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Canadian Science Advisory Secretariat (CSAS)

Research Document 2025/076

Newfoundland and Labrador Region

Assessment of Newfoundland and Labrador Snow Crab (*Chionoectes opilio*) in 2022

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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.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

[http://www.dfo-mpo.gc.ca/csas-sccs/
DFO.CSAS-SCAS.MPO@dfo-mpo.gc.ca](http://www.dfo-mpo.gc.ca/csas-sccs/DFO.CSAS-SCAS.MPO@dfo-mpo.gc.ca)



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ISSN 1919-5044

ISBN 978-0-660-79590-4 Cat. No. Fs70-5/2025-075E-PDF

Correct citation for this publication:

Pantin, J., Mullett, D., Coffey, W., Baker, K., Lefort, K., Cyr, F., Munro, H., and Koen-Alonso, M. 2025. Assessment of Newfoundland and Labrador Snow Crab (*Chionoectes opilio*) in 2022. DFO Can. Sci. Advis. Sec. Res. Doc. 2025/076. vi + 142 p.

Aussi disponible en français :

Pantin, J., Mullett, D., Coffey, W., Baker, K., Lefort, K., Cyr, F., Munro, H., et Koen-Alonso, M. 2025. Évaluation du crabe des neiges (Chionoectes opilio) à Terre-Neuve-et-Labrador en 2022. Secr. can. des avis sci. du MPO. Doc. de rech. 2025/076. vi + 150 p.

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ACKNOWLEDGEMENTS

Shellfish Section technicians and biologists (D. Sullivan, S. Quilty, M. Hurley, K. Charmley, B. Wells, C. Malayny, C. Korchoski, E. Coughlan, K. Skanes, S. Zabihi-Seissan) and many technicians from other sections in the Science Branch helped with data preparation and collection on surveys throughout the year. Fisheries Sampling Section personnel (M. Simpson, P. Higdon, T. Paddle, K. Fitzpatrick, T. Inkpen, and C. Peters) helped organize the Collaborative Post-season crab survey and compile data, as well as oversee the collection of the observer program and data. D. Maddock-Parsons assisted with the Collaborative Post-season trap survey program delivery. C. Barry and K. Tipple key-punched observer data and DFO Policy and Economics Branch personnel compiled and key-punched the logbook data.

ABSTRACT

The status of the Newfoundland and Labrador (NL) Snow Crab (*Chionoecetes opilio*) resource (Northwest Atlantic Fisheries Organization [NAFO] Divs. 2HJ3KLNOP4R) is assessed using a variety of metrics. The resource is assessed at larger-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 [CW] male Snow Crab) biomass indices, fishery catch per unit effort (CPUE), fishery recruitment prospects, and mortality indices. Information was derived from multiple sources: multispecies bottom trawl surveys conducted during fall in ADs 2HJ, 3K, and 3LNO Offshore and spring in AD 3Ps, two collaborative trap surveys covering all ADs, Fisheries and Oceans Canada (DFO) inshore trap surveys in ADs 3K, 3L Inshore, and 3Ps, fishery data from logbooks, landings from the dockside monitoring program, at-sea observer catch-effort data, and oceanographic surveys. Snow Crab landings remained near 50,000 t from 2007 to 2015, but steadily declined to a 25-year low of 26,400 t in 2019. Landings have continued to increase since then and were just under 50,000 t in 2022. Overall effort increased to near 3.4 million trap hauls in 2022. Overall standardized fishery CPUE was at a time-series low in 2018, but has increased to near the time-series high in 2022. The DFO trawl survey did not take place in 2022, therefore the trap survey time series was used to infer trends. The overall exploitable biomass index increased from historic lows in 2016–18 to near the long-term average in the past two years. The trap survey exploitable biomass index declined to a time-series low in 2017 and 2018, but has continued to increase since then. Fishery Exploitation Rate Indices (ERIs) were moderate to low in most ADs in recent years. Status quo removals would reduce or maintain the ERI in all ADs in 2023. Both pre-recruit (>75 mm CW adolescent males) catch indices and model predictions of exploitable biomass based on climate variables indicate that productivity for the next three to five years may remain similar to current levels. In 2023, all ADs are projected to be in the Healthy Zone of the Precautionary Approach (PA) Framework, except AD 2HJ, which is projected to be in the Cautious Zone. These projections assume status quo removals. 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 2023 that focused on identifying the exploitable biomass of Snow Crab available to the fishery.

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 a crab grows (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 (i.e., become 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, but 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 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, leads to delays in 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 not thought to be common 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 (Dawe et al. 2008; Foyle et al. 1989; 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 (Baker et al. 2021; Marcello et al. 2012). 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 cold, shallow areas with hard substrates during early ontogeny to warmer deep areas featuring softer substrate as they grow (Mullowney et al. 2018a). Large 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 separated into inshore and offshore portions where applicable and some 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 and therefore some CMA-level results are included in the Appendices. Snow 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. For example, in the 2019 Snow Crab assessment, there was evidence presented of a large redistribution of exploitable Snow Crab out of AD 3K and into AD 2HJ during the previous year and back into AD 3K the following year (Baker et al. 2021). This situation 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 to 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 2,250 license holders representing three dominant fleet sectors defined by vessel length in 2022.

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 (Figure 1). The AD 2HJ fishery occurs in offshore regions of central and southern Labrador. The bathymetry of the region 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, predominately 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 3L Inshore fishery occurs in coastal bays and near-to-shore regions within 25 nm of headlands off the east coast of Newfoundland, which are overall characterized by cold bottom water. It incorporates Bonavista Bay (CMA 5A), Trinity Bay (CMA 6A), Conception Bay (CMA 6B), Northeast (NE) Avalon (CMA 6C), Southern Avalon (CMA 8A), and St. Mary's Bay (CMA 9A) (Figure 1). The AD 3LNO Offshore fishery occurs 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 shifted earlier over the past decade and is now primarily prosecuted during spring and summer. 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 nm² grids in the offshore and 18 nm² grids in inshore areas of ADs 3L

Inshore, 3K, 3Ps, and 4R3Pn) for the remainder of the season when a threshold level of 20% soft-shelled crab in the legal-sized catch is reached. That threshold has since been reduced to 15% in ADs 3LNO Offshore and 3L Inshore and grids have been partitioned into quarters in some inshore areas in recent years. It became evident during 2010–12 that this protocol, as implemented, was not effective in controlling handling mortality. Among other issues, this reflects very low ASO coverage to monitor thousands of grid cells. Approximately <0.1–0.2% of the catch has been sampled in recent years. Beyond coverage capacity, there has been failure to invoke the protocol even when it was clear that the level of soft-shelled crab had exceeded the threshold, due to small sample sizes of measurements within a given cell associated with low fishery catch rates in recent years (DFO 2020; Mullaney 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 Fisheries and Oceans Canada (DFO). 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 compiling data from the most recent fishery, thus the terminal points are considered preliminary. In most years, the logbooks account for between 80–95% of the landings at the time of the assessment in all ADs, except 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 25–75% completion of the fishery.

Because 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 indicates binned five-day intervals and $Soak$ indicates 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.

OBSERVER CATCH-EFFORT AND AT-SEA SAMPLING DATA

At-sea sampling data by ASOs have been collected 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 AD 3LNO Offshore and consistently low in inshore CMAs. Overall, ASO coverage has decreased in recent years, particularly since 2020 (Figure 4, Figure 5). The increases in total allowable catch (TAC) during this time resulted in a further reduction in the percentage of landings observed. Sampling was particularly low in 2020 due to the COVID-19 pandemic, however, it remained low in ADs 3L Inshore, 3Ps, and 4R3Pn in 2021. There was an increase in the coverage in 2022, however, it remained low or absent in ADs 3L Inshore and 4R3Pn, therefore those ADs were excluded from the analyses.

Various catch rate indices were developed from shell condition staging conducted by ASOs. A three-stage assessment 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 CMA level where data were sufficient.

At-sea 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

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

$$Y_i \sim \text{binomial}(n_i, p_i)$$

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

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

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 on total catch numbers and weights were derived from depth-stratified multispecies bottom trawl surveys. These surveys were conducted during fall in NAFO Divs. 2HJ3KLNO and spring in Divs. 3LNO and Subdiv. 3Ps. The fall (post-season) survey has occurred annually in all but Div. 2H where it was executed each year from 1996 to 1999, bi-annually from 2004 to 2008, and annually from 2010 to present. Data north of 56° latitude in Div. 2H are omitted from the stock

assessment because of consistently low capture of Snow Crab and sporadic frequency of survey coverage in Div. 2H throughout the time series. Sampling of Snow Crab during spring Subdiv. 3Ps surveys began in 1996 and in Divs. 3LNO in 1999. The multispecies bottom trawl surveys did not take place in 2022, rather, a directed survey for comparative fishing between new and outgoing vessels took place in some divisions in the fall, and a survey with the new Canadian Coast Guard ship (CCGS) John Cabot took place in the spring. As the fall survey was not randomly depth-stratified and catchability conversion factors between vessels had not been determined at the time of the assessment, the Snow Crab data collected in 2022 from the trawl surveys was not used.

The survey trawl was changed to a Campelen 1800 shrimp trawl in 1995. This trawl proved to be more efficient in capturing crab than the previously used Engels 145 Hi-rise groundfish trawl that featured larger footgear. Therefore, the trawl survey time series for Snow Crab starts in 1995.

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 (Benoît and Cadigan 2014, 2016; Dawe et al. 2010a). Efficiency is lower and more variable on hard (typically shallow) substrates than on soft (typically deep) substrates, and higher during dark periods when crab appear most active. 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. Further, it differs across survey vessels, being higher on the CCGS Teleost and Alfred Needler than the Wilfred Templeman, which was in use until 2008 (Benoît and Cadigan 2014, 2016). Previous exploratory analyses have shown that conversions to account for time and vessel make negligible difference in scaling raw exploitable biomass indices to standardized estimates. This is because time-series trends within any given AD hold in all combinations of catchability conversions, and the effect size of any given vessel or area-specific conversion is small relative to a subsequent re-scaling adjustment applied to survey exploitable biomass estimates through a comparison with biomass estimates derived through fishery depletion estimations. Accordingly, no vessel or area-specific conversions were applied prior to re-scaling survey exploitable biomasses in this assessment but for some qualitative analyses a vessel conversion factor was applied to the raw data collected from the Wilfred Templeman to aid in interpretation of trends.

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.

Indices of small Snow Crab (<45 mm CW), adolescent (small-clawed) male Snow Crab (45–75 mm CW), pre-recruit Snow Crab (>75 mm CW adolescent males), and mature female Snow Crab (40–75 mm CW) were calculated by the annual number/tow for each Snow Crab group divided by the 2018–22 time-series mean for that group. 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 when hardened and full of meat. For example, a pre-recruit captured in either the 2020 spring or fall survey that undergoes a terminal molt to exploitable size in the subsequent winter or spring (i.e., 2021) would be identified as a recruit into the exploitable biomass in the 2021 survey(s), and should begin contributing to the fishery in 2022. 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.

DFO INSHORE TRAP SURVEYS

Data were available from DFO inshore trap surveys in ADs 3K, 3L Inshore, and 3Ps (Figure 6, Figure 7, Figure 8). In AD 3K, trap surveys were carried out in White Bay (CMA 3B), Green Bay (CMA 3C), and Notre Dame Bay (CMA 3D) during 1994–2022. These surveys have consistently occurred in late August to mid-September, and occupy five of the depth strata developed for multispecies trawl surveys. In AD 3L Inshore, trap surveys were carried out in Bonavista Bay (CMA 5A) and Conception Bay (CMA 6B) during 1979–2022, and Trinity Bay (CMA 6A) and St.

Mary's Bay (CMA 9A) during 2013–22. 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. 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 October. In AD 3Ps, a trap survey was carried out in Fortune Bay (CMA 11E) during 2007–22. This survey has occurred in late May to early June and encompasses 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 (commercial [135 mm]) and small-mesh (27 mm) traps intermittently placed within each 'fleet' of gear, with traps spaced approximately 45 m (i.e., 25 fathoms) 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 includes determination of CW and CH, shell condition (same categories as trawl survey), and presence of BCD. Females are sampled from small-mesh traps for the same morphometrics as males, with examination of the abdomen rather than chela height used to determine maturity, and the relative fullness and stage of egg clutches estimated. Occurrence of visually detectable incidence of BCD was determined as per protocols on the trawl surveys and mortality was inferred from levels of BCD observed in new-shelled males.

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 examined from a collaborative trap survey between the Torngat Joint Fisheries Board (TJFB) and DFO which takes place in CMA 1 (N5440) in AD 2HJ (Figure 9, Figure 10). This survey was initiated in 2013 and has occurred each year from late August to early September. The survey is conducted by technicians or ASOs onboard a commercial fishing vessel and consists of 20 fixed stations. At each station, nine large-mesh (commercial [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 protocols on the DFO inshore 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 by maturity from small-mesh traps were produced for the assessment. All analyses were limited to males, with sizes partitioned into 3 mm CW bins. This survey uses the same three-stage scale as the ASO sampling. In 2022, shell conditions were incorrectly identified, therefore proportions of residual (intermediate to old-shelled male) and recruit (new-shelled male) exploitable crab could not be determined.

COLLABORATIVE POST-SEASON TRAP SURVEY

Data were examined from an industry-DFO Collaborative Post-Season (CPS) trap survey in all ADs (Figure 9, Figure 10). These surveys were initiated in 2003 and have occurred annually following the fishery, typically beginning in late August or early September and ending in 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 vertically-limited 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 fixed (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 (commercial [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 10). Overall, more than 90% of the stations had a small-mesh trap in 2022. More small-mesh traps will be added into the survey in the coming years until every station is occupied by one small-mesh trap.

The same analyses described for the TJFB trap survey for catch rate indices and size frequencies from the large- 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. Only the core stations have been consistently surveyed in AD 4R3Pn, therefore only the core stations time series is presented for that AD.

Indices of small Snow Crab, adolescent male Snow Crab, pre-recruit Snow Crab, and mature female Snow Crab were examined by combining all trap survey data to calculate the annual number/trap for each Snow Crab group divided by the 2018–22 time-series mean for that group in each AD. These were evaluated beside similar trawl survey indices (see Multispecies Trawl Survey Data section). Catches of exploitable males from all trap surveys were used to estimate trap-based exploitable biomass.

EXPLOITABLE BIOMASS INDICES

The exploitable biomass indices were calculated from the survey catch of legal-sized (≥ 95 mm CW) males, regardless of shell condition or maturity. The exploitable biomass index generated

from spring survey data includes a component of soft- or new-shelled males that would not actually be retained by the fishery in the immediate year, but would be fully recruited to the fishery in the following year.

Trawl-Based Estimates

Ogive Mapping (Ogmap) (Evans et al. 2000) was used as the spatial expansion platform for biomass estimation of exploitable males from the trawl data. A nonparametric estimate was made of the probability distribution for trawl catch (unstandardized biomass) at any point in the area to be assessed (Figure 11). Total biomass was computed as the integral over the area of the mean value of the distribution. Confidence bounds were computed by bootstrap resampling from the distribution field. For spring surveys, the indices represent biomasses for the immediately upcoming (or on-going) fishery, whereas for fall (post-season) surveys they represent biomass for the fishery in the following calendar year.

Annual changes in biomass indices of recruits and residual crab in the exploitable biomass were examined. Crab captured as soft- or new-shelled represent recruitment into the exploitable biomass, while the residual biomass is comprised of intermediate to very old-shelled crab. In the absence of fishery effects or other source(s) of error, including subjectivity in shell age classification, annual changes in biomass would be expected to first be seen in recruits and to subsequently occur in residual crab.

Trap-Based Estimates

A stratification scheme conforming to the limited historic survey footprint that was used for estimating biomass indices from this survey in the past was used on the core stations time series. Spatial expansion of survey catch rates over the majority of the NL Shelf area was used for the time series of all stations (Figure 11).

Spatial expansion of trap survey catch rates into biomass indices was conducted using a modified version of Ogmap ('Ogtrap'). Ogtrap utilizes the same vertex points as Ogmap to integrate catch rates over any given spatial area. The input parameter of trawl swept area in Ogmap has been altered to conform to the effective fishing area of a crab trap, with the value set at 0.01 km². 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 from this survey remain as indices and are assessed in a relative sense.

DeLury-Adjusted Biomass Estimates and Exploitation Rate Indices

The exploitable biomass indices derived through Ogmap and Ogtrap were calculated from unstandardized raw survey data. However, it is known that catchability of crab by the survey trawl (i.e., trawl efficiency) is lower than 1, even for the most efficiently captured large males (Dawe et al. 2010a), and that raw survey biomass estimates are underestimated to variable extents across ADs (Mullowney et al. 2017). Accordingly, the 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.

The depletion analysis 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 the season. A linear mixed model (Eq. 4) 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. 4

$$\ln CPUE_i = \alpha + pot_c_i + a_i + \epsilon_i$$

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

where, $\ln CPUE$ 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. For example, no depletion occurred in catch rates during the 2019 fishery in AD 3Ps and a usable depletion-based biomass estimate could not be calculated. 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.

For the trawl time series, the depletion catchability scalars (S) represented the median difference between logbook and survey-based biomass estimates in each AD over the time series (Eq. 5):

Eq. 5

$$S = \sum_{y=2000}^{2022} (Ty/Dy * 1/n)$$

where, T is the raw exploitable biomass estimates from Ogmap, 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 trawl time series for each AD, calculated as the median. Standardized biomass indices were calculated as T/S . Although more realistic, these standardized biomass estimates are not absolute and remain interpreted as relative indices. The DeLury fisheries depletion biomass estimates are applicable to the beginning of the season (spring), therefore a one-year lag was applied to survey estimates in Divs. 2HJ3KLNO in calculating the annual scalars, as these surveys occur in the fall.

As with the trawl survey exploitable biomass estimates, the trap survey exploitable biomass indices derived through Ogtrap were scaled using S developed through fishery depletion regression analysis on catch rate data from logbooks. For the core stations time series, a constant S was calculated as the time-series median and standardized exploitable biomass was calculated as T/S . Only the core stations time series was used for AD 4R3Pn as the stations outside the core polygons have been poorly covered. For the all stations time series which starts in 2018, for ADs with trawl surveys, the trap survey biomass estimates were scaled to the trawl survey estimates based on average ratios over the 2018–22 period. For ADs 3L Inshore, where there is no trawl survey, annual depletion scalars were calculated and the median was calculated. Standardized exploitable biomass was calculated as T/S . The DeLury fisheries depletion biomass estimates are applicable to the beginning of the season (spring), therefore for

surveys occurring in late summer or fall, a one-year lag was applied to survey estimates in calculating the annual S .

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 for both trawl and trap time series (where they exist). 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. For provision of advice, exploitable biomass and ERIs based on smoothed two-period average biomass indices were calculated. This smoother was applied to account for annually variable survey performance and the possibility of year effects in biomass estimates, a feature typically raised during annual assessments.

ECOSYSTEM INDICES

Spring and fall bottom temperature climatological maps (1991–2020 average) and spring and fall 2022 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), the Arctic Oscillation (AO) (Szuwalski et al. 2021), the El-Niño Southern Oscillation (ENSO), and the 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 (Mullowney et al. 2023a; Szuwalski et al. 2021). The CIL is a body of <0°C water that sits intermediate in the water column and covers shallow areas of the NL 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, 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. An autoregressive (AR1) rho parameter on the residuals was included in each model due to the autoregressive nature of stock biomass measurements (i.e., the entire biomass does

not renew each year), with the preceding level of exploitable biomass affecting the subsequent year's measurement. The rho parameter was calculated and set separately from the autocorrelation function for each independent model run. The annual exploitable biomass index was combined with reported fishery landings to derive indices of total exploitable biomass. The long- and mid-term model (Eq. 6) and the full model (short-, mid-, and long-term) (Eq. 7) were plotted to forecast short-term exploitable biomass prospects, with each defined as:

Eq. 6

$$tBIO_t \sim te(Ice12, Ice13) + te(AO7, AO8) + rho_{(t-1)} + \varepsilon t$$

Eq. 7

$$tBIO_t \sim te(Ice12, Ice13) + te(AO7, AO8) + te(AO0, AO1) + rho_{(t-1)} + \varepsilon t$$

where, *tBIO* refers to total exploitable biomass, *t* refers to the year, *Ice* refers to cumulative February to April sea ice extent, *AO* refers to annual Arctic Oscillation Index, and the numerics with each explanatory term refer to the number of lag years. $rho_{(t-1)}$ refers to autoregressive AR1 parameter and ε represents white noise error.

Trends in predation mortality and consumption were not available in the current assessment due to the absence of trawl surveys in 2022, however previous analyses were presented. These indices are presented at the Ecosystem Production Unit (EPU) level (i.e., 2J3K, 3LNO, and 3Ps).

Relative predation mortality was examined with estimates of Snow Crab biomass consumed by fish predators generated by combining three sources of information: 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.

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 (Adams and Breck 1990; Macdonald and Waiwood 1987).

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 only 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) were 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 (D. Mullowney, unpublished 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 key objective of the meeting was to define Limit Reference Points (LRPs) consistent with the PA for NL Snow Crab, based on the best scientific information available. The PA Framework for the NL Snow Crab resource and fishery 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 (Mullowney et al. 2018b).

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 generalized additive mixed model (Eq. 8):

Eq. 8

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

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

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

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

where, ERI is the exploitation rate index based on a 2-period exploitable biomass index, CBI is the combined exploitable biomass index from trawl and trap surveys in the previous year (i.e., an average of the trawl and trap survey exploitable biomass indices and scaled within AD), and $NAO7$ is the index of annual NAO centered and lagged by 6–8 years, calculated as the annual mean NAO based on monthly data values before centering the 3-year average.

Predicted discards ($pDIS$) were estimated based on a generalized additive mixed model (Eq. 9):

Eq. 9

$$pDIS_i = \alpha + f_{1k}(wCPUE_i) + f_{2k}(medFD_i) + f_{3k}(EP_i) + a_i + \epsilon_i$$
$$a_i \sim N(0, \sigma_{AD}^2)$$
$$\epsilon_i \sim N(0, \sigma_{error}^2)$$

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 ratio of exploitable to pre-recruit Snow Crab 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 2020–22 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 2020–22 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 Mullaney 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.

In 2020, industry representatives submitted an alternative PA Framework for Snow Crab to be reviewed. Following peer review, this alternate PA Framework was not accepted and the DFO Science LRPs remained in place (DFO 2023b). A working group was re-established to bring forward a series of recommendations to DFO on the Upper Stock Reference (USR) points and Harvest Control Rules (HCRs). The USRs and HCRs 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 (Mullaney 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 industry, 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 expansion of the fishery to offshore areas (Figure 12). They 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 AD 3K. Landings remained near 50,000 t from 2007 to 2015 but steadily declined to a 25-year low of 26,400 t in 2019. Landings have increased since then and were just under 50,000 t in 2022.

In AD 2HJ, landings remained near 1,700 t from 2014 to 2019 but have since declined due to TAC reductions. Landings were 895 t in 2022 (Figure 13). In AD 3K, landings have increased from a time-series low of around 5,500 t in 2017 to around 9,800 t in 2022. In AD 3L Inshore, landings declined by 67% from a time-series high in 2015 to a low of 2,750 t in 2019. Landings have since increased to around 4,300 t in 2022. In AD 3LNO Offshore, landings declined by 48% from 2016 to 2019 to less than 13,000 t, the lowest level in two decades. The landings have since increased to around 26,600 t in 2022. In AD 3Ps, landings continued to increase from a time-series low of around 1,200 t in 2017 to around 7,700 t in 2022. In AD 4R3Pn, landings declined by 81% from a recent peak in 2013 to a time-series low of 167 t in 2020. Landings have increased since then and were 460 t in 2022.

Fishery timing transitioned from summer-fall to spring-summer throughout the 2000s in most ADs (Figure 14). 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. In 2022, median fishing weeks ranged from mid- to late April in ADs 4R3Pn and 3Ps, mid- to late May in ADs 3L Inshore and 3K, early June in AD 3LNO Offshore, and late June in AD 2HJ.

Fishing effort, as indicated by estimated trap hauls, increased by a factor of five throughout the 1990s as the fishery grew (Figure 15). 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 3.4 million trap hauls in 2022. Spatially, the distribution of fishing has remained relatively broad, but there have been notable changes in some ADs in recent years (Figure 16). 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 to just over 100,000 trap hauls in 2022 (Figure 15). In AD 3K, effort decreased to a 25-year low in 2019, with about 600,000 trap hauls, but increased to around 800,000 trap hauls in 2022. From 2017 to 2022, effort contracted primarily into the Funk Island Deep and areas west, with the furthest offshore portions of this AD appearing to have been abandoned (Figure 16). In AD 3L Inshore, effort reached a historical high of near 1 million trap hauls in 2017, but quickly decreased to a time-series low in 2020, with just over 300,000 trap hauls (Figure 15). Effort remained near this level in 2022. In AD 3LNO Offshore, effort expanded rapidly from 1992 to the mid-2000s and thereafter oscillated between 1.5 to 2 million trap hauls per year until decreasing to approximately 1 million trap hauls in 2019 and 2020. Effort has increased since and was about 1.6 million trap hauls in 2022. A substantial reduction in fishing effort was seen in

CMA 3N200 (eastern edge of the Grand Bank) in the last four years, with virtually no activity along the southern slope edge (tail of the Grand Bank) (Figure 16). In AD 3Ps, effort reached a 25-year low in 2020, but has since increased and was nearly 400,000 trap hauls in 2022 (Figure 15). Since around 2017 and 2018, there has been a reduction in effort in the most southerly portions of CMA 10B and along the southwest edge of CMA 11S (Figure 16). There was virtually no fishing activity in these areas in 2021 and 2022. 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 about a three decade low in 2020 (Figure 15). Effort has increased since and was nearly 50,000 trap hauls in 2022, however it is restricted to 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 16). 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.

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 to 2019, there was considerable spatial contraction of high levels of fishery CPUE; however, increases have been seen in many areas in the last three years (Figure 16). 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. Throughout the past 25 years, CPUE has shown a great deal of variability both across and within ADs (Figure 17).

Overall, the fishery performed poorly in 2017 and 2018, with standardized CPUE at a historical low (Figure 18). The overall standardized CPUE has greatly increased since then and was near the time-series high in 2022. In AD 2HJ, standardized CPUE increased to over 7 kg/trap in 2022, but remained below the time-series average (Figure 17). In AD 3K, standardized CPUE increased from a time-series low of 5 kg/trap in 2017 to above the time-series average, exceeding 11 kg/trap in 2022. In AD 3L Inshore, standardized CPUE remained near the time-series average level of about 11 kg/trap in 2022. In AD 3LNO Offshore, standardized CPUE increased to above the time-series average, exceeding 15 kg/trap in 2022. In AD 3Ps, the decline in fishery CPUE had been both precipitous and broad-based from 2010 to 2017, but all major fishing areas have had improved catch rates since then. The standardized CPUE was at a time-series high of around 19 kg/trap in 2022. In AD 4R3Pn, standardized CPUE was at a time-series high of over 8 kg/trap in 2022, however, logbook returns were very low in this AD, with only 58% of the landings accounted for in the logbooks at the time of the assessment.

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 Offshore, with improvements in the last four years in most ADs.

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. At-sea observer coverage was particularly low in ADs 3L Inshore and 4R3Pn in 2022 and was not used to infer trends in the stock assessment. In AD 2HJ, there have been periods of inconsistent ASO coverage. Catch composition tends to be dominated by recruits in this AD, however this was not the case in 2021 (Figure 19, Figure 20). The AD 3K fishery has observed overall catch rates of both residual crab and recruits at a consistent level since 2008, however, there have been increases observed in the last four years. The observed catch composition has been fairly consistent throughout most of the time series. At-sea observer coverage has been poor in AD 3L Inshore since 2020, however, the most recent ASO

data indicate a catch composition dominated by residual crab. In AD 3LNO Offshore, the compilation of recruit and residual crab were at a time-series low in 2018, however, observed catch rates have increased since then to near the time-series high in 2022. 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 to 2017. In 2018, there was a sharp increase in the observed catch rates and it has remained around that level since then. This increase in catch rates was dominated by recruits which was followed by higher levels of residual crab. In AD 4R3Pn, ASO coverage has habitually been poor and inconsistent, with particularly low coverage over the last five 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 21).

In AD 2HJ, there has been relatively consistent depletion throughout the season in recent years, but there has been replenishment between seasons with the start-of-season catch rates at a similar level each season for the last four years (Figure 22). End-of-season catch rates were slightly higher in 2022 than the previous three years. In AD 3K, the fishery began with relatively high catch rates, but has quickly and precipitously depleted the biomass in recent years. However, end-of-season catch rates have been higher in the last two to three years and start-of-season catch rates were particularly high in 2022, near 20 kg/trap. Increasing start-of-season catch rates indicate recruitment into the exploitable population between seasons. In AD 3L Inshore, a trend in depletion throughout the season and very little replenishment between seasons was particularly evident starting in 2016 and continuing to 2019 when the fishery began near its lowest level and ended at its lowest level in the time series, with precipitous depletion throughout the season. However, the start- and end-of-season catch rates were much higher in the last three years. A precipitous depletion throughout the season has not always been as evident in AD 3LNO Offshore as in some of the other ADs. There have been particularly high start-of-season catch rates in the last three years (near 15 kg/trap). In AD 3Ps, rapid depletion under minimal removals occurred in 2016 and 2017, however minimal depletion has been seen since. There have been increasing start-of-season catch rates indicating recruitment between seasons. 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 23–Figure 29), as described in the DeLury-Adjusted Biomass Estimates and Exploitation Rate Indices section. Start-of-season fishery-based exploitable biomass indices used to calculate scalars for trawl and trap exploitable biomass time series in each AD are depicted by the centered 3-year moving average DeLury-adjusted biomass line plots in Figure 29.

Biomass

Multispecies trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1995–98) (Figure 30). The annual index declined from a peak exceeding 400 kt in the late 1990s to about 150 kt in 2003 and then varied without trend until 2013. From 2013 to 2016, the annual exploitable biomass declined dramatically to a historical low, but has since increased. The trawl survey did not take place in AD 3LNO Offshore in 2021 or in any of the

ADs in 2022, therefore the stock-level trawl exploitable biomass index was not updated. However, the redesign of the CPS survey and subsequent incorporation of stations over a much larger area (Figure 9) has resulted in the trap-based exploitable biomass index becoming more temporally aligned with the trawl-based exploitable biomass index, rather than lagging behind the trawl trends as was evident with the previous survey design. The two surveys are now measuring approximately the same grounds at approximately the same time. Therefore, the trap exploitable biomass index was used exclusively for stock-level exploitable biomass trends in 2021 and 2022, as well as AD-level trends in 2022. The trawl and trap survey exploitable biomass indices increased from historic lows in 2016–18, but the trap exploitable biomass index appeared to stabilize in 2022, with this index remaining around 200 kt over the last two years (Figure 30).

Overall trends in trawl and trap survey exploitable biomass indices mask spatiotemporal variability among ADs (Figure 31, Figure 32), as well as potential confounding factors occurring within any given area. In AD 2HJ, the trap survey exploitable biomass index increased slightly in 2022, but remains low for the time series. Despite consistency across the two time series, stock status interpretation has been compromised in recent years by incomplete trap surveys from 2017–19 and reduced coverage of the fall multispecies trawl surveys in 2019 and 2021. The 2017–19 point estimates from the trap time series in AD 2HJ are considered incomplete due to incomplete and improperly collected data in the CPS survey those years. Large proportions of data were not collected properly and therefore are unavailable for analyses and many core stations were not surveyed. In AD 3K, the trap exploitable biomass index has been increasing since the time-series low in 2018, but remained at a similar level in 2021 and 2022. In AD 3L Inshore, the trap exploitable biomass index increased over the last three years. In AD 3LNO Offshore, the trap survey exploitable biomass index has been increasing since the time-series low in 2018, but remained at a similar level in 2021 and 2022. The survey was not completed correctly in CMA Nearshore (CMA NS) in 2022, therefore the AD-level exploitable biomass index does not include data from that area. In AD 3Ps, the trap survey exploitable biomass index increased to a time-series high in 2022. In AD 4R3Pn, the trap survey exploitable biomass index increased over the past four years to near a time-series high in 2022.

Although almost 50% of the sampling locations have been randomly determined since 2018, the prior spatially restricted coverage of the CPS survey core stations essentially measured the exploitable biomass on primary fishing grounds and constituted an analog of fishery CPUE. The concentrated distribution on strongest aggregations of exploitable biomass in the CPS survey and fishery created hyperstability in both data sources (DFO 2022). Accordingly, the spatially all-encompassing trawl survey generally detected changes in the biomass prior to them being detected in the CPS survey core stations or fishery for most of the time series (Pantin et al. 2022). This lag between measuring signals of change in biomass among metrics likely reflects the inclusion of marginal grounds in the trawl survey, where, operating under an assumption of some degree of density-dependent regulation, signals of change in stock size would be expected to occur first. The inclusion of the random stations since 2018 in the current stock assessment has shifted the CPS survey to a distribution more similar to that of the trawl survey, however a one-year lag in trends can still be seen in some areas.

Collectively, the survey and fishery metrics are consistent in showing an exploitable biomass that has improved in recent years.

Recruitment

In the absence of 2022 trawl data, recruitment into the exploitable biomass was solely examined from catch rates of new-shelled exploitable Snow Crab from the trap surveys. Snow Crab captured as soft- or new-shelled in the current survey represented recruitment into the

exploitable biomass, while the residual biomass was comprised of intermediate- to very old-shelled crab. 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). In AD 2HJ, throughout most of the time series, the exploitable biomass has largely consisted of incoming recruits (Figure 31). There was a small increase in the catch rates of recruits in the CPS survey covering the southern part of the AD in 2022 (Figure 33, Figure 34). Shell condition was not determined correctly in the northern survey (i.e., TJFB trap survey), however it is very likely that the small increase observed in that area was also primarily due to recruits, as catches of residual crab have remained very low in that survey throughout the time series. Despite confusion on shell condition, modest increases in catch rate magnitudes in the surveys indicate there may be a small improvement in fishery prospects for AD 2HJ in 2023. In AD 3K, the exploitable biomass has consisted largely of incoming recruits throughout the time series (Figure 31), however there has been an increase in the proportion of residual crab in the last three to four years, with similar catch rates of recruit and residual crab in the trap time series (Figure 33, Figure 34). There was a decrease in catch rates of recruits in the CPS survey in 2022, returning to levels observed of 2021, suggesting fishery prospects remain the same. In AD 3L Inshore, recruitment into the exploitable biomass has remained steady for the last four years, with a slight increase in catch rates of recruits in the CPS survey in 2022 (Figure 33, Figure 34). This suggests fishery prospects will remain unchanged in 2023. In AD 3LNO Offshore, there was a large increase in recruits in the trawl survey in 2020 (Figure 31), however the trawl survey has been incomplete in this AD for the last two years and catch rates of recruits in the CPS survey indicate a decline in 2022 (Figure 33, Figure 34). Despite incomplete information, the information on recruitment that is available suggests no marked changes in fishery prospects for AD 3LNO Offshore in 2023. In AD 3Ps, recruitment into the exploitable biomass has remained fairly steady for the last four years, with a slight increase in catch rates of recruits in the CPS survey in 2022, returning to similar levels as 2019 and 2020 (Figure 33, Figure 34). The increase in recruits suggests potential improvements in fishery prospects for 2023. With gaps in both the trawl and trap time series, overall trends can be interpreted, but year-to-year changes can be missed. In AD 4R3Pn, most of the trap survey time series has shown higher catch rates of recruit crab than residual crab. However, in 2022 the catch rates of recruits decreased and there were higher catch rates of residual crab (Figure 33, Figure 34).

Toward inferring prospects beyond 2023, trends in pre-recruitment were examined from catch rates of pre-recruits in the trawl and trap time series and provide an indication of recruitment prospects for the next two to four years (Figure 35, Figure 36). However, the proportion of the pre-recruit adolescents measured by these surveys that reach exploitable biomass depends on several factors including natural mortality and the size at which crab terminally molt. The distribution of pre-recruit Snow Crab follows that of exploitable Snow Crab closely and changes seen in exploitable Snow Crab distribution are reflected in the pre-recruits as well (Pantin et al. 2024). Collectively, recent trends in pre-recruit indices from the trawl and trap surveys suggest a moderate level of pre-recruit abundance in all ADs, except 2HJ, where both surveys have shown a declining trend in recent years (Figure 36). These trends suggest limited resource growth in the short term.

Toward inferring long-term prospects, trends in small Snow Crab were examined from catch rates of Snow Crab less than 45 mm CW. Indices of small Snow Crab can provide an indication of recruitment prospects in four to seven years. As with pre-recruit Snow Crab, the proportion of the small crab measured by these surveys that reach exploitable size depends on several factors including mortality, skip-molting incidence, and the size at which crab terminally molt.

Trawl data are primarily used to infer trends in small crab as the small-mesh traps catch very few crab of that size. The distribution of small Snow Crab tends to be broader than exploitable and pre-recruit crab, with small crab caught in the same offshore areas as the larger size categories, as well as more inshore areas (Pantin et al. 2024). There has been an increasing trend in catch rates of small crab in the trawl surveys in ADs 2HJ and 3Ps in the last two to three years (Figure 36).

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 emerged again in recent years (Figure 36). Decreasing catch rates in the small-mesh traps have also been seen in ADs 3L Inshore, 3LNO Offshore, 3Ps, and 4R3Pn. Careful monitoring of the decreasing trend, particularly in light of the declines in male size-at-terminal molt (see Size-at-Maturity section), especially in AD 2HJ, will be important moving forward as this could have serious implications for reproductive potential in AD 2HJ and potentially other ADs considering upstream/downstream population connectivity. The overall spatial distribution pattern observed in recent years is typical of a dominant shallow water presence of mature females (Pantin et al. 2024). For example, relatively high abundance was consistently 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 Offshore. 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. These shallow areas, where the majority of reproduction occurs, are typically very cold. Mullaney 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.

Variability in annual abundance indices of females 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. Further research into the importance of female abundance in regulating stock productivity is required.

Environment

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 (Mullaney 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 to 2017 (Cyr et al. 2024).

The last five years have shown an overall trend towards warmer and potentially less favorable environmental conditions for future Snow Crab productivity (Figure 37, Figure 38). It was particularly warm in 2021 and 2022, with the NL Climate Index (Cyr and Galbraith 2020) indicating 2021 was the warmest year of the time series and 2022 was in the top five warmest years (Cyr et al. 2024). 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 Snow 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 potentially decline over the next five years (Figure 39).

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., AD 3LNO Offshore) (Mullowney et al. 2014). Conversely, recent assessments have highlighted that heavy exploitation has grown in importance over the past decade. While there have been issues in completing trawl surveys over the last two years, in recent years (>2019) there has been a general trend of improvements in the exploitable biomass 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 2014b; Pedersen et al. 2017; Rose and Rowe 2015). There have been no updates in diet information since the last assessment, where it was observed that while the predation mortality index remained among the highest in recent years, there have been declines from the peaks of 2016–18 (Pantin et al. 2024). The predation mortality index in 2019–21 was among the highest levels in 2J3K and 3LNO, but declined to its lowest value in over 25 years in 3Ps by 2021. Predation mortality was higher in 2J than in 3K. 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. Following that consumption occurs primarily on small- to intermediate-sized crab, the predation mortality index may also infer mid- to long-term recruitment prospects. The recent decrease in the index in all ADs since about the mid-2010s is consistent with most other data suggesting forthcoming declines in recruitment.

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). Total fish biomass levels remain much lower than prior to the finfish collapse in the early 1990s, however some ecosystem indicators (i.e., biomass trends and stomach content weights) appear to be improving in the most recent years for which data is available. However, overall biomass has yet to return to the levels of the early 2010s. Increased nutrient availability and phytoplankton 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 (DFO 2023a). 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 can be calculated based on stage-specific biomass indices of exploitable Snow Crab, which indicate the exploitable Snow Crab that remain from the previous year. In the absence of trawl data in 2022, this index could not be updated. Total mortality in exploitable Snow Crab was high in all ADs with trawl surveys during 2015 to 2017 (DFO 2022), and in recent years total mortality has been highest in AD 2HJ. 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 one 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 since the 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, as seen by the lower levels observed in the trawl survey. In the absence of trawl data in 2022, the trawl BCD time series could not be updated. However, prevalence of BCD in new-shelled crab was still captured from the DFO inshore trap surveys (see Appendices A2 and A3).

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 (Dufour et al. 1997; Grant 2003; Miller 1977; 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 ADs 2HJ and 3L Inshore, where discard levels were very high at approximately 40% of the catch in 2019 (Figure 40). At-sea observer sampling data suggest that the discards in AD 2HJ have been comprised of mostly legal-sized soft-shell crab, while the bulk of discards in AD 3L Inshore have been undersized, old-shelled crab (Figure 41). Accordingly, relative levels of resource wastage in the form of discard mortality are likely highest in the AD 2HJ fishery, assuming survival is lowest in soft-shell crab. Due to poor ASO coverage in some areas, trends in discard levels and compositions are not available for all ADs in all years since 2019 (Figure 40, Figure 41). Assessment Division 3K most recently had a peak in discarding in 2017–18 nearing 40% discarded and with higher amounts of legal-sized soft-shell crab. These periods of high soft-shell crab discarding were associated with generally low and declining recruitment and exploitable biomass. In 2022 the majority of discarded crab in AD 3K were represented by undersized hard-shelled crab. In AD 3LNO Offshore, 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, with the majority of the discards consisting of undersized hard-shelled crab.

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 crab 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 related to CPUE, suggesting that maintaining a high fishery CPUE is a good management strategy to avoid high discarding (Figure 42) (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 reexamined.

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). The trawl survey time series is usually used to infer trends in exploitation in ADs 2HJ, 3K, and 3LNO Offshore. The trap-based exploitable biomass index is preferred for AD 3Ps as the trawl survey occurs within-season, as opposed to post-season as in the other ADs. However, with the redesign of the trap survey and consequent agreement in exploitable biomass index between trawl and trap surveys, the trap-based ERIs were used in the absence of 2022 trawl survey data in all ADs. In AD 2HJ, the trap survey-derived ERI increased in 2022; however, under status quo removals in 2023 the ERI is projected to decrease (Figure 43). In AD 3K, the trap survey-derived ERI decreased in 2022 and under status quo removals in 2023 the ERI is projected to remain at a similar level. In AD 3L Inshore, the trap survey-derived ERI remained at a similar level in 2021 and 2022; however, under status quo removals in 2023 the ERI is projected to decrease. In AD 3LNO Offshore, the trap survey-derived ERI remained at a similar level from 2020 to 2022 and no change is projected under status quo removals in 2023. In AD 3Ps, the trap survey-derived ERI increased in 2022; and under status quo removals in 2023 the ERI is projected to remain at that level. In AD 4R3Pn, the trap survey-derived ERI increased in 2022; however, with status quo removals in 2023 the ERI is projected to decrease.

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. For example, exploitation rates above 42% are not permitted under the PA Framework used to manage the Snow Crab fishery in the southern Gulf of St. Lawrence, even when the biomass is extremely high (DFO 2014a). In NL, in historic portions of the time series in ADs 2HJ and 3K, there have been a lack of old-shell crab in the biomass, even at the 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 historic patterns of high exploitation rates have become reduced in recent years in most ADs (Figure 43)

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) was demonstrated during recent stock assessments for the NL Snow Crab stock (Mullowney and Baker 2021; Pantin et al. 2024). This shift occurred in all major ADs around 2015–17, but persisted in AD 2HJ and was well below exploitable size (i.e., 62–76 mm CW from 2015–21). This work has not been updated with data past 2021 due to interruptions in the trawl survey sampling and coverage. 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 should continue to be monitored closely.

Precautionary Approach

In 2023, assuming status quo removals, CPUE is predicted to remain in the Healthy Zone in all ADs, except AD 2HJ, where the predicted CPUE remains in the Cautious Zone (Figure 44).

Discard levels, assuming status quo removals, are predicted to be in the Healthy Zone in all ADs for 2023 (Figure 44).

Data from both the fall and spring surveys throughout Divs. 2HJ3KLNOPs show that in nearly all years the vast majority (i.e., >80%) of mature females are carrying full clutches of viable eggs (Figure 44). In 2022, 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 and 2007, AD 3K in 2015, and AD 3Ps in 2014–16 (Figure 44). 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.

In 2023, the stock status in all ADs are projected to remain in the Healthy Zone in the PA Framework, except AD 2HJ which is projected to remain in the Cautious Zone (Figure 45). These projections assume status quo landings. Recent and ongoing data deficiencies resulted in the exclusion of AD 4R3Pn in the PA Framework.

CONCLUSIONS

Assessment Division 2HJ

Exploitable biomass and recruitment indices have remained low for many years, however there were slight increases in these trap-based indices in 2022. The ERI was high throughout most of the time series relative to other ADs within NL, as well as other fished Snow Crab stocks globally. The trap-based ERI is projected to decline with status quo removals in 2023. In addition to low residual biomass and high fishing pressure in recent years, there have been declines in the male size-at-terminal molt and mature female abundance index in AD 2HJ (DFO 2022). Due to the absence of a trawl survey in 2022, the male size-at-terminal molt could not be updated. However, recent trends are concerning and could dampen recruitment if a higher proportion of males reach their terminal molt below exploitable size. Following the PA Framework, with status quo removals the stock status is projected to be in the Cautious Zone in 2023.

Assessment Division 3K

Exploitable biomass and recruitment indices have increased in the last four years, with the trap-based exploitable biomass index remaining at a similar level in 2021 and 2022. There was a decrease in recruitment in the trap time series in 2022. The ERI was high throughout most of the time series relative to other ADs within NL, as well as other fished Snow Crab stocks globally, but the trawl-derived ERI has been at a much lower level since 2020. With status quo removals, the trap-based ERI is projected to remain at a low level in 2023. Following the PA Framework, with status quo removals the stock status is projected to be in the Healthy Zone in 2023.

Assessment Division 3L Inshore

The exploitable biomass index increased over the last three to four years and recruitment has remained steady for the last four years. The ERI remained at a similar level in 2022; however, under status quo removals in 2023 the ERI is projected to decrease. Following the PA Framework, with status quo removals the stock status is projected to be in the Healthy Zone in 2023.

Assessment Division 3LNO Offshore

There has been an increasing trend in the exploitable biomass index in the trap surveys for the last three to four years, with the index remaining steady in 2022. There was a decrease in recruitment in the trap time series in 2022. The trap-based ERI is projected to remain at a low level with status quo removals in 2023. Following the PA Framework, with status quo removals the stock status is projected to be in the Healthy Zone in 2023.

Assessment Division 3Ps

The trap-based exploitable biomass index has continued to increase to a time-series high in 2022. Recruitment has remained around the same level for the last four years. The trap-based ERI is projected to remain at a low level with status quo removals in 2023. Following the PA Framework, with status quo removals the stock status is projected to be in the Healthy Zone in 2023.

Assessment Division 4R3Pn

The exploitable biomass index has increased over the past four years, nearing time-series high levels. There was a decrease in recruitment in 2022. The ERI increased in 2022, however it is projected to decrease with status quo removals in 2023. Completion of the trap survey outside the major fishing areas has been poor, therefore stock status was attributable primarily to CMAs 12C and 12EF. Recent and ongoing data deficiencies do not allow inclusion of this AD into the PA Framework.

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FIGURES

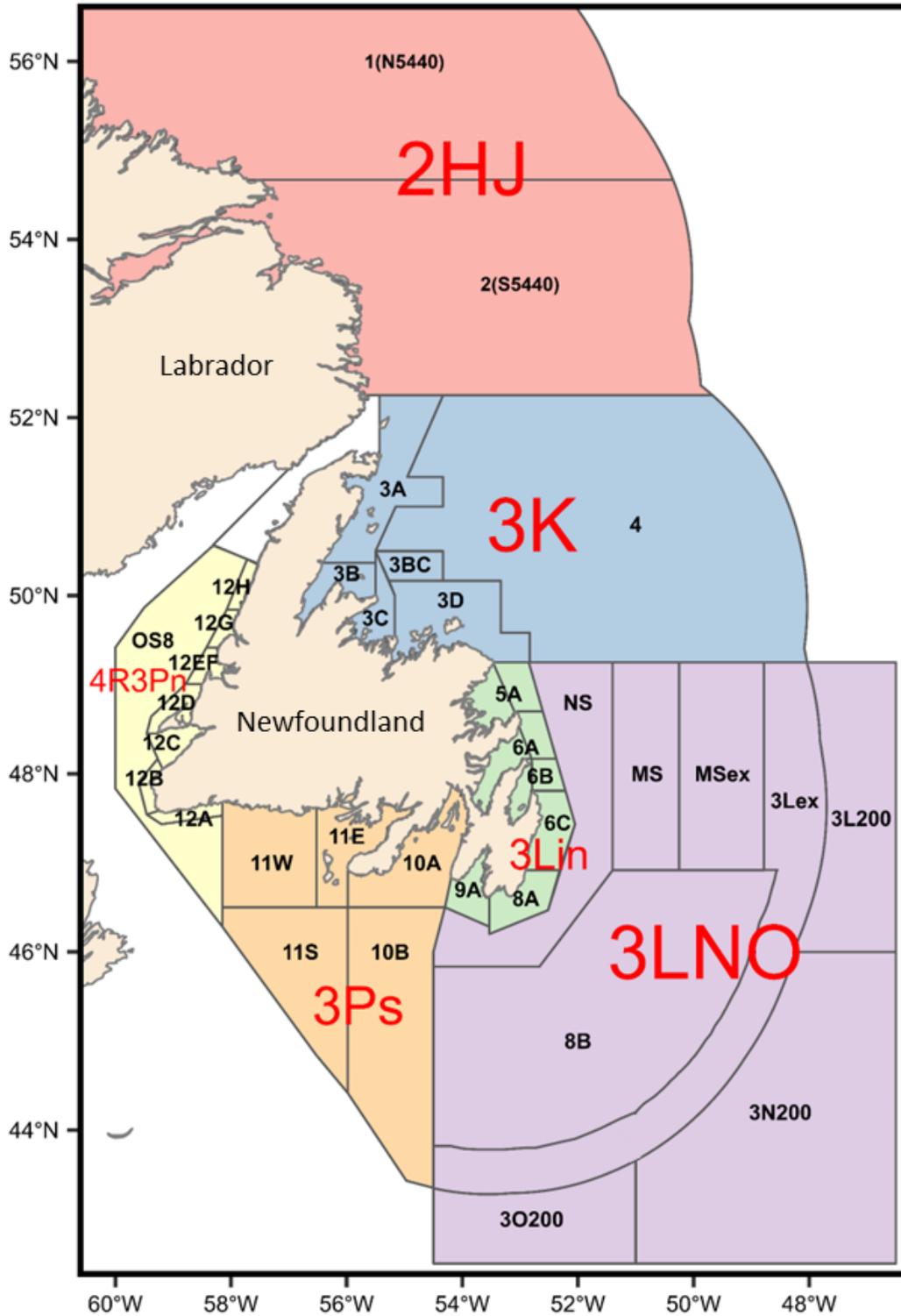


Figure 1. Newfoundland and Labrador Snow Crab Management Areas (CMAs) (black lines) and Newfoundland and Labrador Snow Crab Assessment Divisions (ADs) (colored blocks).

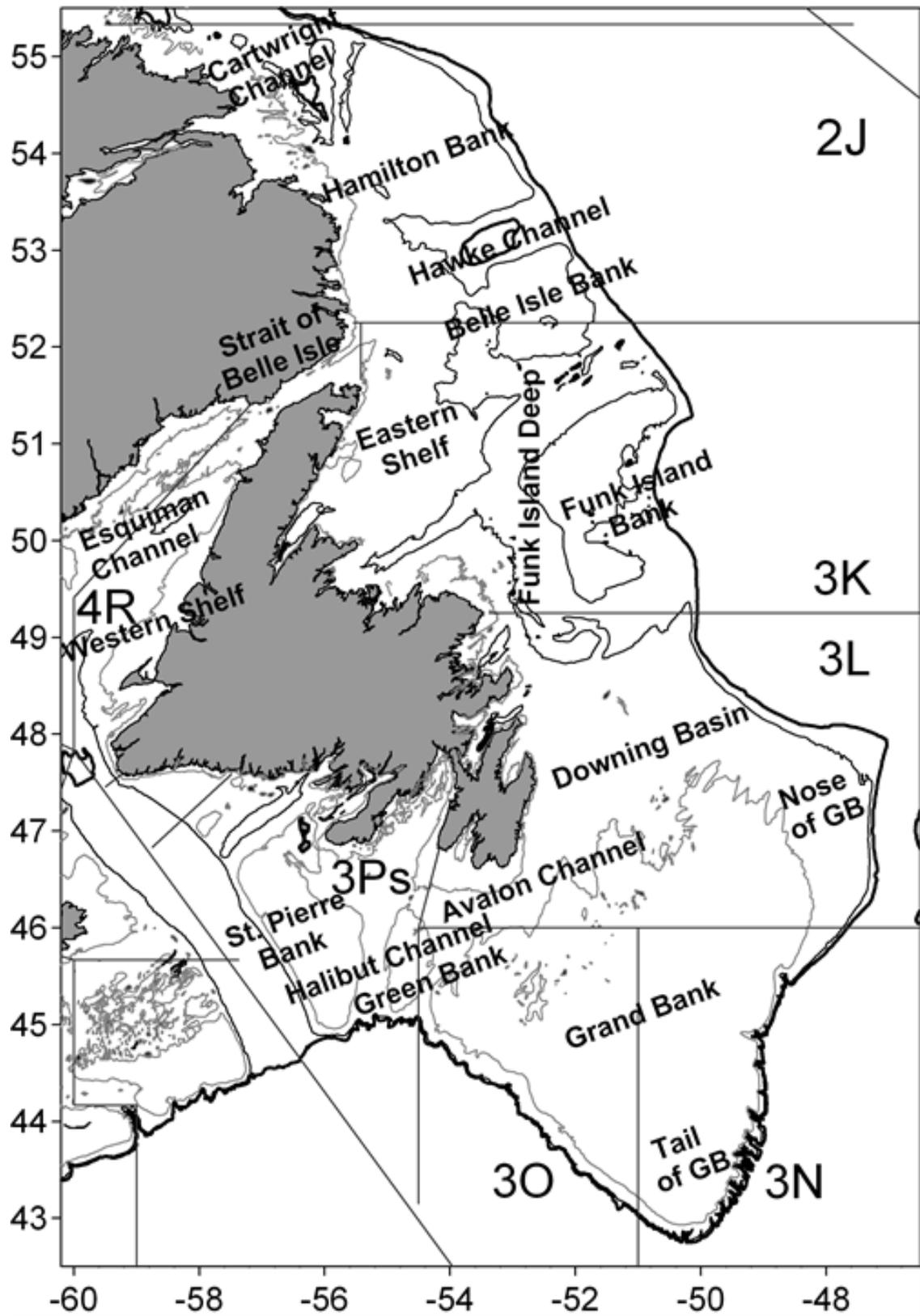


Figure 2. Map of Newfoundland and Labrador Continental Shelf showing place names, bathymetrical features, and NAFO Divisions.

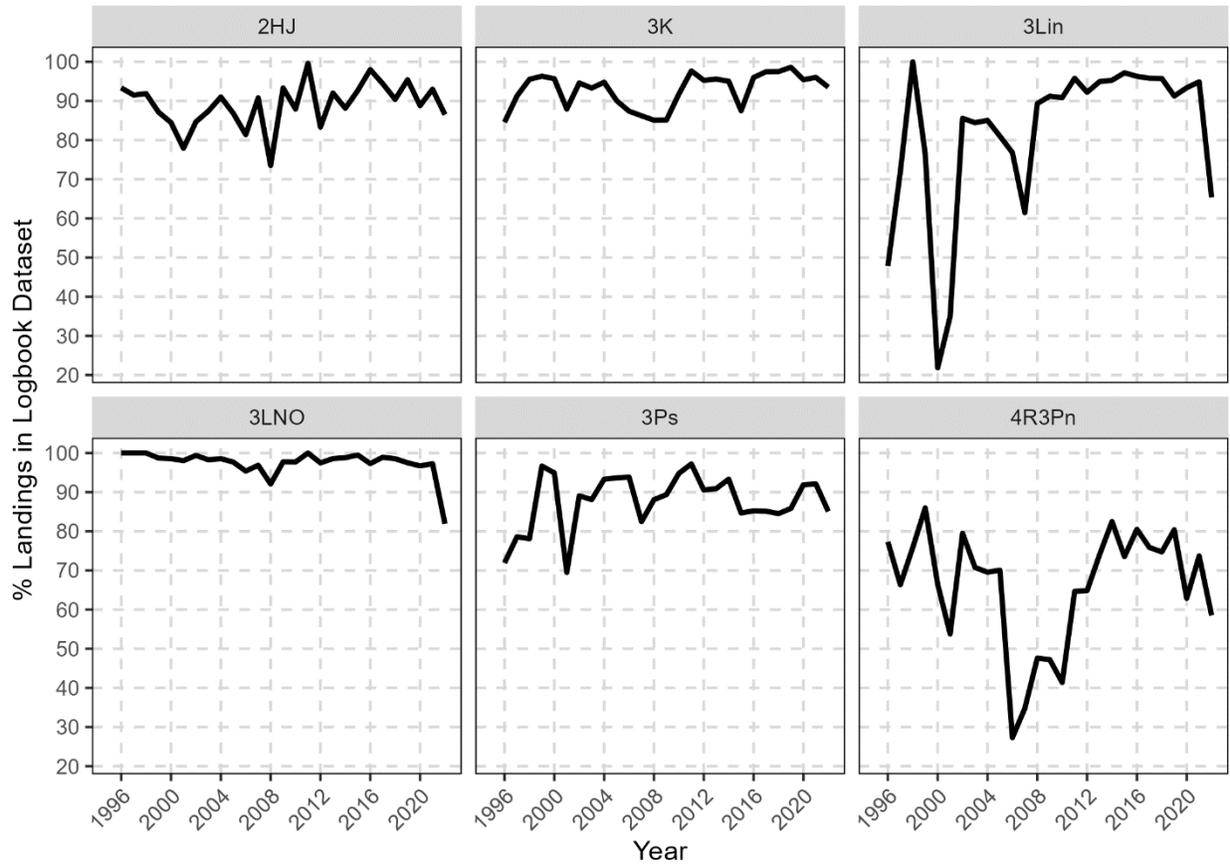


Figure 3. Logbook return rates by Assessment Division and year (1996–2022).

