Analysis of the Enhanced Snow Crab Survey for Monitoring Conservation Priorities in St. Anns Bank Marine Protected Area

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ANALYSIS OF THE ENHANCED SNOW CRAB SURVEY FOR MONITORING CONSERVATION PRIORITIES IN ST. ANNS BANK MARINE PROTECTED AREA

by

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Jeffery, N.W., Daigle, R., Cameron, B.J., Glass, A., Harbin, J., Pettitt-Wade, H., Cassista-Da Ros, M., and Stanley, R.R.E. 2025. Analysis of the Enhanced Snow Crab Survey for Monitoring Conservation Priorities in St. Anns Bank Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci. 3650: x + 69 p. https://doi.org/10.60825/0705-z745

St. Anns Bank, situated offshore of Cape Breton, Nova Scotia/Unama'ki, was designated as a Marine Protected Area (MPA) under the *Oceans Act* in 2017 to conserve and protect benthic, demersal, and pelagic habitats, in addition to the high biodiversity and productivity in the area. Since 2015, the annual Snow Crab Survey (SCS) has been supplemented with enhanced stations inside and adjacent to the MPA, which, in addition to Snow Crab, provide length and weight data on fish and invertebrate bycatch, as well as diet data collected from fish stomachs. Here we investigated trends in biomass, species richness, and animal size data inside and outside the MPA between 2015-2023, as well as community composition and predator diets. Species richness from the SCS continues to increase as additional stations are sampled. Power analyses of the trawl data to investigate catch per unit effort in several key species revealed that additional stations would be required to adequately monitor changes in animal abundance and richness in the MPA at high power (>80%). Overall, the SCS provides vital information for monitoring the MPA's conservation objectives related to biodiversity and productivity, but additional years and stations or new supplementary data streams will be needed to confidently identify trends over time.

RÉSUMÉ

Jeffery, N.W., Daigle, R., Cameron, B.J., Glass, A., Harbin, J., Pettitt-Wade, H., Cassista-Da Ros, M., and Stanley, R.R.E. 2025. Analysis of the Enhanced Snow Crab Survey for Monitoring Conservation Priorities in St. Anns Bank Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci. 3650: x + 69 p. https://doi.org/10.60825/0705-z745

Le banc de Sainte-Anne, situé au large du Cap-Breton, en Nouvelle-Écosse/Unama'ki, a été désigné comme zone de protection marine (ZPM) en vertu de la Loi sur les océans en 2017 afin de conserver et de protéger les habitats benthiques, démersaux et pélagiques, en plus de la biodiversité et de la productivité élevées de la zone. Depuis 2015, le relevé annuel du crabe des neiges a été complété par des stations améliorées à l'intérieur et à proximité de la ZPM, qui, en plus du crabe des neiges, fournissent des données sur la longueur et le poids des prises accessoires de poissons et d'invertébrés, ainsi que des données sur le régime alimentaire recueillies dans l'estomac des poissons. Ici, nous avons étudié les tendances de la biomasse, la richesse des espèces et les données sur la taille des animaux à l'intérieur et à l'extérieur de la ZPM entre 2015 et 2023, ainsi que les composition des communautés et les régimes alimentaires des prédateurs. La richesse en espèces du relevé annuel du crabe des neiges continue d'augmenter à mesure que d'autres stations sont échantillonnées. L'analyse de puissance des données de chalut pour étudier les prises par unité d'effort chez plusieurs espèces clés a révélé que des stations supplémentaires seraient nécessaires pour suivre adéquatement les changements d'abondance et de richesse animales dans la ZPM à haute puissance (>80 %). Dans l'ensemble, le relevé annuel du crabe des neiges fournit des renseignements essentiels pour le suivi des objectifs de conservation de la ZPM liés à la biodiversité et à la productivité. Pour cerner avec certitude les tendances au fil du temps, il est nécessaire d'ajouter des années et des stations supplémentaires ou de nouveaux flux de données supplémentaires.

INTRODUCTION

BACKGROUND

St. Anns Bank (herein SAB) was designated as a Marine Protected Area (MPA) under the *Oceans Act* in June 2017. SAB is a relatively large (4,364 km^2) MPA situated in the Eastern Scotian Shelf, offshore of Cape Breton Island/Unama'ki, Nova Scotia. The MPA is divided into four management zones, comprising one core conservation zone (no-take) and three mixed-use areas where certain fishing activities are permitted, subject to specific regulations and restrictions (DFO 2012). The ecological features of this area were summarized by Ford and Serdynska (2013) in an ecological overview of the then SAB Area of Interest, classifying the area into three benthic habitats: shallow inshore bank, the mid-depth continental shelf, and the continental slope descending into the Laurentian Channel (Figure 1). Important ecosystem components identified by Ford and Serdynska (2013) included diverse habitat features, high benthic and demersal fish diversity, and areas of diverse invertebrates including corals, sponges, echinoderms, and crustaceans. Benthic and demersal fish species typically found in abundance in the MPA include Atlantic Cod (*Gadus morhua*), American Plaice *(Hippoglossides platessoides),* Witch Flounder *(Glyptocephalus cynoglossus*)*,* redfish *(Sebastes* spp.)*,* Atlantic Wolffish *(Anarhichas lupus*)*,* White (*Urophycis tenuis*) and Silver *(Merluccius bilinearis)* hake, Smooth Skate *(Malacoraja senta*)*,* and Thorny Skate *(Amblyraja radiata*)*.* The MPA also forms part of the migration corridor from the Atlantic Ocean into the Gulf of St. Lawrence used by animals such as groundfish, tuna, sharks, cetaceans, and Leatherback Turtles (*Dermochelys coriacea*).

The benthic habitats of SAB have been well-studied since the 2010s. The three primary benthic habitats discussed by Ford and Serdynska (2013) include inshore bank shallower than 100 m, the continental shelf between 100-200 m, and the continental slope and channel deeper than 200 m. The MPA includes significant shallow gravel and cobble areas, several shallow banks (Scatarie and Curdo), and descends into the deep Laurentian Channel along its northeastern border. Depths within the MPA range approximately from 20 to 400 m (Figure 2). The Canadian Hydrographic Service (CHS) conducted multibeam surveys in 2010, 2011, and 2012, and an industry-led multibeam survey occurred in 2013, using different vessels and multibeam frequencies (Lacharité et al. 2018). These surveys covered 2870 km^2 or 66% of the MPA by area. The areas yet to be surveyed primarily include the northwest corner of the MPA and the deeper waters of the slope and Laurentian Channel, which comprise portions of Zones 1 and 2. These multibeam surveys were coupled with benthic imagery surveys that took place in 2009 aboard the CCGS Hudson by both DFO and the Geological Survey of Canada, in 2010 aboard the CCGS Matthew by Natural Resources Canada, and dedicated georeferenced photographic surveys in November 2013 and September 2014 to create a benthoscape map of the MPA (Lacharité et al. 2018). Seven benthoscapes were identified through the combination of multibeam backscatter data and benthic imagery for groundtruthing (Table 1, Figure 1).

Further analyses of the high-resolution imagery used to ground truth the benthoscape classes were conducted by Lacharité and Brown (2019) who identified 70 benthic taxa across 43 stations. These taxa include algae, poriferans, bryozoans, cnidarians, echinoderms, arthropods (crustaceans and sea spiders), and tunicates (including the invasive species *Didemnum vexillum)* (Lacharité and Brown 2019). The species detected form five clusters of epibiotic assemblages in the MPA, three of which are associated with specific benthoscapes, and two clusters associated with multiple benthoscape classes but separated into eastern and western components. Indicator taxa characteristic of each assemblage cluster were also identified by Lacharité and Brown (2019), which could be used as indicator species in MPA monitoring. However, this work did not include fishes or other vertebrates in the assemblage clusters.

MANAGEMENT

SAB MPA contains four distinct management zones. Zone 1, the core conservation zone, encompasses approximately 76% of the MPA's total area and prohibits all commercial fishing activities. Zones 2, 3, and 4 permit some commercial fishing including pot, trap, rod and reel, bottom longline, handline, and gill netting. Zone 1 contains all the species assemblage clusters identified by Lacharité and Brown (2019), while Zone 2 contains the boulders/till with coralline algae, sand with sand dollars, and mixed sediment-West assemblages. Zones 3 and 4 only contain the mud-dominated assemblage (Figure 1). Prior to its designation, commercial fishing activity within the MPA boundaries was relatively minimal. Consequently, while the MPA is expected to offer effective stress mitigation for the existing ecosystem, it is important to recognize that its primary goal is not necessarily to replenish depleted fish stocks or drive significant increases in biodiversity over time. However, the MPA does provide stability to the diverse and representative ecosystems of the Eastern Scotian Shelf.

As an MPA designed for conserving a diverse habitat types and associated species assemblages, SAB has the following conservation objectives structured around three thematic elements:

1. **Habitat**

   Conserve and protect all benthic, demersal, and pelagic habitats in the MPA, the distinctive physical features and their associated ecological characteristics, and the structural habitat provided by sea pens and sponges in the MPA.

2. **Biodiversity**

   Conserve and protect marine areas of high biodiversity at the community, species, population and genetic levels within the St. Anns Bank MPA, including:

   - Priority species and their habitats (including leatherback turtle, Atlantic wolffish, Atlantic cod, and American plaice); and
   - Area(s) of high fish diversity within the site.

3. **Productivity**

   Conserve and protect biological productivity across all trophic levels so that they can fulfill their ecological role in the ecosystems of the St. Anns Bank MPA.

Due to the general nature of these objectives, it is realized the SAB MPA is not designed to protect any one species, but the diverse community of algae, invertebrates, fishes, and other animals characteristic of the area.

MONITORING

Adaptive management aims to sustain the long-term effectiveness of management measures, especially within MPAs. It entails evaluating ecosystem changes and aligning them with MPA activities to prioritize management interventions, thus ensuring conservation efficiency over time. Accurate information on species distribution and diversity within MPAs is pivotal for ongoing site management (Ahmadia et al. 2015, Dunham et al. 2020, Morris et al. 2024). Decisions regarding management zoning, risk assessments, activity approvals, and management effectiveness all depend on data about species distribution and abundance collected in a consistent manner over time. Effective implementation of a monitoring program within an MPA necessitates baseline information on biological communities (e.g., diversity) and ecological properties (e.g., animal movement patters – see Pettitt-Wade et al. 2024). Quantifiable shifts in an MPA's community composition, changes in genetic diversity, or in size classes of particular species can serve as measures of ecological response. These changes can indicate improvements or declines, potentially signalling an MPA as being "effective" (or at least not ineffective) depending on the direction of change relative to a baseline. For example, an increase in species biomass or richness over time suggests that any reductions in anthropogenic impacts may be benefitting the ecosystem, while declines in biomass or richness may trigger new regulatory interventions and adaptive management considerations. Even when trends emerge, it can be difficult to prove they are related to the MPA itself without considering trends occurring over a broader spatial scale.

Similarly, effectiveness can be interpreted as a lack of trend or stability, whereby the effectiveness of an MPA is achieved through the maintenance of ecological processes. This effectiveness becomes important when contrasted against unprotected ecosystems, or as part of a coordinated network monitoring approach, where each MPA contributes to regional scale conservation priorities (Balbar et al. 2019). The SAB MPA was not designed to protect any one specific species or habitat feature, and instead includes representative habitat types characteristic of the Eastern Scotian Shelf. As such, monitoring the MPA should consider the entire ecosystem and community structure, rather than focusing on abundances of a single species. Furthermore, because the MPA was designed to minimize the displacement of existing activities, effectiveness may be evaluated based on the absence of negative trends. However, it is important to acknowledge that many MPAs are not expected to yield immediate improvements in habitat quality or species richness, particularly in temperate systems. Hence, long-term, consistent monitoring of the ecosystem as a whole is essential (Kenchington, 2014).

The establishment of an MPA does not always guarantee conservation success towards established goals (De Santo, 2013; Morris et al. 2024). Various factors contribute to this, including unrealistic conservation objectives and challenges in enforcing MPA restrictions (Claudet, 2018; Giakoumi et al., 2017). The effectiveness of monitoring programs can also be an important factor in the evaluation and successful application of adaptive management principles for spatial conservation measures (Addison et al. 2015; Ahmadia et al., 2015). Regular evaluations of monitoring data are necessary to gauge their effectiveness in evaluating MPA success and critical for maximizing the efficiency of monitoring programs.

The Laurentian Channel MPA lays ~ 40 km to the northeast of the SAB MPA. This MPA was established in a similar area of previously low fishing activity, but, in contrast to the SAB MPA, was designated with primarily species-specific conservation objectives. In a review of monitoring programs, namely the multispecies RV survey, Morris et al. (2024) found that the survey sets conducted in he MPA – but not directed towards monitoring - lacked the statistical power to detect any significant change in biomass of conservation objective species. This analysis highlighted the utility in monitoring program evaluations and provided a basis on which monitoring program approaches could be realigned to better match the unique features and conservation context of the MPA.

Kenchington (2014) recommended 76 monitoring indicators to assess the effectiveness of the then SAB AOI in achieving its proposed conservation objectives. These indicators were chosen based on their feasibility for obtaining high-quality data in a cost-efficient manner, maximizing information while minimizing overall costs. Of these 76, 28 are categorised as “Background” and “Effectiveness” indicators, referring to primarily oceanographic and physical indicators and ecological indicators respectively. The remaining indicators are related to anthropogenic pressures and socio-economic indicators. The 28 Background and Effectiveness indicators will typically be monitored using science programs within the federal government, but with the assistance of partners in academia, other agencies and levels of government, and industry.

Based on the framework assessment criteria by Choi et al. (2018), the snow crab survey was selected for monitoring program evaluation, as it is a part of an on-going sampling program and has both sufficient spatial and temporal coverage across the bioregion (>100 sampling locations and >10 years). Additionally, the snow crab survey addresses each of the broad conservation objective themes for the MPA: habitat, biodiversity, and productivity (Choi et al. 2018). Supported by the MPA science program, the survey has been modified to include 20 "enhanced" survey stations sampled annually between the Gully and SAB MPAs since 2015 (Figure 3). While the Maritimes Research Vessel Ecosystem Trawl Survey also meets these criteria, however, mechanical problems with vessels since 2018 have meant that this survey has not regularly sampled NAFO regions 4VW, rendering this dataset insufficient for examination in this data review (DFO 2023). Moreover, the ecosystem trawl survey is a random stratified survey and thus the number of sets within the MPA varies annually introducing further spatial – temporal variability.

The Maritimes Region Snow Crab Survey uses a Nephrops trawl net with mesh sizes of 80, 60, and 40 mm in the wings, bottom, and cod-end, respectively (Choi et al. 2018). Tows are conducted for approximately five minutes at a speed of two knots. Positional and water temperature data are collected during each tow. There are over 400 tow locations conducted across the Scotian Shelf. The “enhanced” survey stations target a variety of bottom types in the SAB and Gully MPAs in a fixed survey design (sites are sampled annually). Sampling at these stations identifies all catch to species level, weighing and counting all species, and stomach samples taken from finfish to provide diet data inside and adjacent the MPAs (Choi et al. 2018). This survey contributes data to the majority of Effectiveness Indicators identified by Kenchington (2014), particularly Indicators 10-12 relating to benthic diversity and community composition in the MPA, Indicators 14, 15, 18, 20, 21, and 26 relating to abundances, biomass, and size distributions of fishes and trophic interactions in the MPA (Table 2).

In this report, we conduct the first comprehensive review of trends in conservation priorities of the St. Anns Bank MPA using the snow crab survey data. Our analysis focuses on changes in species richness, abundance, and community composition over time. Additionally, we examine potential changes in size and biomass of benthic and demersal fishes and invertebrates, linking these findings to the MPA's conservation objectives. We also investigate patterns of habitat association and species turnover, connecting species captured in the crab survey to habitat benthoscapes and unique epibenthic community assemblages previously identified for the MPA (from Lacharité et al. 2018, Lacharité and Brown 2019). We utilize power analysis and a BACI (Before-After-Control-Impact) design approach to evaluate the statistical power of the enhanced stations within the St. Anns Bank MPA to assess trends in richness and species abundance, similar to analyses conducted for the neighbouring Laurentian Channel MPA (Morris et al. 2024). Finally, diet data from fish stomachs collected in the SCS is assessed for trends in diet composition and species richness. This preliminary analysis aims to determine if indicator species can be effectively monitored across SAB's benthoscapes using the crab trawl survey.

METHODS

OPEN DATA AVAILABILITY

All data, including survey catch data, metadata, shapefiles, and code used in this report are available in Github (https://github.com/dfo-mar-mpas/stannsbank_mpa). All analyses were conducted in R 4.3.1.

SNOW CRAB SURVEY DATA

Data from the regular and enhanced snow crab survey stations from 2015 to 2023 (n=14 stations inside the MPA, and n=5 stations outside the MPA) were downloaded from DFO's Industry Surveys Database (ISDB - retrieved December 12, 2023), which is maintained by the Population Ecology Division, Maritimes Region. While some stations have been sampled since 2004, we opted to analyze data encompassing 2015 to present, starting when the enhanced stations began as part of the MPA establishment (Figure 1). Standard snow crab survey sets deploy trawls for about 5 minutes and sweeping an average area of approximately 0.0039 km^2 (Choi 2023). Weight, size, and claw hardness of snow crab captured are measured in each set. Bycatch species composition is also record but length or weight are not measured. The 2019 survey extended into January 2020, but there was no crab survey in fall 2020 due to the COVID-19 pandemic, leaving a gap in the time series data. In 2022, several vessel breakdowns occurred and less stations were fished than in other years, which may bias results on richness.

The enhanced survey stations record the size (length for most species but carapace width for crabs) and weight of all bycatch, and also collects stomach contents for diet data at stations inside and adjacent the MPA. Thus, the data for all stations used in this analysis (enhanced and regular) contain information on the number of individuals per species per set captured each year, while solely the enhanced survey stations include data on individual size and weight of all bycatch captured. All sets are standardized to a standard distance. Of note, while pelagic species are occasionally captured in the trawl net, it is not designed to capture these species effectively, similar to the ecosystem trawl survey. As a result, we note the presence and size distribution of pelagic fishes and plankton but exclude them from community and species richness analyses. These data were used to examine trends in species richness between 2015 and 2023, catch per unit effort (CPUE) of species over time, the length and weight distributions of each species, and map the distributions of key species within and adjacent to the MPA.

We also collated data on species occurrence within the MPA from the Ocean Biodiversity Information System (OBIS), which is primarily populated by DFO's seasonal RV ecosystem surveys since the 1950s. Additional datasets that populate OBIS from within the MPA include animals tagged for acoustic telemetry (from the Ocean Tracking Network database – see Pettitt-Wade et al. 2024), some fisheries surveys, the Census of Marine Life, and FishBase. This data was used as a record of community assemblage within the MPA and used to estimate the asymptotic diversity based on species accumulation curves.

DIVERSITY STATISTICS

Species richness, accumulation curves, and analyses of community structure among stations and benthoscape classes were conducted. Species richness per sample was calculated as the number of unique taxa, including species, genus, family, and class levels. Richness was also modeled using linear regression with sample depth, where depth was extracted from available multibeam and digital elevation models from the Government of Canada. Species accumulation curves were generated by creating a matrix of counts per species per sample station and using this as input for the *specaccum* function in vegan. Separate curves were generated for the stations inside and outside the MPA respectively.

Non-metric multidimensional scaling (NMDS) was used to visualize dissimilarities in species compositions among sampling stations. The *metaMDS* function in vegan was used with a distance matrix of among-station community differences based on Bray-Curtis dissimilarity to cluster sampling stations on NMDS axes 1 and 2. Each NMDS was considered to be a good fit for the data when stress levels were <0.1.

POWER ANALYSES

Power analyses can be used to quantify the ability to confidently detect changes in abundance using existing or simulated survey designs (Livermore et al. 2023). We modeled CPUE as individuals caught per km^2 over time for seven species (Snow Crab, Atlantic Cod, American Plaice, Witch Flounder, Thorny Skate, Redfish, and Atlantic Wolffish) and species richness (the total number of species caught per sample) using a generalized linear mixed effects model with a negative binomial distribution via the *glmer.nb* function in the lme4 R package (Bates et al. 2015). We compared the power to detect both small and large effects on abundance changes across different numbers of sample stations We divided the data into year blocks of 2015-2018 and 2019-2023 for a before-after-control-impact (BACI) design which was used as a fixed effect in the model, while station depth and benthoscape class were set as random variables (see equation).

glme.nb(CPUE ~ Time.Period + (1 | Depth.Class) + (1 | Benthoscape.Class))

The benthoscape class used in the model is the corresponding benthoscape where a given trawl sample takes place. Depth.Class was derived from the *getNOAA.bathy* function in the marmap R package (Pante et al. 2023), and consisted of samples collected from shallower than 100 metres, and deeper than 100 m. Following the model fitting using the survey data, we simulated the dependent values for each model using the negative binomial shape parameter (theta) value extracted from the model for each species. We simulated and modeled the dataset for each species and species richness 1000 times with varying sample stations (n=10, 25, 50, 100), effect sizes (i.e., changes in richness or abundance, from 0.1 to 1.0), and effect direction (increase or decrease) to determine the overall impact on the number of sampling stations on our ability to detect changes in species richness and CPUE over time. These results were then plotted in R to show changes in power with effect size and the number of sampling stations, per species.

DIET DATA

Stomach content data (herein referred to as diet data) collected in the SCS was analyzed from 2015 to 2022; at the time of this report, data was not available from samples collected in 2023. The diet data contains the identity of all predators captured in the enhanced SCS, as well as their identified stomach contents, and measures of stomach fullness and digestion level of food. Species richness of prey within predator stomachs at stations inside and outside the MPA was calculated to examine trends over time. We investigated prey richness per main predator species (all predatory fish) over time within and outside the MPA. NMDS was used to visualize the community of prey species in two dimensions both within and outside the MPA and per year and to detect potential changes in diet over time. NMDS analyses were deemed to be a good fit for the data when stress <0.1.

RESULTS

SUMMARY OF CATCH DATA

The mean area swept across all trawl sets and years was 0.004357 km^2 ± $6.730e^{-5}$ (mean ± s.e.), which comprises a small fraction of the MPA by area, ~ $9.98e^{-5}$ %. The survey stations are predominantly in zone 1 (the core protection zone) with only two stations in zone 2, and no stations within zones 3 and 4. There are no stations in the deepest portion of zone 1 below 250m. The benthic temperature recorded during each trawl set is consistent with monitoring conducted by the Atlantic Zone Monitoring Program, where the cold intermediate layer in the MPA occurs around 90m, with temperatures increasing to near 8°C around 200m (Figure 4, Layton et al. 2020).

Since 2015, the crab survey has recorded over 110 species within and around the MPA. However, because many invertebrates, such as sponges, cnidarians, and shrimp, were not identified to the species level, this number is an underestimate. As per the nature of a trawl designed to catch benthic crustaceans, most of captured fish species were benthic or demersal, including Atlantic Cod, redfish, skates, Silver and White hake, Witch Flounder, American Plaice and other flatfish, wolffish, and eelpouts (Table 3). The most abundant fish species caught in the trawl are redfish and Witch Flounder, though some species such as Thorny Skate, Atlantic Cod, and American Plaice are captured regularly each year (Figure 5, Figure 6). Dominant invertebrates include Snow Crab, Northern Stone Crab, other crabs and shrimps, echinoderms such as sea stars and urchins, tunicates, sea pens, and sponges which are typically not identified below the phylum or class level. Unsurprisingly Snow Crab were captured every year in the MPA, as the survey is designed for their assessment and the MPA is in an area of highly suitable habitat (Figure 5, Figure 6). Some pelagic fish species are occasionally caught incidentally, either while swimming near bottom or as the trawl net descends in the water column. These include Atlantic Saury, Mackerel, Alewife, and Herring (Table 3). Absent from the survey are any crinoids, which are a notable feature of the MPA (crinoid fields were observed during benthic imaging surveys in 2023 and 2024). This absence is likely attributed to the lack of survey stations within the identified 'gravel with crinoids' benthoscape classification, which constitutes a relatively small proportion of the benthic area. More conspicuously, no lobsters were caught in any of the crab survey sets analyzed for this study.

We found that trends were consistent inside and outside the MPA (Figure 7, Figure 8). For the most part, body length and weight per species remained stable throughout the time series, varying without any significant trend. The only exception to this was a slight increase in both metrics of redfish (*Sebastes* spp.) from 2015 to 2023. Increases in the prevalence of redfish was consistent inside and outside the MPA. The median and 90th percentile sized-fish of the most common species captured are generally stable, but also variable over time (Figure 9, Figure 10). Specifically inside the MPA, the length and biomass of Atlantic Wolffish seem to be increasing since 2015, though their abundances have remained stable (Figure 11). Similarly, the mean carapace width of Snow Crab in the MPA is larger in 2023 relative to 2015, and seems to be stable since 2017 (Figure 12). This is true for both males and females, with males being slightly larger than females in most years, but also greater variation in carapace width (Figure 12).

Species Catch Distributions

The relative abundance and location of key species of conservation interest were plotted through time inside and outside the MPA (Figure 13 Figure 14 Figure 24). American Plaice, Atlantic Cod, Witch Flounder, Porifera, and Snow Crab are distributed evenly across Zone 1 of the MPA but are generally captured in lower average abundances in Zone 2. The Polar Sea-Star *L. polaris,* which was proposed as an indicator of three benthoscape classes, has only been caught in relatively shallow, gravel/cobble areas (Figure 16). Silver Hake are typically captured in deeper sections of Zone 1, but are also caught in similar frequency at stations immediately south of the MPA (Figure 20). Finally, several species are only caught in the deep mud and sand benthic habitats descending the continental slope into the Laurentian Channel. These species include sea pens (Pennatuloidea), White Hake, and redfish (*Sebastes* spp.).

BENTHIC COMMUNITY DIVERSITY

Species richness is slightly higher inside the MPA relative to outside, even when accounting for differences in sampling effort. Species accumulation curves show that richness both inside and outside the MPA continues to increase, though these trends are leveling off (Figure 25). However, the species accumulation curve for the SCS trawl stations shows lower richness than the diet data (discussed below), and substantially lower than species richness from publicly available OBIS data for the area (Figure 26), likely owing the differences between the small footprint of samples in the SCS in comparison to the ecosystem trawl survey. Species richness appears stable through time within the MPA but shows a slight decline across the five stations outside the MPA (Figure 27). Species richness both inside and outside the MPA increased with depth, but was slightly higher within the MPA relative to outside (Figure 28, Figure 29).

