023 (Figure 5). Effort remained moderately consistent for the last decade, at around 200,000 trap hauls per year, but declined in the last two years and was 93,000 trap hauls in 2023 (Figure 6). In AD 3K, landings have increased since a time-series low of around 5,500 t in 2017 to around 10,400 t in 2023, while effort increased to around 1.1 million trap hauls. In AD 3LNO, landings were at the lowest level in two decades in 2019 (around 15,600 t) but have since increased to around 31,700 t in 2023. Effort decreased slightly in 2023 to around two million trap hauls. In AD 3Ps, landings continued to increase from a time-series low of around 1,200 t in 2017 to around 8,100 t in 2023, while effort increased to nearly 527,000 trap hauls. In AD 4R3Pn, landings have increased from a time-series low of around 160 t in 2020, but decreased slightly from 2022 to 2023 to around 450 t. Effort decreased in 2023 to near 44,000 trap hauls.

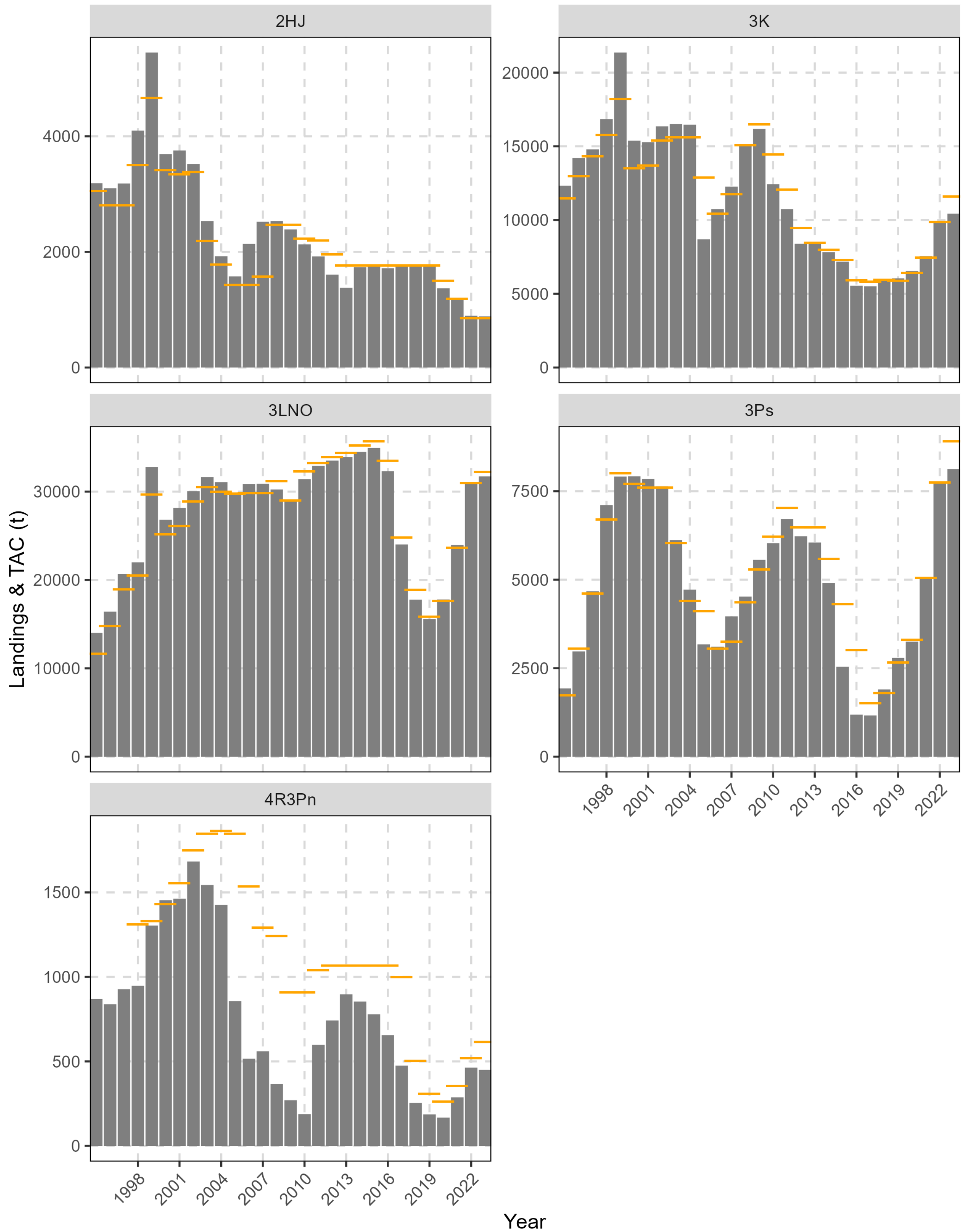

Figure 5. Annual landings (gray bars) and TAC (yellow lines) by AD (1995–2023).

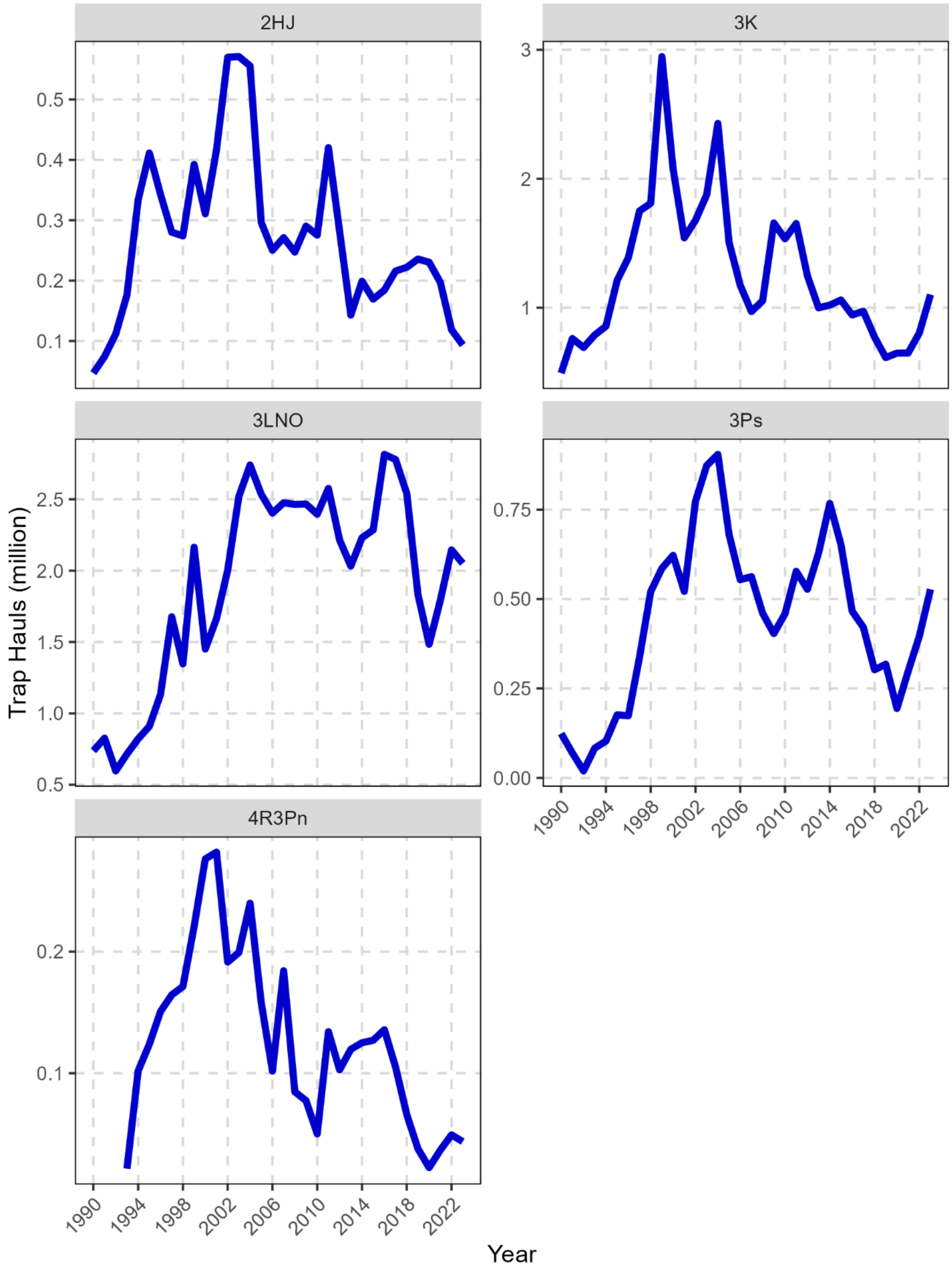

Figure 6. Annual effort (trap hauls) by AD from fishery logbook data (1990–2023). Data in the most recent year is considered preliminary due to delays in logbook returns and data entry.

