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Assessment of Northern Shrimp (*Pandalus borealis)* in North and South Stock Assessment Regions in 2024

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Foreword

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

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ABSTRACT

The status of Northern Shrimp (*Pandalus borealis*) in the North and South Stock Assessment Regions (NSAR and SSAR, respectively) has been evaluated for the first time under the recently adopted (December 2024) Precautionary Approach (PA) Framework for Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4–7, Eastern Assessment Zone, and Western Assessment Zone. Stock statuses differ from those previously reported at the scale of Shrimp Fishing Areas, resulting from revised stock assessment areas that better reflect the stock structure and the implementation of a stock assessment model. The assessment of NSAR and SSAR incorporated data from the Fisheries and Oceans Canada (DFO) Newfoundland and Labrador (NL) fall multispecies survey and the annual Northern Shrimp Research Foundation–DFO (NSRF) summer trawl survey, alongside analyses of fishery performance, oceanographic conditions, lower trophic level dynamics, and fish community trends. A Bayesian size-structured stock assessment model (SISCALS) that incorporated fishery and survey biomass indices from spatiotemporal modeling and size composition data was used to estimate trends in Northern Shrimp biomass, recruitment, natural mortality rates, and stock status for each stock assessment region.

In the northern portion of the NSAR, summer ocean bottom temperatures for 2024 were average to slightly above average. In the southern portion of the NSAR and in the SSAR, the warm phase in ocean climate that started around 2020 continues, with record high sea surface temperature in 2024. The potential predator index has increased in both the NSAR and SSAR. The total biomass of the fish and shellfish community in the SSAR is at the highest levels since the 1990s, but remains below their pre-ecosystem collapse levels (late 1980s). These increases are driven by groundfish, with the community having returned to a groundfish dominated structure. Based on information from Atlantic Cod (*Gadus morhua*) diets, the current shrimp biomass in the core of the SSAR (NAFO Div. 2J3KL) is estimated to be around the level of the pre-ecosystem collapse period.

In the NSAR, spawning stock biomass (SSB) derived from SISCALS increased by 56% in 2024 relative to the 2023 value, and remained below the time-series mean (1996–2023). The fishable biomass (FB) spatiotemporal survey index in 2024 declined by 19.7% relative to the 2023 value and remained below the time-series mean (1996–2023). In 2024, the SSB for Northern Shrimp in the NSAR was above the Limit Reference Point (LRP) (greater than 99% probability) and above the proposed Upper Stock Reference (USR) (greater than 99% probability). If the proposed USR were adopted, this would place the stock in the Healthy Zone of the PA Framework.

In the SSAR, SSB derived from SISCALS increased by 2.2% in 2024 relative to the 2023 value which was the lowest in the time series, and remained below the time-series mean (1996–2023). The FB spatiotemporal survey index in 2024 declined by 20.8% relative to the 2023 value and reached a time-series low (1996–2023). In 2024, the SSB for Northern Shrimp in the SSAR was above the LRP (greater than 99% probability) and above the proposed USR (greater than 98% probability). If the proposed USR were adopted, this would place the stock in the Healthy Zone of the PA Framework.

1. INTRODUCTION

1.1. SPECIES OVERVIEW

Shrimp are forage species (Policy on New Fisheries for Forage Species) and play a key role in the ecosystem, acting as an intermediary in the transfer of energy from the lower trophic levels (*e.g.*, zooplankton) to the higher ones (*i.e.*, predators, such as fish, marine mammals, and seabirds). Ecological relationships (*e.g.*, predator-prey and competition) must be maintained among the species affected directly or indirectly by the fishery within the bounds of natural fluctuations in these relationships.

1.1.1. Life Cycle

Northern Shrimp (*Pandalus borealis*) are protandrous hermaphrodites; in northern waters, most are born and first mature as males, mate as males for several years beginning in their second year, and then change sex at approximately 17–21 mm carapace length (CL) (Bergström 2000; Hansen and Aschan 2000; DFO 2023, 2024a). Shrimp alter their size of transition in response to environmental and ecological conditions (Charnov and Anderson 1989; Bergström 2000). After transitioning, shrimp spend the rest of their lives as mature females. Although accurate ageing in wild populations remains difficult, Northern Shrimp are generally thought to live for 6–8 years. Shrimp in northern parts of their range, such as those assessed herein, are thought to grow more slowly, have longer life spans, and reach larger sizes than shrimp in more southerly regions (Bergstrom 2000). The smallest shrimp caught by the fishery are generally between 15 and 17 mm carapace lengths (DFO 2018; Fulton et al. 2024), and commercial trawls generally catch shrimp with CL greater than 17 mm (Aschan and Ingvaldsen 2009; Le Corre et al. 2024, 2026)**,** thereby targeting the largest males, transitional individuals and females.

Female Northern Shrimp generally produce eggs in the late summer-fall and carry the eggs on their pleopods until they hatch in the spring (Allen 1959; Bergström 2000; Aschan and Ingvaldsen 2009). Larvae remain pelagic for several months (Ouellet and Chabot 2005; Rasmussen and Aschan 2011). At the end of the summer, larvae increasingly resemble adults and adopt suprabenthic (bottom-based) behaviour (Pedersen and Storm 2002). These postlarvae and juveniles are too small to be caught by commercial fishing trawls. Spawning females can occur as either first time spawners or multiparous individuals, with the latter recognizable to those who have never spawned by the disappearance of sternal spines in the prenuptial moult (Hansen and Aschan 2000). Environmental conditions (*e.g.*, timing of the spring phytoplankton bloom) influence the reproductive cycle of Northern Shrimp (*e.g.*, spring egg hatching) (Koeller et al. 2009). For example, bottom water temperatures influence the duration of egg development on the female abdomen. Different populations of Northern Shrimp have adapted to local temperatures and bloom timing, matching egg hatching to food availability under average conditions (Koeller et al. 2009). However, this strategy is vulnerable to interannual oceanographic variability and long-term climate change.

1.1.2. Habitat

Environmental conditions (e.g., temperature and depth) are widely recognized as a key determinant of Northern Shrimp distribution (Shumway et al. 1985; Baker et al. 2024c), abundance (Garcia 2007), growth (Squires 1996; Bergström 2000), reproductive success (Lund 1988), and survival (Bergström 2000). Northern Shrimp are found in the Northwest Atlantic from Baffin Bay to the Gulf of Maine, where they typically inhabit soft and muddy substrates in bottom temperatures ranging from 1°C to 6°C (Shumway et al. 1985; Ouellet

et al. 2007; Bourdages et al. 2022; Baker et al. 2024c). In Atlantic Canada, the highest densities of Northern Shrimp generally occur on slightly sloped bottoms in waters between 0°C and 5°C (range: -1.6°C to 9.2°C), with the greatest probability of encountering fishable densities observed at bottom temperatures between 2°C and 3°C (Baker et al. 2024c). These conditions typically occur at depths of 150–600 m throughout the Newfoundland and Labrador (NL), Eastern Assessment Zone (EAZ), and Western Assessment Zone (WAZ) offshore areas (Baker et al. 2024c, 2025). The highest Northern Shrimp densities are generally observed at depths of 250–300 m along slope edges, with the proportion of males declining as depth increases, and larger females typically found in waters deeper than 400 m (e.g., shelf edge) and in more northern areas (e.g., EAZ) (Baker et al. 2025). Other environmental factors, such as phytoplankton blooms and sea surface temperatures (SSTs), also influence Northern Shrimp recruitment from the larval stage through to juvenile settlement on the seafloor (Brosset et al. 2019; Le Corre et al. 2020).

1.1.3. Larval Dispersal and Behavior

There is a strong connectivity both within and between the North Stock Assessment Region (NSAR) and the South Stock Assessment Region (SSAR) (Le Corre et al. 2019, 2020) (Figure 1). Northern Shrimp larval dispersal biophysical modeling shows that larvae may travel several hundreds of kilometers prior to settlement, connecting all the different areas along the northeastern shelves of Canada and western Greenland consistently over the years. Those simulations suggest that Northern Shrimp larvae originating in the north (*e.g.*, source: NSAR) provide potential settlers to the SSAR. However, recent research on Northern Shrimp larval dispersal did not consider potentially important factors such as temperature-dependent development or mortality (*e.g.*, predation and post-settlement), and there were no recruitment data for Northern Shrimp to validate the simulated dispersal patterns. Genetic studies between Northern Shrimp populations in the northeastern shelves of Canada demonstrated that individuals in these areas are largely genetically homogenous (Jorde et al. 2015; Bourret et al. 2024), but also identified genetically-distinct pools in localized areas (*e.g.*, Newfoundland Shelf) that may be linked to smaller-scale oceanographic features (*i.e.*, gyres) (DFO 2023; Bourret et al. 2024). This is most likely due to larval and pelagic transport by the Labrador Current, Hudson Strait Current, and Baffin Island Current.

1.1.4. Vertical and Horizontal Movements of Adults

In some areas, Pandalid shrimp exhibit diel vertical migrations (Crawford et al. 1992; Hudon et al. 1992), ascending into the water column at night to feed on plankton and descending to the bottom during daylight hours (Hudon et al. 1992). The extent of vertical migration appears to vary with Pandalid shrimp developmental stage and environmental conditions (Hudon et al. 1992; Bergström 2000; Baker et al. 2021). Although specific data on Northern Shrimp are currently lacking, related species such as *P. montagui* in Canadian Arctic waters have demonstrated higher male catch rates during daylight, with catches 1.52 times greater than those recorded at night (Baker et al. 2021). Notably, it has been hypothesized that ovigerous Northern Shrimp may not undertake vertical migrations due to reduced swimming capacity caused by the presence of eggs attached to their pleopods (Bergström 2000).

Some adult shrimp (*i.e.*, not only larvae) could also be transported a great distance in a relatively short period of time in areas like the Hudson Strait, which is a highly dynamic system with strong currents and mixing (Drinkwater 1986). Such transportation could then result in rapid shifts of shrimp spatial distribution. The most recent Precautionary Approach (PA) Framework's consideration of stock assessment regions at the population scale (Johnson et al. In press) allows for the implicit acknowledgment of exchange (export/import) within each region, thereby

enhancing the understanding of overall resource dynamics (DFO 2023, 2024b; Le Corre et al. 2024).

1.1.5. Predators

Northern Shrimp are important prey for many species such as Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossoides*), redfish (*Sebastes* spp.), American Plaice (*Hippoglossoides platessoides*), skates (*Raja radiata*, *Raja spinicauda*), wolffish (*Anarhichas* spp.), and harp seal (*Pagophilus groenlandicus*). Varying predation pressure plays an important role in regulating Northern Shrimp abundance throughout its range, including throughout NSAR and SSAR (Baker et al. 2024c; Zabihi-Seissan et al. 2024), Greenland (Wieland et al. 2007), Iceland (Jónsdóttir et al. 2013), the Gulf of Maine (Richards and Hunter 2021), and the Gulf of St. Lawrence, although recent studies in the Gulf of St. Lawrence also highlight the important role of plankton dynamics in Northern Shrimp growth (Brosset et al. 2019). The amount of shrimp consumed by predators varies in response to predator stock size, spatial overlap, size of predators, and alternative prey options.

Atlantic Cod is generally recognized as one of the primary predators of Northern Shrimp in the area (particularly in the SSAR) (Parsons 2005; Baker et al. 2024c), and was shown to exhibit a positive relationship with shrimp abundance at low to moderate cod densities, but a negative relationship at high densities due to intensified predation pressure (Wieland et al. 2007; Baker et al. 2024c). Redfish have also been identified as significant predators of Northern Shrimp across multiple regions, including West Greenland (Pedersen and Riget 1993), the Gulf of St. Lawrence (Brown-Vuillemin et al. 2022), the Flemish Cap (Pérez-Rodríguez et al. 2017), and Atlantic Canada (Baker et al. 2024c). Baker et al. (2024b) documented a substantial increase in redfish populations in Atlantic Canada waters since 2021. The potential impact of this emerging large biomass of juvenile redfish on *Pandalus* spp. populations should be thoroughly investigated, particularly given the observed negative effects on Northern Shrimp occurrence probabilities and the lower shrimp population densities in areas with high redfish densities (Baker et al. 2024c). Greenland Halibut are also recognized as important predators of Northern Shrimp across their range (Wieland et al. 2007; Dwyer et al. 2010), especially along the shelf slope (Baker et al. 2024c), despite not forming dense aggregations like redfish and cod. Greenland Halibut are generally considered more opportunistic feeders (Dwyer et al. 2010), and their consumption of Northern Shrimp tend to be lower compared to that of Atlantic Cod (Wieland et al. 2007; Fulton et al. 2024). The role of the harp seal was more notable during the period of low groundfish abundance on the NL shelves (Pedersen et al. 2022).

Multiple regime shifts have altered the productivity of the Northern Shrimp fishery since the early 1990s. The first regime, in the early-1990s, shifted the marine ecosystem off NL (i.e., SSAR) from a groundfish-dominated community to a shellfish-dominated community (Pedersen et al. 2022; DFO 2024a). More recently in the late 2010's in the SSAR, shrimp appear to be moving to a new, low productivity regime characterized by low recruitment and/or high natural mortality. In the NSAR (Figure 1), there is currently less evidence of regime shifts affecting Northern Shrimp.

1.2. COMMERCIAL FISHERY

The fishery for Northern Shrimp off the coast of Atlantic Canada began in Shrimp Fishing Area (SFA) 5 in the mid-1970s (Figure 1), primarily around the Hopedale Saddle, in the Cartwright Channel, and in the Davis Strait (SFA 1) (Figure 2). Soon after, concentrations of Northern

Shrimp were located within SFAs 4 and 6, off Baffin Island (SFA 2), and in Ungava Bay and Hudson Strait (SFA 3), leading to an expansion of the fishery into those areas (DFO 2007, 2009).The fishery expanded to Hawke Channel, St. Anthony Basin, Funk Island Deep, and slope edges of the continental shelf in SFAs 4–7 during the early-1990s, with associated total allowable catches (TACs) periodically increasing over the next two decades (Figure 1, Figure 2, Figure 3, Figure 4).

Until 1996, the Northern Shrimp fishery in SFA 6 was executed solely by a large-vessel (LV, tonnage > 500 t) fleet, which currently consists of 17 licenses. Commercial catch of Northern Shrimp increased rapidly from the mid-1990s into the early-2000s within SFA 6, where the resource was considered to be healthy and fisheries exploitation low. The majority of TAC increases in this period were allocated to a small-vessel (SV, vessel size < 100 feet) fleet, which has since grown to include about 250 license holders. The number of active licenses varies by year and has been less than 250 for the past several years.

In the Arctic region, the shrimp fishery began in the late 1970s in SFA 1. Exploratory fishing expanded into what is now Davis Strait-East management unit (previously SFA 2 or Eastern Assessment Zone (EAZ)) and then to areas southeast of Resolution Island in Hudson Strait. Quotas in these areas were initially based on fishery performance and not scientific survey data. In the mid-1990s, the fishery moved southeast of Resolution Island in the former SFA 2, where the main fishery remains to date. Implementation of the Nunavut Agreement in 1999 shifted the main fishery east of the Nunavut Settlement Area. In the EAZ and Western Assessment Zone (WAZ), the fishing season is limited by the seasonality of sea ice, and is conducted by offshore large vessels between May and December in most years.

In 2003, the management year was changed from a calendar (January 1 – December 31) to a fiscal (April 1 – March 31) year such that the catches shown for 2003/04 are based on a 15-month fishing season. A seasonal “bridging” program was established that allows each licence holder in the LV fleet (starting in 2007) and SV fleet (in 2012–15) to carry over some unused quota from the previous year, or borrow from next year’s quota. Each large-vessel license can bridge up to 750 t in each SFA and each SV licence can bridge up to 5% of their quota, up to 1,500 t for the SV fleet combined, in SFA 6. Bridging had not been permitted in SFA 6 since about 3,200 t was bridged in 2015/16. However, some exceptions were made in SFA 6 in 2020/21 due to impacts of the COVID-19 pandemic *(i.e.*, a high portion of unfished quota due to market conditions).

All Northern Shrimp fisheries in eastern Canada are subject to the Atlantic Fisheries Regulations, established under the *Fisheries Act*. Pertinent regulations apply to bycatch, discards and vessel logs, and include a minimum mesh size of 40 mm and mandatory use of sorting grates to minimize bycatch of non-target species (DFO 2023). Grate size is dependent upon the area fished. In SFAs 4, 5, EAZ, and WAZ the maximum bar spacing is 28 mm, and it is 22 mm in SFA 6. At-sea observers are required on all trips by the LV fleet (*i.e.*, 100% observer coverage). A target of 10% observer coverage has been established for the SV fleet (DFO 2023), although coverage has ranged between 5–8% over the last 10 years. Observers onboard vessels are responsible for recording fishing positions (Figure 2, Figure 3), catch size, and discards.

2. MATERIAL AND METHODS

A new understanding of Northern Shrimp population structure in Atlantic/Arctic Canada, based upon their distribution, dispersal, and life history traits, was adopted in December 2024 (DFO 2026, in press, Baker et al. 2025). Therefore, in 2025, the spatial scale of assessment for Northern Shrimp has changed from six areas (*i.e.*, EAZ, WAZ, and SFAs 4, 5 ,6, and 7) to two

stock assessment regions (*i.e.*, NSAR and SSAR) divided by the boundary between Northwest Atlantic Fisheries Organization (NAFO) Divisions 2H and 2J (Figure 1).

In 2025, the status of Northern Shrimp was assessed separately for the NSAR and SSAR using a new Bayesian size-structured stock assessment modeling framework (hereafter, SISCALS), which was adopted in December 2024. The new framework incorporates fishery and biomass indices from spatiotemporal modeling and size composition to estimate trends in Northern Shrimp biomass, recruitment, natural mortality rates, and exploitation rates for each stock assessment region (Johnson et al. In press).

Multiple data sources were employed to quantify the different indices integrated within the stock assessment model, in addition to scrutinizing other dimensions of the stock dynamics:

- DFO fall multispecies trawl survey data for both NSAR and SSAR;
- Northern Shrimp Research Foundation (NSRF)-DFO summer trawl survey data for the NSAR, henceforth referred to as the NSRF survey;
- Commercial catch landings from the Atlantic Quota Monitoring System (AQMS) in both stock assessment regions;
- Information on commercial shrimp fishing from at-sea observer reports (covering the NL, Nova Scotia, and Quebec regions) and logbook datasets (NL region);
- DFO's Atlantic Zonal Monitoring Program (AZMP).

Ecosystem and environment status was considered by examining available oceanographic conditions, biological community structure, and predator-prey interactions. Data on ecosystem status in NSAR are more limited than in SSAR. Stock status is determined based on reference points from SISCALS and exploitation rate indices are calculated using spatiotemporal fishable biomass indices and catch data in each stock assessment region.

2.1. ECOSYSTEM AND ENVIRONMENT

Relevant physical and biological oceanographic information is provided based on AZMP and NAFO Scientific Council Standing Committee on Fisheries Environment (STACFEN) analyses (Bélanger et al. 2022; Cyr et al. 2024b, 2024c).

Relevant information on the broader fish community, focusing on status and trends of fish functional groups, diet composition of key fish predators, and estimations of food consumption is provided by the NL Ecosystem Research Program (Koen-Alonso and Cuff 2018; NAFO 2021). Analyses focusing on shrimp production, predation, fishing pressures, and predation mortality index are also included, as well as analyses looking at potential drivers of per-capita net shrimp production (DFO 2016; 2017). The examination of the sustainability of aggregated catches at the functional ecosystem level is based on the approach used by NAFO (Koen-Alonso et al. 2022; NAFO 2022).

2.1.1. Climate Index

The NL climate index (NLCI) (Cyr and Galbraith 2021) summarizes selected time series deemed representative of the ocean climate on the NL shelf and the Northwest Atlantic as a whole. The NLCI is available between 1951 to present and is updated annually. It integrates 10 equally weighted climate indicators over the time series (Cyr and Galbraith 2021). The NLCI can be interpreted as a measure of the overall state of the climate system, with positive values representing warm and fresh conditions with less sea-ice and, conversely, negative values representing cold and salty conditions.

2.1.2. Bottom Temperature

The bottom temperature maps and statistics were obtained from the Canadian Atlantic Bottom Observations of Temperature-Salinity (CABOTS) data product (Coyne and Cyr 2024). This data product in NSAR and SSAR heavily relies on trawl-mounted Conductivity-Temperature-Depth (CTD) observations collected by both DFO multispecies (1980–2023) and the NSRF surveys (2006–23) and is completed with other available temperature-salinity profiles (*e.g.*, from DFO's AZMP surveys, international oceanographic campaigns, and Argo program). CABOTS is derived by data gridding using inverse distance-weighted interpolation that accounts for land barriers (see Cyr et al. 2024c for details). Bottom observations are restricted between 10 and 1,000 m and are available for all years and all seasons between 1980–2023, from which the climatological seasonal averages (averages over 1991–2020) are derived.

Before calculating statistics on bottom observations (*e.g.*, mean temperature or salinity, and area of the sea floor covered by a certain temperature range), missing observations on the annual maps (for example when no observations are available for a specific year) are filled with the climatological average. This allows for calculation of these metrics on the same seafloor area (especially important for areas covered by a certain temperature range), however this method is conservative as it will tend to pull anomalies towards zero and can therefore be misleading, particularly in years with poor survey coverage. The percentage area of each NAFO division covered is provided in CABOTS so users can assess the confidence of the observations for a certain year and season.

Bottom temperature maps for 2024, as well as their anomalies (difference between 2024 observations and the climatology), are shown together with the climatology. A number of statistics were derived from these maps to characterize the oceanographic seafloor habitat.

2.1.3. Nutrients and Plankton Community

Nutrient and chlorophyll a (chl a) concentrations as well as zooplankton abundance and biomass were estimated using data collected along standard oceanographic sections (Figure 5) during AZMP seasonal surveys since 1999. Integrated nitrate (50–150 m) and chl a (0–100 m) inventories were calculated from concentration measured in Niskin water samples collected at discrete depths, while copepod abundance and zooplankton biomass were estimated from depth-integrated (near-bottom to surface) vertical plankton tows performed with a conical ring net (200-µm). Spring bloom timing (i.e., the time when chl a concentration is at the maximum) was estimated using daily average near-surface chl a concentration derived from satellite observations of ocean colour by the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua sensor. Spring bloom timing was calculated for several subregions (Figure 5) using the R Shiny app PhytoFit (Clay et al. 2021). Standardized anomalies were calculated using the climatology of 1999–2020 for nutrients, chl. a, and zooplankton abundance and biomass, and 2003–20 for spring bloom timing. More details on AZMP and satellite-derived metric calculations can be found in Bélanger et al. (2024).

2.1.4. Ecosystem and Predation

Overview of the long-term trends in the fish community are provided based on biomass indices derived from the DFO multispecies survey in the NL region. This information alongside diet data from key predators are used to examine trends in shrimp as an important forage species across the region, and are combined to derive consumption estimates of the fish community, but also of key forage species such as shrimp.

Predator-prey theory suggests that a predator's consumption rate of a given prey species is a function of prey availability. A predator diet index is used to examine the levels of shrimp prior to

the ecosystem collapse, a period characterized by differences in survey protocols compared to current methods (*e.g.,* gear, timing) and the introduction of the present shrimp sampling approach. This index is derived using a model structure with a generic predator functional response formulation and was applied to Northern Shrimp during the 2024 PA Framework meeting, estimating Northern Shrimp biomass to 2019 (details available in Johnson et al. In press, Appendix I). Indices from Atlantic Cod and Greenland Halibut diets within NAFO divisions 2J3KL were predicted and compared to a biomass index derived using weighted averages of shrimp catch from the RV survey, which used a random stratified design.

An analysis contrasting shrimp availability to predation and catch impact is performed in the SSAR. Shrimp availability is estimated using pandalid shrimp biomass from the DFO multispecies survey plus the associated production that the estimated Northern Shrimp biomass is expected to generate, using a P/B ratio of 1.7 (Robertson 1979; Hopkins 1988). Predation is presented as the estimated fraction of consumption of shrimp by key predators. Nominal catch impact is the catch of shrimp in a given year plus the associated production that biomass is expected to generate, using the same ratio as above. This gives perspective on predation vs catch impacts but also shows how that relates to the amount of shrimp in the system. A shrimp predation mortality index is calculated by dividing the estimated total shrimp consumed by predators by the estimated shrimp availability and is used to inform on the predation pressure in the SSAR.

2.1.5. Predator Indices by Stock Assessment Region

Predator abundance influences mortality rates of Northern Shrimp throughout the study area (Pedersen et al. 2022; Baker et al. 2024c; Zabihi-Seissan et al. 2024). Greenland Halibut, Atlantic Cod, and redfish (*Sebastes spp.*) are particularly abundant throughout the stock assessment regions, have been documented feeding on Northern Shrimp in various studies, and have been identified as significant drivers of Northern Shrimp abundance (*e.g.*, Parsons (2005), Hedeholm et al. (2017), Fulton et al. (2024), Baker et al. (2025)). Therefore, basic spatiotemporal models were developed to estimate an annual biomass index for Atlantic Cod, Greenland Halibut, and redfish in both stock assessment regions. Data from NSRF-DFO (2005–24) and DFO fall multispecies surveys (1995–2024) were used in this analysis. More details on the method are available in Appendix 3 of Johnson et al. (In press).

2.2. DFO MULTISPECIES SURVEY

Shrimp abundance, biomass, maturity, and CL data have been collected since autumn 1995 in the SSAR and the southern portion of the NSAR, as part of the DFO multispecies surveys conducted using the Canadian Coast Guard Ship (*CCGS) Wilfred Templeman* (hereafter, *Templeman*), *CCGS Alfred Needler* (hereafter, *Needler*), *CCGS Teleost* (hereafter, *Teleost*), *CCGS Capt. Jacques Cartier* (hereafter, *Cartier*), and *CCGS John Cabot* (hereafter, *Cabot*). Set allocations vary by NAFO division (Figure 1) and are determined based on survey strata defined by depth range (Figure 6). Fishing sets of 15-minute duration and a towing speed of 3 knots were randomly allocated within depth strata, to depths of 1500 m. All vessels used a Campelen 1800 shrimp trawl with a 40-mm codend mesh size and a 12.7-mm liner. SCANMAR sensors estimated that the mean wingspread was 16.8 m (Orr and Sullivan 2013).

Though the timing of the survey, survey coverage (with the exception of specific years), and proportion of sets performed by different research vessels may change slightly from year to year, it is assumed that the effects are minimal. Survey coverage in NAFO divisions 2J3K has been extensive in areas where Northern Shrimp occur and reliable estimates of distribution, abundance, and biomass have been obtained for most years since 1995. In the southern portion of the NSAR, the coverage of the DFO multispecies survey was limited from 2000–04

(Figure 7). This was prior to the implementation of the NSRF survey in 2005, which subsequently provided enhanced coverage. Since 2010, NAFO divisions 2HJ3KLNO have been surveyed in their entirety in most years. In 2022, there was no stratified random DFO multispecies survey because a DFO Comparative Fishing (CF) program, to quantify differences in catchability between outgoing and new vessels, had been performed in the NL Region. However, during the December 2024 PA Framework meeting, it was decided to incorporate CF data from Fall 2022 into the spatiotemporal modeling of biomass indices. Additionally, the variable "vessel" might be included as a random effect if it improves the model. This decision was facilitated by the use of similar gear as in the previous year and the availability of catchability conversion factors.

During the survey, shrimp were subsampled after each tow and sorted to species, counted, and weighed. Maturity/sex (male, transitional, primiparous, multiparous, or ovigerous stages; Allen 1959; McCrary 1971), overall condition (*e.g.*, presence of parasites), shell condition, and CL were recorded (Orr and Sullivan 2013). Fish and invertebrates were also sorted to species-level when possible, then counted and weighed. Following the survey, all weights and numbers were standardized to a 0.8-nautical miles (NM) tow.

2.2.1. Implementation of Conversion Factors

The DFO CF program in 2022 provided the data necessary to make adjustments that account for differences in how the outgoing research vessels (*Teleost, Templeman,* and *Needler*) and the new Offshore Fishery Science Vessels (*Cabot* and *Cartier*) fish, ensuring the continuity of the existing survey time series (DFO 2024c). *Cabot/Cartier and Needler/Templeman* are sister ships and as such have a similar fishing performance.

Following the recommendations from the July 2023 Comparative Fishing CSAS peer review meeting (Wheeland et al. 2023; DFO 2024c), and the SFAs 4, 5, 6, and 3LNO Northern Shrimp peer-reviewed assessment meetings (FSAR 2024 and NAFO doc), conversion factors were applied to Northern Shrimp in NAFO divisions 2HJ3KLNO. These factors, both length-based and size-aggregated, calibrated DFO trawl survey catches for Northern Shrimp across the DFO multispecies survey area considered in the shrimp assessment (2HJ3KLNO) (Trueman et al. 2025). Differences in catchability between outgoing and new vessels were taken into account. Further details on the application of the conversion factors can be found in the related documents (DFO 2024a; Le Corre et al. 2026).

2.3. NORTHERN SHRIMP RESEARCH FOUNDATION SURVEY

The NSRF survey is a stratified random trawl survey conducted during the summer months, utilizing a commercial shrimp trawler with gear and survey protocols similar to those used in the DFO fall multispecies survey (McCallum and Walsh 2002). Since 2014, the NSRF survey is deemed to effectively cover the entire distribution range of Northern Shrimp in the WAZ , EAZ, and SFA 4 (Figure 1). Partial survey coverage was available in previous years for SFA 4 (2005–14) and the EAZ (2009–14), while the WAZ was surveyed starting in 2014 (Figure 7). Pre 2009 data in the EAZ are not considered compatible with the current time series Walkusz and Atchison 2020). Data based on this survey coverage have been shown to be sufficient for generating accurate survey indices from 2005–23, even in years when the EAZ or WAZ were not covered (Baker et al. 2024a; DFO 2024d; Fulton et al. 2024). In most years the survey occurred from July through August using the Ocean Choice International (OCI) vessel *Aqvik*. However, operational issues sometimes resulted in alternate OCI vessels being utilized or delays/breaks/extensions in survey timing. The effects of these adjustments have not been quantified. Sampling locations within each depth strata are allocated in accordance with Doubleday's (1981) method. The sampling locations were proportionally allocated to the size of

the stratum area, with a minimum of two sets per stratum, regardless of its size, until 2018. In 2018, the Hatton Basin Marine Refuge (MR) area was removed from the NSRF survey sampling area, resulting in the redefinition of several strata that overlapped the closure. Given that the assessment methodology utilized for SFA 4 does not require two sets per stratum, three small strata with minimal historical shrimp catches were allocated only one set per strata from 2018 to present in SFA 4. In the EAZ and WAZ, the sets from removed strata were reallocated to areas with historically higher variability in catch.

Vessels used to conduct the NSRF survey have varied since its inception in 2005. These included the F/V (Fishing Vessel) *Cape Ballard* (2005–11), F/V *Kinguk* (2014), F/V *Katsheshuk* II (2015, 2020, 2023, 2024), and F/V *Aqviq* (2012, 2013, 2016–19, 2021–22, 2023). The *Cape Ballard*, *Aqviq* and *Kinguk* had similar specifications, but the *Katsheshuk II* was a larger, more powerful vessel. The relative catchabilities for the four research vessels (*Cape Ballard*, *Aqviq*, *Kinguk*, and *Katsheshuk II*) that have been used throughout the time series in the NSAR are unknown. Considering the strong similarities in specification among three of these sampling platforms, it has been concluded that conversion factors are not required to continue with a comparable time series (S. Walsh, DFO Emeritus, pers. comm.). However, research has demonstrated that there are catchability effects resulting from vessel changes despite survey gear and protocols being equal (Benoit 2006; Perez-Rodriguez and Koen-Alonso 2010; Thorson and Ward 2014). Vessel effects were tested in spatiotemporal modelling of Pandalid shrimp density throughout the study area (Baker et al. 2024a, Johnson et al. In press), but efforts should continue to test the assumption of vessel comparability as additional years of data are accumulated. Frequent vessel changes are undesirable and lead to uncertainty in interpreting survey results due to the likely violation of an assumed constant annual survey catchability.

Similar to the DFO multispecies survey, the NSRF survey in SFA 4 used a standard Campelen 1800 shrimp trawl. In the EAZ and WAZ a modified Campelen 1800 shrimp trawl was used (Siferd and Legge 2014). Each tow aimed for 15 minutes of bottom contact traveling at a targeted speed of 3.0 knots. A trawl-mounted CTD instrument recorded bottom temperature, salinity, and depth values corresponding with each tow. Further details on the survey are available in Siferd (2015).

During the survey, shrimp were subsampled (n ≈ 300 individuals) during each tow and sorted to species, counted, and weighed. Maturity/sex (male, transitional, primiparous, multiparous, or ovigerous stages), overall condition (*e.g.*, presence of parasites), shell condition, and CL were recorded (Siferd 2015). Fish and invertebrates (i.e., bycatch) were sorted to species-level, then counted and weighed. Following the survey, all weights and numbers were standardized to a 0.8 nautical miles tow. More details on design and practices, trawl monitoring, environmental data sampling, shrimp catch processing, and additional field sampling during the NSRF survey are available in Fulton et al. (2024).

2.4. ASSESSMENT DATA ANALYSIS

2.4.1. Spatiotemporal Modeling for Northern Shrimp Density

To align with assessment best-practices (Punt 2023), spatiotemporal modeling is now used to estimate annual biomass indices of total (i.e., all shrimp), female, and fishable Northern Shrimp density ($kg.km^{-2}$) from the Fall survey data spanning 1995 (SSAR) or 1996 (NSAR) to 2024 (Johnson et al. In press, Appendix A).

Following adopted methods from the 2024 PA Framework meeting and in recognition of varying structure between stock assessment regions (Johnson et al. In press, Appendix A), models were developed separately for total, female, and fishable Northern Shrimp density in the NSAR

and SSAR. Spatiotemporal models were used to develop annual indices of abundance for total Northern Shrimp biomass in both stock assessment regions using the R package 'sdmTMB' (Anderson et al. 2024). Meshes with a minimum distance of 25 km (SSAR) and 20 km (NSAR) were created and models were built on data slightly beyond the boundary of the region. Based on various covariates and model components (see Johnson et al. In press for details), the best model for each stock assessment region was chosen based on ability to converge, diagnostic checks, lowest Akaike Information Criterion (AIC), and diagnostics (*e.g.*, residual patterns). Residual diagnostics were checked using Markov chain Monte Carlo sampling to estimate random effects and fixed effects at their maximum likelihood values.

A prediction surface based on the General Bathymetric Chart of the Oceans (GEBCO) depth layer (35 to 750 m depths) was developed using grid cells 27.339 km^2 restricted within each region (*i.e.*, this did not extend beyond the boundary of the stock assessment region). The best model for each stock assessment region was used to predict density across the prediction surfaces. Using the prediction surface, annual biomass indices were estimated from 1996–2024 for both regions. Note that spatiotemporal indices were also calculated for 1995 in the SSAR, but not used in SISCALS. Previous simulation analyses of NSRF data illustrated that similar spatiotemporal models could accurately predict density within years of missing survey coverage in WAZ (Baker et al. 2024a).

The annual fishable (FB, ≥ 17.5 mm CL), female, and total biomass spatiotemporal indices (and associated lower and upper confidence intervals) were presented in the March 2025 Northern Shrimp assessment meeting, as well as the yearly shrimp density distribution (*i.e.*, maps) of the FB indices. Changes (indicated by % change) from the previous year were also calculated and presented. Spatiotemporal index values from years with limited survey coverage in the NSAR (2000–04), which introduced considerable uncertainty, were deemed unsuitable for use in the assessment model and are therefore not included in this document.

2.4.2. Survey Length Frequency Distribution

Northern Shrimp length frequency was assessed for all survey sets (*i.e.*, unlike in Section 2.4.1, where experimental sets were included) conducted from 1995–2024 (DFO fall survey) and from 2005–24 (NSRF summer survey) within the two stock assessment regions. Oblique carapace lengths (to the nearest 0.1 mm) were recorded for the entire shrimp catch from each set or a subsample, with the number and weight per set estimated and standardized using the sampling data (Orr and Sullivan 2013; DFO 2024a; Le Corre et al. 2026). Following recommendations from the July 2023 CF CSAS peer review meeting (DFO 2024c), conversion factors (both length-based and size-aggregated) were applied to calibrate DFO trawl survey catches for Northern Shrimp across the DFO multi-species survey area, accounting for differences in catchability between DFO research vessels (Le Corre et al. 2026). This adjustment brought the data from the DFO fall survey into units equivalent to those of the new research vessels.

For each survey set, male and female shrimp counts (*i.e.*, including transitional, primiparous, ovigerous, and multiparous), standardized by survey set, were grouped into 0.5-mm CL bins, ranging from 0 to 40 mm CL (*i.e.*, 80 bins in total). Each year, regardless of survey spatial coverage, survey sets were separated by stock assessment region, and shrimp counts were summed by size bins for each sex. The proportion of male and female shrimp was then calculated by dividing the number of shrimp in each size bin by the estimated total number of shrimp caught for that year, standardized by survey sets, in the corresponding stock assessment region.