NMDS analyses (stress=0.086, k=5) of all SCS catch data showed a high concordance between species composition and benthoscape class (Figure 30). NMDS showed separation of each benthoscape class on axes 1 and 2, with soft bottomed substrates differing in community structure than hard bottomed substrates. There was no obvious distinction between communities within and outside the MPA. This trend was stable across all years, with no significant differences in community structure over time inside and outside the MPA (Figure 31).

POWER ANALYSES

We conducted power analyses of CPUE against time period (2015-2018 or 2019-2023) using station depth and benthoscape class as random effects in the model for Atlantic Wolffish, Atlantic Cod, Thorny Skate, Redfish, American Plaice, Witch Flounder, and Snow Crab. We also modeled species richness for each time period again using station location as random effects (Figure 32). Power was generally low when sampling only 10 stations, and only increased to >80% for large effect sizes when 25 or more stations were sampled. However, ten (or more) sampling stations could be used to achieve 80% power or higher for moderate effect sizes (0.25 or more, representing a change in abundance >25%) for species richness, and Thorny Skate, Atlantic Wolffish. Power to detect increases in abundance of the most abundant species, including Atlantic Cod, Witch Flounder, American Plaice, Redfish, and Snow Crab, was generally low (<60% even with 100 samples with the exception of American Plaice, Figure 32). Decreases in abundance of these species were more readily detectable, but 80% power was only achievable for effect sizes >0.5 and generally with mor than 25 sampling stations.

DIET DATA

Between 2015 and 2021 5,674 stomachs were examined from the Snow Crab survey. Approximately 24% of these stomachs were empty (fullness = 0), while the remainder ranged from less than 25% full to completely full (fullness = 1-4; Figure 33). Stomach fullness in key predator species was comparable inside and outside the MPA, but were variable over time, showing no clear trend (Figure 34). Species richness in the diet data increased more rapidly than the SCS trawl survey catch data and does not appear to have leveled off (Figure 35). Diet richness in seven predator species (American Plaice, Atlantic Cod, Atlantic Wolffish, redfish, Thorny Skate, White Hake, and Witch Flounder) was generally comparable but slightly higher inside relative to outside the MPA, overall remaining relatively stable between 2015 and 2022 (Figure 36). NMDS based on Bray-Curtis and presence-absence dissimilarities of diet data within each predator showed a high degree of overlap inside and outside the MPA, with the exception of Atlantic Cod and American Plaice where diet showed little overlap inside and outside the MPA (Figure 37, Figure 38). When split by benthoscape, predators captured in the mud class had the highest diet richness, while diet richness was lowest in the till-coralline algae benthoscape class (Figure 39).

DISCUSSION

The Maritimes annual snow crab survey has conducted enhanced sampling stations in both the Gully and SAB MPAs since 2015, providing valuable information on the benthic communities, size distributions of animals, and diet data for these two MPAs. In this report we analyzed trends in species diversity, size structure, diet data, and community structure over time both inside and outside the MPA. Temperature data collected by the trawl net, while limited in spatial and temporal scale, shows trends with depth consistent with data from the fall Atlantic Zone Monitoring Program (AZMP) surveys (Layton et al. 2020). These temperature data provide an important snapshot of benthic temperatures across the MPA and may be useful for evaluating species thermal habitat preferences. The species captured in this survey are largely reflective of those discussed by Ford and Serdynska (2013), and of the broader Eastern Scotian Shelf (O’Brien et al. 2022). Witch Flounder and redfish are the most abundant fish species caught in this survey, while Snow Crab, sea stars, sand dollars, sea pens, Northern Shrimp (*Pandalus* *borealis*), and sponges are the dominant invertebrates captured. Species richness in trawl sets within the MPA is generally higher than in those immediately outside the MPA, though these differences were not significant. Communities inside and outside the MPA appear to be stable through time, though with increased sampling effort and time these patterns may change. There is no benthoscape classification for stations immediately outside of the MPA. If the benthoscape classifications in the MPA are simply extended outside the MPA, then at least four of five outside stations may take place over mud habitat (Figure 1). Benthoscape classification could thus be extended beyond the MPA boundaries to determine if the higher diversity within SAB is potentially due to the MPA's conservation regulations or differences in habitat types.

Some species, such as sponges, sea stars, American Plaice, Atlantic Cod, and Snow Crab are captured relatively uniformly across the MPA. Others, including sea pens, hake, redfish, and Witch Flounder are typically found in deeper portions of the MPA, and on muddy substrates common in deeper waters, indicative of more narrow niche characteristics. Differences in substrate type, benthic temperature, and salinity all play a role in a species' distribution and overall fitness, with some species possessing only narrow physiological thresholds in which they can survive and reproduce. Our analysis demonstrate that fish and invertebrate assemblages captured by the SCS consistently varied across benthic habitat types, highlighting that it will be critical that long-term sampling programs account for this variation and sample across a range of habitat types and depths to fully resolve patterns of species diversity that characterize the MPA.

Kenchington (2014) and Choi et al. (2018) proposed monitoring frameworks for St. Anns Bank MPA. The framework proposed by Kenchington (2014) was based on the conservation objectives of the MPA and structured into 76 indicators. Indicators were selected based on their relevance to conservation objectives and priorities, and the availability of data streams, including institutional and collaborative research programs. Information from these enhanced stations can be used to inform benthic effectiveness indicators (i.e., indicators 10-12) providing information on diversity and community composition across habitats within and outside the MPA, as well as Indicators 14, 15, 18, 21, and 26, particularly through analysis of diet data for the latter (Table 2). Indicator 20 specifically refers to abundance of large wolffish, which are a conservation priority for the MPA, in subtidal rocky areas adjacent to the MPA using SCUBA diver transect surveys, which have not yet occurred since the establishment of the MPA. However, the snow crab survey does collect wolffish (primarily Atlantic, only a single Spotted Wolffish) and could be used to detect changes in abundance, biomass, and size distributions of these species over time.

Power analyses conducted using the SCS data suggest that additional sampling stations will be required to detect changes in abundance (both increases and decreases) in species commonly found in the MPA. In most cases, at a minimum 25 stations are required for >80% power to detect change, though in others, such as for American Plaice, over 100 stations are modeled to be required. The power to detect moderate effect sizes (~0.25 and higher) was generally >80% when sampling 10 or more stations for species richness, Thorny Skate, and Atlantic Wolffish (Figure 32). However, the power to detect increases in abundance was low (<80%) in the most abundant species in the MPA (Atlantic Cod, Witch Flounder, American Plaice, Redfish, and Snow Crab). The power to detect decreases in abundance was higher in these species, but still requires sampling 50 or more stations to achieve higher than 80% power. Given the current sampling design of the Snow Crab Survey within the MPA (around 10 stations per year), we can expect to have >80% power to detect moderate to large (0.25-1.0) changes in species richness and abundance of Thorny Skate and Atlantic Wolffish, but <80% power to detect both increases and decreases in abundance of the more abundant species in the MPA even at large effect sizes (>0.75). Power analyses conducted in other Canadian MPAs (e.g., Anderson et al., 2024; Morris et al., 2024) have reached similar conclusions, indicating that additional data is needed for adequate monitoring. Morris et al. (2024) show that research trawls have little statistical power for detecting changes in abundance of three fish species in the large Laurentian Channel MPA. Anderson et al. (2024) note the importance of research trawl surveys in the creation of conservation areas in the Pacific, and in monitoring species richness and abundance. While trawling in sensitive benthic habitats often found in MPAs can be contentious and should avoid vulnerable marine ecosystems, Anderson et al. (2024) note that an absence of research trawls may have negative consequences for fish stock assessments and monitoring. Nevertheless, these studies also highlight the need for non-invasive sampling techniques, such as camera surveys and eDNA sampling, to complement direct sampling methods like research trawls. These complementary methods can help improve statistical power to detect changes in abundance and species diversity, and can be particularly useful for monitoring sessile invertebrates such as sea pens that are otherwise vulnerable to disturbance (Morris et al. 2024).

Diet data paired with trawl surveys can improve estimates of species richness and help understand food web complexity, which can be important for MPAs which focus on conserving general biodiversity (Cook and Bundy 2012). Diet data from fish stomachs can also inform Indicator 26 (trophic relationships in the MPA) proposed by Kenchington (2014) and can also be used to analyze ingestion of microplastics (Bray et al. 2019). Here we found that species richness increases at a steeper rate than the SCS catch data alone, though diet richness within predators was generally stable over time. Similarly, stomach fullness showed no trends over time, and was highly variable among predators and years. Kenchington (2014) suggests using diet data to assign trophic levels to each size class of the main predator fish species in the MPA, or, ideally, to even track changes in diets over time. This would provide information on diversity and productivity in the MPA, and could provide information for changes of abundance of predator and prey species. As our results show at least short-term temporal stability in diet richness and fullness in fish predators, sampling for diet data may not necessarily need to occur every year.

Fish stomachs often contain smaller species and size classes of organisms relative to trawl catches, and thus can provide important data on fitness and ecosystems as a whole that would otherwise be missed by net-based approaches (Cook and Bundy 2012). Diet data does have some caveats, as predators may travel long distances and thus species richness of an area can be artificially inflated relative to species actually present in an area. Additionally, it can be difficult to identify species that are partially digested inside stomachs, which will vary with the amount of time the prey has been its predator’s stomach (Cook and Bundy 2012). Identification of digested stomach contents can however be identified by DNA metabarcoding, and has been shown to complement visual assessments and lead to increased richness estimates from stomach samples (e.g., Gül et al. 2023). We find that the diet data collected as part of the enhanced survey stations provides valuable information towards understanding species richness and potentially food web complexity, but additional data is needed to identify significant trends. As the diet data is primarily obtained from the summer trawl survey and the fall snow crab survey, short-term studies could be designed to sample fish stomachs in the winter and spring to obtain seasonal information on diet composition and stomach fullness. In addition to fish, diet data could also be obtained from zooplankton and benthic invertebrates to provide a fuller picture of trophic relationships in the MPA.

As discussed by Dunham et al. (2020), the focus of monitoring and downstream management decisions should focus on improving MPAs rather than strictly attempting to prove their effectiveness. Monitoring requires robust, long-term datasets in order to detect changes and trends in conservation priorities. Adaptive management requires a monitoring program that can provide the requisite information to base tactical decisions at the site or network scale to ensure that conservation objectives are being met. The effectiveness of these programs will ultimately be contingent on the ability of monitoring programs to track conditions within the MPA and evaluate trends over the long-term. The SCS meets the criteria for monitoring some of the indicators proposed for the MPA, in that the survey is long-term and contributes multiple types of data, but additional years of data are needed to identify trends and determine the stability of the biodiversity and productivity of the MPA.

REGIONAL AND INTER-REGIONAL CONTEXT

Efforts are underway to understand connectivity between SAB MPA and The Gully MPA using animal tracking (acoustic tagging and telemetry) in several species of interest, including Atlantic Cod and Halibut (Pettitt-Wade et al. 2024). The Gully is a large, offshore canyon characterised by a resident population of Northern Bottlenose Whales *(Hyperoodon ampullatus),* a diversity of benthic sessile invertebrates, and populations of benthic and demersal fishes. Like in SAB MPA, since 2015 the SCS has included additional trawl stations inside and outside the Gully MPA. An analysis of five years of SCS stations in the Gully showed little in the way of trends, though increased landings of three species of flatfish and a decrease in landings of Haddock, Snow Crab, and Rock Crab were observed (Kenchington 2023). Kenchington (2023) noted that while the SCS appears to provide useful information for monitoring the Gully, additional sampling with less variability in time of year would be beneficial to reveal trends in species biomass. The same can be said for SAB MPA, where at the very least additional years of data are required to understand longer-term trends.

St. Anns Bank may also be connected with the Gully MPA and *Lophelia* Coral Conservation Area through larval dispersal of different organisms. Particle dispersal models simulate high retention of particles released within SAB MPA with a pelagic larval duration (PLD) of 2 weeks or one month, while PLDs of 3 months showed connections to these other areas across all seasons (Wang et al. 2022). While the soft coral *Paragorgia arborea*, a VME indicator species, has not been observed in SAB MPA, it may be present in the deepest portion of the MPA and may be present in the future, particularly under climate change as the MPA becomes more suitable for this species (Wang et al. 2022). Should *P. arborea* colonise or be found present in the MPA, it would likely contribute larval source-sink dynamics to the Maritimes region’s network of conservation areas (Wang et al. 2022).

SAB MPA is geographically proximate to the Laurentian Channel MPA, which is a large (>11,000km^2) no-take conservation area, and both MPAs share similar deepwater species diversity, including sea pens, skates, and wolffish, in addition to the large pelagic animals that migrate through both areas. Like the SAB MPA, the Laurentian Channel is primarily monitored using trawl surveys, which impact less than 1km^2 of trawled area per survey mission (Morris et al. 2024). Power analyses conducted by Morris et al. (2024), which the power analyses in this report are based on, showed unsurprisingly that greater effort is required to adequately monitor several benthic species in the Laurentian Channel.

The SAB MPA shares several similarities with the Banc-des-Américains MPA, designated in 2019 off the Gaspé Peninsula. Both MPAs contain representative ocean bank habitat, with varying substrate types and topography, and similar conservation objectives focusing on the conservation of biodiversity and habitat types (Faille et al. 2023). A number of cold-water stenotherm species occur in both MPAs and can be used as indicators of ecosystem status and temperature-related change. Greenland Halibut, American Plaice, Witch Flounder, Atlantic Wolffish, Fourline Snakeblenny, Snow Crab, and Polar Sea Star are regularly captured in the SCS in SAB, and in Banc-des-Américains these species are suggested as indicators of benthic community change (Faille et al. 2023). In conjunction with monitoring the presence and abundance of cold-water species in these MPAs, the presence and abundance of warm-water species should also be monitored (Faille et al. 2023). This is especially important under climate change, where warm-water associated species found in the western Scotian Shelf and further south are shift their distributions further north (O'Brien et al. 2022).

DATA GAPS

The data analyzed here exists in relative isolation from other monitoring programs, and could benefit from combined analysis with AZMP oceanographic data, and acoustic telemetry data (Chung et al. 2021). Similarly, acoustic tagging studies could benefit from the information presented here, to target species of conservation interest in the MPA such as Atlantic Wolffish. An understanding of catch distribution in the MPA provides valuable information on where to collect and tag these species, and also where to potentially deploy acoustic receivers to detect their movement patterns.

The crab survey only includes two sampling stations in zone 2 and does not have any stations in zones 3 and 4 of the MPA, and thus whether species richness and community structure are impacted by these management zones is unknown. Adding a station to each of these relatively small zones may be of benefit for monitoring but should avoid the "gravel with crinoids" benthoscape class due to the density of these organisms in these areas. Crinoids have been identified as indicator taxa for vulnerable marine ecosystems (VMEs) and should thus be monitored in a non-destructive manner, such as visual surveys (Laura and Mariano 2021). There is also a lack of sampling stations in the deepest portion of the MPA in the Laurentian Channel. Camera and eDNA surveys in this deep water may serve as an alternative to conducting trawl sets, which may be limited by time or water depth.

Beyond the spatial extent of the survey, the SCS regularly occurs in the fall and into the winter each year, and thus does not capture seasonal diversity or biomass changes through spawning, migration, and predation. In fact, the SCS occurs across a number of months (September to December in St. Anns Bank) among years, which may also yield different catches and estimates of richness. Though not directly comparable due to differences in set and net parameters, the summer ecosystem survey could complement the snow crab survey by providing information in the summer months, before the crab survey takes place. An analysis comparing both trawl surveys was not possible for the current study due to vessel mechanical issues occurring between 2018 and 2022, but a comparison of these surveys could be conducted when more data is available.

The snow crab and seasonal trawl surveys do not quantitatively capture pelagic fish and invertebrates such as squid, jellyfish, euphausiids, and other plankton (Choi et al. 2018). Infauna and meiofauna are also not captured in trawl surveys, and while often not explicitly monitored, these taxa play important roles in trophic energy transfer and ecosystem health (Balsamo et al. 2012). While the Snow Crab survey can incidentally capture pelagic and planktonic species, such as Atlantic Herring and Mackerel, it is not a reliable source of data for these species. Trawl nets can also be less efficient for catching some taxa, such as sea pens. To assess sessile invertebrates at fine spatial scales, imagery from remotely operated vehicles or drop cameras can be more effective and accurate (de Mendonça and Metaxas 2021). Another data gap noted by Choi et al. (2018) is genetic diversity, at least of species noted as conservation priorities for the MPA. Both data gaps have not currently been remedied since the development of the framework assessment for the MPA, though the snow crab (and longline) surveys could be used to sample fish for genetic diversity indices in future years.

CONCLUSIONS

Ultimately the snow crab trawl survey provides valuable information for monitoring benthic and demersal animal diversity within the MPA. The diet data collected in this survey also contributes to the overall species richness of the MPA, though predators caught in the MPA may be feeding outside the MPA, artificially inflating estimates of total richness. The diet data can be used to assign trophic levels to various predator species and could be monitored over time along with fish and invertebrate diversity and abundance. Due to the survey’s function as a seasonal benthic sampling device, information on infaunal animals, as well as plankton and migratory pelagic animals are not captured in these data. By combining the snow crab survey with other sources of data, such as AZMP phyto- and zooplankton samples, *in situ* visual surveys, cetacean and seabird monitoring programs, and environmental DNA metabarcoding, a more synoptic picture of the MPA can be developed. Overall, the snow crab survey appears to be a useful monitoring tool for SAB MPA, but additional sampling stations and years of sampling may be required to examine trends in some species abundance and richness over time. Complementing trawl surveys with camera and eDNA surveys, especially in regions with particularly sensitive benthic environments, may help to increase power to detect changes in a cost-efficient and non-invasive manner.

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TABLES AND FIGURES

Table 1. Seven benthoscape classes identified within St. Anns Bank Marine Protected Area with their mean depth range listed (Modified from Lacharité et al. 2018 and Lacharité and Brown 2019). The mean depth and range of each benthoscape is provided, as well as proposed indicator species for each class.

Benthoscape	**Mean Depth (m) [range]**	**Species Assemblage (Indicator species)**
Mud	139 [89-197]	Mud-dominated (*Bathysiphon* sp., *Pennatula* sp., Cerianthids)
Mud with seapens	243 [218-272]	Mud-dominated (*Bathysiphon* sp., *Pennatula* sp., Cerianthids)
Gravelly sand/mud; <50% cobbles/gravel	129 [57-213]	Mixed Sediment – East and West (East: Crinoidea, Porifera; West: Ophiuroidea, *Hyas* sp., *Leptasterias polaris*)
Till >50% cobbles/gravel	94 [62-195]	Mixed Sediment – East and West (East: Crinoidea, Porifera; West: Ophiuroidea, *Hyas* sp., *Leptasterias polaris*)
Till with coralline algae	52 [33-62]	Boulders/till with coralline algae (*Lithothamnion* sp., Porifera, Bryozoa, *Lucernaria quadricornis, Henricia* sp., *Flustra folicea*, Actiniaria, *Pteraster militaris*, *Molgula* sp.)
Gravel with crinoids	84 [75-97]	Mixed Sediment – East and West (East: Crinoidea, Porifera; West: Ophiuroidea, *Hyas* sp., *Leptasterias polaris*)
Sand with sand dollars	64 [51-91]	Sand with sand dollars (*Echinarachnius parma*)

Table 2. List of indicators and their descriptions from Kenchington (2014) for St. Anns Bank MPA that could be monitored using the Maritimes Snow Crab Survey (SCS).

Benthic Environments	**Description**	**Assessment**
Indicator 10	Diversity and community composition of the benthos, abundance or biomass and size composition of selected benthic taxa, and characteristics of surficial geology at selected sampling stations, distributed across the seabed environment types represented in the MPA	The SCS uses a standard Nephrops trawl to sample a small area of the MPA. Sample stations exist in different benthoscapes (Figure 1), which collect a diversity of benthic and demersal fish and invertebrate species. Each

Benthic Environments	Description	Assessment
	(with particular emphasis on the habitats of species named in the objectives of the MPA, such as wolffish), as determined from selected dredge, grab, core, video and/or diver sampling methods	trawl set measures the size and weight of snow crab caught, and 'enhanced' stations provide measurements of bycatch size distributions. Thus the SCS can be used to address this indicator.
Indicator 11	Diversity and community composition of the benthos, abundance or biomass and size composition of selected benthic taxa and characteristics of surficial geology at comparable sampling stations outside the MPA, as determined from the same sampling methods used within the MPA	The SCS samples regular and enhanced stations within and outside the MPA using the same methods (i.e., a Nephrops trawl). Our results show that at least for the data period analyzed, there is little difference in community structure at sampling sites inside and immediately outside the MPA. However, some stations outside the MPA do capture relatively larger amounts of some species, such as Snow Crab and Silver Hake. The SCS can be used to address this indicator.
Indicator 12	Diversity and community composition of the benthos and characteristics of surficial geology at selected sampling stations located in the identified distinctive seabed features of the AOI, plus abundance or biomass and size composition of the defining benthic taxa of those features, as determined from selected dredge, grab, core, video and/or diver sampling	The SCS uses a standard Nephrops trawl to sample a small area of the MPA. Sample stations exist in different benthoscapes (Figure 1), which collect a diversity of benthic and demersal fish and invertebrate species. Each trawl set measures the size and weight of snow crab caught, and 'enhanced' stations provide measurements of bycatch size distributions. Thus the SCS can be used to address this indicator.
Fish and Fishery Resources		
Indicator 14	Population-wide abundances and size distributions of those populations of resource species which utilize the MPA, as	The SCS is used by the Snow Crab Stock Assessment Team in the Maritimes Region to inform

Benthic Environments	Description	Assessment
	determined by fishery stock assessments	population-wide abundances and size distributions.
Indicator 15	Relative abundances, biomasses, size distributions and population fecundities of selected groundfish and invertebrates, plus diversity and community composition of trawl-vulnerable species, in appropriate portions of the MPA, as determined by groundfish and snow-crab trawl surveys	The SCS uses a standard Nephrops trawl to sample a small area of the MPA. Sample stations exist in different benthoscapes (Figure 1), which collect a diversity of benthic and demersal fish and invertebrate species. Each trawl set measures the size and weight of snow crab caught, and 'enhanced' stations provide measurements of bycatch size distributions. Fecundity of individuals caught could in theory be included in this survey at enhanced stations. Thus the SCS can be used to address this indicator.
Indicator 18	Relative abundances, biomasses, size distributions and population fecundities of selected groundfish and invertebrates, plus diversity and community composition of trawl-vulnerable species, in comparable areas outside the MPA, as determined by groundfish and snowcrab trawl surveys	Similar to Indicator 15, the SCS could be used to address this indicator. Five enhanced stations exist outside the MPA which collect a diversity of benthic and demersal fish and invertebrate species. Each trawl set measures the size and weight of snow crab caught, and 'enhanced' stations provide measurements of bycatch size distributions. Fecundity of individuals caught could in theory be included in this survey at enhanced stations. Thus the SCS can be used to address this indicator.
Indicator 20	Abundance of large wolffish in sub-tidal rocky areas along the coastline adjacent to the MPA, as determined by diver transect surveys	The SCS does not target wolffish specifically in shallow, coastal environments, but does capture wolffish in the MPA regularly. Wolffish size is

Benthic Environments	Description	Assessment
		recorded in the enhanced SCS stations, but diver transects would be needed to collect data on this specific indicator.
Indicator 21	Fluxes of fish and other nekton across the boundaries of the MPA	The SCS has stations inside and outside the MPA which can quantify distributions and abundance of fish and invertebrates across the boundaries of the MPA. These data provide only a seasonal (fall) snapshot of animal fluxes, and could be paired with telemetry methods to more accurately address this indicator.
Indicator 26	Trophic relationships in the MPA	Diet data from the enhanced SCS stations shows prey diversity in predator fish species and thus information on trophic relationships in and around the MPA. Tissue samples could also be collected from species of interest for stable isotope and food web analyses.

Table 3. Fish species captured in the annual snow crab survey occurring within and adjacent to St. Anns Bank MPA since 2015, sorted by the total number caught across all years. Note that there was no survey in 2020.