Catch per Unit Effort (CPUE)

Fishery CPUE trends often lag behind survey biomass trends by one to two years in most ADs; thus, the fishery is typically delayed in reflecting stock status. In AD 2HJ, standardized CPUE increased to near 9 kg/trap in 2023 (Figure 7). In AD 3K, standardized CPUE decreased from a recent peak in 2022, but remains high for the time series at 9 kg/trap in 2023. In AD 3LNO, standardized CPUE continued to increase from the time-series low in 2018 to around 15 kg/trap in 2023. In AD 3Ps, standardized CPUE was at a time-series high of around 19 kg/trap in 2022, but decreased in 2023 to around 15 kg/trap. However, the standardized CPUE remains at a high level. In AD 4R3Pn, standardized CPUE was at a time-series high near 10 kg/trap in 2023.

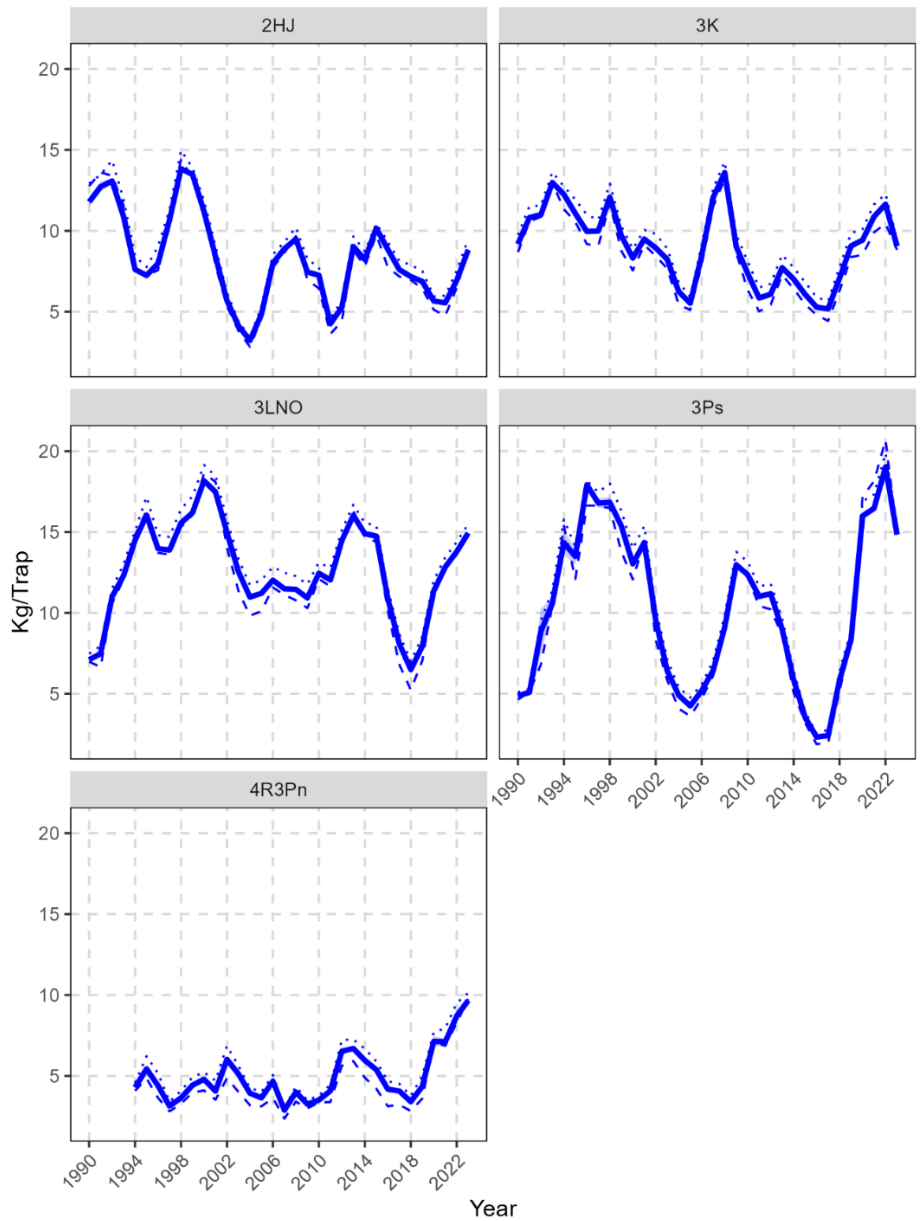

Figure 7. Fishery CPUE (kg/trap) by AD from fishery logbook data (1990–2023), where: solid line = standardized CPUE, dotted line = raw mean CPUE, dashed line = raw median CPUE, and shaded band = 95% confidence intervals (CIs). Data in the most recent year is considered preliminary due to delays in logbook returns and data entry.

Exploitable Biomass

Past multispecies trawl survey data from outgoing research vessels has been adjusted to account for conversion factors of catchability with new vessels used for these surveys going forward. Multispecies trawl surveys indicate that the exploitable biomass index was highest at the start of the survey series (1996–98) (Figure 8). The annual index declined from a peak exceeding 400 kt in the late-1990s to about 150 kt in 2003 and then varied without trend until 2013. From 2013–16, the annual exploitable biomass index declined by 70% to a historical low of about 42 kt. The redesign of the CPS trap survey and subsequent incorporation of stations over a much larger area has resulted in the trap survey exploitable biomass index becoming more temporally in-line with the trawl survey exploitable biomass index (Figure 8), rather than lagging behind the trawl trends as was evident with the previous survey design. The trawl and trap survey exploitable biomass indices have increased from historic lows in 2016–18, but remained around the same level in 2023 as that observed in 2022.

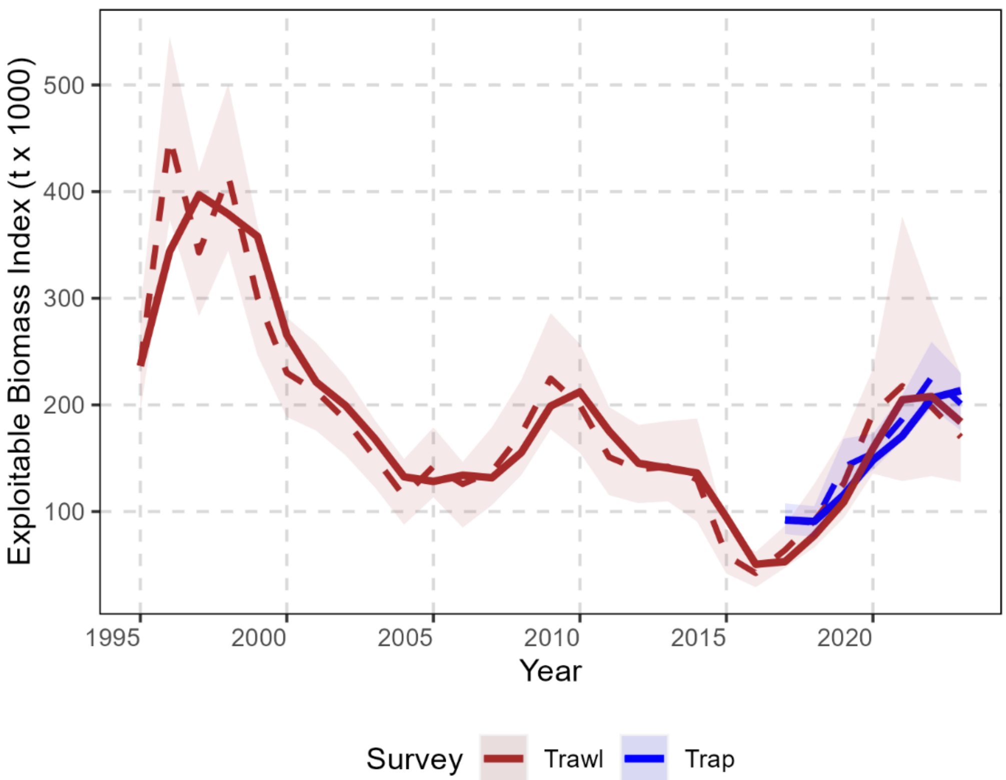

Figure 8. Annual trawl survey-based exploitable biomass index (red) (1995–2023) and trap survey-based exploitable biomass index (blue) (2018–23), where: solid line = two-year moving average of exploitable biomass, dashed line = annual estimate, and shaded band = 95% confidence intervals (CIs) of annual estimate.

In AD 2HJ, the exploitable biomass indices have remained low for many years; however, there were slight increases in these indices in the last two years (Figure 9). In AD 3K, the exploitable biomass indices increased to high levels in recent years; however, declined significantly over the last two years. In ADs 3LNO and 3Ps, the exploitable biomass indices have increased in recent years, but remained near similar levels from 2022 to 2023. In AD 4R3Pn, the trap survey exploitable biomass index has increased in recent years, but remained near a similar level from 2022 to 2023.