2.4.3. Mean Size of Shrimp

Subsample catches from both the NSRF and DFO surveys (including comparative fishing sets from the DFO survey in 2022), standardized to a 0.8-NM survey tow, provided length frequency data that were used to compute the annual average size of shrimp at various stages of maturity, spanning 1995–2024, across both assessment regions.

2.4.4. Size at 50% Female

The annual size at which 50% of shrimp in a population are transitional or female was estimated using data from both surveys and generalized additive models (GAM) with binomial distributions (Eq. 1) for each stock assessment region:

Eq. 1:

$$Y_i \sim binomial(1, p_i)$$

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

$$logit\ (p_i) = \beta_o + f_j(CL_i, by\ = Year_i) + f_j(North_i) + Year_i$$

where, Y_i represents transitioned (*i.e.*, transitional or female, 1) or not yet transitioned (*i.e.*, male, 0) for an individual of a given carapace length (mm) in a given year, β_0 is the intercept, and f_j is a unique smooth function of carapace length and UTM Northing (*North*) estimated using a thin-plate smoothing spline for each year ($Year_i$) (Baker et al. 2021). Each observation was weighted by the number of individuals in the set of that particular transitional-size category. The size at which 50% of shrimp are transitional or female was estimated for each year by determining the length at which the model fitted value was 0 (on the logit scale) at the mean Northing of each stock assessment region, which corresponds to 50% probability of shrimp being transitional or female (since $logit(0) = e^0/(1 + e^0)$ = 50% probability) (Pedersen et al. 2022). NSAR and SSAR were modelled separately.

2.4.5. Exploitation Rate

In the NSAR, the exploitation rate index (ERI) was determined by dividing the commercial catch (derived from the AQMS) from the fishing season by the spatiotemporal FB index (*i.e.*, from the survey data; pre-fishing season) from the current year (i.e., 2024/25 commercial catch is divided by the 2024 FB index). In the SSAR, due to the survey occurring in the fall (*i.e.*, post-fishing season), the ERI was calculated by dividing the commercial catch (derived from the AQMS) from the fishing season by the spatiotemporal FB index from the previous year (*i.e.*, 2024/25 commercial catch is divided by the 2023 FB index).

The ERI was expressed as a percentage of the spatiotemporal FB index and 95% confidence intervals corresponded to the FB confidence interval estimates. Because the fishing season for Northern Shrimp was still open at the time of the annual assessment, the reported ERI for the current year (*i.e.*, 2024/25) is considered preliminary and will be updated during the next assessment. Due to the timing of the NSRF survey in the summer and the schedule of fishery removals (April to October for the most part), it is not possible to calculate the potential ERI for the following year in advance within the NSAR.

The trawls used in the survey generally have a catchability coefficient that is not equal to one, making the biomass estimate an index of biomass rather than a precise measure. The total fishery-induced mortality, encompassing both landed catch and incidental trawling deaths, is unknown, resulting in exploitation rates being relative rather than absolute.

2.5. COMMERCIAL FISHERY DATA

2.5.1. Annual TACs and Catches

With the change from six SFAs to two stock assessment regions, SFA-specific TACs and reported catch, as defined and still used to manage the Northern Shrimp fisheries, were summed within each stock assessment region. This aggregation was done to support a clearer understanding of catch history at the stock assessment region scale. A portion of the SFA 5 TAC was attributed to either the NSAR or SSAR each year based on the proportion of catch in each stock assessment region within that year.

TACs and catches from 1977–2024/25 for the LV and SV fleets fishing Northern Shrimp were based upon the AQMS as of January 15, 2025 for EAZ and WAZ and February 4, 2025 for SFAs 4–7. Aggregated TACs and catches were calculated by summing the values from EAZ, WAZ, SFA 4, and the northern portion of SFA 5 for the NSAR, as well as from the southern portion of SFA 5, SFA 6, and SFA 7 for the SSAR. Quota transfers, bridging, and overruns were reflected in all catches. All 2024/25 catches were preliminary. At-sea observer and logbook data were incomplete for 2024, therefore, fishery results shown for 2023/24–2024/25 management years are preliminary. While the TACs in SFAs 4, 5, and 6 tend to be fully utilized, the TAC is generally not fully exploited in the EAZ and WAZ due to various fishing-related circumstances.

To divide catches reported in SFA 5 between the two regions, the north/south proportion of landings from observer (LVs: 1977–2024) or logbook (SVs: 1998–2024) data were used, assigning landings to NAFO division 2H (NSAR) or 2J (SSAR). During the 1977–97 period a single fleet was considered, largely dominated by LVs, and all available information from at-sea observers was considered for each year to split SFA 5 catch between the NSAR and SSAR. In contrast, from 1998–2024, the SV and LV fleets were analyzed separately, using annual fishing location data from logbooks for the SV fleet and from observer data for the LV fleet. When data were unavailable for a given year, average north/south proportions from specific historical periods (1977–84, 1985–89, 1990–94, and 1995–97) were used to allocate SFA 5 catches between the two stock assessment regions.

2.5.2. Quarterly Catches

Following the approach adopted at the Northern Shrimp PA Framework meeting in December 2024 (Appendix 8 in Johnson et al. In press), the seasonality of fishing was determined annually for each stock assessment region. This was done by multiplying the reported aggregated catches (Section 2.5.1) by the proportion of fishing activity occurring in the corresponding quarter of the year across the entire region, based on observer data for LVs (1977–2024) or logbook data for SVs (1998–2024). Due to the relatively low contribution of the SV in the overall fishing efforts (averaging 6.4% of total NSAR catches between 2014–23), data on SV and LV catches were combined; consequently, all catches in the NSAR were attributed to the LV fleet for analytical purposes in SISCALS.

Because the fishing season was still ongoing when AQMS data were extracted for the assessment, catch estimates for the final quarter of the most recent year (January – March 2025, corresponding to Q4 of the 2024/25 management year) were derived based on the remaining TAC in the management areas within each stock assessment region and historical seasonal fishing patterns observed over the last five complete management years (2019/20–2023/24: 65% of the TAC taken in the EAZ and 35 % in the WAZ). As of January 5, 2025, 65% of the 2024/25 TAC had been harvested in the EAZ and 35% in the WAZ. Given that these numbers align with the average TAC completion rates for the same zones over the previous five years, it was assumed that no additional Northern Shrimp would be harvested in

either the EAZ or WAZ during Q4 of 2024/25 (January-March), which corresponds to the ice covered, thus inaccessible, period of the year. In SFA 5, the TAC had already been fully harvested prior to Q4, leaving no remaining quota. For SFAs 4 and 6, the unharvested portion of the 2024/25 TAC was projected to be taken by the LV fleet, consistent with typical winter fishing patterns historically observed in these areas.

2.5.3. Catch Per Unit Effort

Catch per unit effort (CPUE) is a measure of fishery performance for the Northern Shrimp fisheries in the NSAR and SSAR. Temporal trends of CPUE (kg/hour) can be derived from numerous sources, including those that are directly related to shrimp availability and those that influence shrimp catchability. Therefore, CPUE should be standardized as much as possible to ensure drivers of catchability are accounted for in CPUE modelling, thereby helping CPUE reflect trends in the relative abundance of fishable shrimp and minimal bias from changes in fishing practices. As introduced at the December 2024 PA Framework meeting, spatiotemporal models were employed to compute standardized CPUE indices for the Northern Shrimp LV fleet in both regions (separately), using the observer database (Appendix 4 in Johnson et al. n press). A generalized linear modeling approach was utilized on the logbook dataset to calculate the SV fleet's standardized CPUE index in the SSAR. The CPUE of the SV fleet could not be calculated in the NSAR due to the scarcity of data and the applicability of the “rule of five[1]”.

2.5.3.1. Standardized Large Vessel CPUE indices

The spatiotemporal modeling approach to estimate the LV fleet CPUE used a mesh with a minimum distance edge of 25 km throughout each stock assessment region and multiple covariates and model components were considered during model formulation (i.e., month (cyclic), foot length, speed, depth, gear type, year, vessel, and hour (cyclic) or zenith angle). The best model was chosen based on ability to converge, diagnostic checks, lowest AIC, and diagnostics (e.g., residual patterns). A prediction surface based on a GEBCO depth layer (35 to 750 m depths) was developed using grid cells 46 km^2 within each stock assessment region to standardize CPUE by space. Only grid cells where fishing had occurred in more than 2 years were used. The mean CPUE for each year was identified (see Appendix 4 in Johnson et al. In press, for further information).

2.5.3.2. Standardized Small Vessel CPUE index

The NL Northern Shrimp logbook database (1998–2024) was utilized to calculate the CPUE for the Northern Shrimp SV fleet (< 100 ft long) in the SSAR because every Canadian vessel targeting Northern Shrimp fills out logbooks and reports catch size and location, while at-sea observer coverage in the SV shrimp fishery can be as low as 3% (as opposed to 100% in the LV fleet). Raw CPUE data were standardized using multiple regression and weighted by effort to account for yearly, monthly, statistical area, and vessel variations. The annual CPUE was standardized to July (the month with the most fishing activity), the largest fishing area (statistical area 69), and the vessel with the longest fishing history. To focus on experienced fishers, only data from vessels with more than a year of shrimp fishing experience were included in the standard dataset. The analyses were conducted using the generalized linear model (GLM)

[1] To protect the privacy and confidentiality of fisheries data, DFO applies a 'rule of five' policy, whereby data are not released if there are fewer than five units of personally identifying variables (such as fishers, vendors, buyers, licenses, or vessels) in a given dataset.

procedure of the SAS software (SAS 9.4). Commercial CPUE models for Northern Shrimp are detailed in Orr and Sullivan (2013).

2.5.4. Length Frequencies From At-Sea Observer Program

At-sea observers onboard vessels targeting Northern Shrimp in Atlantic and Arctic Canada waters measured randomly collected detailed samples of Northern Shrimp, which consisted of 250–300 individuals and included information on maturity (male, primiparous female, multiparous females, and ovigerous females), CL (to the closest 0.5 mm), and pathogens (e.g., parasites). These sexed length frequency data (1990–2024) from the at-sea observer program were categorized by sex, vessel fleet (LV and SV), and stock assessment region to provide annual estimates of size frequencies of commercially caught males and females in NSAR and SSAR, as well as the annual mean CL of Northern Shrimp caught by the different fleets.

2.6. STOCK ASSESSMENT MODEL

The model-based SISCALS stock assessment framework for Northern Shrimp was accepted during a CSAS multi-regional PA Framework review meeting in December, 2024. The SISCALS framework is a Bayesian size-structured stock assessment framework that is fit to fishery and biomass indices from spatiotemporal modeling, size composition data, and fishery catch to estimate Northern Shrimp recruitment, biomass, time-varying natural mortality rates, exploitation rates, biological reference points, and stock status with respect to reference points for the NSAR and SSAR.

The SISCALS model comprises two main components. First, the core biological processes are represented by a size-/sex-structured population dynamics model that describes changes in Northern Shrimp abundance and size-composition in response to fishing mortality from SV and LV fleets, recruitment, and length-based natural mortality that varies over time with ecosystem regimes. SISCALS models these processes on a seasonal (quarterly) time step within a joint 2-area size-/sex-structured model with biological linkage between the two stock assessment regions (*i.e.*, representing larval dispersal). The second component of SISCALS is a likelihood-based statistical model that relates observed data to corresponding expected values derived from the population dynamics model. More specifically, SISCALS incorporates the spatiotemporal total biomass indices, LV and SV standardized CPUE indices, size composition of male and female Northern Shrimp from both the survey and fishery datasets, and fishery catch statistics in the NSAR and SSAR from 1996–2024 (Figure 8).

Estimation of leading model parameters is accomplished by fitting SISCALS to data and using Hamiltonian Monte Carlo (HMC) sampling techniques to approximate the associated joint Bayes posterior probability density function. The posterior combines data likelihoods with prior distributions representing prior belief for the values of certain model parameters. The resulting approximations are then used to estimate posterior probability distributions for model quantities of interest, including historical biomass, exploitation rates, natural mortality rates, recruitment, several key biological parameters, and reference points. More details on the structure of SISCALS and estimation of model parameters are available in Johnson et al. (in press).

During the PA Framework meeting, the effect of groundfish predation on natural mortality rates of Northern Shrimp in both regions was discussed. For the SSAR, it is widely accepted that changes in Northern Shrimp natural mortality and biomass are related to groundfish predation; however, the impact of predation on the Northern Shrimp NSAR is uncertain. In SISCALS, the effects of predation are currently implicitly depicted in the model through time-varying natural mortality.

Northern Shrimp reference points in the PA Framework were developed using SISCALS, and reflect estimated natural mortality and size at sex-transition from the most recent 8 years (amounting to approximately one Northern Shrimp generation) (Johnson et al. In press). The reference points were derived from the B_{MSY}-proxy for each stock assessment region, separately:

- B_{MSY}-proxy values were defined for each stock assessment region as 40% of unfished biomass (*i.e.*, B_{MSY}-proxy = 0.40 x B_0).
- The limit reference point (LRP) was defined as 50% of the B_{MSY}-proxy for each stock assessment region.
- The upper stock reference point (USR) was proposed at 80% of the B_{MSY}-proxy for each stock assessment region.

Following recommendations from the December 2024 meeting and further data quality checks, some adjustments were made to the data incorporated in SISCALS and several components of the model. These changes are as follows:

2.6.1. Changes to Fisheries Data in SISCALS

Small-vessel catch was incorporated into the LV catch in the NSAR (*i.e.*, one single fleet remains in the NSAR). Given the limited information available on the SV fleet in the NSAR, and considering that this fleet primarily operates in the same fishing area as the LVs (mostly in the southern part of the NSAR), the catch from the SVs was classified as part of the LV fleet.

Some commercial fishing trips/sets were excluded from the LV length distribution dataset (which is based on observer data) due to a misidentification of vessel size. Some vessels were previously incorrectly classified as LVs when they should have been identified as SVs. This has resulted in a minor discrepancy in the number of trips/sets included in the LV and SV fleets' quarterly length frequency datasets, when compared to the data presented at the PA Framework meeting.

The catch data in the Arctic region (*i.e.*, WAZ and EAZ) has been refined with more accurate catch values from the 1990s, which were not available at the PA Framework meeting. This primarily resulted in slightly larger catch values in the NSAR at the end of the 1990s.

The catch data in NAFO divisions 3LNO has been refined with more accurate LV catch values over the time series, which were not available at the PA Framework meeting. This primarily resulted in larger catch values in the SSAR at the end of the 1990's and 2000's.

Catches from the LV fleet in the final quarter of the time series (*i.e.*, January – March 2025) in both the NSAR and SSAR were estimated based on the average proportion of the TAC caught during that quarter over the past five management years (see section 2.5.2).

2.6.2. Changes to Survey Data Inputs in SISCALS

To address catchability-related research recommendations identified during the PA Framework meeting, survey years with notably low coverage (2000–04) were excluded from the spatiotemporal total biomass indices in the NSAR. To maintain data consistency and avoid the use of potentially unrepresentative length frequency data, the corresponding survey length frequencies for these years were also removed from the time series in SISCALS.

Additionally, the length frequency data were subsampled to include only survey sets conducted at depths between 0 and 750 meters, ensuring consistency with the depth range used in the spatiotemporal total biomass indices (Johnson et al. In press).

These adjustments affected the catchability parameter in SISCALS (*i.e.*, q = 1); however, the impact on stock status was minimal, as it is primarily informed by absolute values from SISCALS that reflect estimated natural mortality and size at sex transition based on data from the most recent eight years.

2.6.3. Other Changes Incorporated in SISCALS

2.6.3.1. Dispersal Matrix

As recommended at the PA Framework meeting, the dispersal matrix in SISCALS was updated to consider the southern portion of the SSAR (NAFO divisions 3NO) as a potential settlement area within the biophysical larval modeling framework. The version of SISCALS reviewed at the PA Framework meeting incorporated a dispersal matrix based on a potential settlement area covering only NAFO divisions 2J3KL. The impact of this update on the model outcomes was minimal, as SISCALS uses recruitment process errors, independent among the stock assessment regions, to adjust and fit the data.

2.6.3.2. Recruitment in Recent Years

A recommendation of the 2024 PA Framework meeting was to replace the final 5 years of SISCALS recruitment estimates with simulated recruitments to reflect considerable uncertainty for that period. For this assessment, we simulated recruitments for the 2020–24 period. For each draw, a deterministic Beverton-Holt (BH) stock-recruitment relationship was estimated based on 2009–18 spawning biomass and 2010–19 recruitment estimates (i.e., a recent 10 year reference window of stock and recruitment). Parameters estimated for each recruitment simulation are unfished biomass (B_0) and stock-recruit steepness (h), and the stock-recruitment model assumes that sex-transition and natural mortality rates are the average of the last 8 estimated years (2016–23) based on the 2024 PA Framework review. All other model parameters remained consistent with those used in the assessment.

When simulating 2020–24 recruitments, expected (deterministic) recruitments from the BH model were deviated by post-dispersal recruitment process errors with similar spatial and temporal correlation to the reference window. Finally, based on reviewer suggestions at the 2024 PA Framework review, the recruitments that enter the populations were 2-year moving averages of the deviated BH recruitment, intended to make the simulated recruitments look more like SISCALS estimates. Historical estimates are subject to a smearing effect, where cohorts are spread over recruitment years given the difficulty of estimating year class strength from uncertain length data. The simulated recruitments then worked their way through the population in each SAR, affecting all model states (e.g., spawning biomass, fishable biomass, etc.) and stock status with respect to the reference points.

2.6.3.3. Short-term Projections

Constant catch short-term projections have been incorporated into SISCALS since the PA Framework meeting. The projection period spans from five years after the current assessment year (i.e., 2025–29 for this assessment). However, only the three-year period from 2025–27 was considered for providing scientific advice during the March 2025 assessment. Recruitment projections were generated from the same BH stock-recruitment relationship used to simulate recruitments for the 2020–24 period.

Using this recruitment projection method, expected SSB values (medians over the posterior distributions) under a range of constant catch scenarios in both the NSAR and SSAR were evaluated against reference points. Each posterior draw was assessed individually to determine the probability of the stock being above or below the limit reference points. For the current assessment, projections were run in both the NSAR and SSAR over 2025–27 under five

constant aggregated catch scenarios derived from an ERI applied to the 2024 FB spatiotemporal index:

- Current ERI: ERI based on the most recent aggregated TAC.
- 0% ERI: represents a zero catch scenario.
- 10% ERI: corresponds to the lower limit of the current Harvest Decision Rule (HDR).
- 20% ERI: based on the upper target of the HDR.
- 30% ERI: based on the maximum allowable ERI from the HDR.

2.6.3.4. Differences Between SISCALS and Spatiotemporal Indices Estimates

Throughout this document, all quantities derived from the survey spatiotemporal model are referred to as indices. Fishable and spawning stock biomass values from SISCALS differ from their corresponding survey indices due in part to survey catchability, selectivity, and the inclusion of observational error in SISCALS. For example, in the NSAR, where survey catchability is estimated to be 1, average fishable and spawning biomass values from SISCALS are approximately comparable to the average survey indices. In contrast, in the SSAR, where survey catchability is approximately 0.67, SISCALS estimates of fishable and spawning biomass are higher than their respective survey indices.

Additionally, minor discrepancies between the SISCALS and spatiotemporal models were noted during the March 2025 assessment. One notable difference was the threshold size used to define fishable biomass: the spatiotemporal index applied a threshold of ≥17.5 mm based on previous assessments, whereas SISCALS used a slightly lower threshold of ≥16.5 mm based on catchability.

3. RESULTS AND DISCUSSION

3.1. SURVEY SUMMARY

In 2024, the NSRF survey was conducted aboard the F/V *Katsheshuk II* and collected data from 327 survey sets in the northern portion of the NSAR (*i.e.*, SFA4/EAZ/WAZ), all in the 0–750 m depth range, corresponding to 100% of planned sets being surveyed (Figure 6, Table 1). Sampling occurred between July 16 and August 28, 2024. The relative catchabilities for the four research vessels (*Cape Ballard, Aqviq, Kinguk,* and *Katsheshuk II*) that have been used throughout the time series in NSAR have not been empirically tested through direct study, and thus the relative catchability among the vessels remains unknown.

In 2024, the DFO fall multispecies survey was conducted in the southern portion of the NSAR aboard the *CCGS Cartier* and in the SSAR aboard *CCGS Cartier* and *CCGS Cabot.* Due to unforeseen circumstances (*i.e.*, bad weather and technical issues with the vessel), only 23 sets were surveyed in the NSAR (*i.e.*, NAFO division 2H) between October 10 to 27, 2024, representing 34% of all planned sets. Despite most strata being surveyed only once, the spatial coverage was not significantly impacted. As a result, the uncertainties surrounding the biomass indices, calculated using spatiotemporal modeling, remain comparable to those of previous years. In the SSAR, a total of 365 survey sets were collected, all in the 0–750 m depth range (Figure 6, Table 2), corresponding to most planned sets being surveyed in this depth range. Sampling in the SSAR occurred between October 27 and December 15, 2024.

3.2. ECOSYSTEM AND ENVIRONMENT

3.2.1. Oceanography and Climate Index

The NL ocean climate varies between cold and warm phases on near-decadal time scales with known impacts on ecosystem productivity (Cyr et al. 2024a). The NL ecosystem collapsed in the late 1980s and early 1990s during an extreme cold phase and extensive overfishing. The NL bioregion also experienced a cooler climate in the mid-2010s (~2014–17), followed by a warming phase that has been ongoing since about 2018 (including the warmest year on record in 2021). These changes in climate regimes prevailing since the early 1950s are well captured by the NLCI (Figure 9). In 2024, the NLCI was high at +1.1 (the 4th warmest year on record). All NLCI components for 2024, excluding winter North Atlantic Oscillation, showed warm anomalies including record high sea surface temperatures.

The environmental conditions at the seafloor in the assessment regions are partly driven by the mean climate conditions, especially in the winter, and partly by the associated changes in the large-scale ocean circulation that accompany the changing climate (Figure 10 and Figure 11). Three main water sources converge in northern Labrador shelf and continue south towards the SSAR. The Baffin Island Current, which carries Arctic-origin waters outflowing from the Davis Strait, eventually merges with the outflow from the Hudson Strait to form the Coastal Labrador Current. This current carries frigid and relatively fresh waters southward along the coast of Labrador. Farther offshore at the shelf break, the Labrador Current, which carries sub-polar North Atlantic waters originating from the West Greenland Current, flows southward after bifurcating to the west and eventually to the south at the northern end of the Labrador Sea.

The coastal Labrador Current and the offshore (main) branch of the Labrador Current create an offshore-onshore gradient in bottom temperature along the Newfoundland and Labrador shelves, with temperature ranging from 3 to 4°C along the shelf break to near freezing (<-1°C) close to the coast of Labrador (Figure 10 and Figure 11). This temperature gradient is also accompanied by salinity changes, with fresher water along the coast and the more saline waters offshore along the shelf break and in the deeper channels (not shown, see Cyr et al. 2024c for details). In the Hatton Basin, a deeper trough bounding the northern part of NAFO division 2G, bottom temperatures are generally characterized by warmer (temperature >4°C) and saltier (salinity >34.5) sub-polar waters.

Despite the relatively short time series available (since after 2006 for a large portion of NSAR), it is possible to identify near decadal fluctuations in some parts of the region. For example, the year 2011, and also 2010 for SSAR, stand as the warmest years of the time series for all areas. After a cooler period between about 2012 and 2017 that also characterized all areas, a warming phase was observed between about 2018–21. In the last three years, conditions have been slightly cold or normal, except for the Labrador shelf, which was slightly warm in Northern Labrador in 2024 and in central Labrador in 2023. Ocean bottom temperatures were close-to-normal to slightly warm for the remainder of the NSAR. Although surface temperature is generally correlated with bottom temperature, the assessment highlighted that additional information on the spatiotemporal variation of annual sea surface temperature (SST) could offer valuable insights—particularly given the life history of Northern Shrimp, such as their larval phase occurring in the upper water column.

3.2.2. Nutrients and Plankton Community

The increase in nutrient inventories that occurred in the mid-2010s had a positive impact on total zooplankton biomass and chl*a* concentrations, a proxy of net primary production (Figure 12). The ongoing warm phase also likely contributed to the improved conditions

observed at the lower trophic levels since 2020. These include a shift toward an earlier timing of the spring phytoplankton bloom (Figure 13) associated with an increase in the abundance of large, energy-rich *Calanus finmarchicus* copepods (Cyr et al. 2023), a key food item for fish (Figure 14).

3.2.3. Ecosystem and Predation

The NL bioregion underwent a regime shift in the early-1990s involving the collapse of the groundfish community and increases in shellfish productivity. During this time, the increases in biomass of the shellfish did not compensate for the declines in groundfish, indicating a reduction in the overall ecosystem productivity. Since this shift, the NL ecosystems continue to experience overall low productivity conditions, likely driven by bottom-up processes (*e.g.,* food limitation) with total biomass remaining well below pre-collapse levels. Since this shift the total biomass increased slightly in the early 2010's and saw declines in the late 2010s. Ecosystem trends in recent years (*e.g.*, biomass trends and stomach content weights) indicate improvements from the lows in the late-2010s,with and reaching levels around the post-collapse highs in 2024. These recent increases have been driven by groundfish. Both NAFO divisions 2H and 2J3KL have returned to a groundfish dominated community structure, from the shellfish dominated one that characterized these areas in the years after the ecosystem collapse. This transition started in the south and occurred a few years later in the north of the NL bioregion.

Estimates of shrimp biomass based on predators stomach contents data suggest that the levels of shrimp in 2J3KL are at similar levels to those observed prior to the groundfish collapse before 1990's in recent years (Figure 15).

Pandalid Shrimp (*i.e.*, Northern Shrimp for the vast majority of the SSAR) are an important forage species throughout the region appearing in diet analysis of key predators such as Atlantic Cod, Greenland Halibut, American Plaice and redfish. Shrimp are most dominant in the diets in the northern areas of SSAR of the NL region but its dominance has decreased in recent years. Accounting for the amount of shrimp available in the system and the estimated consumption by the fish predators in the system, the predation mortality index on shrimp remains at a high level in NAFO divisions 2J3KL even with the reduction in proportion of shrimp in the diets. The predation mortality index is four times lower in 2H (Figure 16).

When contrasting the shrimp availability to predation and catch impacts across the NL region, both fishing and predation have been shown to be potential drivers of the stock in NAFO division 2H, while predation has been the stronger potential stock driver in NAFO divisions 2J3KL (Figure 17). Periods where shrimp availability is much larger than predation and potential catch impacts indicate a potentially large scope for growth in the shrimp stock (*i.e.*, potentially large shrimp surplus production), while periods where shrimp availability is of similar magnitude of predation and potential catch impacts indicate little scope for growth of the shrimp stock. In the most recent period, there is more scope for growth in the north than in the south.

The trend in shrimp per capita net production in NAFO divisions 2J3KL is likely associated with impacts from predation, fishing, and ocean climate. Since the late-2010s, per capita net production has been relatively stable at low levels, and no major changes would be expected within the next 1–3 years based on these associations.

3.2.4. Potential Predators Indices

In the NSAR, Atlantic Cod had low biomass throughout the late 1990s and 2000s (see 3.2.3); however, in more recent years Atlantic Cod biomass has been increasing, reaching its peak in the time series in 2023 and showing its second highest value in the time series in 2024 (Figure 18). In the SSAR, Atlantic Cod biomass peaked in the early to mid-1980s, drastically

declined in the late-1980s and early 1990's, where the biomass remained low until gradually increasing from 2010–15; it has maintained a similar level since then (Figure 18).

In the NSAR, redfish had high, but declining biomass throughout the late 1970s and early 1980s (not shown). Between 1986–2006, biomass levels remained low. Since 2021, redfish biomass levels have been at (or near) time series highs (Figure 18). The emergence of such a large biomass of juvenile redfish over the last three years has been identified as a potential driver that may have indirect (competition) and/or direct (future predation) impacts on the shrimp population (Baker et al. 2024c; DFO, unpublished data). The magnitude and duration of these impacts are currently not fully understood, but it seems justifiable to assume that juvenile redfish resurgence, indirectly, will have a major impact on the ecosystem, including potential productivity of the shrimp population. In the SSAR, redfish biomass was high until 1984 (not shown), fell to low levels between 1986–2005, and has fluctuated at relatively high levels since 2007 (Figure 18).

Greenland Halibut was identified as a potential driver of Northern Shrimp abundance throughout the study area, but its effect size varies with space (Baker et al. 2024c). In the NSAR, Greenland Halibut had high, but declining biomass throughout the 1980s (not shown). Since 1996, the biomass has remained at a low and steady level with signs of increasing trends over the 2019–22 period, but has declined since then (Figure 18). In the SSAR, Greenland Halibut biomass index peaked in the early to late-1970s and early 1980s, then drastically declined in the late-1980s to a time series low in 1992 (not shown). Since 1996, the biomass has regularly fluctuated near a time series average (Figure 18).

3.2.5. Uncertainties

Sources of uncertainty were acknowledged and discussed during the Northern Shrimp assessment meeting, underscoring the need for enhanced data collection and integration to support more robust and adaptive assessment and management strategies. The NSAR currently lacks critical ecosystem and environmental data, including predation mortality indices, comprehensive physical oceanographic information, and pelagic production metrics. These data gaps hinder the ability to incorporate environmental and ecological drivers into the assessment and limit progress toward implementing an ecosystem-based approach to fisheries management.

To address these limitations, additional research on the relationships between shrimp population dynamics and key environmental and ecological factors, such as sea ice cover, ocean currents, predation, and larval transport, could help improve understanding of population responses to changing conditions and support more informed, ecosystem-based decision-making, particularly in the NSAR.

3.3. NORTHERN SHRIMP (*PANDALUS BOREALIS)* IN THE NORTH STOCK ASSESSMENT REGION

3.3.1. Biomass

In the NSAR, Northern Shrimp biomass indices (*i.e.*, total, spawning stock, and fishable) derived from the spatiotemporal modeling of survey data have varied, predominately without trend, throughout the time series. In recent years, these indices hit a time series low in 2019, then displayed an upward trend until 2023. However, they experienced a decline in 2024 compared to 2023 (Figure 19, Figure 20, Figure 21, Table 1, Table 3).

The spatiotemporal models for the three biomass indices in the NSAR had a similar structure. Each used a delta-gamma family and included anisotropy (estimated separately for each model

component), scaled depth and year (as a factor) as covariates, and spatial, spatiotemporal ("iid"), and spatially varying coefficients for scaled depth as random fields.

The total biomass spatiotemporal index in 2024 (199,400 t) declined (-19.3%) relative to the 2023 value and remained below the long-term mean (1996–2023; 279,300 t) (Figure 19, Table 1). The female SSB spatiotemporal index in 2024 (142,200 t;) decreased (-8.9%) relative to the 2023 value and was slightly above the long-term mean (1996–99 & 2005–2023; 134,100 t) (Figure 20, Table 1). The FB spatiotemporal index in 2024 (185,200 t) declined (-19.7%) relative to the 2023 value and remained below the long-term mean (1996–99 & 2005–23; 238,200 t) (Figure 21, Table 3). Most of the decline in total and fishable biomass spatiotemporal indices resulted from a decrease in the biomass of males over 17.5 mm. Similar to most previous years, in 2024, the highest concentrations of Northern Shrimp survey catch and derived predicted density (*e.g.*, FB from spatiotemporal modeling) in the NSAR were found in a relatively continuous band within 201–400 m strata (Figure 6, Figure 22).

In the NSAR, the size distribution of females showed a higher proportion of small females in 2024 compared to previous years, and males showed a lower proportion (Figure 23). The proportion of males relative to females has declined since the beginning of the survey time series, reaching its lowest recorded level in 2023 (Figure 24). The mean CL of all Northern Shrimp maturity stages (females, fishable, total, males, and pre-fishable) decreased since 2023 (Figure 25). Mean size of total and fishable shrimp remained above the long-term means, and mean female and male carapace length declined steeply in 2024 compared to 2023 to some of the lowest values in the time-series (Figure 25, Table 4). Similarly, in 2024, the length at 50% transitional and female declined to below the previous time-series low. Northern Shrimp size at 50% transition to female was above the long-term mean (22.4 mm) since 2019, but decreased considerably from 22.8 mm in 2023 to 19.1 mm in 2024, the lowest value in the time series (Figure 26). Size at transition is an important component of productivity; smaller females typically have fewer eggs and a long-term change could have negative impacts on stock productivity.

3.3.2. Fishery

Over the 1977–2023/24 period, Northern Shrimp aggregated TAC in the NSAR has changed from a minimum of 2,125 t (1986) to a maximum of 50,000 t in 2016/2017 (Figure 4, Table 5). Aggregated TAC decreased from 39,472 t in 2023/24 (87% taken) to 39,232 t in 2024/25. Commercial aggregated catch typically follows the same pattern as the TAC with >85% of the aggregated TAC taken. Total aggregated catch in 2024/25 was 29,141 t, 74% of the 39,232 t aggregated TAC (preliminary AQMS data) (Figure 4, Table 5). Commercial catch data from 2024/25 were considered preliminary. Following the recalculation of the SFA 5 North and South proportions after the assessment meeting, please note that minor discrepancies may exist between the aggregated TAC and catch values for each stock assessment region and those reported in the Fisheries Science Advice Report (DFO 2025).

Within the NSAR, the LV fleet has accounted for the majority of the catch over the time series; fishing mostly occurred during the period from April to December, corresponding to Q2–Q4 of the calendar year (Figure 27). Catch from the SV fleet, which primarily fish over the third quarter (Q3) of the calendar year, peaked around 2016–19 but at a much lower level than the LV fleet (Figure 27).

In the NSAR, the best spatiotemporal model predicting CPUE was from the Tweedie family (*link = log*) and included anisotropy (varied by model component), multiple covariates (month, zenith angle, speed, foot length, depth, gear type, year, and vessel), and spatial and spatiotemporal (*iid*) random fields. In the NSAR, the standardized LV CPUE remained low until the early 1990s

(Table 6, Figure 28). From 1996–2016, the standardized CPUE fluctuated at a relatively high level without trend. A significant decline in the standardized CPUE was observed between 2016–21, although the values are still considerably higher than those in the 1980s and early 1990s. The time series of annual standardized LV CPUE estimates is characterized by a high degree of uncertainty. Factors such as ice cover, bycatch, and market conditions can influence commercial effort, while changes in fishing practices can unpredictably bias CPUE estimates.

Several factors, including changes in management measures (*i.e.*, different allocation tables) and species composition of catches (*i.e.*, catches of both Northern and Striped Shrimp (*Pandalus montagui*) in the same area such that less Northern Shrimp catch might be recorded for equivalent effort), makes the interpretation of LV fishery performance more complex in this area.

The areas within the NSAR that support Northern Shrimp fishing have remained relatively stable in recent years (Figure 2, Figure 3), and mainly correspond to regions consistently showing the highest predicted CPUE values over years (Figure 29). These areas visually align with locations where high shrimp concentrations were typically observed during the NSRF and DFO surveys (Figure 6). The LV fleet predominantly operates in depths of 200–400 m, extending up to approximately 750 m.

In 2024, observer length frequency data indicated a higher proportion of smaller females compared to previous years, as well as an overall increased proportion of males (Figure 30). The mean CL of Northern Shrimp caught by LVs in the NSAR has continued its decreasing trend that initiated in 2021 (Figure 31). This recent trend aligns with the observations of mean size and size at 50% transitional and female, as derived from the size distribution in the survey data. While this assessment summarizes the length composition of harvested Northern Shrimp over the entire management year, a seasonal pattern may also be present (e.g., smaller shrimp in the summer and larger shrimp in the fall). However, further research is needed to better understand and confirm the extent and drivers of this potential seasonal trend.

3.3.3. Exploitation Rate Index

The ERI fluctuated between 7.2% and 27.3% from 1996–2024/25 (Figure 32, Table 3). Based on the preliminary data retrieved from the AQMS in early-2025, the reported ERI for 2024/25 was 15.7% with 74% of the aggregated TAC taken. If the entire 2024/25 aggregated TAC were to be taken, the ERI would be 21.2%. The ERI experienced an increase from 2004 to its highest values in the period from 2017/18–2019/20, coinciding with a period of low fishable biomass indices. Following this period of higher ERI, both the catch and FB index began to decline, resulting in the ERI being slightly above the long-term average in recent years.

In 2025, a new series of ERI values was introduced, based on the two stock assessment regions and the newly adopted FB indices resulting from spatiotemporal modeling. Consequently, these newly presented numbers are not directly comparable to the previous values, which were derived from a different modeling method (Ogmap or STRAP) and at a different spatial scale (SFAs).

For all the ERI calculations, including in the SSAR (see section 3.4.3 below), both the numerator (catch) and denominator (FB) were uncertain. The true catchability of trawls remains unknown. As a result, the survey likely underestimates biomass by an unknown and potentially variable percentage each year. Although commercial catch is assumed to be known without error, the allocation of the SFA 5 catch and TAC to each stock assessment region, based on observer and logbook data, introduces additional uncertainty into the estimated ERI. These estimates are subject to revision as more data become available. Furthermore, total fishery-induced mortality

(i.e., landed catch plus incidental mortality from trawling) is also uncertain. Consequently, the ERI is likely underestimated by an unknown margin.