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
SEBASTES SPP.	Redfish unsorted	4627	1976	2475	1828	487	588	2266	984	15231
GLYPTOCEPHALUS CYNOGLOSSUS	Witch Flounder	736	658	956	3520	1723	707	1323	1292	10915
HIPPOGLOSSOIDES PLATESSOIDES	American Plaice	455	536	388	299	538	451	367	368	3402
GADUS MORHUA	Atlantic Cod	159	46	44	63	82	122	136	225	877
NEZUMIA BAIRDII	Marlin-spike Grenadier	108	100	75	81	85	89	202	73	813
AMBLYRAJA RADIATA	Thorny Skate	68	59	63	61	82	89	61	63	546
PHYCIS CHESTERI	Longfin Hake	221	97	9	73	30	17	64	34	545

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
UROPHYCIS TENUIS	White Hake	149	71	32	79	35	31	65	62	524
MERLUCCIUS BILINEARIS	Silver Hake	4	58	38	47	12	164	66	46	435
CLUPEA HARENGUS	Atlantic Herring	6	91	2	3	1	50	157	30	340
MALACORAJA SENTA	Smooth Skate	20	18	30	53	62	22	29	45	279
ANARHICHAS LUPUS	Atlantic Wolffish	20	17	8	17	6	17	19	17	121
MYZOPSETTA FERRUGINEA	Yellowtail Flounder	9	5	12	10	4	24	21	11	96
TRIGLOPS PINGELII	Ribbed Sculpin	26	6	13	1	3	1	6	1	57
MYOXOCEPHALUS SCORPIUS	Shorthorn Sculpin	5	5	3	3	5	15	13	NA	49
REINHARDTIUS HIPPOGLOSSOIDES	Greenland Halibut	10	4	5	4	7	1	6	3	40
ENCHELYOPUS CIMBRIUS	Fourbeard Rockling	14	7	2	2	2	2	5	3	37
LEPTAGONUS DECAGONUS	Atlantic Poacher	1	4	2	0	16	0	11	1	35
AGONIDAE	Alligatorfishes	10	3	4	2	5	2	7	1	34
LOPHIUS AMERICANUS	American Anglerfish	4	3	7	2	5	1	5	3	30
LYCODES VAHLII	Vahl's Eelpout	6	4	1	3	2	0	3	3	22
GYMNOCANTHUS TRICUSPIS	Arctic Staghorn Sculpin	0	0	0	0	0	0	3	15	18
TRIGLOPS MURRAYI	Moustache Sculpin	0	3	5	0	3	0	6	0	17
ARTEDIELLUS SP.	Sculpins	0	0	0	0	13	3	0	0	16
LYCODES	Eelpouts	8	0	1	0	1	3	0	2	15
EUMESOGRAMMUS PRAECISUS	Fourline Snakeblenny	4	0	2	0	0	1	2	2	11
ARTEDIELLUS ATLANTICUS	Atlantic Hookear Sculpin	0	0	10	0	0	0	0	0	10
MYOXOCEPHALUS OCTODECEMSPINOSUS	Longhorn Sculpin	1	2	0	0	1	3	1	2	10
ARTEDIELLUS UNCINATUS	Arctic Hookear Sculpin	0	0	0	8	0	0	0	0	8
LEPTOCLINUS MACULATUS	Daubed Shanny	1	1	0	1	2	3	0	0	8

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
HIPPOGLOSSUS HIPPOGLOSSUS	Atlantic Halibut	2	1	0	1	0	1	0	1	6
SCOMBER SCOMBRUS	Atlantic Mackerel	1	0	0	0	1	0	3	0	5
EUMICROTREMUS SPINOSUS	Atlantic Spiny Lumpsucker	2	0	0	0	1	0	0	1	4
LUMPENUS LAMPRETAEFORMIS	Snakeblenny	0	0	0	0	0	3	0	0	3
LYCODES RETICULATUS	Arctic Eelpout	2	0	0	0	0	1	0	0	3
LYCODES TERRAENOVAE	Newfoundland Eelpout	0	0	0	0	0	0	0	3	3
ALOSA PSEUDOHARENGUS	Alewife	0	0	0	0	0	1	1	0	2
LYCODES PALLIDUS	Pale Eelpout	0	0	2	0	0	0	0	0	2
MYOXOCEPHALUS AENAEUS	Grubby Sculpin	2	0	0	0	0	0	0	0	2
ANARHICHAS MINOR	Spotted Wolffish	0	1	0	0	0	0	0	0	1
HEMITRIPTERUS AMERICANUS	Sea Raven	0	0	0	0	0	1	0	0	1
ICELUS BICORNIS	Twohorn Sculpin	0	0	0	0	0	0	1	0	1
LEUCORAJA OCELLATA	Winter Skate	0	0	0	0	0	1	0	0	1
LIPARIS	Snailfishes	1	0	0	0	0	0	0	0	1
LYCODES LAVALAEI	Newfoundland Eelpout	0	0	0	0	0	0	1	0	1
MELANOGRAMMUS AEGLEFINUS	Haddock	0	0	0	0	0	0	1	0	1
MYXINE LIMOSA	Hagfish	0	0	0	0	0	0	0	1	1
POLLACHIUS VIRENS	Pollock	0	0	0	0	0	0	0	1	1
SCOMBERESOX SAURUS	Atlantic Saury	0	0	1	0	0	0	0	0	1

Table 4. Invertebrate species captured in the annual snow crab survey occurring within and adjacent to St. Anns Bank MPA since 2015, sorted by the total number caught across all years. Note that there was no survey in 2020.

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
CTENODISCUS CRISPATUS	Cookie-cutter Seastar	634	5330	3163	2113	497	187	2331	374	14629
PENNATULOIDEA	Sea Pens	2818	1308	1094	2037	905	1007	685	1275	11129
PORIFERA	Sponges	597	250	543	821	364	6692	634	348	10249
CHIONOECETES OPILIO	Snow Crab	430	294	409	515	997	383	205	311	3544
PANDALUS BOREALIS	Northern Shrimp	542	843	650	554	446	86	112	21	3254
BOLTENIA	Stalked Tunicate	315	103	130	261	97	105	174	209	1394
OPHIUROIDEA	Brittle Stars	278	272	198	61	208	65	61	28	1171
CLYPEASTEROIDA	Sand Dollars	4	496	0	204	10	30	173	86	1003
HIPPASTERIA PHRYGIANA	Cushion Star	51	66	65	104	79	132	159	179	835

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
ASTEROIDEA	Sea Stars	13	36	37	83	67	176	133	212	757
EURYALIDA	Basket Stars	56	44	51	56	128	261	43	98	737
ACTINIARIA	Sea Anemones	79	73	48	57	84	49	91	89	570
STRONGYLOCENTROTUS DROEBACHIENSIS	Green Sea Urchin	17	14	32	23	76	57	68	154	441
LITHODES MAJA	Northern Stone Crab	38	21	28	43	38	59	104	81	412
PANDALUS MONTAGUI	Pink Shrimp	115	15	92	76	27	36	21	19	401
BRISASTER FRAGILIS	Heart Urchin	37	82	11	126	52	14	3	1	326
BUCCINUM	Whelks	43	33	30	35	54	26	46	51	318
HYAS COARCTATUS	Arctic Lyre Crab	26	41	29	60	29	21	11	29	246

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
HENRICIA SANGUINOLENTA	Northern Blood Star	18	24	10	24	50	43	45	16	230
PAGURIDAE	Hermit Crabs	33	43	46	19	34	5	15	5	200
HOLOTHUROIDEA	Sea Cucumbers	19	26	12	38	8	28	0	0	131
CAUDINA ARENATA	Sand Dwelling Sea Cucumber	0	0	0	0	0	1	3	116	120
OCTOPODA	Octopus	13	12	10	15	12	24	16	13	115
CROSSASTER PAPPOSUS	Common Sunstar	11	5	8	14	13	14	21	23	109
MEDIASTER BAIRDI	Sea Star	69	17	8	0	0	0	0	0	94
SOLASTER ENDECA	Purple Sunstar	6	4	5	3	23	22	8	4	75

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
OPHIURA SARSII	Common Brittle Star	0	0	0	0	0	0	59	0	59
ASCIDIA	Tunicates	1	6	6	3	13	5	17	7	58
CRANGON	Sand Shrimps	8	5	17	5	14	2	0	0	51
LEPTASTERIAS (HEXASTERIAS) POLARIS	Polar Six-rayed Star	11	3	2	5	0	0	17	3	41
SCYPHOZOA	Jellyfish	16	4	1	8	3	7	1	0	40
ILLEX ILLECEBROSUS	Northern Shortfin Squid	2	2	7	14	6	7	1	0	39
CIRRIPEDIA	Barnacles	0	2	0	0	0	35	0	0	37
CUCUMARIA FRONDOSA	Orange-footed Sea Cucumber	0	0	0	0	0	0	16	20	36
HYAS ARANEUS	Great Spider Crab	6	1	8	1	9	6	1	0	32

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
PYCNOGONIDA	Sea Spiders	9	4	3	6	7	1	1	0	31
SCLEROCRANGON	Shrimps	13	3	8	0	0	1	0	5	30
CHLAMYS ISLANDICA	Iceland Scallop	5	0	1	2	2	2	7	7	26
ANTHOZOA	Corals and Anemones	4	2	1	1	4	4	1	6	23
SEMIROSSIA TENERA	Lesser Bobtail Squid	11	2	1	0	3	0	4	0	21
POLYCHAETA	Polychaete worms	2	0	2	1	8	2	5	0	20
DECAPODA	Decapod crustaceans	0	0	0	0	4	8	1	0	13
PORANIOMORPHA HISPIDA	Sea Star	2	0	3	1	4	1	0	0	11
HORMATHIA	Rugose Anemones	0	0	0	0	0	0	9	0	9

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
BOLOCERA	Sea Anemones	0	0	0	0	0	0	7	0	7
CANCER BOREALIS	Jonah Crab	0	1	0	0	0	0	3	3	7
SPIRONTOCARIS SPINUS	Parrot Shrimp	5	0	0	0	0	0	1	0	6
ARGIS DENTATA	Arctic Shrimp	0	2	0	0	0	0	3	0	5
PONTOPHILUS NORVEGICUS	Sand Shrimp	5	0	0	0	0	0	0	0	5
FLUSTRA FOLIACEA	Hornwrack	0	0	0	0	0	0	0	4	4
PTERASTER MILITARIS	Wrinkled Star	0	0	0	0	1	0	1	2	4
STRONGYLOCENTROTUS	Sea Urchins	0	4	0	0	0	0	0	0	4
ASTERIAS SP.	Sea Stars	0	0	0	0	0	3	0	0	3
PENTAGONASTER	Sea Stars	3	0	0	0	0	0	0	0	3
SCLEROCRANGON BOREAS	Sculptured Shrimp	0	0	0	0	0	0	3	0	3
VAZELLA POURTALESII	Russian Hat Sponge	0	0	0	0	0	0	3	0	3

Species	Common Name	2015	2016	2017	2018	2019	2021	2022	2023	Total Caught
APHRODITA HASTATA	Sea Mouse	0	0	0	1	1	0	0	0	2
ATLANTOPANDALUS PROPINQVUS	Pandalid Shrimp	0	0	0	0	0	0	2	0	2
CANCER IRRORATUS	Rock Crab	0	1	0	0	1	0	0	0	2
LEBBEUS POLARIS	Polar Shrimp	0	0	0	0	0	0	2	0	2
ASTERIAS RUBENS	Common Starfish	0	0	0	0	1	0	0	0	1
CALATHURA BRACHIATA	Marine Isopod	0	0	0	0	0	1	0	0	1
HALOCYNTHIA PYRIFORMIS	Sea Peach	0	0	0	0	0	0	1	0	1
NUDIBRANCHIA	Sea Slugs	0	0	0	1	0	0	0	0	1
PASIPHAEA MULTIDENTATA	Pink Glass Shrimp	0	0	0	1	0	0	0	0	1
PLACOPECTEN MAGELLANICUS	Atlantic Sea Scallop	0	0	0	0	1	0	0	0	1
SPIRONTOCARIS LILJEBORGII	Friendly Blade Shrimp	1	0	0	0	0	0	0	0	1

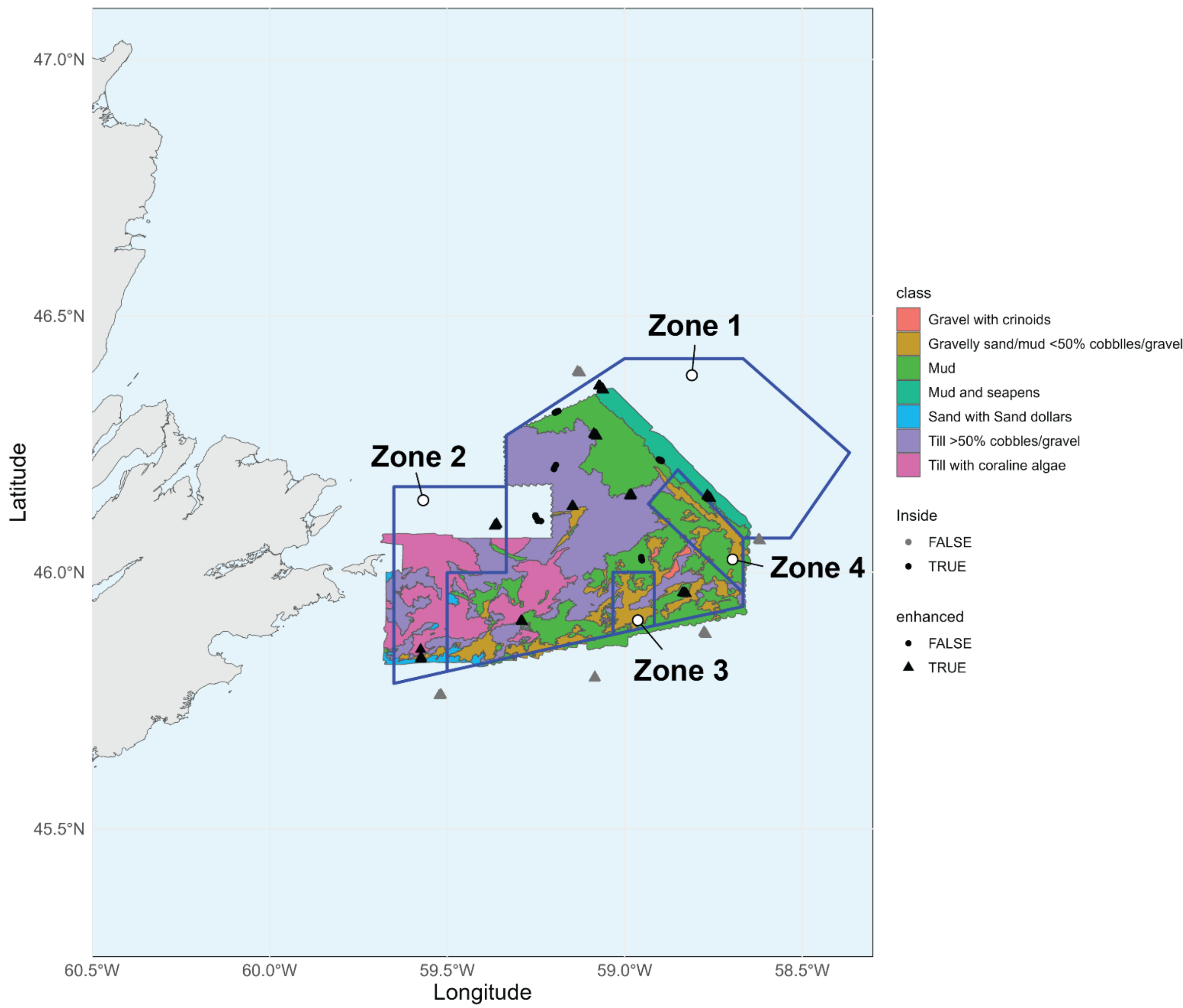

Figure 1. Locations of the regular and enhanced snow crab survey stations within and adjacent to St. Anns Bank Marine Protected Area between 2015 and 2023. The SAB benthoscape classifications (Lacharité and Brown 2018) are plotted to show which benthic classes are surveyed.

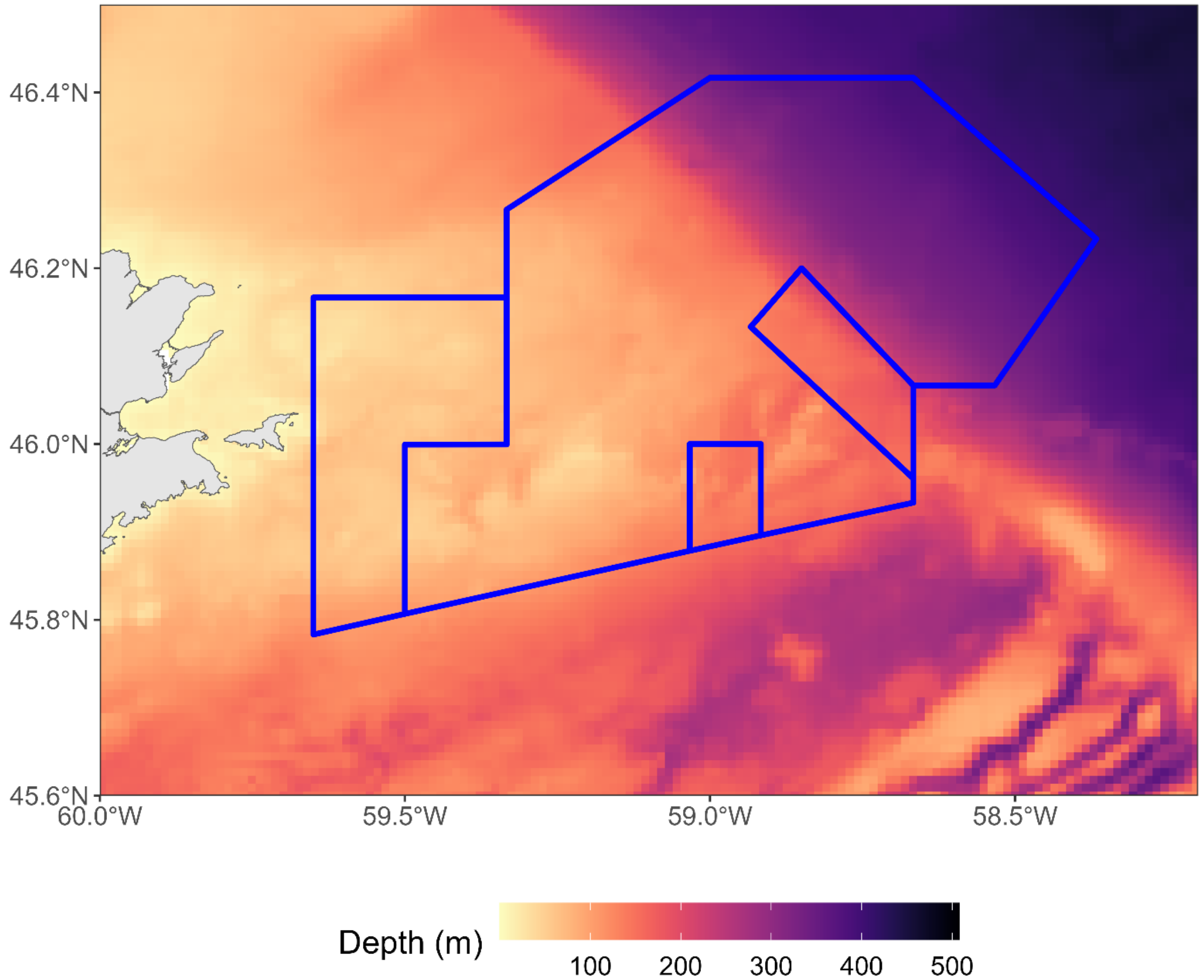

Figure 2. Depth ranges in St. Anns Bank MPA (blue polygon) and the adjacent area. Depths in the MPA range from approximately 25 to 400 metres. The shallowest parts of the MPA include Scatarie and Curdo banks, while the deepest portion of the MPA lies within the Laurentian Channel.

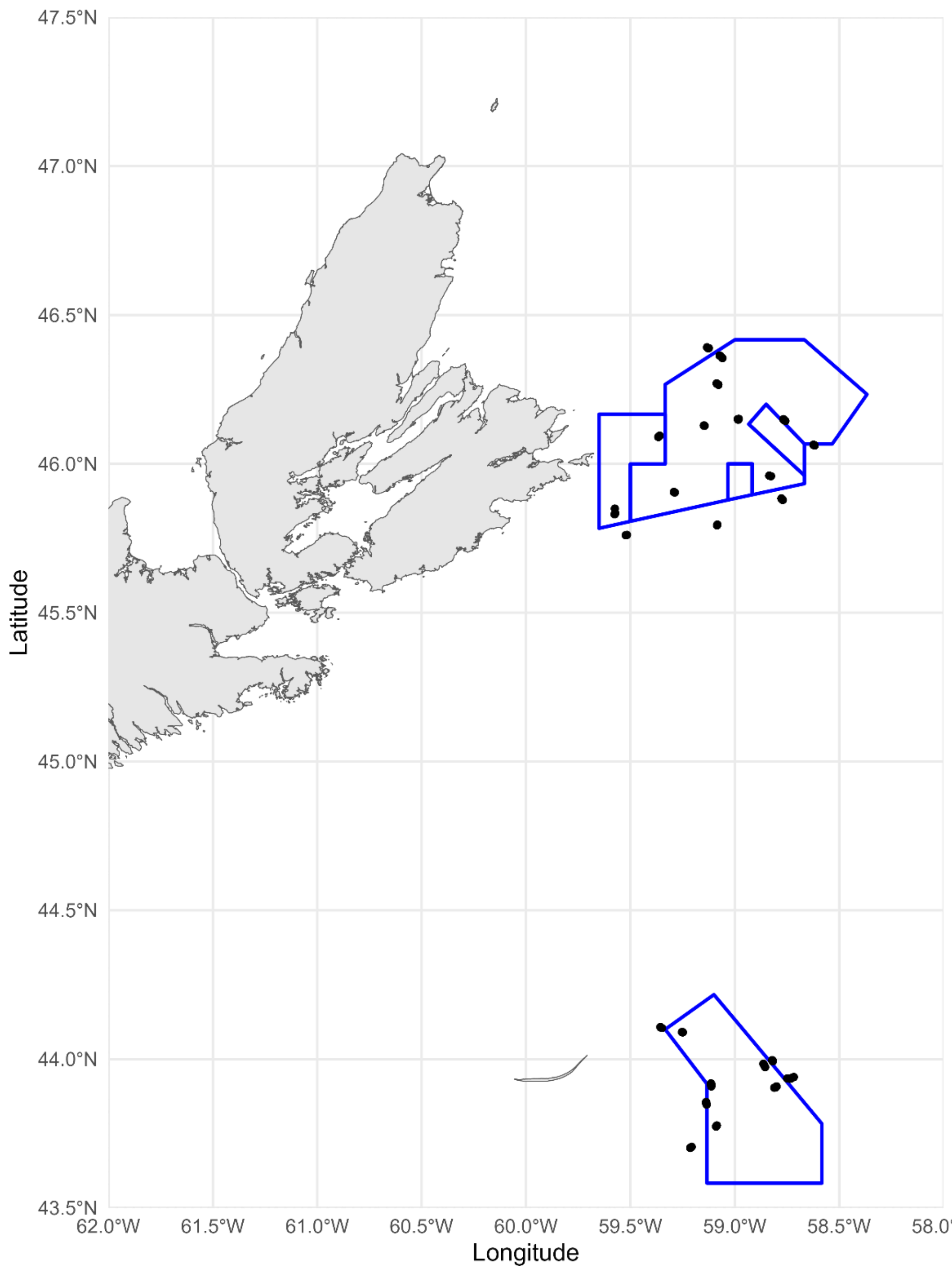

Figure 3. The locations of the enhanced snow crab survey stations within the St. Anns Bank Marine Protected Area and the Gully MPA (blue polygons) between 2015 and 2023.

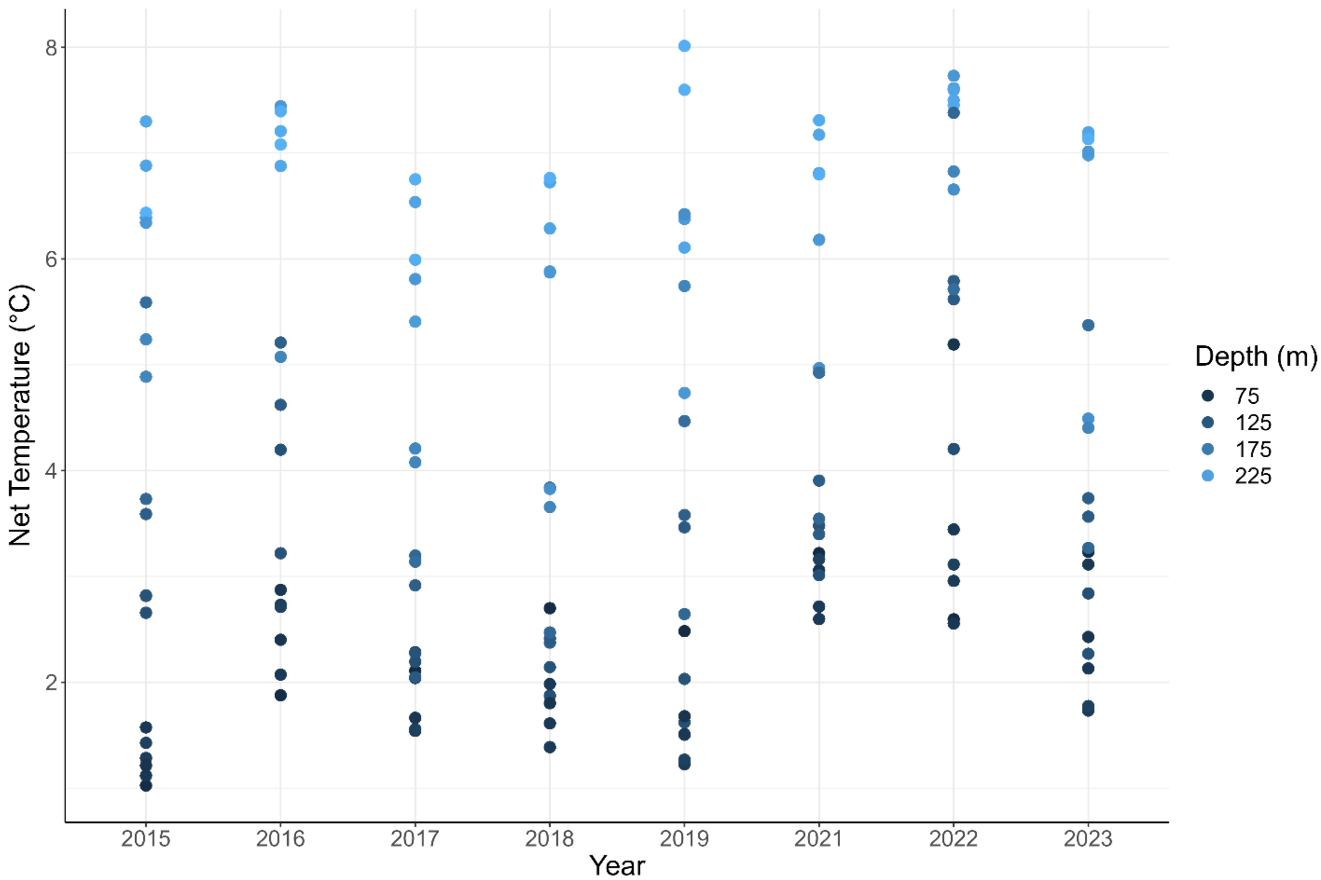

Figure 4. Temperature (degrees Celsius) recorded by the trawl net at various stations within St. Anns Bank MPA between 2015 and 2023. Points are coloured by trawl depth, showing a pattern of generally colder water at approximately 75-125 m, and warmer water in the deeper stations at 200-225 m.

