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Assessment of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) in 2024

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The status of the Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) resource (Northwest Atlantic Fisheries Organization [NAFO] Divs. 2HJ3KLNOP4R) is assessed using a variety of metrics. The resource is assessed at large-scale Assessment Divisions (ADs), which are comprised of combinations of NAFO Divisions or Subdivisions. Resource status was evaluated based on trends in survey exploitable (≥ 95 mm carapace width male Snow Crab) biomass index, fishery CPUE, fishery recruitment prospects, and mortality indices. Information was derived from multiple sources: multispecies bottom trawl surveys conducted during the fall in ADs 2HJ, 3K, and 3LNO and in the spring in AD 3Ps, two collaborative trap surveys covering all ADs, DFO (Fisheries and Oceans Canada) inshore trap surveys in ADs 3K, 3LNO, and 3Ps, fishery data from logbooks, landings from the dockside monitoring program, at-sea observer fishery data, and oceanographic surveys. Snow Crab 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 increased since then to over 56,000 t in 2024 and overall effort increased to near 3.9 million trap hauls. Standardized fishery CPUE was at a time-series low in 2018 but has increased since then and oscillated around 12–13 kg/trap for the last four years. The overall exploitable biomass index has increased from historic lows in 2015–17, and in 2024 it remained near the same level as 2023. There have been declines in the exploitable biomass indices in ADs 3K and 3Ps over the last two years. Fishery Exploitation Rate Indices (ERIs) decreased in most ADs in recent years. However, status quo landings in 2025 would result in ERIs outside the range permitted in the PA Framework in ADs 3K and 3Ps and ERIs are high in AD 4R3Pn. Overall abundance indices of pre-recruit crab, small males, and mature females have declined and are near the lowest levels observed. The overall pre-recruit abundance index indicates poor recruitment prospects in the next 2–4 years, and model predictions of exploitable biomass based on climate variables indicate that resource growth may be limited in the short-term. In 2025, ADs 3LNO and 3Ps are projected to remain in the Healthy Zone of the Precautionary Approach (PA) Framework, while ADs 2HJ and 3K are projected to be in the Cautious Zone. These projections assume status quo landings. Recent and ongoing data deficiencies resulted in the exclusion of AD 4R3Pn from the PA Framework.

INTRODUCTION

This document assesses the status of the Newfoundland and Labrador (NL) Snow Crab (*Chionoecetes opilio*) resource in Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) 2HJ3KLNOP4R (Figure 1, Figure 2). The information presented follows from a formal scientific assessment and Regional Peer Review process conducted during February 2025.

SPECIES BIOLOGY

Snow Crab are sexually dimorphic, with mature males normally achieving larger sizes than females. The Snow Crab life cycle features a spring hatching followed by a planktonic larval period that involves several stages before settlement. Small benthic stages of both sexes molt multiple times annually, but molt frequency slows as crab grow (Comeau et al. 1998). Females cease molting during their ninth or tenth molt at the same time that sexual maturity is achieved at approximately 40–75 mm carapace width (CW) (Alunno-Bruscia and Sainte-Marie 1998). Males enter puberty at their eighth or ninth molt and, during this sexually mature adolescent stage, will generally continue to molt near-annually until their terminal molt, when they develop enlarged claws (becoming adults) that likely enhance their competitive ability in mating. Males can molt to adulthood at any size greater than approximately 40 mm CW, but terminal molt typically occurs after 10 to 13 molts over a size range spanning about 55–135 mm CW (Sainte-Marie et al. 1995).

The minimum legal size in the NL Snow Crab fishery is 95 mm CW and therefore females and a portion of adult males are excluded from the fishery and remain available for reproduction. Age determination methods remain exploratory and at-present male Snow Crab are believed to recruit to the fishery at 9–13 years of age across the stock range, with the majority of legal-sized Snow Crab being 9–11 years of age (Mullowney et al. 2023b). Skip-molting, when a crab does not undergo a molt in a given year, delays when a crab recruits to the fishery. It 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). Adult legal-sized males remain soft- or new-shelled with less-than-full meat yield for almost a year following their terminal molt and are not likely to efficiently contribute to the fishery (i.e., render maximum meat yield) until the following year when their shells are fully hardened and are full of meat. Crab are commonly believed to be more susceptible to handling and discard mortality when in this soft-shell condition. Males may live a maximum of six to eight years as adults after their terminal molt (Fonseca et al. 2008), but such prolonged longevity is uncommon in the presence of commercial fisheries.

Snow Crab typically inhabit a narrow range of temperatures and variation in temperature has a profound effect on production, early survival, and subsequent recruitment to the fishery (Foyle et al. 1989; Dawe et al. 2008; Marcello et al. 2012). Cold conditions during early to mid-ontogeny are associated with increased survey biomass and fishery catch per unit effort (CPUE) indices several years later (Marcello et al. 2012; Baker et al. 2021). While growth rates are positively affected by temperature, with overall higher molt frequency and molt increments occurring in warm conditions, the overriding positive benefits of cold water on early to mid-life stages appears stronger than the dampening effects on growth rates, with highest productivity occurring in cold areas.

Historically, the most productive fisheries have been associated with intermediate-depths and slope edges of offshore banks and inshore bays, which generally have cold bottom temperatures (Baker et al. 2021; Cyr et al. 2024). Snow Crab typically undertake ontogenetic movements from shallow cold areas with hard substrates during early ontogeny to warmer deep areas featuring softer substrates as they grow (Mullowney et al. 2018a). The largest males are most commonly distributed on mud or mud/sand, while small Snow Crab are more common on harder substrates. Some Snow Crab also undertake an upslope migration in winter or spring for mating and/or molting (Mullowney et al. 2018a).

Snow Crab diet includes fish, clams, polychaete worms, brittle stars, shrimp, Snow Crab, and other crustaceans (Squires and Dawe 2003). Predators of Snow Crab include various groundfish, seals, and other Snow Crab.

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). However, large-scale movements of individuals within the stock are thought to be limited, therefore assessments are conducted at the Assessment Division (AD) level, where some NAFO Divisions are combined (Figure 1). Accordingly, ADs differ from both NAFO Divisions and the small spatial scale Crab Management Areas (CMAs) used to manage the fishery. The spatial scale of the assessment approach accommodates different types and amounts of available information among ADs and better conforms with broad-scale resource status indicators than the CMAs, which have no biological basis. While the assessment does not consider processes at the CMA level, partition by CMA is of utility and interest to managers and industry; therefore, some CMA-level results are included in the Appendices. 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. This highlights the difficulties in assessing a stock based on delineations (ADs and CMAs) that are not set based on biological criteria as much as resource management considerations. Particle drift simulations by Dawe et al. (2010b) highlighted the importance of circulation patterns in regulating the distribution of larval crab and pathogens. Particle release from various locations off the Labrador Shelf slope showed different patterns in resulting southern distribution in conjunction with the Labrador Current, emphasizing connectivity processes in this ecosystem. With respect to Snow Crab, this may suggest a disconnect between management (CMA), assessment (AD), and biological scales.

FISHERY

The NL Snow Crab fishery began in Trinity Bay (CMA 6A) in 1967. 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 Divs. 3KL. Until the early 1980s, the fishery was prosecuted by approximately 50 vessels limited to 800 traps each. In 1981, fishing became restricted to the NAFO Division adjacent to where the license holder resided. The fishery expanded throughout all areas of the province from the 1970s–2000s, especially following groundfish stock and fishery collapses in the early 1990s. Between 1982 and 1987, there were major declines in the Snow Crab resource in traditional areas in Divs. 3K and 3L, while new fisheries started in Div. 2J, Subdiv. 3Ps, and offshore Div. 3K. A Snow Crab fishery began in Div. 4R in 1993. Management of the increasingly diverse and complex fishery during the expansion years led to progressive development and refinement of the many quota-controlled areas (CMAs), with approximately 3,500 active license holders representing various vessel-size fleet sectors participating in the fishery in the mid-2000s. Resource declines and rationalization measures have led to reduced participation during the past two decades. The fishery was prosecuted by approximately 2,200 license holders representing three dominant fleet sectors defined by vessel length in 2024.

The fishery typically spans from the fringes of the Makkovik Bank off central Labrador in the north to the far offshore slope edges of the Grand Bank in Divs. 3LNO in the south, to near the border of Québec in the westernmost portions of Div. 4R. The AD 2HJ fishery occurs in offshore regions of central and southern Labrador (Figure 1) where the bathymetry is characterized by a series of shallow water offshore banks separated by deep channels (Figure 2). The bottom water temperature in the two dominant fishing grounds in these channels is warmer than the surrounding shallow banks. The AD 3K fishery occurs off the northeast coast of Newfoundland, predominantly within a network of deep trenches located between nearshore shallow water plateaus and the Funk Island Bank in the offshore (i.e., St. Anthony Basin and Funk Island Deep) (Figure 2). Bottom temperatures are cooler in the shallow nearshore areas and on the Funk Island Bank and warmer in the Funk Island Deep area. The AD 3LNO fishery occurs in coastal bays and near-to-shore regions off the east coast of Newfoundland and offshore on and surrounding the Grand Bank off Newfoundland's southeast coast (Figure 2). This is a massive, shallow, cold, and productive environment for Snow Crab. Virtually the entire AD consists of cold bottom temperatures, with the exception of the southwest slope of the bank which is affected by the Gulf Stream current, as well as the deepest peripheries of the slope edges surrounding the bank. The AD 3Ps fishery occurs off the south coast of Newfoundland (Figure 1). Relative to other ADs along the NL continental shelves, AD 3Ps is shallow. The shallow areas of the AD, where the bulk of the fishery occurs, are cold, but temperatures increase abruptly at the slope edges. The AD 4R3Pn fishery occurs along the west and southwest coasts of Newfoundland in and adjacent to the Gulf of St. Lawrence (Figure 1). The bathymetry off the west coast is characterized by a shallow water nearshore plateau that borders the deep Esquiman Channel, while the bathymetry off the south coast is characterized by the presence of the Burgeo Bank (Figure 2). Bottom temperatures in this AD are the warmest along the NL Shelf.

In the late 1980s, quota control was initiated in all CMAs of each NAFO Division. Current management measures include trap limits, individual quotas, spatial and temporal closures within divisions, and differing seasons. Annual management decisions are made following a consultation and recommendation process with harvester groups and other industry stakeholders. Mandatory use of the electronic vessel monitoring system was fully implemented in mid-shore and offshore fleet sectors in 2004 to ensure compliance with regulations regarding area fished. The fishery is prosecuted using conical baited traps set in longlines ('fleets'), typically with a trap spacing of approximately 45 m. The minimum legal mesh size is 135 mm to allow small crab to escape. Undersized and soft-shelled crab that are captured in traps are returned to the sea, however rates of damage or discard mortality are unknown.

The fishery was traditionally prosecuted during summer and fall, but has been prosecuted during spring and summer for the last two decades. The fishery can be delayed in northern NAFO Divisions (Divs. 2HJ3K) due to ice conditions or fleet preferences in some years. The fishery can also be delayed (or extended) for other reasons, such as price disputes or difficulties in capturing quotas. Late fishing seasons are often associated with a high incidence of soft-shelled immediate pre-recruits in the catch, particularly under high fisheries exploitation rates (Mullowney et al. 2021). A soft-shell protocol for at-sea observers (ASOs) was initiated in 2004 to protect soft-shelled immediate pre-recruits from handling mortality by closing localized areas (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% soft-shell crab in the legal-sized catch is reached. That threshold has since been reduced to 15% in AD 3LNO, and grids have been partitioned into quarters in some inshore areas in recent years. While this protocol was developed with the intention of conservation, it is not effective in controlling handling mortality. The low observer coverage cannot monitor thousands of grids and there has been a failure to invoke the protocol even when it is clear that the level of soft-shelled crab has exceeded the threshold, due to small sample sizes of measurements within a given cell associated with low fishery catch rates (DFO 2020; Mullowney et al. 2020).

METHODOLOGY

FISHERY LOGBOOK DATA

Data on commercial catch (kg) and fishing effort (number of trap hauls) were obtained from vessel logbooks. These data were compiled by the Statistics Division, Policy and Economics Branch, NL Region of DFO (Fisheries and Oceans Canada). Return of complete and accurate fishing logbooks is a condition of license in this fishery. Logbook return rates are calculated as the percentage of the fishery landings accounted for in the logbook data in comparison to landings recorded by the dockside monitoring program. During the past decade, the dataset is normally most incomplete in the current assessment year (Figure 3), resulting from a time lag associated with receiving and compiling data from the most recent fishery, thus the terminal points are considered preliminary. In most years, the logbooks account for between 80 to 95% of the landings at the time of the assessment in all ADs, except 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.

Trends in the timing of the fishery over the time series were investigated by plotting the fishery start and end weeks, the median week of the fishery, and the lower and upper quantiles depicting 25 and 75% completion of the fishery. Since the logbook dataset is incomplete, annual fishing effort (number of trap hauls) within any given AD was estimated based on annual dockside monitored landings (kg) divided by unstandardized CPUE (kg/trap).

Standardized logbook CPUE (kg/trap) was calculated by year and AD, as well as by CMA. Annual fishery CPUE estimates are standardized for time and space using a linear mixed model (Eq. 1). The model regresses the response variable of square-root transformed CPUE (catch/trap haul) from individual observations (normally on a per set basis) against fixed effects of time and gear soak time. Random effects were used to model square-root CPUE: calendar day*year*AD*CMA groupings. The model has a random intercept for CMA within AD within year and a random slope for scaled day, so that the relationship between day and square-root CPUE is allowed to vary by year:AD:CMA. The AD:CMA parameter accounts for spatial variation across multiple management areas within any AD. The positively-skewed response variable was square-root transformed to normalize it, as stronger transformations such as logarithms were found to produce negatively-skewed distributions in some cases. Finally, the model is weighted by consistency of fishing (i.e., cumulative number of years fished within 10 x 10 nm cells). This model was used to predict average annual CPUE by averaging set-specific predicted values (as well as 95% lower and upper confidence estimates) for each AD and year.

Eq. 1

$$\sqrt{CPUE_{y,t,D}} = \alpha_{y,D} + \beta_{Day,y,D} \cdot Day_{y,t,D} + \beta_{Soak} \cdot Soak_{y,t,D} + \epsilon_{y,t,D}$$

$$\alpha_{y,D} \sim N(\mu, {\sigma^2}_{intercept})$$

$$\beta_{Day,y,D} \sim N(\overline{\beta_{Day}}, {\sigma^2}_{Day})$$

$$\epsilon_{y,t,D} \sim N(0, \frac{{\sigma^2}_{error}}{effort})$$

where y indicates a given year, t indicates a given day, and D indicates a given AD. α terms indicate intercepts, β terms indicate coefficients for specific covariates, the ϵ term indicates unmodelled error around predicted CPUE, and σ^2 terms indicate variances on random effects or the error term. Day represents binned five-day intervals and $Soak$ represents gear soak time measured in hours. Late season data (November and December) were omitted because of their sporadic presence in the dataset. Entries of CPUE equal to 0 were also removed because it was unclear if they represented real catch rates or other practices such as dumping traps once quotas were subscribed.

Catch per unit effort is used as an index of latent biomass, but it is recognized that it can be biased by variation in fishing practices such as soak time, trap mesh size, bait type, bait quantity, bait quality, bait jars, high-grading, gear spacing, artificial lighting, and presence or absence of escape mechanisms. Fishery CPUE is characterized by both a lag in response to changes in stock size and an asymptotic curve indicative of trap saturation which affects its ability to measure exploitable biomass. However, one factor supporting the interpretation of CPUE as an index of relative latent biomass is the consistent broad-spatial coverage of the fishery each year generated by the numerous CMAs.

Standardized annual logbook CPUEs were mapped in 10 x 10 nm cells, encompassing the entire fishery distribution each year, and used to qualitatively assess spatial fishery performance within each AD. Further, time-binned (five-day increment) CPUEs were plotted for individual ADs and CMAs within each AD for a six-year timespan to assess fishery performance over a prolonged continuous timescale. The five-day estimates were fit with least squares loess regression curves to visually depict changes occurring in the fishery over time.

AT-SEA OBSERVER DATA

At-sea sampling data have been collected by ASOs since 1999. For each trip, ASOs sampled entire catches of males for CW (mm) and shell condition for as many traps as time allowed. Overall levels of sampling have been generally highest in the offshore CMAs of AD 3LNO and consistently low in inshore CMAs. Overall, ASO coverage has decreased in recent years, particularly since 2020 (Figure 4, Figure 5). Approximately < 0.1–0.2% of the catch has been sampled by ASOs in recent years. Considering the increases in total allowable catch (TAC) during this time, this has resulted in a reduction in the percentage of landings observed. Due to low ASO coverage in certain years in some ADs, they have been excluded from analyses.

Various catch rate indices were developed from shell condition staging conducted by ASOs. A three-stage classification of shell condition is used, whereby ASOs classify crab as soft-shelled, new hard-shelled, or old hard-shelled. The total catch rate of legal-sized Snow Crab by shell condition for each AD was calculated as an index of in-season exploitable biomass from the fishery. Similarly, size frequency distributions of catch rates of male Snow Crab by shell condition and size (binned to 3-mm CW intervals) were constructed to interpret the composition of the catch. Size frequency distributions were presented and examined at both the AD and the CMA level, where data were sufficient.

Observer sampling data formed the basis for estimating fishery discards. Total discard rates as well as the percentage of the catch discarded in the fishery were examined, with undersized (< 95 mm CW) and soft-shelled crab measured during commercial fishing activities deemed to have been discarded. A generalized linear mixed model was used to standardize discard percentages. The binomial model (Eq. 2) with a logit link function regressed raw data from observations of discarded weights from individual fishing sets:

Eq. 2

$$logit\ (p_i) = \beta_0 + Day + Soak + \gamma_i$$

$$Y_i \sim binomial(n_i, p_i)$$

$$E(Y_i) = p_i \times n_i$$

$$var(Y_i) = n_i \times p_i \times (1 - p_i)$$

where Y_i is the weight of discarded Snow Crab observed in each fishing set in a particular AD, CMA, day, and year, n_i is the total number of Snow Crab observed in each fishing set in a particular AD, CMA, day, and year, p_i is percentage discarded, β_0 is the intercept, Day is the calendar day when the fishing set occurred, $Soak$ is the soak time (hours) of the fishing set, and γ_i is a random intercept for soak time in each combination of AD, CMA, and year. As per the CPUE standardization model (Eq. 1), the interacting AD:CMA term accounts for the multiple management areas within each AD.

Annual percentages of discards were related to fishery CPUE, with both indices standardized to mean = 0 and standard deviation = 1, to assess the relationship between the two variables. Bubble plots of weekly catch rates and percentages of soft-shell crab captured in the fishery were also constructed and examined for each AD. Soft-shell crab prevalence is interpreted as both an index of mortality and wastage because it is assumed that the majority of crab discarded as soft-shell die. Soft-shell prevalence can also be used to infer the relative strength of recruitment potential for forthcoming fisheries. For example, under the scenario of high catch rates of large residual crab (i.e., most competitive) and a high discard rate of soft-shell crab, it would be inferred that recruitment prospects for the forthcoming fishery are favourable. However, a high incidence of soft-shell crab in the catch during a period of low residual biomass would be indicative of wastage.

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 relating 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.

MULTISPECIES TRAWL SURVEY DATA

Data were available from DFO depth-stratified multispecies bottom trawl surveys. These surveys were conducted during fall in NAFO Divs. 2HJ3KLNO and during spring in Divs. 3LNO and Subdiv. 3Ps using a Campelen 1800 shrimp trawl. The fall trawl survey has occurred annually in all but Div. 2H where it was executed each year from 1996–99, bi-annually from 2004–08, and annually from 2010 to present. Sampling of Snow Crab during spring Subdiv. 3Ps surveys began in 1996 and in Divs. 3LNO in 1999. 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 2021–22. However, there are 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 depth-stratified.

The catchability of the survey trawl for Snow Crab is known to be low, particularly at the smallest sizes, but even at the largest sizes efficiency is below 100% (Dawe et al. 2010a). Trawl efficiency is also affected by substrate type, depth, diurnal cycle and season (Dawe et al. 2010a; Benoît and Cadigan 2013; 2014; 2016). Efficiency is lower and more variable on hard (typically shallow) substrates than on soft (typically deep) substrates (Dawe et al. 2010a), and higher during dark periods when crab appear most active (Benoît and Cadigan 2013). Based on comparative data from Divs. 3LNO, where both a spring and fall survey occur, fall trawl surveys are deemed to have a higher catchability for Snow Crab. Spring surveys are considered less reliable because some population components are believed to be relatively poorly sampled during this time, when mating and molting typically occur.

Trawl catchability can differ by vessel and gear configuration. With the retirement of the *Canadian Coast Guard Ships (CCGS) Alfred Needler* and *Teleost* and introductions of the *CCGS Capt. Jacques Cartier* and *CCGS John Cabot*, a comparative fishing program (i.e., direct side-by-side comparison between old and new vessels) was conducted from 2021–23 to determine differences in catchability due to vessel changes and associated modifications to the Campelen trawl gear. Comparative fishing success varied by year, NAFO division, and vessel combinations. Details on methodology and results of the comparative fishing program can be found in DFO (2024) and Trueman et al. (2025a). From these analyses, conversion factors were developed for *CCGS Teleost* to new vessels for Spring Subdiv. 3Ps and Fall Divs. 2HJ3KL and *CCGS Alfred Needler* to new vessels for Fall Divs. 3KL. Work in the previous assessment allowed for the extension of conversion factors into Divs. 3NO for Fall (Trueman et al. 2026) Exploratory analyses to inform whether potential vessel differences have a significant impact on the estimation of indices derived for Snow Crab < 70 mm CW in AD 3Ps were conducted to determine whether the *CCGS Teleost* conversion could be applied to the *CCGS Alfred Needler* data in this area. Various spatiotemporal models were applied to the unconverted survey data to determine whether there was a vessel effect following the same protocols as used for Snow Crab > 70 mm CW at the previous assessment (Pantin et al. 2025; Trueman et al. 2026). Conversion factors were applied to the previous time series (1995–2023) to rescale indices into units equivalent to the new vessels going forward. The conversion factors for Snow Crab data from the trawl surveys conducted by the *CCGS Teleost* and *CCGS Alfred Needler* included uncertainty estimates which were not considered in this assessment. Further, 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.

Snow Crab catches from each survey set were sorted, weighed, and counted by sex. Catches were sampled in their entirety or sub-sampled by sex. Sampling of individual crab of both sexes included determination of CW (mm) and shell condition. Shell condition was assigned one of five categories:

1. soft-shelled—recently molted with a carapace that is very pliable. Shell filled with water and virtually no meat content.
2. new-shelled—molted within the past year. Carapace becoming rigid and still generally clean. Low meat content.
3. intermediate-shelled—molted over a year ago. Carapace lightly fouled and meat content high.
4. old-shelled—molted two or more years ago. Carapace moderately to heavily fouled and meat content high.
5. very old-shelled—molted several years (i.e., ≥ 4 years) ago. Carapace heavily fouled and turning black.

Males were sampled for chela (claw) height (CH, 0.1 mm). Males develop enlarged chelae when they undergo their terminal molt, which may occur at any size larger than approximately 40 mm CW. Therefore, only males with small chelae will continue to molt and subsequently recruit to the fishery. To standardize data capture, only the right chelae of males were measured. A model which separated males into two ‘clouds’ based on the relationship between CH and CW (Eq. 3) was applied (Dawe et al. 1997) to classify each individual as either adult (‘large-clawed’) (above the modelled line) or adolescent (‘small-clawed’) (below the modelled line).

Eq. 3

$$CH = 0.0806 * CW^{1.1999}$$

Maturity status was determined for females based on visual examination of the abdominal flap (small = immature, enlarged = mature), and the relative fullness and stage of egg clutches and development were subjectively assessed. Both sexes were also visually assessed for the presence of Bitter Crab Disease (BCD), a fatal affliction and source of natural mortality. In cases of unclear external characteristics, crab were dissected and classified based on observation of the hemolymph (i.e., blood). Observation of cloudy or milky hemolymph supported the classification of such specimens as infected. Mortality was inferred from levels of BCD observed in new-shelled males.

The spatial distributions of exploitable males (> 94 mm CW), pre-recruits (adolescent males 70–94 mm CW), small males (< 45 mm CW), and mature females were mapped and examined using catch rates for each survey set. Theoretically, pre-recruits would be expected to begin contributing to the exploitable biomass in the following one to three years and to the fishery in the following two to four years. For example, a pre-recruit captured in either the 2022 spring or fall survey that undergoes a terminal molt to exploitable size in the subsequent winter or spring (i.e., 2023) would be identified as a recruit into the exploitable biomass in the 2023 survey(s), and should begin contributing to the fishery in 2024. However, a portion of pre-recruits would molt but remain adolescent, which would further delay their contribution to the exploitable biomass and fishery by a year. The issue of transition rate of crab into the fishery is further complicated by the presence of skip-molting, whereby not all identified pre-recruits will molt in the following winter or spring and their arrival into the exploitable biomass and fishery would be delayed even further. Skip-molting is most common in mid- to large-sized adolescent males in cold areas (Dawe et al. 2012) and under high population density conditions, whereby skip-molting is more common than terminally molting for crab not undergoing a regular molt in any given year (Mullowney and Baker 2021). Small Snow Crab would be expected to begin contributing to the exploitable biomass in four to seven years.

To examine demographic size compositions of both sexes, crab were grouped by maturity and partitioned into 3-mm CW bins. A square root of mean numbers per tow for each maturity-size grouping was plotted. A square root transformation was applied simply for visual aid as trawl size frequency distributions often exhibit a trough pattern, with crab ranging from 30 to 70 mm CW poorly represented in the sample population. In relative terms, the square root transformation visually dampens the magnitude of the dominant modes of smallest and largest crab and elevates the magnitude of the sparsely captured intermediate-sized groups of crab.

DFO INSHORE TRAP SURVEYS

Data were available from DFO inshore trap surveys in ADs 3K, 3LNO, and 3Ps (Figure 6, Figure 7). In AD 3K, surveys were carried out in White Bay (CMA 3B), Green Bay (CMA 3C), and Notre Dame Bay (CMA 3D) during 1994–2024. These surveys have consistently occurred in late August to mid-September, and occupy five of the depth strata developed for multispecies trawl surveys. The White Bay survey did not take place in 2024. In AD 3LNO, long-term trap surveys in Bonavista Bay (CMA 5A) and Conception Bay (CMA 6B) occurred during 1979–2024. Historically, the Bonavista and Conception Bay surveys covered only the deepest stratum in each bay where the fishery was concentrated. However, shallower strata have been occupied in the surveys since 2013. Depth-stratified surveys have been conducted in Trinity Bay (CMA 6A) and St. Mary’s Bay (CMA 9A) since 2013, covering virtually the entire vertical distribution of each bay. The St. Mary's Bay surveys have occurred during early to mid-June, the Bonavista Bay surveys have occurred during late July, the Trinity Bay surveys have occurred during early August, and the Conception Bay surveys have occurred during late September or early November. In AD 3Ps, a trap survey was conducted in Fortune Bay (CMA 11E) in late May to early June during 2007–24 and encompassed the entire vertical distribution of the bay.

All surveys follow a depth-stratified survey design with set locations randomly distributed within each stratum, and stratum-specific set allocations weighted by area. All surveys utilize large-mesh (135 mm) and small-mesh (27 mm) traps alternately placed within each 'fleet' of gear, with traps spaced approximately 45 m apart. Each fleet includes six baited traps, with two additional end traps not baited. Squid (*Illex* spp.) hung on skivers is attached to the inner entry cone of each trap as bait, with approximately 2–3 pounds of squid on each skiver. Although soak times are intended to be standardized to 24–48 hours, weather and other factors can affect the surveys, and soak times are ultimately variable. Biological sampling is conducted at sea from all traps at each station. Sampling of males and females is the same as for the trawl survey (see Multispecies Trawl Survey Data section for details).

For each survey series, catch rate indices of legal-sized Snow Crab by shell condition from large-mesh traps (i.e., comparable to fishery index) and size frequency distributions of males by maturity status from small-mesh traps were produced for the assessment.

TORNGAT JOINT FISHERIES BOARD POST-SEASON TRAP SURVEY

Data were available from a collaborative trap survey between the Torngat Joint Fisheries Board (TJFB) and DFO which takes place in CMA 2JNorth and a portion of Div. 2H (Figure 8, Figure 9). This survey was initiated in 2013 and has occurred each year from late August to early September. The survey is conducted by technicians or observers onboard a commercial fishing vessel and consists of 20 fixed stations. At each station, nine large-mesh (133–140 mm) and two small-mesh traps are set in a fleet. Prior to 2017, the fleets consisted of ten large-mesh and one small-mesh trap. Biological sampling is conducted at sea from all traps at each station. Sampling of males includes determination of CW and CH, shell condition (soft, new, or old), leg loss, and presence of BCD. Females are sampled from small-mesh traps as per maturity and egg protocols on the DFO trawl and trap surveys.

Catch rate indices of legal-sized Snow Crab by shell condition and size frequency distributions by shell condition from large-mesh traps, and size frequency distributions of males by maturity status from small-mesh traps were produced for the assessment.

COLLABORATIVE POST-SEASON TRAP SURVEY

Data were available from a collaborative post-season (CPS) trap survey between the Fish, Food & Allied Workers' Union (FFAW) and DFO in all ADs (Figure 8, Figure 9Figure 8Figure 9). These surveys were initiated in 2003 and have occurred annually following the fishery, typically beginning in late August or early September and ending in late November. They are conducted by Snow Crab harvesters accompanied by ASOs and historically focused on commercial (i.e., deep) fishing grounds within individual CMAs. Thus, at localized spatial scales these surveys were more depth-constrained than the multispecies trawl surveys in the offshore or the DFO inshore trap surveys in select inshore CMAs. The CPS survey began transitioning to a partly random-stratified design in 2017. Since 2018, approximately 50% of survey stations are randomly allocated, while 50% remain the original fixed stations (referred to as core stations). The changes were invoked to increase both vertical and horizontal coverage in areas beyond prime commercial fishing grounds to encompass a more representative depiction of all population components in the assessment.

Historical survey stations generally followed a grid pattern, with a maximum station spacing of 10 x 10 nm, while newer randomized stations follow no systematic spatial design. At each station, six (inshore) or ten (offshore) large-mesh (133–140 mm) traps were set in a fleet. Biological sampling of male Snow Crab was conducted by ASOs from a single large-mesh trap at each station, however in 2020, sampling expanded to include two large-mesh traps. Inshore stations with a small-mesh trap used a fleet of seven traps and offshore stations with a small-mesh trap used a fleet of eleven traps. The biological measurements described for the TJFB trap survey were used in this survey, however due to larger catches and time restrictions, ASOs were required to measure at least 75 males and 25 females caught in the small-mesh traps and count any additional Snow Crab caught.

Stemming from the temporal and spatial inconsistencies and limitations in the distribution of small-mesh traps, indices are not available for all areas in all years. Furthermore, small-mesh traps have not adequately sampled small crab in some areas because the survey design focused near-exclusively on capturing exploitable crab and had limited sampling in shallow water, which tends to be associated with small-crab distribution in many areas. To address concerns about the limited utility of small-mesh traps in the survey, more small-mesh traps were incorporated in the survey starting in 2016 (Figure 9) and now all stations include a small-mesh trap.

The same analyses described for the TJFB trap survey for catch rate indices and size frequencies from the large-mesh and small-mesh traps were performed on the CPS survey data. Catch rate indices from all stations were used for science advice, however indices from just the core stations were also produced at the CMA-level and are available in the Appendices.

ABUNDANCE AND BIOMASS INDICES

Spatiotemporal models were used to predict Snow Crab density of various size and maturity categories using the R package ‘sdmTMB’ (Anderson et al. 2024). sdmTMB modelling combines Template Model Builder (TMB, Kristensen et al. 2016) and stochastic partial differential equation (SPDE) matrices to fit spatiotemporal models. A SPDE mesh using Integrated Nested Laplace Approximation was constructed for each dataset. For each model, both spatial and spatiotemporal autocorrelation were included as Gaussian random fields estimated by Delaunay triangulation over the mesh. These random fields accounted for static (spatial) and variable (spatiotemporal) unmeasured or latent habitat suitability. The spatiotemporal random fields were assumed to be independent across years. Anisotropy (directional dependence in data) was explored for both shared and separate model components, and a depth covariate (with and without a spatial-varying coefficient), as well as various data distributions (Tweedie, delta-gamma, and delta-lognormal) were considered for each model formulation. The best models for final estimation of density in any given data series and area were chosen based on model diagnostic checks and Akaike Information Criterion (AIC) (Akaike 1973). Diagnostic checks followed Anderson (2023) and Anderson et al. (2024) and included the ability of the models to converge and application of a ‘sanity’ function to ensure maximum gradient log-likelihood with respect to all fixed effects was < 0.001, the Hessian matrix was positive definite, and no random field marginal standard deviations were less than 0.01. Residuals were checked to ensure they met assumptions of normality and had no spatiotemporal patterns.

Trawl-based Abundance Indices

Model-based estimates of trawl-derived abundance indices for pre-recruit crab, small male crab, and mature female crab were developed using the methodology above. Separate models were developed for trawl data for NAFO Divisions 2HJ3KLNO and Subdiv. 3Ps due to the timing of these surveys.

Available data included all regular trawl sets through the time series and comparative fishing sets in 2021–23. Density (number/km^2) was predicted across a gridded depth surface, constructed using GEBCO bathymetry data (GEBCO Compilation Group 2021). Annual abundance estimates were calculated using the predicted density surface. The best-fitting models are described in Equations 4–9, using notation from the R package 'mgcv' (Wood 2017).

Pre-recruit Abundance

Trawl-based Estimates, AD 3Ps

The best model for predicting pre-recruit Snow Crab density within AD 3Ps from the spring trawl survey is described in Eq. 4.

Eq. 4

$$DensitypreTRAWL \;=\; s(Scaled\ depth, k = 5) \;+\; 0 \;+\; as.factor(Year)$$

where $DensitypreTRAWL$ was the standardized abundance (number/km^2) of pre-recruit Snow Crab in a standard trawl survey set during spring DFO trawl surveys, $Scaled\ depth$ was the average depth (m) during each trawl scaled [(set depth - mean(depth)) / sd(depth)], and $Year$ was the year of the survey, represented as a factor. Depth was scaled because the best-fitting model included a spatial-varying coefficient for depth. Anisotropy was included with separate Matérn ranges (distance correlations) estimated for the spatial and spatiotemporal random fields. The best-fitting model used a Tweedie distribution with log link. Density predictions were made on a 5.421 km^2 gridded surface restricted to depths between 30 and 500 m from 1995–2024.

Trawl-based Estimates, ADs 2HJ, 3K, 3LNO

The best model for predicting pre-recruit Snow Crab density within NAFO Divs. 2HJ3KLNO from the fall trawl survey is described in Eq. 5.

Eq. 5

$$DensitypreTRAWL \;=\; s(Scaled\ depth, k = 5) \;+\; 0 \;+\; as.factor(Year)$$

where $DensitypreTRAWL$ was the standardized abundance (number/km^2) of pre-recruit Snow Crab in a standard trawl survey set during fall DFO trawl surveys, $Scaled\ depth$ was the average depth (m) during each trawl scaled [(set depth - mean(depth)) / sd(depth)], and $Year$ was the year of the survey, represented as a factor. Depth was scaled because the best-fitting model included a spatial-varying coefficient for depth. Anisotropy was included with separate Matérn ranges estimated for the spatial and spatiotemporal random fields. The best-fitting model was a hurdle (two-part) model, represented by a binomial model predicting the presence of Snow Crab and a lognormal model predicting the density at positive locations. Density predictions were made on a 14.122 km^2 gridded surface restricted to depths between 30 and 750 m from 1995–2024. Annual abundance indices were estimated for each AD.

Small Male Abundance

Trawl-based Estimates, AD 3Ps

The best model for predicting small male Snow Crab density within AD 3Ps from the spring trawl survey is described in Eq. 6.

Eq. 6

$$DensitysmallTRAWL \;=\; s(Scaled\ depth, k = 5) \;+\; 0 \;+\; as.factor(Year)$$

where $DensitysmallTRAWL$ was the standardized abundance (number/km^2) of small male Snow Crab in a standard trawl survey set during spring DFO trawl surveys, $Scaled\ depth$ was the average depth (m) during each trawl scaled [(set depth - mean(depth)) / sd(depth)], and $Year$ was the year of the survey, represented as a factor. Depth was scaled because the best-fitting model included a spatial-varying coefficient for depth. Anisotropy was included with separate Matérn ranges estimated for the spatial and spatiotemporal random fields. The best-fitting model was a hurdle (two-part) model, represented by a binomial model predicting the presence of Snow Crab and a lognormal model predicting the density at positive locations. Density predictions were made on a 5.421 km^2 gridded surface restricted to depths between 31 and 500 m from 1995–2024.

Exploration of a vessel effect was undertaken on the 3Ps dataset of Snow Crab with < 70 mm CW to determine whether the conversion factors developed for converting the *CCGS Teleost* data to the new vessel time series could also be applied to the *CCGS Alfred Needler* data, as there was not enough comparative fishing undertaken by the *CCGS Alfred Needler* in 3Ps to calculate conversion factors. This exercise was undertaken, and conversion factors were accepted, for Snow Crab with > 70 mm CW at the previous stock assessment. The entire spring 3Ps time series was used, which included surveys conducted by *CCGS Teleost*, *CCGS Alfred Needler*, *CCGS Wilfred Templeman*, and *CCGS John Cabot*. Survey vessel as a factor and scaled calendar day were tested for inclusion in the above model (Eq. 6) to evaluate whether the different vessels, as well as timing of the survey, had an effect on the estimated abundance of Snow Crab < 70 mm CW. The models were tested for their ability to converge and the 'sanity' function was applied (as described above). Residuals and the conditional effects of the vessel were examined. The inclusion of survey vessel and/or calendar day did not improve model performance, there were no patterns upon examination of residuals, and no significant difference was evident in evaluation of the conditional effect of the vessel (Figure 10). Therefore, the conversion factors developed to convert the *CCGS Teleost* data to the new vessel time series were applied to the *CCGS Alfred Needler* time series. These are the same results as for crab with > 70 mm CW presented at the previous assessment.

Trawl-based Estimates, ADs 2HJ, 3K, 3LNO

The best model for predicting small male Snow Crab density within NAFO Divs. 2HJ3KLNO from the fall trawl survey is described in Eq. 7.

Eq. 7

$$DensitysmallTRAWL \;=\; s(Scaled\ depth, k = 5) \;+\; 0 \;+\; as.factor(Year)$$

where $DensitysmallTRAWL$ was the standardized abundance (number/km^2) of small male Snow Crab in a standard trawl survey set during fall DFO trawl surveys, $Scaled\ depth$ was the average depth (m) during each trawl scaled [(set depth - mean(depth)) / sd(depth)], and $Year$ was the year of the survey, represented as a factor. Depth was scaled because the best-fitting model included a spatial-varying coefficient for depth. Anisotropy was included with separate Matérn ranges estimated for the spatial and spatiotemporal random fields. The best-fitting model was a hurdle (two-part) model, represented by a binomial model predicting the presence of Snow Crab and a lognormal model predicting the density at positive locations. Density predictions were made on a 14.122 km^2 gridded surface restricted to depths between 30 and 750 m from 1995–2024. Annual abundance indices were estimated for each AD.

Mature Female Abundance

Trawl-based Estimates, AD 3Ps

The best model for predicting mature female Snow Crab density within AD 3Ps from the spring trawl survey is described in Eq. 8.

Eq. 8

$$DensityfemTRAWL \;=\; s(Scaled\ depth, k = 5) \;+\; 0 \;+\; as.factor(Year)$$

where $DensityfemTRAWL$ was the standardized abundance (number/km^2) of mature female Snow Crab in a standard trawl survey set during spring DFO trawl surveys, $Scaled\ depth$ was the average depth (m) during each trawl scaled [(set depth - mean(depth)) / sd(depth)], and $Year$ was the year of the survey, represented as a factor. Depth was scaled because the best-fitting model included a spatial-varying coefficient for depth. The best-fitting model was a hurdle (two-part) model represented by a binomial model predicting the presence of Snow Crab and a model with a gamma distribution predicting the density at positive locations. Density predictions were made on a 5.421 km^2 gridded surface restricted to depths between 30 and 500 m from 1995–2024.

Trawl-based Estimates, ADs 2HJ, 3K, 3LNO

The best model for predicting mature female Snow Crab density within NAFO Divs. 2HJ3KLNO from the fall trawl survey is described in Eq. 9.

Eq. 9

$$DensityfemTRAWL \;=\; s(Scaled\ depth, k = 5) \;+\; 0 \;+\; as.factor(Year)$$

where $DensityfemTRAWL$ was the standardized abundance (number/km^2) of mature female Snow Crab in a standard trawl survey set during fall DFO trawl surveys, $Scaled\ depth$ was the average depth (m) during each trawl scaled [(set depth - mean(depth)) / sd(depth)], and $Year$ was the year of the survey, represented as a factor. Depth was scaled because the best-fitting model included a spatial-varying coefficient for depth. Anisotropy was included with separate Matérn ranges estimated for the spatial and spatiotemporal random fields. The best-fitting model was a hurdle (two-part) model, represented by a binomial model predicting the presence of Snow Crab and a lognormal model predicting the density at positive locations. Density predictions were made on a 14.122 km^2 gridded surface restricted to depths between 30 and 750 m from 1995–2024. Annual abundance indices were estimated for each AD.

Integrated Exploitable Biomass Index

Spatiotemporal models were developed to predict exploitable Snow Crab density using available trap and trawl survey data in the R package ‘sdmTMB’ (Anderson et al. 2024). Available trawl data (1995–2024) included all regular trawl sets through the time series and comparative fishing sets in 2021–23. Densities (kg/km^2) of exploitable Snow Crab were predicted across a 14.1215 km^2 gridded depth surface with a maximum depth of 750 m, constructed using GEBCO bathymetry data (GEBCO Compilation Group 2021). Annual biomass estimates for each AD were calculated using the predicted density surface. The best-fitting models are described below, using notation from the R package ‘mgcv’ (Wood 2017).

Initial model selection (as described above) was undertaken with covariates for depth, gear (trawl, large-mesh trap, and small-mesh trap), survey (DFO, TJFB, CPS), month, and year. Table 1 shows the models compared to determine the best model, which was used for further exploration:

1. Incorporation of a survey-gear covariate (e.g., DFO-trawl, TJFB-small mesh, CPS-large mesh) to account for potential survey effects due to the differing protocols of the three trap surveys (e.g., number of traps on a fleet, soak times, number of traps sampled on a fleet, large-mesh trap mesh sizes). The CPS trap survey and DFO inshore trap survey data were used in this analysis. Only data since 2018 were used to account for the changing survey design of the CPS trap survey in 2017–18. This analysis was restricted to CMAs where both surveys occur. Table 2 shows the models compared in this analysis.
2. Use of a barrier mesh to account for the island of Newfoundland. The '*sdmTMB'* package does not allow the use of anisotropy with a barrier mesh therefore model selection did not include models with anisotropy.
3. Designation of the CPS trap survey data with respect to the survey redesign:
    a. Before and after survey redesign (pre: 2003–17 and post: 2018–23). Survey-gear covariate included pre or post for CPS trap survey data (e.g., CPS-small mesh-post, CPS-large mesh-pre)
    b. Fixed stations (core) and random stations (random). Survey-gear covariate included core or random for CPS trap survey data (e.g., CPS-small mesh-core, CPS-large mesh-random)
    c. Only CPS data collected after the survey redesign (2018–23).

To investigate whether all trap survey data should be restricted to 2018 to present or just the CPS survey data, model outputs and diagnostics of both scenarios were compared.

Table 3 shows all models compared to determine the final integrated exploitable biomass model.

The following model was determined to be the best model for estimating an integrated exploitable biomass index:

Eq. 10

$$Density = s(scaled\ depth, k = 5) + as.factor(survey - gear) + s(month, bs = \mathrm{cc}, k = 12) + 0 \\ + as.factor(year)$$

where $Density$ was the standardized biomass (kg/km^2) of exploitable Snow Crab in a standardized trawl survey set, small-mesh trap, or large-mesh trap, $scaled\ depth$ was the average depth (m) during each trawl or trap soak scaled [(set depth - mean(depth)) / sd(depth)], $survey - gear$ was a factor of the gear and survey combined (DFO-trawl, DFO-small mesh, DFO-large mesh, CPS-small mesh, CPS-large mesh, TJFB-small mesh, TJFB-large mesh), $month$ was the month of the year, and $year$ was the year of the survey, represented as a factor. Month was specified as a cyclic cubic spline as this is a seasonal term and there should be no discontinuity between January and December. Depth was scaled because the best-fitting model included a spatial-varying coefficient for depth. The effective fishing areas of the trawl was calculated as the trawl swept area, and the effective fishing area of a crab trap was set at 0.01 km^2. This effective fishing area parameter represents an intermediate value from estimates reported by Miller (1977), Brêthes et al. (1985), and Dawe et al. (1993). Nonetheless, because uncertainties remain regarding the accuracy of the effective fishing area parameter, biomass estimates developed remain as indices and are assessed in a relative sense. Anisotropy was included with separate Matérn ranges estimated for the spatial and spatiotemporal random fields. Data were restricted to a maximum depth of 1000 m to minimize the effects of outlier data from extreme depths well outside the usual depths for Snow Crab. The best-fitting model used a delta-gamma distribution. The CPS trap data earlier than 2018 was excluded from the model.

Diagnostic output was reviewed, including consideration of the patterns in residuals, probability distributions, fixed effects, spatial random effects, spatial temporal random effects, spatial-varying effects of depth, and uncertainty (Figures 11–20). Densities were predicted to $survey-gear$ of DFO-trawl, and $month$ of November, representing the survey series with the longest time series and the most common month for trawl survey sets.

A retrospective analysis peeling back five years was performed on the final model for each AD and showed agreement of trends in all ADs and agreement in magnitude in all ADs except 3Ps (Figure 21). It is thought that the magnitude differences in AD 3Ps could potentially reflect lower catchability in the spring trawl time series.

To determine the proportions of recruits (soft- and new-shelled exploitable males) and residual crab (intermediate-, old-, and very old-shelled exploitable males) in the exploitable biomass, the model in Eq. 10 was used to estimate the biomass of recruits. These Snow Crab are expected to have recruited to the fishery (i.e., become commercial size) in the last year, also referred to as immediate recruits. While all soft- and new-shelled Snow Crab of exploitable size are considered immediate recruits here, some of these Snow Crab may have been exploitable size in the previous year and molted to become a larger exploitable crab. These proportions were applied to the Delury-adjusted exploitable biomass index (see below) to evaluate the exploitable biomass in terms of recruits and residual crab.

Delury-adjusted Exploitable Biomass Estimates and Exploitation Rate Indices

As per previous assessments, raw exploitable biomass estimates were scaled to more realistic values using catchability scalars (S) developed through fishery Delury depletion regression analysis on catch rate data from logbooks. Neither trawl- nor trap-based estimates are deemed absolute due to unknown catchabilities for both gear types. The depletion analysis for adjusting raw exploitable biomass estimates used five-day unstandardized CPUEs in each AD beginning in the year 1999. Prior data were omitted due to less evidence of strong seasonal depletion in the fishery, with rapid expansion and substantial increases in removals occurring throughout the 1990s to a peak in 1999. To estimate biomass, five-day CPUEs were natural log transformed and regressed on cumulative pots. Catch data associated with the first and last 5% of the effort (measured by number of pots), and data later than July in any given AD and year were omitted to control for small sample size effects potentially associated with atypical fishing practices such as high levels of searching at the beginning of the season, dumping of excess catches near the end of the season, or recruitment of exploitable males at the end of season. A linear mixed model (Eq. 11) was fit to log-catch rate versus cumulative effort (i.e., number of pots) data by AD and year, with the predicted intercept used to calculate the beginning of the season biomass:

Eq. 11

$$lnCPUE_i = \alpha + pot\_c_i + a_i + \epsilon_i$$

$$\epsilon_i \sim N(0, \sigma^2_{error})$$

where $lnCPUE$ is the natural log of fishery catch per unit effort (kg/trap) and pot_c is the cumulative number of pots.

A limitation associated with biomass estimation based on depletion methods is that a resource must be depleted for the method to work. Therefore, years where there was no depletion were removed from the analysis. To account for other variability resulting from sporadic depletion patterns, a centered three-period moving average was used to smooth annual logbook-based biomass estimates prior to making comparisons for survey biomass conversion.

The depletion catchability scalars (S) were calculated as the time series median difference between logbook and integrated exploitable biomass estimates in each AD (Eq. 12):

Eq. 12

$$\mathrm{S} = \sum_{y=2000}^{2024} (Ty/Dy * 1/n)$$

where T is the raw model-based exploitable biomass estimates, D is the depletion biomass estimates from logbooks, y is the year beginning in 2000, and n is the number of years in the analysis.

A constant S was applied to the time series for each AD, calculated as the median, with the exclusion of any annual S that fell outside 2 standard deviations of the mean of the annual S for each AD. Standardized biomass indices were calculated as T/S. The Delury depletion biomass estimates are applicable to the beginning of the season (spring), therefore a one-year lag was applied to estimates in calculating the annual scalars, as these estimates were predicted to November.

An annual exploitation rate index (ERI) for each AD was calculated as the ratio of dockside-monitored landings to the most recent depletion-adjusted exploitable biomass index. As exploitable biomass indices are not absolute, neither are ERIs. Given evidence to suggest exploitable biomass is slightly over-estimated (Baker et al. 2021), ERIs likely slightly underestimate absolute harvest rate. Nonetheless, long-term trends in ERIs provide a useful indication of trends of relative effects from fishing.

TOTAL MORTALITY

Total annual mortality rates (A_t) were calculated based on stage-specific biomass indices of exploitable crab using trawl data (Eq. 13):

Eq. 13

$$A_t = 1 - \frac{B_{old_t}}{\left(B_{new_{t-1}} + B_{old_{t-1}}\right)}$$

where B_{new} is the recruitment (soft- and new-shelled conditions) biomass index, B_{old} is the residual (intermediate-, old-, and very old-shelled conditions) biomass index, and t denotes survey year.

A three-year moving average total mortality rate index was calculated for each AD to smooth annual variability. Caution should be used in interpreting this index as it is inherently uncertain due to subjectivity in shell condition assignment between later new-shelled and early intermediate-shelled crab.

SIZE-AT-TERMINAL MOLT

Indices of size-at-terminal molt in males were developed based on trawl and small-mesh trap survey data. For this analysis, proportions of Snow Crab undertaking terminal molt in any given year (becoming morphometrically as opposed to sexually mature) were identified. The analysis was limited to Snow Crab that had either just molted (i.e., soft- or new-shelled) or skip-molted (were adolescent male in intermediate- or old-shelled condition) to focus on the most recent molting outcomes with size-specific proportions of molt-type outcomes (terminal molt versus other [adolescent/immature molt or skip-molt]) estimated in a binomial generalized additive mixed model (GAMM) defined as (Eq 14):

Eq. 14

$$logit(M_i) = \beta_o + f_1(CW_i) + f_2(Year_i) + f_3(fYear_i) + ti(CW_i * Year_i) + a_i + \epsilon_i$$

$$a_i \sim N(0, \sigma^2_{AD,Year})$$

$$\epsilon_i \sim N(0, \sigma^2_{error})$$

where M_i represents the category of terminally molted or non-terminally molted for an individual of a given CW, in a given AD and year, β_o is the intercept, f_j are unique smooth function of both year and CW estimated using a thin-plate smoothing spline for each AD, and ti denotes a tensor-interaction spline. The $fYear$ term denotes year treated as a factor variable. a_i denotes an interactive random effect of AD and year, and ϵ_i is error. The model was run separately for each AD and each explanatory term was fit by gear type (trawls versus small-mesh traps), with small-mesh traps restricted to years after the CPS survey re-design (beginning in 2018) due to increased numbers of traps in the dataset along with more representative spatial coverage.

The model was originally produced at 3-mm CW size bins and a weighting term of the total number of Snow Crab measured in a given size bin and year was applied to help offset influences of small sample sizes in the data in fitting the model. Subsequently, to increase precision in estimating the size at which 50% of the Snow Crab were predicted to undertake their terminal molt in any given year, the model was refit with a dataset consisting of 0.5-mm CW increments over a 15–125 mm CW size range to refine predictions of proportional molt type outcomes to a finer incremental scale.

ECOSYSTEM INDICES

Spring and fall bottom temperature climatological maps (1991–2020 average) and spring and fall 2024 observations and anomalies were determined using the methodology described in Cyr and Galbraith (2021). Spring temperature indices are preferred because they are more closely associated with critical life history events in Snow Crab, such as mating and molting.

Several atmospheric teleconnection patterns have been related to Snow Crab productivity either in short-, mid-, or long-term scales, such as the Pacific Decadal Oscillation (PDO) (Szuwalski and Punt 2013), Arctic Oscillation (AO) (Szuwalski et al. 2021), El-Niño Southern Oscillation (ENSO), and North Atlantic Oscillation (NAO) (Baker et al. 2021). These teleconnections are believed to affect Snow Crab at different life stages through regulation of ocean climate conditions over large geographic scales (e.g., sea ice extent, thermal and gas exchanges at the sea surface, and impacts of water exchanges within and among ocean current systems). A correlation analysis was performed with all teleconnections cited above, however, the assessment analysis ultimately focused on the AO as per Mullowney et al. (2023a). The AO is the first mode of variability of atmospheric pressure over the Arctic. It is constructed from the anomaly in the height of the 1000 mb pressure above the Northern Hemisphere (20–90°N). Monthly values of the AO since 1951 were obtained from the National Oceanographic and Atmospheric Administration (NOAA) Climate Prediction Center. Beyond direct forcing from atmospheric teleconnection systems, sea ice extent and in-turn spatiotemporal distribution of the Cold Intermediate Layer (CIL) of bottom water have also been shown to be related to recruitment strength in Snow Crab (Szuwalski et al. 2021; Mullowney et al. 2023a). The CIL is a body of < 0°C water that sits intermediate in the water column and covers shallow areas of the Newfoundland and Labrador Shelf. It represents a proxy for thermal crab habitat. The data for monthly sea ice extent extending back to 1978 were available from the National Sea and Ice Data Center (Stroeve and Meier 2018).

A predictive model of total stock-level (Divs. 2HJ3KLNOPs) exploitable biomass was developed using a three life-stage approach of explanatory variables affecting Snow Crab at long-, mid-, and short-term stages using the inputs described in Mullowney et al. (2023a). Sea ice extent was used as the explanatory variable for the long-term life stage with a 12–13 year lag. For the mid-term life stage, the AO with a 7–8 year lag was used, with the AO at lags of zero and one years used to model short-term stock drivers. The prediction model was fit as a generalized additive model (GAM), assuming a Gaussian family distribution and identity link. Tensor product interaction smooths (te) were used on thin-plate splines for explanatory variables for each life stage. Each interaction term was set to a low number of basis knots (k = 3) to allow the model to converge. The long- and mid-term model (Eq. 15) and the full model (short-, mid-, and long-term) (Eq. 16) were plotted to forecast short-term exploitable biomass prospects, with each defined as:

Eq. 15

$$eBIOt \sim te(Ice12, Ice13) + te(AO7, AO8) + \varepsilon t$$

Eq. 16

$$eBIOt \sim te(Ice12, Ice13) + te(AO7, AO8) + te(AO0, AO1) + \varepsilon t$$

where $eBIO$ refers to survey exploitable biomass, t refers to the year, Ice refers to cumulative February to April sea ice extent, AO refers to annual Arctic Oscillation Index, numerics with each explanatory term refer to the number of lag years, and ε represents white noise error.

The relative predation mortality of Snow Crab was examined at the geographic scale of the Ecosystem Production Unit (Pepin et al. 2014) and is generally defined as consumption of Snow Crab by fish predators relative to Snow Crab in the system. The estimates of Snow Crab biomass consumed by fish predators are generated by combining biomass estimates for fish predators, estimations of total food consumption per unit of biomass for those predators, and fractionation of that consumption using diet compositions to estimate the proportion of Snow Crab in the diet by the fish predator functional groups. As each step involves assumptions and generalizations, the resulting index is not a precise estimate of consumption, but intended to generate a plausible envelope for the order of magnitude for consumption.

Among all fish species recorded in multispecies trawl surveys, only those classed as piscivores and large benthivores were considered Snow Crab predators due to gape limitation of smaller fishes and the available evidence from stomach contents. The total biomass of fish predators was approximated from multispecies trawl survey random stratified biomass estimates, assuming the sample populations reflect fish community composition. However, as species-specific estimates were not corrected for gear catchability they likely reflect minimum estimates of predator biomass.

Estimation of consumption rates per unit of biomass were derived using two separate approaches:

1. Allometric methods. Two different models were used:
    a. bioenergetic-allometric consumer-resource modelling framework, based on empirical allometric scaling relationships (Yodzis and Innes 1992)
    b. an allometric framework derived from growth principles based on the von Bertalanffy equation and rationale (Wiff and Roa-Ureta 2008).
2. Daily ration. These estimates are based on assuming daily consumption as a percent fraction of body weight. Two daily ration scenarios of 1% and 2% were assumed based on

the typical range of values from literature reports (Macdonald and Waiwood 1987; Adams and Breck 1990).

These approaches estimate average food requirements and assume that all predators achieve their food requirements. Using these estimates of consumption rates together produce a plausible envelope for consumption that likely contains the actual consumption rate.

Diet composition data were available since 2008 for fall trawl series and 2013 for spring trawl series and for a small subset of Snow Crab predators (American Plaice [*Hippoglossoides platessoides*], Atlantic Cod [*Gadus morhua*], and Greenland Halibut [*Reinhardtius hippoglossoides*]). Estimates of the overall fraction of Snow Crab in their diets, as well as relative contributions of these species to the overall biomass of the Snow Crab predator assemblage, were used to approximate the fraction of Snow Crab consumed by all piscivore and large benthivore fishes. Since these predator species are a major component of the biomass of the corresponding fish functional groups, using their diets to represent the functional groups is a reasonable proxy. The mean diet data from 2008–10 (in the fall) and 2013–15 (in the spring) are used for the earlier time periods when diet composition data were not available. Estimates of consumption of Snow Crab by piscivores and large benthivores were presented as the median (point estimate) and range from all consumption models considered, along with a predation mortality index (predation estimate / total Snow Crab survey biomass). Predation mortality indices should be interpreted with caution as they are calculated using total Snow Crab biomass; however the influence of predation is exerted primarily on small-sized crab. Unpublished work has shown trends across methods using total Snow Crab biomass versus small-sized Snow Crab biomass as the denominators tightly correspond to one another. As conversion factors for outgoing to new vessels were not available for all species used in these analyses, consumption and predation mortality indices used unconverted data.

PRECAUTIONARY APPROACH

In 2018, DFO Science held a CSAS Regional Peer Review process to develop a Precautionary Approach (PA) Framework for Snow Crab in the NL Region. The PA Framework for the NL Snow Crab resource and fishery (Mullowney et al. 2018b) was based on three key metrics of stock health:

1. predicted CPUE ($pCPUE$),
2. predicted discards ($pDIS$), and
3. proportion of females with full egg clutches.

Limit Reference Points, as set by the peer-review process, are $pCPUE$ = 5 kg/trap, $pDIS$ = 20%, and proportion of females with full egg clutches = 0.6.

Predicted CPUE ($pCPUE$) was estimated based on a GAMM (Eq. 17):

Eq. 17

$$pCPUE_i = \alpha + f_{1k}(ERI_i) + f_{2k}(CBI_i) + f_{3k}(NAO7_i) + a_i + \zeta_i + \epsilon_i$$

$$a_i \sim N(0, \sigma_{AD}^2)$$

$$\zeta_i \sim N(0, \sigma_{year}^2)$$

$$\epsilon_i \sim N(0, \sigma_{error}^2)$$

where ERI is the exploitation rate index, CBI is the integrated exploitable biomass index, and $NAO7$ is the index of the annual NAO lagged seven years, with the annual index based on the mean of monthly data values. A scaled two-year average of exploitable biomass is used as the stock size term in the model because trends in fishery CPUE are known to lag behind survey signals for more than one year and this approach helps generate independence from the ERI term and in-turn offset influences of multicollinearity in model term formulation.

Predicted discards ($pDIS$) were estimated based on a GAMM (Eq. 18):

Eq. 18

$$pDIS_i = \alpha + f_{1k}(wCPUE_i) + f_{2k}(medFD_i) + f_{3k}(EP_i) + a_i + \epsilon_i$$

$$a_i \sim N(0, \sigma^2_{AD})$$

$$\epsilon_i \sim N(0, \sigma^2_{error})$$

where $wCPUE$ is the cell-weighted catch per unit effort (with the number of years a 5 x 5 nm cell was occupied used as the weighting factor), $medFD$ is the median fishing day based on effort (i.e., pots), EP is the log-ratio of integrated exploitable index to trawl pre-recruit abundance index in the previous year, and AD is the Assessment Division.

The percentage of the catch discarded is based on ASO data, but due to low ASO coverage levels in recent years, the predictive model used in the PA Framework is only fit to observation data up to 2019. Therefore, conditioning of predicted outcomes for 2020–24 is based on responses to fishery CPUE, median fishing day, and the exploitable to pre-recruit abundance ratio that occurred over the 2004–19 period. The predicted values over 2020–24 are plotted against an estimate of percent discarded based on averaging data from two sources, the limited available ASO data and a reference fleet of anonymous vessels (based on Vessel Registration Numbers) identified as consistently and accurately reporting total discards in logbooks prior to 2019. The determination of accurate reporting of discards by a vessel is defined as a significant correlation ($p < 0.05$) with annual total discards reported by ASOs over the time series in any given AD.

Both the CPUE and discard predictive models project one year based on scenarios of various exploitation rates in the forthcoming fishery, with the zonation for each metric in the PA Framework for the forthcoming year based on an assumption of status quo landings from the most recent fishery.

As presented in Mullowney et al. (2018b), egg clutches are calculated directly based on visual assessment (as a 2-year moving average). Prior to 2022, only trawl survey data were used to calculate egg clutch fullness levels. However, with improved coverage of small-mesh traps in the CPS surveys in recent years, data from all trap surveys from 2018 to present are now used. Given projections of egg clutch fullness are not possible, the zonation of the egg clutch metric in the PA Framework is based on the current year’s estimate.

The Upper Stock References (USR) and Harvest Control Rules were developed over several years and approved in 2023. To determine stock status, the three assessment metrics are combined into an integrated stock health score (Mullowney and Baker 2023) through a weighted scoring matrix that produces a range of outcomes for the integrated health score. The scoring matrix was established collaboratively between stakeholders, management, and Science, and among other considerations, weightings reflect the ability of management measures to directly affect outcomes of each metric (i.e., most direct effect on $pCPUE$), as well as dynamic data ranges within historical time series for each metric (i.e., most stability in the egg clutch index). Upon summation, the integrated health score index is differentiated into either the Healthy, Cautious, or Critical Zone.

RESULTS AND DISCUSSION

BROAD-SCALE TRENDS: DIVISIONS 2HJ3KLNOP4R

Fishery

Landings for Divs. 2HJ3KLNOP4R increased steadily from 1989 to a peak of 69,100 t in 1999, largely due to the expansion of the fishery to offshore areas. 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 AD 3K. Landings remained near 50,000 t from 2007–15 but steadily declined to a 25-year low of 26,400 t in 2019. They have increased since then to over 56,000 t in 2024 (Figure 22).

In AD 2HJ, landings remained near 1,700 t from 2014–19 but have since declined due to TAC reductions. Landings were around 960 t in 2024 (Figure 23). In AD 3K, landings have increased from a time-series low of around 5,500 t in 2017 to around 10,400 t in 2023. Landings decreased to around 9,600 t in 2024 following a reduction in TAC. In AD 3LNO, landings were at the lowest level in two decades in 2019 (around 15,600 t), but have since increased to around 36,200 t in 2024. In AD 3Ps, landings have been particularly variable throughout the time series. Landings continued to increase from a time-series low of around 1,200 t in 2017 to a time-series high of around 8,600 t in 2024. In AD 4R3Pn, landings have increased from a time-series low of around 160 t in 2020 to over 600 t in 2024.

Fishery timing transitioned from summer-fall to spring-summer throughout the 2000s in most ADs (Figure 24). In recent years, the fishery has generally begun in early April for all but AD 2HJ, where it usually starts in early to mid-May due to ice cover in the spring. The 2024 fishery was delayed by a week due to an industry dispute. Consequently, median fishing weeks ranged from late April in AD 4R3Pn and mid to late May for the rest of the ADs.

Fishing effort, as indicated by estimated trap hauls, increased by a factor of five throughout the 1990s as the fishery grew (Figure 25). Overall effort remained at approximately 3.5 to 4.5 million trap hauls per year over that time period, but decreased to around 2.5 million trap hauls in 2020, the lowest level in over two decades. Overall effort has increased since then to near 3.9 million trap hauls in 2024. Spatially, the distribution of fishing has remained relatively broad, but there have been notable changes in some ADs in recent years (Figure 26). In the north, effort in the northernmost portion of AD 2HJ has gradually dissipated since 2011, with NAFO Div. 2H virtually abandoned since then, as the Cartwright and Hawke Channels have near-exclusively become the two areas of fishing activity. The abandonment of the northernmost fishing grounds reflects both resource shortages and a regulation change after the 2012 fishery whereby vessels previously restricted to Div. 2H were allowed access to the northern portion of the Cartwright Channel, inside Div. 2J, at the southernmost portion of CMA 1. In AD 2HJ, effort remained relatively consistent for the last decade, at around 200,000 trap hauls per year, but declined in the last two years and was 94,000 trap hauls in 2024 (Figure 27). In AD 3K, effort decreased to a 25-year low in 2019, with about 600,000 trap hauls, but increased to around 1.1 million trap hauls in 2023. It declined to around 928,000 trap hauls in 2024. From 2017–22, effort contracted primarily into the Funk Island Deep and areas west, with the farthest offshore portions of this AD appearing to have been abandoned (Figure 26). However, fishing activity expanded farther offshore again in 2023–24. In AD 3LNO, effort expanded rapidly from 1992–mid-2000s and thereafter oscillated between two and three million trap hauls per year until decreasing to under 1.5 million trap hauls in 2020. Effort has since increased and was over 2.1 million trap hauls in 2024 (Figure 27). A substantial reduction in fishing effort was seen in CMA 3N200 (eastern edge of the Grand Bank) in the last five years, with virtually no activity along the southern slope edge (tail of the Grand Bank) (Figure 26). In AD 3Ps, effort reached a

25-year low in 2020, but has since increased and was over 710,000 trap hauls in 2024 (Figure 27). Since around 2017–18, there has been a reduction in effort in the most southerly portions of CMA 10B and along the southwest edge of CMA 11S. There was virtually no fishing activity in these areas in 2021–24 (Figure 26). The change in fishing activity in CMA 10B corresponds with a regulation change whereby a management line was removed and some harvesters were no longer restricted to the southern portion of the CMA. In AD 4R3Pn, effort has remained at a low level relative to other ADs and decreased to around a three-decade low in 2020. Effort has increased since and was over 53,000 trap hauls in 2024 (Figure 27), however, it mainly occurred in a few CMAs. There has been a substantial reduction in fishing activity in the offshore area (CMA OS8) of this AD and fishing is primarily focused in CMAs 12C, 12D, 12E, and 12F (Figure 26Figure 26Figure 26). Trends in fishing activity do not solely represent trends in the resource, as fishery dynamics such as fuel costs, processing capacity and timing, and other socio-economic factors may influence fishing operations in all ADs.

Fishery CPUE tends to lag behind survey biomass trends by one to two years in most ADs, thus the fishery is typically delayed in reflecting stock status, indicative of hyperstability in the CPUE index. From 2015–19, there was considerable spatial contraction of high levels of fishery CPUE (Pantin et al. 2024); however, increases have been seen in many areas since then (Figure 26). Fishery CPUE is typically highest in NAFO Div. 3L; however, in recent years, ADs 3K and 3Ps have also had high levels of fishery CPUE, particularly in 2020–22. Throughout the past 25 years, overall fishery CPUE has shown a great deal of variability, both across and within ADs (Figure 26, Figure 28).

Overall, the fishery performed poorly in 2017–18, with standardized CPUE at a historical low (Figure 29). The overall standardized CPUE has oscillated around 12–13 kg/trap for the last four years. In AD 2HJ, standardized CPUE increased to over 9 kg/trap in 2024 (Figure 28). In AD 3K, standardized CPUE recently peaked at over 11 kg/trap in 2022 and has been between 9 and 10 kg/trap in the last two years. In AD 3LNO, standardized CPUE continued to increase from the time-series low in 2018 to over 16 kg/trap in 2024. In AD 3Ps, standardized CPUE was at a time-series high of around 19 kg/trap in 2022, but decreased since to around 11 kg/trap in 2024. In AD 4R3Pn, standardized CPUE was at a time-series high of around 11 kg/trap in 2024.

Overall, the combination of landings, spatial patterns, and spatial distribution of catch rates from the various sources of fishery data suggest the fishery remains strongest in an aggregated area along the northern Grand Bank in AD 3LNO, with some declines from very high levels emerging in ADs 3K and 3Ps.

At-sea observer data on shell composition are used to infer dynamics of recruitment into the biomass. Observer coverage has been poor in recent years, and consequently, some ADs have been excluded from analyses in those years. In AD 2HJ, there have been periods of inconsistent ASO coverage, however there have been some improvements in recent years. Catch composition tends to be dominated by recruits in this AD, which was particularly evident in the last three years (Figure 30, Figure 31). The observed catch composition in AD 3K has been fairly consistent throughout most of the time series; however, catches of recruits were particularly low in 2023–24. In AD 3LNO, the compilation of recruit and residual crab were at a time-series low in 2018, however, observed catch rates have since increased to near the time-series high in 2022–24. The catch composition has been fairly consistent throughout the time series with a mostly even mix of new- and old-shelled crab. In AD 3Ps, both the recruitment and residual components of the biomass observed in the fishery decreased by more than half from 2011–17. In 2018, there was a sharp increase in the observed catch rates and it has remained around that level, with a further increase in 2023–24. This initially included a sharp increase in recruits which was followed by higher levels of residual crab, but there were very low catch rates of recruits in 2023–24. In AD 4R3Pn, ASO coverage has habitually been poor and inconsistent, with particularly low coverage over the last seven years.

In the early years following the fishery expansion, catch rates were variable or steady throughout the season in most ADs. However, starting in the late 1990s, patterns of early to mid-season depletion began to emerge, which progressed to season-long depletion patterns beginning in the early 2000s. By the mid- to late 2000s, consistent progressive depletion patterns throughout the season occurred in most ADs in most years (Figure 32).

In AD 2HJ, there has been relatively consistent depletion throughout the season in recent years, with replenishment between seasons (Figure 33). Start-of-season and end-of-season catch rates were progressively slightly higher each of the last three years. In AD 3K, start-of-season catch rates increased from 2020–22, nearing 20 kg/trap in 2022. This period was characterized by high start-of-season catches, steep depletion throughout the season, and strong replenishment between seasons. Start-of-season catch rates were lower in 2023–24. A precipitous depletion throughout the season has not always been as evident in AD 3LNO as in some of the other ADs. There have been particularly high start-of-season catch rates in the last five years (around 15 kg/trap). Catch rates remained around this level throughout the season in 2024. In AD 3Ps, there has been a pattern of a quick increase in catch rates shortly after the start of the season and then depletion, with end-of-season catch rates similar to start-of-season catch rates. This pattern was not evident in 2023, likely due to the delayed start of the fishery. The peak catch rate and end-of-season catch rate were lower in 2024 than the previous five years. In AD 4R3Pn, there have been some periods of rapid depletion of the biomass, however in recent years there has not been much evidence of depletion as the catch rates were more variable throughout the relatively short fishing season. This may reflect the more opportunistic nature of the fishery in this AD.

The relatively consistent within-year depletion in most years across ADs allowed for the calculation of Delury-based exploitable biomass estimates that could be used as scaling factors (Figure 34–Figure 38), as described in the Delury-adjusted Exploitable Biomass Estimates and Exploitation Rate Indices section. Start-of-season fishery-based exploitable biomass indices used to calculate scalars for the integrated exploitable biomass time series in each AD are depicted by the centered 3-year moving average Delury-adjusted biomass line plots in Figure 39.

