Summary of acoustic telemetry data in St. Anns Bank Marine Protected Area from 2015-2023

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by

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ABSTRACT

Pettitt-Wade, H., Jeffery, N.W., Zisserson, B., Stanley, R.R.E. 2025. Summary of acoustic telemetry data from 2015-2023 in St. Anns Bank Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci. 3651: ix + 66 p. https://doi.org/10.60825/zzt8-6t53

St. Anns Bank, situated offshore of Cape Breton, Nova Scotia, was designated 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. Monitoring programs have been ongoing for St. Anns Bank MPA (SAB MPA) both before and after its establishment. This report summarizes the acoustic telemetry data collected in SAB MPA from 2015 to 2023. To date the gates of receivers in the MPA (26 to 46 receivers per year) have detected 330 tagged animals and 13 species from 33 distinct research projects, including Canadian DFO and international projects. In addition, 174 separate animals and seven species have been detected that were tagged in the MPA by the SABMPA tagging program. The most frequently detected species tagged by other projects were Atlantic Salmon, Bluefin Tuna, Blue Shark, Atlantic Cod, and White Shark. Atlantic Cod were detected migrating seasonally to spend winter in the Gulf of St. Lawrence and much of the rest of the year in SABMPA. Receivers deployed near shallow banks (e.g., Scatarie Bank) had the highest residency for species that spent the majority of the year in SAB MPA (Atlantic Cod, Atlantic Halibut, Atlantic Striped Wolffish) and species generally only present during summer/fall months (e.g., White Shark, Bluefin Tuna). Thirty-nine individuals and six species have been detected returning to SAB MPA at least once in a sequential year since 2015, demonstrating the value of a long-term monitoring platform for detecting possible changes in these species' behaviour. Detections of these animals informs on the importance of the MPA as a seasonal migratory corridor with common seasonal latitudinal pathways identified in the MPA and connectivity to the Gulf of St. Lawrence, Nova Scotian south shore, Newfoundland coast, the USA eastern seaboard, and eleven different freshwater systems throughout Canada and the USA. This large dataset provides direct evidence of species occurrence in the MPA and informs on spatial and temporal variation in the timing of migration and residency. We explore several potential drivers of variation in detections and residency, including MPA Zone, bottom temperature, habitat type, and depth, and discuss the implications for conservation objectives and indicators for long-term monitoring.

RÉSUMÉ

Pettitt-Wade, H., Jeffery, N.W., Zisserson, B., Stanley, R.R.E. 2025. Summary of acoustic telemetry data from 2015-2023 in St. Anns Bank Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci. 3651: ix + 66 p. https://doi.org/10.60825/zzt8-6t53

La zone de protection marine du banc de Sainte-Anne située au large du Cap-Breton, en Nouvelle-Écosse, a été désignée comme une 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 grande biodiversité et de la productivité de la zone. Des programmes de surveillance ont été mis en place pour la ZPM du banc de Sainte-Anne avant et après sa création. Le présent rapport résume les données de télémétrie acoustique recueillies dans la ZPM du banc de Sainte-Anne de 2015 à 2023. À ce jour, les barrières de récepteurs dans la ZPM (26 à 46 récepteurs par année) ont permis de détecter 330 animaux marqués et 13 espèces provenant de 33 projets de recherche distincts, y compris des projets canadiens du MPO et des projets internationaux. En outre, 174 animaux distincts et sept espèces ont été détectés qui ont été marqués dans la ZPM par le programme de marquage de la ZPM du banc de Sainte-Anne. Les espèces les plus fréquemment détectées par d'autres projets sont le saumon atlantique, le thon rouge, le requin bleu, le cabillaud et le requin blanc. La morue franche a été détectée en migration saisonnière, passant l'hiver dans le golfe du Saint-Laurent et une grande partie du reste de l'année dans la ZPM du banc de Sainte-Anne. Les récepteurs déployés près des bancs peu profonds (p. ex., le banc Scatarie) ont enregistré le taux de résidence le plus élevé pour les espèces qui passent la majeure partie de l'année dans la ZPM du banc de Sainte-Anne (morue franche, flétan de l'Atlantique, loup à tête rayée) et les espèces qui ne sont généralement présentes que pendant les mois d'été et d'automne (p. ex., le requin blanc et le thon rouge). Trente-neuf individus et six espèces ont été détectés revenant dans la ZPM du banc de Sainte-Anne au moins une fois au cours d'une année séquentielle depuis 2015, démontrant la valeur d'une plateforme de suivi à long terme pour détecter d'éventuels changements dans le comportement de ces espèces. Les détections de ces animaux renseignent sur l'importance de la ZPM en tant que couloir migratoire saisonnier, avec des voies latitudinales saisonnières communes identifiées dans la ZPM et une connectivité avec le golfe du Saint-Laurent, la côte sud de la Nouvelle-Écosse, la côte de Terre-Neuve, la côte est des États-Unis et onze systèmes d'eau douce différents dans l'ensemble du Canada et des États-Unis. Ce vaste ensemble de données fournit des preuves directes de la présence d'espèces dans la ZPM et renseigne sur les variations spatiales et temporelles des périodes de migration et de résidence. Nous explorons plusieurs facteurs potentiels de variation dans les détections et la résidence, y compris la zone de la ZPM, la température du fond, le type d'habitat et la profondeur, et nous discutons des implications pour les objectifs de conservation et les indicateurs pour le suivi à long terme.