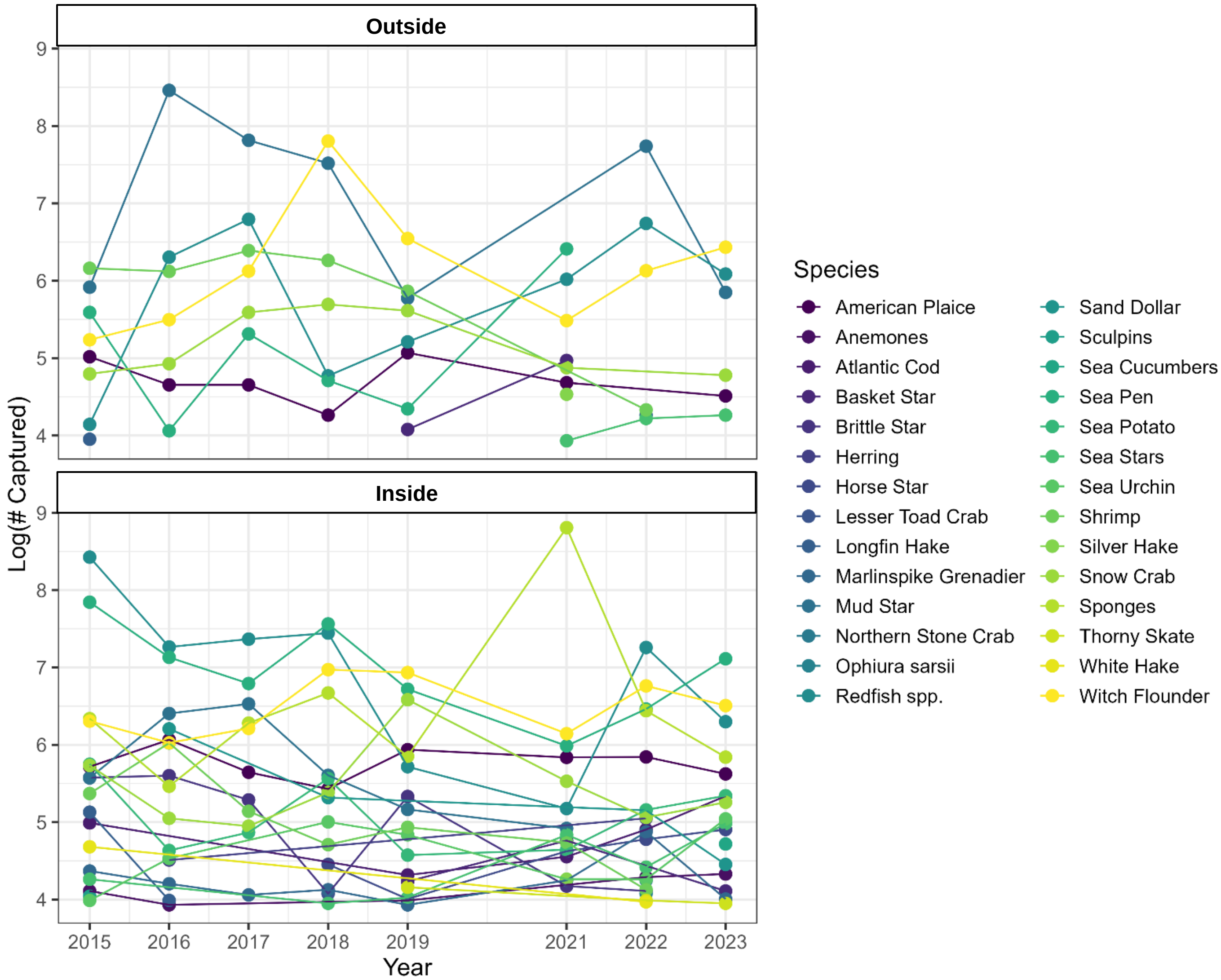

Figure 5. Trends in log-transformed numbers of individual species captured per year in St. Anns Bank MPA. The species shown in this plot had at least five individuals captured in a set for each of the years they are represented. The data are split into outside (top panel) and inside (bottom panel) the MPA.

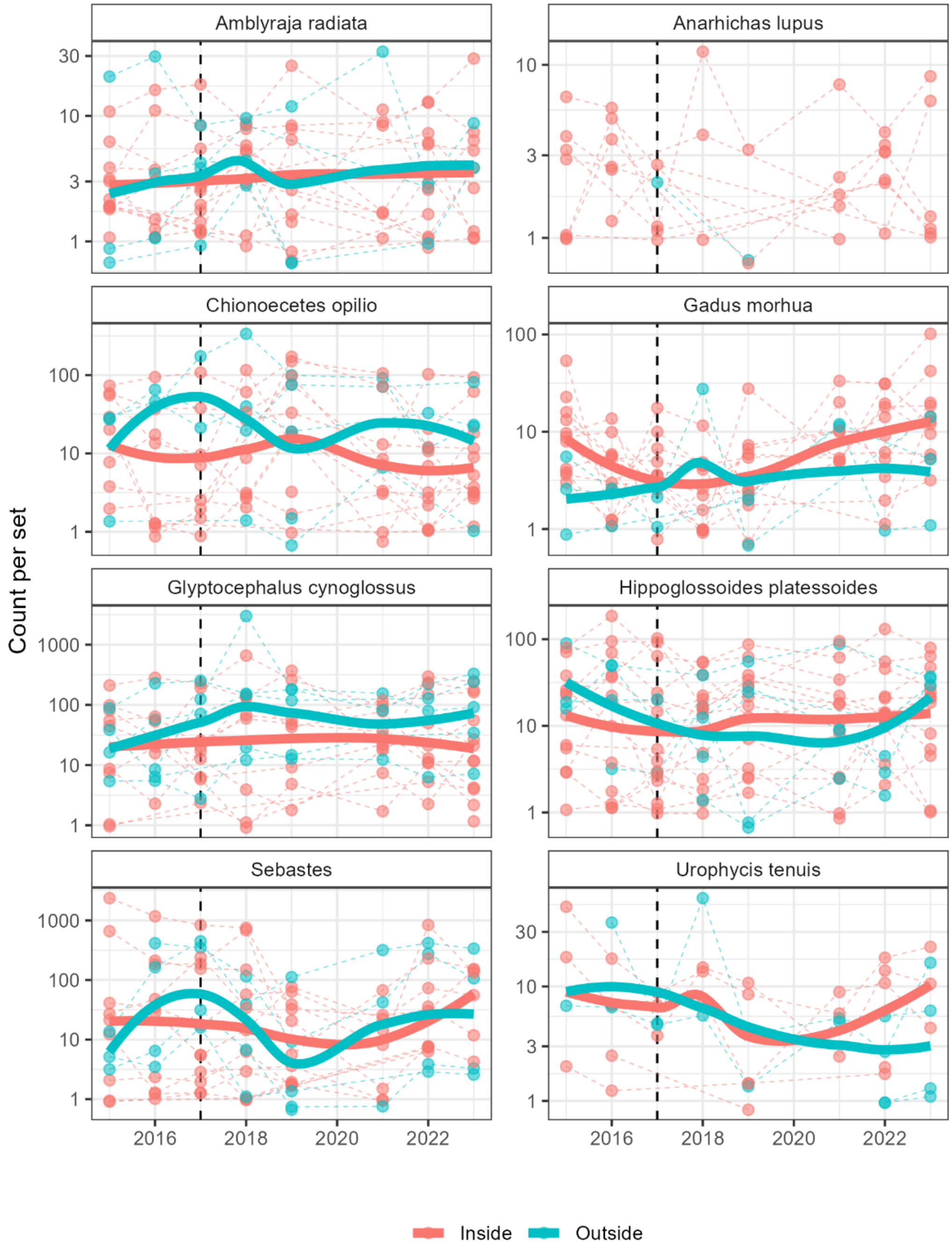

Figure 6. Counts per species per year across all survey sample stations. The species shown here represent the most abundant predator fish species, and Snow Crab (Chionoecetes opilio) for which the Snow Crab survey was designed. Note the values differ on the y-axis for each species. The vertical dashed line indicates the year the SAB MPA was designated, 2017.

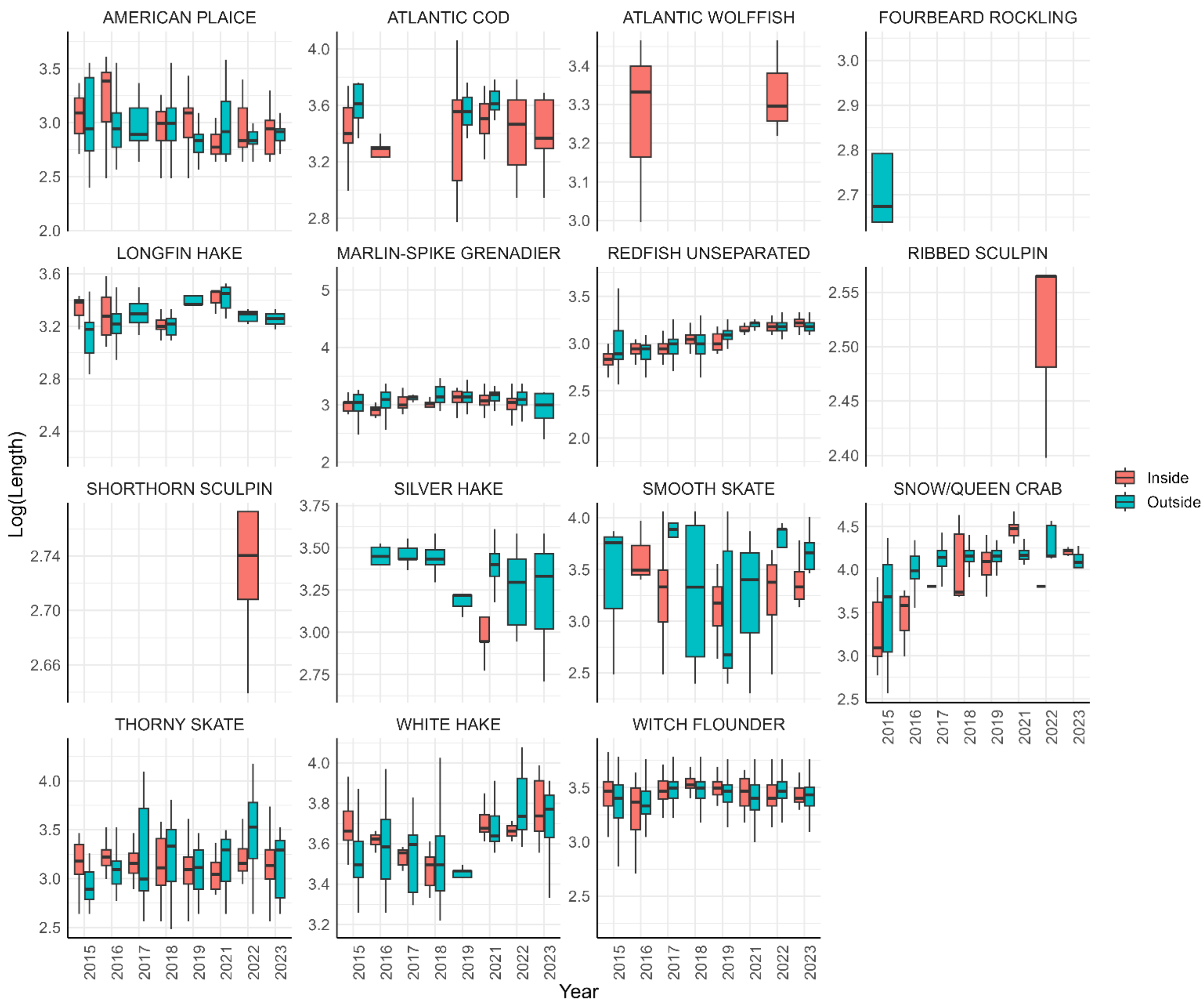

Figure 7. Boxplots representing length distributions for the most abundant species captured in the Snow Crab Survey in St. Anns Bank MPA between 2015 and 2023. Error bars on each box represent standard error. Length distributions are coloured by inside (red) and outside (green) the MPA for each year that they were captured.

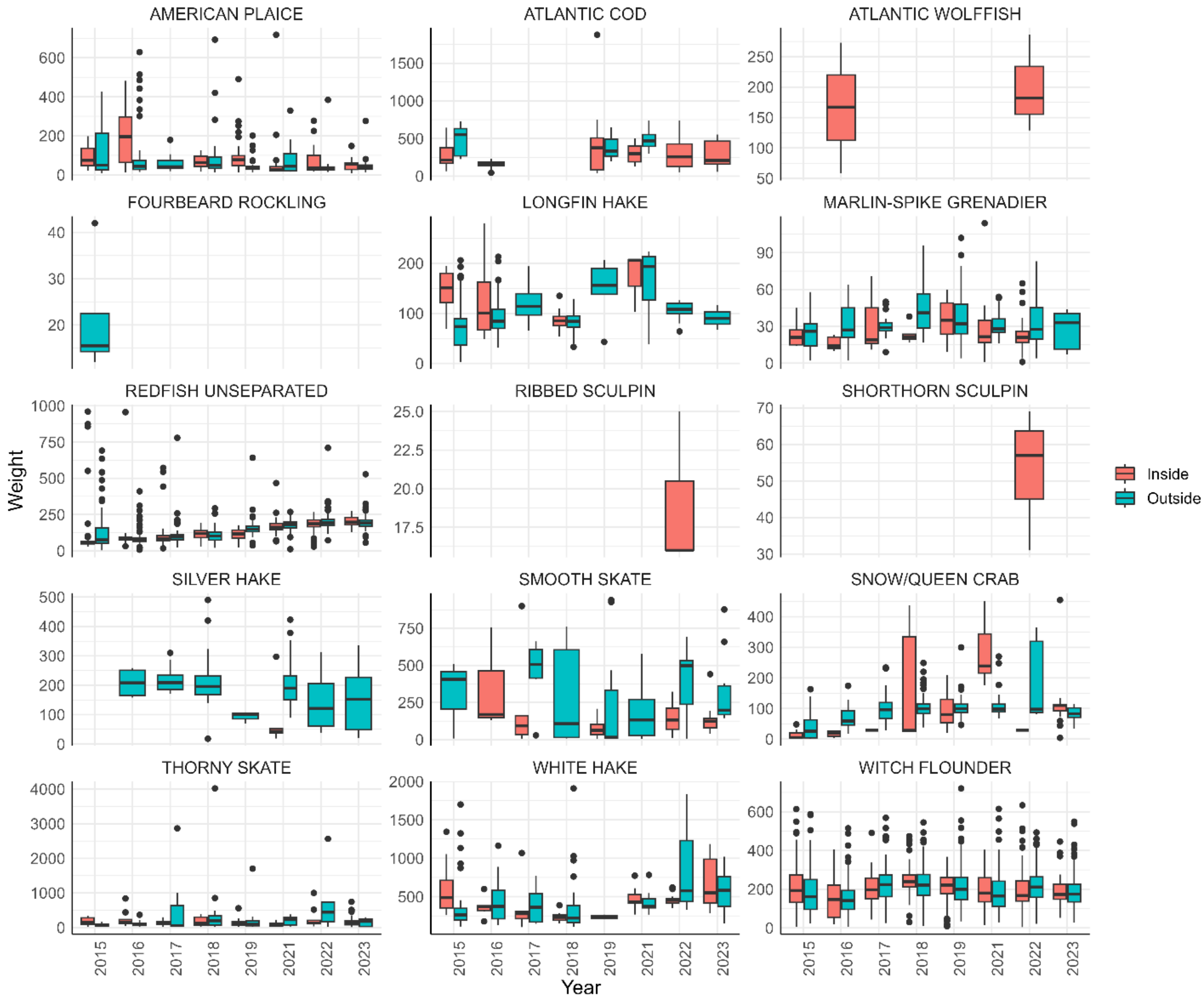

Figure 8. Boxplots representing weight distributions for the most abundant species captured in the Snow Crab Survey in St. Anns Bank MPA between 2015 and 2023. Outliers are represented by individual points, while the error bars represent standard error. Weight distributions are coloured by inside (red) and outside (green) the MPA for each year that they were captured.

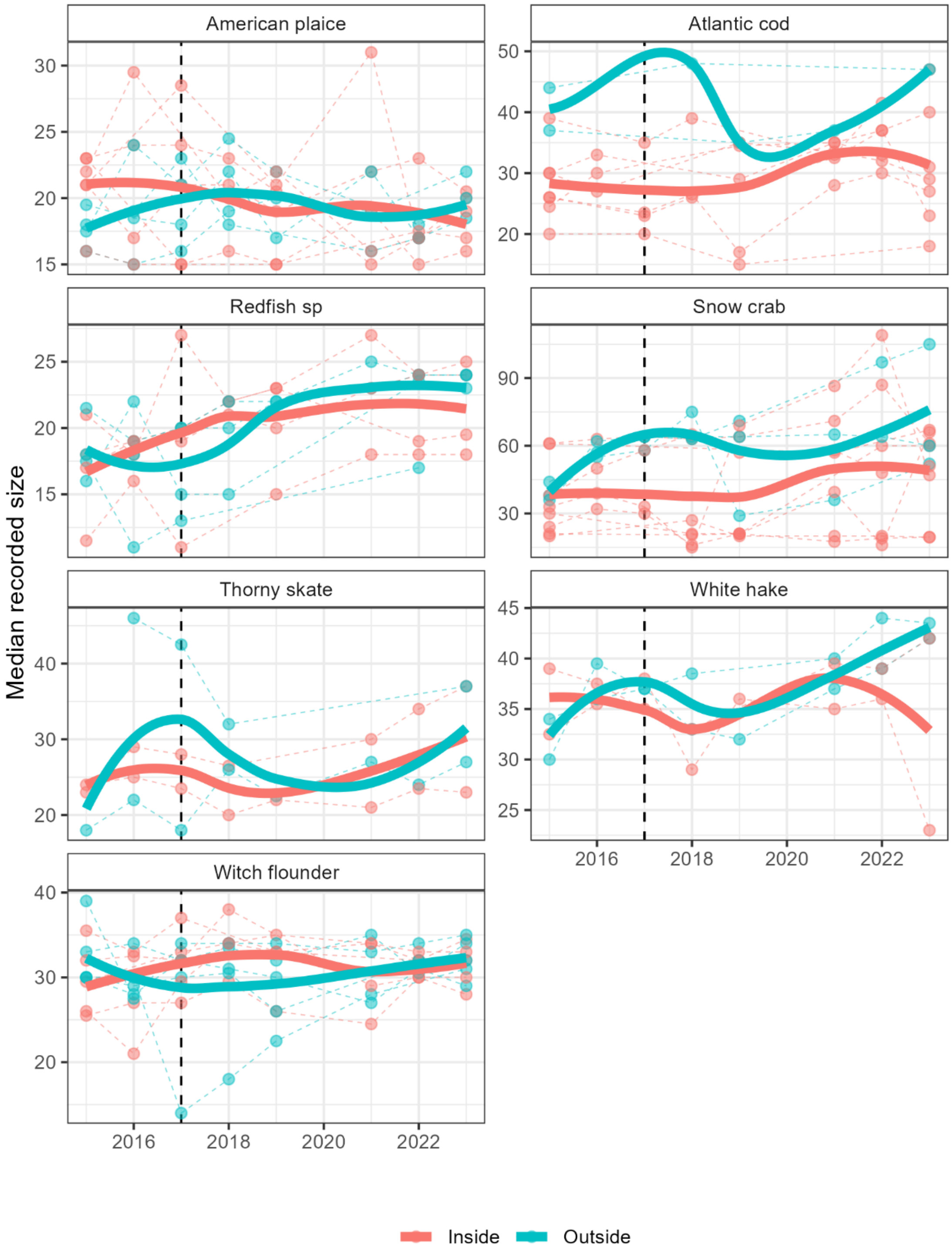

Figure 9. Size distributions inside and outside the SAB MPA of the median recorded size of seven fish and invertebrate species. In most species, size distributions largely overlap inside and outside the MPA or are highly variable due to low sample sizes.

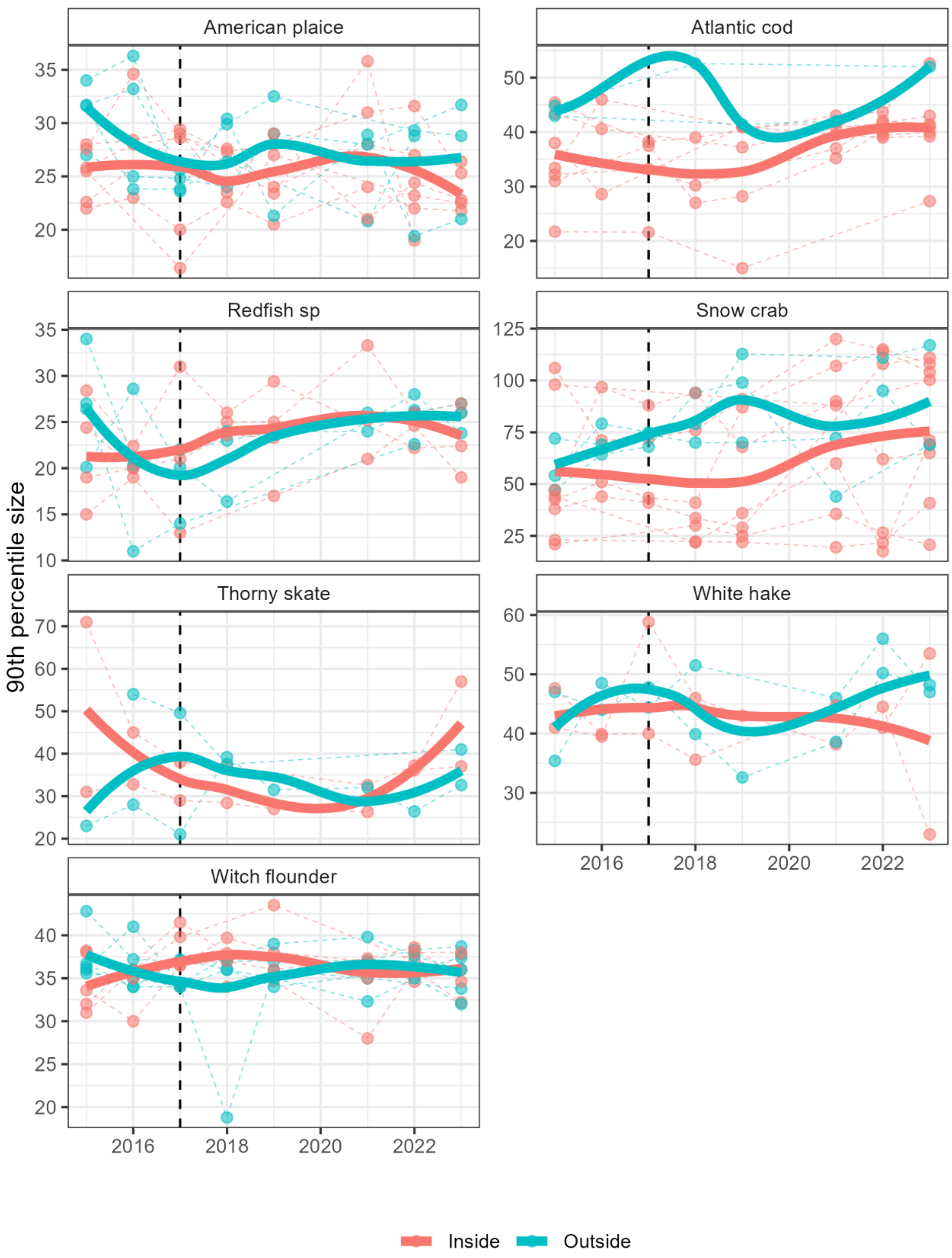

Figure 10. Size distributions inside and outside the SAB MPA of the largest (90th percentile) individuals of seven fish and invertebrate species. In most species, size distributions largely overlap inside and outside the MPA or are highly variable due to low sample sizes.

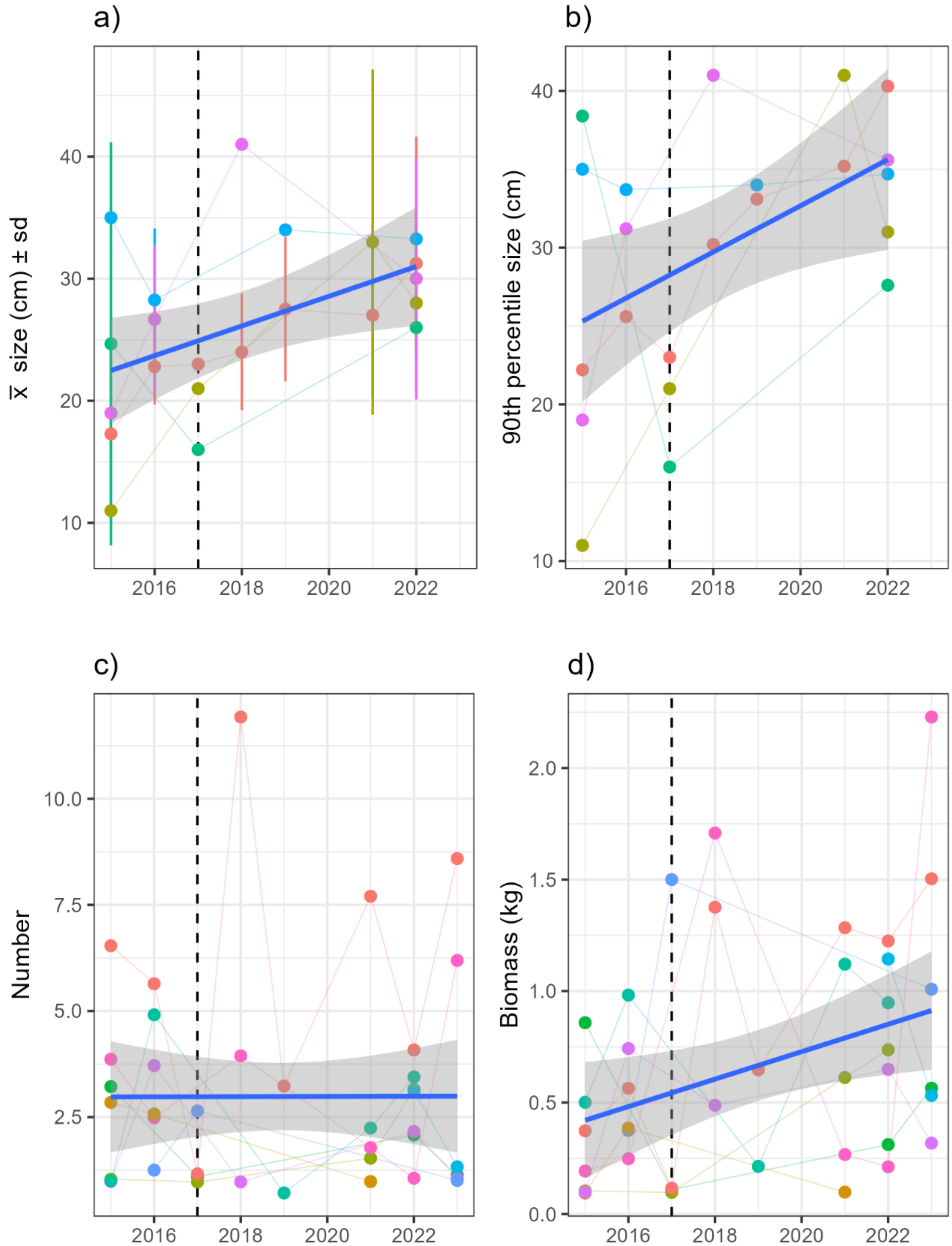

Figure 11. Size, abundance, and biomass trends in Atlantic Wolffish caught inside St. Anns Bank MPA between 2015 and 2023. While the number of wolffish has remained stable over time (c), their overall length (a,b) and mass (d) have increased since 2015.