3.3.4. Stock Assessment Model (SISCALS)

3.3.4.1. Model Diagnostics

Observation model residual standard errors (SEs) are good indicators of the quality of SISCALS model fits errors, with smaller values indicating a better fit to the data (Figure 33, Table 7). For example, for the NSAR the survey has a residual standard error of 0.209 (τ_{Surv}^{idx}), which can be interpreted as approximately a 21% coefficient of variation (CV). In this assessment, the model fits with the additional year of data and further slight modification to the input data in SISCALS reflect a similar or better fit when compared to the December PA Framework meeting accepted model outputs for both the indices and length distribution data (e.g., τ_{Surv}^{idx} for the North was 0.28; Johnson et al. In press). Notably, due to the removal of data with poor survey coverage in the early 2000's, the NSAR survey catchability $q_{\text{North,Surv}}$ now equals 1 (Figure 33).

Similarly to the results presented at the PA Framework meeting, standard errors are in the poor range (i.e., > 0.4) for the LV CPUE index in the NSAR (τ_{LV}^{idx}, Table 7). Visually, however, the model residuals appear to indicate a better fit than indicated by the standard error value. Specifically, all residuals are at most 0.5 standard errors in magnitude (Figure 33). Smaller residuals are enabled by the time-varying catchability for the LV fleet and suggest that the effective residual standard error (i.e., the root mean squared error of the residuals) is smaller than the estimated standard error.

Standard Bayesian posterior chain diagnostics suggest that chains converged (Figure 34) with most leading parameters having potential scale reduction factor $\hat{R}$ values less than 1.01 (i.e., that posterior standard deviations within each chain are within 1% of each other across chains), and effective sample sizes greater than 100 per chain.

3.3.4.2. Recruitment

NSAR recruitment has been oscillating around the long-term mean but has mostly been below the mean since 2010. It remained below the mean in the last three non-simulated data points (i.e., 2017–19) (Figure 35). Recruitment estimates for the final five years of the model and the projection period are highly uncertain, as few young individuals have been observed in either the fishery or the survey. Consequently, these years were populated with estimated values. Although these estimates are informed by recent recruitment trends, they may either overestimate or underestimate actual recruitment. It remains unclear whether the observed conditions accurately reflect current or future dynamics. Similar uncertainties are present in the SSAR stock as well.

3.3.4.3. Mortality

In the NSAR, natural mortality has been oscillating without a clear trend over the time series (Figure 35). It increased steadily from 2017–22 but has shown a declining pattern since then. Although natural mortality in the model is length-based, meaning larger shrimp are less susceptible, and varies annually to reflect ecosystem changes, the same temporal trend is applied across all length bins in SISCALS. As a result, potential size-specific annual variations in natural mortality are not captured. This represents a noteworthy consideration, particularly in light of a recent preliminary study that highlight body size as an important factor in predator-prey dynamics (DFO, unpublished data; Fulton et al. 2024), especially when new predator cohorts are introduced into the system (e.g., redfish, see section 3.2.4).

3.3.4.4. Precautionary Approach Framework

In 2024, the SSB derived from SISCALS was 177,800 t (Figure 35, Figure 36, Table 8, Table 9), representing an increase (+56%) relative to 2023 (114,200 t), however it remains below the long-term mean (1996–2023; 207,900 t).

The 2024 Northern Shrimp SSB is above the LRP with a greater than 99% probability and above the proposed USR with a greater than 99% probability, which, if the proposed USR were adopted, would place the stock in the Healthy Zone of the PA Framework (Figure 35, Figure 36, Table 8).

3.3.4.5. Projections

In the NSAR, the four constant catch SISCALS projected scenarios indicate a decline in SSB levels over the next three years (2025–27), except for the no-fishing scenario, which shows an increase beginning in 2025, and the 10% ERI scenario, which begins to rise in 2026 (Figure 36, Table 10). In contrast, the scenarios with the highest catch levels (20% and 30% ERI) project a continued decline through 2027 (Figure 36, Table 10).

Catch is assumed to be equal to the TAC in all projection years, whereas TAC utilization has been less than 100% in recent years, therefore, all else being equal in this particular assessment, the projected biomass estimates in Table 10 could be underestimated. Moreover, assessment projections assume that average conditions from recent years will continue, though these conditions may shift over time. Additional uncertainty in projected biomass estimates may stem from implementation uncertainty—specifically, deviations in how management actions such as TACs translate into actual catch and their effects on the population. Further bias may result from rollovers and other management decisions that are difficult to quantify. These uncertainties also applied to the projections in the SSAR.

3.4. NORTHERN SHRIMP (*PANDALUS BOREALIS)* IN THE SOUTH STOCK ASSESSMENT REGION

3.4.1. Biomass

In the SSAR, the Northern Shrimp biomass indices (i.e., total, SSB, and FB) derived from the spatiotemporal modeling of survey data have steadily increased from 1995–2006. Between 2006–17, the biomass indices declined sharply, and since that time has remained steady at a low level. In 2024, these indices experienced a decline (for example, a 25% decrease for the total biomass index) compared to 2023, hitting the lowest levels in the series (Figure 19, Figure 20, Figure 21, Table 2, Table 11).

The spatiotemporal models in the SSAR had a similar structure for the three biomass indices (delta gamma family), including anisotropy (separate for each model component), scaled depth and year (as factor) as covariates, and spatial, spatiotemporal (‘iid’) and spatial-varying coefficient for scaled depth as random fields. In addition to the regular survey sets, most recent comparative fishing sets (using the same gear as the survey sets) were also included in the spatiotemporal modeling, and the type of set was found to be non-significant. The best-performing FB spatiotemporal model included a random vessel effect, whereas incorporating this effect did not improve the total and SSB models.

All three spatiotemporal survey indices declined from 2023–24 in the SSAR, reaching their lowest levels in the survey time series. The total biomass spatiotemporal survey index in 2024 (103,300 t) declined (-25.1%) relative to the 2023 value and remained below the survey time series mean (1995–2023; 646,200 t) (Figure 19, Table 2). The female SSB spatiotemporal survey index in 2024 (55,400 t) decreased (-27%) relative to the 2023 value and remained

below the survey time series mean (1995–2023; 311,200 t) (Figure 20, Table 2). The FB spatiotemporal survey index in 2024 (92,300 t) declined (-20.8%) relative to the 2023 value (116,000 t) and is the lowest level in the survey time series (Figure 21, Table 11). Similar to most previous years, in 2024, the highest concentrations of Northern Shrimp survey catch and derived predicted density (e.g., FB spatiotemporal survey index) in the SSAR were mostly found in the more inshore areas of the northeast of Newfoundland by comparison to the 2000's, while Northern Shrimp densities remains low along the shelf edge (Figure 6, Figure 37).

In the SSAR, the size distribution of females showed an overall higher proportion of females in 2024 compared to previous years, whereas males showed a lower proportion and a narrower length distribution than previous years (Figure 38, Figure 24). The mean CL of most Northern Shrimp maturity stages (*i.e.,* fishable, total, males, and pre-fishable) has slightly increased since 2023, with the exception of females whose mean CL decreased slightly. Mean size of all stages remained above the long-term means in 2024 (Figure 25, Table 12). Over the last 5 years, Northern Shrimp size at 50% transition to female has fluctuated above the long-term mean (21.2 mm), and slightly increased from 21.4 mm in 2023 to 21.7 mm in 2024 (Figure 26).

3.4.2. Fishery

Over the 1977–2023/24 period, the Northern Shrimp aggregated TAC in the SSAR has changed from a minimum of 1,378 t (1981) to a maximum of 129,879 t in 2009/10 (Figure 4, Table 13). The aggregated TAC within the SSAR of 11,215 t in 2023/2024 (83% taken) was reduced for 2024/2025. Total aggregated catch in 2024/2025 was 7,180 t, 68% of the 10,547 t aggregated TAC (preliminary AQMS data) (Figure 4, Table 13). Commercial catch data from 2024/25 were considered preliminary. Commercial catch typically follows the same pattern as the TAC with generally ~80-90% of the TAC taken in the SSAR. Following the recalculation of the SFA 5 North and South proportions after the assessment meeting, please note that minor discrepancies may exist between the aggregated TAC and catch values for each stock assessment region and those reported in the Fisheries Science Advice Report (DFO 2025).

Within the SSAR, the SV fleet has been responsible for the majority of the catch over the time series (Figure 39). Most of the fishing activity has taken place from July to September, which corresponds to the third quarter (Q3) of the calendar year (Figure 39). Catch from the LV fleet, which primarily fishes from January-March (Q1), were historically lower than the SV fleet in the SSAR over the 2000's. Catches for both fishery fleets peaked between 2000–15 and are currently at much lower levels. In the most recent years, the proportion of catch taken by the LV fleet has increased (Figure 39).

In the SSAR, the best spatiotemporal model for the LV fleet was from the Tweedie family (link = log) and included anisotropy (varies by model component), multiple covariates (month, speed, depth, gear type, year, and vessel), and spatial and spatiotemporal (iid) random fields. The standardized LV CPUE was low until 1991 (Figure 28, Table 14). After 1991, the standardized CPUE increased until it reached a time series high in 2000. After 2000, the predicted CPUE declined until 2019. Since then, it has varied without trend at a relatively low level, but still remains above the 1980s level. There is a large degree of uncertainty associated with annual CPUE estimates throughout the time series.

Standardized SV CPUE was around average in the early years of the fishery (1998–2003) and the early 2010s, with a peak between 2004–08 (Figure 28, Table 15). In 2016, the SV CPUE dropped below average to the lowest values in the time series and has remained at a low level since, with slight improvement in 2021–22.

The areas within the SSAR that support most of the Northern Shrimp fishing have remained relatively stable in recent years (Figure 2, Figure 3), and generally coincide with regions that

have consistently exhibited the highest LV standardized predicted CPUE values across years (Figure 40). These areas visually align with locations where high shrimp concentrations were typically observed during the DFO surveys (Figure 6, Figure 37). Both the SV and LV fleets predominantly operate in depths of 200–400 m south of the Hawke Channel Closure and around the Funk Island Closure (Figure 2).

In 2024, the limited LV observer length frequency data indicated a higher proportion of larger males compared to previous years, as well as an increased proportion of smaller females (Figure 41). A similar trend was observed in the limited data from the SV fleet in 2023, with fewer smaller males and more smaller females (Figure 42). The mean CL of Northern Shrimp caught by LVs in the SSAR showed a slight increase from 2023, though it remains below the long-term average. This follows an overall decline that began in 2019. However, data for 2024–25 are limited and should be considered preliminary (Figure 31). This trend is consistent with patterns observed in mean size and size at 50% transition, as derived from the size distribution in the survey data. Observer data for the SV fleet in 2024 are extremely limited, making it difficult to draw any reliable conclusions or identify trends from such a constrained data source.

3.4.3. Exploitation Rate Index

The ERI fluctuated between 5.8% (1996) and 18% (2010/11) from 1996–24/25 (Figure 43, Table 11). As of February 4, 2025, the reported ERI for 2024/25 was 6.2% with 68% of the aggregated TAC taken. If the entire 2024/25 aggregated TAC of 10,547 t were to be taken, the ERI would be 9%. The ERI experienced a notable increase from the late 2000's to early 2010's, coinciding with a shift from a period of relatively high fishable biomass indices that began in the early 2000s, followed by a biomass decrease starting in 2010. The constant fishable biomass decline occurring at a relatively high rate compared to TAC reduction led to a period of relatively high ERI until 2015/16. After 2016/17, decreases in catch/TAC (i.e., mostly due to SFA 6 rebuilding plan limiting the exploitation rate to 10%) have led to ERI values slightly below to the long-term average in recent years.

In 2025, a new series of ERI values was introduced, based on the two stock assessment regions and the newly adopted FB indices resulting from spatiotemporal modeling. Consequently, these newly presented numbers are not directly comparable to the previous values, which were derived from a different modeling method (Ogmap) and at a different spatial scale (SFAs).

3.4.4. Stock Assessment Model (SISCALS)

3.4.4.1. Model Diagnostics

The same diagnostics for model residual standard errors (survey and CPUE indices, Bayesian posteriors) dehttps://doi.org/10.1111/oik.10524ibed for the NSAR apply to the SSAR. The SISCALS fit to the 2024 SSAR survey point was poor, close to 3 SD (bottom right panel, Figure 33). However, similar deviations were observed in previous years (e.g., 2008).

3.4.4.2. Recruitment

The recruitment in the SSAR was mostly above the long-term average during the first part of the time series (1996–2008) but has been below average since 2009. It reached the lowest level in the time series in the last five non-simulated data points (i.e., 2015–19) (Figure 35).

3.4.4.3. Mortality

In the SSAR, natural mortality has increased over much of the time series but has plateaued since 2015 (Figure 35). Changes in natural mortality are consistent with increased predator

abundance in the region (see3.2.3 and 3.2.4). SISCALS also suggest a slight decline in natural mortality from 2023–24, but more data will be required to confirm this trend.

3.4.4.4. Precautionary Approach Framework

In 2024, the SSB derived from SISCALS was 134,700 t (Figure 35, Table 8, Table 9), an increase of 2.2% relative to the 2023 value (131,700 t) which was the lowest in the time series, and remained below the long-term mean (1996–2023; 707,500 t).

The 2024 Northern Shrimp SSB is above the LRP with a greater than 99% probability, and above the proposed USR with a 98% probability, which, if the proposed USR were adopted, would place the stock in the Healthy Zone of the PA Framework (Table 8).

3.4.4.5. Projections

In the SSAR, the constant-catch SISCALS projection scenarios indicate that spawning stock biomass (SSB) levels are expected to increase over the next three years (2025–27) (Figure 44, Table 10). If the proposed Upper Stock Reference (USR) is adopted, it is highly likely that SSB will remain within the corresponding Healthy Zones throughout this period (Table 10).

3.5. UNCERTAINTIES

Observation uncertainty, or measurement error, is an important component of the assessment, particularly in relation to direct data inputs such as catch, survey indices, length composition, and biological characteristics. While survey biomass data are typically standardized using spatiotemporal models to account for variability across space and time, length composition data are not currently treated in the same way. This lack of standardization means that regions not covered by surveys may be underrepresented in the length composition dataset, potentially introducing bias into stock assessment estimates (Johnson et al. In press). Implementing spatiotemporal standardization for length composition data would help address this issue by reducing the potential for catchability bias, accounting for partial survey coverage, and improving the design and representativeness of both fishery-dependent and fishery-independent sampling programs. This enhancement would contribute to more accurate and reliable stock assessments. Additionally, the vertical distribution of Northern Shrimp (i.e., position in the water column) is not well understood and may vary across space and time. Since biomass estimates rely on bottom trawl surveys, shrimp located higher in the water column may be missed, leading to observed fluctuations that reflect survey limitations rather than true changes in population size.

Uncertainties in stock assessments using SISCALS arise from both process and structural sources. Process uncertainty involves the inherent variability and limited precision in estimating key biological parameters such as recruitment, natural mortality, growth, and sex-transition. These factors are influenced by environmental conditions and biological complexity, making their estimation subject to error and variability. On the other hand, model (structural) uncertainty stems from the assumptions and simplifications made in representing shrimp population dynamics, stock structure, and ecosystem interactions such as predation. This type of uncertainty reflects the limitations of the model in fully capturing the complexity of real-world ecological and biological processes. Together, these uncertainties influence the reliability and robustness of stock assessment outcomes.

4. CONCLUSION

4.1. NORTH STOCK ASSESSMENT REGION NORTHERN SHRIMP (*PANDALUS BOREALIS)*

In the NSAR, SSB derived from SISCALS increased by 56% in 2024 relative to the 2023 value, and remained below the time-series mean (1996–2023). The FB spatiotemporal survey index in 2024 declined by 19.7% relative to the 2023 value and remained below the time-series mean (1996–2023). In 2024, the female SSB for Northern Shrimp in NSAR was above the LRP (greater than 99% probability) and above the proposed USR (greater than 99% probability). If the proposed USR were adopted, this would place the stock in the Healthy Zone of the PA Framework.

4.2. SOUTH STOCK ASSESSMENT REGION NORTHERN SHRIMP (*PANDALUS BOREALIS)*

In the SSAR, SSB derived from SISCALS increased by 2.2% in 2024 relative to the 2023 value which was the lowest in the time series, and remained below the time-series mean (1996–2023). The FB spatiotemporal survey index in 2024 declined by 20.8% relative to the 2023 value and reached a time-series low (1995–2023). In 2024, the female SSB for Northern Shrimp in SSAR was above the LRP (greater than 99% probability) and above the proposed USR (greater than 98% probability). If the proposed USR were adopted, this would place the stock in the Healthy Zone of the PA Framework.

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7. GLOSSARY

AQMS: Atlantic Quota Monitoring System

AZMP: Atlantic Zonal Monitoring Program

CPUE: Catch Per Unit Effort

CL: Carapace Length

DFO: Fisheries and Oceans Canada

EAZ: Eastern Assessment Zone

ERI: Exploitation Rate Index

F/V: Fishing Vessel

FB: Fishable Biomass

IFMP: Integrated Fisheries Management Plan

LV: Large Vessel

LRP: Limit Reference Point

MSC: Marine Stewardship Council

NM: Nautical Miles

NL: Newfoundland and Labrador

NLCI: Newfoundland and Labrador Climate Index

NSAR: North Stock Assessment Region

NSRF: Northern Shrimp Research Foundation

OCI: Ocean Choice International

PA: Precautionary Approach

SISCALS: Spatially Integrated Statistical Catch-At Length/Size model

SFA: Shrimp Fishing Area(s)

SSAR: South Stock Assessment Region

SSB: Spawning Stock Biomass

SV: Small Vessel

TAC: Total Allowable Catches

USR: Upper Stock Reference

WAZ: Western Assessment Zone

8. TABLES

Table 1. North stock assessment region (NSAR) Northern Shrimp spawning stock biomass (SSB) and total biomass (1996–2024) spatiotemporal survey indices, with percentage change from previous survey year, number of successful survey sets, and the proportion of sets containing* Pandalus borealis*. Information was collected during DFO Fall multispecies surveys and NSRF summer surveys. Estimates were calculated using spatiotemporal modelling.* Note: years 2000–04 were excluded due to poor survey coverage.*

Year	SSB Survey Index Lower CI (x 1,000 t)	SSB Survey Index (x 1,000 t)	SSB Survey Index Upper CI (x 1,000 t)	Total Biomass Survey Index Lower CI (x 1,000 t)	Total Biomass Survey Index (x 1,000 t)	Total Biomass Survey Index Upper CI (x 1,000 t)	Change in Total Biomass Survey Index from Previous Years (%)	Number of Survey Sets in NSAR	% Sets with *P. borealis*
1996	36.6	60.7	100.7	142.4	230.2	372.1	-	101	68.3
1997	78.2	119.5	182.6	231	348.2	524.9	51.3	110	84.6
1998	63.2	106	177.8	169.9	283.6	473.6	-18.6	91	83.5
1999	71.5	110.1	169.4	199.8	299.6	449.2	5.6	127	81.9
2005	92.5	166.8	301	176.7	324.1	594.4	-	74	64.9
2006	141.5	211.9	317.3	309.9	450.2	654	38.9	141	80.1
2007	95.8	136.5	194.3	181.4	270.1	402	-40	234	70.5
2008	108.9	145.9	195.4	228.5	309	417.8	14.4	284	79.6
2009	112	152.9	208.8	231.2	325.6	458.5	5.4	250	85.2
2010	93.2	124.6	166.6	220	294.3	393.5	-9.6	304	73.0
2011	112.3	146.4	191	242	316.7	414.6	7.6	318	72.3
2012	157.5	206.3	270.2	313	411.2	540.3	29.8	317	78.9
2013	96.8	130.1	174.8	176.9	235.8	314.4	-42.7	319	76.8
2014	136.9	171.4	214.6	262.3	332.3	420.9	40.9	362	72.1
2015	146.3	185.5	235.3	286.3	360.3	453.4	8.4	374	84.8
2016	93.2	118.9	151.6	198.6	259.2	338.4	-28.1	380	65.8
2017	72.6	91.3	114.9	140.6	176.2	220.7	-32	387	66.4
2018	81.8	102.2	127.6	141.5	180.8	231.1	2.6	391	70.3
2019	72.2	92.5	118.6	129.5	164.4	208.7	-9.1	377	69.0
2020	74.1	93.7	118.4	128.8	167.5	217.8	1.9	355	57.8
2021	94.9	128.2	173.3	159.8	209.1	273.6	24.8	371	58.8
2022	96.8	125.9	163.8	173.9	228.5	300.2	9.3	341	69.8
2023	123.4	156.1	197.4	194.1	247	314.4	8.1	356	57.9

Year	SSB Survey Index Lower CI (x 1,000 t)	SSB Survey Index (x 1,000 t)	SSB Survey Index Upper CI (x 1,000 t)	Total Biomass Survey Index Lower CI (x 1,000 t)	Total Biomass Survey Index (x 1,000 t)	Total Biomass Survey Index Upper CI (x 1,000 t)	Change in Total Biomass Survey Index from Previous Years (%)	Number of Survey Sets in NSAR	% Sets with *P. borealis*
2024	111.9	142.2	180.8	154.1	199.4	258	-19.3	350	58.0

Table 2. South stock assessment region (SSAR) Northern Shrimp spawning stock biomass (SSB) and total biomass (1995–2023) spatiotemporal survey indices, with percentage change from previous survey year, number of successful survey sets, and the proportion of sets containing Pandalus borealis*. Information was collected during DFO fall multispecies surveys and biomass estimates were calculated using spatiotemporal modelling.*

Year	SSB Survey Index Lower CI (x 1,000 t)	SSB Survey Index (x 1,000 t)	SSB Survey Index Upper CI (x 1,000 t)	Total Biomass Survey Index Lower CI (x 1,000 t)	Total Biomass Survey Index (x 1,000 t)	Total Biomass Survey Index Upper CI (x 1,000 t)	Change in Total Biomass Survey Index from Previous Years (%)	Number of Survey Sets in SSAR	% Sets with *P. borealis*
1995	157.5	191.6	233.0	416.2	416.2	508.3	-	526	43.2
1996	180.5	219.0	265.8	489.8	580.1	687.1	+39.4	559	65.7
1997	191.3	226.3	267.7	451.1	524.2	609.1	-9.6	575	73.7
1998	235	275.8	323.8	530.6	612.2	706.3	16.8	571	78.1
1999	284.8	332.9	389.1	583.2	670.7	771.4	9.6	518	73.4
2000	326.5	389.7	465	729	844.1	977.4	25.9	533	74.9
2001	449.2	535.7	639	1090.3	1274.3	1489.3	51	569	74.9
2002	493.1	579.5	681	1008.2	1160.9	1336.7	-8.9	576	81.4
2003	412.5	478.6	555.3	875.6	1006.2	1156.3	-13.3	567	78.8
2004	533.9	636.7	759.2	1006.8	1178.7	1380	17.1	521	74.7
2005	589.5	699.8	830.8	1214	1402	1619.2	18.9	567	70.2
2006	574.4	685.0	816.9	1233.5	1432	1662.5	2.1	537	65.4
2007	634.6	752.7	892.8	1195.8	1385	1604.1	-3.3	489	64.6
2008	574.5	692.4	834.5	1186	1388.7	1626.2	0.3	444	62.8
2009	245.6	291.3	345.5	536.9	624.4	726.3	-55	483	61.3
2010	256.4	300.9	353	540.8	620.2	711.3	-0.7	558	59.7
2011	266.5	318.7	381.3	553.7	650.1	763.3	4.8	449	53.9
2012	213.6	254.4	302.9	474.3	554	647.1	-14.8	506	52.8
2013	170.9	205.5	247.1	344.7	403.8	473	-27.1	519	53.2
2014	143	174.2	212.1	301.4	356.8	422.4	-11.6	371	76.6
2015	92.5	111.7	134.9	221.5	259.1	303	-27.4	514	54.5
2016	78.2	95.8	117.5	184.3	217.4	256.3	-16.1	506	56.1
2017	69	84.9	104.3	136.2	162.1	193	-25.4	514	49.8
2018	65.3	80.4	99	127.9	153.9	185.2	-5.1	486	49.8
2019	54.4	69.5	88.7	125.5	155.4	192.3	1	428	43.9

Year	SSB Survey Index Lower CI (x 1,000 t)	SSB Survey Index (x 1,000 t)	SSB Survey Index Upper CI (x 1,000 t)	Total Biomass Survey Index Lower CI (x 1,000 t)	Total Biomass Survey Index (x 1,000 t)	Total Biomass Survey Index Upper CI (x 1,000 t)	Change in Total Biomass Survey Index from Previous Years (%)	Number of Survey Sets in SSAR	% Sets with *P. borealis*
2020	74.4	91.7	113.1	162.8	197.6	239.8	27.2	372	51.6
2021	66.8	88	115.9	134.4	175.9	230.2	-11	144	86.8
2022	65.9	83.9	106.8	150.2	195.1	253.3	10.9	574	77.0
2023	63.1	76.9	93.7	115.7	137.9	164.3	-29.3	454	62.1
2024	43.1	55.4	71.3	82.9	103.3	128.6	-25.1	365	52.3

*Table 3. NSAR Northern Shrimp aggregated commercial catch to date, fishable biomass spatiotemporal survey indices and exploitation rate indices (aggregated commercial catch divided by the fishable biomass spatiotemporal index in the same year). Biomass indices are derived from spatiotemporal modelling using NSRF summer survey data and fall DFO multispecies survey data. Catch is taken from the AQMS as of January 15 (EAZ, WAZ) and February 4, 2025 (SFAs 4–5) such that 2024/25 catch and exploitation rate (indicated with *) are preliminary. ** Aggregated commercial catch were based on the sum of the values from the appropriate SFAs, with SFA 5 values being split between the NSAR and SSAR according to the yearly proportion of catch in each stock assessment region, using observer data (1979–2024) and logbook data (1998–2024).*

Catch Year	Aggregated Catch (t) **	Survey Year	Fishable Biomass Index Lower CI (x 1,000 t)	Fishable Biomass Index (x 1,000 t)	Fishable Biomass Index Upper CI (x 1,000 t)	ER Index Lower CI (%)	ER Index (%)	ER Index Upper CI (%)
1996	9765	1996	59.9	117.7	231.3	4.2	8.3	16.3
1997	18493	1997	134.7	247.2	453.7	4.1	7.5	13.7
1998	16299	1998	95.8	177.5	329	5	9.2	17
1999	18165	1999	55.7	105.6	200.1	9.1	17.2	32.6
2000	18195	2000	-	-	-	-	-	-
2001	18831	2001	-	-	-	-	-	-
2002	18734	2002	-	-	-	-	-	-
2003/04	28500	2003	-	-	-	-	-	-
2004/05	29837	2004	-	-	-	-	-	-
2005/06	31542	2005	184.4	343.2	638.7	4.9	9.2	17.1
2006/07	31197	2006	294.7	434.2	639.8	4.9	7.2	10.6
2007/08	31053	2007	167.4	246.3	362.3	8.6	12.6	18.5
2008/09	25239	2008	187.9	252.7	339.7	7.4	10	13.4
2009/10	28646	2009	203.9	283.8	395	7.3	10.1	14.1
2010/11	33076	2010	194.9	261	349.5	9.5	12.7	17
2011/12	33199	2011	214.6	279.5	364	9.1	11.9	15.5
2012/13	34516	2012	289	378.4	495.5	7	9.1	11.9
2013/14	38212	2013	158.2	211.1	281.6	13.6	18.1	24.2
2014/15	39323	2014	236.6	298.3	376.1	10.5	13.2	16.6
2015/16	37170	2015	258.2	324.7	408.5	9.1	11.4	14.4
2016/17	42363	2016	180.1	242	325.2	13	17.5	23.5
2017/18	43430	2017	127.2	159.3	199.7	21.8	27.3	34.2
2018/19	44542	2018	132.8	168.2	213.1	20.9	26.5	33.5
2019/20	37686	2019	118.8	150.8	191.5	19.7	25	31.7
2020/21	25909	2020	123.4	160.9	209.6	12.4	16.1	21
2021/22	28306	2021	146.3	197.7	267.2	10.6	14.3	19.4
2022/23	34127	2022	158.5	207.5	271.6	12.6	16.4	21.5
2023/24	34277	2023	182.5	230.6	291.5	11.8	14.9	18.8
2024/25	29141*	2024	143.9	185.2	238.3	12.2*	15.7*	20.2*

Table 4. NSAR Mean size of Northern Shrimp (mm) from NSRF survey and DFO fall multispecies survey by various maturity/size categories including females, males, fishable (≥17.5 mm), pre-fishable (<17.5 mm) and totals. Note: years 2000–04 were excluded due to poor survey coverage.

Year	Females	Males	Fishable	Pre-fishable	Totals
1996	23.8	18.7	20.4	16.2	19.7
1997	23.7	18.6	20.4	16.2	19.7
1998	22.9	18.5	20.2	16.0	19.5
1999	23.4	18.9	20.8	16.0	20.1
2005	24.5	18.9	21.8	15.6	20.9
2006	23.6	18.5	21.2	15.3	20.2
2007	24.1	19.1	22.1	15.3	21.3
2008	23.9	18.6	22.0	15.8	20.7
2009	23.2	18.3	21.3	16.0	20.4
2010	23.5	18.3	20.8	16.0	19.9
2011	22.9	18.4	21.1	15.4	20.2
2012	22.5	18.6	20.8	16.0	20.1
2013	22.7	18.5	21.1	15.9	20.2
2014	23.0	17.8	21.1	15.5	19.7
2015	23.3	18.4	21.4	15.6	20.5
2016	23.5	18.6	21.2	15.8	20.3
2017	24.2	18.6	22.5	15.7	21.8
2018	24.0	19.1	22.2	15.5	21.5
2019	24.5	20.1	22.9	15.2	22.3
2020	25.1	20.5	23.6	15.3	23.1
2021	25.3	20.0	23.7	14.9	23.0
2022	24.7	19.6	22.9	15.6	22.1
2023	24.9	19.0	22.9	15.5	22.0
2024	23.0	17.7	22.5	15.2	21.4

*Table 5. NSAR TACs and catches (in tons) from 1977 to 2024/25 for the combined LV and SV fleets fishing Northern Shrimp in the EAZ, WAZ, SFA 4, and northern portion of SFA 5, as well as aggregated TAC and catch (in tons). In 2003 the fishing season was switched from a calendar year to a management year such that the catches shown for 2003/04 are based on a 15-month fishing season. Quota transfers, bridging and overruns are reflected in all catches. *All 2024/25 catches and TACs are preliminary and based upon the AQMS. **TAC and Catch in the northern portion of SFA 5 (i.e., SFA 5 North) were based on the values from SFA 5, split between North and South according to the yearly proportion of catch in each stock assessment region, using observer data (1979–2024) and logbook data (1998–2024). Empty cells correspond to years when no TAC was defined.*

Year	EAZ		WAZ		SFA 4		SFA 5 North**		NSAR (aggregated)	
	Catch (t)	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*
1977	0	-	0	-	0	-	2585	-	2585	-
1978	0	-	0	-	0	500	3494	5101	3494	5601
1979	1	-	0	-	3	500	3175	3408	3179	3908
1980	487	-	0	-	1	500	4041	4722	4529	5222
1981	1	-	0	-	2	500	3429	4772	3432	5272
1982	46	-	0	-	5	500	1731	4191	1782	4691
1983	21	-	0	-	30	500	962	4620	1013	5120
1984	0	-	0	-	0	500	984	4123	984	4623
1985	0	-	0	-	0	500	1674	3539	1674	4039
1986	50	-	0	-	2	500	1783	1625	1835	2125
1987	0	-	0	-	7	500	3995	3220	4002	3720
1988	2873	-	0	-	1083	500	5041	3087	8997	3587
1989	3133	3500	0	-	3842	2580	4451	4462	11426	10542
1990	1634	3500	0	-	2945	2580	3813	4268	8392	10348
1991	1150	3500	0	-	2561	2635	4504	4693	8215	10828
1992	1210	3500	0	-	2706	2635	4677	4721	8593	10856
1993	68	3500	0	-	2723	2735	4362	4863	7153	11098
1994	456	3500	0	-	3982	4000	4296	4383	8734	11883
1995	2489	3500	0	-	5104	5200	1692	1699	9285	10399
1996	3346	3500	0	-	5160	5200	1259	1304	9765	10004
1997	5870	5250	0	-	5216	5200	7407	7503	18493	17953
1998	5372	5250	0	-	8051	8320	2876	2901	16299	16471
1999	5465	8750	0	-	7884	8320	4816	4876	18165	21946
2000	5718	8750	0	-	7382	8320	5095	5310	18195	22380
2001	6275	8750	0	-	8117	8320	4439	4493	18831	21563
2002	5695	8750	0	-	8387	8320	4652	4640	18734	21710
2003/04	5617	8750	0	-	13020	13122	9863	10695	28500	32567
2004/05	5842	8750	0	-	9644	10320	14351	13908	29837	32978
2005/06	6387	8773	0	-	10247	10320	14908	15161	31542	34254
2006/07	6028	9127	0	-	10084	10320	15085	15543	31197	34990
2007/08	6359	9150	0	-	10009	10320	14685	14396	31053	33866
2008/09	5184	9092	0	-	9682	11320	10373	11788	25239	32200
2009/10	5159	8525	0	-	10656	11320	12831	11913	28646	31758
2010/11	6908	9680	57	400	11134	11320	14977	16307	33076	37707
2011/12	7687	8903	0	400	10441	11320	15071	13852	33199	34475
2012/13	5555	9492	13	400	13908	13018	15040	14290	34516	37200
2013/14	6793	9767	973	1500	14969	14971	15477	16280	38212	42518
2014/15	4972	8250	847	2080	14958	14971	18546	17804	39323	43105
2015/16	4816	8250	353	2080	15050	14971	16951	18315	37170	43616

Year	EAZ		WAZ		SFA 4		SFA 5 North**		NSAR (aggregated)	
	Catch (t)	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*
2016/17	6667	9488	643	2080	14377	14971	20676	23461	42363	50000
2017/18	6488	9488	918	2080	16439	15725	19585	16591	43430	43884
2018/19	6198	7840	1307	2080	15697	15725	21340	23492	44542	49137
2019/20	5508	8610	1612	3163	11232	10845	19334	18255	37686	40873
2020/21	6165	10653	1438	3163	8280	8658	10026	10644	25909	33118
2021/22	8359	12252	1245	5090	10272	9957	8430	12042	28306	39341
2022/23	5691	10732	475	3958	14889	12944	13072	11445	34127	39079
2023/24	6188	7383	2080	4788	13624	14886	12385	12415	34277	39472
2024/25*	5560	8513	1446	4186	11079	15553	11056	10980	29141	39232

*Table 6. NSAR Standardized LV CPUE for Northern Shrimp over the 1989–2024/25 period. Data from 2003 to present were converted to management year. Catch per assessment region is calculated from the catch taken from the AQMS and proportion of catch reported in the observer data (LV) such that 2024/25 catch, CPUE, and calculated effort (indicated with *) are preliminary.*

Management Year	Fleet Catch (t)	CPUE (kg/hour) Lower CI	CPUE (kg/hour)	CPUE (kg/hour) Upper CI	Calculated Effort (Hours)
1988	8972	17.8	604.9	3309.0	14832
1989	11404	45.3	537.7	2189.0	21209
1990	8386	19.4	339.0	1097.9	24738
1991	8238	27.9	639.9	3123.5	12874
1992	8588	31.7	586.2	2221.1	14650
1993	7136	24.0	656.2	3205.5	10875
1994	8711	25.6	624.2	2800.1	13956
1995	9270	41.0	565.2	2022.9	16401
1996	9761	56.1	1003.1	3999.2	9731
1997	18486	17.6	1262.1	5994.8	14647
1998	16108	61.9	1271.3	3970.2	12671
1999	17949	29.5	1410.0	4760.6	12730
2000	18112	22.4	1224.2	3586.3	14795
2001	18819	32.9	1352.0	4446.8	13919
2002	18638	35.3	1198.7	3712.0	15549
2003/04	27950	32.5	1322.1	4024.6	21141
2004/05	27962	50.5	1449.5	3903.1	19291
2005/06	30564	27.7	1121.1	2918.4	27263
2006/07	31092	23.3	1115.9	3167.9	27863
2007/08	31053	102.9	1143.4	2821.2	27159
2008/09	25184	81.3	1467.7	4072.5	17159
2009/10	28646	91.4	1806.8	5255.2	15855
2010/11	33026	35.7	1461.9	4357.5	22591
2011/12	32456	84.1	1663.4	4544.0	19512
2012/13	33428	47.2	1535.7	4149.7	21767
2013/14	37285	50.0	1412.7	3888.3	26393
2014/15	37992	58.3	1720.5	4934.1	22082
2015/16	35280	50.5	1411.5	3677.5	24995
2016/17	38861	44.8	1598.7	5038.9	24308
2017/18	40141	71.4	1490.7	4432.7	26928
2018/19	40514	52.7	1515.3	4154.3	26737
2019/20	34452	37.9	1389.6	4287.9	24793
2020/21	24606	23.0	1262.8	3980.7	19485
2021/22	26503	26.1	1040.9	2787.3	25462
2022/23	32554	34.3	1002.3	3153.5	32479
2023/24	32036	41.2	1212.2	4621.4	26428
2024/25	29462*	26.0*	757.4*	2442.8*	38899*

Table 7. Estimated standard errors for observational data (SV: small vessel fleet; LV: large vessel fleet; Surv.: survey fleet). The first six rows show length data sampling error standard deviations from the logistic-normal compositional likelihood function, and the last three rows show biomass index log-residual standard errors. For length composition residual standard errors, values of 0.3–0.5 are considered very good, 0.5–0.8 are good, 0.8–1.0 are adequate, and above 1.0 indicates that there may be model mis-specification and the stock assessment model is failing to sufficiently capture the data generating process. For stock index data CVs in the range 0.05–0.1 are considered very good, 0.1–0.2 are good, 0.2–0.3 are moderate, and 0.3–0.4 are marginally acceptable but tend to reflect a higher noise data set with low statistical power or potential model mis-specification.