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Research on St. Anns Bank MPA and DFO offices are located on the ancestral and unceded territory of the Mi'kmaq people. Thank you to the Captains and Crew of the CCGS *M. Perley*, Ray Sherwood and Danni Harper for their assistance in the field, Susan Heaslip for project planning and field logistics, Neil McMullin and crew with Area 22 Snow Crab Harvester's Association in-kind support for maintenance of the SAB array. We acknowledge the Ocean Tracking Network (OTN) for their assistance in the field, quality control of acoustic telemetry data, and facilitating access to detections of SABMPA project tags on other arrays and of tags deployed by other projects who share their tagging data via the OTN. All project codes who provided data via the OTN are listed in Table 4 (See "https://members.oceantrack.org/" for full project information). This includes Dr. Bryan Franks and Chris Fischer who provided metadata for OCEARCH White Sharks. Thank you to Brent Cameron and Amy Glass for providing code for the previous reproducible report that this report builds on, and Camille Mancion for reviewing French translation. Finally we are grateful to reviewers Geneviève Faille and Paul Snelgrove, the chair Catalina Gomez, and attendees of the Canadian Science Advisory Process for St. Anns Bank MPA in March 2024 for providing suggestions that contributed to this report, including the Unama'ki Institute of Natural Resources (UINR). Note that although Indigenous Knowledge and two-eyed seeing was not conducted as part of this research, a two-eyed seeing approach is being implemented for DFO conservation research and monitoring in the St. Anns Bank MPA moving forward (DFO 2023).

INTRODUCTION

ST. ANNS BANK MARINE PROTECTED AREA

St. Anns Bank (SAB), situated offshore of Cape Breton, Nova Scotia, was designated a Marine Protected Area (MPA) under the *Oceans Act* in 2017 to conserve and protect benthic, demersal, and pelagic habitats, as well as the high biodiversity and productivity in the area. SAB is a large (4,364km^2) MPA, divided into four management zones. The MPA features a variety of habitat types, categorized into three primary depth-based strata according to Ford and Serdynska (2013). These strata include shallow inshore bank (>100m), the mid-depth continental shelf (100-200m), and the continental slope descending into the Laurentian Channel (>200m; Ford and Serdynska 2013). Lacharité et al. (2018) further stratified benthic habitats into 7 'benthoscapes' based on substrate characteristics and benthic imagery. Associated with these benthic habitats are key ecosystem components identified as priority features of the area, including high benthic and demersal fish diversity, areas of diverse invertebrates including corals, sponges, echinoderms, and crustaceans (Ford and Serdynska 2013). The MPA serves as key migratory habitat, situated as the interface between the Gulf of St. Lawrence and the Atlantic Ocean. It functions as a migration corridor, facilitating the movement of various species including groundfish, tuna, sharks, cetaceans, and turtles (Choi et al. 2018; DFO 2023) travelling between the Gulf of St. Lawrence and the Atlantic Ocean via the Cabot Strait.

Conservation objectives for the MPA have been categorized under three themes:

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 (*Dermochelys coriacea*), Atlantic Striped Wolffish (*Anarhichas lupus*), Atlantic Halibut (*Hippoglossus hippoglossus*), Atlantic Cod (*Gadus morhua*), and American Plaice (*Hippoglossoides platessoides*); and
- The 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.

It is essential to effectively monitor MPAs to verify the achievement of conservation objectives and to document ecosystem changes that may necessitate management actions. Ongoing methods for monitoring within SAB MPA include acoustic telemetry, eDNA sampling, oceanographic monitoring through the Atlantic Zone Monitoring Program, and trawl surveys to monitor benthic and demersal fish and invertebrate diversity (Jeffery et al. 2025). This report summarizes acoustic telemetry data collected by Fisheries and Oceans Canada (DFO) and the Ocean Tracking Network (OTN, Dalhousie University, Halifax, NS) collaborative receiver arrays in St. Anns Bank Marine Protected Area from 2015 to 2023. Fish tagging conducted in SAB MPA by DFO is also summarized.