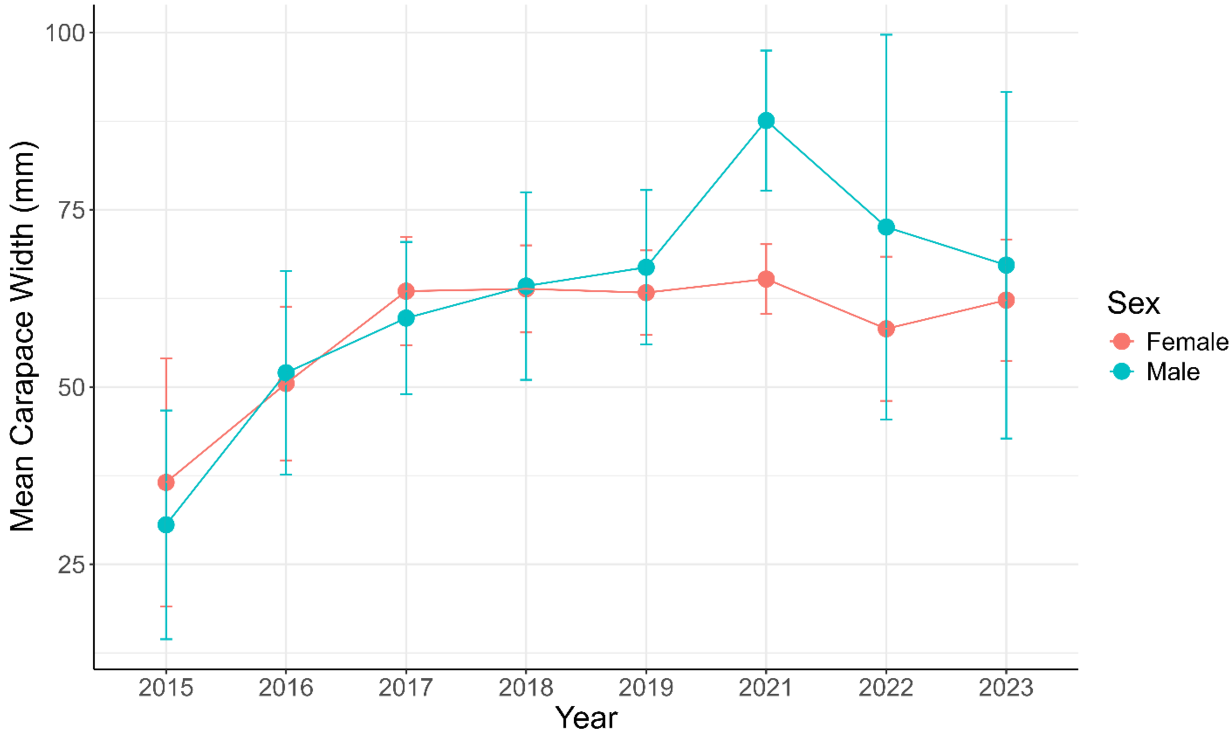

Figure 12. Mean carapace width in Snow Crab (Chionoecetes opilio) captured in the Maritimes Snow Crab survey in St. Anns Bank from 2015 to 2023. The green line indicates male crab while red indicates female. This figure is only intended to show the distribution of crab sizes measured within the MPA since 2015 and should not be used to infer region-wide trends in Snow Crab stocks.

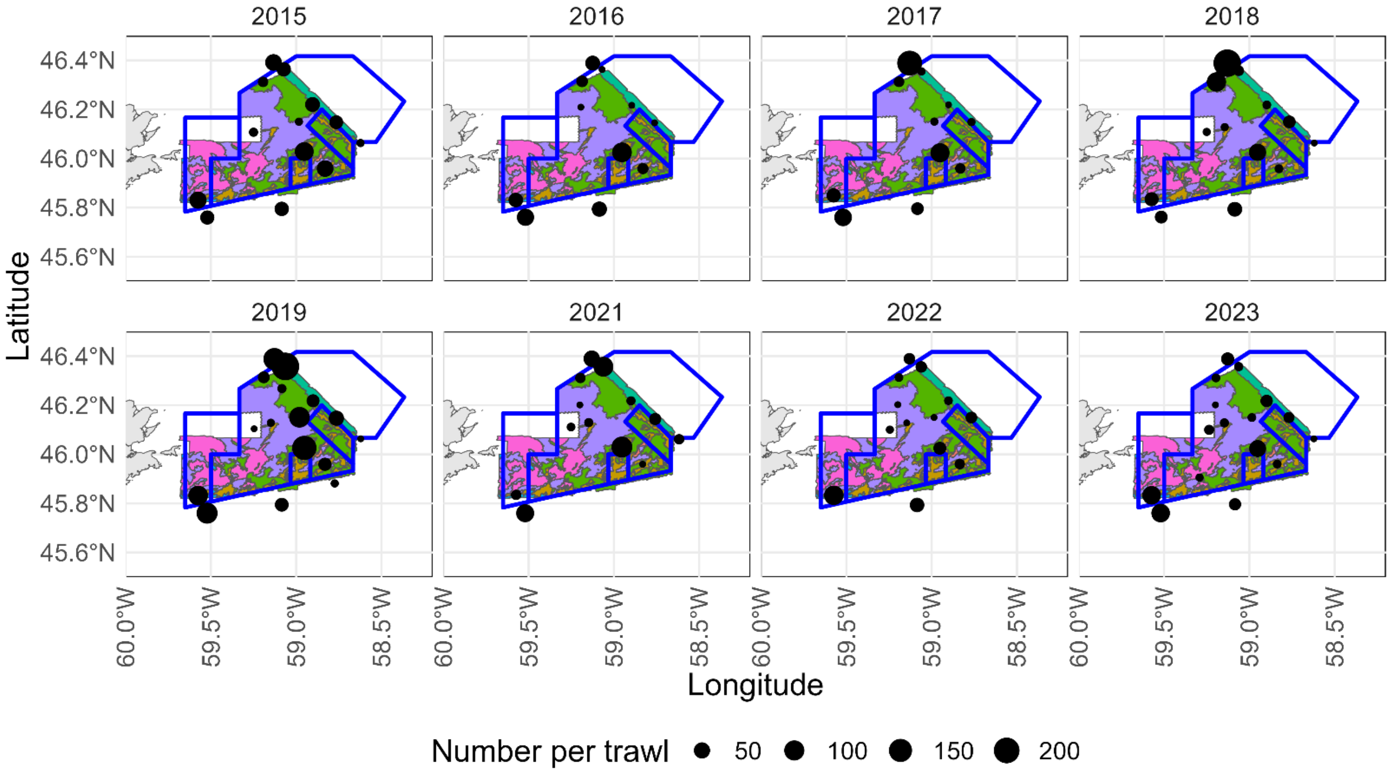

Figure 13. Distributions of Snow Crab captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. Snow Crab are relatively evenly distributed across the MPA, but appear relatively more abundant in the deeper muddier habitats in the MPA. Colours in the plots represent the same benthoscape classes as Figure 1.

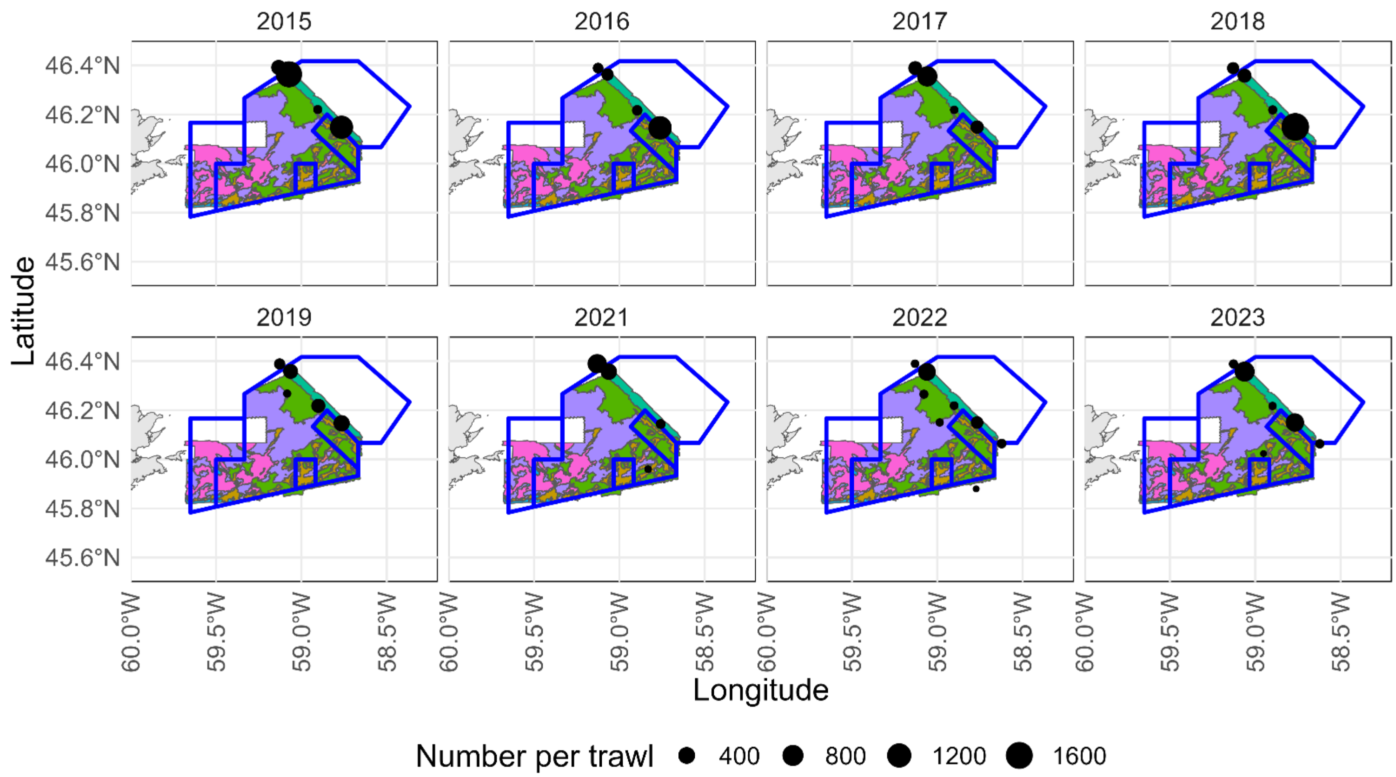

Figure 14. Distributions of sea pens (Pennatulacea) captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. Sea pens are primarily found in the deeper mud habitats in the MPA along the slope and Laurentian Channel. Colours in the plots represent the same benthoscape classes as Figure 1.

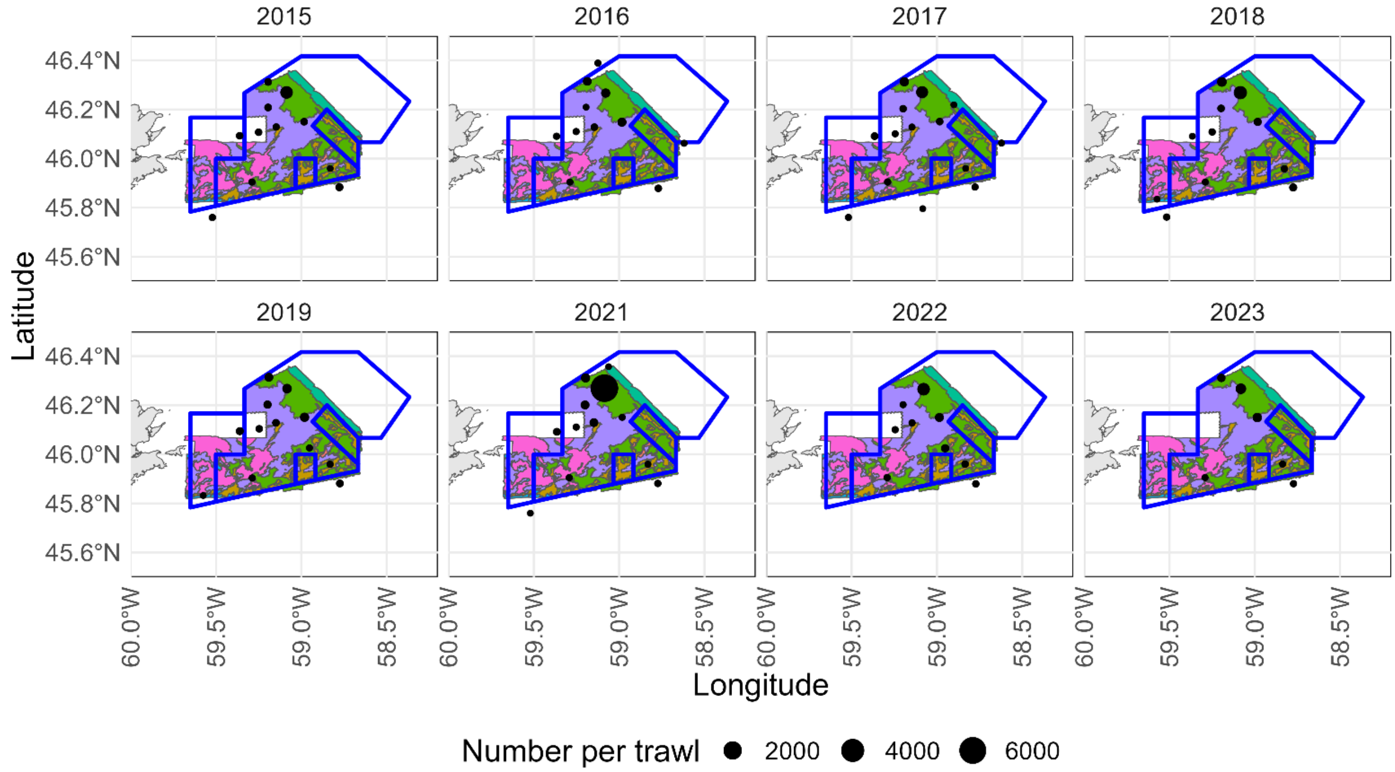

Figure 15. Distributions of sponges (Porifera) captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. Sponges are relatively evenly distributed across the MPA, but appear relatively more abundant in the deeper habitats in the MPA. Colours in the plots represent the same benthoscape classes as Figure 1.

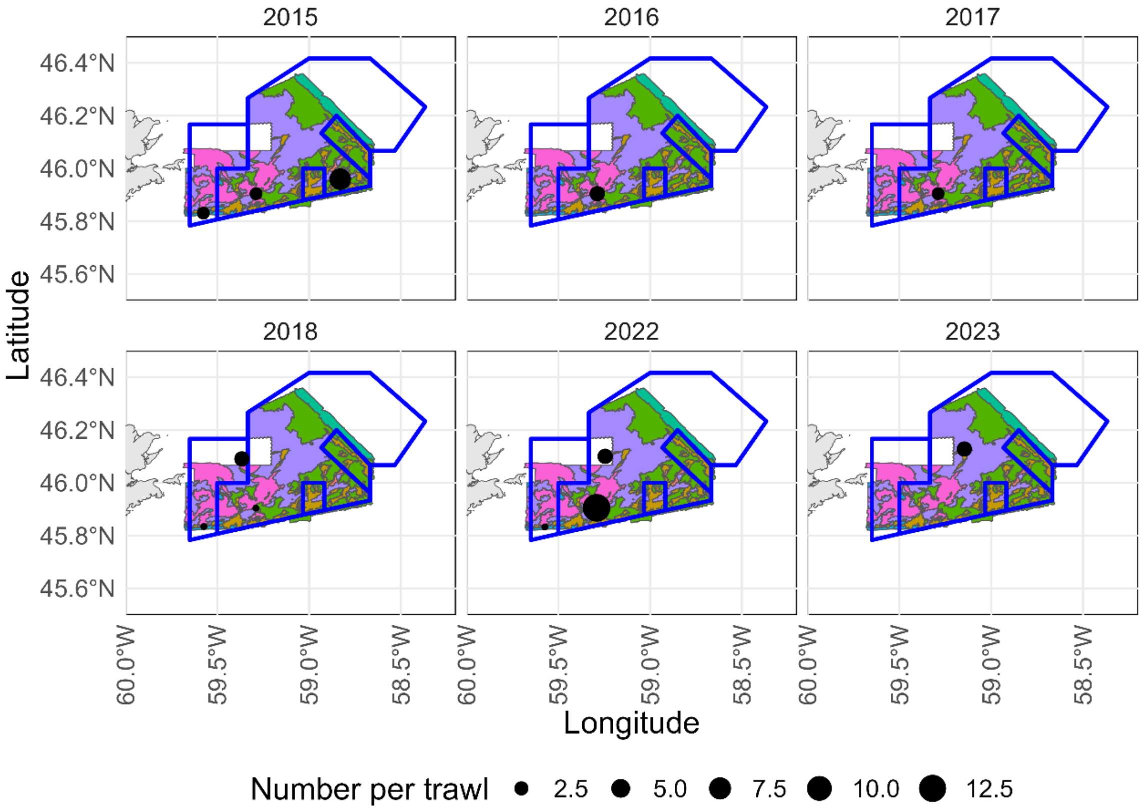

Figure 16. The distribution of Polar Six-rayed Star (Leptasterias polaris) captured in the Maritimes snow crab trawl survey within St. Anns Bank between 2015 and 2023; however, no individuals of this species were captured in 2019 or 2021. This species is proposed as an indicator of three of the gravel-dominant benthoscape classes found in the MPA. Colours in the plots represent the same benthoscape classes as Figure 1.

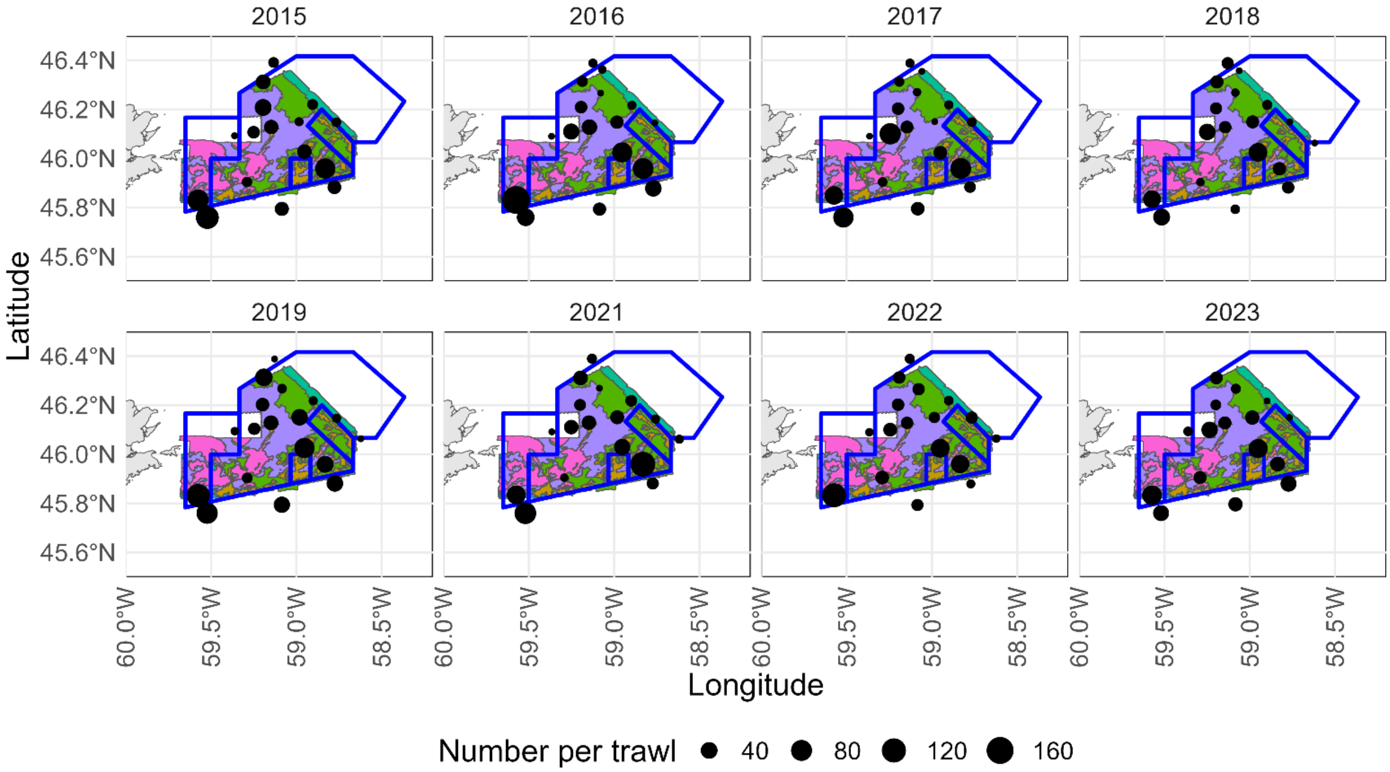

Figure 17. Distributions of American Plaice captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. American Plaice are relatively evenly distributed across the MPA, but appear relatively more abundant in shallower, hard bottom areas of the MPA. Colours in the plots represent the same benthoscape classes as Figure 1.

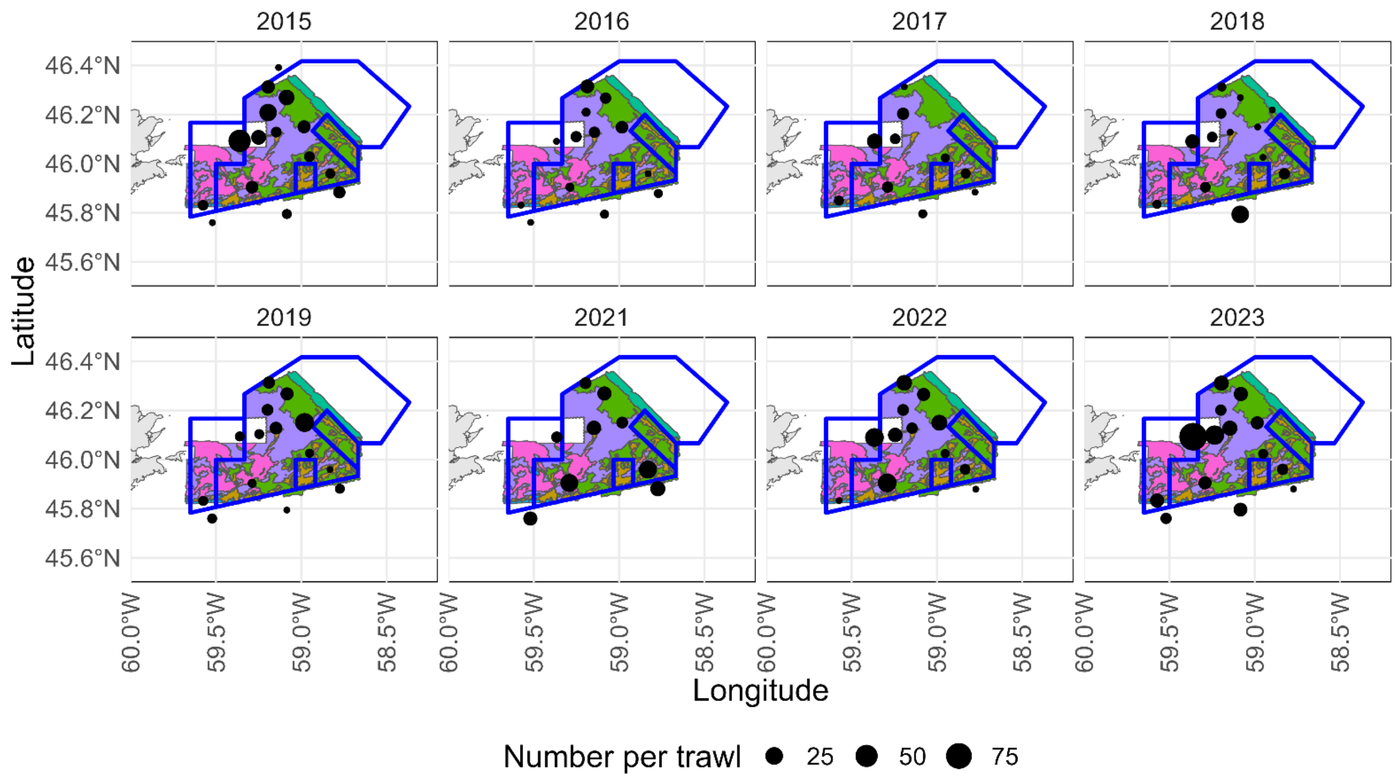

Figure 18. Distributions of Atlantic Cod captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. Atlantic Cod are relatively evenly distributed across the MPA, but appear more abundant in shallower, hard bottom areas of the MPA and are absent from the deepest areas. Colours in the plots represent the same benthoscape classes as Figure 1.