Exploitable Biomass

A new exploitable biomass index was introduced which integrates trawl, large-mesh trap, and small-mesh trap data. The exploitable biomass was highest at the start of the survey time series (1995–98) (Figure 40). The index declined from a peak exceeding 400 kt in the late 1990s to about 120 kt in 2004 and then varied without trend until 2014. From 2014–16, the exploitable biomass index declined by almost 60% to a historical low of about 58 kt. The exploitable biomass consisted of a fairly even mix of recruits (soft- and new-shelled) and residual (intermediate-, old-, and very old-shelled) Snow Crab (Figure 40). The overall low exploitable biomass level in 2015–17 was coupled with the concentration of exploitable Snow Crab into localized areas in all ADs (Figure 41, Baker et al. 2021). The exploitable biomass index increased from historic lows in 2015–17 to a recent peak in 2022. Aside from the 2022 peak, it has remained between 210 and 240 kt over the last five years (Figure 40). While coverage of the trawl survey has been patchy in recent years, particularly in 2021–22 due to a focus on comparative fishing between incoming and outgoing vessels, there has been a noticeable constriction in the distribution of catches (Figure 41). However, there were concentrations of strong catches of Snow Crab along the entire Div. 3N slope in 2023–24, where there were virtually no Snow Crab caught in the period prior to 2019.

Overall trends in exploitable biomass index mask spatiotemporal variability among ADs (Figure 42), as well as potential confounding factors occurring within any given area. In AD 2HJ, the exploitable biomass index oscillated at a low level for the last decade and remained at a low level in 2024 (Figure 42). It was dominated by recruits, and recruitment into the exploitable biomass changed little in 2024. Catch rates of exploitable crab from the CPS trap survey appeared relatively steady in 2024 (Figure 43, Figure 44). In AD 3K, the exploitable biomass index increased from a time-series low in 2015–18 to peak in 2021–22, and decreased by almost half in the last two years (Figure 42). It consisted largely of incoming recruits throughout the time series, with 50% or more being recruits. In years of declining exploitable biomass there was higher proportions of recruits, indicating a reliance on new recruits in times of low biomass. Recent years showed a fairly even mix of recruits and residual crab. There was a noticeable decline in the catches from the trawl survey, with most catches restricted to the western shelf and Funk Island Deep (Figure 41). Catch rates of exploitable crab from the CPS trap survey indicated decreased catches of recruits followed by residual crab in 2024 (Figure 43, Figure 44). In AD 3LNO, the exploitable biomass index increased from a time-series low in 2016–17 and was at some of the highest levels observed in the time series (Figure 42). It consisted of a fairly even mix of recruit and residual crab throughout the time series. While the distribution of exploitable crab in the trawl survey appeared consistent in 2024, there was an indication of declining catches from the survey (Figure 41). Catch rates from the CPS trap survey remained steady from 2023–24 (Figure 43). In AD 3Ps, the exploitable biomass index increased from a time-series low in 2015–17 to near a time-series high in 2022 (Figure 42). This index decreased by 65% over the last two years. For most of the time series, the exploitable biomass consisted of a fairly even mix of recruit and residual crab, with a slightly higher proportion of residual crab. However, in 2024 the exploitable biomass was dominated by residual crab, indicating a decline in immediate recruitment. In the trawl survey, catches have remained concentrated in Placentia Bay and south into the Halibut Channel area (Figure 41). There was a notable decrease in catch rates of exploitable crab in the CPS trap survey from 2022–24 (Figure 43). There were issues with completion of this survey in 2023, resulting in a gap in the results for that year. In AD 4R3Pn, precision of estimation of the exploitable biomass index was low due to the absence of a trawl survey and limited coverage throughout the AD in the CPS trap survey. The exploitable biomass index remained at a low level in this AD (Figure 42). For most of the time series, catches of exploitable Snow Crab in the CPS trap survey were dominated by recruits; however the last three years had catches dominated by residual crab, indicating a decline in immediate recruitment (Figure 43, Figure 44).

Collectively, the survey and fishery metrics are consistent in showing an exploitable biomass that has improved in recent years, but is showing signs of a decline. This is particularly evident in ADs 3K and 3Ps in the last two years.

Recruitment

Prospects beyond 2024 can be explored through trends in pre-recruits (70–94 mm CW adolescent males). The stock assessment presented a trawl-based abundance index, which provides an index of recruitment prospects for the next two to four years (Figure 40). 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 the density of large males, with terminal molt at small sizes more common at lower densities (Mullowney and Baker 2021). Natural mortality and skip-molting incidence are also important factors that influence the proportion of pre-recruit crab measured in the surveys. The distribution of pre-recruit crab follows that of exploitable crab closely and changes seen in exploitable crab distribution is reflected in the pre-recruits as well (Figure 45). All ADs in which the trawl survey takes place have shown declines in the pre-recruit crab abundance index and were near or at a time-series low in 2024 (Figure 46). The most recent peaks in the pre-recruit crab abundance index occurred in 2021 in AD 3K, 2020 in AD 3LNO, and 2018 in AD 3Ps. While there is no pre-recruit crab abundance index from trap survey data, catch rates of these crab are presented from the small-mesh traps in the CPS trap survey. In the short time series since wide implementation of small-mesh traps in that survey, declining catch rates of adolescent crab of pre-recruit size were apparent (Figure 47). This was particularly evident in ADs 3K, 3LNO, and 4R3Pn. Both the trawl and trap survey results suggested diminishing recruitment prospects over the next two to four years.

Long-term recruitment prospects can be explored through trends in small male Snow Crab (< 45 mm CW). The stock assessment presented a trawl-based abundance index, which provides an index of recruitment prospects in four to seven years. Again, the proportion and rate of these crab measured by the surveys that reach exploitable biomass depends on several factors including natural mortality, skip-molting incidence, and the size at which crab terminally molt. The relatively low abundance of small male crab since the early 2000s (Figure 40), suggests overall weak recruitment potential in the long term relative to levels experienced in the mid- to late-1990s. The pulse of small male crab that emerged in the trawl surveys in 2013–14 was largely localized to ADs 2HJ and 3K (Figure 48). There have been some increases in small male abundances in most areas in recent years, however, with the exception of AD 3LNO, these indices have returned to low levels. Recent abundance levels of small male crab are generally not nearly as large as historic pulses. For example, the spring trawl surveys showed a relatively high level of small male crab in AD 3Ps in 2010 (Figure 48) that was almost certainly associated with marked improvements in new-shelled recruits in 2017–19 in that AD (Figure 42). There was a relatively steady-state broad distribution of low catch magnitude of small male crab in AD 3Ps from 2013–19 (Figure 49) inferring weak prospects after the recent pulse of recruitment benefits the exploitable biomass and fishery over the next few years, however, this index increased slightly in 2021 (Figure 48). The spike in small crab abundance seen in the 2010 AD 3LNO trawl survey likely contributed to the exploitable biomass in that AD in the last few years (Figure 48). The distribution of small male crab has not contracted in recent years to the same extent seen in exploitable crab (Figure 49), with small male crab still caught in most of the same areas despite generally lower catch magnitudes relative to the early part of the time series. The trawl survey results suggest diminishing recruitment prospects over the next four to seven years.

Females

The management regime of the NL (and most other commercially harvested) Snow Crab stock restricts all females and a large proportion of breeding males from exploitation. The fishery targets only the largest males, which constitute a small fraction of the overall population. A management strategy of maintaining a sufficient residual biomass of the largest males, coupled with the ability of sub-legal-sized adolescent and adult males to successfully copulate and breed, is thought to safeguard reproductive capacity in the stock.

Low catch rates of females in the trawl surveys were seen in all ADs for which there were data in the early to mid-2010s, and a decreasing trend has reemerged in recent years, with abundances at some of the lowest levels in the time series (Figure 40, Figure 50). Careful monitoring of the decreasing trend, particularly in light of the declines in male size-at-terminal molt (see Size-at-Maturity section below), will be important moving forward. A combination of declines in mature female abundances and male size-at-terminal molt could have serious implications for reproductive potential in the ADs where they are occurring, as well as other areas considering upstream/downstream population connectivity. The overall spatial distribution pattern observed historically in the trawl survey is typical of a dominant shallow water presence of mature females (Figure 51) (Pantin et al. 2024). For example, relatively high abundance has consistently been found on top of the Hamilton Bank and nearshore plateaus in AD 2HJ, in the shallow western portions of AD 3K, and along the shallow northern Grand Bank in AD 3LNO. Assessment Division 3Ps is overall the shallowest of all ADs, with females typically concentrated in the central portions of the division near the fringes of the St. Pierre and Green Banks, and into Placentia Bay. These shallow areas, where the majority of reproduction occurs, are typically very cold. Mullowney et al. (2018a) described winter and spring breeding migrations of female and male Snow Crab into shallow water along offshore parts of the NL Shelf, a behavior known to occur in some inshore bays for decades.

The sporadic capture of females by the trawl survey throughout the time series could reflect their affinity to form aggregations, demographic pulses, or their small size. Their general size corresponds with a trough in size frequency distributions from the Campelen trawl (Figure 52, Figure 53), and assumed poor catchability. However, variability in annual abundance indices could also reflect demographic changes in this component of the population. Cyclic pulses of female abundance have been described in other areas, including the Northern Gulf of St. Lawrence (Sainte-Marie 1993; Sainte-Marie et al. 1996).

It is unknown to what extent mature female abundance influences future recruitment. Historically, some of the largest recruitment pulses observed in the stock have been born from periods of low mature female abundance. For example, the large pulse of 15–25 mm CW crab observed in the 2000–01 trawl surveys in 3K would have almost certainly been 2–3 years of age (Sainte-Marie et al. 1995) and therefore produced from the relatively low abundance levels of mature females that occurred in 1997–99 (Figure 52). Further research into the importance of female abundance in regulating stock productivity is required.

Ecosystem Indices

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). This outcome appears particularly applicable under low population densities of large males (Mullowney and Baker 2021). 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 the positive benefits of cold conditions in promoting early to mid-life survival and subsequently increased densities of Snow Crab in the population. Cold bottom temperature conditions were experienced between the mid-1980s and the mid-1990s, and from about 2012–17 (Coyne et al. 2025).

The last seven years have shown an overall trend towards warmer and potentially less favourable environmental conditions for future Snow Crab productivity. It was particularly warm in 2021–22, with the NL Climate Index (Cyr and Galbraith 2020) indicating 2021 was the warmest year of the time series and 2024 was the fourth warmest year on record (Figure 54, Figure 55). Although a return to cooler conditions in recent years (2012–17) is positive because it appears to have promoted the emergence of a modest pulse of small crab likely fueling the recent fishery, expectations for the future should be tempered as climatic conditions are still relatively warm. The ocean climate indices have varied considerably over the past decade, introducing uncertainty beyond the short-term, but the overall trend is warming. Recent cold bottom conditions are not as spatially or temporally expansive as they were in the late 1980s and early 1990s, from which the highest exploitable biomass levels in the mid- to late 1990s originated (Mullowney et al. 2014). Long-term abundance may heavily hinge on the extent to which the recent warming conditions are sustained, although it is unclear how environmental, anthropogenic, or other factors such as predation will affect the survival and progression of recruitment pulses throughout life.

Bottom temperature is not the only climatic factor influencing Snow Crab productivity; the AO 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 AO 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. Although the association of these indices and future biomass is consistent with a linkage between cold conditions and high stock productivity (e.g., positive AO and NAO generally leads to cold conditions along the NL Shelf), other climatic factors such as plankton bloom strength and timing, water mixing, food availability, or predator field dynamics may affect Snow Crab survival during early ontogeny. The short-term prediction model predicts that exploitable biomass may remain at similar levels or decline over the next two years (Figure 56).

There is much uncertainty regarding the reliability of qualitatively relating recent climate events to long-term recruitment potential. One factor contributing to this uncertainty is inconsistency in levels of fishing, in particular if exploitation rates are allowed to increase during unproductive periods (Mullowney et al. 2014). The history of the stock trajectory depicts oscillating periods of changes in bottom-up versus top-down control. For example, 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 was largely under bottom-up control, in association with low exploitation rates in the largest areas of abundance (i.e., offshore areas in AD 3LNO) (Mullowney et al. 2014). Conversely, subsequent assessments highlighted that heavy exploitation has grown in importance over the past decade. However, in recent years (> 2019) there has been a general trend of improvements in the exploitable biomass index associated with substantially decreased fisheries exploitation rates coupled with a period of moderately cool oceanographic conditions.

Inconsistencies in rates of predation are another top-down factor that can affect the degree of climate control on Snow Crab productivity. A general prolonged shift toward warmer conditions throughout the 2000s appears to have affected the Snow Crab resource in the form of increased predation, as temperate finfish populations responded positively to warming (DFO 2014; Rose and Rowe 2015; Pedersen et al. 2017). The predation mortality index remained among the highest in recent years, however there have been declines from the peaks of 2016–18 (Figure 57). The predation mortality index has remained generally high within the Divs. 2J3K and 3LNO time series and remained lower in the 3Ps time series, with the highest predation mortality rates in Divs. 2J3K. The regulating effect of predation is thought to be most important on small- to intermediate-sized crab (Chabot et al. 2008); thus, a delay would be expected between decreases in the predation mortality index and recruitment into the exploitable biomass and vice versa. Following that consumption occurs primarily on small- to intermediate-sized crab, the predation mortality index may also infer mid- to long-term recruitment prospects.

With respect to overall ecosystem productivity, ecosystem conditions in the NL bioregion remain indicative of a low productivity state, likely driven by bottom-up processes (e.g., food limitation). However, improvements in total biomass have been observed since 2020 after the lows in the mid-2010s. These increases have been driven by groundfish. Increased nutrient availability and zooplankton biomass, along with a higher abundance of 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.

Mortality

An index of total mortality from trawl survey data was calculated based on stage-specific biomass indices of exploitable Snow Crab, which indicates the exploitable Snow Crab that remain from the previous year. Caution should be used in interpreting this index as it is inherently uncertain due to subjectivity in shell condition assignment between later new-shelled and early intermediate-shelled crab. Throughout the time series, total mortality in exploitable Snow Crab has been highest in ADs 2HJ and 3K (Figure 58). Total mortality has consistently been around 50% in AD 3LNO throughout the time series. There is high variability in the total mortality index in AD 3Ps which likely reflects the shell condition-based methodology, with a spring survey potentially affecting the subjective shell condition classifications.

Natural Mortality

Bitter Crab Disease is an important source of consistently measured natural mortality in the population. It is fatal to crab, occurs primarily in new-shelled crab of both sexes, and is most commonly acquired during molting (Dawe 2002). The most reliable size group of Snow Crab assessed for the impact of BCD on the population is the 40–59 mm CW size group, with these small- to mid-sized animals commonly visibly infected (Mullowney et al. 2011). Although the macroscopic analyses used to classify crab as infected are known to underestimate true prevalence, a study using advanced polymerase chain reaction techniques on specimens collected in the early to mid-2000s to identify infections has shown trends closely reflect the visually observed patterns seen throughout the region (DFO, unpublished data).

Bitter Crab Disease has been observed in the trawl and trap surveys in Divs. 2J3KLNOPs throughout the time series. The prevalence and distribution of BCD throughout the NL Shelf has been described in detail by Dawe (2002) and appears related to circulation features (Dawe et al. 2010b) and the density of small crab (Mullowney et al. 2011). Spatially, the disease has tended to follow a pattern of being most prominent in shallow nearshore areas of the NL Shelf with a virtual absence in deeper areas farther offshore. Bitter Crab Disease has been consistently low in fall trawl surveys in AD 2HJ, although prevalence exceeding 10% occurred for 60–75 mm CW Snow Crab in 2015–16 (Figure 59). However, there have been no reports of BCD in this AD in the trawl survey since then. Bitter Crab Disease is normally most prevalent in AD 3K and in 2024 it was present in most size categories of Snow Crab in this AD, with a particularly high prevalence in legal-sized crab. The disease is also very prevalent in the DFO inshore trap surveys in White Bay and Notre Dame Bay (inshore 3K), where often over 10% of the catches of new-shelled males have BCD. Bitter Crab Disease is normally uncommon in AD 3LNO, but a prolonged pulse of relatively high incidence was observed in this AD from approximately 2001–06, most prominent in 40–59 mm CW Snow Crab. This sustained pulse of BCD likely reflected progression of the recruitment pulse detected in the trawl surveys as 20–30 mm CW Snow Crab in 2001–03 (Figure 52), which was subsequently tracked as pre-recruits in surveys from 2008–10 (Figure 46). The disease is uncommon in AD 3Ps, however this is likely due to the timing of the survey in spring, as chronic infections are most apparent in the fall (Mullowney et al. 2011).

Fishing Mortality

Beyond direct removals of Snow Crab from the system, the fishery also imposes mortality on Snow Crab through discarding. Crab that are caught and released as undersized or legal-sized soft-shell males are subject to multiple stresses and have unknown survival rates. Time out of water, air temperature, water temperature, wind speed, sunlight, shell hardness, and size may all influence the mortality level on discarded Snow Crab (Miller 1977; Dufour et al. 1997; Grant 2003; van Taemelen 2005; Urban 2015). Soft-shell crab are likely subject to more damage and mortality than hard-shelled crab. Poor handling practices, such as prolonged exposure on deck and dropping or throwing crab, can induce limb loss and lead to increased mortality levels associated with catching and discarding (Grant 2003).

In a study in the Bering Sea, Urban (2015) predicted only about 5% mortality for discarded Snow Crab. This estimate is virtually identical to the estimate of Grant (2003) in NL for Snow Crab subjected to best handling practices, specifically in the form of minimal dropping distances and exposure time on deck. However, Grant (2003) showed that mortality rates increased substantially under poor handling practices. It must be noted that both studies featured predominately hard-shelled crab and both authors cautioned that unobserved latent mortality was unaccounted for in their studies. Despite not knowing absolute discard mortality rates, minimizing fisheries-induced mortality and wastage of crab not retained in the fishery (particularly the most vulnerable soft-shell pre-recruits which are suspected to experience higher rates of discard mortality) is an advised best practice for the NL Snow Crab fishery.

There was particular concern in recent years for AD 2HJ, where the discard level was very high at approximately 40% of the catch in 2019 (Figure 60) and was comprised of mostly legal-sized soft-shell crab throughout the time series (Figure 61). Accordingly, relative levels of resource wastage in the form of discard mortality were likely highest in the AD 2HJ fishery, assuming survival is lowest in soft-shell crab. Assessment Division 3K most recently had a peak in discarding in 2017–18 nearing 40% discarded and again in 2024 (Figure 60). Past peaks showed higher amounts of legal-sized soft-shell crab, while the 2024 discarding was primarily undersized old-shelled crab (Figure 61). These periods of high soft-shell crab discarding were associated with generally low and declining recruitment and exploitable biomass. In AD 3LNO, the majority of discards were composed of undersized, hard-shelled crab. Historically, there had to be higher levels of soft-shell crab in the population in this area, as the resource was consistently productive and strong recruitment occurred each year. The historic situation likely reflects the imposition of an efficient harvest that maintained a strong residual biomass that prohibited persistent high levels of soft-shell crab from emerging as a major concern in the fishery through trap competition. In AD 3Ps, there was a high period of discarding in 2016–17, however it has been consistently around 20% since 2019, and even lower in 2024 (Figure 60). The majority of the discards in this AD consist of undersized hard-shelled crab (Figure 61). At-sea observer coverage is poor in AD 4R3Pn, with much greater uncertainty surrounding the estimates (Figure 60) resulting from a low number of traps sampled.

Measures should be taken not only to reduce soft-shell encounters overall, but to better quantify prevalence of soft-shell crab in the fishery and afford better protection to incoming recruitment. A high incidence of soft-shell crab in the catch ultimately reflects inefficiency in resource extraction. It is wastage that occurs on pre-recruits and constitutes an opportunity cost to the future fishery as well as a biological loss to future reproductive potential.

Prevalence of legal-sized soft-shell males in the fishery is affected by fishery timing and exploitable biomass level. From a biological perspective, the optimal time to harvest Snow Crab to avoid soft-shell individuals in the catch is winter. However, in the absence of an ability to conduct a winter fishery, mortality on soft-shell males can be minimized by fishing early in spring before recently-molted crabs are capable of climbing into traps. It can 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-shell immediate pre-recruits, even during peak soft-shell periods (Mullowney et al. 2021). Discard levels in the fishery are generally negatively correlated with CPUE, suggesting that maintaining a high fishery CPUE is a good management strategy to avoid high discarding (Figure 62) (Mullowney et al. 2018b).

Overall, the many shortcomings of the soft-shell protocol (described in the Fishery section) undermine its intent of safeguarding against handling mortality in the fishery. As it has been and continues to be invoked, the soft-shell protocol can serve as a basis to enable and prolong fishing on soft-shell crab under the auspice of conservation rather than preventing mortality to soft-shell crab. The soft-shell protocol as currently invoked is not an effective conservation tool to safeguard against handling mortality in this fishery and should be re-examined.

Trends in total mortality generally reflect those of fishing-induced mortality, as measured by ERIs. Previous assessments have demonstrated that ADs experiencing notable recovery in the exploitable biomass were associated with reduced total mortality rates and associated reductions in exploitation rates, while ADs remaining at low levels with little signs of recovery were associated with persistently high total mortality and exploitation rates (Pantin et al. 2024). In AD 2HJ, the ERI decreased in 2023 and remained at that level in 2024. Under status quo landings in 2025 the ERI is projected to increase slightly (Figure 63). In AD 3K, the ERI increased in 2024 and under status quo landings in 2025 it is projected to increase to over 60%. This is beyond the maximum exploitation level of 42% in the Healthy Zone permitted under the PA Framework. In AD 3LNO, the ERI has remained around 20% for the last six years and no change is projected under status quo landings in 2025. In AD 3Ps, the ERI increased in 2024 and under status quo landings it is projected to increase to near 50% in 2025. This is beyond the maximum exploitation level permitted under the PA Framework. In AD 4R3Pn, precision of estimation of the exploitable biomass index is low due to the absence of a trawl survey and limited coverage throughout the AD in the CPS trap survey, therefore precision of estimation of ERI is also low. The ERI has been variable and at a high level in this AD and in 2024 the ERI increased. Under status quo landings in 2025 the ERI is projected to increase further. With the implementation of the PA Framework for decision-making in all other ADs for the 2023 fishery and beyond, ERIs will be prohibited from increasing to the very high levels of the past.

The consequences of high exploitation (as seen in some ADs in the past) are unknown, but the potential for biological harm to the resource through fishing elevates as exploitation reaches and becomes sustained at high levels. In the NL Snow Crab fishery, historic ERIs in some ADs and years have been overall very high relative to other major fisheries for the species in Atlantic Canada and Alaska, particularly the high ERIs seen in most ADs in the late 2010s and later in AD 2HJ. In NL, in historic portions of the time series in ADs 2HJ and 3K, there has been a lack of old-shell crab in the biomass, even at largest sizes associated with terminally molted animals, which is not typical of the population structure for most other fished Snow Crab populations globally. The strategy of exploiting heavily and near-wholly relying on incoming recruitment each year is risky with respect to the possibility of unforeseen events that affect recruitment. Moreover, areas with low residual biomasses are generally associated with wasteful practices and recruitment overfishing, with soft-shell prevalence and discard rates generally high in the presence of high exploitation and low residual biomass. Overall, these historically high exploitation rates have become reduced in recent years, with most ADs exploiting the biomass at rates in a range of about 25–45% or lower. This shift toward overall more moderate exploitation of the resource is associated with the development of a PA Framework in 2018 (Mullowney and Baker 2023).

Beyond promoting risk and wastage in the fishery, high exploitation rates greatly increase the potential for negative biological outcomes in the population. The strategy of removing most large males from the population could have serious consequences, such as sperm limitation in females or changes in growth patterns or maturation sizes (Baker et al. 2022). Large hard-shelled males are the prime breeders and likely serve to introduce sufficient intraspecific competition in the population to promote large size-at-terminal molt. Large competitive males serve to maintain reproductive integrity as well as physically structure population demographics.

The outcomes of the scenario of rendering the population virtually void of large males in some areas will be important to continue to monitor from biological and management advice perspectives. Baker et al. (2022) concluded that conservative exploitation rates are important in safeguarding an adequate proportion of large, hard-shelled males in the population and necessary to ensure that existing low sperm reserves do not hamper the reproductive potential of the population.

Size-at-maturity

A broad-scale decline in male size-at-maturity (i.e., the size at which a crab undergoes terminal molt into morphometric maturity) has been evident for the NL Snow Crab stock (Figure 64, Figure 65). This shift occurred in most ADs around 2015–17, but persisted in AD 2HJ and was well below exploitable size (i.e., 64–72 mm CW from 2015–21). Assessment Division 3K has seen some variation around the size at 50% terminal molt in recent years, however there is still an overall downward trend in this AD. The declines in male size-at-maturity suggest that any improvements in recruitment potential could be significantly dampened unless male size-at-maturity recovers to previous levels.

Mullowney and Baker (2021) found that the pronounced shift in male size-at-maturity in AD 2HJ was a consequence of a concomitant combination of cold conditions and low density of large males. This study showed that low densities of large males promoted a small terminal molt size and, consequently, high exploitation could affect molting dynamics. While temperature also affects molting and growth dynamics, this study asserted that other factors interacted with temperature to regulate molting, as this shift has not been seen in female size-at-maturity under the same environmental conditions or more extreme historical cold periods. The emergence or potential reversal of this phenomenon will be important to monitor moving forward as persistent decreased size-at-maturity would negatively impact stock and, subsequently, fishery productivity. The potential for these changes to affect reproductive success is possible; the mating behaviors of Snow Crab rely on large males and small females. Trends in size-at-maturity will continue to be monitored closely.

Precautionary Approach

In 2025, assuming status quo landings, CPUE is predicted to remain in the Healthy Zone in ADs 3LNO and 3Ps, and the Cautious Zone in ADs 2HJ and 3K (Figure 66). Discard levels, assuming status quo landings, are predicted to be in the Healthy Zone in all ADs in 2025. Data from both the fall and spring surveys throughout Divs. 2HJ3KLNOPs showed that in nearly all years the vast majority (i.e., > 80%) of mature females were carrying full clutches of viable eggs (Figure 66). In 2024, all ADs were in the Healthy Zone for egg clutches.

Mature females store sperm and can produce multiple clutches of eggs from a single mating season (Sainte-Marie 1993). The ability of males to mate with multiple females and of females to store sperm ensures that a large portion of mature females should have full egg clutches. Although it is believed that per-capita fecundity can be impacted by excessive fishery exploitation of males, it has not been persistently observed to date in NL Snow Crab. However, some notable exceptions have occurred in the clutch fullness index, such as observed in AD 2HJ in 2006–07, AD 3K in 2015, and AD 3Ps in 2014–16 (Figure 66). There is an emerging trend of lower proportion of females with a full clutch in AD 3LNO, however this metric is still above the USR. With no broad-scale prolonged periods of low clutch fullness presently, the overall evidence suggests that the stock may maintain a high level of reproductive resiliency to historic levels of fishery exploitation. Investigations into possible top-down fishery effects in light of current high exploitation rates on males in some ADs, and the extent to which these high exploitation rates can be sustained before unwanted changes or harm is caused to the resource, would be beneficial to the management of the fishery. This includes more in-depth monitoring of female insemination levels.

For stock status in 2025, ADs 2HJ and 3K are projected to be in the Cautious Zone of the PA Framework, while ADs 3LNO and 3Ps are projected to remain in the Healthy Zone (Figure 67). These projections assume status quo landings. Recent and ongoing data deficiencies resulted in the continued exclusion of AD 4R3Pn in the PA Framework.

CONCLUSIONS

ASSESSMENT DIVISION 2HJ

The exploitable biomass index has oscillated at a low level for the last decade and remained at a low level in 2024. The exploitable biomass is dominated by new-shelled recruits, with virtually no residual biomass. There was a decline in the trawl-based pre-recruit abundance index over the last two decades, with a time-series low in 2024. This suggests poor recruitment prospects over the next 2–4 years. As well, there was a downward trend in size-at-terminal molt in males and mature female abundance was low, which could negatively affect future recruitment and productivity. The ERI decreased since 2022 and remained around the same level in 2024 as 2023. Under status quo landings in 2025, the ERI is projected to increase to 33%. Following the PA Framework, with status quo landings the stock status is projected to remain in the Cautious Zone in 2025.

ASSESSMENT DIVISION 3K

The exploitable biomass index increased from a time-series low in 2015–18 to peak in 2021–22, and has decreased by almost half in the last two years. The trawl-based pre-recruit abundance index recently peaked in 2021 but declined to a time-series low in 2024, suggesting diminishing recruitment prospects over the next 2–4 years. As well, there were signals of an emergent downward trend in size-at-terminal molt in males and mature female abundance was low, which could negatively affect future recruitment and productivity. Although the ERI has decreased since 2019, it increased to high levels in 2024. Under status quo landings in 2025 the ERI is projected to increase to 66% which is beyond the allowable level in the NL Snow Crab PA Framework. Following the PA Framework, with status quo landings the stock status is projected to be in the Cautious Zone in 2025.

ASSESSMENT DIVISION 3LNO

The exploitable biomass index has increased from a time-series low in 2016–17 and has been at some of the highest levels observed in the time series. The trawl-based pre-recruit abundance index recently peaked in 2020 and has declined since to near the time-series low in 2024, suggesting diminishing recruitment prospects over the next 2–4 years. The size-at-terminal molt in males remains high, however mature female abundance is low, which may negatively affect future productivity. The ERI has remained below 20% since 2019 and under status quo landings in 2025 is projected to be 18%. Following the PA Framework, with status quo landings the stock status is projected to remain in the Healthy Zone in 2025.

ASSESSMENT DIVISION 3PS

The exploitable biomass index increased from a time-series low in 2015–17 to near a time-series high in 2022, however this index has decreased by 65% over the last two years. The exploitable biomass has consisted of an even mix of both new-shelled recruits and old-shelled residuals throughout most of the time series, but was dominated by residual crab in 2024, indicating low immediate recruitment. The trawl-based pre-recruit abundance index peaked in 2018 and has declined since to near a time-series low in 2024, suggesting diminishing recruitment prospects over the next 2–4 years. The size-at-terminal molt in males remains high, however mature female abundance is low, which may negatively affect future productivity. The ERI had remained below 25% since 2018, but increased in 2024. Under status quo landings in 2025 the ERI is projected to increase to 48% which is beyond the allowable level in the NL Snow Crab PA Framework. Following the PA Framework, with status quo landings the stock status is projected to remain in the Healthy Zone in 2025.

ASSESSMENT DIVISION 4R3PN

The exploitable biomass index remains at a low level in this AD, however precision of estimation of the exploitable biomass index is low due to the lack of trawl survey data and incompletion of the trap survey in most years. The exploitable biomass has been dominated by new-shelled recruits throughout most of the time series, however the exploitable biomass was dominated by residual crab in the last three years, indicating low immediate recruitment. Catch rates of pre-recruit crab in the CPS trap survey indicate a decline in pre-recruit crab, suggesting poor recruitment prospects over the next 2–4 years. The ERI has been at a high level and with status quo landings in 2025 the ERI is projected to increase further. Recent and ongoing data deficiencies do not allow inclusion of this AD into the PA Framework.

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TABLES

Table 1. The set of spatiotemporal models initially applied to exploitable Snow Crab trawl and trap survey data and associated Akaike Information Criterion (AIC) values in the determination of the best model for estimating exploitable biomass.

Model	Description	AIC
$Density = s(depth) + gear + survey + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Tweedie (link = log)	831150.2
$Density = s(depth) + gear + survey + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Tweedie (link = log) Anisotropy	831128.5
$Density = s(depth) + gear + survey + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Tweedie (link = log) Split anisotropy	831103.1
$Density = s(depth) + gear + survey + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Delta gamma Split anisotropy	828010.6
$Density = s(depth) + gear + survey + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Delta log normal Split anisotropy	830384.5
$Density = s(depth) + gear + survey + 0 + as.factor(year)$	Delta gamma Split anisotropy No month term	828551.9
$Density = s(scale\_depth) + gear + survey + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Delta gamma Split anisotropy Spatial varying depth	825460.2

Table 2. The set of spatiotemporal models applied to exploitable Snow Crab survey data from the CPS and DFO inshore trap surveys occurring in the same Crab Management Areas and associated Akaike Information Criterion (AIC) values in the determination of a survey effect.

Model	Description	AIC
$Density = s(scale\_depth, k = 5) + as.factor(gear) + as.factor(survey) + s(month, k = 5) + 0 + as.factor(year)$	Delta gamma Split anisotropy Spatial varying depth	108619.4
$Density = s(scale\_depth, k = 5) + as.factor(gear) + as.factor(survey) + s(month, k = 5) + 0 + as.factor(year)$	Delta gamma Split anisotropy Spatial varying depth	108642.2

Model	Description	AIC
$Density = s(scale\_depth, k = 5) + as.factor(gear) + as.factor(survey) + s(month, k = 5) + 0 + as.factor(year)$	Delta gamma Split anisotropy Spatial varying depth	108601.5

Table 3. The set of spatiotemporal models applied to exploitable Snow Crab trawl and trap survey data and associated Akaike Information Criterion (AIC) values in the determination of the final model for estimating exploitable biomass, including evaluation of a model with a barrier mesh.

Model	Description	AIC
$Density = s(depth) + as.factor(survey - gear) + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Tweedie (link = log)	831122.3
$Density = s(depth) + as.factor(survey - gear) + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Tweedie (link = log) Anisotropy	831100.7
$Density = s(depth) + as.factor(survey - gear) + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Tweedie (link = log) Split anisotropy	831075.1
$Density = s(depth) + as.factor(survey - gear) + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Delta gamma Split anisotropy	827991.7
$Density = s(depth) + as.factor(survey - gear) + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Delta log normal Split anisotropy	830364.4
$Density = s(depth) + as.factor(survey - gear) + 0 + as.factor(year)$	Delta gamma Split anisotropy No month term	828531.7
$Density = s(depth) + as.factor(survey - gear) + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Delta gamma (spatial varying depth model did not pass the ‘sanity’ check) Barrier mesh	828330.8
$Density = s(scale\_depth, k = 5) + as.factor(survey - gear) + s(month, bs = cc, k = 12) + 0 + as.factor(year)$	Delta gamma Split anisotropy Spatial varying depth	825441.2

FIGURES

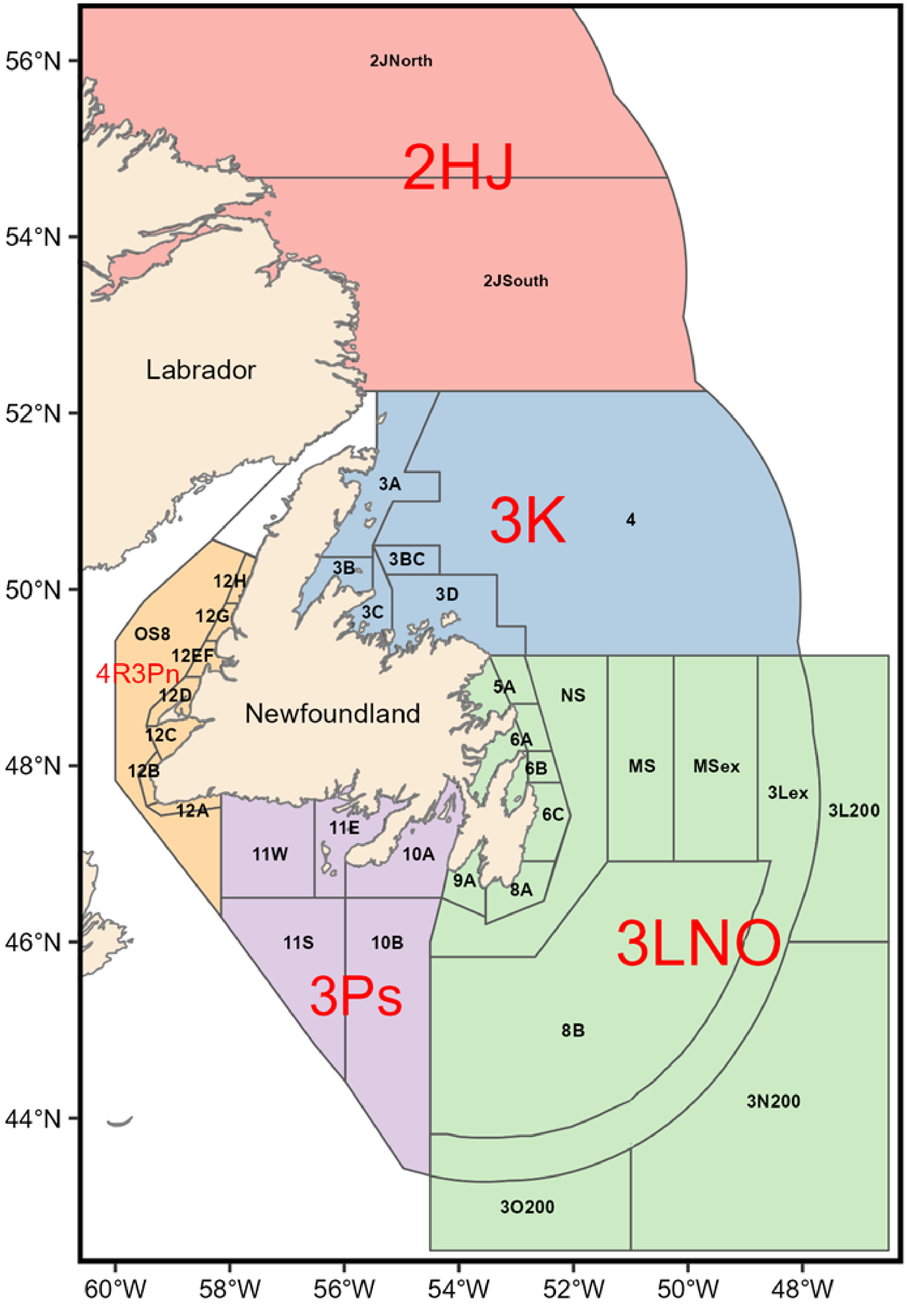

Figure 1. Newfoundland and Labrador Snow Crab Management Areas (CMAs) (black lines) and Newfoundland and Labrador Snow Crab Assessment Divisions (ADs) (colored blocks).

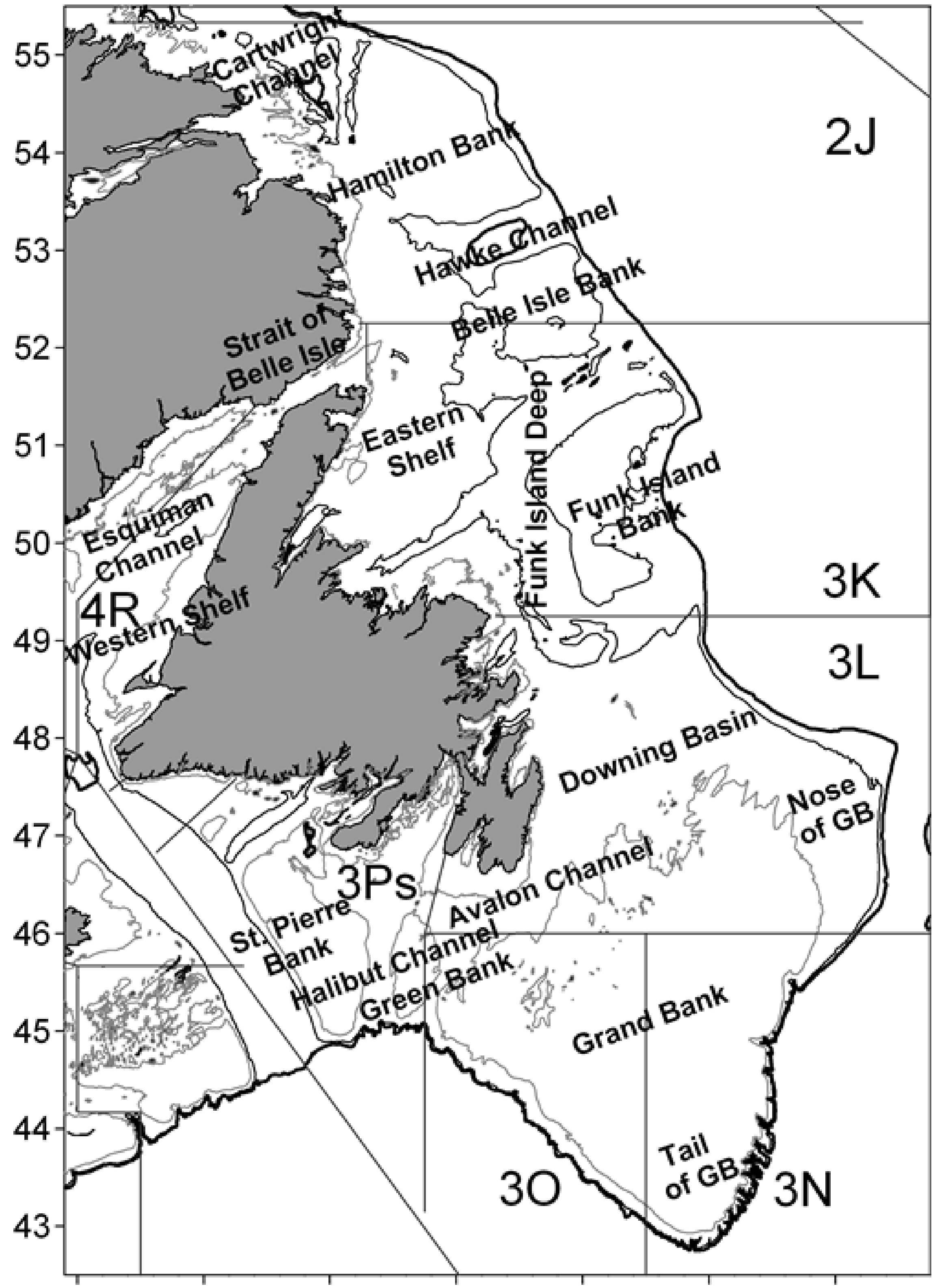

Figure 2. Map of the Newfoundland and Labrador Continental Shelf showing place names, bathymetrical features, and NAFO Divisions.

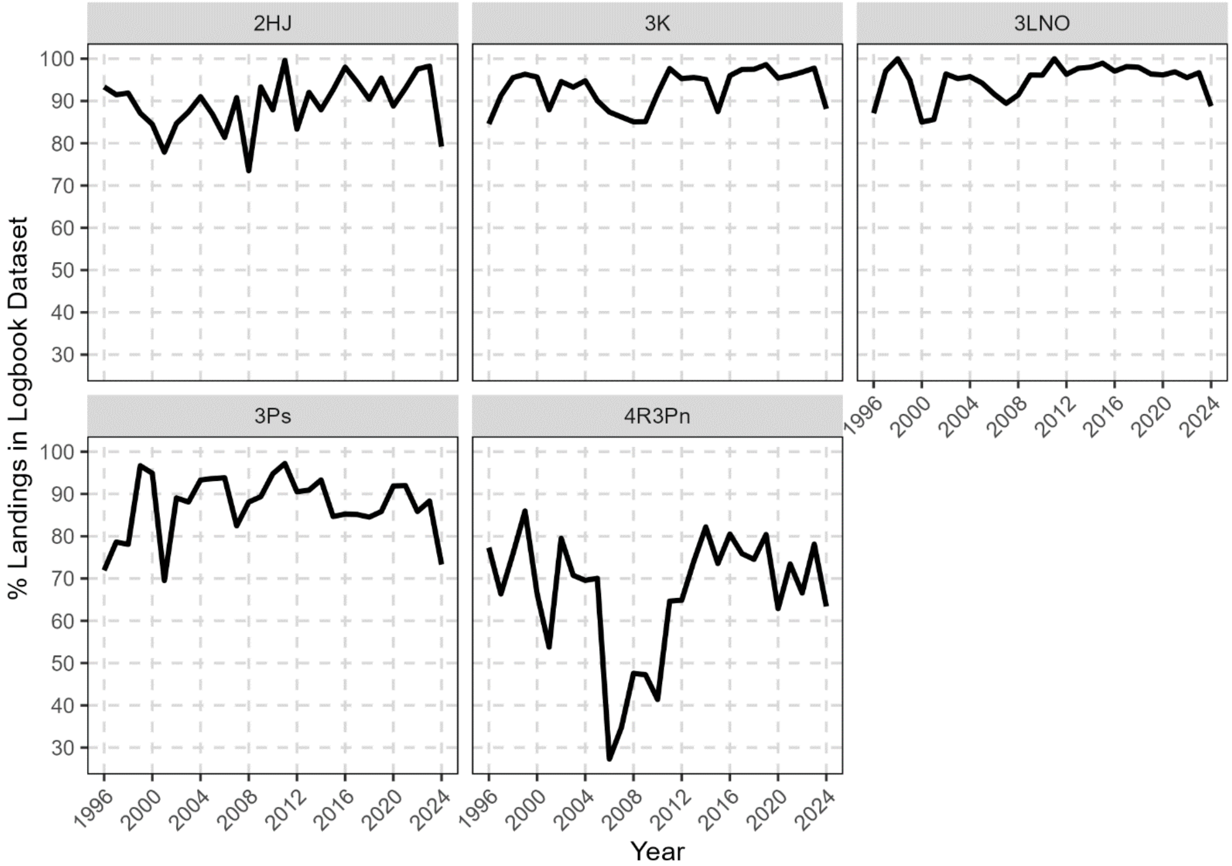

Figure 3. Logbook return rates by Assessment Division (1996–2024).

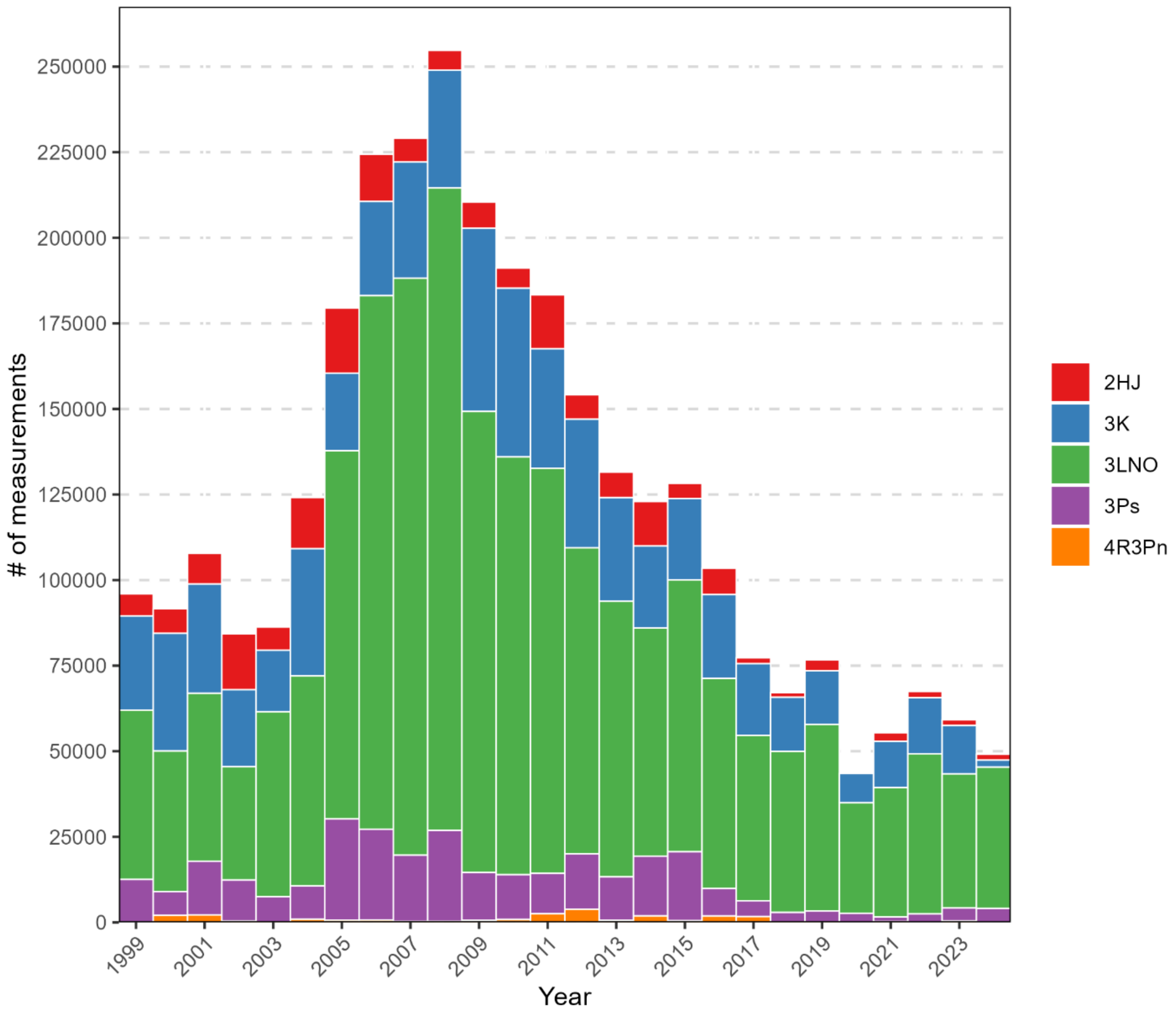

Figure 4. Number of Snow Crab measurements by at-sea observers by year (1999–2024). Colored bars represent Assessment Divisions.

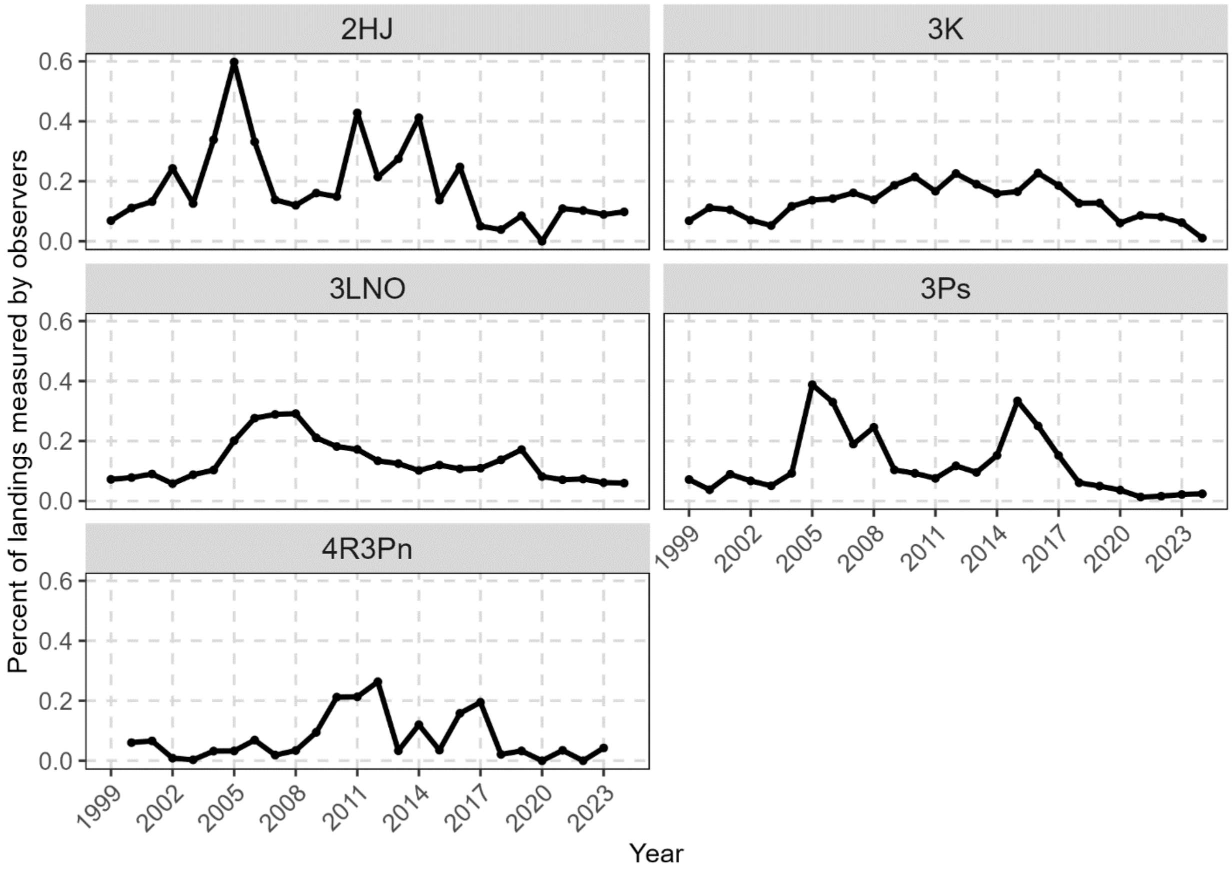

Figure 5. Percent of landings measured by at-sea observers by Assessment Division (1999–2024).

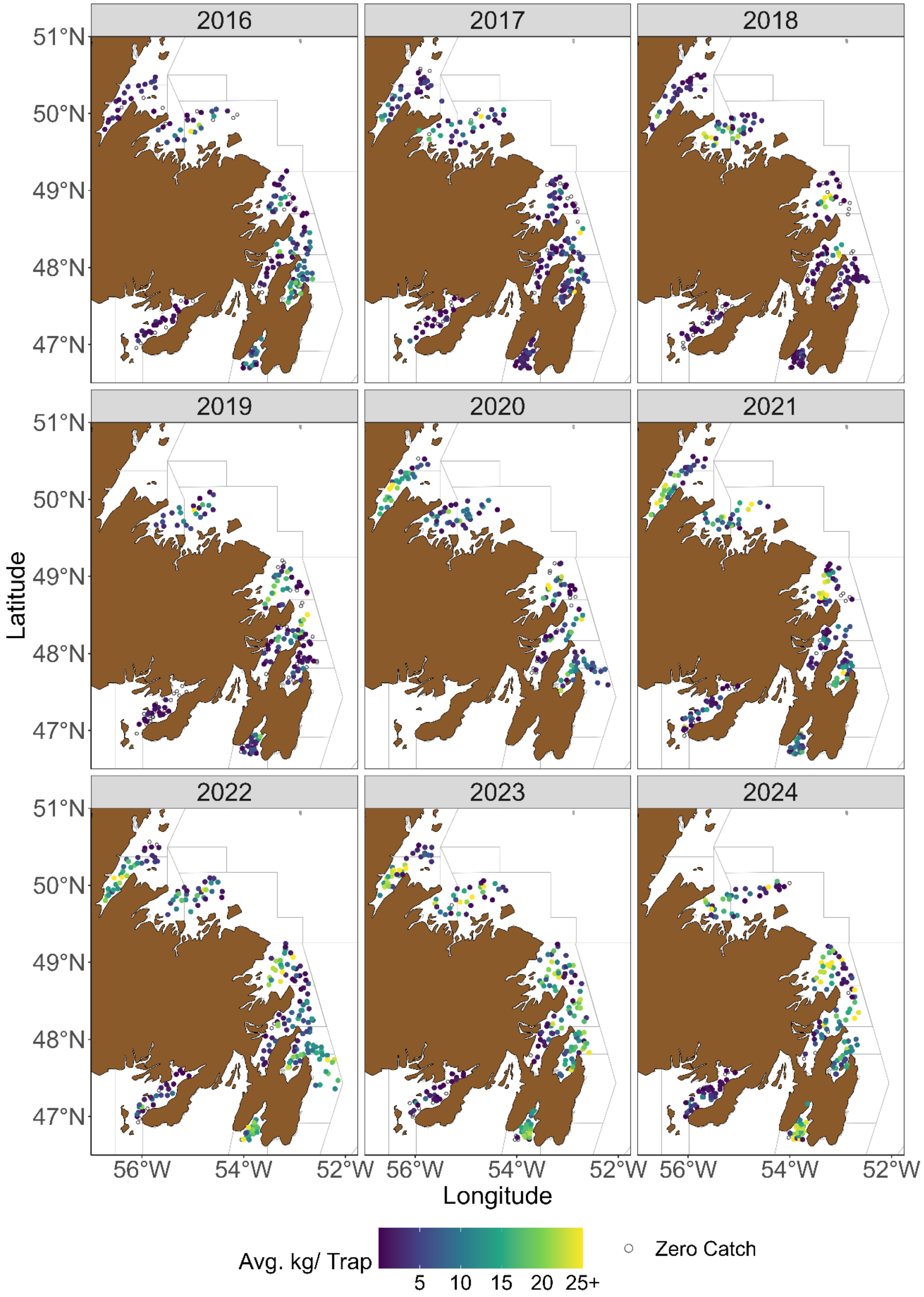

Figure 6. Location of sets and CPUE (kg/trap) of exploitable Snow Crab in large-mesh traps from the DFO inshore trap surveys (2016–24).

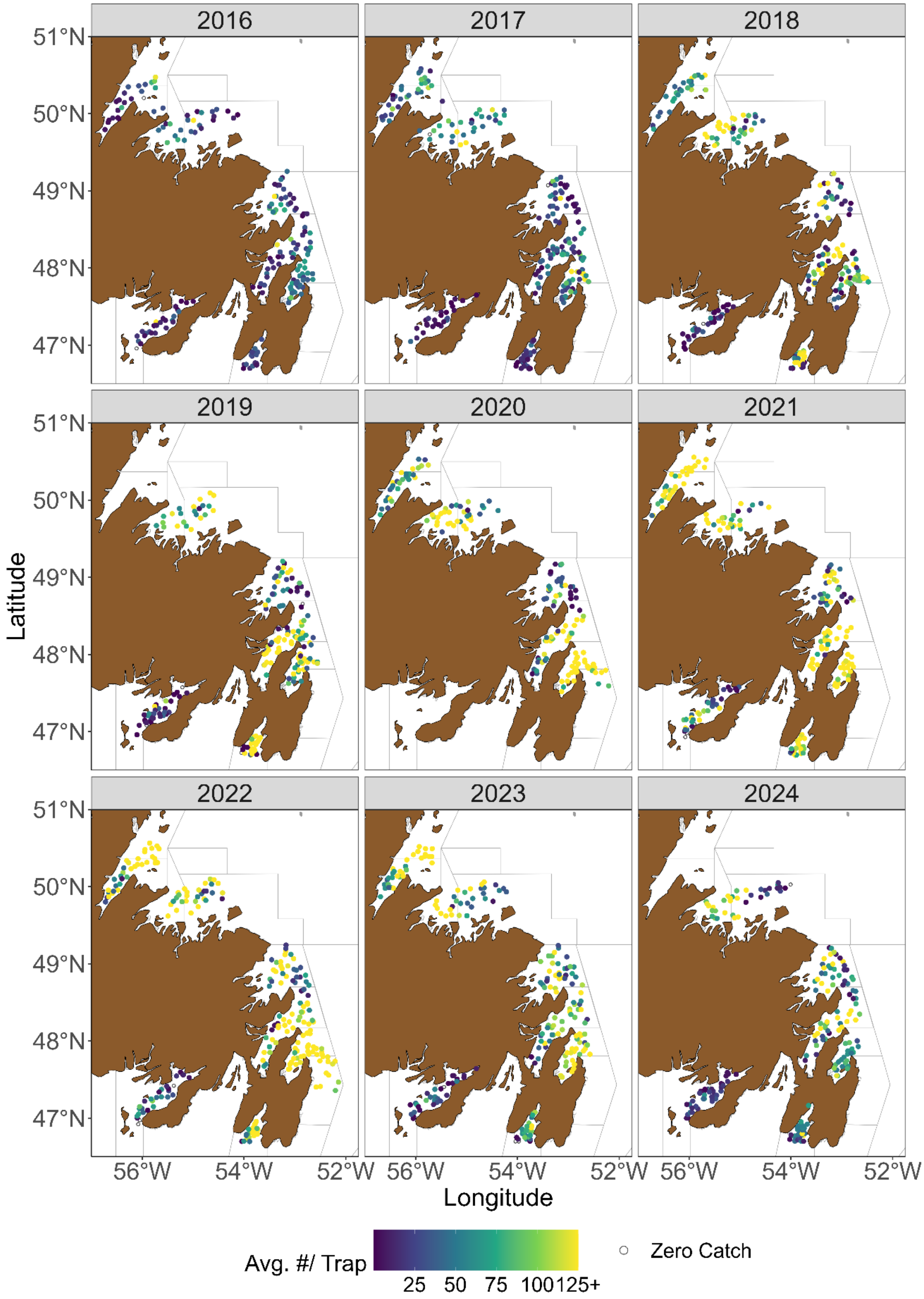

Figure 7. Location of sets and CPUE (#/trap) of all Snow Crab in small-mesh traps from the DFO inshore trap surveys (2016–24).

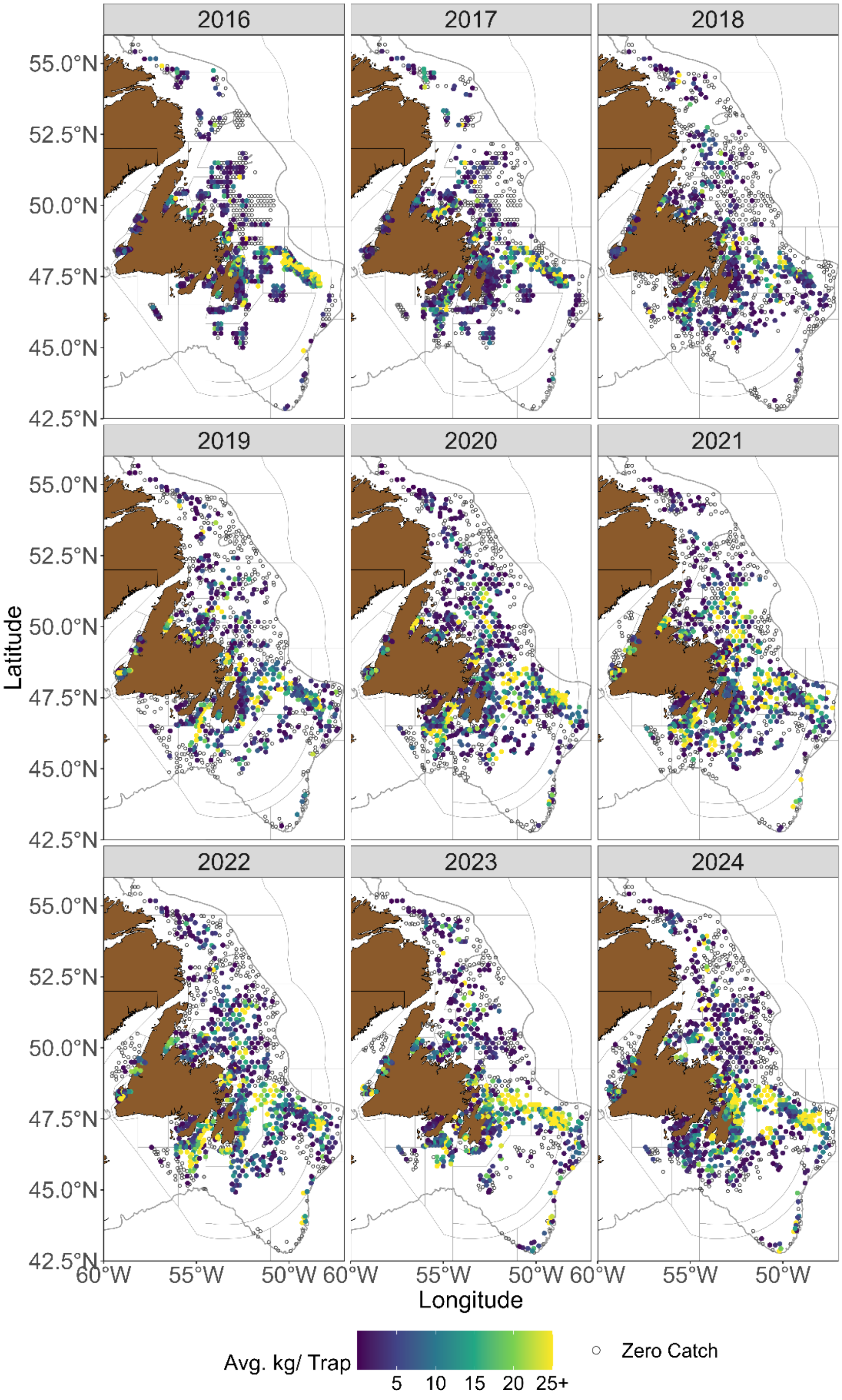

Figure 8. Location of sets and CPUE (kg/trap) of exploitable Snow Crab in large-mesh traps from the Collaborative Post-Season trap survey and Torngat Joint Fisheries Board trap survey (2016–24).

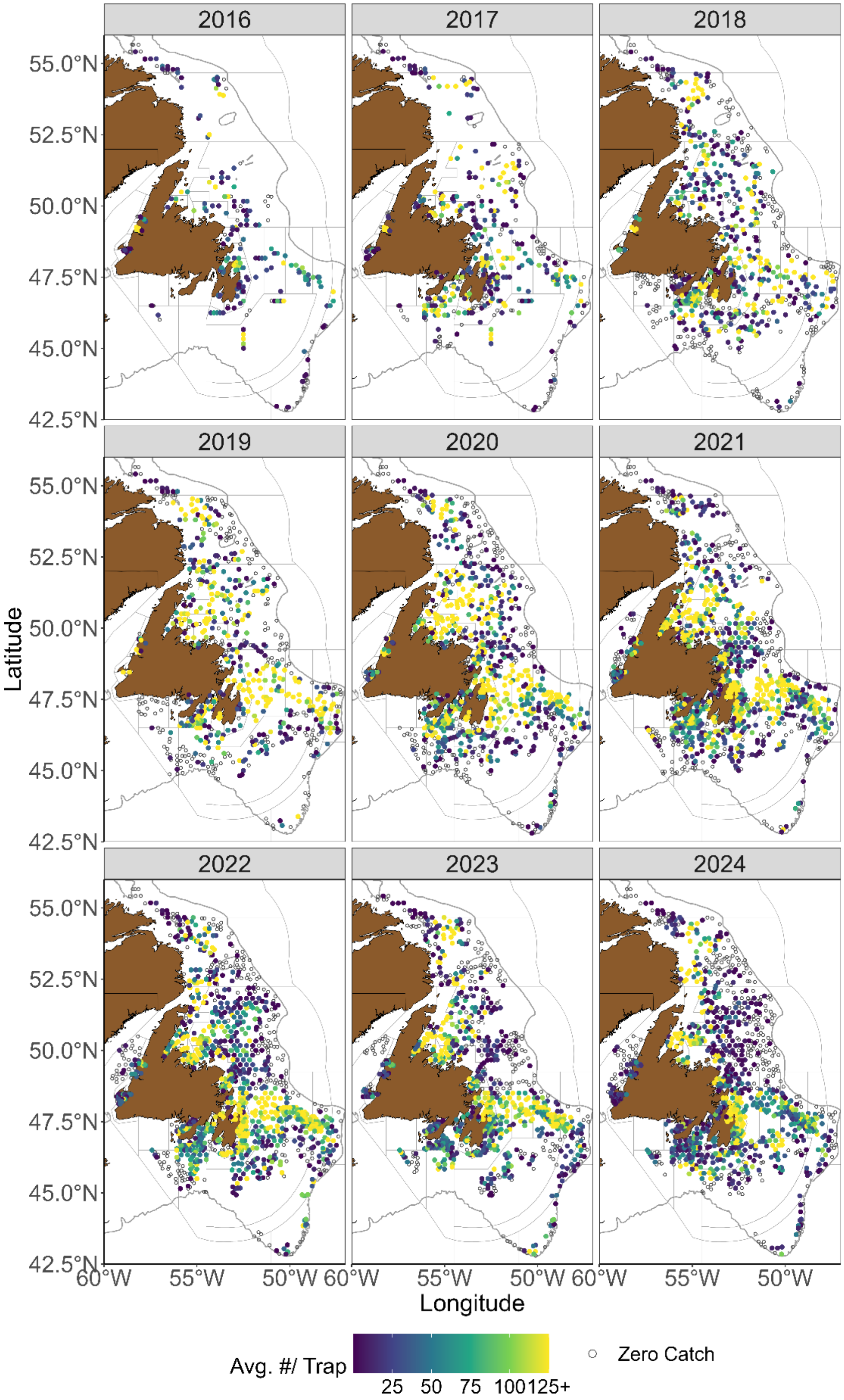

Figure 9. Location of sets and CPUE (#/trap) of Snow Crab in small-mesh traps from the Collaborative Post-Season trap survey and Torngat Joint Fisheries Board trap survey (2016–24).

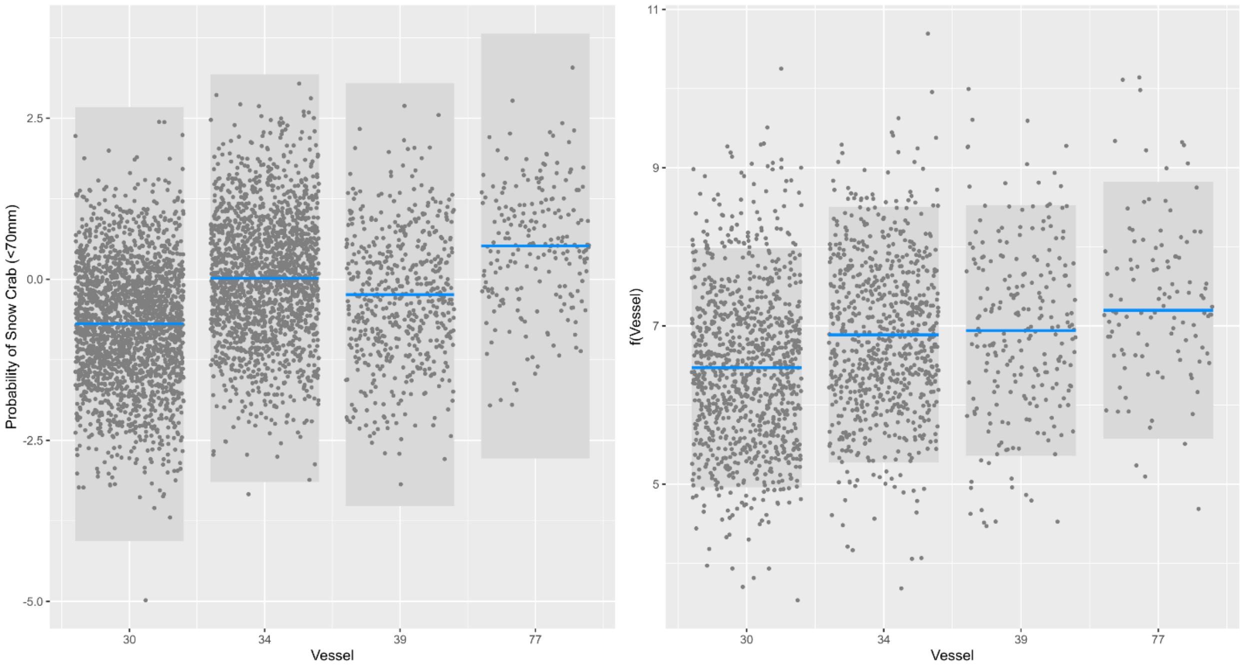

Figure 10. Conditional effects of vessel (30 = CCGS Templeman*, 34* = CCGS Alfred Needler*, 39* = CCGS Teleost*, 77* = CCGS John Cabot*) on Snow Crab with < 70 mm CW density for the binomial component (left) and lognormal component (right) of the spatiotemporal delta lognormal model. Lines represent means and shaded ribbons represent 95% confidence intervals.*

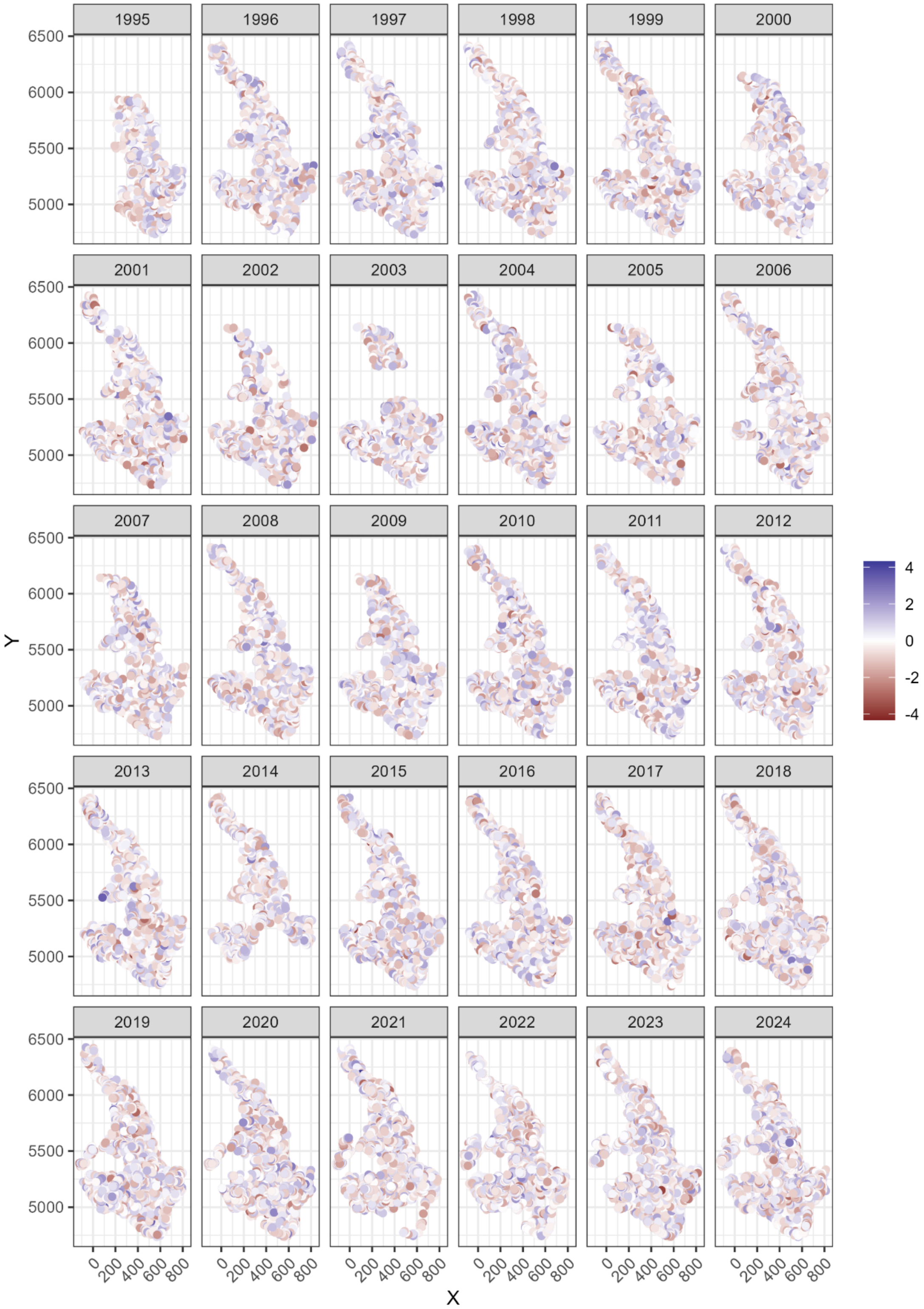

Figure 11. Spatial and temporal distribution of residuals for the binomial components of the exploitable biomass estimation final model.