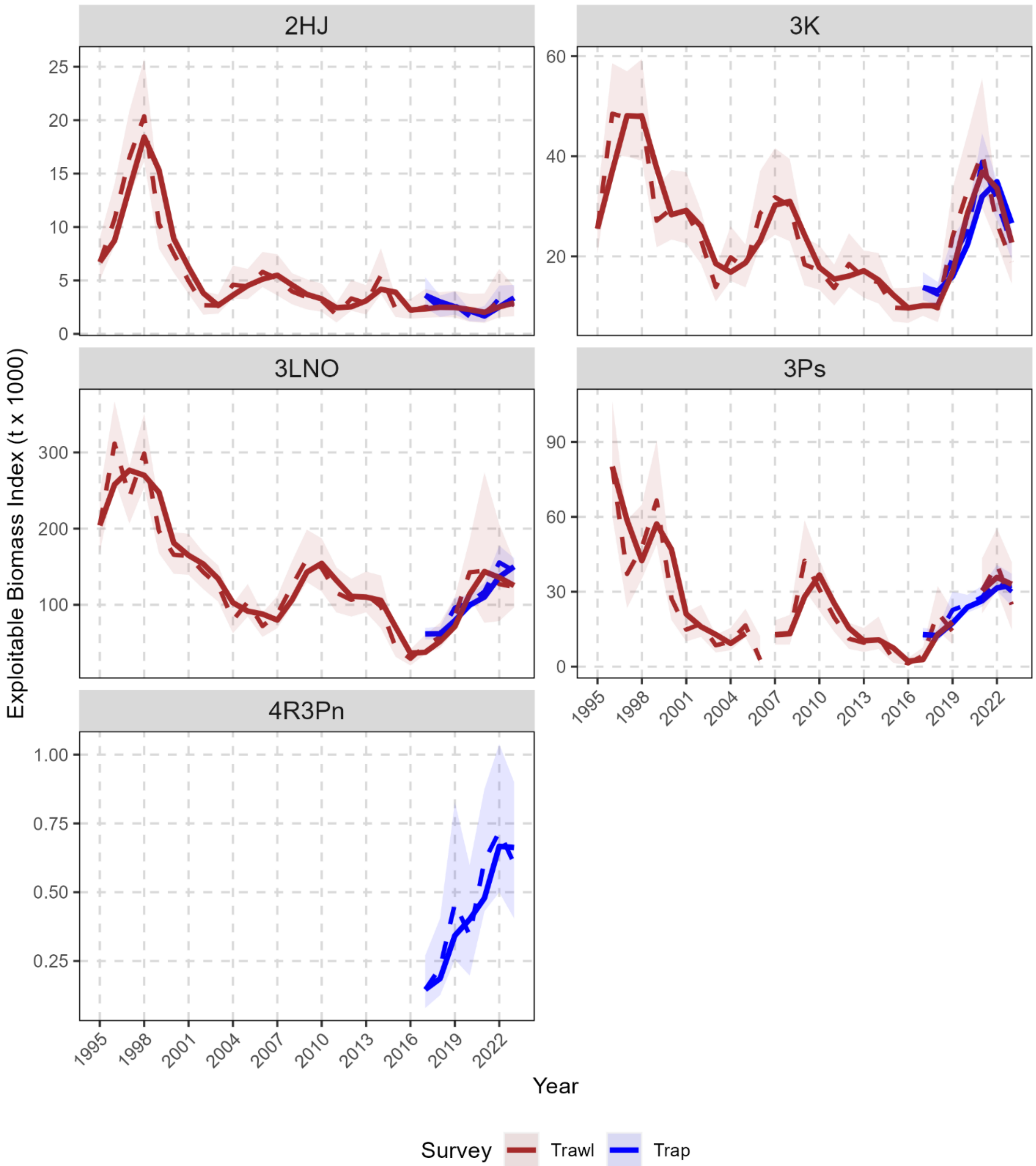

Figure 9. Annual trawl survey-based exploitable biomass index (red) (1995–2023) and trap survey-based exploitable biomass index (blue) (2018–23) by AD, where: solid line = two-year moving average of exploitable biomass, dashed line = annual estimate, and shaded band = 95% confidence intervals (CIs) of annual estimate.

Mortality

Trends in total mortality generally reflect those of fishing-induced mortality, as measured by ERIs. In AD 2HJ, the ERIs decreased in 2023 and under status quo removals in 2024 the ERIs are projected to continue to decrease (Figure 10). In AD 3K, the ERIs remained at similar levels in 2023 as those observed in 2022; however, under status quo removals in 2024 the ERIs are projected to increase, with the trawl-derived ERI projected around 42%. This is the maximum exploitation level permitted under the PA Framework. In AD 3LNO, the ERIs remained at similar levels in 2023 as those observed in 2022 and no change is projected under status quo removals in 2024. In AD 3Ps, ERIs remained around the same level in 2023 as those observed in 2022 and no significant change is projected under status quo removals in 2024. In AD 4R3Pn, the trap survey-derived ERI has been variable and at a high level. In 2023, the ERI decreased and under status quo removals in 2024 the ERI is projected to decrease slightly, but remain high.

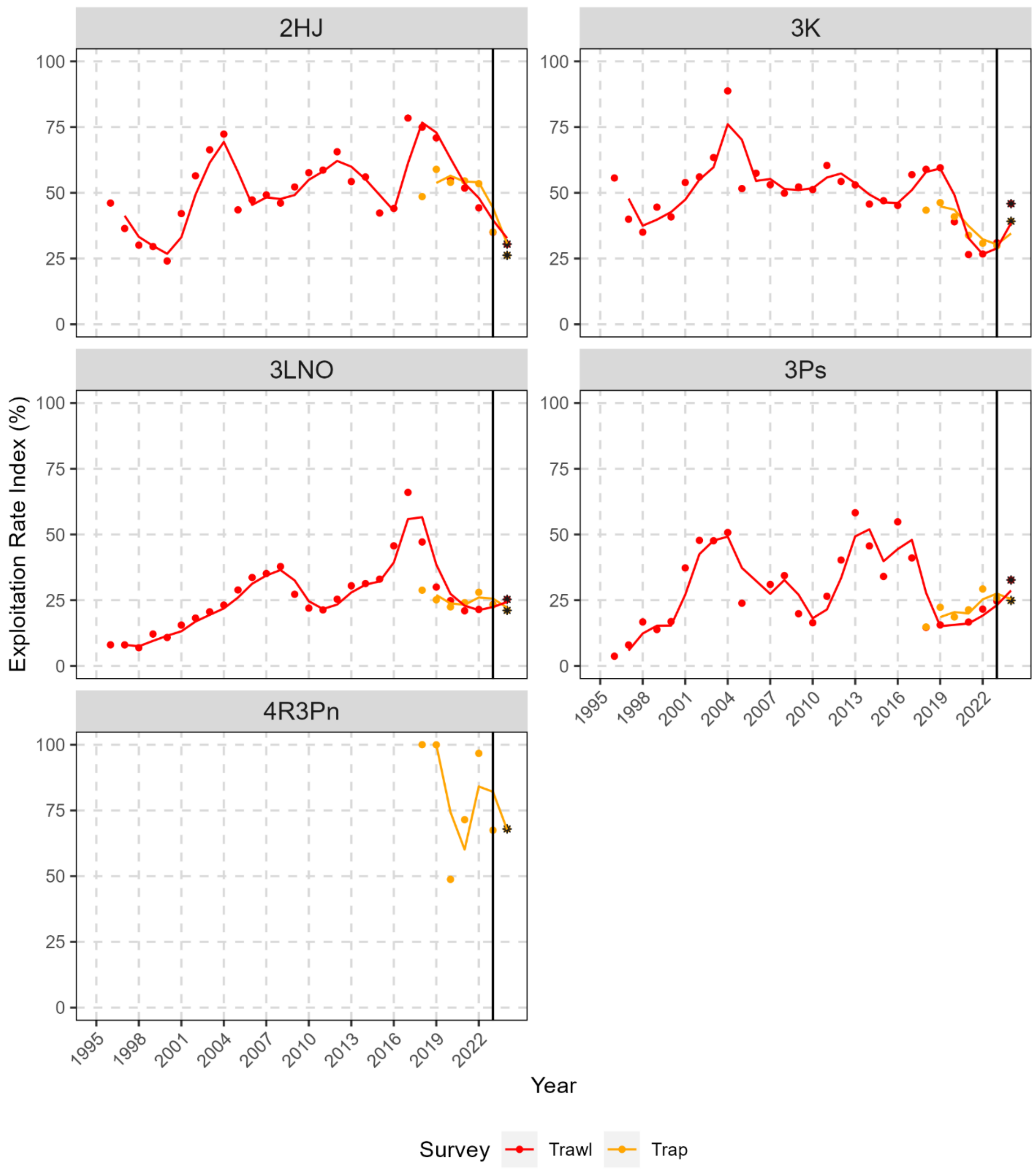

Figure 10. Annual trawl survey-based ERI (red) (1995–2023) and trap survey-based ERI (orange) (2018–23) by AD, where: solid line = two-year moving average of ERI, dashed line = annual estimate, and 2024 points (*) depict projected annual ERIs under status quo removals in the 2024 fishery.