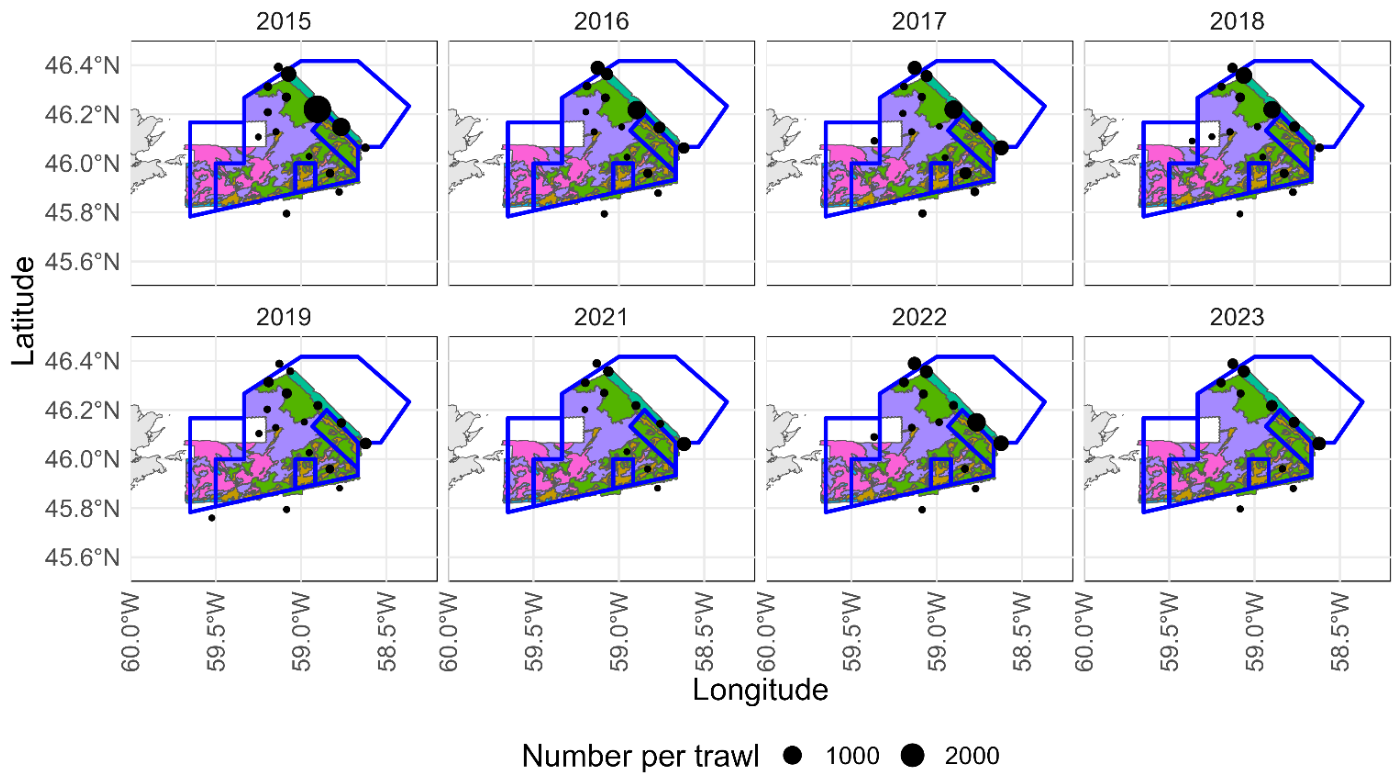

Figure 19. The distribution of Redfish (Sebastes spp.) captured in the Maritimes snow crab trawl survey within St. Anns Bank between 2015 and 2023. The majority of redfish are captured in the deeper portions of the MPA, where the slope descends into the Laurentian Channel. Colours in the plots represent the same benthoscape classes as Figure 1.

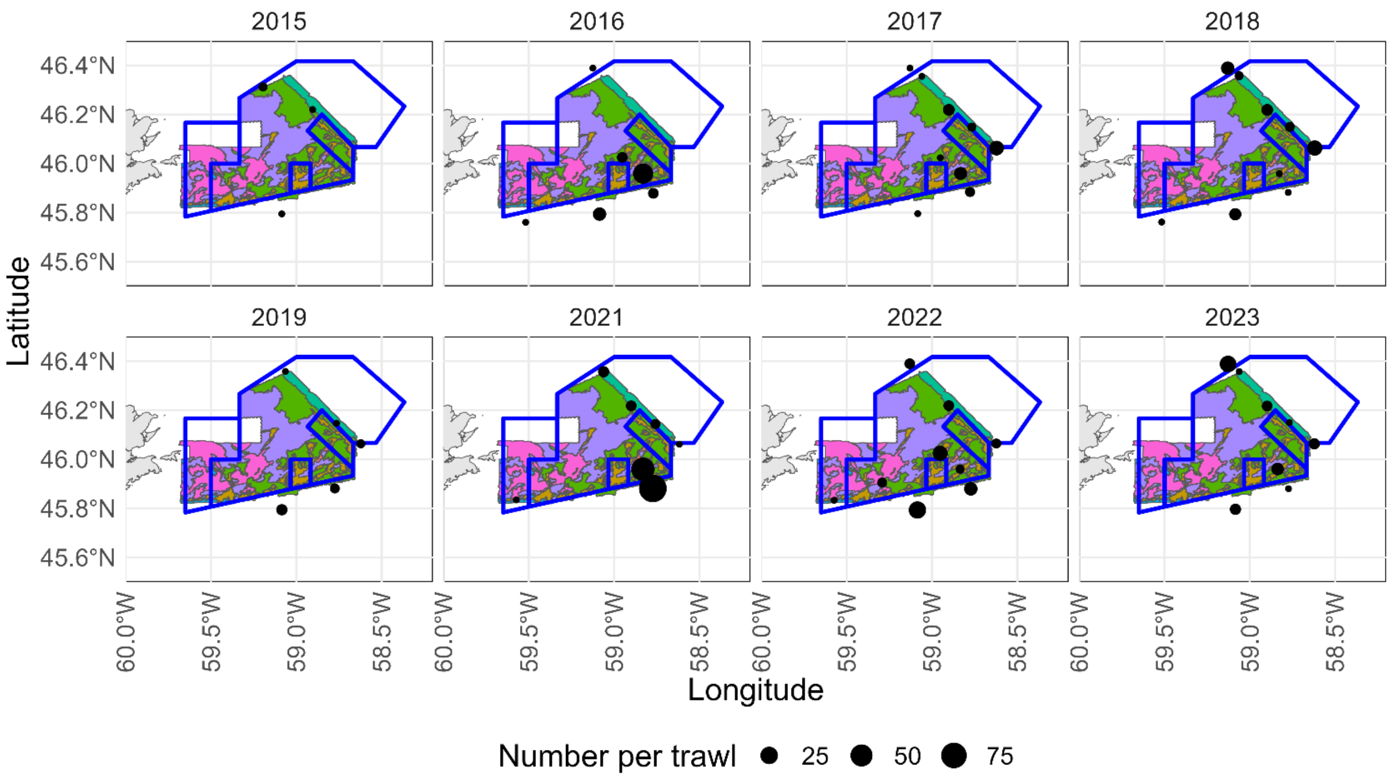

Figure 20. The distribution of Silver Hake (Merluccius bilinearis) captured in the Maritimes Snow Crab Survey within St. Anns Bank between 2015 and 2023. In general, more Silver Hake are caught adjacent to the MPA than within it. Colours in the plots represent the same benthoscape classes as Figure 1.

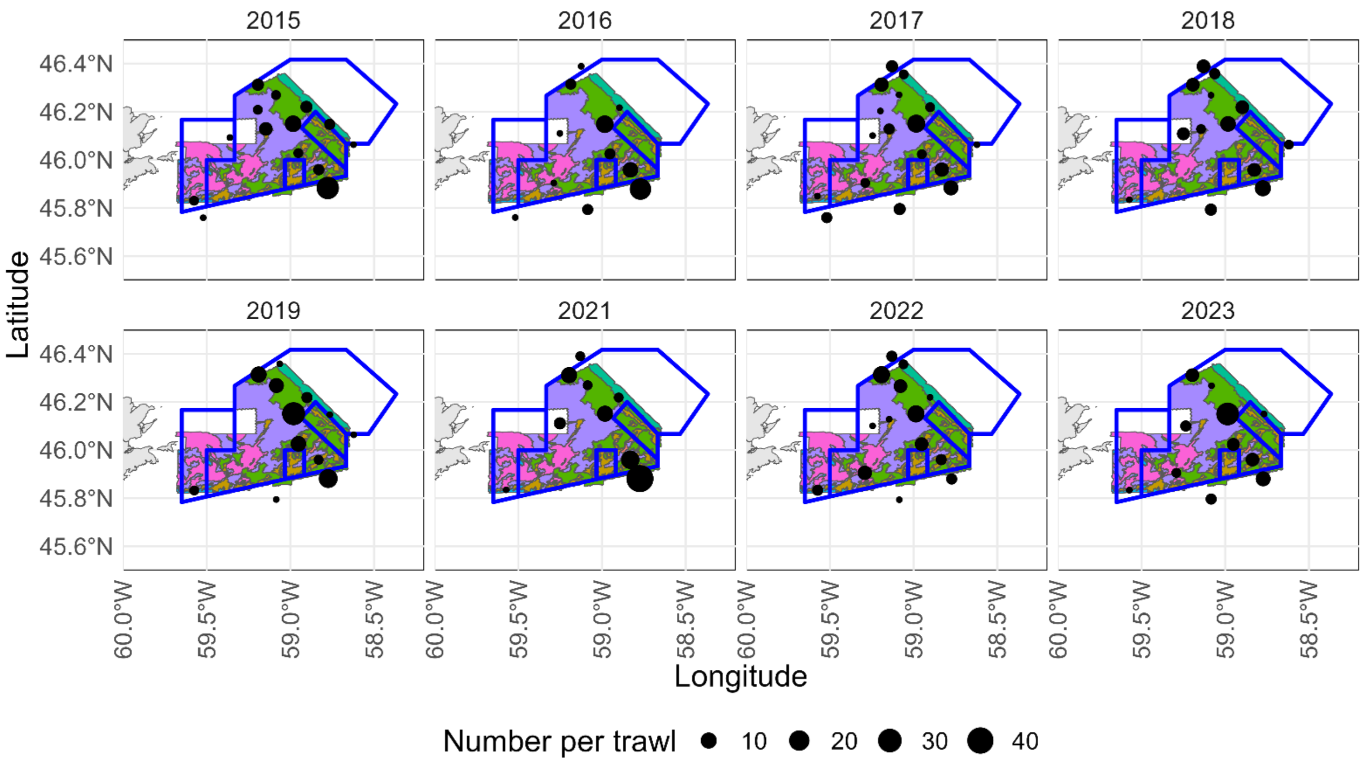

Figure 21. Distributions of Thorny Skate captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. Thorny Skate are typically found in the deeper, soft bottomed portions of the MPA, but can also be found on hard substrates less frequently. Colours in the plots represent the same benthoscape classes as Figure 1.

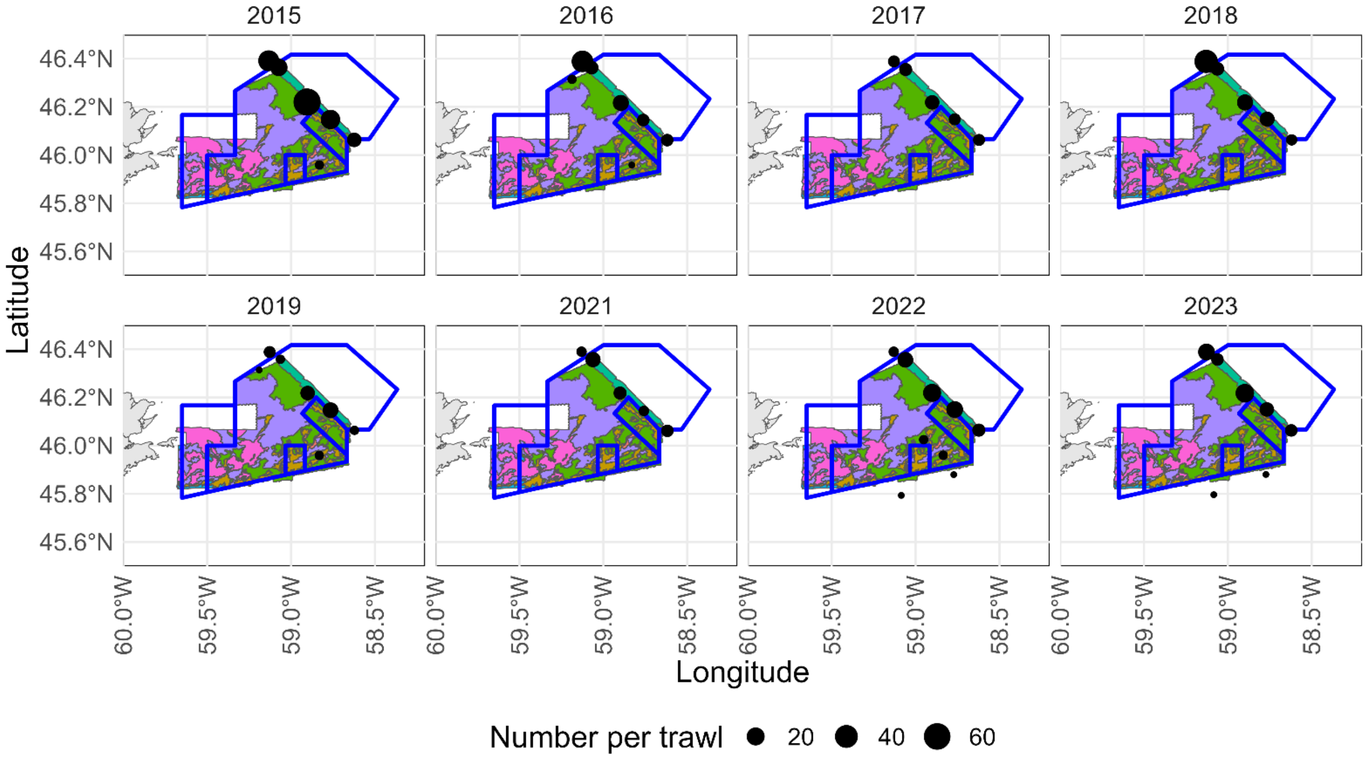

Figure 22. Distributions of White Hake (Urophycis tenuis) captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. White Hake are primarily found in the deeper portions of the MPA, and most frequently over soft bottomed habitat. Colours in the plots represent the same benthoscape classes as Figure 1.

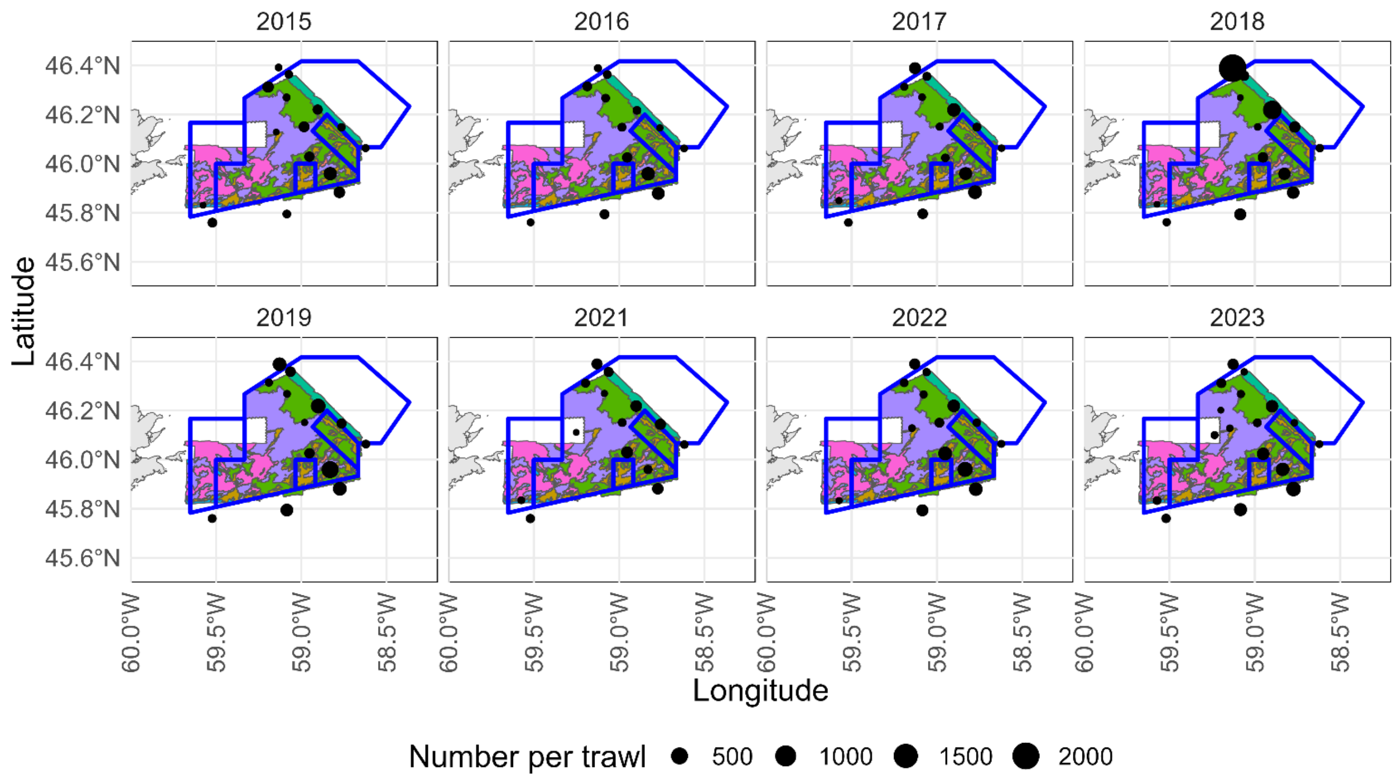

Figure 23. Distributions of Witch Flounder captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. Witch Flounder are typically found in the deeper, soft bottomed portions of the MPA, but can also be found on hard substrates less frequently. Colours in the plots represent the same benthoscape classes as Figure 1.

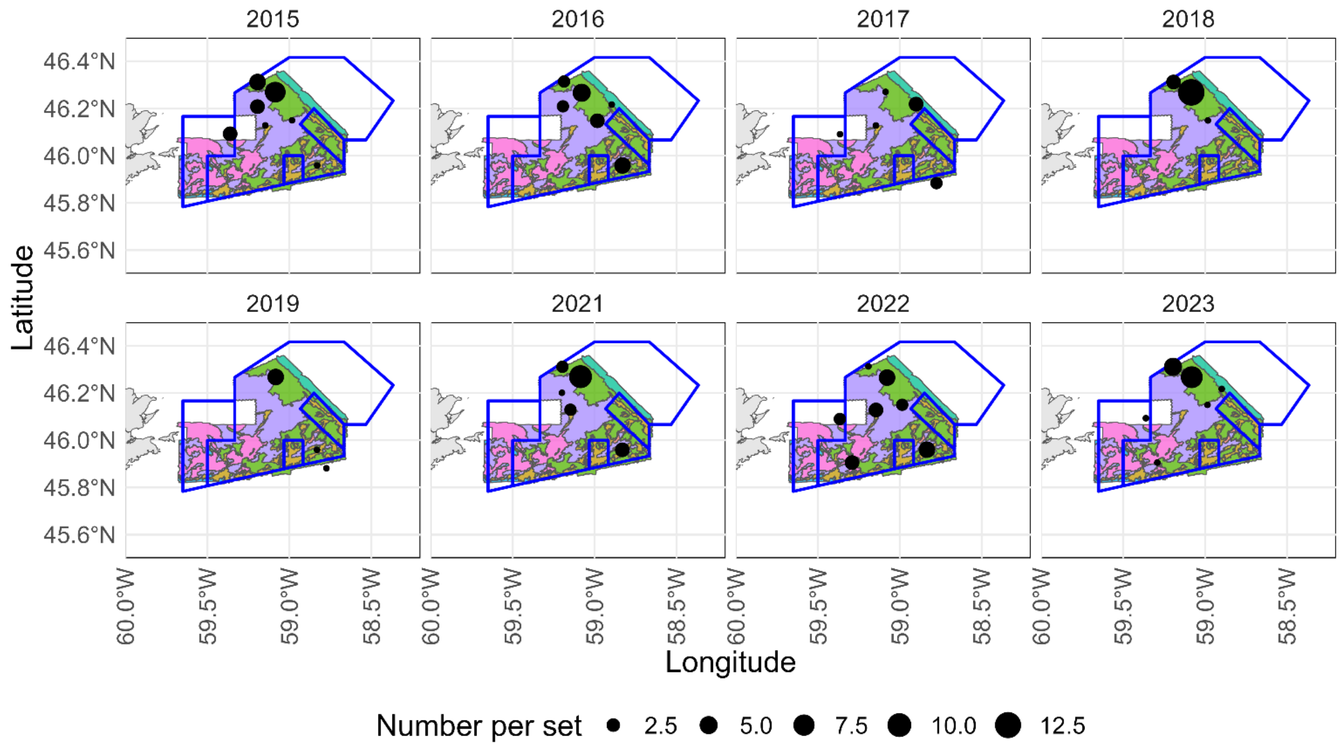

Figure 24. Distributions of Atlantic Wolffish captured in the Snow Crab Survey inside and outside St. Anns Bank MPA between 2015 and 2023. Atlantic Wolffish are typically found in deeper portions of the MPA on cobble or muddy substrate, but can occasionally be found in the shallower Zone 2. Colours in the plots represent the same benthoscape classes as Figure 1.

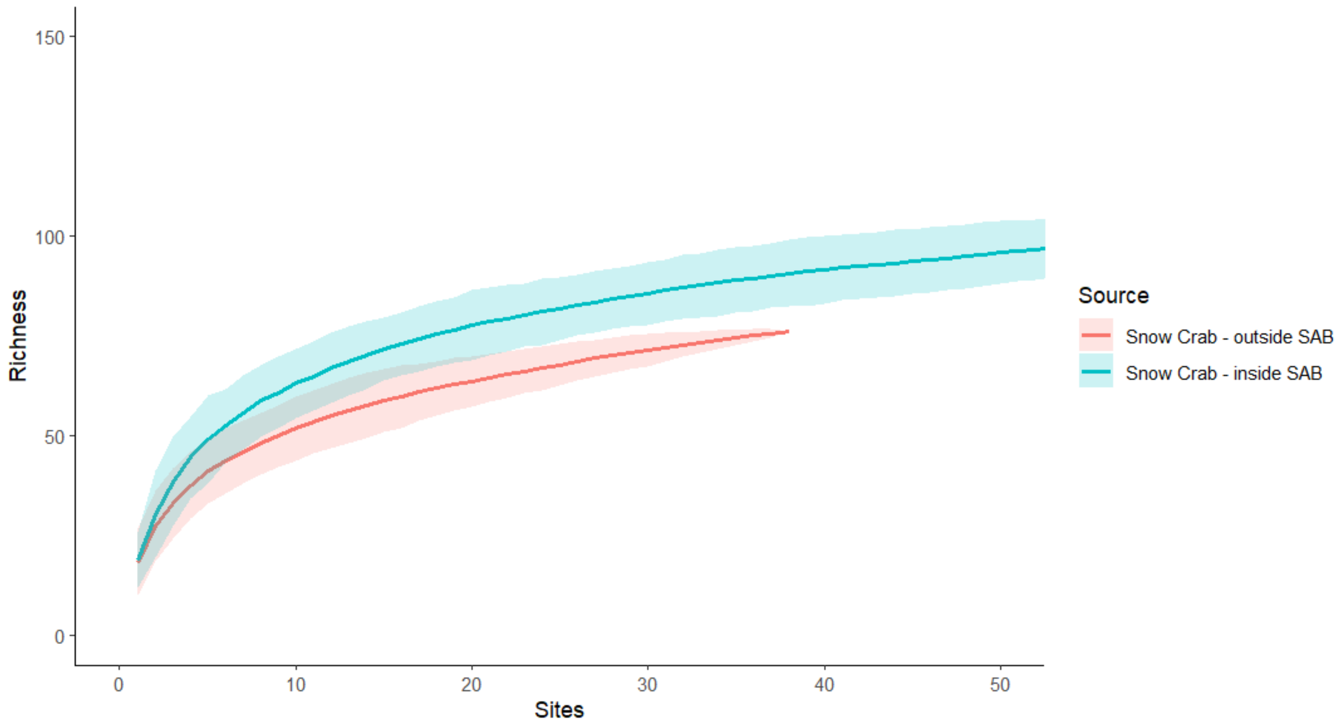

Figure 25. Species accumulation curve from the Maritimes Snow Crab Survey based on the number of species captured for set numbers of stations. Richness is generally higher within the MPA compared to stations adjacent to the MPA, and continues to increase as additional years and stations are sampled.