ACOUSTIC TELEMETRY

Acoustic telemetry is a technique used for tracking aquatic animal movement and residency whereby electronic transmitters are attached to the animal either externally or internally using minor surgery. After release, the animal is detectable using acoustic telemetry receivers that are placed in fixed positions close to the seabed, attached to glider drones that conduct programmed surveys, or large animals using recoverable packages (Barkley et al. 2020; Hussey et al. 2015). When a tagged animal moves near a receiver (detectable approximately within 1km), the sequence of transmissions from the tag is recorded by the receiver, providing a unique identifier for each individual. The time and date of each detection is also logged. Some tags are equipped with sensors (e.g., depth, temperature, activity rates) in which case the sensor data also transmits with the detection data. The average delay (nominal delay) between each transmission is pre-programmed based on the species expected swim speed and study design, typically falling within 1-2 minutes. The receivers are later recovered, and the data downloaded from the devices. Once serviced, the receivers can be redeployed to form a continuous period of detection.

The OTN offers support and technical expertise to researchers using acoustic telemetry technologies. OTN manages a database of acoustic telemetry data intended for widespread collaboration throughout the globe. By integrating data on deployed receivers including location, duration, and researchers with tag detections, the OTN provides a valuable opportunity to enhance understanding of animal movement across various projects. This integration offers significant benefits to researchers who upload and share data through OTN’s database (Lennox et al., 2024).

ST. ANNS BANK MPA ACOUSTIC TELEMETRY

In 2015, Snow Crab (*Chionoecetes opilio*) fishers initiated a study in collaboration with OTN and DFO Science to evaluate potential Snow Crab movement between management areas (N-ENS and CFA 23) using acoustic telemetry. Conveniently, the study area for the Crab movement project overlapped with the St Anns Bank Area of Interest (“AOI”), which in 2015 was an area of potential MPA designation. The overlap created provided the opportunity for baseline data collection in the AOI, which came with interest and financial support from within DFO’s Oceans and Coastal Management Division.

Since 2015, acoustic receivers have been deployed in the MPA under various configurations with two primary objectives. Firstly, to ascertain the movement and residency patterns of marine animals tagged within SAB, most of which are likely to be temporarily or permanently resident within the area. Secondly, to determine the movement and residency of animals tagged by other projects (DFO and external) that are detected by receivers in the MPA. These animals predominantly utilize the habitats of the MPA when transiting between the Gulf of St. Lawrence and the Atlantic Ocean.

Ultimately, this project is intended to provide new information to contribute to our understanding of the MPA’s biodiversity conservation objectives. In addition, this telemetry data provides invaluable information on transient habitat use and biological connectivity within the MPA and surrounding areas, including other conservation areas. Information on connectivity is an important expansion on site-based monitoring, providing information needed to evaluate ecological coherence within the regional conservation network (Balbar et al. 2020).

Tracking animals from one place to the next is dependent on the placement of receivers. Aside from the SAB MPA array, there are two major fixed “single gate” receiver lines (arrays) maintained by OTN in our region: one between Northern Cape Breton and Southwestern Newfoundland (Cabot Strait line) and one extending southward from Halifax towards the continental shelf edge (Halifax line, Tress et al. 2023, Figure 1). Recently arrays were greatly expanded in the Bay of Fundy through DFO-OTN collaboration providing a third major fixed gate that stretches across the entrance to the Bay of Fundy (Bay of Fundy line, QRPT project). There are3anada3ss other arrays situated throughout coastal zones in the west Atlantic with various levels of consistency, including receivers around Scatarie Island, Eastern Shore Islands Area of Interest, and the Gully MPA (Figure 1). These OTN receiver arrays greatly increase the detection opportunities beyond those of our St Anns Bank receivers. Opportunistic detections of animals tagged through this project also occur on other worldwide acoustic telemetry projects maintaining receivers as well as mobile Wave Gliders carrying telemetry receivers that are programmed by OTN to conduct search patterns in key areas (Coastal Environmental Observation Technology and Research (CEOTR), “https://ceotr.ocean.dal.ca/gliders/home”, last accessed 28 July 2025).

The annual fish tagging program implemented as part of long-term monitoring in SAB occurs aboard chartered commercial fishing vessels using either baited fish traps or long-line. Tagging protocols are designed to help ensure minimal negative animal health consequences while maintaining catch efficiency. These methods are also designed to minimize impacts to habitat in the MPA. Fish traps were used to primarily target Atlantic Cod and long-lines were used to primarily target Atlantic Halibut. Both Atlantic Cod and Halibut are ideal species for tagging studies because they survive gear release well, are relatively long-lived, have migratory behaviours (i.e., are not sedentary), and have extensive supporting research given the considerable fisheries interest. All animal handling protocols are reviewed annually by the regional Animal Care Committee in alignment with Canadian Guidelines.