Recruitment

There were no separate biomass estimates for recruit and residual exploitable Snow Crab from the trawl surveys generated in the present stock assessment; however, immediate recruitment into the exploitable biomass can be inferred from catch rates of new-shelled exploitable Snow Crab from the CPS trap survey. Snow Crab captured as soft-shelled or new-shelled in the current survey represent recruitment into the exploitable biomass, while the residual biomass is comprised of intermediate-shelled to very old-shelled Snow Crab. Catch rates of recruit Snow Crab have been fairly consistent in ADs 2HJ, 3LNO, and 3Ps in the last four years; however, there was no value for ADs 3LNO or 3Ps in 2023 due to incomplete trap survey coverage in those ADs (Figure 11). There have been declines in catch rates of recruit Snow Crab in ADs 3K and 4R3Pn in 2023 since a peak in 2021, with a time-series low in AD 3K in 2023.

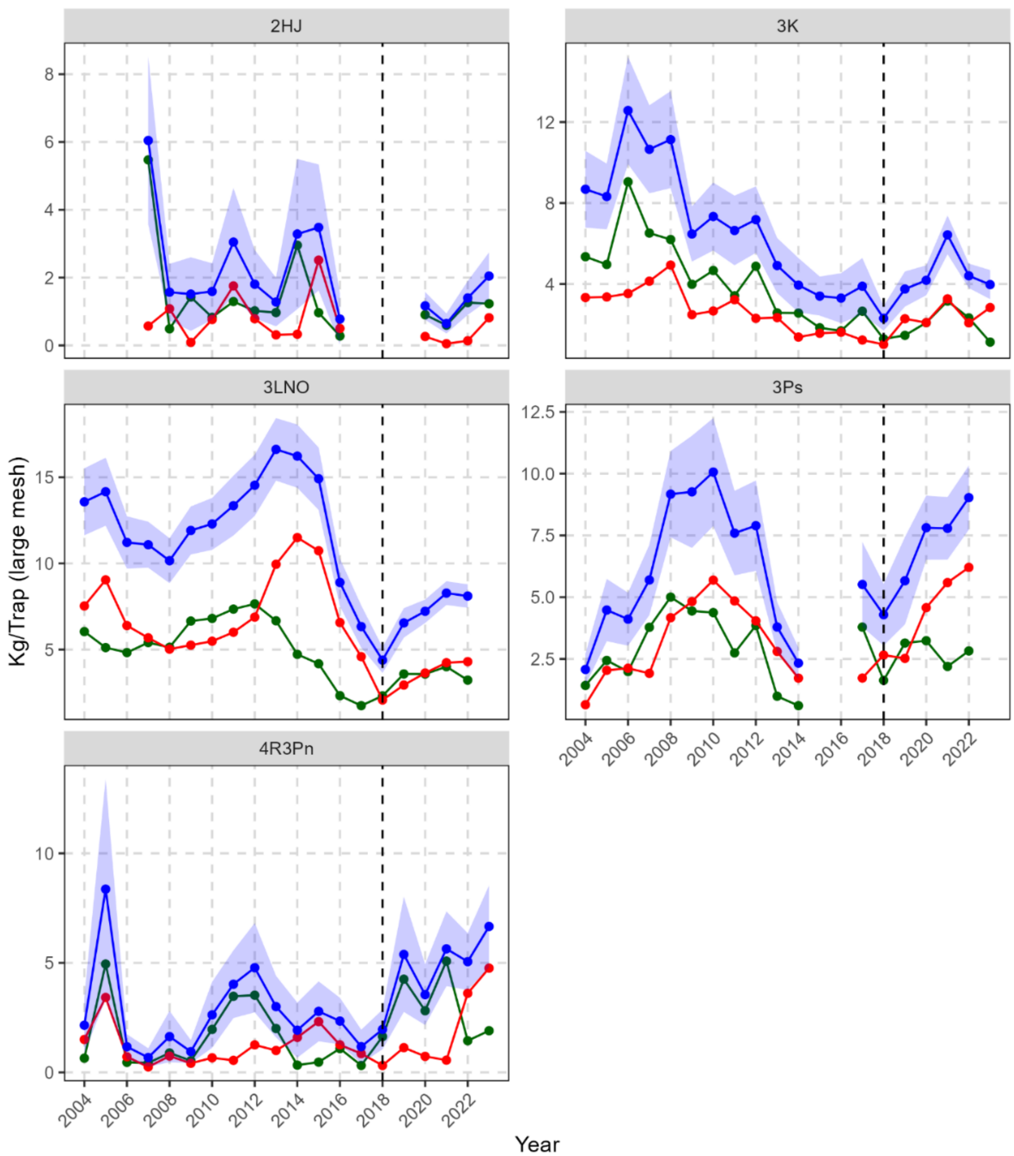

Figure 11. Trends in CPUE (kg/trap) by shell condition (blue = total, red = residuals, green = recruits) for exploitable Snow Crab from large-mesh traps at all stations in the CPS trap survey by AD (2004–23). Shaded area represents the 95% confidence intervals (CI). Dashed vertical line denotes the first year of the trap survey redesign.

Trends in pre-recruitment were examined from catch rates of 70–94 mm CW adolescent males in the trawl and trap time series and provide an index of recruitment prospects in the short-term (approximately 2–4 years). However, the proportion of these adolescents measured in the surveys that reach the exploitable biomass depends on several factors, including natural mortality and the size at which Snow Crab terminally molt. Recent declining trends in catch rates of small sizes of Snow Crab and pre-recruits from the trawl and trap surveys in some areas suggest limited resource growth in the short-term. The catch rates of these sub-legal categories of Snow Crab were lower in 2023 than the average catch rates of the last five years (Figure 12); particularly, in the trawl survey and the small-mesh traps from the trap surveys.

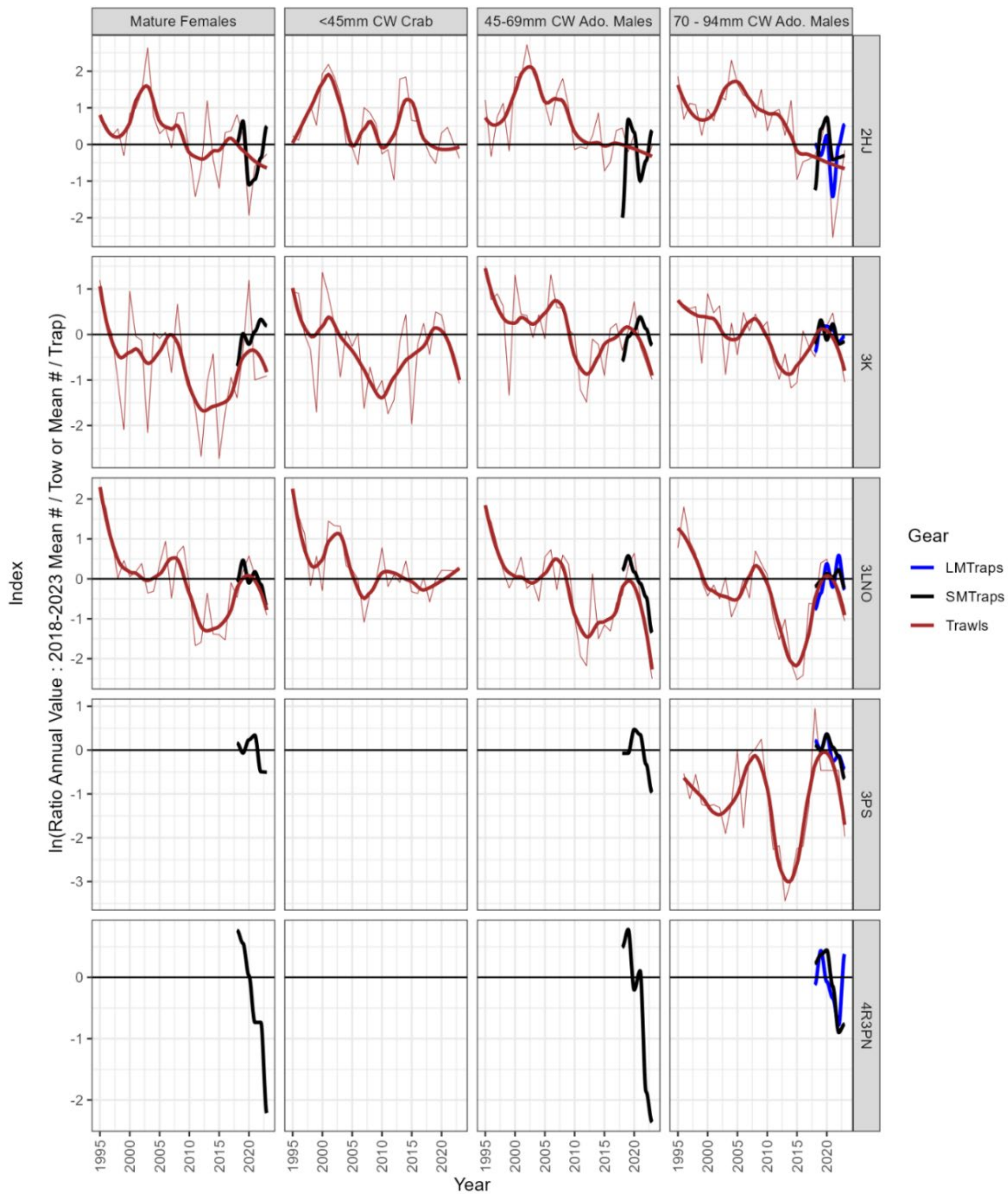

Figure 12. Indices of mature female Snow Crab, small Snow Crab (less than 45 mm CW), 45–69 mm CW adolescent male Snow Crab, and pre-recruit Snow Crab (70–94 mm adolescent males) from the trawl (red), large-mesh trap (blue), and small-mesh trap (black) surveys. The index represents the ratio of the annual value (#/tow for trawl, #/trap for traps) to the 2018–23 mean. Thin lines = annual estimates and thick lines = loess regression curves fit to the annual estimate.