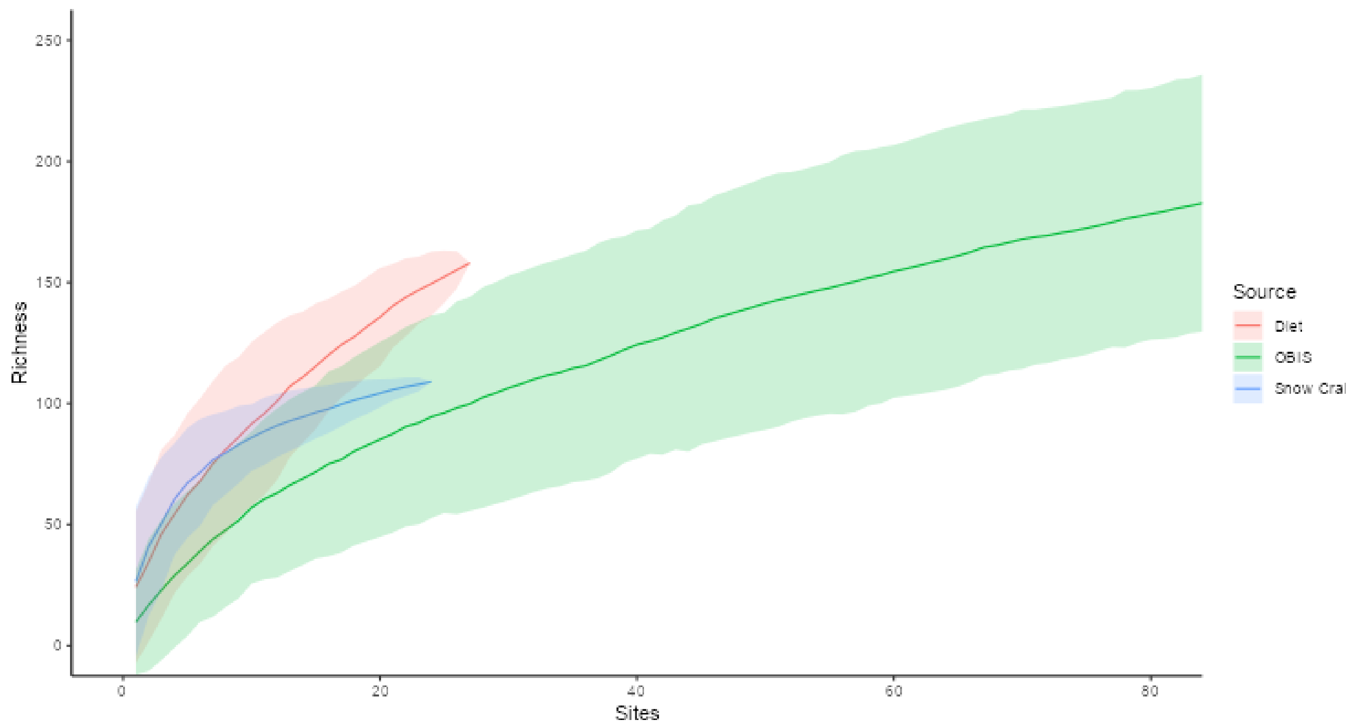

Figure 26. Species accumulation curves for the Snow Crab Survey data, diet data, and records pulled from the Ocean Biodiversity Information System (OBIS). Species richness in the trawl survey is beginning to plateau, while richness from OBIS records and the diet data continue to increase as more samples are added.

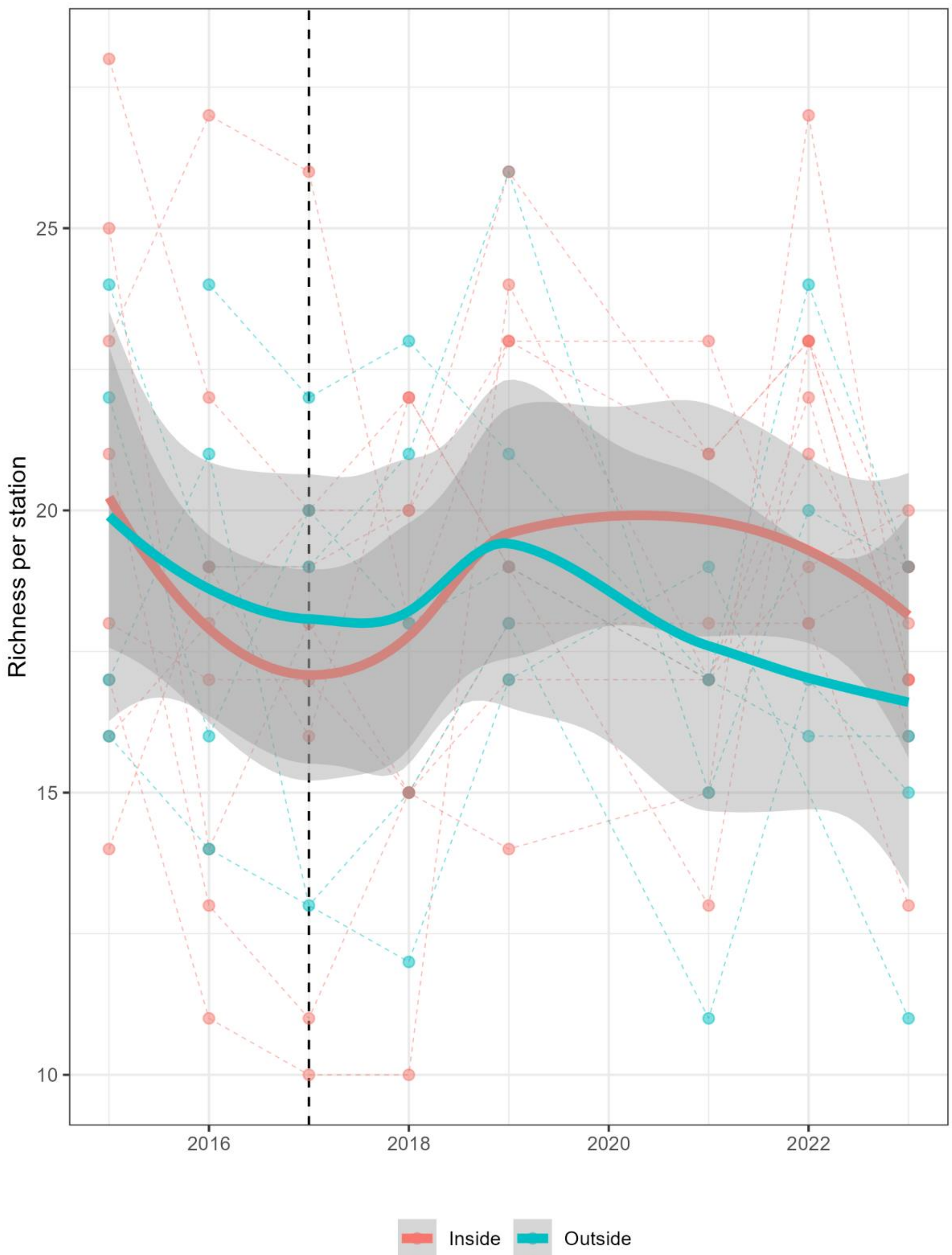

Figure 27. Species richness (as the number of species caught) per station in the Maritimes Snow Crab Survey inside and outside the SAB MPA. Richness per station has remained relatively stable from 2015 to 2023. The grey shading represents standard error around the model fit.

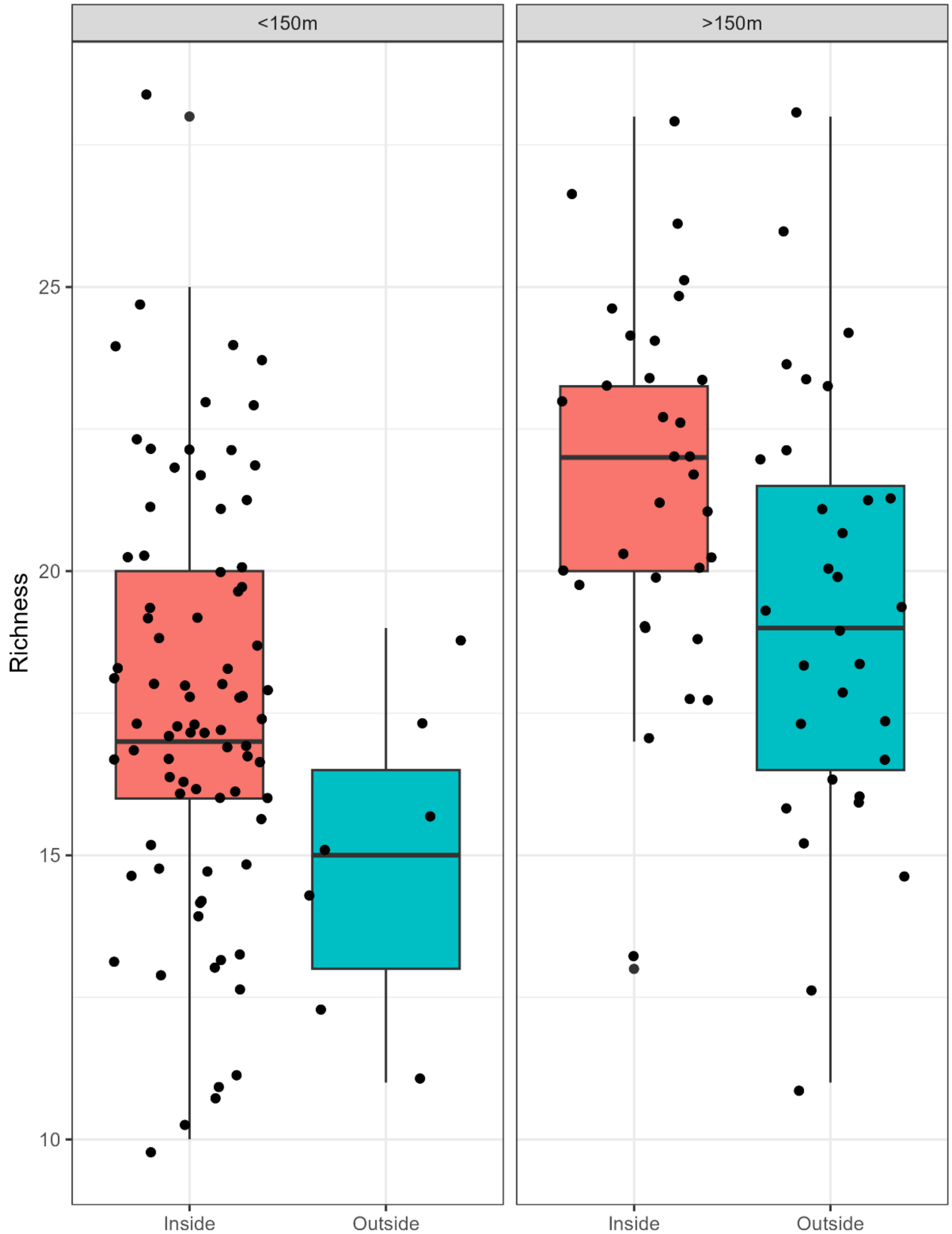

Figure 28. Boxplots displaying species richness (as the number of species caught) inside and outside the St. Anns Bank MPA separated into depths shallower and deeper than 150 metres. Species richness is slightly higher inside the MPA, and in stations deeper than 150 m.

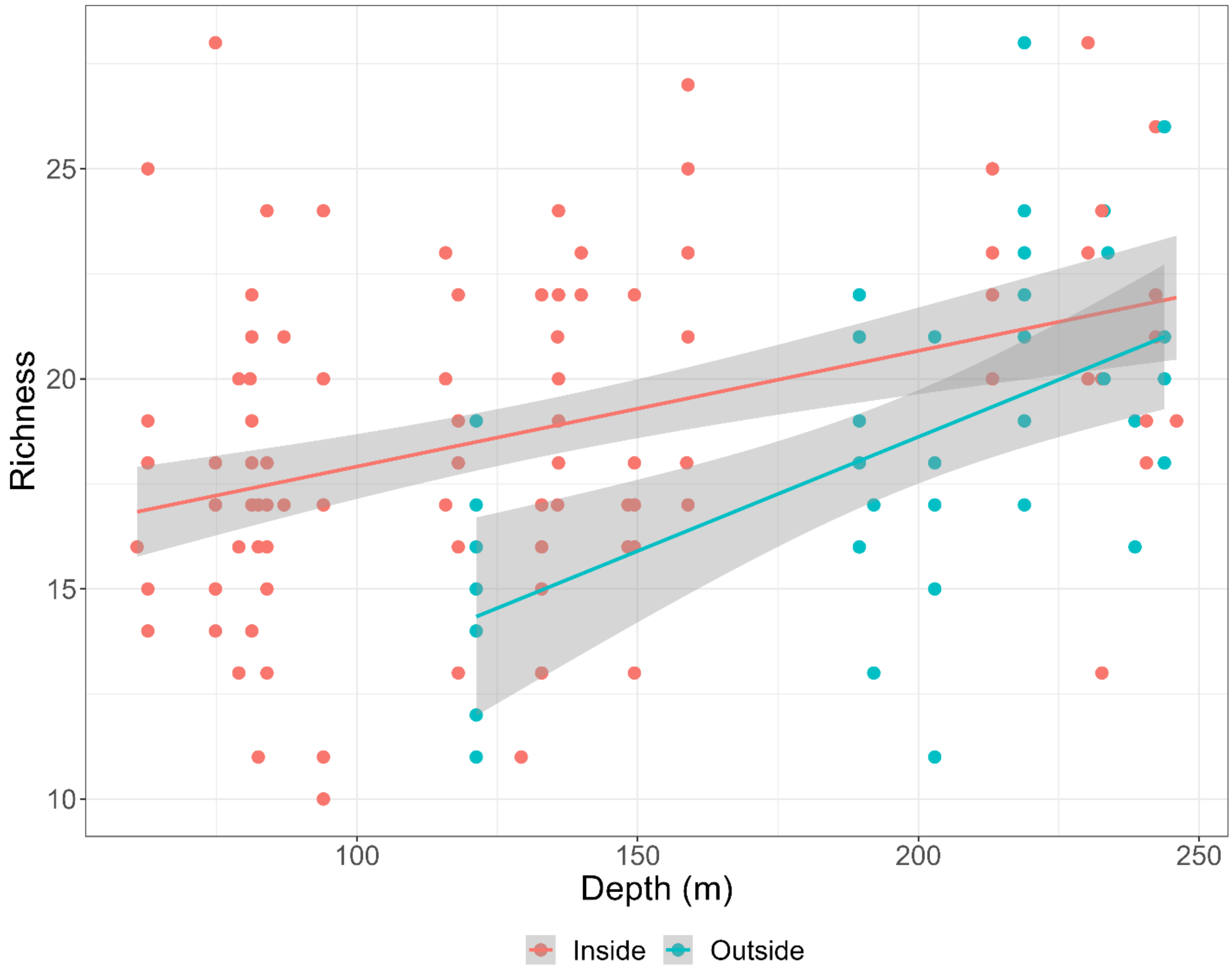

Figure 29. Linear models of species richness with depth based on the snow crab survey stations within SAB MPA. Richness increases with depth in the MPA and is generally higher in stations within the MPA (green points) compared with outside the MPA (red points). The grey shading represents the standard error around the linear model fit.

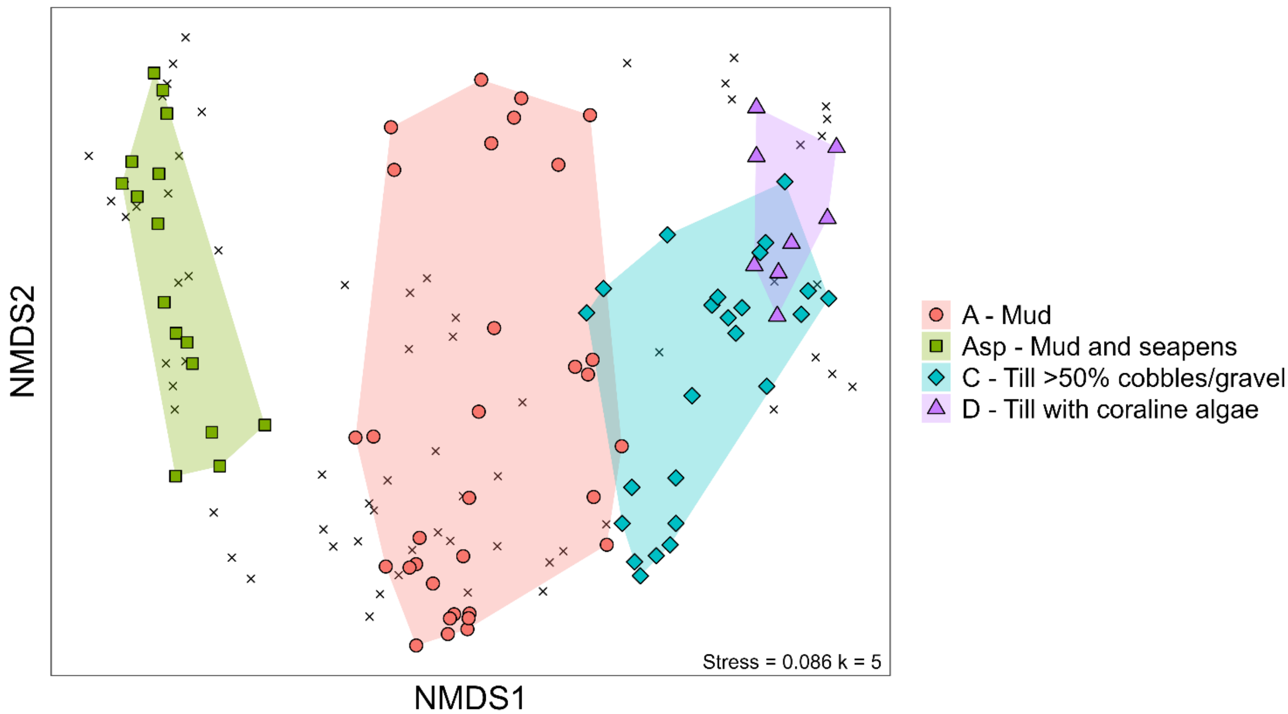

Figure 30. Non-metric multidimensional scaling (NMDS) plot of species composition for all snow crab survey stations in St. Anns Bank MPA from 2015 to 2023. Community composition varies across depth and benthoscape class, with different benthoscape communities separating primarily on axis NMDS1 (see legend). The majority of unclassified stations (represented by x) are from the enhanced survey stations outside the MPA where no benthoscape maps exist.

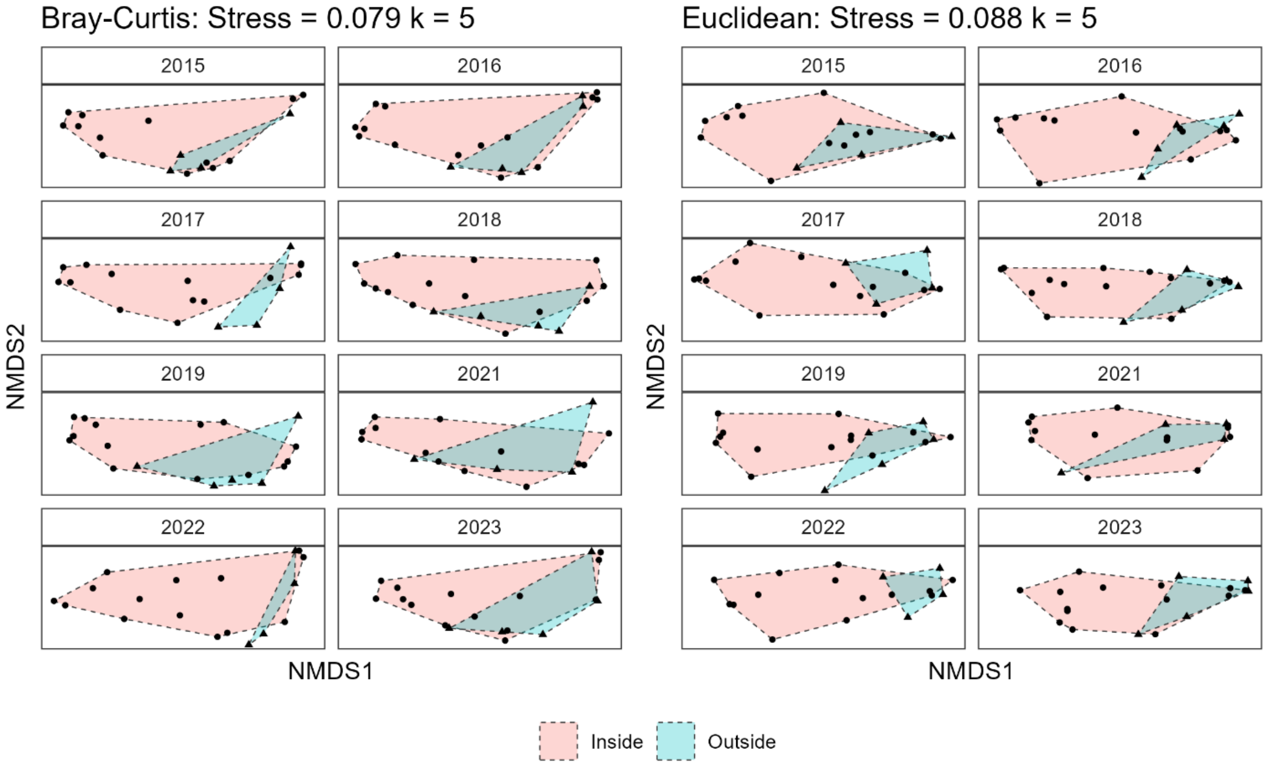

Figure 31. Non-metric multidimensional scaling comparisons of catch data inside and outside the MPA across years. NMDS based on Bray-Curtis and Euclidean dissimilarities are shown. Overall, communities inside and outside the MPA are similar across years and also appear stable. Both dissimilarity analyses yielded a stress <0.1, indicating both are a good fit for the data.

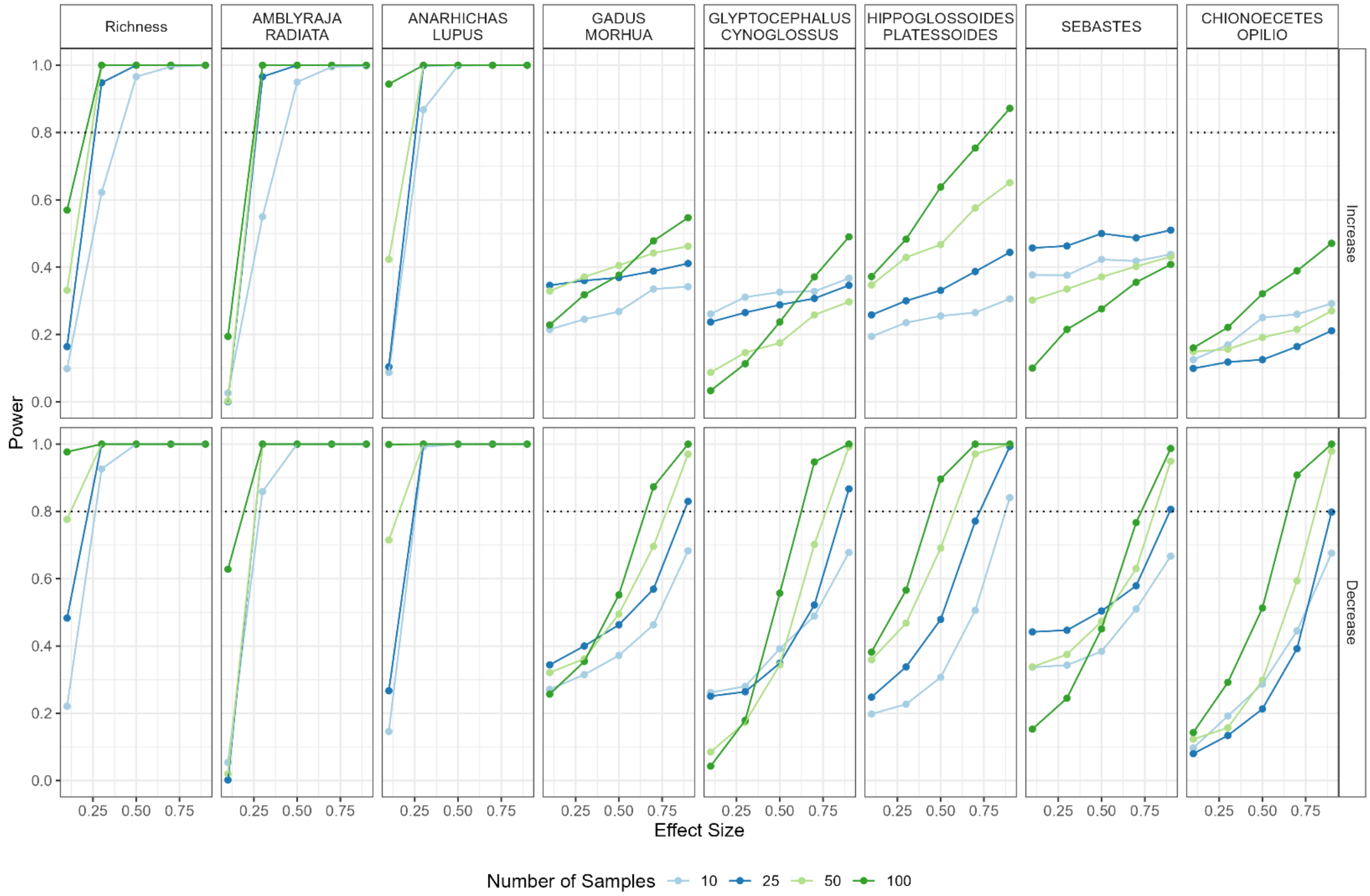

Figure 32. Power analyses conducted to determine the number of samples (trawl sets) required to detect increases and decreases in Catch Per Unit Effort of Hippolglossoides platessoides, Amblyraja radiata, Anarhichas lupus, Gadus morhua, Glyptocephalus cynoglossus, Chionoecetes opilio, Sebastes spp., and species richness in St. Anns Bank MPA. In general, the power to detect both small and large effect sizes increases with the number of samples collected.