Variable	NSAR	SSAR
$\tau_{SV}^{length,male}$	-	0.284
$\tau_{SV}^{length,fem}$	-	0.403
$\tau_{LV}^{length,male}$	0.532	0.409
$\tau_{LV}^{length,fem}$	0.802	0.553
$\tau_{Survey}^{length,male}$	0.248	0.194
$\tau_{Survey}^{length,fem}$	0.235	0.195
τ_{SV}^{index}	-	0.624
τ_{LV}^{index}	0.769	0.552
τ_{Survey}^{index}	0.209	0.163

Table 8. SISCALS model spawning biomass levels associated with the B_{MSY} proxy ($0.4B_0$), upper stock ($0.32B_0$), and limit ($0.2B_0$) reference points, and stock status with respect to those reference points in the NSAR (left panel) and SSAR (right panel). Biomass quantities are shown as medians and 95% credibility intervals (in brackets), with units of thousands of tons (kt).

Value	NSAR	SSAR
B_0	262.11 (193.81, 359.23)	251.06 (153.13, 417.71)
$B_{MSY} = 0.4\ B_0$	104.84 (77.52, 143.69)	100.42 (61.25, 167.08)
$USR = 0.8\ B_{MSY}$	83.88 (62.02, 114.95)	80.34 (49, 133.67)
$LRP = 0.5\ B_{MSY}$	52.42 (38.76, 71.85)	50.21 (30.63, 83.54)
B_{2024}	177.75 (112.22, 294.11)	134.65 (87.47, 218.14)
$P(B_{2024} >= B_{MSY})$	> 0.99	0.90
$P(B_{2024} >= USR)$	> 0.99	0.98
$P(B_{2024} >= LRP)$	> 0.99	> 0.99

Table 9. SISCALS model spawning stock biomass (SSB) levels in the NSAR (left panel) and SSAR (right panel). Biomass quantities are shown as medians of the posterior distribution and upper and lower limits of the 95% credibility intervals (CI), with units of thousands of tons (kt). The last 3 years (gray cells: 2025–27) are based on constant catch projections at the 2024–25 aggregated TAC level.

Year	NSAR			SSAR		
	SISCALS SSB Lower CI (kt)	SISCALS SSB (*k*t)	SISCALS SSB Upper CI (kt)	SISCALS SSB Lower CI (kt)	SISCALS SSB (kt)	SISCALS SSB Upper CI (kt)
1996	169.1	237	336.8	507.5	668.2	889.6
1997	168.4	237.5	337.9	540.8	701.3	930.4
1998	163.6	235.1	346.1	583.9	761.8	1015
1999	146.5	214.1	314.6	570.6	750.3	995.3
2000	128.5	190.1	281.1	597.8	788.7	1067.6
2001	151.8	212.9	302.4	658.4	870.7	1172.3
2002	160.5	220.9	308.6	809.4	1058.5	1420.2
2003	166.1	224.4	312.4	897.7	1183.7	1577.6
2004	166	223.3	311	1082.6	1401.9	1855
2005	164.3	220.8	310.2	971.4	1258.8	1671.5
2006	151.7	215.3	314	953.9	1241	1644.1
2007	133.8	193.2	282.5	898.7	1173.8	1556.4
2008	138.5	197.4	283.7	792.4	1052.8	1412.6
2009	151.1	214.8	312.9	864.6	1146.6	1552.1
2010	155.3	225.6	331.6	768.2	1019.3	1396.2
2011	188.9	270.6	390	669.1	896.7	1225.7
2012	222.5	316.4	450.9	578.9	767.3	1039.2
2013	219.3	319.2	467.3	454.4	614.4	840.5
2014	204.2	302.5	449.2	344	477.1	673.4
2015	159	241.8	364.3	287.2	401.8	568.4
2016	130.5	205	314	242.3	345.8	494.9
2017	98.1	161.1	255.8	179.2	258.6	382.3
2018	101.5	165.1	257.9	142.9	209	310.5
2019	74	121.3	191.3	125.3	183.2	273.3
2020	62.5	103.7	166	109.6	159	235.9
2021	66.9	103.7	161	101.3	146.8	218.7
2022	90.1	132.9	200.6	96.2	141.2	209.7
2023	74.4	114.2	181.2	89.7	131.7	198
2024	112.2	177.8	294.1	87.5	134.7	218.1
2025	*78.4*	*134.6*	*234.6*	*100.3*	*165.8*	*334.6*
2026	*62.2*	*119.5*	*216.6*	*96.3*	*180.1*	*425.1*
2027	*54.8*	*114.1*	*214.7*	*90.3*	*190*	*479.5*

Table 10. SISCALS SSB projections for NSAR (left panel) and SSAR (right panel) over 2025–27 under five constant catch scenarios derived from an ERI multiplied by the 2024 FB spatiotemporal index: (1) ERI based on most recent aggregated TAC (Current ERI 21.2%); (2) 0% based on zero catch; (3) 10% based on the lower limit of the current harvest decision rule (HDR); (4) 20% based on the upper target of the HDR; and (5) 30% based on the maximum allowable ERI from the HDR. Results are shown for the probabilities of SSB being greater than BMSY-proxy - P(SSB > BMSY); SSB greater than USR – P(SSB > USR); and SSB greater than LRP – P(SSB > LRP). Expected SSB values (kt) are medians over the posterior distributions.

SISCALS Projections	NSAR					SSAR				
	2024 NSAR FB spatiotemporal index (kt): 185.2					2024 SSAR FB spatiotemporal index (kt): 92.3				
Exploitation Rate Index	**0%**	**10%**	**20%**	**Current ERI (21.2%)**	**30%**	**0%**	**10%**	**Current ERI (11.5%)**	**20%**	**30%**
Aggregated TAC	0	18.5	37.0	39.2	55.6	0	9.2	10.6	18.5	27.7
SSB_{2025}	141.4	138.2	134.9	134.6	131.8	167.5	166.1	165.8	164.5	162.9
$P(SSB_{2025} \geq B_{msy})$	0.97	0.95	0.93	0.92	0.90	0.96	0.96	0.96	0.96	0.95
$P(SSB_{2025} \geq USR)$	> 0.99	> 0.99	> 0.99	0.99	0.99	> 0.99	0.99	0.99	0.99	0.99
$P(SSB_{2025} \geq LRP)$	> 0.99	> 0.99	> 0.99	> 0.99	> 0.99	> 0.99	> 0.99	> 0.99	> 0.99	> 0.99
SSB_{2026}	150.9	136.2	121.3	119.5	106.6	189.1	181.2	180.1	173.9	166.5
$P(SSB_{2026} \geq B_{msy})$	0.98	0.91	0.74	0.72	0.52	0.97	0.95	0.95	0.94	0.91
$P(SSB_{2026} \geq USR)$	> 0.99	0.99	0.95	0.94	0.82	0.99	0.99	0.99	0.98	0.97
$P(SSB_{2026} \geq LRP)$	> 0.99	> 0.99	> 0.99	> 0.99	0.99	> 0.99	> 0.99	> 0.99	> 0.99	> 0.99
SSB_{2027}	169.4	142.9	117.1	114.1	92.4	205.1	192.0	190.0	179.0	166.9
$P(SSB_{2027} \geq B_{msy})$	> 0.99	0.92	0.66	0.62	0.35	0.97	0.94	0.94	0.90	0. 85
$P(SSB_{2027} \geq USR)$	> 0.99	0.99	0.90	0.87	0.61	0.99	0.98	0.98	0.96	0.93
$P(SSB_{2027} \geq LRP)$	> 0.99	> 0.99	> 0.99	0.99	0.93	> 0.99	> 0.99	> 0.99	> 0.99	0.99

*Table 11. SSAR Northern Shrimp aggregated commercial catch to date, fishable biomass indices and exploitation rate indices (aggregated commercial catch divided by the fishable biomass index in the previous year). Biomass indices are derived from spatiotemporal modelling using fall DFO multispecies survey data. Catch is taken from the AQMS such that 2024/25 catch and exploitation rate (indicated with *) are preliminary. **Projected ERI for 2025/26 is calculated using the 2024/25 aggregated TAC and assuming it is fully taken in 2025/26. *** Aggregated commercial catch were based on the sum of the values from the appropriate SFAs, with SFA 5 values being split between the NSAR and SSAR according to the yearly proportion of catch in each stock assessment region, using observer data (1979–2024) and logbook data (1998–2024).*

Catch Year	Aggregated Catch or TAC (t) ***	Survey Year****	Fishable Biomass Index Lower CI (x 1,000 t)	Fishable Biomass Index (x 1,000 t)	Fishable Biomass Index Upper CI (x 1,000 t)	ER Index Lower CI (%)	ER Index (%)	ER Index Upper CI (%)
1996	17226	1995	234.6	297.0	375.9	4.6	5.8	7.3
1997	29199	1996	352.4	442.0	554.4	5.3	6.6	8.3
1998	59257	1997	370.8	457.7	565	10.5	12.9	16
1999	62290	1998	460	560.1	681.9	9.1	11.1	13.5
2000	77880	1999	480.9	584.2	709.7	11.0	13.3	16.2
2001	68943	2000	585.9	720.3	885.7	7.8	9.6	11.8
2002	76965	2001	871.3	1043.6	1250	6.2	7.4	8.8
2003/04	103723	2002	831.9	972.7	1137.5	9.1	10.7	12.5
2004/05	100225	2003	741.7	879.9	1043.7	9.6	11.4	13.5
2005/06	97007	2004	858.7	1045.4	1272.8	7.6	9.3	11.3
2006/07	105816	2005	1056.9	1237.7	1449.3	7.3	8.5	10
2007/08	112363	2006	1059.2	1270.6	1524.2	7.4	8.8	10.6
2008/09	110732	2007	1013.3	1207.7	1439.5	7.7	9.2	10.9
2009/10	85027	2008	969.5	1155.9	1378.2	6.2	7.4	8.8
2010/11	87694	2009	401.8	487.9	592.4	14.8	18.0	21.8
2011/12	82897	2010	417.7	502.0	603.3	13.7	16.5	19.8
2012/13	77930	2011	463.3	574.2	711.7	11.0	13.6	16.8
2013/14	73422	2012	389.3	478.8	588.9	12.5	15.3	18.9
2014/15	51927	2013	267	326.8	400.1	13.0	15.9	19.4
2015/16	53300	2014	245.1	310.3	392.8	13.6	17.2	21.7
2016/17	27019	2015	162.8	202.3	251.4	10.7	13.4	16.6
2017/18	16582	2016	140.8	174.0	215.1	7.7	9.5	11.8
2018/19	10619	2017	117.2	147.9	186.7	5.7	7.2	9.1
2019/20	12744	2018	97.4	121.8	152.4	8.4	10.5	13.1

Catch Year	Aggregated Catch or TAC (t) ***	Survey Year****	Fishable Biomass Index Lower CI (x 1,000 t)	Fishable Biomass Index (x 1,000 t)	Fishable Biomass Index Upper CI (x 1,000 t)	ER Index Lower CI (%)	ER Index (%)	ER Index Upper CI (%)
2020/21	9836	2019	97.6	125.9	162.4	6.1	7.8	10.1
2021/22	12253	2020	120.7	152.1	191.6	6.4	8.1	10.1
2022/23	11581	2021	96.9	131.8	179.4	6.5	8.8	12
2023/24	9314	2022	116.6	156.7	210.6	4.4	5.9	8
2024/25	7180	2023	91.9	116.6	147.8	4.9*	6.2*	7.8*
2025/26	10547**	2024	68.8	92.3	123.8	8.5**	11.4**	15.3**

Table 12. SSAR Mean size of Northern Shrimp (mm) from DFO fall multispecies surveys by various maturity/size categories including females, males, fishable (≥ 17.5 mm), pre-fishable (< 17.5 mm) and totals.

Year	Females	Males	Fishable	Pre-fishable	Totals
1996	23.1	16.7	20.5	15.4	17.8
1997	22.8	17.1	20.4	15.3	18.5
1998	22.4	16.9	20.5	15.3	18.4
1999	22.5	16.6	20.9	15.0	18.4
2000	22.5	16.6	20.7	15.1	18.2
2001	22.5	16.9	20.5	15.1	18.5
2002	22.1	16.9	20.5	15.5	18.5
2003	22.2	16.8	20.6	15.0	18.6
2004	22.0	16.9	20.7	15.3	18.7
2005	22.4	17.0	20.7	15.6	18.9
2006	22.7	16.5	20.8	14.6	18.3
2007	22.8	16.8	21.1	15.0	18.7
2008	22.7	17.2	20.8	15.4	18.9
2009	22.5	16.4	20.6	15.0	18.1
2010	22.4	17.0	20.7	15.3	18.7
2011	22.5	16.9	20.7	15.2	18.7
2012	22.4	16.7	20.5	14.9	18.3
2013	22.8	16.6	21.0	15.0	18.4
2014	23.0	16.6	20.8	14.9	18.2
2015	23.3	16.2	21.1	15.0	17.9
2016	23.3	16.7	20.8	15.2	18.3
2017	23.2	17.1	21.0	15.2	18.9
2018	23.6	16.4	22.0	14.9	19.0
2019	23.7	16.3	21.6	15.1	18.6
2020	23.9	16.2	21.6	14.9	18.2
2021	24.0	15.8	22.2	14.9	18.8
2023	23.4	16.6	21.4	14.9	18.8
2024	23.3	16.9	21.5	15.2	19.1

*Table 13. SSAR TACs and catches (in tons) from 1977–2024/25 for the combined LV and SV fleets fishing Northern Shrimp in the southern portion of SFA 5, SFA 6, and SFA 7, as well as aggregated TAC and catch (in tons). In 2003 the fishing season was switched from a calendar year to a management year such that the catches shown for 2003/04 are based on a 15-month fishing season. Quota transfers, bridging and overruns are reflected in all catches. All 2024/25 catches and TACs are preliminary and based upon the AQMS. * TAC and Catch in the northern portion of SFA 5 (i.e., SFA 5 South) were based on the values from SFA 5, split between North and South according to the yearly proportion of catch in each stock assessment region, using observer data (1979–2024) and logbook data (1998–2024). Empty cells correspond to years when no TAC was defined.*

Year	SFA 5 South*		SFA 6		SFA 7		SSAR (aggregated)	
	Catch (t)	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*
1977	101	-	1	-	0	-	102	0
1978	136	199	0	1300	0	-	136	1499
1979	552	592	5	2250	0	-	557	2842
1980	67	78	0	1350	0	-	67	1428
1981	20	28	135	1350	0	-	155	1378
1982	252	609	0	1350	0	-	252	1959
1983	38	180	0	1350	0	-	38	1530
1984	18	77	0	1350	0	-	18	1427
1985	15	31	0	1350	0	-	15	1381
1986	3043	2775	0	2050	0	-	3043	4825
1987	5956	4800	3523	3000	0	-	9479	7800
1988	2797	1713	11596	3000	0	-	14393	4713
1989	1534	1538	8517	5600	0	-	10051	7138
1990	1547	1732	7527	5600	0	-	9074	7332
1991	1614	1682	7476	4301	0	-	9090	5983
1992	1638	1654	9624	7565	0	-	11262	9219
1993	1357	1512	11707	9180	1791	-	14855	10692
1994	3203	3267	10978	11050	1910	-	16091	14317
1995	5924	5951	10914	11050	70	-	16908	17001
1996	6124	6346	10923	11050	179	-	17226	17396
1997	7696	7797	21018	23100	485	-	29199	30897
1998	12294	12399	46337	46200	626	-	59257	58599
1999	10293	10424	51202	58632	795	-	62290	69056
2000	9599	9990	63224	61632	5057	6000	77880	77622
2001	10677	10807	52590	61632	5676	6000	68943	78439
2002	10687	10660	60384	61632	5894	6000	76965	78292
2003/04	20574	22389	71227	85575	11922	14200	103723	122164
2004/05	9682	9392	77776	77932	12767	14199	100225	101523
2005/06	7996	8139	74728	77932	14283	14200	97007	100271

Year	SFA 5 South*		SFA 6		SFA 7		SSAR (aggregated)	
	Catch (t)	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*	*Catch (t)*	*TAC (t)*
2006/07	7527	7757	75673	77932	22616	24029	105816	109718
2007/08	9083	8904	80725	77932	22555	24029	112363	110865
2008/09	10130	11512	74505	85725	26097	27306	110732	124543
2009/10	12264	11387	45527	85725	27236	32767	85027	129879
2010/11	6448	6993	61501	61632	19745	32767	87694	101392
2011/12	10276	9448	59608	52387	13013	20971	82897	82806
2012/13	9504	9010	58327	60245	10099	13108	77930	82363
2013/14	6669	7020	58834	60245	7919	9393	73422	76658
2014/15	3305	3166	46340	48196	2282	4697	51927	56059
2015/16	4578	4985	48722	48196	0	0	53300	53181
2016/17	1876	2169	25143	27825	0	0	27019	29994
2017/18	6517	5409	10065	10400	0	0	16582	15809
2018/19	1917	2138	8702	8730	0	0	10619	10868
2019/20	4106	3845	8638	8961	0	0	12744	12806
2020/21	3569	3806	6267	8290	0	0	9836	12096
2021/22	2699	4038	9554	9535	0	0	12253	13573
2022/23	3176	2755	8405	9430	0	0	11581	12185
2023/24	1780	1785	7534	9430	0	0	9314	11215
2024/25	1649	1638	5531	8909	0	0	7180	10547

*Table 14. SSAR Standardized LV CPUE for Northern Shrimp over the 1988–2024/25 period. Data from 2003 to present were converted to management year. Catch per assessment region is calculated from the catch taken from the AQMS and proportion of catch reported in the observer data (LV) such that 2024/25 catch, CPUE, and calculated effort (indicated with *) are preliminary.*

Management Year	Fleet Catch (t)	CPUE (kg/hour) Lower CI	CPUE (kg/hour)	CPUE (kg/hour) Upper CI	Calculated Effort (hours)
1988	14419	24.6	447.1	2393.2	32250
1989	10073	34.3	427.5	1942.7	23563
1990	9080	11.5	334.2	1416.3	27169
1991	9067	28.6	365.4	1229.2	24814
1992	11266	39.7	859.9	3289.7	13102
1993	13079	76.2	923.5	3922.5	14162
1994	14203	168.4	893.5	2724.9	15896
1995	16854	210.5	1355.7	3844.8	12432
1996	17051	180.0	1667.3	5208.6	10227
1997	22658	236.8	1803.0	5119.7	12567
1998	28273	272.0	1911.0	5901.7	14795
1999	27841	116.3	1743.1	4948.4	15972
2000	29294	415.4	2521.3	7135.8	11619
2001	30467	524.1	2316.6	6372.2	13152
2002	31027	368.4	1977.3	5470.3	15692
2003/04	49864	464.9	1922.6	4902.4	25936
2004/05	32667	284.8	1813.0	4305.1	18018
2005/06	32828	782.9	2321.8	5335.9	14139
2006/07	32377	679.1	2096.9	4853.4	15440
2007/08	36569	583.6	2200.4	4937.6	16619
2008/09	26832	775.9	2149.9	4993.8	12481
2009/10	30897	220.4	1367.6	3533.5	22592
2010/11	26497	285.8	1637.0	4063.7	16186
2011/12	35751	184.2	1257.3	3228.6	28435
2012/13	28512	229.5	1760.8	4688.5	16193
2013/14	26712	147.5	1413.5	4442.6	18898
2014/15	17013	123.5	1442.1	5003.7	11797
2015/16	21922	75.9	965.8	3369.2	22698
2016/17	9389	58.3	862.3	2923.8	10888
2017/18	9762	19.3	565.6	2275.2	17260
2018/19	4583	29.0	569.3	2368.8	8050
2019/20	6810	47.3	416.8	1528.7	16339

Management Year	Fleet Catch (t)	CPUE (kg/hour) Lower CI	CPUE (kg/hour)	CPUE (kg/hour) Upper CI	Calculated Effort (hours)
2020/21	6283	85.7	592.0	2464.8	10613
2021/22	5502	69.5	863.8	3425.5	6370
2022/23	6143	67.1	547.4	2206.1	11222
2023/24	4700	45.8	487.8	1965.3	9635
2024/25	131*	46.8*	409.7*	2058.8*	320*

*Table 15. SSAR Standardized SV CPUE for Northern Shrimp over the 1989–2024/25 period. Data from 2003 to present were converted to management year. Catch per assessment region is calculated from the catch taken from the AQMS and proportion of catch reported in the NL logbook data (SV) such that 2024/25 catch, CPUE, and calculated effort (indicated with *) are preliminary.*

Management Year	Fleet Catch (t)	CPUE (kg/hour) Lower CI	CPUE (kg/hour)	CPUE (kg/hour) Upper CI	Calculated Effort (hours)
1997	6064	401.9	569.9	808.0	10640
1998	30235	345.2	488.9	692.4	61843
1999	33708	278.3	392.6	553.9	85858
2000	43503	257.6	363.3	512.5	119744
2001	32800	260.7	367.6	518.4	89227
2002	40049	273.9	386.2	544.5	103700
2003/04	42193	268.8	379.0	534.5	111327
2004/05	53899	292.7	413.1	583.1	130474
2005/06	50314	299.4	422.8	596.8	119002
2006/07	50837	203.6	287.6	406.3	176763
2007/08	53239	155.5	220.3	312.2	241666
2008/09	57785	144.8	205.3	291.0	281466
2009/10	26894	147.6	209.3	296.7	128495
2010/11	41452	147.4	209.8	298.6	197579
2011/12	43883	202.5	287.5	408.3	152637
2012/13	47292	257.4	366.9	523.2	128896
2013/14	44919	159.7	226.9	322.5	197968
2014/15	34401	169.7	241.1	342.6	142684
2015/16	31378	252.7	360.3	513.8	87089
2016/17	17630	246.2	349.2	495.3	50487
2017/18	6819	260.8	369.1	522.3	18475
2018/19	6038	300.2	425.7	603.7	14184
2019/20	5933	257.6	364.4	515.3	16282
2020/21	3553	265.1	375.0	530.3	9475
2021/22	6750	350.0	495.3	700.8	13628
2022/23	5438	367.0	520.2	737.3	10454
2023/24	4614	401.3	568.6	805.8	8115
2024/25	5492*	401.9*	569.9*	808.0*	9637*

9. FIGURES

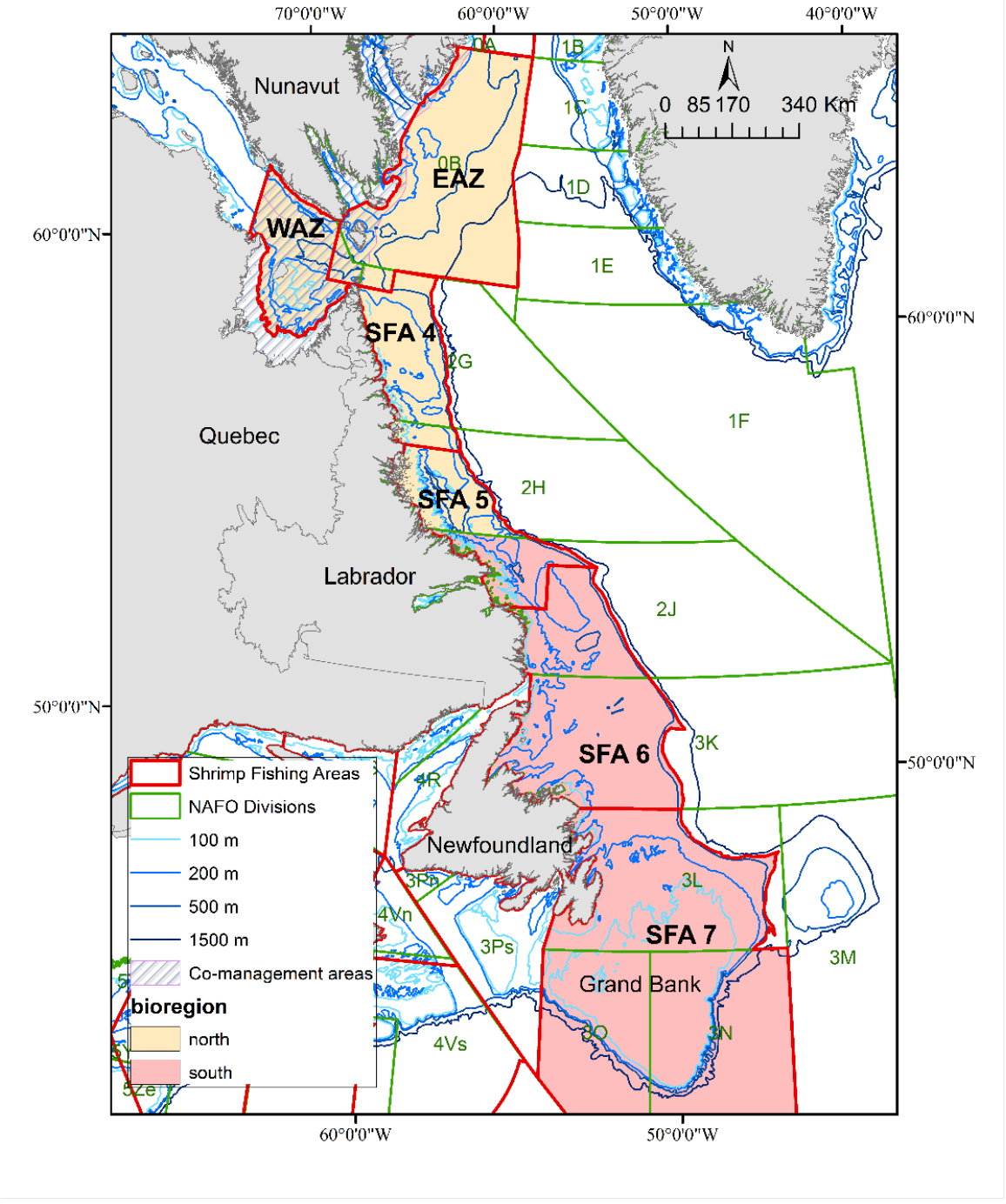


Figure 1. The north and south Northern Shrimp stock assessment regions (red/yellow shading), management areas (SFAs, EAZ, and WAZ), and NAFO divisions. The border between NAFO divisions 2H and 2J defines the boundary between the north and south stock assessment regions.

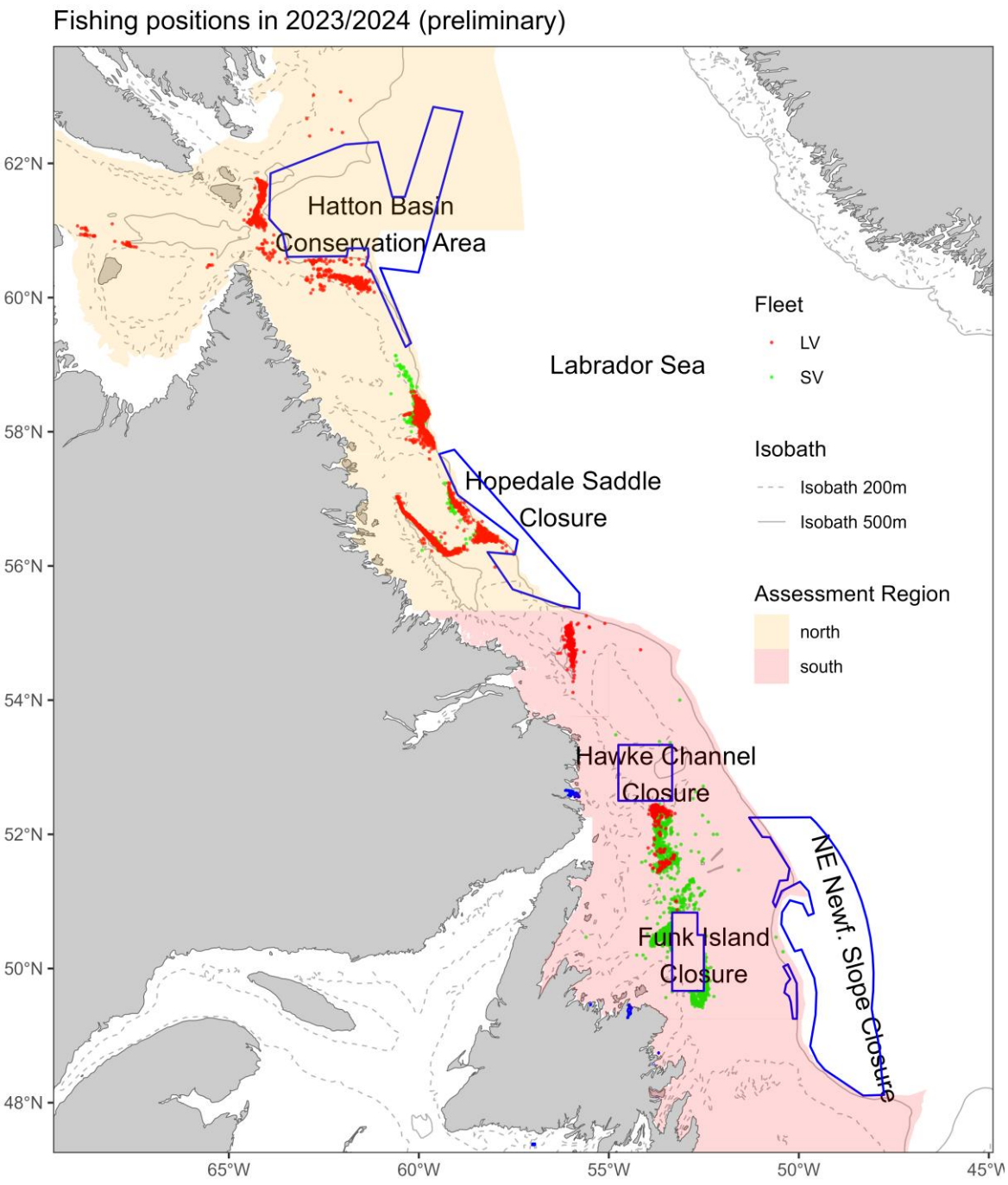


Figure 2. Preliminary Northern Shrimp fishing positions directing for Northern Shrimp for 2023/24. Red dots indicate fishing positions of large vessels and green dots indicate fishing positions of small vessels. Hatton Basin Conservation Area, Hopedale Saddle, Hawke Channel, Northeast Newfoundland Slope Closure, Funk Island, and inshore closures (i.e., blue areas along the coast) are represented with blue lines, indicating areas where fishing is prohibited. Large vessels positions were taken from preliminary observer data and small vessels from preliminary logbook data.

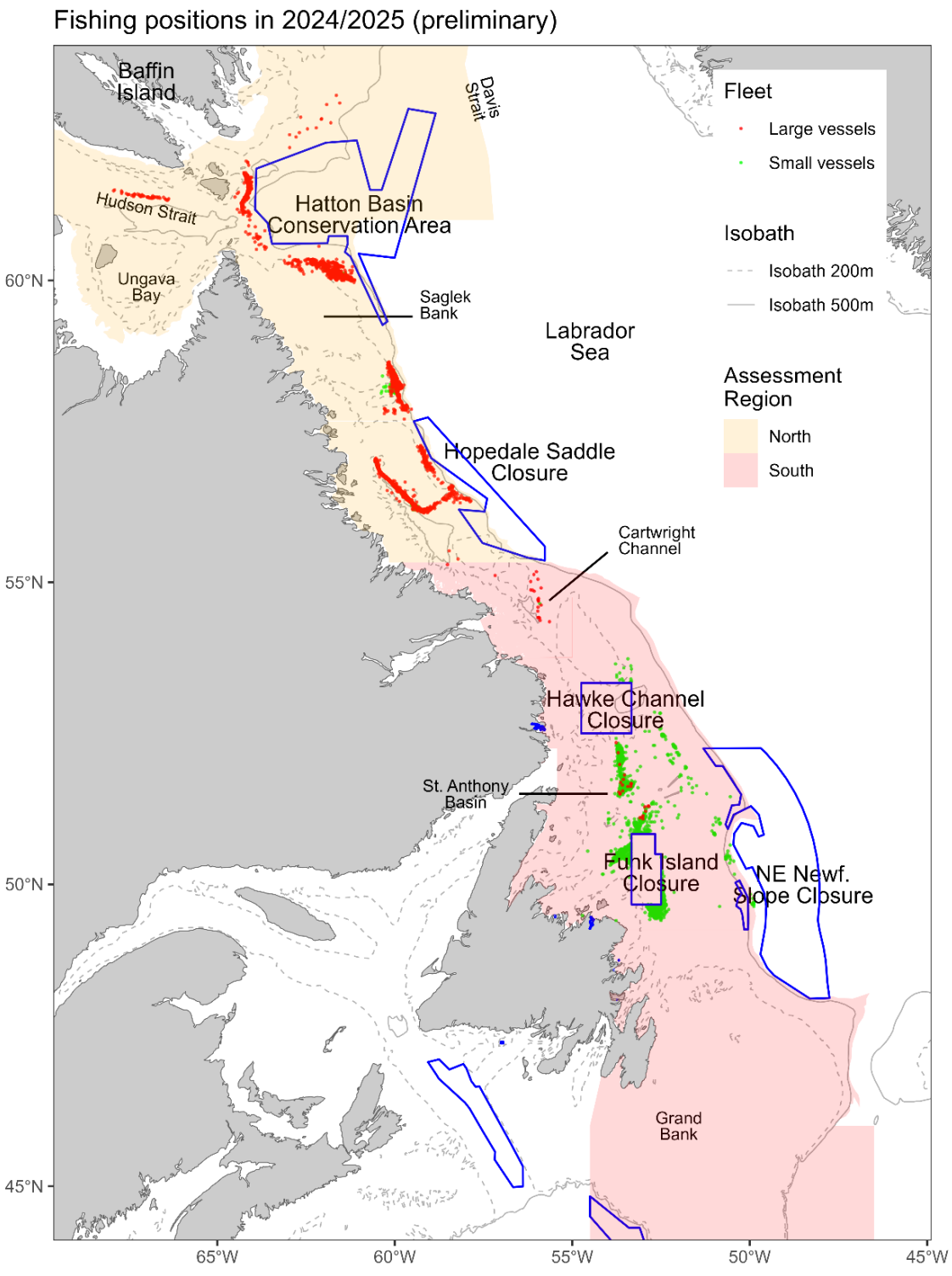


Figure 3. Preliminary Northern Shrimp fishing positions directing for Northern Shrimp for 2024/25. Red dots indicate fishing positions of large vessels and green dots indicate fishing positions of small vessels. Hatton Basin Conservation Area, Hopedale Saddle, Hawke Channel, Northeast Newfoundland Slope Closure and Funk Island Closures are represented with blue lines, indicating areas where fishing is prohibited. Large vessels positions were taken from preliminary observer data and small vessels from preliminary logbook data.

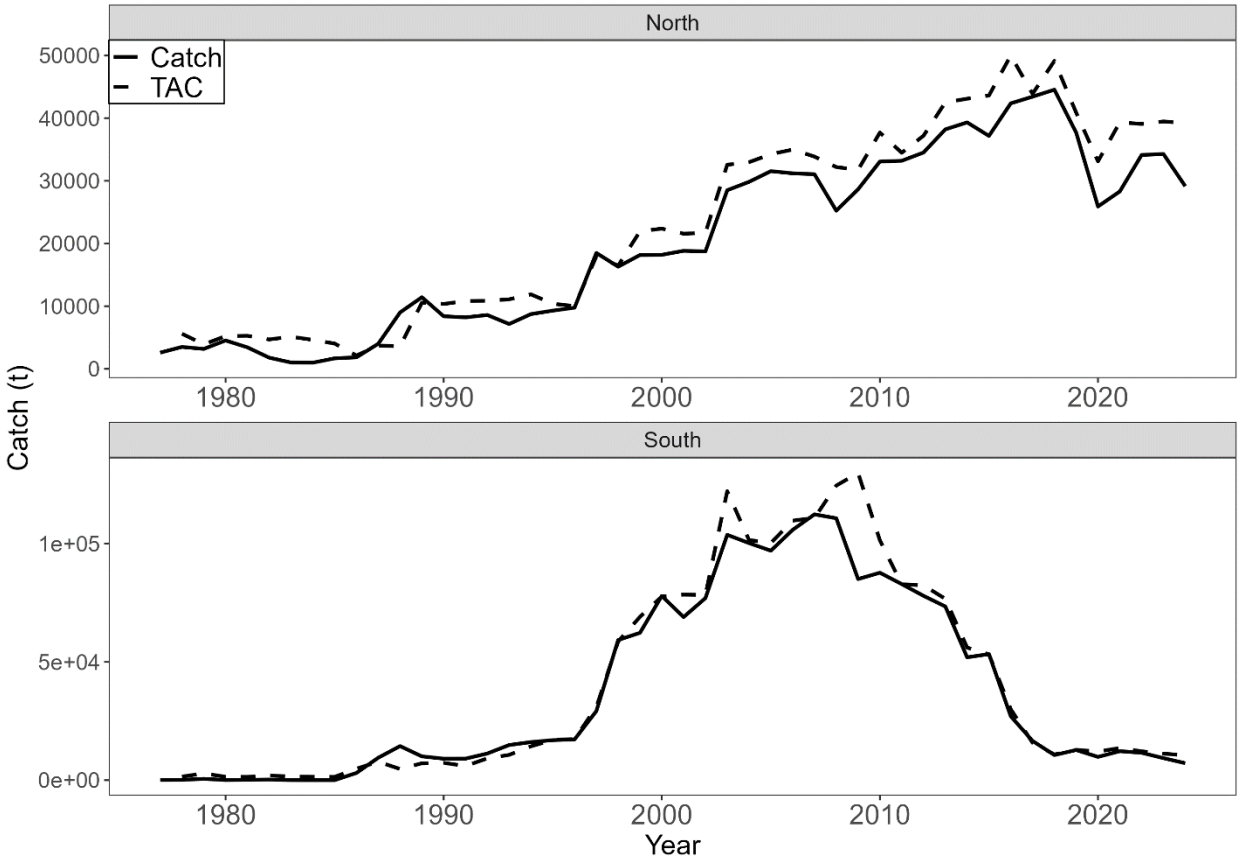


Figure 4. Historical Northern Shrimp aggregated TACs and commercial catch for 1977–2024/25 in the north (top panel) and south (bottom panel) stock assessment regions. Catches are from the AQMS and are preliminary for 2024–25. In 2003, the management year was switched from a calendar year to a management year such that 2003/04 represents a 15-month-long fishing season. In SFA 5, catches and quotas were split based on the amount of shrimp reported by at-sea-observers.