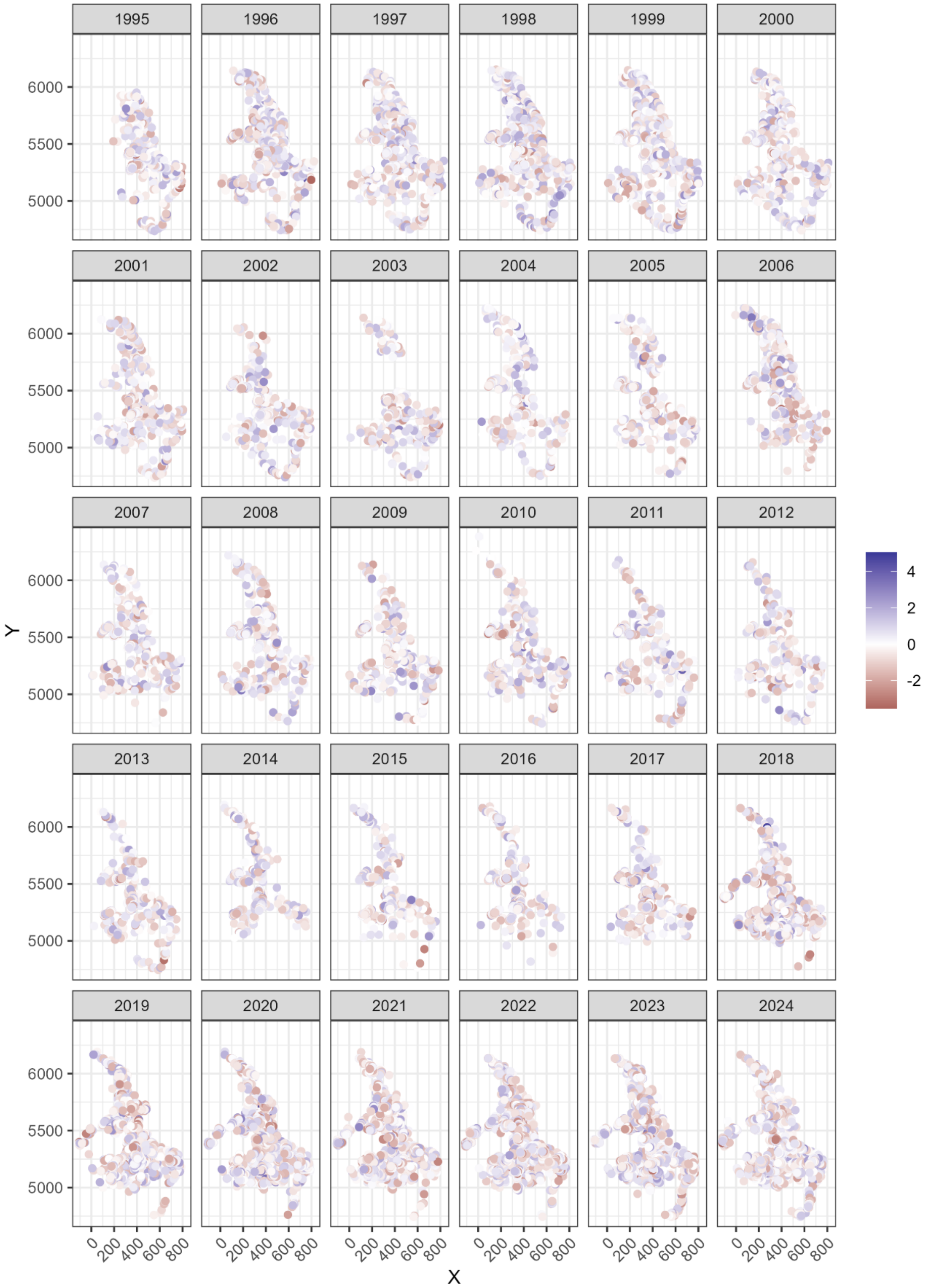

Figure 12. Spatial and temporal distribution of residuals for the gamma components of the exploitable biomass estimation final model.

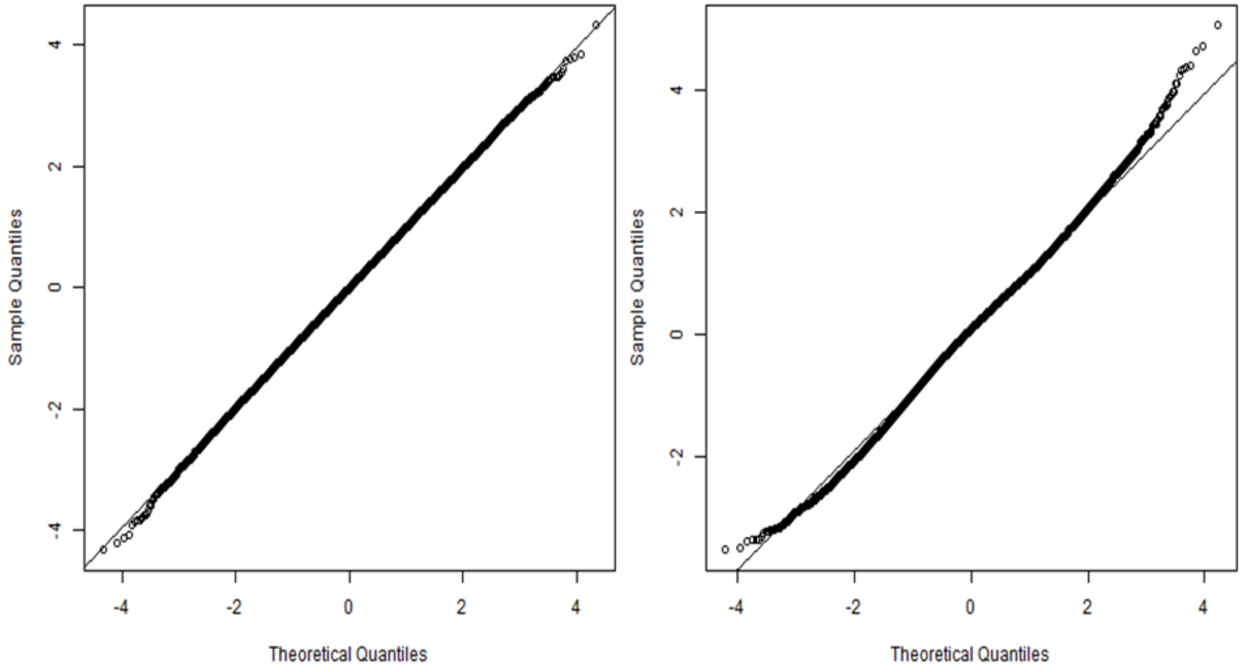

Figure 13. Quantile-quantile plot of residuals for binomial (left) and gamma (right) components of the exploitable biomass estimation final model.

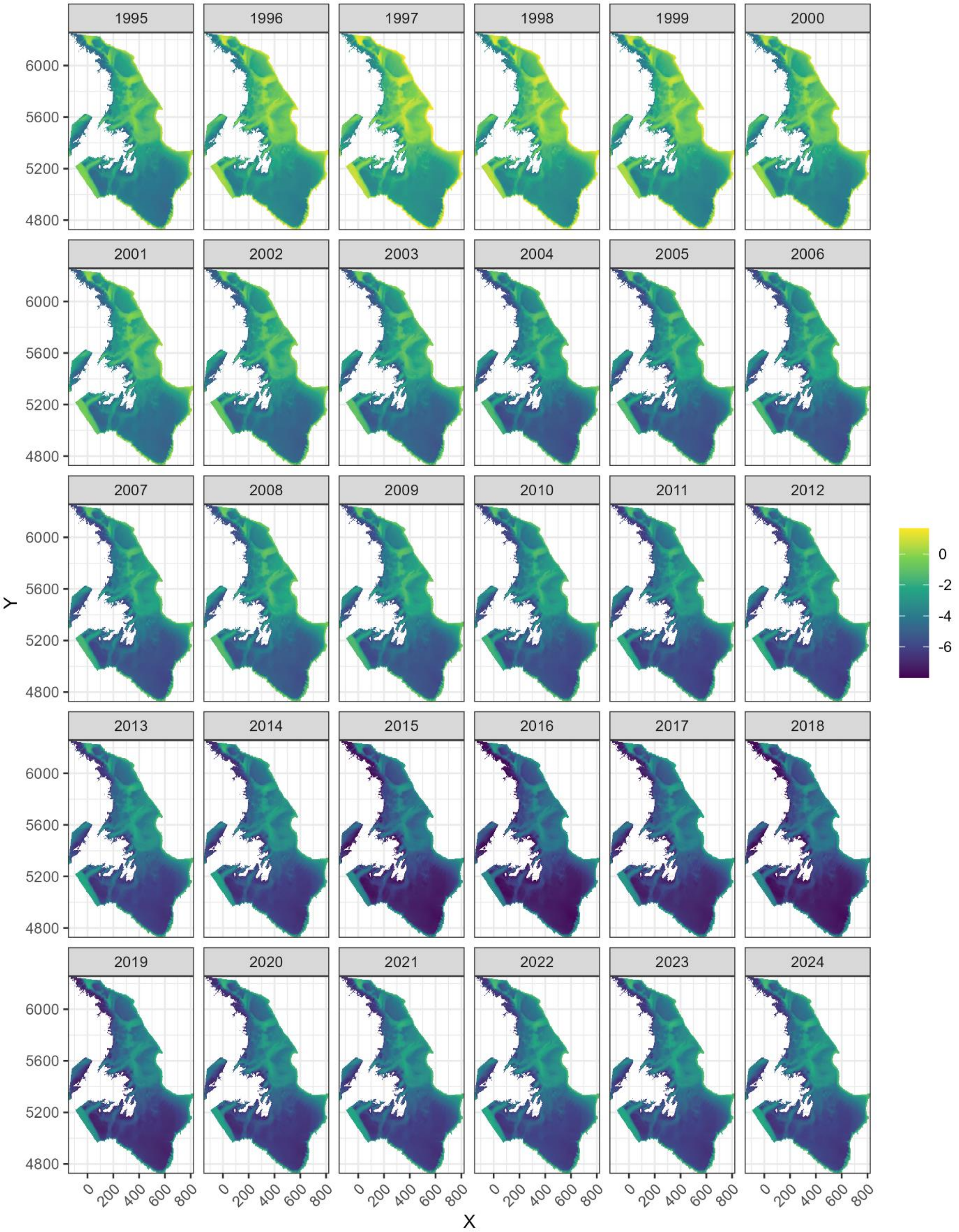

Figure 14. Fixed effects for binomial components of the exploitable biomass estimation final model.

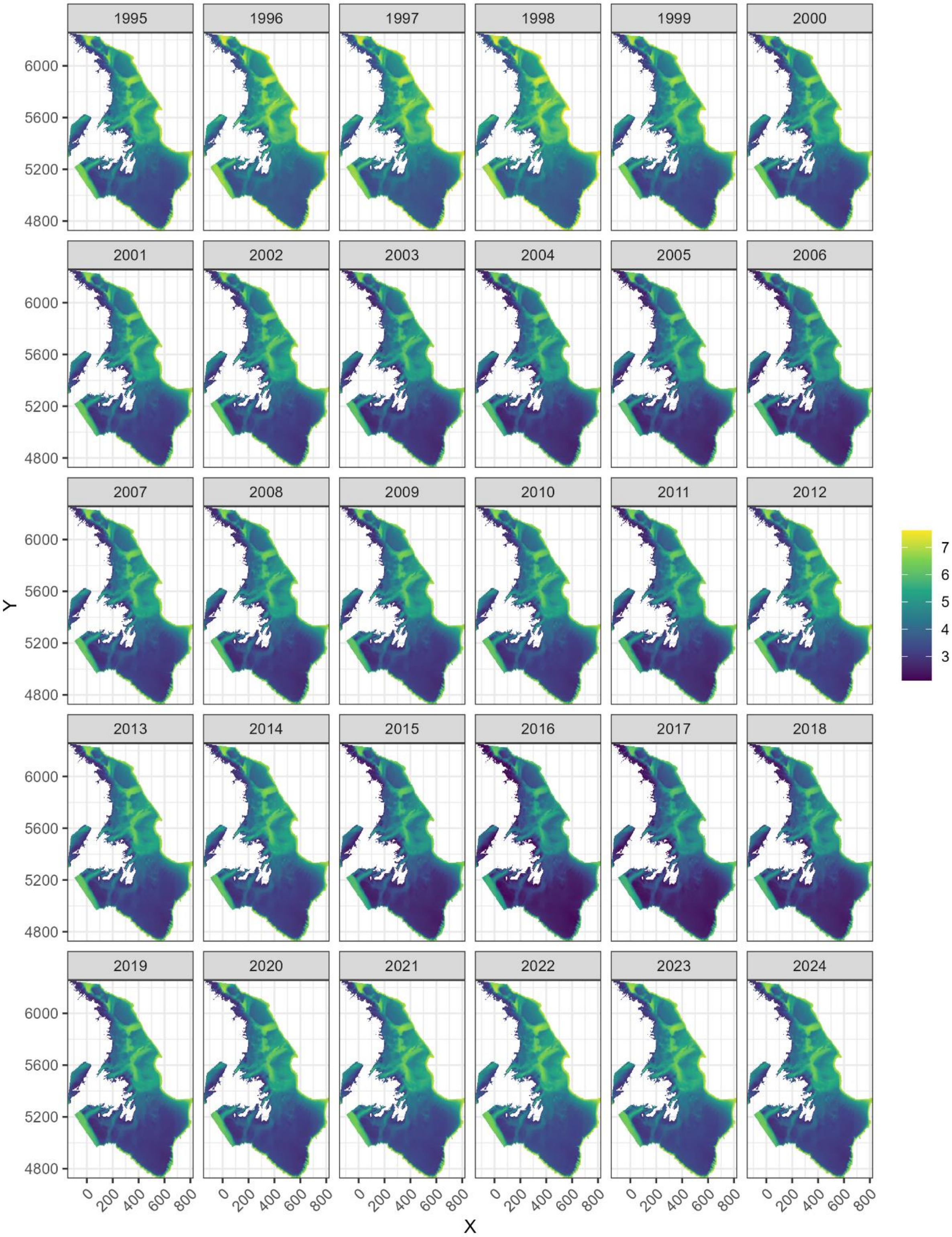

Figure 15. Fixed effects for gamma components of the exploitable biomass final model.

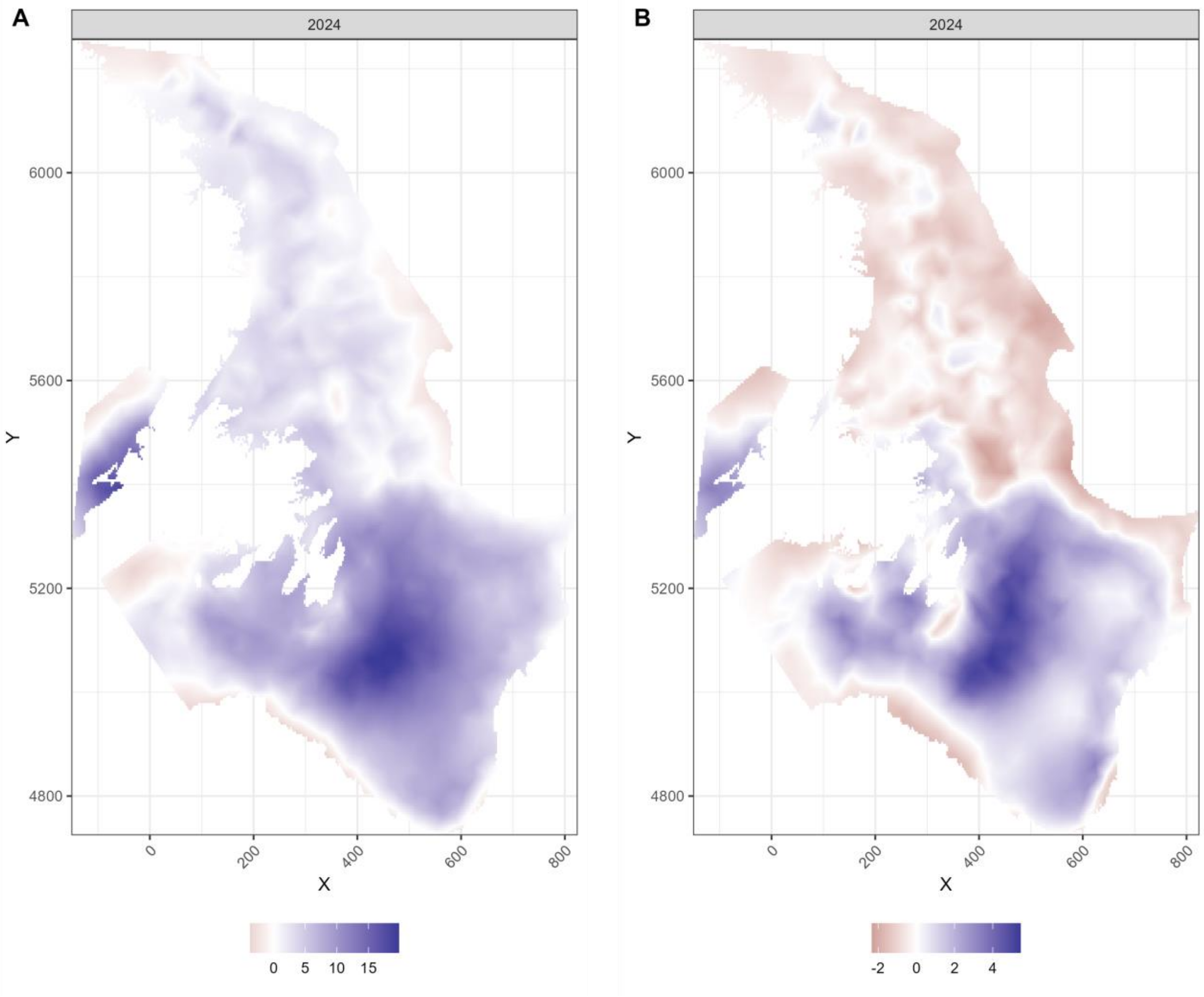

Figure 16. Spatial random effects of binomial (A) and gamma (B) components of the exploitable biomass estimation final model.

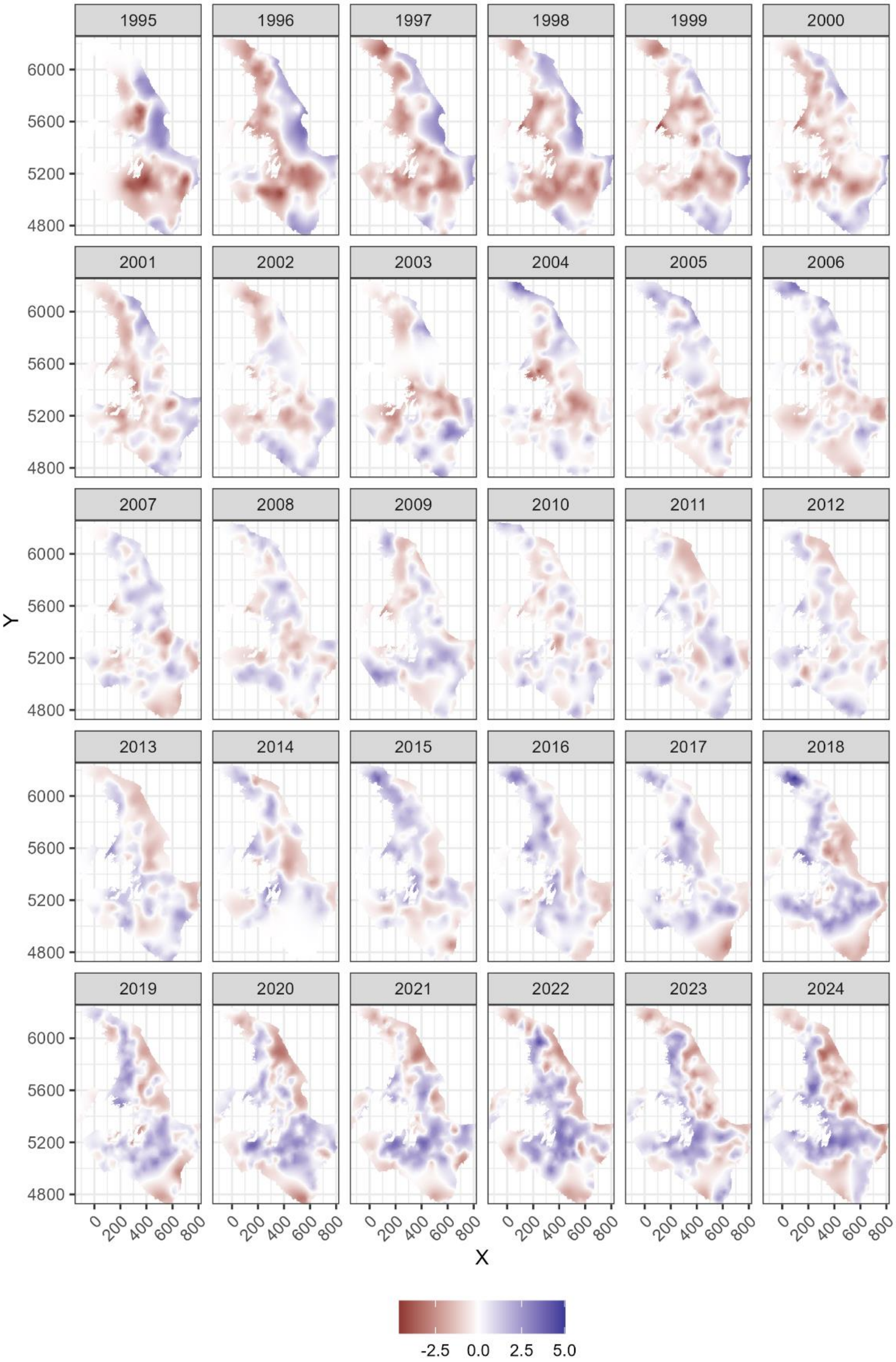

Figure 17. Spatiotemporal random effects for binomial components of the exploitable biomass estimation final model.

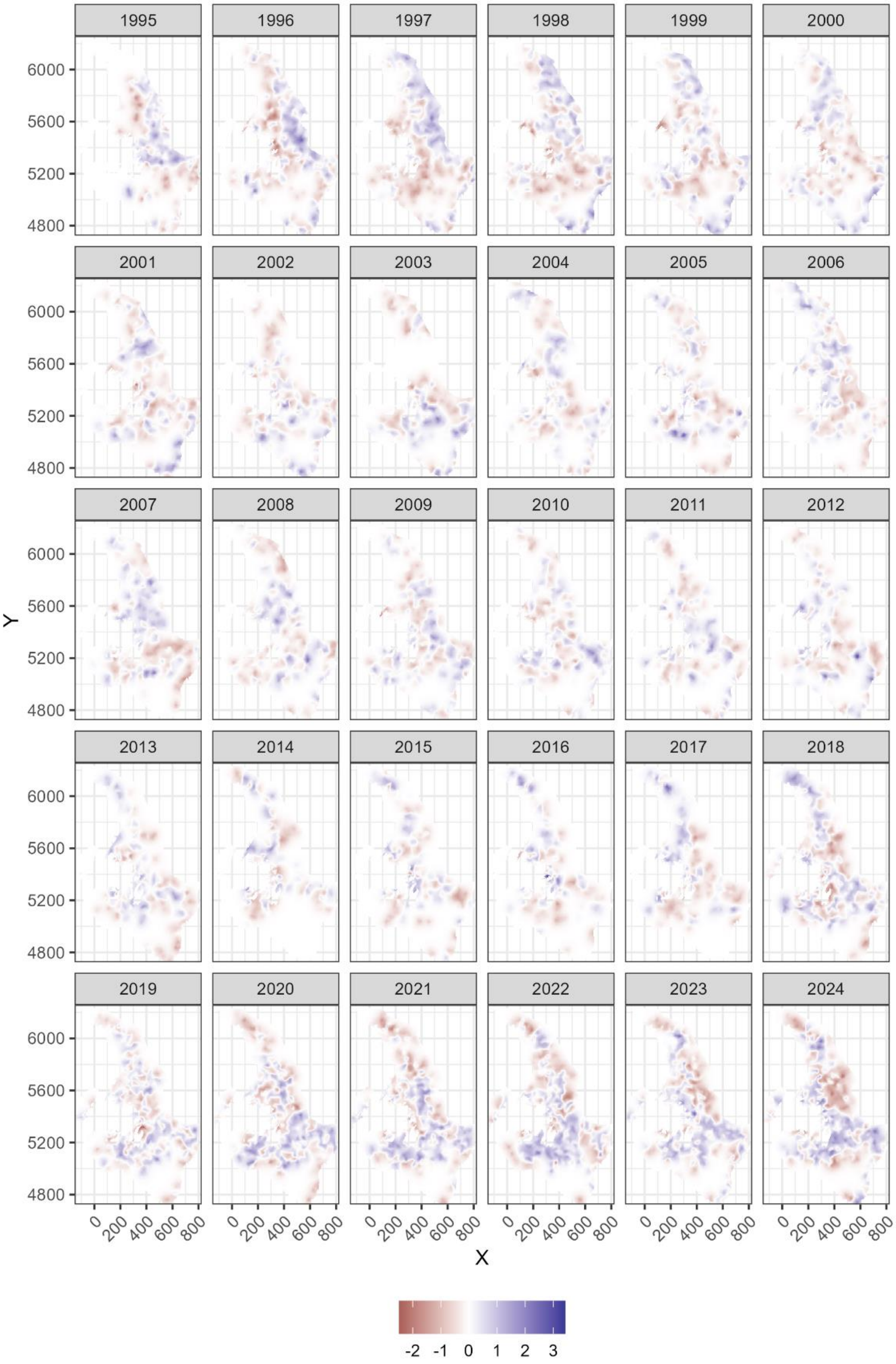

Figure 18. Spatiotemporal random effects for gamma components of the exploitable biomass estimation final model.

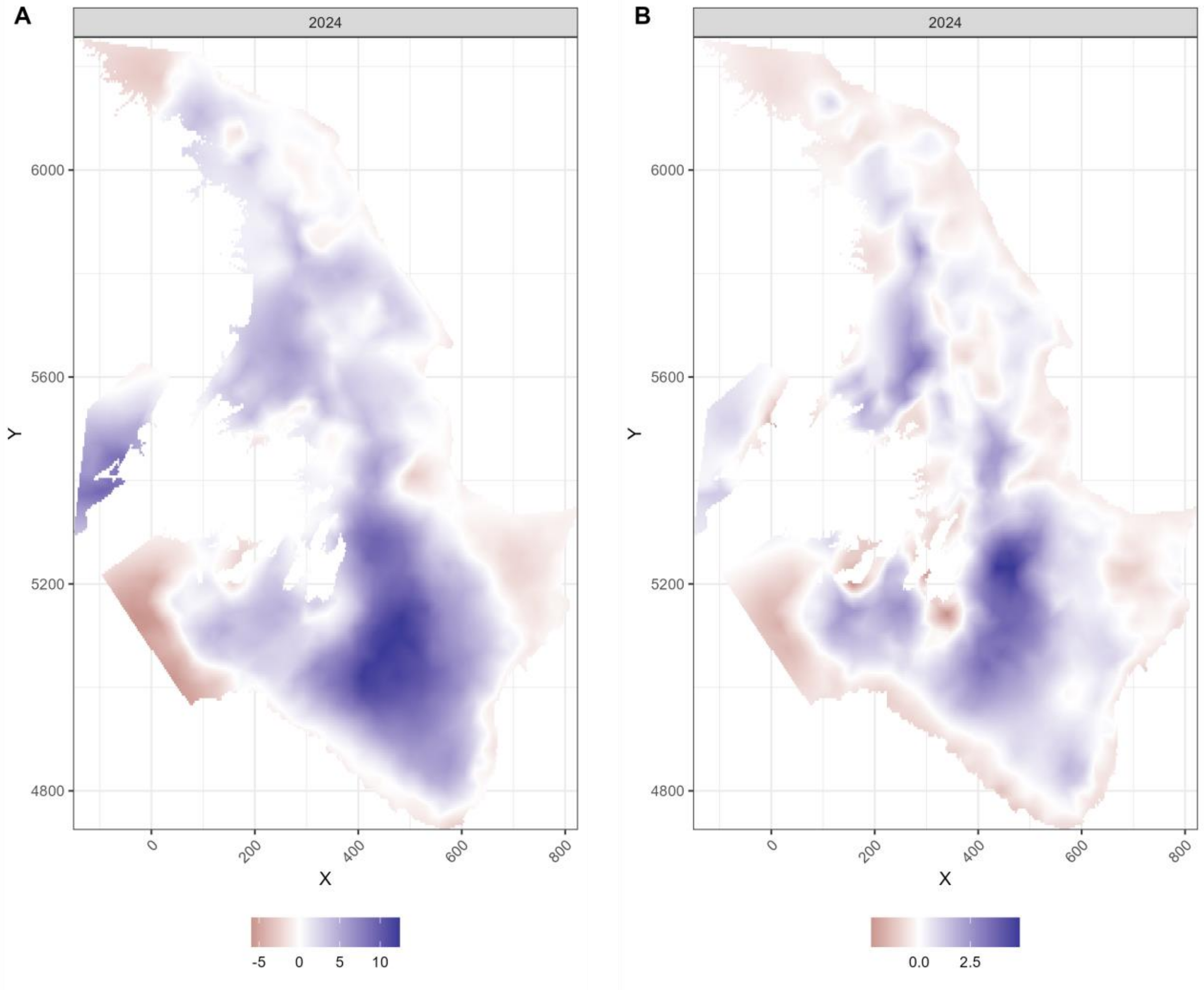

Figure 19. Spatial varying effects of depth for the binomial (A) and gamma (B) components of the exploitable biomass estimation final model.

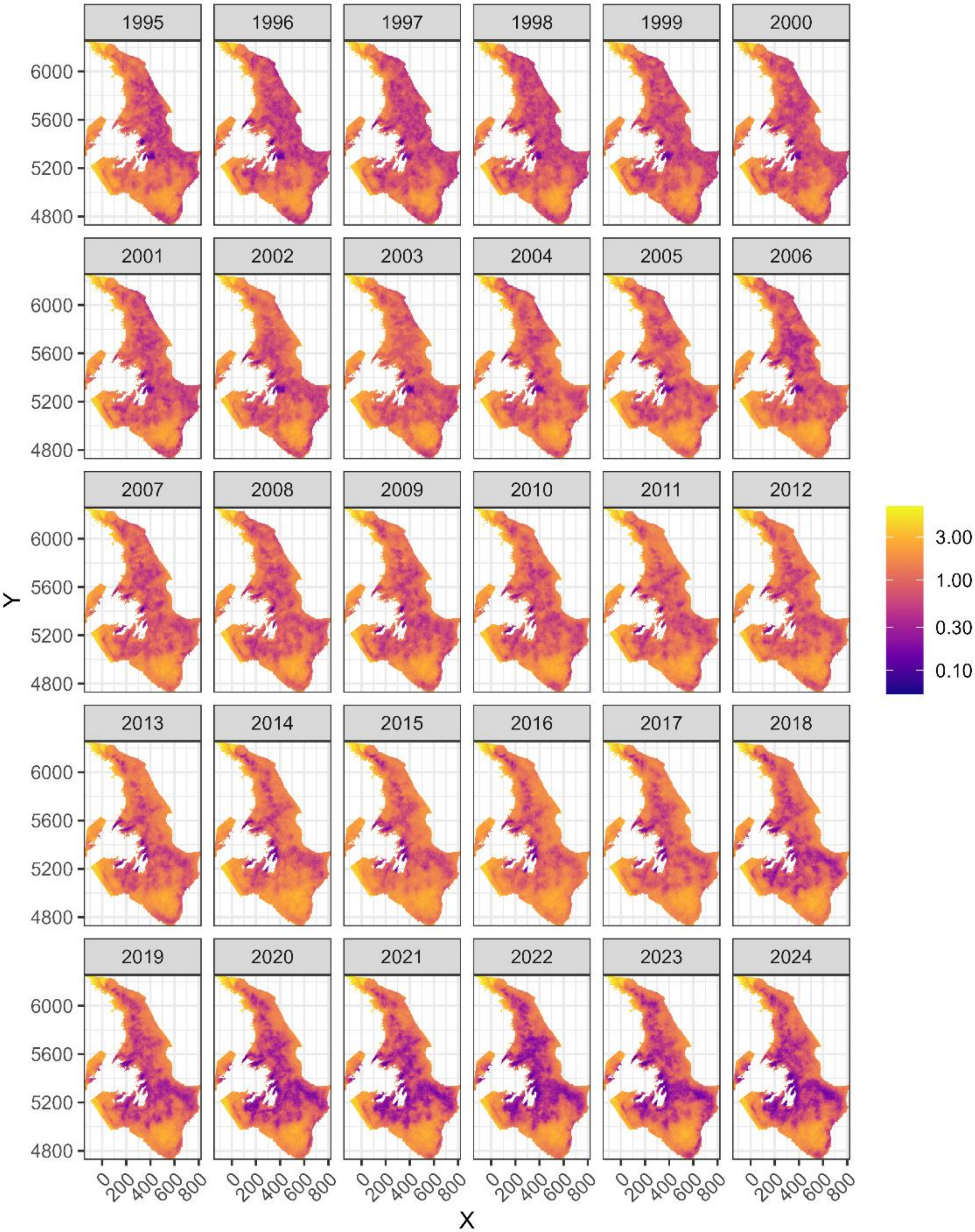

Figure 20. Spatiotemporal distribution of uncertainty (standard error) of exploitable biomass estimation final model predictions.

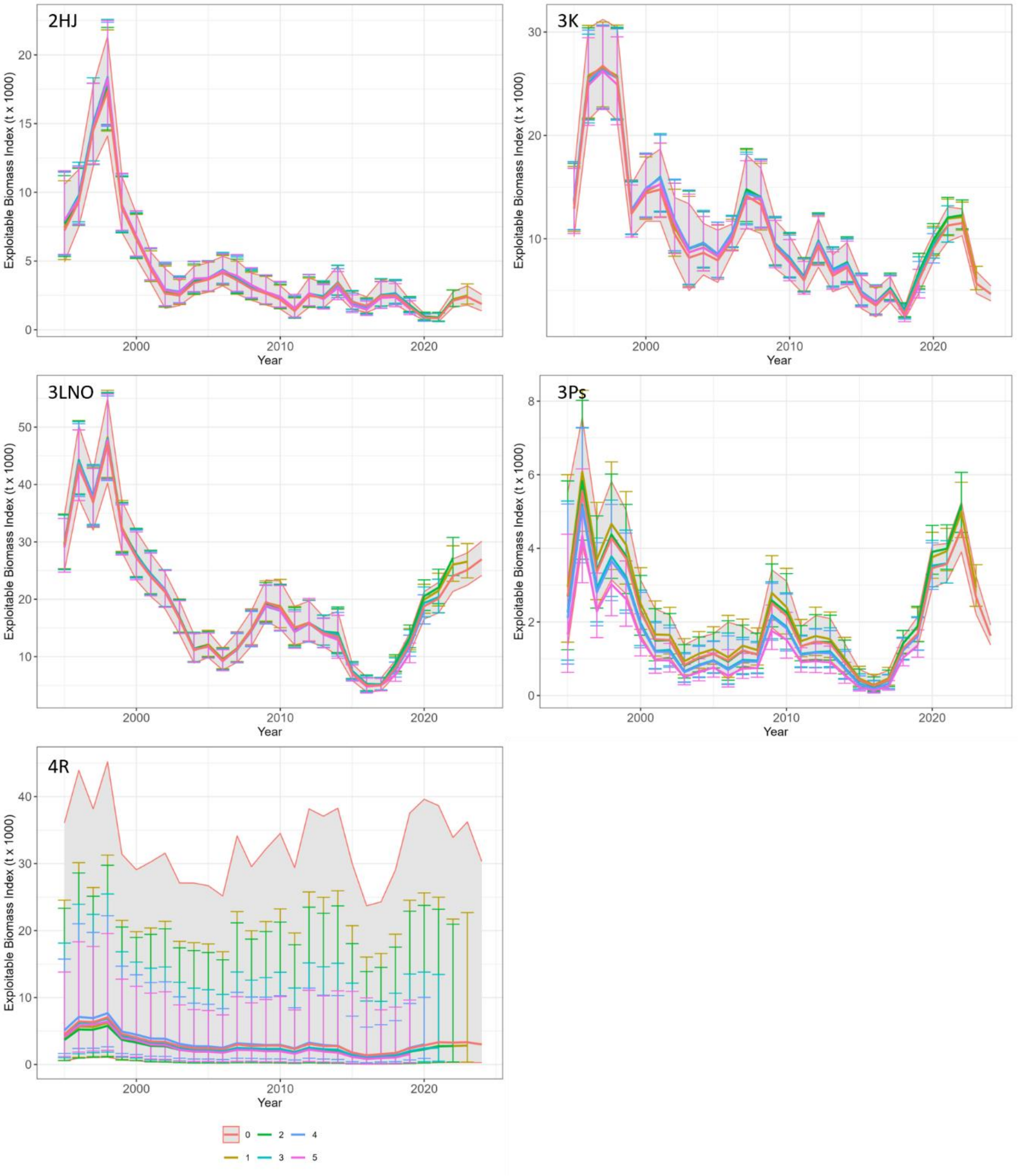

Figure 21. Retrospective analysis with peel back of five years for all ADs. These are raw model estimates that do not have Delury biomass adjustment applied.

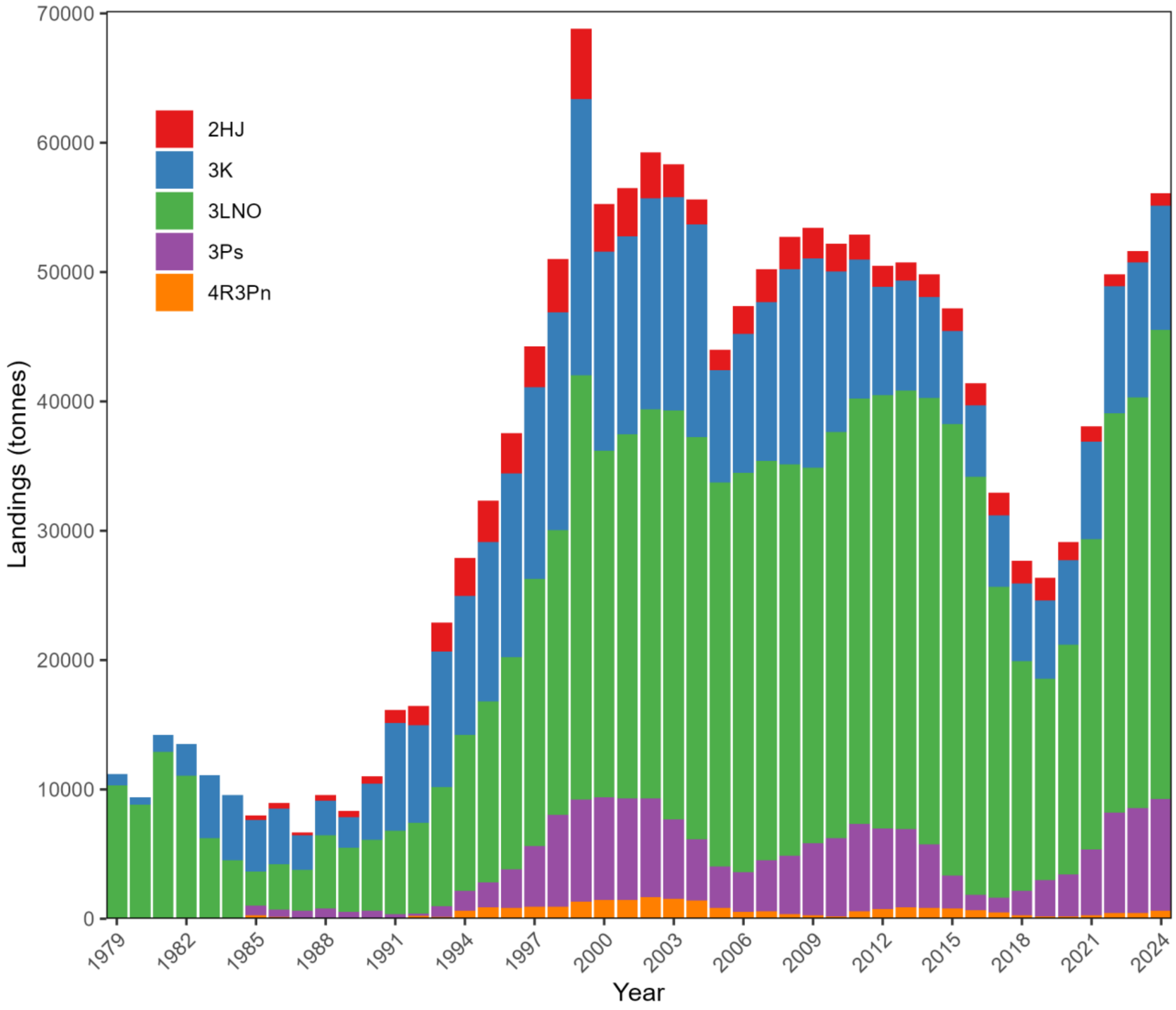

Figure 22. Annual landings (tonnes) of Snow Crab by Assessment Division (1979–2024).

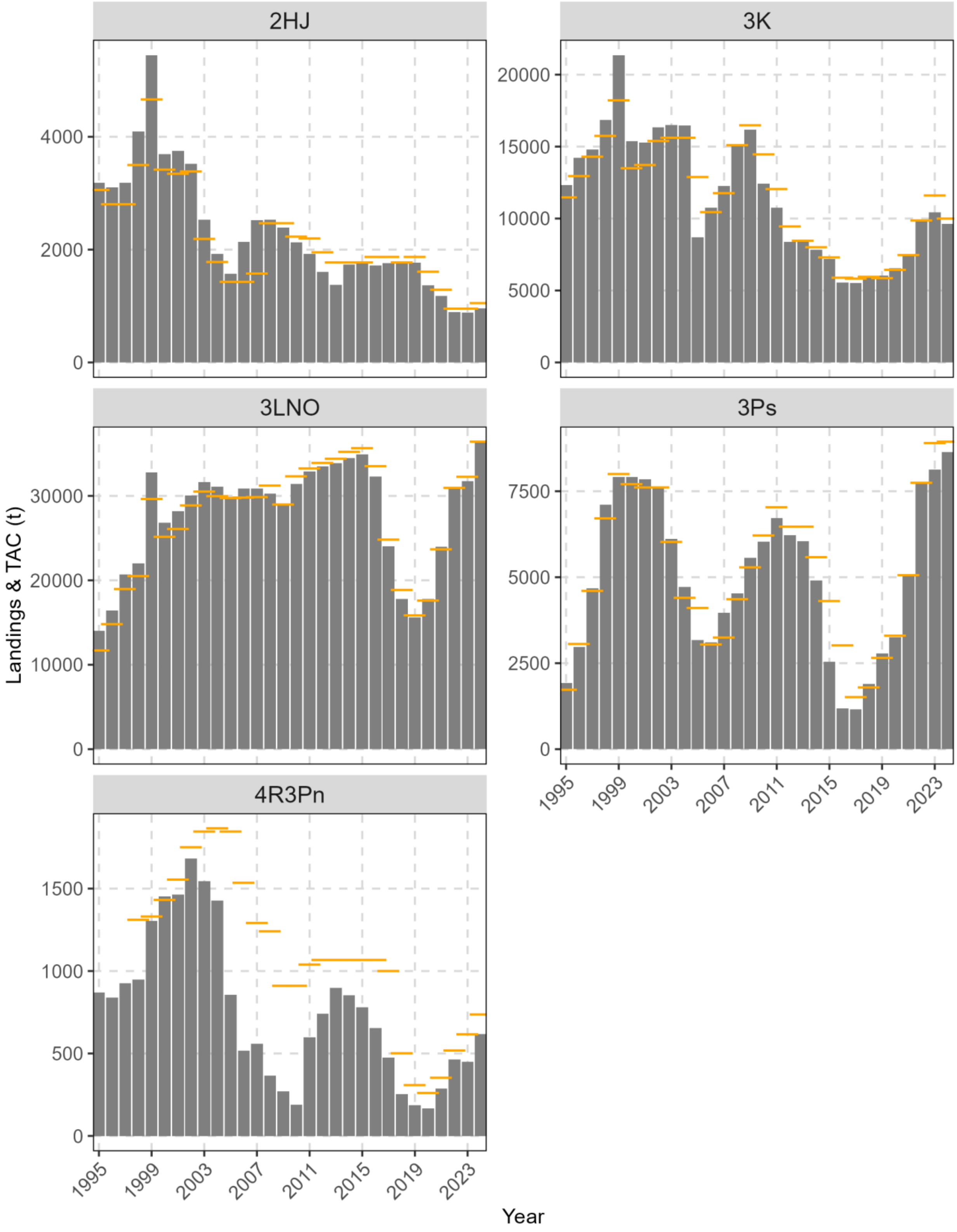

Figure 23. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) by Assessment Division (1995–2024).

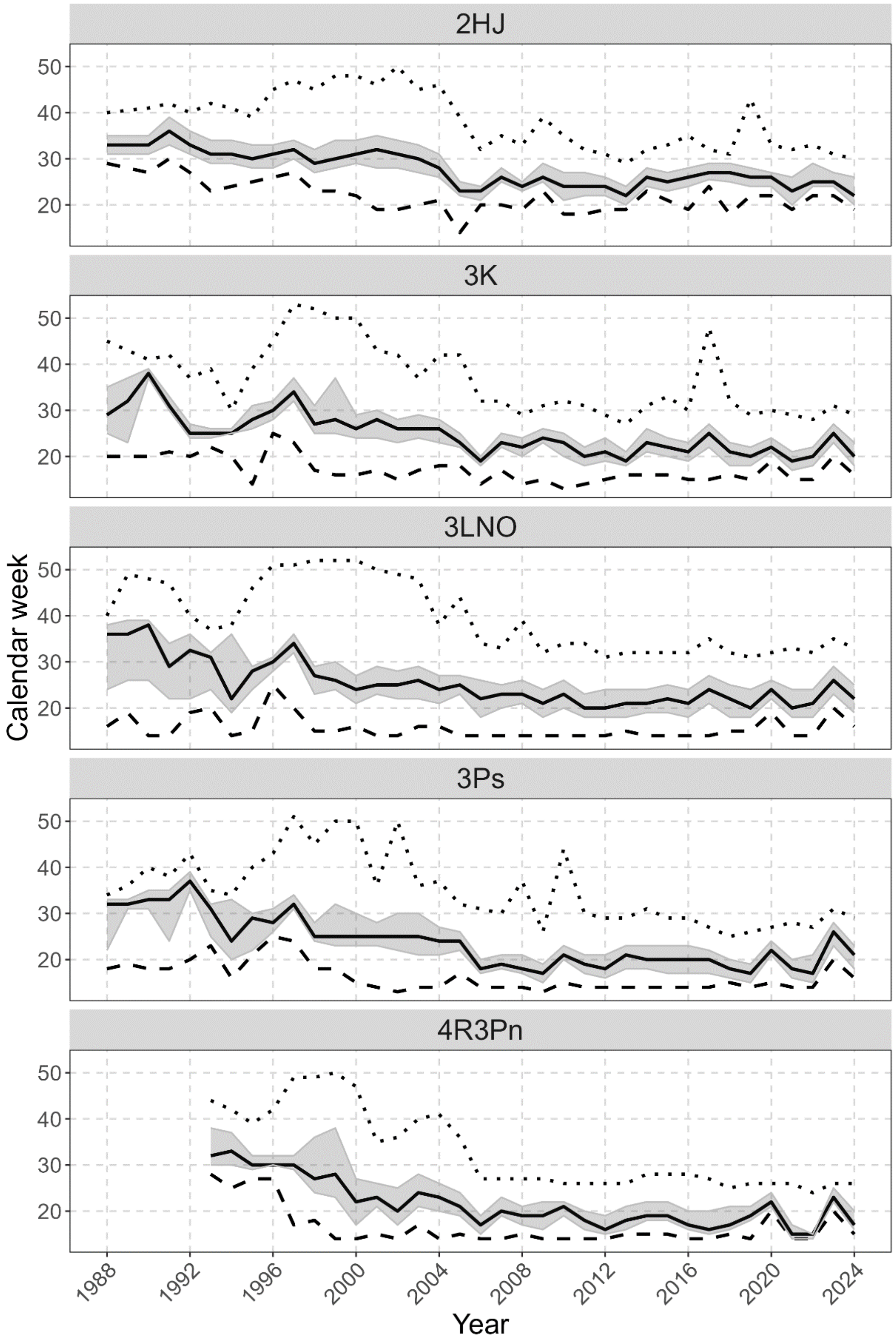

Figure 24. Trends in timing of the fishery by Assessment Division (1988–2024). Solid line = median timing of fishery, dashed line = start of fishery, dotted line = end of fishery, and shaded area = fishery 25–75% complete. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

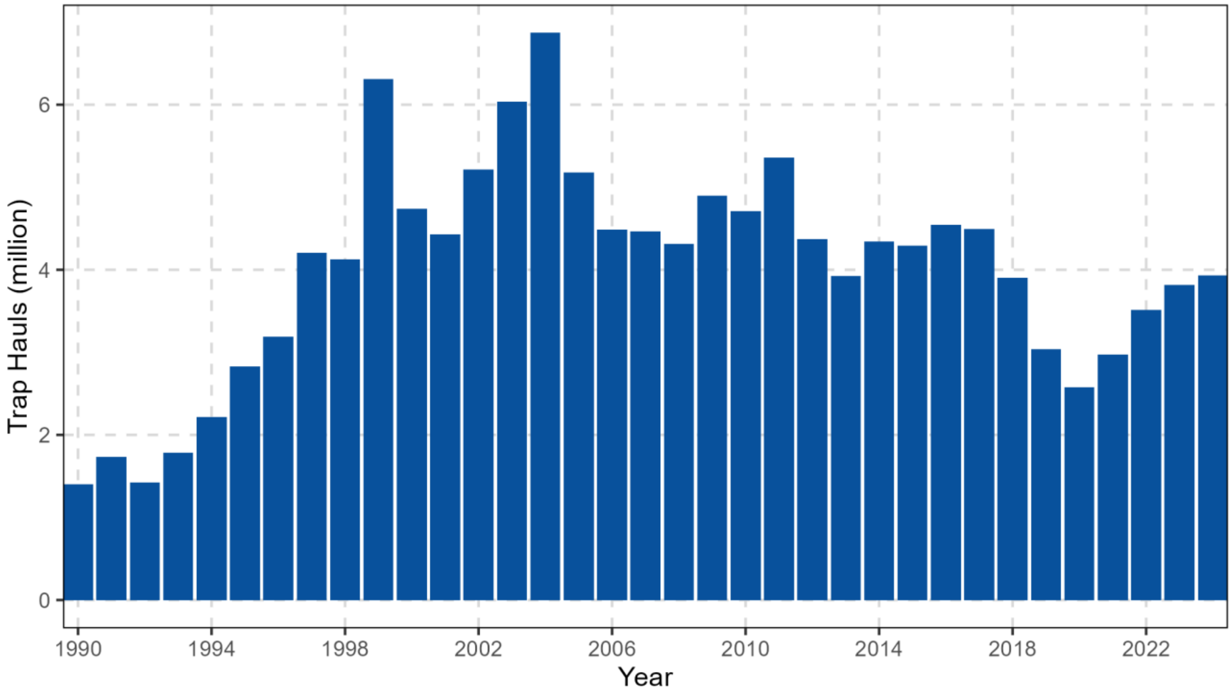

Figure 25. Estimated effort (number of trap hauls) in NAFO Divs. 2HJ3KLNOP4R combined (1990–2024). Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

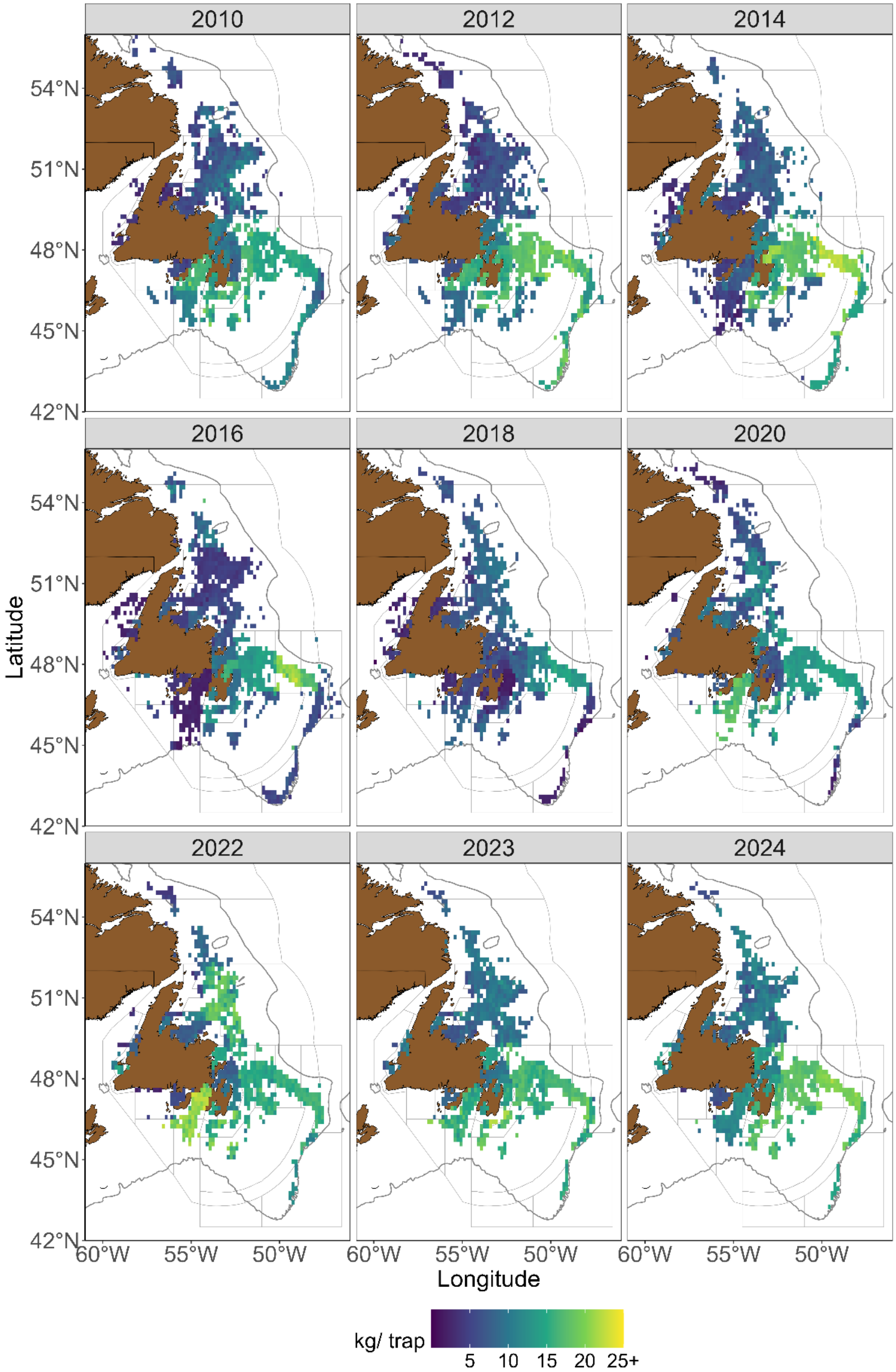

Figure 26. Fishing locations and catch rates (kg/trap) from fishery logbooks (2010, 2012, 2014, 2016, 2018, 2020, 2022–24). Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

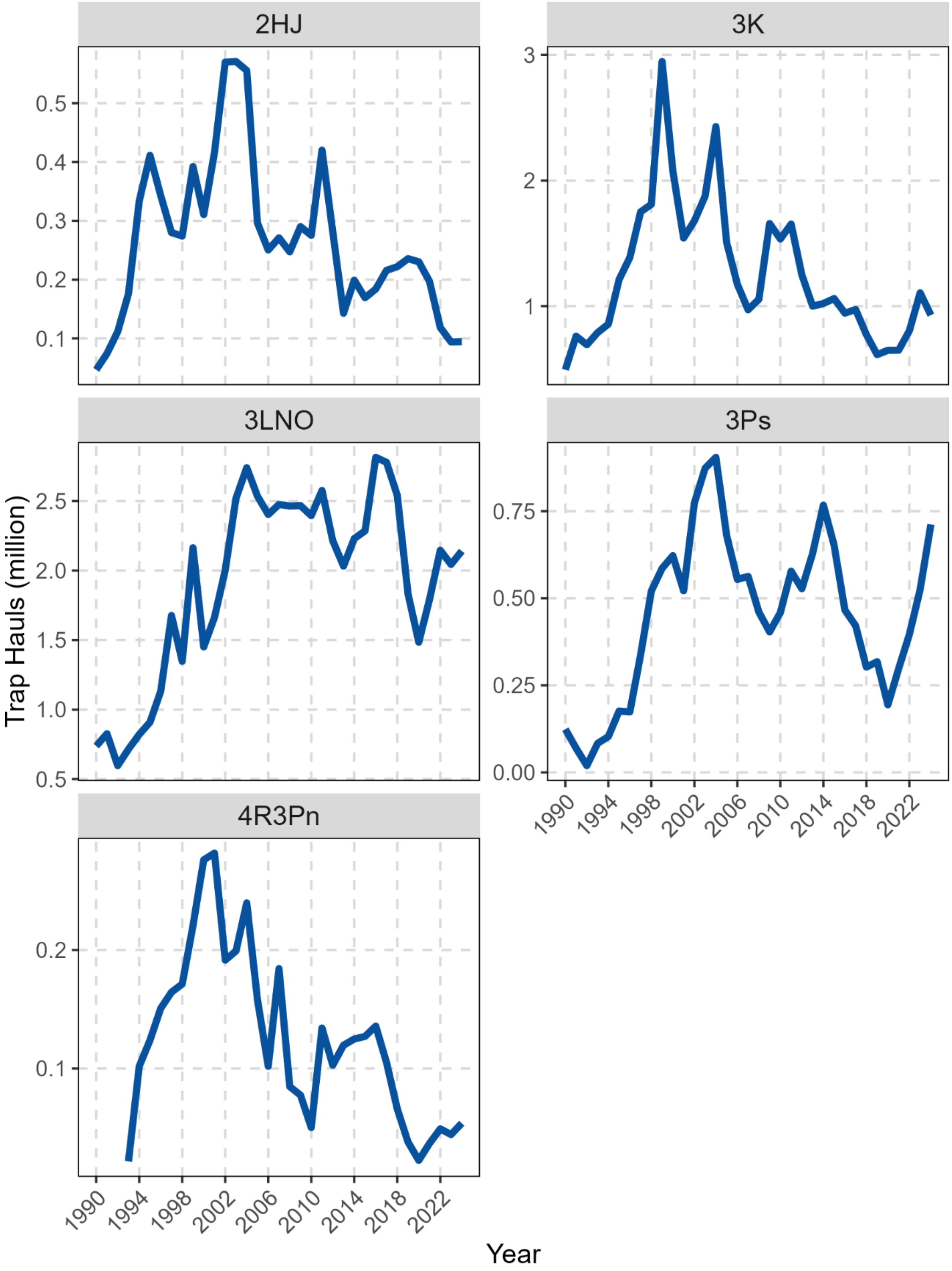

Figure 27. Estimated effort (number of trap hauls) by Assessment Division (1990–2024). Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

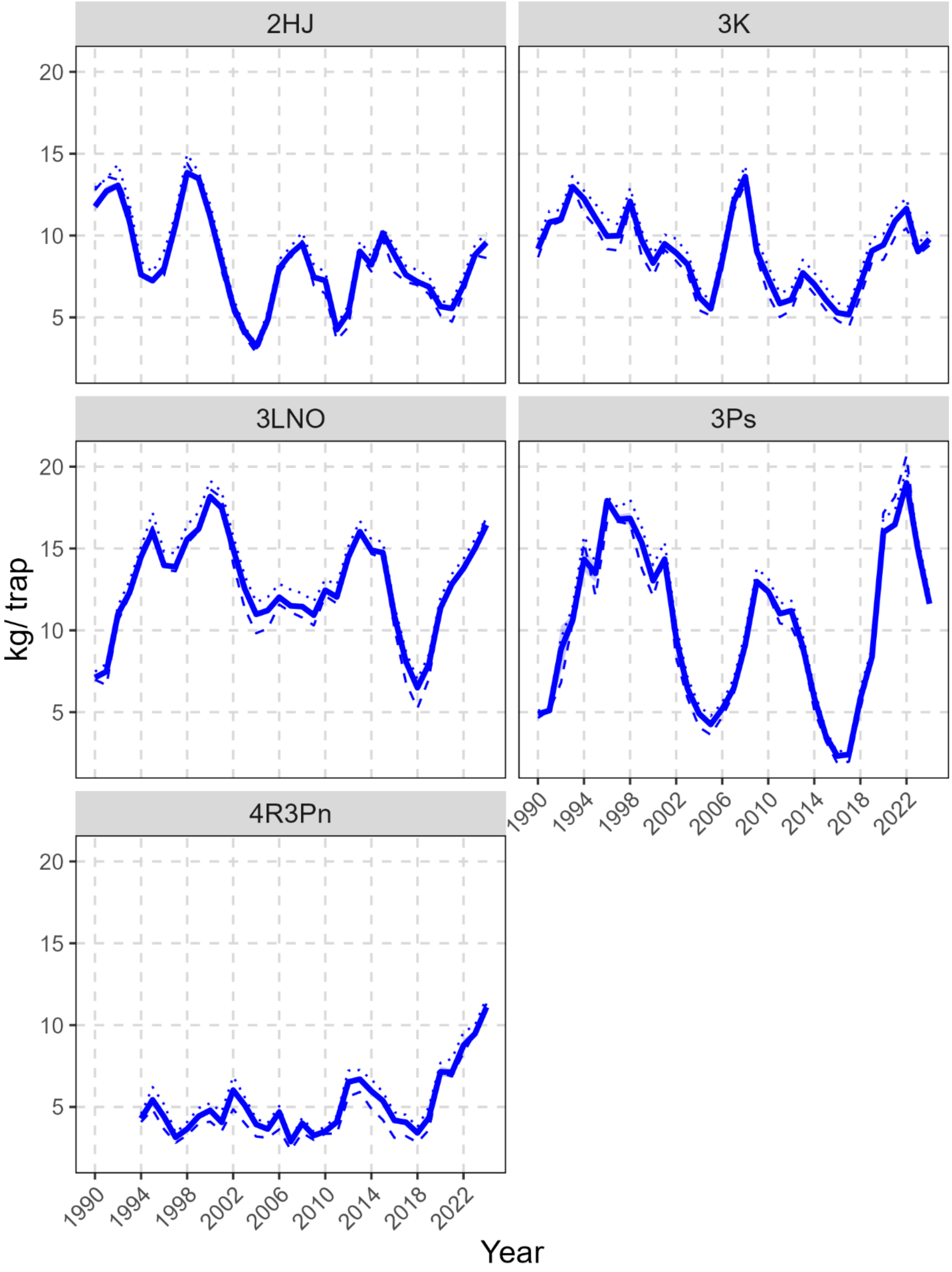

Figure 28. Standardized fishery CPUE (kg/trap) by Assessment Division (1990–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

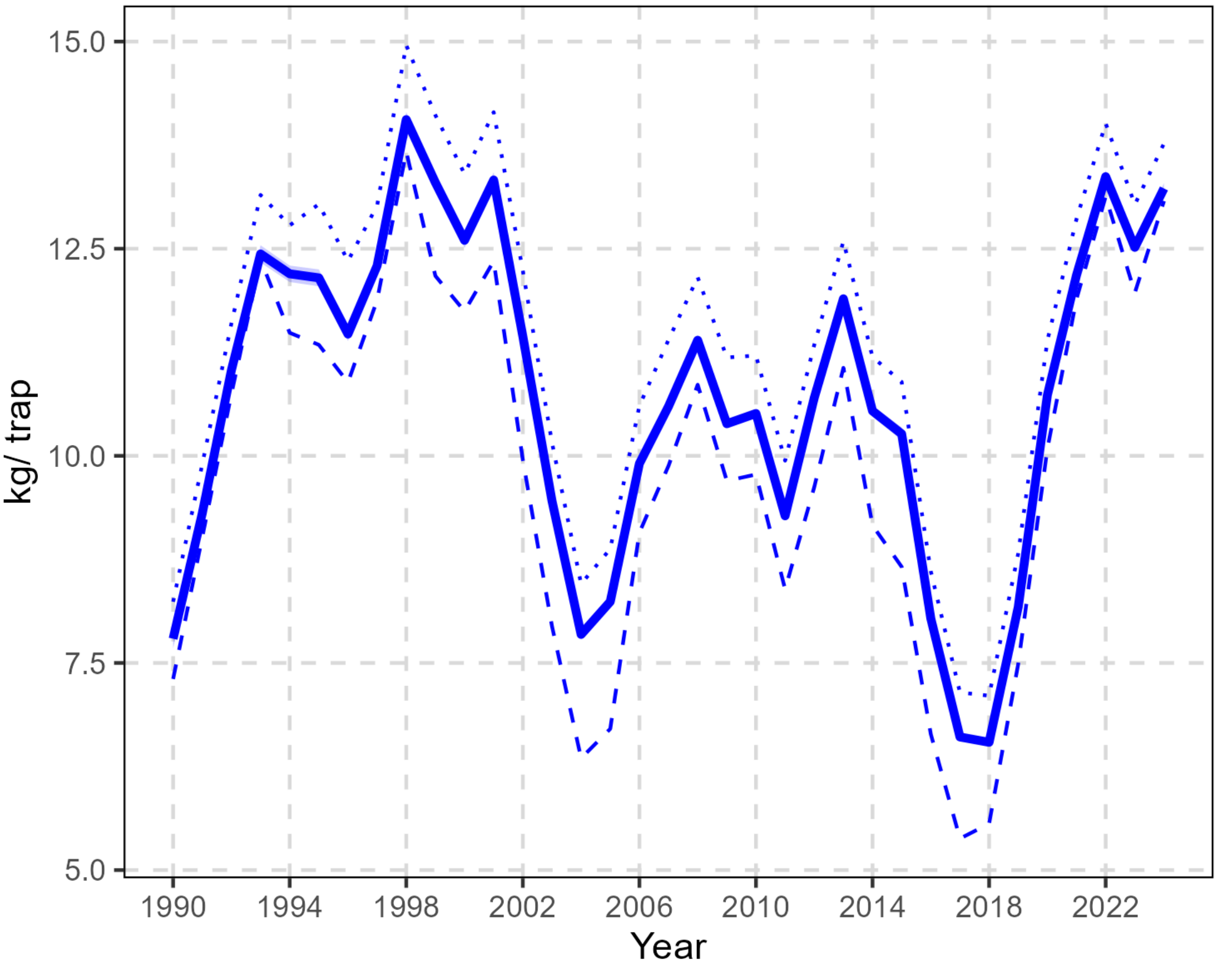

Figure 29. Standardized fishery CPUE (1990–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

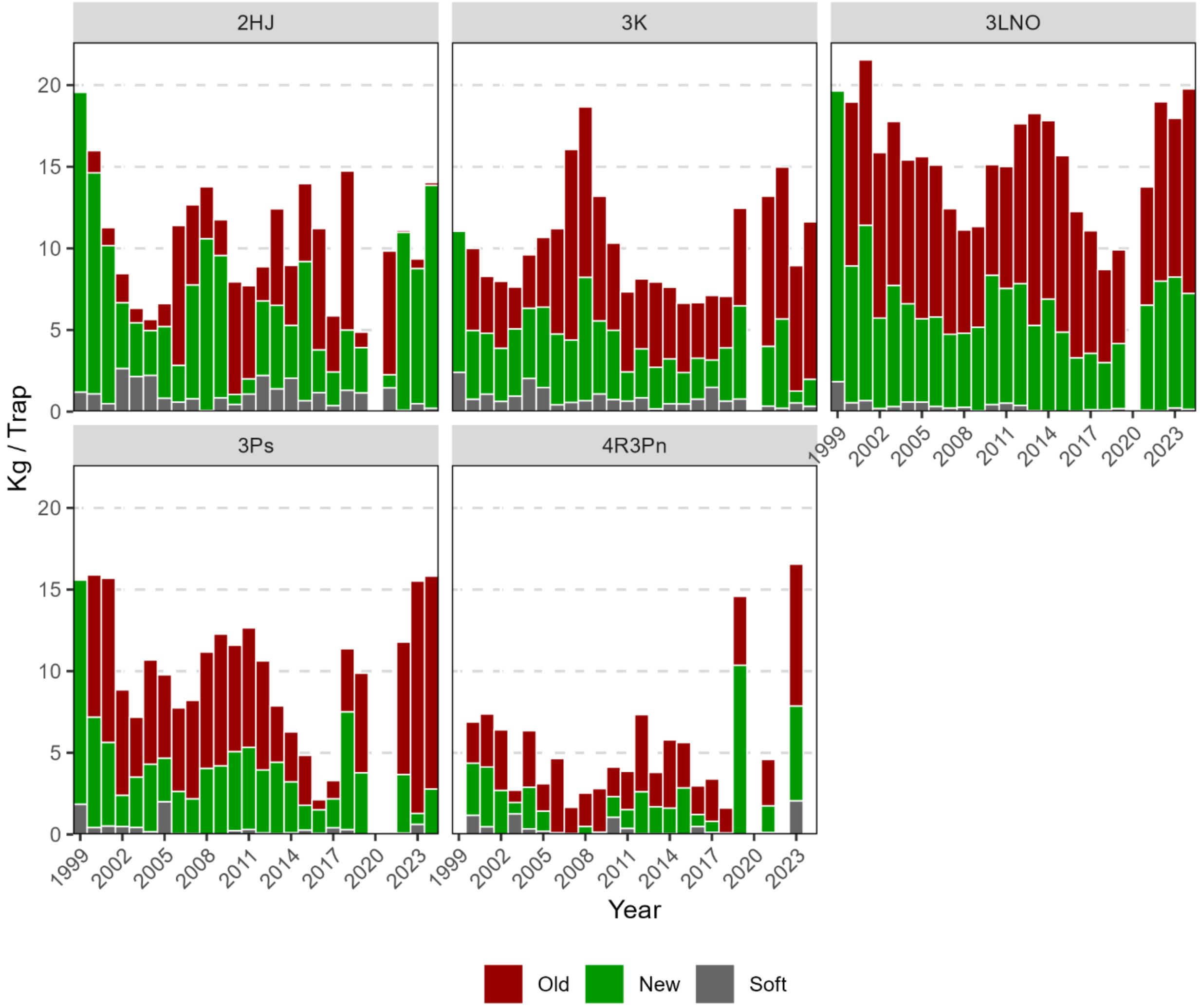

Figure 30. Catch rates (kg/trap) of legal-sized Snow Crab by shell condition from at-sea observer sampling by Assessment Division (1999–2024). Years without results represent low or absent at-sea observer coverage.