Ecosystem Perspective

Increased bottom temperature has been shown to relate positively to size and negatively to abundance in regulating stock productivity and ultimately biomass. Cold bottom temperatures appear to promote terminal molt at small sizes in Snow Crab, resulting in relatively low recruitment and yield-per-crab from a given year class (Dawe et al. 2012). However, recruitment is more strongly affected by the positive effects of cold environmental conditions on year class production (Dawe et al. 2008; Marcello et al. 2012) than it is by the negative effects of cold conditions on size-at-terminal molt. This is consistent with positive benefits of cold conditions in promoting early-life to mid-life survival and subsequently increased densities of Snow Crab in the population. The last six years have shown an overall trend towards warmer and potentially less favourable environmental conditions for future productivity that continued in 2023. However, it was particularly warm in 2021 and 2022, with the NL Climate Index (Cyr and Galbraith 2020) indicating 2021 was one of the two warmest years of the time series (Cyr et al. 2022) and 2022 was in the top ten warmest years.

Bottom temperature is not the only climatic factor influencing Snow Crab productivity; the Arctic Oscillation and sea ice extent are important variables in predicting abundances of different life stages (Mullowney et al. 2023a). Sea ice extent has shown positive correlations with Snow Crab exploitable biomass index at lags longer than 10 years, indicating an effect on early life stages, while the Arctic Oscillation has been shown to be positively related to Snow Crab exploitable biomass index at lags of 7–8 years, indicating an effect on mid-life stages. The short-term model presented at the assessment predicts that stock growth may be limited in the next few years (Figure 13).

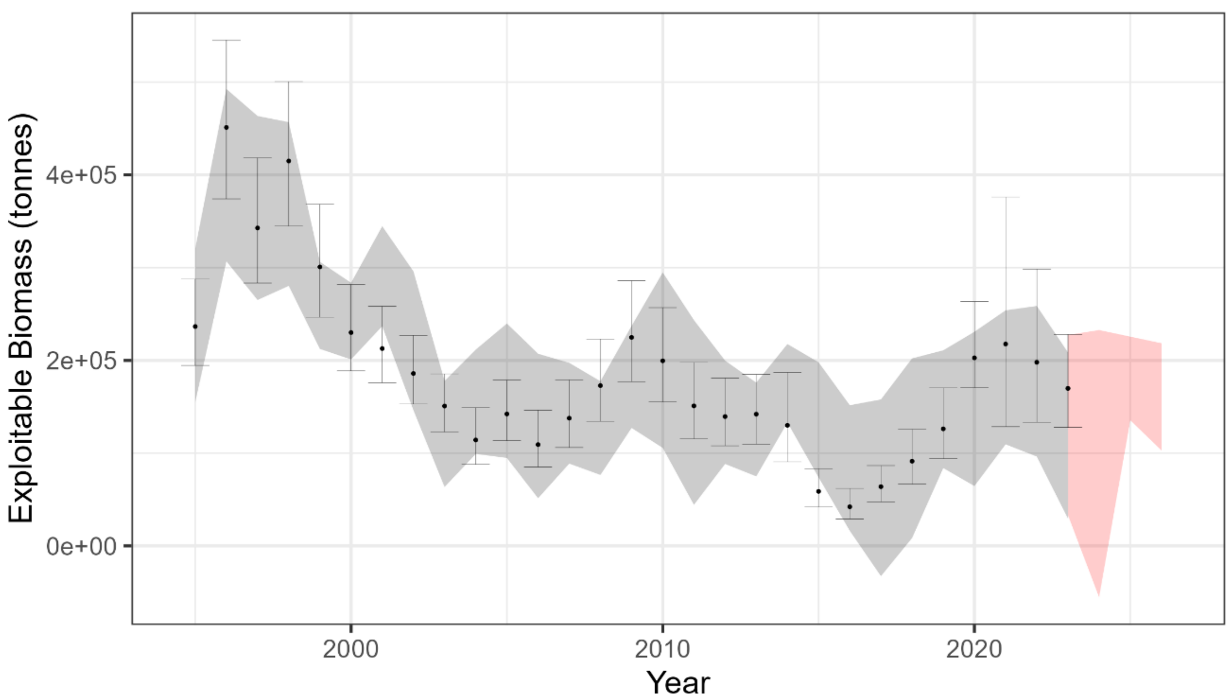

Figure 13. Short-term prediction model of exploitable biomass. Black points are trawl survey measured exploitable biomass in Divs. 2HJ3KLNOP. Black lines, points, error bars, and shaded area are associated with full model fits (short-term, mid-term, long-term effects) and the red shaded area is associated with the model fit with no short-term effects. Shaded areas are 95% confidence intervals of model fits.

Until the past few years, following a regime shift culminating in a collapse of most of the finfish community in the late-1980s and early-1990s (Buren et al. 2014), the Snow Crab resource appears to have largely been under bottom-up control, in association with low exploitation rates in the largest areas of abundance (i.e., AD 3LNO offshore areas) (Mullowney et al. 2014). However, recent assessments have highlighted that other factors, such as top-down forcing from heavy exploitation and increased predation, have grown in importance. In recent years there has been a general trend of improvements in the exploitable biomass associated with substantially decreased fisheries exploitation rates.

The regulating effect of predation is thought to be most important on small-sized to intermediate-sized Snow Crab (Chabot et al. 2008); thus, a delay would be expected between decreases in the predation mortality index and recruitment into the exploitable biomass. The predation mortality index remained among the highest in recent years; however, there have been declines from the peaks of 2016–18. The predation mortality index is applied at the Ecosystem Production Unit (EPU) level and has remained generally high within the 2J3K and 3LNO time series and remained lower in the 3Ps time series. Predation mortality rates have been higher in 2J3K than 3LNO and 3Ps (DFO 2022).

With respect to overall ecosystem productivity, ecosystem conditions in the NL bioregion remain indicative of a low productivity state. Total fish biomass levels remain much lower than prior to the finfish collapse in the early-1990s; however, some ecosystem indicators (e.g., biomass trends and stomach content weights) appear to be improving in the most recent years for which data is available. Increased nutrient availability and phytoplankton biomass, along with high zooplankton abundance, including large, energy-rich *Calanus* copepods, are indicative of improved productivity at the lower trophic levels in recent years. This has the potential for positive impacts on the energy-transfer to higher trophic levels and overall ecosystem productivity.

Analyses of aggregate fishing pressure (i.e., all fisheries combined) at the ecosystem level in relation to ecosystem productivity in 2J3K and 3LNO indicate these ecosystem units have experienced significant levels of ecosystem overfishing in the past (pre-collapse), but since the mid-2000s, fisheries exploitation has remained below the level that indicates a high risk of ecosystem overfishing.

Outlook

The overall exploitable biomass index for NL Snow Crab increased from historic lows in 2016–18 and remained around the same level in 2023 as that observed in 2022. There are signs in both the trawl and trap surveys that the overall stock is starting to decline. There were indications that reductions in fishing mortality and several ecosystem-related factors, including cool bottom water temperatures from 2012–17, may have encouraged the recent growth seen in the exploitable biomass. However, since 2017, there has been an overall trend towards warmer, potentially less favourable environmental conditions for future resource productivity. While the overall stock status remains relatively stable, lower levels of pre-recruit and small Snow Crab, as well as model predictions of exploitable biomass based on climate variables, indicate that resource growth may be limited in the short-term.

Precautionary Approach

In 2018, DFO Science held a CSAS Regional Peer Review process to develop a PA Framework for Snow Crab in the NL Region. The PA Framework for the NL Snow Crab resource and fishery is based on three key metrics of stock health:

1. predicted CPUE (pCPUE);

2. predicted discards (pDiscards); and
3. proportion of females with full egg clutches (Mullowney et al. 2018b).

Using generalized additive models that incorporate a variety of available data sources, the framework projects forward one year anticipated fishery CPUE and discard rates. The three metrics of stock health are incorporated into one stock health score using a decision-making rule that weights and scores the metrics (Figure 14; Figure 15).

Zone	Egg Clutch	pDiscards	pCPUE
Healthy	1	2	4
Cautious	0.5	1	2
Critical	0	0	0

Zone	Points
Healthy	5.5 to 7
Cautious	2.5 to 5
Critical	0 to 2

Figure 14. Decision-making rule for Snow Crab PA Framework.