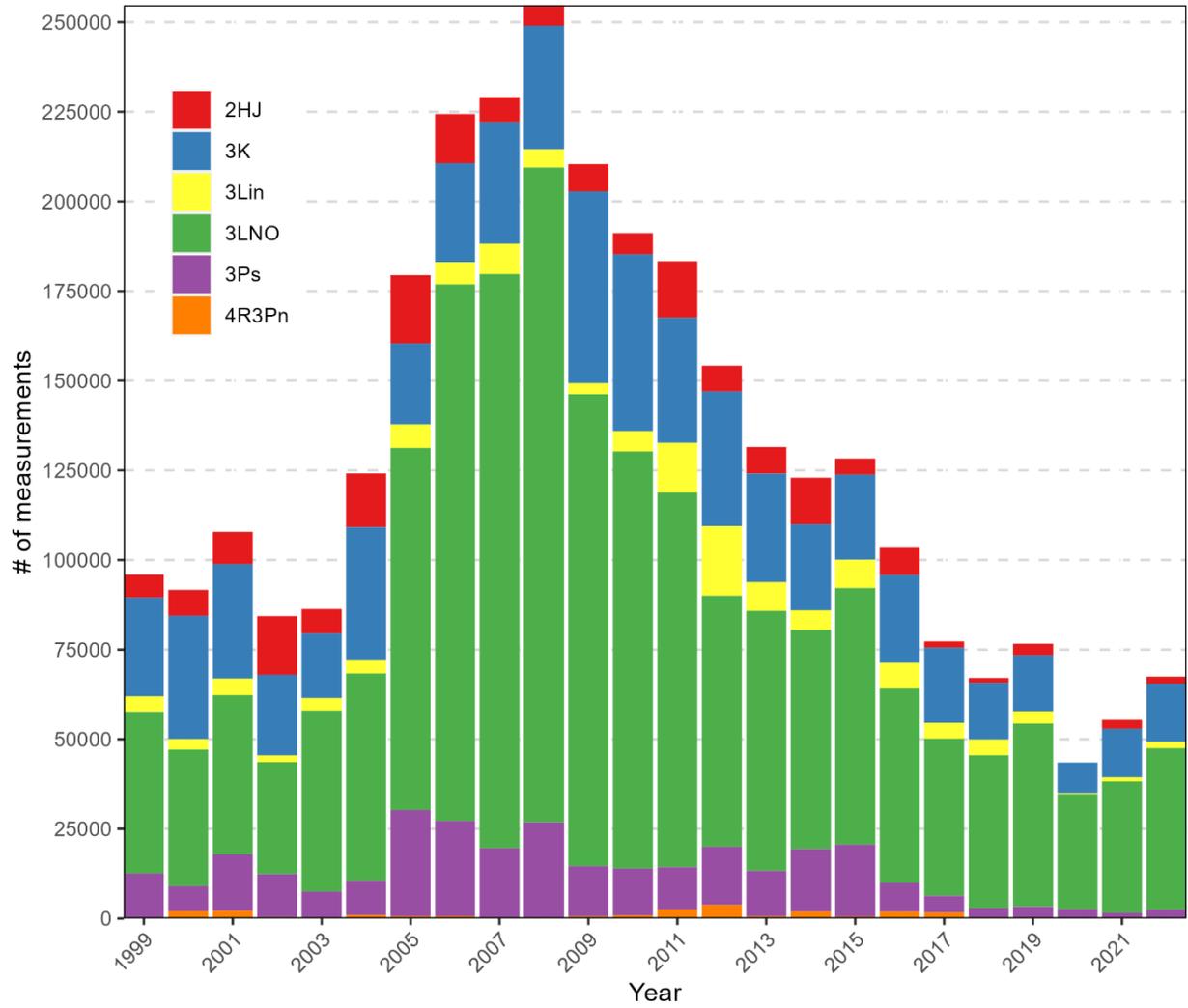


Figure 4. Number of Snow Crab measured by at-sea observers by year (1999–2022). Colored bars represent Assessment Divisions.

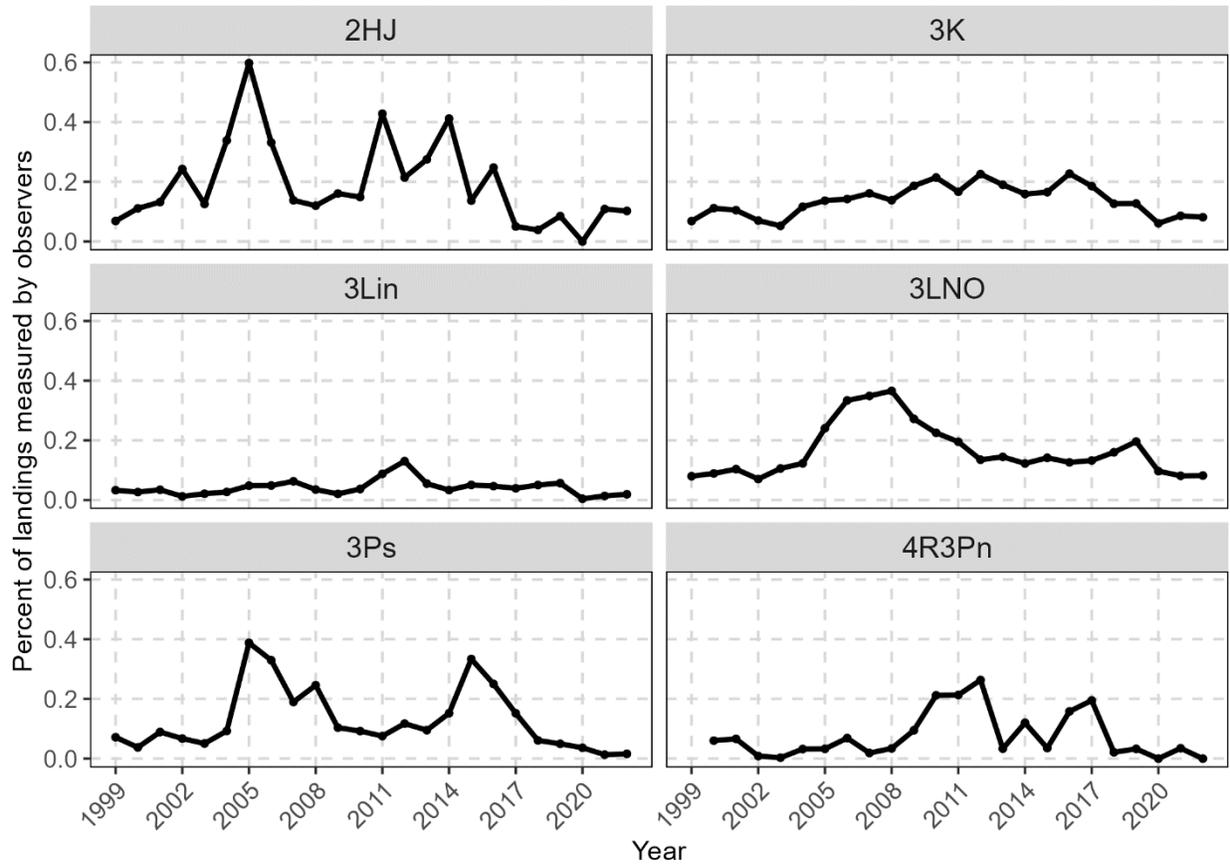


Figure 5. Percent of landings measured by at-sea observers by Assessment Division and year (1999–2022).

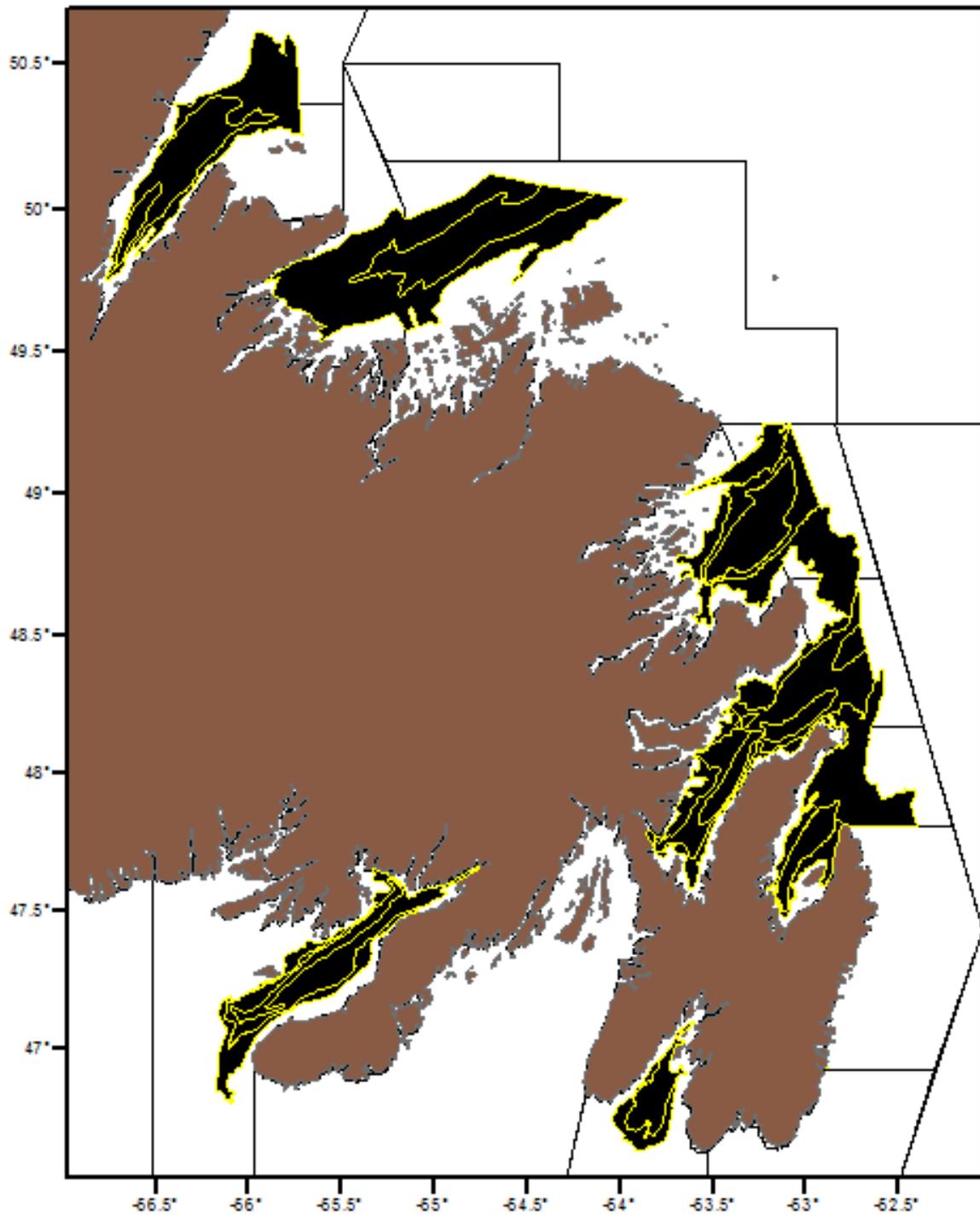


Figure 6. Strata occupied during DFO inshore trap surveys. Yellow lines outline the individual depth strata and black areas represent the area over which stations can be allocated.

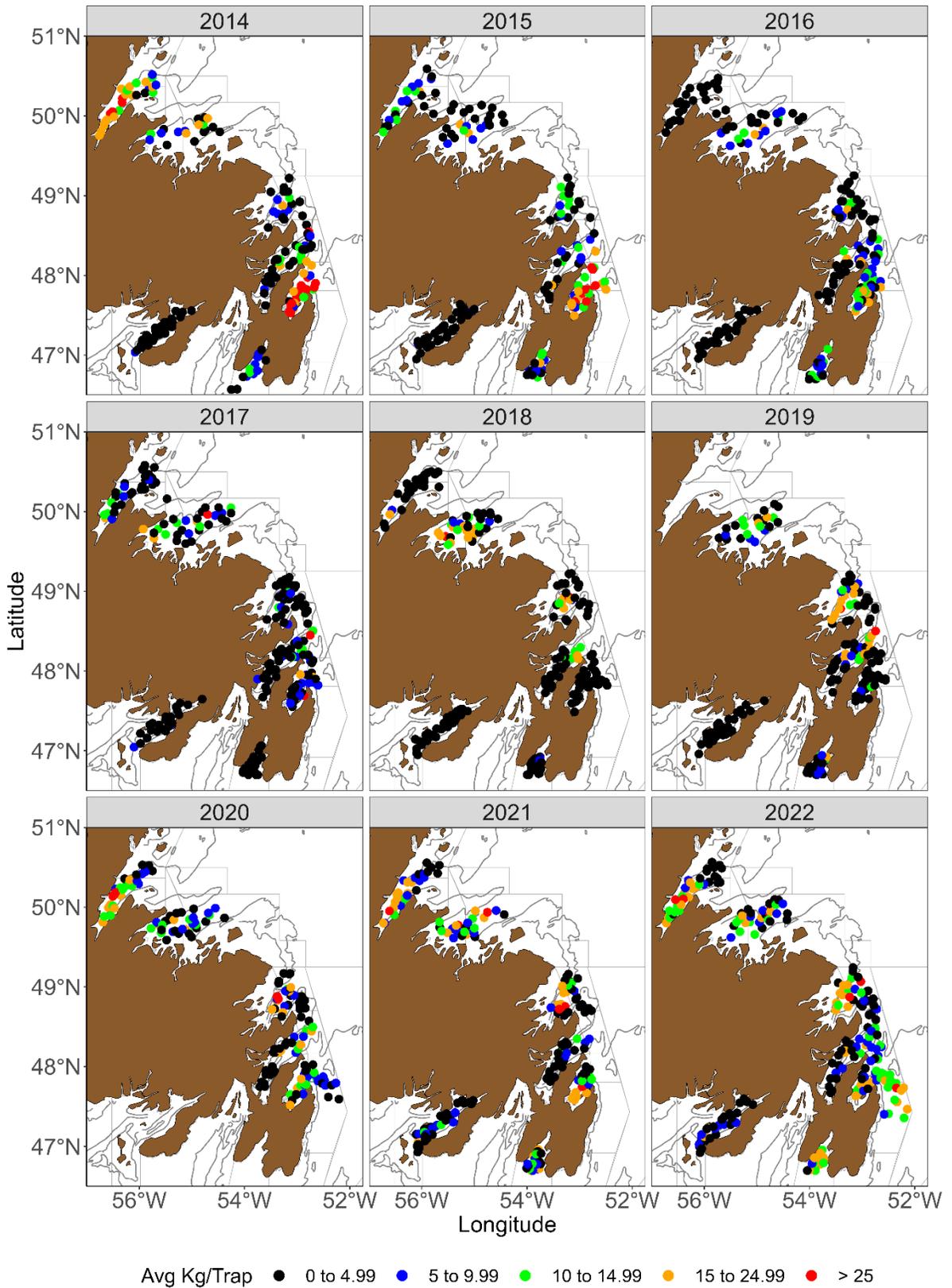


Figure 7. Location of sets and CPUE (kg/trap) of exploitable Snow Crab in large-mesh traps from the DFO inshore trap surveys (2014–22).

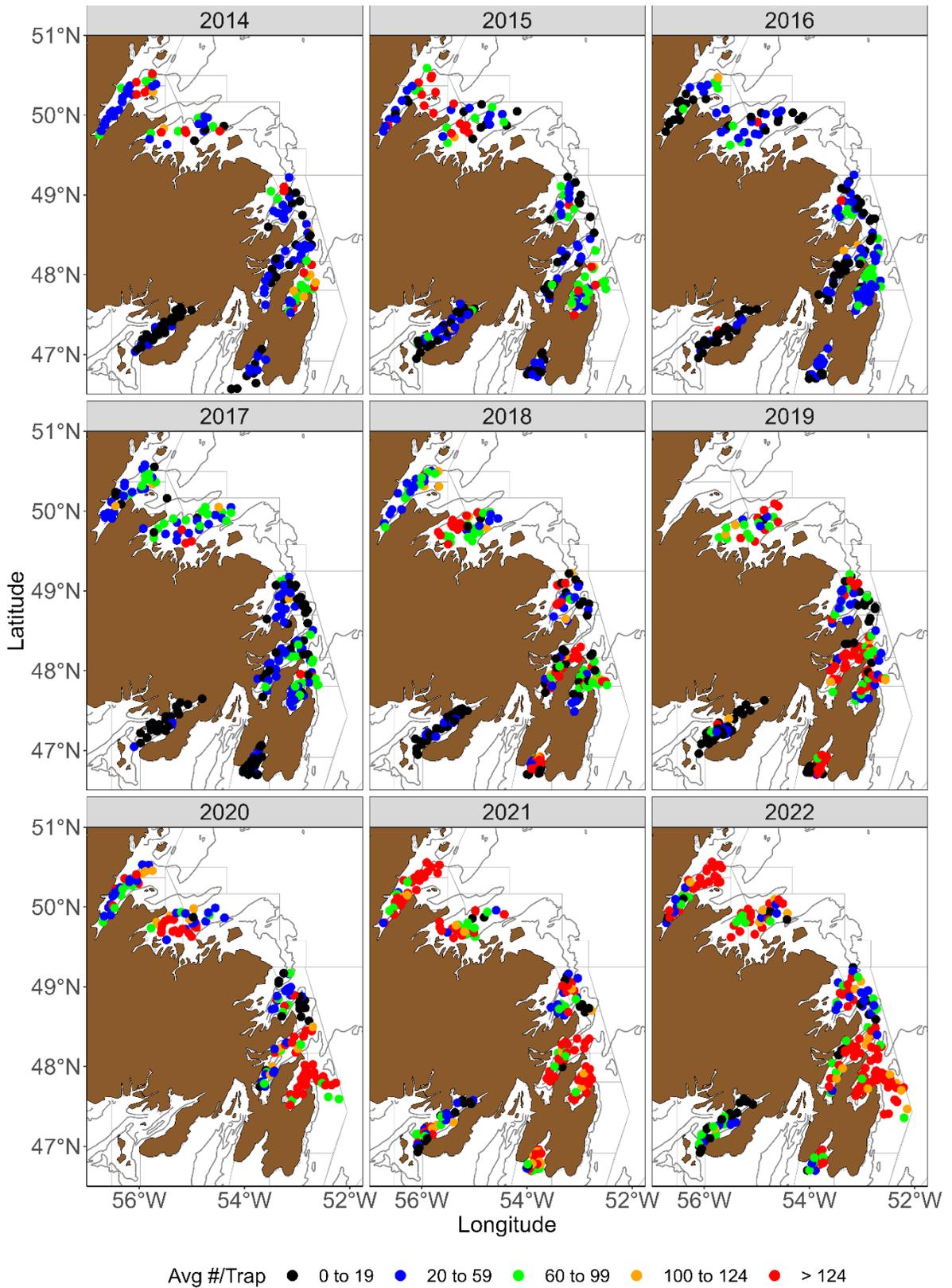


Figure 8. Location of sets and CPUE (#/trap) of all Snow Crab in small-mesh traps from the DFO inshore trap surveys (2014–22).

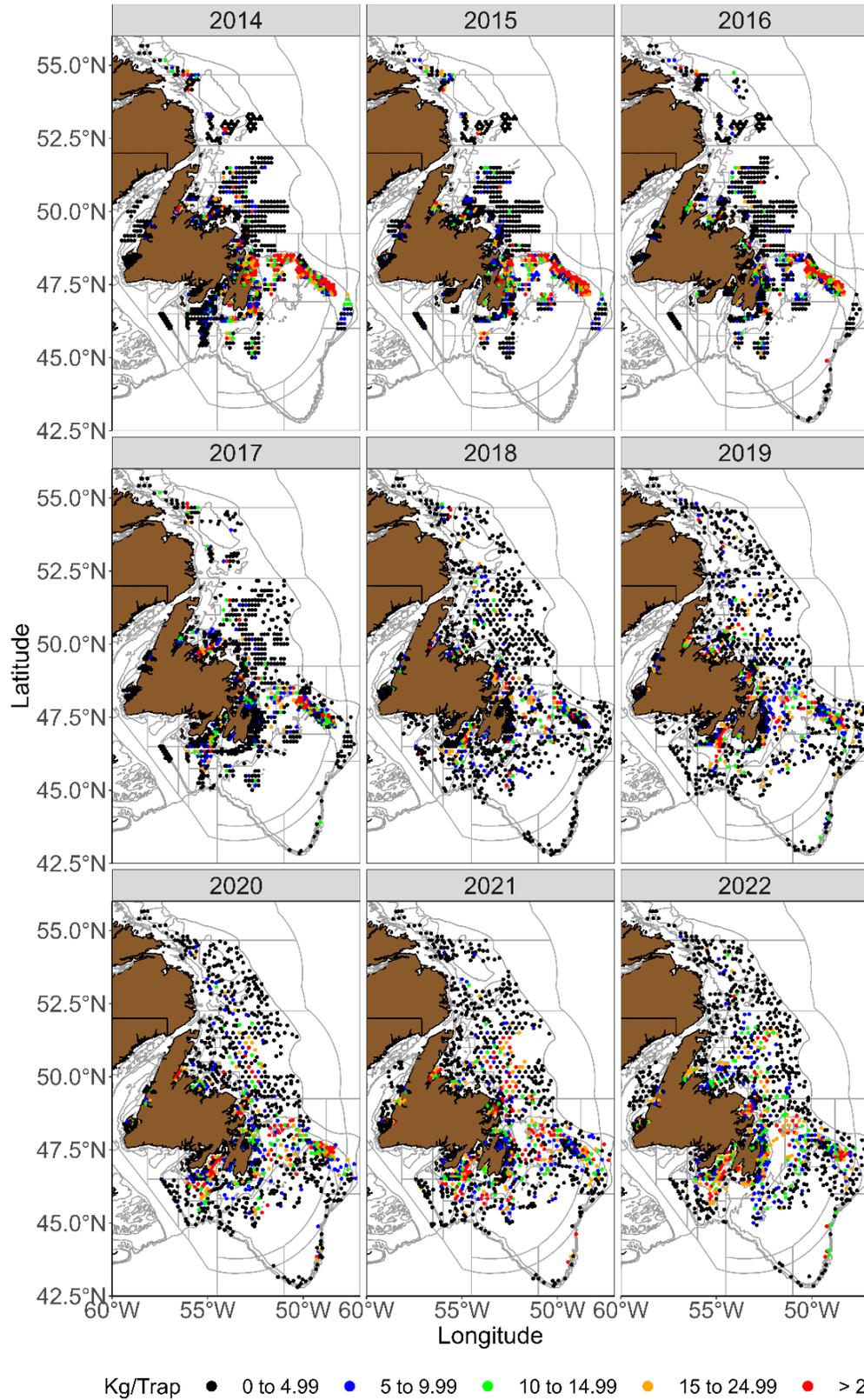


Figure 9. Location of sets and CPUE (kg/trap) of exploitable Snow Crab in large-mesh traps from the Collaborative Post-Season trap survey and Torngat Joint Fisheries Board trap survey (2014–22).

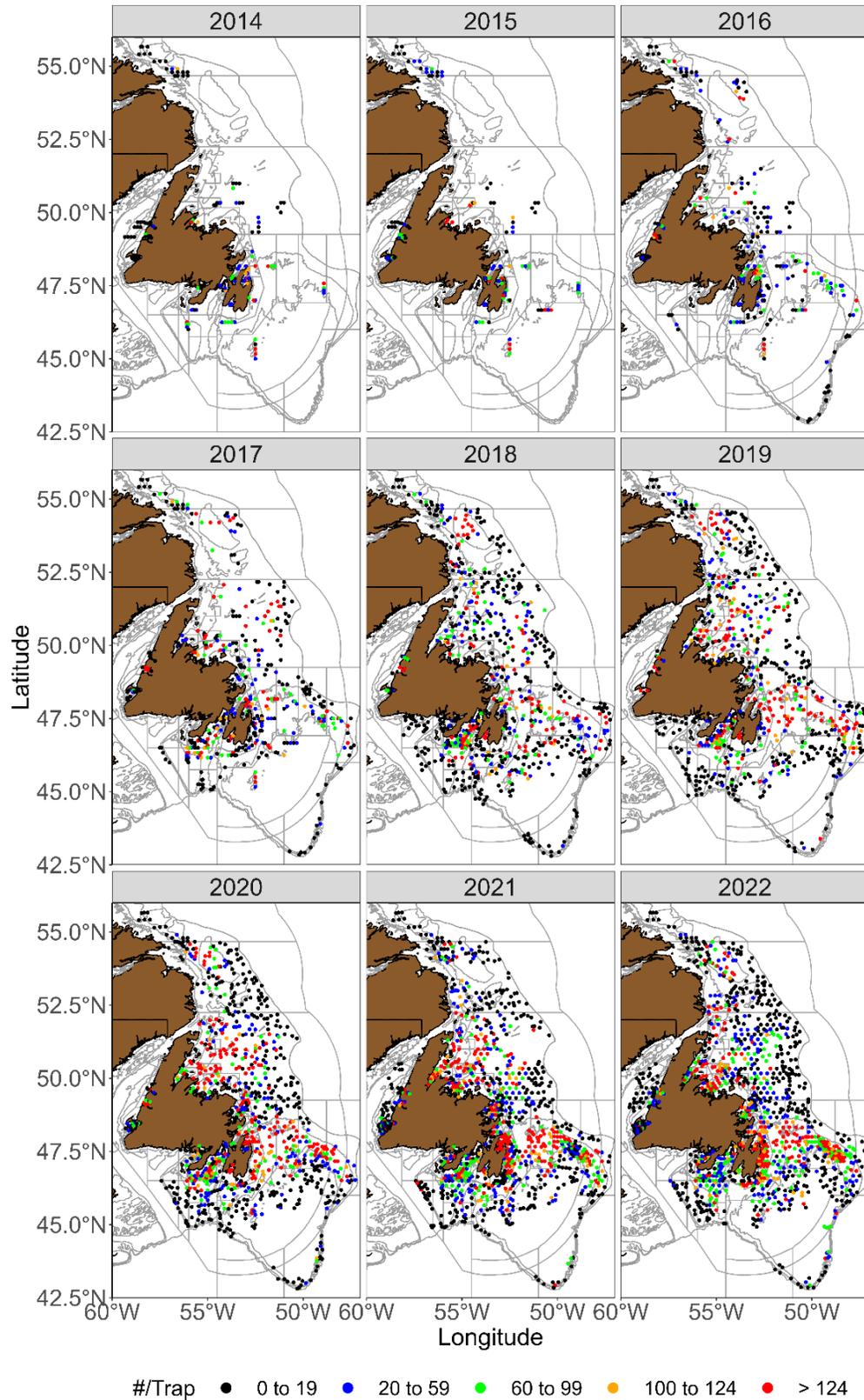


Figure 10. Location of sets and CPUE (#/trap) of Snow Crab in small-mesh traps from the Collaborative Post-Season trap survey and Torngat Joint Fisheries Board trap survey (2014–22).

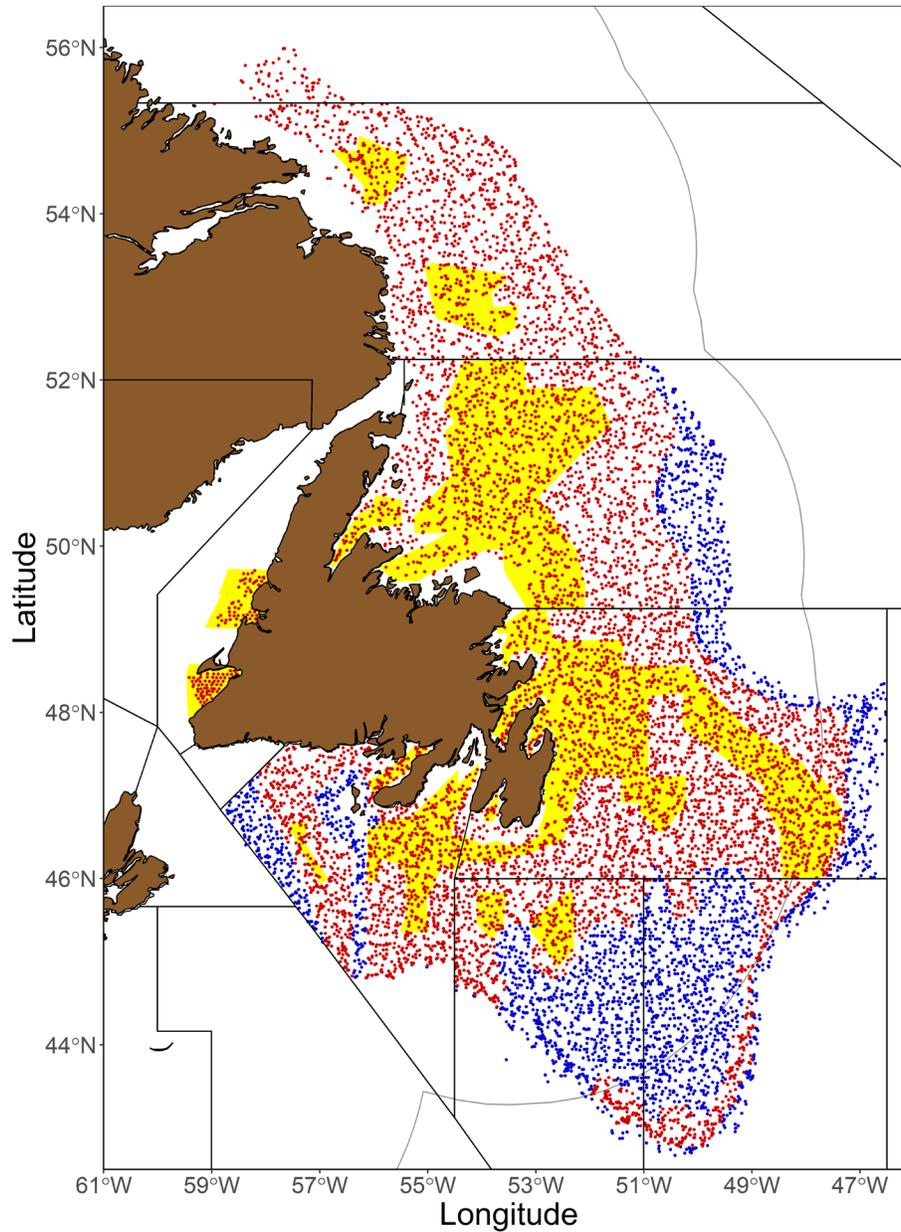


Figure 11. Map of Ogmap vertices (red + blue points) used for biomass estimation from trawl survey data, and Ogtrap vertices (red points) and Ogtrap strata (yellow polygons) for biomass estimation for all stations and core stations, respectively, from the DFO inshore, Collaborative Post-Season, and Torngat Joint Fisheries Board trap surveys.

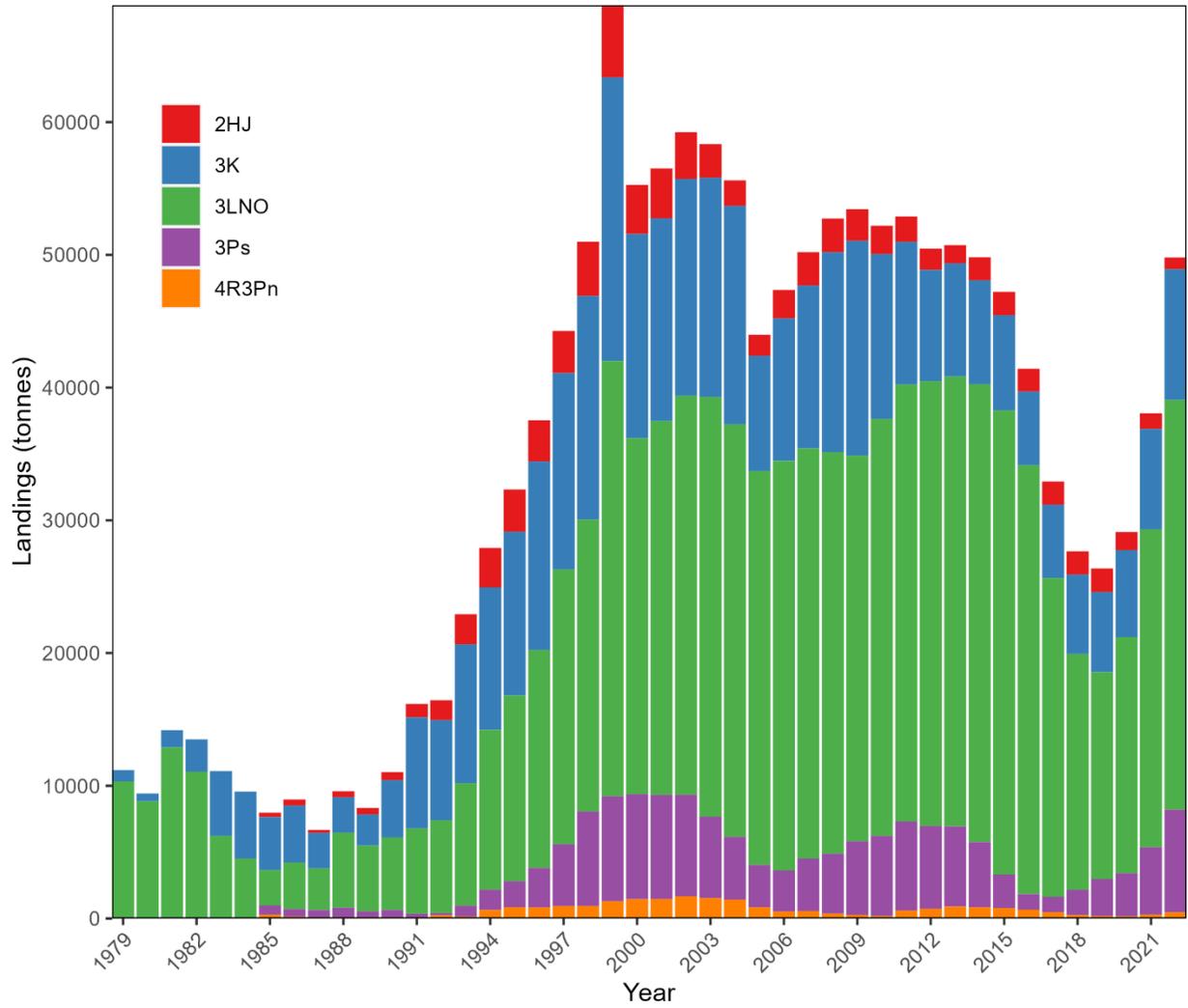


Figure 12. Annual landings (tonnes) of Snow Crab by Assessment Division (3LNO = 3LNO Offshore + 3L Inshore) (1979–2022).

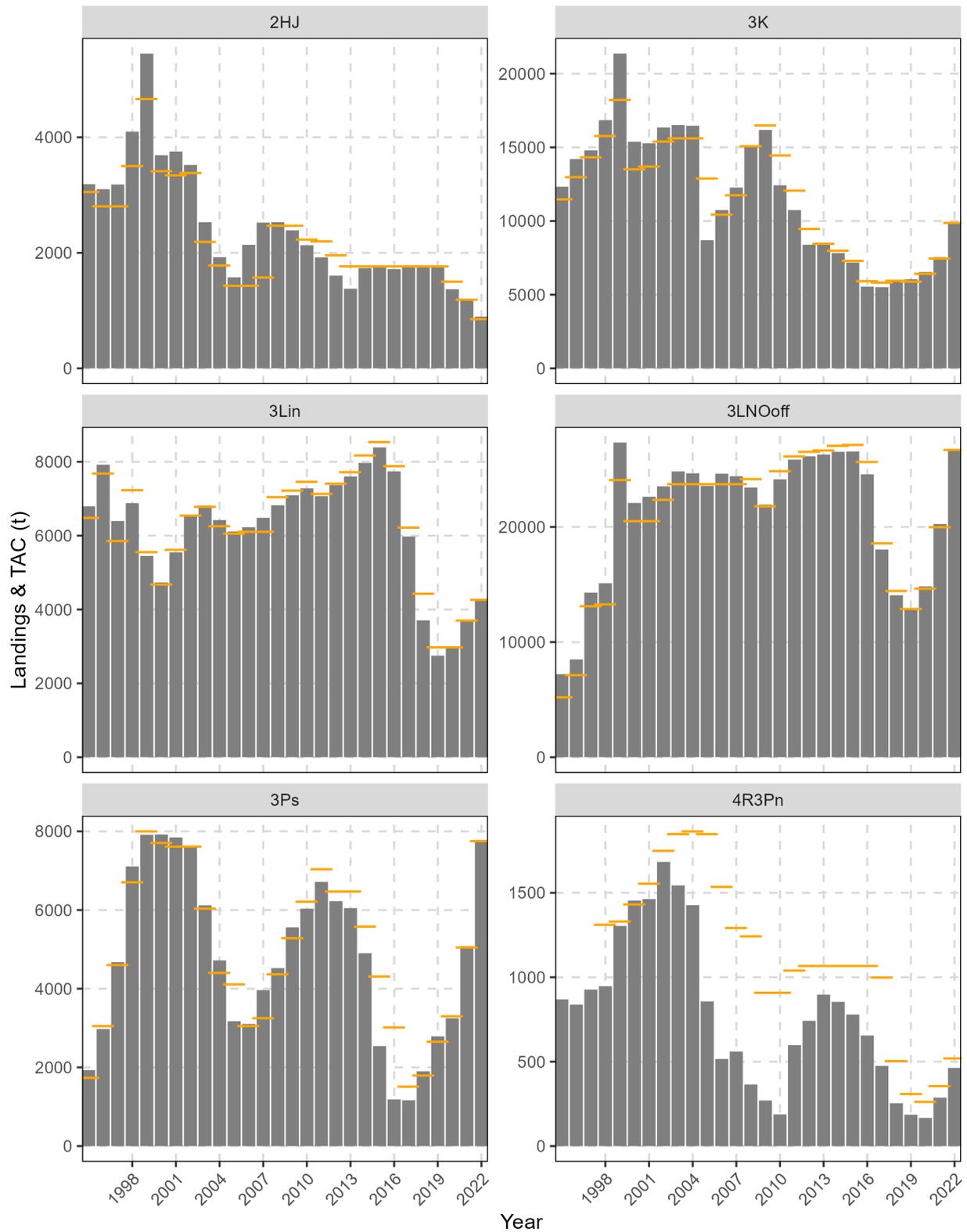


Figure 13. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) by Assessment Division (1995–2022).

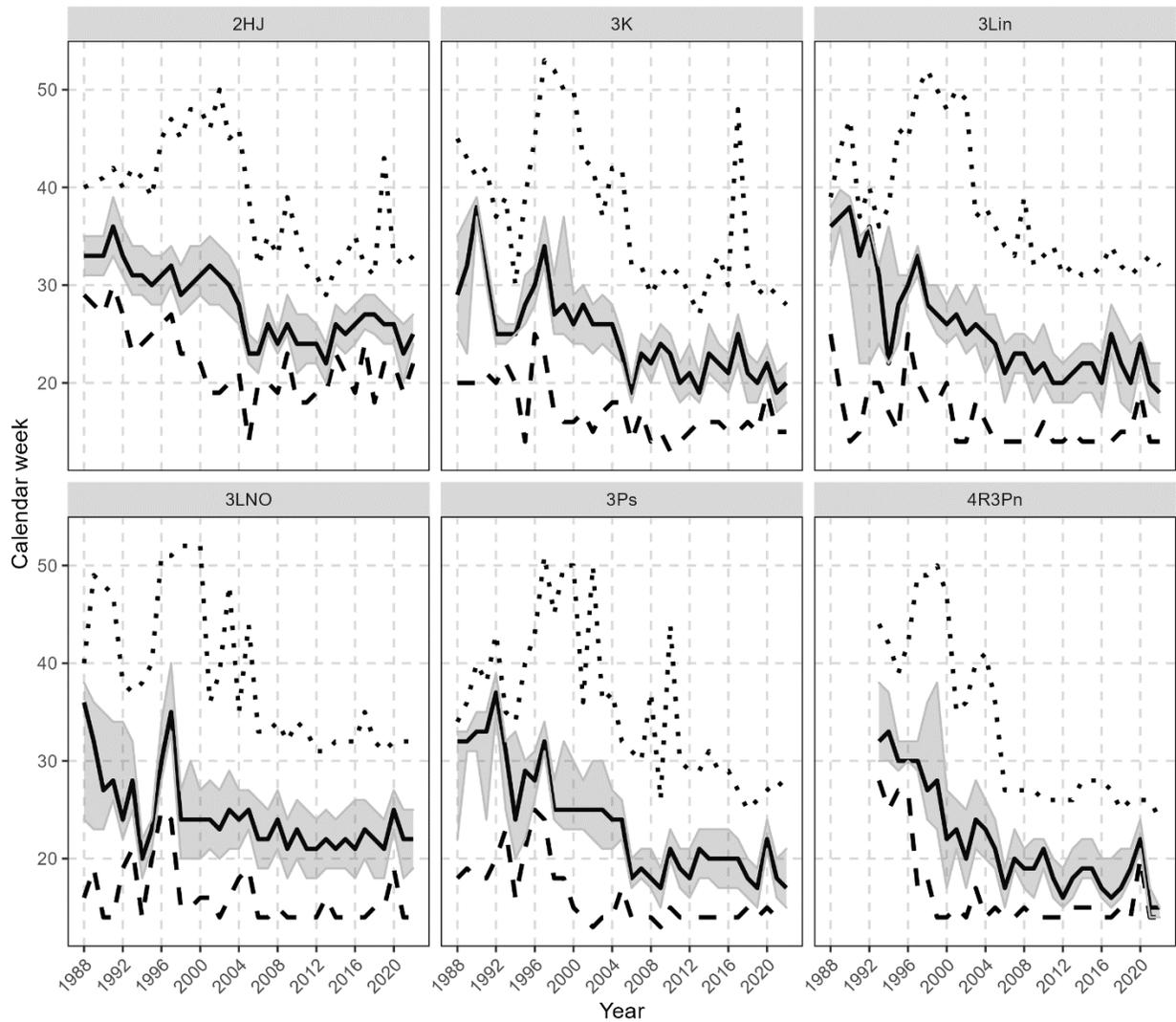


Figure 14. Snow Crab fishery timing by Assessment Division (1988–2022). Solid line = median timing of fishery, dashed line = start of fishery, dotted line = end of fishery, and shaded area = fishery 25–75% complete. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

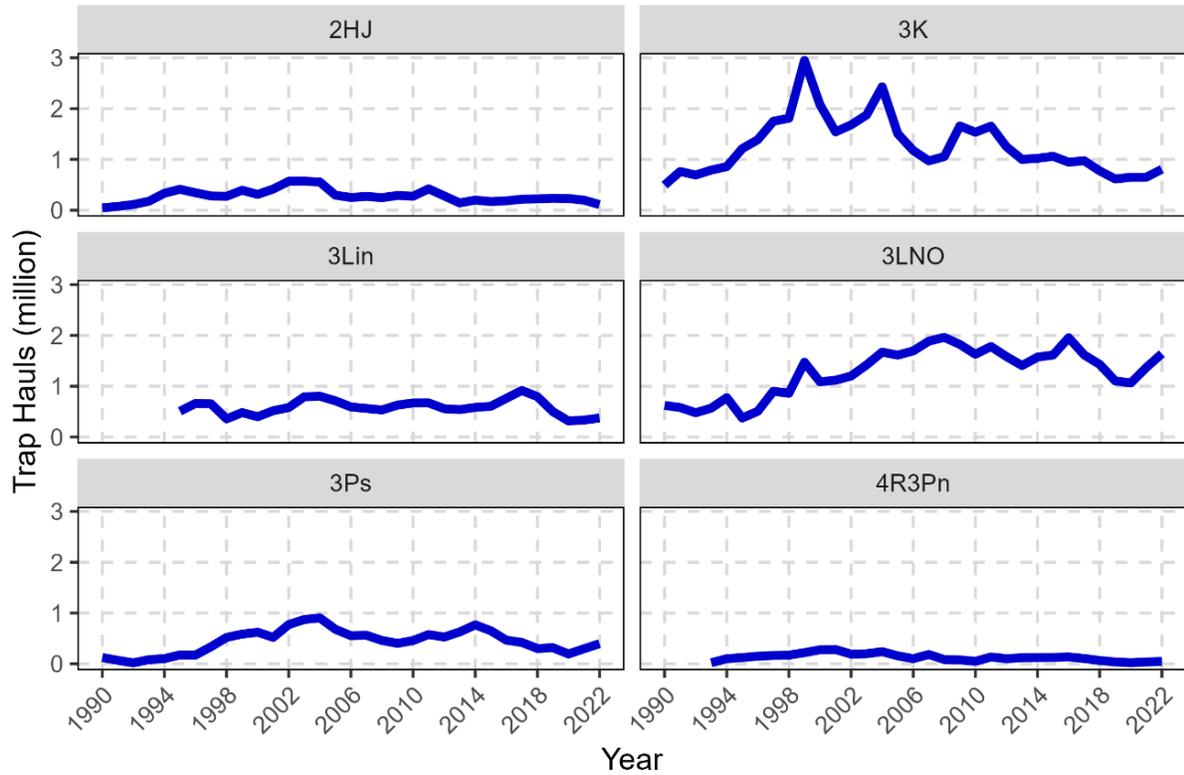
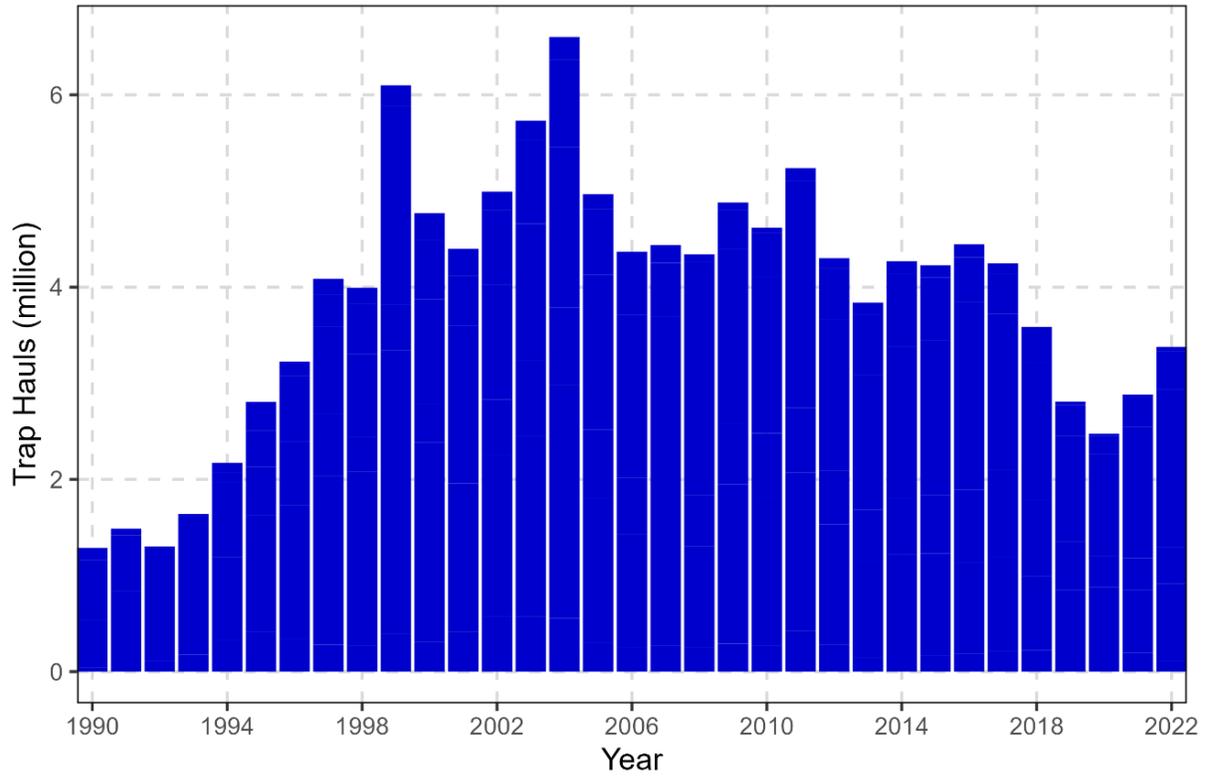


Figure 15. Estimated effort (number of trap hauls) in total (top) and by Assessment Division (bottom) (1990–2022). Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

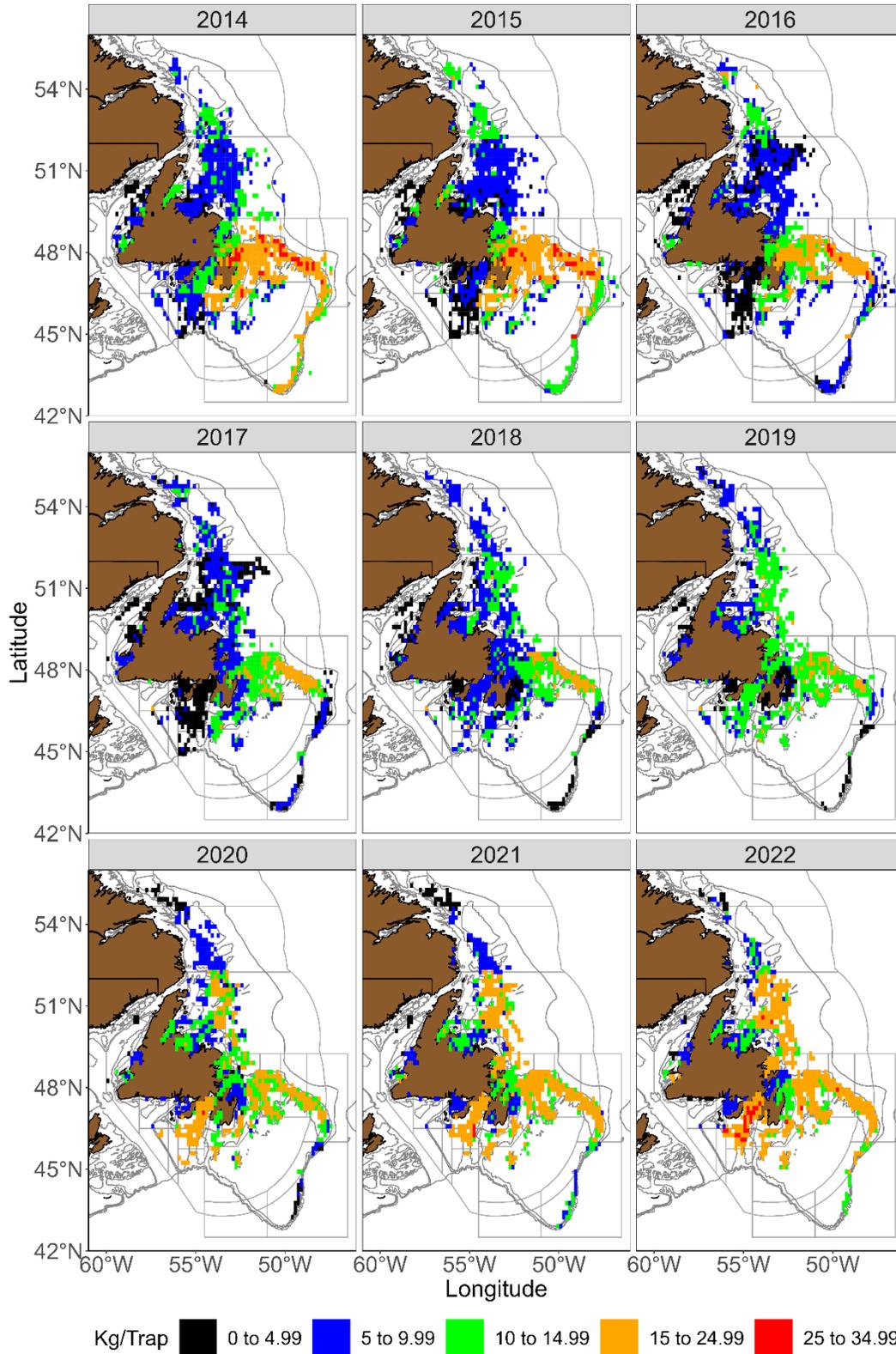


Figure 16. Fishing locations and catch rates (kg/trap) from Snow Crab fishery logbooks (2014–22). Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

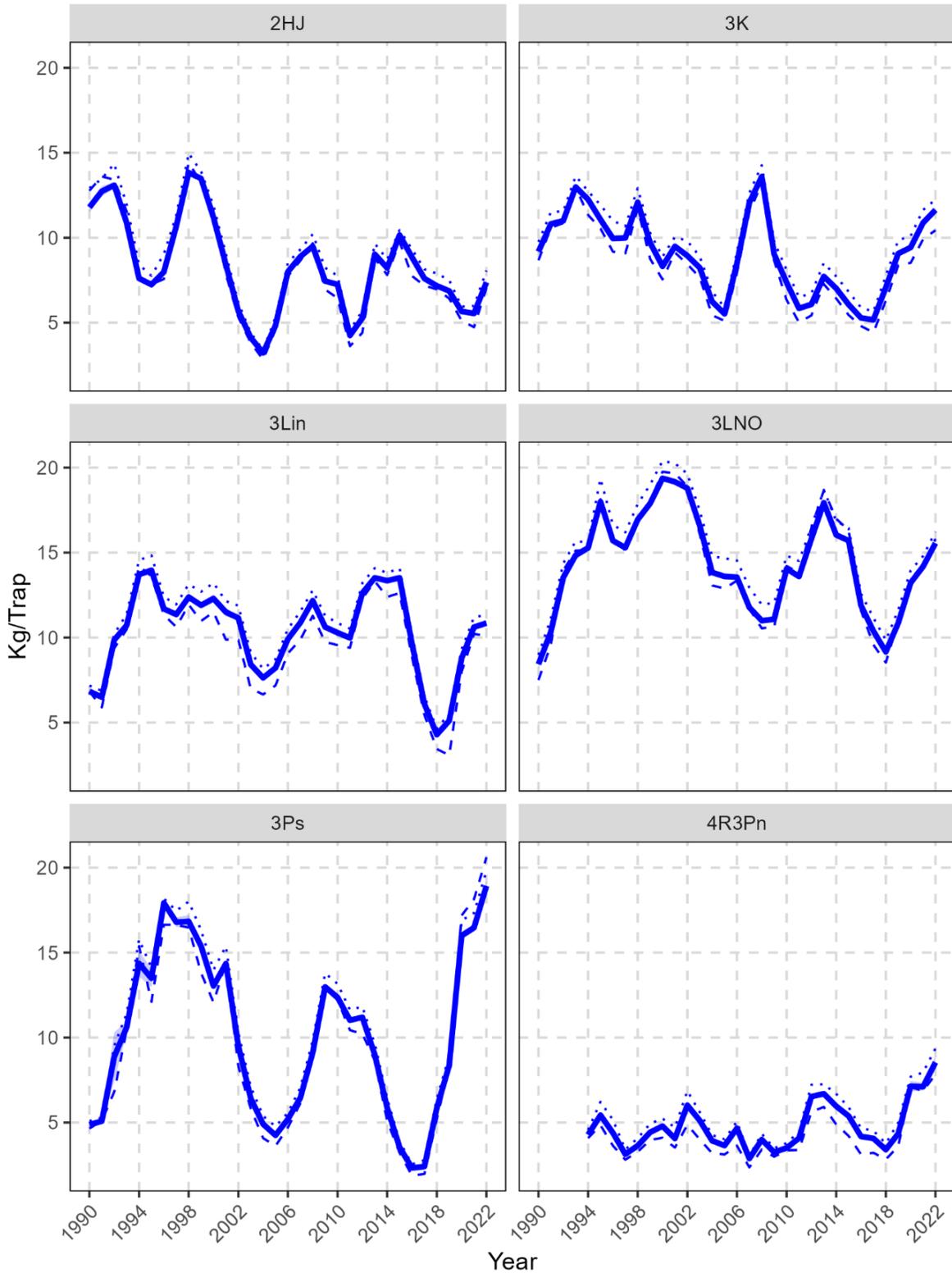


Figure 17. Standardized fishery CPUE (kg/trap) by Assessment Division (1990–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

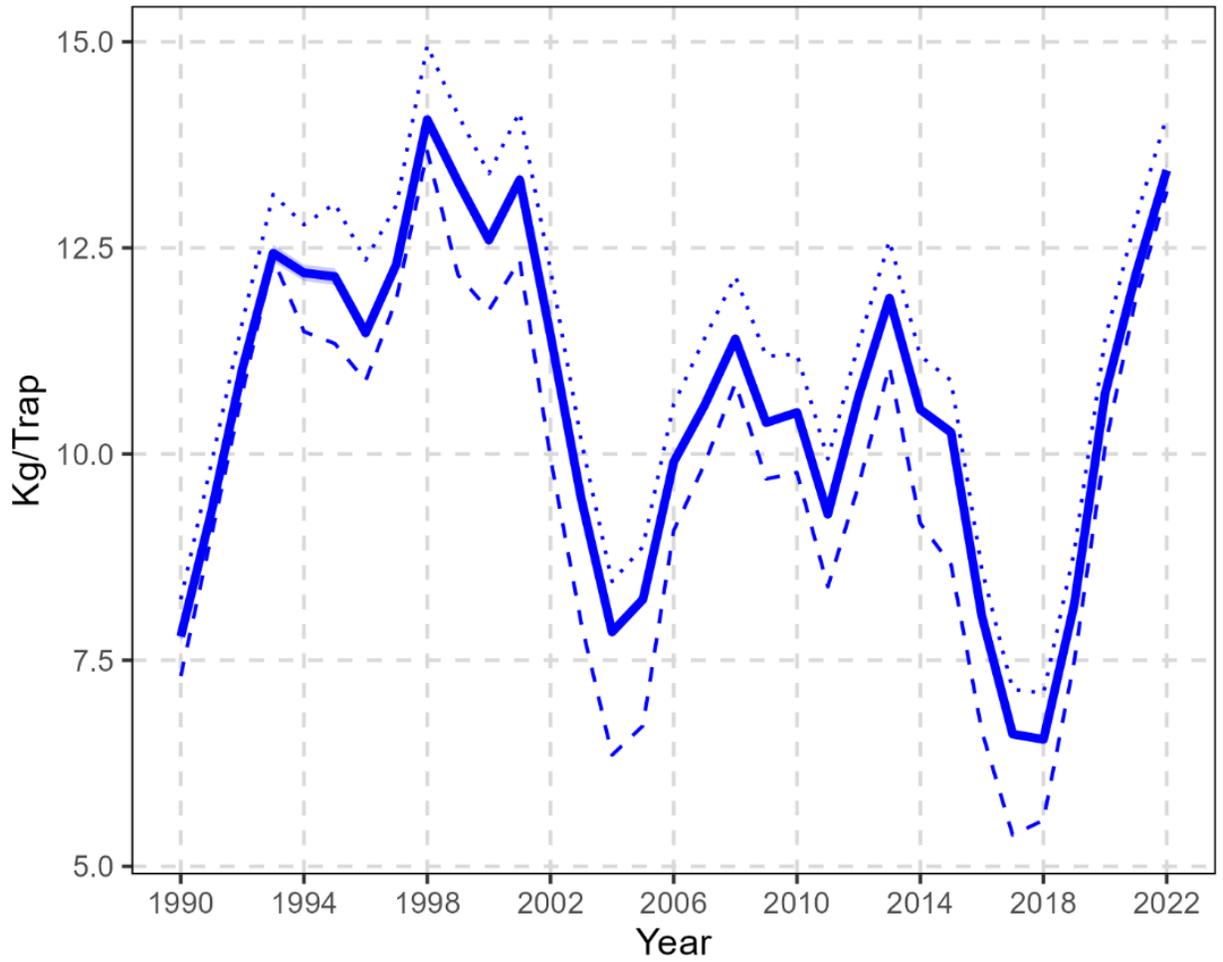


Figure 18. Standardized fishery CPUE (1990–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

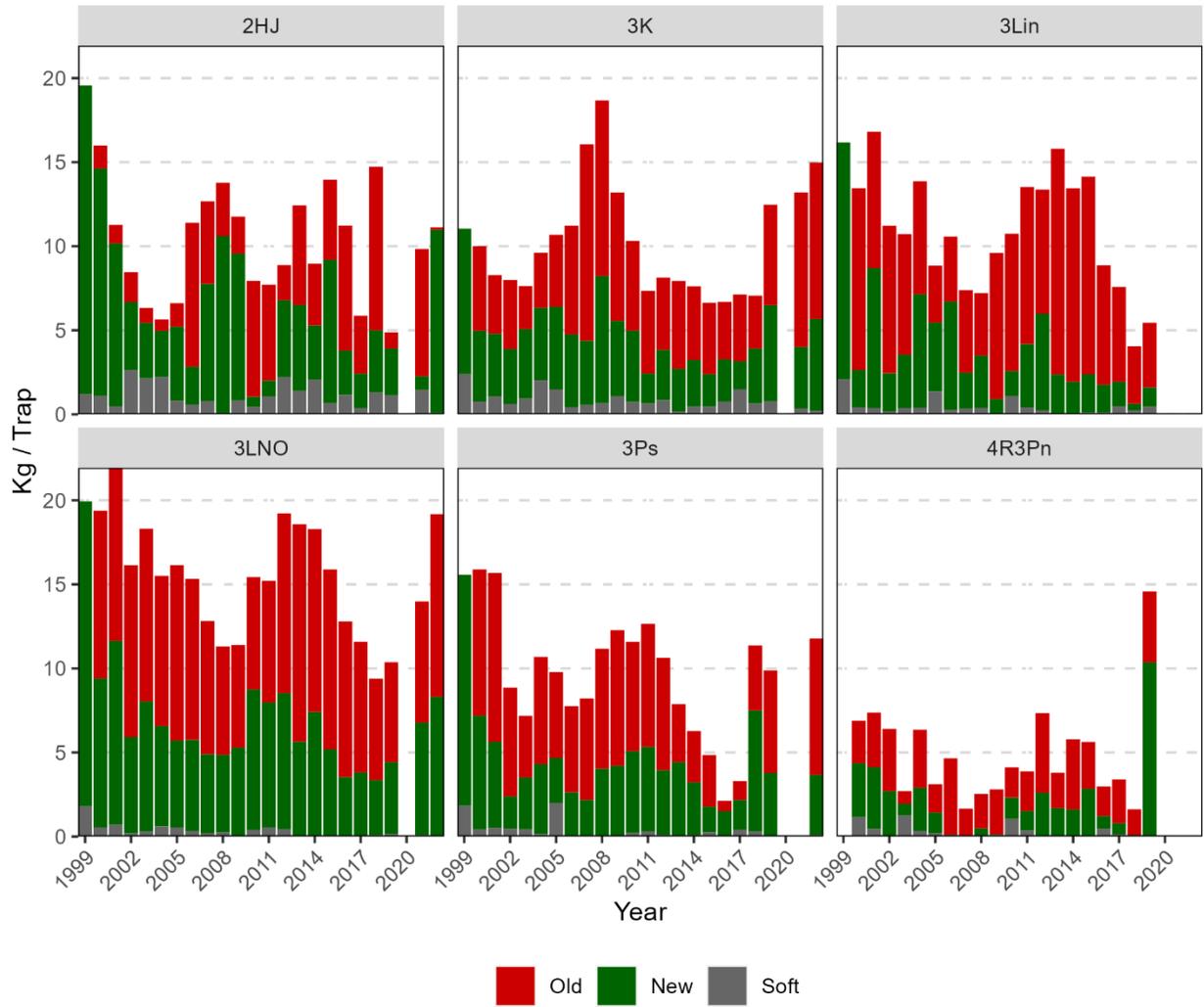


Figure 19. Catch rates (kg/trap) of legal-sized Snow Crab by shell condition from at-sea observer sampling by Assessment Division (1999–2022). Years without results represent low or absent at-sea observer coverage.