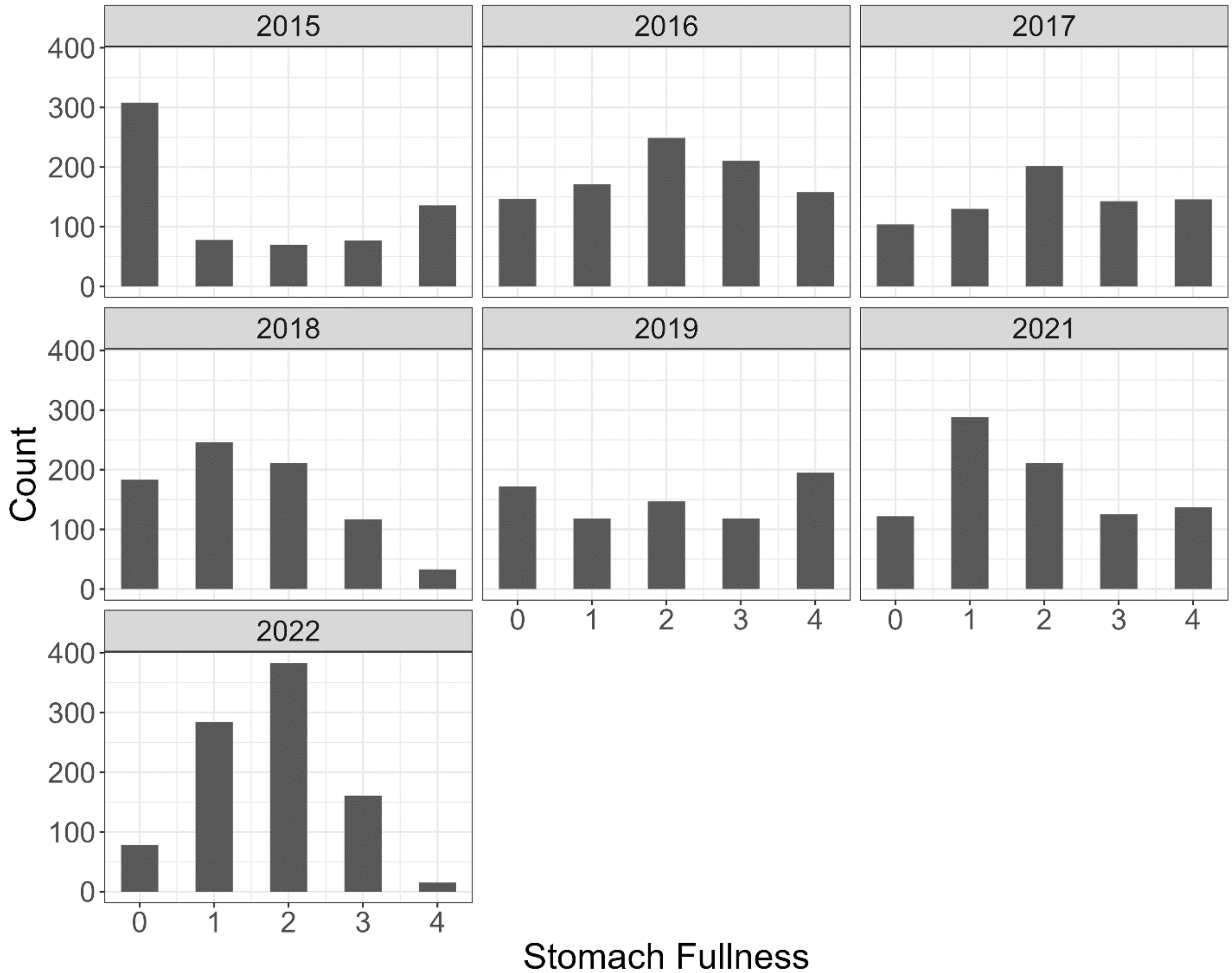

Figure 33. Stomach fullness scores per year from the enhanced Snow Crab survey stations. The count numbers represent stomachs from all fish species pooled across stations per year. Score descriptions: 0=empty, 1=<25% full, 2=25-50% full, 3=50-75% full, 4=75-100% full.

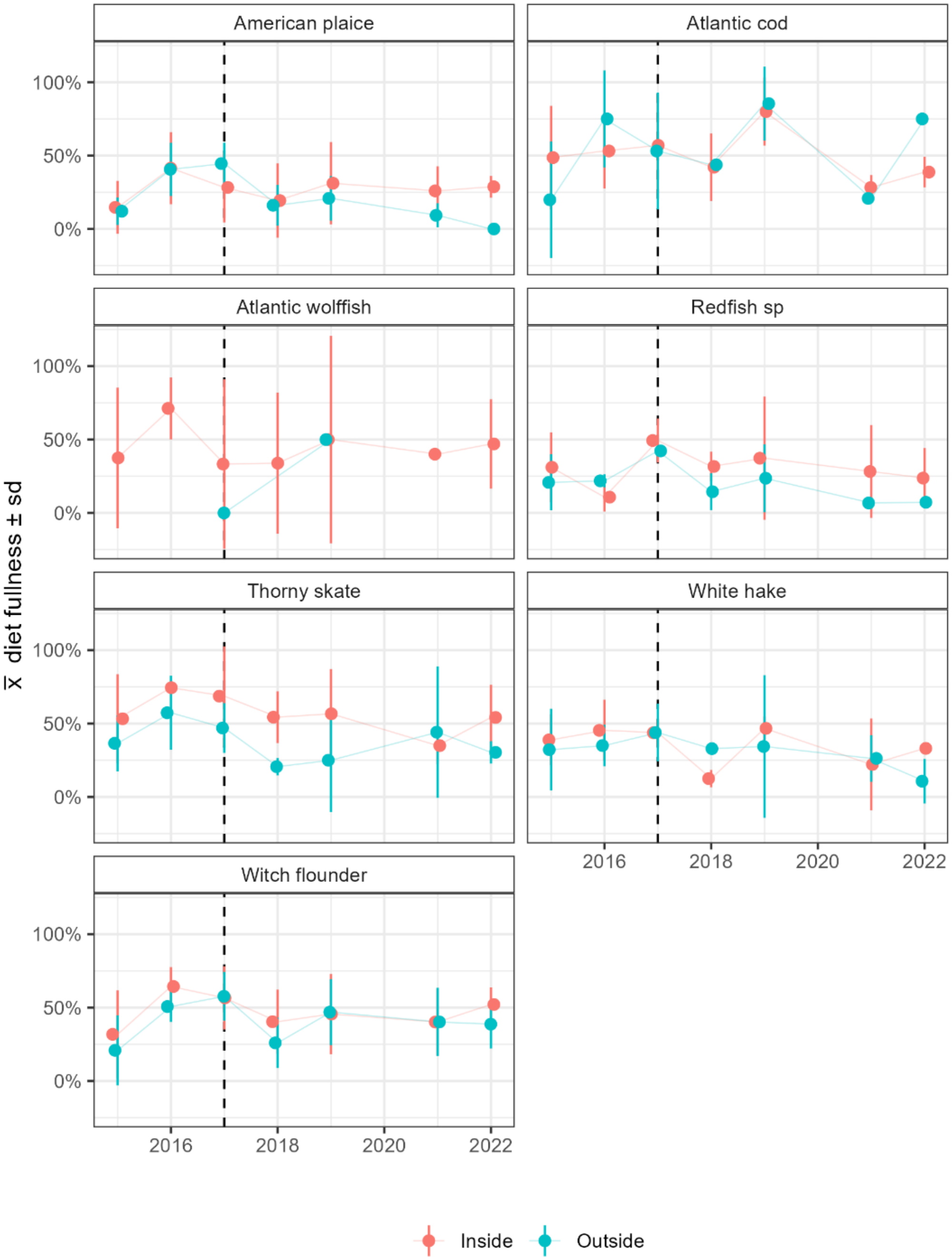

Figure 34. Stomach fullness in seven key predator species captured within and outside the St. Anns Bank MPA over time. The error bars for each point represent standard error around the mean fullness score. Trends among species and within and outside the MPA are highly variable, but also generally stable from 2015 to 2022.

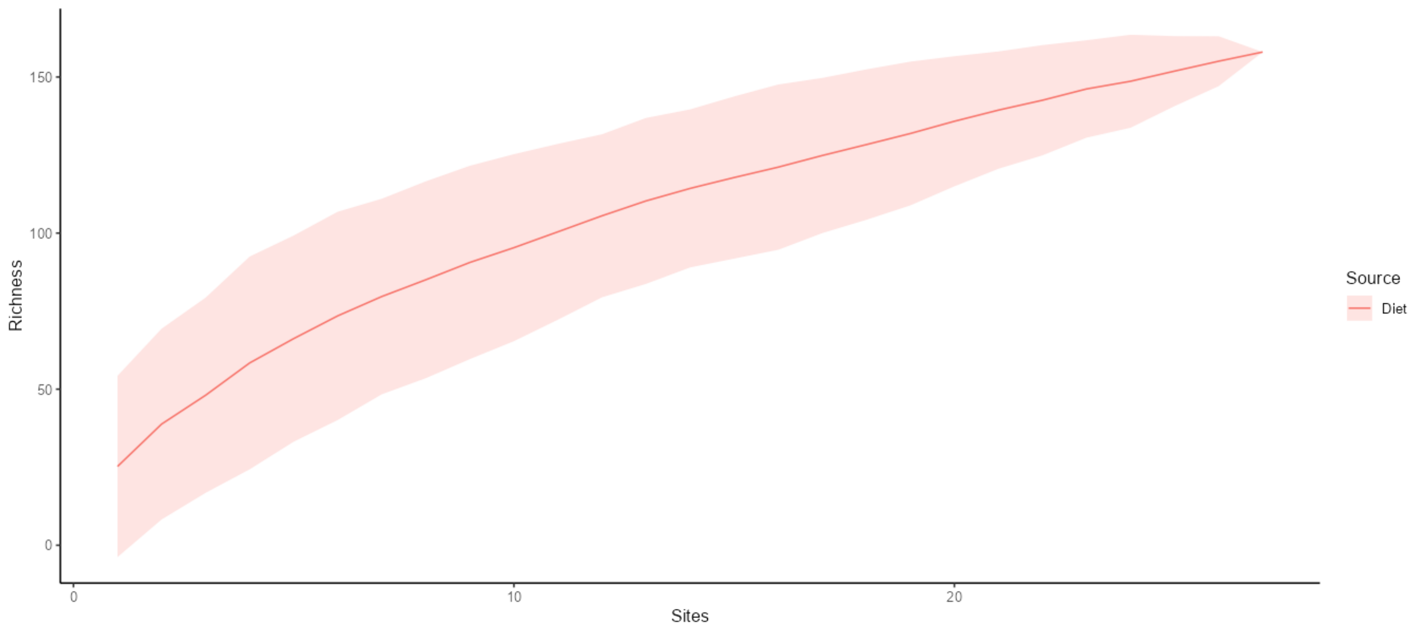

Figure 35. Species accumulation curve for diet data collected from the enhanced snow crab stations. Species richness across all stomach content data is continuing to increase as new samples are added.

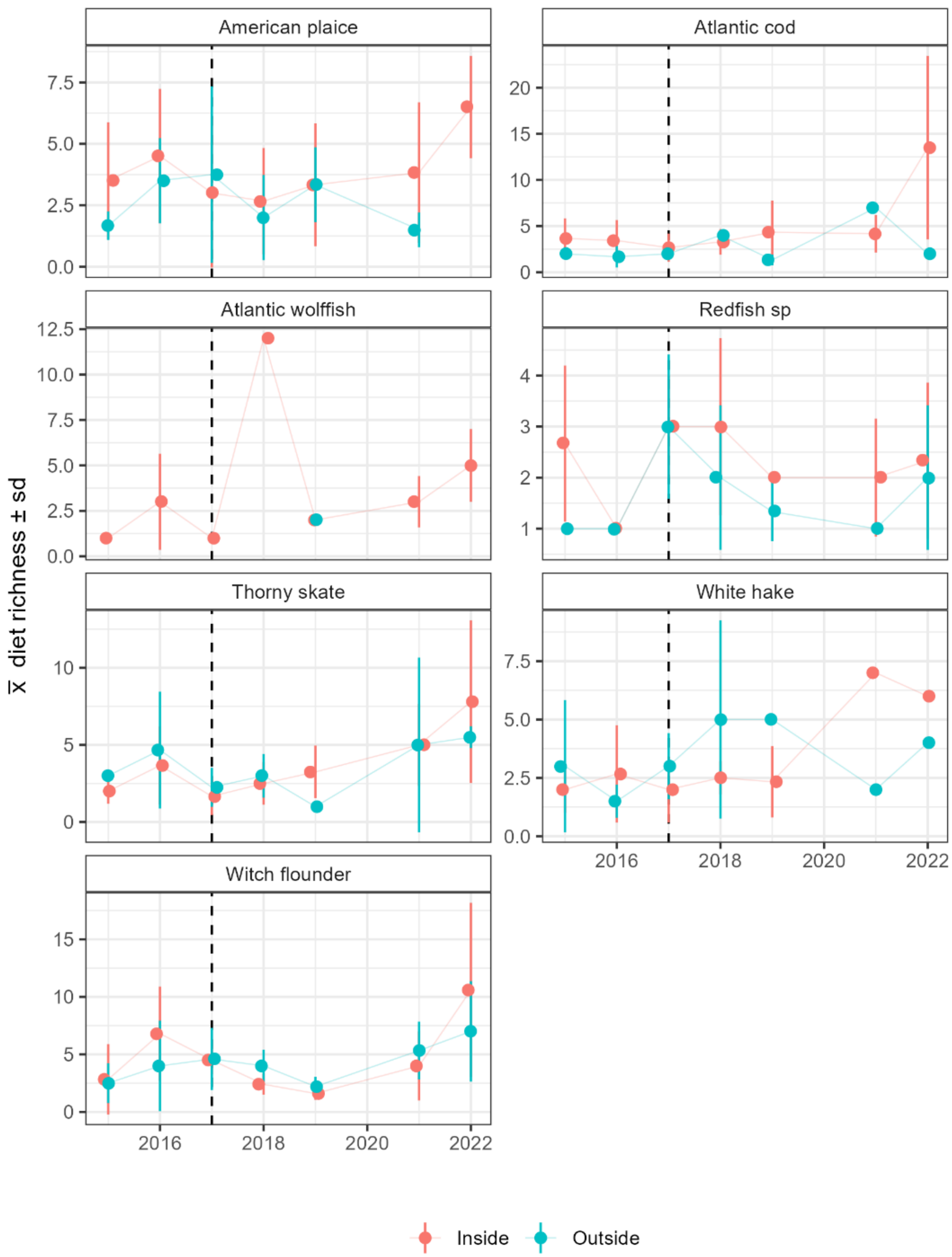

Figure 36. Diet richness in seven predator species captured within and outside the St. Anns Bank MPA over time. The error bars for each point represent standard error around the mean fullness score. Richness seems to be relatively stable for each predator, though trends are variable. Diet richness is slightly higher in some species inside the MPA, but most differences are not statistically significant.

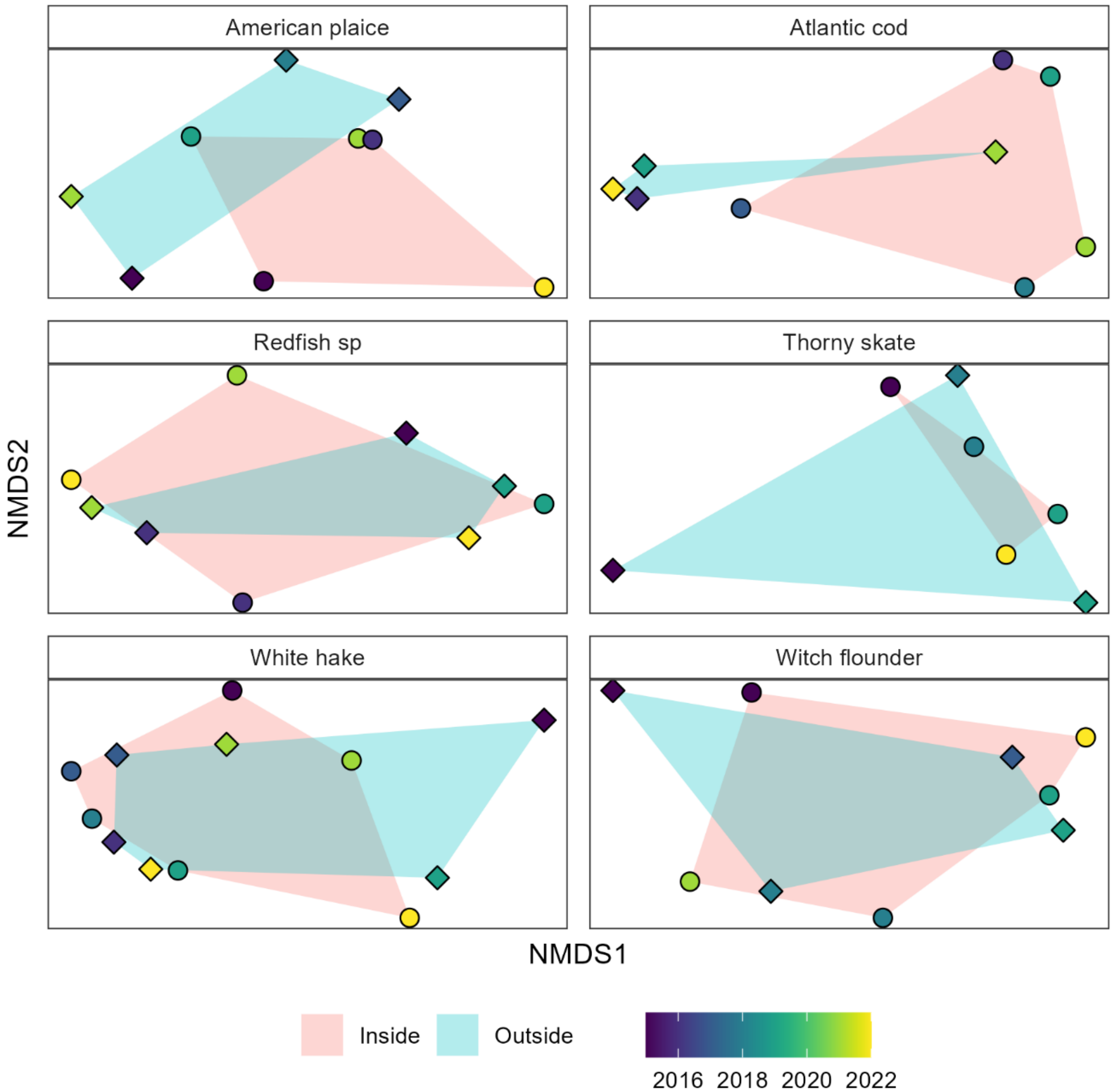

Figure 37. NMDS plots based on Bray-Curtis dissimilarity of diets found within six fish predator species both inside and outside the SAB MPA. Points are coloured by the year they were sampled. In most species, the polygons for inside versus outside the MPA largely overlap, suggesting prey composition is similar. Atlantic Cod and American Plaice are exceptions, where the prey composition appears different inside and outside SAB MPA.

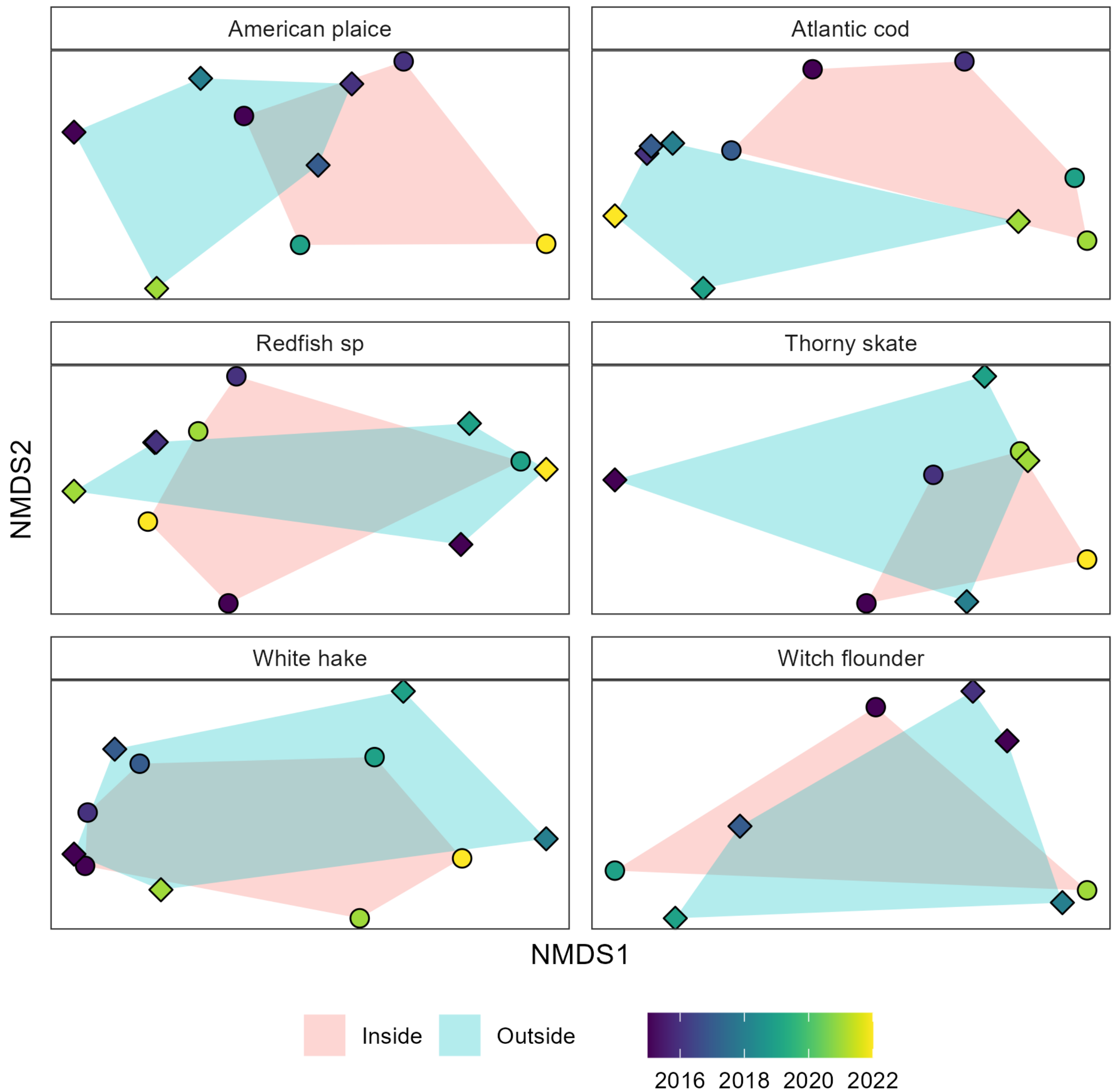

Figure 38. NMDS plots based on presence-absence data of diets found within six fish predator species both inside and outside the SAB MPA. Points are coloured by the year they were sampled. In most species, the polygons for inside versus outside the MPA largely overlap, suggesting prey composition is similar. Atlantic Cod and American Plaice are exceptions, where the prey composition appears different inside and outside SAB MPA.

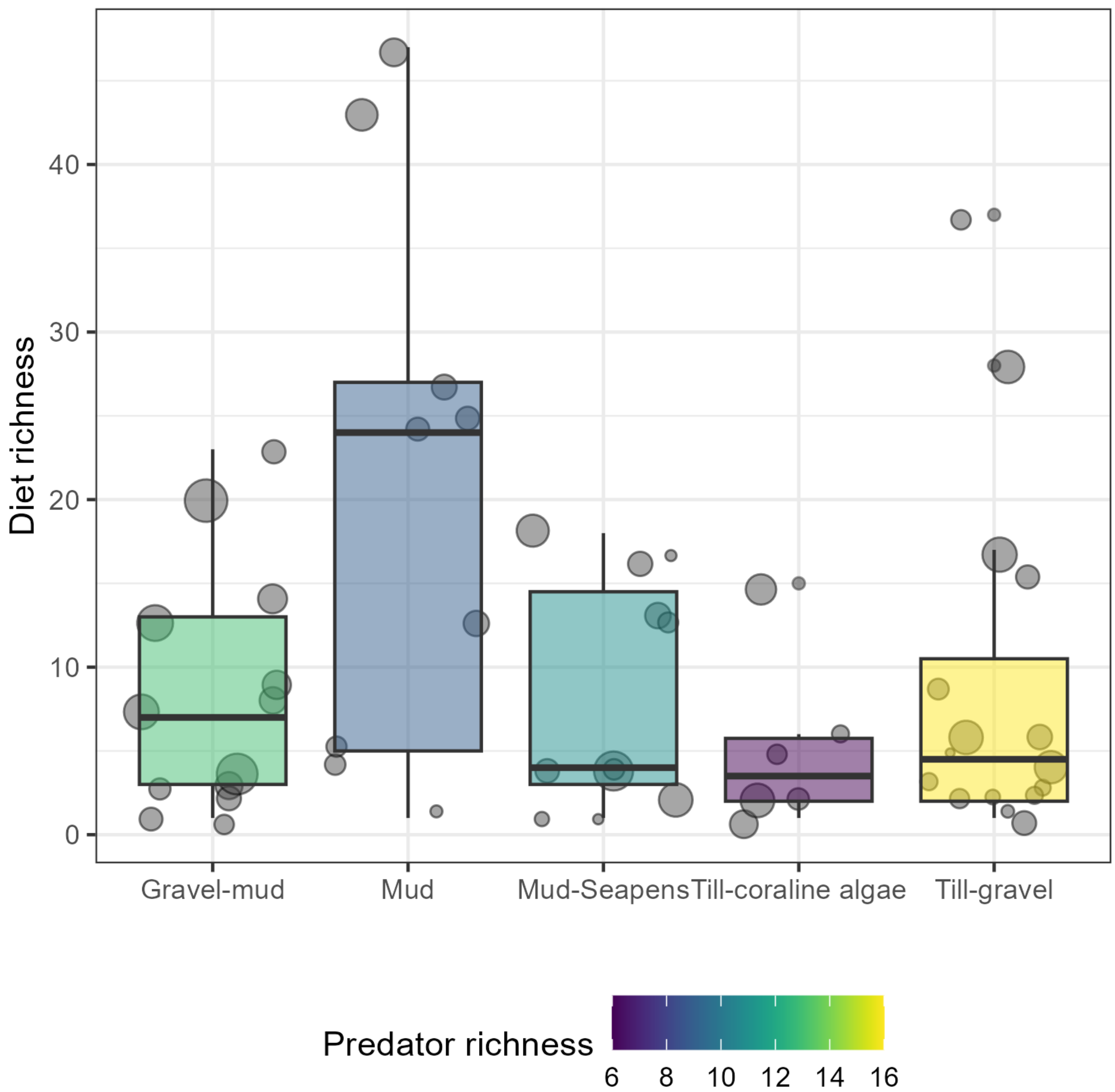

Figure 39. Diet richness of predators across benthoscape classes within SAB MPA. Diet richness is highest in the mud benthoscape class, though predator richness is lowest in this class. Diet richness is lowest in the till-coralline algae class. The points indicate individual fish from which diet richness estimates are derived, and are scaled by the size of the individual fish.

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