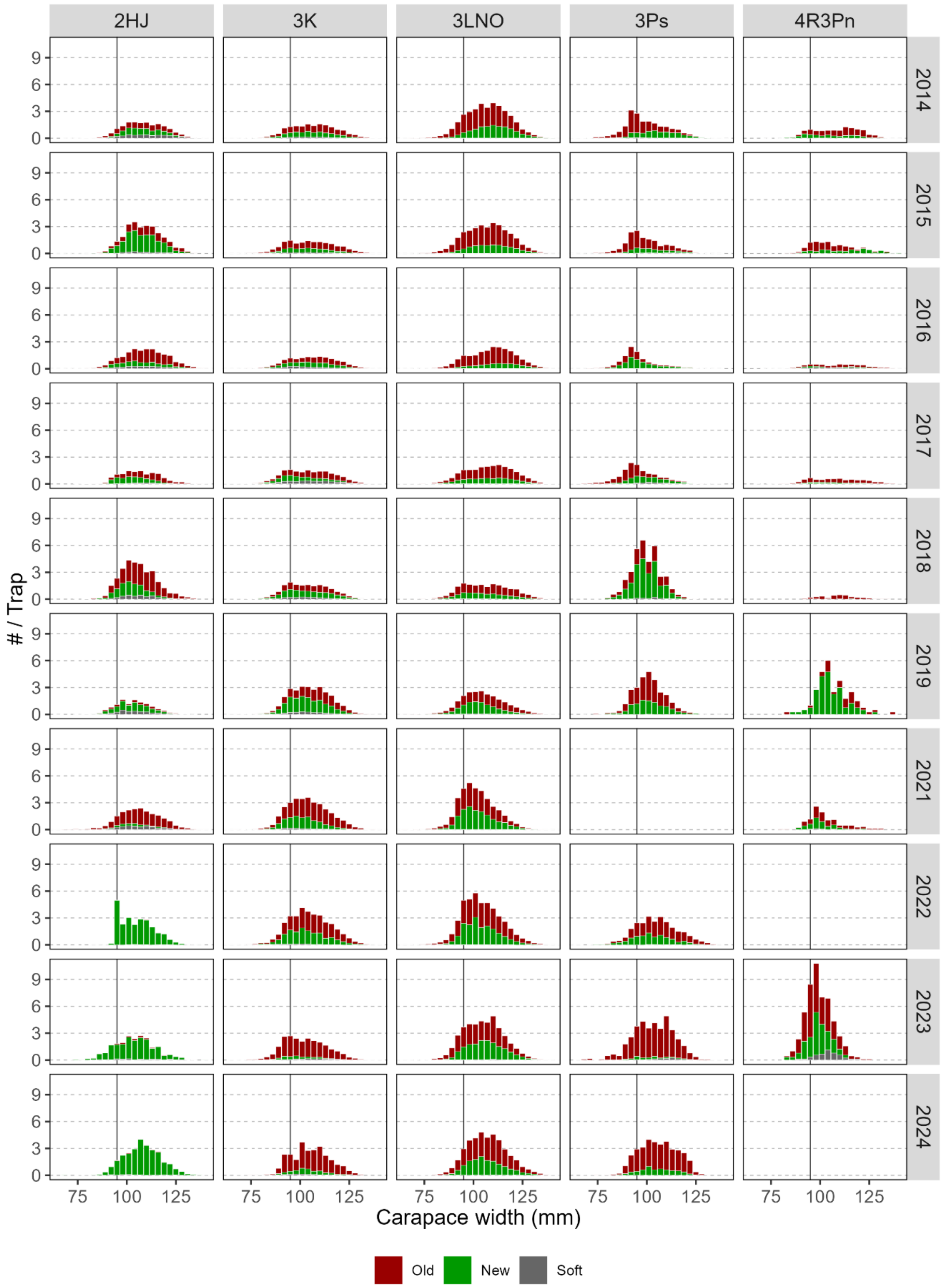

Figure 31. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling by Assessment Division (2014–24). The vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

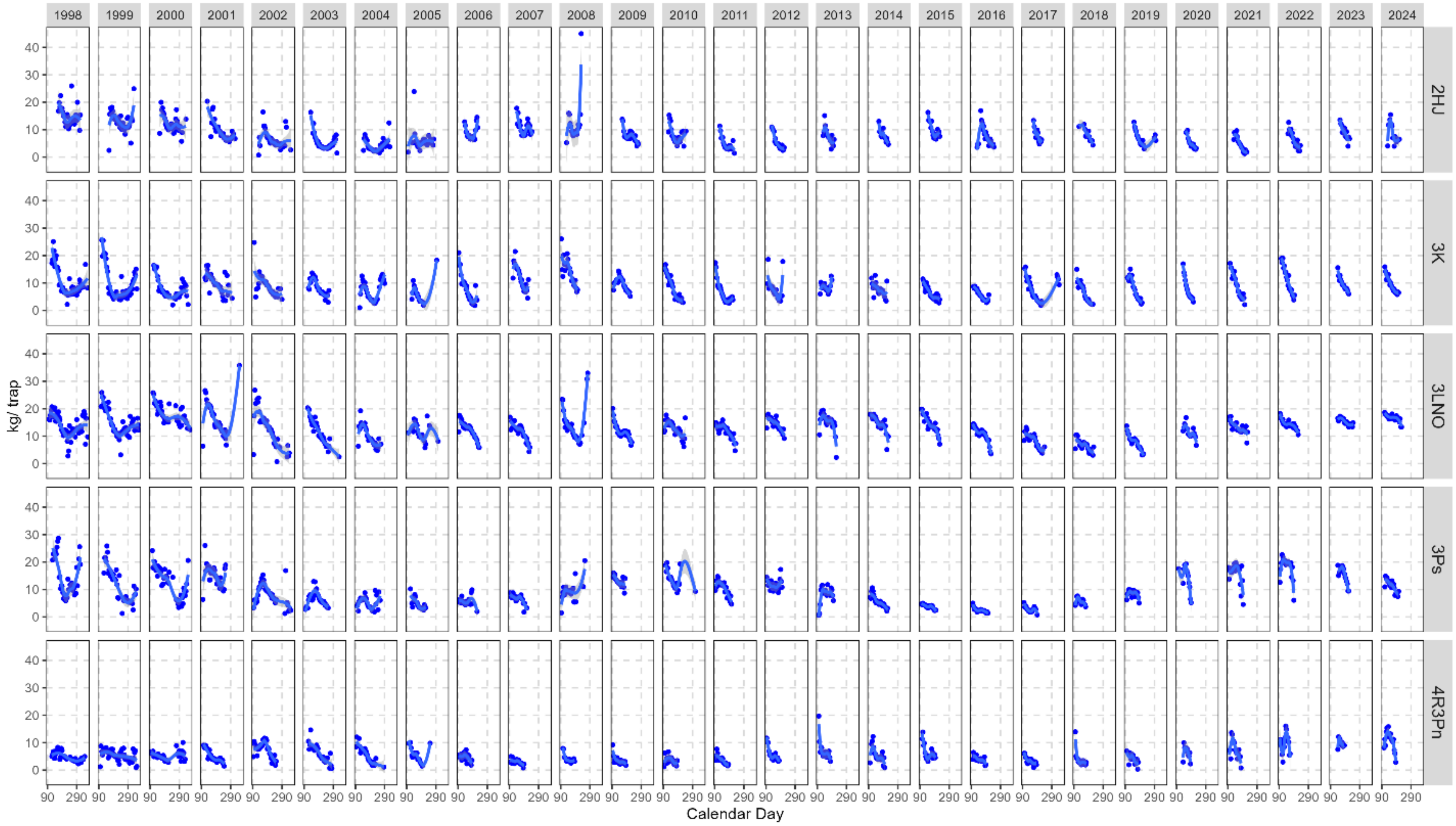

Figure 32. Unstandardized fishery CPUE (kg/trap) throughout the season (calendar day) by Assessment Division (1998–2024), derived from logbooks. Points denote mean CPUE in five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

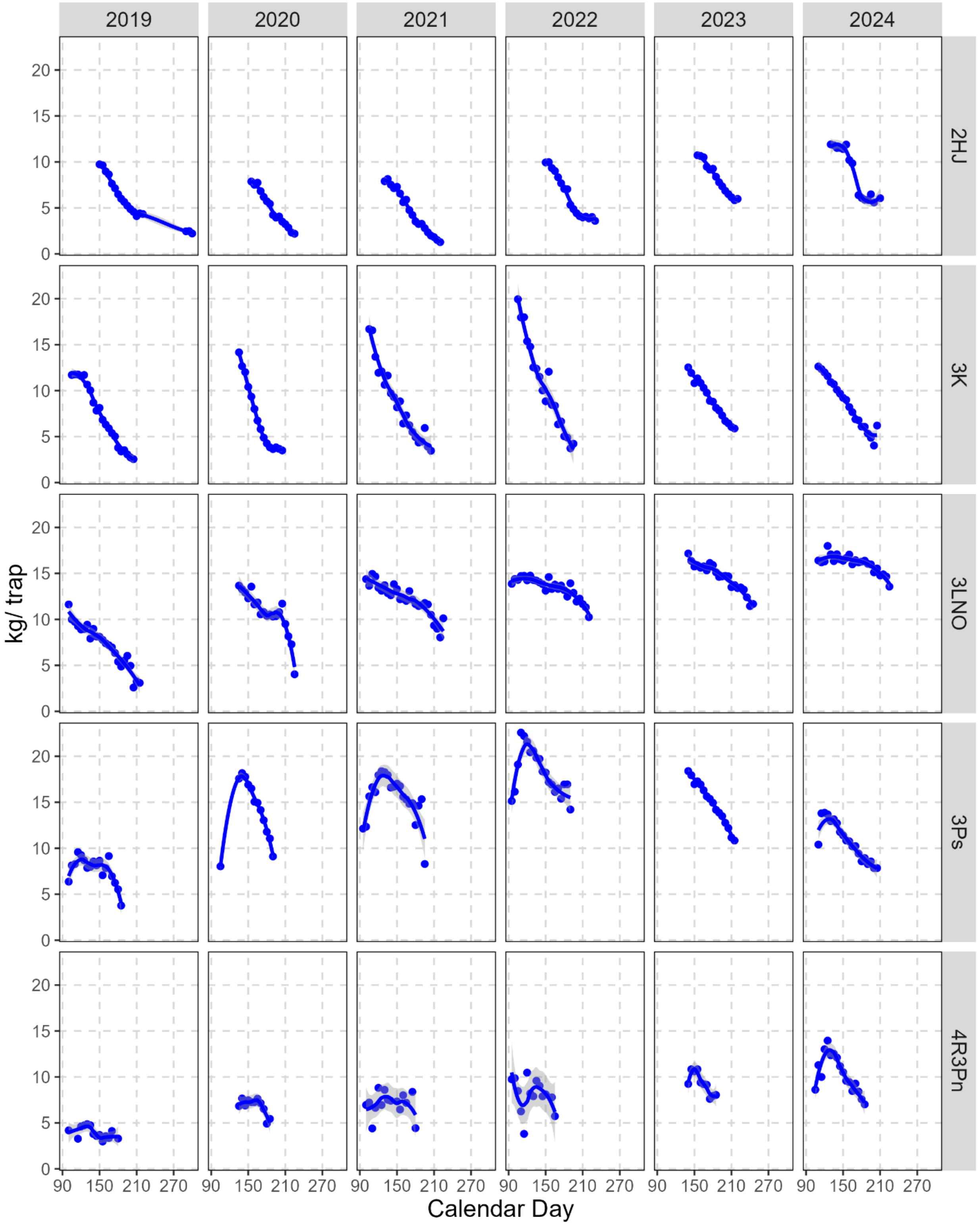

Figure 33. Standardized fishery CPUE (kg/trap) throughout the season (calendar day) by Assessment Division (2019–24), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

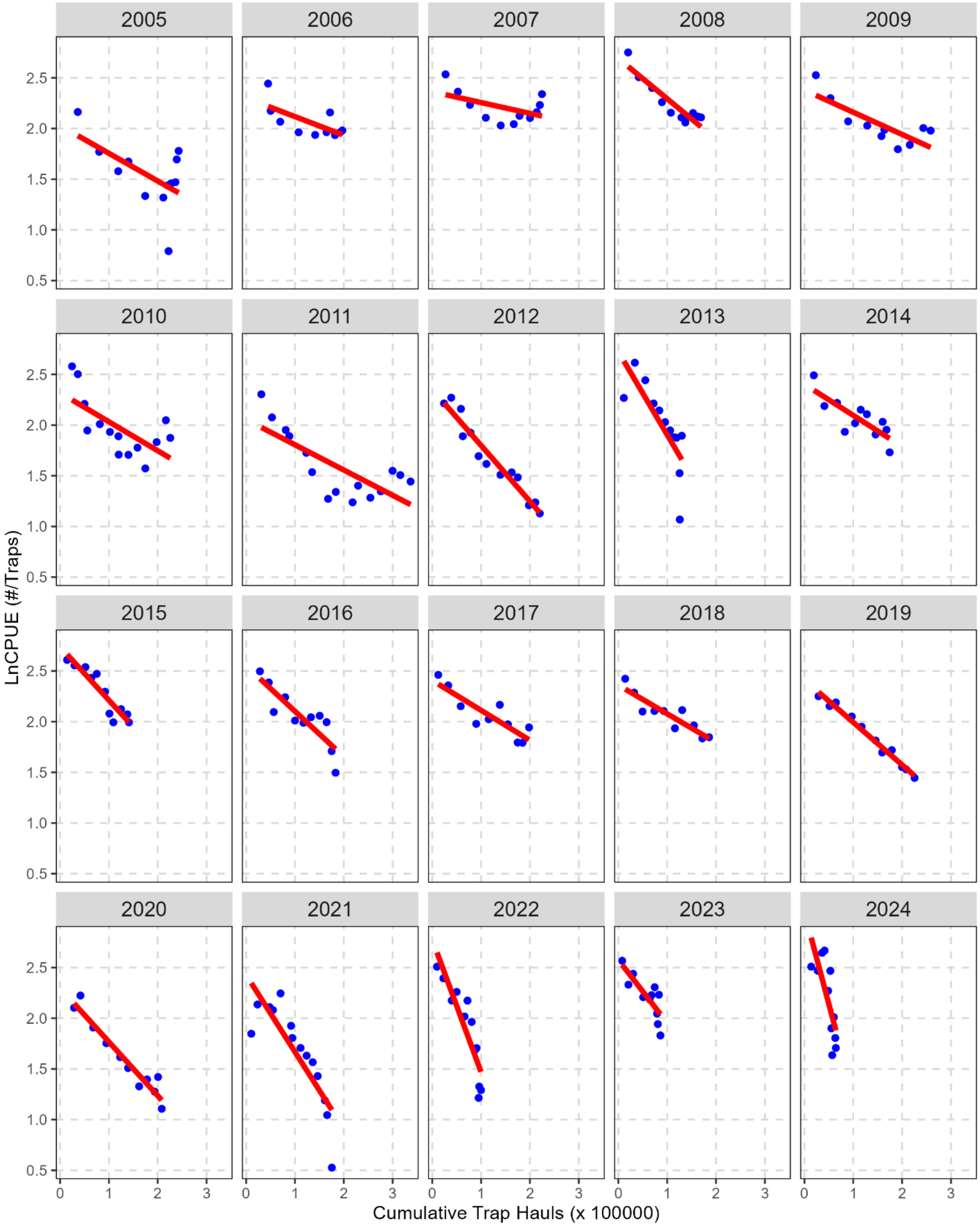

Figure 34. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 2HJ (2005–24). Blue points represent unstandardized catch rates and red line is fitted Delury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

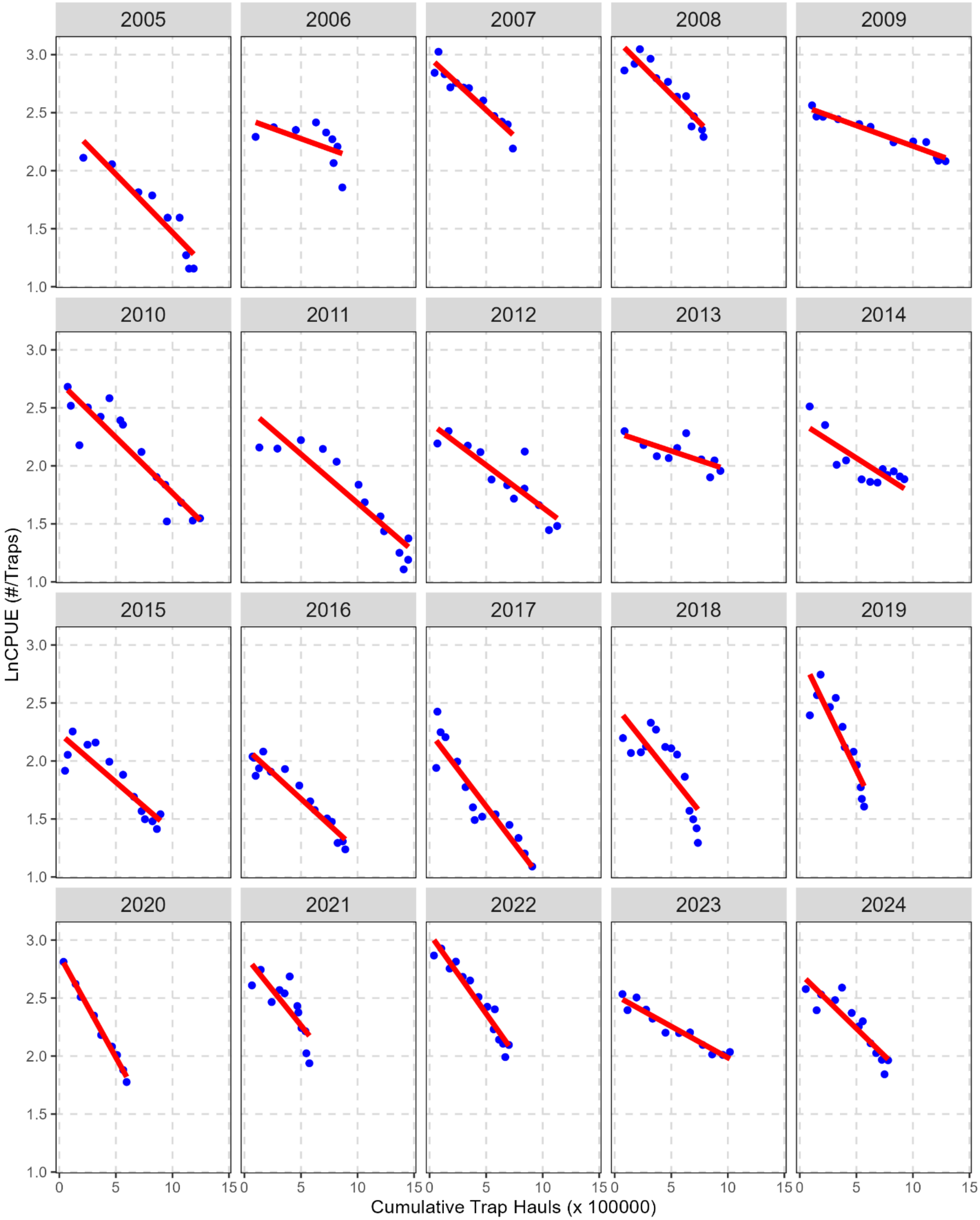

Figure 35. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 3K (2005–24). Blue points represent unstandardized catch rates and red line is fitted Delury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

Figure 36. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 3LNO (2005–24). Blue points represent unstandardized catch rates and red line is fitted Delury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

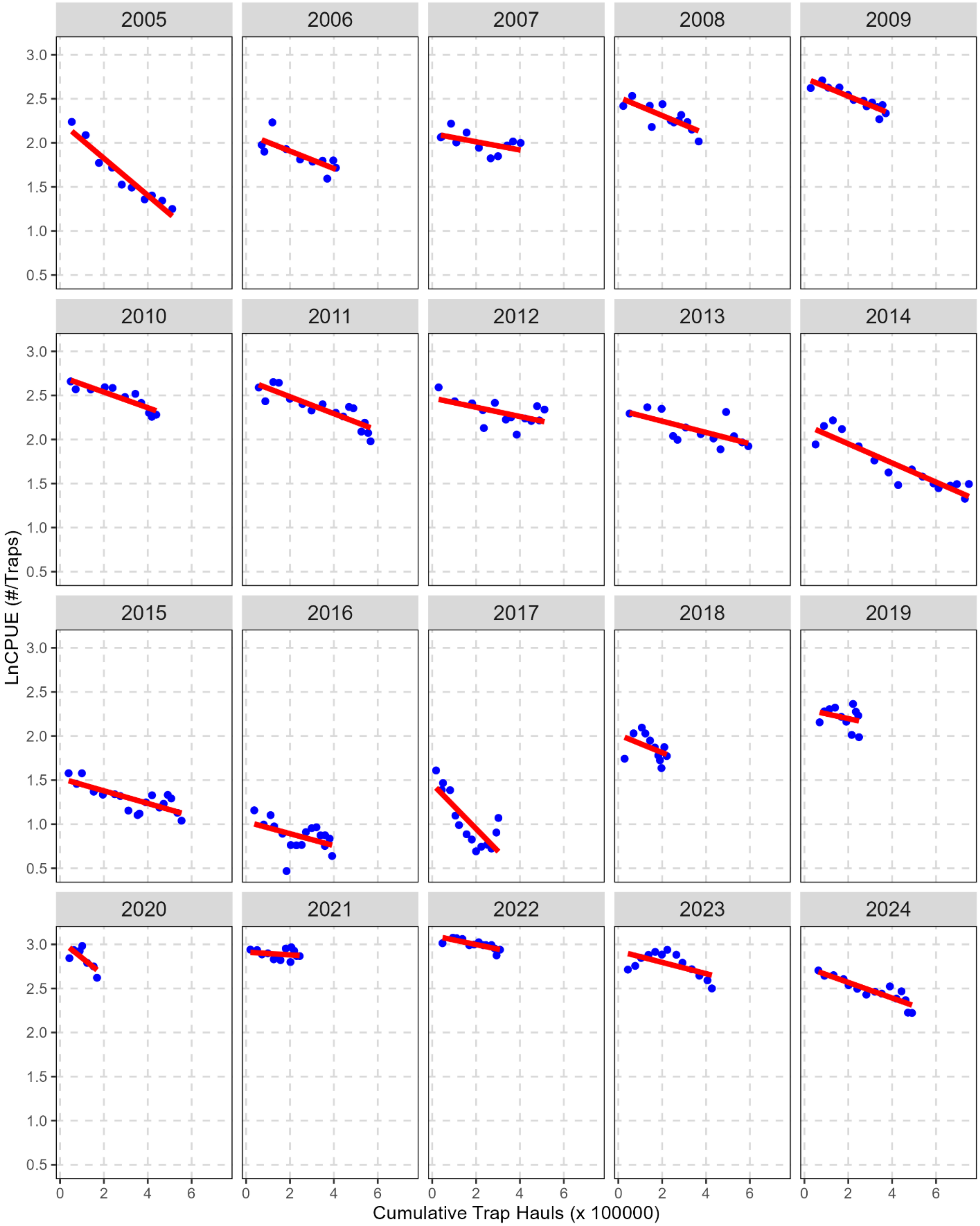

Figure 37. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 3Ps (2005–24). Blue points represent unstandardized catch rates and red line is fitted Delury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

Figure 38. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 4R3Pn (2005–24). Blue points represent unstandardized catch rates and red line is fitted Delury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

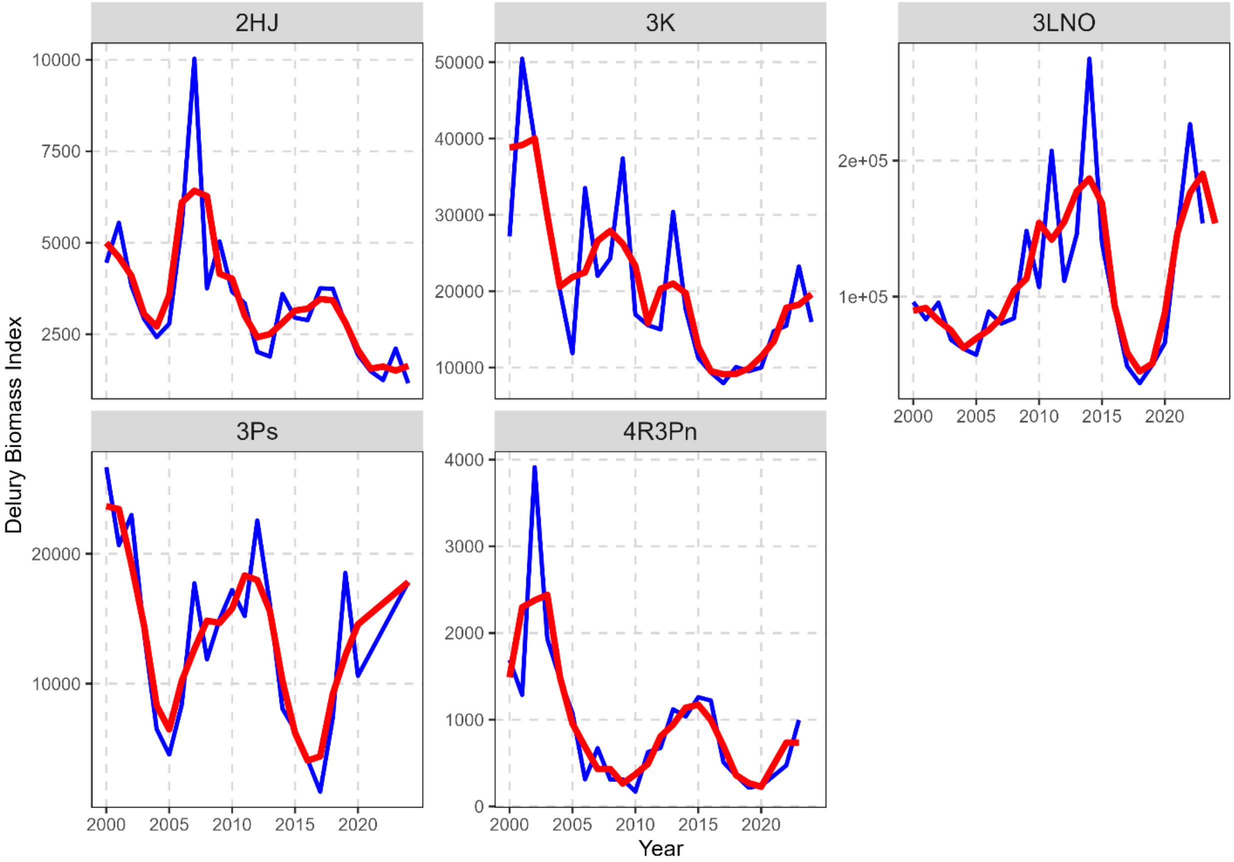

Figure 39. Fishery depletion model biomass estimates of exploitable Snow Crab (t) from logbooks (blue) and three-year centered moving averages (red) by Assessment Division (2000–24). Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

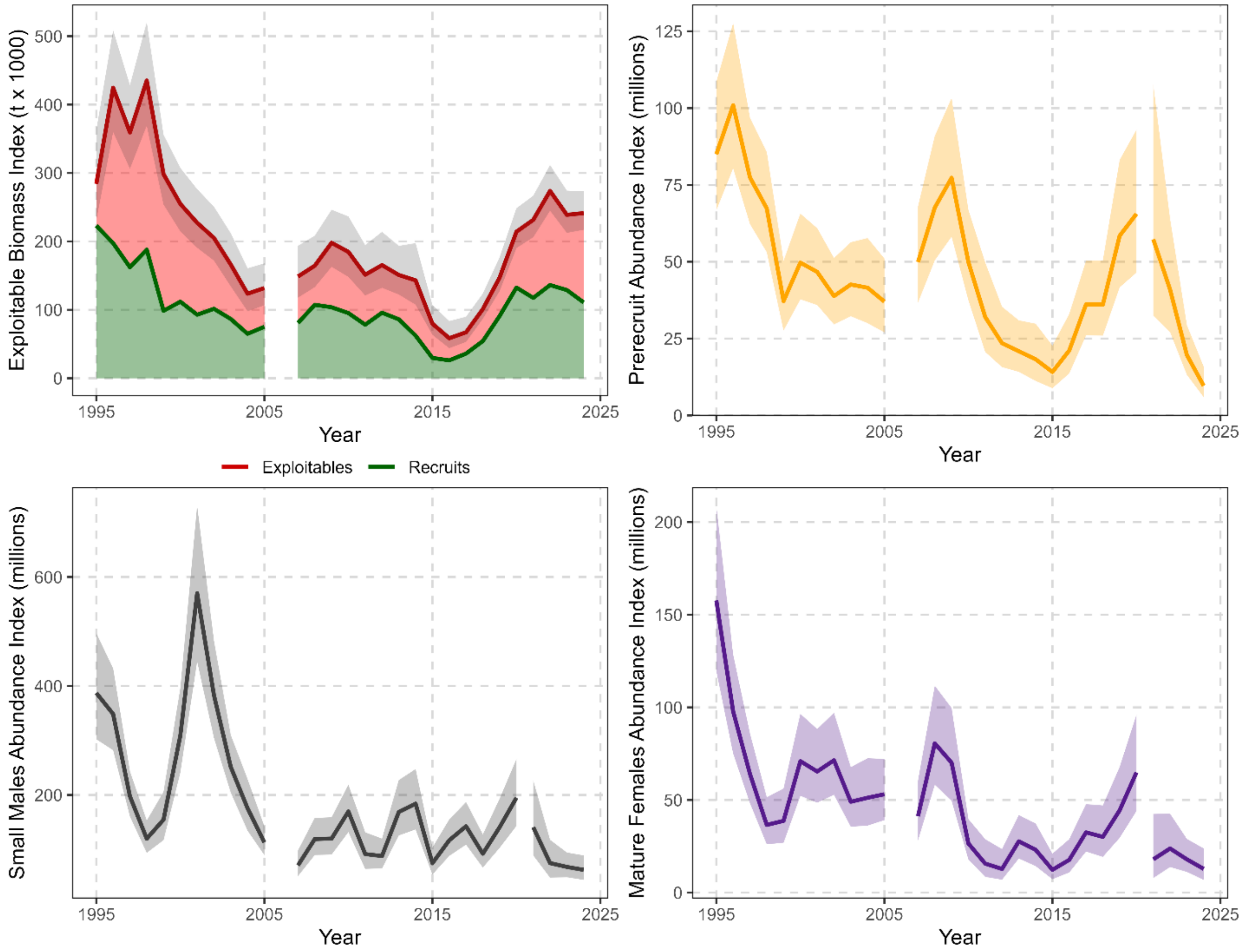

Figure 40. Summary of Snow Crab stock in Assessment Divisions 2HJ3KLNOP4R: Top-left: Annual integrated exploitable biomass index by shell condition (red = total exploitable crab, green = recruit crab) (1995–2024). Top-right: Annual pre-recruit abundance index from trawl surveys (1995–2024). Bottom-left: Annual small male abundance index from trawl surveys (1995–2024). Bottom-right: Annual mature female abundance index from trawl surveys (1995–2024). Solid line = annual estimate and shaded band = 95% confidence intervals of annual estimate.

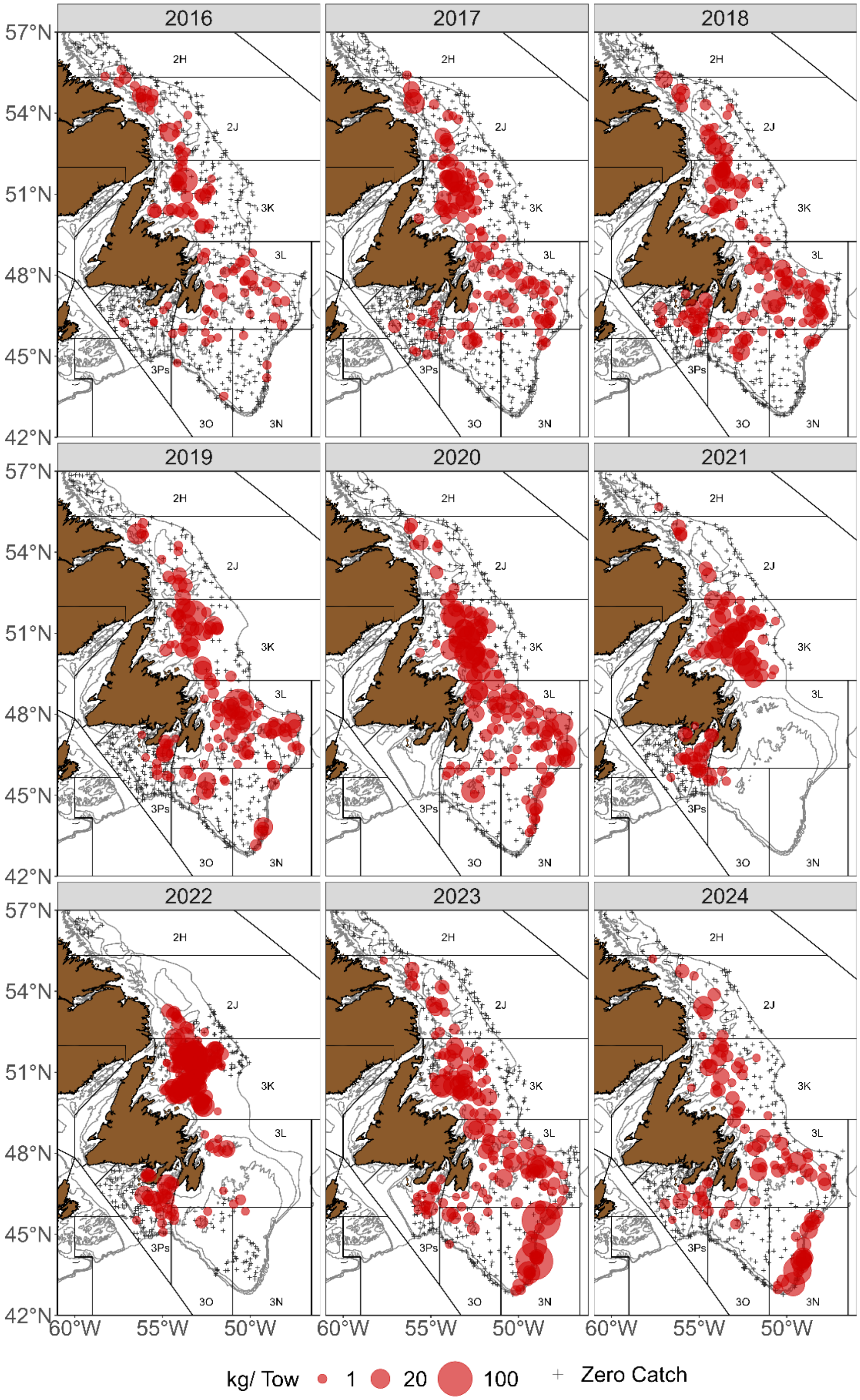

Figure 41. Distribution of exploitable males (kg/tow) from 2HJ3KLNO fall and 3Ps spring trawl surveys (2016–24). + denotes tow with zero exploitable Snow Crab caught. This map does not include paired comparative fishing tows (2021–23) included in models for estimating exploitable biomass.

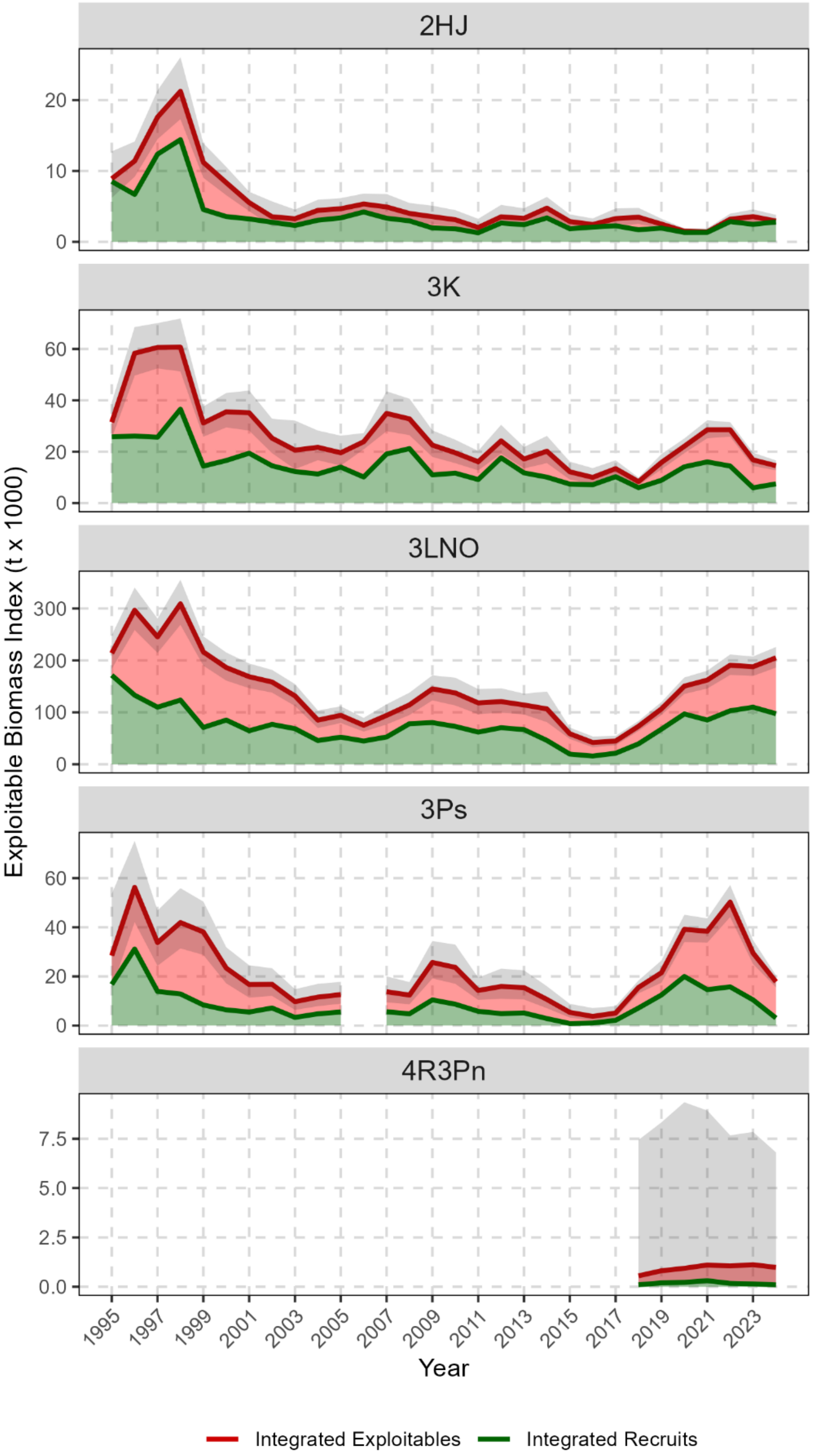

Figure 42. Annual integrated exploitable biomass index (red = total exploitable crab, green = recruit crab) by Assessment Division (1995–2024). Solid line = annual index and grey bands = 95% confidence intervals of annual estimate.

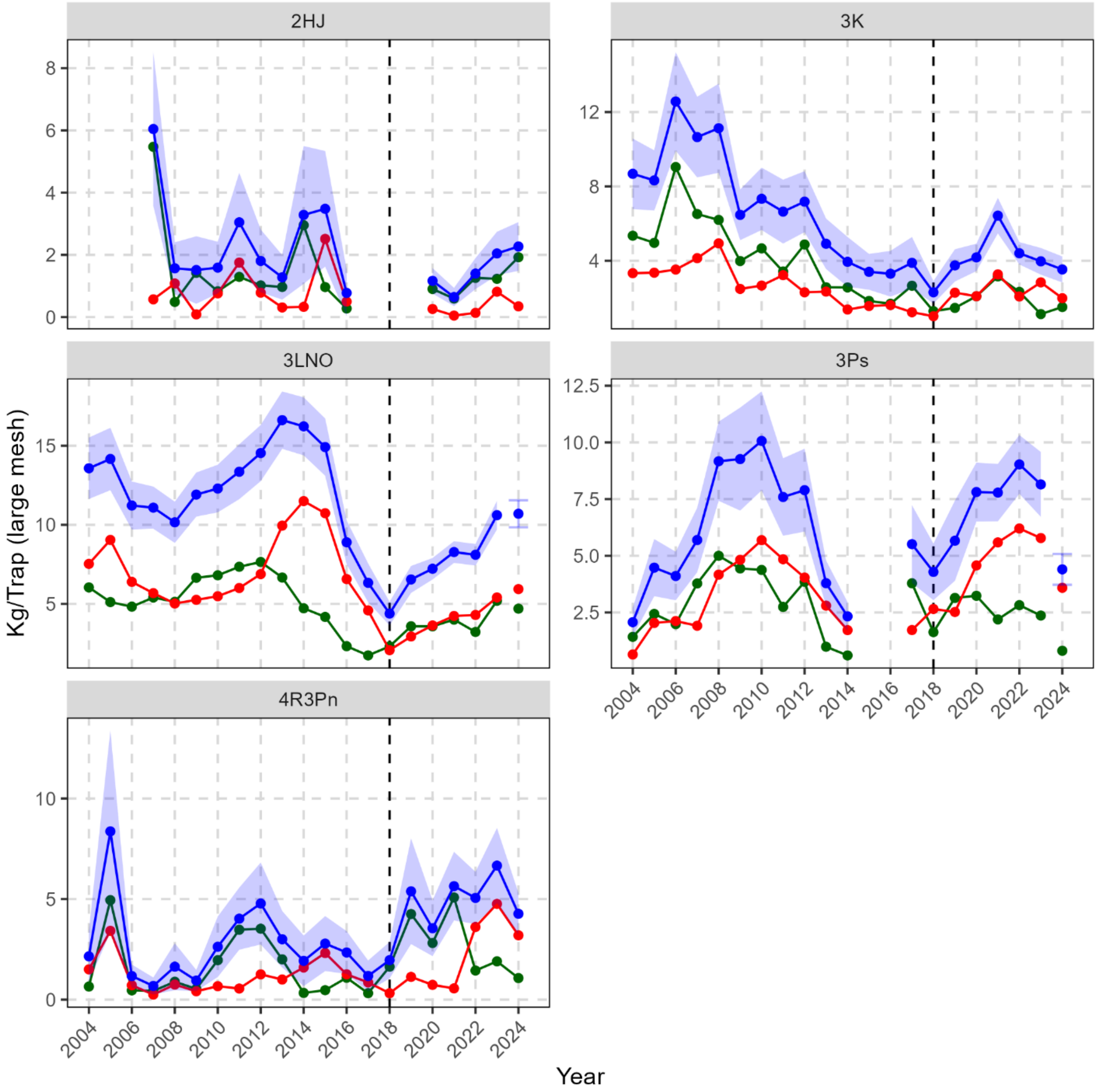

Figure 43. CPUE (kg/trap) by shell condition (blue = total, red = residual, green = recruits) for exploitable Snow Crab from all stations in the Collaborative Post-Season (CPS) trap survey by Assessment Division (2004–24). Shaded area represents the 95% confidence interval. The dashed vertical line represents the change in CPS survey design of reduction of core stations and expansion of random stations. Years without results represent incomplete or absent survey coverage.

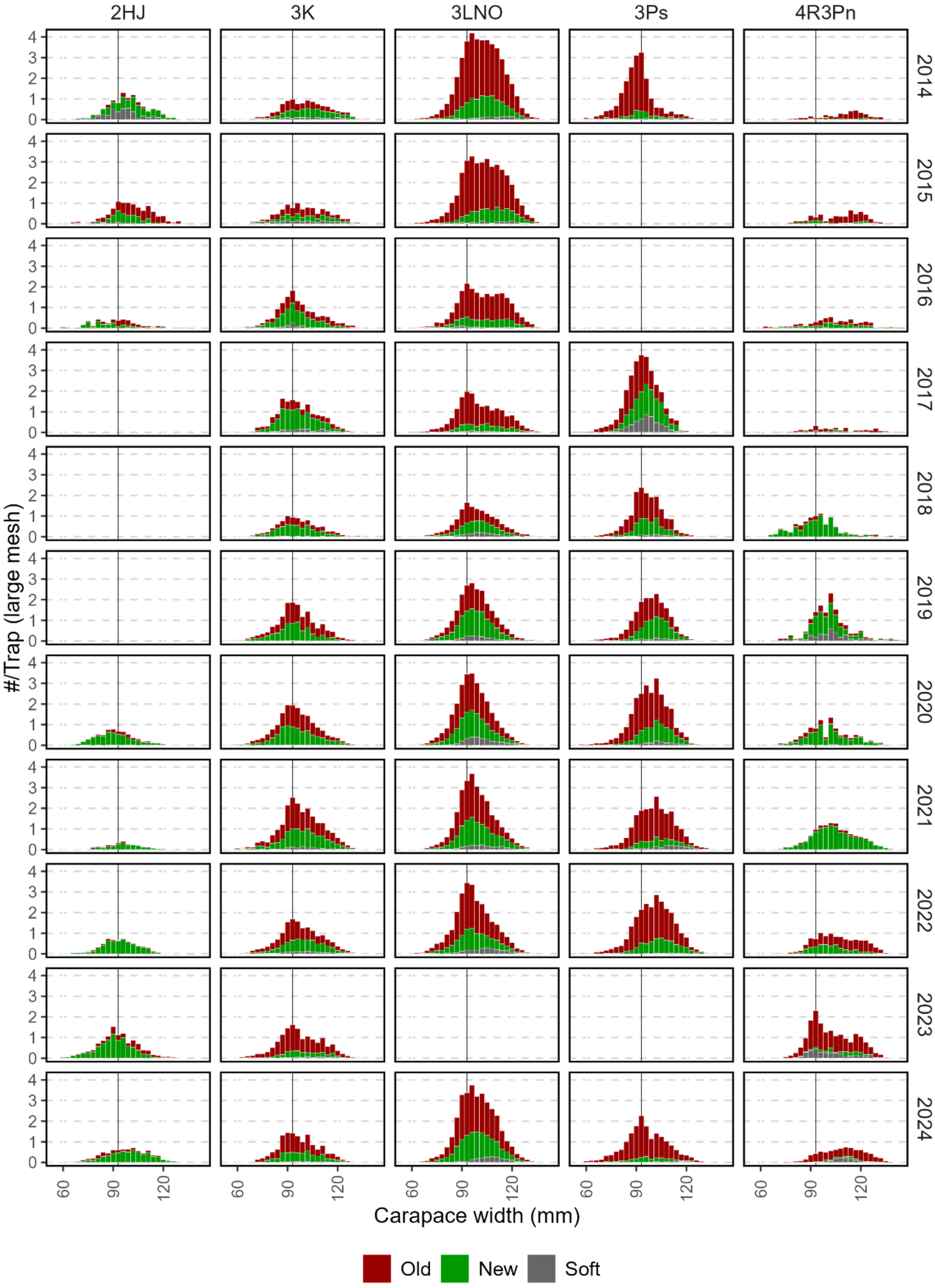

Figure 44. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations for the Collaborative Post-Season trap survey by Assessment Division (2014–24). The vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

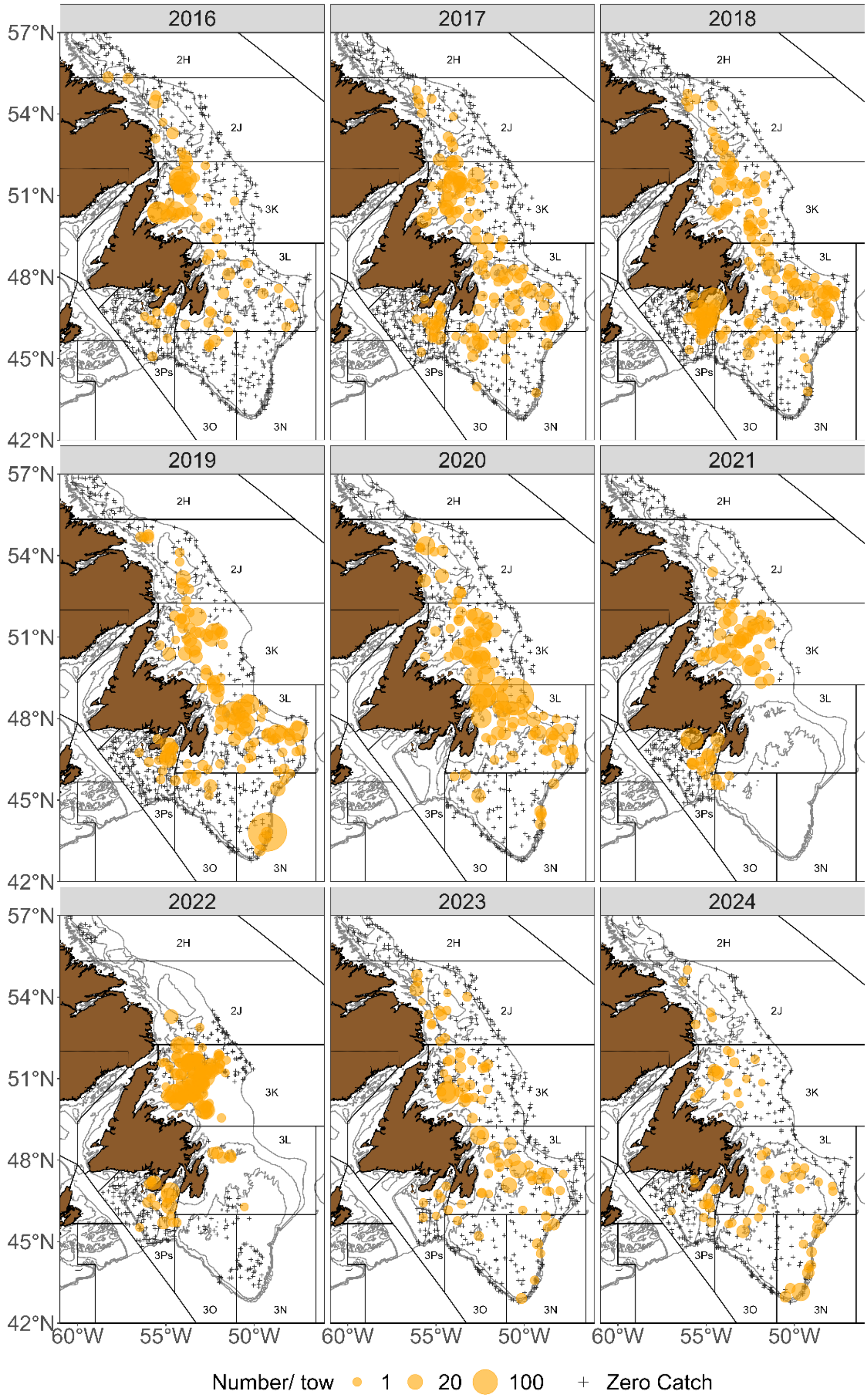

Figure 45. Distribution of pre-recruit (70–94 mm CW) males (#/tow) from 2HJ3KLNO fall and 3Ps spring trawl surveys (2016–24). + denotes tow with zero pre-recruit Snow Crab caught. This map does not include paired comparative fishing tows (2021–23) included in models for estimating pre-recruit abundance.

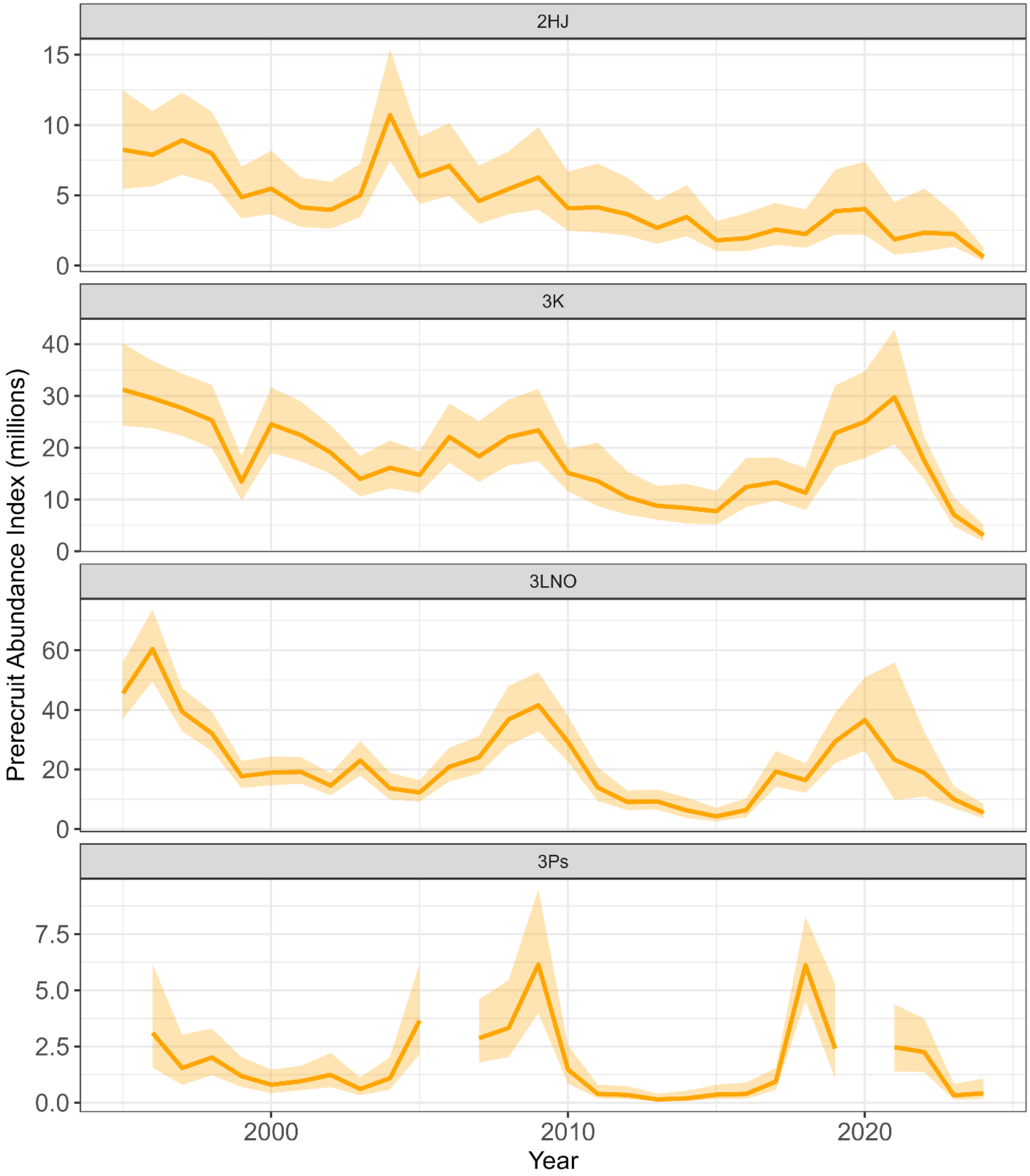

Figure 46. Annual trawl survey-based pre-recruit abundance index by Assessment Division (1995–2024). Solid lines = annual abundance estimate and shaded bands = 95% confidence intervals.

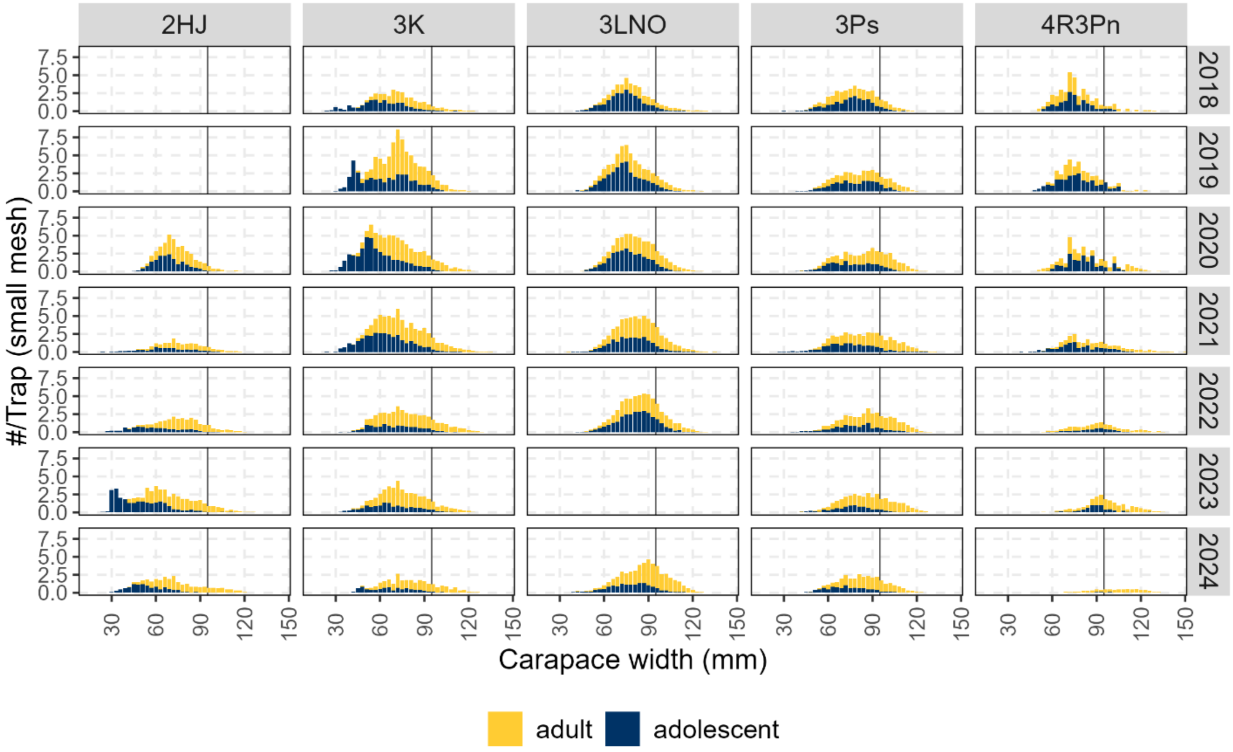

Figure 47. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations from the Collaborative Post-Season trap survey by Assessment Division (2018–24). The vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

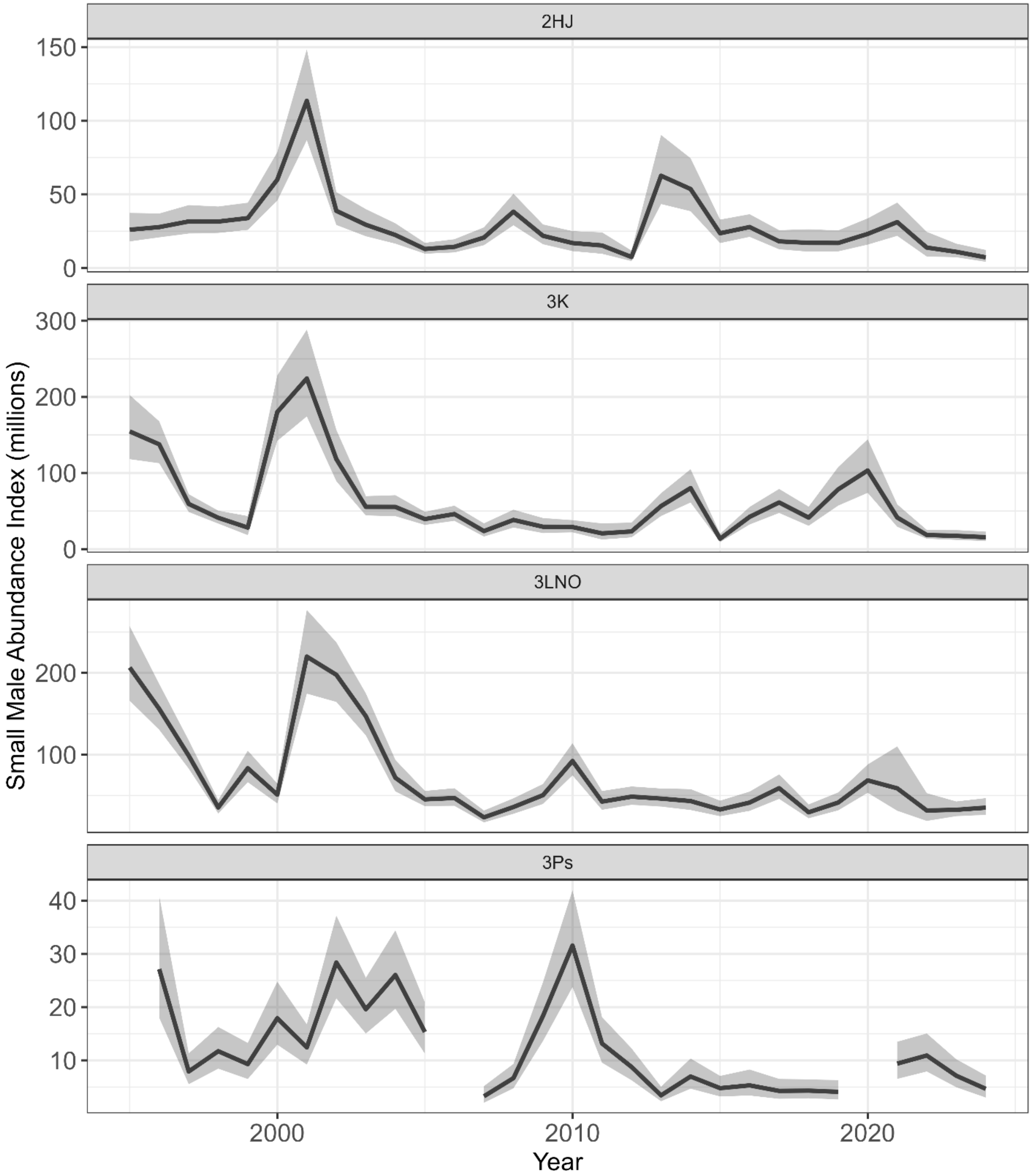

Figure 48. Annual trawl survey-based small male abundance index by Assessment Division (1995–2024). Solid lines = annual abundance estimate and shaded bands = 95% confidence intervals of annual estimate.

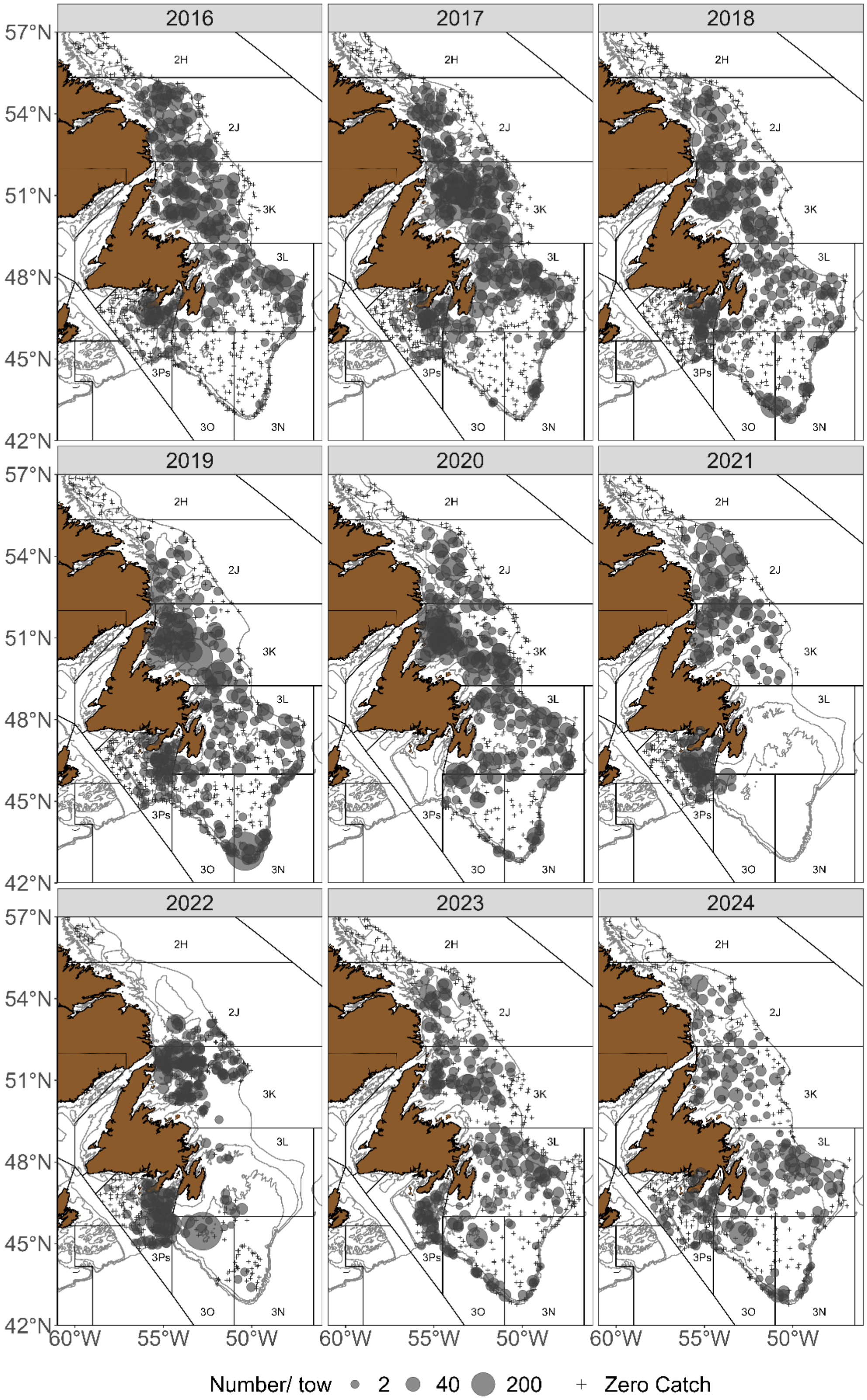

Figure 49. Distribution of small (< 45 mm CW) males (#/tow) from 2HJ3KLNO fall and 3Ps spring trawl surveys (2016–24). + denotes tow with zero small male Snow Crab caught. This map does not include paired comparative fishing tows (2021–23) included in models for estimating small male abundance.

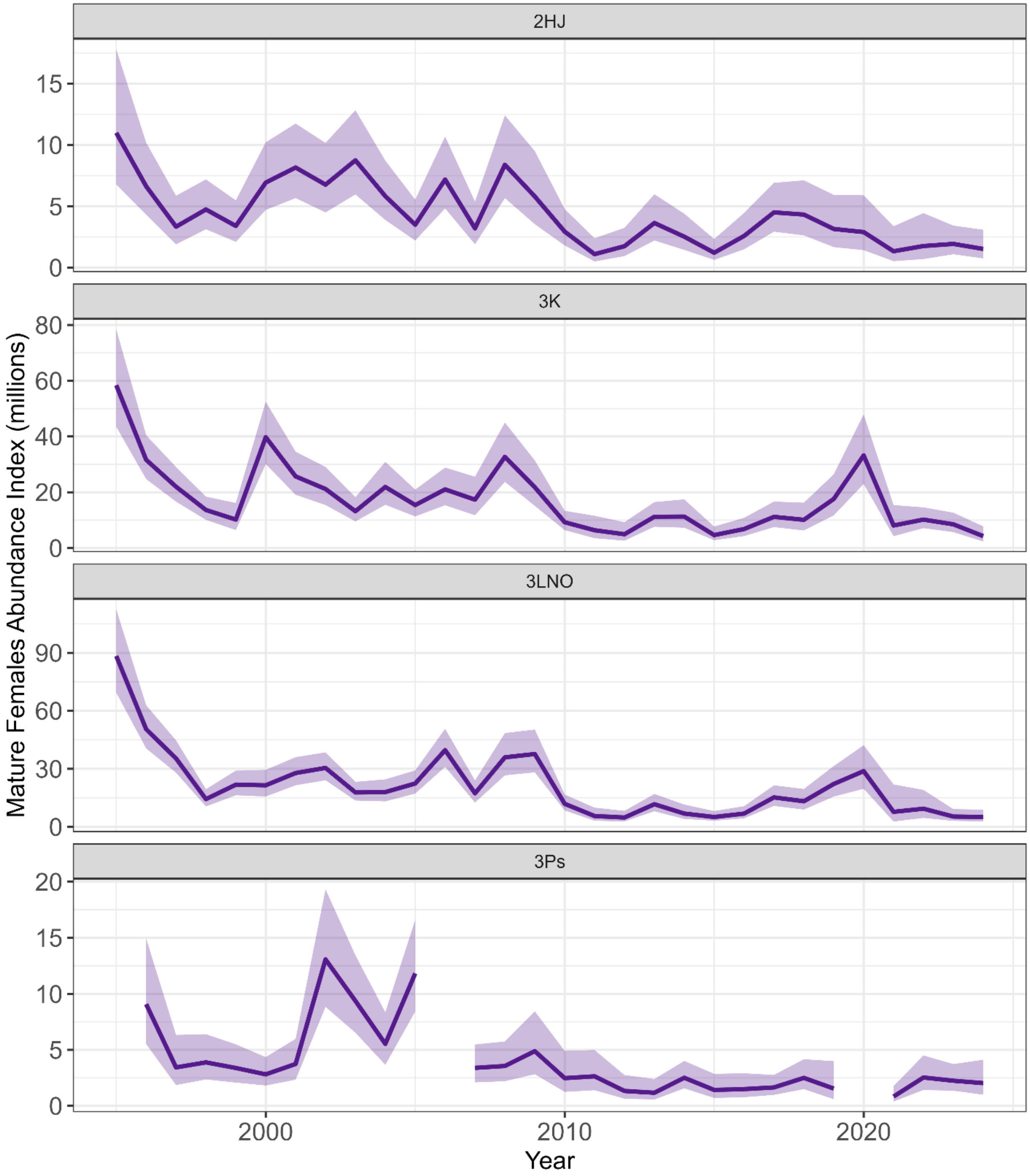

Figure 50. Annual trawl survey-based mature female abundance index by Assessment Division (1995–2024). Solid lines = annual abundance estimate and shaded bands = 95% confidence intervals of annual estimate.