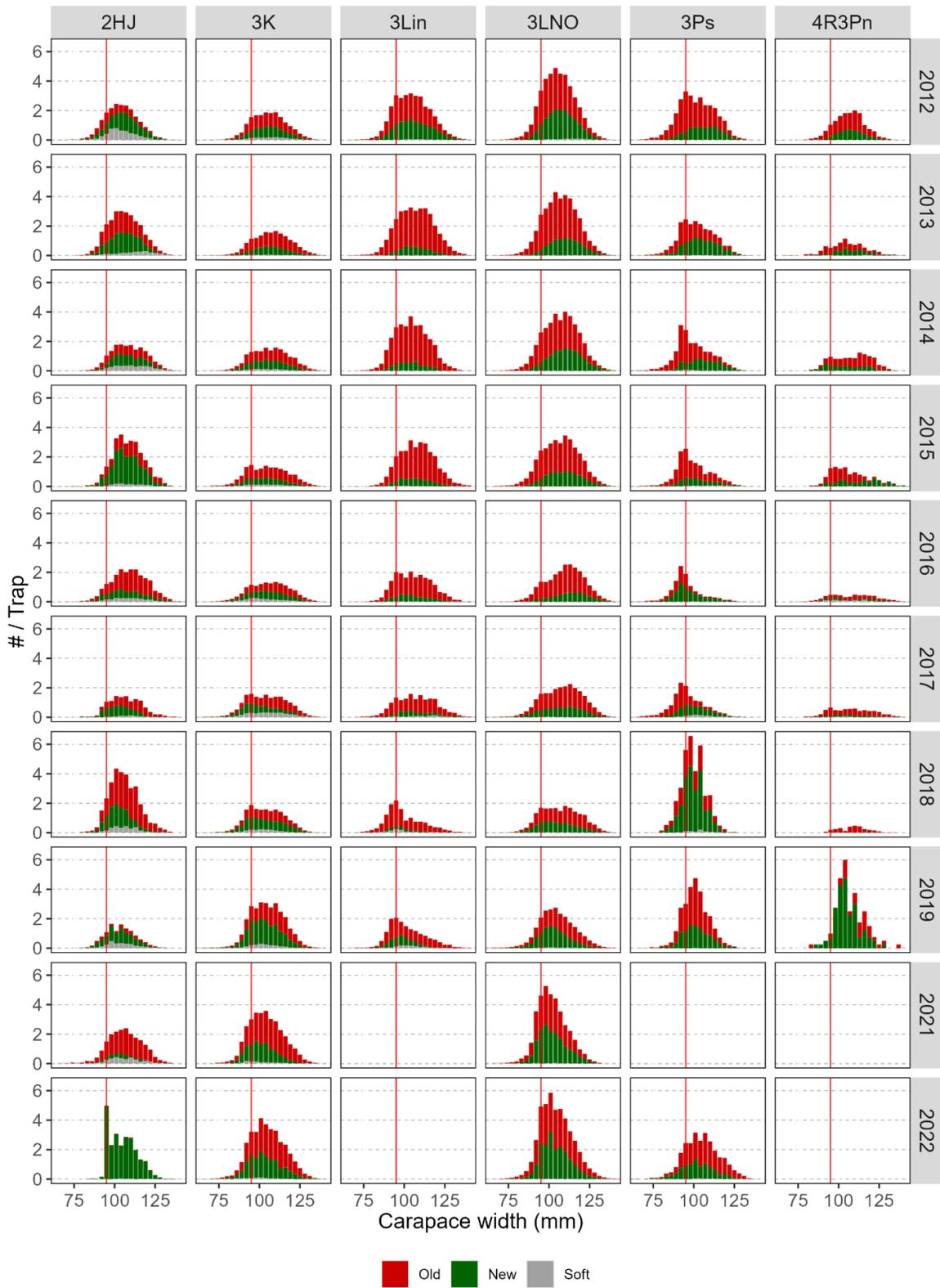


Figure 20. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling by Assessment Division (2012–22). The red vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

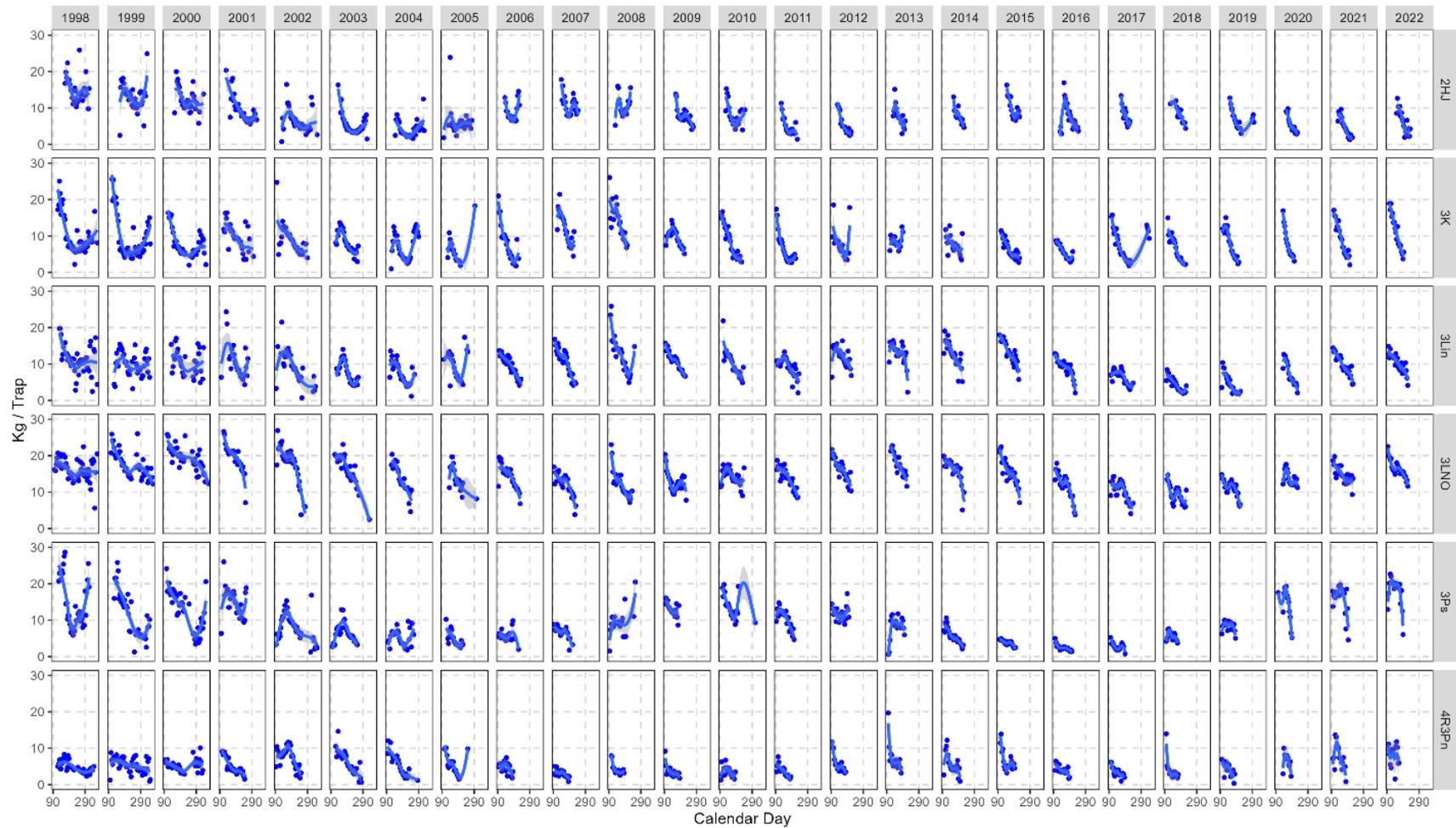


Figure 21. Unstandardized fishery CPUE (kg/trap) throughout the season (calendar day) by Assessment Division (1998–2022), derived from logbooks. Points denote mean CPUE in five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

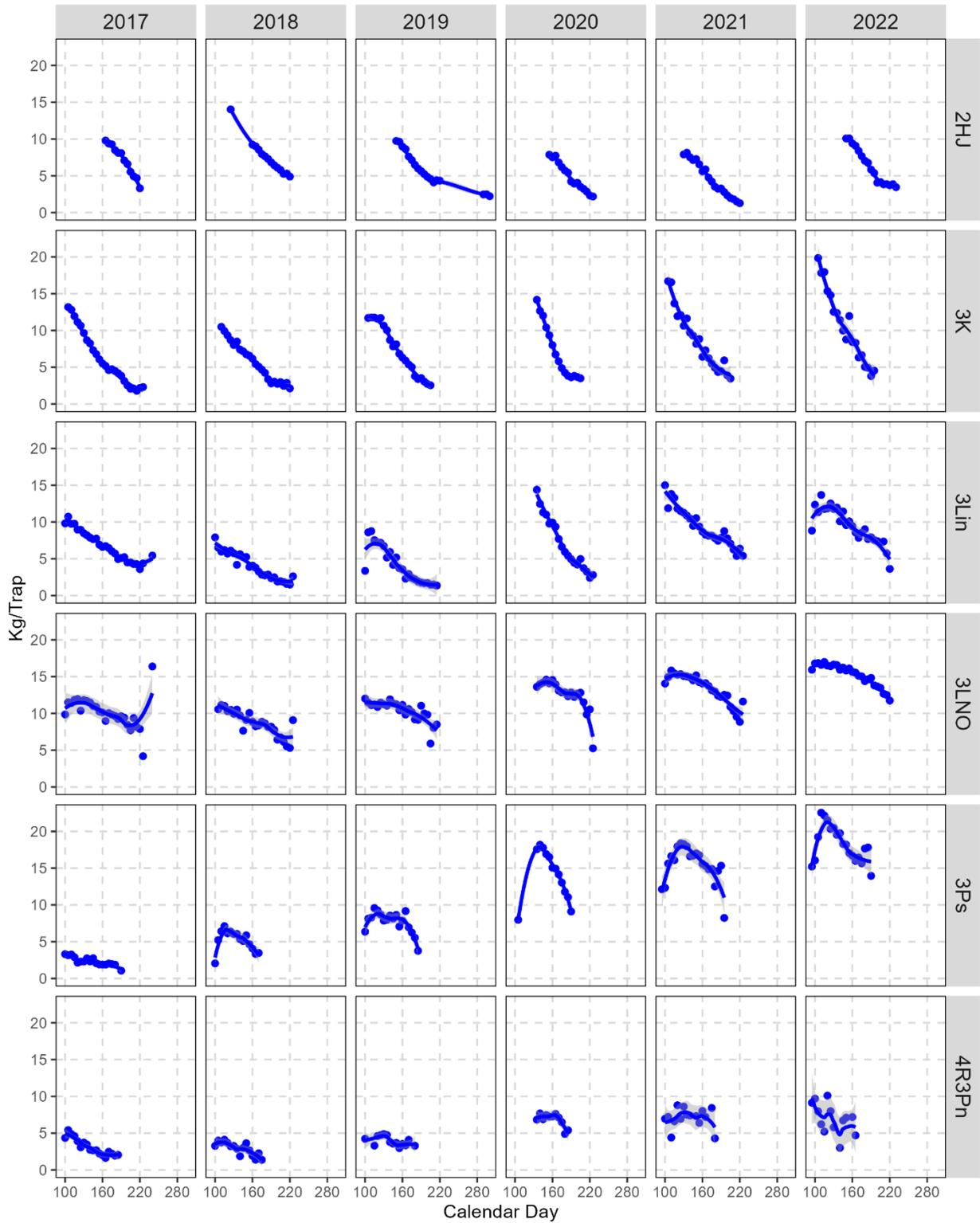


Figure 22. Standardized fishery CPUE (kg/trap) throughout the season (calendar day) by Assessment Division (2017–22), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

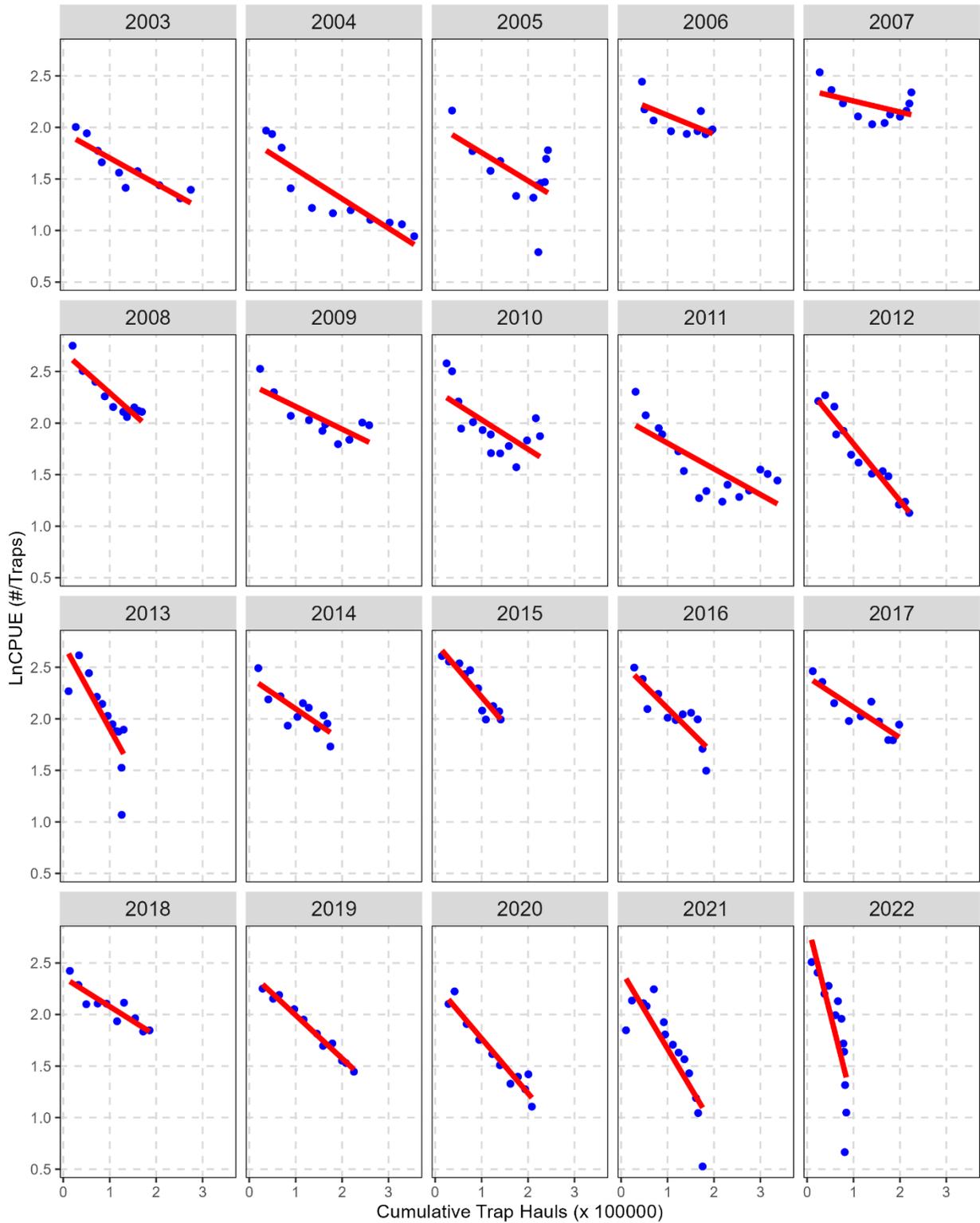


Figure 23. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 2HJ (2003–22). Blue points represent unstandardized catch rates and red line is fitted DeLury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

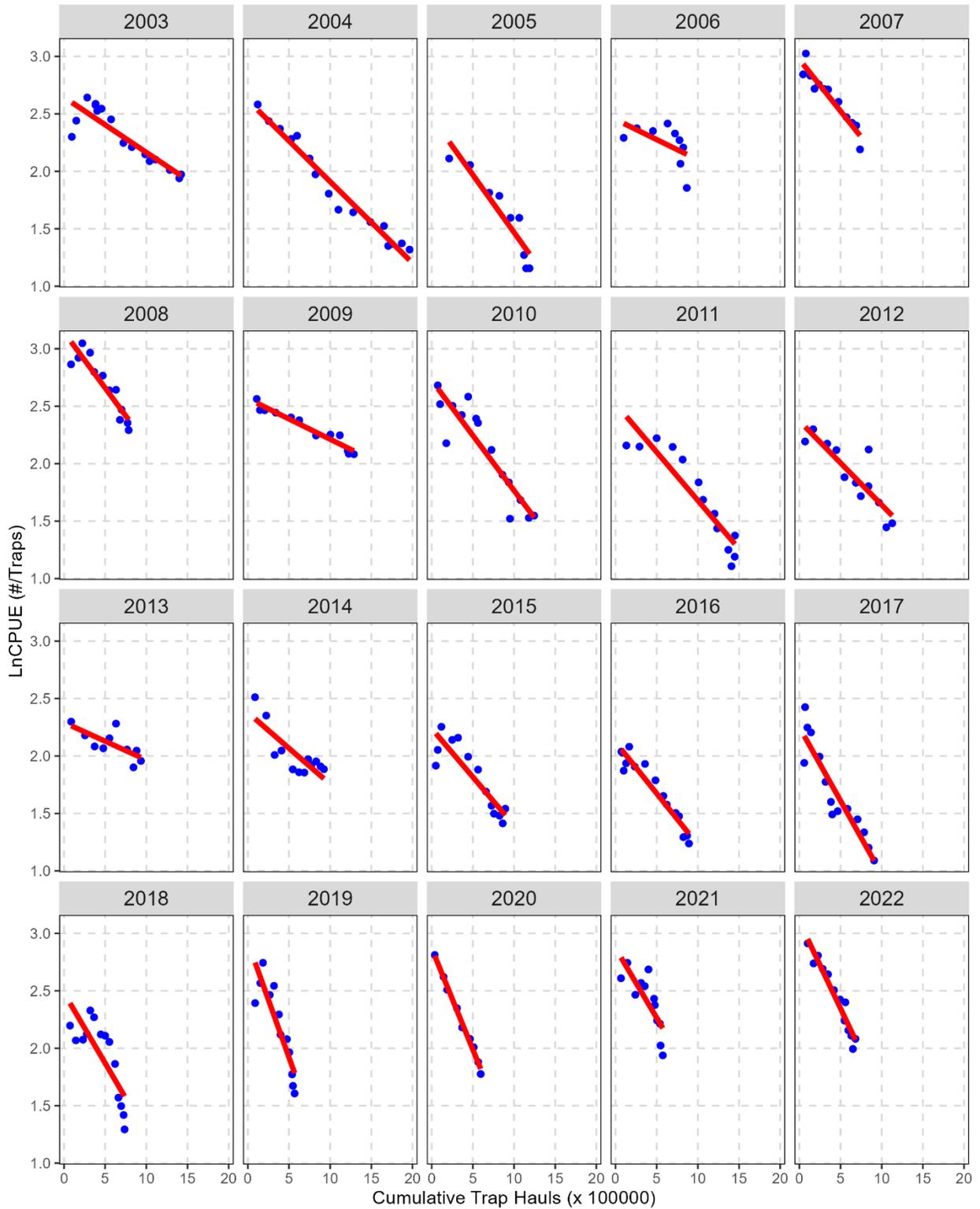


Figure 24. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 3K (2003–22). Blue points represent unstandardized catch rates and red line is fitted DeLury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

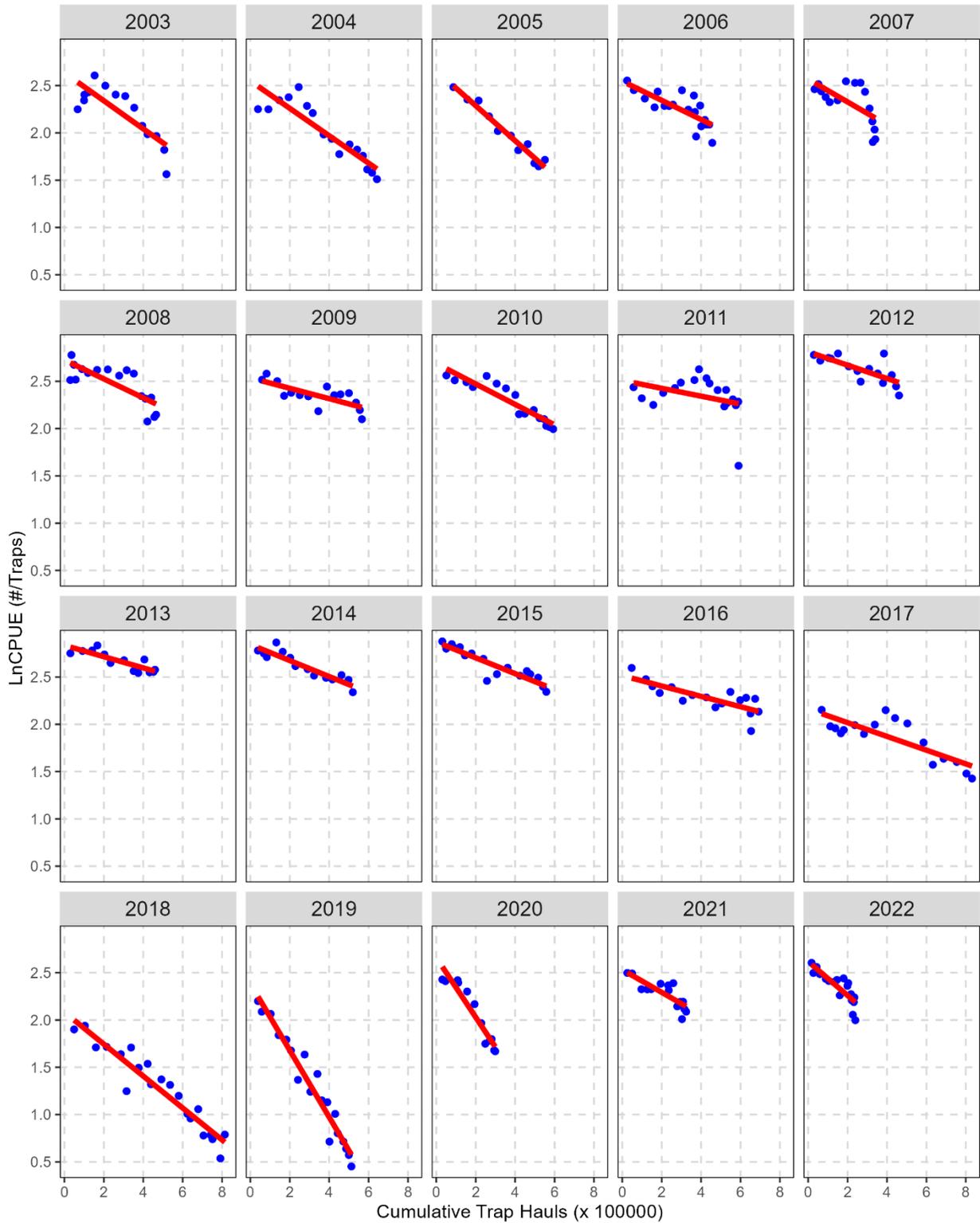


Figure 25. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 3L Inshore (2003–22). Blue points represent unstandardized catch rates and red line is fitted DeLury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

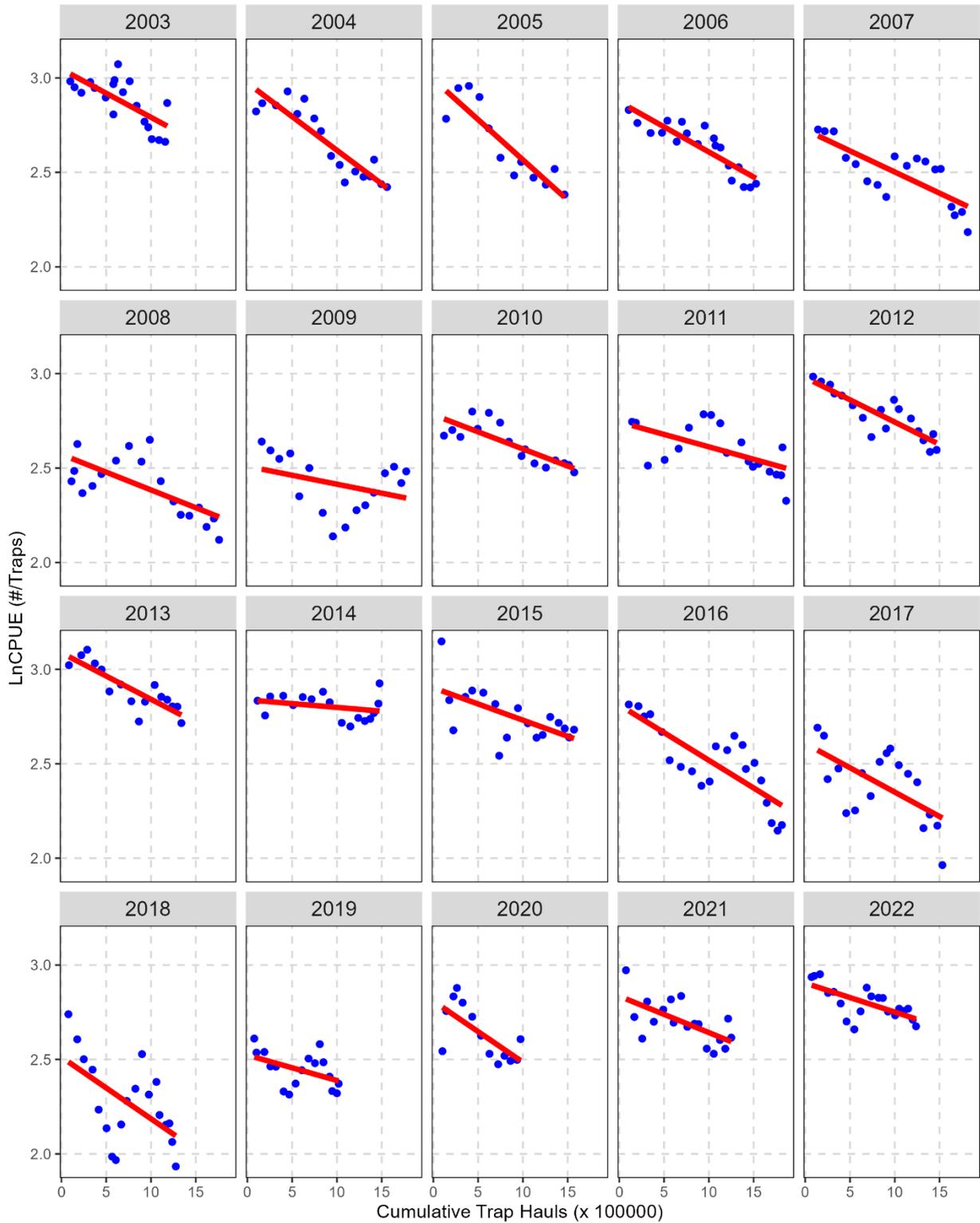


Figure 26. Snow Crab fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 3LNO Offshore (2003–22). Blue points represent unstandardized catch rates and red line is fitted DeLury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

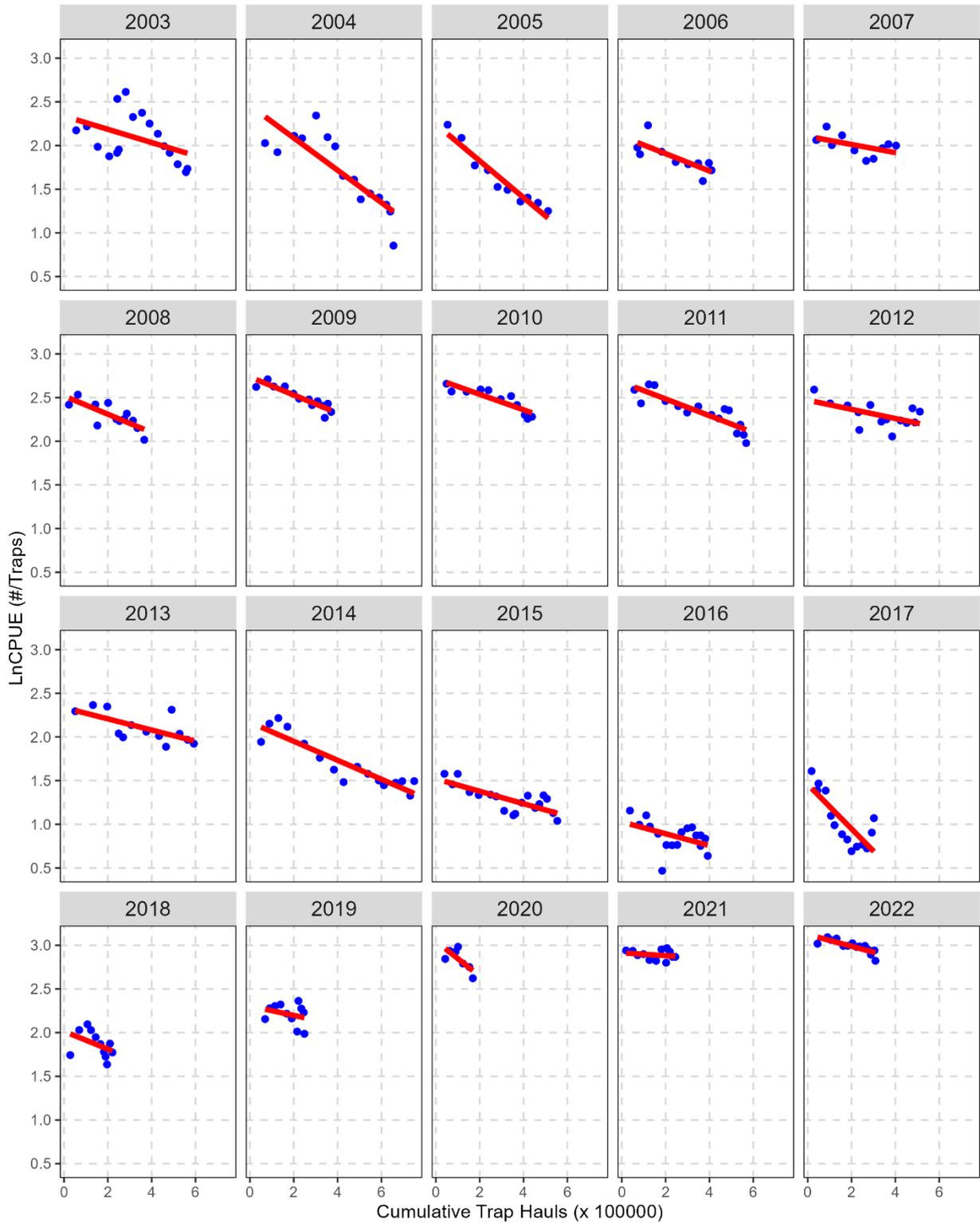


Figure 27. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 3Ps (2003–22). Blue points represent unstandardized catch rates and red line is fitted DeLury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

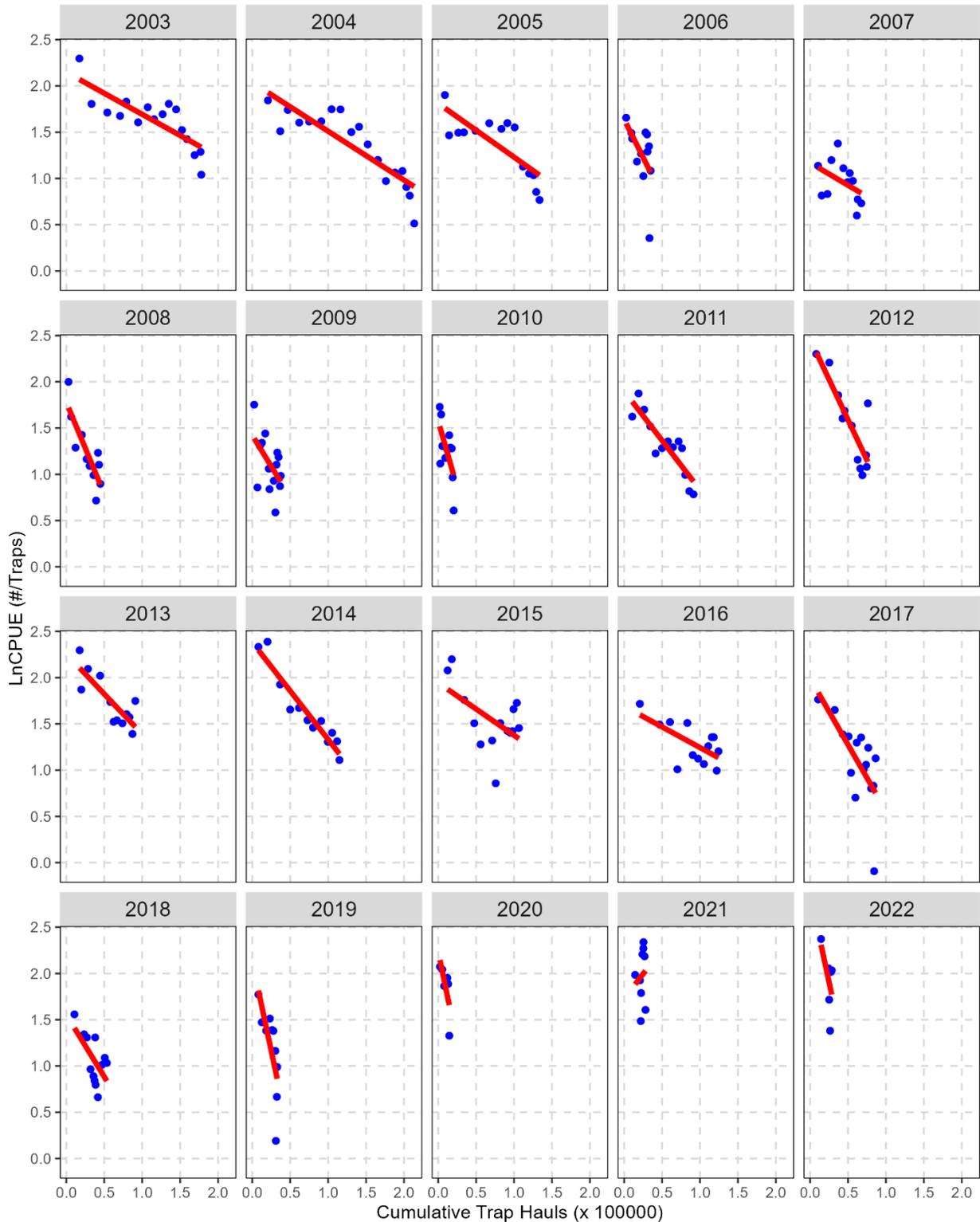


Figure 28. Fishery catch rate depletion regression models on five-day increment catch rates from logbooks in Assessment Division 4R3Pn (2003–22). Blue points represent unstandardized catch rates and red line is fitted DeLury depletion estimates. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

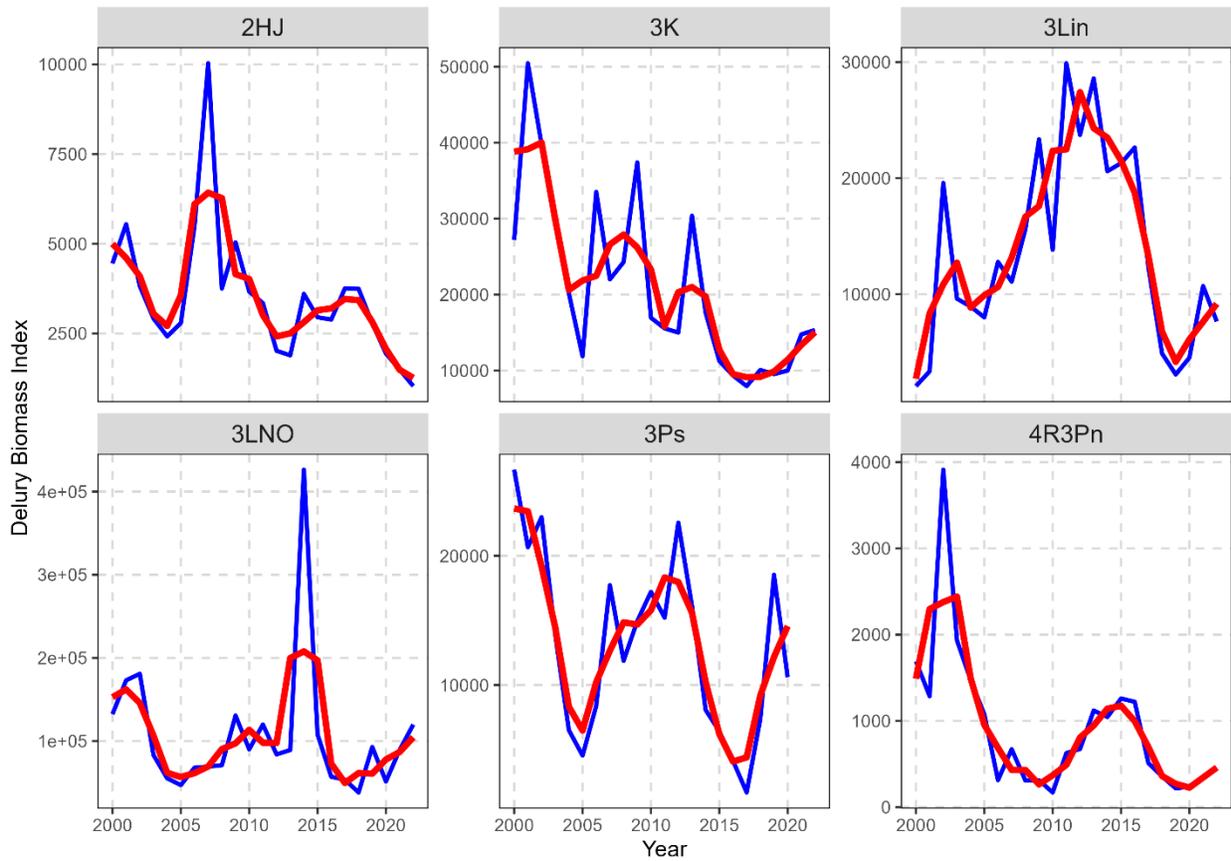


Figure 29. Fishery depletion model biomass estimates of exploitable Snow Crab (t) from logbooks (blue) and three-year centered moving averages (red) by Assessment Division (2000–22). Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

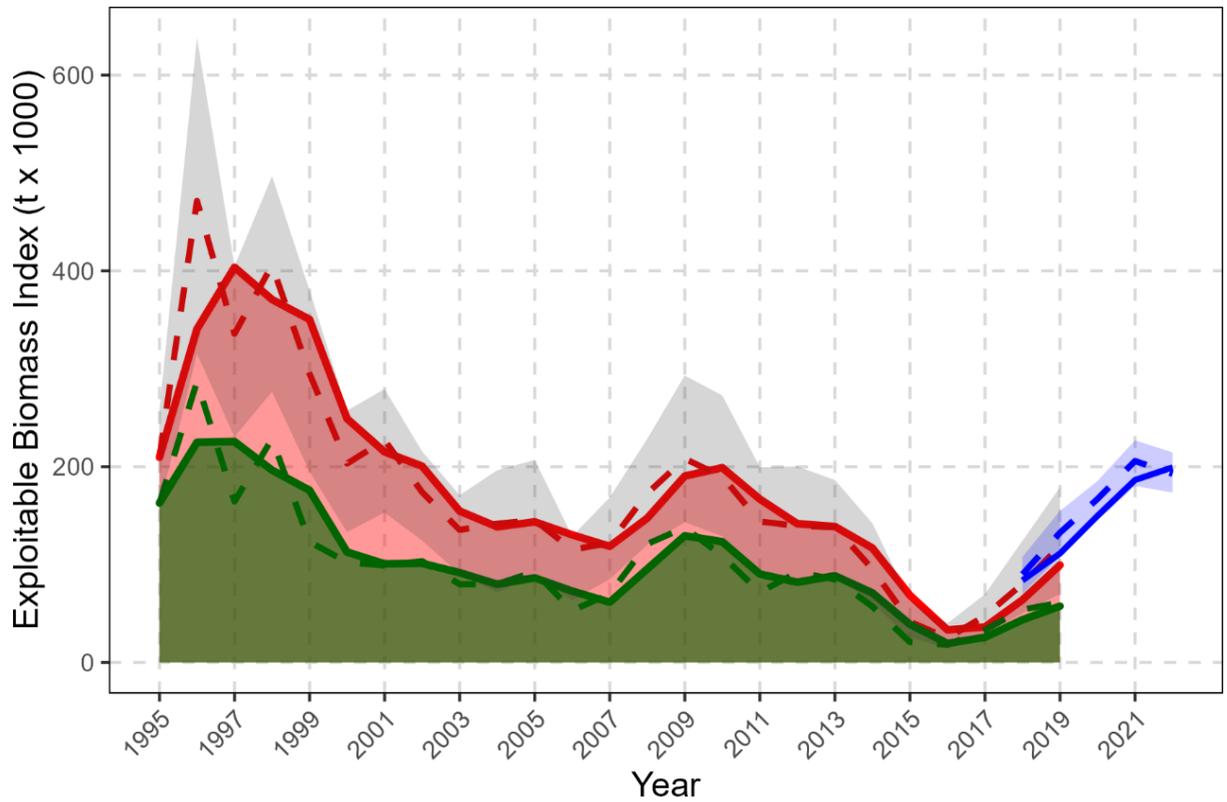


Figure 30. Annual trawl survey-based exploitable biomass index by shell condition (red = residual crab, green = recruits) (1995–2019) and trap survey-based exploitable biomass index (blue) (2018–22). Solid lines = 2-year moving average of exploitable biomass, dashed lines = annual estimate, and grey or blue bands = 95% confidence intervals of annual estimate.

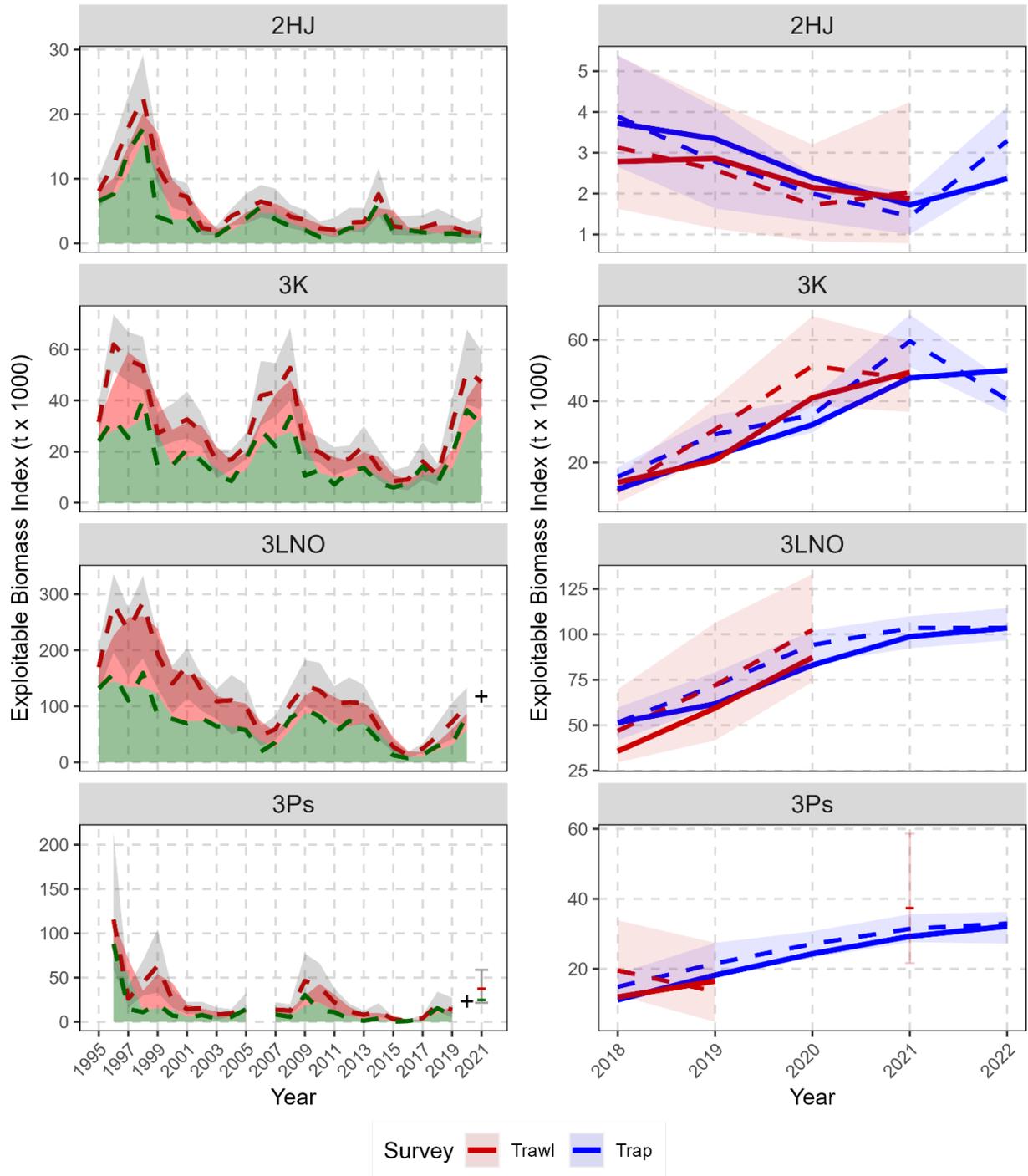


Figure 31. Left: Annual trawl survey-based exploitable biomass index by shell condition (red = residual crab, green = recruits) and Assessment Division (1995–2021). Solid colours = 2-year moving average of exploitable biomass, dashed lines = annual estimates, and grey band = 95% confidence intervals of annual estimate. “+” denotes years without a trawl survey where an estimate was calculated from other data sources. Right: Annual trawl (red) and trap (blue) survey-based exploitable biomass index (2018–22). Solid lines = 2-year moving average of exploitable biomass, dashed lines = annual estimates, and shaded bands = 95% confidence intervals of annual estimates.

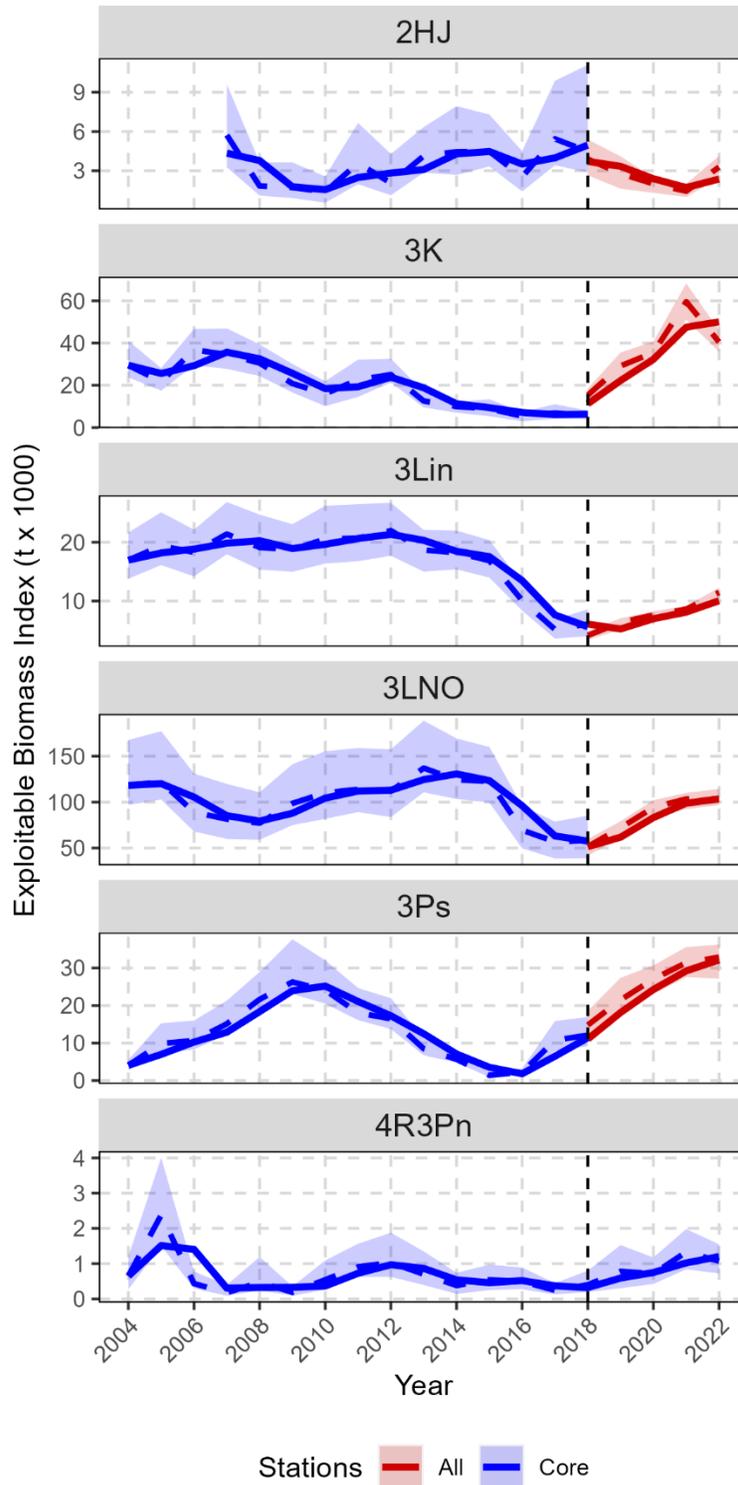


Figure 32. Trap survey-based exploitable biomass index by Assessment Division (2004–22). Solid lines = 2-year moving average of exploitable biomass, dashed lines = annual estimates, and shaded bands = 95% confidence intervals of annual estimates. Red represents using stations covering the entire trap survey area and blue represents using stations only within core polygons. The dashed vertical line denotes the first year of the trap survey redesign.

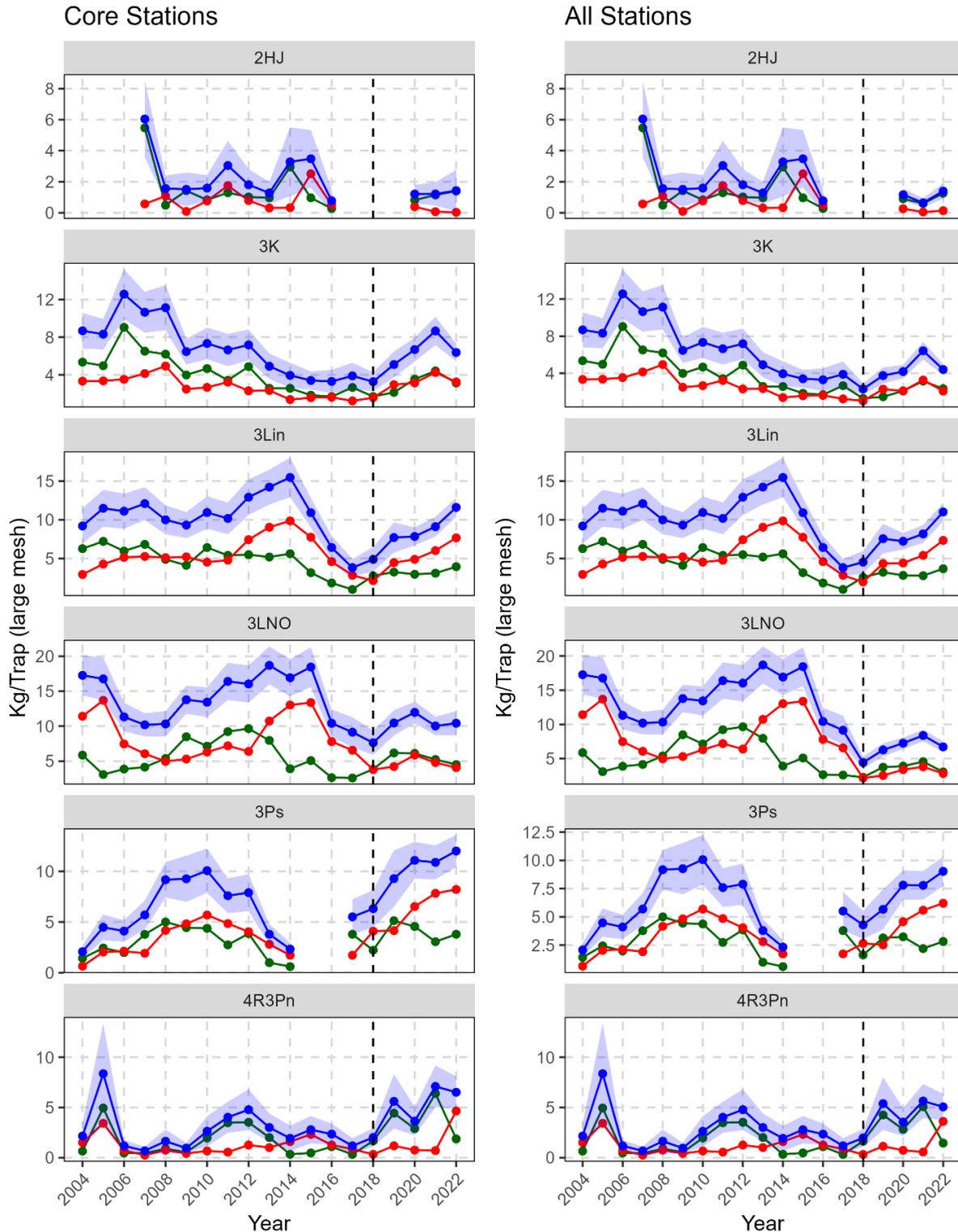


Figure 33. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from core stations (left) and all stations (right) in the Collaborative Post-Season trap survey by Assessment Division (2004–22). Shaded area represents the 95% confidence interval. The dashed vertical line represents the change in survey design. Years without results represent incomplete or absent survey coverage.