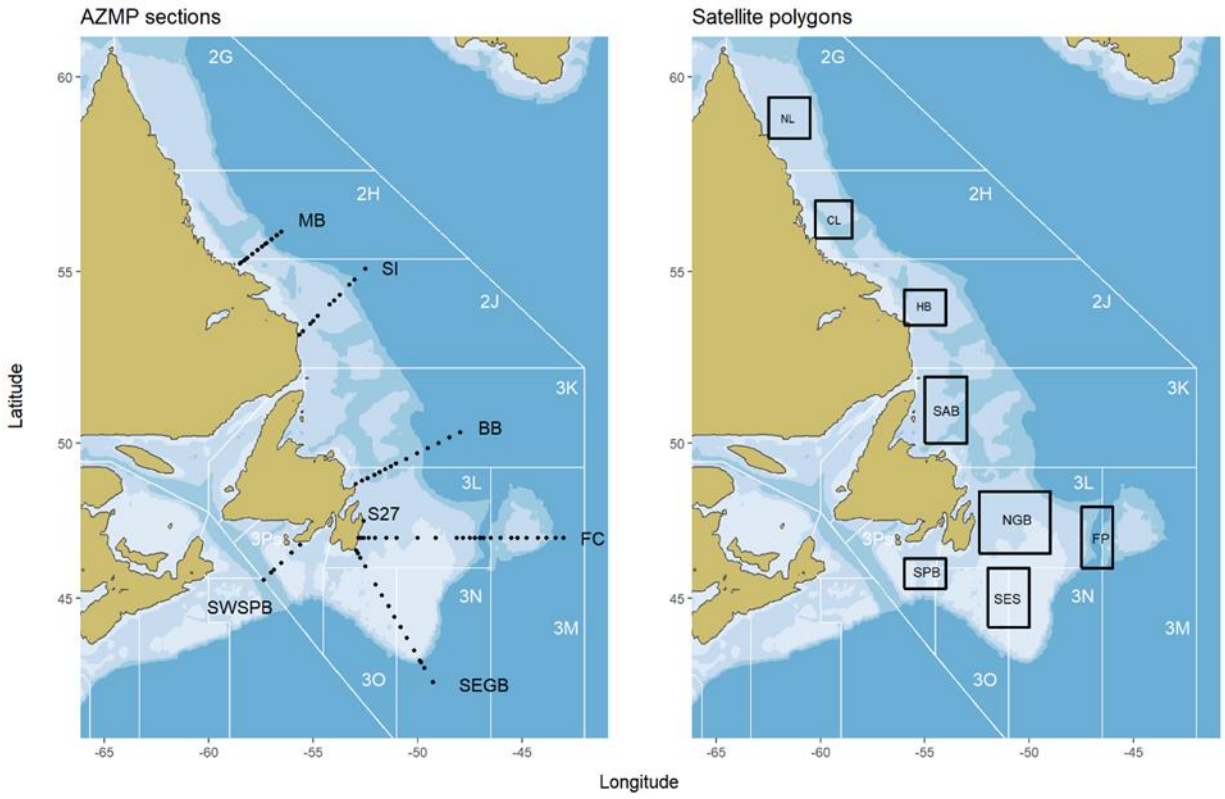


Figure 5. Left: Location of standard oceanographic sections Beachy Island (BI), Makkovik Bank (MB), Seal Island (SI), Bonavista Bay (BB), and Flemish Cap (FC) and high frequency sampling site Station 27 (S27) where nutrient, chlorophyll a, and zooplankton data were collected during seasonal AZMP surveys. Right: Polygons of Northern Labrador (NL), Central Labrador (CL), Hamilton Bank (HB), St. Anthony Basin (SAB), Northern Grand Bank (NGB), Saint-Pierre Bank (SPB), Southeast Shoal (SES), and Flemish Pass (FP) for which the spring bloom timing metric was calculated using satellite ocean colour observations.

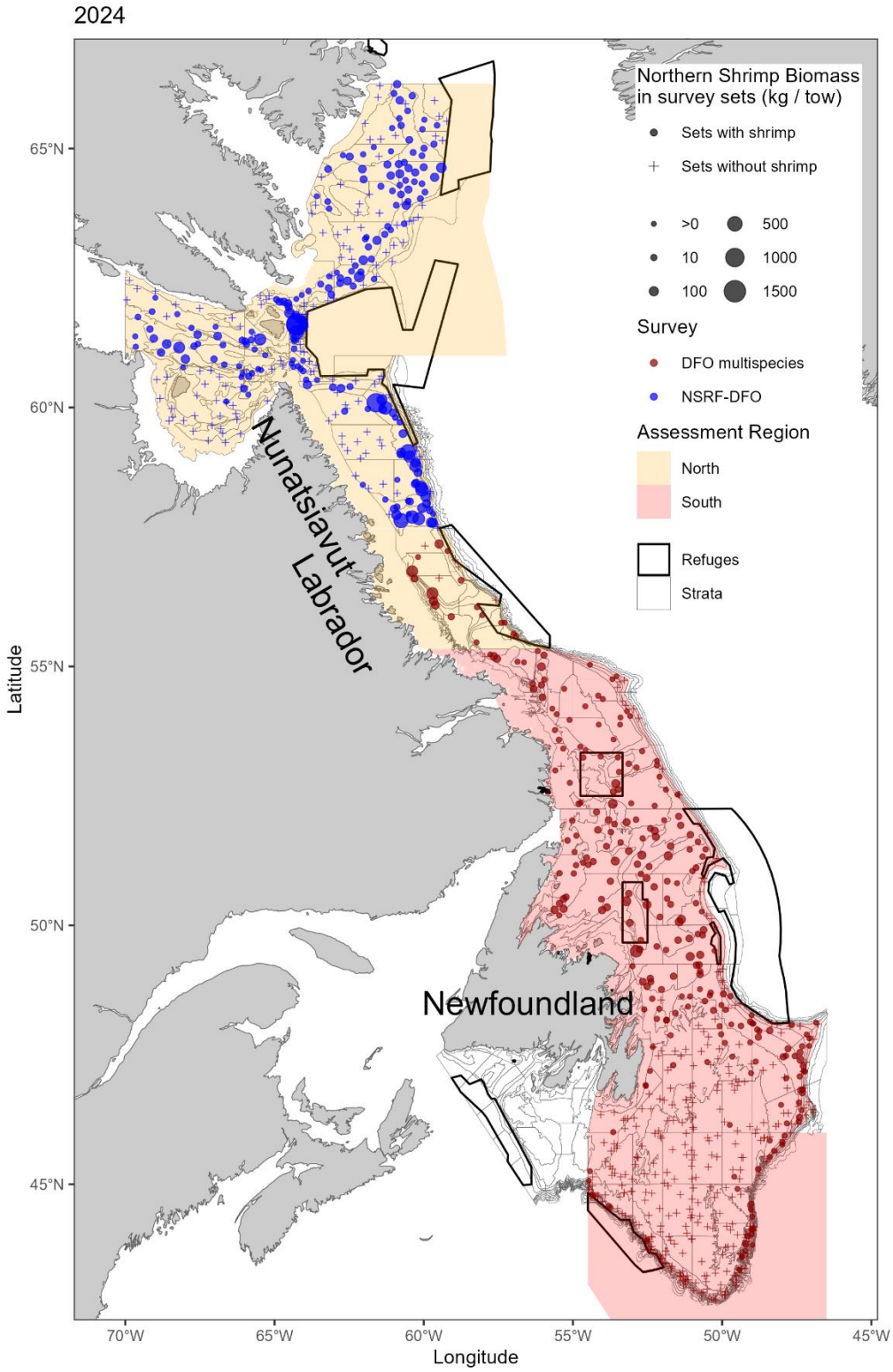


Figure 6. Positions occupied by the DFO fall multispecies survey (red circles) and the NSRF shrimp survey (blue circles) in 2024. Circle sizes are scaled to size of Northern Shrimp catch (kg / tow – see legend). Crosses (+) indicate DFO multispecies (red) and NSRF (blue) survey sets with no Northern Shrimp caught. Solid black lines indicate Marine Refuges and light gray line indicate survey strata.

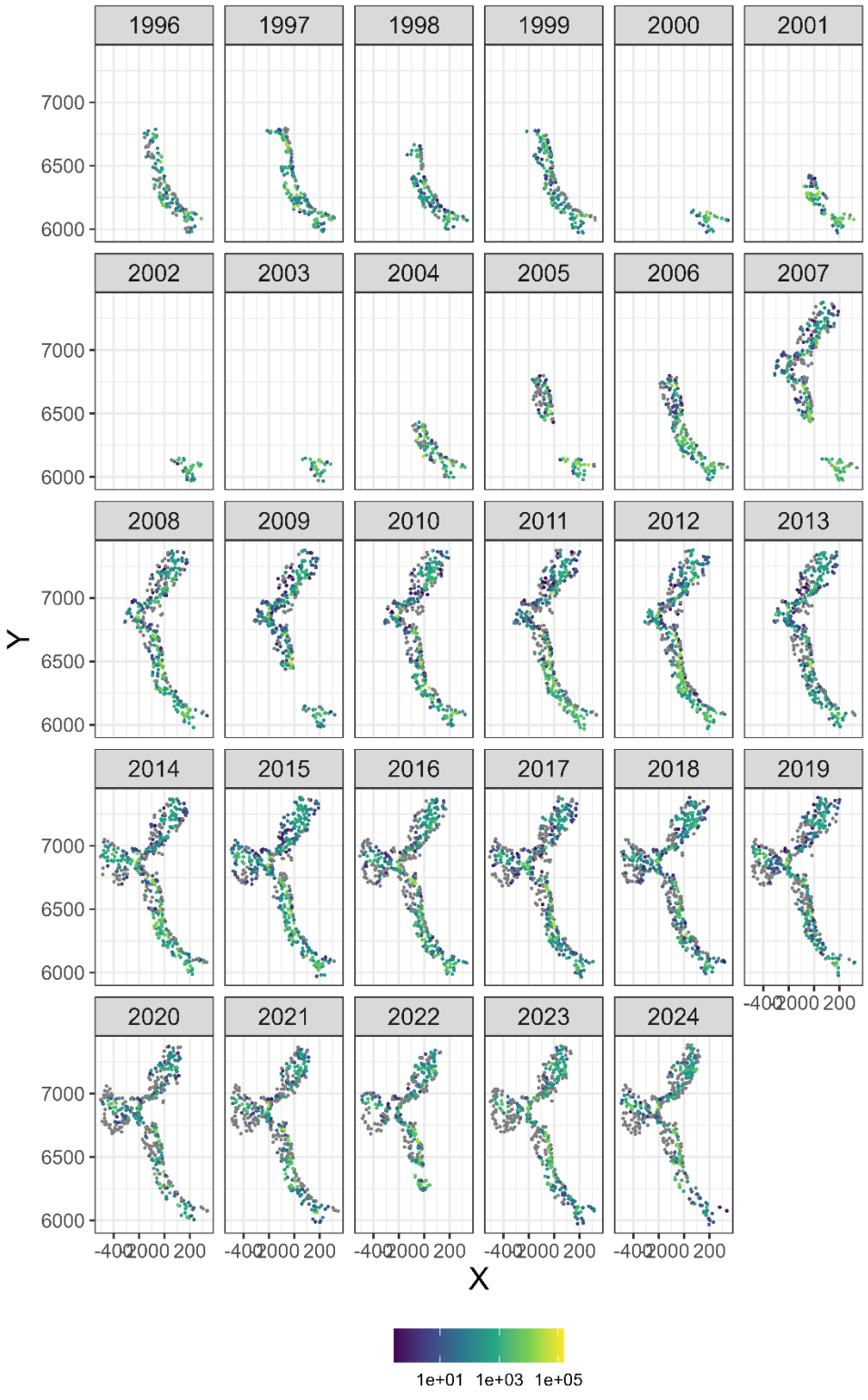


Figure 7. DFO and NSRF survey sets available in the north stock assessment region for spatiotemporal modeling of the annual total shrimp density index (unit: kg·km^{-2} in log scale to improve visibility) over the time series (1996–2024). X and Y are longitude and latitude projected in UTM Zone 22N (km).

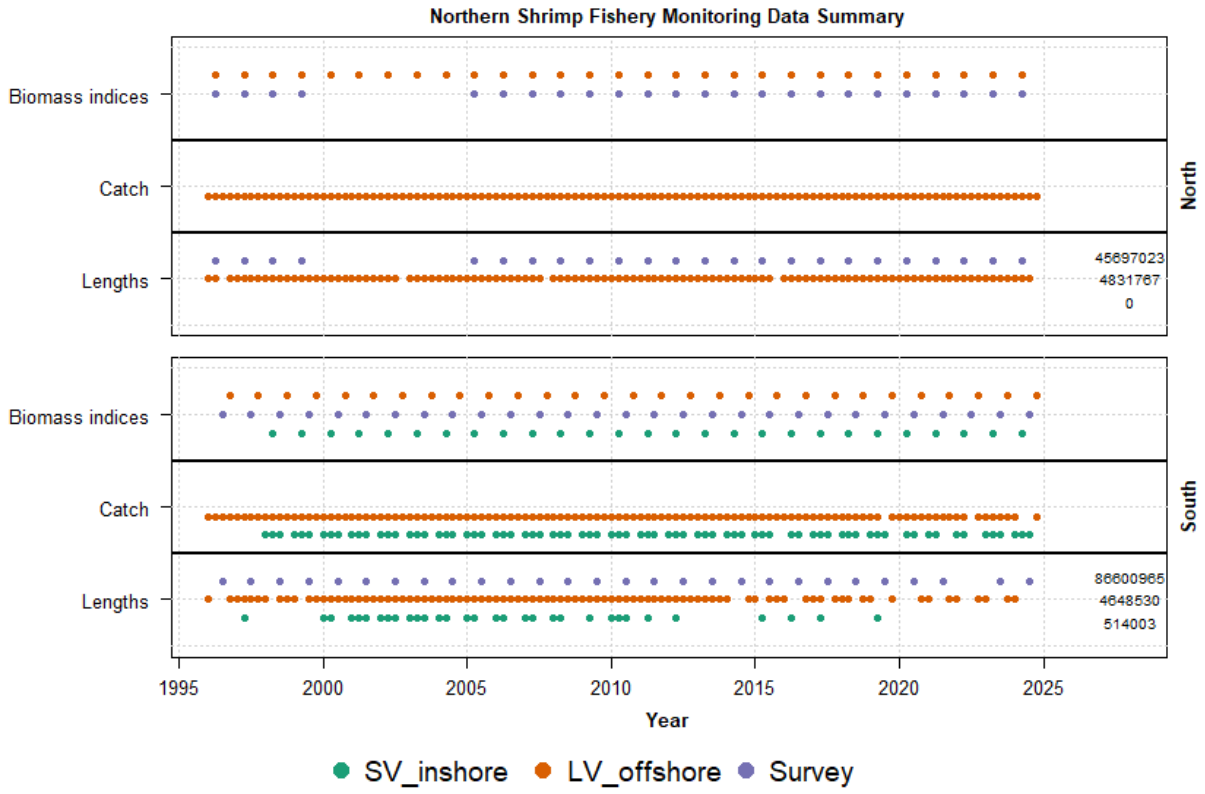


Figure 8. Summary of data available after 1996 for stock assessment of the Northern Shrimp fishery in each Stock assessment region. Closed circles are plotted by model season, and indicate that fishery monitoring data for the labeled source exists in the associated season. Length composition sample sizes are shown on the right-hand side and, for the survey fleet, correspond to raised sample sizes (i.e., numbers-at-length scaled to the total catch).

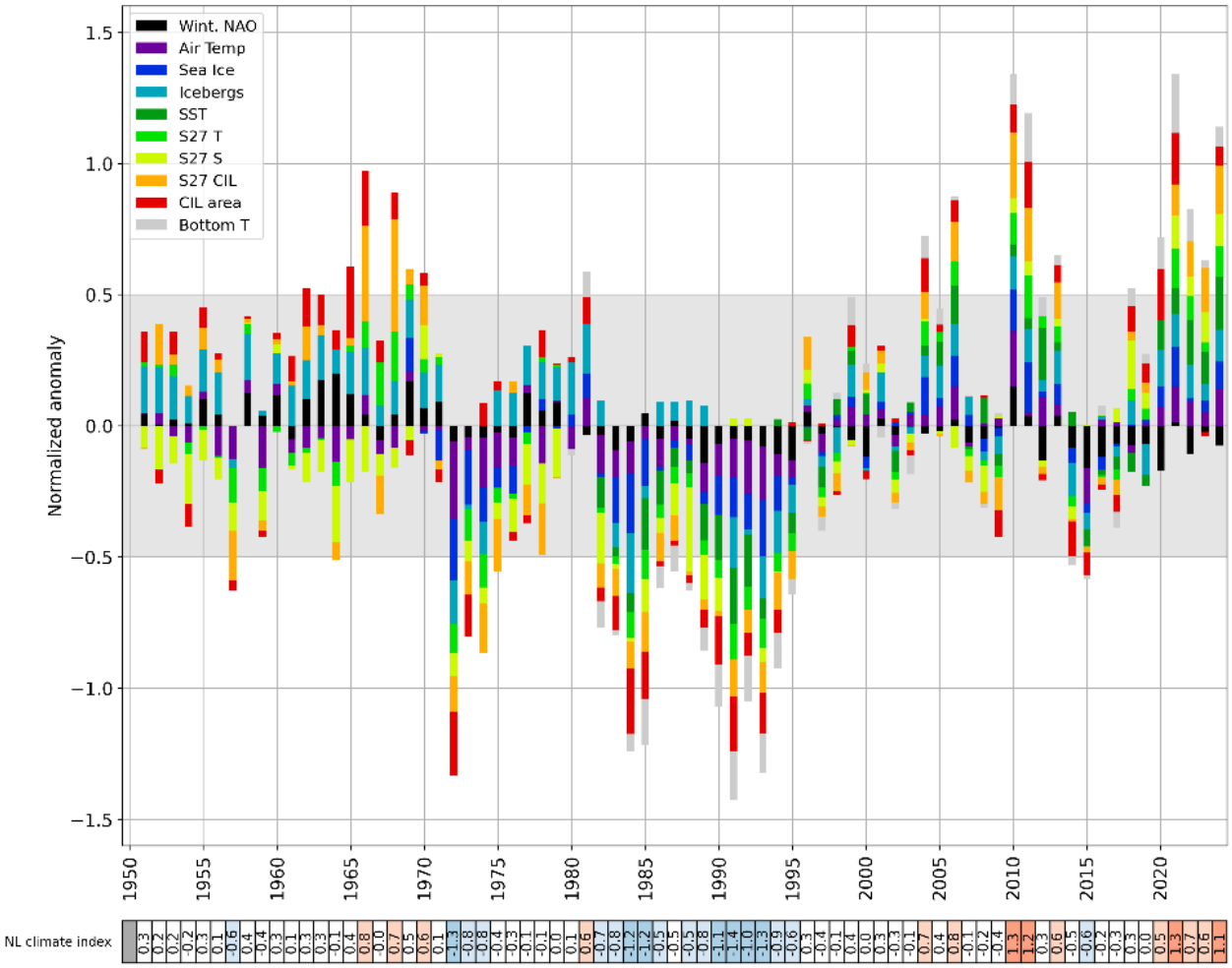


Figure 9. Newfoundland and Labrador Climate Index (Cyr and Galbraith 2021).This normalized index is made of the average of 10 sub-indices representing different aspects of the ocean climate (see legend). A positive index is generally indicative of a warmer climate, while a negative index is indicative of a colder climate. Values within the grayed area (±0.5 SD) are considered normal. The numerical values of this time series are reported in a colour-coded scorecard at the bottom of the figure. Positive anomalies (> 0.5 SD) are coloured red, while negative anomalies (SD) are coloured blue.

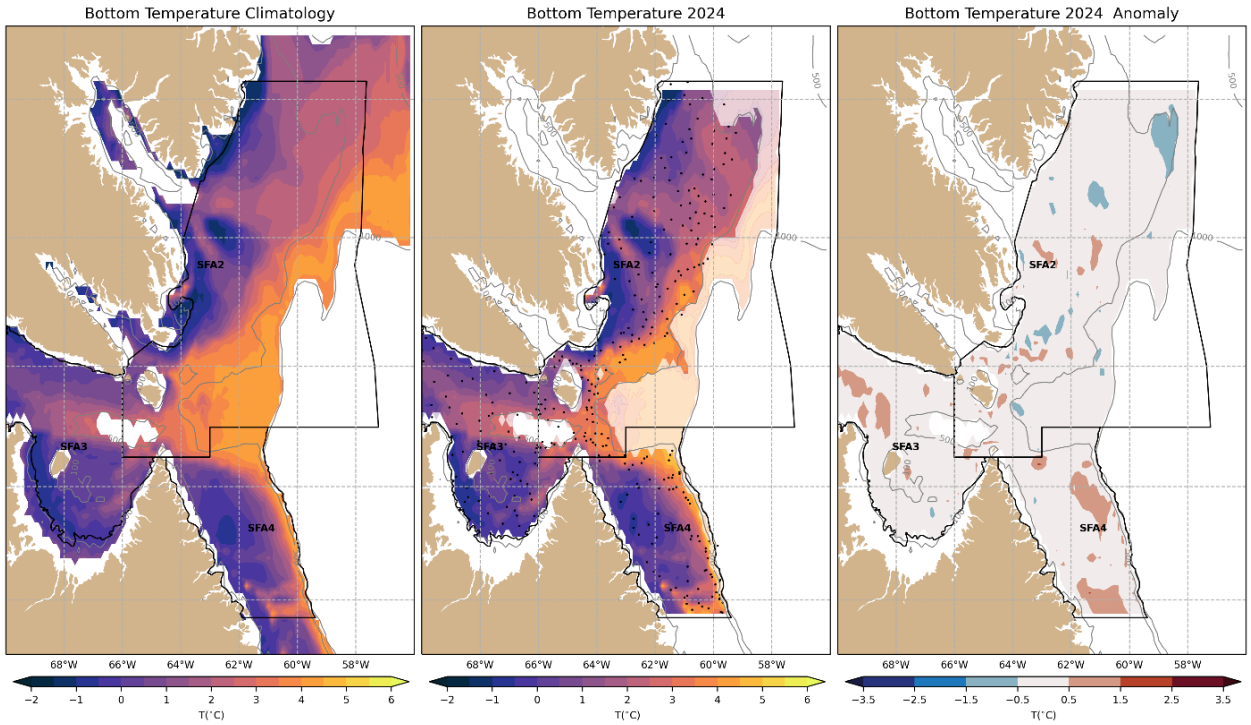


Figure 10. Maps of the climatological (1991–2020) mean summer bottom temperature (left), and summer 2024 bottom temperature (center) and anomalies (right) for NAFO 0A2G and Hudson Strait (formerly SFA 2–4). The location of observations used to derive the temperature field is shown as black dots in the center panel. When applicable, the portion of the shelf where missing bottom temperatures were filled in with the climatology and left semi-transparent (center panel).

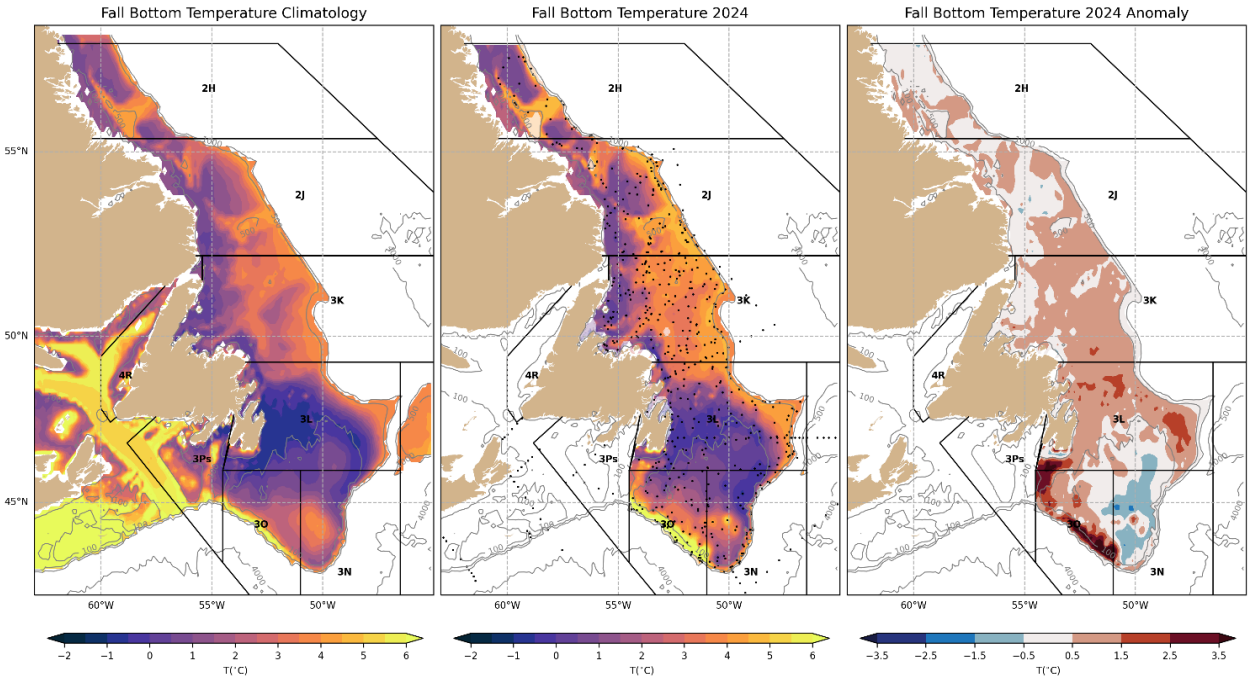


Figure 11. Maps of the climatological (1991–2020) mean fall bottom temperature (left), fall 2024 bottom temperature (center) and anomalies (right) for NAFO 2HJ3KLNO. The locations of observations used to derive the temperature field are shown as black dots on the center panel. When applicable, the portion of the shelf where missing bottom temperature were filled with the climatology are left semi-transparent (center panel).

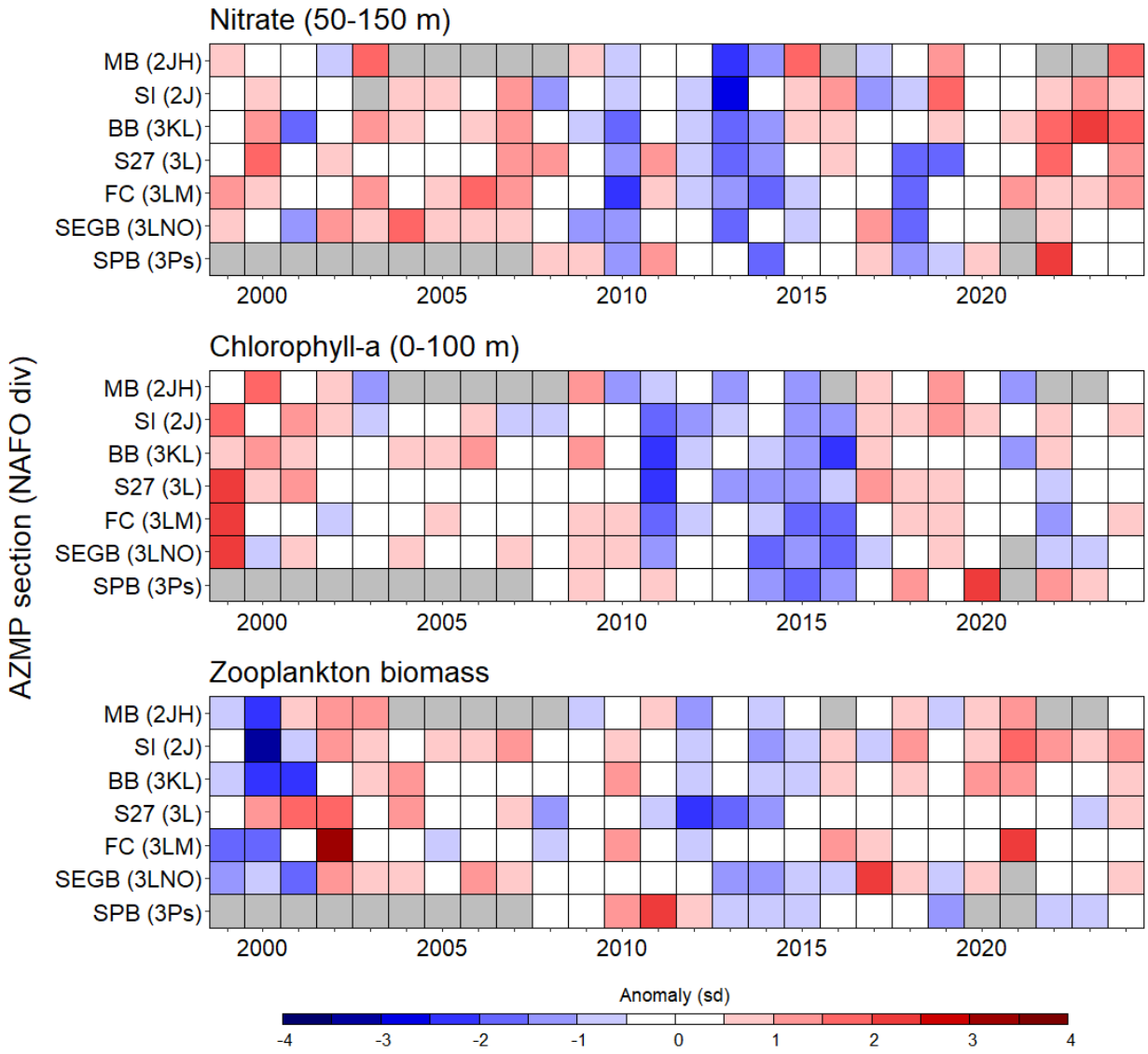


Figure 12. Anomaly scorecards of nitrate and chlorophyll a inventories, and total zooplankton biomass derived from AZMP seasonal surveys. Colour shades indicate deviation from long-term mean conditions in standard deviation (sd). White cells indicate near normal conditions (±0.5 sd). Red/blue cells indicate conditions above/below (top and middle) or later/earlier (bottom) than normal. Grey cells indicate missing data. See Figure 5 for locations of AZMP sections.

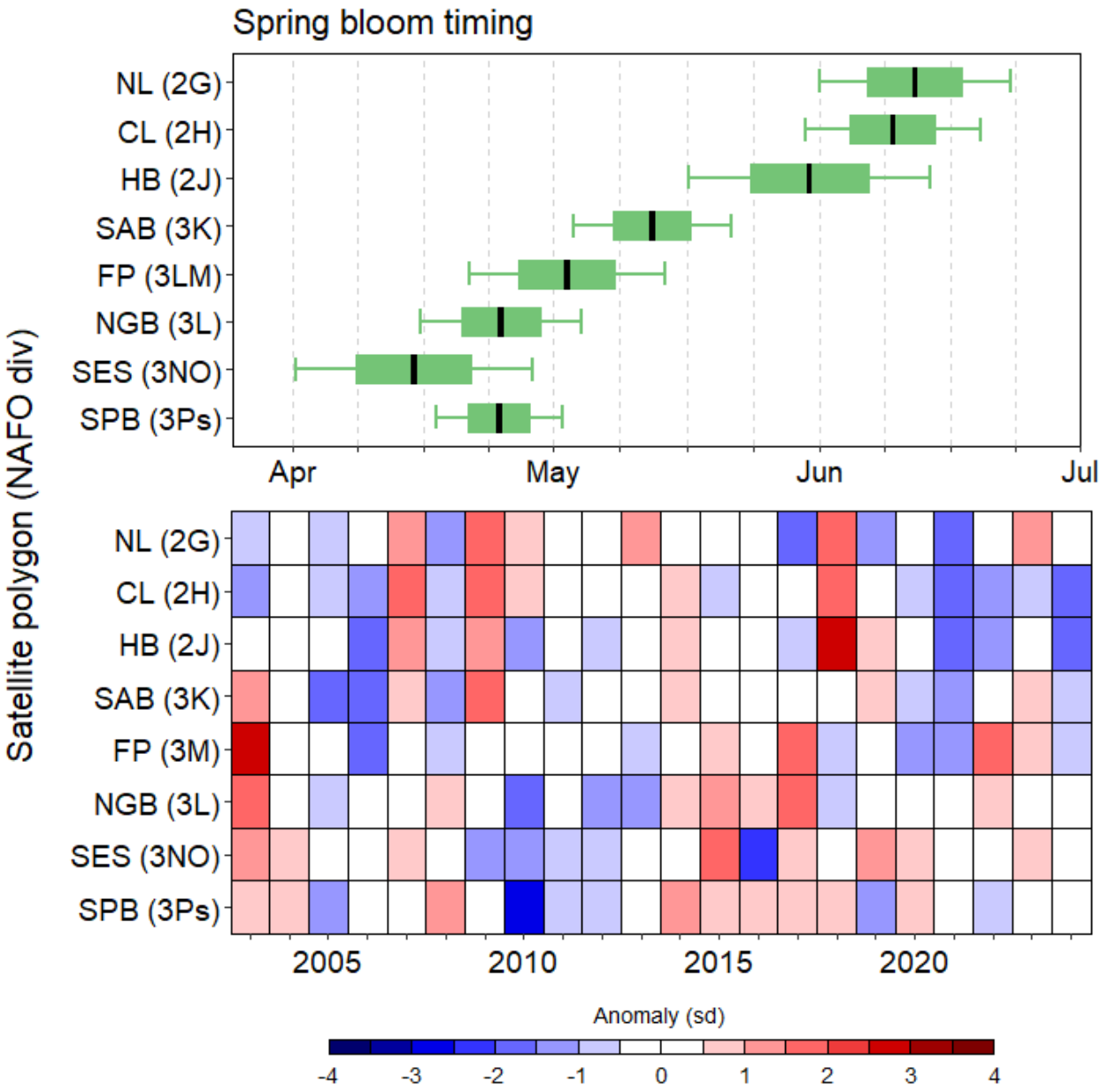


Figure 13.Timing of the spring phytoplankton bloom peak concentration. Boxplots (top) indicate the long-term mean bloom timing for the 2003–20 reference period with boxes and whiskers indicating 0.5 and 1 standard deviations (sd), respectively. The anomaly scorecard (bottom) shows interannual variability in bloom timing with colour shades indicating deviation from the reference period in standard deviation (sd). White cells indicate near normal conditions (±0.5 sd). Red/blue cells indicate conditions above/below normal. See Figure 5 for locations of satellite polygons.