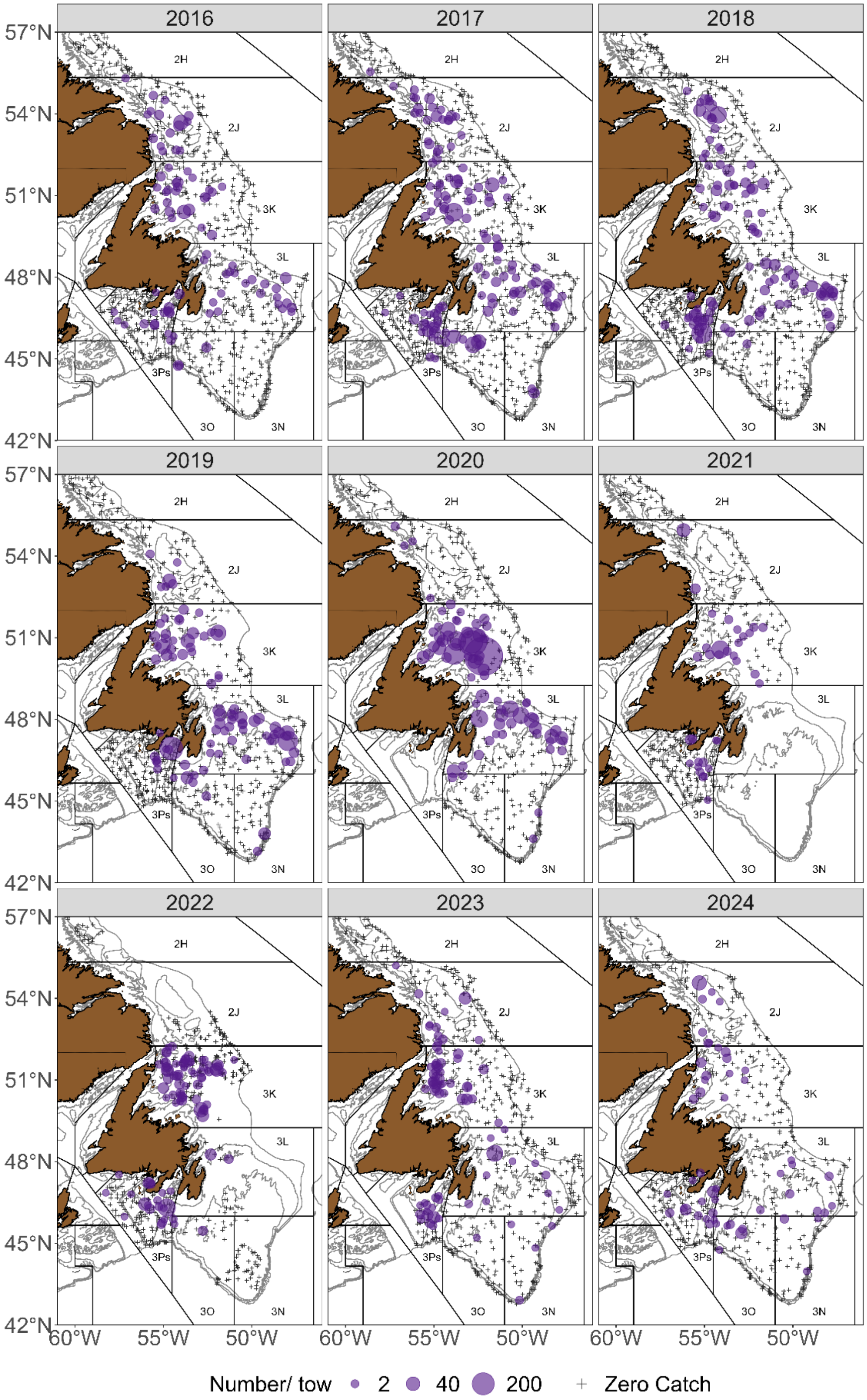

Figure 51. Distribution of mature females (#/tow) from 2HJ3KLNO fall and 3Ps spring trawl surveys (2016–24). + denotes tow with zero mature female Snow Crab caught. This map does not include paired comparative fishing tows (2021–23) included in models for estimating mature female abundance.

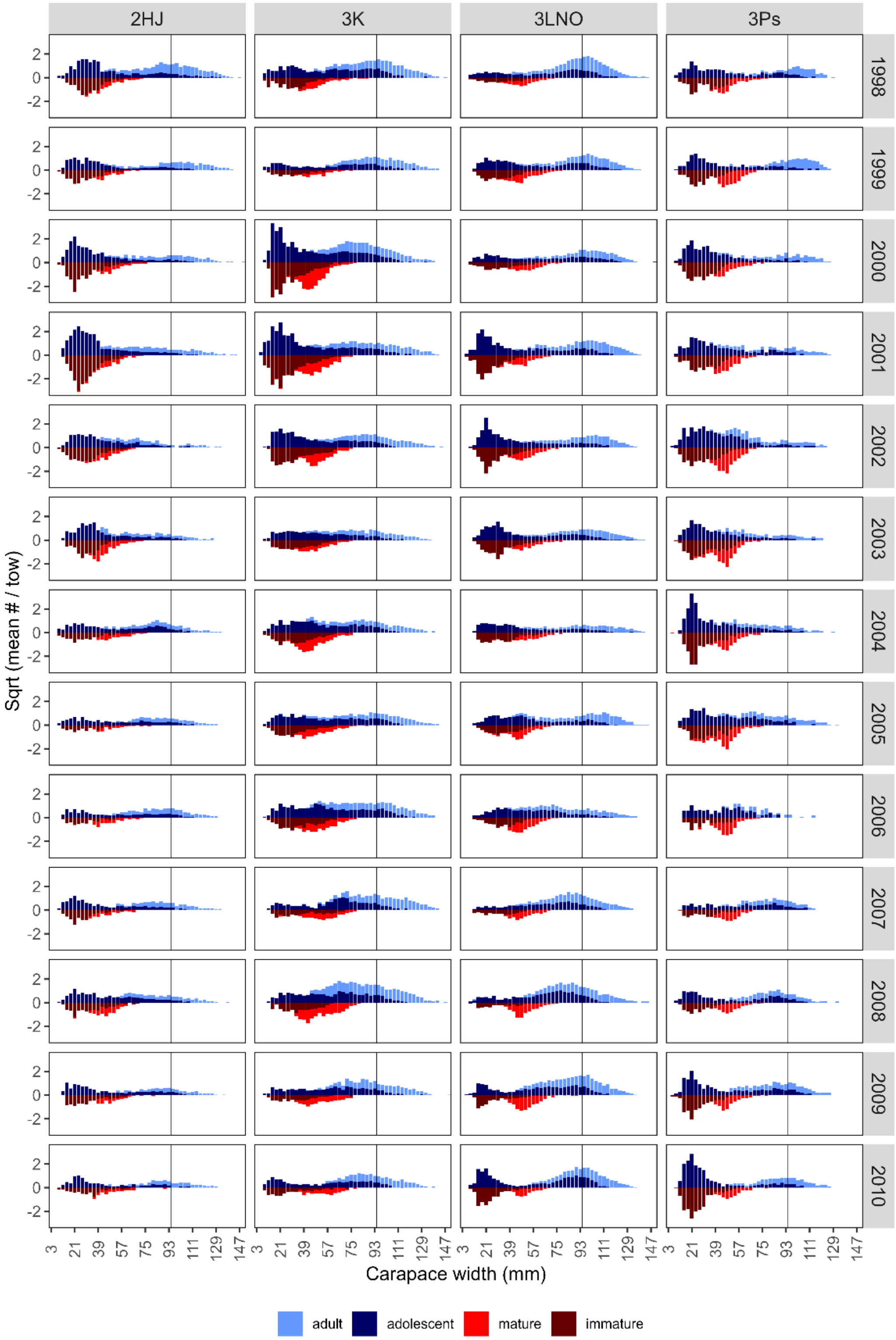

Figure 52. Abundance indices (#/tow) by carapace width for juveniles + adolescent males (dark blue), adult males (light blue), immature females (dark red), and mature females (red) from fall (Assessment Divisions 2HJ, 3K, and 3LNO) and spring (Assessment Division 3Ps) trawl surveys (1998–2010). Information on females, while displayed on the negative y-axis, represent positive abundance indices. The vertical line is the minimum legal size.

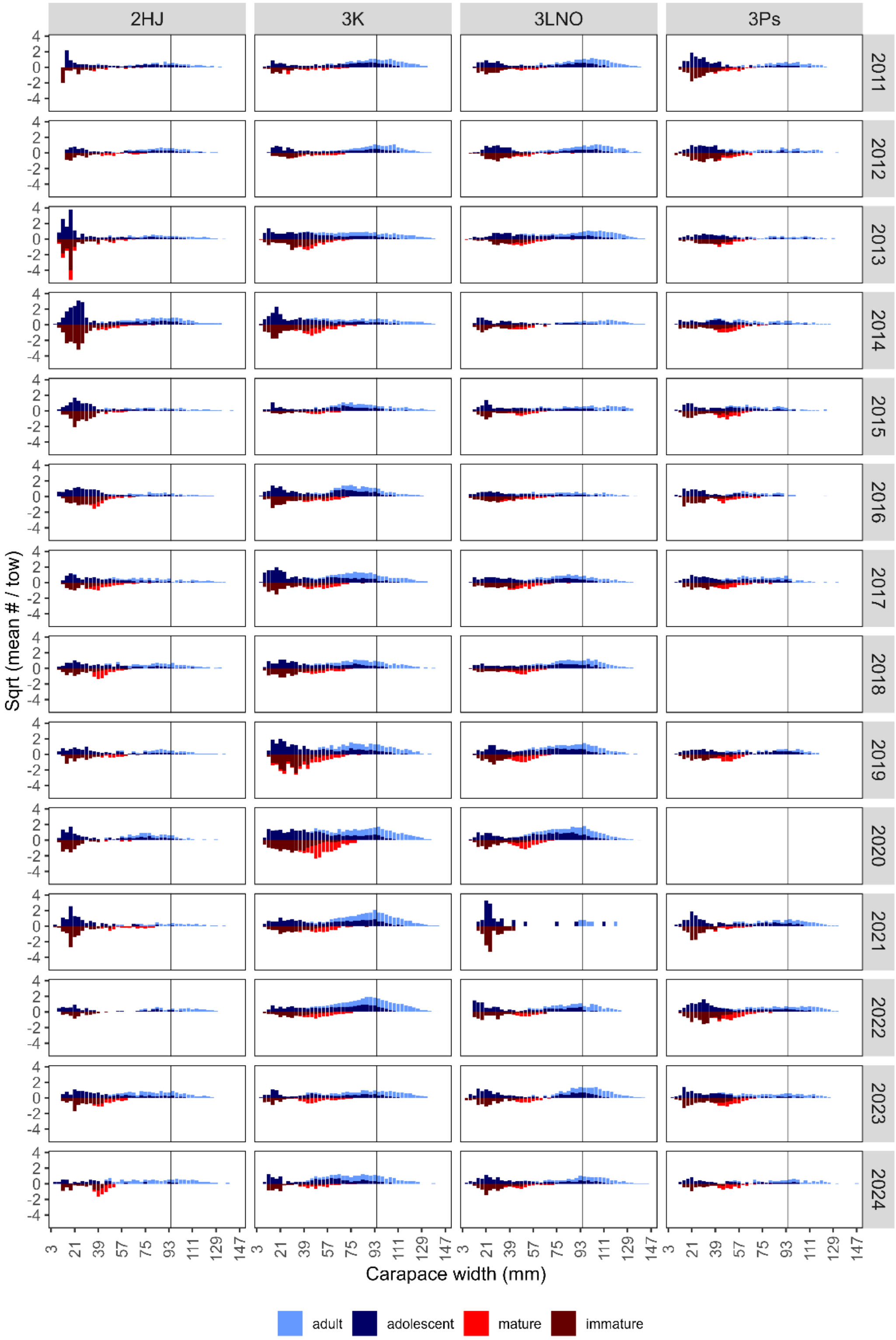

Figure 53. Abundance indices (#/tow) by carapace width for juveniles + adolescent males (dark blue), adult males (light blue), immature females (dark red), and mature females (red) from fall (Assessment Divisions 2HJ, 3K, and 3LNO) and spring (Assessment Division 3Ps) trawl surveys (2011–24). Information on females, while displayed on the negative y-axis, represent positive abundance indices. The vertical line is the minimum legal size.

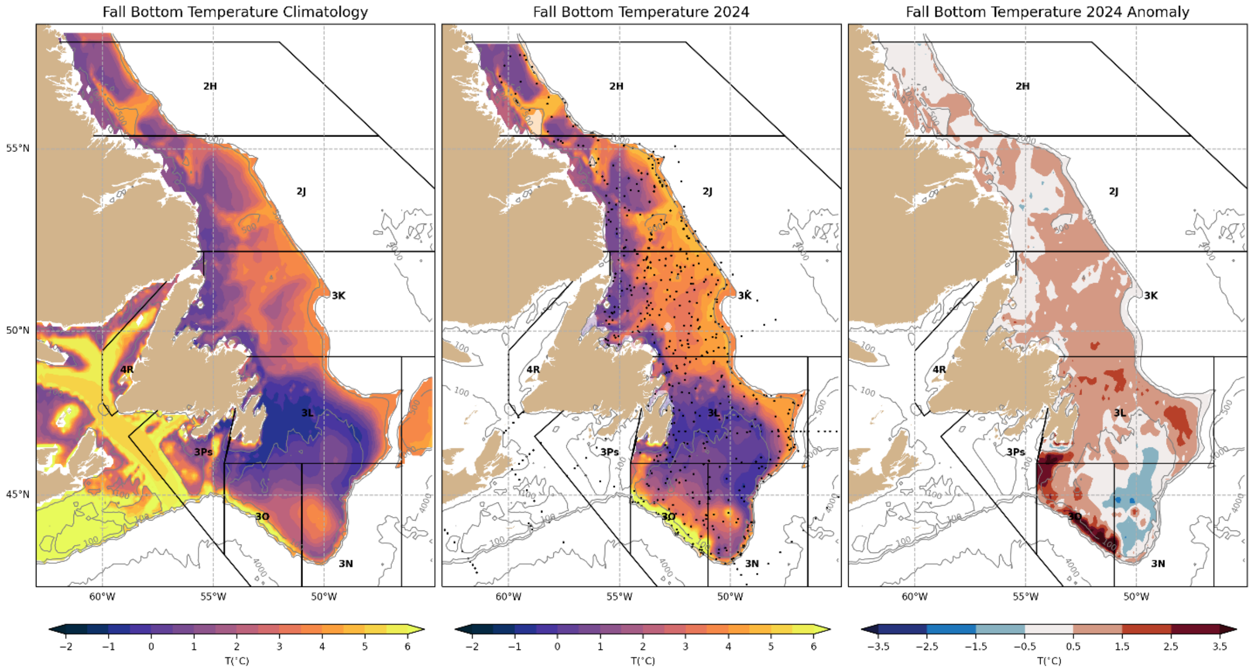

Figure 54. Fall bottom temperatures on the Newfoundland and Labrador Shelf averaged over the 1991–2020 climatological period (left), during 2024 (middle), and temperature anomalies for 2024 in relation to the climatology (right). Black points indicate the location of the profiles used to calculate the 2024 update (mostly multispecies survey observations).

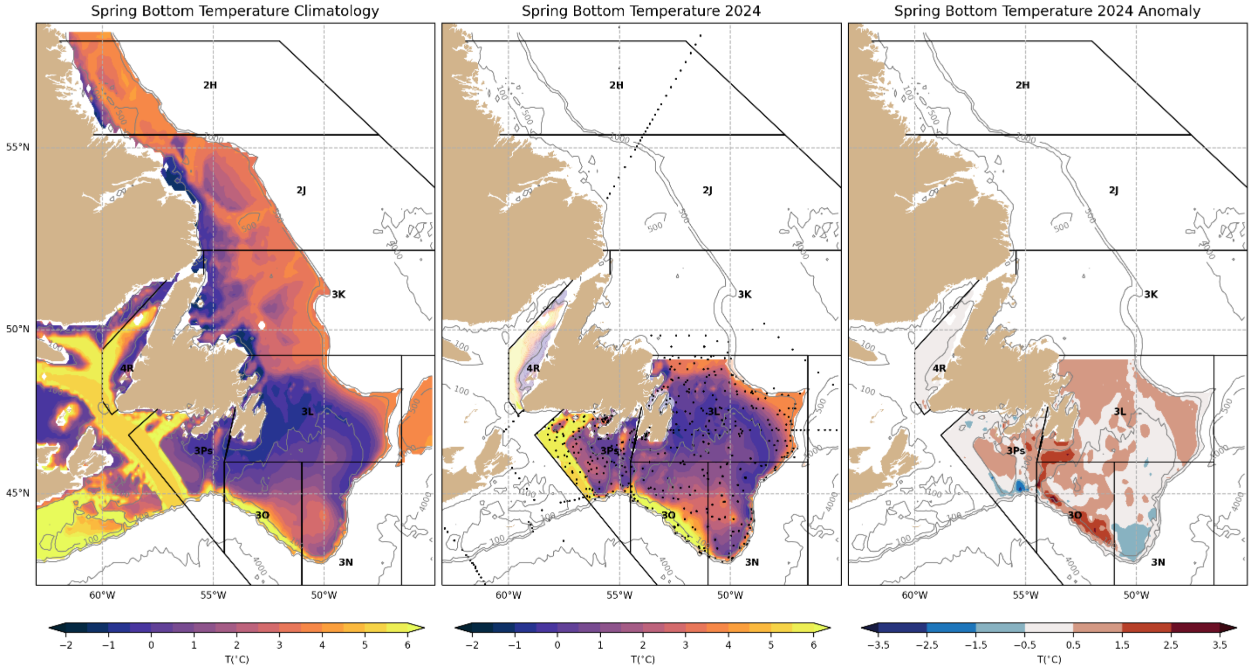

Figure 55. Spring bottom temperatures on the Newfoundland and Labrador Shelf averaged over the 1991–2020 climatological period (left), during 2024 (middle), and temperature anomalies for 2024 in relation to the climatology (right). Black points indicate the location of the profiles used to calculate the 2024 update (mostly multispecies survey observations).

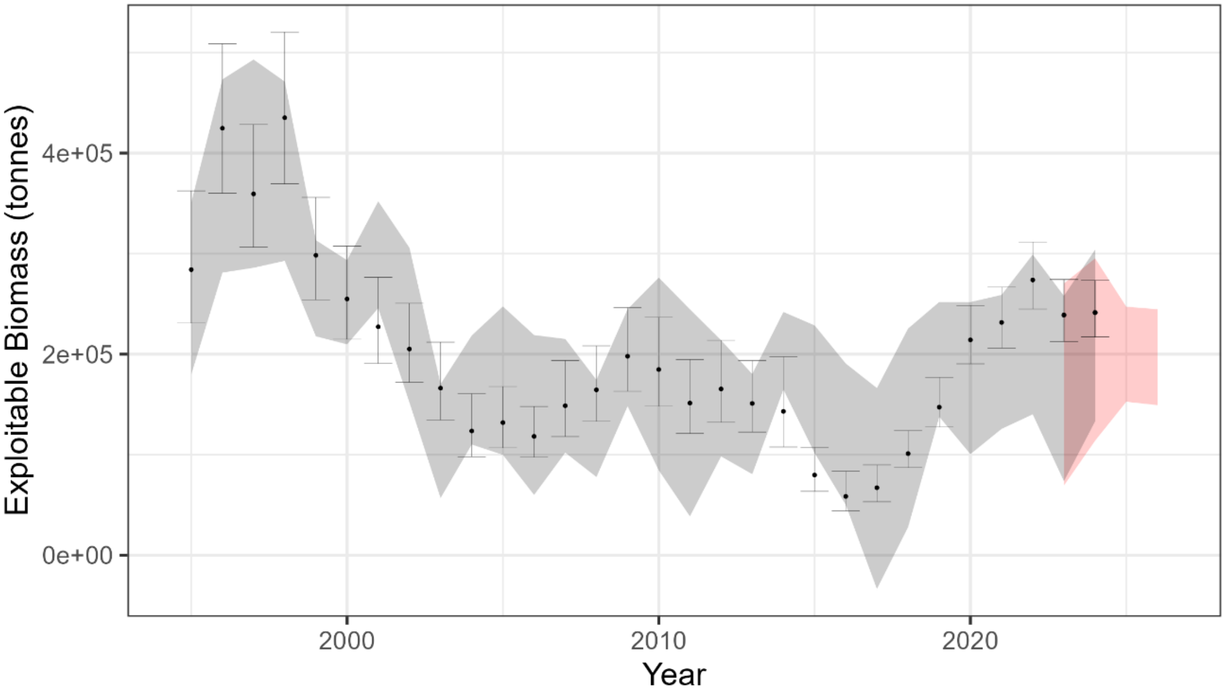

Figure 56. Short-term prediction model of exploitable biomass. Black points and associated error bars are integrated exploitable biomass in NAFO Divs. 2HJ3KLNOP (1995–2024). Black = the full model run (short-, mid-, long-term effects) and red = the model run with no short-term effects. Shaded areas are 95% confidence intervals of model fits.

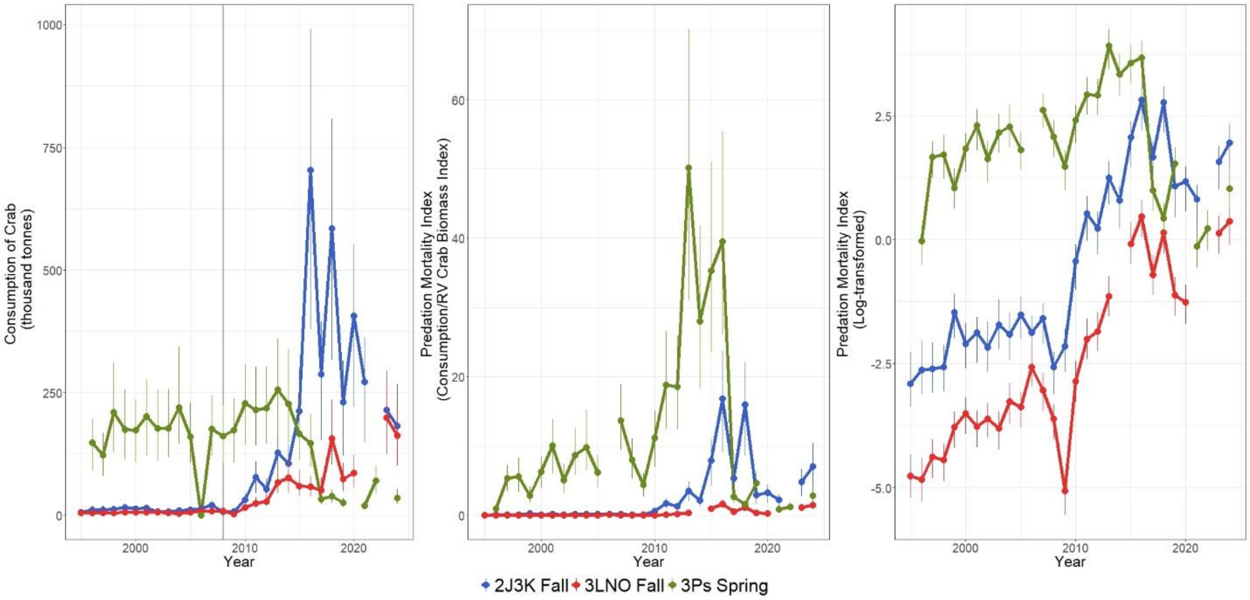

Figure 57. Consumption of Snow Crab by finfish predators (left) and predation mortality index (middle and right) by Ecosystem Production Unit; blue is 2J3K fall series, red is 3LNO fall series, and green is 3Ps spring series. Solid vertical line represents the restart of the stomach collection program.

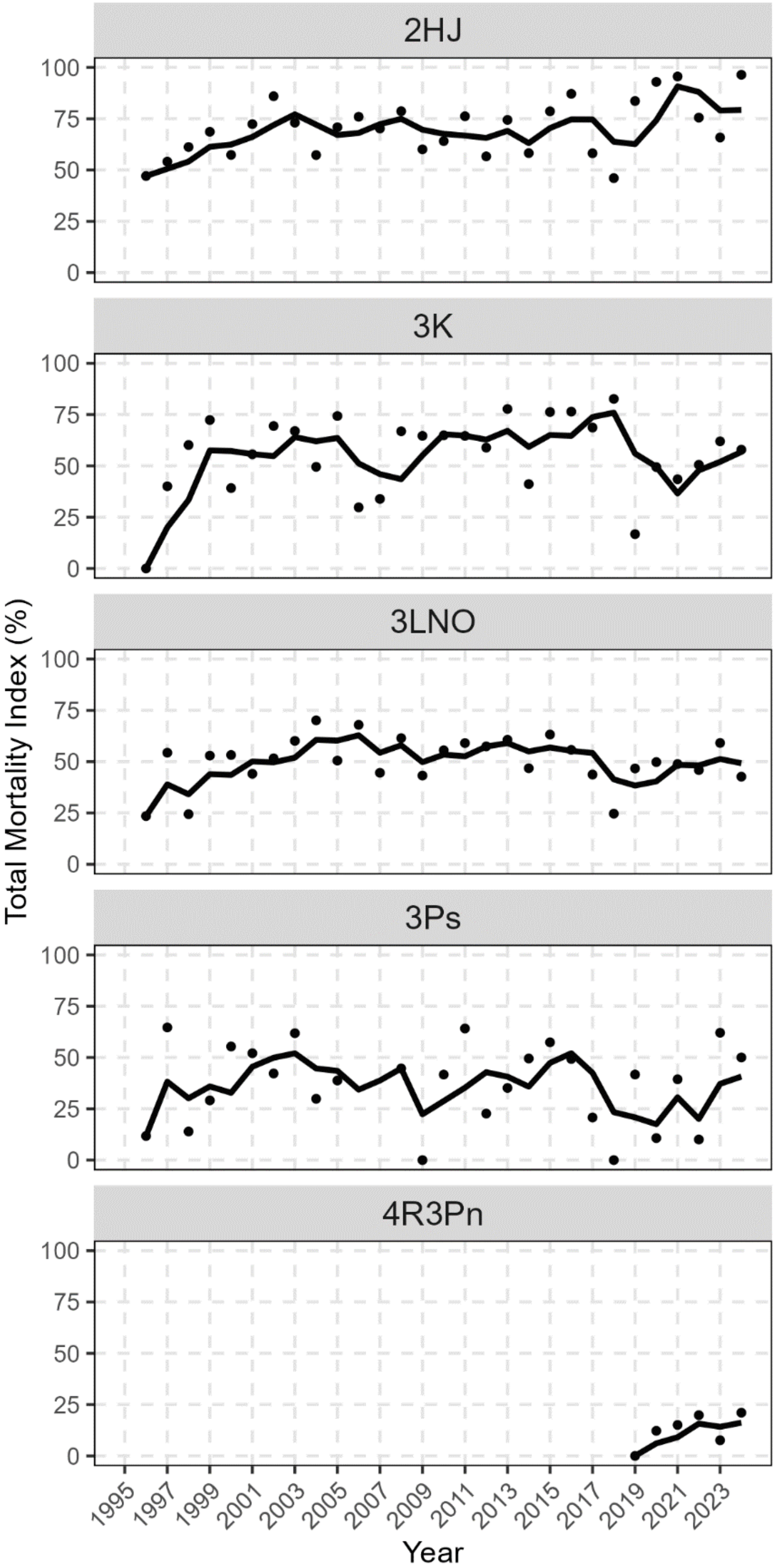

Figure 58. Annual (points) and 3-year moving average (solid line) total annual mortality index (%) of exploitable Snow Crab by Assessment Division. Note if annual mortality index was < 0 it was plotted as 0 for presentation.

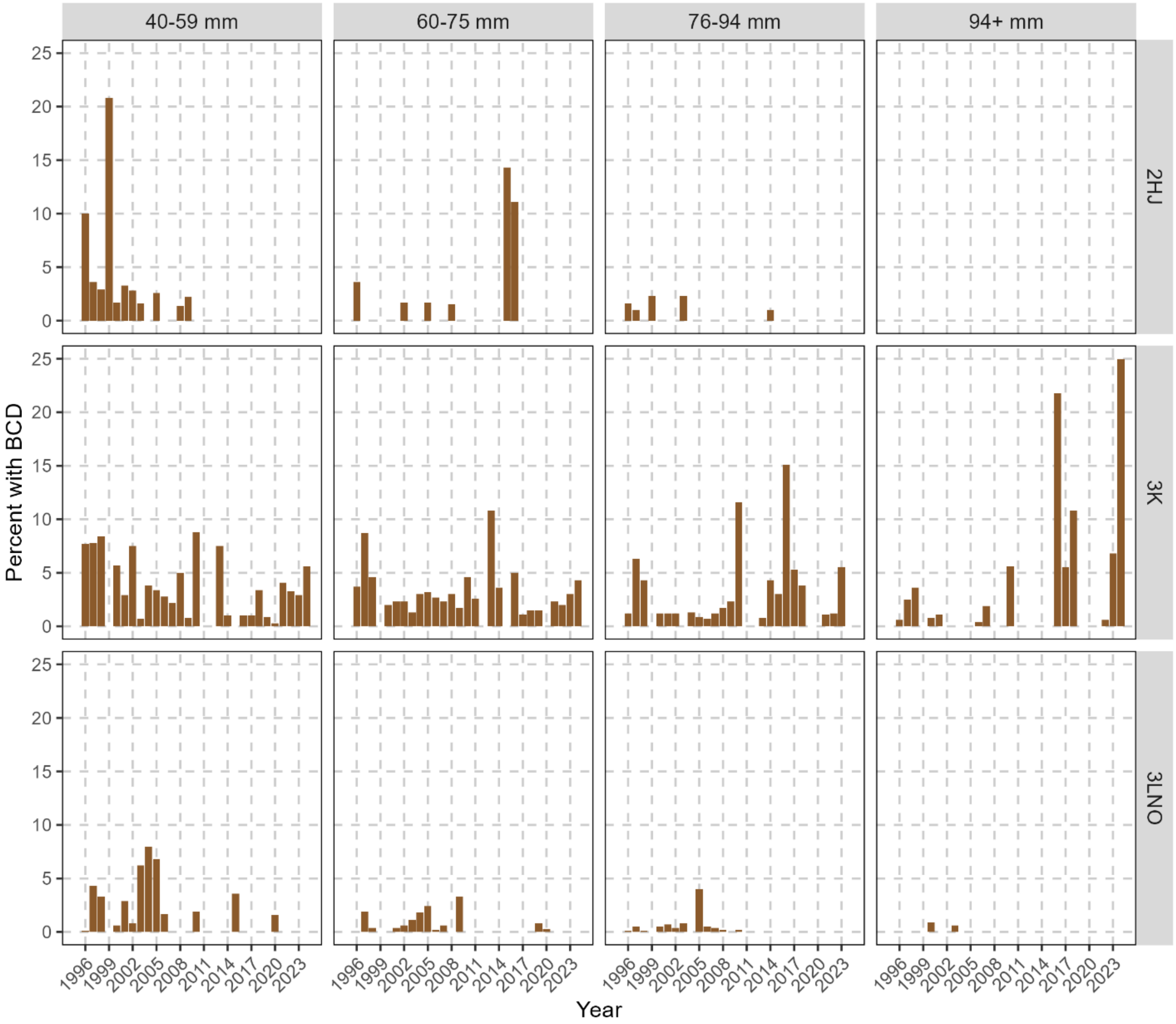

Figure 59. Annual prevalence of Bitter Crab Disease (BCD) from macroscopic observations in new-shelled adolescent male Snow Crab in fall trawl surveys by Assessment Division and carapace width (1996–2024).

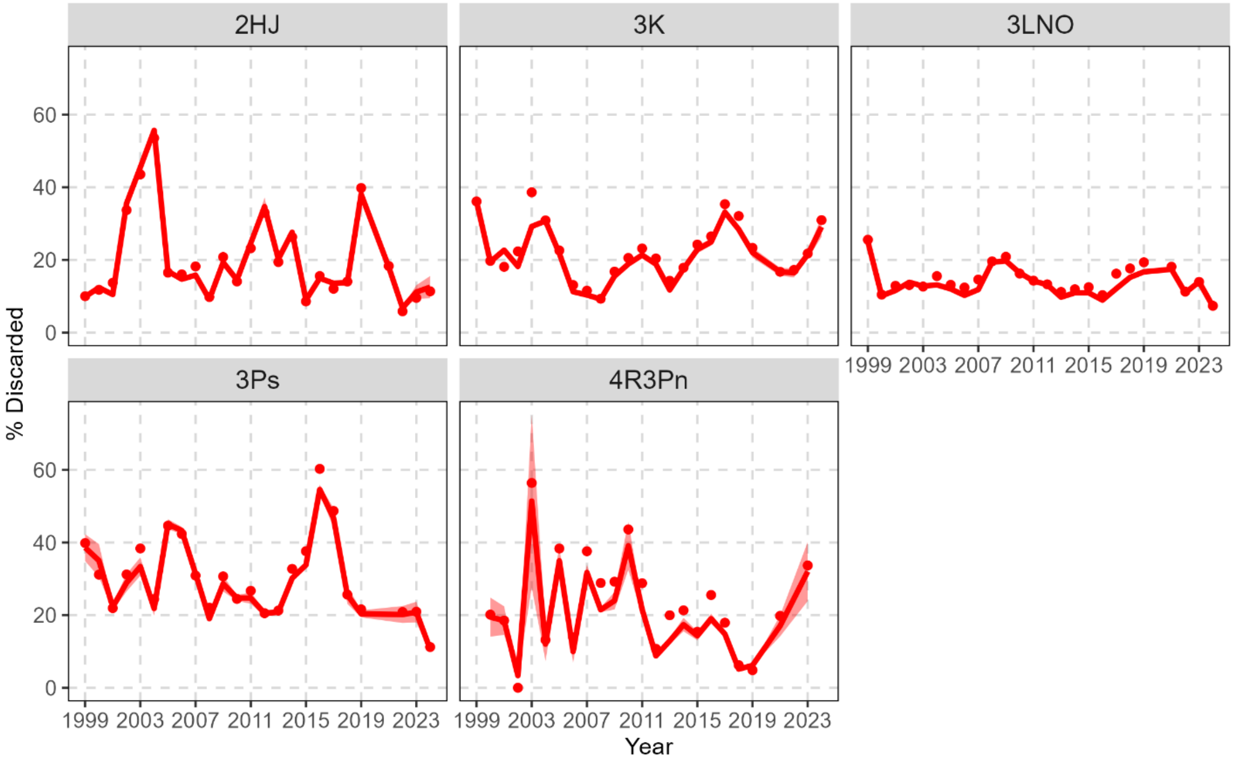

Figure 60. Discards (%) based on raw estimates (points) and standardized values (solid lines) by Assessment Division (1999–2024). The shaded area represents the 95% confidence interval. Years without results represent low or absent at-sea observer coverage.

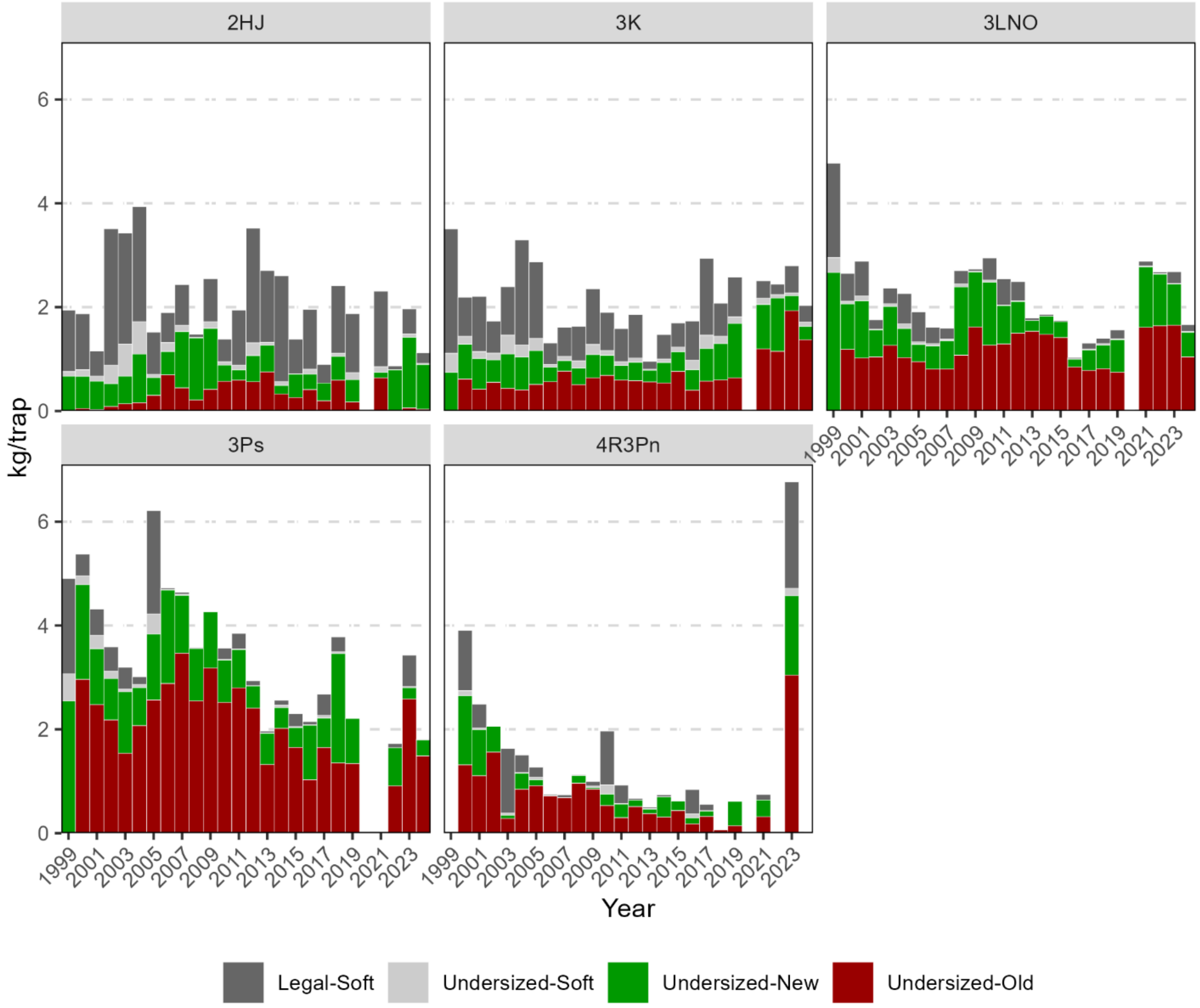

Figure 61. Catch rates of discards (kg/trap) by size and shell condition groups (legal-sized soft-shelled, undersized soft-shelled, undersized new-shelled, and undersized old-shelled) by Assessment Division (1999–2024) from at-sea observer sampling. Years without results represent low or absent at-sea observer coverage.

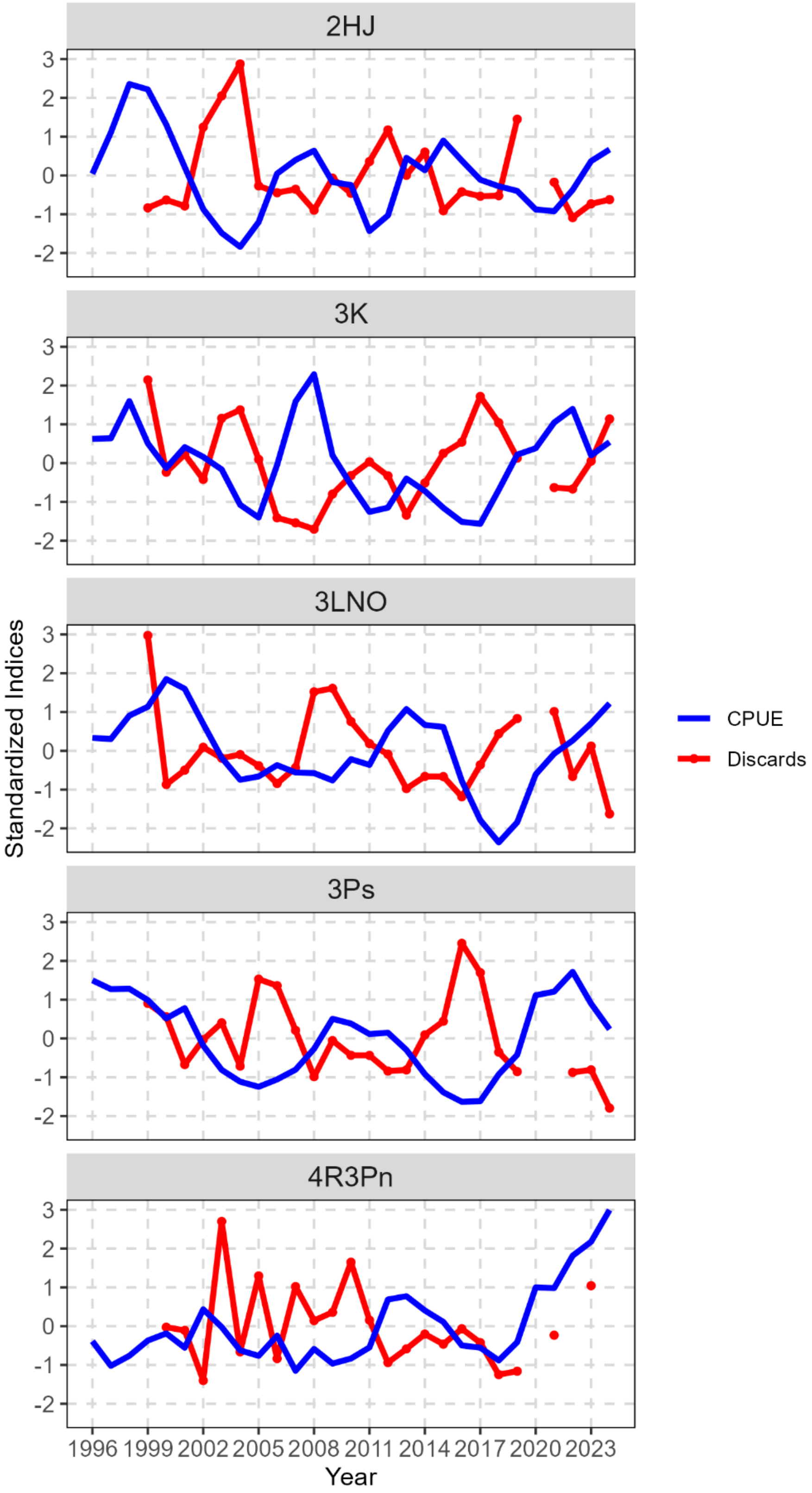

Figure 62. Standardized fishery CPUE (blue) and discard rates (red) by Assessment Division (1996–2024). Years without results represent low or absent at-sea observer coverage.

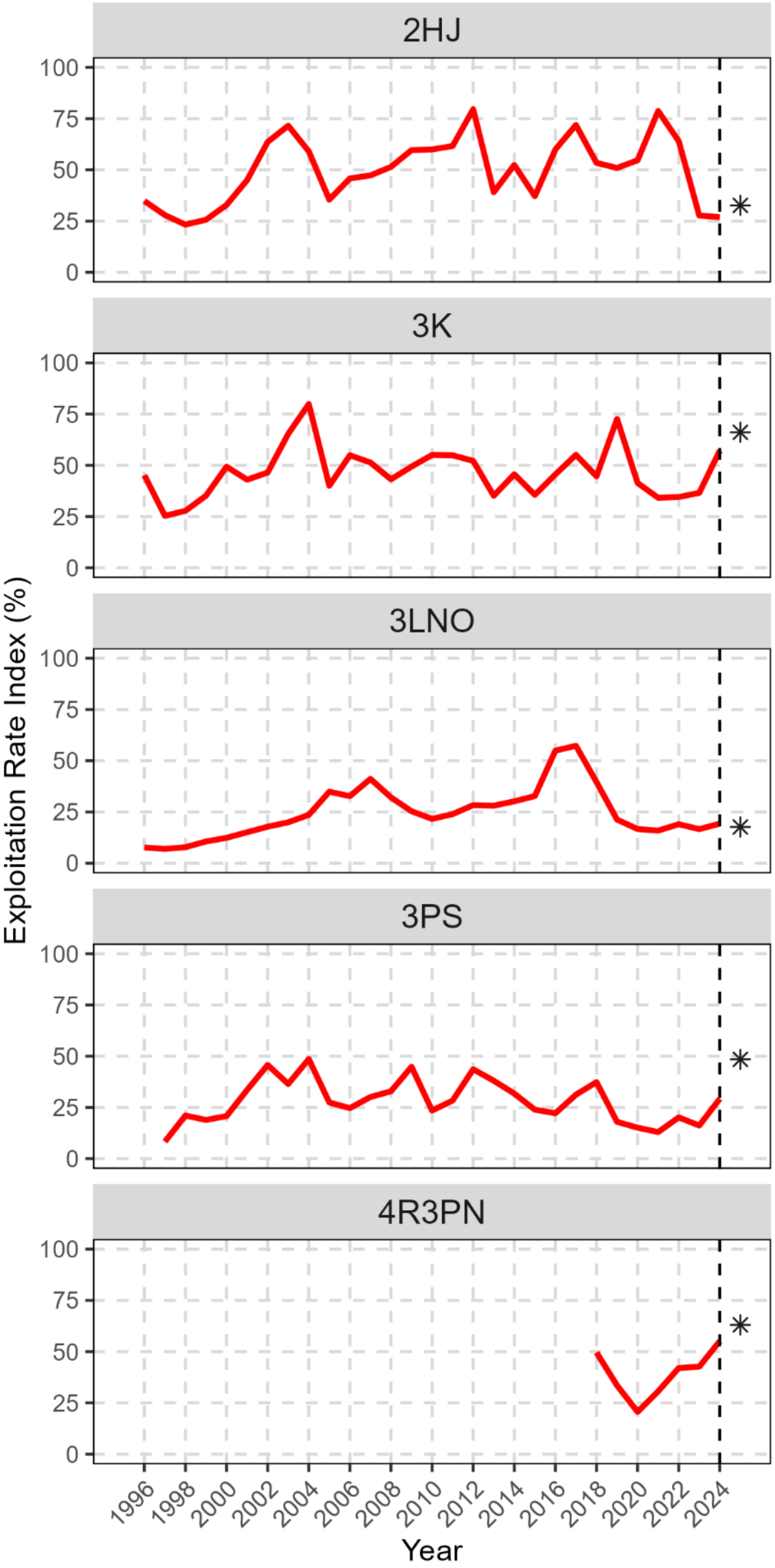

Figure 63. Annual Exploitation Rate Index (ERI) by Assessment Division (1996–2024). Solid line = annual estimate and 2025 points (*) depict projected annual ERIs under status quo landings in the 2025 fishery.

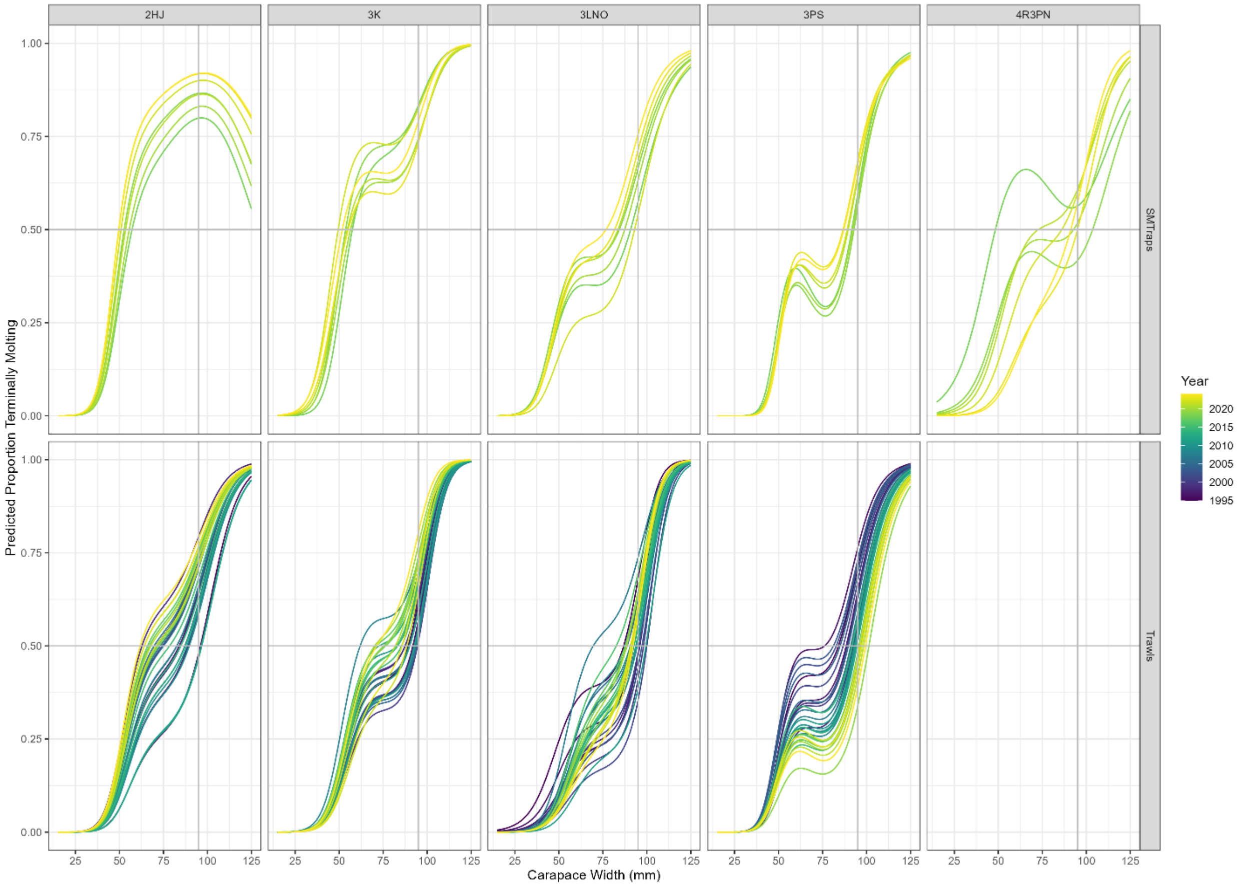

Figure 64. *Predicted size at terminal molt for male Snow Crab by Assessment Division (1995–2024) from Collaborative Post-Season trap survey small-mesh traps (top) and DFO trawls (bottom). Vertical grey line represents minimum legal size and horizontal grey line represents 50% terminally molting.*

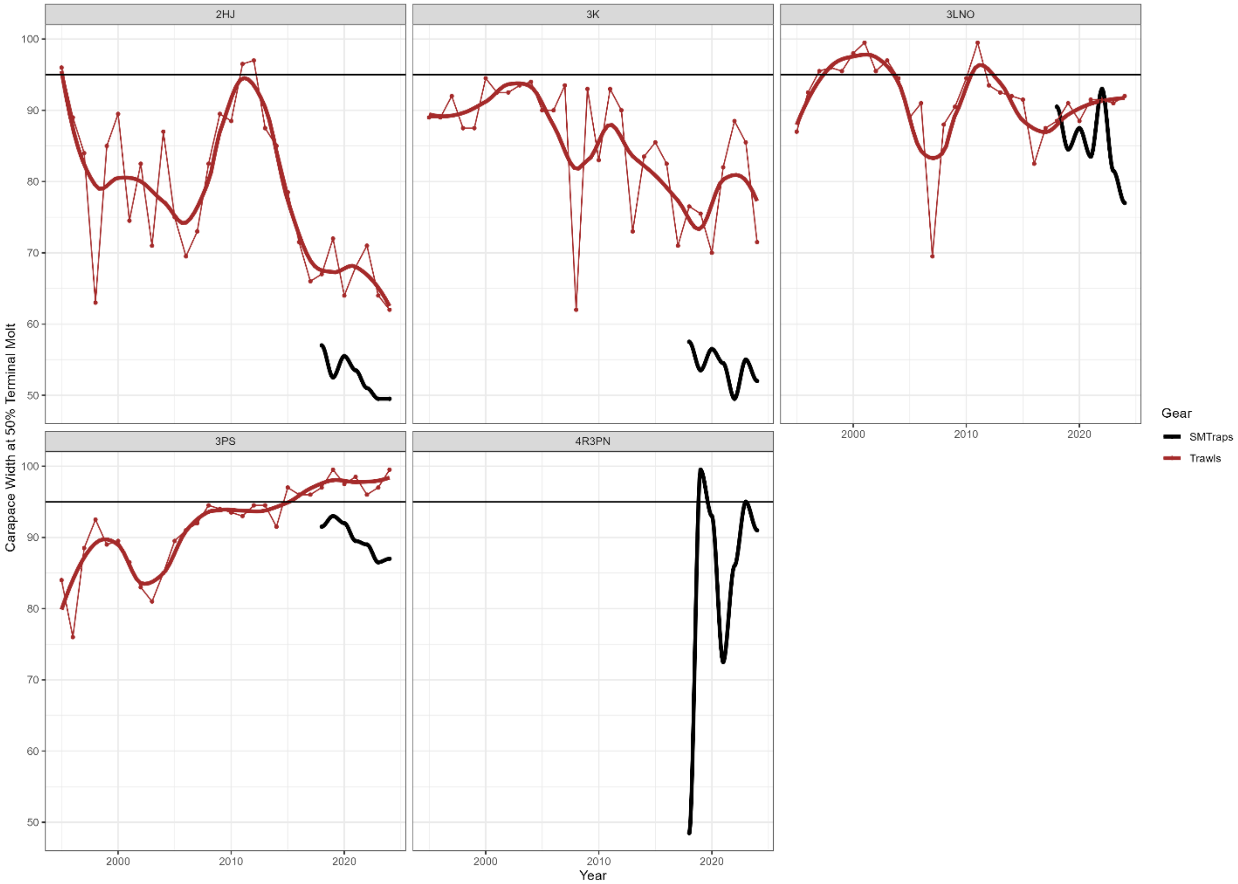

Figure 65. Male size at 50% terminal molt from small-mesh traps (black) and trawls (red) by Assessment Division. Points represent annual estimates from GAM and solid lines represent loess regression curves. Horizontal line is minimum legal size.

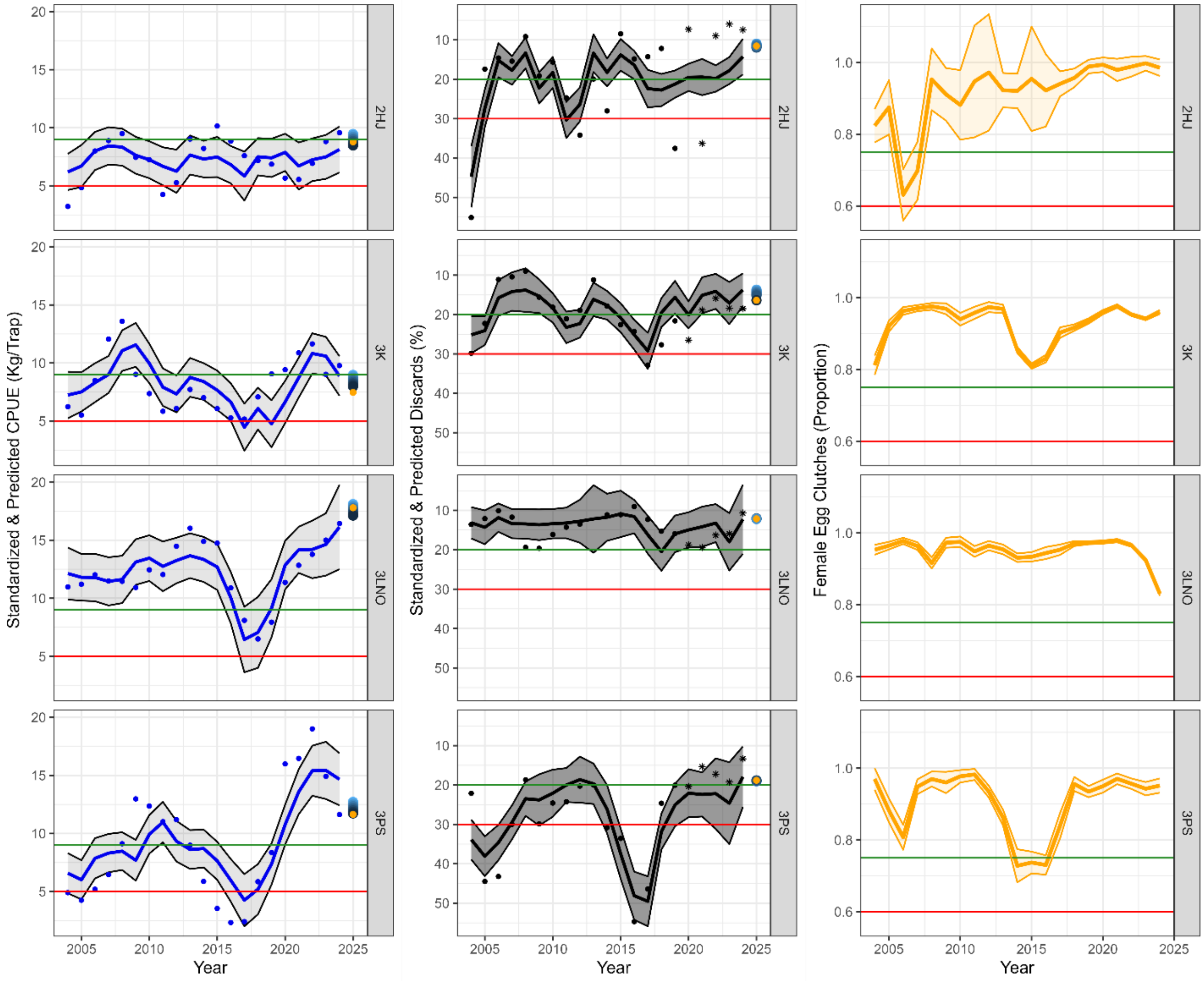

Figure 66. Predicted CPUE (left), predicted % discards (middle), and observed proportion of females with full egg clutches (right) (solid lines), as well as standardized CPUE and % discards (points) in the Precautionary Approach Framework, by Assessment Division (2004–24). Shaded areas = prediction intervals (CPUE and discards) or 1 standard deviation (egg clutches), orange points = predicted values under status quo landings in the 2025 fishery, vertical blue shades in 2025 = predicted values under varying levels of Exploitation Rate Index (ERI) (light to dark blue: ERI = 5–45%), Red horizontal line = Limit Reference Point, green horizontal line = Upper Stock Reference.

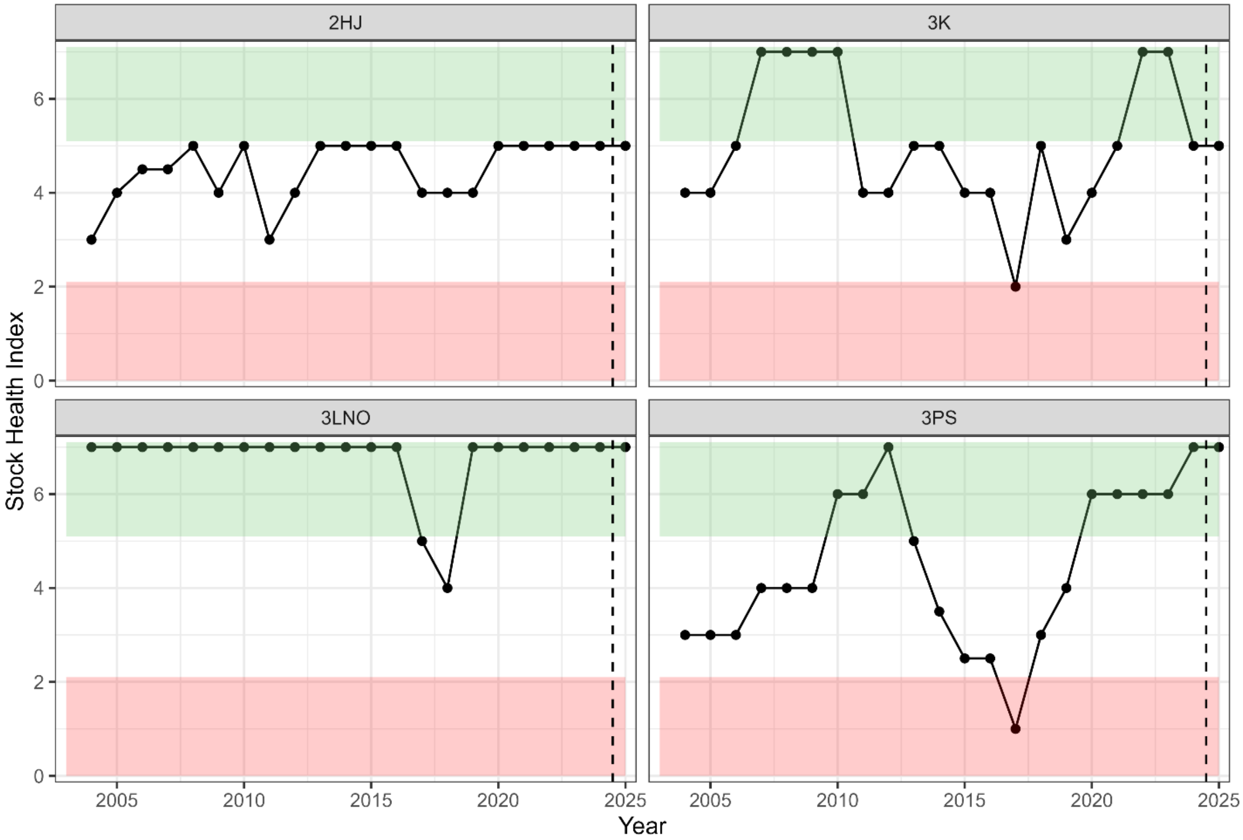

Figure 67. Projected stock status (black points) in the NL Snow Crab Precautionary Approach Framework, by Assessment Division (2004–25). The green, white, and red shaded areas represent the Healthy, Cautious, and Critical Zones, respectively. The dashed vertical line represents the present year (2024), after which the stock status is predicted with status quo landings for 2025.

APPENDIX 1: ASSESSMENT DIVISION 2HJ DETAILS

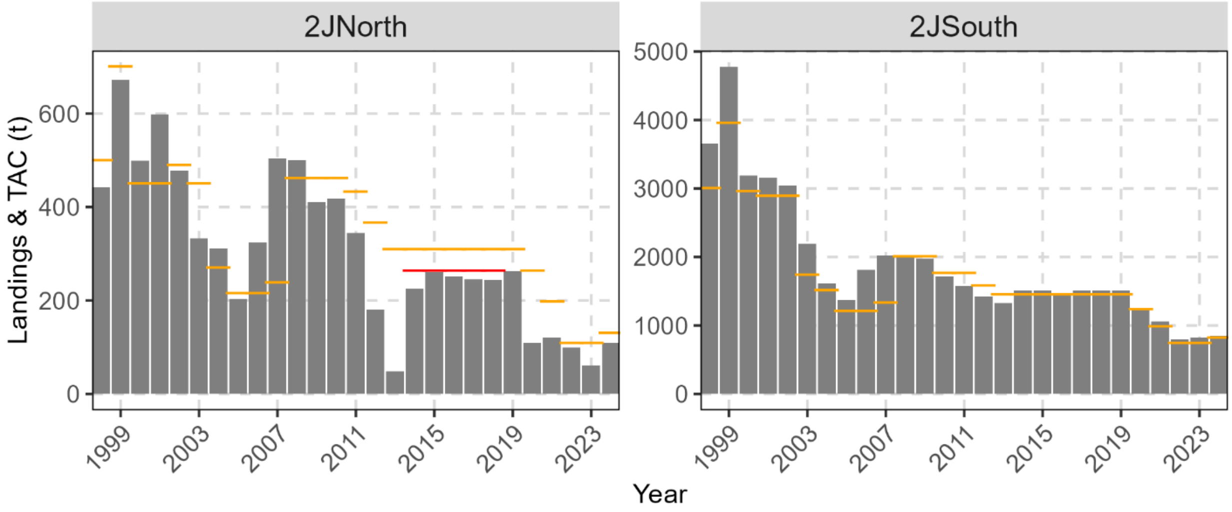

Figure A1.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 2HJ (1998–2024). Red dashes are the voluntary TAC (15% reduction of TAC) set by harvesters in 2JNorth from 2014–18.