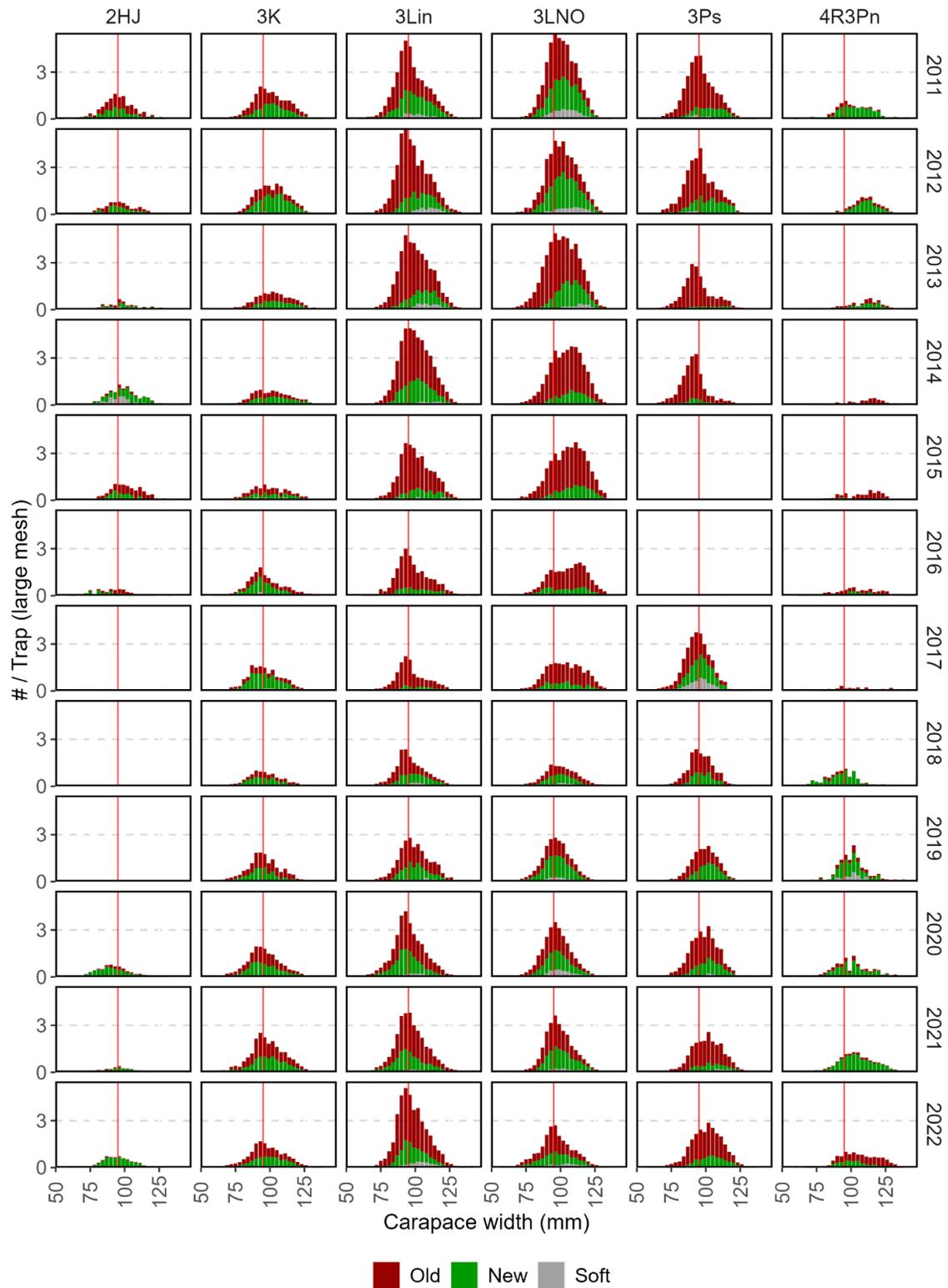


Figure 34. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations for the Collaborative Post-Season trap survey by Assessment Division (2011–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

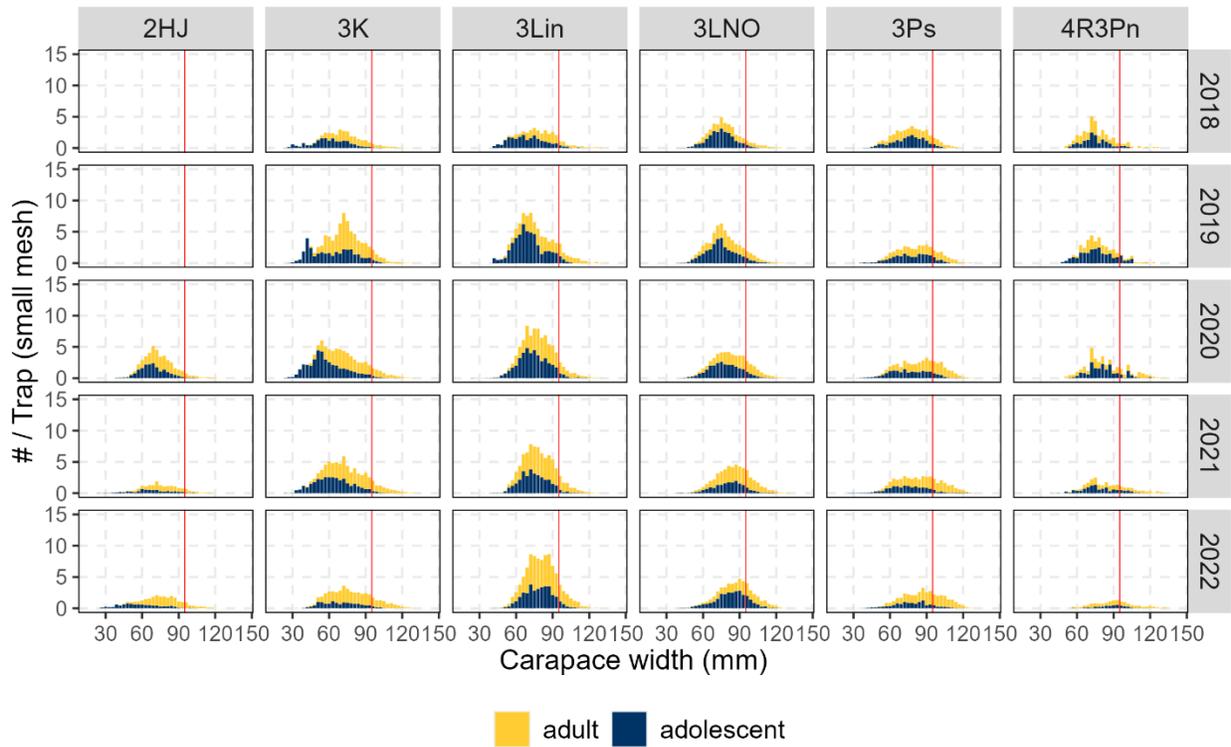


Figure 35. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations from the Collaborative Post-Season trap survey by Assessment Division (2018–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

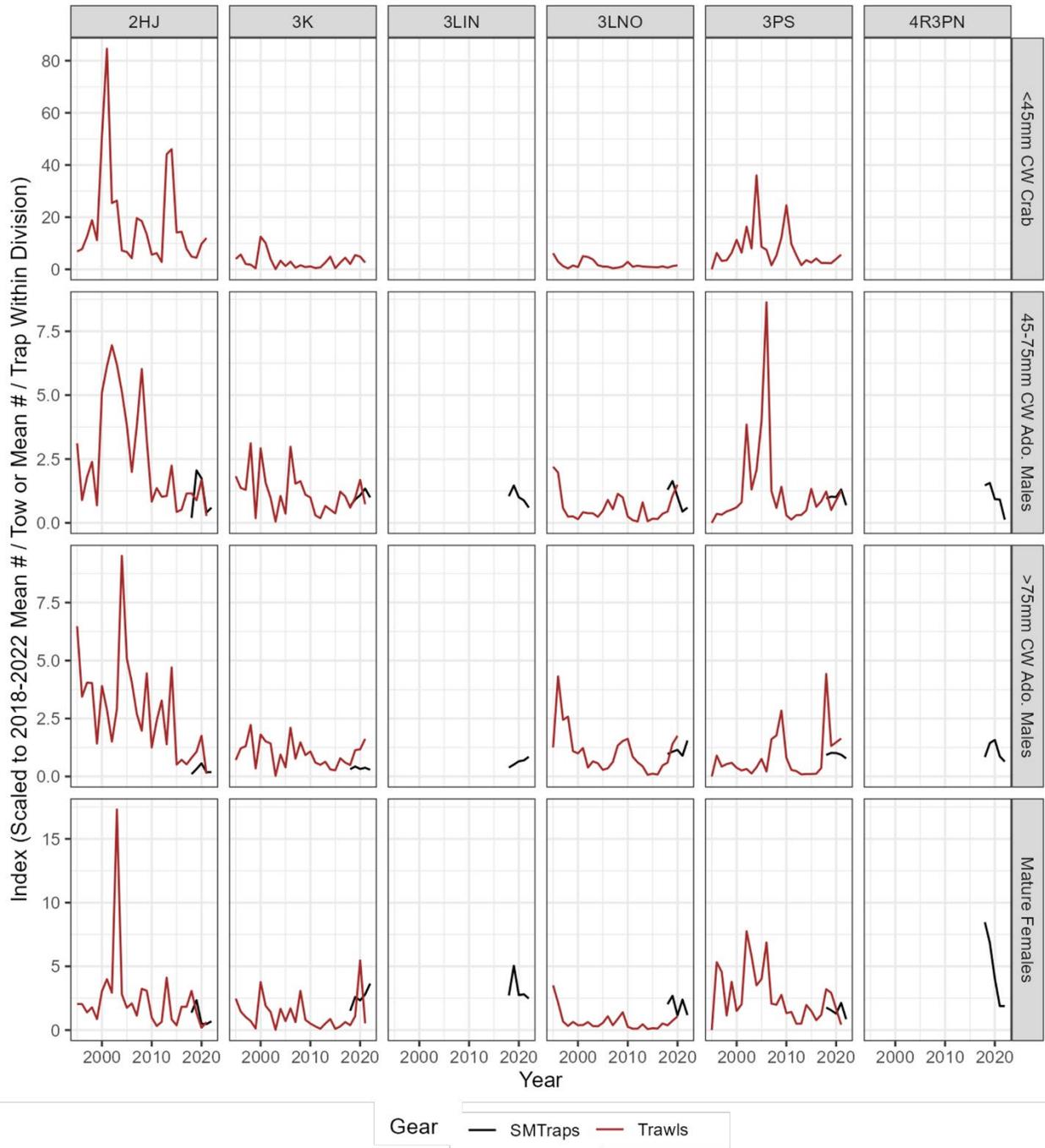


Figure 36. Indices of small, pre-recruit (>75 mm carapace width adolescent male), and mature female Snow Crab from the trawl (red) and small-mesh trap (black) surveys. Annual value (#/tow for trawl, #/trap for traps) scaled to the 2018–22 mean.

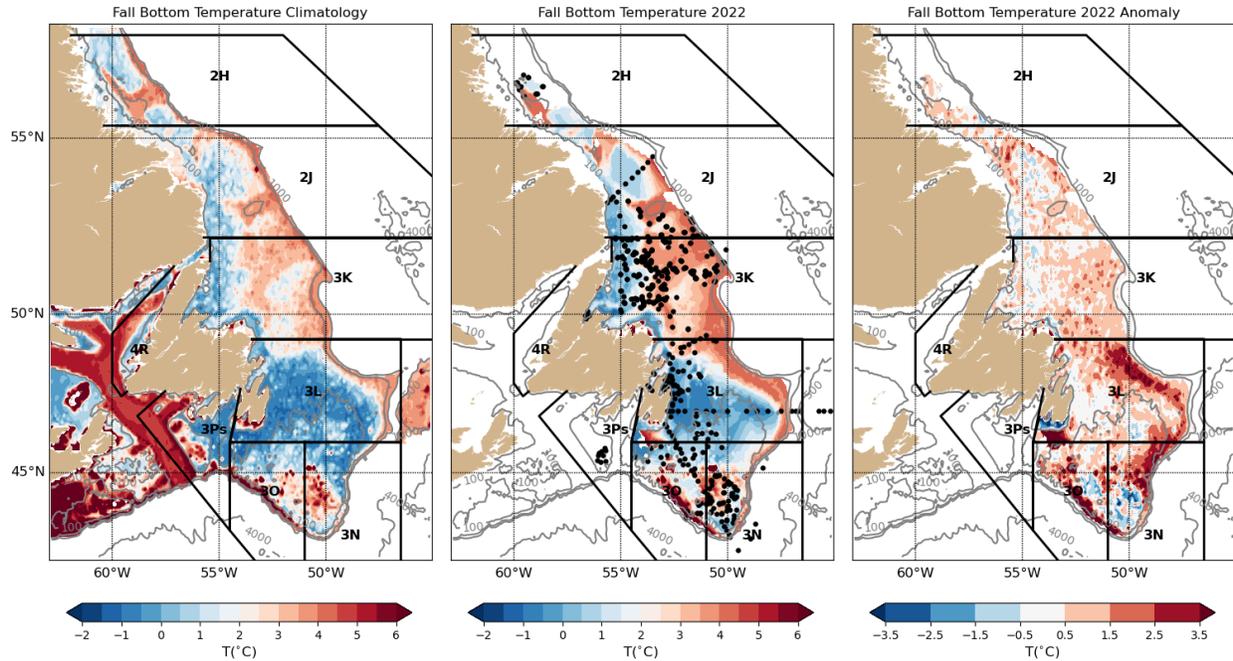


Figure 37. Fall bottom temperatures on the Newfoundland and Labrador Shelf averaged over the 1991–2020 climatological period (left panel) and during 2022 (center). Temperature anomalies for 2022 in relation to the climatology is shown in the right panel. Black dots in the center panel indicate the location of the profiles used to calculate the 2022 update (mostly multispecies survey observations).

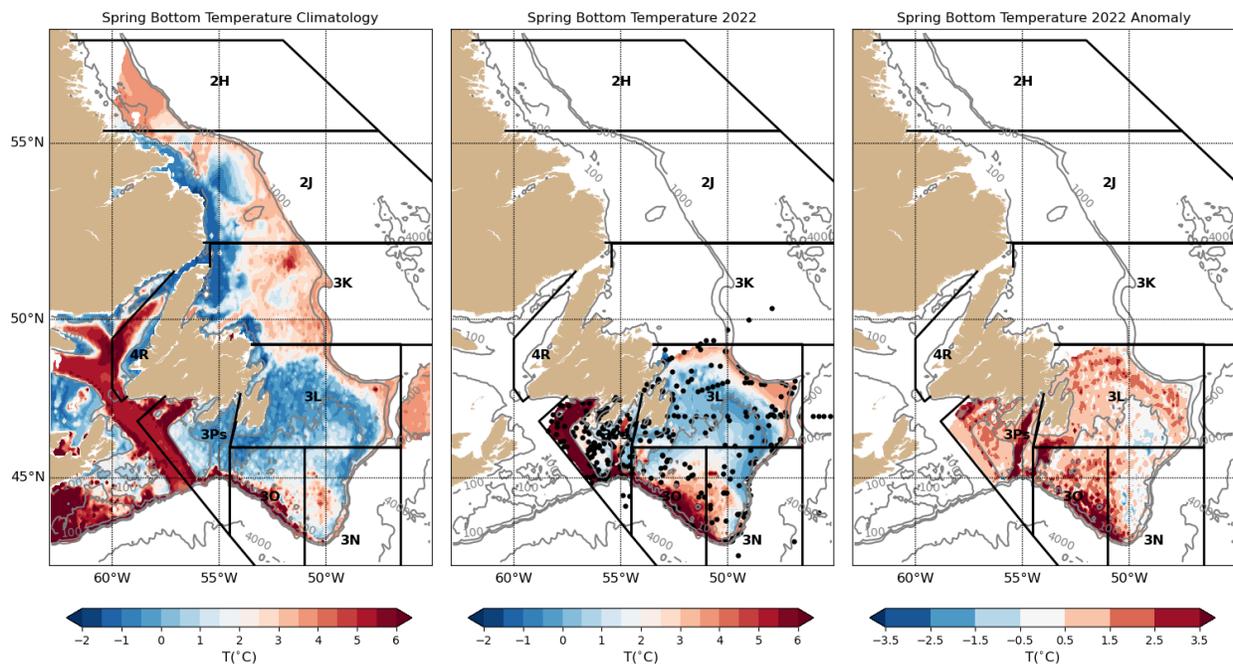


Figure 38. Spring bottom temperatures on the Newfoundland and Labrador Shelf averaged over the 1991–2020 climatological period (left panel) and during 2022 (center). Temperature anomalies for 2022 in relation to the climatology are shown in the right panel. Black dots in the center panel indicate the location of the profiles used to calculate the 2022 update (mostly multispecies survey observations).

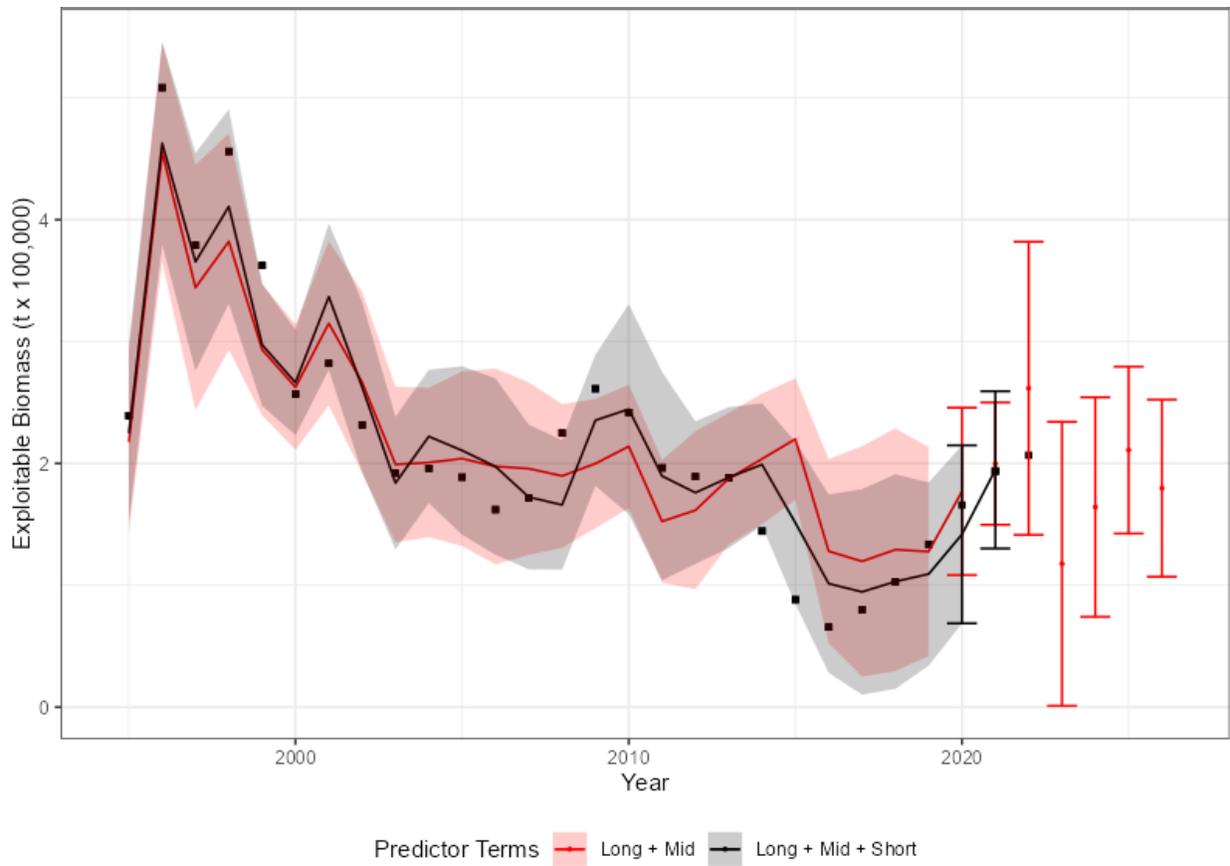


Figure 39. Short-term prediction model of exploitable biomass. Black squares are trawl survey-measured exploitable biomass in NAFO Divs. 2HJ3KLNOP (1995–2022). Black lines, points, and associated error bars are full model fits (short-, mid-, long-term effects) and red lines, dots, and associated error bars are model run with no short-term effects. Shaded areas are 95% confidence intervals of model fits.

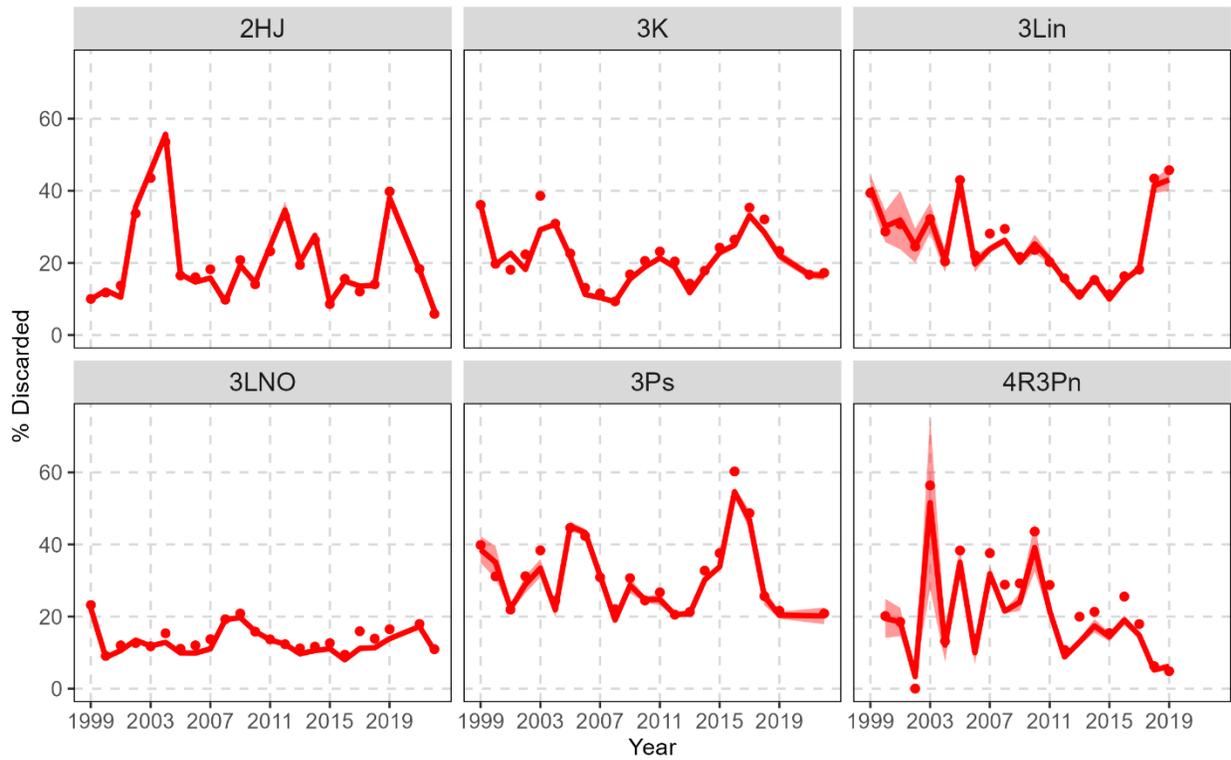


Figure 40. Discards (%) based on raw estimates (points) and standardized values (solid lines) by Assessment Division (1999–2022). The shaded area represents the 95% confidence interval. Years without results represent low or absent at-sea observer coverage.

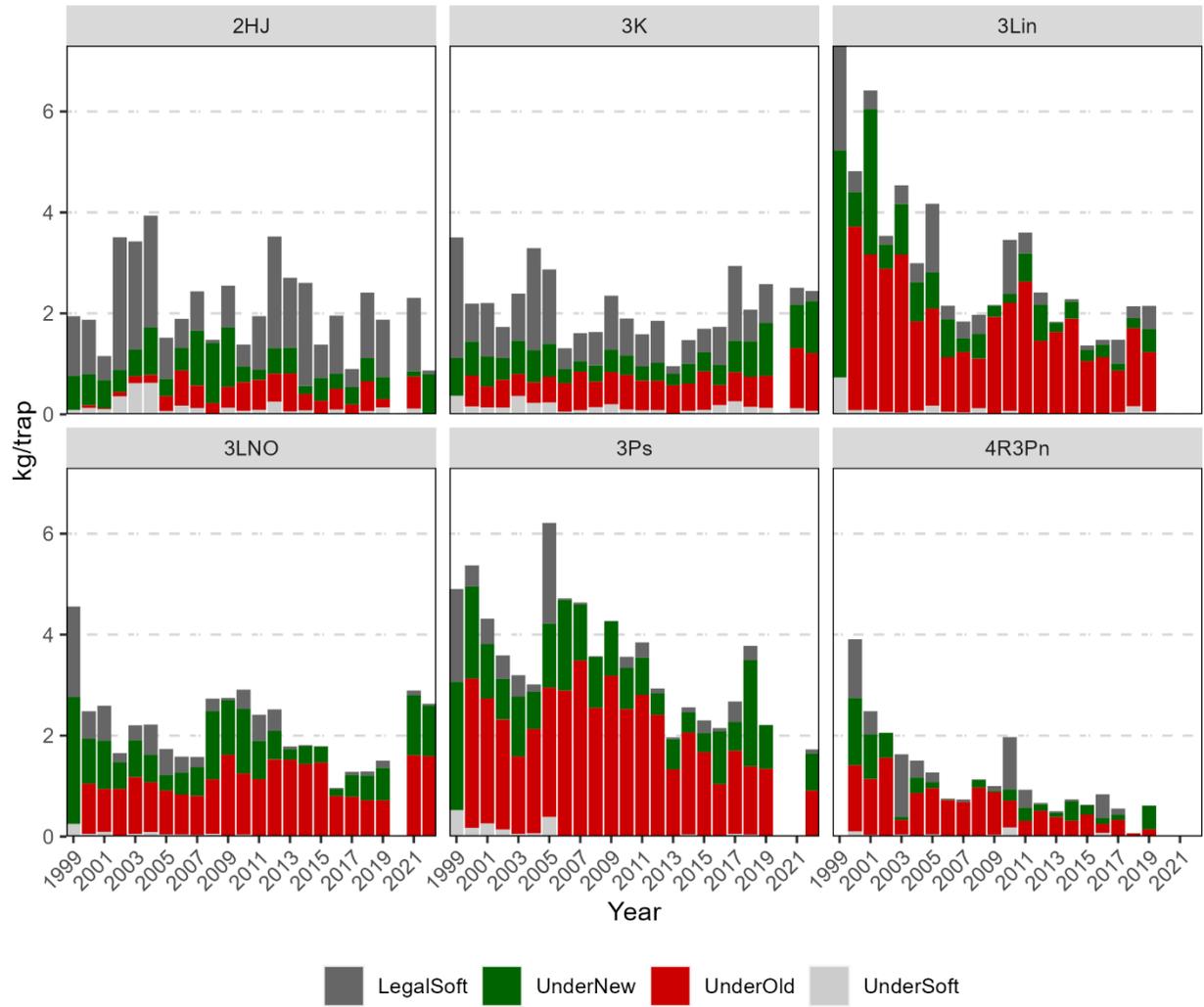


Figure 41. Catch rates of discards (kg/trap) by size and shell condition groups (legal-sized soft-shelled, undersized new-shelled, undersized old-shelled, and undersized soft-shelled) by Assessment Division (1999–2022) from at-sea observer sampling. Years without results represent low or absent at-sea observer coverage.

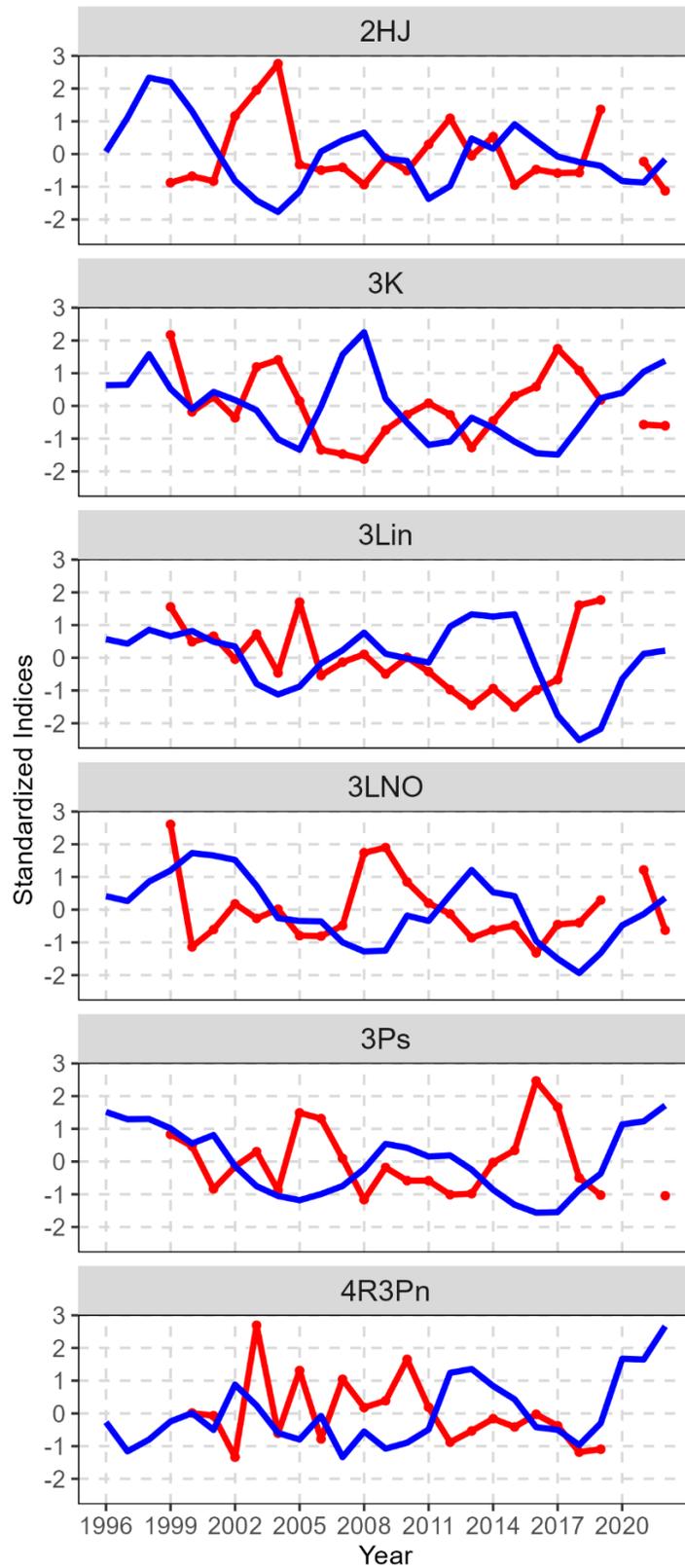


Figure 42. Standardized CPUE (blue) and discard rates (red) by Assessment Division (1996–2022). Years without results represent low or absent at-sea observer coverage.

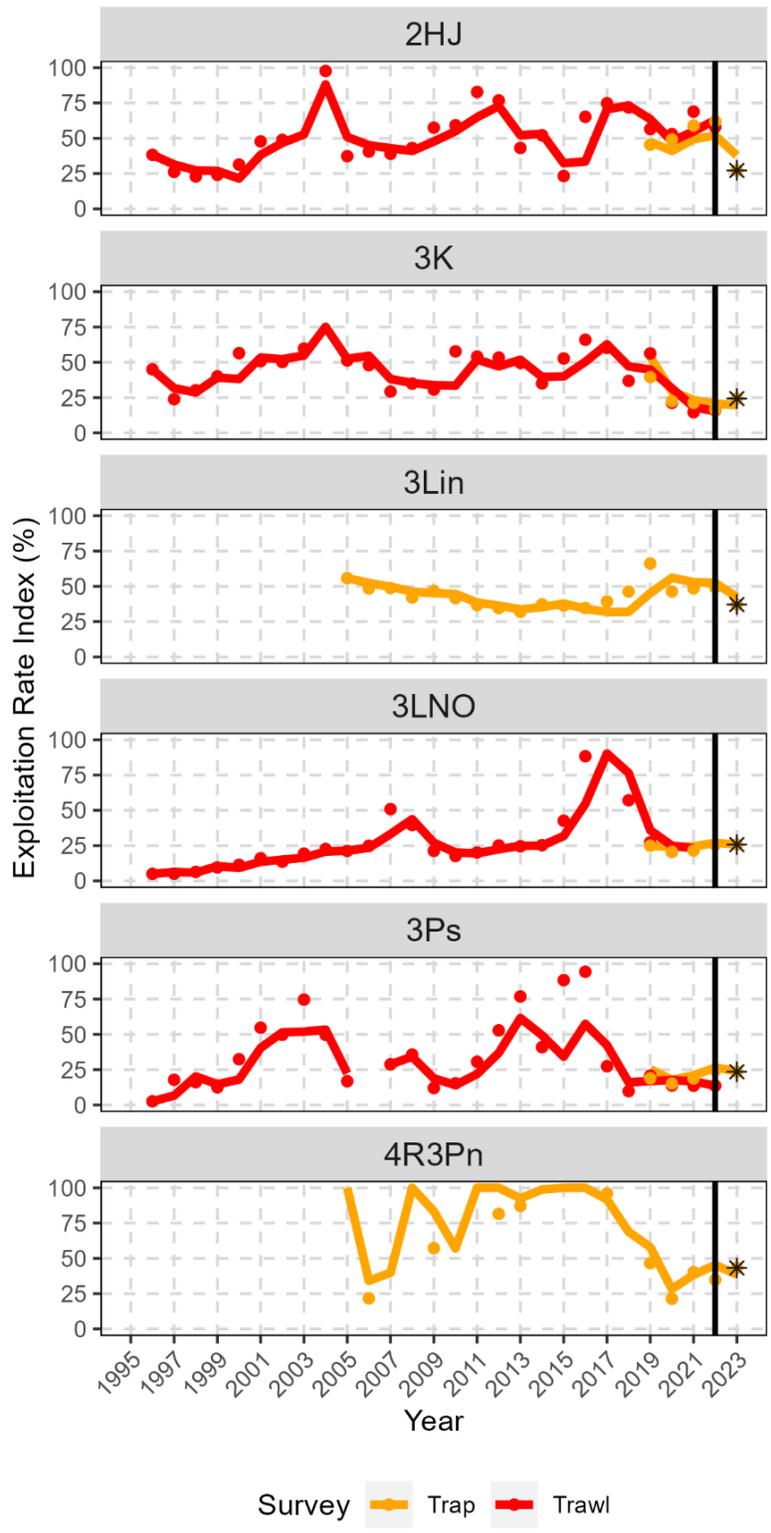


Figure 43. Annual trawl survey-based Exploitation Rate Index (ERI) (red) (1996–2022) and trap survey-based ERI (orange) (2005–22) by Assessment Division. Solid line = two-year moving average of ERI, point = annual estimate, and 2023 points (*) depict projected annual ERIs under status quo removals in the 2023 fishery.

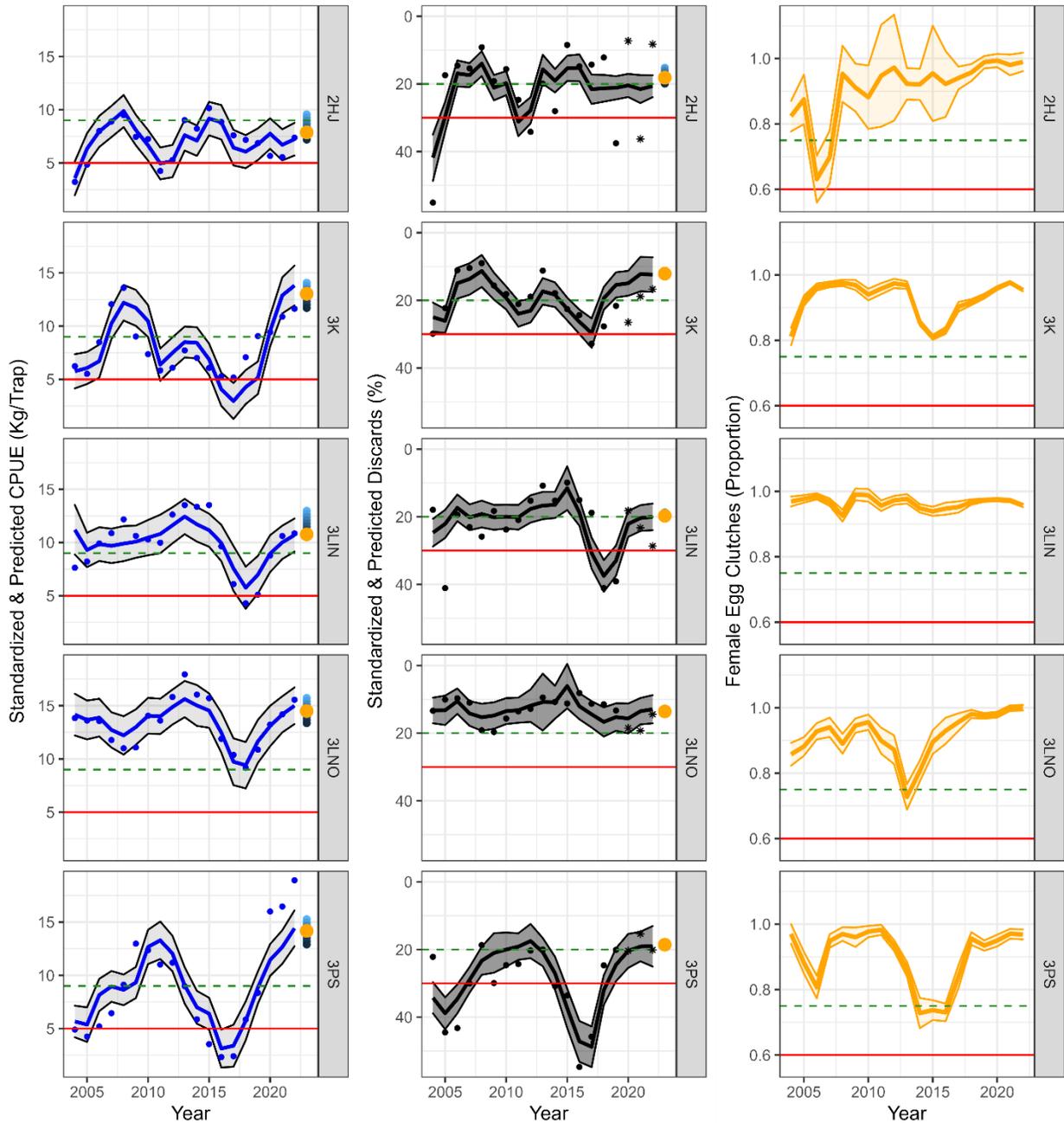


Figure 44. Predicted CPUE (left), predicted % discards (middle), and observed proportion of females with full egg clutches (right) (solid lines), as well as standardized CPUE and % discards (points) in the Precautionary Approach Framework, by Assessment Division (2004–22). Shaded areas = prediction intervals (CPUE and discards) or 1 standard deviation (egg clutches), orange points = predicted values under status quo landings in the 2023 fishery, vertical blue shades in 2023 = predicted values under varying levels of Exploitation Rate Index (ERI) (light to dark blue: ERI = 5–42%), Red horizontal line = Limit Reference Point, green horizontal line = Upper Stock Reference.

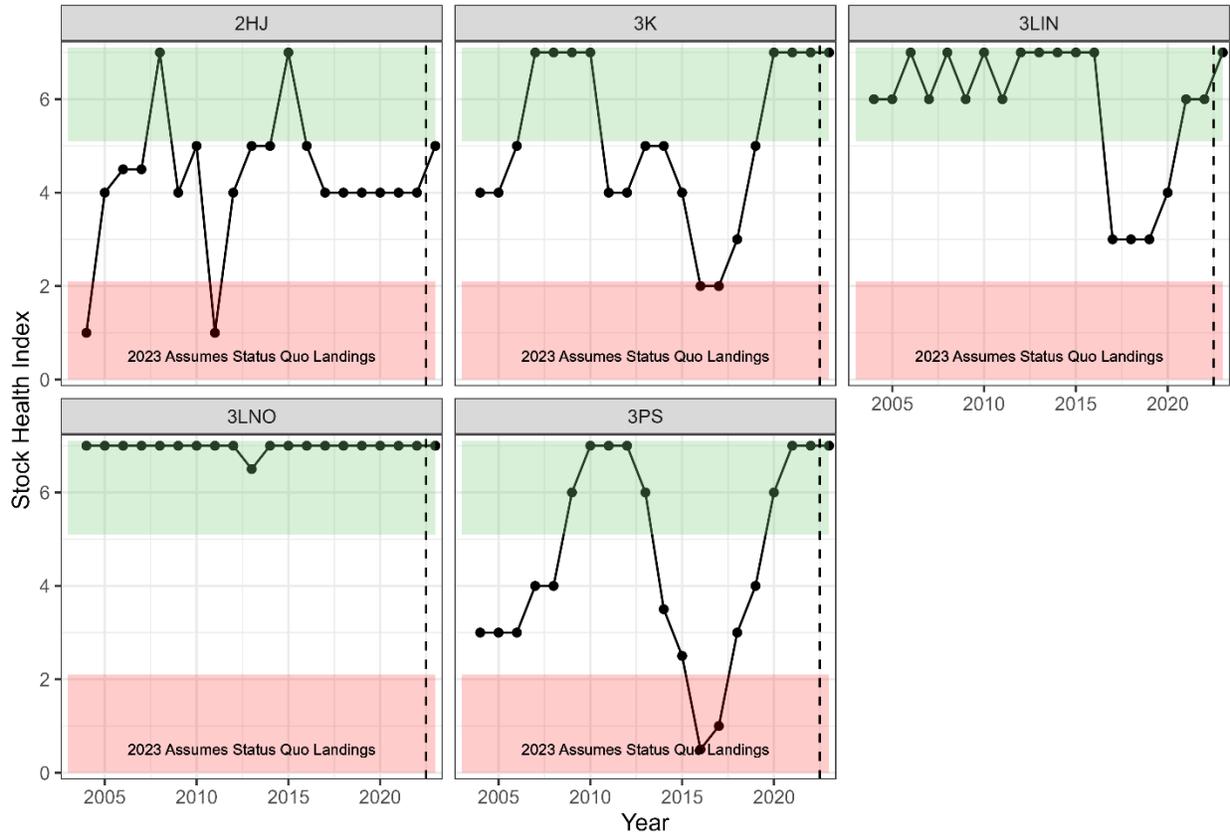


Figure 45. Projected stock status (black points) in the NL Snow Crab Precautionary Approach Framework, by Assessment Division (2004–23). The green, white, and red shaded areas represent the Healthy, Cautious, and Critical Zones, respectively. The dashed vertical line represents the present year (2022), after which the stock status is predicted with status quo landings for 2023.

APPENDIX 1: ASSESSMENT DIVISION 2HJ DETAILS

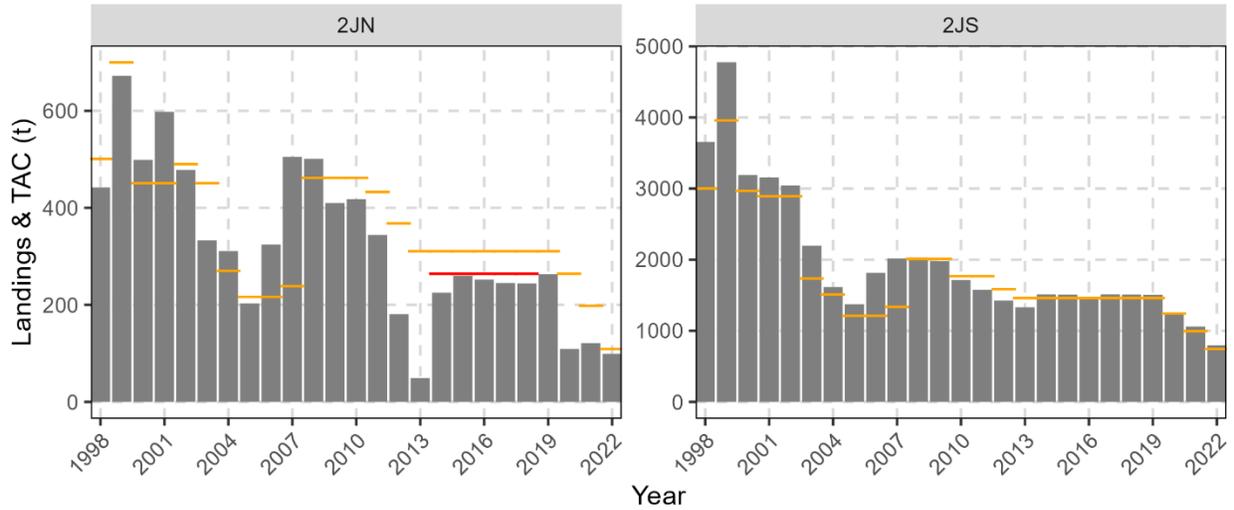


Figure A1.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 2HJ (1998–2022). Red dashes are the voluntary TAC (15% reduction of TAC) set by harvesters in 2JN from 2014 to 2018.

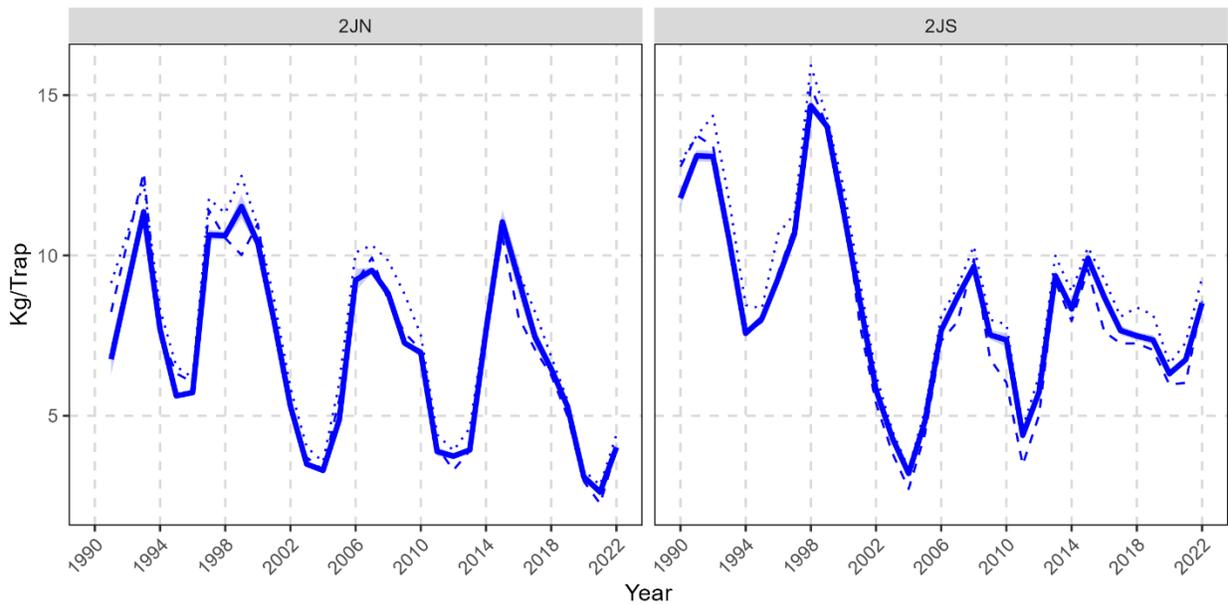


Figure A1.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 2HJ (1990–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

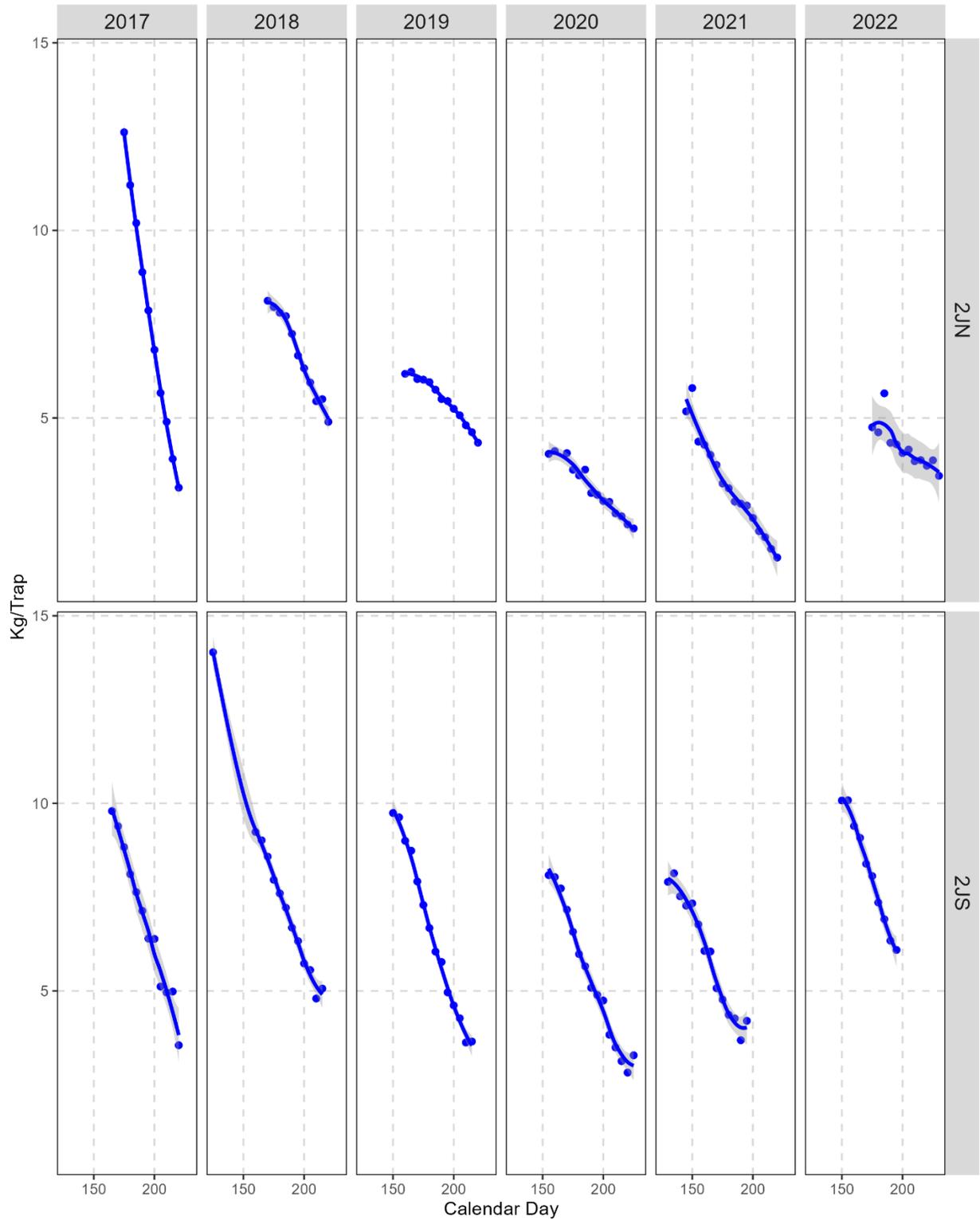


Figure A1.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 2HJ (2017–22), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

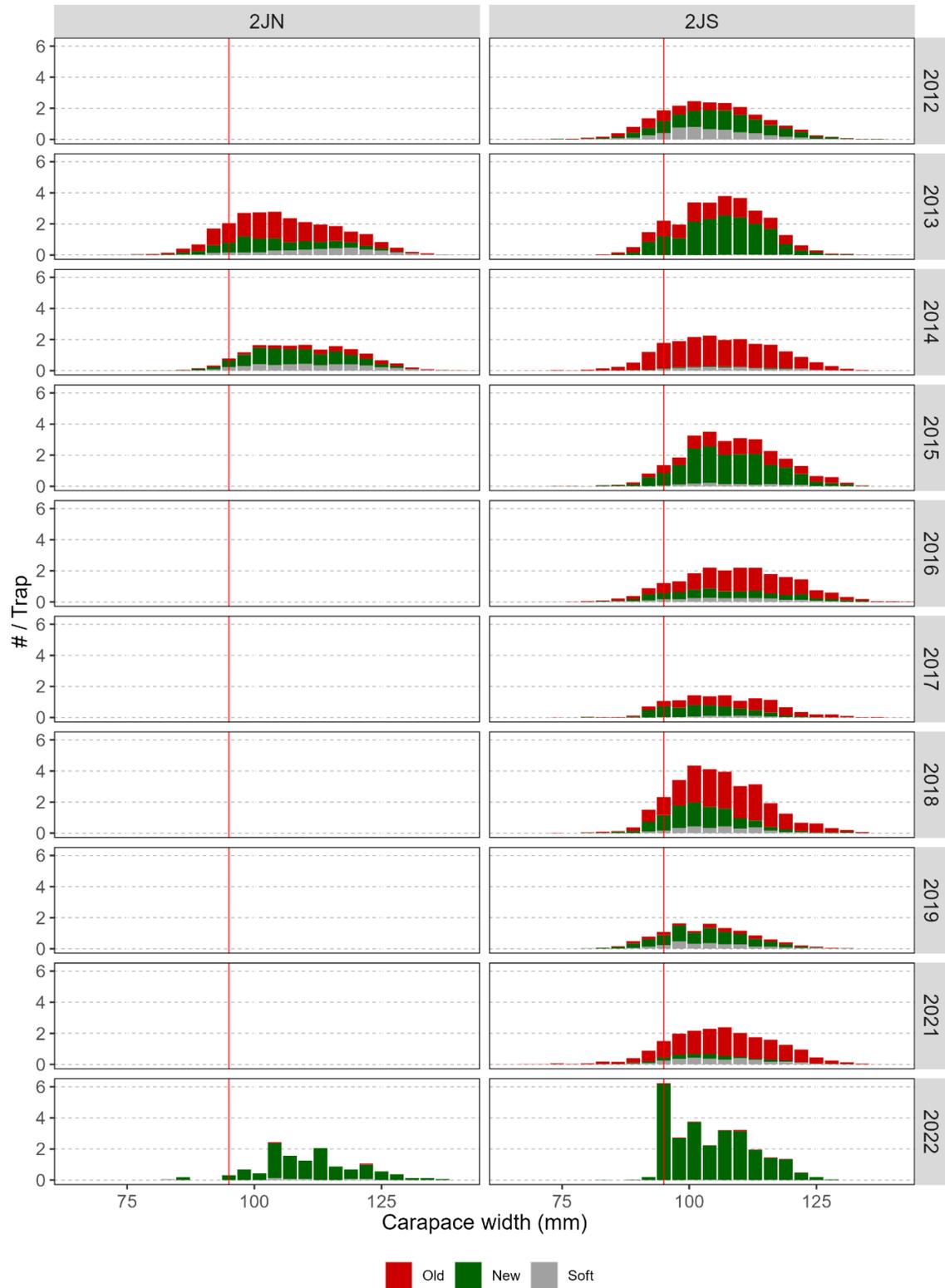


Figure A1.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 2HJ (2012–22). The red vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

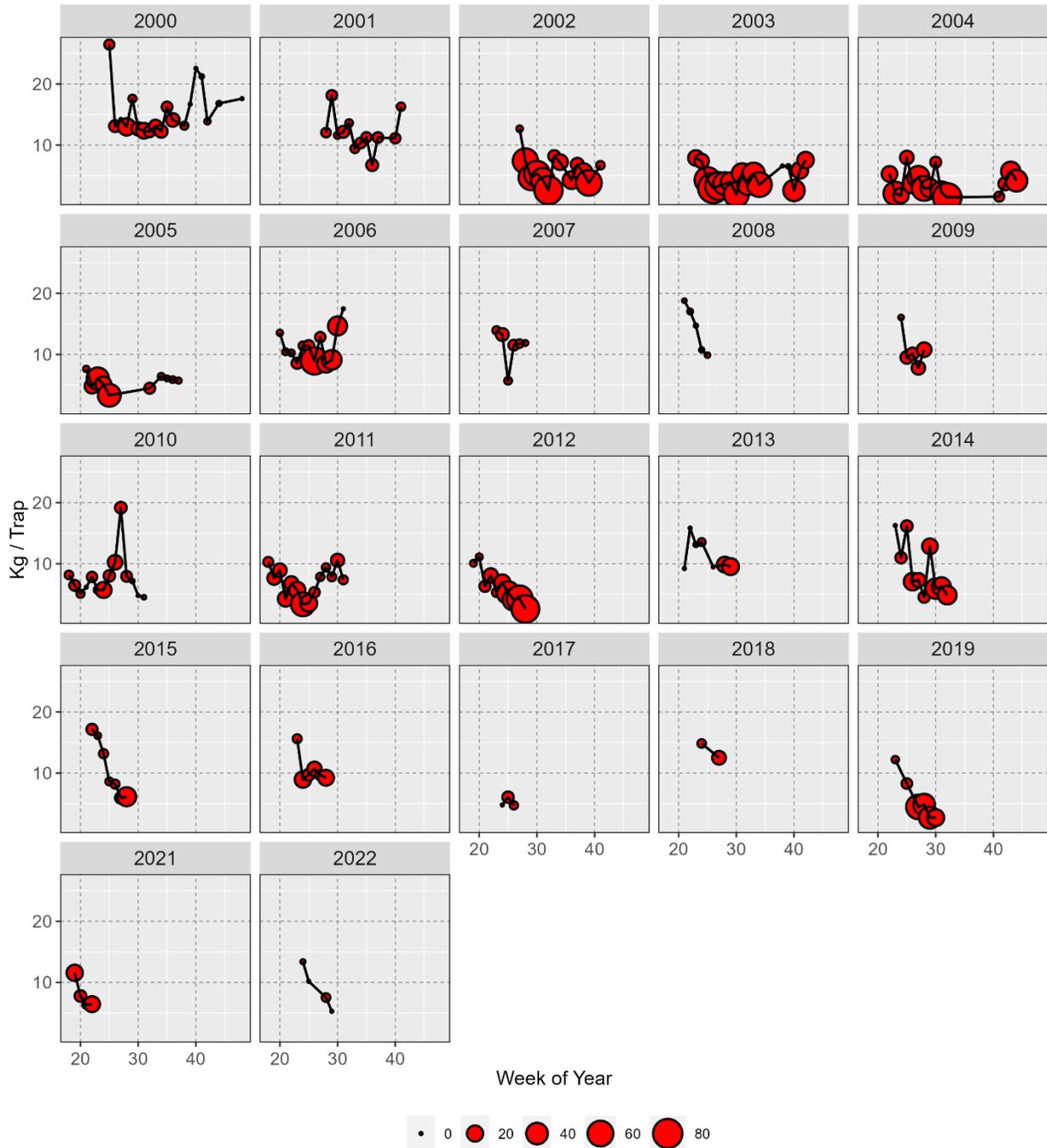


Figure A1.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling in Crab Management Areas within the Assessment Division 2HJ (2000–22). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

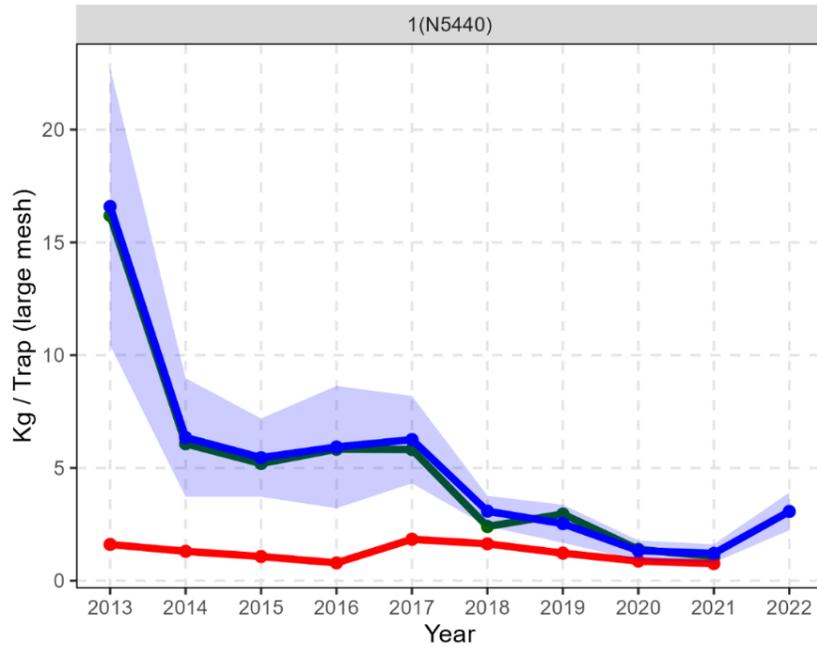


Figure A1.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable crab from large-mesh traps in the Torngat Joint Fisheries Board trap survey in Crab Management Area 1 (N5440/2JN) (2013–22). Shaded area represents the 95% confidence interval. Note: No shell conditions for 2022.