In 2024, all ADs are projected to remain in the Healthy Zone under the PA Framework, except AD 2HJ which is projected to remain in the Cautious Zone (Figure 15). These projections assume status quo landings. Recent and ongoing data deficiencies result in the exclusion of AD 4R3Pn from the PA Framework.

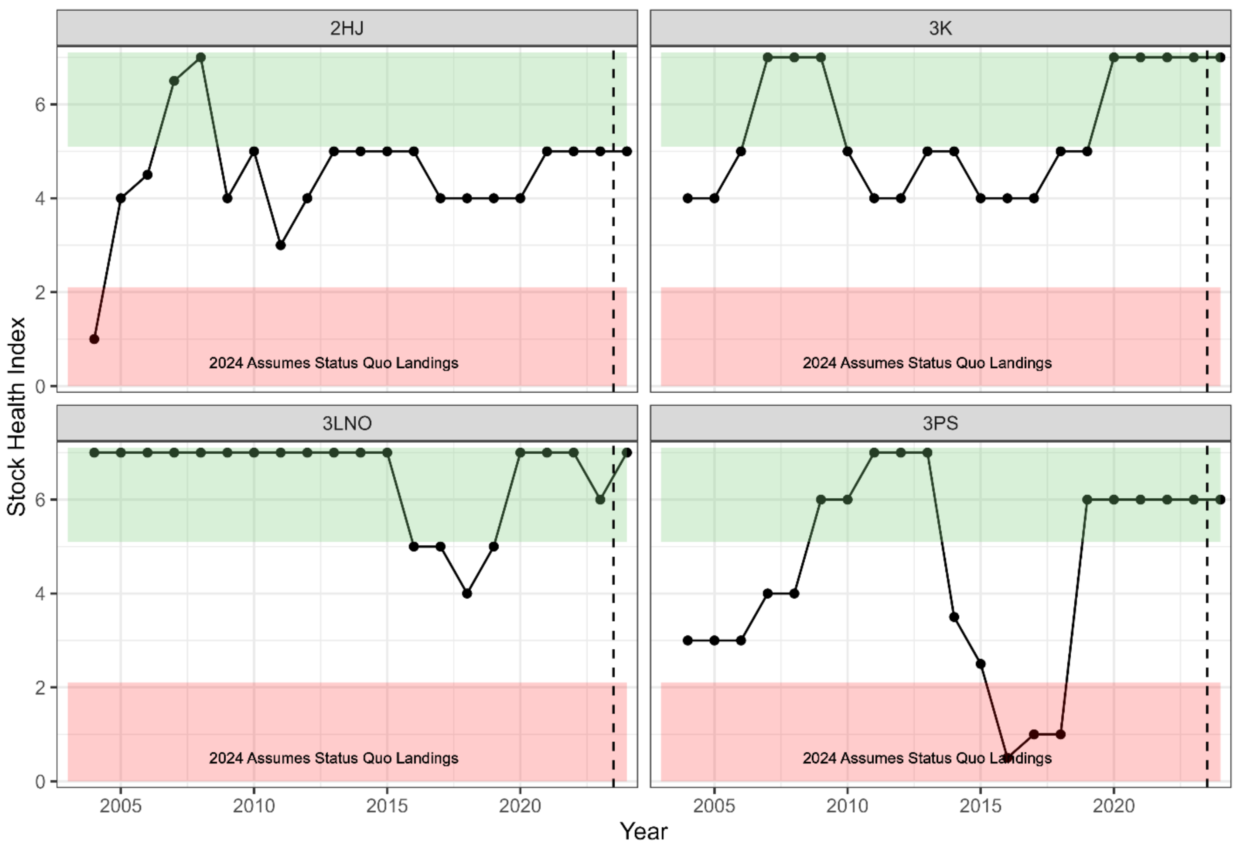

Figure 15. Projected stock status (black point) by AD in the NL Snow Crab PA Framework from 2004–24, assuming status quo landings. The green, white, and red shaded areas represent the Healthy, Cautious, and Critical Zones, respectively. The vertical dashed line denotes 2024.

Sources of Uncertainty

There are several sources of uncertainty influencing the interpretation of trends that represent the basis of this assessment.

Surveys

Interpretation of trends in exploitable biomass and pre-recruit indices from surveys is highly uncertain when surveys are incomplete. There have been issues with completion, and therefore patchy spatial coverage, of the CPS trap survey in certain years, as well as reduced coverage or cancelled (in the case of 2021 and 2022 to focus on comparative fishing) trawl surveys in recent years.

The conversion factors for Snow Crab data from the trawl surveys conducted by the *CCGS Teleost* and *CCGS Alfred Needler* included uncertainty estimates that were not considered in the current assessment. As well, the majority of the sampling used to determine conversion factors for the *CCGS Alfred Needler* series in Divs. 3KL, which was extended into Divs. 3NO, was conducted in Div. 3K and any uncertainty associated with this cannot be directly quantified.

Crab movements across divisional boundaries may affect survey indices, resulting in uncertainties in distributions and the extent to which modes of growth progression can be followed from one year to the next. In the 2019 Snow Crab assessment, there was evidence presented of a large redistribution of exploitable Snow Crab out of AD 3K and into AD 2HJ during the previous year and back into AD 3K the following year (Baker et al. 2021). Such issues have the potential to greatly affect stock status interpretations at small spatial scales, such as the CMAs used to manage the fishery.

Short-Term Recruitment

Predicting recruitment is complicated by variations in the proportion of pre-recruits that molt in any given year. Molt frequency is inversely related to body size and directly related to temperature, such that growth is slower under cold regimes (e.g., Divs. 3LNOPs) than under warm regimes (e.g., Divs. 2J3K4R). Molt frequency is also affected by density of large males, with terminal molt at small sizes more common at lower densities (Mullowney and Baker 2021).

Fishery Indices

Completion and timely return of logbooks is mandatory in this fishery. Data for the current year is typically incomplete at the time of the assessment and therefore the associated CPUE and effort values are potentially biased and considered preliminary. In most years, the logbooks account for between 80–95% of the landings at the time of the assessment in all ADs, except AD 4R3Pn which typically has lower returns. The reliability of the logbook data can be suspect with respect to effort (i.e., under-reporting) and areas fished. However, logbook data provide the broadest coverage and therefore the most representative fishery performance index.

There is uncertainty regarding the effects of changes in some fishing practices (e.g., location, seasonality, soak time, trap mesh size, high-grading, artificial lighting, and bait efficiency) on commercial catch rates and their interpretation as indicators of trends in exploitable biomass. Some of these changes (e.g., in mesh size and soak time) also affect catch rates of undersized Snow Crab and can compromise the utility of these data as an index of future recruitment. Fishery catch rates are standardized in a mixed model incorporating fishing day and soak time to account for potential inaccuracies, but other factors remain that can potentially bias their utility as indices of fisheries performance. Fishery CPUE is also characterized by both a lag in response to changes in stock size and an asymptotic curve, indicative of trap saturation that affects its ability to measure exploitable biomass.

There are concerns regarding the utility of ASO data from at-sea sampling during the fishery due to low and inconsistent spatiotemporal coverage. There is concern that current coverage introduces bias in interpreting trends in catch rates at broad spatial scales and introduces high uncertainty in interpreting indices of biomass, recruitment, and mortality. ASO-based indices are also biased by inconsistent sampling methods and levels resulting from changing priorities. There are also concerns related to variability in experience of ASOs in subjectively assigning shell stages. Measures should be taken to ensure representative ASO coverage to improve data quality from this program.

The use of fishery catch rate DeLury depletion models to adjust survey-based exploitable biomass estimates requires depletion of a resource, as well as similar coverage by the fishery and the survey. Years with no depletion during the fishery cannot be used for calculating the depletion catchability scalars and are omitted. In the previous assessment, the potential effects of a constricting fishery in recent years, particularly in ADs 2HJ, 3K, and 3Ps, on the efficacy of DeLury depletion models was highlighted. There was low depletion-based biomass estimates associated with increasing divergence between the fishery and the survey footprints, which plausibly reflects localized depletion by the fishery in some areas and negligible depletion of the resource in areas no longer being fished. This was corrected by scaling the trap survey to the trawl survey in these ADs of concern; however, close examination of effects of this ongoing fishery contraction on time series catchability scalars is required in future assessments.

CONCLUSIONS AND ADVICE

Assessment Division 2HJ

Exploitable biomass indices (i.e., trawl and trap) have remained low for many years; however, there were slight increases in these indices in the last two years. Both trawl and trap surveys indicate that immediate recruitment (i.e., new-shelled exploitable Snow Crab) did not change between 2022 and 2023, with the increase in exploitable Snow Crab in 2023 attributable to residual Snow Crab. The ERI has been high throughout most of the time series relative to other ADs within NL, as well as other fished Snow Crab stocks globally. However, the ERI has decreased in recent years to a more moderate level and under status quo removals in 2024 it is projected to continue to decrease. Following the PA Framework, with status quo removals the stock status is projected to remain in the Cautious Zone in 2024. Catch rates of pre-recruit Snow Crab have been low in the last couple years, although there was a slight increase in catch rates in the trap surveys in 2023.