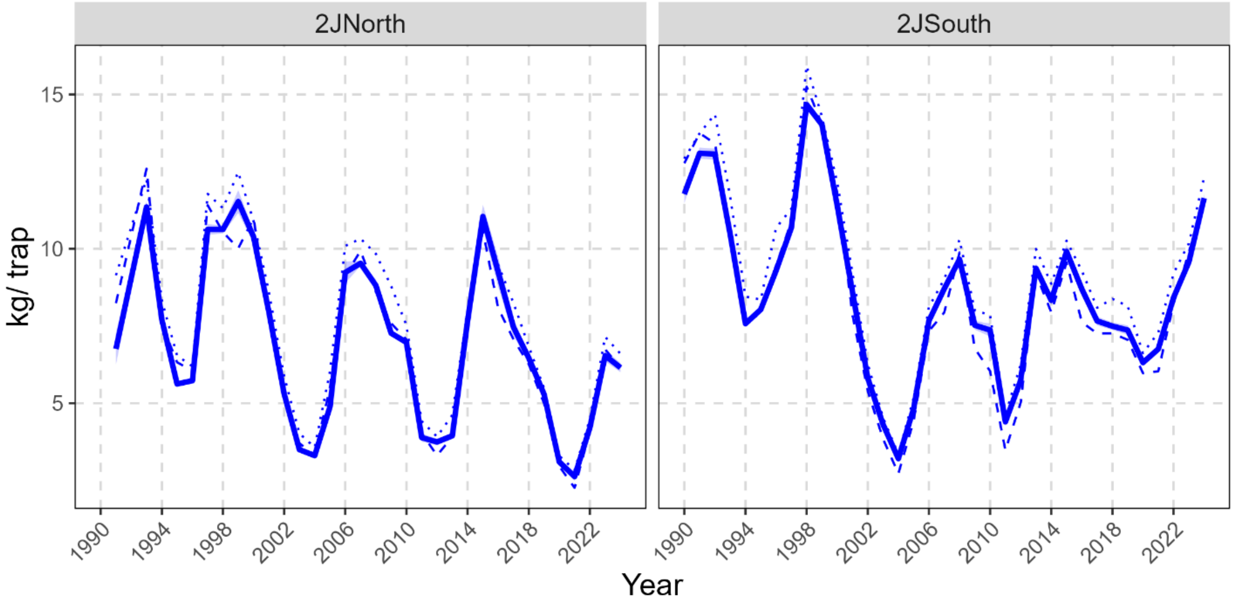

Figure A1.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 2HJ (1990–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

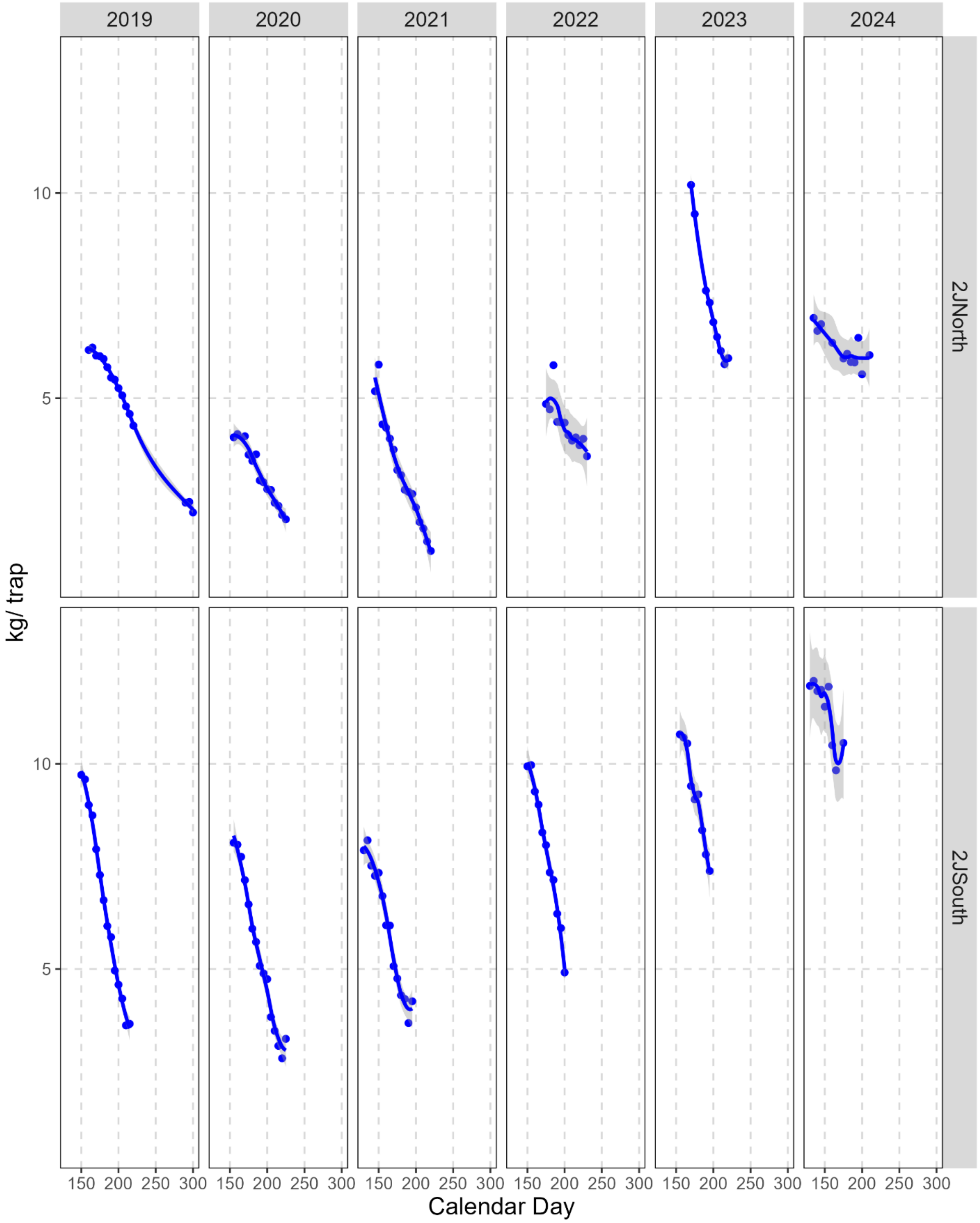

Figure A1.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 2HJ (2019–24), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

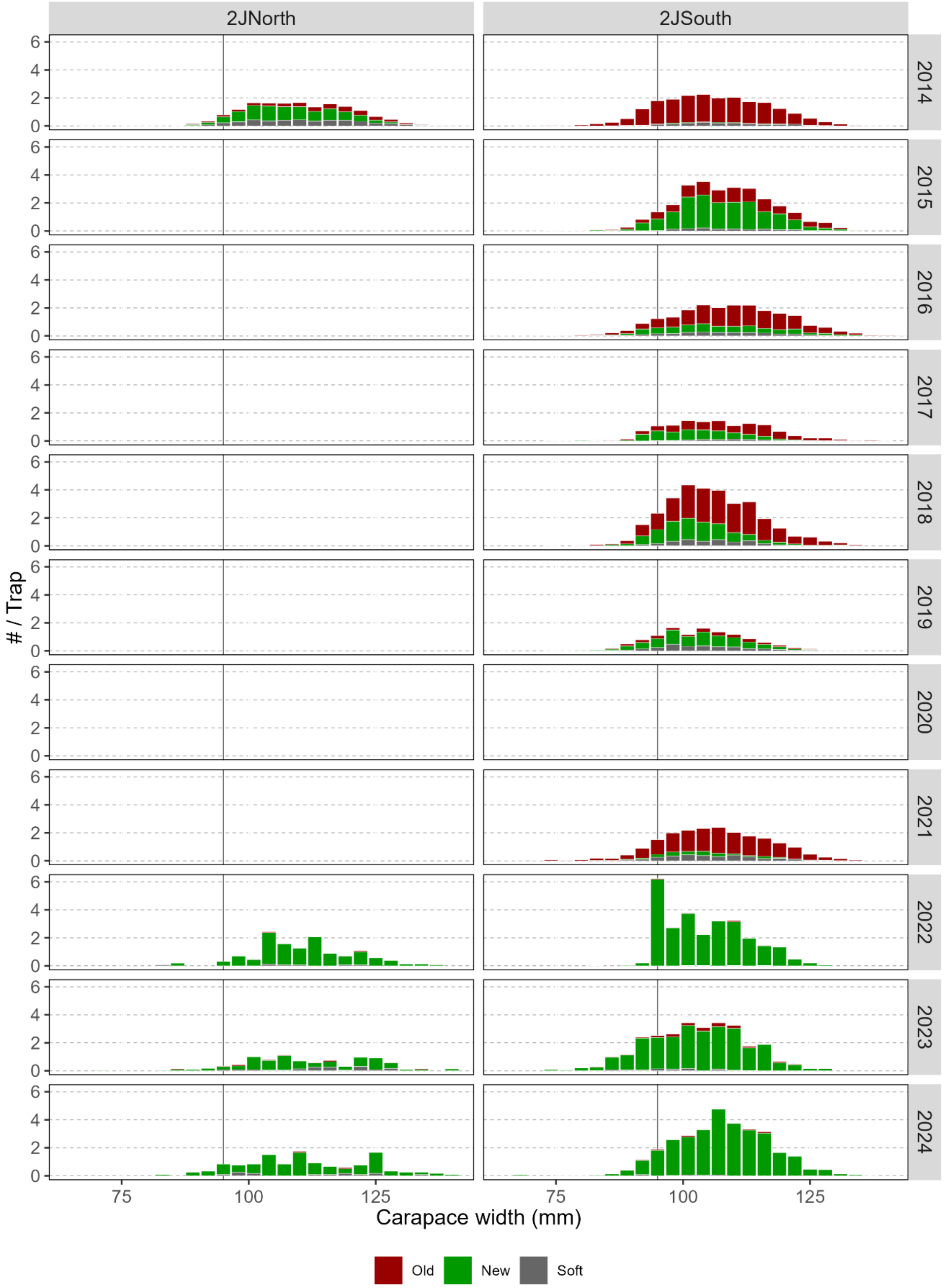

Figure A1.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 2HJ (2014–24). The black vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

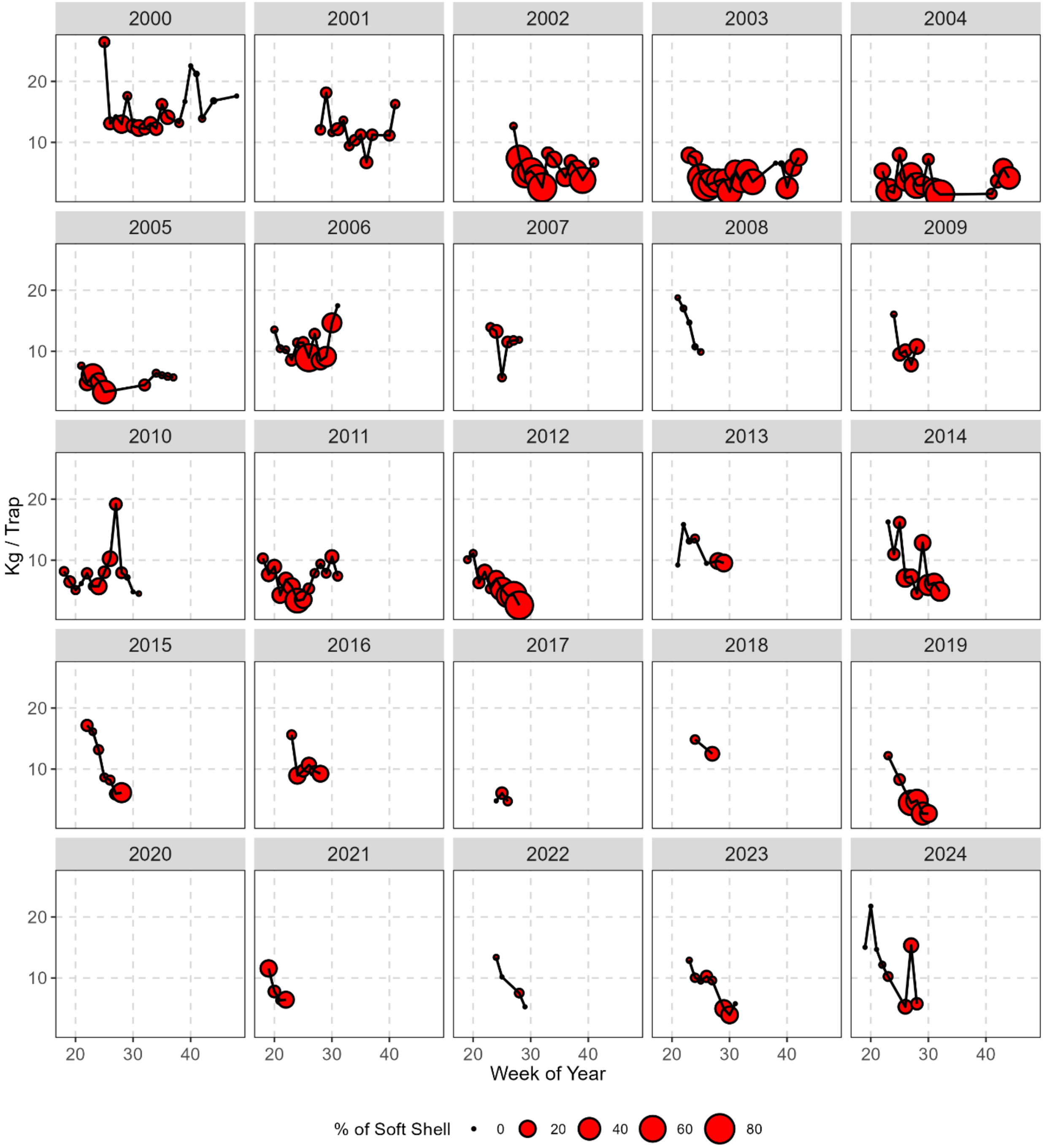

Figure A1.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling within Assessment Division 2HJ (2000–24). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

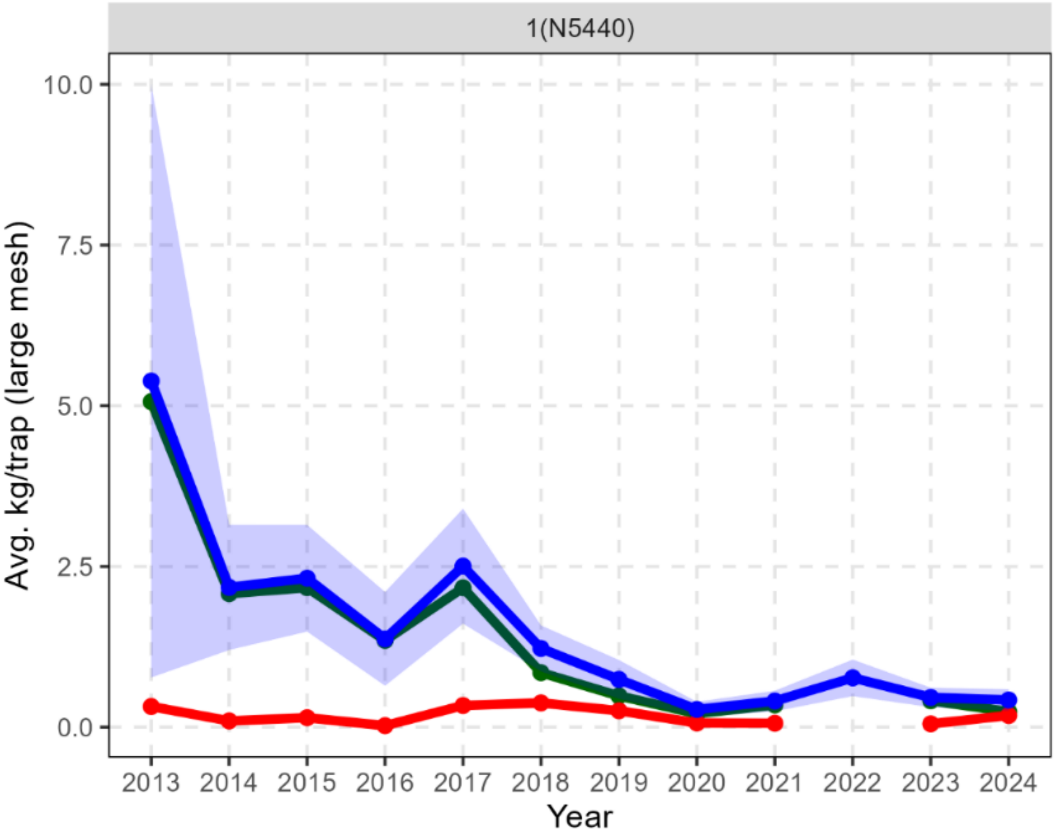

Figure A1.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps in the Torngat Joint Fisheries Board trap survey in Crab Management Area 1 (N5440/2JNorth) (2013–24). Shaded area represents the 95% confidence interval. Note: No shell conditions for 2022.

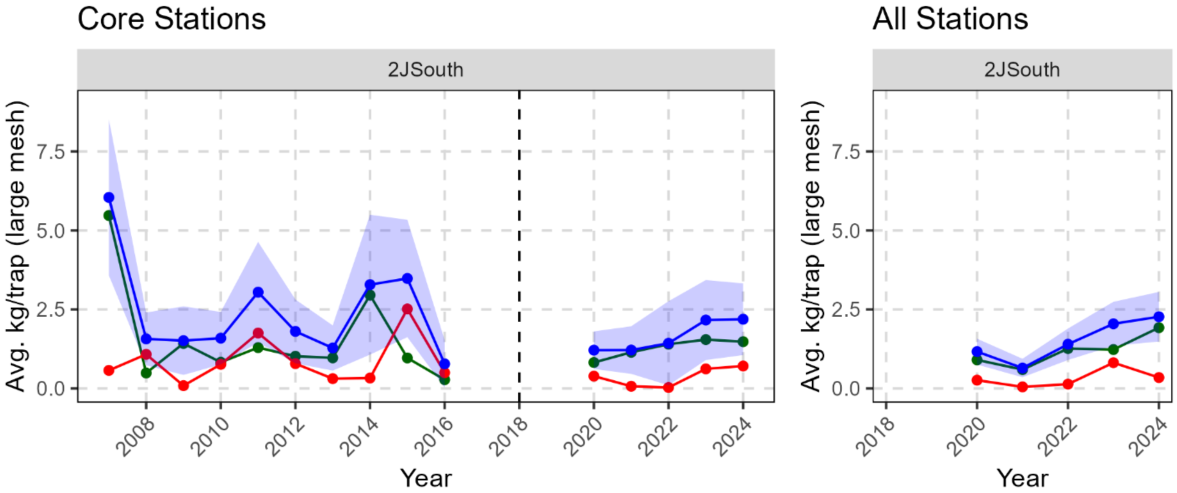

Figure A1.7. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Area 2 (2JSouth) (2007–24). Shaded area represents the 95% confidence interval. The dashed vertical line denotes the CPS survey re-design. Years without results represent incomplete or absent survey coverage.

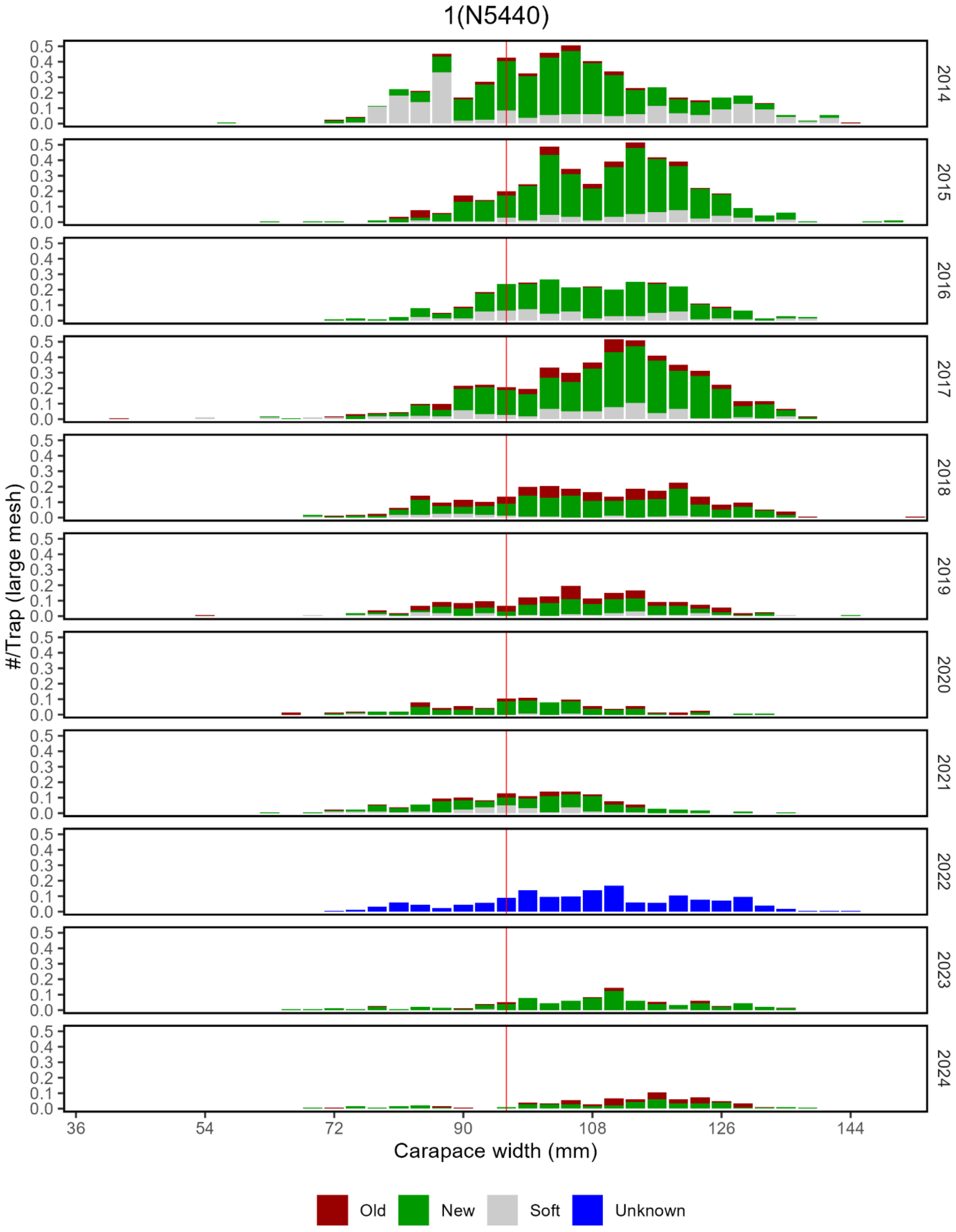

Figure A1.8. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps in the Torngat Joint Fisheries Board trap survey in Crab Management Area 1 (N5440/2JNorth) in Assessment Division 2HJ (2014–24). The red vertical line indicates the minimum legal size. Note: No shell conditions for 2022.

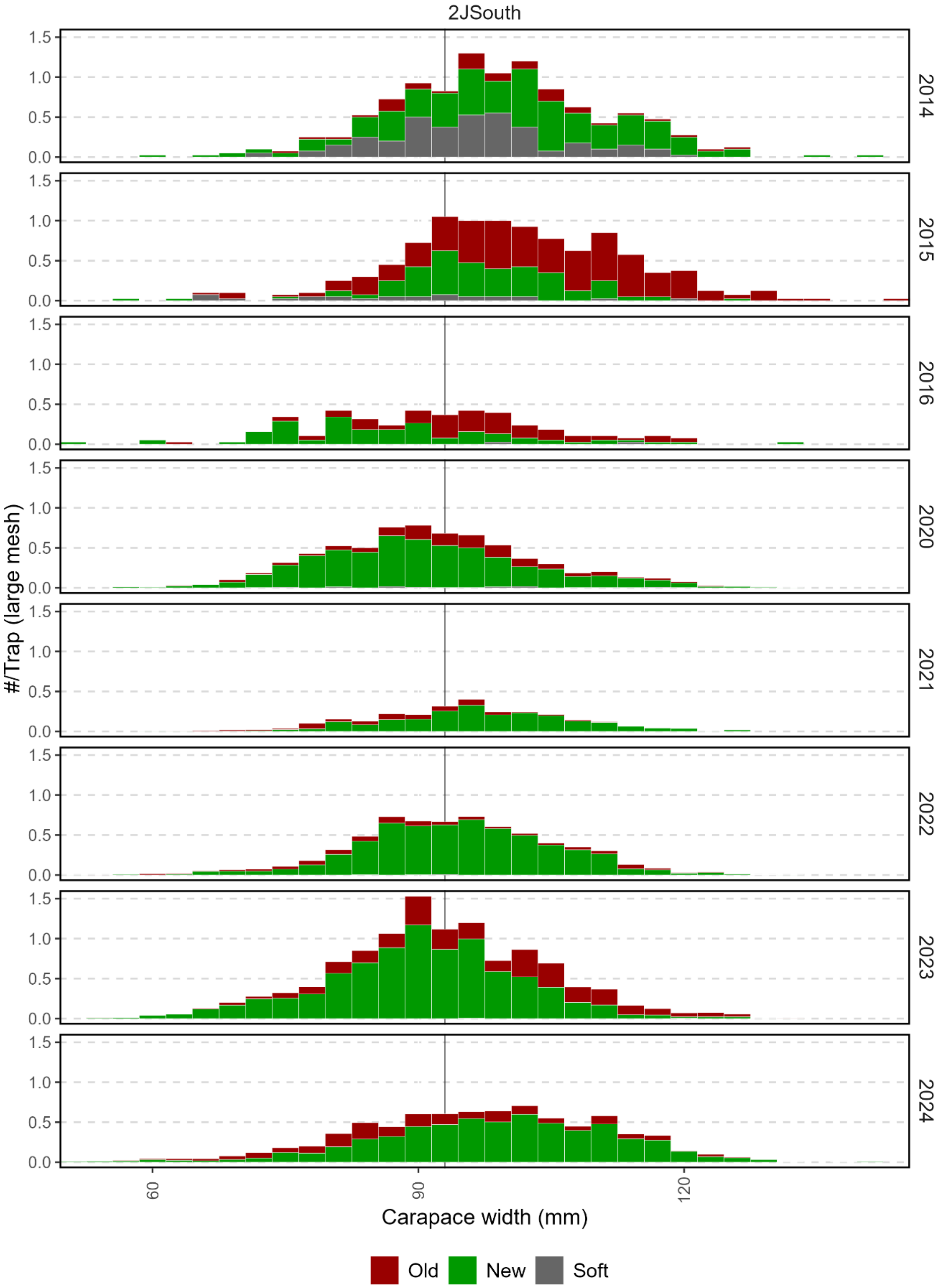

Figure A1.9. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Area 2 (2JSouth) in Assessment Division 2HJ (2014–16, 2020–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

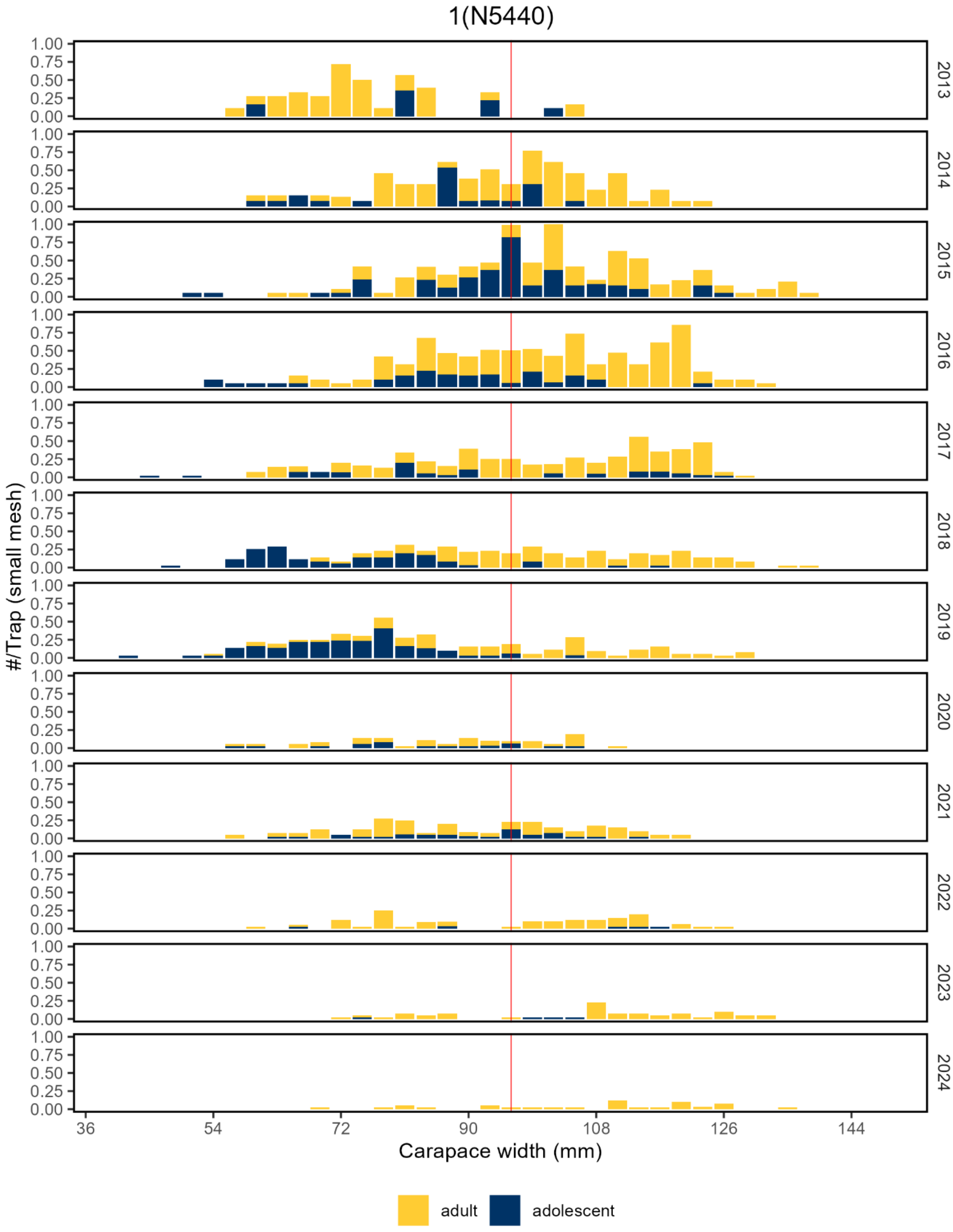

Figure A1.10. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the Torngat Joint Fisheries Board trap survey in Crab Management Area 1 (N5440/2JNorth) in Assessment Division 2HJ (2013–24). The red vertical line indicates the minimum legal size.

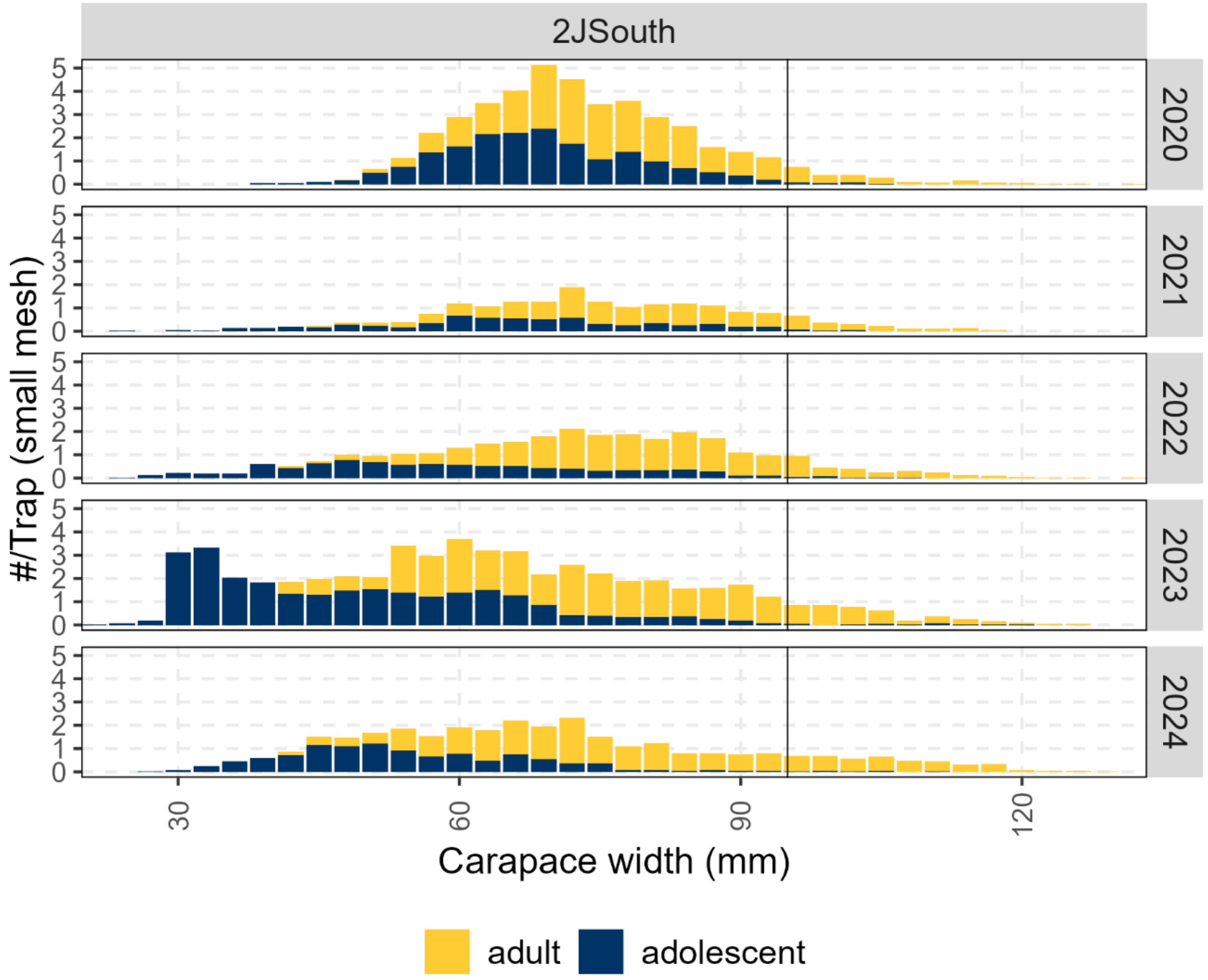

Figure A1.11. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Area 2 (2JSouth) in Assessment Division 2HJ (2020–24). The black vertical line indicates the minimum legal size.

APPENDIX 2: ASSESSMENT DIVISION 3K DETAILS

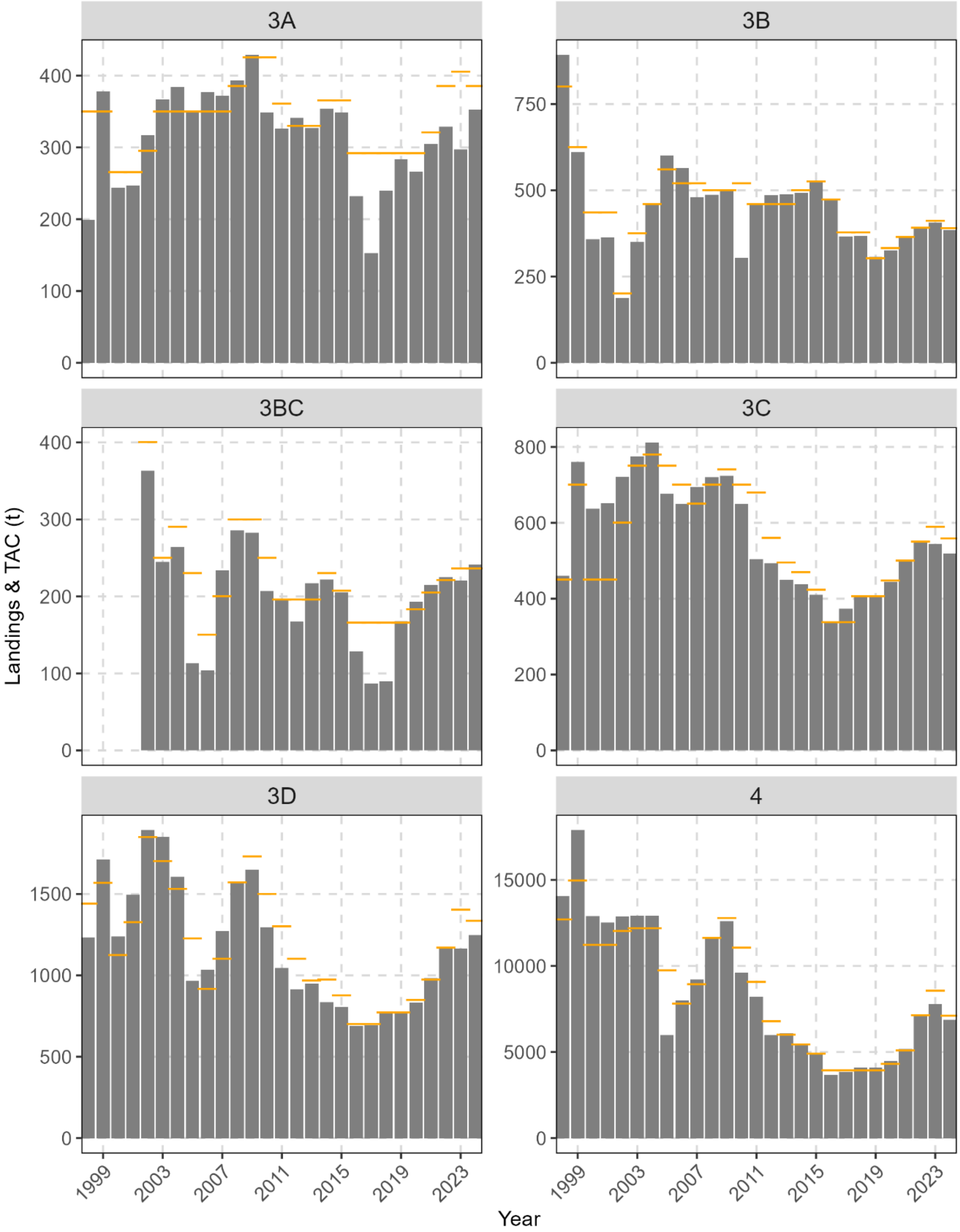

Figure A2.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 3K (1998–2024).

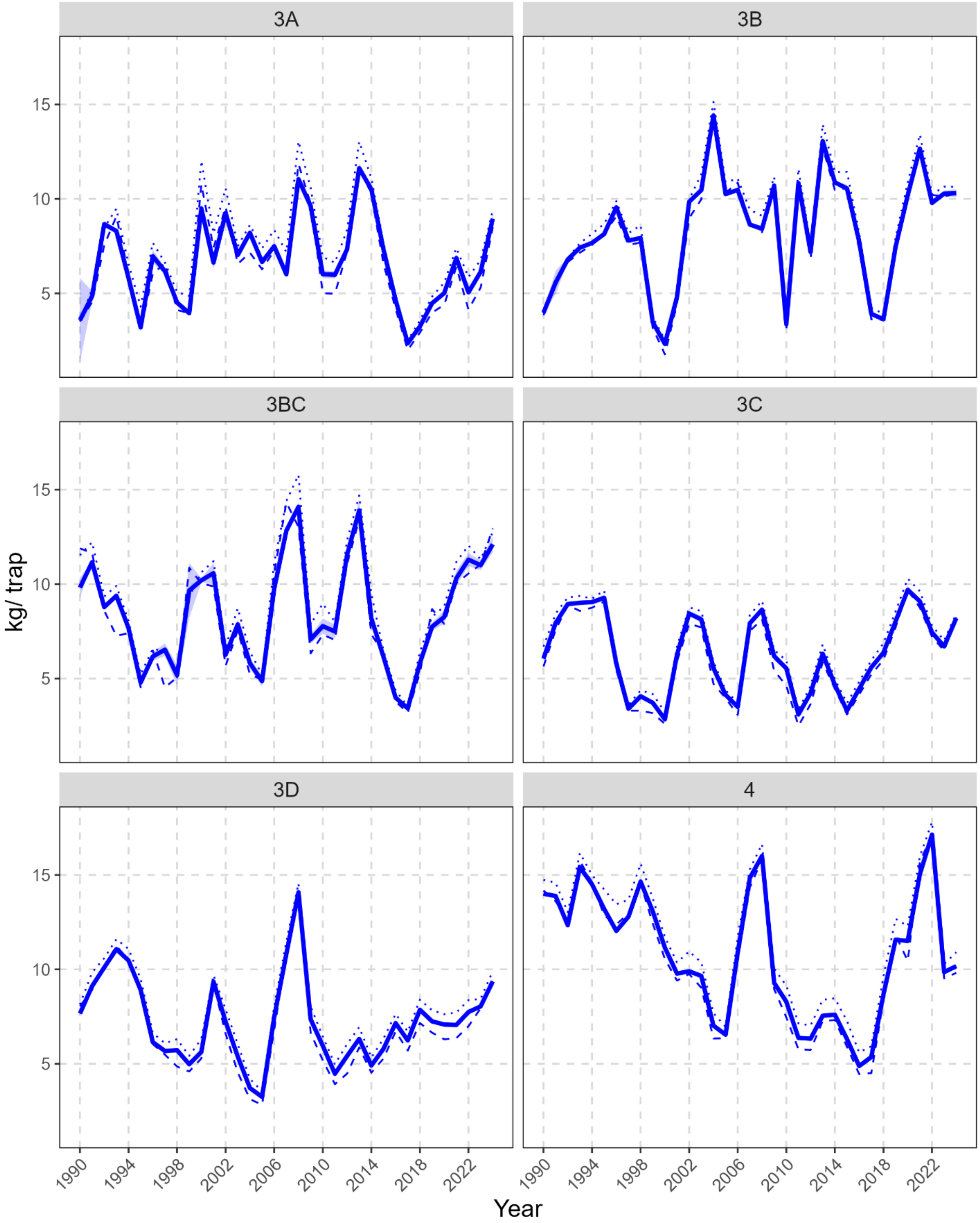

Figure A2.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 3K (1990–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

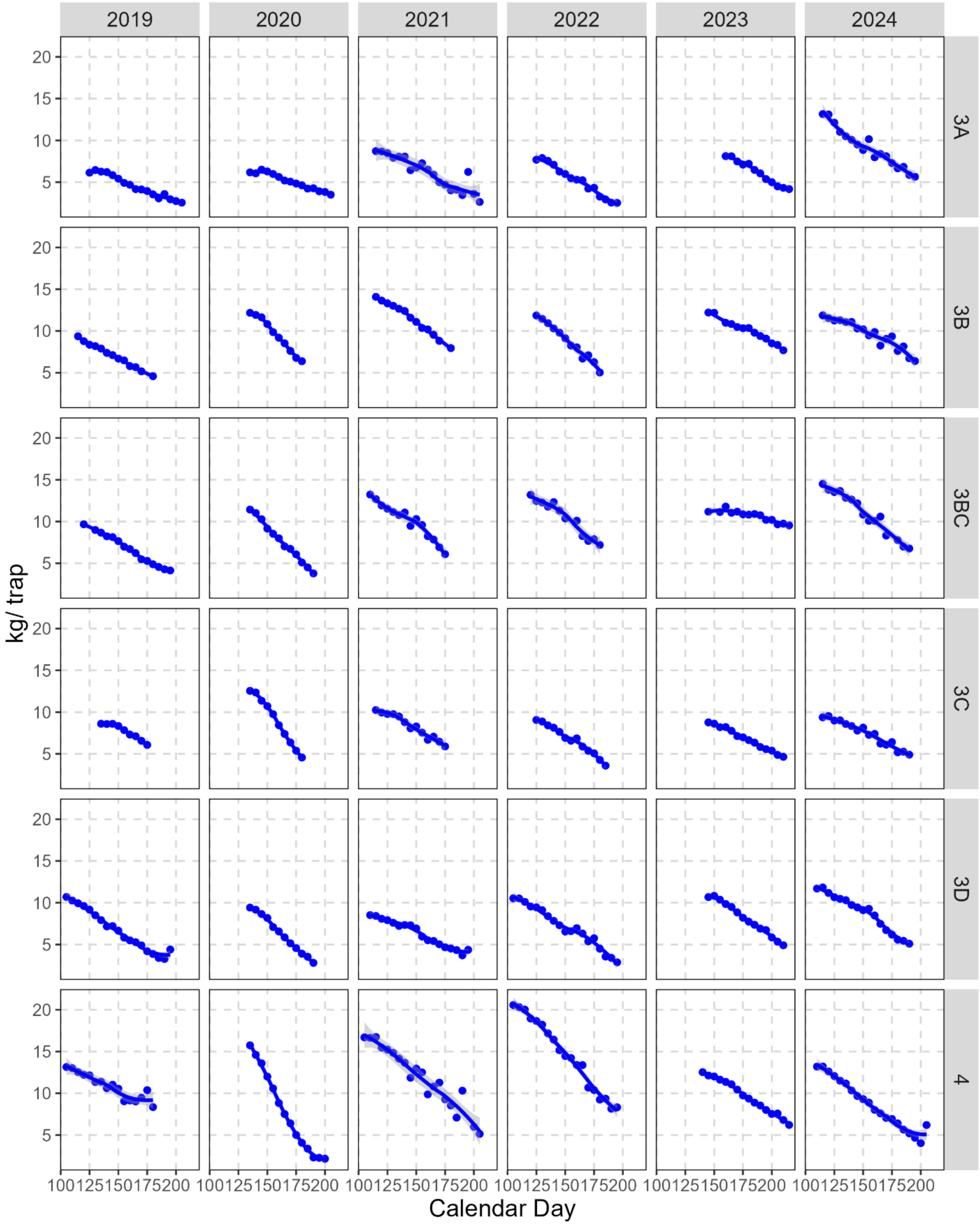

Figure A2.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 3K (2019–24), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

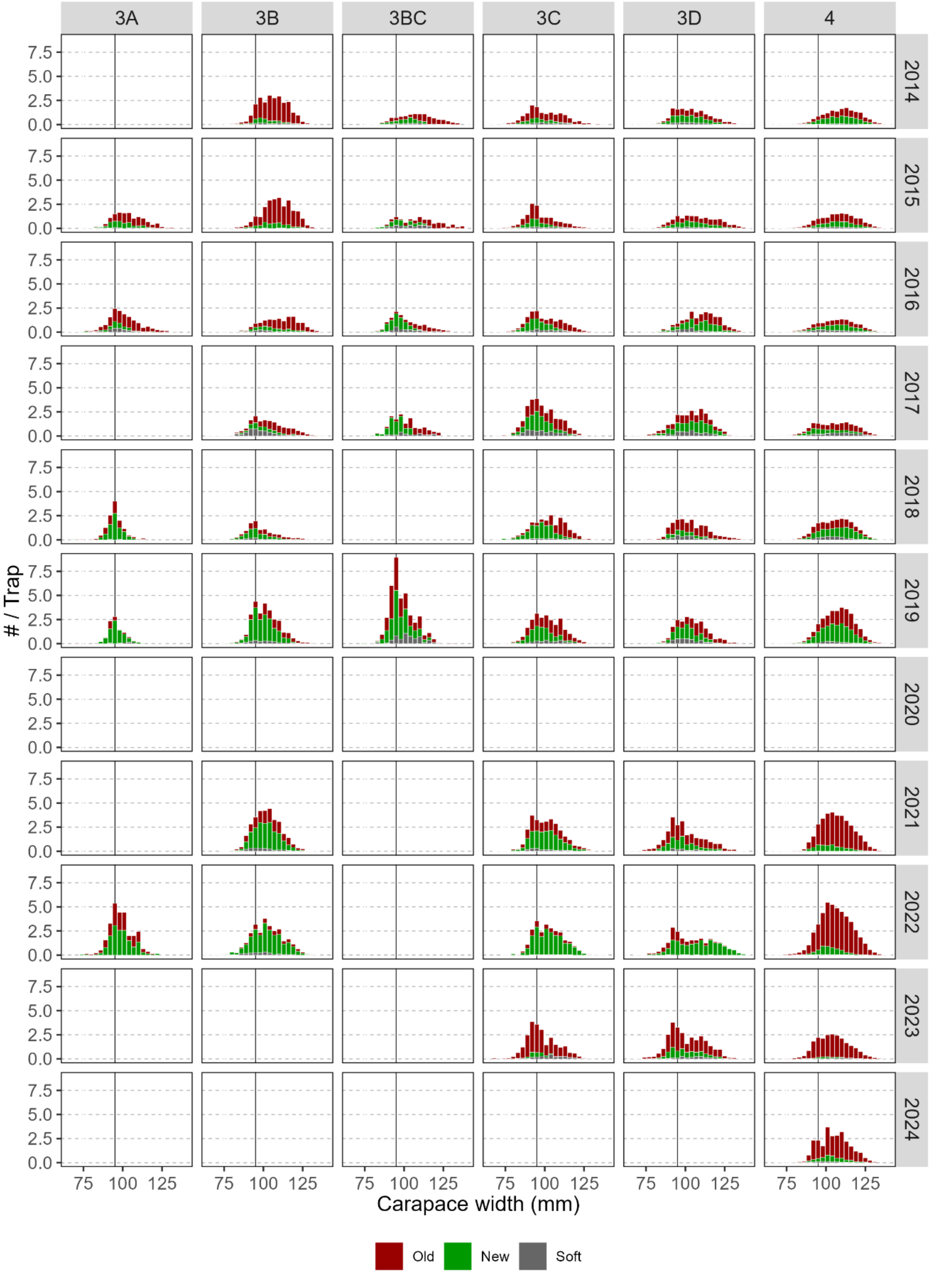

Figure A2.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 3K (2014–24). The black vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

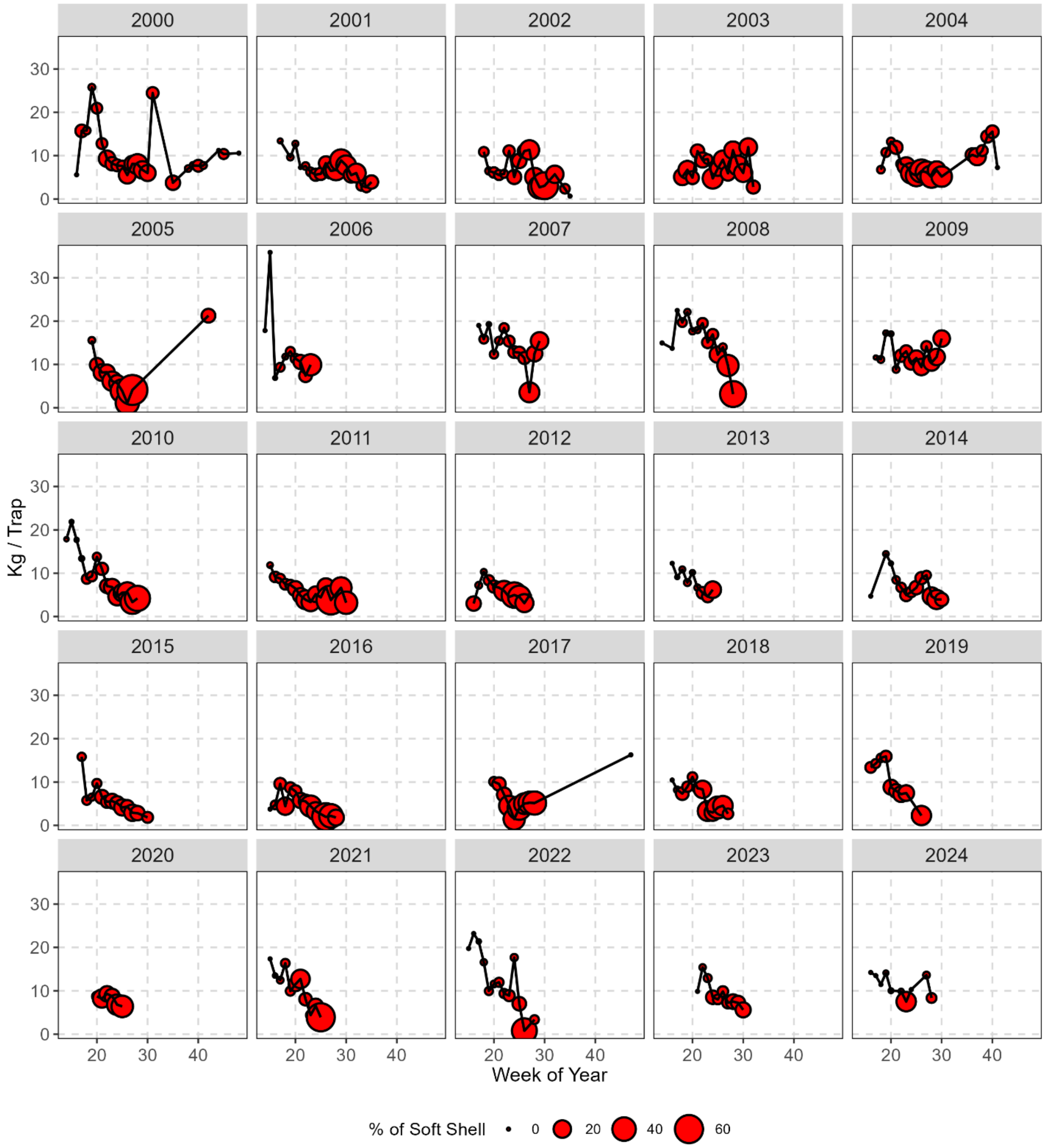

Figure A2.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling within Assessment Division 3K (2000–24). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates.

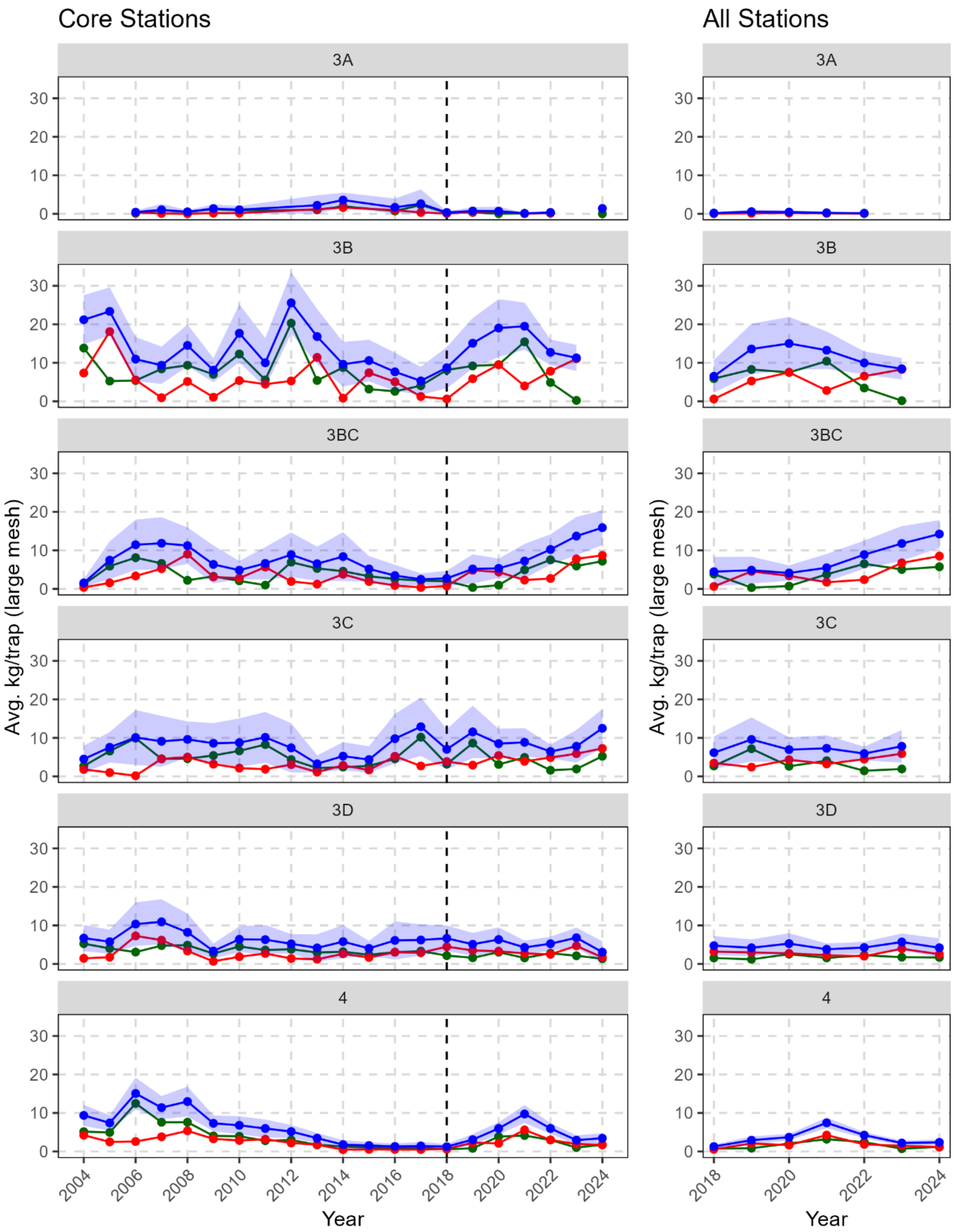

Figure A2.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 3K (2004–24). Shaded area represents the 95% confidence interval. The dashed vertical line denotes CPS survey re-design. Years without results represent incomplete or absent survey coverage.

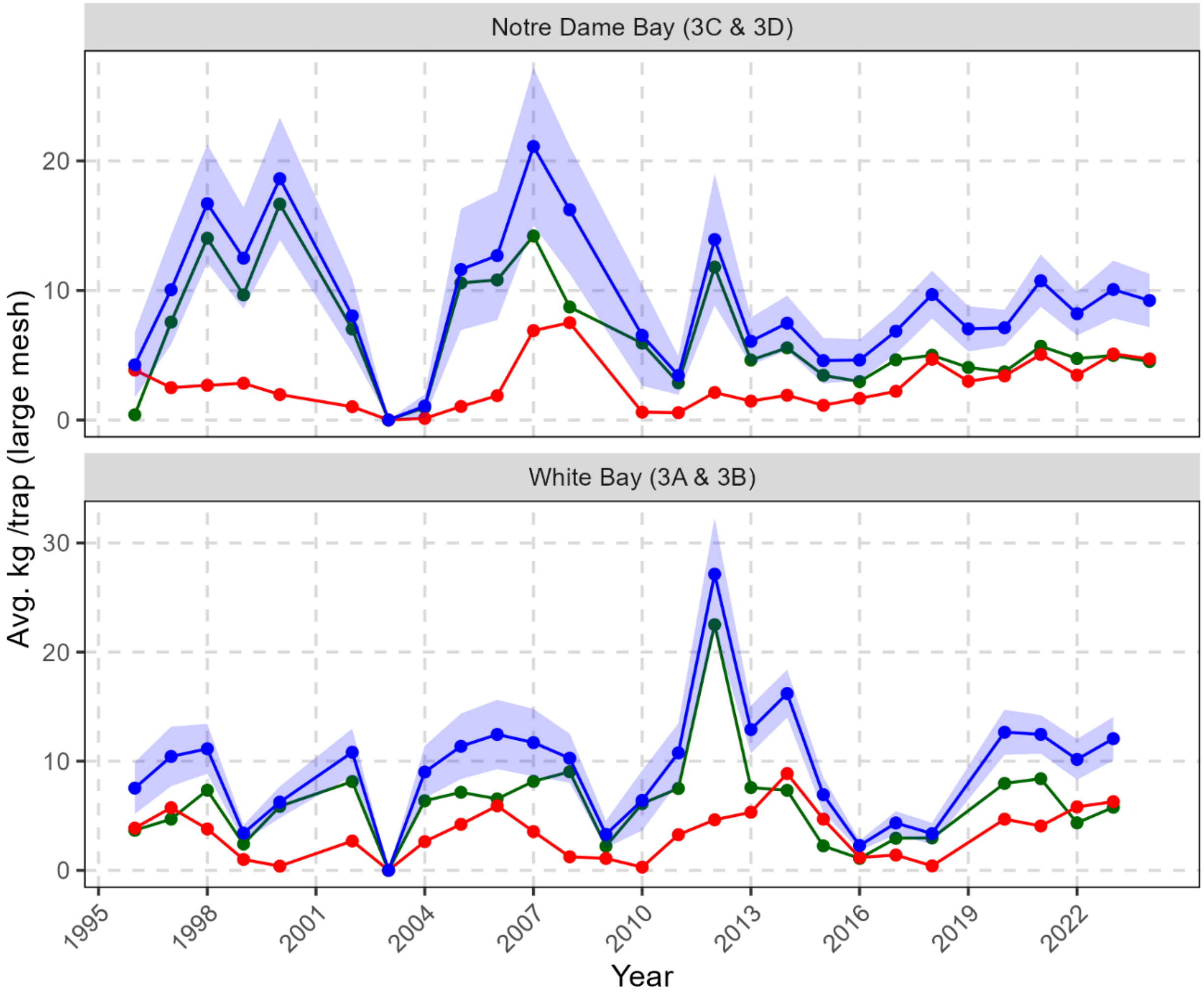

Figure A2.7. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable Snow Crab from large-mesh traps in the DFO inshore trap surveys in Notre Dame Bay (top; Crab Management Areas 3C and 3D) and White Bay (bottom; Crab Management Areas 3A and 3B) (1996–2024). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

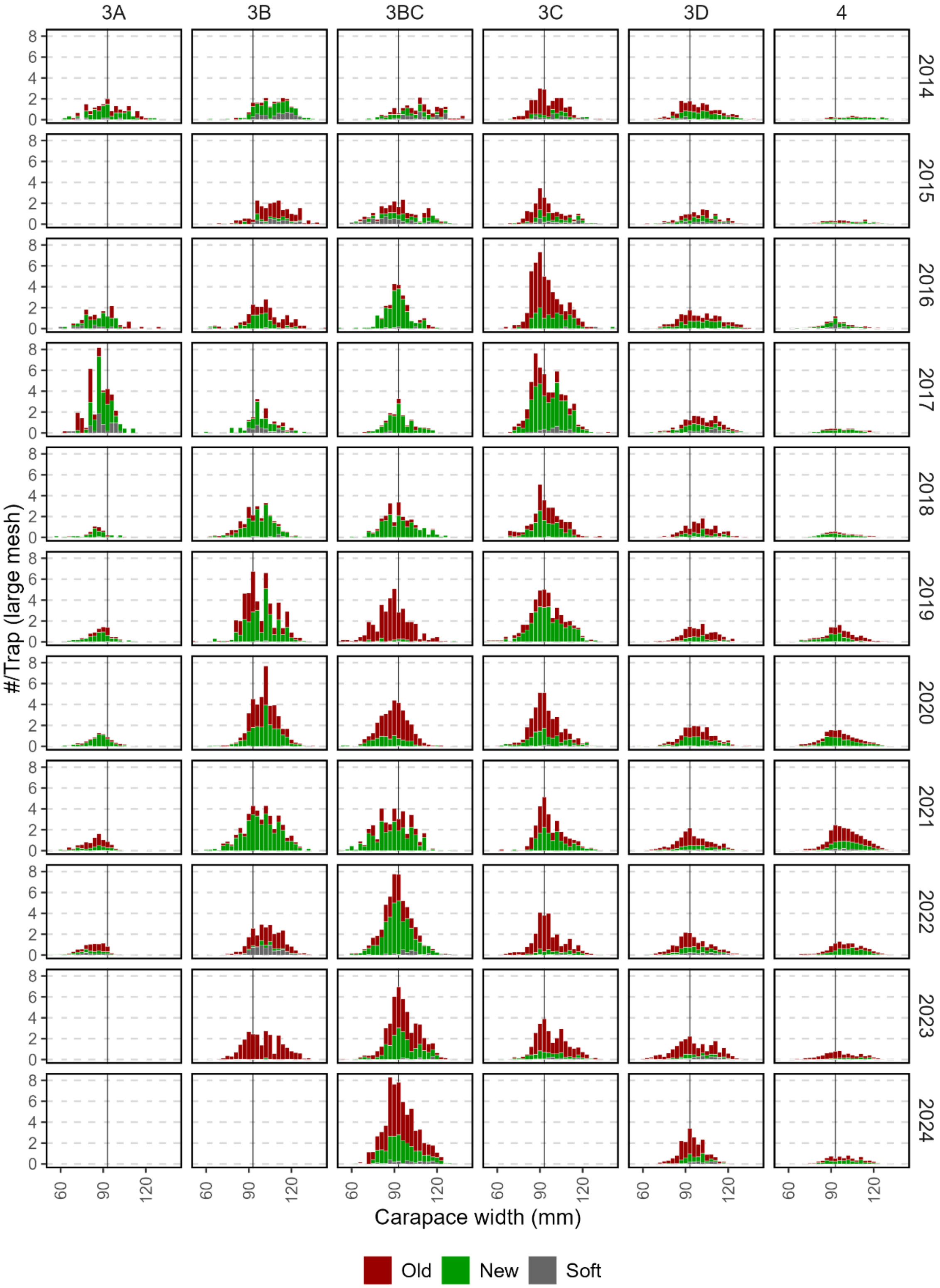

Figure A2.8. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3K (2014–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

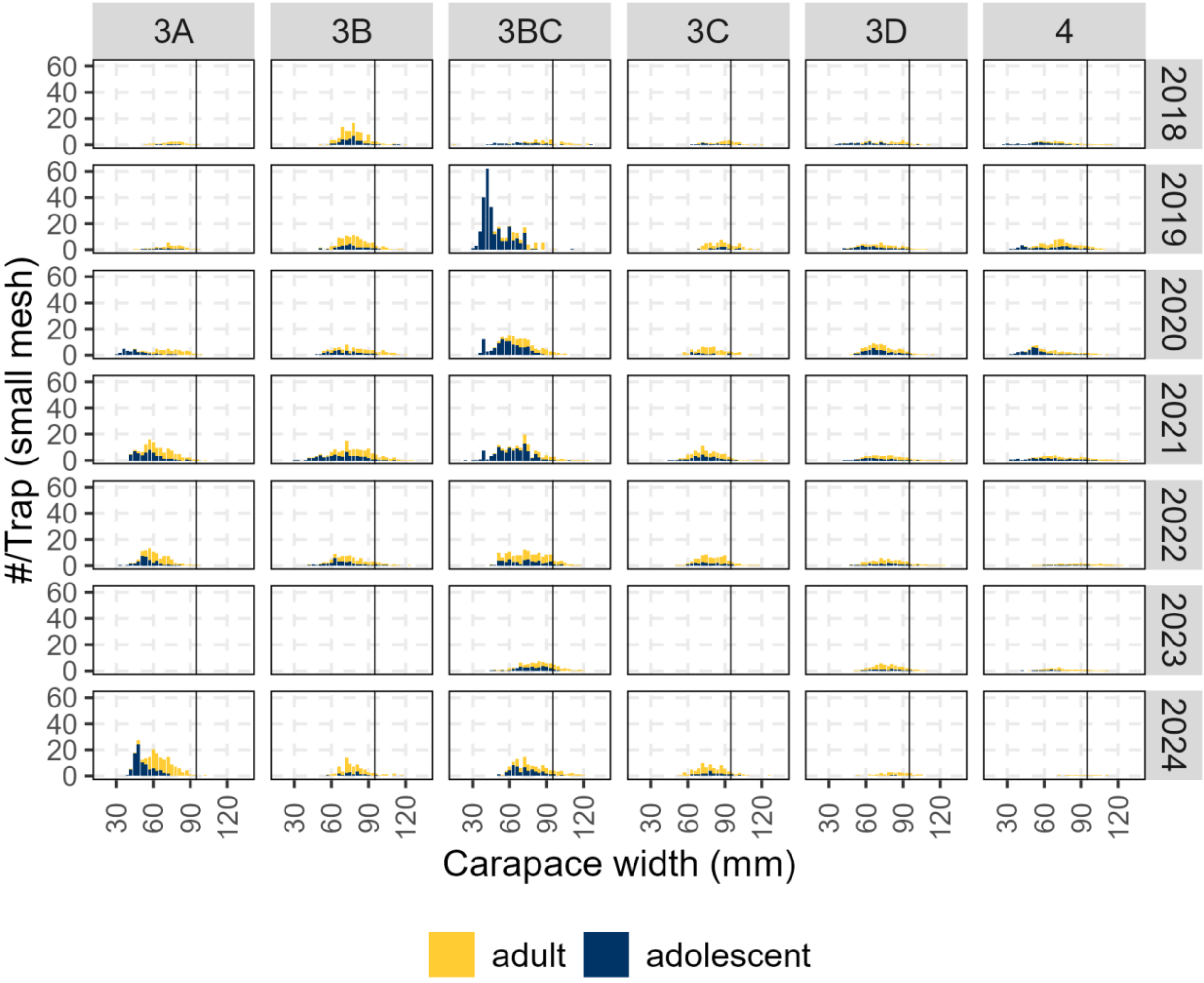

Figure A2.9. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3K (2018–24). The black vertical line indicates the minimum legal size.

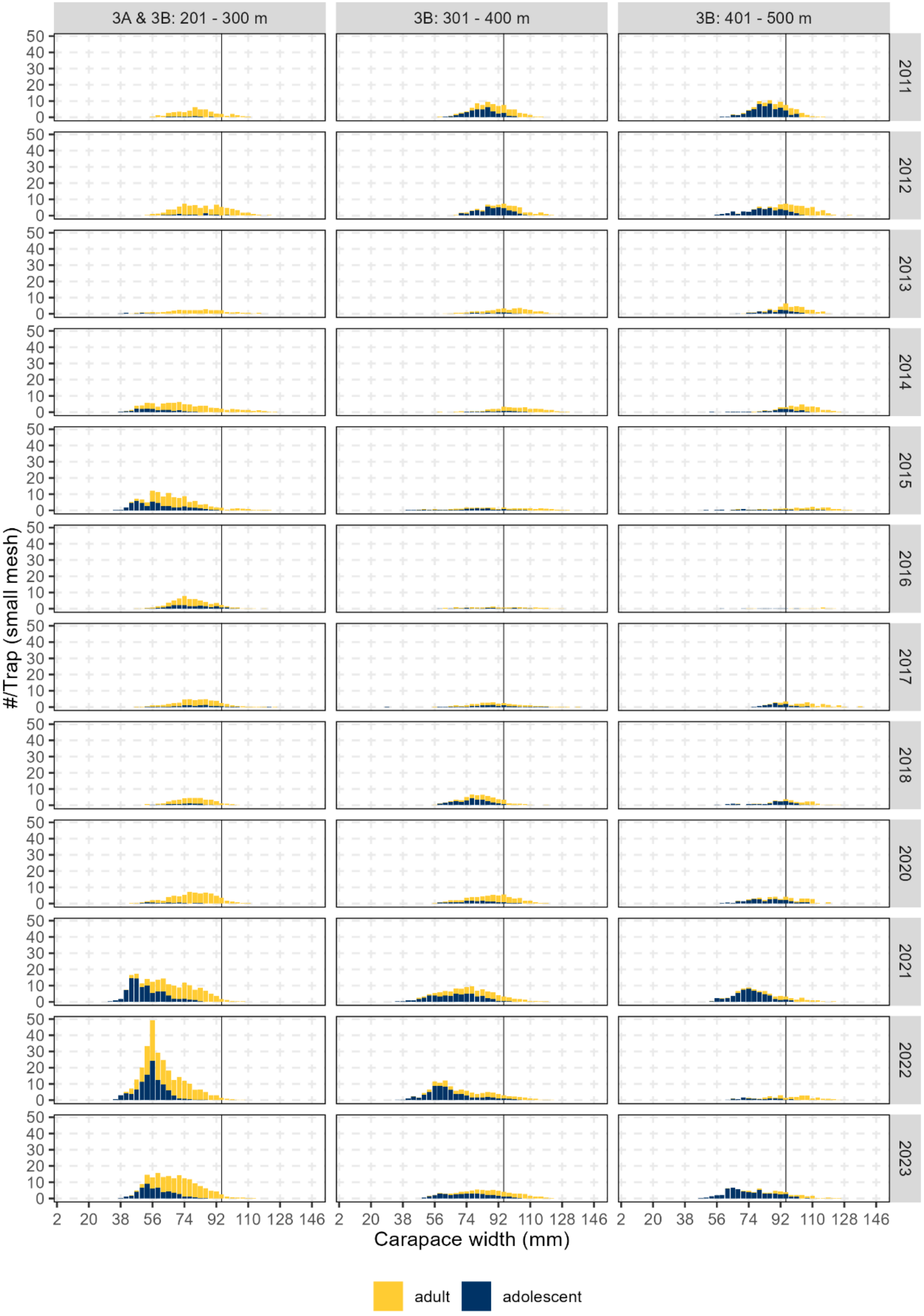

Figure A2.10. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey from White Bay (Crab Management Areas 3A and 3B) (2011–23). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage. Note: No survey in 2024.

Figure A2.11. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey from Green Bay and Notre Dame Bay (Crab Management Areas 3B, 3C, and 3D) (2011–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

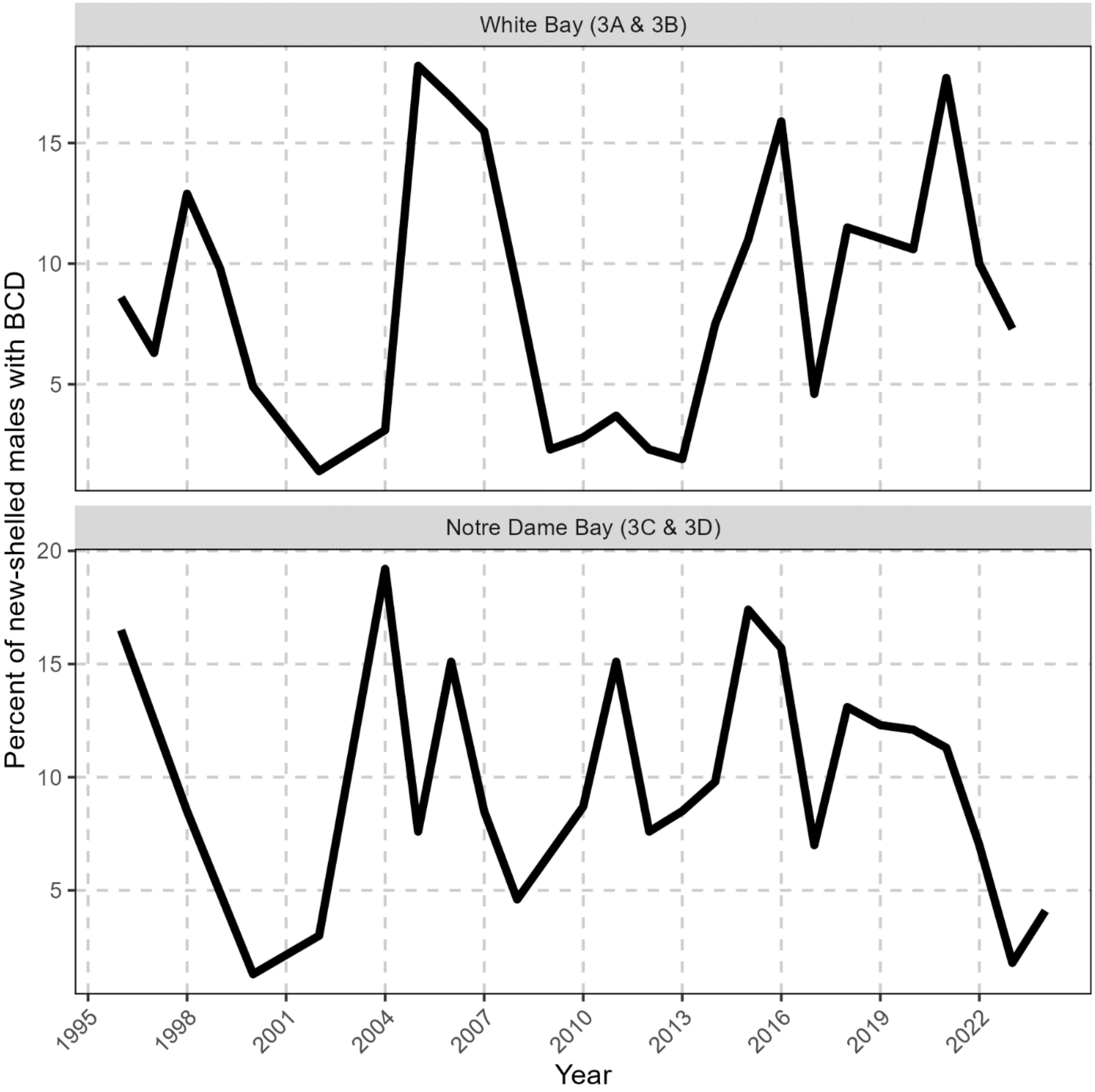

Figure A2.12. Visually observed percentage of Bitter Crab Disease (BCD) in new-shelled males from DFO inshore trap surveys in White Bay (Crab Management Areas 3A and 3B), and Green Bay and Notre Dame Bay (Crab Management Areas 3C and 3D) (1996–2024).

APPENDIX 3: ASSESSMENT DIVISION 3LNO DETAILS

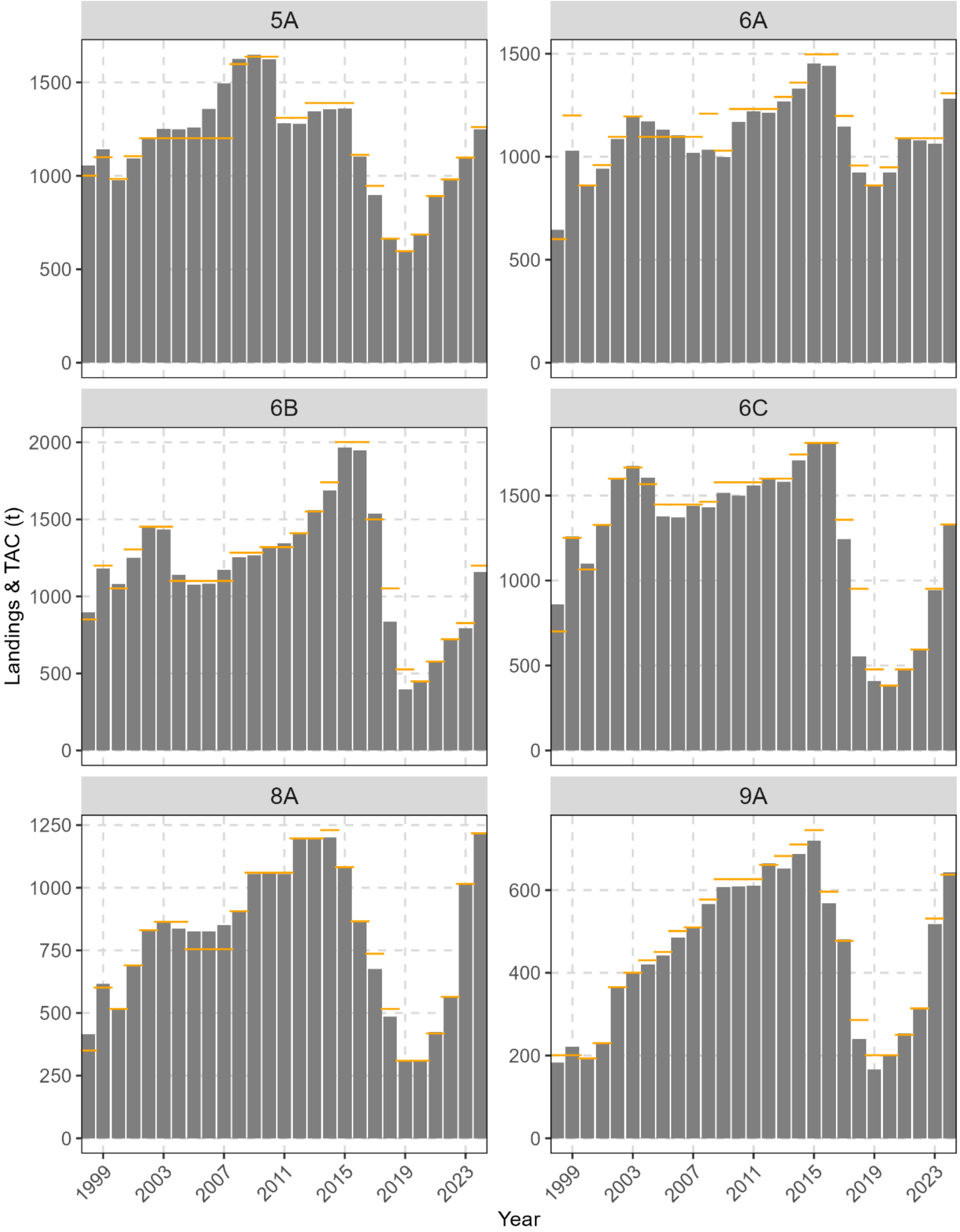

Figure A3.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas 5A, 6A, 6B, 6C, 8A, and 9A within Assessment Division 3LNO (1998–2024).