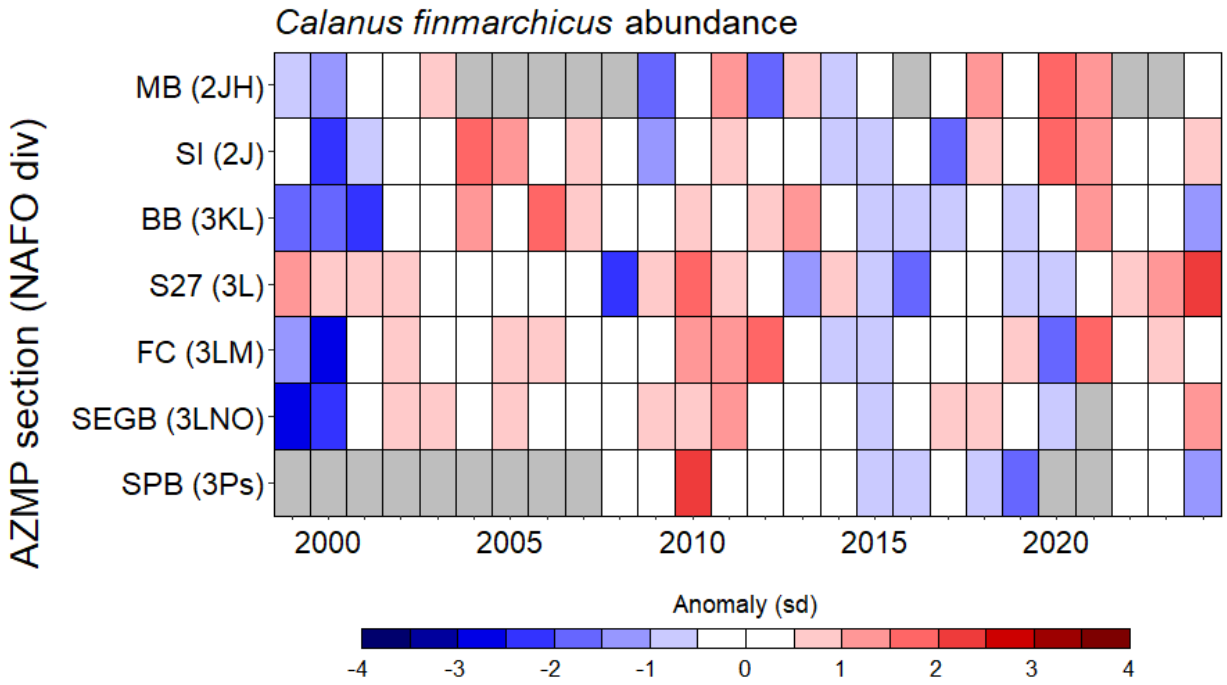


Figure 14. Anomaly scorecard for Calanus finmarchicus *abundance. Colour shades indicate deviation from the long-term (1999–2020) mean conditions in standard deviation (sd). White cells indicate near normal conditions (±0.5 sd), and red/blue cells indicate conditions above/below normal. Grey cells indicate missing data. See Figure 5 for location of AZMP sections.*

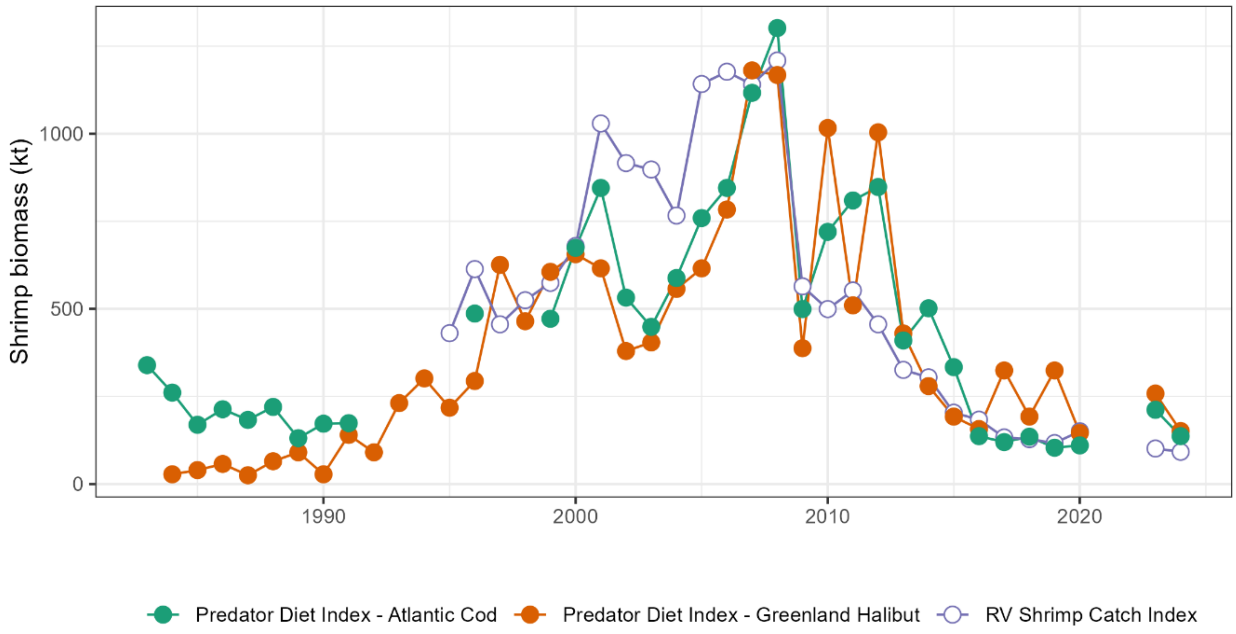


Figure 15. Predator diet index (solid circles) of shrimp biomass predicted from diets of Atlantic Cod (green) and Greenland Halibut (orange) compared to the RV Shrimp Catch Index (purple open circles) in the Fall of NAFO Div. 2J3KL.

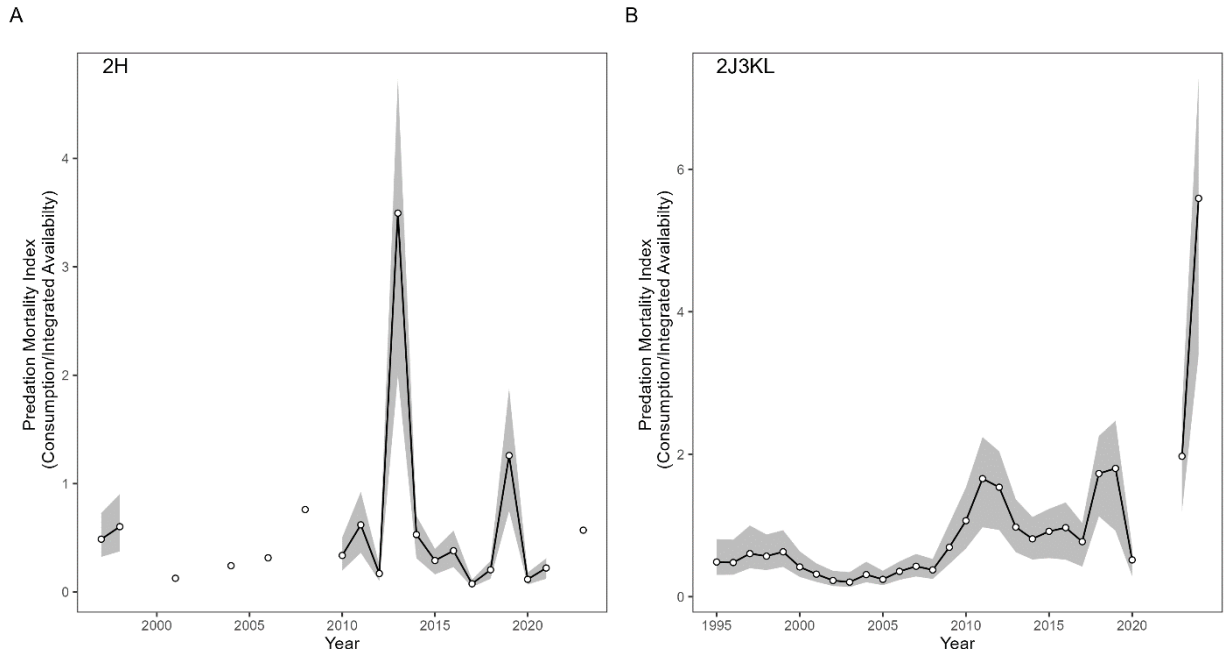


Figure 16. Predation mortality index for Northern Shrimp in NAFO Div. 2H (A) and 2J3KL (B). White dots are estimates based on median consumption of Northen Shrimp by fish predators and gray ribbon is the range based on minimum and maximum consumption.

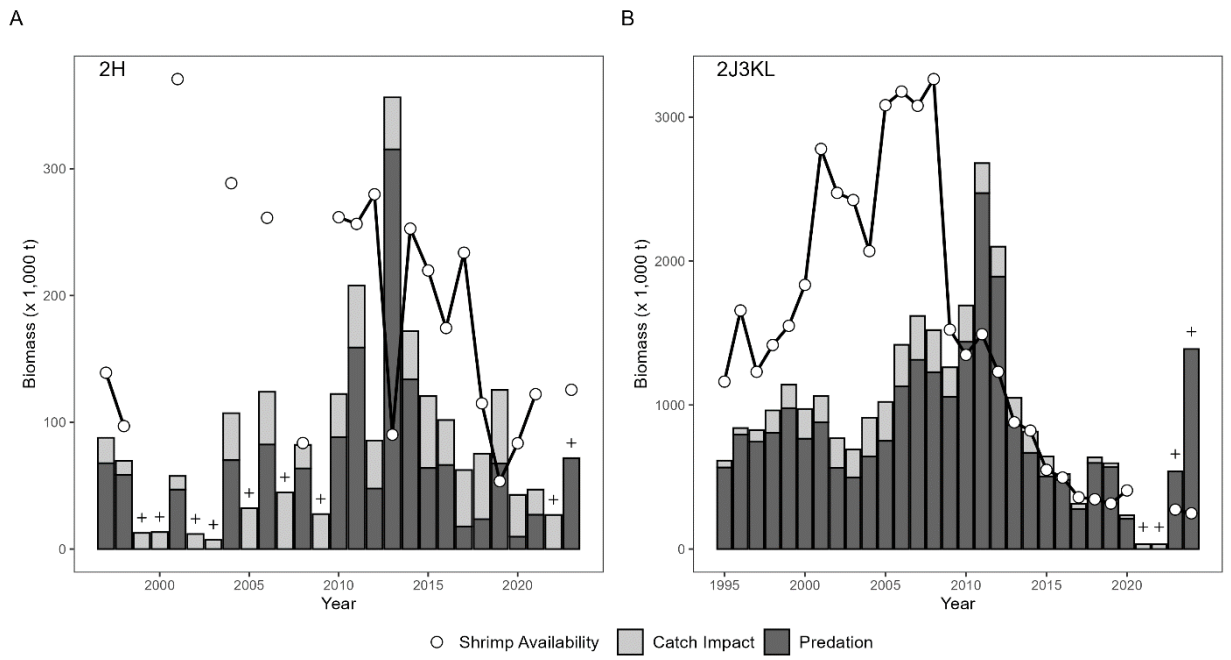


Figure 17. Evaluation of the potential impacts of predation and fishing in relation to Northern Shrimp availability in NAFO Div. 2H (A) and 2J3KL (B). Estimated magnitudes of predation (dark gray) and potential catch impacts (light gray) vs estimated Northen Shrimp availability (white points). The "+" marker indicates that either predation or potential catch impact estimates are missing that year.

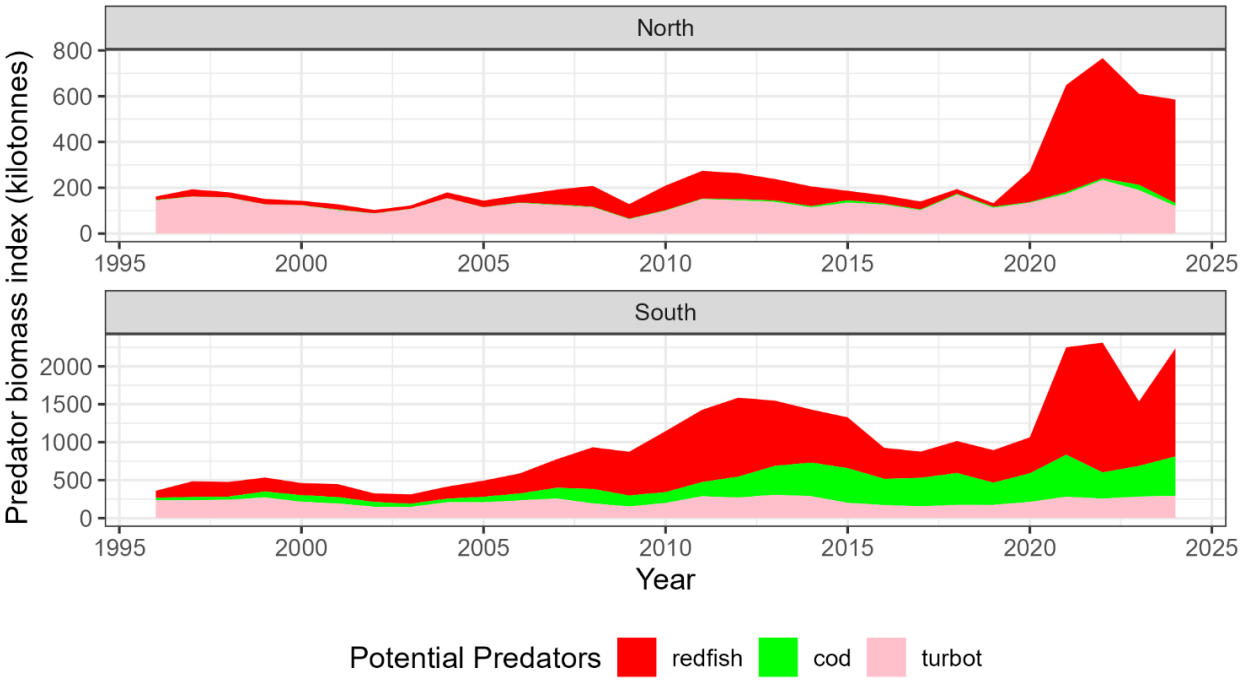


Figure 18. Modelled annual biomass indices (stacked shaded areas) of potential predator indices (kilotonnes) in the north (top panel) and south (bottom panel) stock assessment regions. Green area – annual Atlantic Cod biomass index, red area – annual Redfish biomass index, pink area – annual Turbot (Greenland halibut) biomass index.

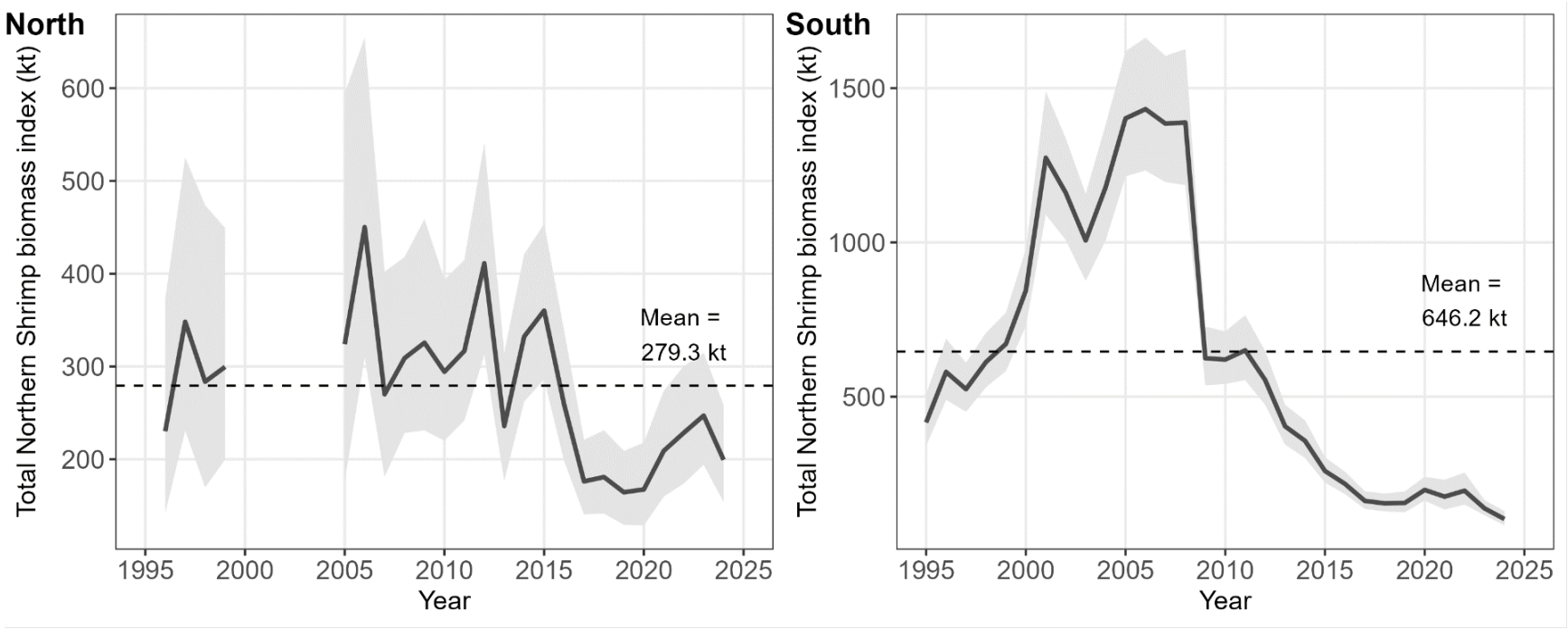


Figure 19. Total Northern Shrimp biomass indices (in kilotonnes) as derived by spatiotemporal modeling using shrimp survey data in the north (left) and south (right) stock assessment regions. Shaded areas indicate 95% confidence intervals. Horizontal dashed lines indicate the arithmetical mean over the survey time series (NSAR: 1996–2023, SSAR: 1995–2023).

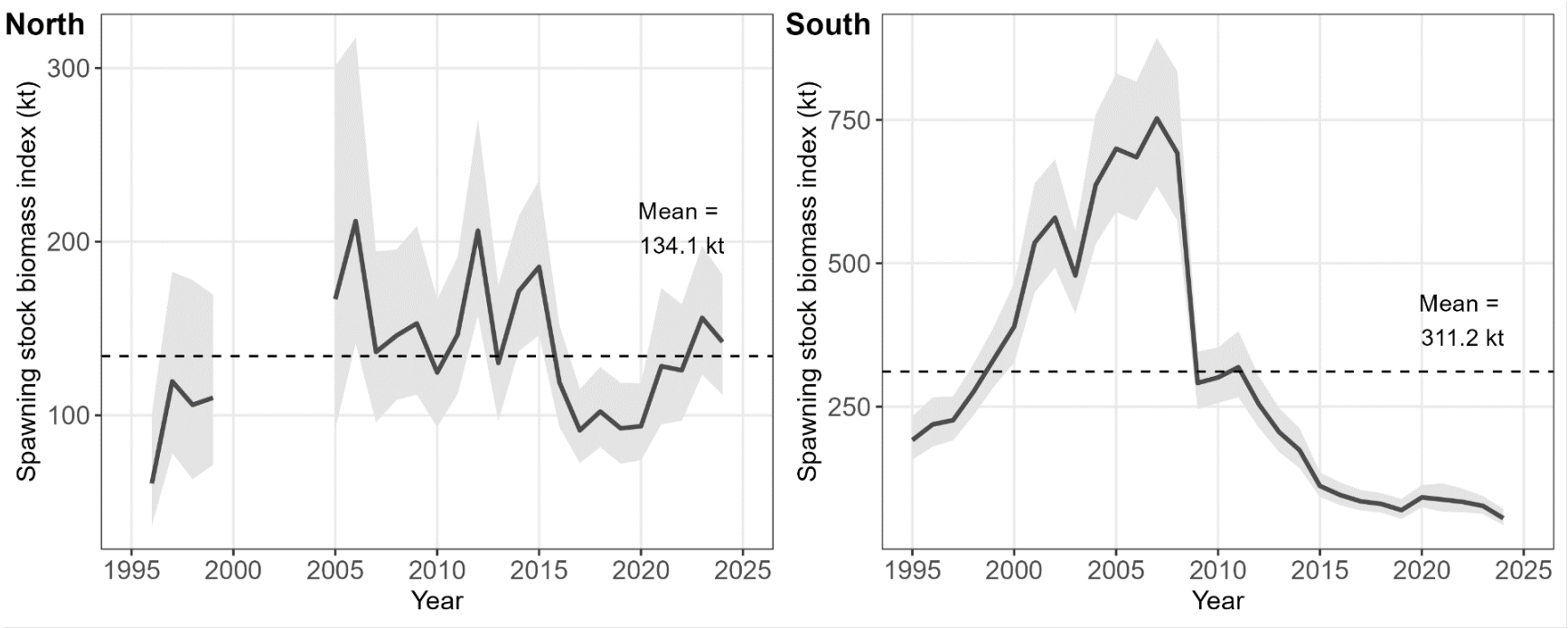


Figure 20. Spawning stock biomass indices of Northern Shrimp (in kilotonnes) as derived by spatiotemporal modeling using shrimp survey data in the north (left) and south (right) stock assessment regions. Shaded areas indicate 95% confidence intervals. Horizontal dashed lines indicate the arithmetical mean over the survey time series (NSAR: 1996–2023, SSAR: 1995–2023).

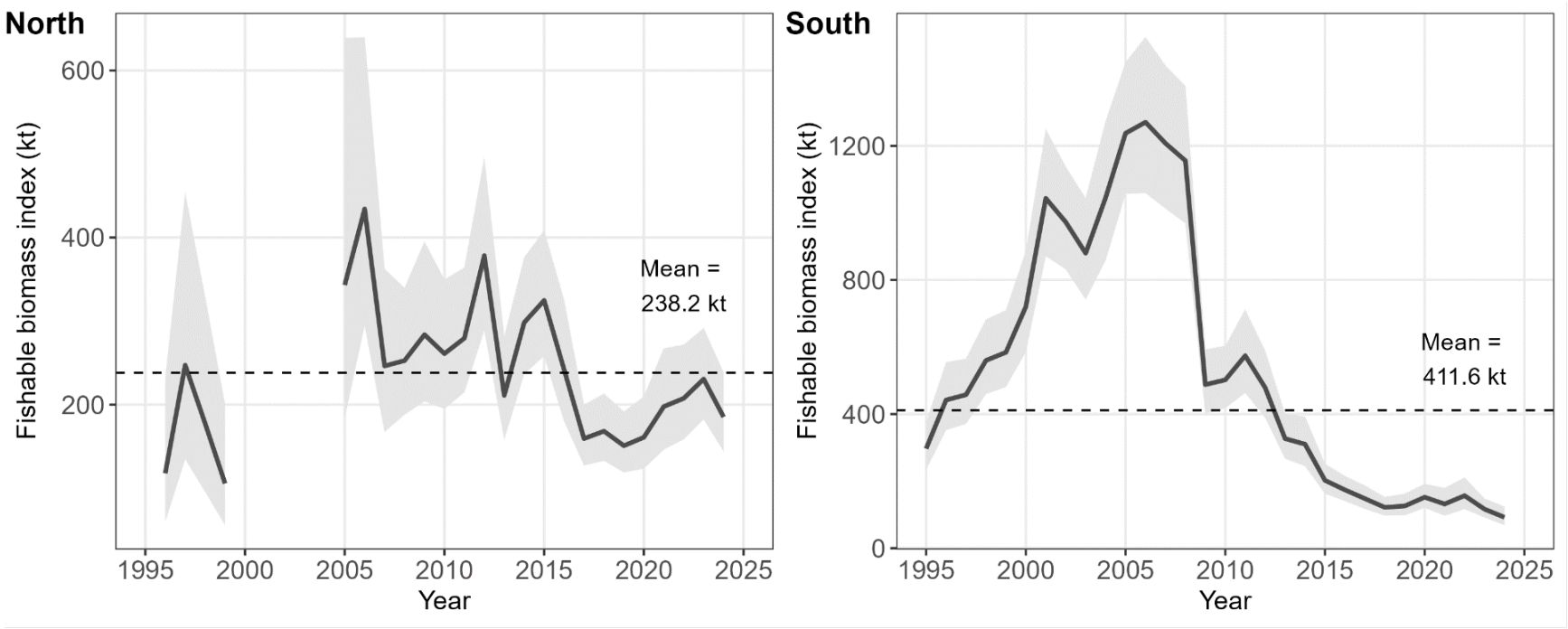


Figure 21. Fishable Northern Shrimp biomass indices (in kilotonnes) as derived by spatiotemporal modeling using shrimp survey data in the north (left) and south (right) stock assessment regions. Shaded areas indicate 95% confidence intervals. Horizontal dashed lines indicate the arithmetical mean over the survey time series (NSAR: 1996–2023, SSAR: 1995–2023).

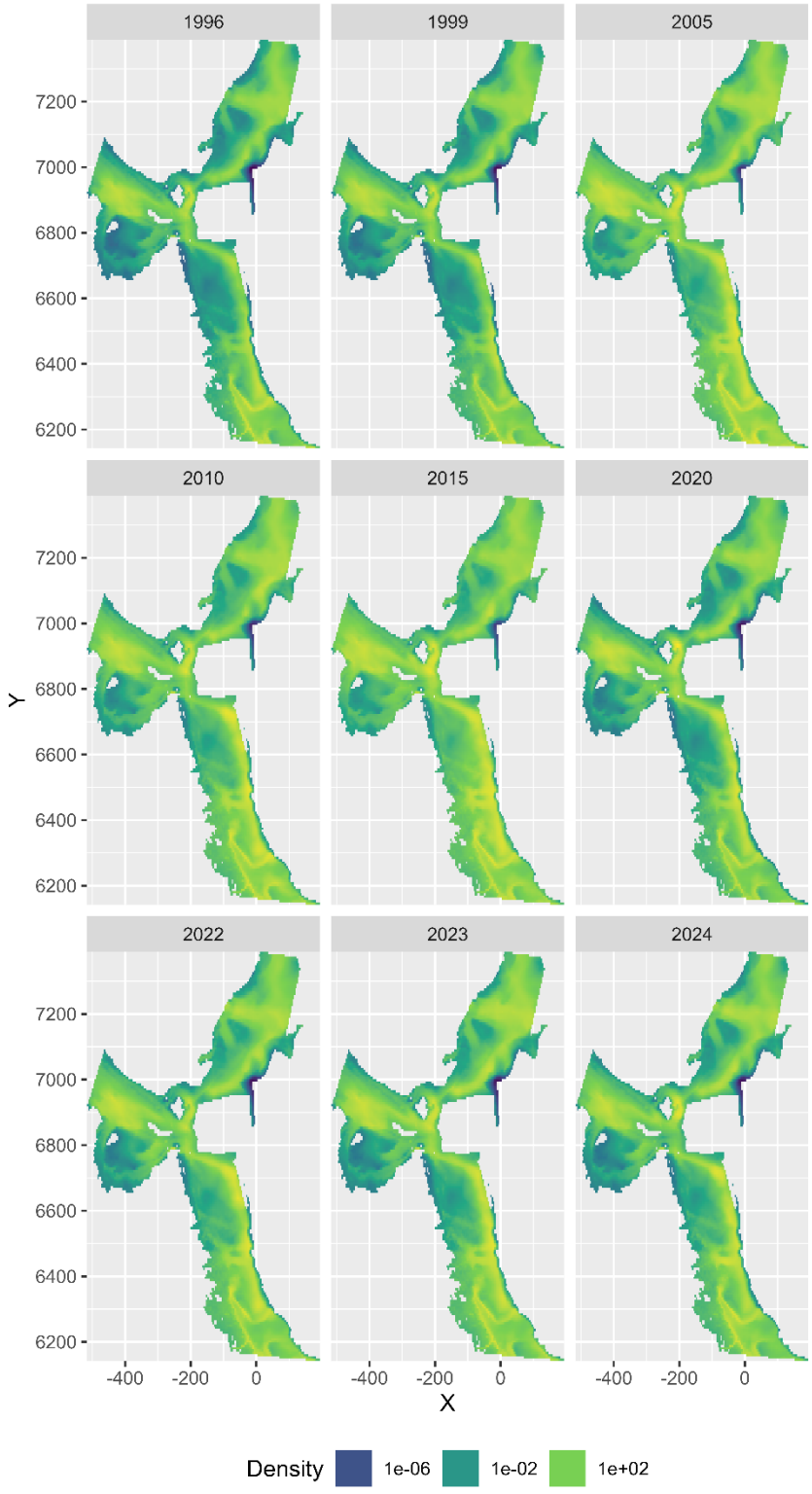


Figure 22. Density predictions (kg·km^{-2} in log scale to improve visibility) from the North stock assessment region (NSAR) Northern Shrimp fishable biomass spatiotemporal model every ~5 years, along with the data from the last three years of the time series. X and Y are longitude and latitude projected in UTM Zone 22N (km).

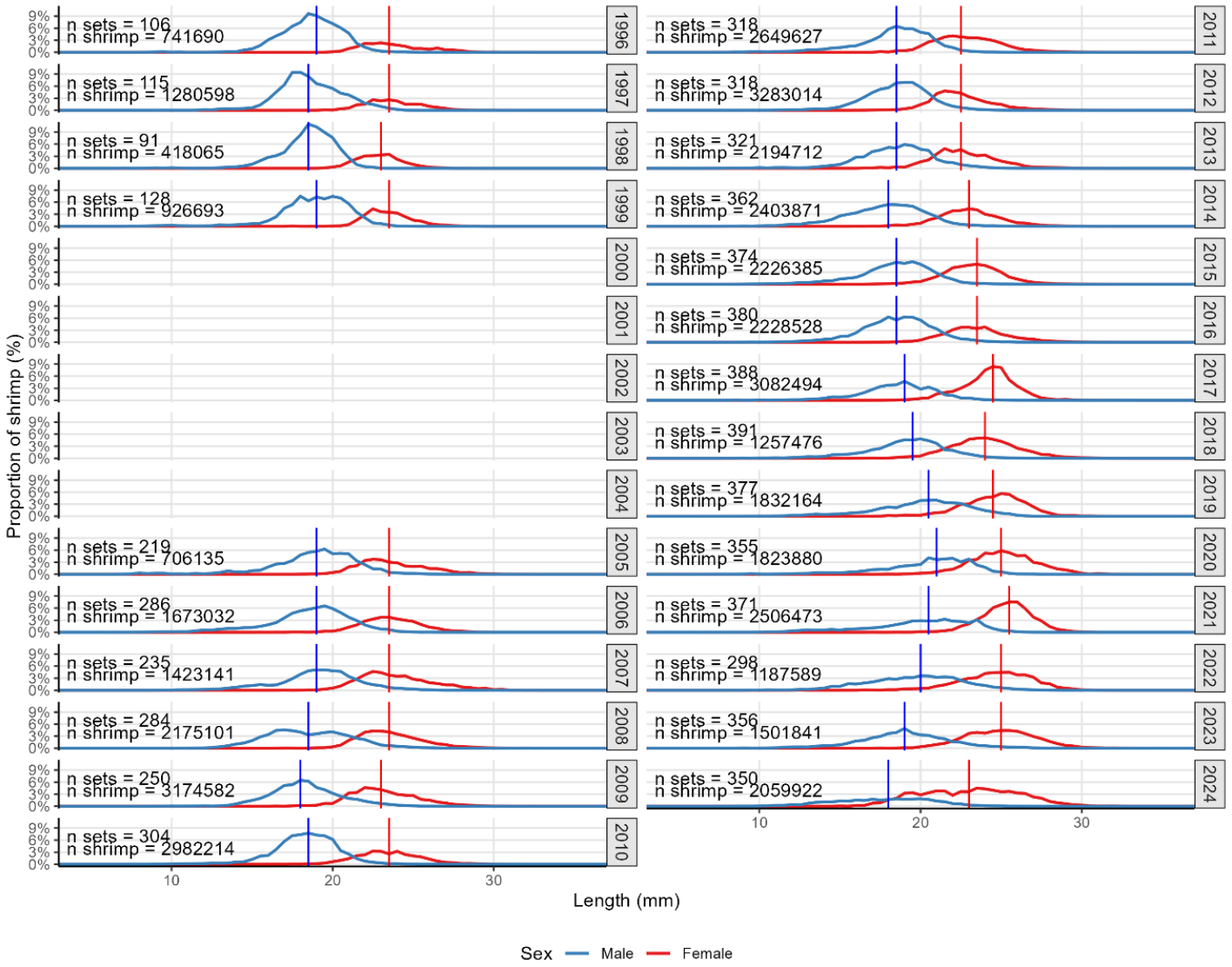


Figure 23. NSAR Northern Shrimp abundance at length for males and females (expressed as a percentage of total abundance) based on survey sets for 1996–2024. Vertical lines represent the median value of each length distribution. The annual number of survey sets and the standardized estimate of shrimp caught in 15 min trawls are provided on each panel.

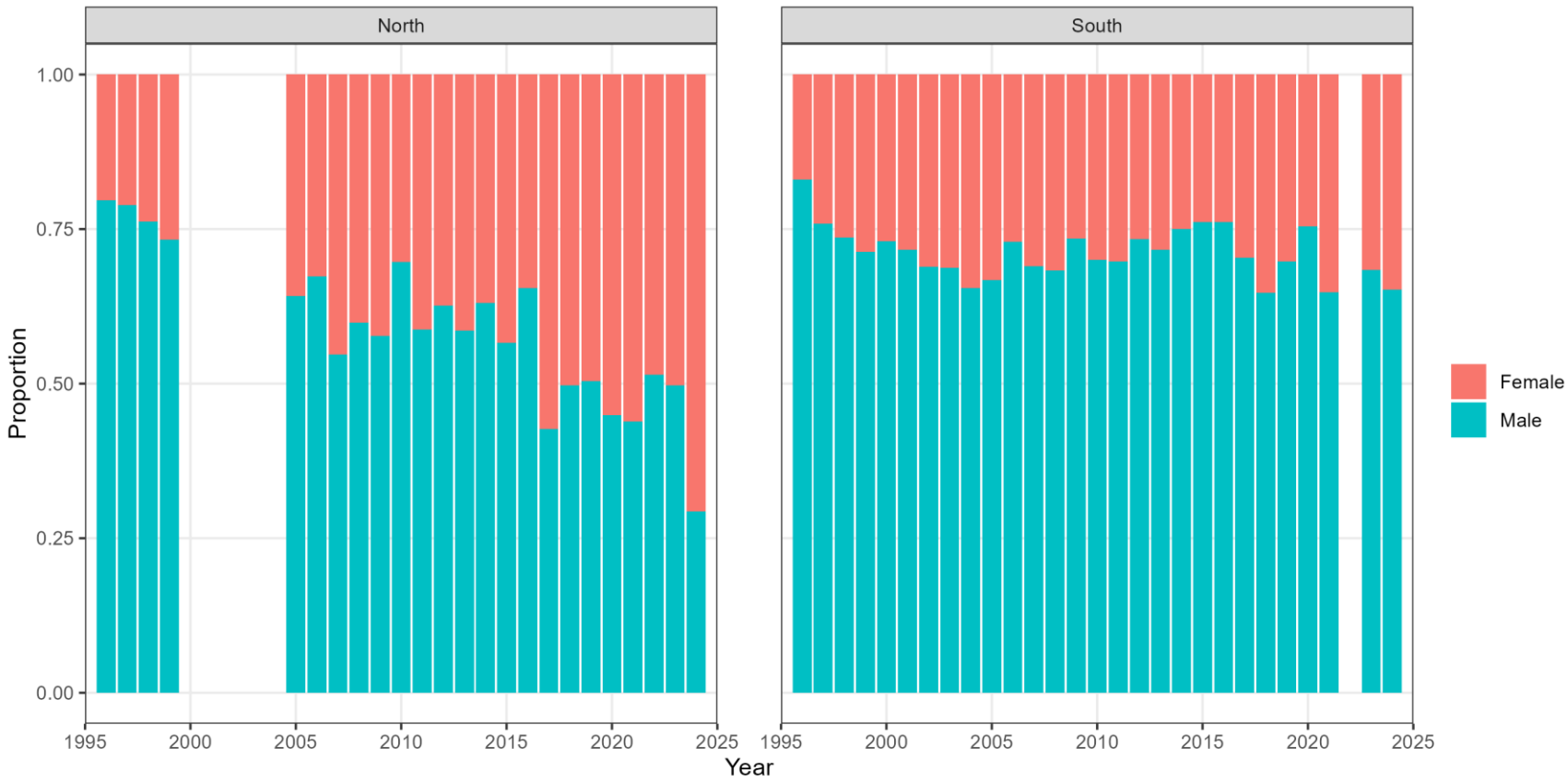


Figure 24. Proportion of Northern Shrimp male (blue) and female (red) abundance (based on overall count) by year in the north (left panel) and south (right panel) stock assessment regions.