Assessment Division 3K

Exploitable biomass indices (i.e., trawl and trap) increased to high levels in recent years; however, declined significantly over the last two years. Both trawl and trap surveys indicate a decrease in immediate recruitment in 2023. The ERI has been high throughout most of the time series relative to other ADs within NL, as well as other fished Snow Crab stocks globally, but has been at a much lower level since 2020. The ERI remained at a similar level in 2023 as that observed 2022; however, under status quo removals in 2024 the ERI is projected to increase to a high level of 42%. This is the maximum ERI permitted in the Healthy Zone of the PA Framework. Following the PA Framework, with status quo removals the stock status is projected to remain in the Healthy Zone in 2024. Catch rates of pre-recruit Snow Crab have decreased in the last three years; particularly, in the trawl time series.

Assessment Division 3LNO

Former ADs 3L Inshore and 3LNO Offshore were combined into one Assessment Division based on revised models for trap and trawl surveys at the 2024 stock assessment. Exploitable biomass indices (i.e., trawl and trap) have increased in recent years, but remained near similar levels from 2022 to 2023. The trap survey was incomplete in this AD in 2023; however, the data collected indicate overall immediate recruitment likely remained unchanged or increased. The ERI remained at similar levels from 2022 to 2023. Following the PA Framework, with status quo removals the stock status is projected to remain in the Healthy Zone in 2024. Catch rates of pre-recruit Snow Crab have decreased in the last year in both the trawl and trap surveys.

Assessment Division 3Ps

Exploitable biomass indices (i.e., trawl and trap) have increased to high levels in recent years, but remained near similar levels from 2022 to 2023. Neither the trawl nor trap survey had complete coverage in this AD in 2023; however, the data collected indicate a possible decrease in immediate recruitment in 2023. The ERI remained at similar levels from 2022 to 2023. Following the PA Framework, with status quo removals the stock status is projected to remain in the Healthy Zone in 2024. Catch rates of pre-recruit Snow Crab have decreased in the last three years in both the trawl and trap surveys.

Assessment Division 4R3Pn

The trap-based exploitable biomass index has increased in recent years, but remained near a similar level from 2022 to 2023. There has been a decrease in immediate recruitment in the trap survey in the last two years. The ERI has been variable and at a high level in this AD and is projected to remain high with status quo removals in 2024. Catch rates of pre-recruits has been variable in the short time series; however, there was an increase in catches of these Snow Crab in 2023. Completion of the trap survey outside the major fishing areas has been poor; therefore, determining stock status for the entire AD is more uncertain. Recent and ongoing data deficiencies result in the exclusion of AD 4R3Pn from the PA Framework.

OTHER CONSIDERATIONS

Bitter Crab Disease

Bitter Crab Disease (BCD) is fatal and predominately occurs in small, new-shelled Snow Crab of both sexes (Mullowney et al. 2011). It appears to be acquired during molting and can be detected visually in the fall. The prevalence and distribution of BCD appears related to circulation features (Dawe et al. 2010b) and the density of small Snow Crab (Mullowney et al. 2011). Bitter Crab Disease is observed in the trawl survey most often in AD 3K. There were higher incidences of BCD in sub-legal-sized Snow Crab in AD 3K in 2021 and 2023 (no data for 2022) than had been seen in the few years prior. Bitter Crab Disease had been unusually high in large males in AD 3K from 2016–18; however, there have been no large males observed with BCD since then.

Reproductive Biology

The percentage of mature females carrying full clutches of viable eggs has generally remained high throughout the time series wherever measured, but localized declines in heavily fished areas have been observed in the time series. Fishery-induced mortality of mature males, including undersized males, could adversely affect insemination of females in the presence of high exploitation. A study is currently investigating the presence of sperm limitation in females associated with high exploitation rates of males in some areas in recent years.

Management Considerations

In an aim to protect reproductive potential, conservation measures exclude females and males less than 95 mm CW, including a portion of adult (large-clawed) males, from the fishery. Nevertheless, it remains unclear how the persistence of a low exploitable biomass in areas such as AD 2HJ may impact reproductive potential at either localized or broad spatial scales (e.g., sperm limitation and reduced post-molt guarding of females in association with downstream connectivity).

Fishery-induced mortality of non-exploitable Snow Crab could possibly impair future recruitment. Pre-recruit mortality is reduced by avoidance in the fishery and, when encountered, careful handling and quick release of pre-recruits. Mortality of sub-legal-sized males, including adolescent pre-recruits, can also be reduced by increasing trap mesh size and soak time, as well as trap modifications such as escape mechanisms. Such initiatives reportedly have increasingly been implemented in recent years.

Prevalence of soft-shelled, legal-sized males in the fishery is affected by fishery timing and exploitable biomass level (Mullowney et al. 2021). Mortality of soft-shelled males can be minimized by fishing early in spring before recently-molted crab are capable of climbing into traps. It may be further reduced by maintaining a relatively high exploitable biomass level; thereby, maintaining strong competition for baited traps and low catchability of less-competitive soft-shelled immediate pre-recruits.

Among other uses, the ASO program forms the basis of the soft-shell protocol, which was introduced in 2005 to protect soft-shelled immediate pre-recruits from handling mortality. It closes localized areas (i.e., 70 nm^2 grids in the offshore and 18 nm^2 grids in inshore areas of ADs 3LNO, 3K, 3Ps, and 4R3Pn) for the remainder of the season when a threshold level of 20% (or 15% in some areas) of the legal-sized catch is soft-shelled. It became evident during 2010–12 that this protocol, as implemented, is inappropriate and ineffectual in controlling handling mortality. This is largely due to very low ASO coverage, paired with the decision to treat unobserved grids as not impacted. In addition, failure to draw all possible inferences from moderate-sized samples frequently resulted in failure to invoke the protocol even when it was clear that the level of soft-shelled Snow Crab had exceeded the threshold. An analysis at the 2019 Snow Crab stock assessment (DFO 2020) showed that a high proportion of cells had no ability to invoke closure due to complete absence of ASO coverage in a given year. This was further compounded by low sample sizes prohibiting adherence to closure thresholds when ASO coverage was present. These shortcomings undermine the intent of the protocol. Measures should be taken to ensure adequate and representative ASO coverage, as well as adjust sample size thresholds to better quantify prevalence of soft-shelled Snow Crab in the fishery and therefore afford better protection to recruitment.

The CPS trap survey is one of the primary data sources used to assess the resource. It operates under a compensation scenario of ‘quota-for-survey’ whereby harvesters are allocated additional quota in the following season in exchange for conducting the survey. However, due to resource shortages and the perception that additional quota would not be catchable, and therefore would not meet the costs of conducting the survey, the survey was abandoned in some areas in past years. In the future, under the scenario of low exploitable biomass in any given AD or low market price, there are concerns the integrity of this survey could further deteriorate. This survey is of great benefit to the stock assessment; therefore, deployment and sampling schemes should be strictly followed moving forward.

Snow Crab in NL are part of a larger genetic stock unit in Canadian Atlantic waters, ranging from southern Labrador to the Scotian Shelf (Puebla et al. 2008). The NL Snow Crab resource is assessed at the AD level, but managed at the spatially smaller CMA level. To both assess and manage a natural resource at scales that do not conform to biologically meaningful units increases the likelihood of providing inaccurate advice and making decisions based on sub-optimal information. The probability of accurately and precisely forecasting stock health separately in the numerous CMAs in a given year is relatively low; particularly, considering transboundary movements.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Karen Dwyer	DFO-NL – Science
Julia Pantin	DFO-NL – Science
Eugene Lee	DFO-NL – Centre for Science Advice
Robert Deering	DFO-NL – Centre for Science Advice
David Small	DFO-NL – Resource Management
Kelly Dooley	DFO-NL – Resource Management
Laurie Hawkins	DFO-NL – Resource Management
Mark Simms	DFO-NL – Resource Management
Martin Henri	DFO-NL – Resource Management
Aaron Adamack	DFO-NL – Science
Bruce Wells	DFO-NL – Science
Charmain Hamilton	DFO-NL – Science
Chelsea Malayny	DFO-NL – Science
Darrell Mullowney	DFO-NL – Science
David Belanger	DFO-NL – Science
Elizabeth Coughlan	DFO-NL – Science
Erika Parrill	DFO-NL – Science
Frédéric Cyr	DFO-NL – Science
Hannah Munro	DFO-NL – Science
Jonathan Coyne	DFO-NL – Science
Kate Charmley	DFO-NL – Science
Katherine Skanes	DFO-NL – Science
Katie Morrissey	DFO-NL – Science
Kayla Silver	DFO-NL – Science
Krista Baker	DFO-NL – Science
Kyle Lefort	DFO-NL – Science
Laura Wheeland	DFO-NL – Science
Mariano Koen-Alonso	DFO-NL – Science
Michael Hurley	DFO-NL – Science
Morgan Simms	DFO-NL – Science
Nicolas Le Corre	DFO-NL – Science
Pierre Pepin	DFO-NL – Science