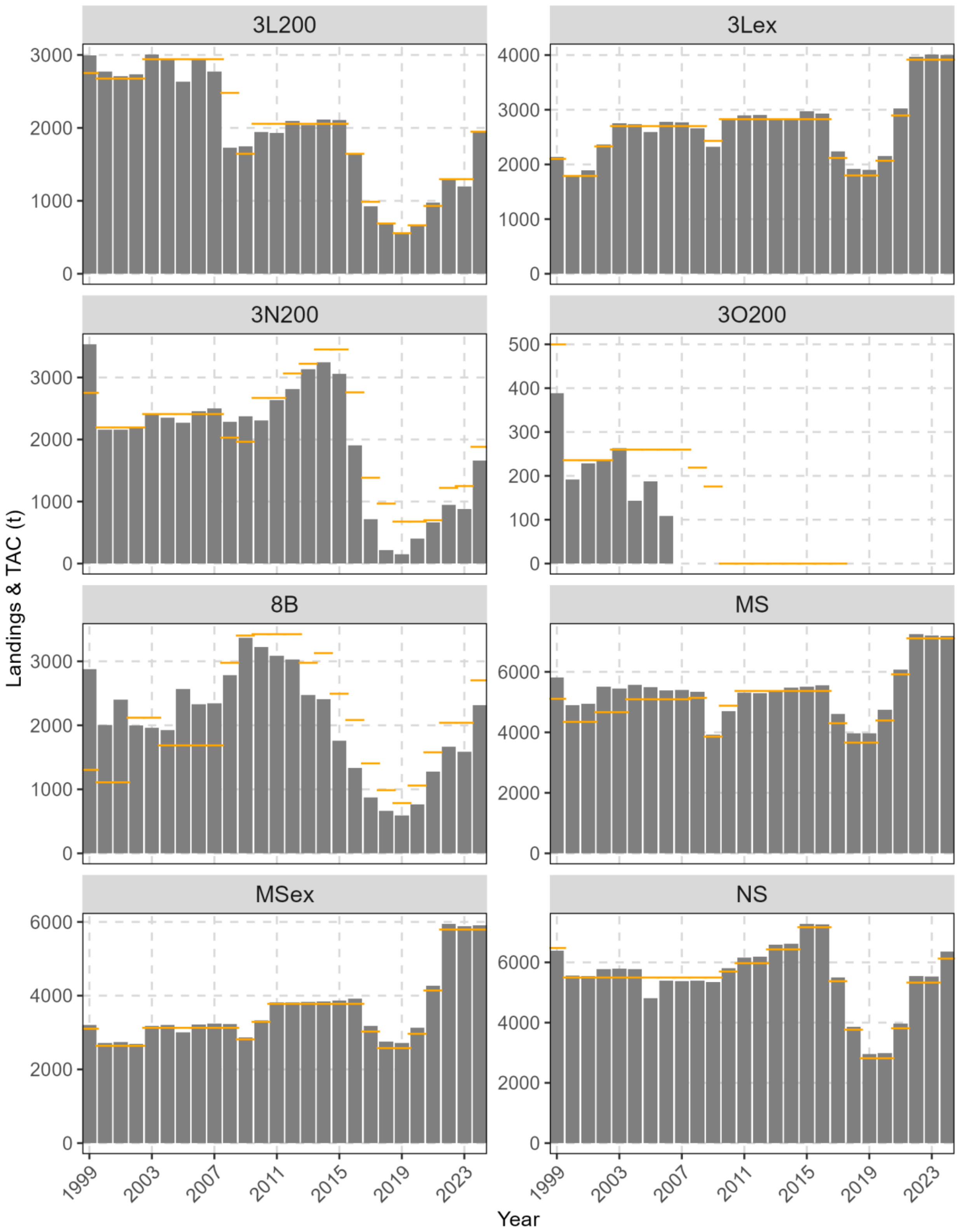

Figure A3.2. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas 3L200, 3Lex, 3N200, 3O200, 8B, MS, MSex, and NS within Assessment Division 3LNO (1999–2024).

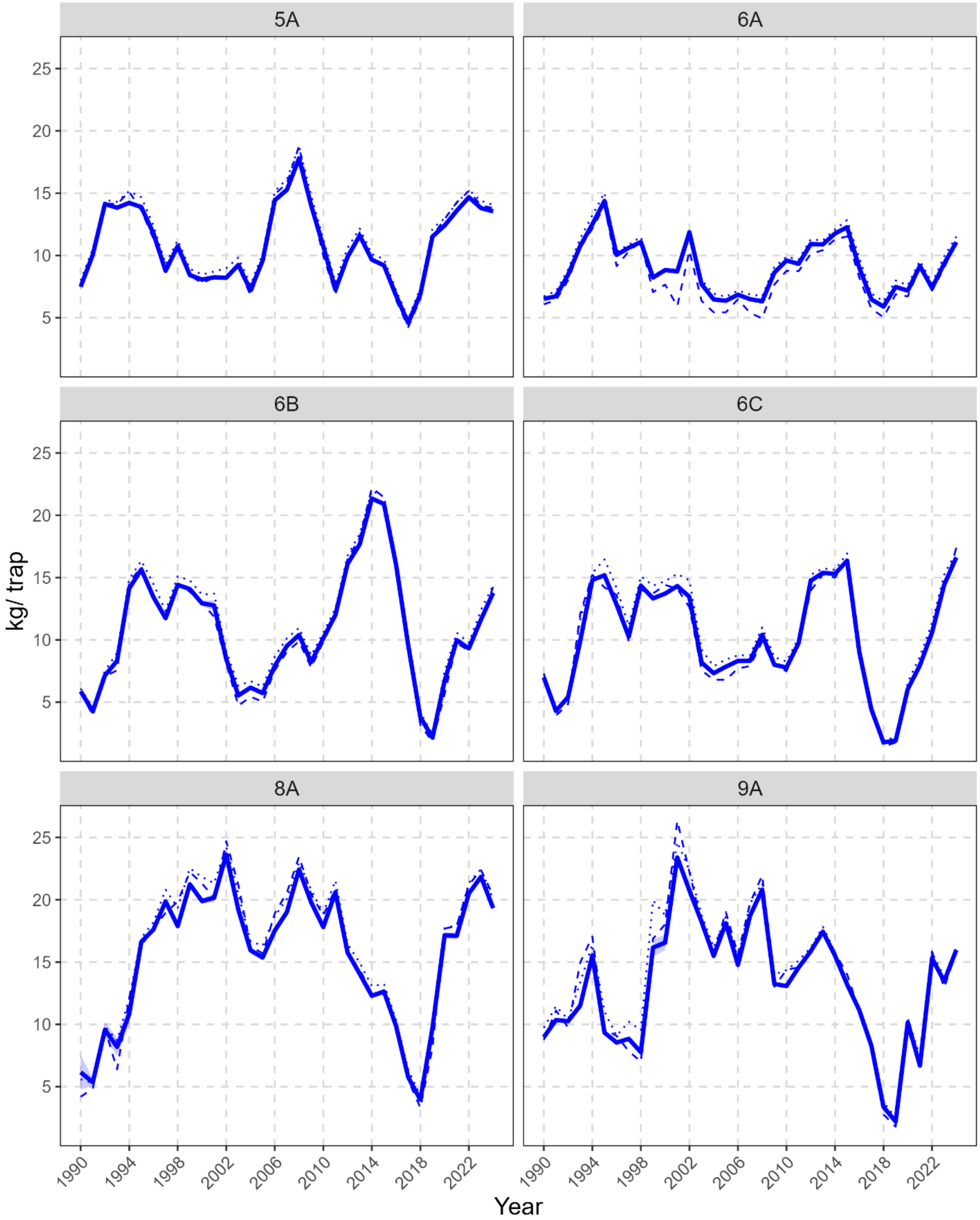

Figure A3.3. Standardized fishery CPUE (kg/trap) in Crab Management Areas 5A, 6A, 6B, 6C, 8A, and 9A within Assessment Division 3LNO (1990–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

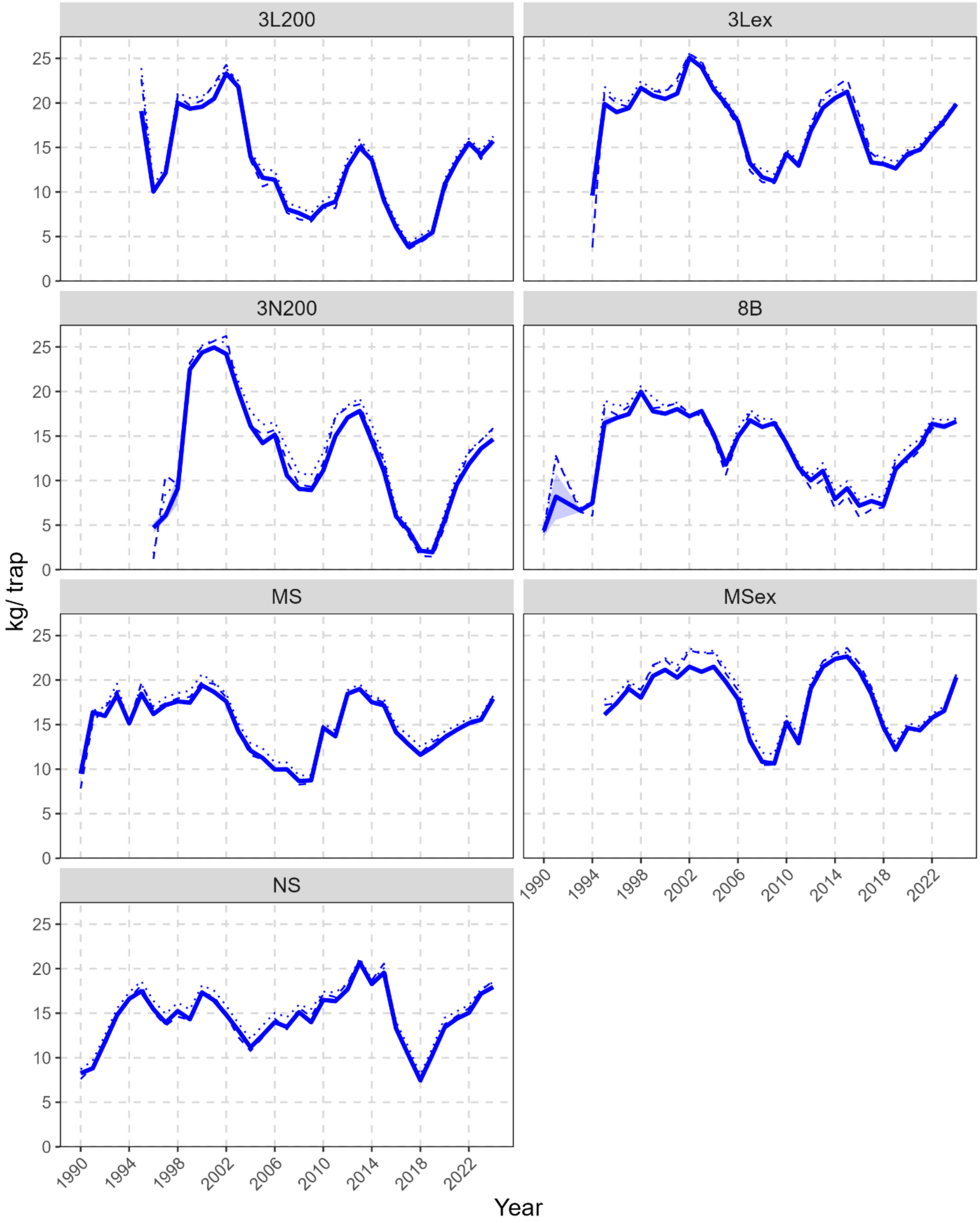

Figure A3.4. Standardized fishery CPUE (kg/trap) in Crab Management Areas 3L200, 3Lex, 3N200, 8B, MS, MSex, and NS within Assessment Division 3LNO (1990–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

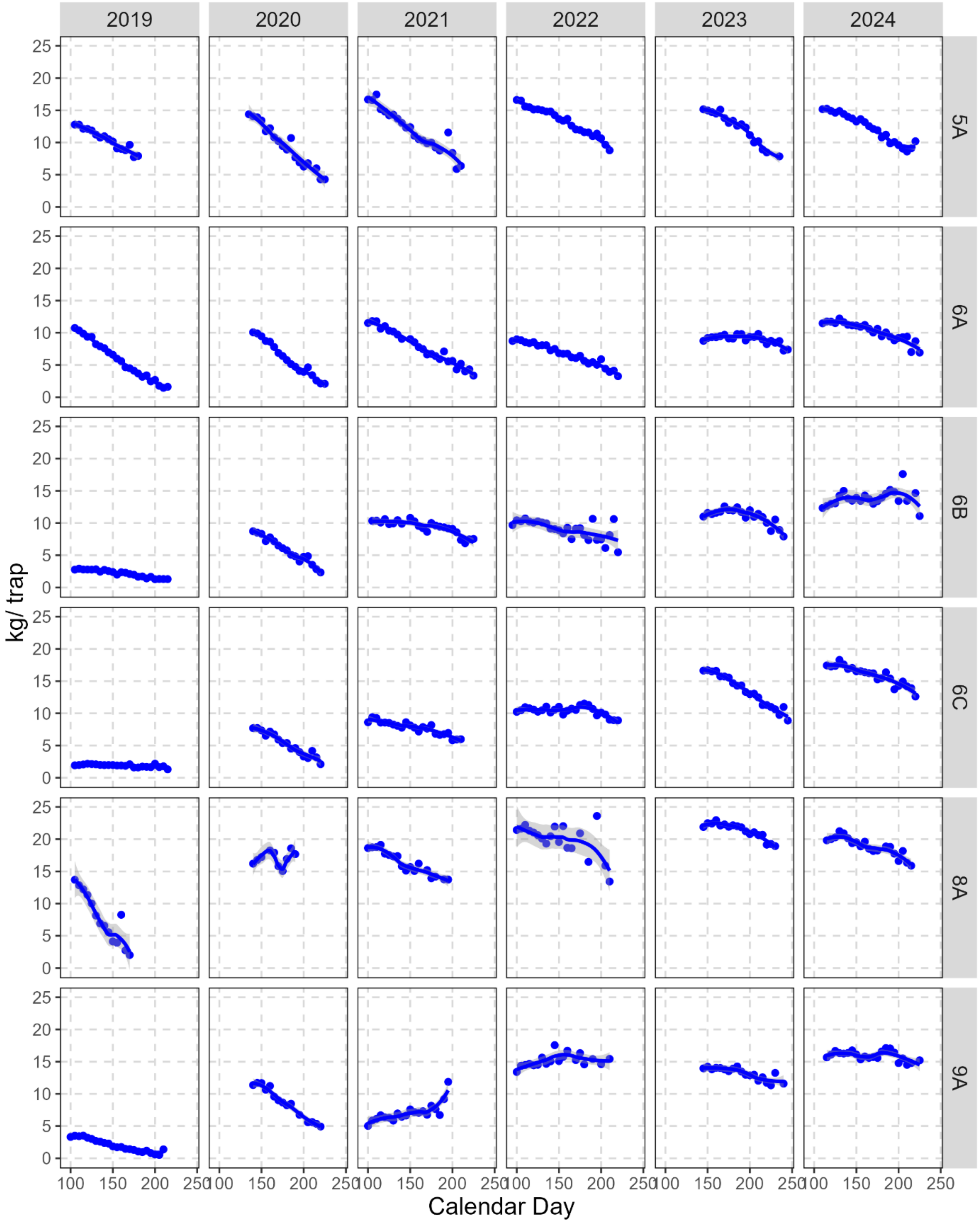

Figure A3.5. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas 5A, 6A, 6B, 6C, 8A, and 9A within Assessment Division 3LNO (2019–24), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

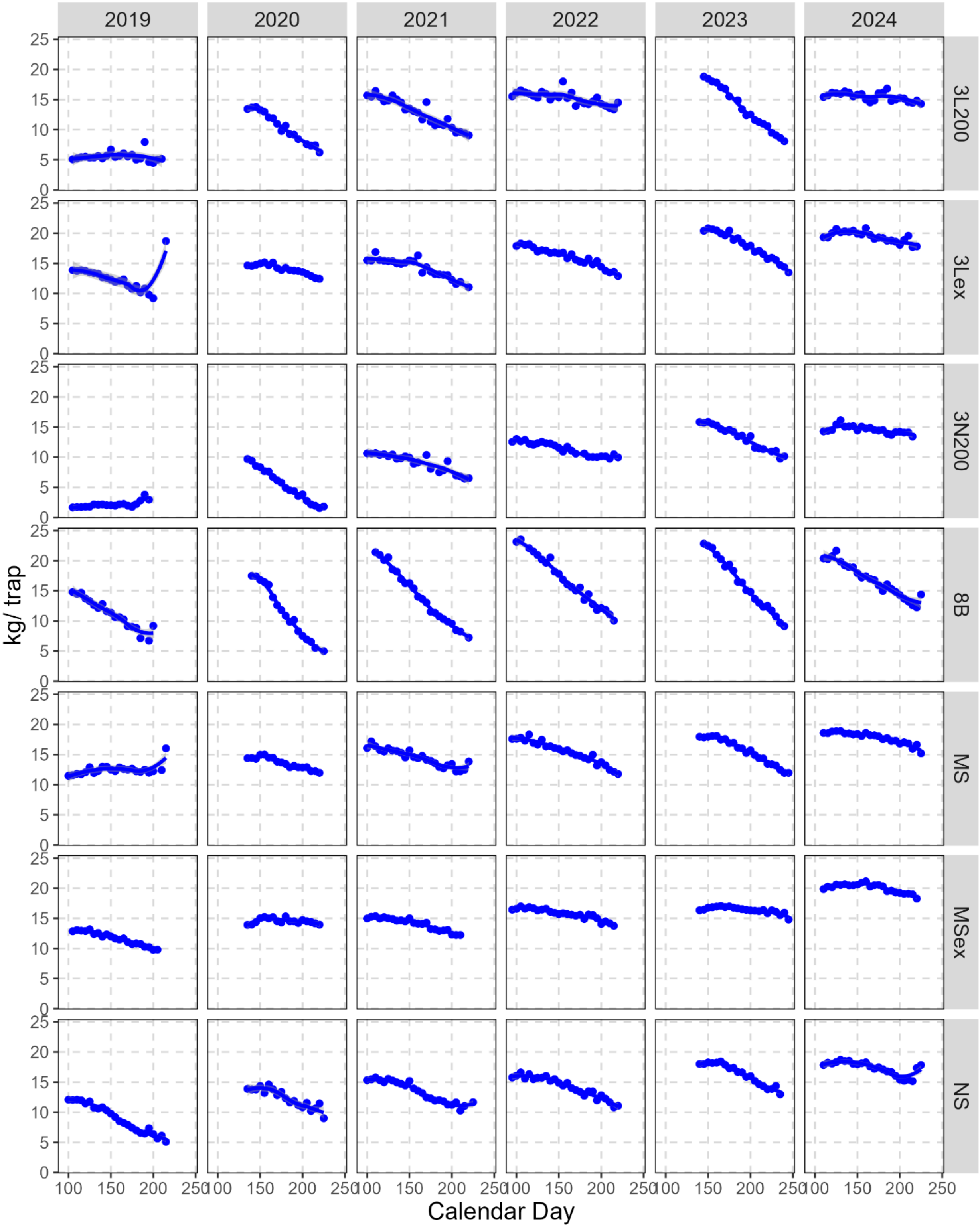

Figure A3.6. Standardized CPUE (kg/trap) throughout the season (calendar day) in Crab Management Areas 3L200, 3Lex, 3N200, 8B, MS, MSex, and NS within Assessment Division 3LNO (2019–24), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

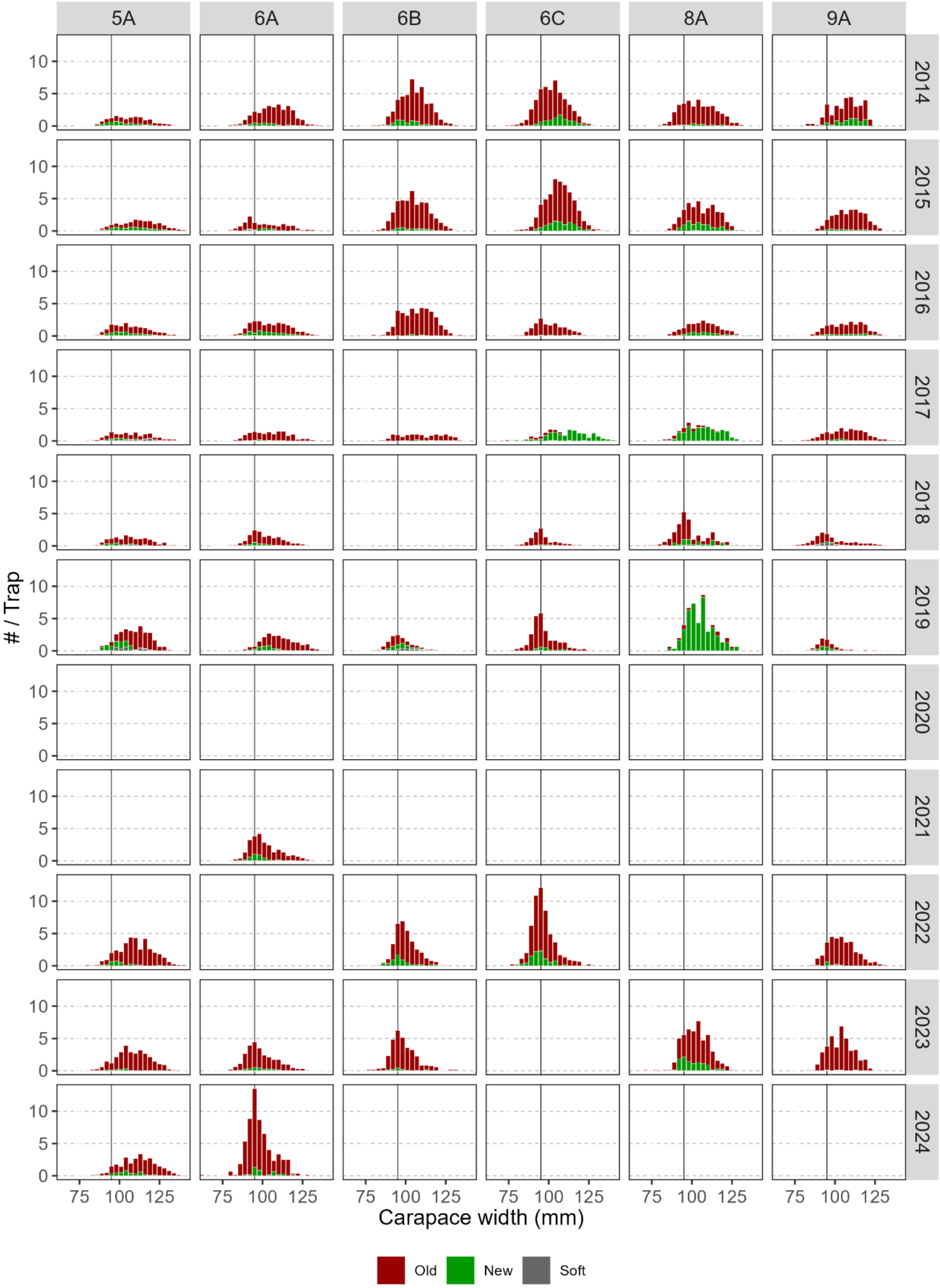

Figure A3.7. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas 5A, 6A, 6B, 6C, 8A, and 9A within Assessment Division 3LNO (2014–24). The black vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

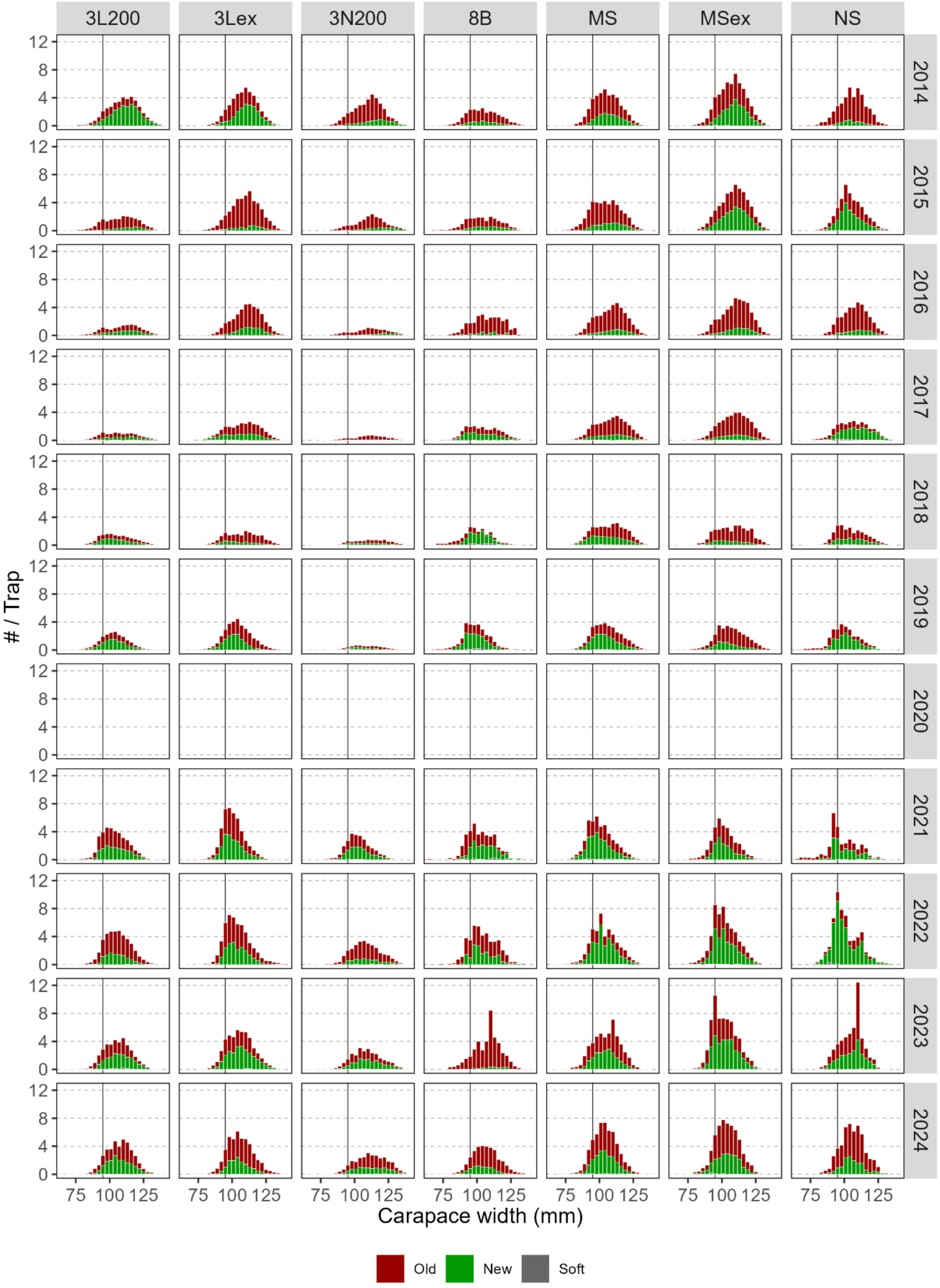

Figure A3.8. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas 3L200, 3Lex, 3N200, 8B, MS, MSex, and NS within Assessment Division 3LNO (2014–24). The black vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

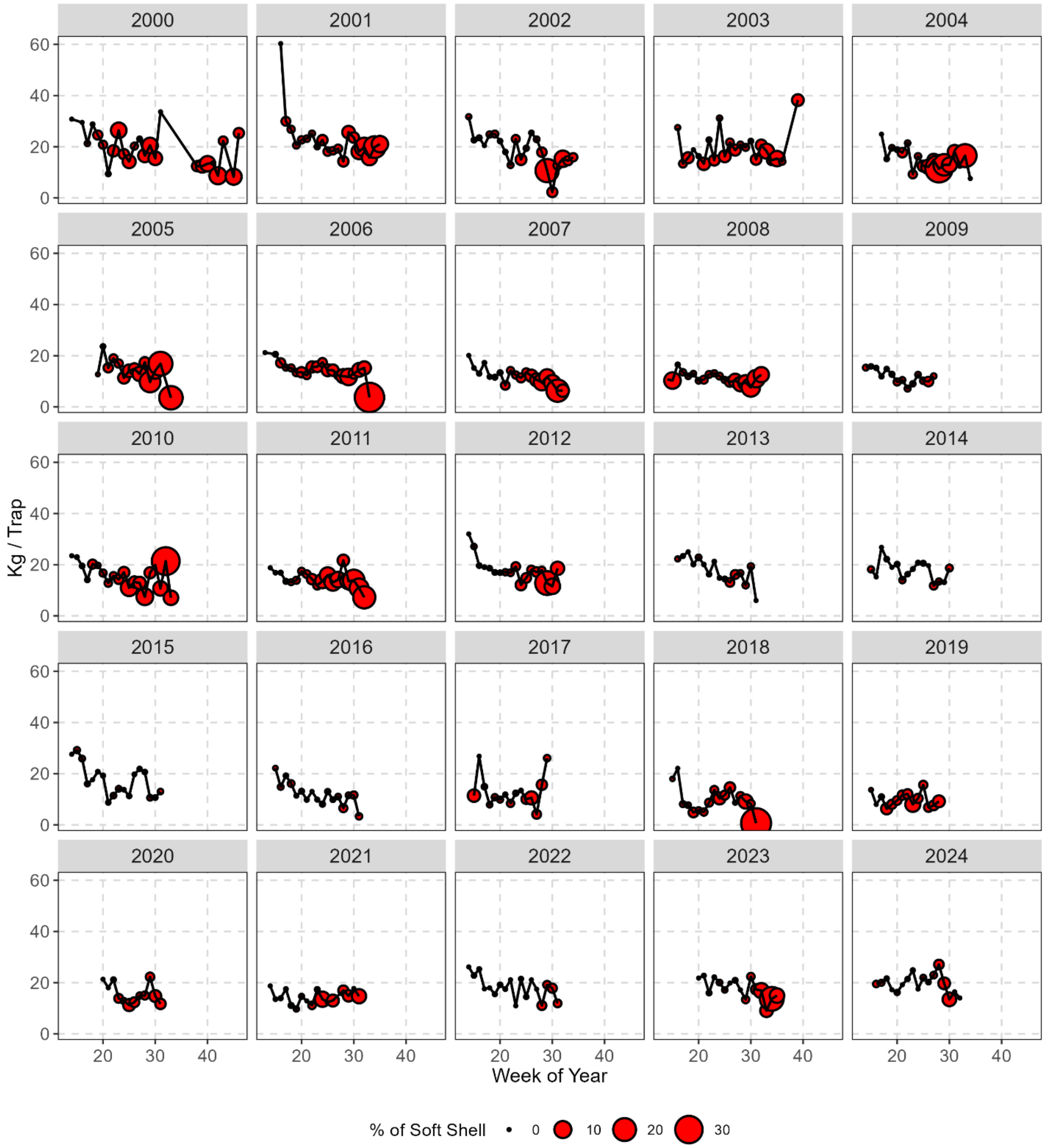

Figure A3.9. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling within Assessment Division 3LNO (2000–24). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates.

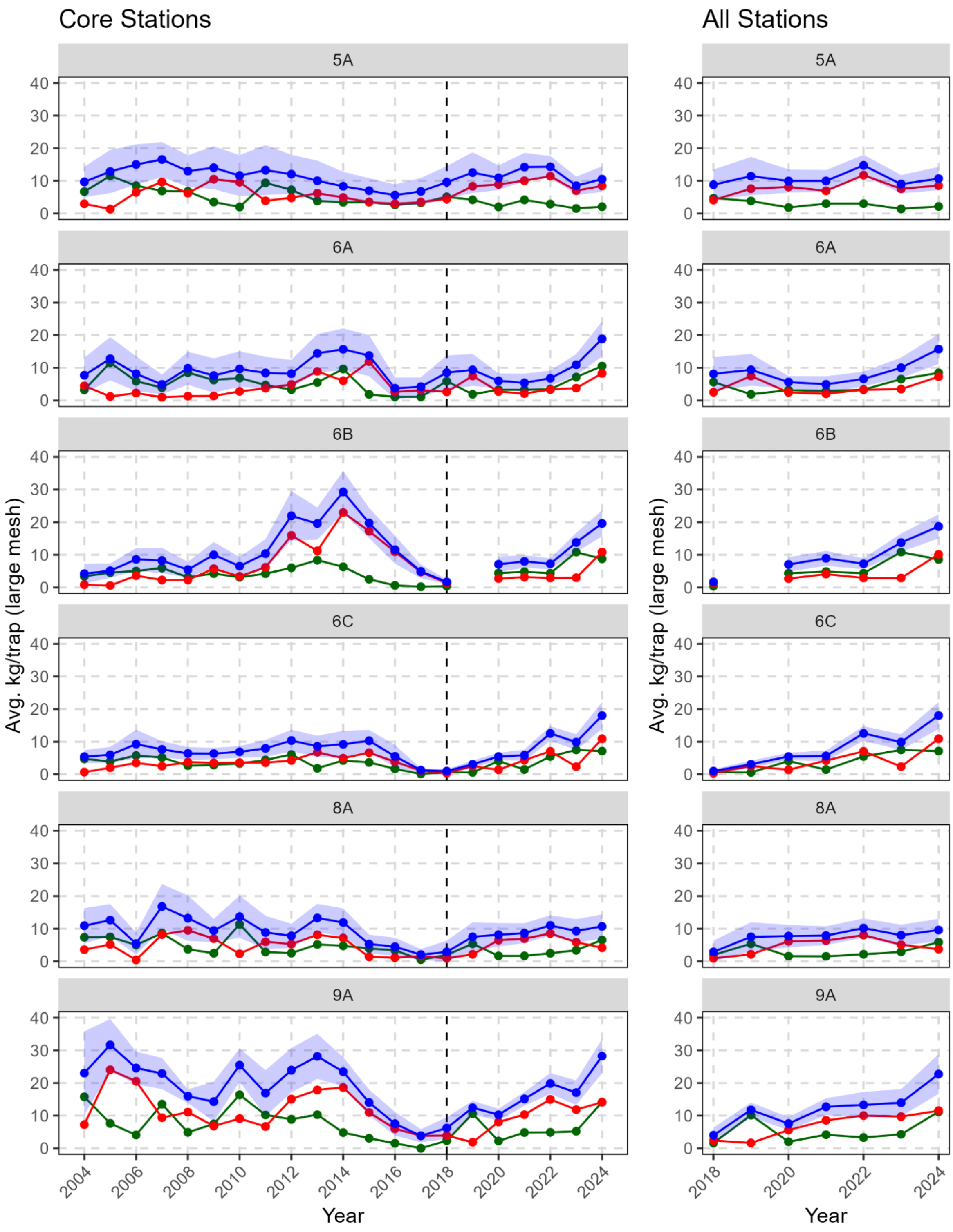

Figure A3.10. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas 5A, 6A, 6B, 6C, 8A, and 9A within Assessment Division 3LNO (2004–24). Shaded area represents the 95% confidence interval. The dashed vertical line denotes CPS survey re-design. Years without results represent low or absent at-sea observer coverage.

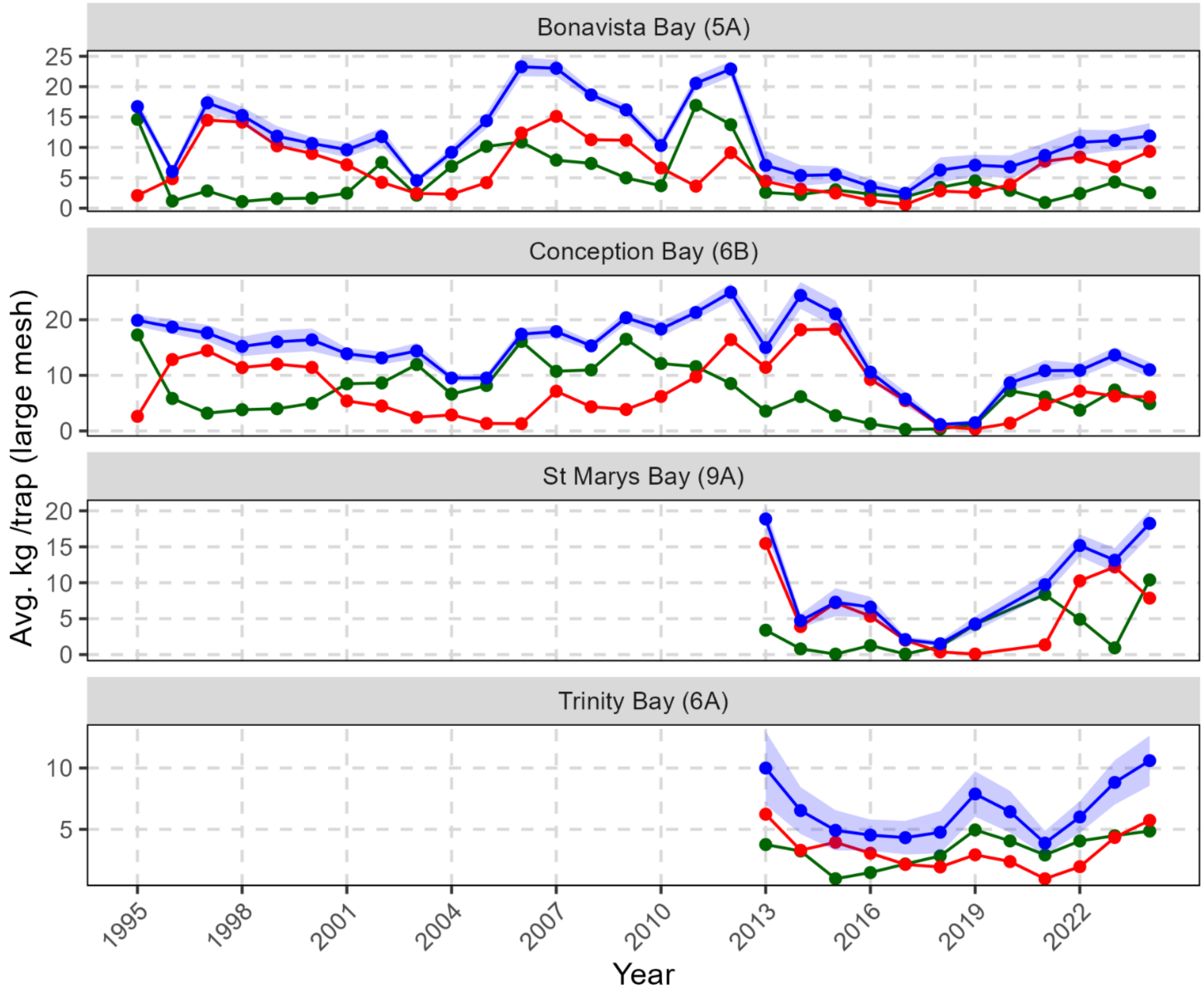

Figure A3.11. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable Snow Crab from large-mesh traps in the DFO inshore trap surveys in, from top to bottom, Bonavista Bay (Crab Management Area 5A), Conception Bay (Crab Management Area 6B), St. Mary's Bay (Crab Management Area 9A), and Trinity Bay (Crab Management Area 6A) (1995–2024). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

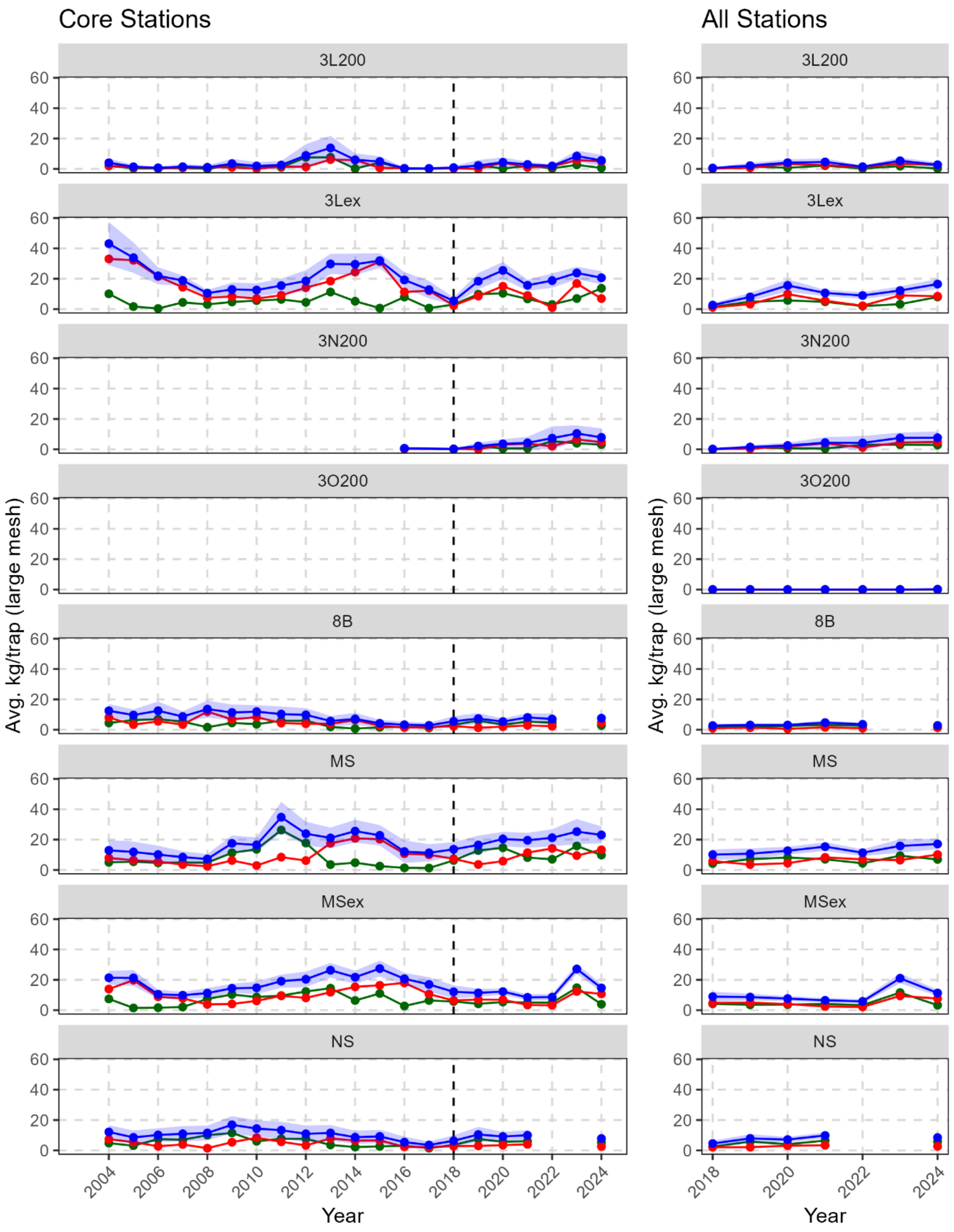

Figure A3.12. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas 3L200, 3Lex, 3N200, 3O200, 8B, MS, MSex, and NS within Assessment Division 3LNO (2004–24). Shaded area represents the 95% confidence interval. The dashed line denotes CPS survey re-design. Years without results represent incomplete or absent survey coverage.

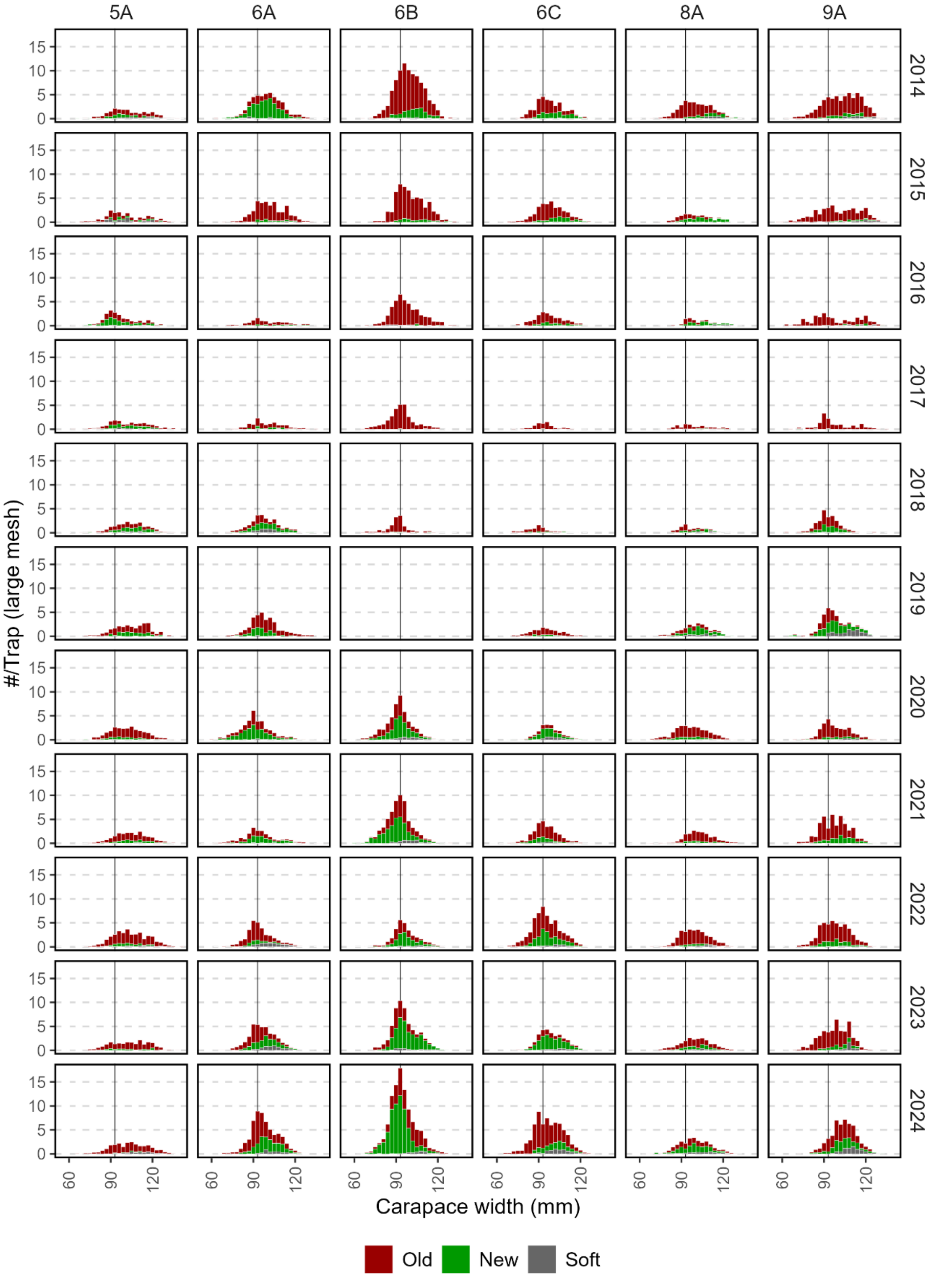

Figure A3.13. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas 5A, 6A, 6B, 6C, 8A, and 9A within Assessment Division 3LNO (2014–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

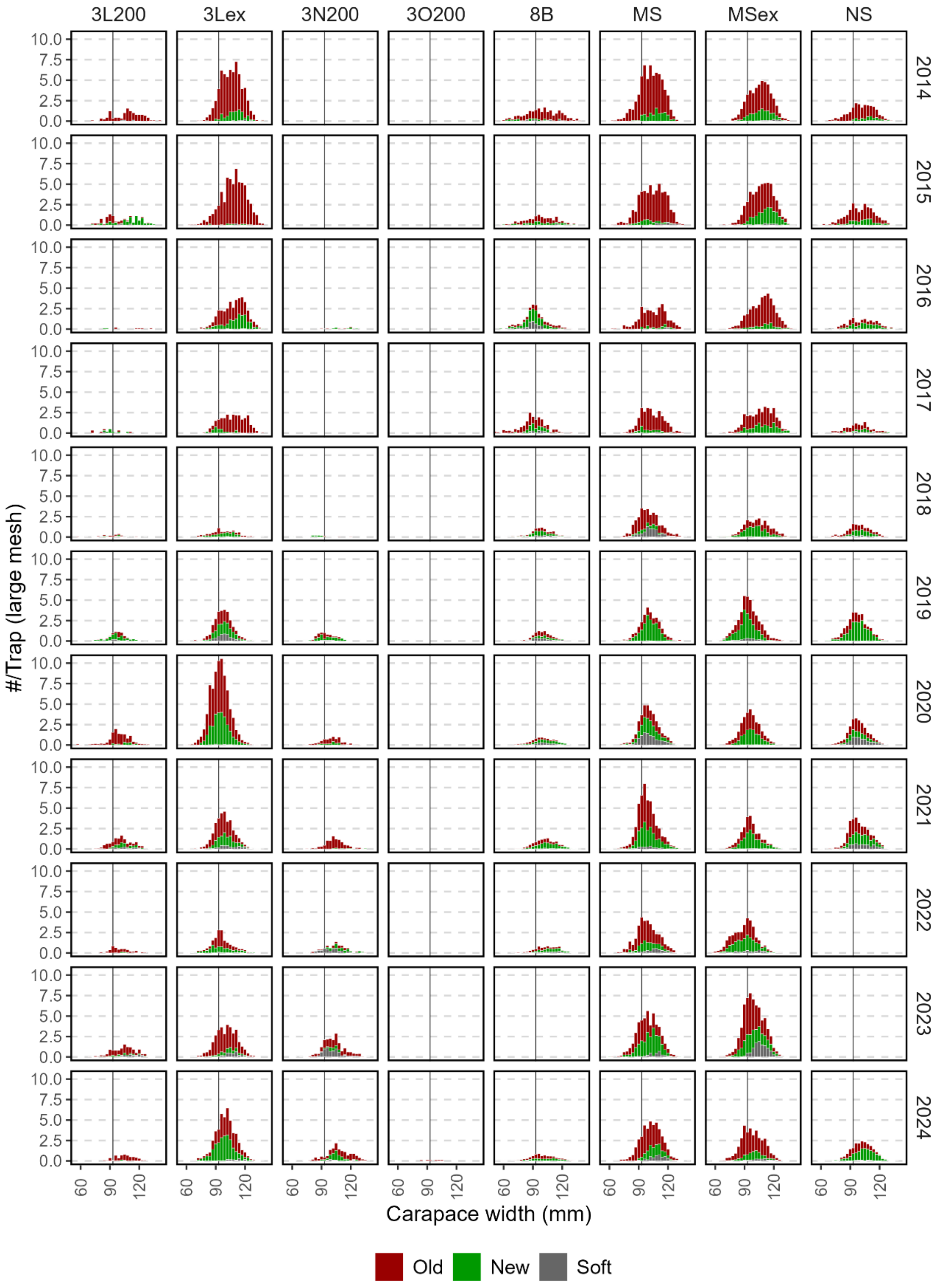

Figure A3.14. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas 3L200, 3Lex, 3N200, 3O200, 8B, MS, MSex, and NS within Assessment Division 3LNO (2014–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

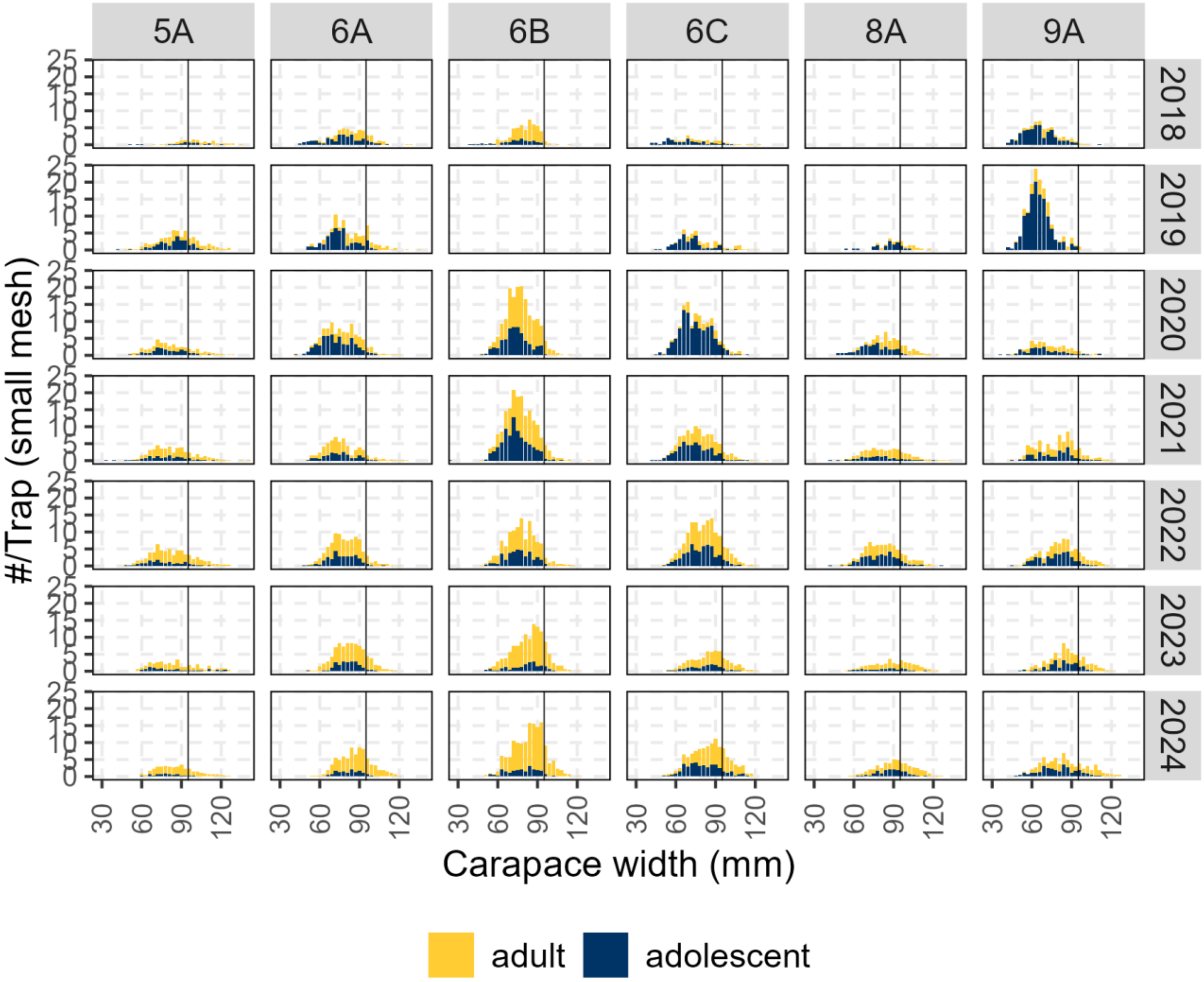

Figure A3.15. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas 5A, 6A, 6B, 6C, 8A, and 9A within Assessment Division 3LNO (2018–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

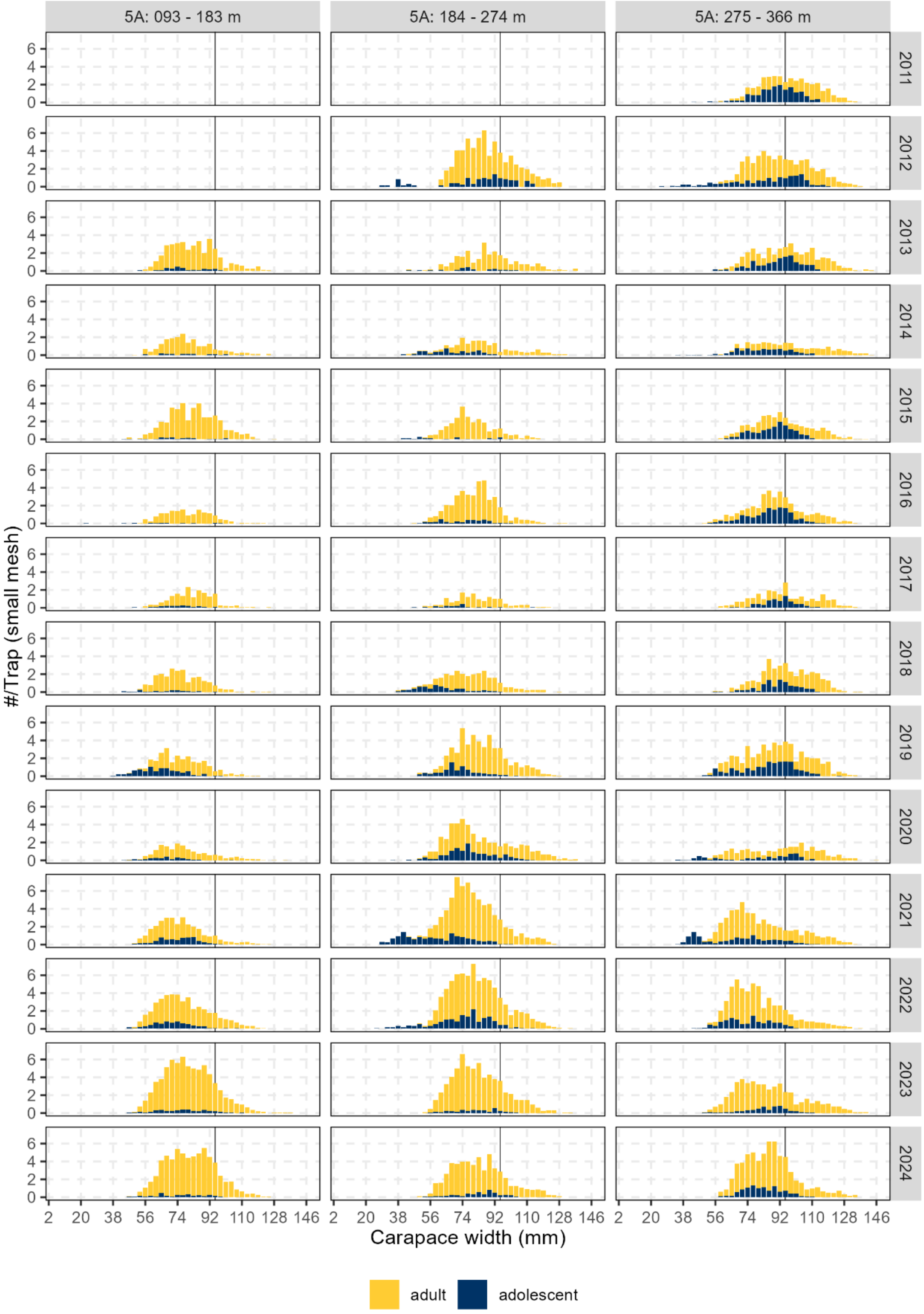

Figure A3.16. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey from Bonavista Bay (Crab Management Area 5A) (2011–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

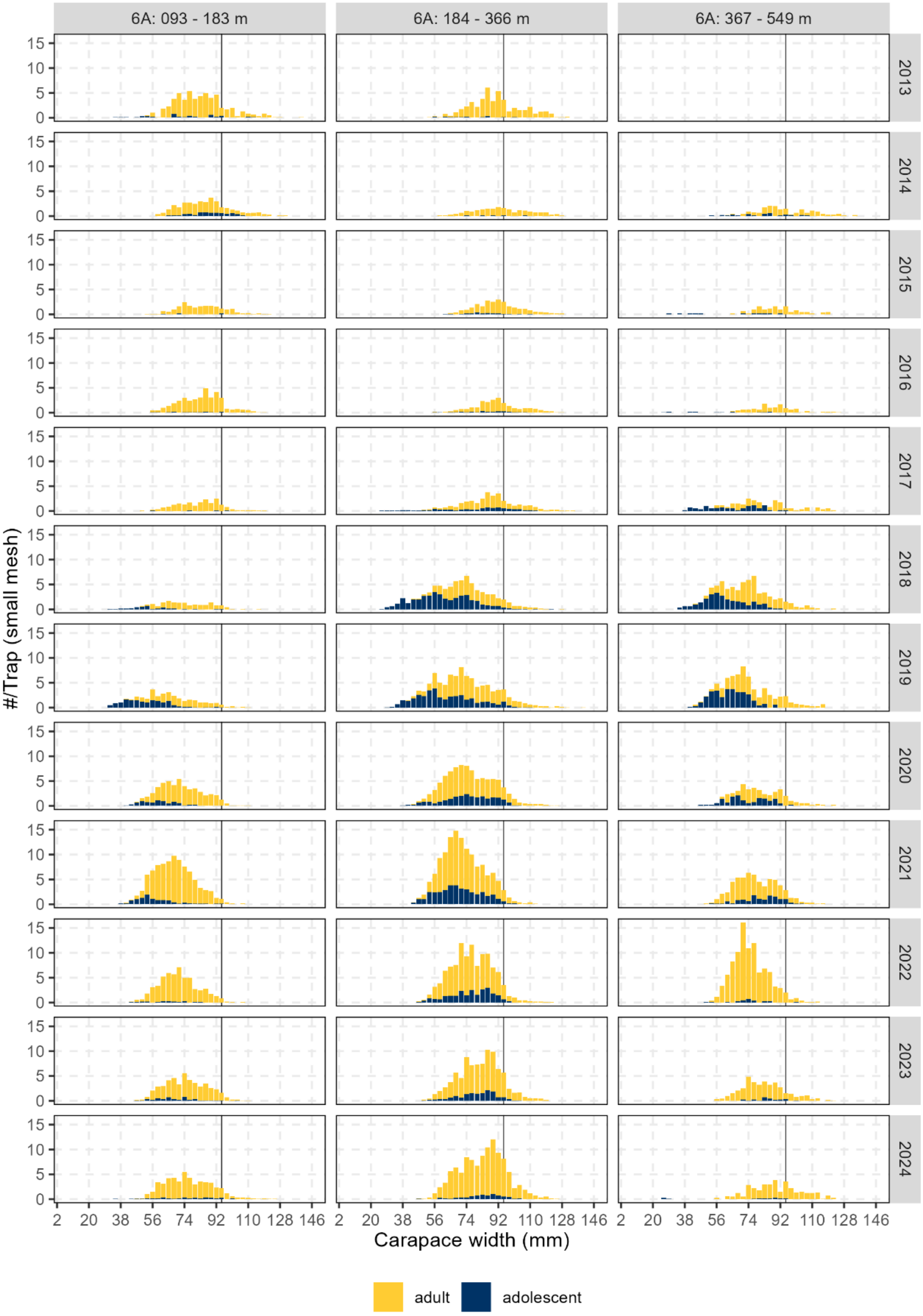

Figure A3.17. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey from Trinity Bay (Crab Management Area 6A) (2013–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

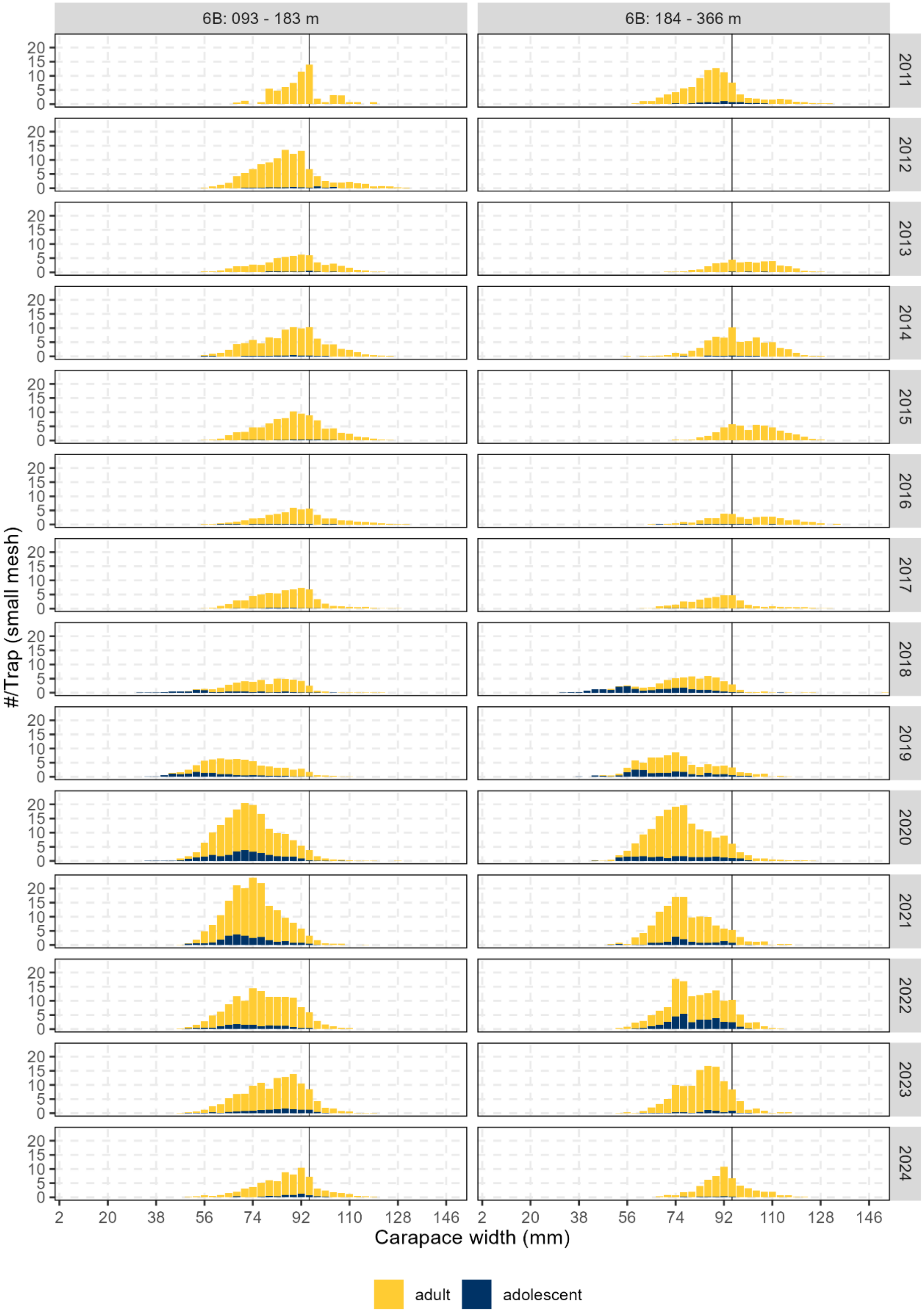

Figure A3.18. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey from Conception Bay (Crab Management Area 6B) (2011–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

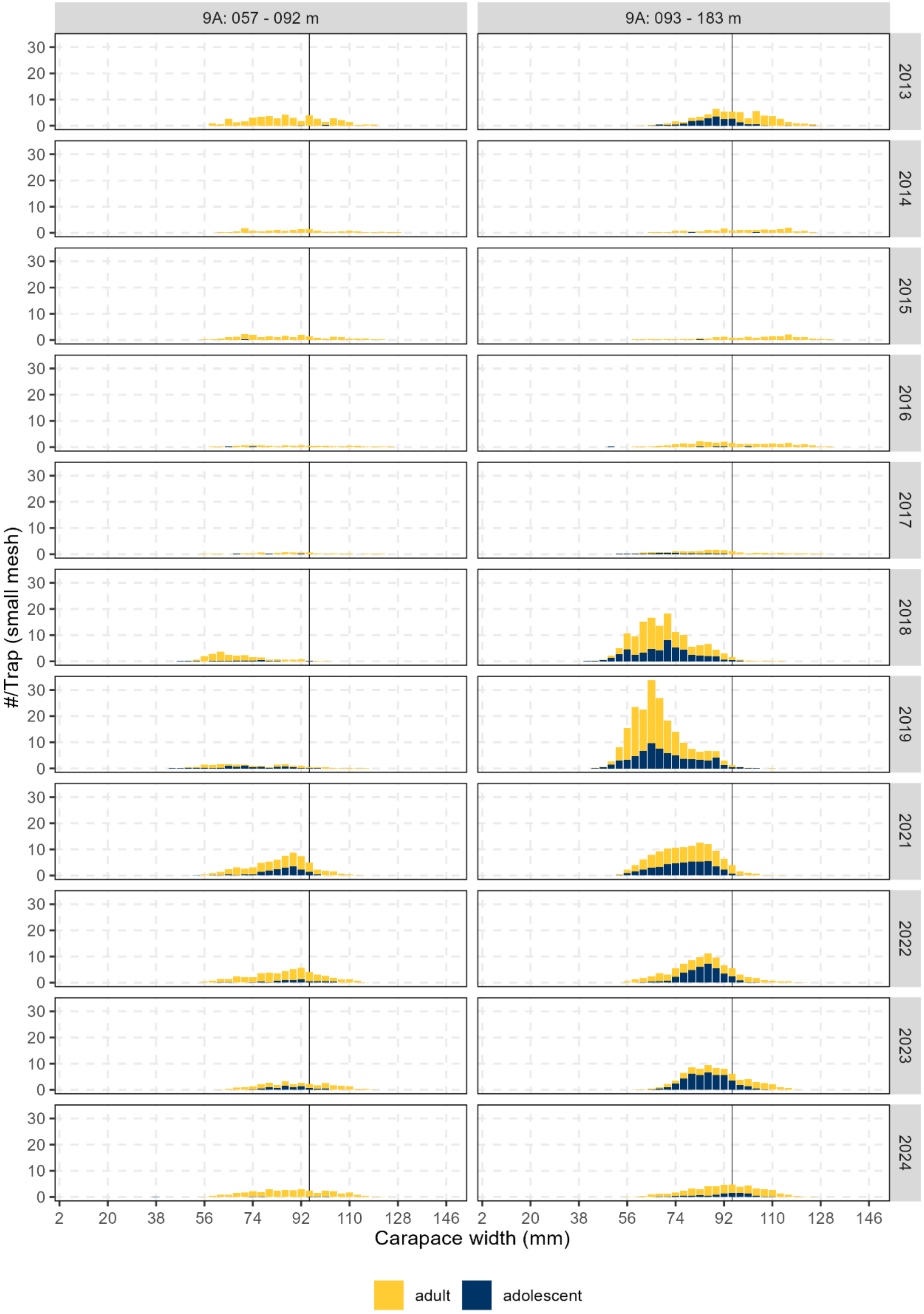

Figure A3.19. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey from St. Mary's Bay (Crab Management Area 9A) (2013–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

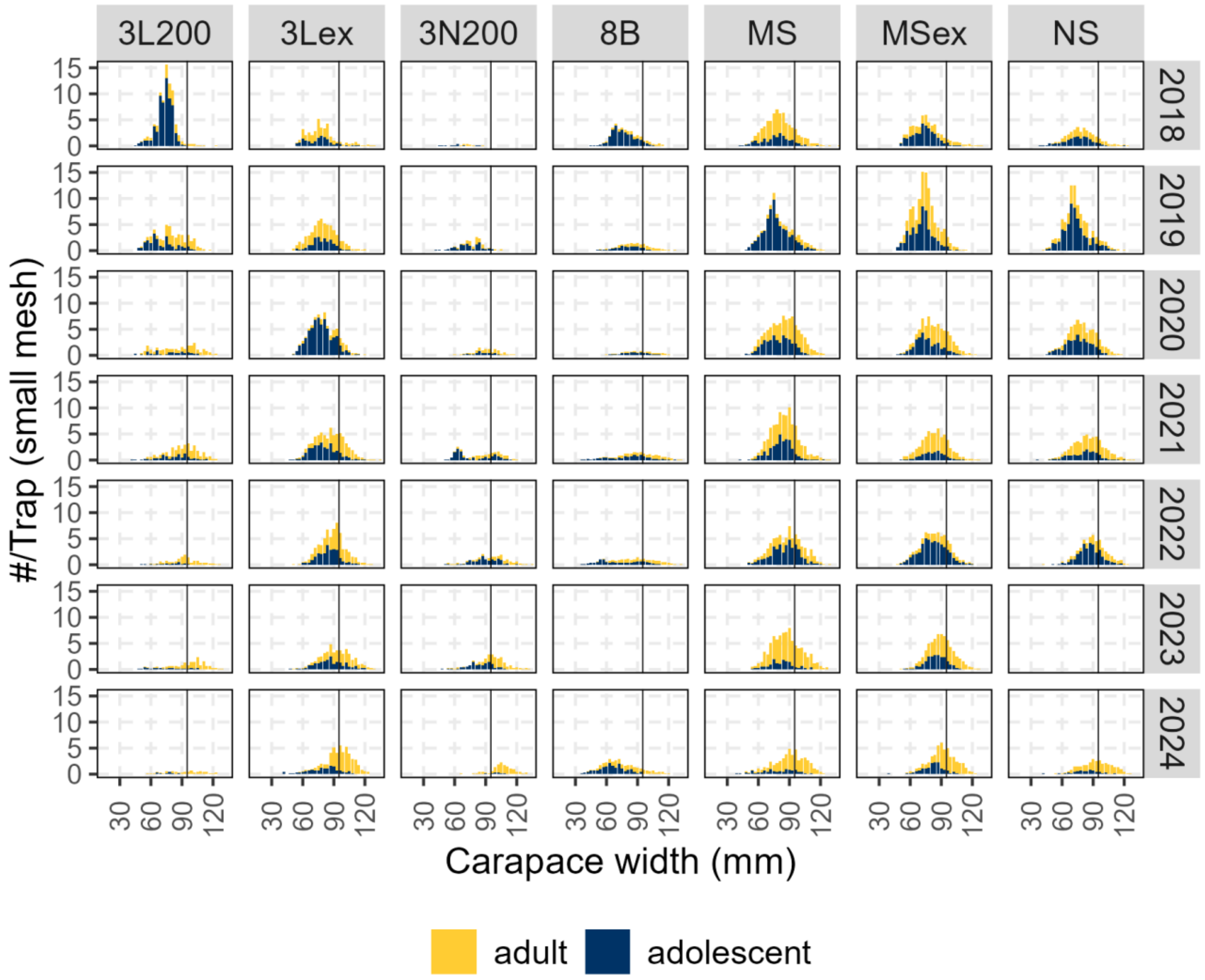

Figure A3.20. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas 3L200, 3Lex, 3N200, 8B, MS, MSex, and NS within Assessment Division 3LNO (2018–24). The black vertical line indicates the minimum legal size.