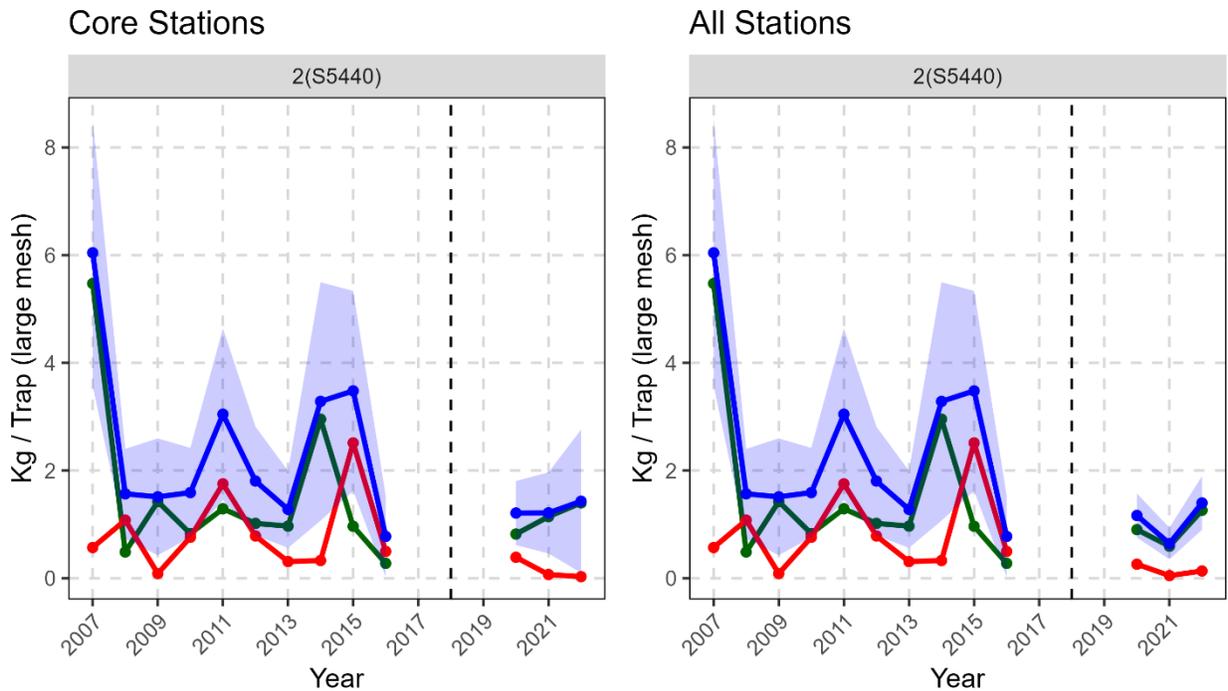


Figure A1.7. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Area 2 (S5440/2JS) (2007–22). Shaded area represents the 95% confidence interval. The dashed vertical line denotes the CPS survey re-design. Years without results represent incomplete or absent survey coverage.

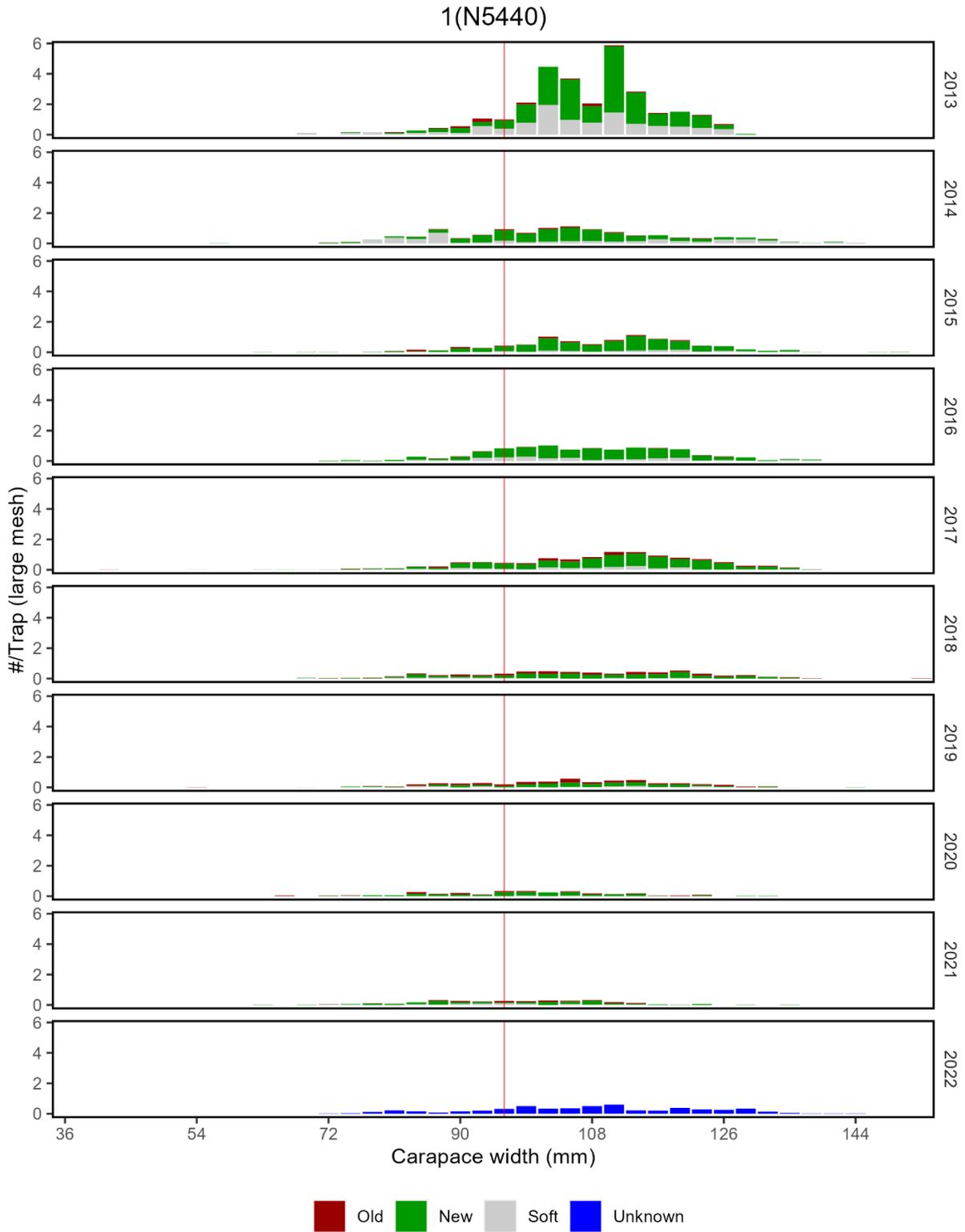


Figure A1.8. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps in the Torngat Joint Fisheries Board trap survey in Crab Management Area 1 (N5440/2JN) in Assessment Division 2HJ (2013–22). The red vertical line indicates the minimum legal size. Note: No shell conditions for 2022.

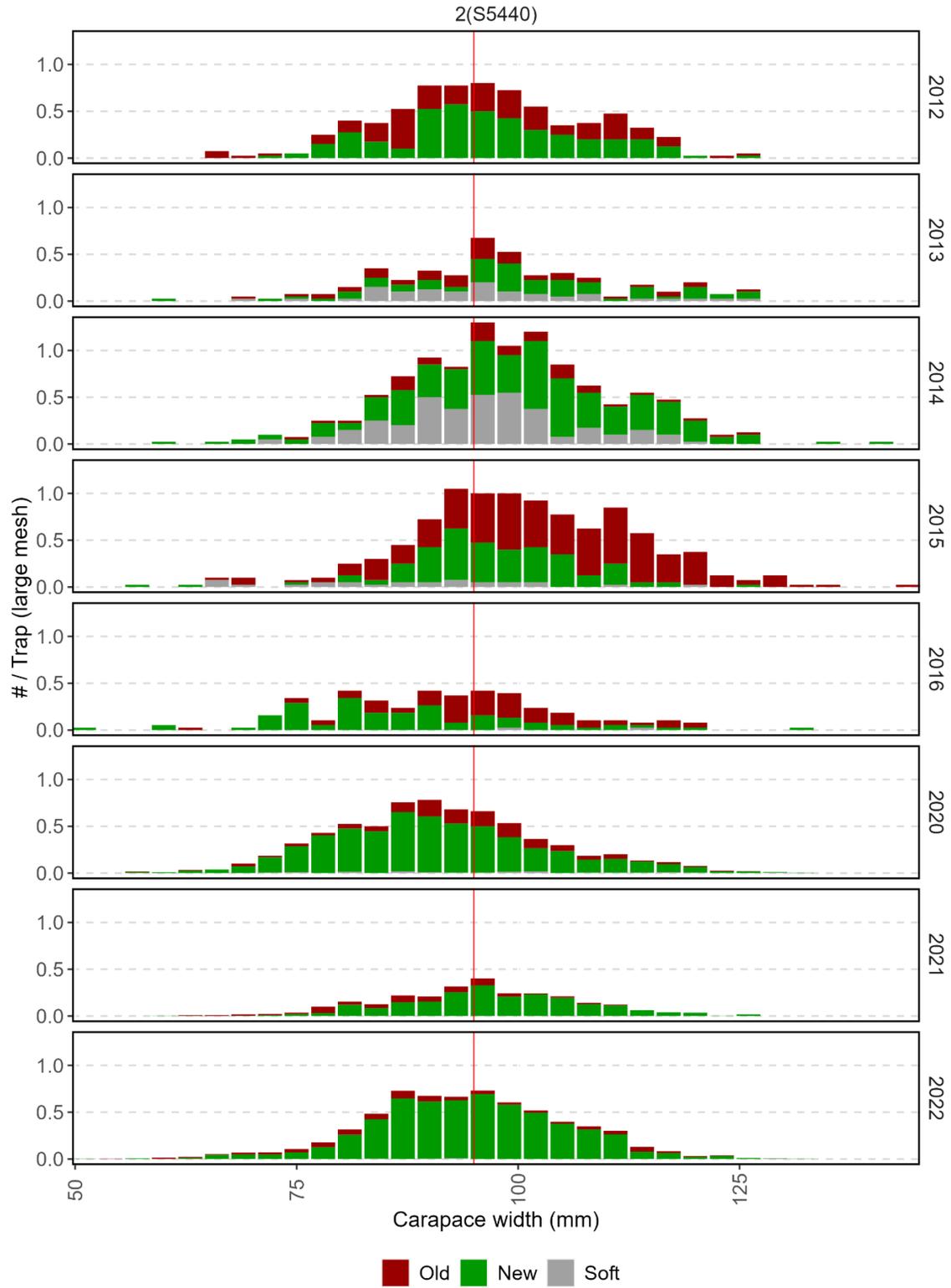


Figure A1.9. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Area 2 (S5440/2JS) in Assessment Division 2HJ (2012–16, 2020–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

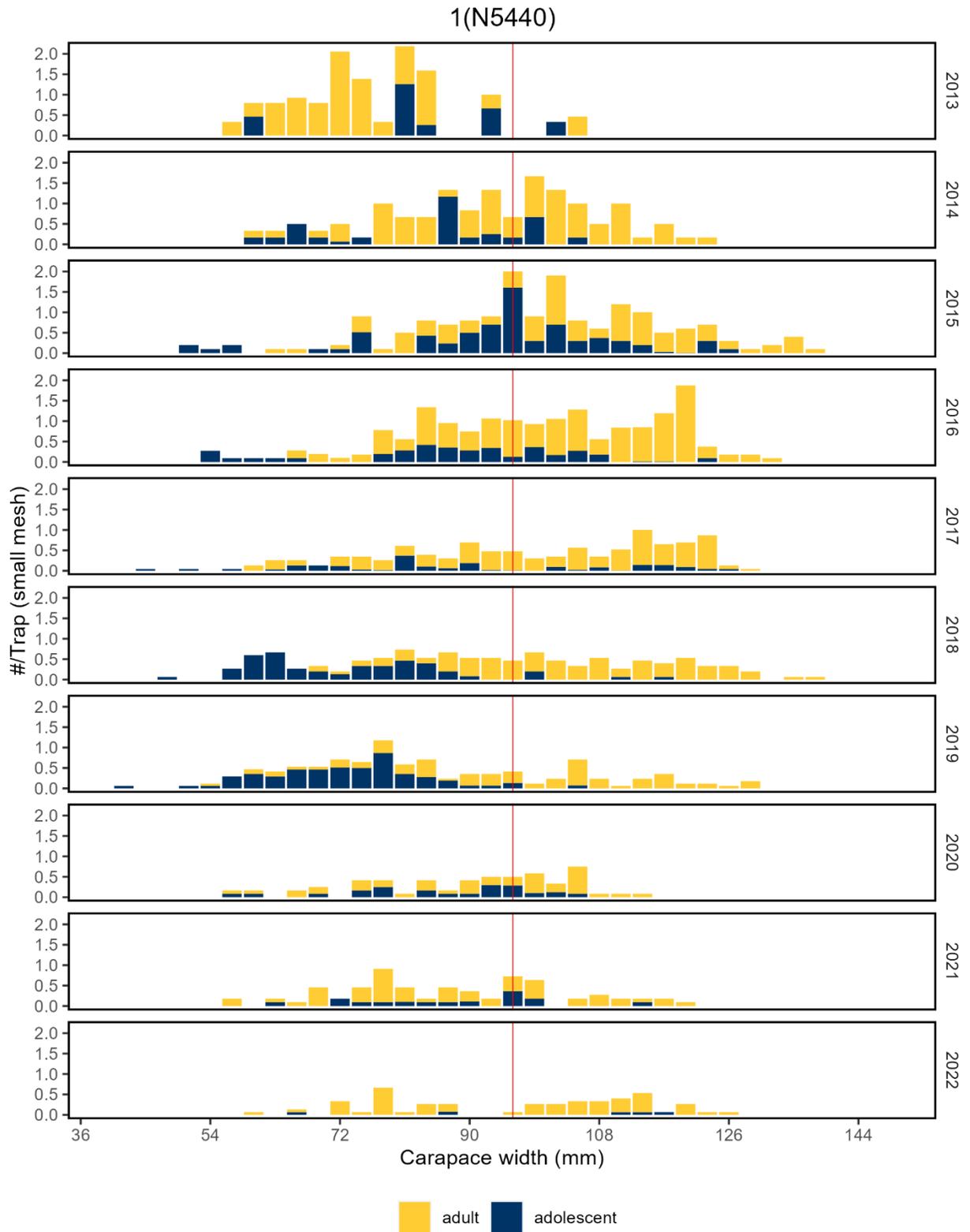


Figure A1.10. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the Torngat Joint Fisheries Board trap survey in Crab Management Area 1 (N5440/2JN) in Assessment Division 2HJ (2013–22). The red vertical line indicates the minimum legal size.

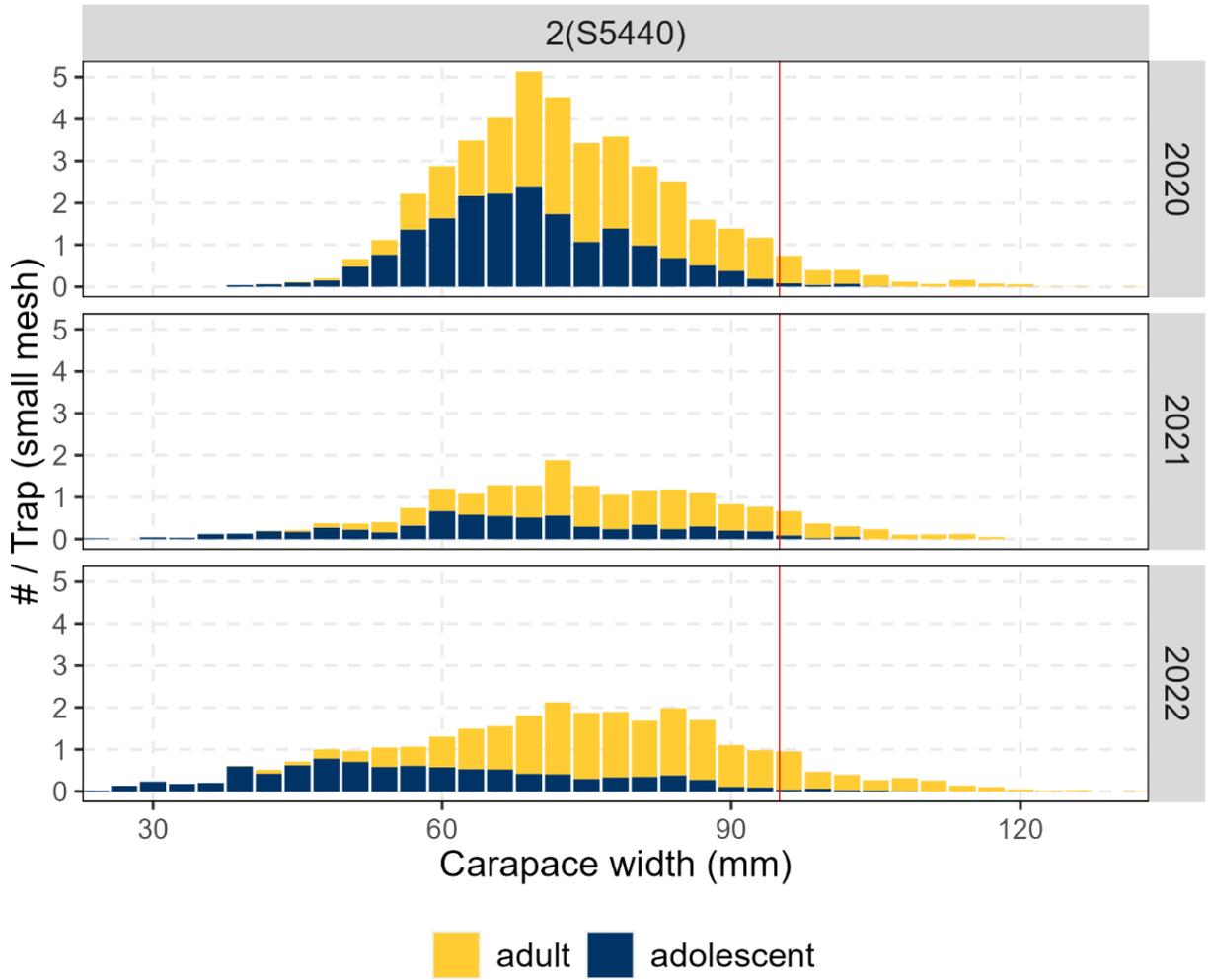


Figure A1.11. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Area 2 (S5440/2JS) in Assessment Division 2HJ (2020–22). The red vertical line indicates the minimum legal size.

APPENDIX 2: ASSESSMENT DIVISION 3K DETAILS

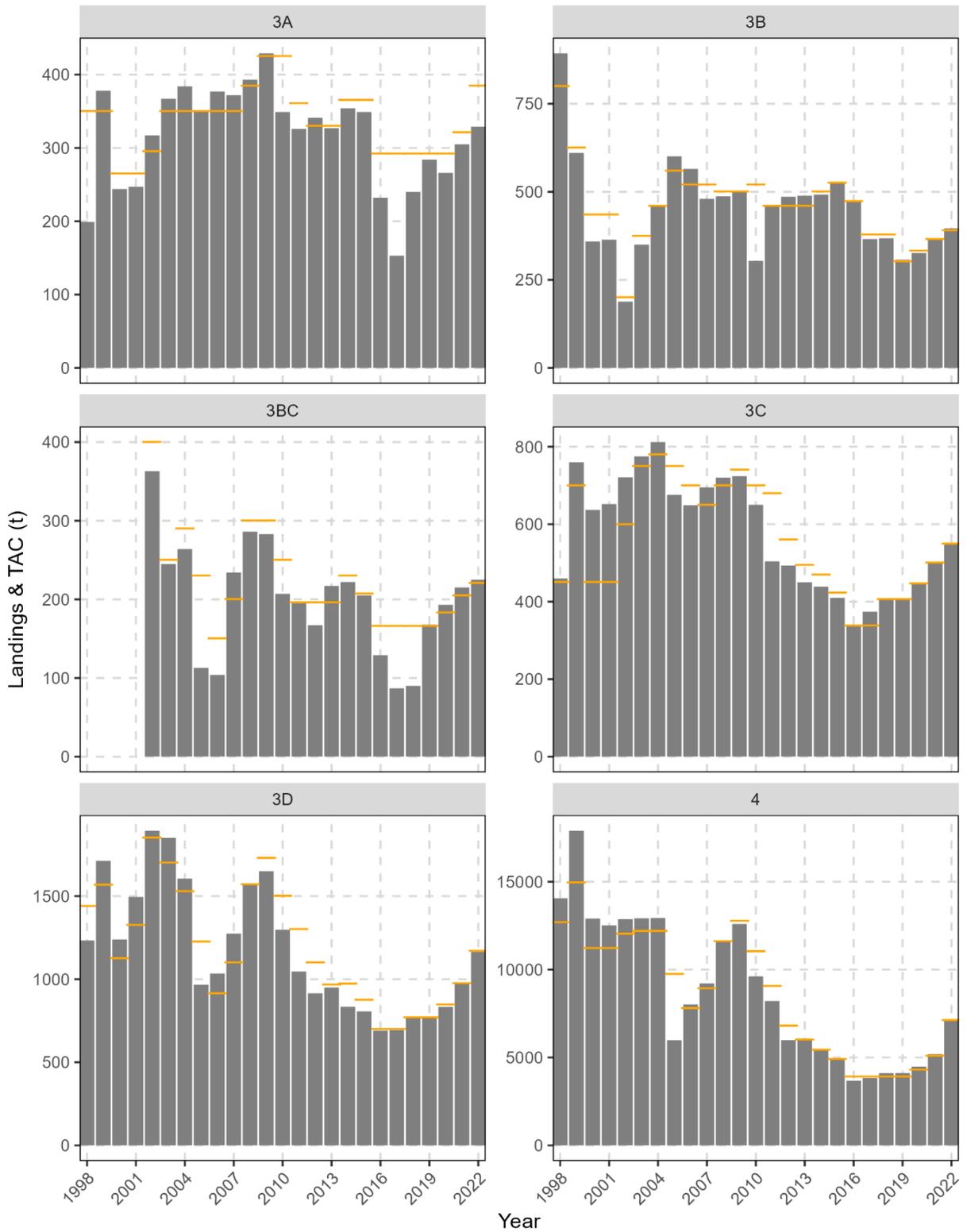


Figure A2.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 3K (1998–2022).

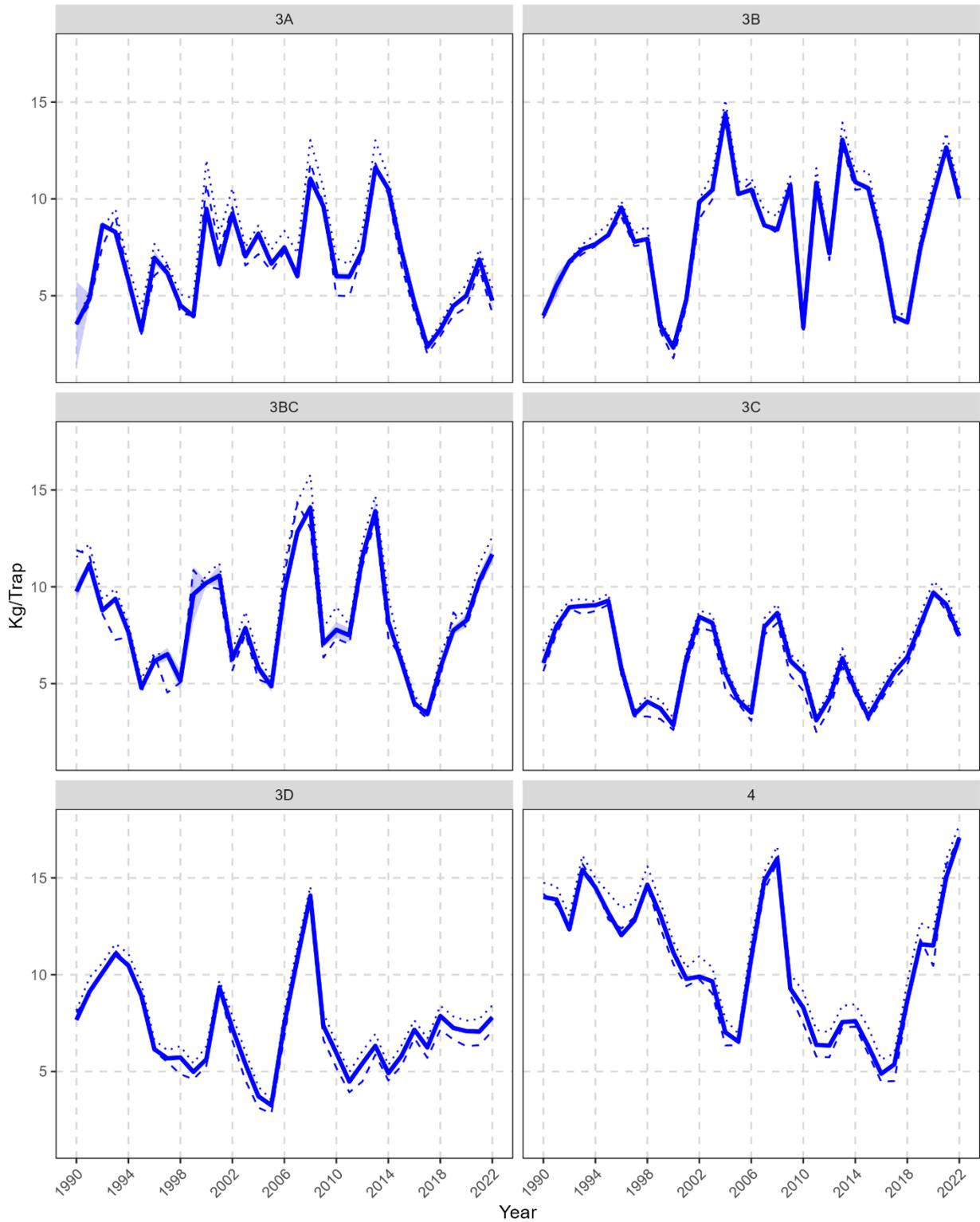


Figure A2.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 3K (1990–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

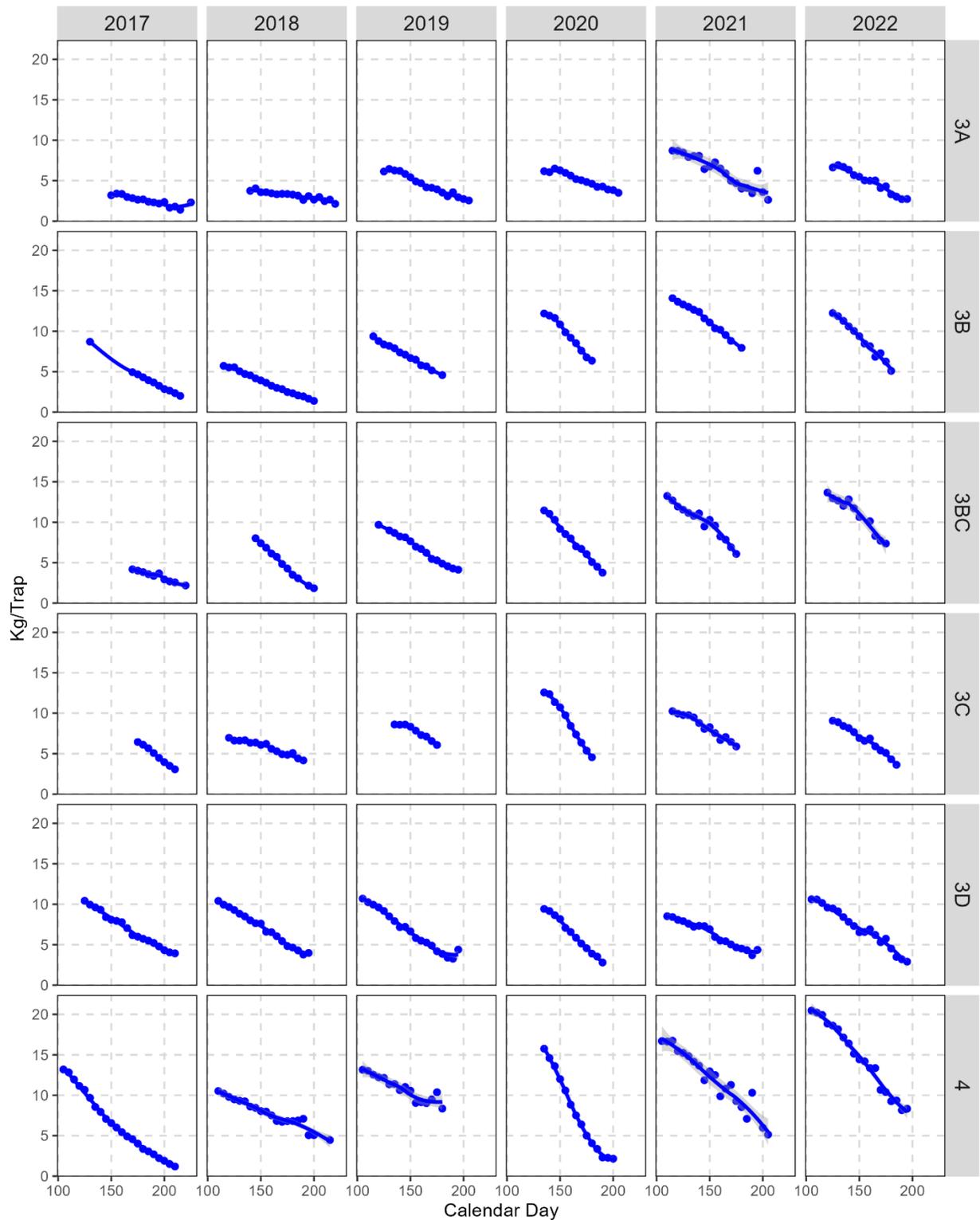


Figure A2.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 3K (2017–22), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

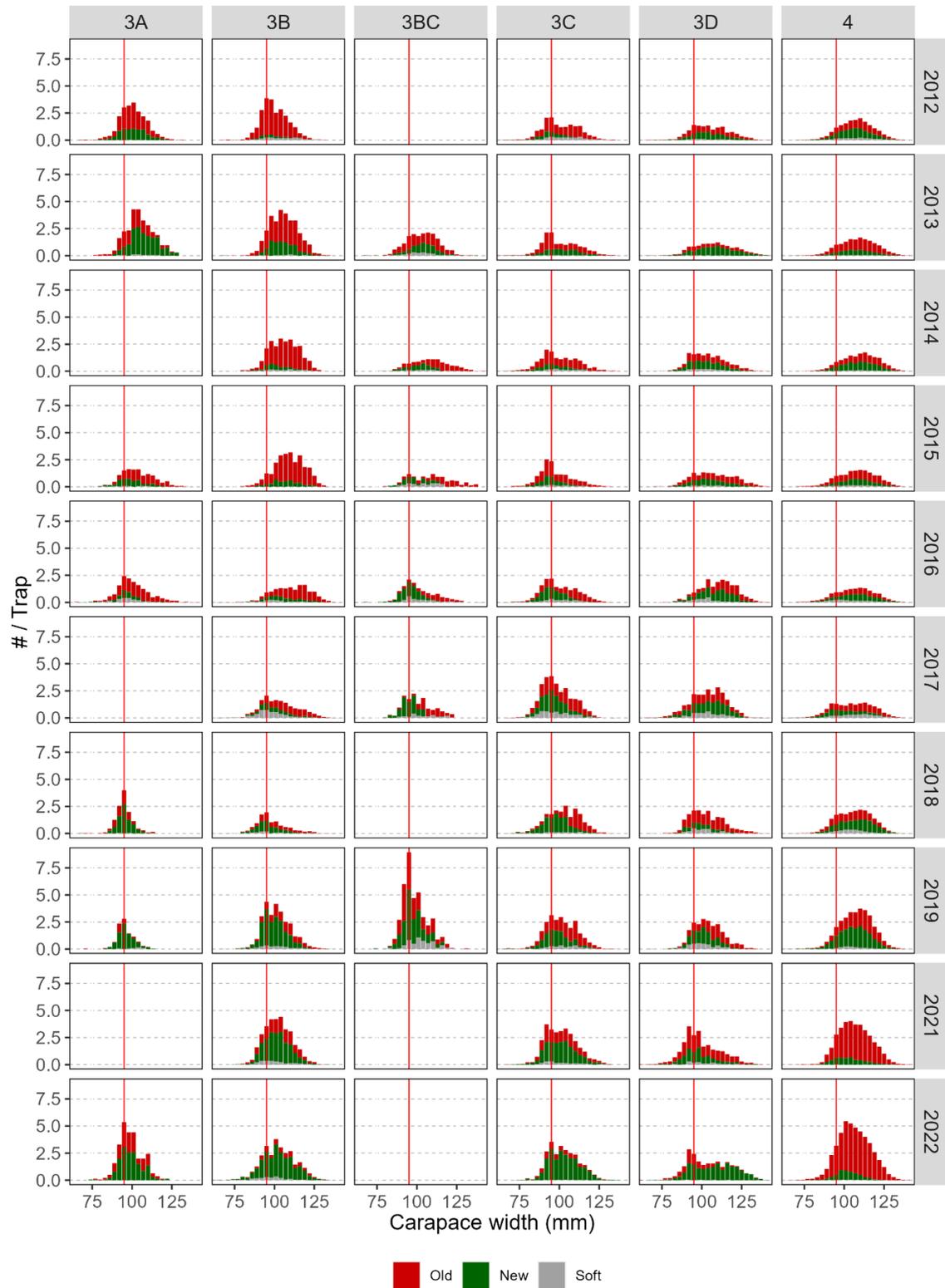


Figure A2.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 3K (2012–22). The red vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

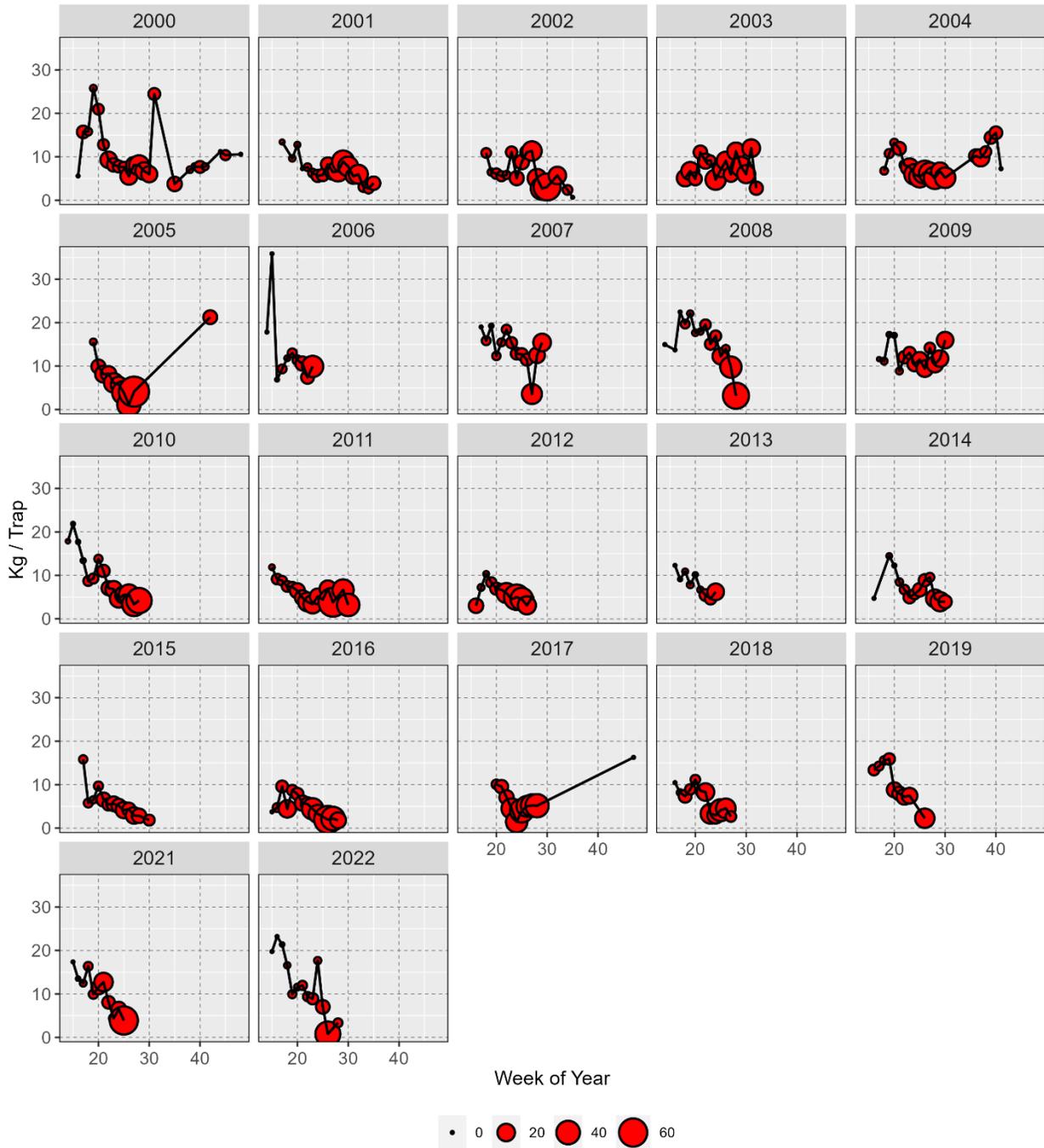


Figure A2.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling in Crab Management Areas within Assessment Division 3K (2000–22). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

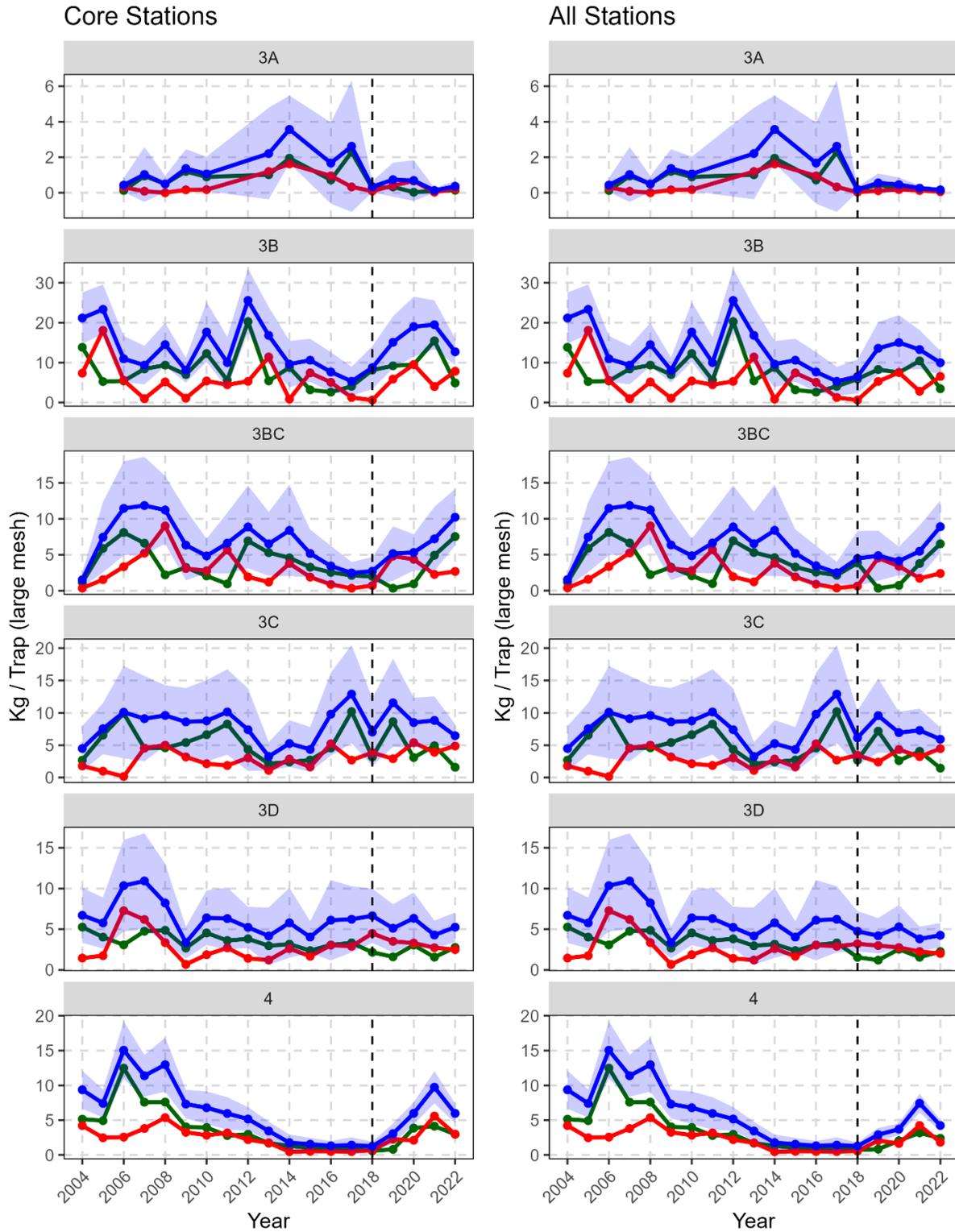


Figure A2.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 3K (2004–22). Shaded area represents the 95% confidence interval. The dashed vertical line denotes CPS survey redesign. Years without results represent incomplete or absent survey coverage.

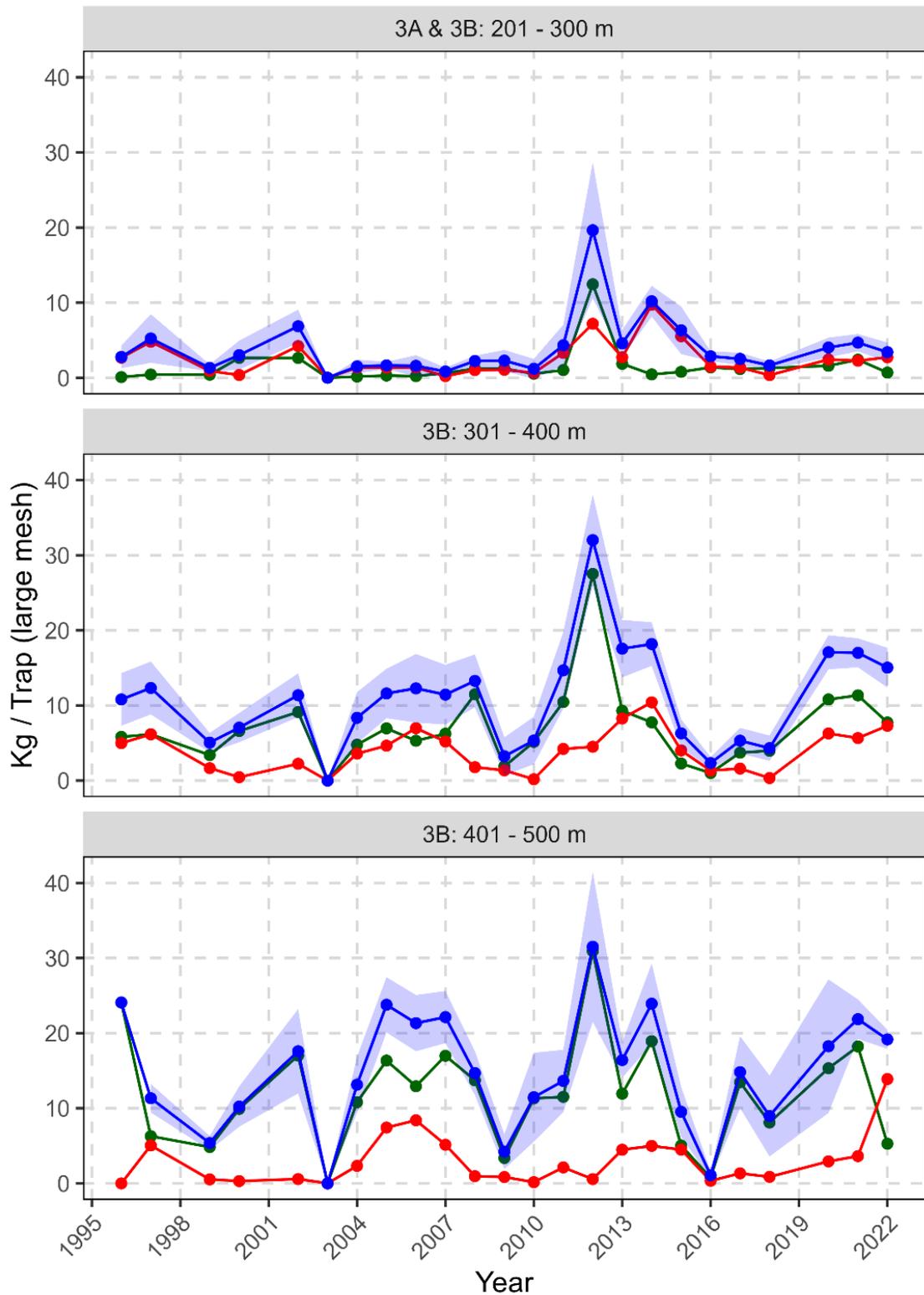


Figure A2.7. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys by depth strata in White Bay (Crab Management Areas 3A and 3B) (1996–2022). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

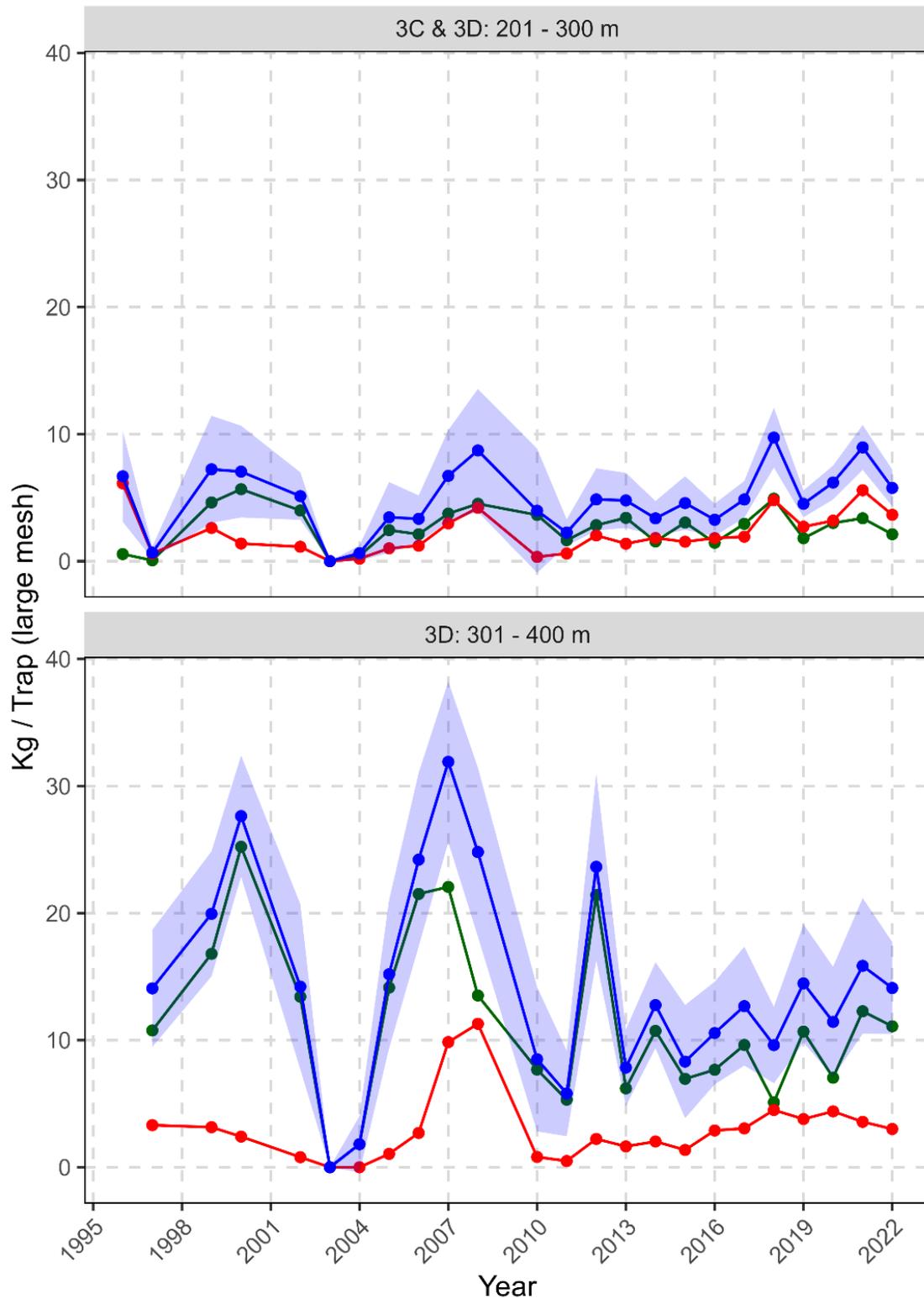


Figure A2.8. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys by depth strata in Green Bay and Notre Dame Bay (Crab Management Areas 3C and 3D) (1996–2022). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

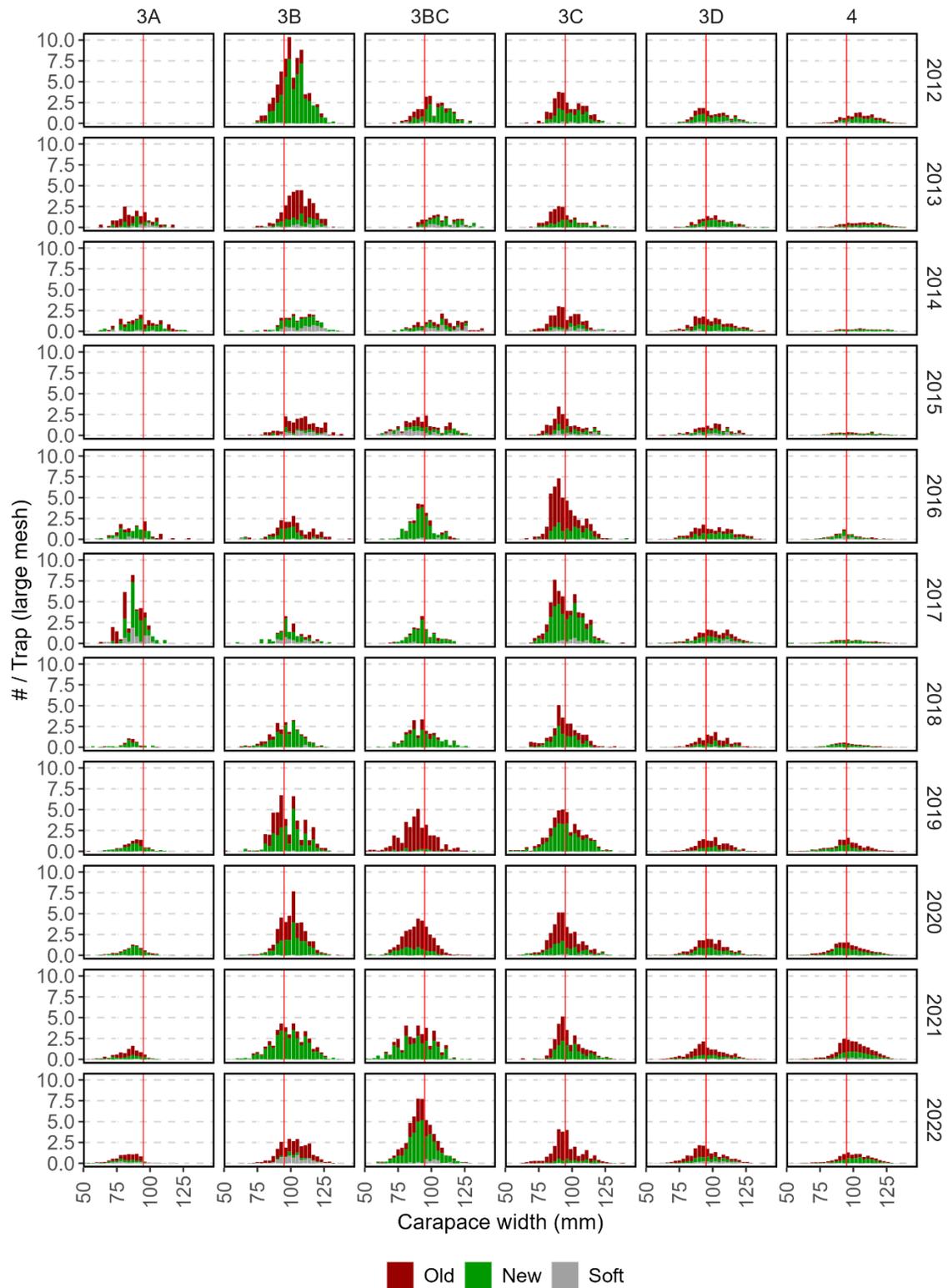


Figure A2.9. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3K (2012–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

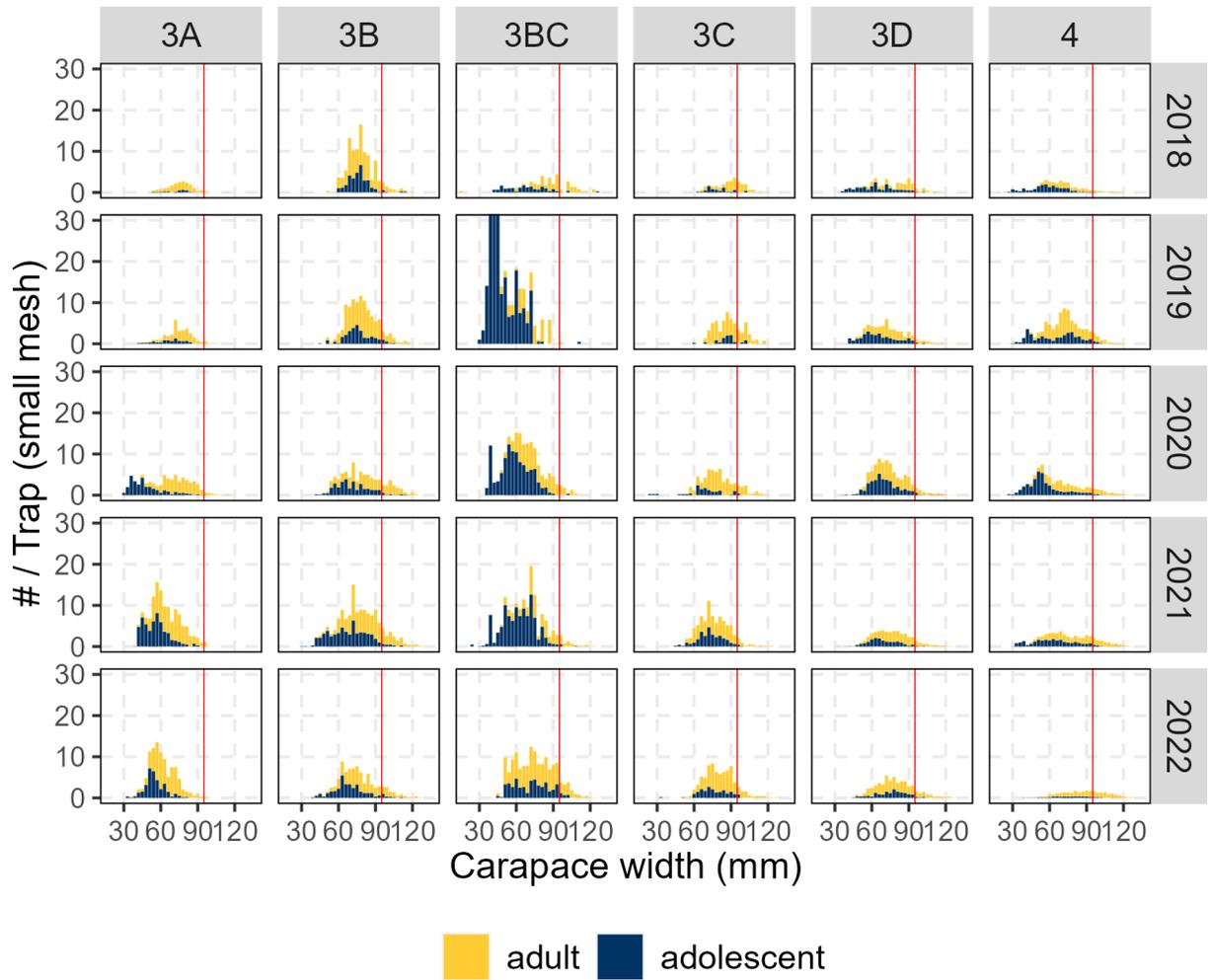


Figure A2.10. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3K (2018–22). The red vertical line indicates the minimum legal size.