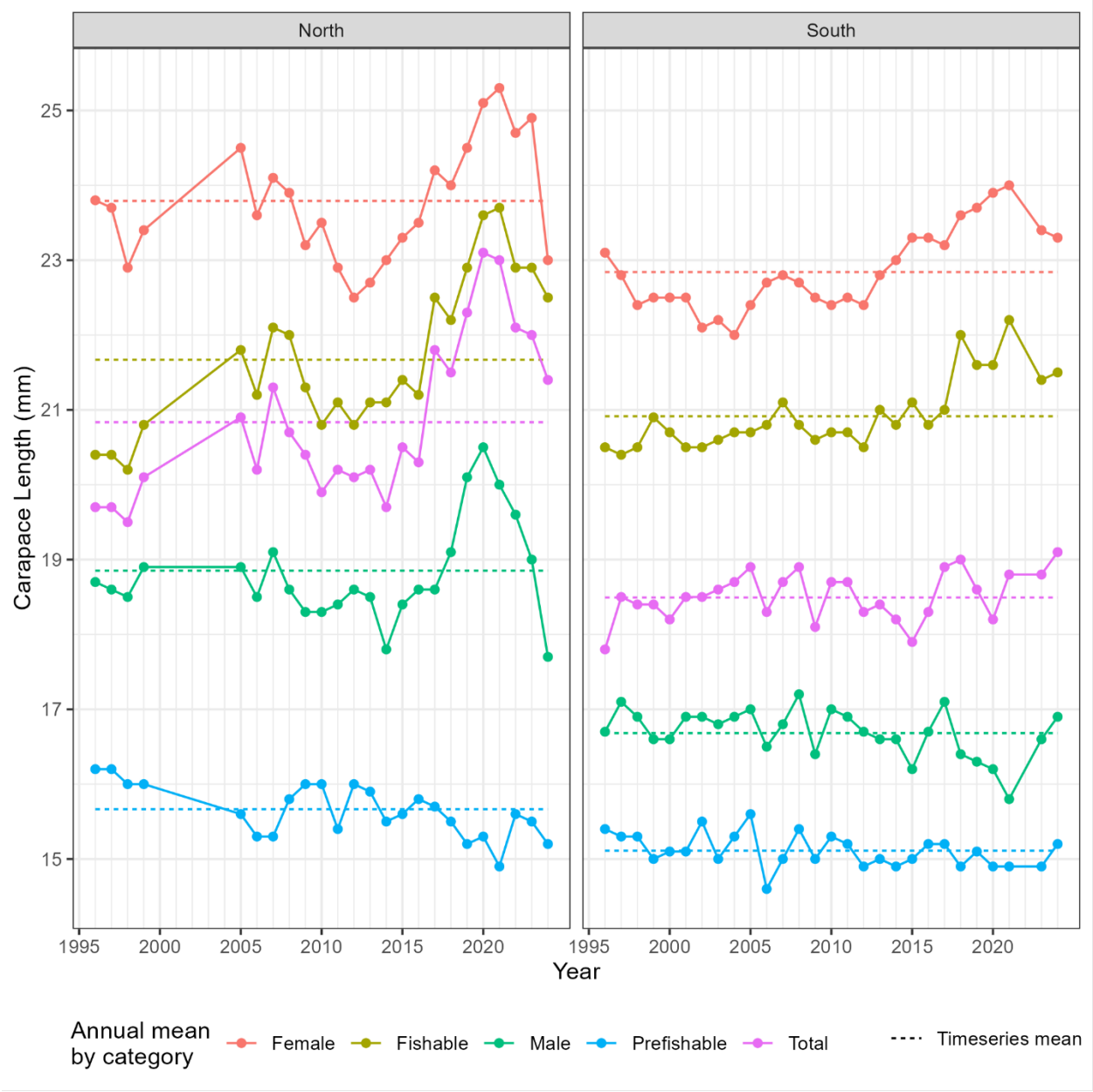


Figure 25. Survey mean size of totals, females, males, pre-fishable (or pre-recruit, CL < 17.5 mm) and fishable (CL ≥ 17.5 mm) Northern Shrimp in the north (left) and south (right) stock assessment regions. Long-term average size for each maturity is indicated by the horizontal dotted line for each series.

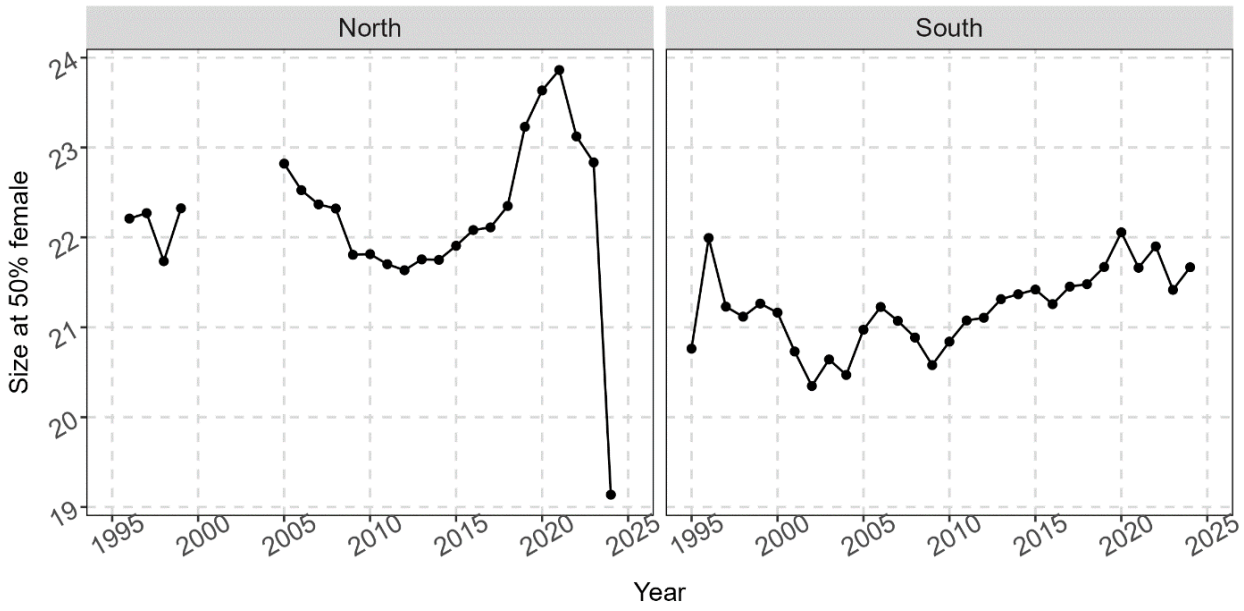


Figure 26. Annual Northern Shrimp estimated size (mm) at 50% female in north (left panel) and south (right panel) stock assessment regions. The black dots represent annual GAM predictions.

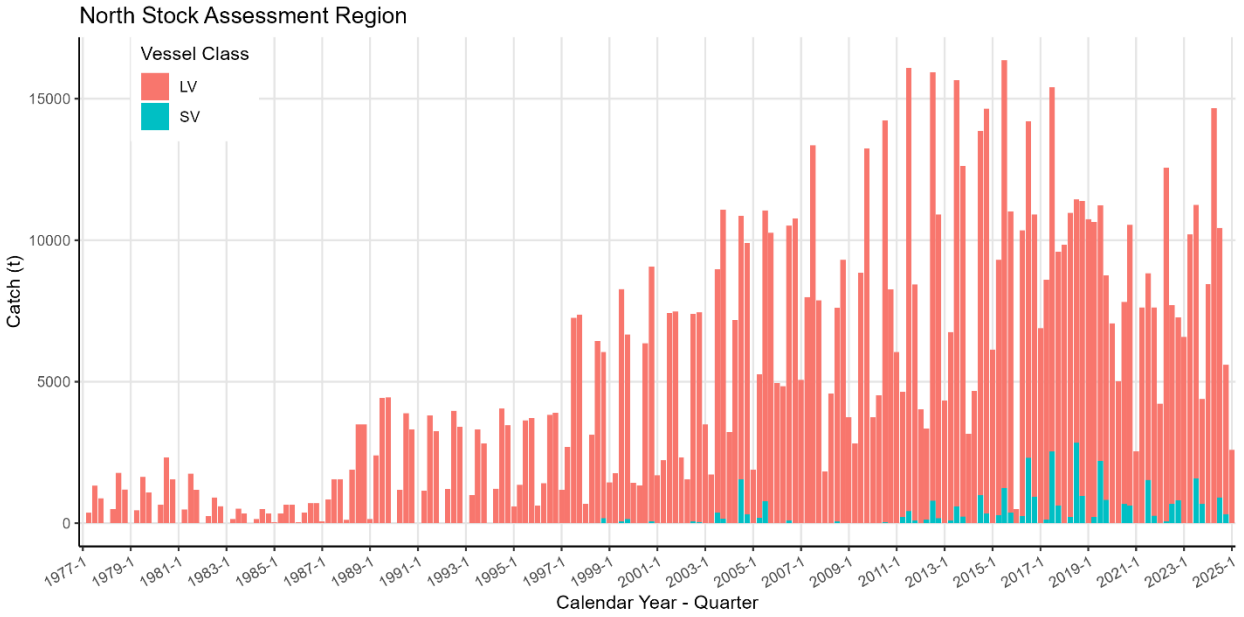


Figure 27. Nominal quarterly reported catches (in tons) of Northern Shrimp by large (red) and small (blue) vessels, aggregated within the North stock assessment region from 1977–2025. Quarter 1 represents January to March, while Quarter 4 represents October to December of each year. Catches in 2024–25 are preliminary as of the January 15, 2025 (EAZ and WAZ) and February 04, 2025 (SFAs 4–7), AQMS. Catches from the large vessel fleet in the final quarter of the time series (January–March 2025) were estimated based on the average proportion of the TAC caught during that quarter over the past five management years.

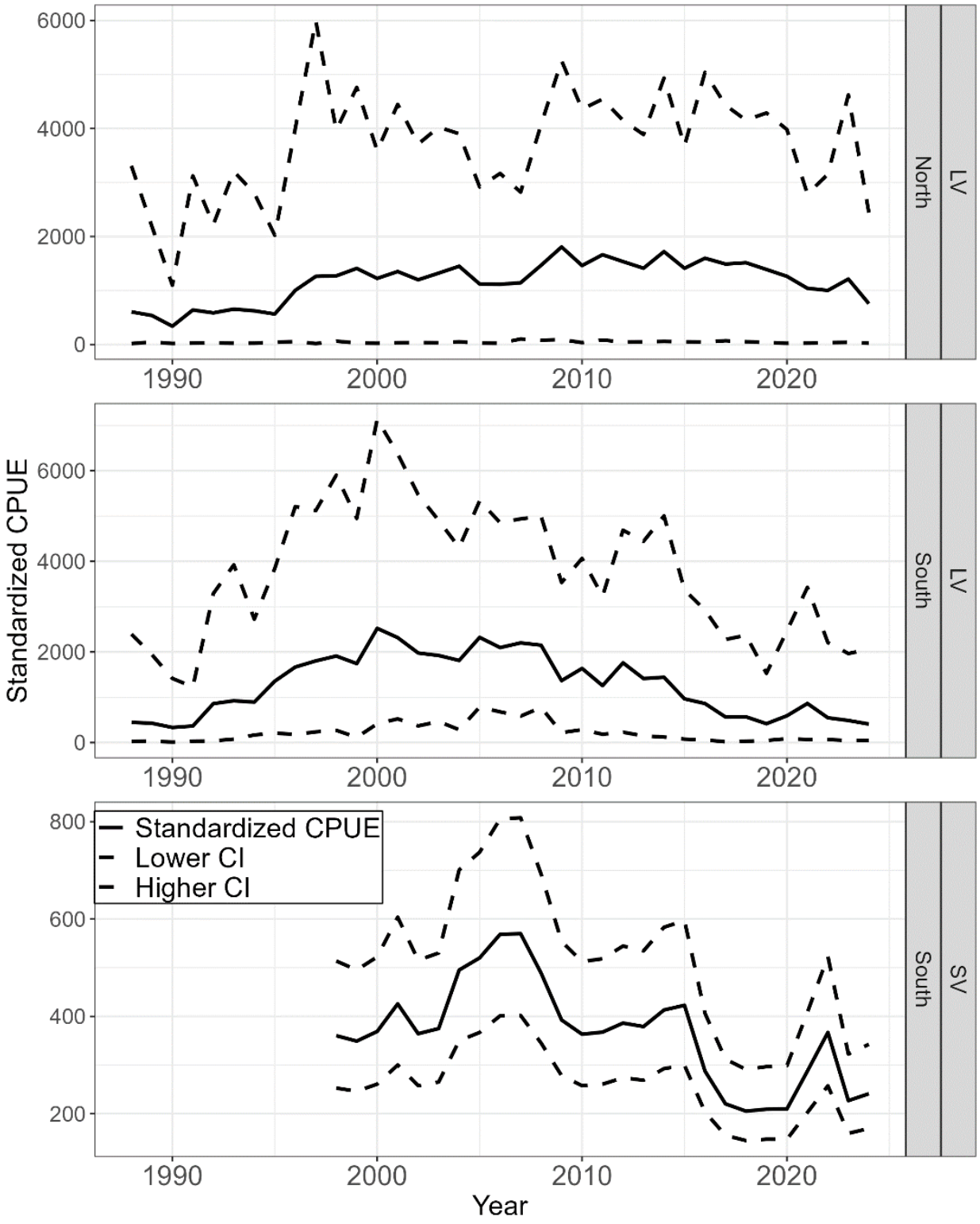


Figure 28. Standardized catch per unit effort (CPUE – kg/hour) index of the large vessel fleet in the north (top panel) and south (middle panel)) stock assessment regions as captured in observer records from 1988–2024/25 (based on spatiotemporal modeling). Bottom panel: Standardized CPUE index for the SV fleet fishing for Northern Shrimp in the south stock assessment region from 1998–2024/25 (based on generalized linear modeling). Data for 2023/24–2024/25 are incomplete.

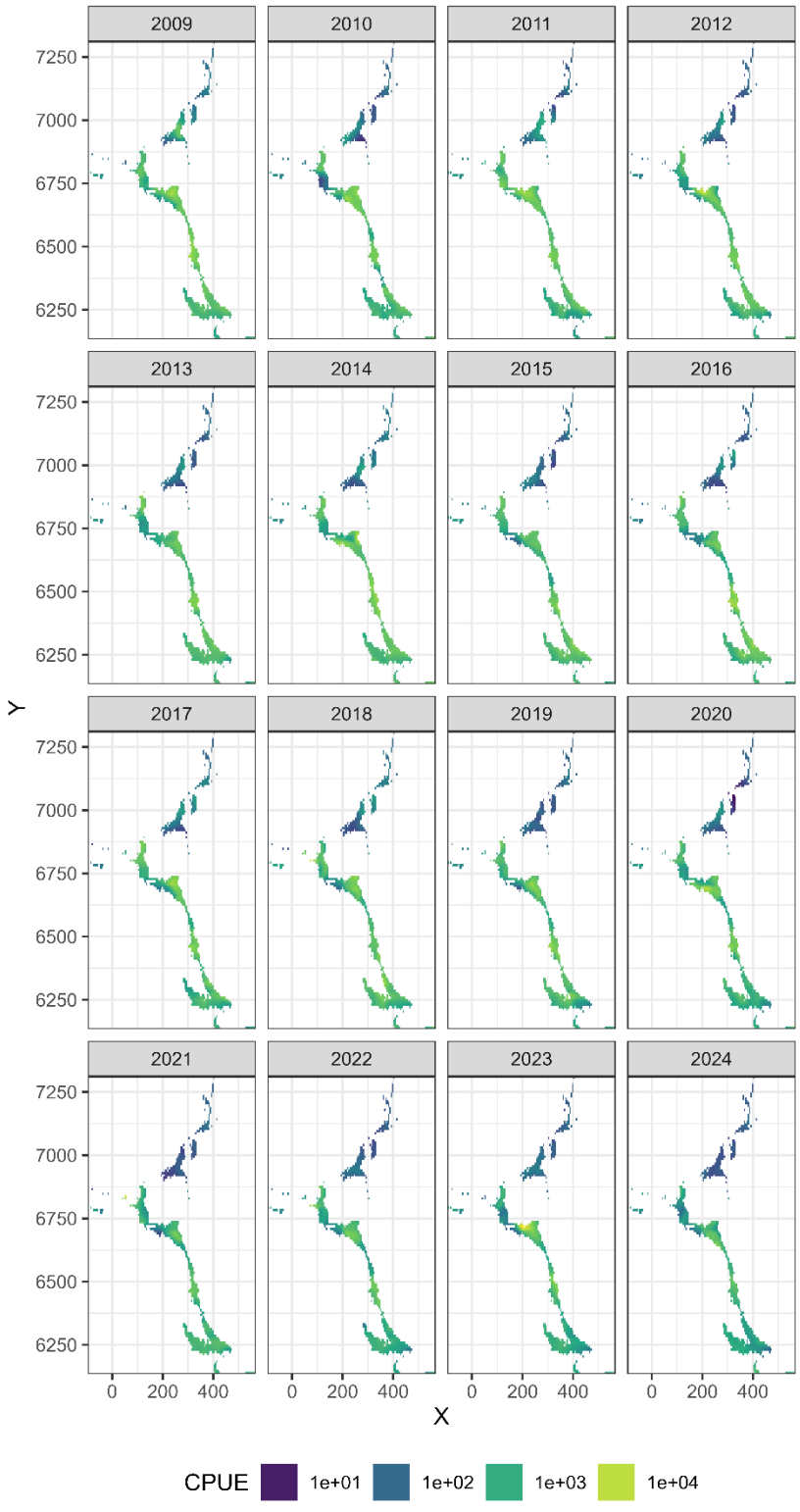


Figure 29. Predictions from the large-vessel CPUE (kg.hour^{-1} in log scale to improve visibility) spatiotemporal model for the North stock assessment region (NSAR) over the 2009–24 period. X and Y are longitude and latitude projected in UTM Zone 21N (km).

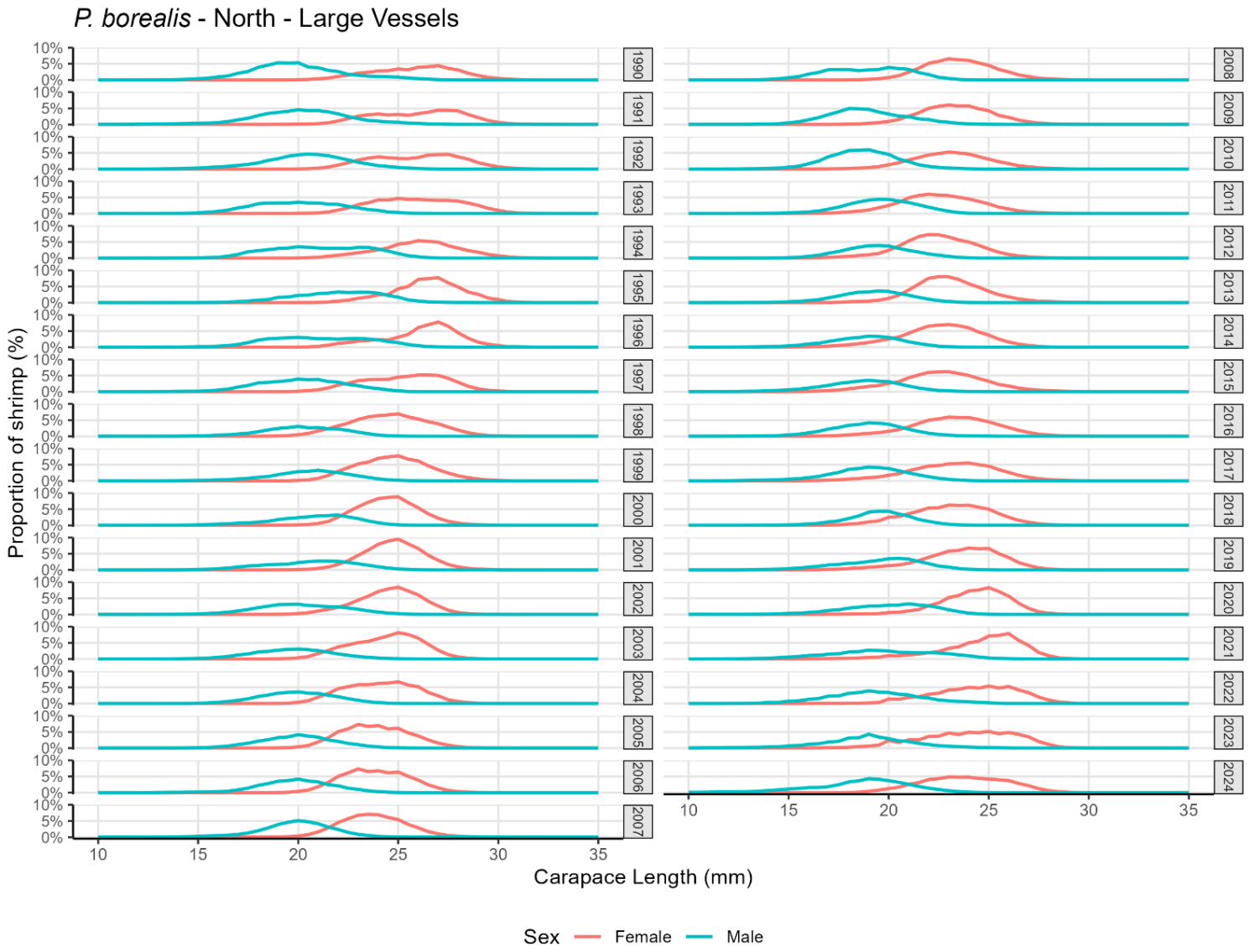


Figure 30. NSAR observer length frequencies of male and female Northern Shrimp (i.e., Primiparous, Multiparous, and Ovigerous combined) from the large vessel fleet targeting Northern Shrimp over the 1990–2024 period. Data for 2023–24 and 2024–25 are preliminary.

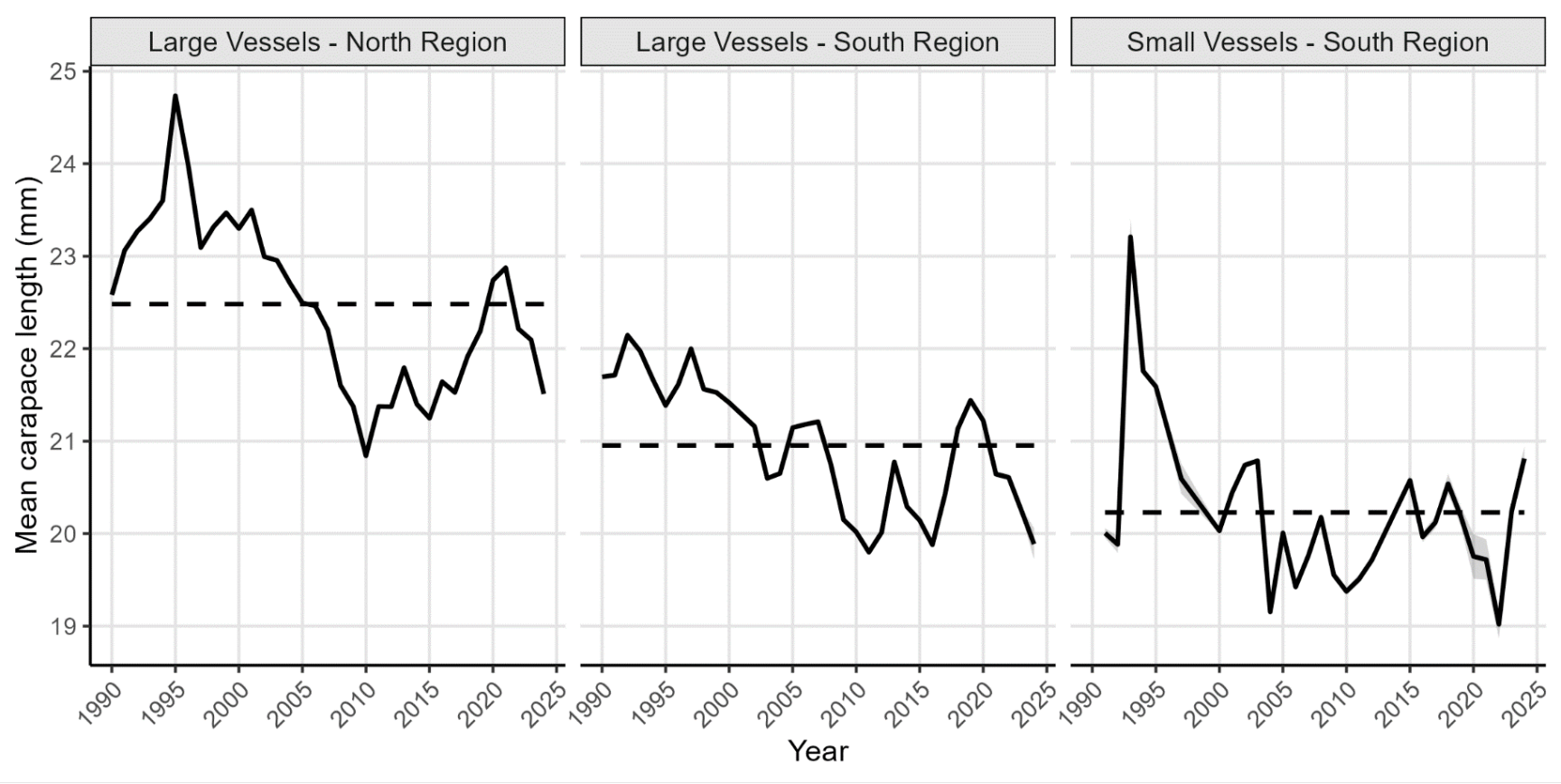


Figure 31. Mean (±95% Confidence Intervals) carapace length of Northern Shrimp caught by the large vessel fleet in the NSAR (left panel), large vessel fleet (middle panel) and small vessel fleet (right panel) in the SSAR. Data are from detailed observer sampling. Long-term average size is indicated by the dashed line for each series. Confidence intervals are included in the plots but are generally not discernible due to their narrow width, except in instances where the number of shrimp measured is low, resulting in wider intervals.

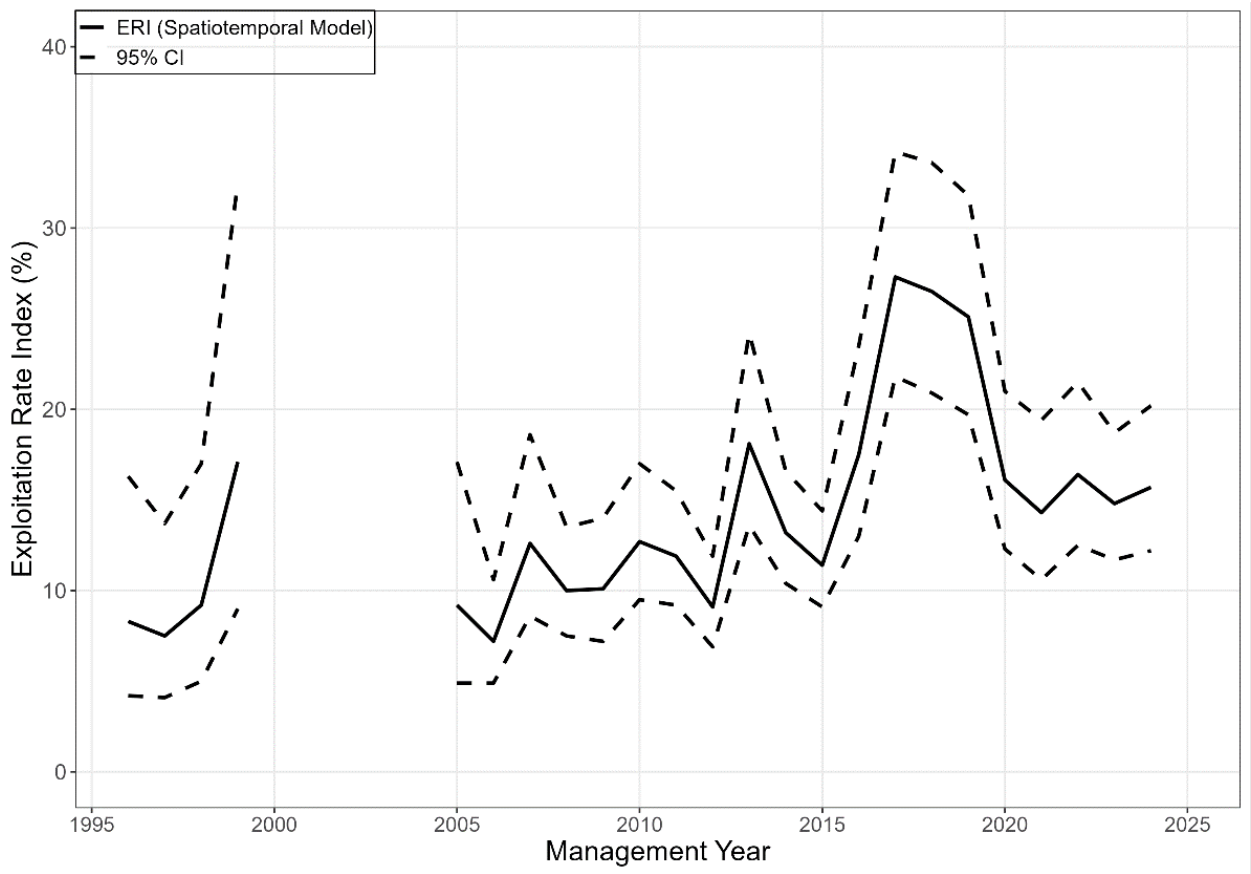


Figure 32. NSAR Northern Shrimp exploitation rate index based on total catch divided by the survey fishable biomass (sdmTMB) from the same year, expressed as a percentage. Dashed lines indicate 95% confidence intervals. The 2024/25 value is based on the preliminary catch (64% of the aggregated TAC) from the AQMS.

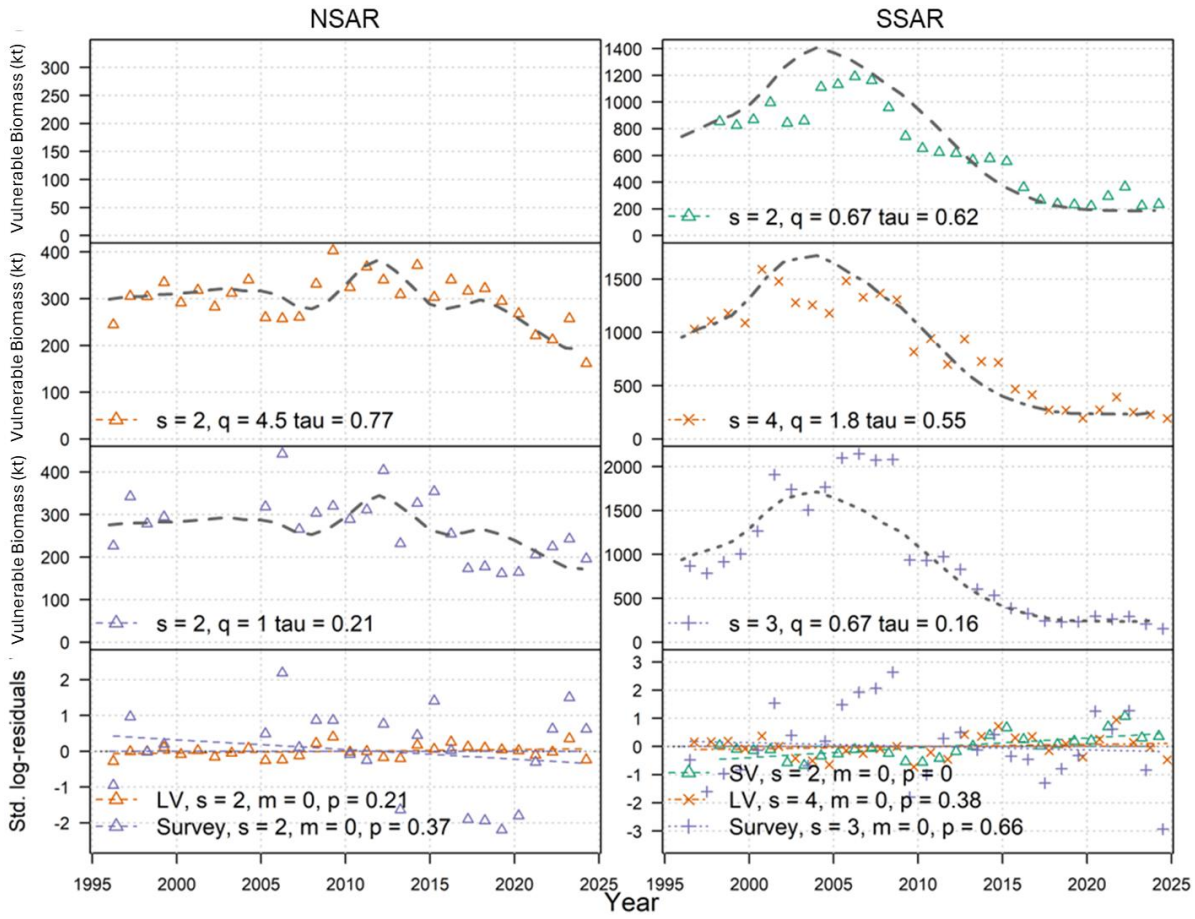


Figure 33. Fits to stock indices (top three panels) and standardized residuals (bottom panel) for each fleet/area combination. Points show stock index data scaled by catchability, while lines show model estimates of vulnerable biomass. Seasons are indicated by point type and line type (explained in the legend). The legend in the bottom panel also reports the mean residual m and the significance of the average temporal trend (p-value of the gradient).

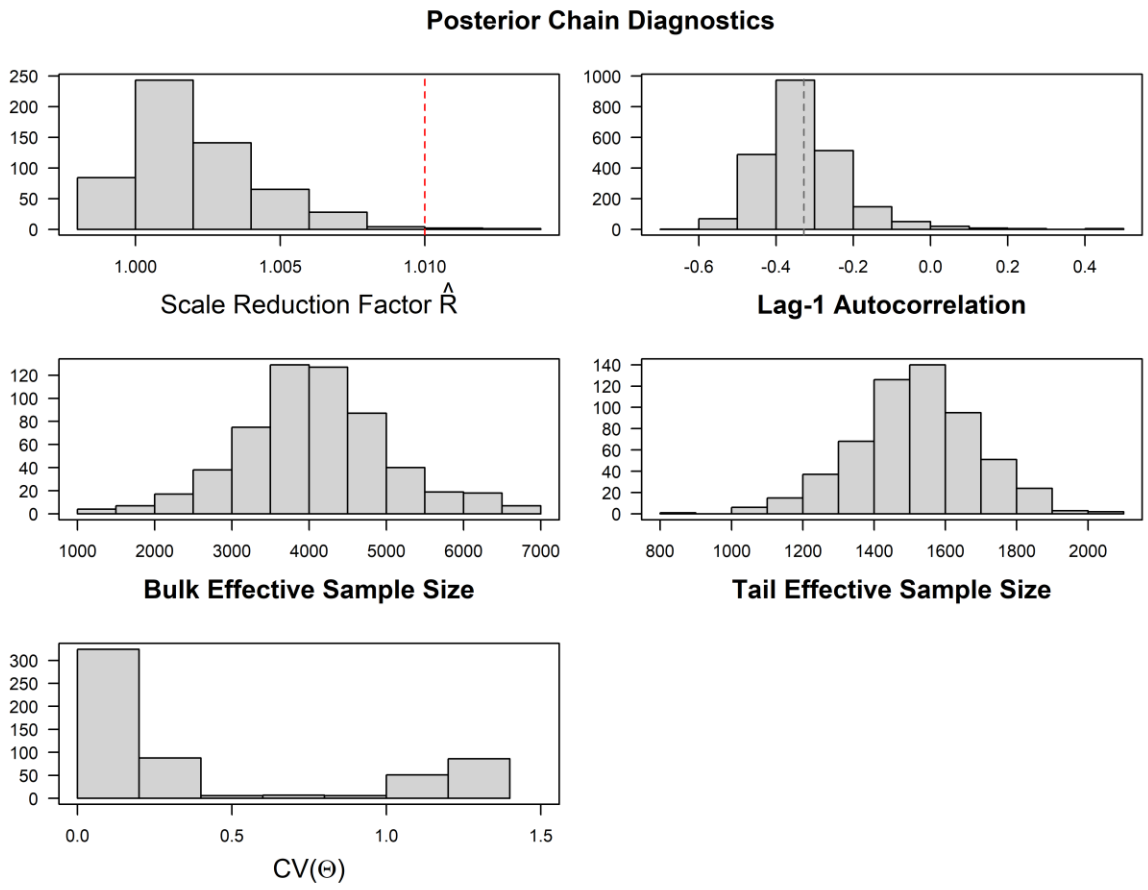


Figure 34. Hamiltonian Monte Carlo convergence diagnostic plots. Convergence occurs when scale reduction factors $\widehat{R}$ < 1.01 (red line). Lag-1 Autocorrelation should be unimodal and centered around 0 or slightly lower. Bulk effective sample size (Bulk ESS) and tail effective sample size (Tail ESS) should be greater than 100 per chain (here, 400), and for CV(Θ), smaller is better.