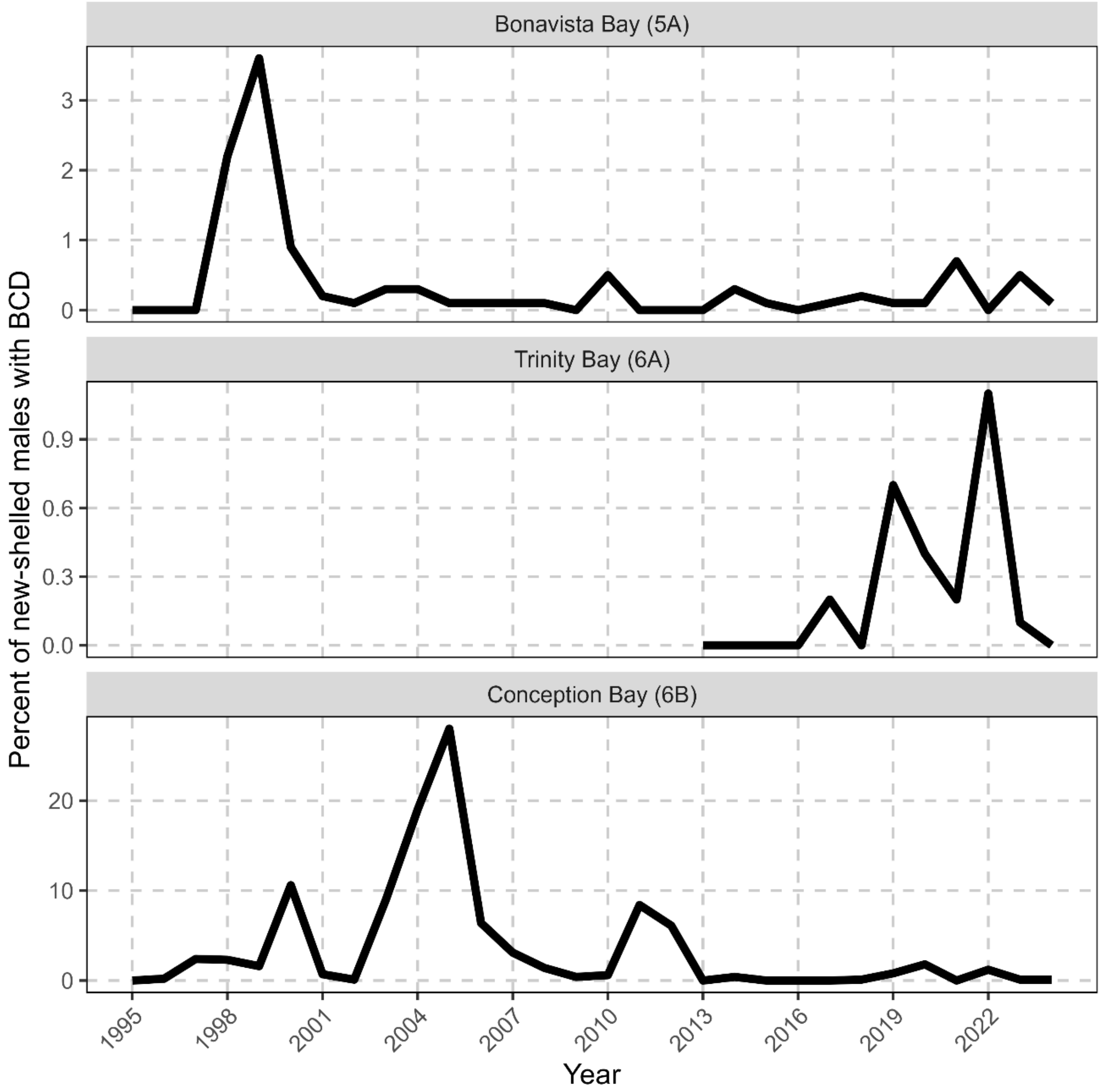

Figure A3.21. Visually observed percentage of Bitter Crab Disease (BCD) in new-shelled males from DFO inshore trap surveys in Bonavista Bay (Crab Management Area 5A), Trinity Bay (Crab Management Area 6A), and Conception Bay (Crab Management Area 6B) (1995–2024).

APPENDIX 4: ASSESSMENT DIVISION 3PS DETAILS

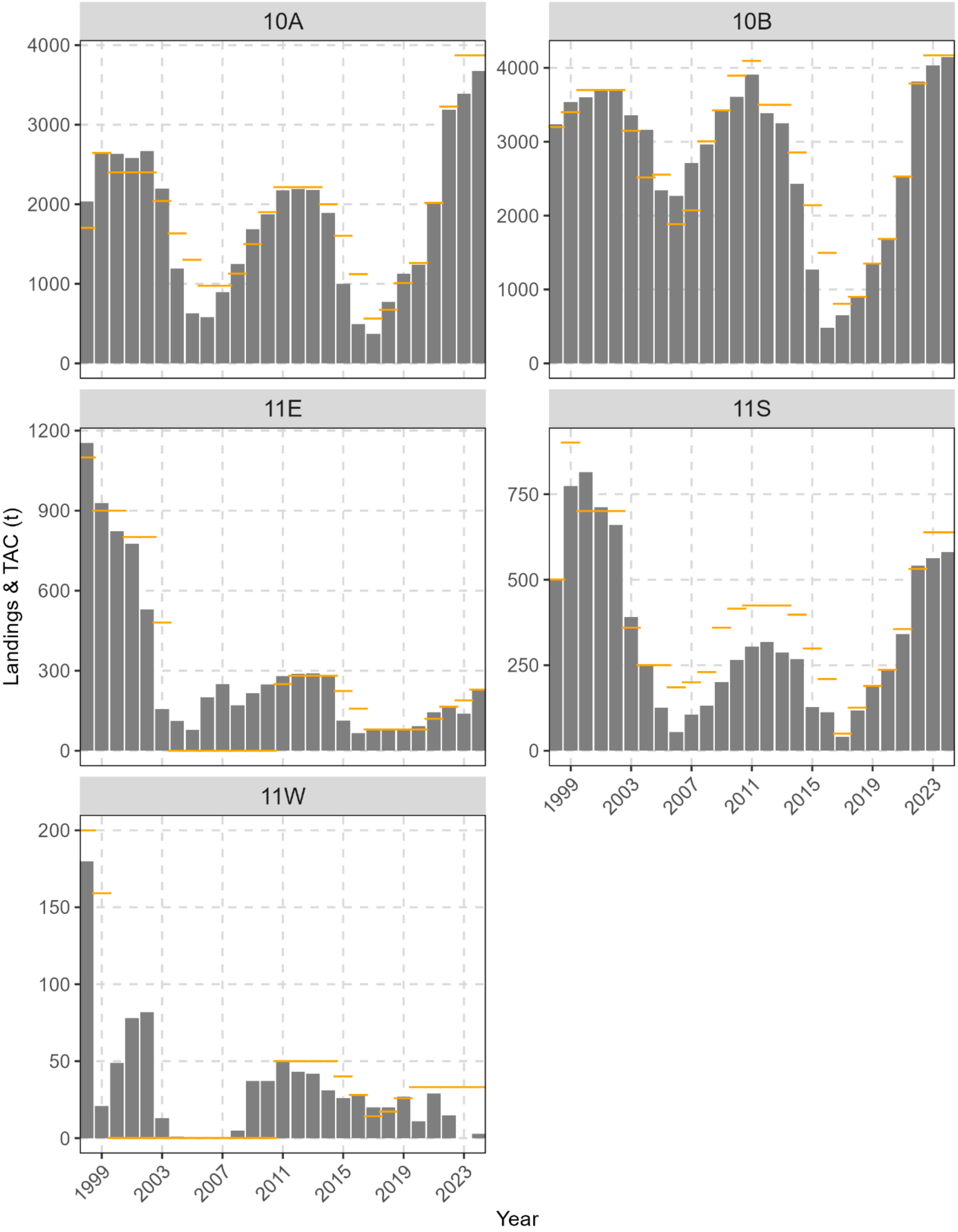

Figure A4.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 3Ps (1998–2024).

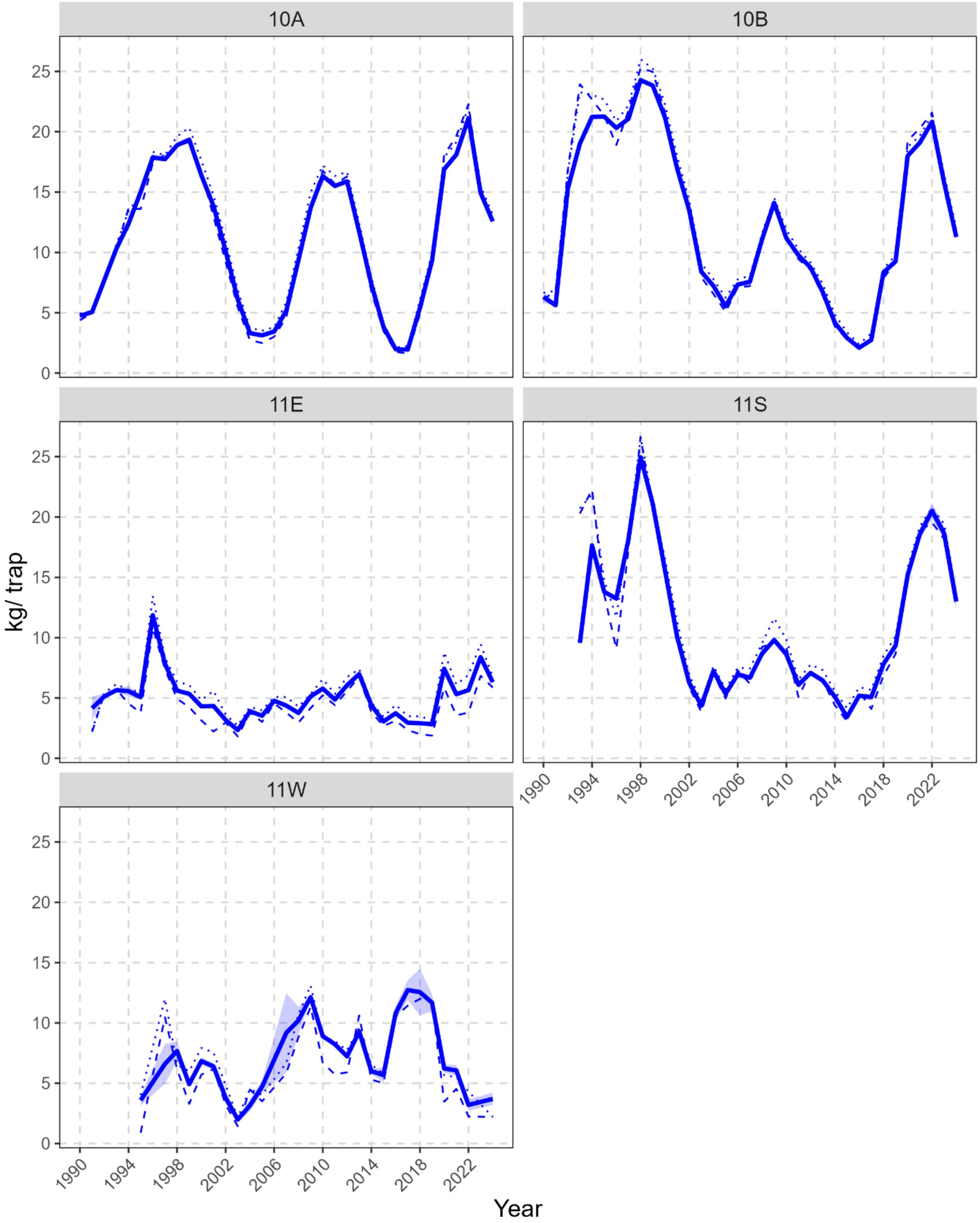

Figure A4.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 3Ps (1990–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

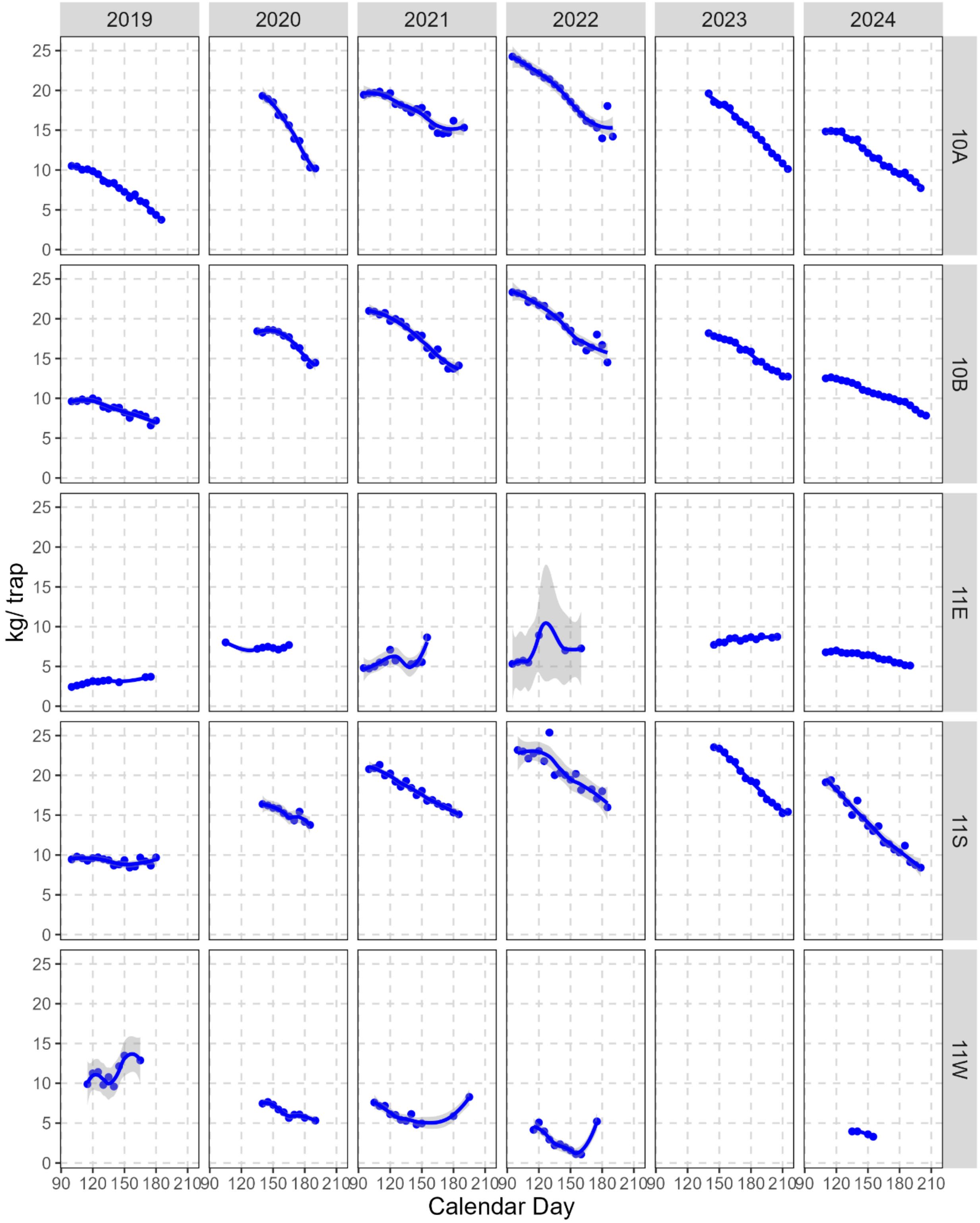

Figure A4.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 3Ps (2019–24), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

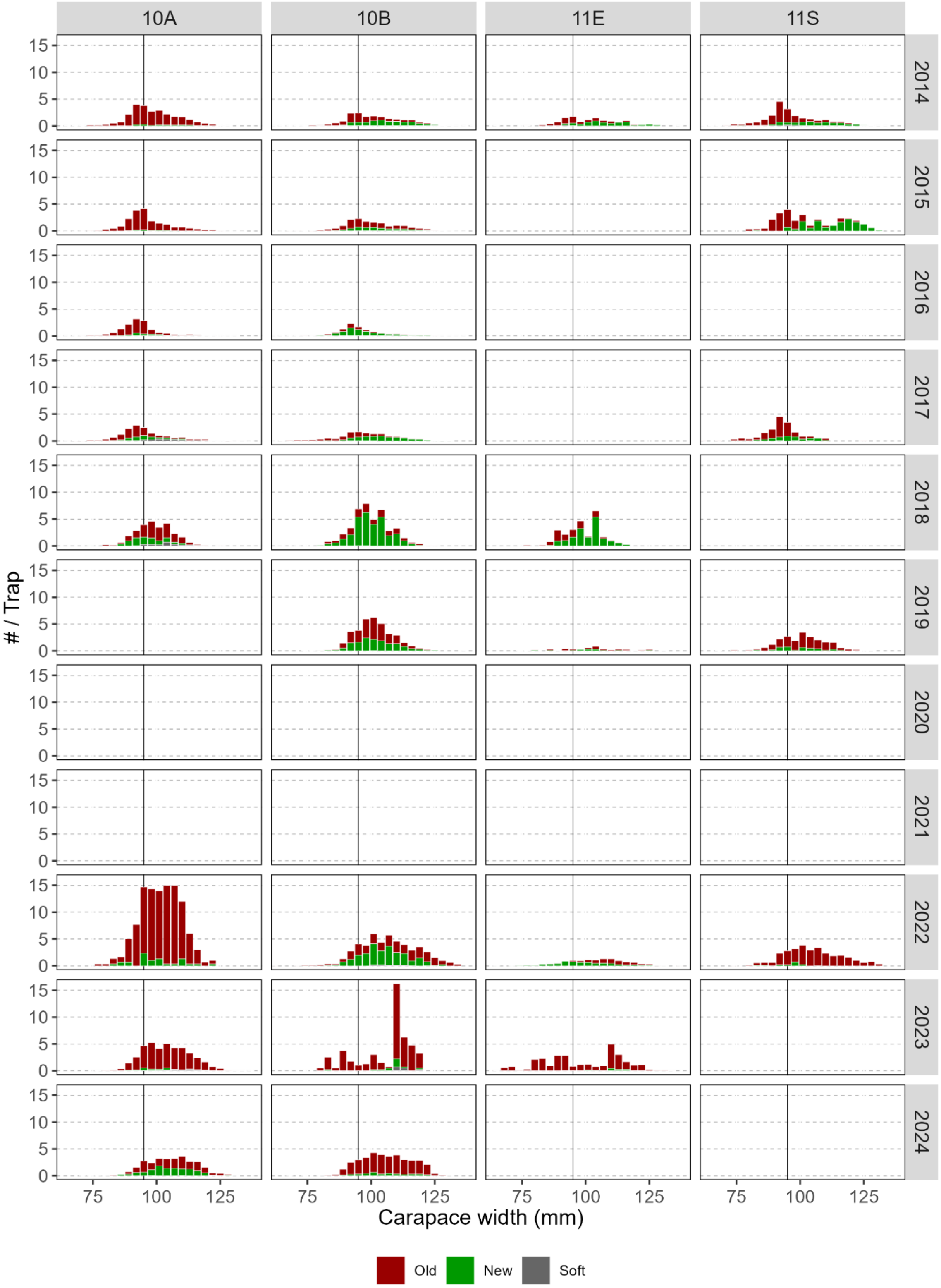

Figure A4.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 3Ps (2014–24). The black vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

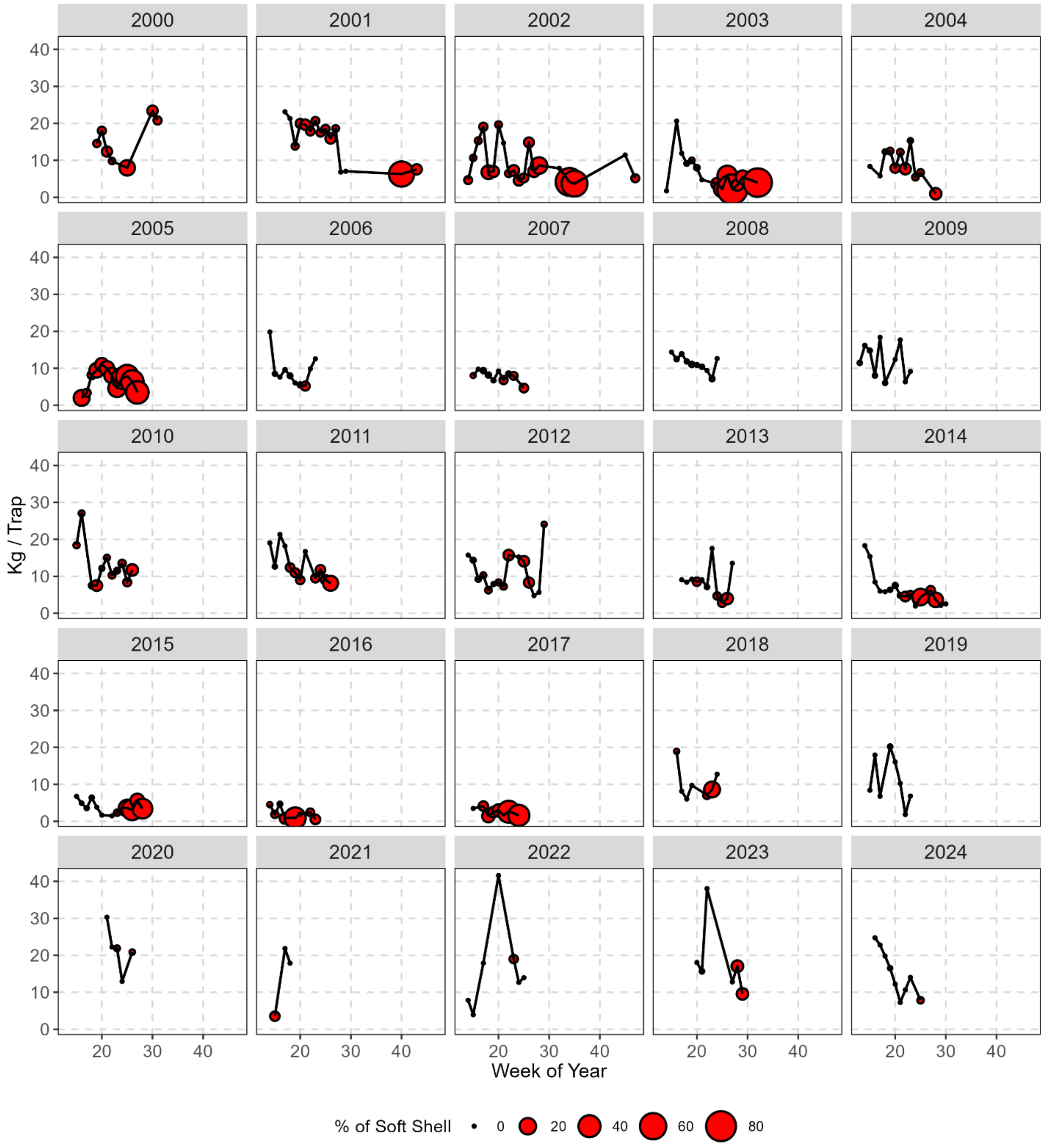

Figure A4.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling within Assessment Division 3Ps (2000–24). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates.

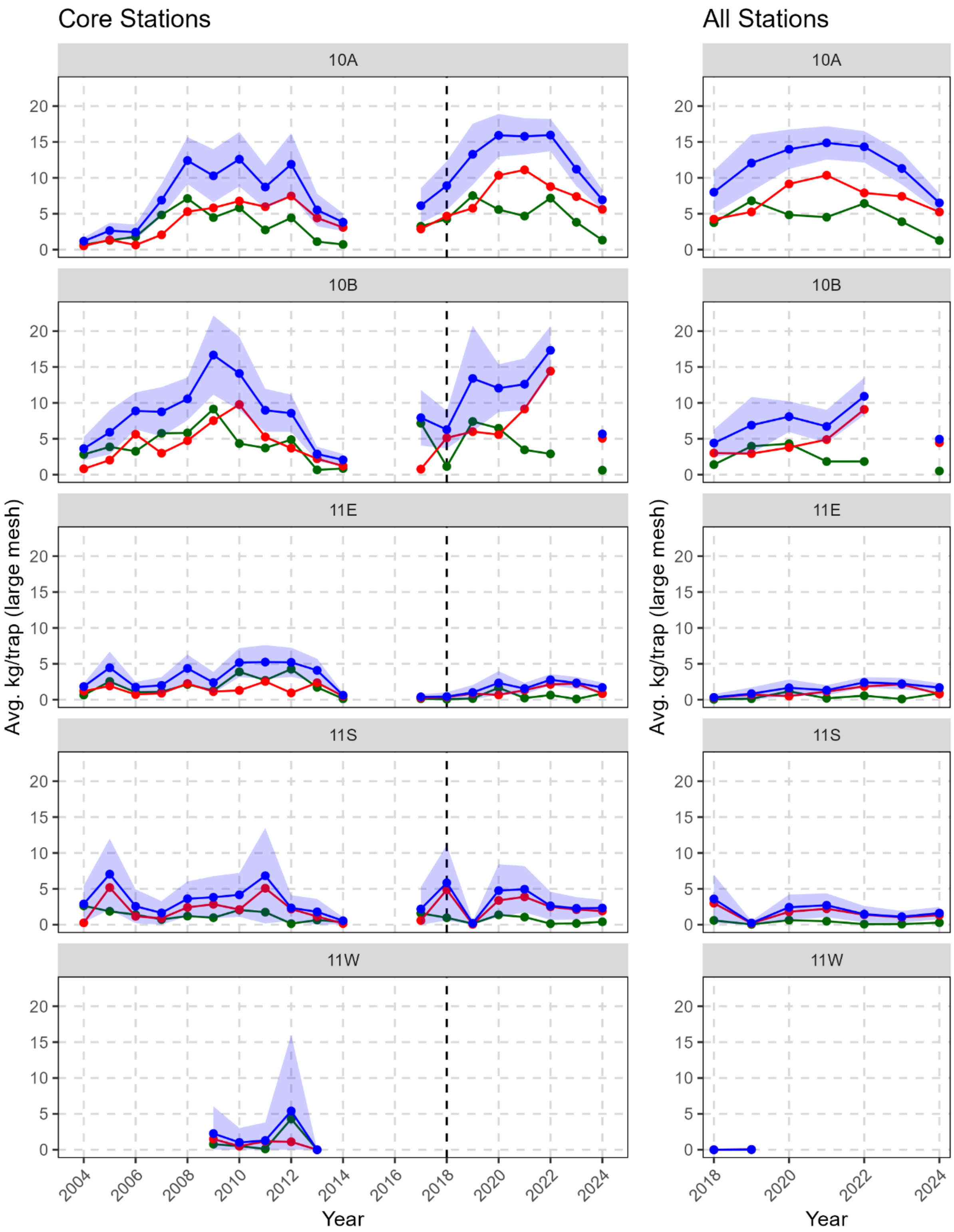

Figure A4.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 3Ps (2004–24). Shaded area represents the 95% confidence interval. The dashed vertical line denotes CPS survey re-design. Years without results represent incomplete or absent survey coverage.

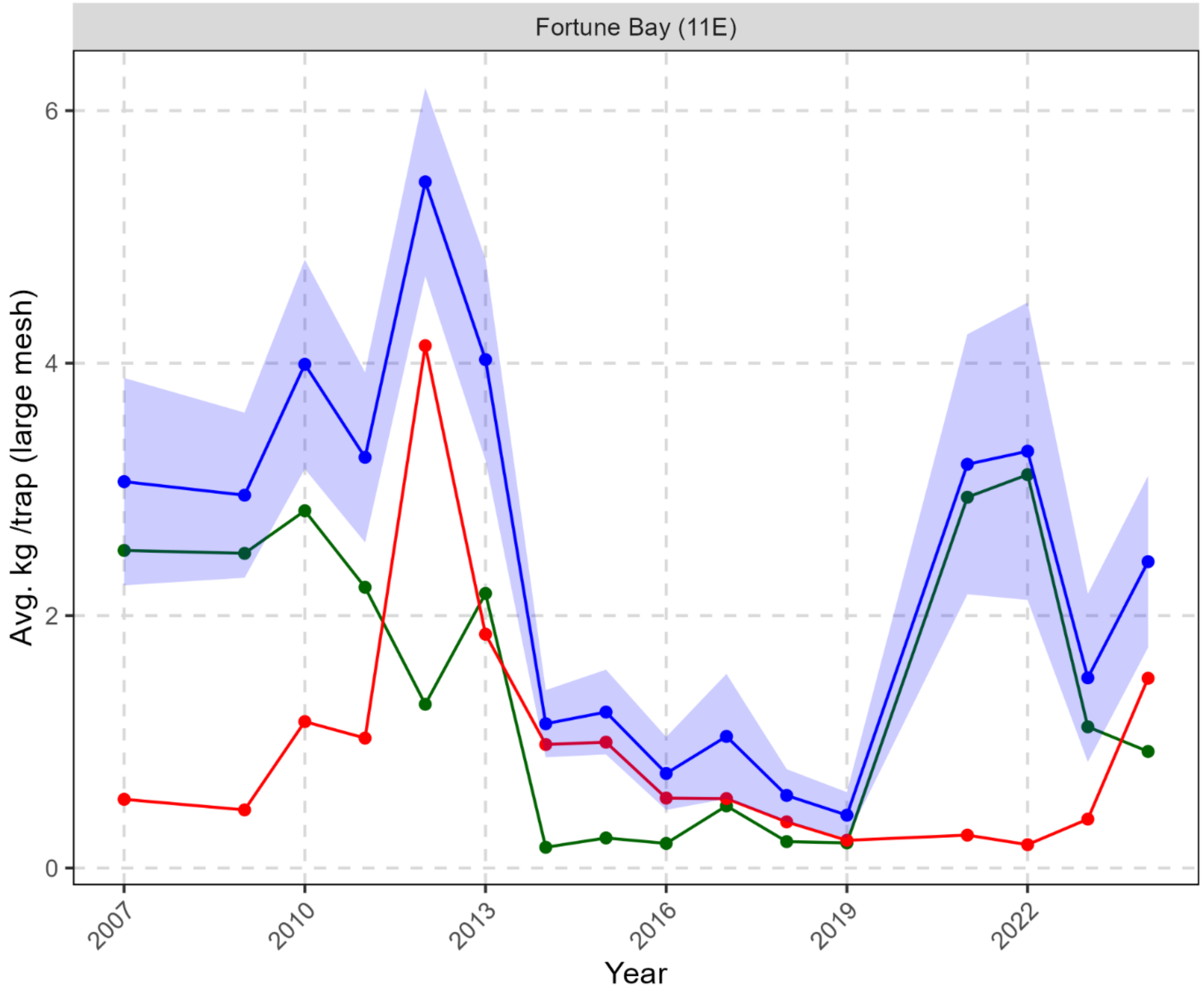

Figure A4.7. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys in Fortune Bay (Crab Management Area 11E) (2007–24). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

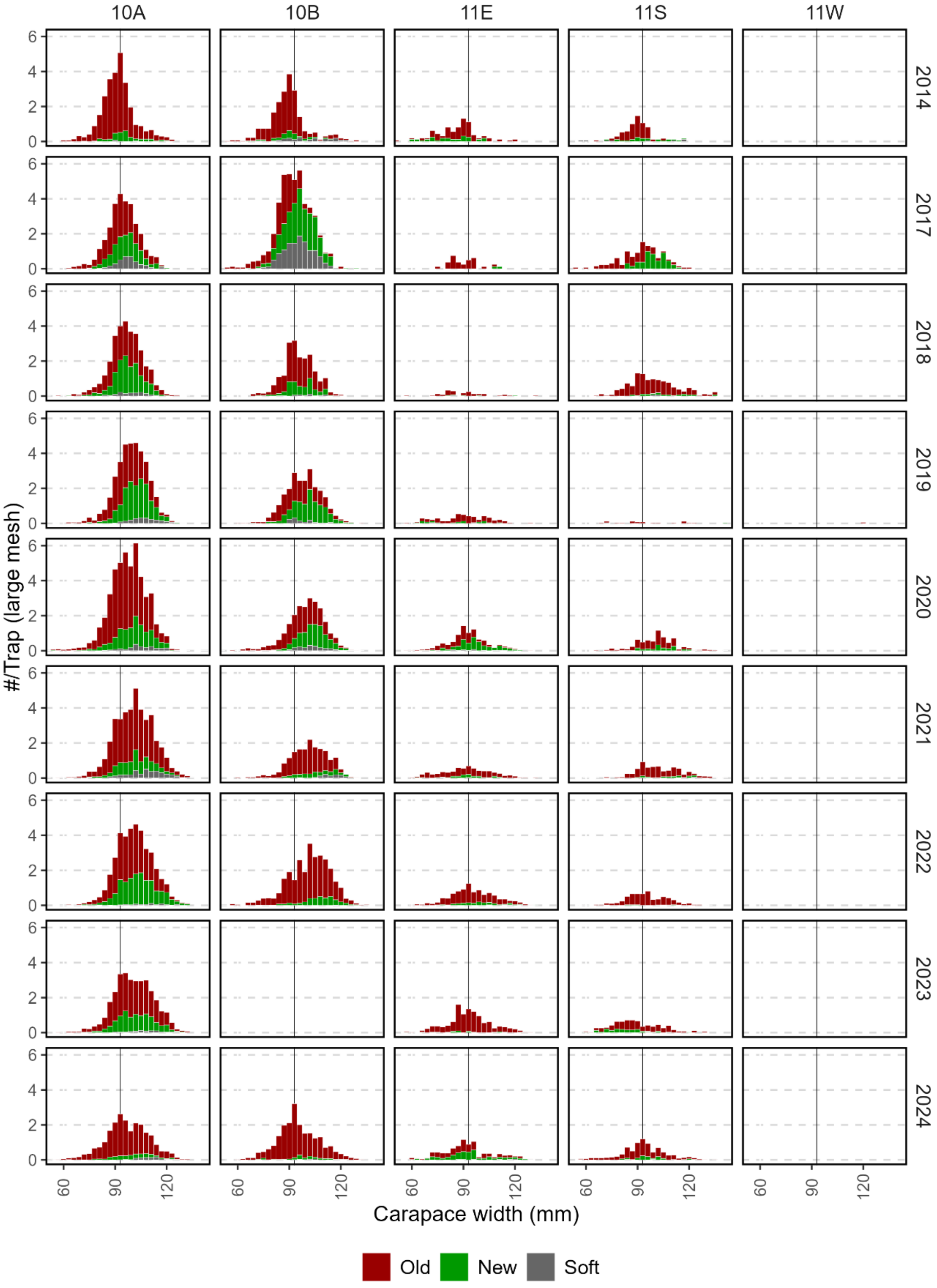

Figure A4.8. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3Ps (2014, 2017–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

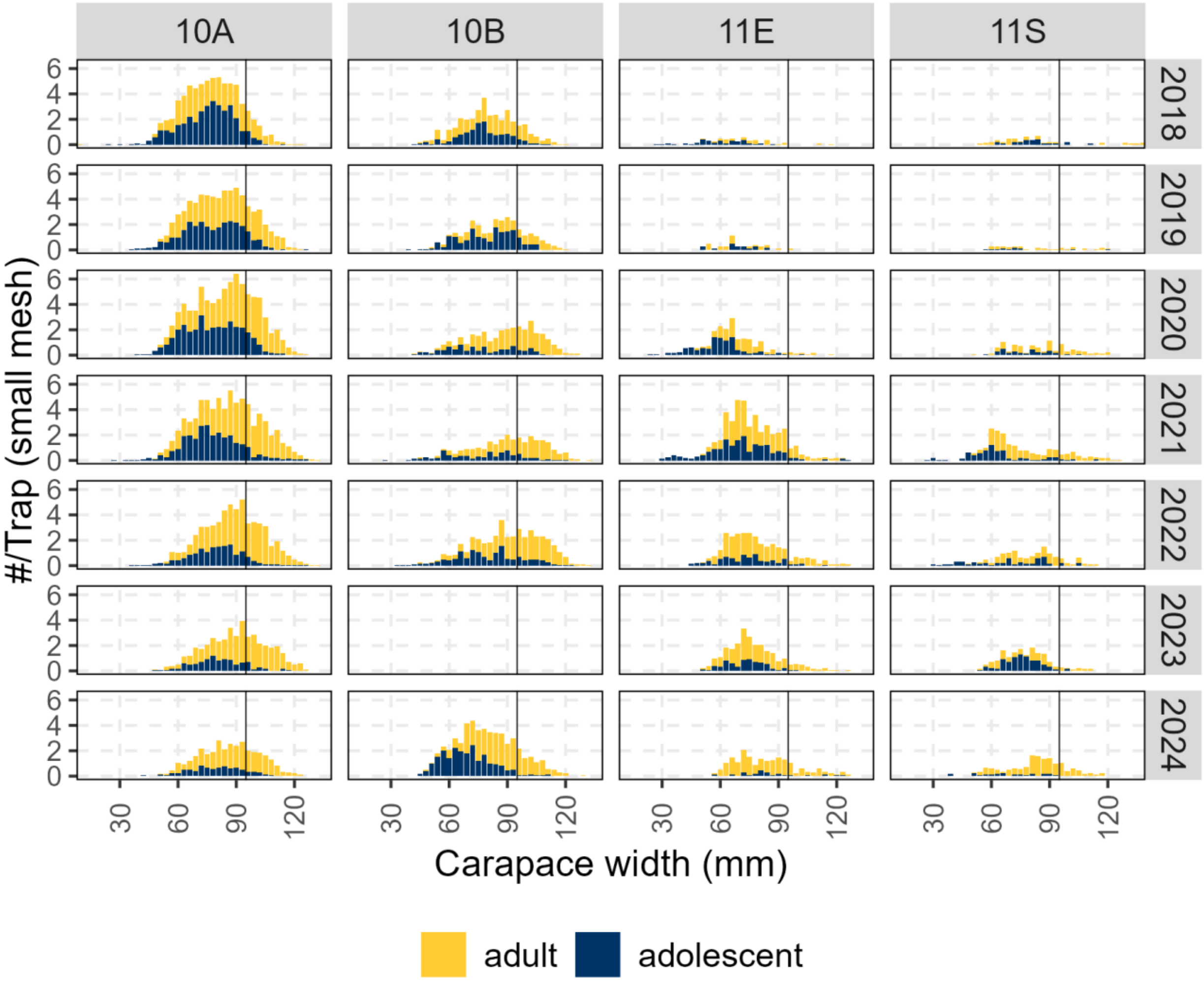

Figure A4.9. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3Ps (2018–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

Figure A4.10. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey from Fortune Bay (Crab Management Area 11E) (2011–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

APPENDIX 5: ASSESSMENT DIVISION 4R3PN DETAILS

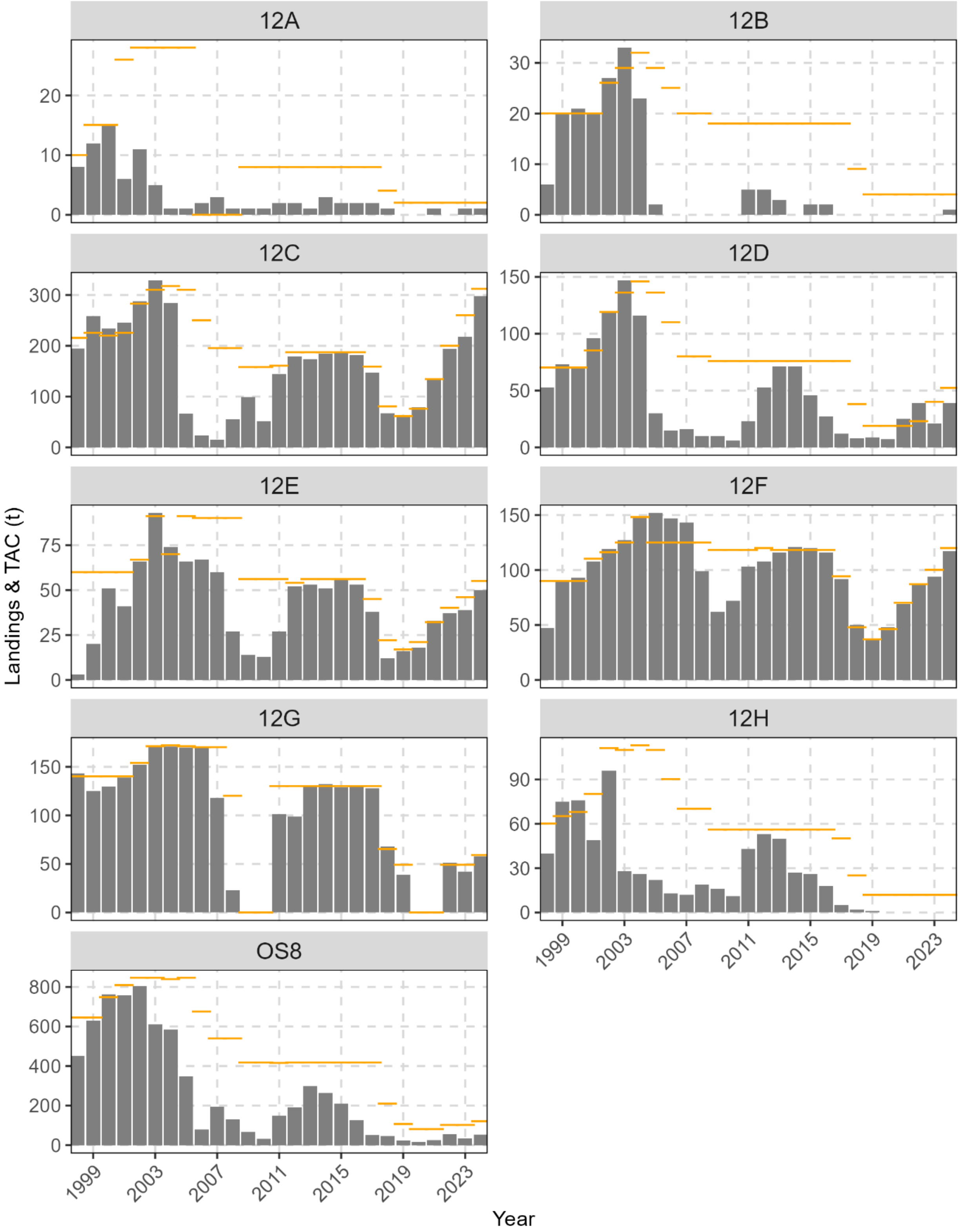

Figure A5.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 4R3Pn (1998–2024).

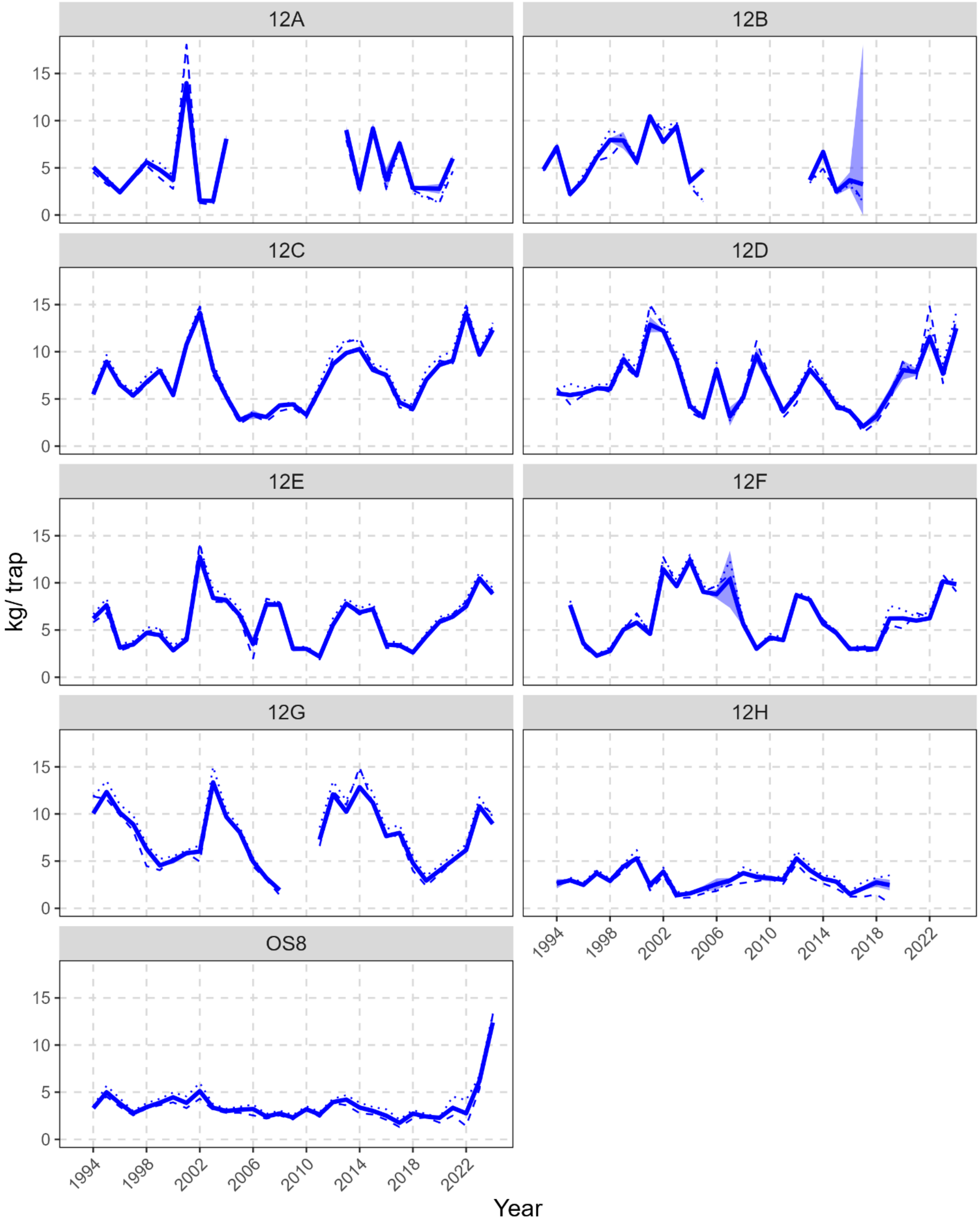

Figure A5.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 4R3Pn (1993–2024). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

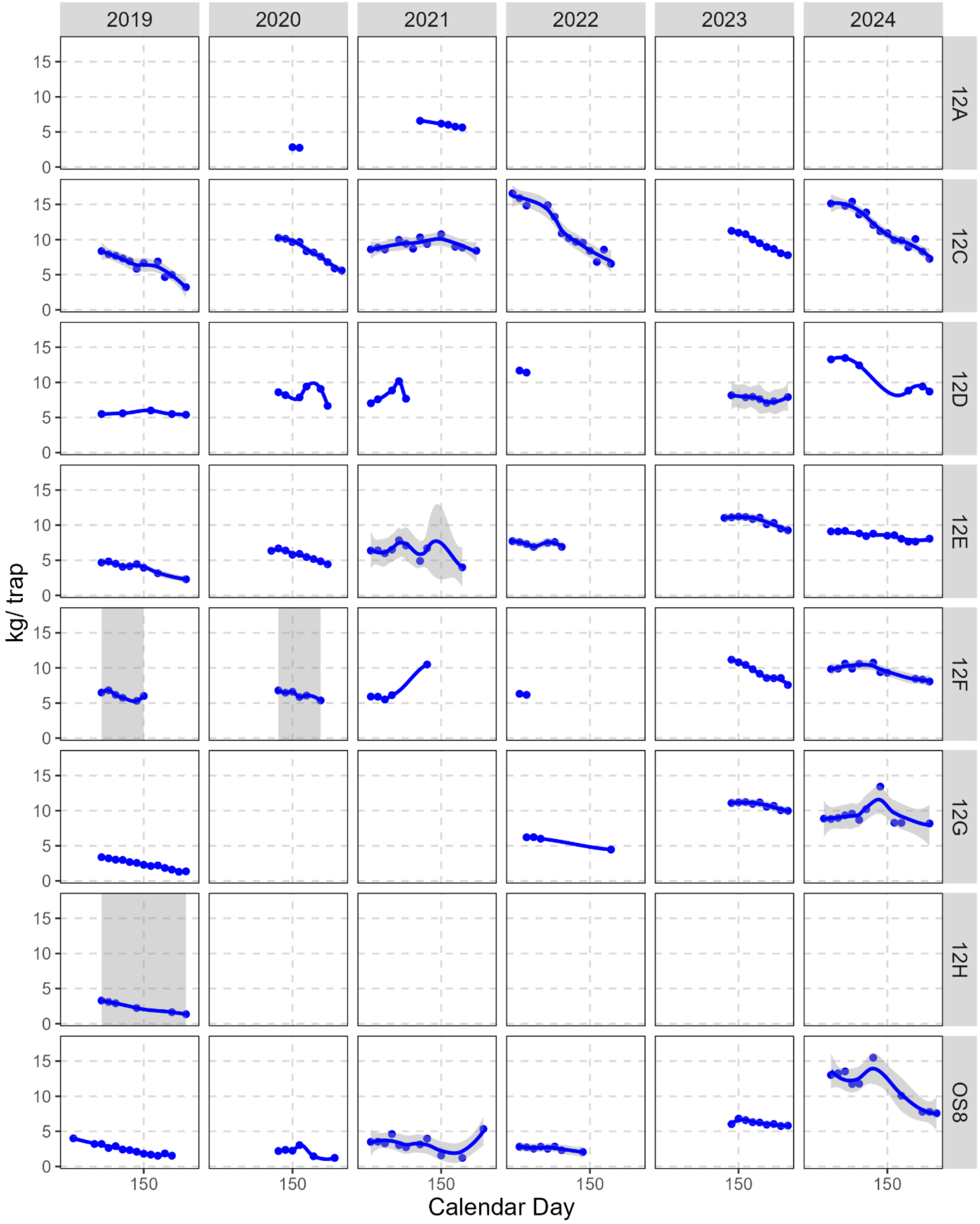

Figure A5.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 4R3Pn (2019–24), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

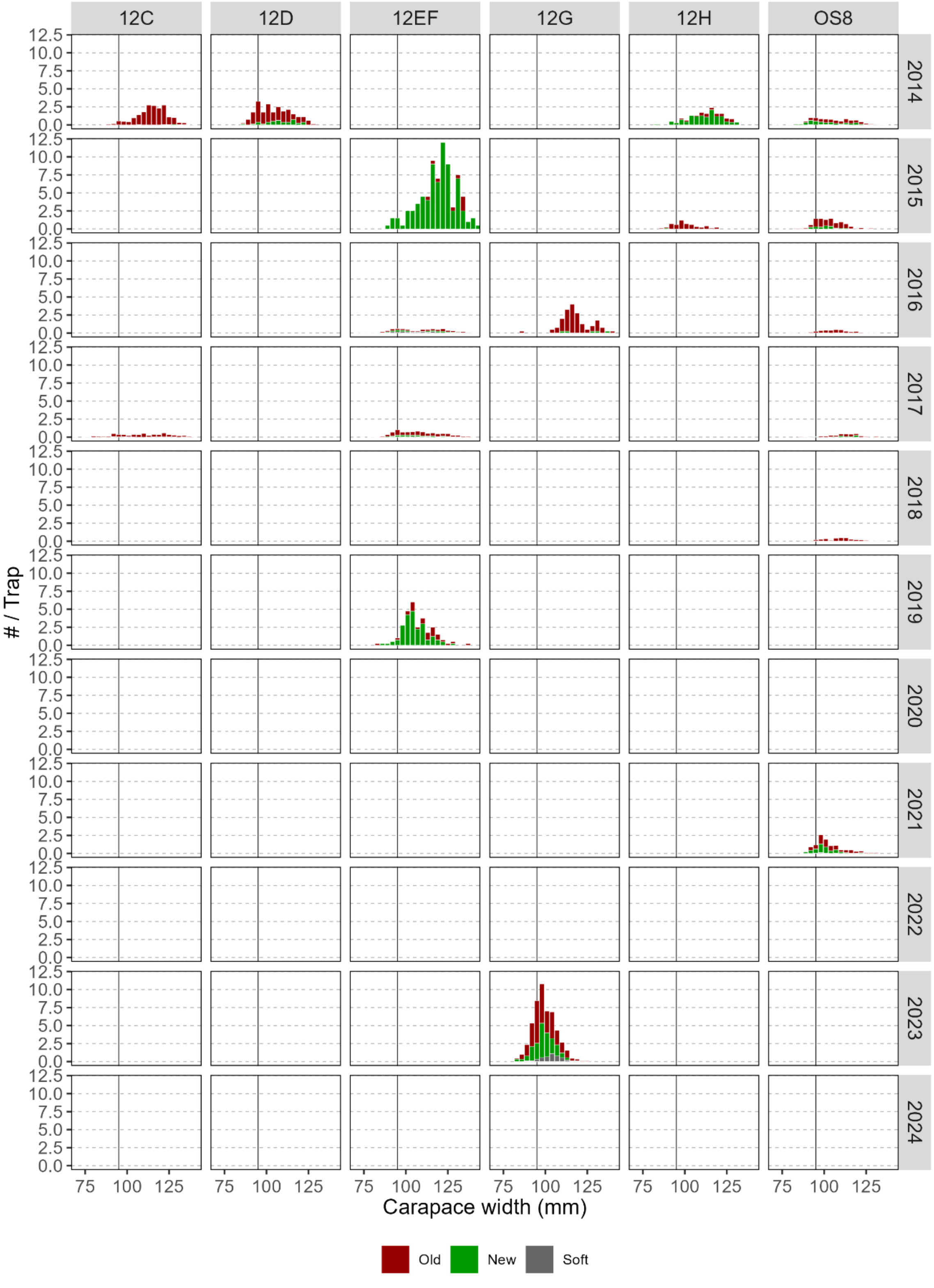

Figure A5.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 4R3Pn (2014–24). The black vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

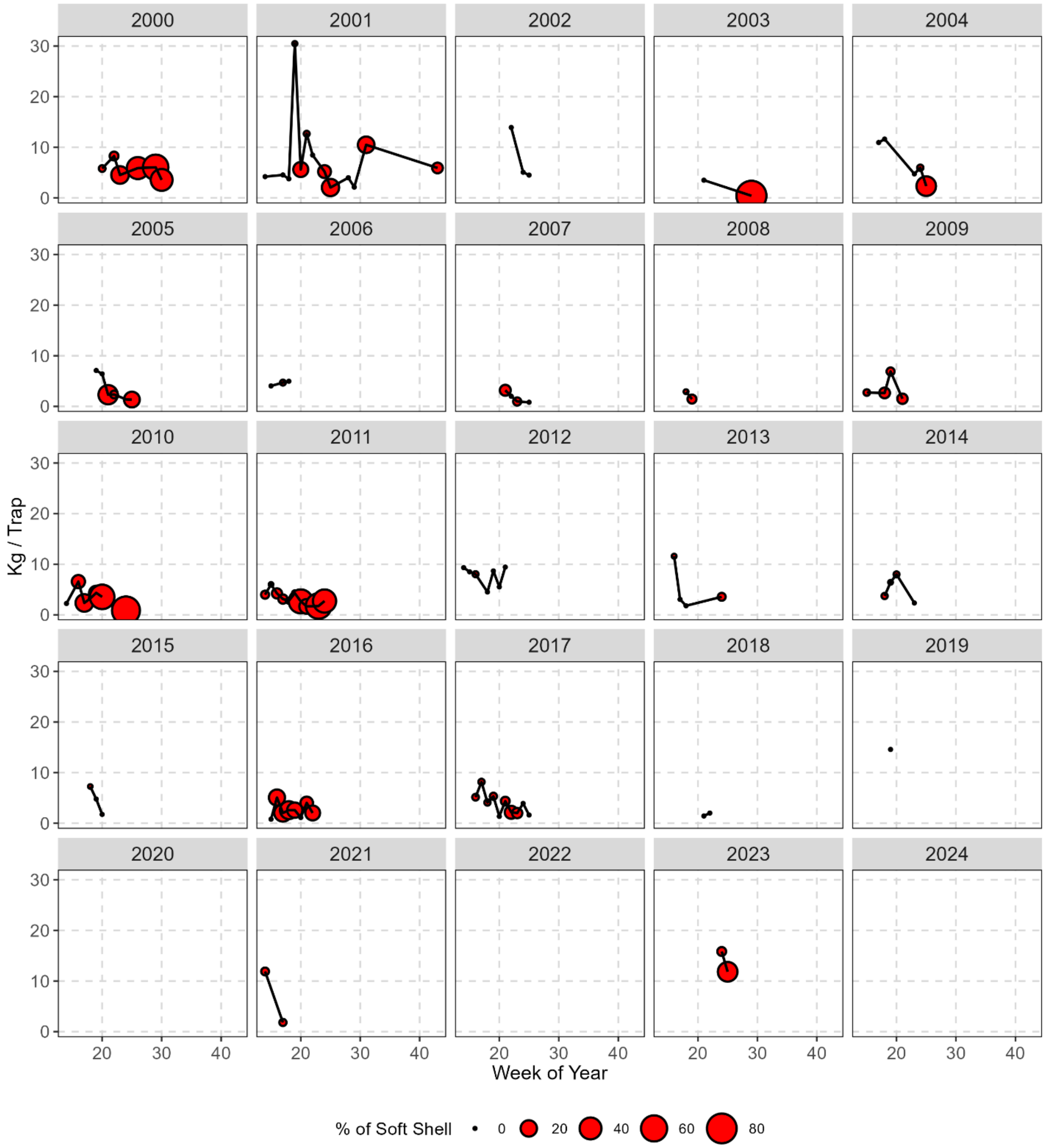

Figure A5.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling within Assessment Division 4R3Pn (2000–24). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

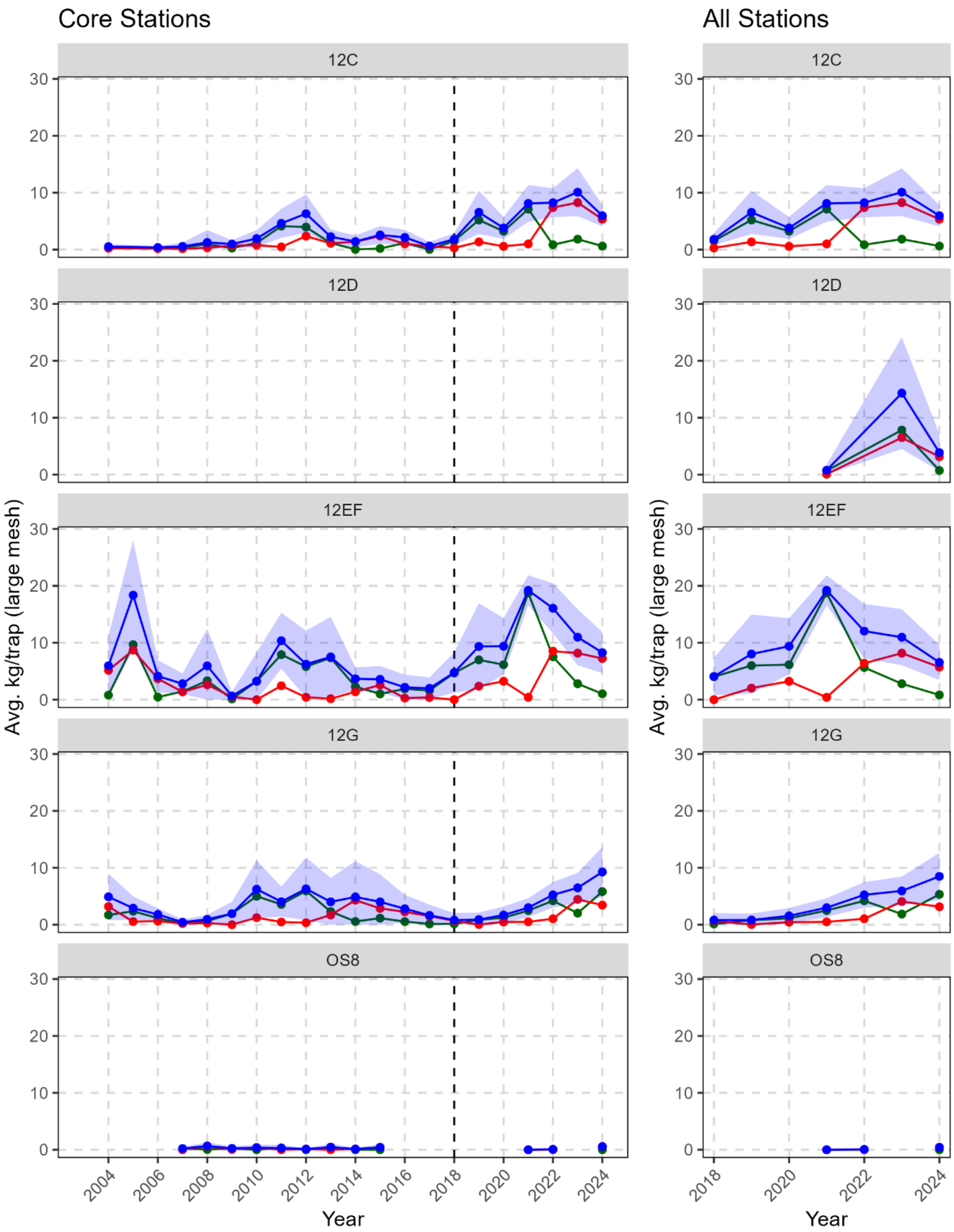

Figure A5.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 4R3Pn (2004–24). Shaded area represents the 95% confidence interval. The dashed line denotes CPS survey re-design. Years without results represent incomplete or absent survey coverage.

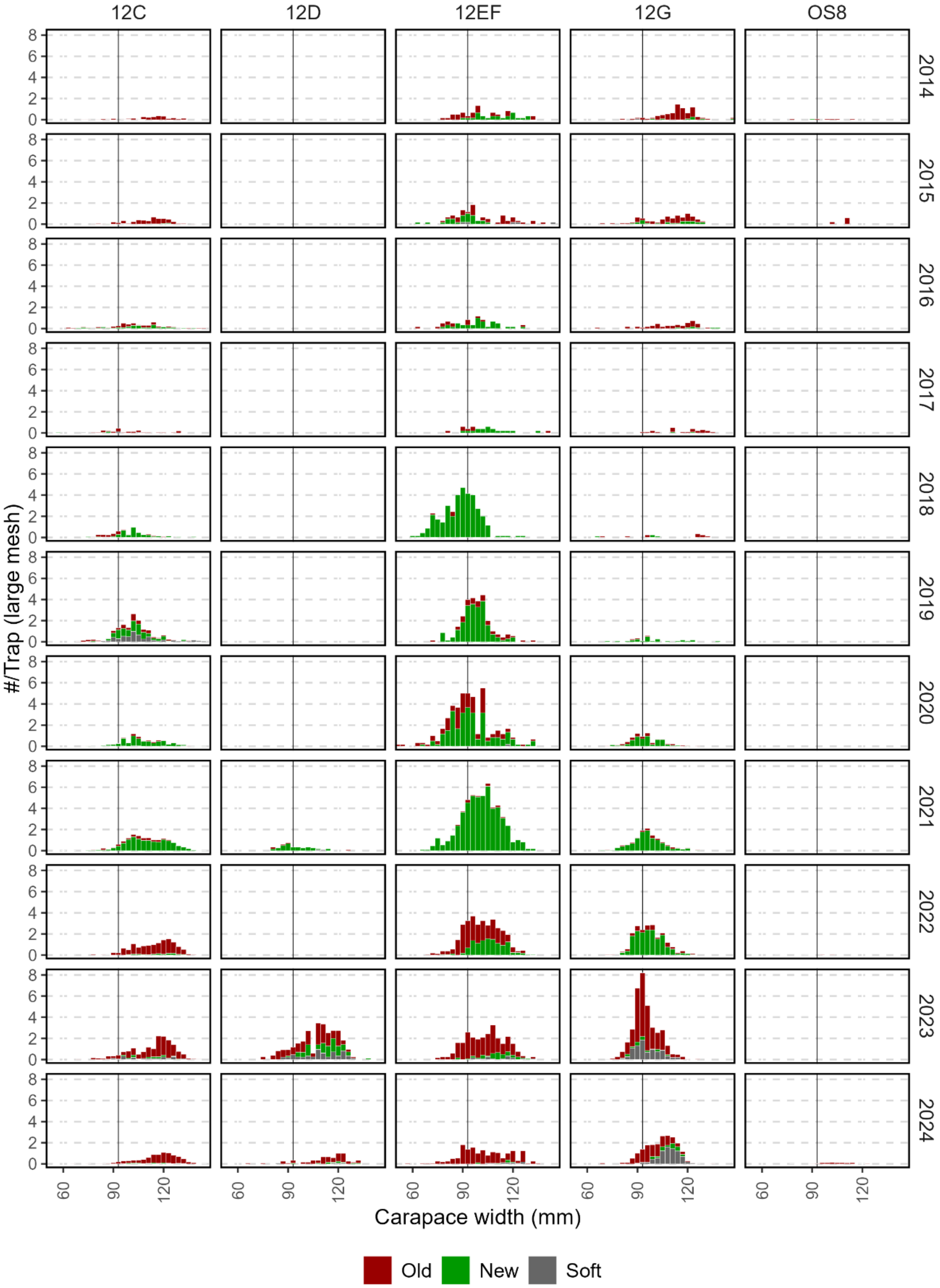

Figure A5.7. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 4R3Pn (2014–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

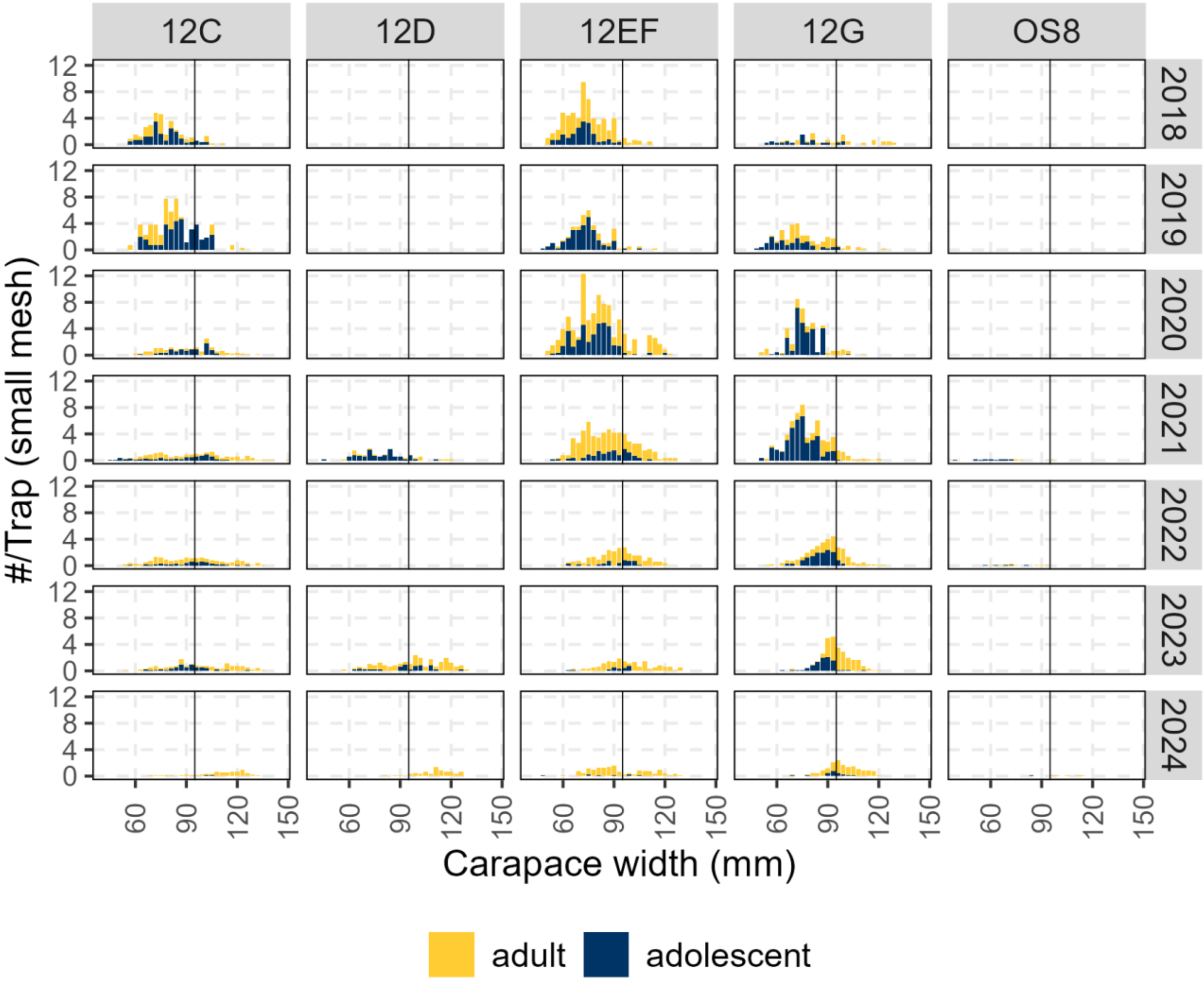

Figure A5.8. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey from Crab Management Areas within Assessment Division 4R3Pn (2018–24). The black vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.