Name	Affiliation
Rachel Morrison	DFO-NL – Science
Samantha Trueman	DFO-NL – Science
Semra Yalcin	DFO-NL – Science
Will Coffey	DFO-NL – Science
Melissa Olmstead	DFO-NCR – Science
Bill Dennis	Fisheries, Forestry and Agriculture NL
Craig Taylor	Torngat Wildlife, Plants & Fisheries Secretariat
Rob Coombs	Nunatukavut Community Council
April Wiseman	Fish, Food and Allied Workers Union
Chad Waterman	Fish, Food and Allied Workers Union
Dwight Russel	Fish, Food and Allied Workers Union
Erin Carruthers	Fish, Food and Allied Workers Union
Jamie Barnett	Fish, Food and Allied Workers Union
Robbie Green	Fish, Food and Allied Workers Union
Trevor Jones	Fish, Food and Allied Workers Union
Renae Butler	Association of Seafood Producers
Keith Watts	Torngat Fish Coop
Raquel Ruiz-Diaz	Memorial University – Marine Institute
Shannon Bayse	Memorial University – Marine Institute
Tyler Eddy	Memorial University – Marine Institute
Fabian Zimmerman	Institute of Marine Research - Norway

SOURCES OF INFORMATION

Anderson, S.C., Ward, E.J., English, P.A., and Barnett, L.A. 2022. sdmTMB: An R Package for fast, Flexible, And User-Friendly Generalized Linear Mixed Effects Models with Spatial and Spatiotemporal Random Fields. bioRxiv.

Baker, K., Mullowney, D., Pedersen, E., Coffey, W., Cyr, F., and Belanger, D. 2021. An Assessment of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) in 2018. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/028. viii + 180 p.

Buren, A.D., Koen-Alonso, M., Pepin, P., Mowbray, F., Nakashima, B., Stenson, G., Ollerhead, N., and Montevecchi, W.A. 2014. Bottom-Up Regulation of Capelin, a Keystone Forage Species. PLoS ONE. 9(2): e87589.

Chabot, D., Sainte-Marie, B., Briand, K., and Hanson, J.M. 2008. Atlantic cod and snow crab predator–prey size relationship in the Gulf of St. Lawrence, Canada. Mar. Ecol. Prog. Ser. 363: 227–240.

Cyr, F. and Galbraith, P. 2020. Newfoundland and Labrador climate index. Federated Research Data Repository.

Cyr, F., Snook, S., Bishop, C., Galbraith, P.S., Chen, N., and Han, G. 2022. Physical Oceanographic Conditions on the Newfoundland and Labrador Shelf during 2021. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/040. iv + 48 p.

Dawe, E.G., Parsons, D.G., and Colbourne, E.B. 2008. Relationships of sea ice extent and bottom water temperature with abundance of snow crab (*Chionoecetes opilio*) on the Newfoundland - Labrador Shelf. ICES CM 2008/B:02. 18 p.

Dawe, E.G., Walsh, S.J., and Hynick, E.M. 2010a. Capture efficiency of a multi-species survey trawl for Snow Crab (*Chionoecetes opilio*) in the Newfoundland region. Fish. Res. 101(1–2): 70–79.

Dawe, E.G., Mullowney, D.R., Colbourne, E.B., Han, G., Morado, J.F., and Cawthorn, R. 2010b. Relationship of Oceanographic Variability with Distribution and Prevalence of Bitter Crab Syndrome in Snow Crab (*Chionoecetes opilio*) on the Newfoundland-Labrador Shelf. *In*: Biology and Management of Exploited Crab Populations under Climate Change. Edited by G.H. Kruse, G.L. Eckert, R.J. Foy, R.N. Lipcius, B. Sainte-Marie, D.L. Stram, and D. Woodby. Alaska Sea Grant, University of Alaska. Fairbanks. 175–198.

Dawe, E.G., Mullowney, D.R., Moriyasu, M., and Wade, E. 2012. Effects of temperature on size-at-terminal molt and molting frequency in Snow Crab *Chionoecetes opilio* from two Canadian Atlantic ecosystems. Mar. Ecol. Prog. Ser. 469: 279–296.

DFO. 2020. Proceedings of the Newfoundland and Labrador Regional Peer Review of the 4R Iceland Scallop Assessment, and the 2HJ3KLNOP4R Snow Crab Assessment; February 19-21, 2019. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2020/003.

DFO. 2022. Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/054.

DFO. 2024. Newfoundland & Labrador Comparative Fishing Analysis – Part 1. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/002. (Erratum: August 2024).

Evans, G.T., Parsons, D.G., Veitch, P.J., and Orr, D.C. 2000. A Local-influence Method of Estimating Biomass from Trawl Surveys, with Monte Carlo Confidence Intervals. J. Northw. Atl. Fish. Sci. 27: 133–138.

Fonseca, D.B., Sainte-Marie, B., and Hazel, F. 2008. Longevity and Change in Shell Condition of Adult Male Snow Crab *Chionoecetes opilio* Inferred from Dactyl Wear and Mark-Recapture Data. Trans. Am. Fish. Soc. 137(4): 1029–1043.

Foyle, T.P., O'Dor, R.K., and Elner, R.W. 1989. Energetically Defining the Thermal Limits of the Snow Crab. J. Exp. Biol. 145(1): 371–393.

Marcello, L.A., Mueter, F.J., Dawe, E.G., and Moriyasu, M. 2012. Effects of temperature and gadid predation on snow crab recruitment: comparisons between the Bering Sea and Atlantic Canada. Mar. Ecol. Prog. Ser. 469: 249–261.

Mullowney, D.R., Dawe, E.G., Morado, J.F., and Cawthorn, R.J. 2011. Sources of variability in prevalence and distribution of bitter crab disease in snow crab (*Chionoecetes opilio*) along the northeast coast of Newfoundland. ICES J. Mar. Sci. 68(3): 463–471.

Mullowney, D.R.J., Dawe, E.G., Colbourne, E.B., and Rose, G.A. 2014. A review of factors contributing to the decline of Newfoundland and Labrador snow crab (*Chionoecetes opilio*). Rev. Fish Biol. Fish. 24: 639–657.

Mullowney, D., Morris, C., Dawe, E., Zagorsky, I., and Goryanina, S. 2018a. Dynamics of snow crab (*Chionoecetes opilio*) movement and migration along the Newfoundland and Labrador and Eastern Barents Sea continental shelves. Rev. Fish Biol. Fish. 28: 435–459.

Mullowney, D., Baker, K., Pedersen, E., and Osborne, D. 2018b. Basis for A Precautionary Approach and Decision Making Framework for the Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) Fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/054. iv + 66 p.

Mullowney, D.R.J. and Baker, K.D. 2021. Size-at-maturity shift in a male-only fishery: factors affecting molt-type outcomes in Newfoundland and Labrador snow crab (*Chionoecetes opilio*). ICES J. Mar. Sci. 78(2): 516–533.

Mullowney, D.R.J., Baker, K.D., and Pantin, J.R. 2021. Hard to Manage? Dynamics of Soft-Shell Crab in the Newfoundland and Labrador Snow Crab Fishery. Front. Mar. Sci. 8:591496.

Mullowney, D.R.J., Baker, K.D., Szuwalski, C.S., Boudreau, S.A., Cyr, F. and Kaiser, B.A. 2023a. Sub-Arctic no more: Short- and long-term global-scale prospects for snow crab (*Chionoecetes opilio*) under global warming. PLOS Clim. 2(10): e0000294.

Mullowney, D., O’Connell, N., Kilada, R., and Rochette, R. 2023b. Refining age at legal-size estimation in the Newfoundland & Labrador populations of the snow crab *Chionoecetes opilio* (Fabricius, 1788) (Decapoda: Brachyura: Oregoniidae). J. Crustacean Biol. 43(4): 1–14.

Puebla, O., Sévigny, J.-M., Sainte-Marie, B., Brêthes, J.-C., Burmeister, A., Dawe, E.G., and Moriyasu, M. 2008. Population genetic structure of the snow crab (*Chionoecetes opilio*) at the Northwest Atlantic scale. Can. J. Fish. Aquat. Sci. 65(3): 425–436.

Wheeland, L., Skanes, K., and Trueman, S. 2024. Summary of Comparative Fishing Data Collected in Newfoundland & Labrador from 2021 - 2022. Can. Tech. Rep. Fish. Aquat. Sci. 3579: iv + 132 p.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Newfoundland and Labrador Region
Fisheries and Oceans Canada
PO Box 5667
St. John’s, NL A1C 5X1

E-Mail: DFONLCentreforScienceAdvice@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-77769-6 Cat. No. Fs70-6/2025-031E-PDF

Correct Citation for this Publication:

DFO. 2025. Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow Crab in 2023. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2025/031.

Aussi disponible en français :

MPO. 2025. Évaluation du crabe des neiges de Terre-Neuve-et-Labrador en 2023 (divisions 2HJ3KLNOP4R). Secr. can. des avis sci. du MPO. Avis sci. 2025/031.