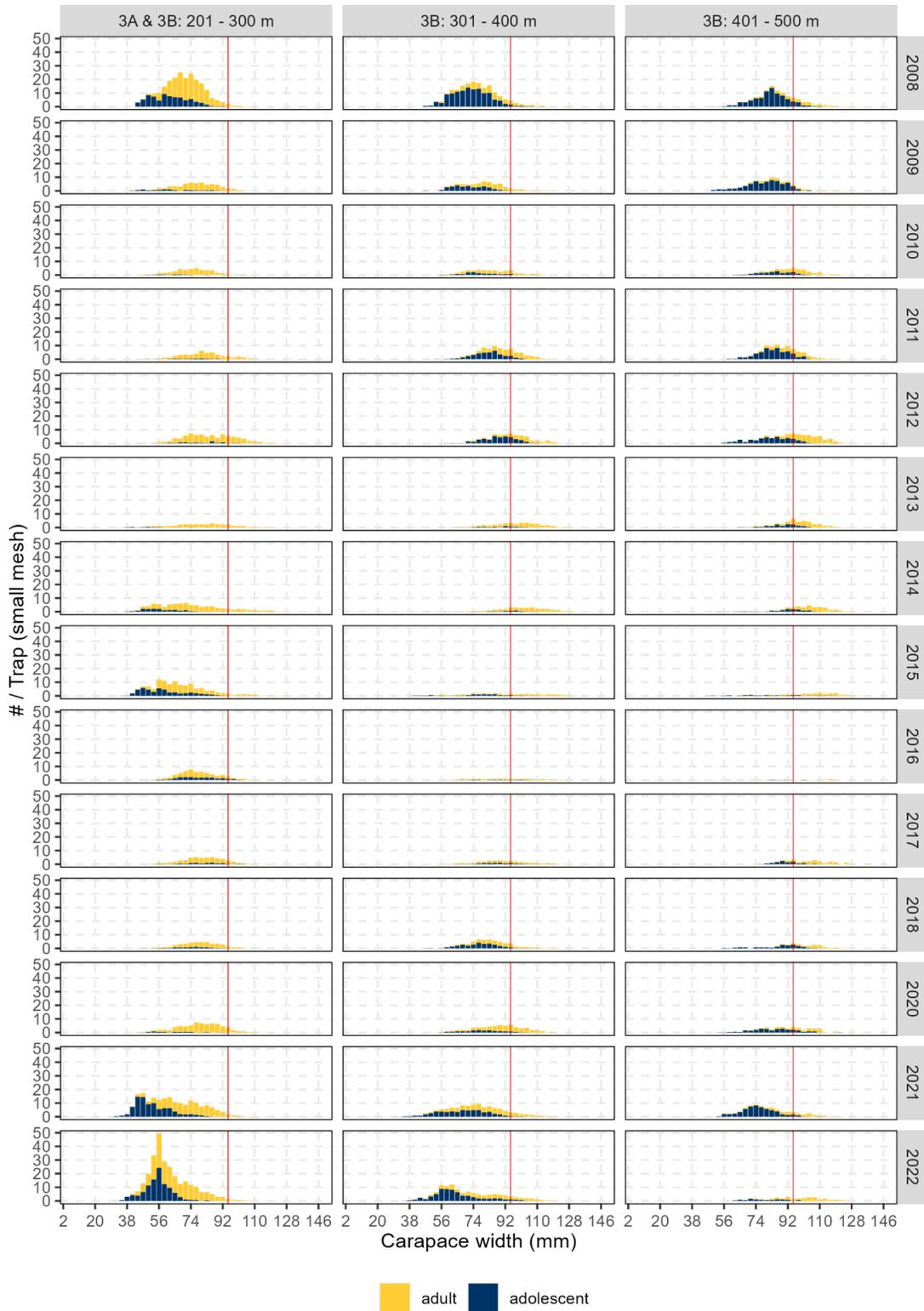


Figure A2.11. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey by depth strata in White Bay (Crab Management Areas 3A and 3B) (2008–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

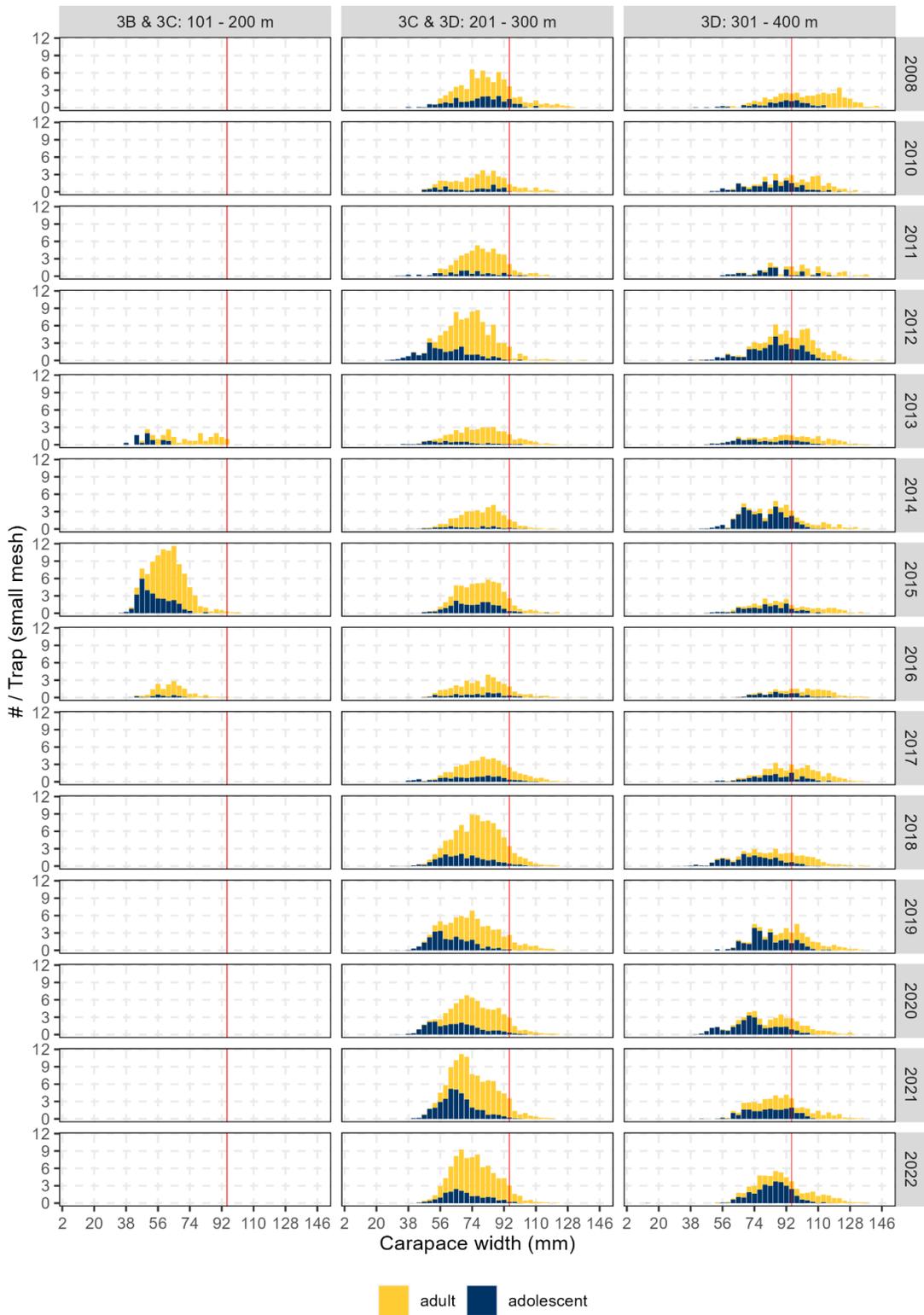


Figure A2.12. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey by depth strata in Green Bay and Notre Dame Bay (Crab Management Areas 3B, 3C, and 3D) (2008–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

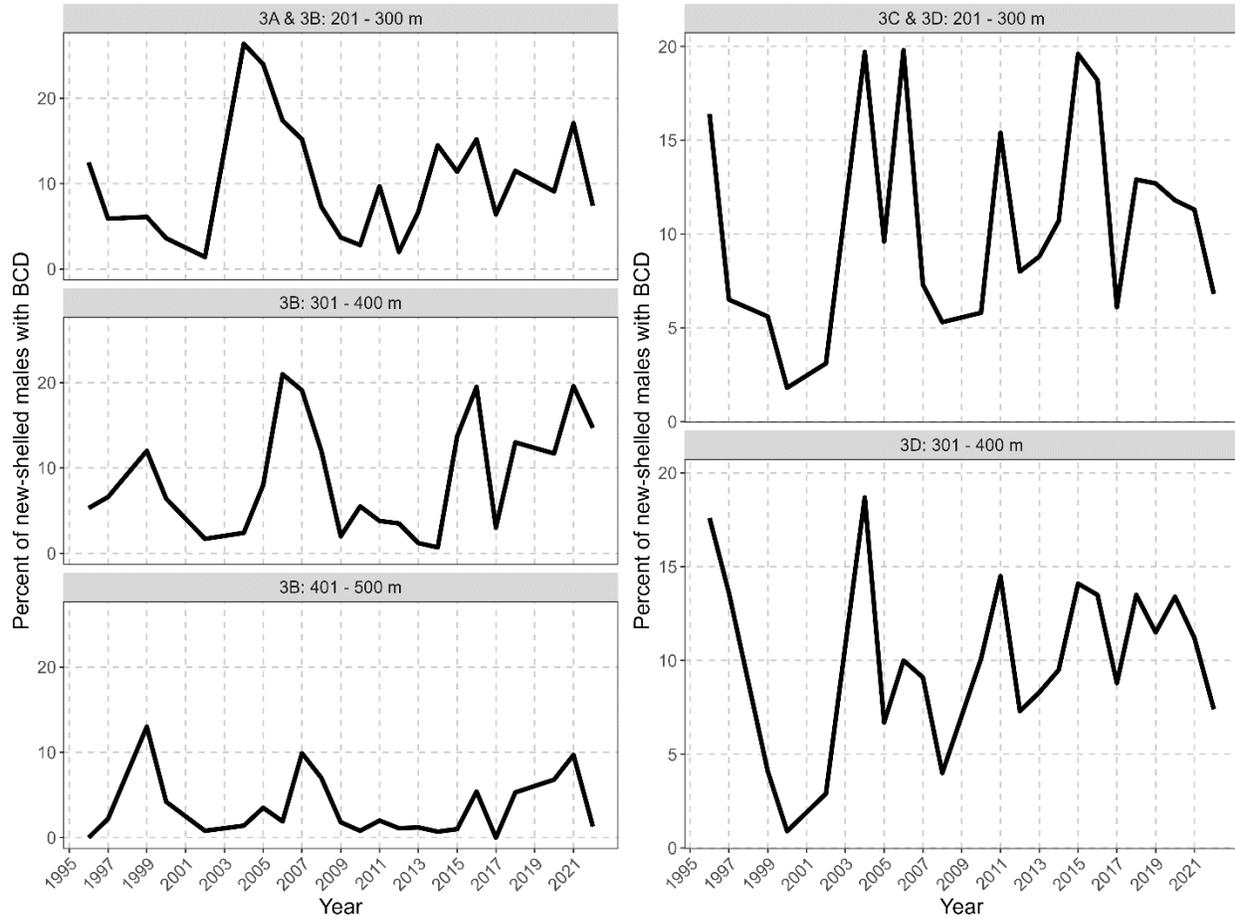


Figure A2.13. Visually observed percentage of Bitter Crab Disease (BCD) in new-shelled males from DFO inshore trap surveys by depth strata in White Bay (Crab Management Areas 3A and 3B), and Green Bay and Notre Dame Bay (Crab Management Areas 3C and 3D) (1996–2022).

APPENDIX 3: ASSESSMENT DIVISION 3L INSHORE DETAILS

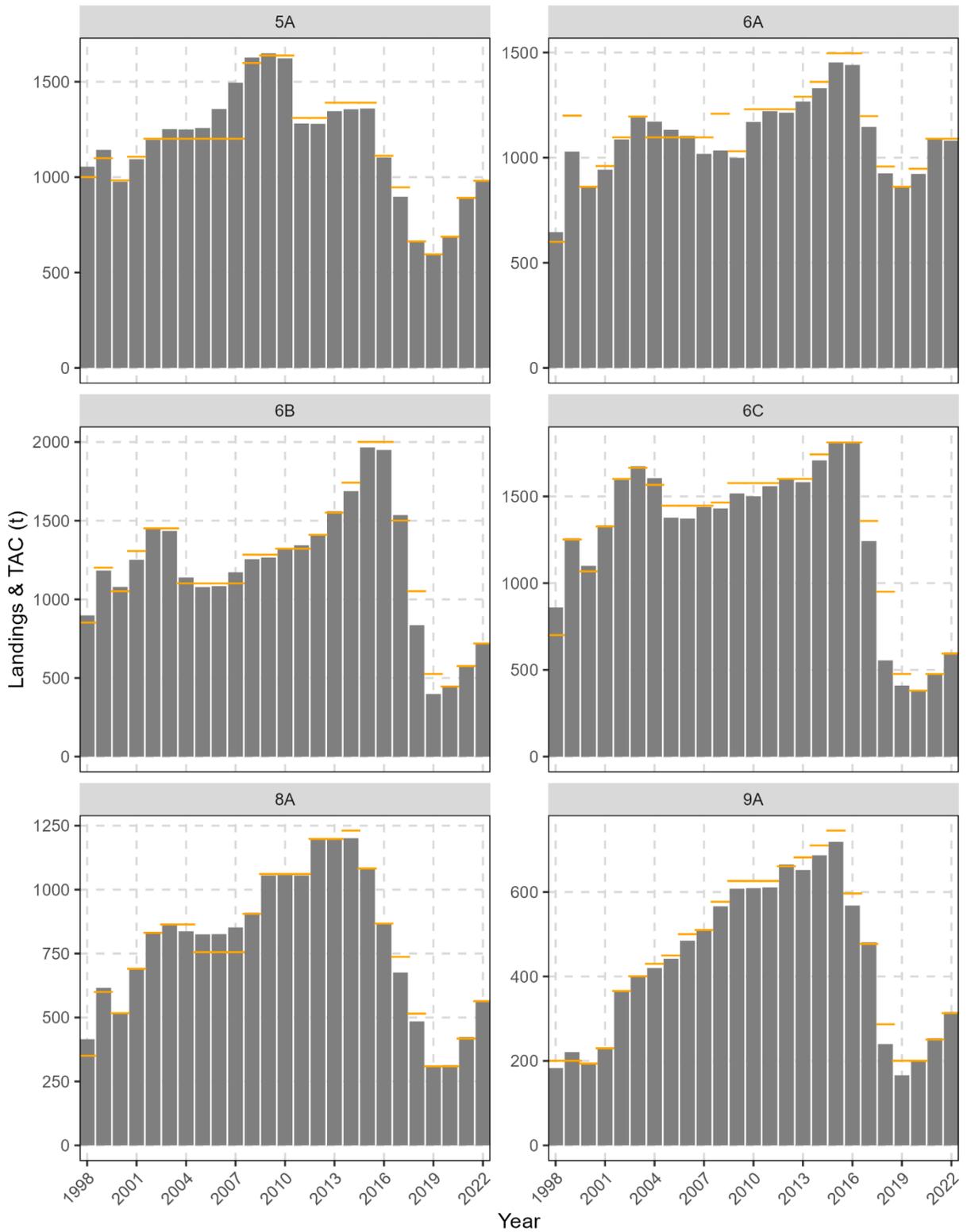


Figure A3.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 3L Inshore (1998–2022).

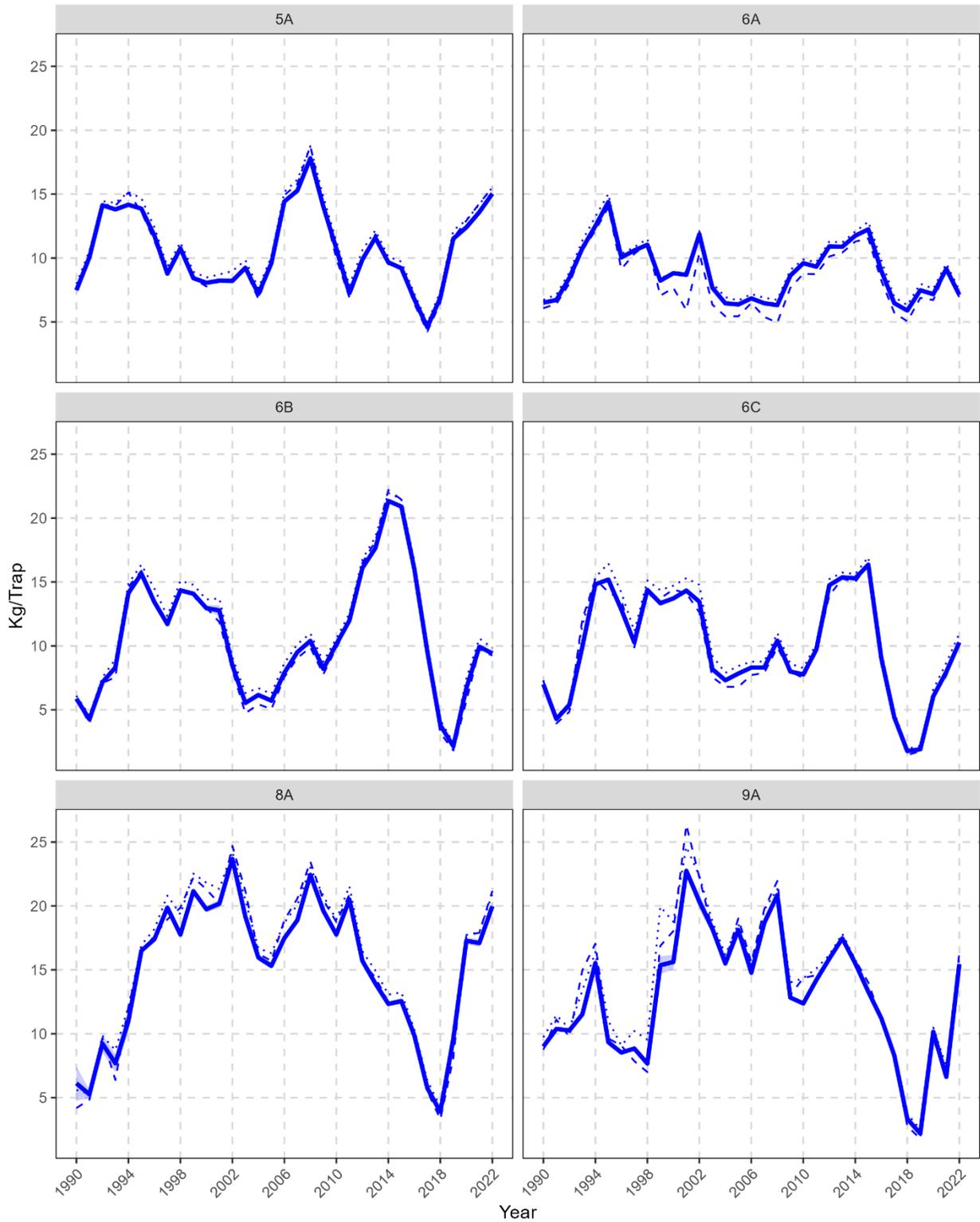


Figure A3.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 3L Inshore (1990–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

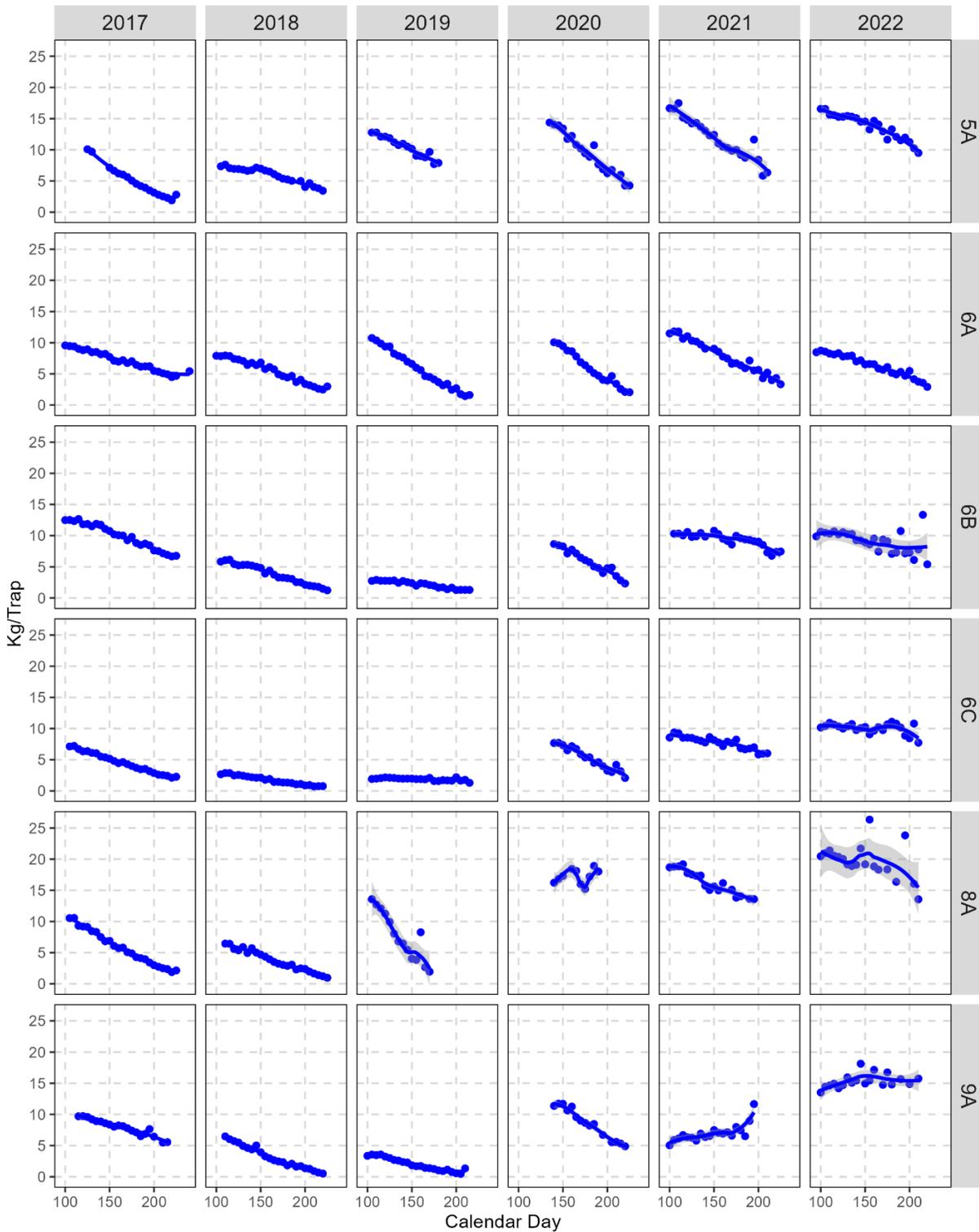


Figure A3.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 3L Inshore (2017–22), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

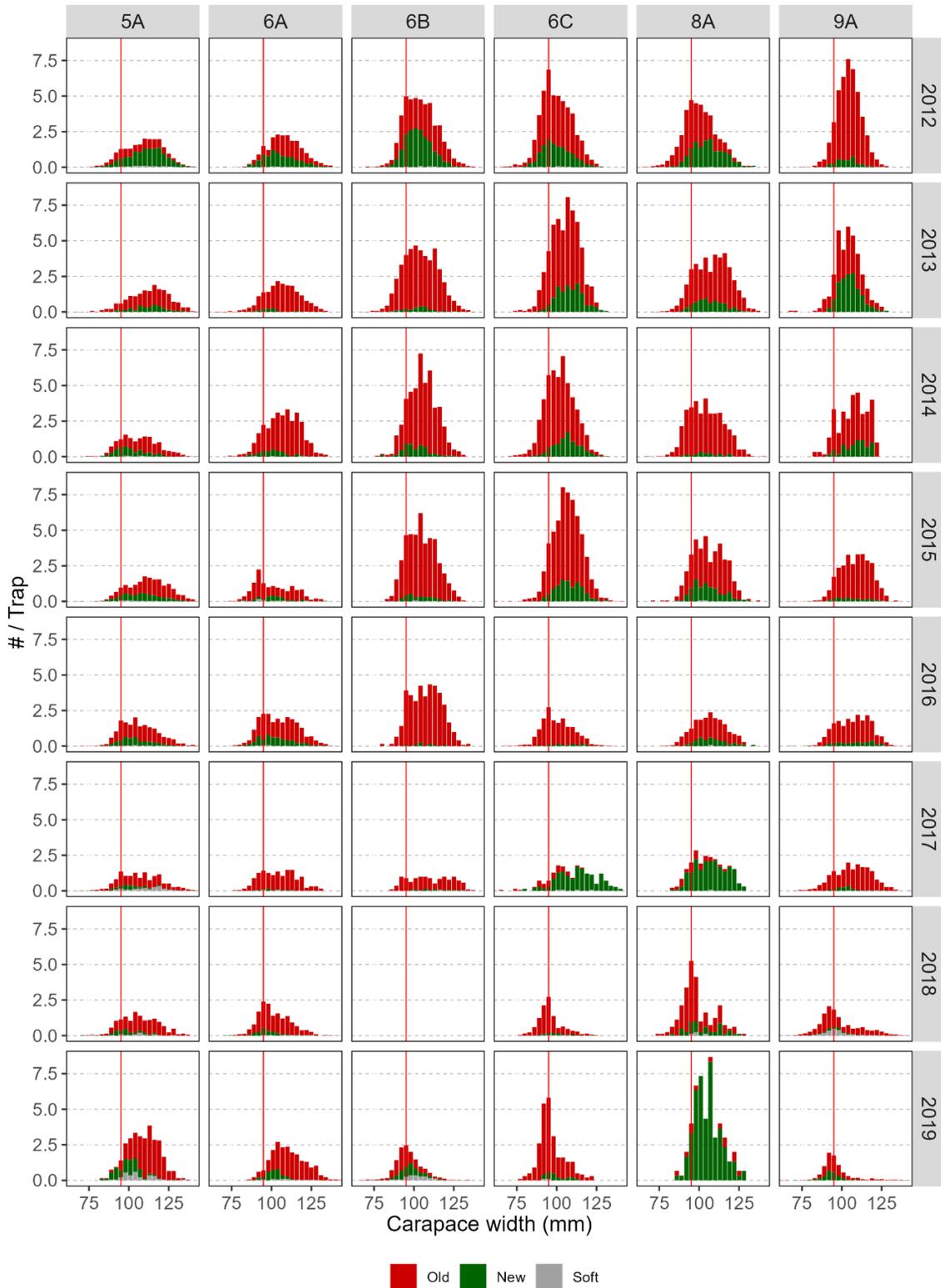


Figure A3.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 3L Inshore (2012–19). The red vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

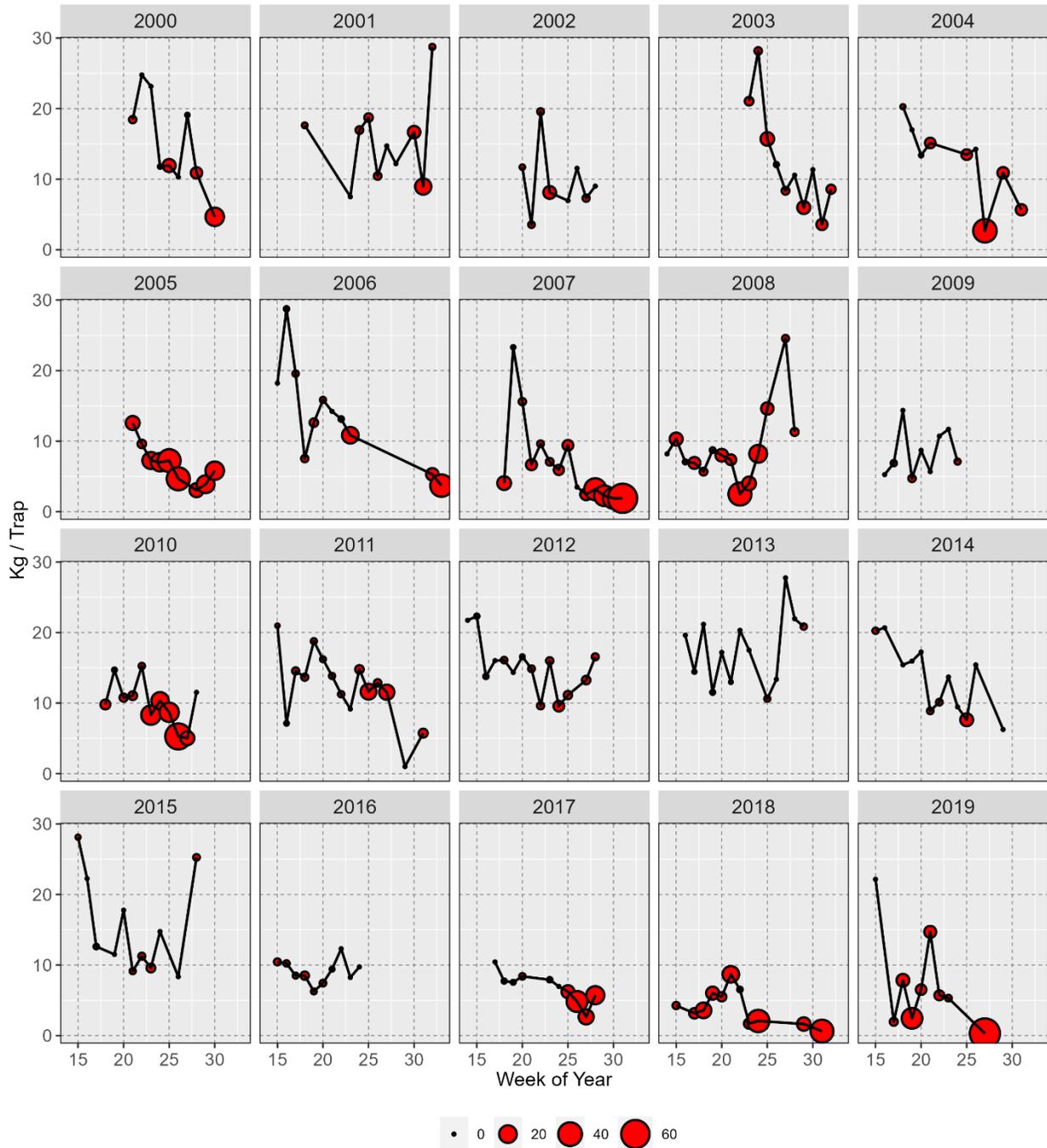


Figure A3.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling in Crab Management Areas within Assessment Division 3L Inshore (2000–19). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

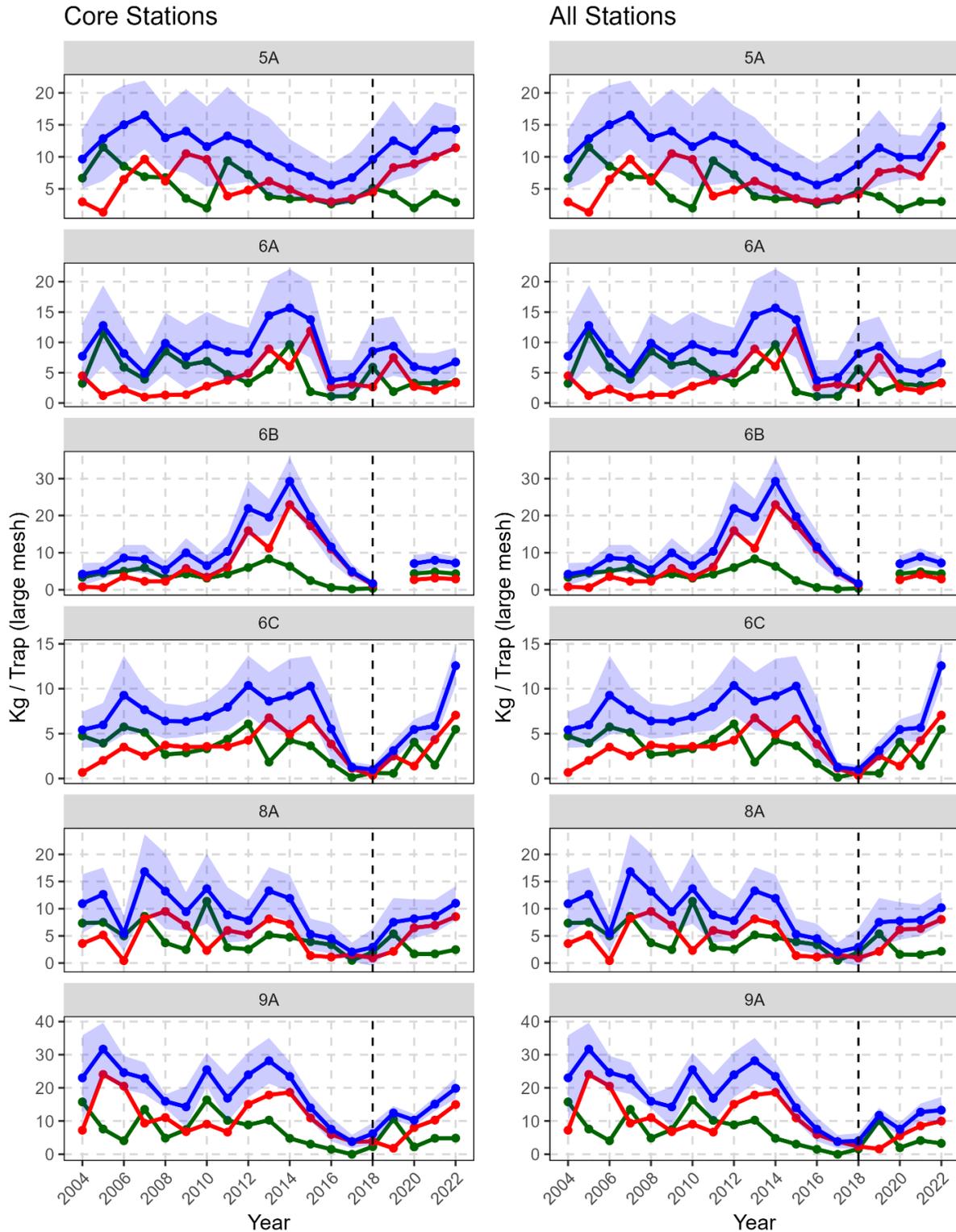


Figure A3.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 3L Inshore (2004–22). 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.

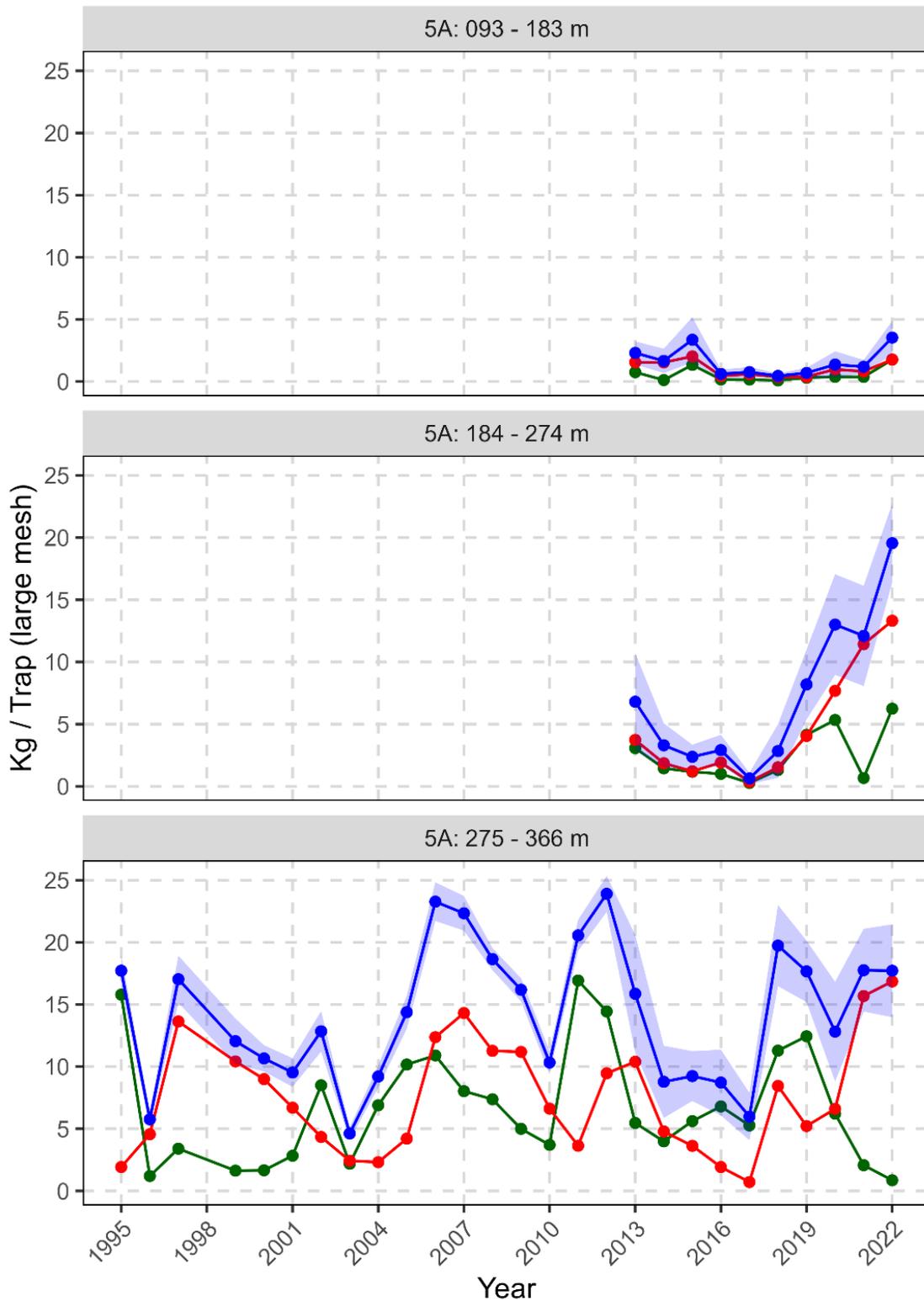


Figure A3.7. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys by depth strata in Bonavista Bay (Crab Management Area 5A) (1995–2022). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

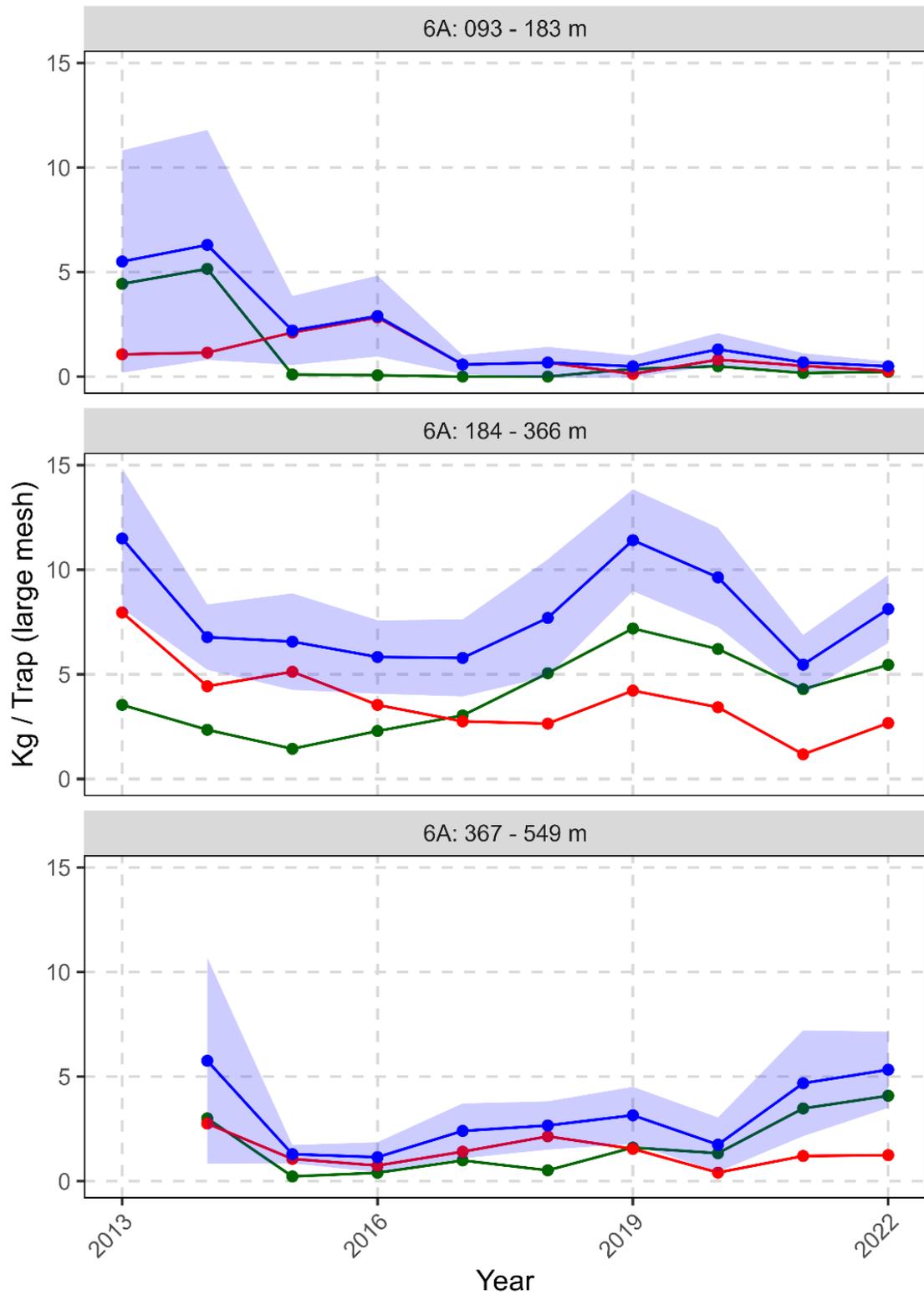


Figure A3.8. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys by depth strata in Trinity Bay (Crab Management Area 6A) (2013–22). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

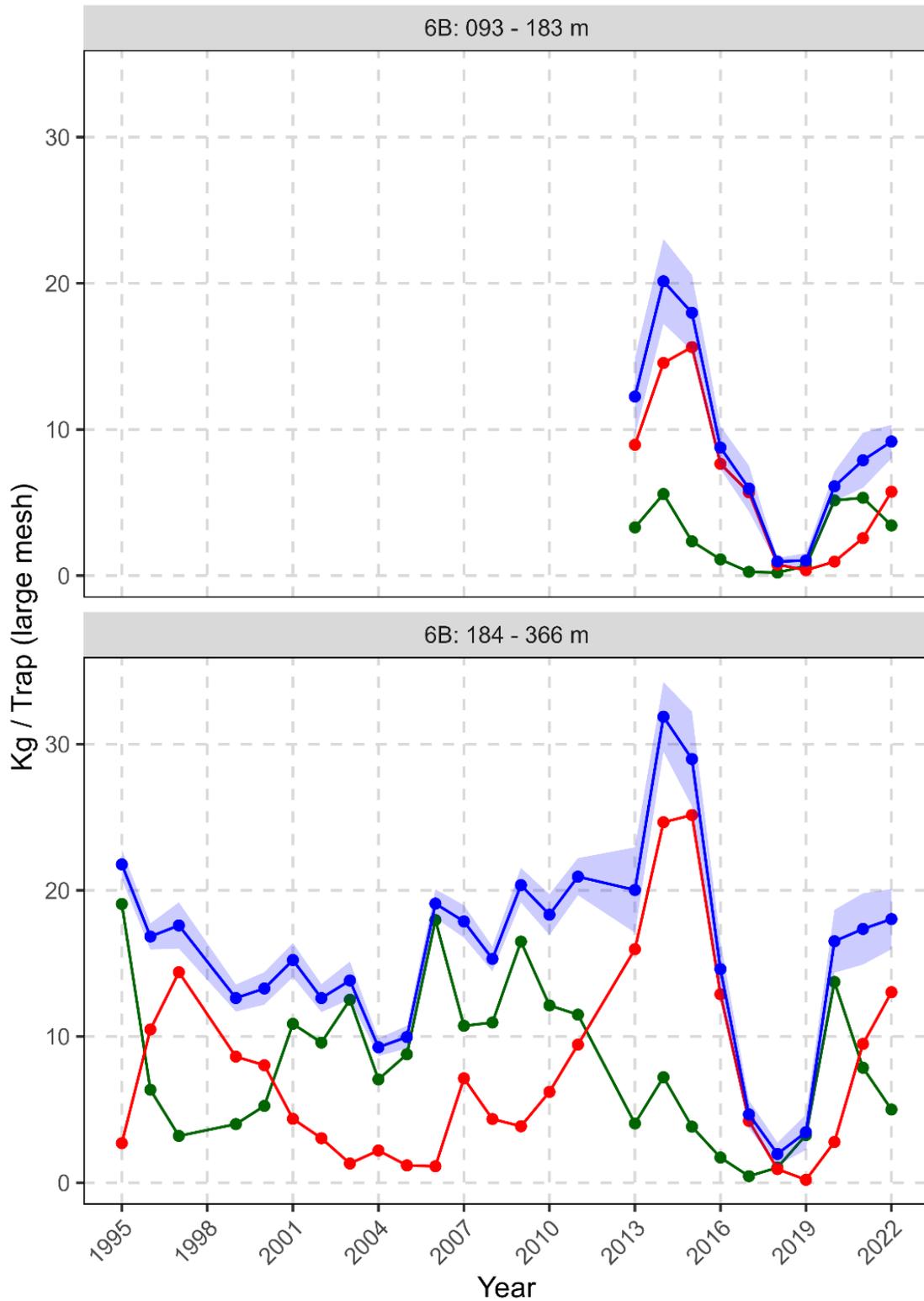


Figure A3.9. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys by depth strata in Conception Bay (Crab Management Area 6B) (1995–2022). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

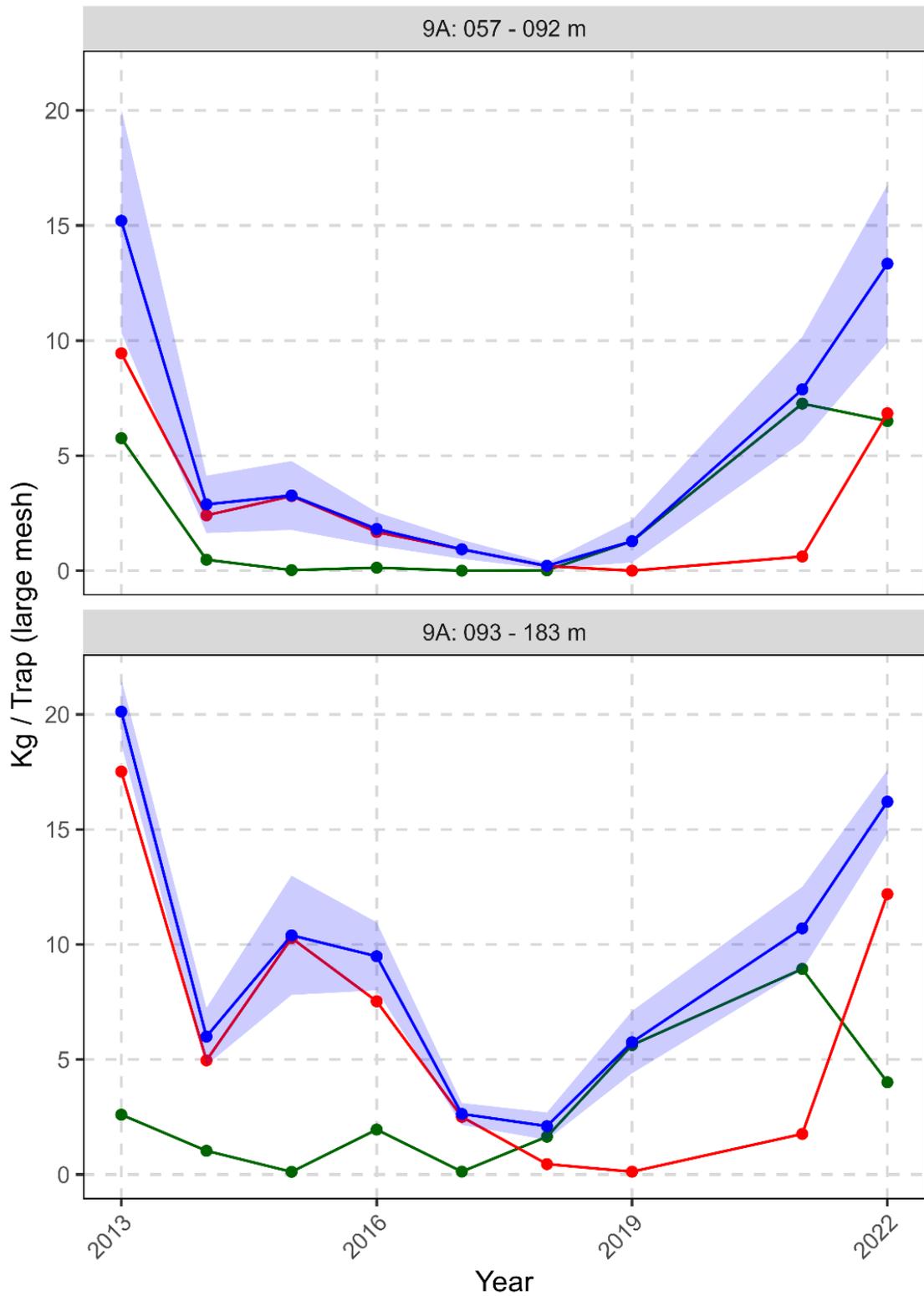


Figure A3.10. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys by depth strata in St. Mary's Bay (Crab Management Area 9A) (2013–22). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

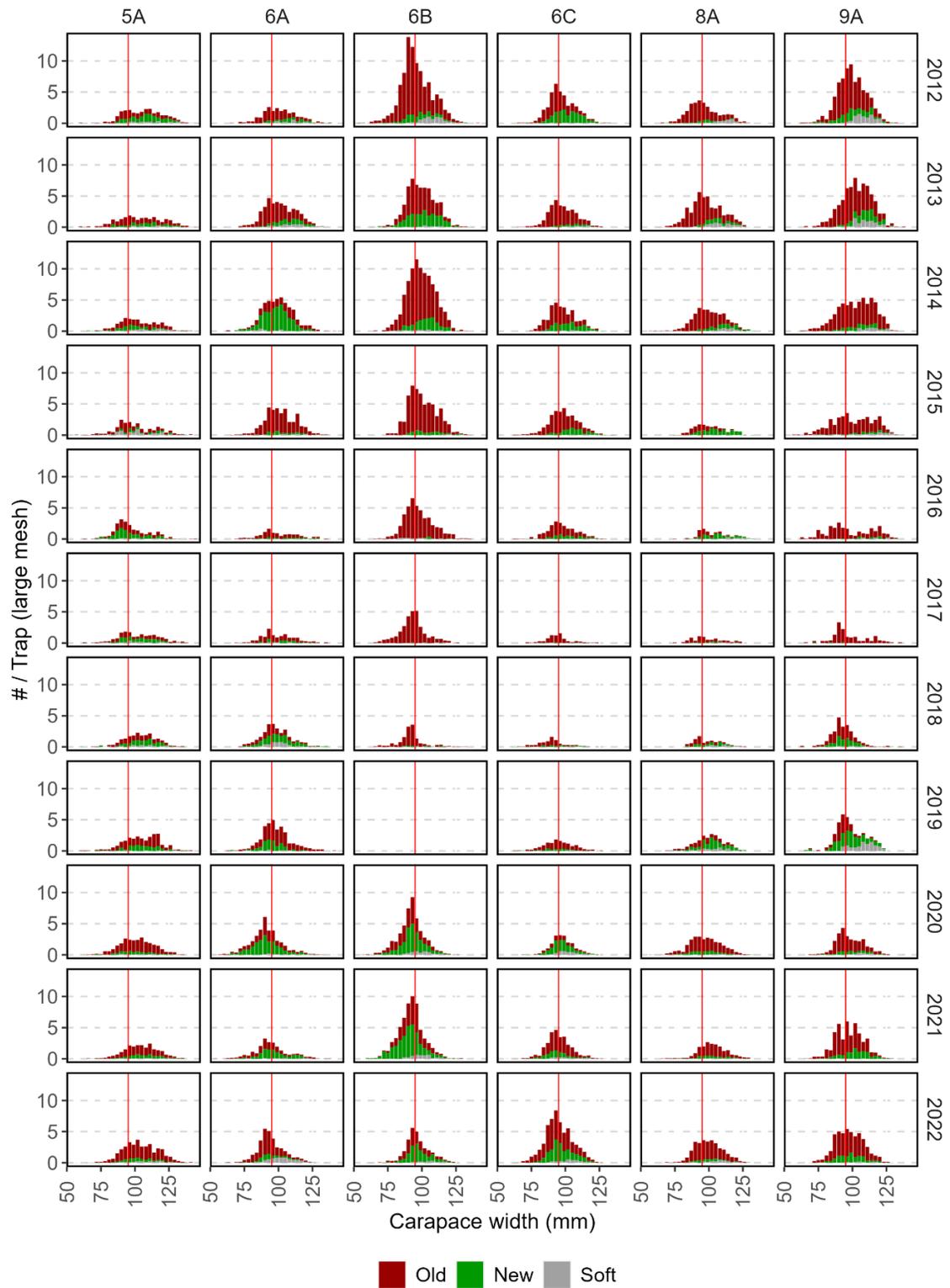


Figure A3.11. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3L Inshore (2012–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

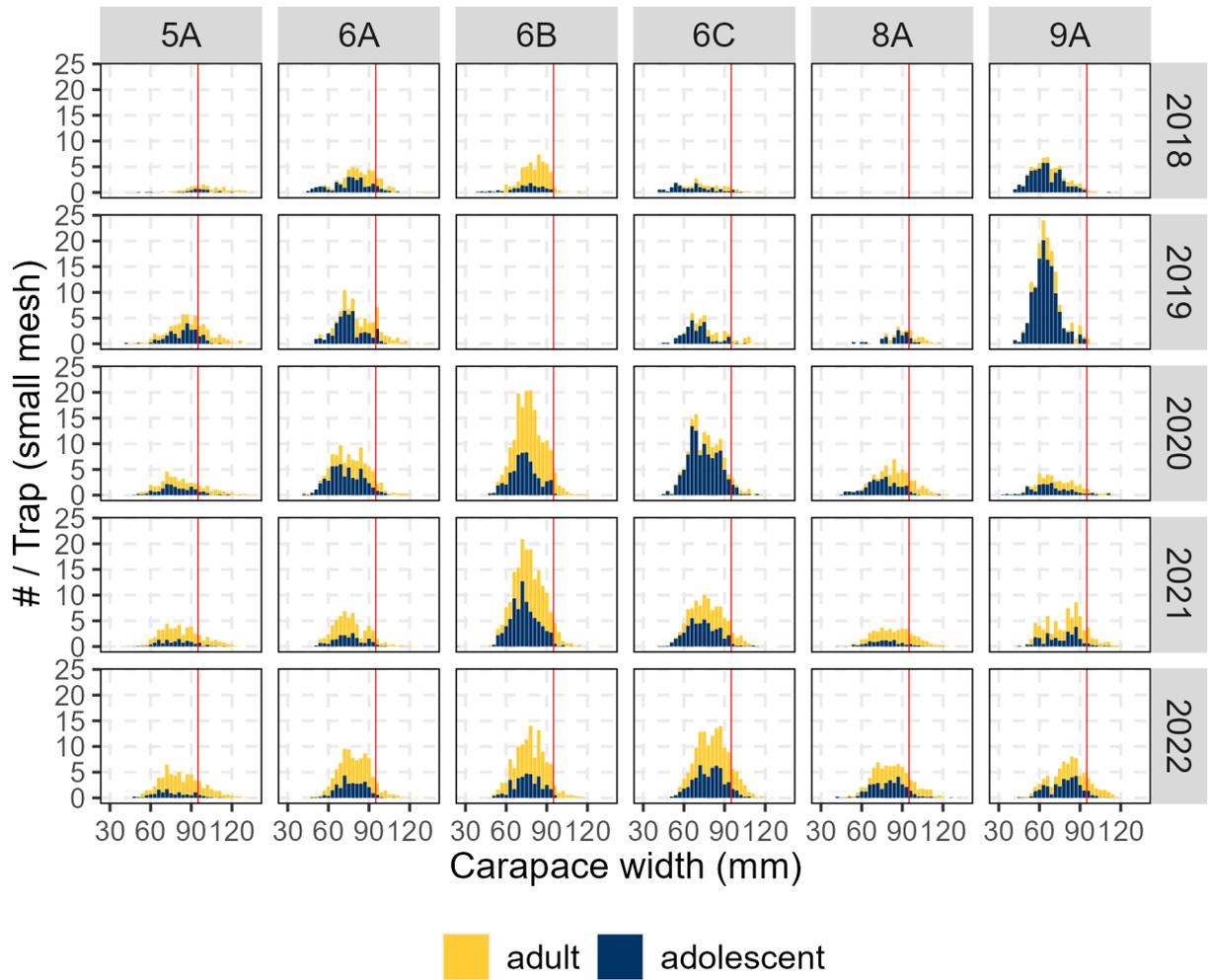


Figure A3.12. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3L Inshore (2018–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

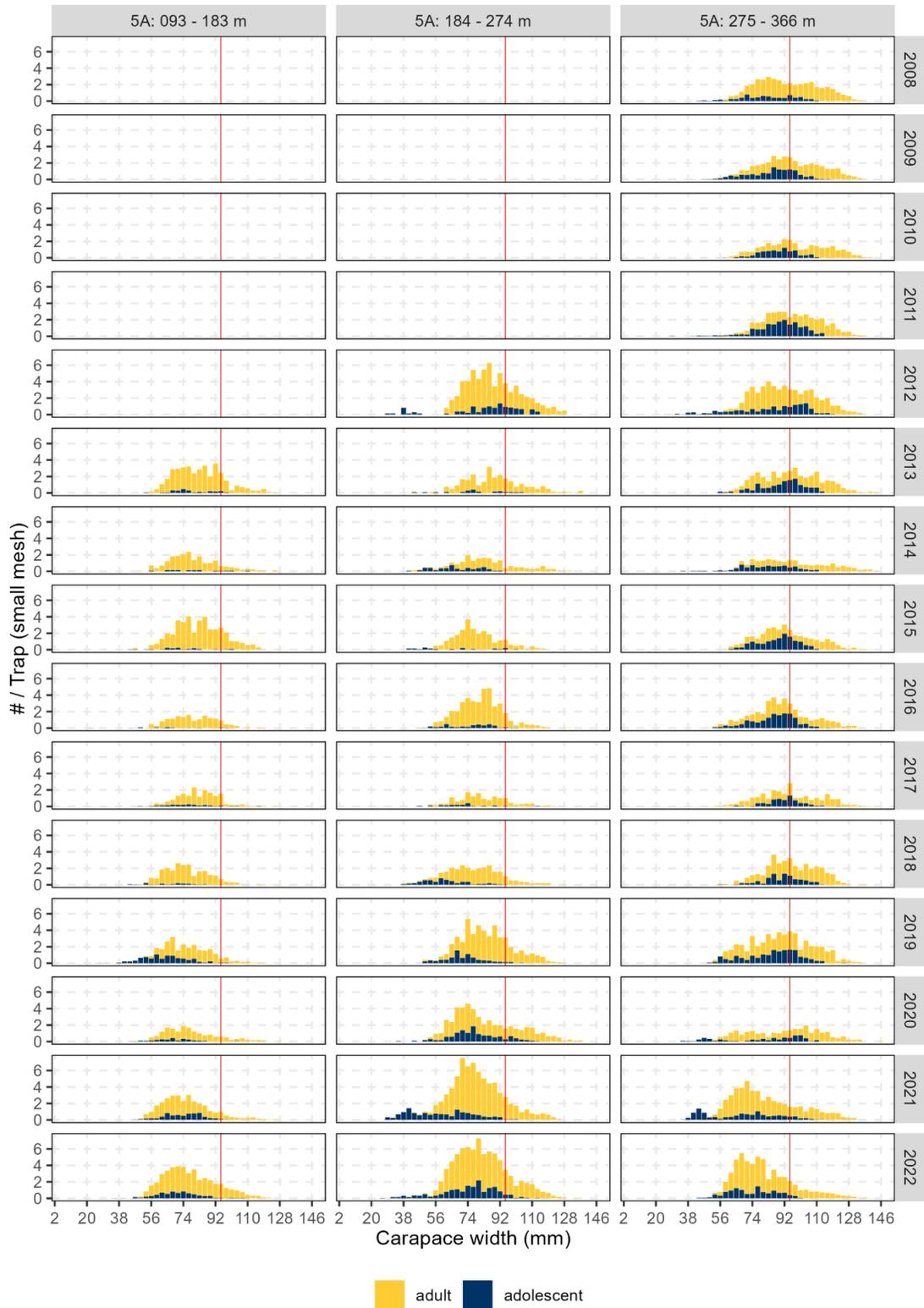


Figure A3.13. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey by depth strata in Bonavista Bay (Crab Management Area 5A) (2008–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