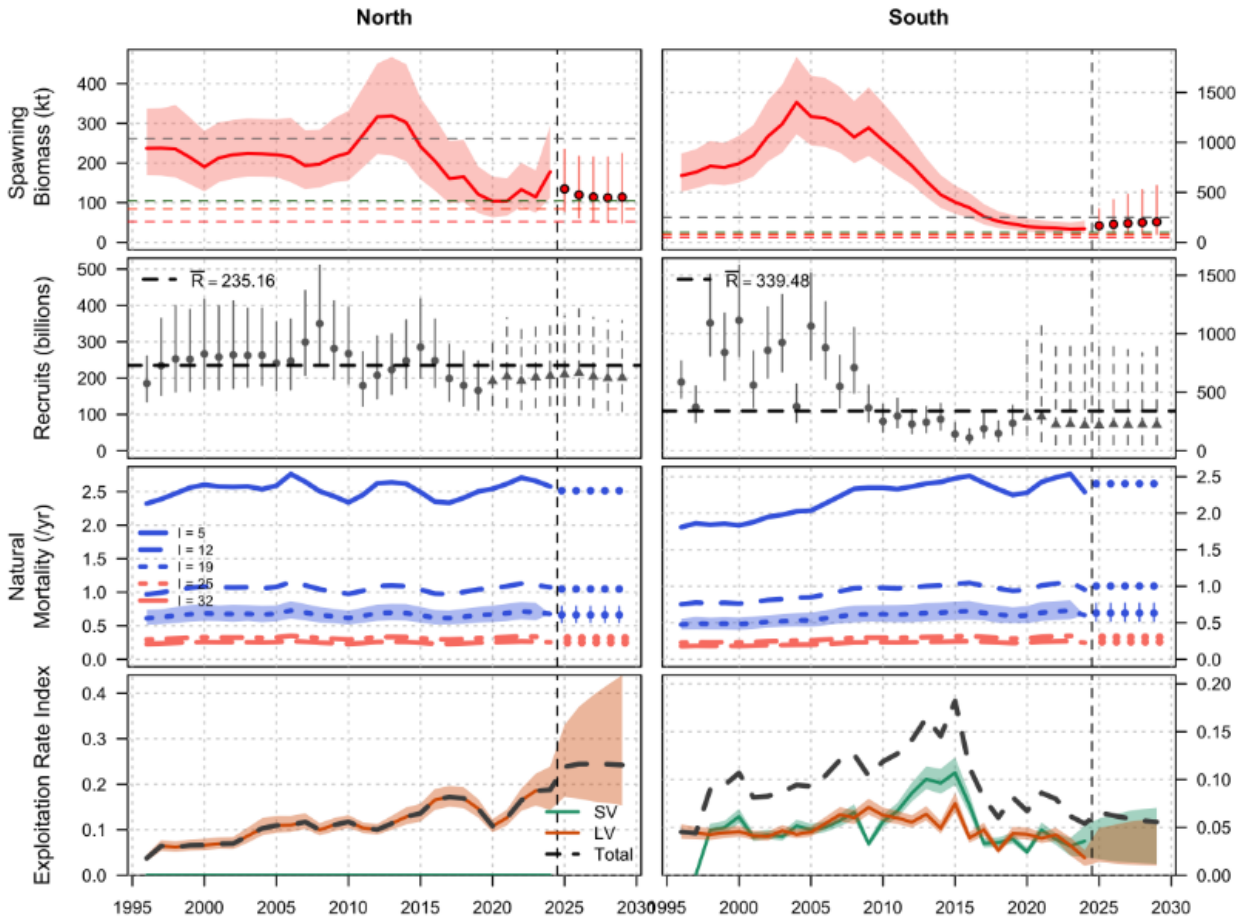


Figure 35. Time series of (top) historical estimates of spawning biomass (red line and pink envelope) with the Bmsy (green dashed line), proposed USR (orange dashed line), and LRP (red dashed line), (second row) historical recruitments (points and line segments), simulated recruitment (points and dashed segments), and average recruitment $\bar{R}$, (third row) time-varying natural mortality for selected shrimp length bins (CL: 5, 12, 19, 25, and 32 mm, with 95% credible intervals only shown for 19 mm CL), and (bottom row) harvest rates as a fraction of 17+ mm exploitable biomass for Northern Shrimp NSAR (left panel) and SSAR (right panel). Spawning biomass, recruitment, and harvest rate plots show 95% credibility intervals. The vertical dashed lines indicate the start of a five year projection assuming a fixed input catch (same as the last year aggregated TAC: 39.2 kt in the NSAR and 10.6 kt in SSAR) and average mortality and transition rates for the last eight years of the model history.

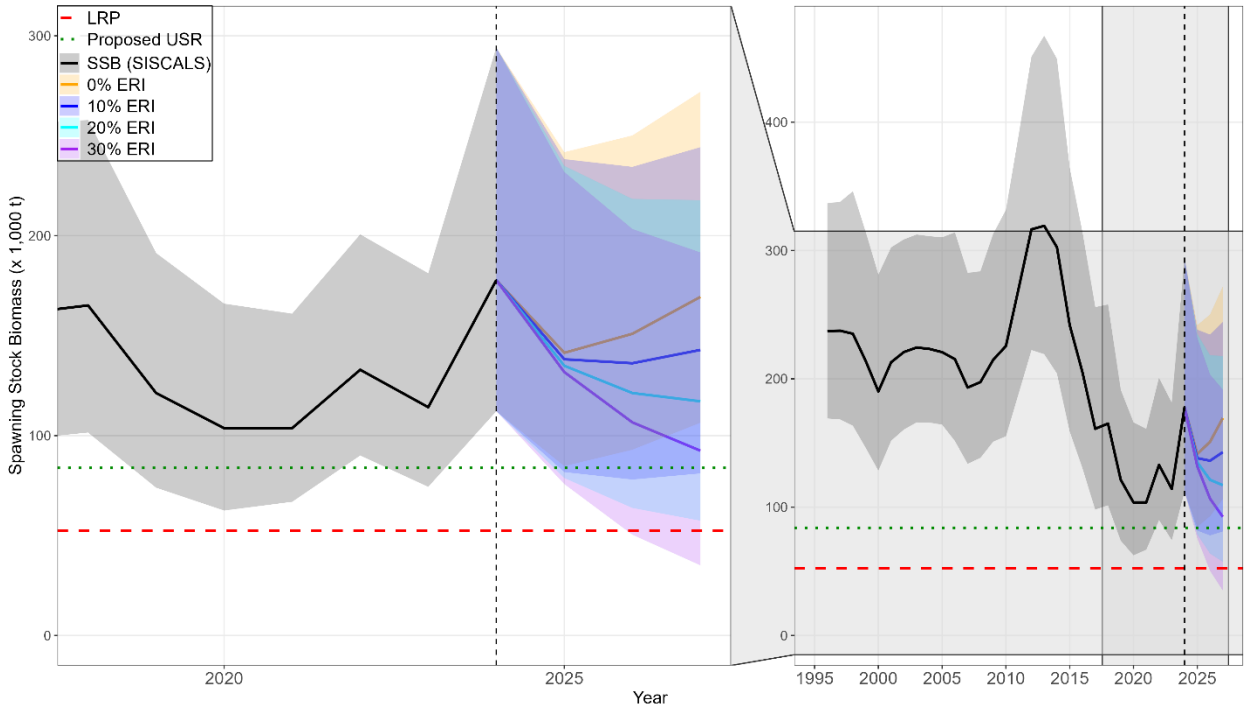


Figure 36. SISCALS spawning stock biomass (SSB) estimates (1996–2024) and projections (2025–27) for NSAR under four constant catch scenarios. These scenarios are based on exploitation rate indices (ERI) of 0%, 10%, 20%, and 30%, applied to the 2024 FB spatiotemporal index. The left panel highlights recent years (2018–27), while the right panel displays the full time series. The bold solid black line represents the historical median SSB, with the surrounding shaded area indicating the 95% confidence interval. Colored lines and shaded areas show projected SSB and their respective 95% confidence intervals for each scenario (see legend for color coding). The red dashed line marks the limit reference point (LRP), the green dotted line indicates the proposed upper stock reference (USR), and the black dashed vertical line denotes the last surveyed year. Horizontal and vertical grey shading in the right panel highlights the inset focus area.

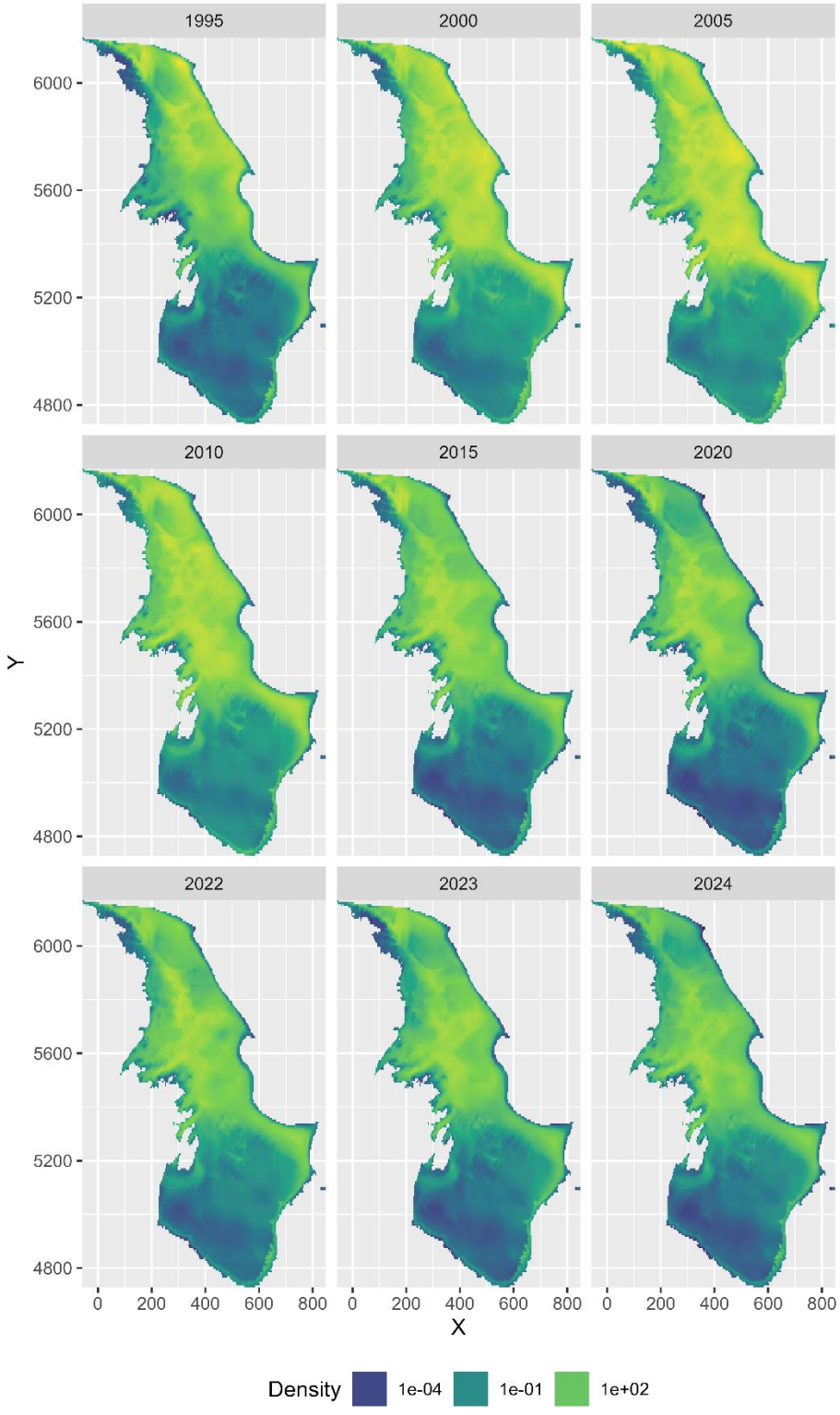


Figure 37. Density predictions (kg.km^{-2} in log scale to improve visibility) from the South stock assessment region (SSAR) Northern Shrimp fishable biomass spatiotemporal model every 5 years, along with the data from the last three years of the time series. The density predictions for 1995 are shown for information only and were not included in SISCALS. X and Y are longitude and latitude projected in UTM Zone 22N (km).

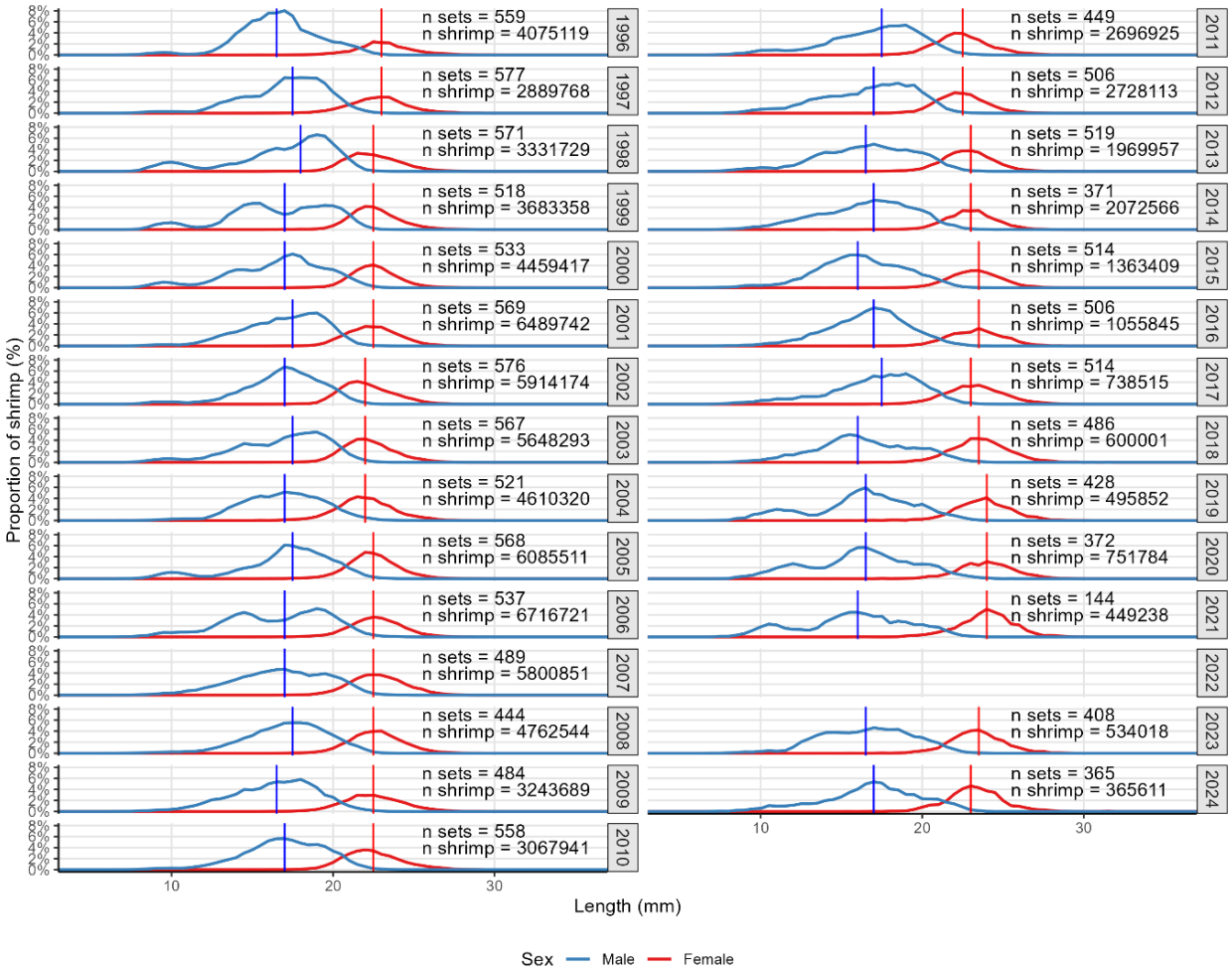


Figure 38. SSAR Northern Shrimp abundance at length for males (blue) and females (red) (expressed as a percentage of total abundance) based on survey sets for 1996–2024. Vertical lines represent the median value of each length distribution. The annual number of survey sets and the standardized estimate of shrimp caught in 15 min trawls are provided on each panel.

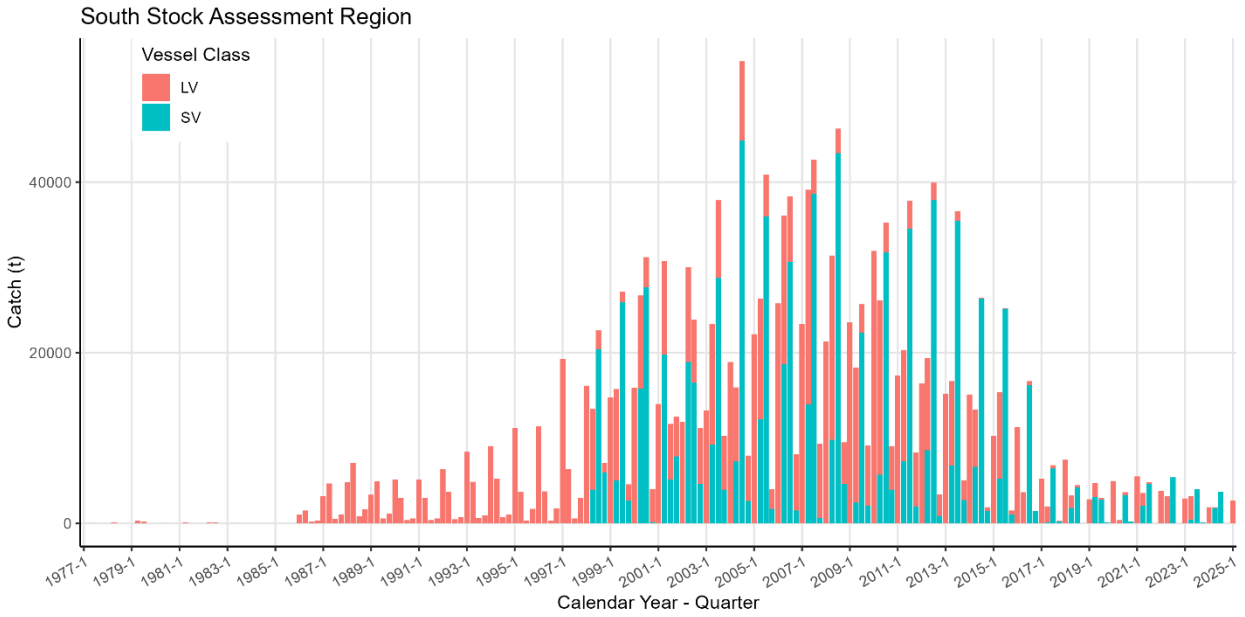


Figure 39. Nominal quarterly reported catches (in tons) of Northern Shrimp by large (red) and small (blue) vessels, aggregated within the South stock assessment region from 1977–2025. Quarter 1 represents January to March, while Quarter 4 represents October to December of each year. Catches in 2024–25 are preliminary as of the February 04, 2025, AQMS. Catches from the large vessel fleet in the final quarter of the time series (January–March 2025) were estimated based on the average proportion of the TAC caught during that quarter over the past five management years.

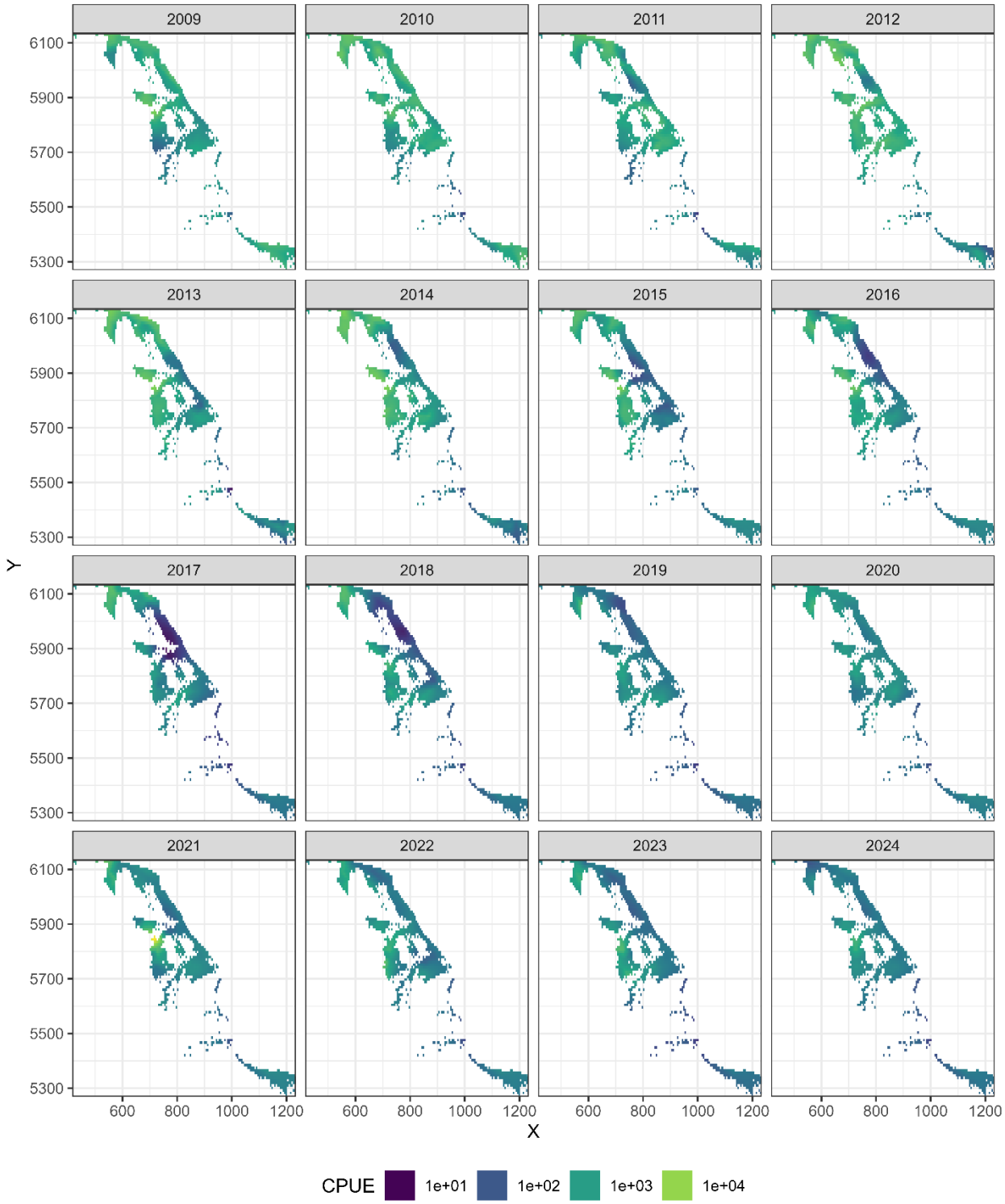


Figure 40. Predictions from the large-vessel CPUE (kg.hour^{-1} in log scale to improve visibility) spatiotemporal model for the South stock assessment region (SSAR) over the 2009–24 period. X and Y are longitude and latitude projected in UTM Zone 21N (km).

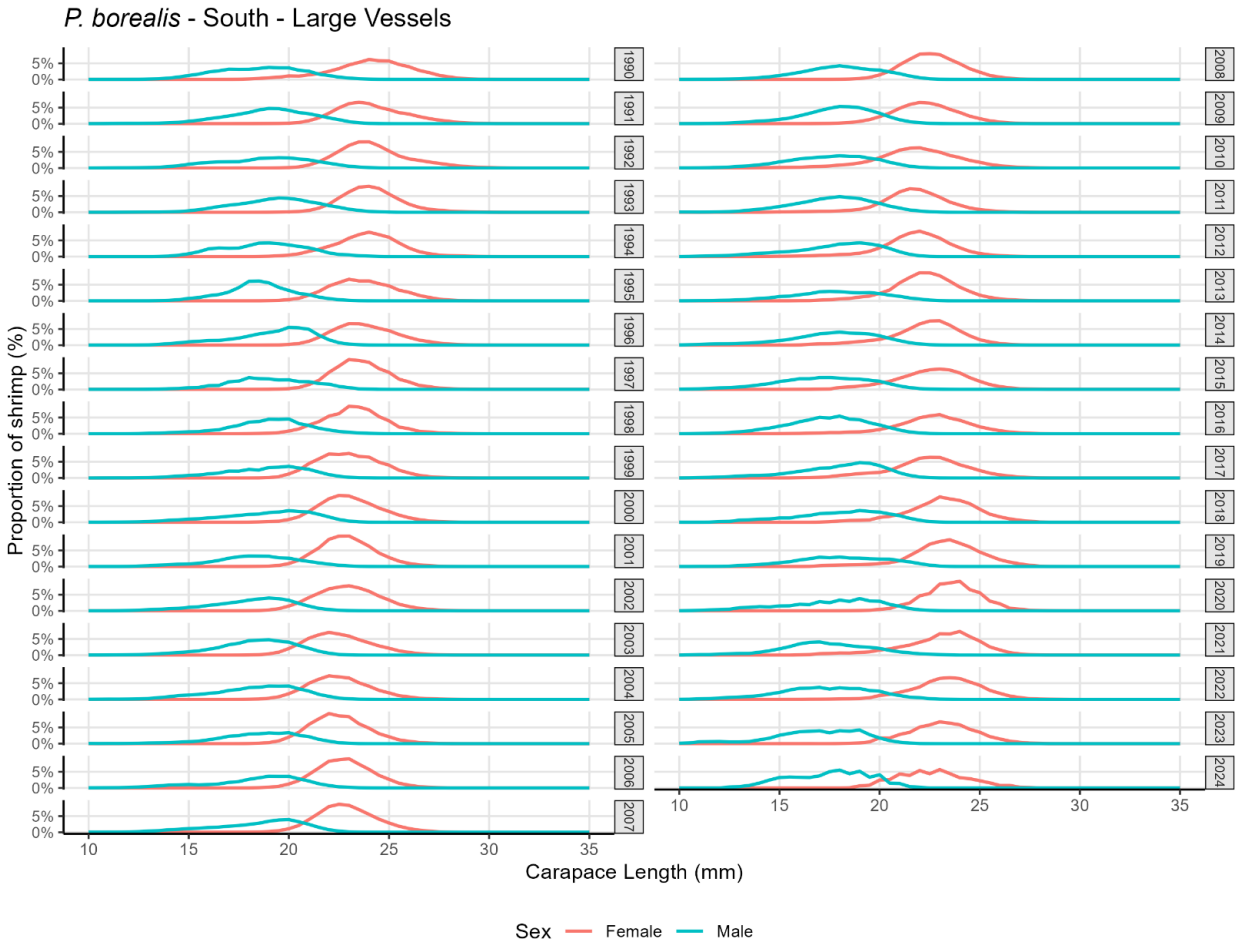


Figure 41. SSAR observer length frequencies of male and female Northern Shrimp (i.e., Primiparous, Multiparous, and Ovigerous combined) from the large vessel fleet targeting Northern Shrimp over the 1990–2024 period. Data for 2023–24 and 2024–25 are preliminary.

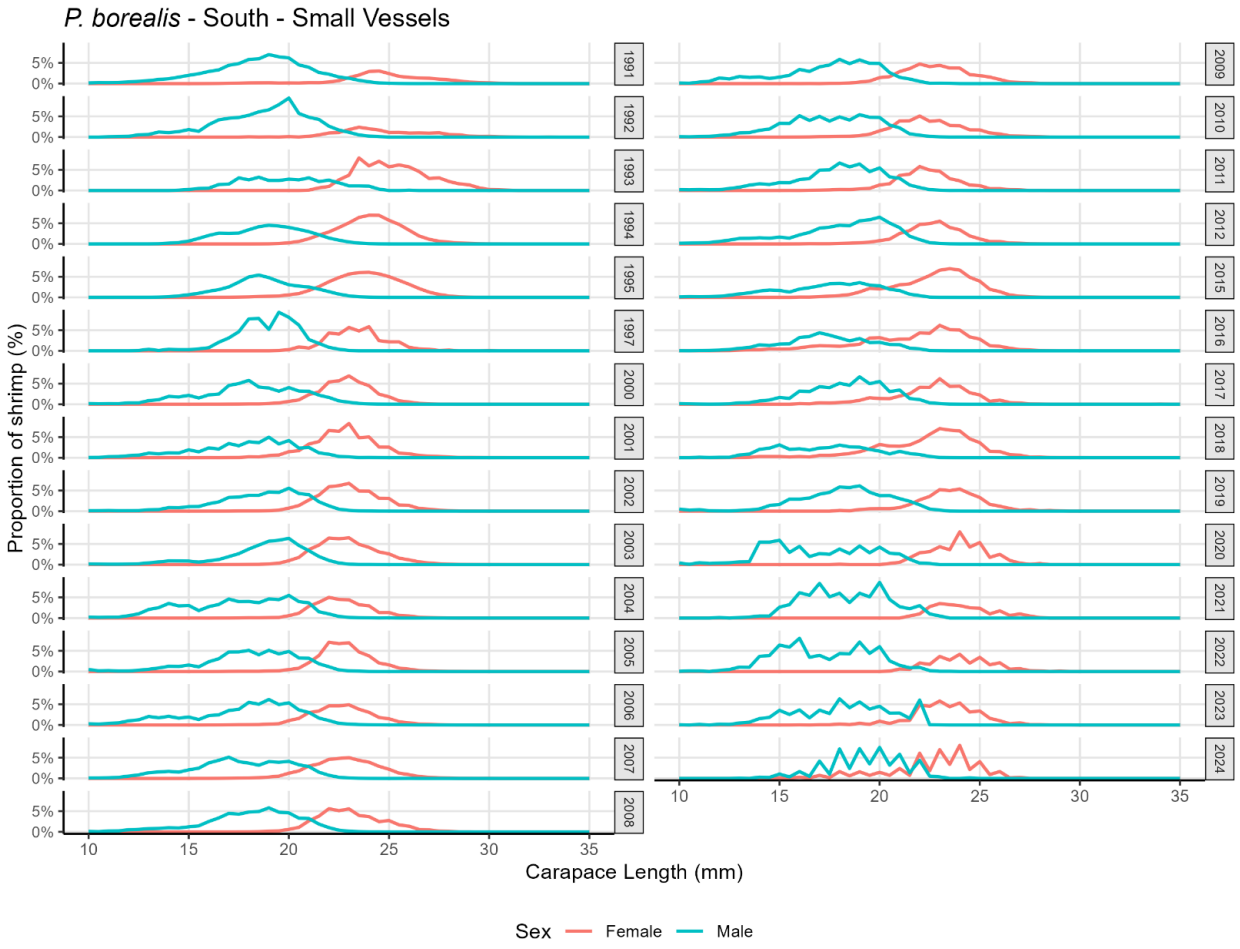


Figure 42. SSAR observer length frequencies of male and female Northern Shrimp (i.e., Primiparous, Multiparous, and Ovigerous combined) from the small vessel fleet targeting Northern Shrimp over the 1991–2024 period. Data for 2023–24 and 2024–25 are preliminary.

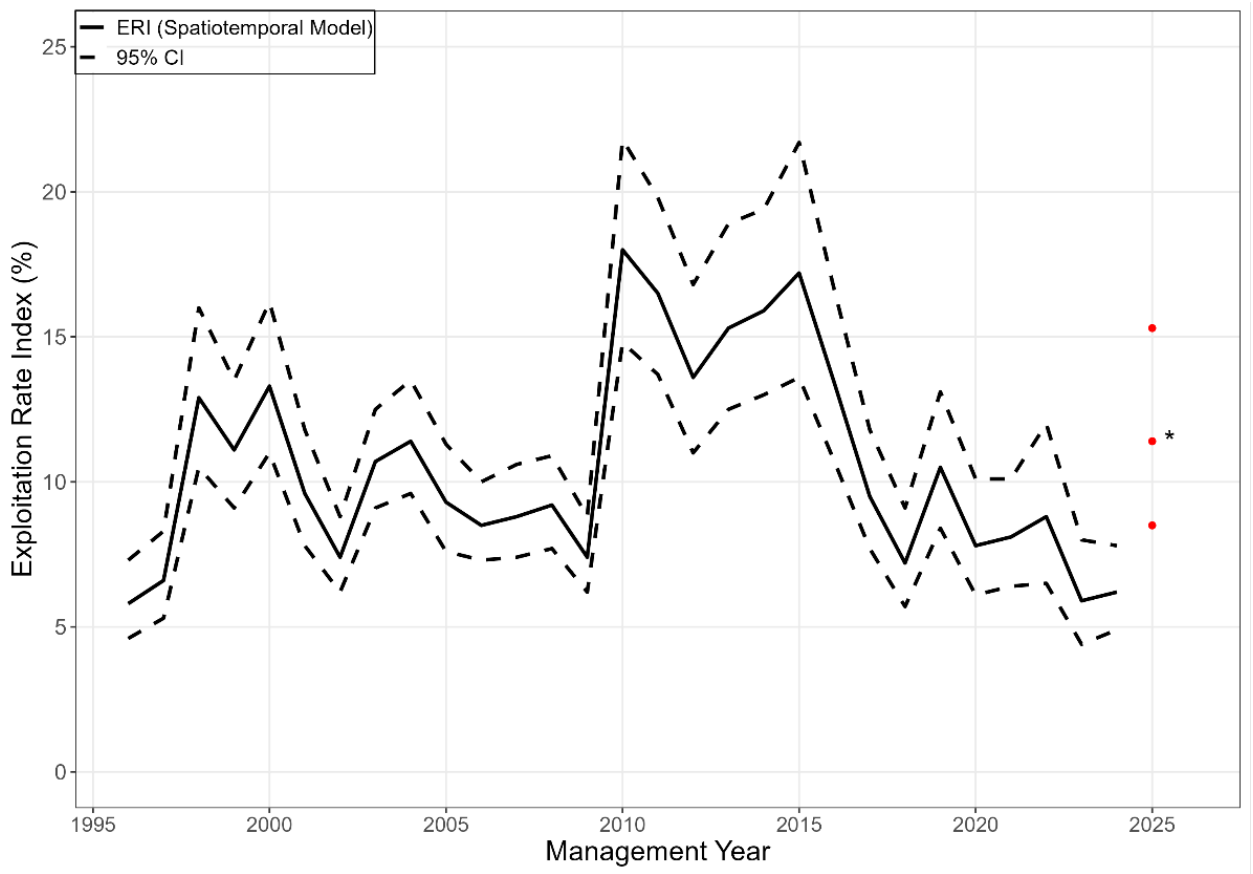


*Figure 43. SSAR Northern Shrimp exploitation rate index based on total catch divided by the survey fishable biomass (sdmTMB) from the previous year, expressed as a percentage. Dashed lines indicate 95% confidence intervals. The 2024/25 value is based on the preliminary catch (62% of the aggregated TAC) from the AQMS. *The 2025/26 value is based on the previous year's aggregated TAC, assuming it is fully taken.*

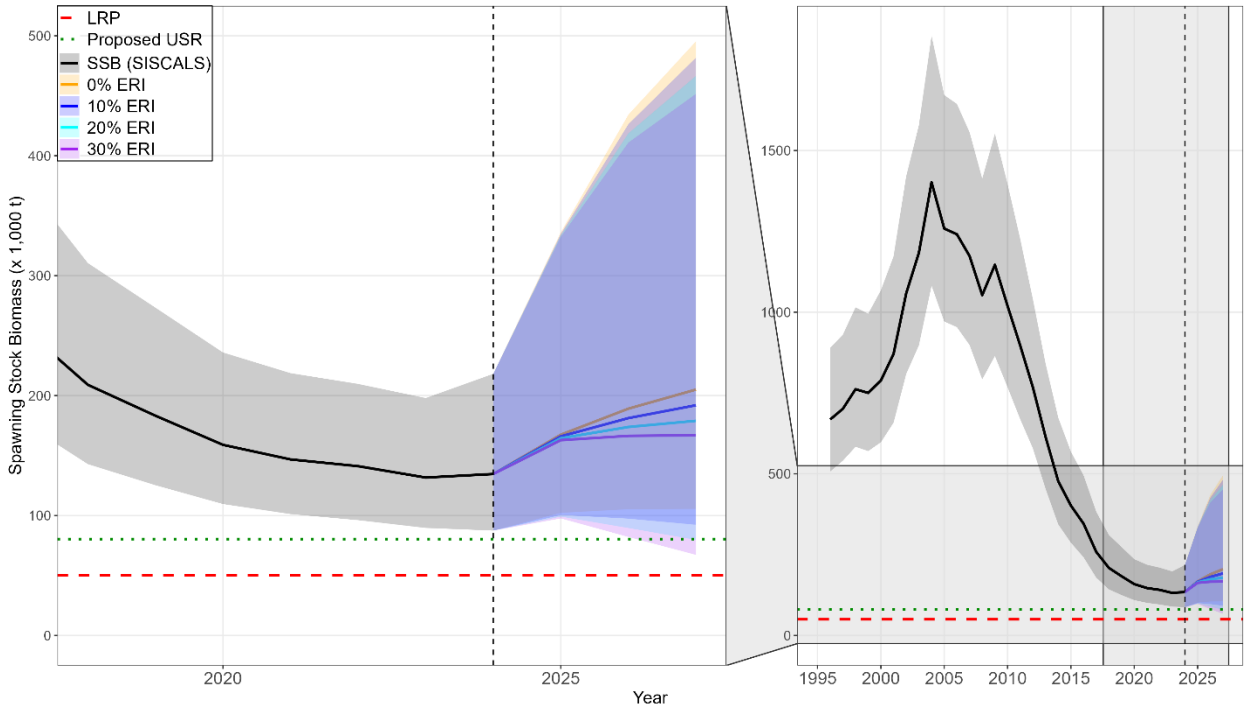


Figure 44. SISCALS spawning stock biomass (SSB) estimates (1996–2024) and projections (2025–27) for SSAR under four constant catch scenarios. These scenarios are based on exploitation rate indices (ERI) of 0%, 10%, 20%, and 30%, applied to the 2024 FB spatiotemporal index. The left panel highlights recent years (2018–27), while the right panel displays the full time series. The bold solid black line represents the historical median SSB, with the surrounding shaded area indicating the 95% credibility interval. Colored lines and shaded areas show projected SSB and their respective 95% confidence intervals for each scenario (see legend for color coding). The red dashed line marks the limit reference point (LRP), the green dotted line indicates the proposed upper stock reference (USR), and the black dashed vertical line denotes the last surveyed year. Horizontal and vertical grey shading in the right panel highlights the inset focus area.