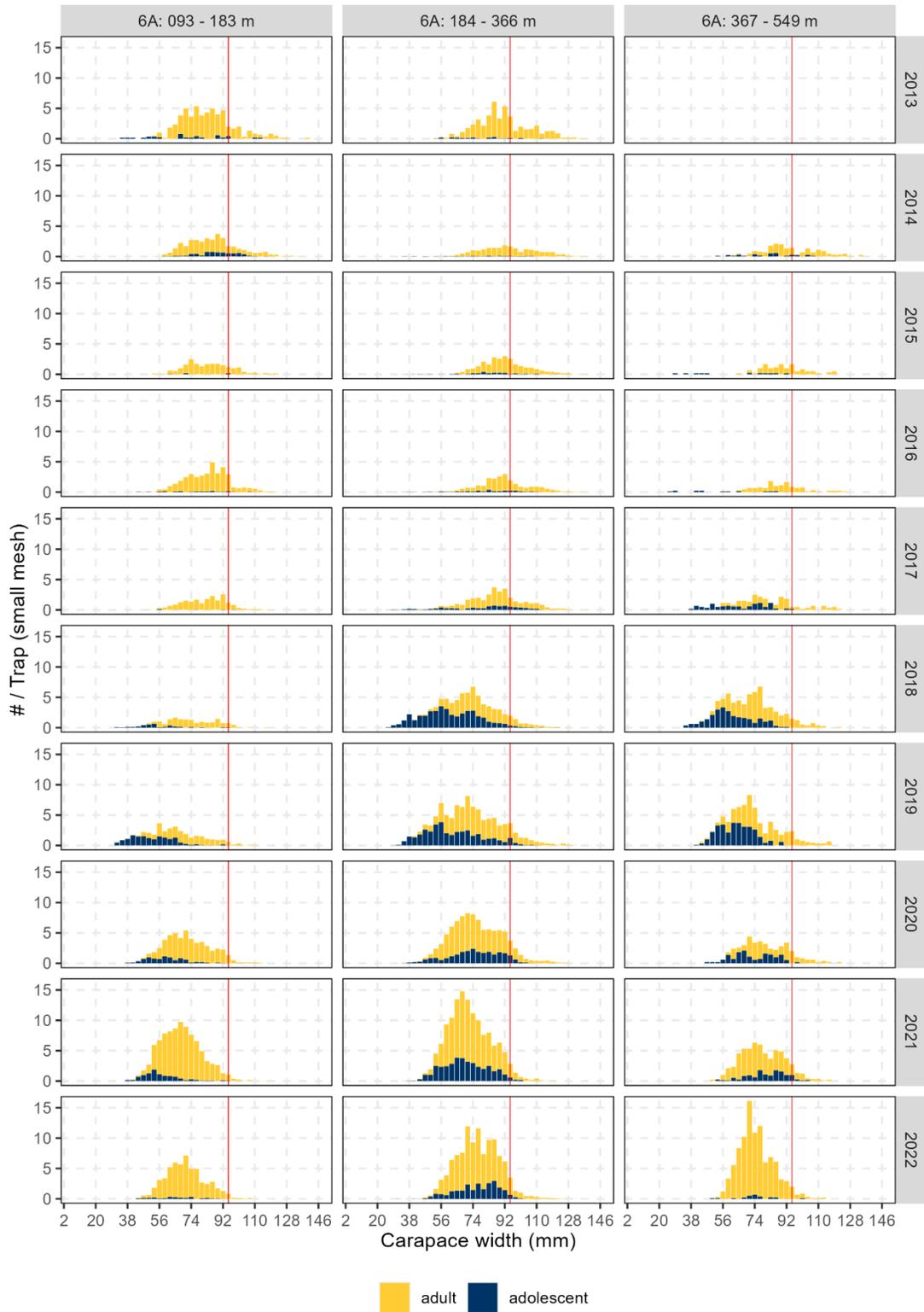


Figure A3.14. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey by depth strata in Trinity Bay (Crab Management Area 6A) (2013–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

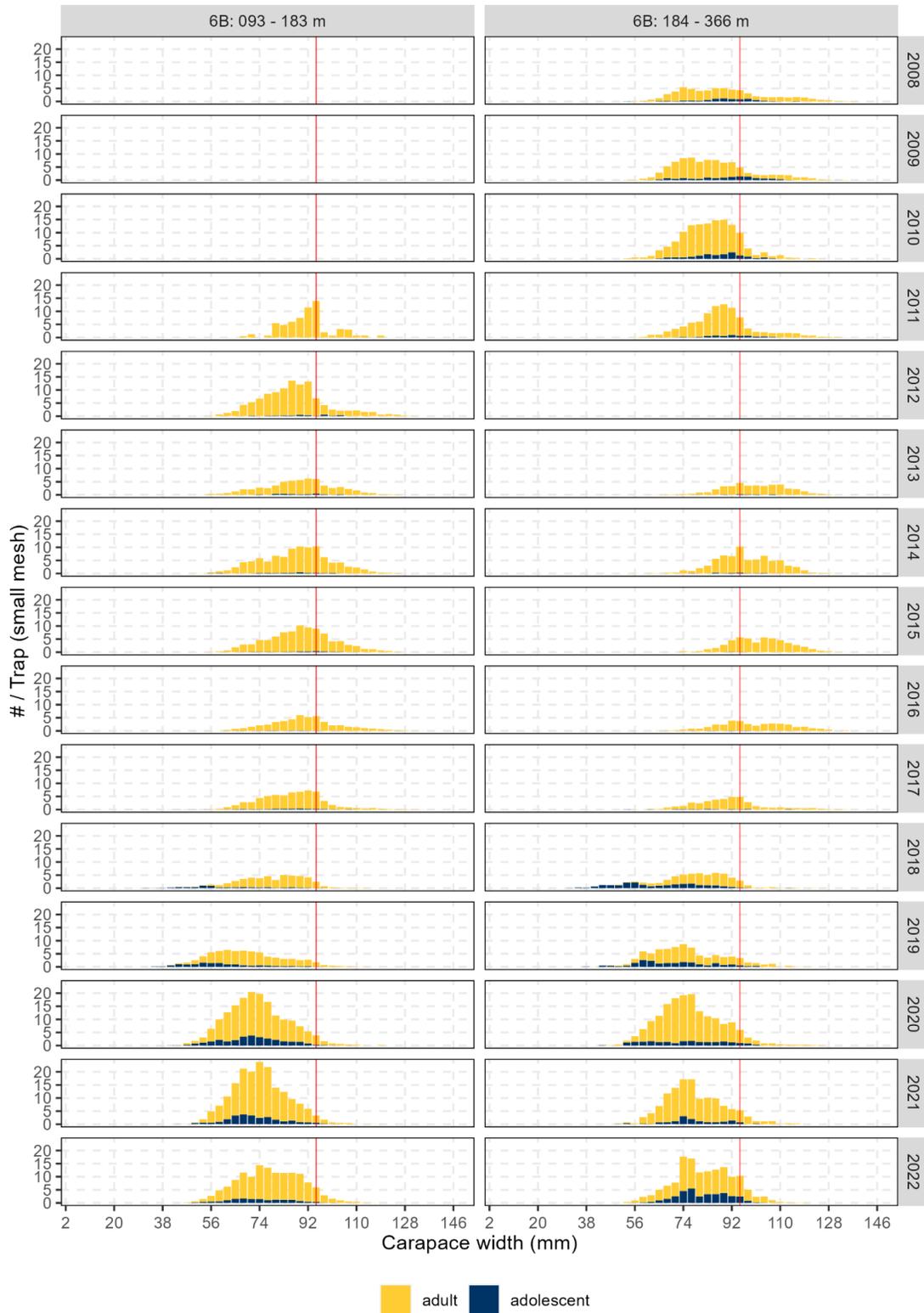


Figure A3.15. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey by depth strata in Conception Bay (Crab Management Area 6B) (2008–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

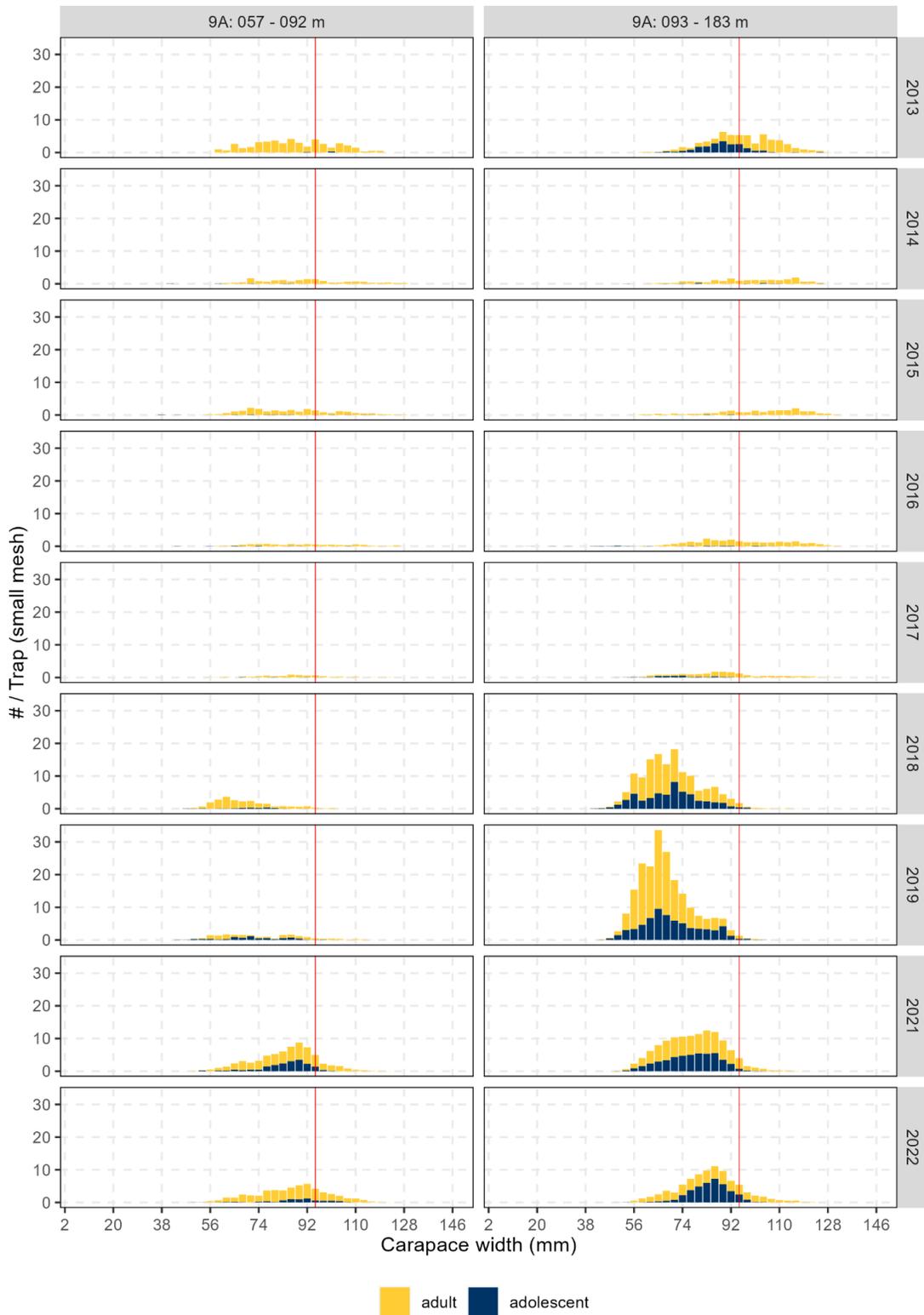


Figure A3.16. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey by depth strata in St. Mary's Bay (Crab Management Area 9A) (2013–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

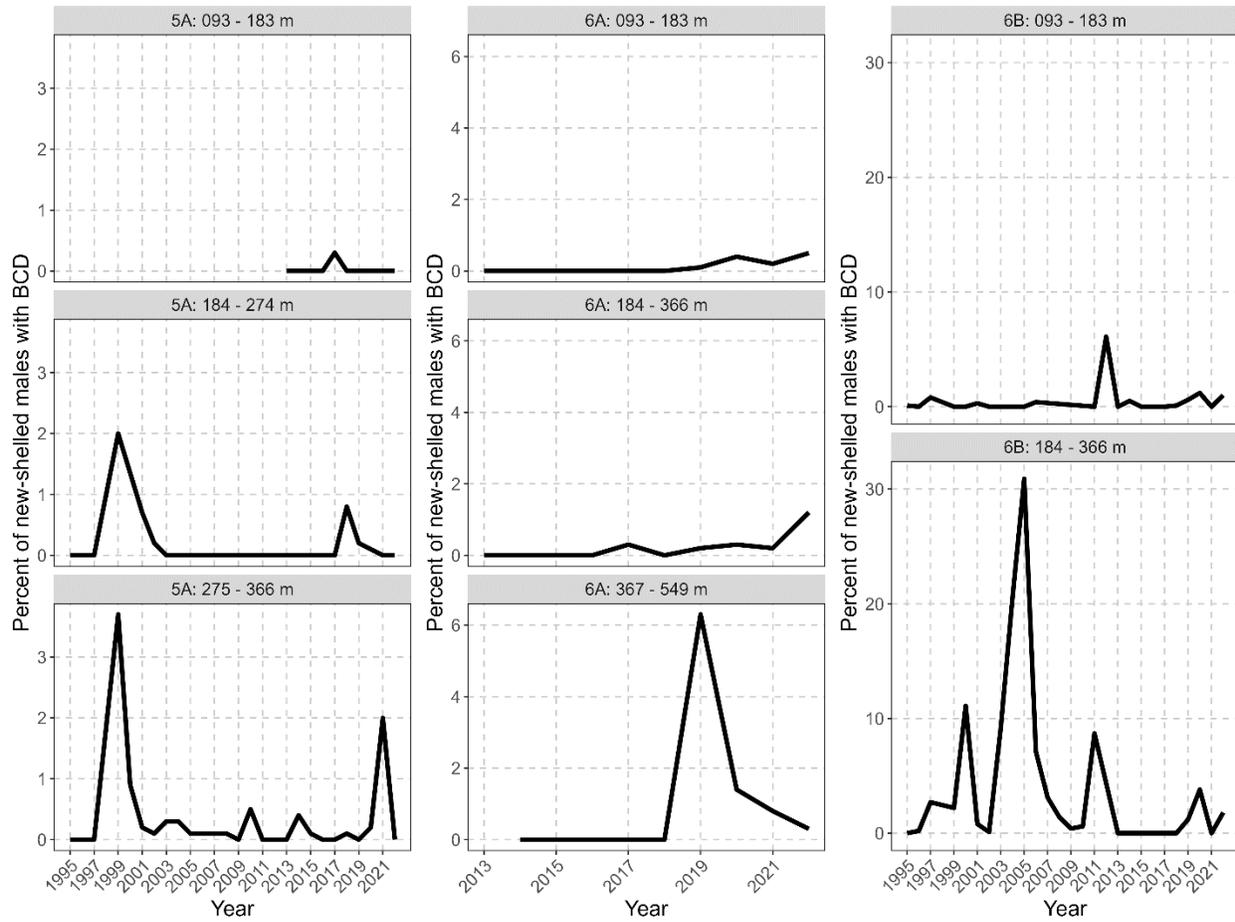


Figure A3.17. Visually observed percentage of Bitter Crab Disease (BCD) in new-shelled males from DFO inshore trap surveys by depth strata in Bonavista Bay (Crab Management Area 5A), Trinity Bay (Crab Management Area 6A), and Conception Bay (Crab Management Area 6B) (1995–2022).

APPENDIX 4: ASSESSMENT DIVISION 3LNO OFFSHORE DETAILS

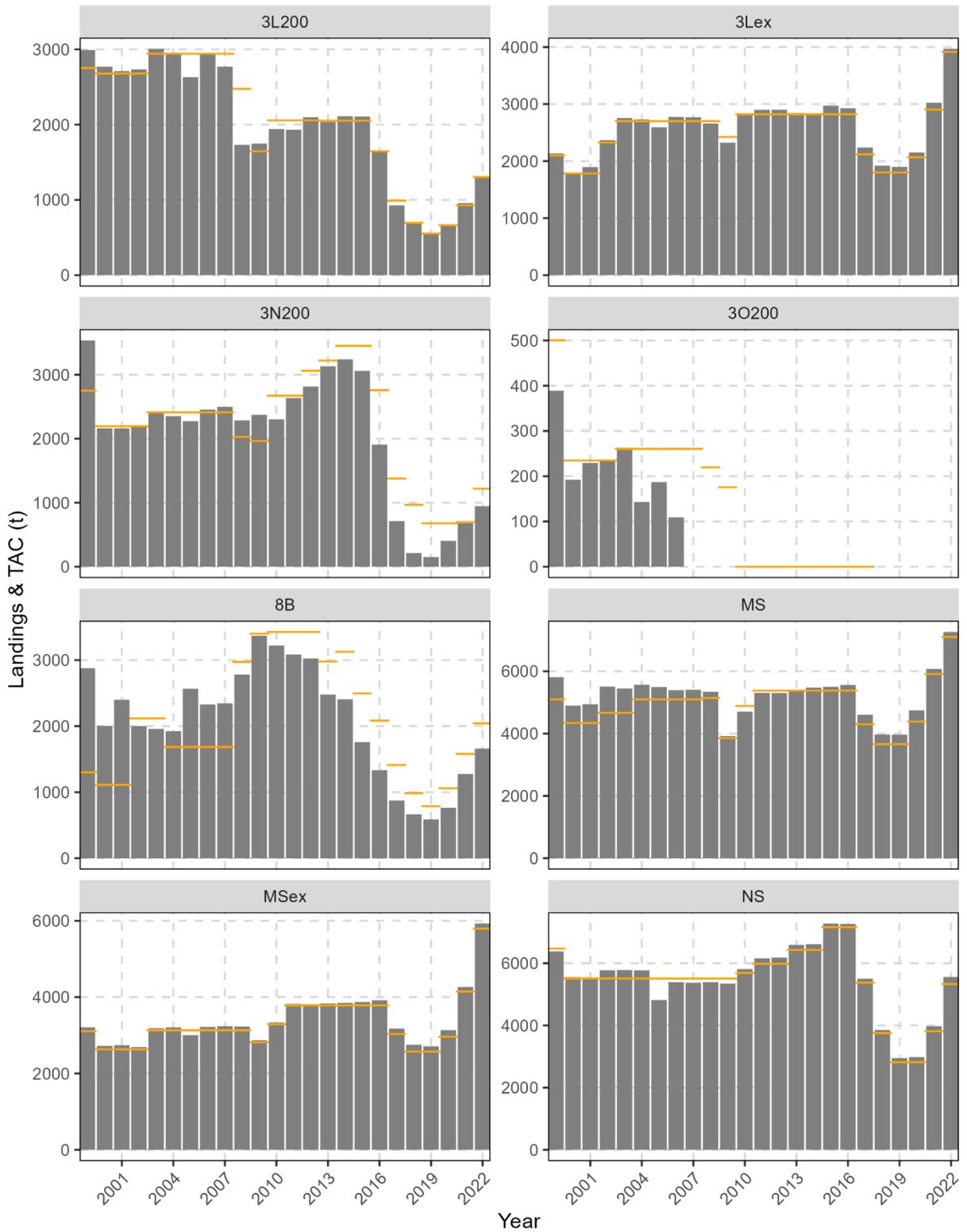


Figure A4.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 3LNO Offshore (1999–2022).

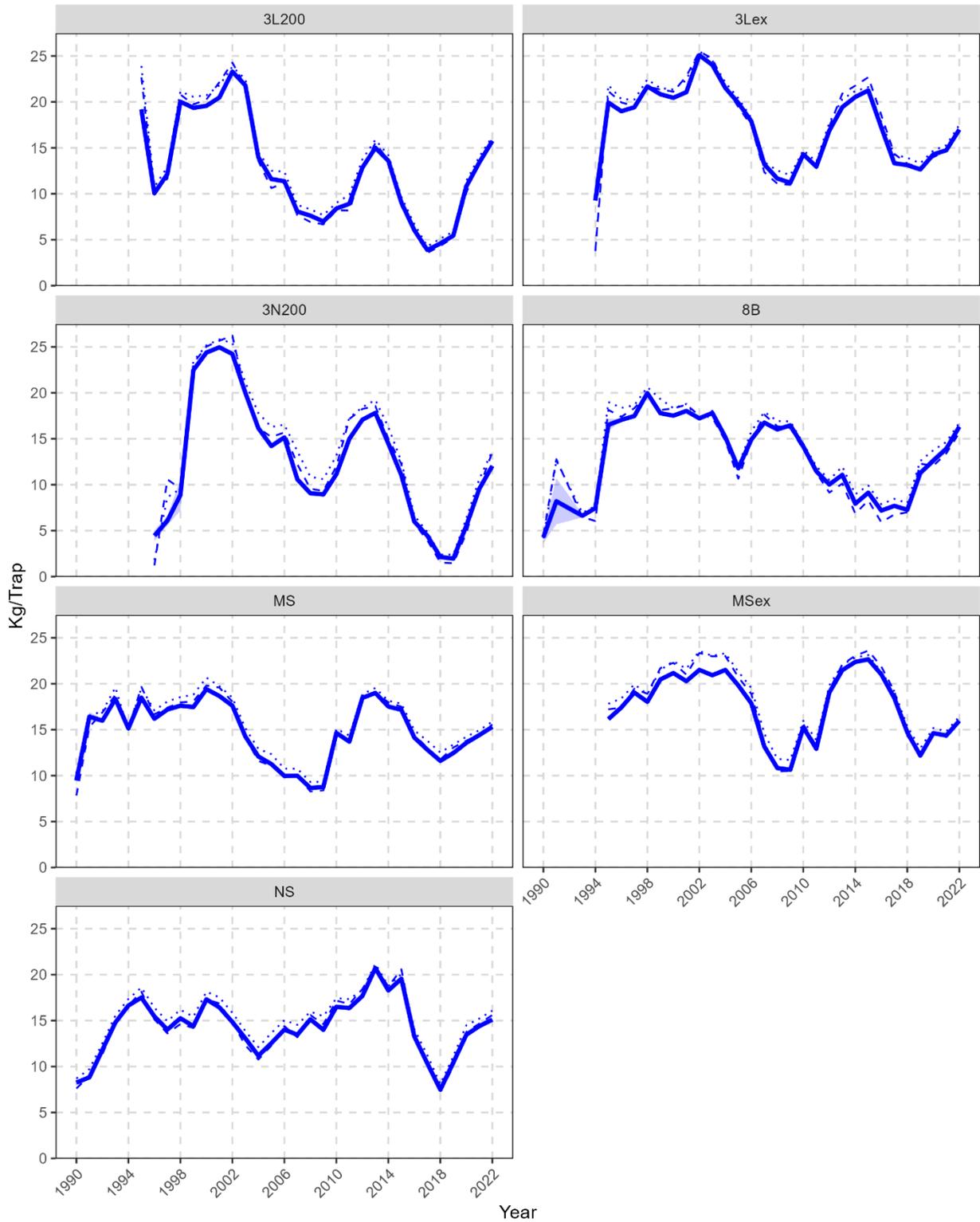


Figure A4.2. Standardized Snow Crab fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 3LNO Offshore (1990–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

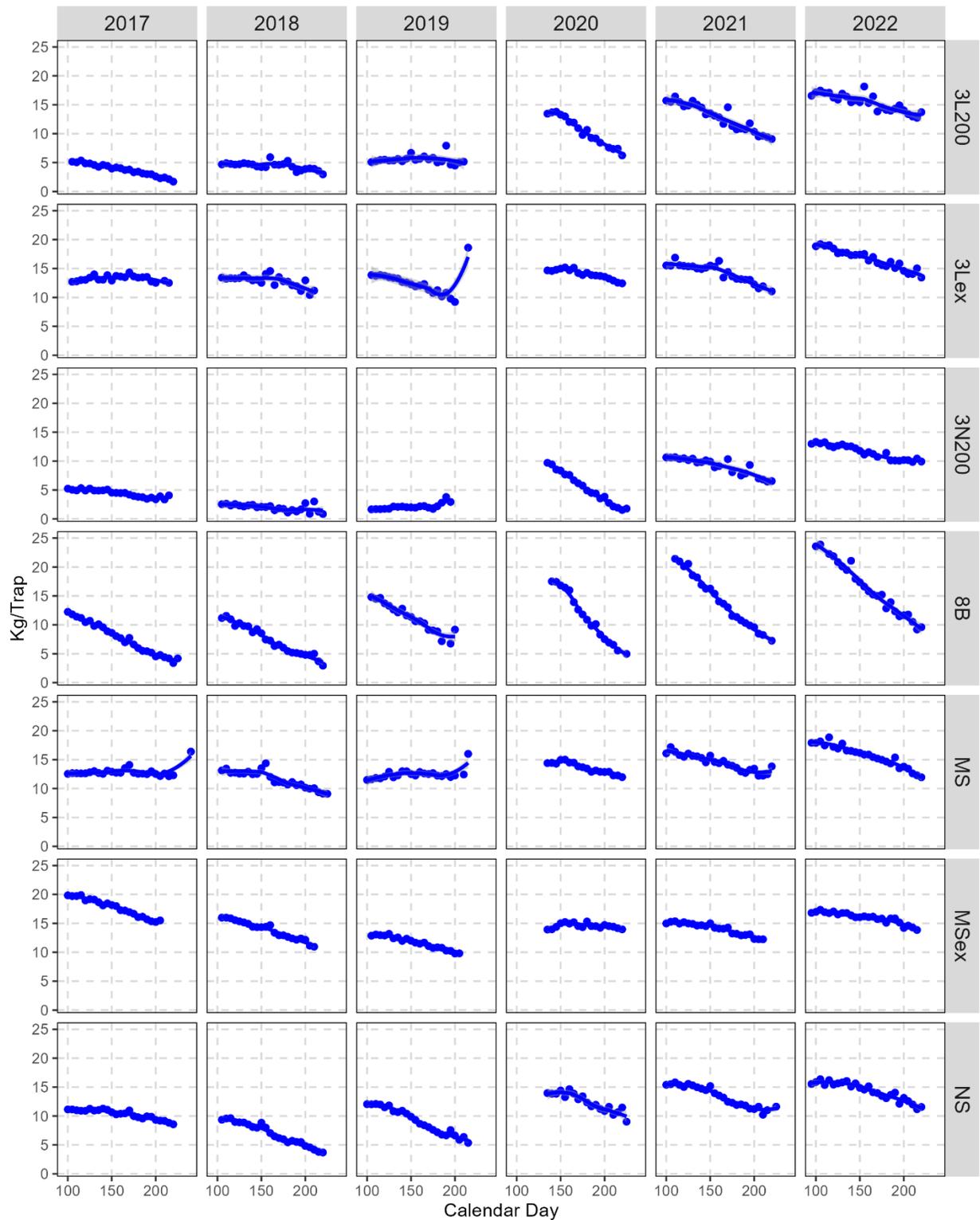


Figure A4.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 3LNO Offshore (2017–22), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

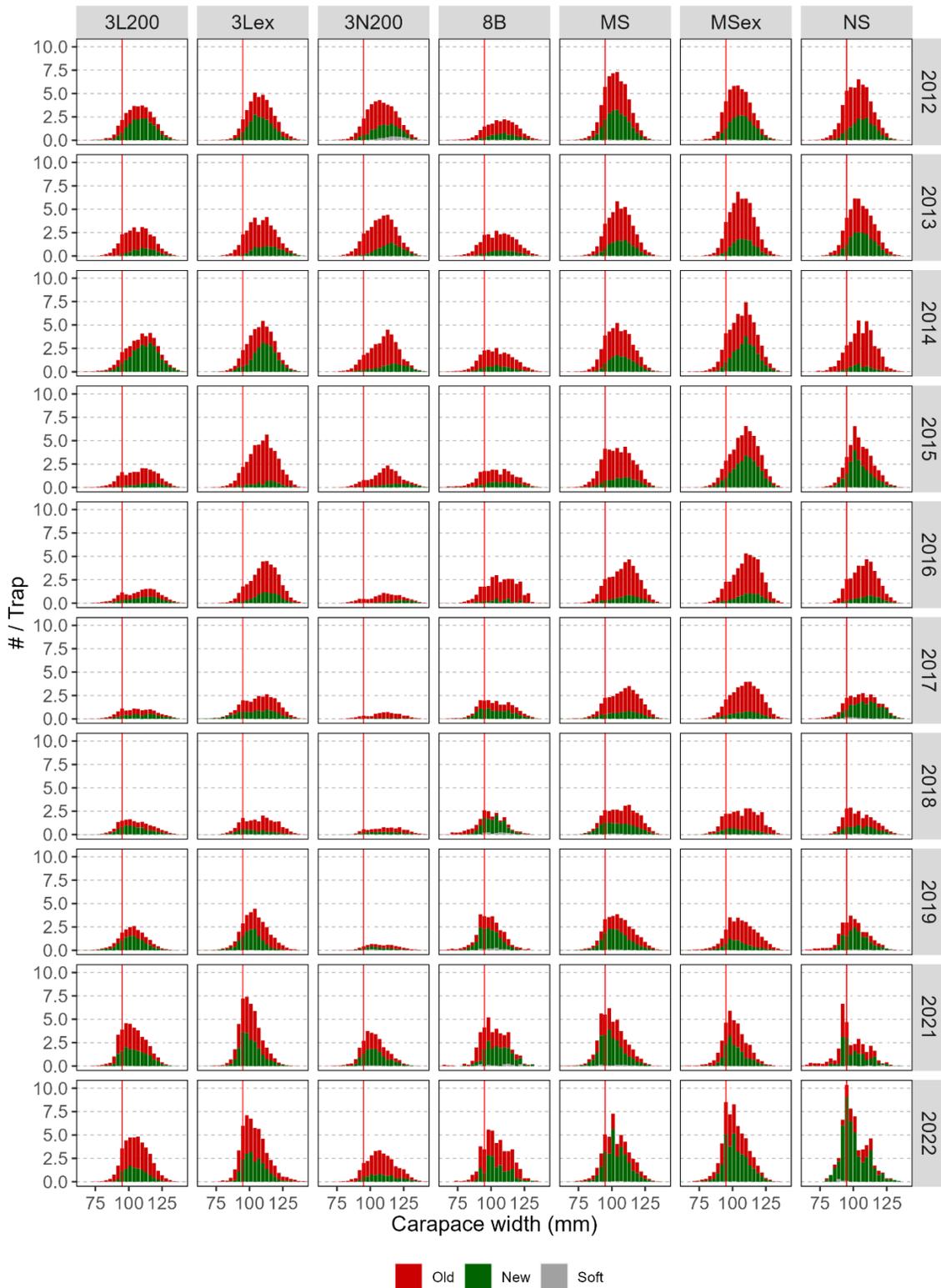


Figure A4.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 3LNO Offshore (2012–22). The red vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

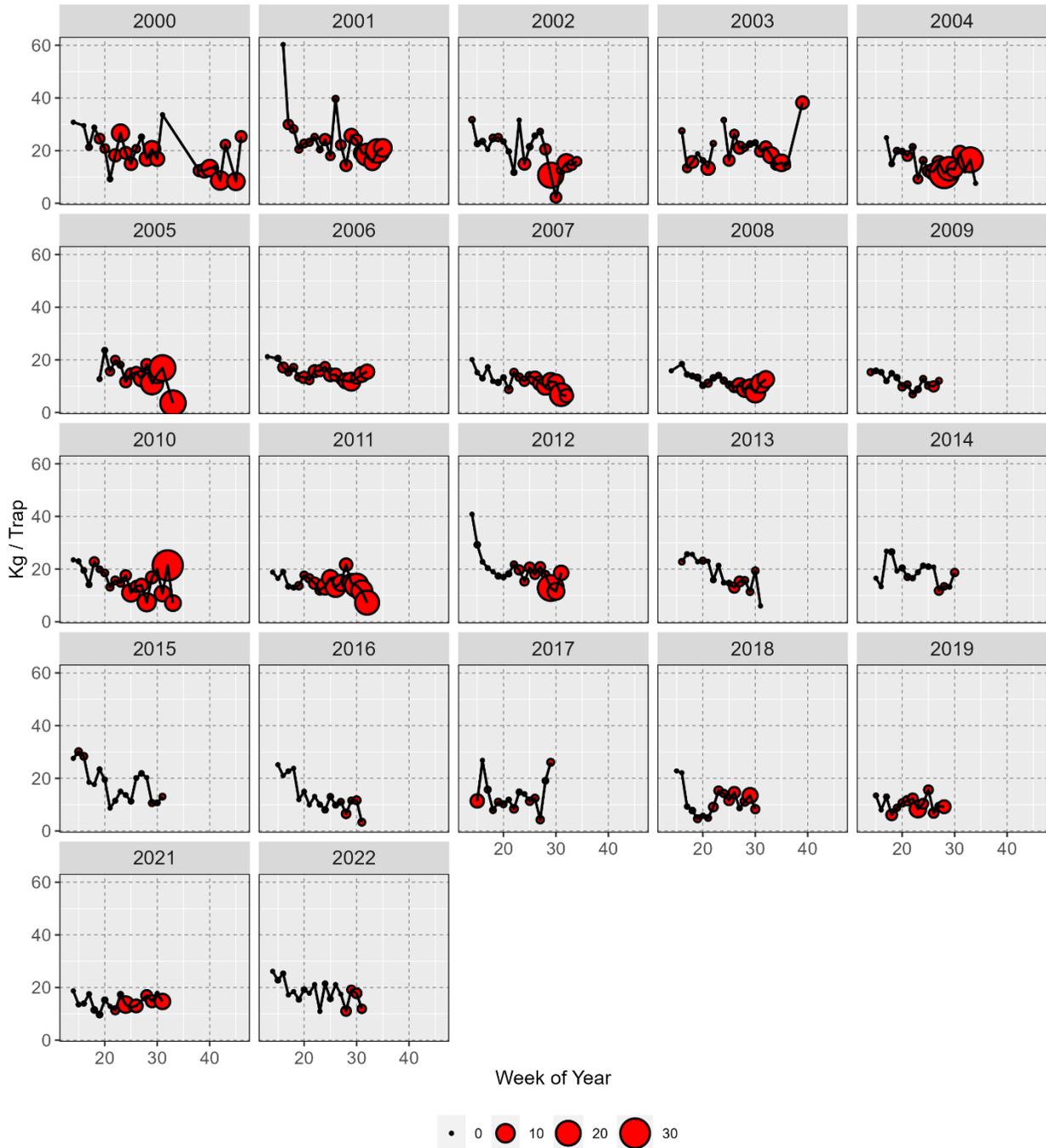


Figure A4.5. Weekly catch rates (kg/trap) and the percentage of soft-shell Snow Crab in the catch from at-sea observer sampling in Crab Management Areas within Assessment Division 3LNO Offshore (2000–22). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

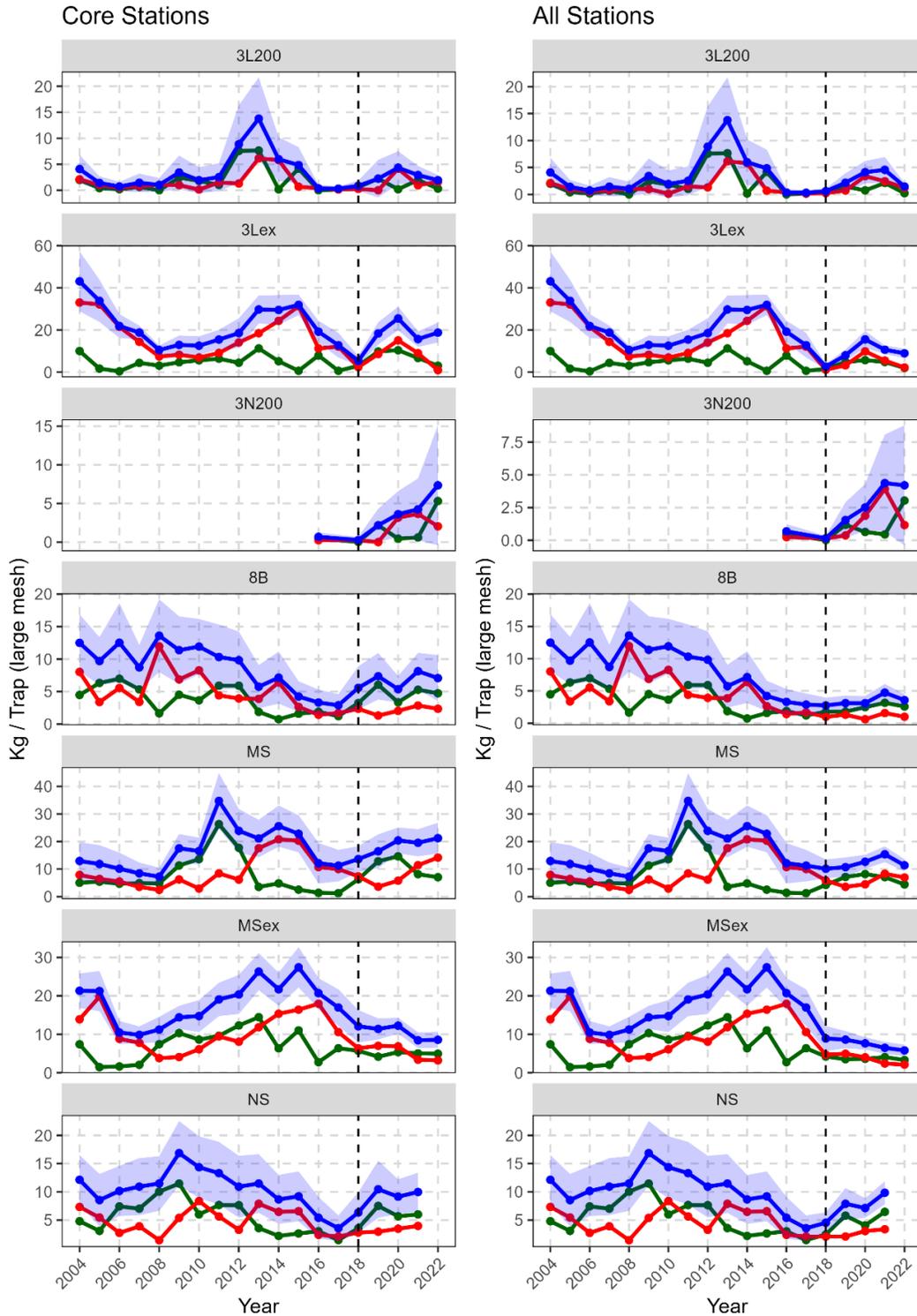


Figure A4.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable Snow Crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 3LNO Offshore (2004–22). 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.

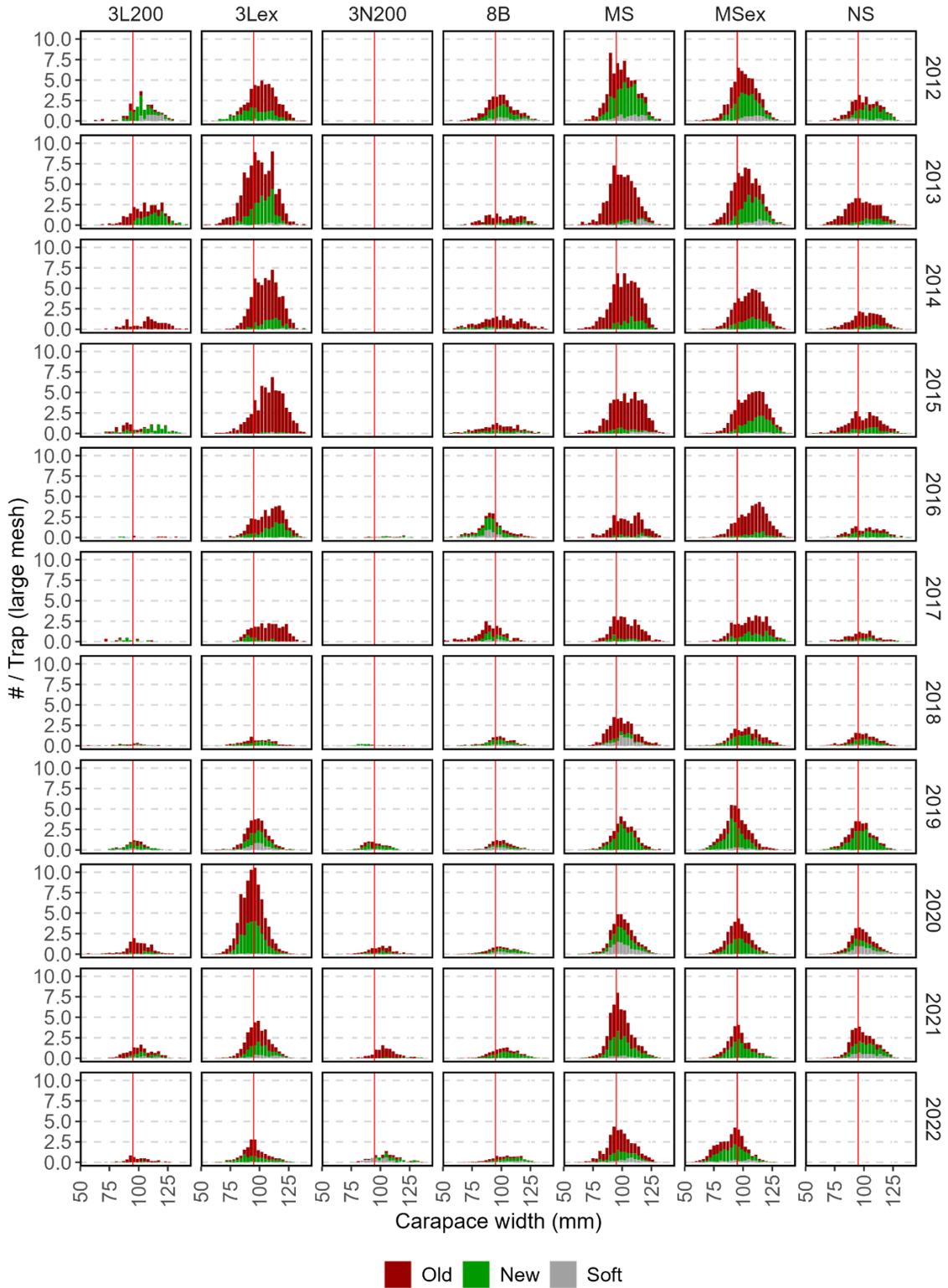


Figure A4.7. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3LNO Offshore (2012–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

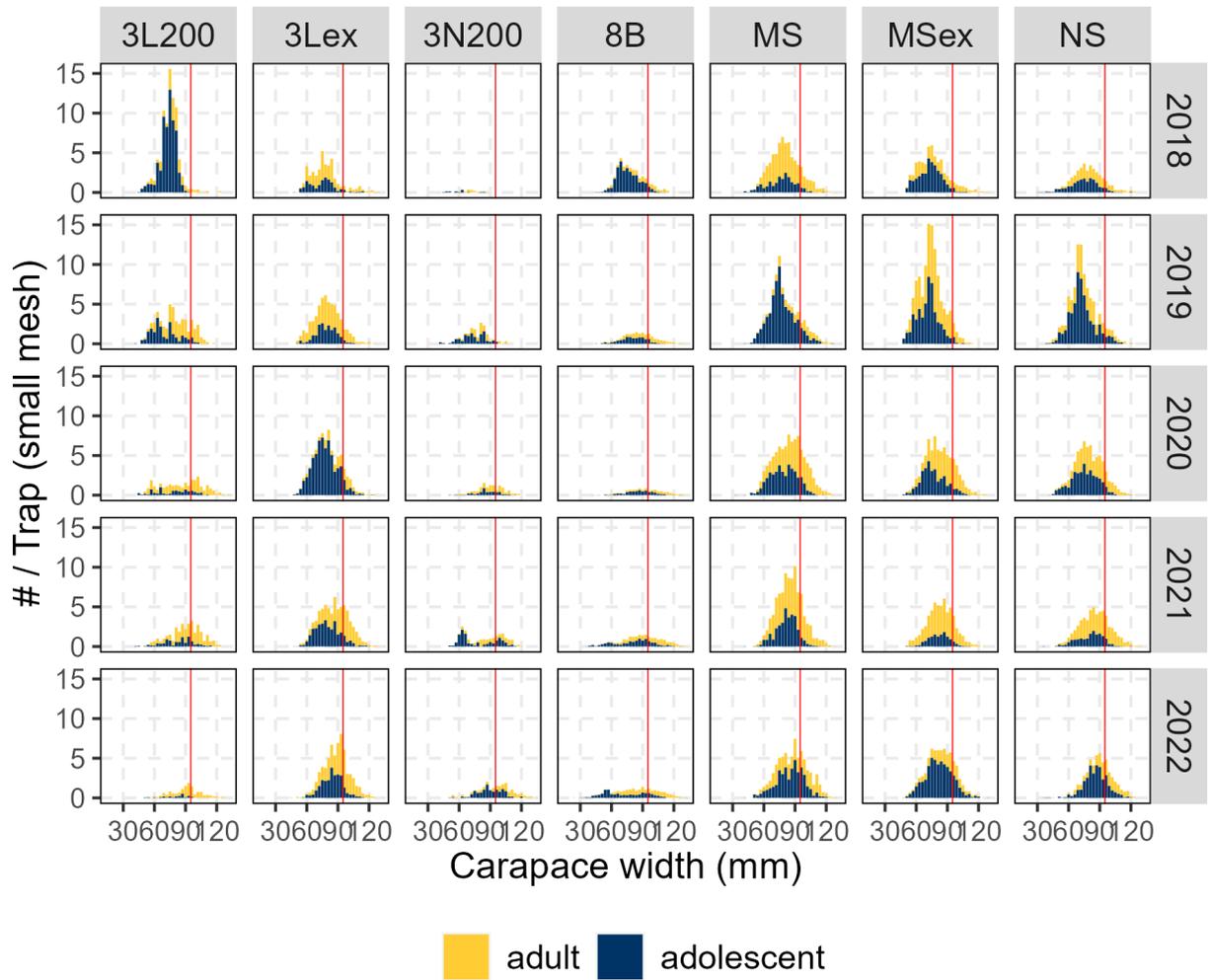


Figure A4.8. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3LNO Offshore (2018–22). The red vertical line indicates the minimum legal size.

APPENDIX 5: ASSESSMENT DIVISION 3PS DETAILS

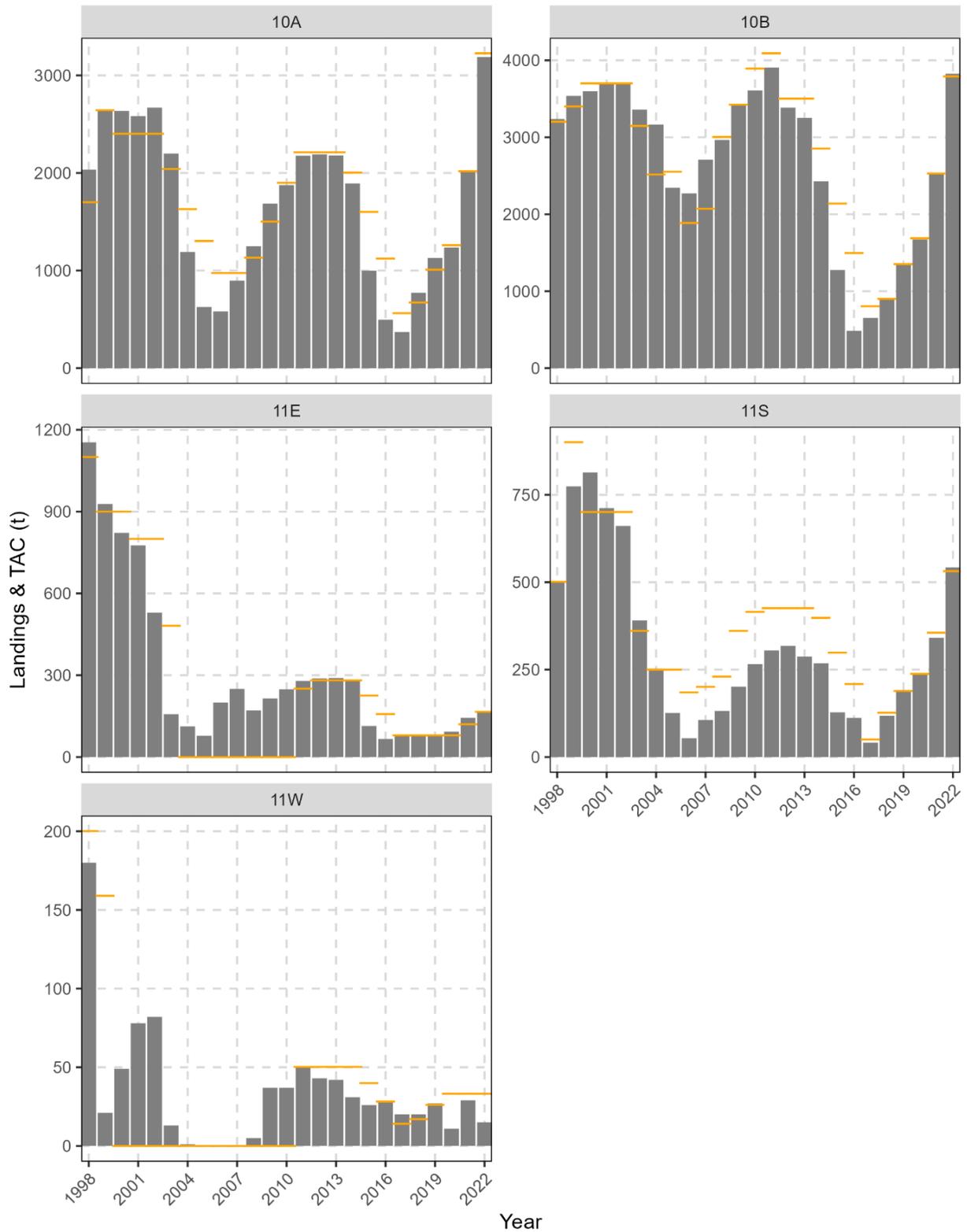


Figure A5.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 3Ps (1998–2022).

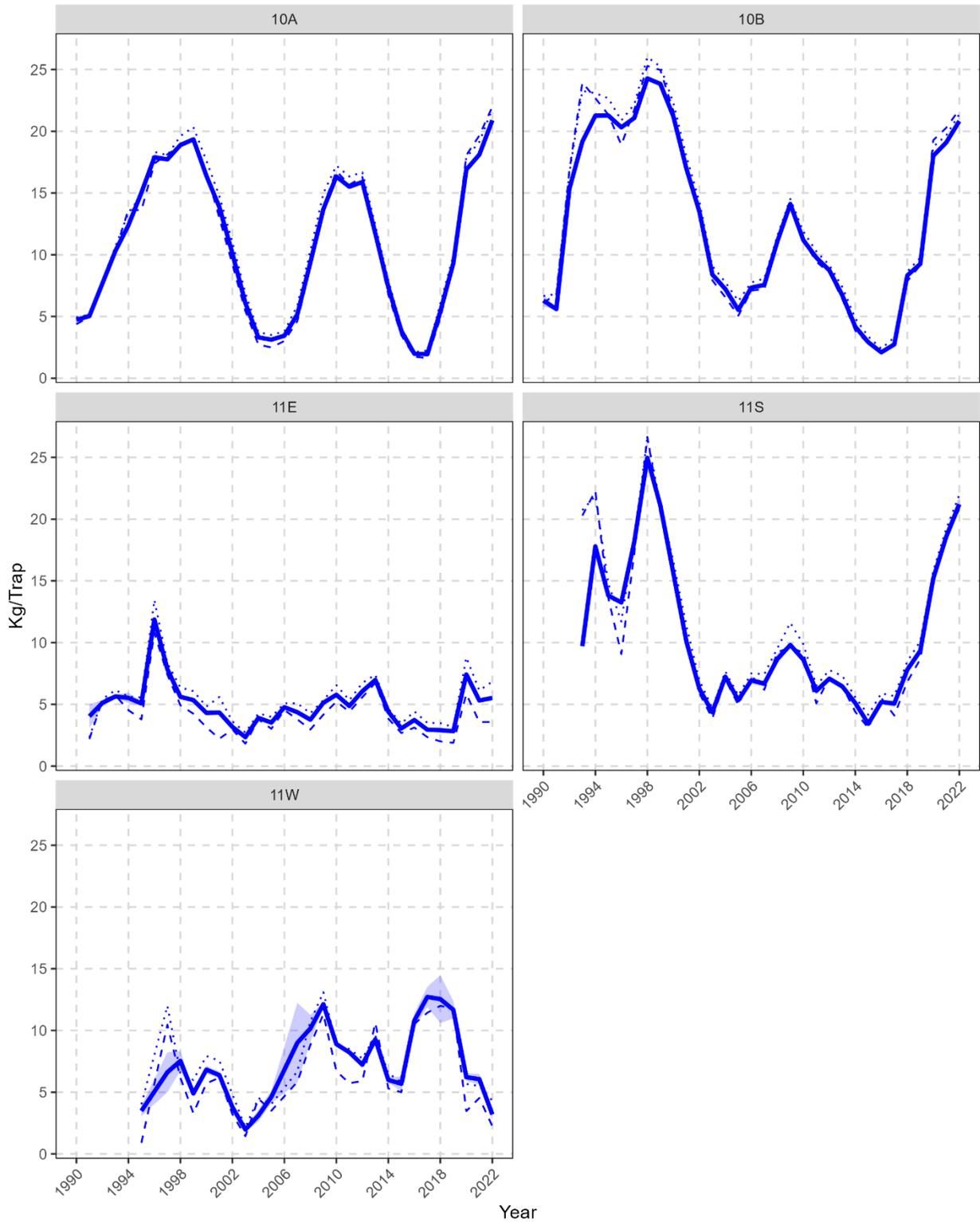


Figure A5.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 3Ps (1990–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

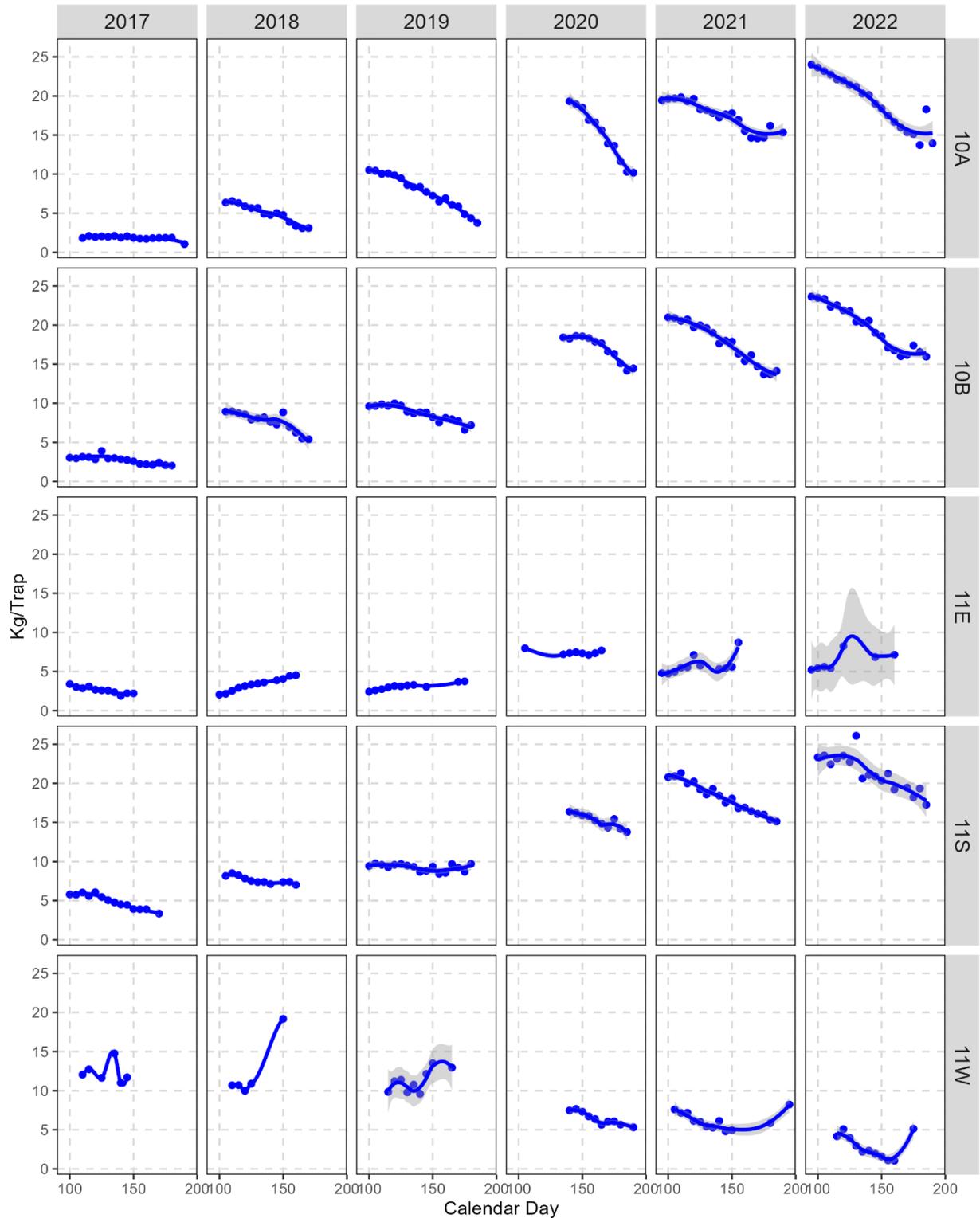


Figure A5.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 3Ps (2017–22), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

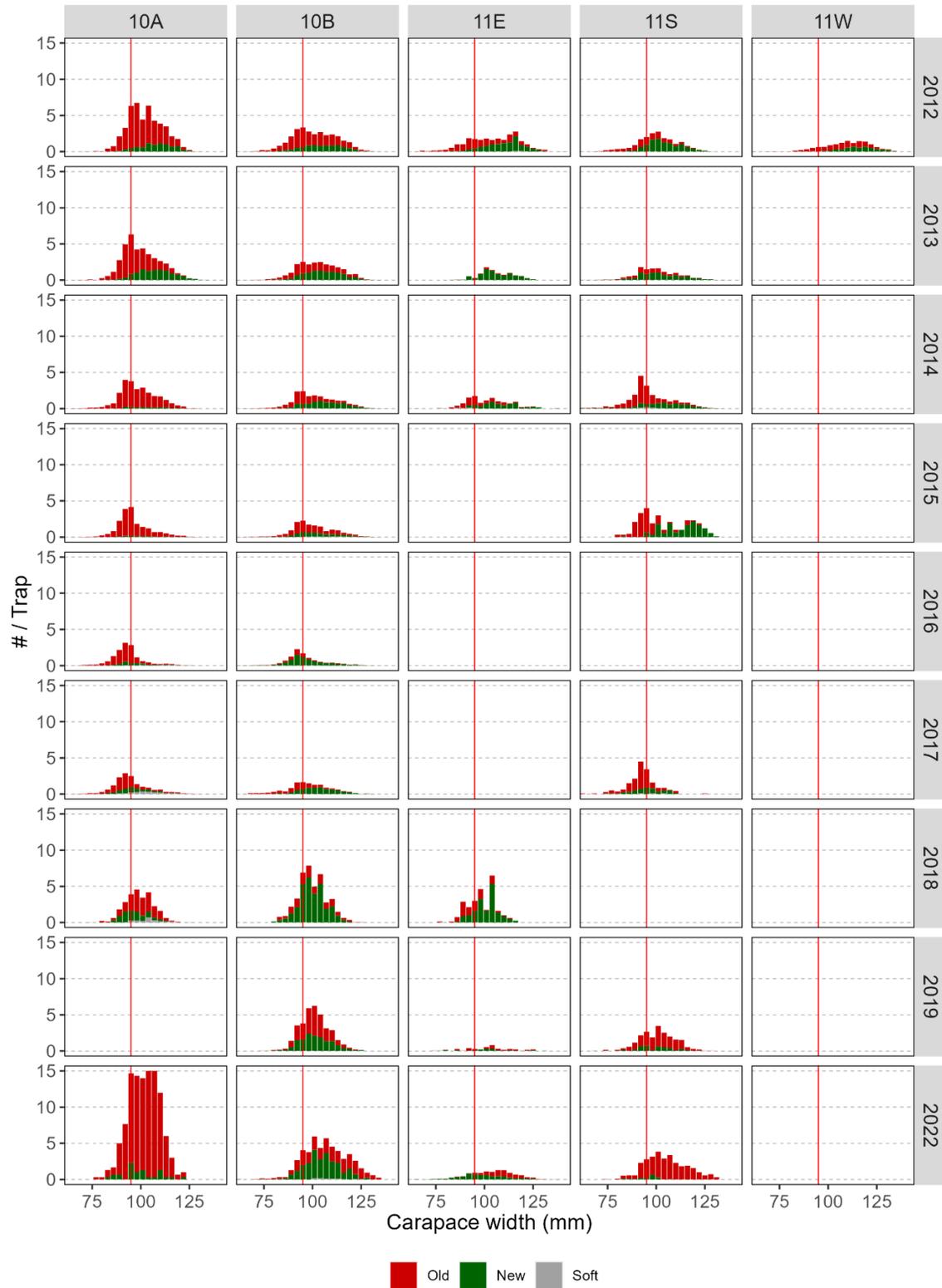


Figure A5.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 3Ps (2012–22). The red vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

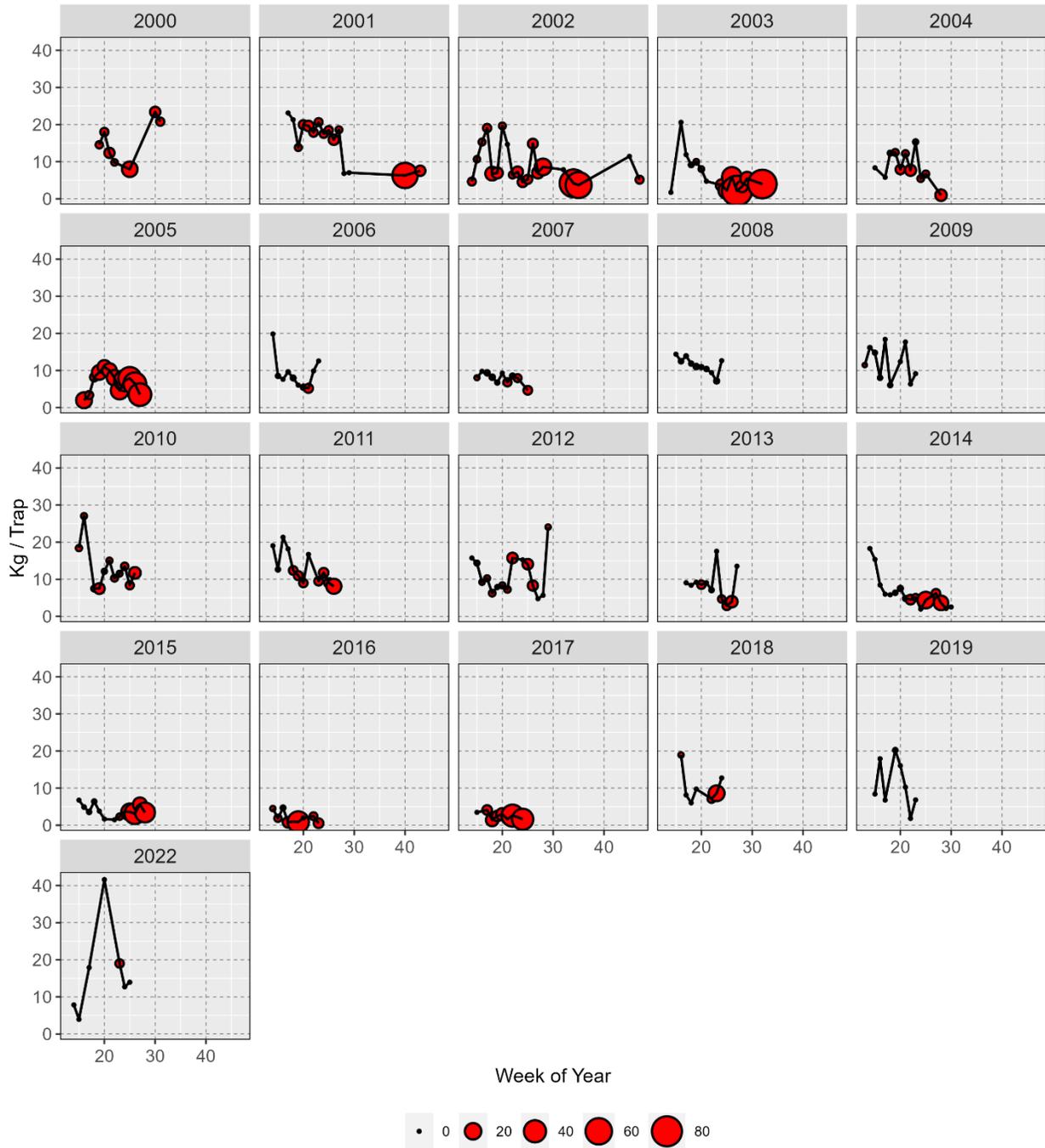


Figure A5.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling in Crab Management Areas within the Assessment Division 3Ps (2000–22). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

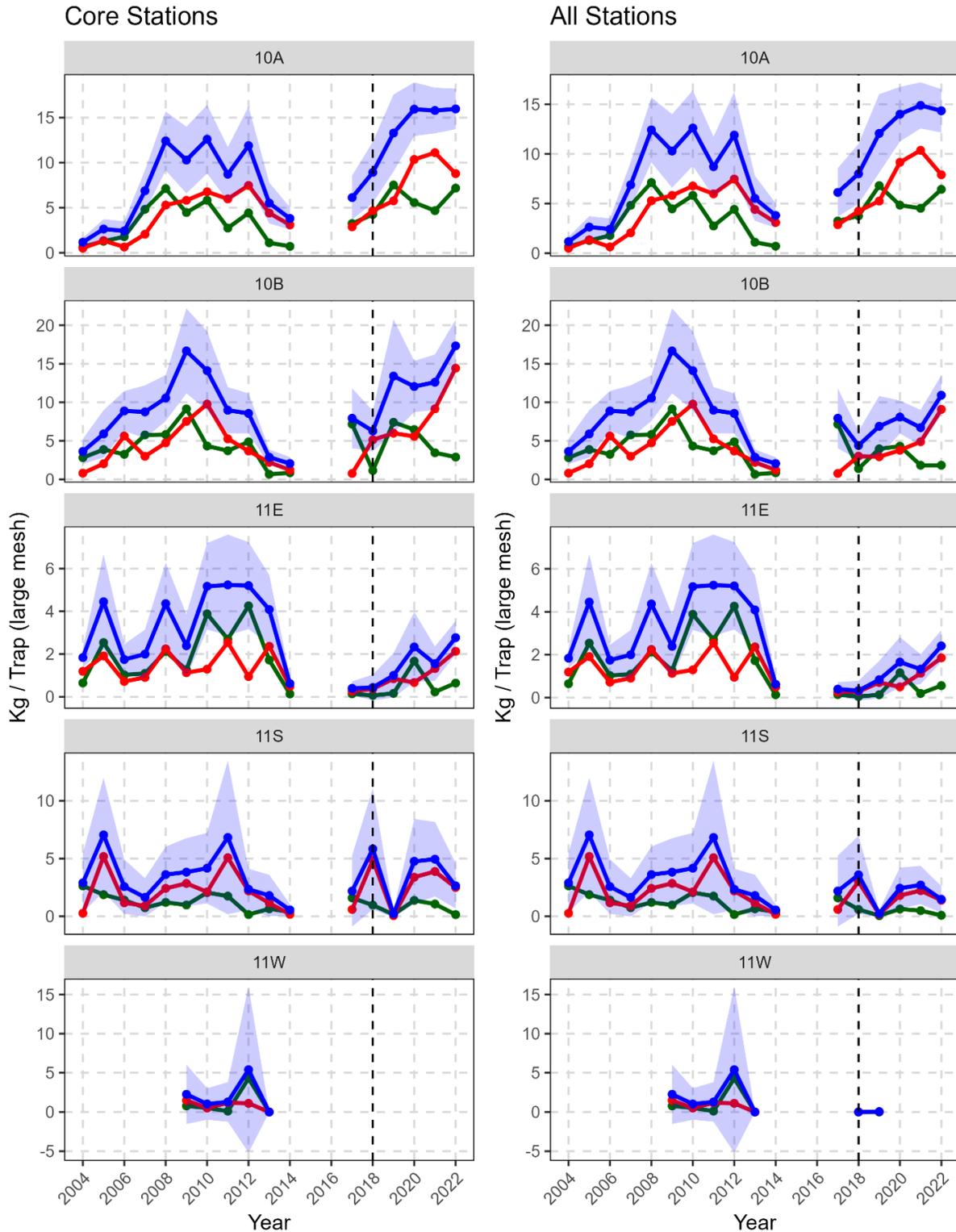


Figure A5.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 3Ps (2004–22). Shaded area represents the 95% confidence interval. The dashed vertical line denotes CPS survey redesign. Years without results represent incomplete or absent survey coverage.

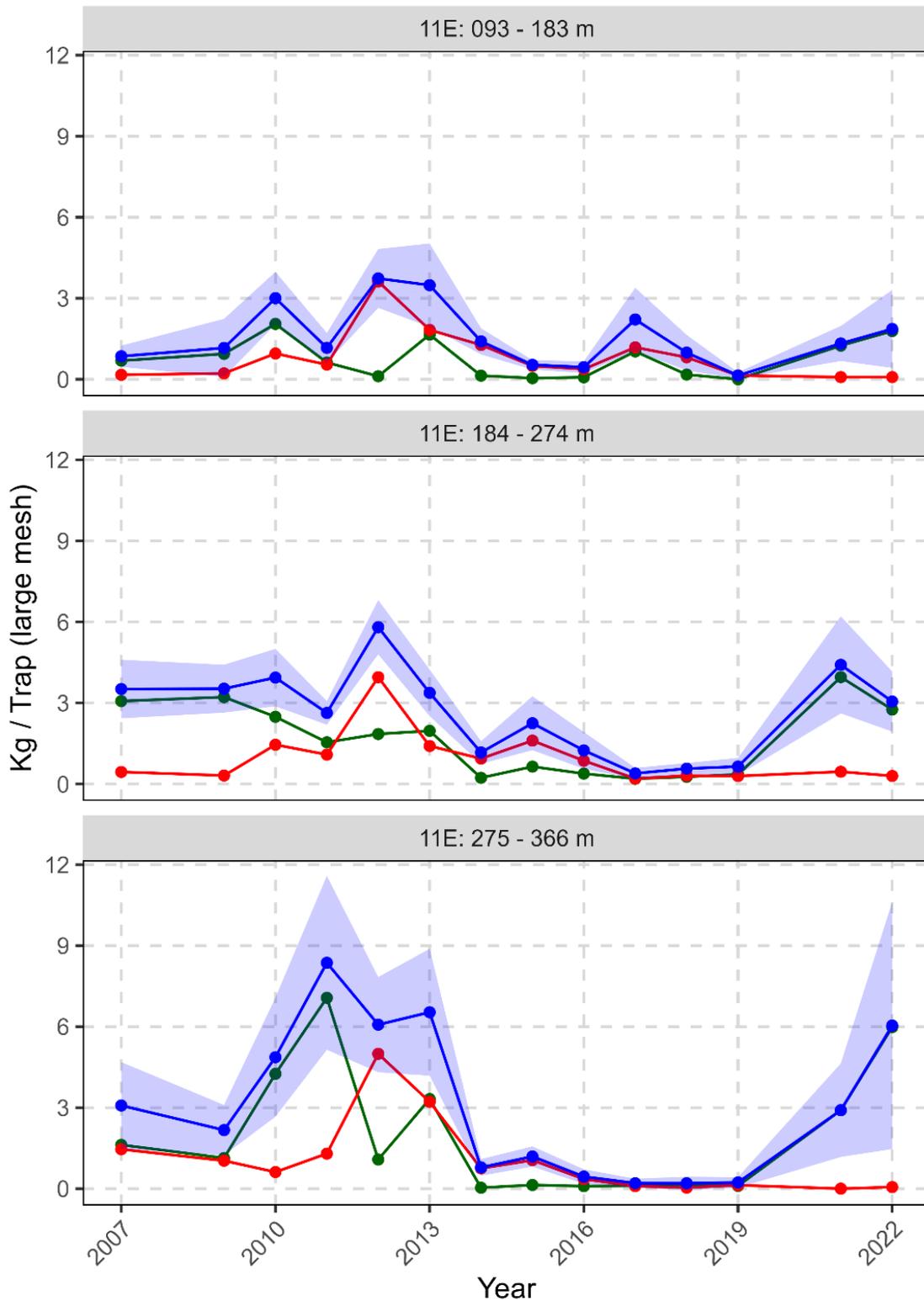


Figure A5.7. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) of exploitable crab from large-mesh traps in the DFO inshore trap surveys by depth strata in Fortune Bay (Crab Management Area 11E) (2007–22). Shaded area represents the 95% confidence interval. Years without results represent incomplete or absent survey coverage.

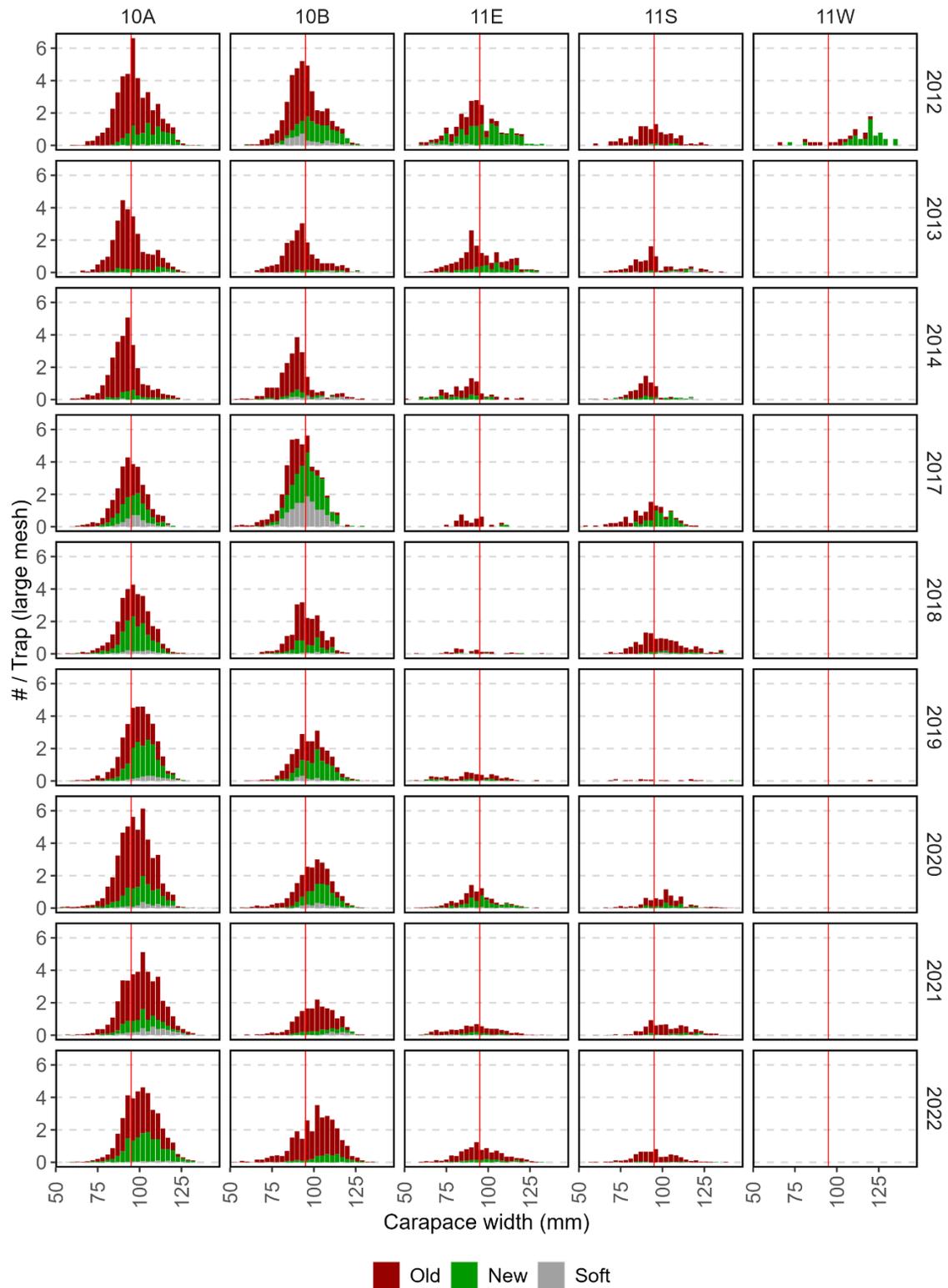


Figure A5.8. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3Ps (2012–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

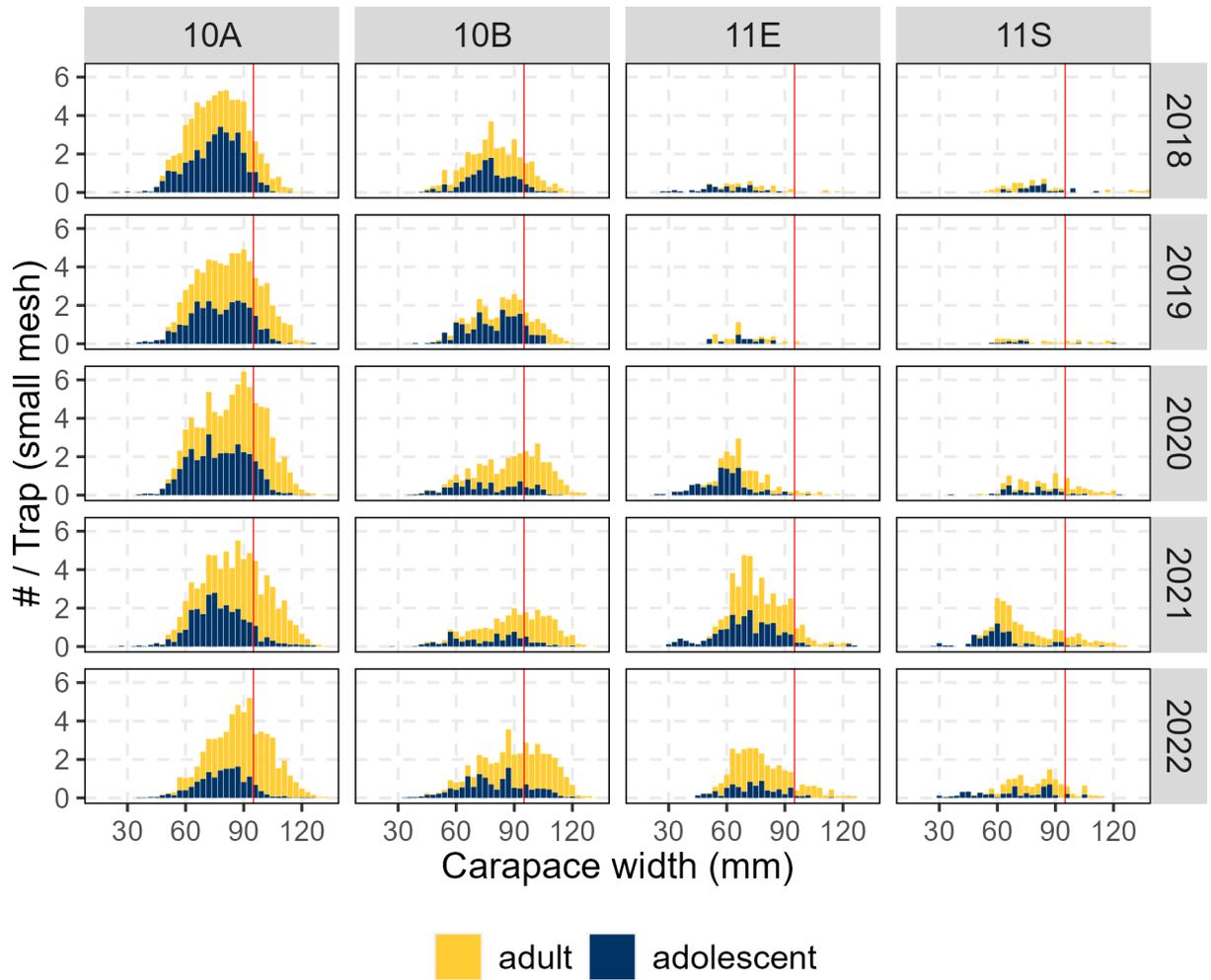


Figure A5.9. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 3Ps (2018–22). The red vertical line indicates the minimum legal size.

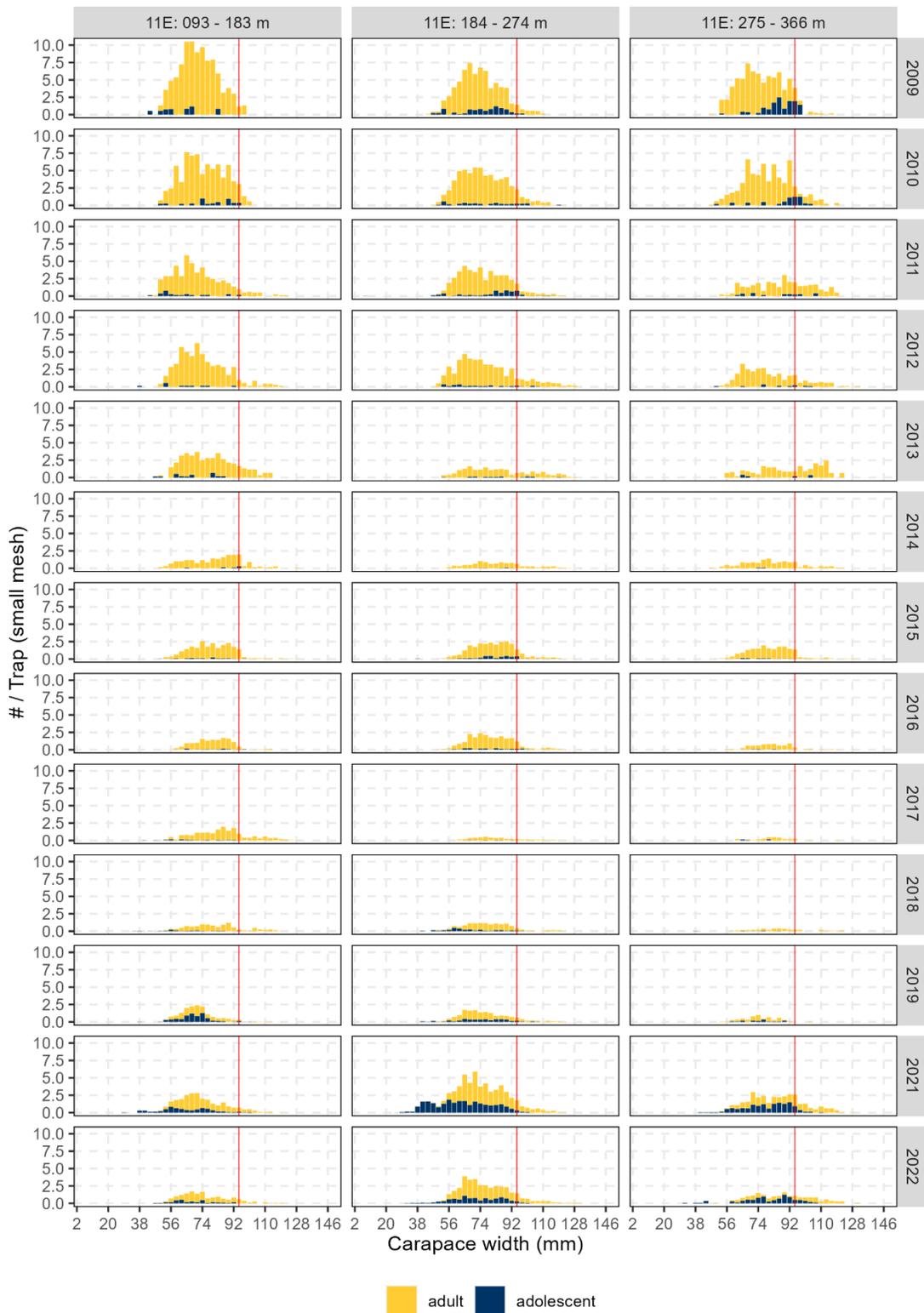


Figure A5.10. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps in the DFO inshore trap survey by depth strata in Fortune Bay (Crab Management Area 11E) (2009–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

APPENDIX 6: ASSESSMENT DIVISION 4R3PN DETAILS

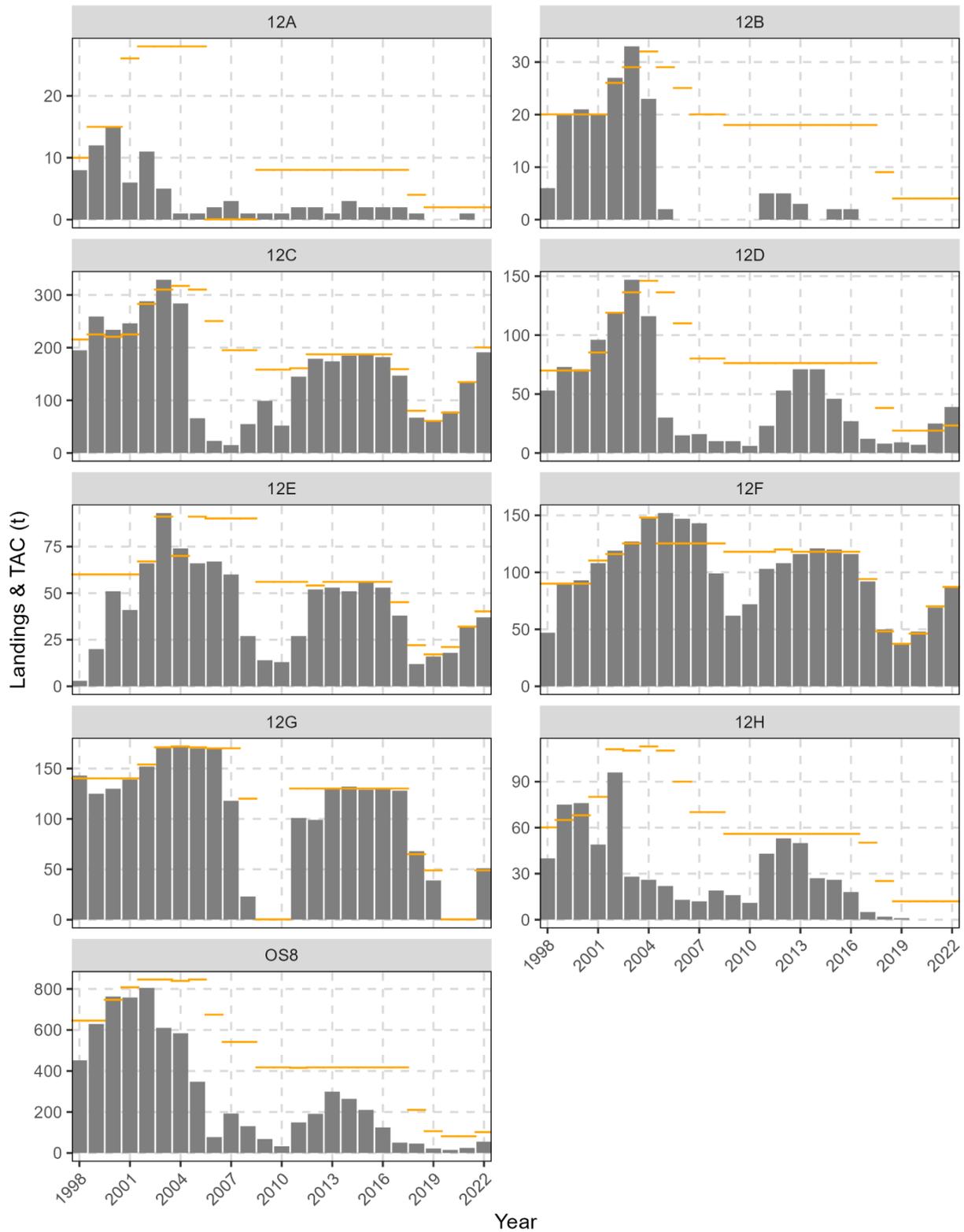


Figure A6.1. Annual landings (tonnes) of Snow Crab (grey bars) and total allowable catch (TAC) (yellow dashes) in Crab Management Areas within Assessment Division 4R3Pn (1998–2022).

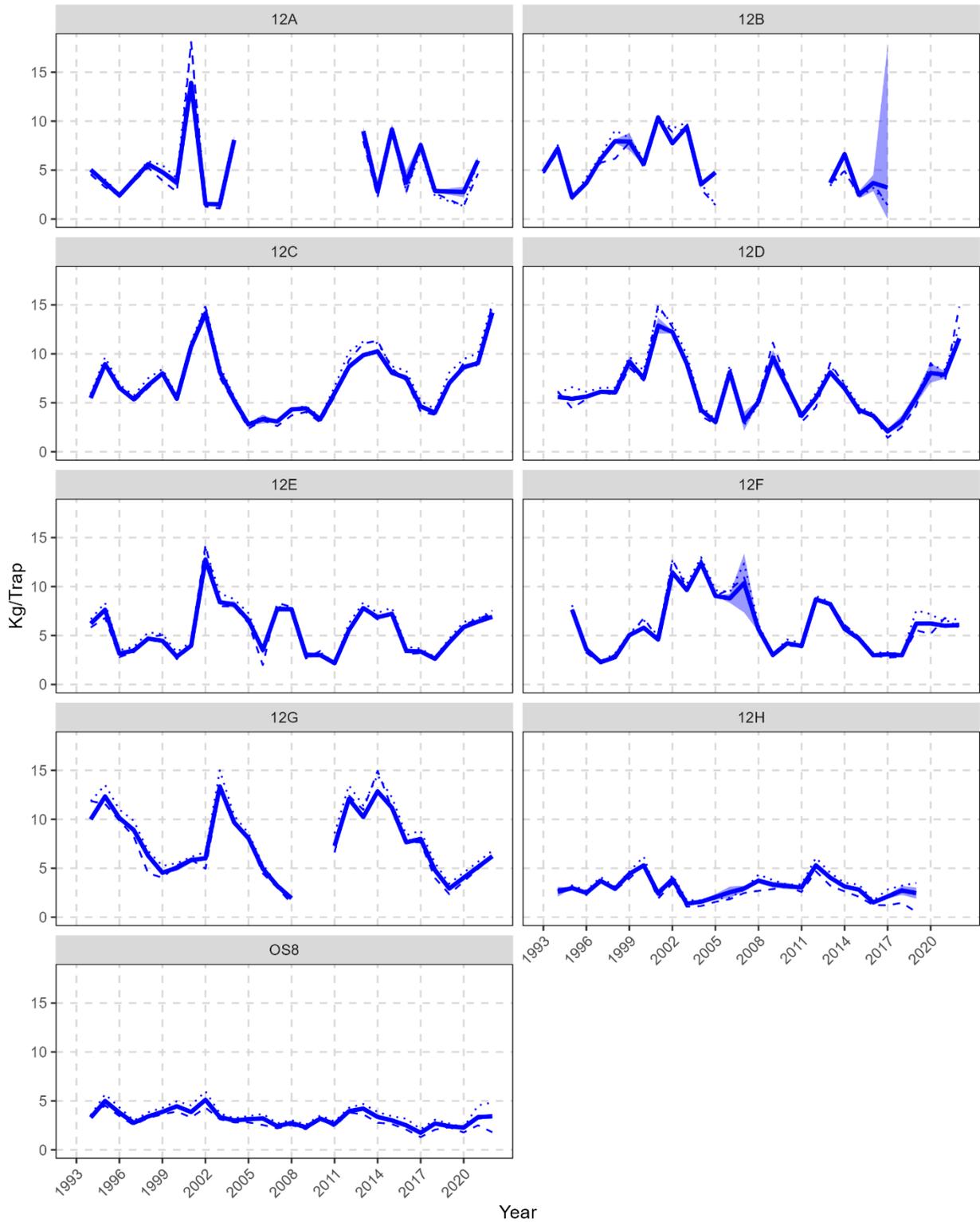


Figure A6.2. Standardized fishery CPUE (kg/trap) in Crab Management Areas within Assessment Division 4R3Pn (1993–2022). Solid line = standardized CPUE, dotted lines = raw mean CPUE, dashed lines = raw median CPUE, and shaded band = 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

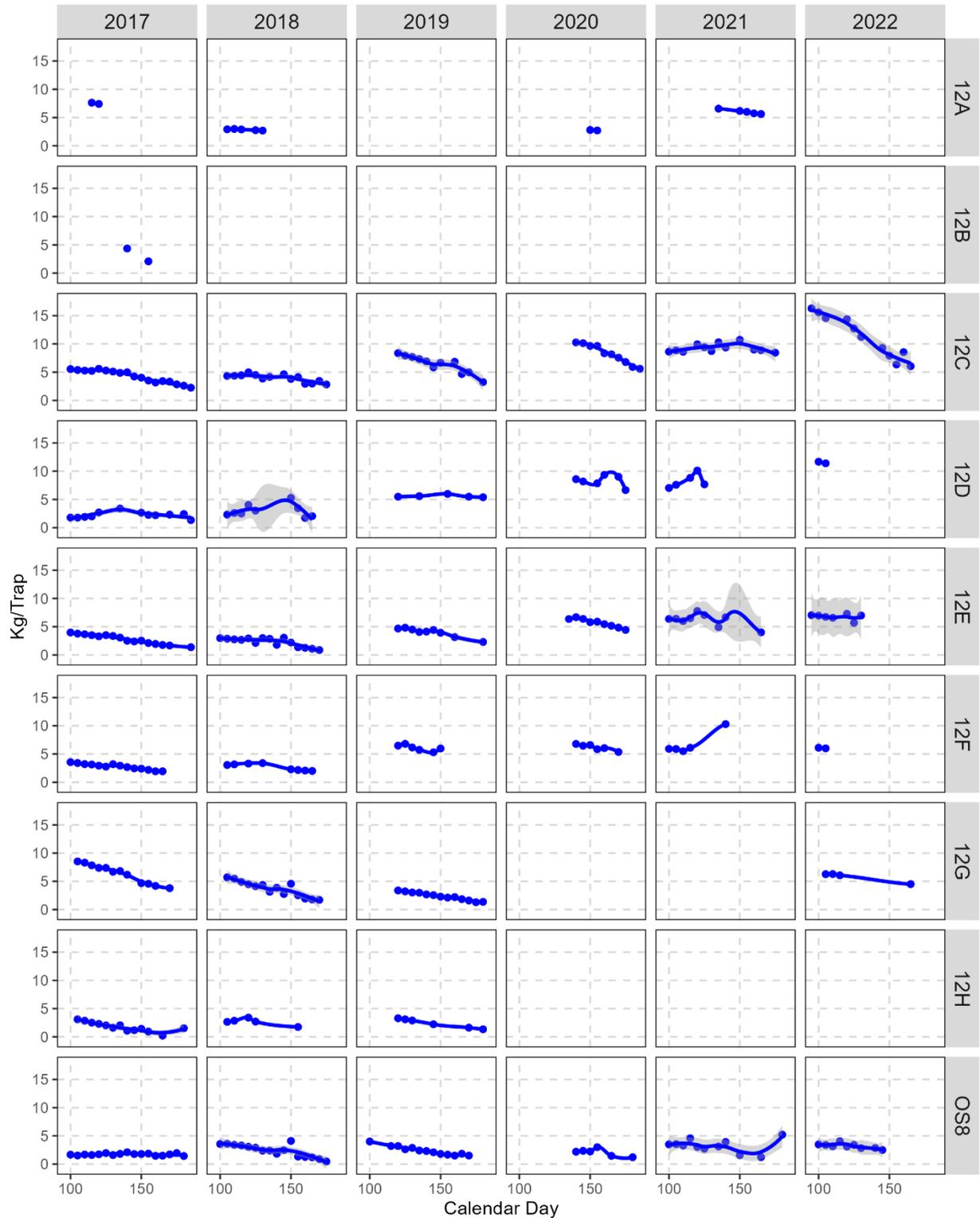


Figure A6.3. Standardized CPUE (kg/trap) of Snow Crab throughout the season (calendar day) in Crab Management Areas within Assessment Division 4R3Pn (2017–22), derived from logbooks. Points denote mean CPUE of five-day increments, trend lines are loess regression curves, and grey bands are 95% confidence intervals. Data in the most recent year are considered preliminary due to delays in logbook returns and data entry.

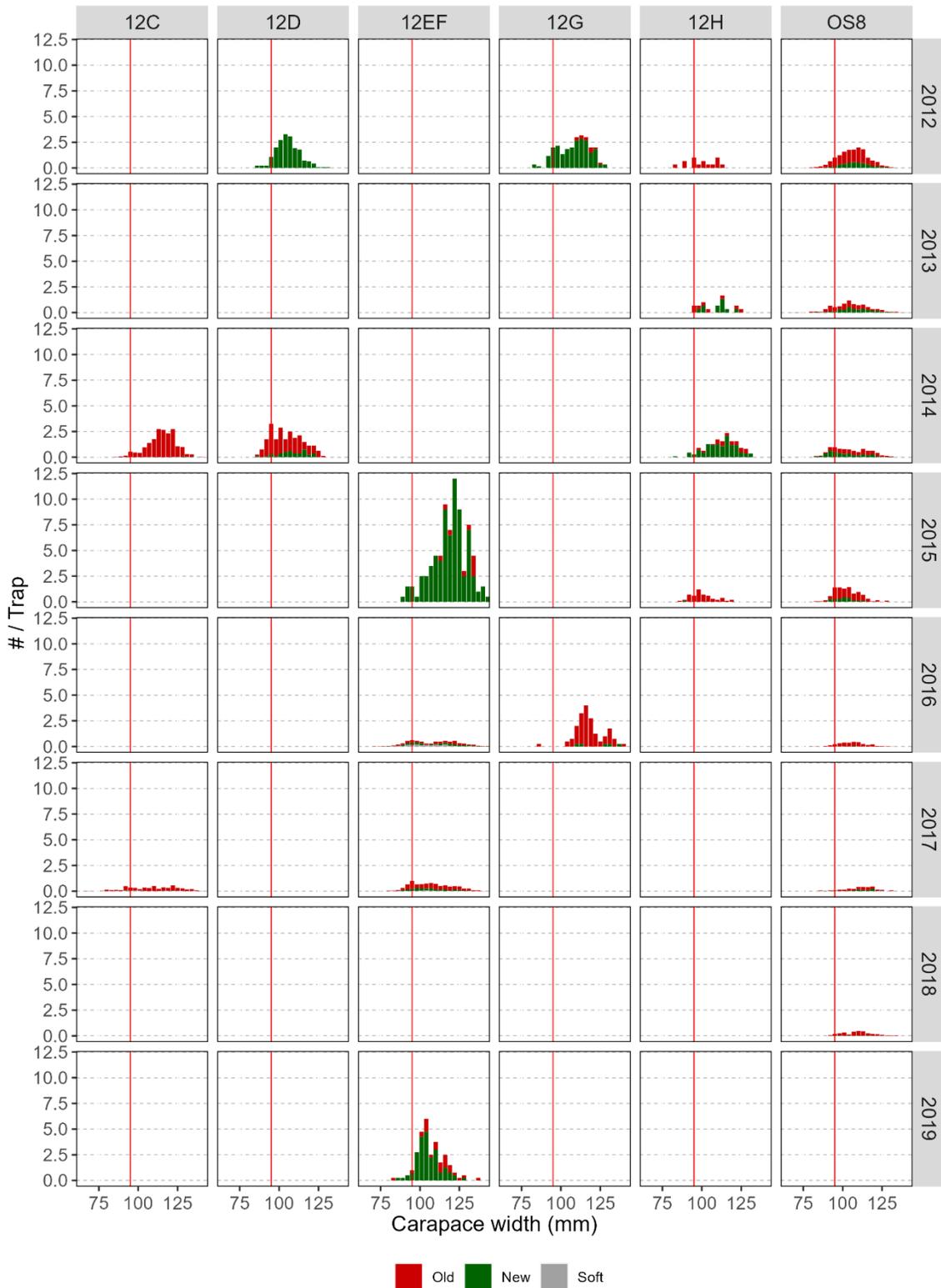


Figure A6.4. Catch rates (#/trap) by male carapace width distributions and shell condition from at-sea observer sampling in Crab Management Areas within Assessment Division 4R3Pn (2012–19). The red vertical line indicates the minimum legal size. Years without results represent low or absent at-sea observer coverage.

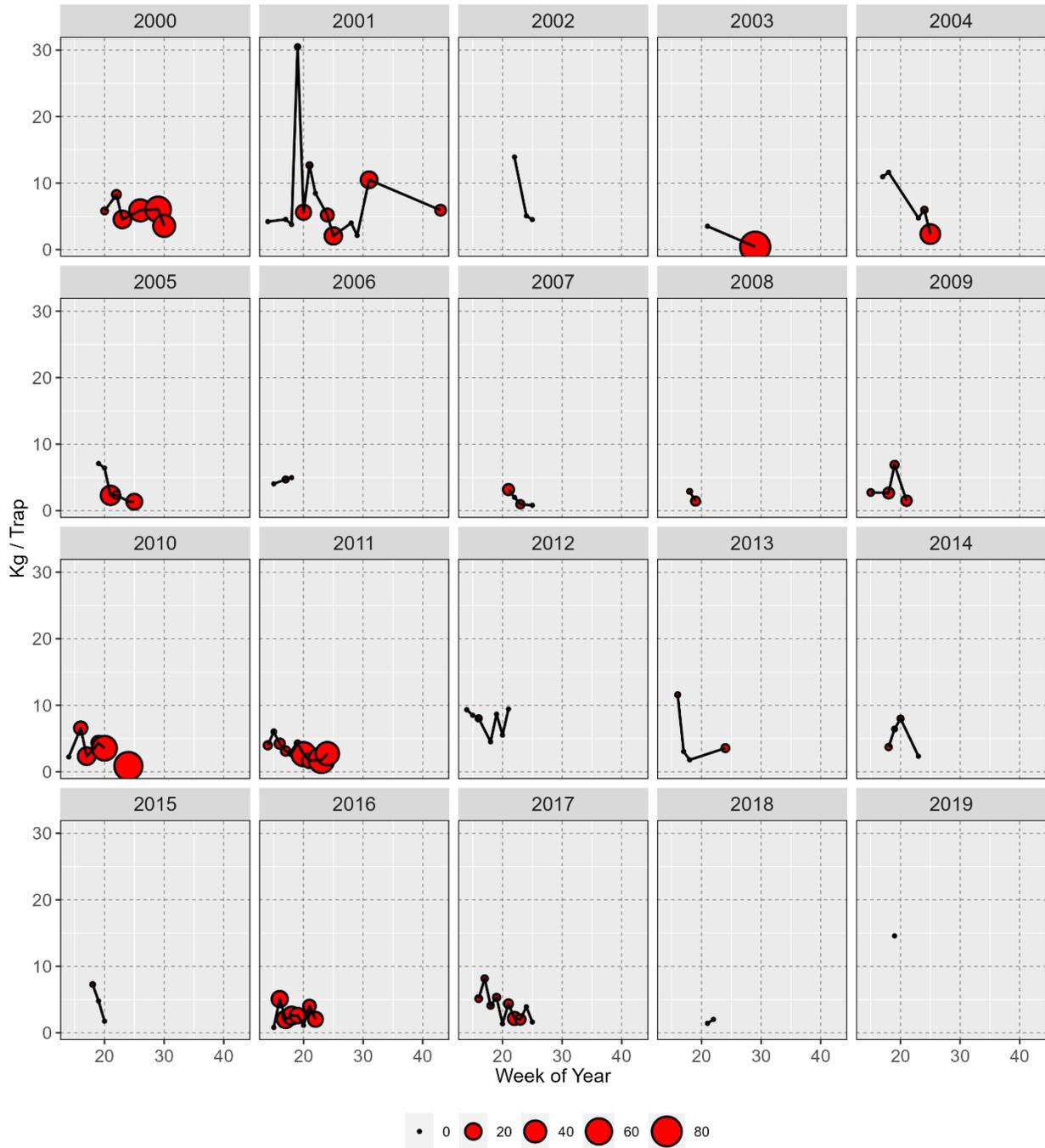


Figure A6.5. Weekly catch rates (kg/trap) and the percentage of soft-shell crab in the catch from at-sea observer sampling in Crab Management Areas within the Assessment Division 4R3Pn (2000–19). Bubble size depicts percentage of soft-shell crab and solid line depicts unstandardized observed catch rates. Years without results represent low or absent at-sea observer coverage.

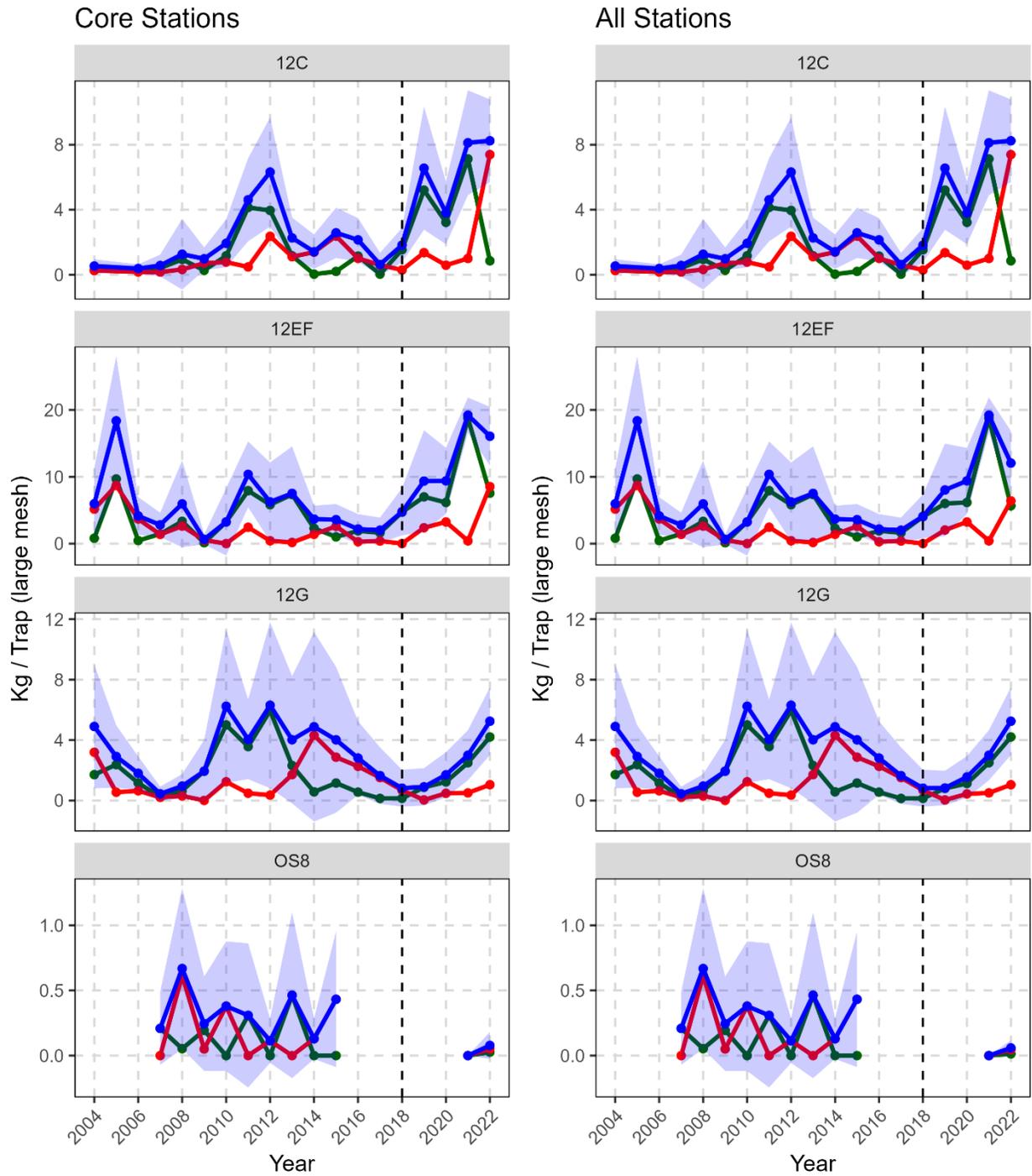


Figure A6.6. CPUE (kg/trap) by shell condition (blue = total, red = residual crab, green = recruits) for exploitable crab from large-mesh traps at core stations (left) and all stations (right) in the Collaborative Post-Season (CPS) trap survey in Crab Management Areas within Assessment Division 4R3Pn (2004–22). Shaded area represents the 95% confidence interval. The dashed line denotes CPS survey re-design. Years without results represent incomplete or absent survey coverage.

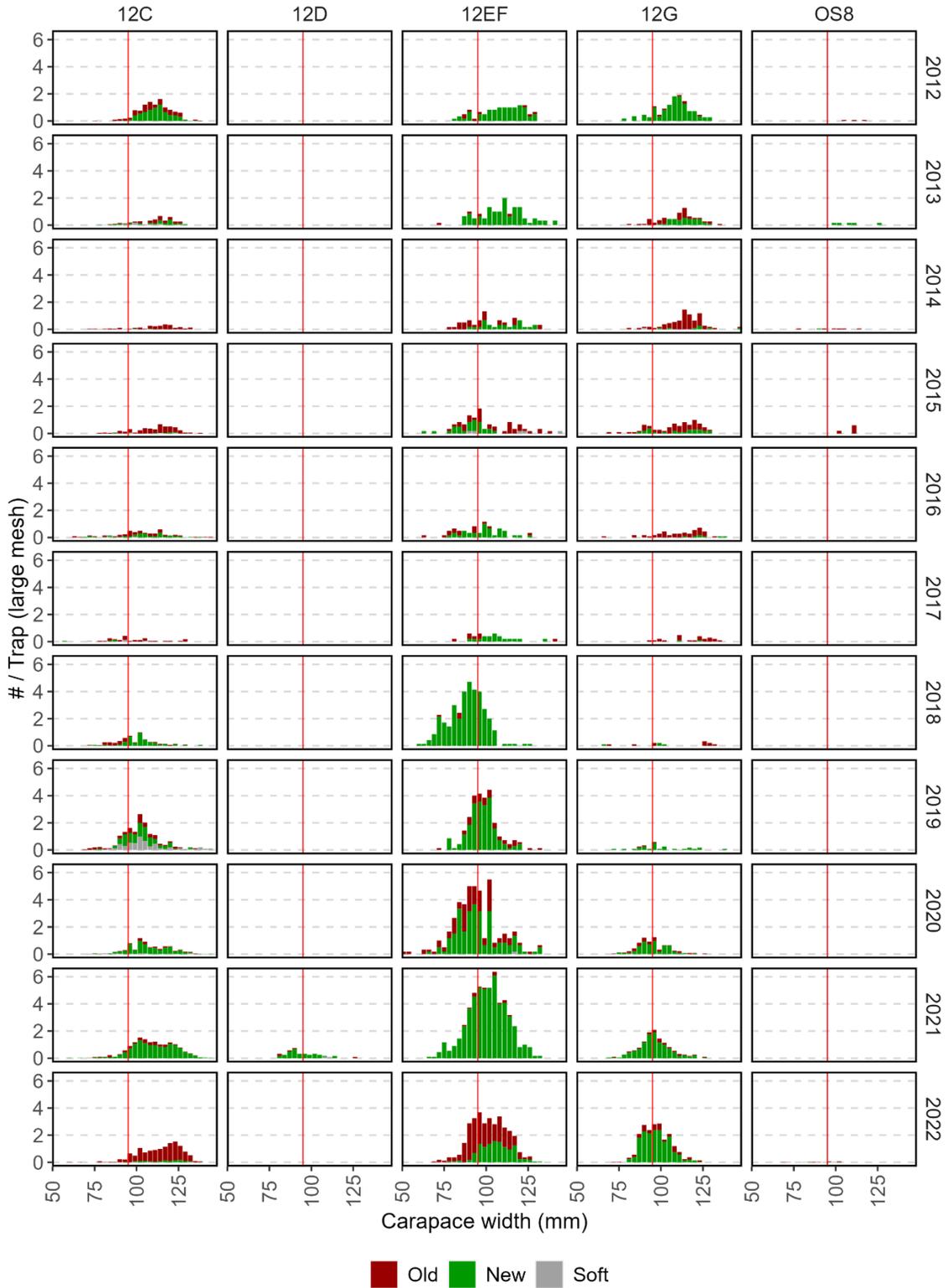


Figure A6.7. CPUE (#/trap) by male carapace width distributions and shell condition from large-mesh traps at all stations in the Collaborative Post-Season trap survey in Crab Management Areas within Assessment Division 4R3Pn (2012–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.

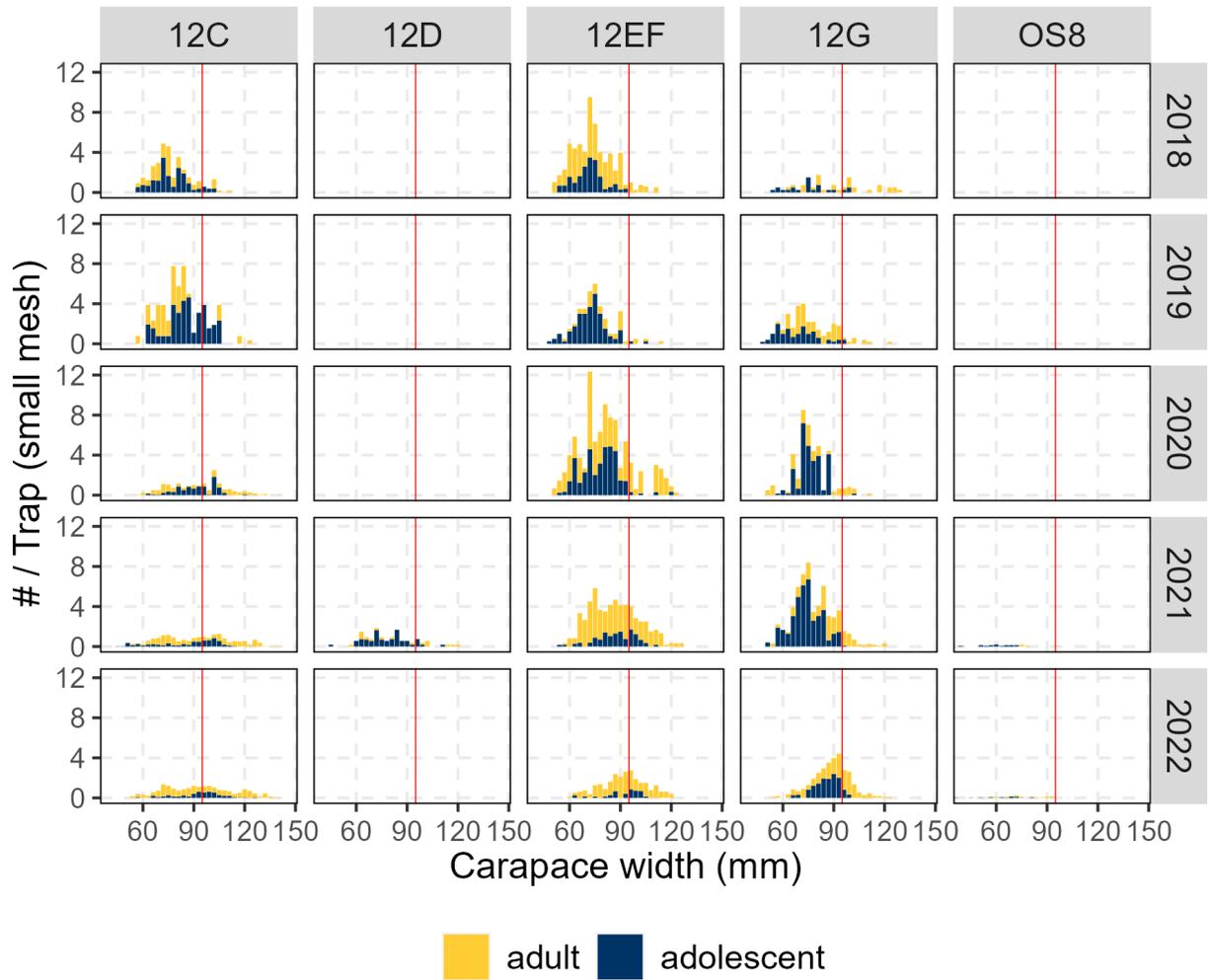


Figure A6.8. CPUE (#/trap) by male carapace width distributions and maturity from small-mesh traps at all stations in the Collaborative Post-Season trap survey from Crab Management Areas within Assessment Division 4R3Pn (2018–22). The red vertical line indicates the minimum legal size. Years without results represent incomplete or absent survey coverage.