The detection of tagged animals within the MPA is currently accomplished through the maintenance of a single line array consisting of 46 receivers (Figure 1). This requires annual retrieval of each receiver for offloading detection data, replacement of the battery, acoustic release lug, anchor and subsequent redeployment. Since beginning the acoustic receiver deployment program in 2015, the vessel, crew, and labour for this work has been provided by local fishermen, with technical assistance from OTN and DFO. Receiver rollovers and data offloads are conducted annually. Raw detection data is processed by OTN and uploaded to the open access data portal where it is accessible by DFO. Tag detection summaries are produced annually. These reports sometimes require contacting tag owners external to DFO to determine some detail on species, timing and location of tag application. In addition to tag detections, these receivers record hourly bottom temperature and depth data which is made open access on the Open Government Portal (Pettitt-Wade et al. 2024) and is a critical contribution towards indicators of climate change and modelling under future climate change scenarios.

METHODS

STUDY SITE AND ACOUSTIC RECEIVER STATIONS

Moorings were constructed with VR2AR (acoustic release receiver, Innovasea Systems Inc., Halifax, NS) acoustic receiver units tied to floats above the receiver and a 150 lb anchor approximately 1.5 m below the receiver. The anchor was attached via a chain, a shackle-swivel-shackle arrangement, and tied to a lug that screws into the receiver. Receivers were deployed at depths ranging from 34m to 163m. After deployment, a VR100 (Innovasea Systems Inc.) deck box and transducer were used to communicate with the receiver from the surface to receive diagnostic information and trigger the lug to unscrew, which allows the float to bring the device back to the surface for data recovery. In 2015 two fixed lines (or "gates") were deployed composed of 26 receivers, 13 in each line, that were designed to examine Snow Crab movement (Figure 1). At each annual recovery receivers were gradually added to this double gate array to expand the spatial coverage to 46 receivers in 2019-2021 (23 in each line). In 2021 the array was redesigned in collaboration with OTN into one long line with a bend in the middle to refocus on monitoring all tagged species that use the MPA as a migration corridor (46 receivers, Figure 1).

OCEANOGRAPHIC DATA

The VR2AR receivers recorded bottom temperature and depth hourly at fixed positions (°C; manufacturer provided accuracy ±0.5 °C, resolution 0.1 °C, Innovasea Systems Inc.). Habitat type was determined at each receiver position from benthoscape classifications based on multibeam backscatter data (Lacharité et al. 2018; 2019).

FISH CAPTURE AND TAGGING

Fish tagged by the SABMPA project were either captured by longline (targeting Atlantic Halibut) or using fish traps (targeting Atlantic Cod) by DFO staff on chartered fishing vessels. Long-lines were deployed in sets of ~4 and left to soak for ~4 hours before being recovered. Fish traps (3' x 4' x 4') were deployed and recovered by winch and carefully emptied on to the deck after capture for sorting. Regardless of the method, all species not intended for tagging were released immediately upon capture. After capture, healthy fish were tagged with acoustic telemetry transmitters by surgically implanting the transmitter (or tag) into the stomach cavity. Focal species intended for tagging (Atlantic Cod and Atlantic Striped Wolfish) were first held in aerated recovery tanks for approximately 15 minutes then placed in a tagging trough ventral side up. Atlantic Halibut were tagged on a flat bench, eye side facing down, immediately following capture. A wet rag was placed over the eyes, the fish measured (Fork length, FL), and a fin clip taken and divided for genetics (ethanol preservation) and stable isotope (frozen) analysis. A small incision (~2 cm) was made to one side of the posterior abdominal midline using a clean scalpel (#11) and an acoustic transmitter was inserted (V13, Innovasea Systems Inc.) ensuring < 2% b/w to avoid tag burden, Klinard et al. 2018). After inserting the tag, the incision was sewn up using 2 or 3 simple interrupted sutures (non-braided antibacterial coated sutures; VICRYL*Plus). The fish was then tagged with a floy-tag using a floy tagging gun at the base of the first dorsal fin (Atlantic Halibut only) and placed in a recovery tank and monitored for ~15 minutes to ensure full recovery prior to release (i.e. oriented upright, regular opercular movement, response to stimuli). Given the excessive size of Atlantic Halibut, individuals were monitored throughout and immediately after surgery, then released and monitored at the surface. All animal handling procedures were reviewed and approved by the regional Animal

Care Committee of DFO (AUP 23-16 and 23-17). Tags used by the SABMPA project (V13) were typically programmed to have a nominal delay of 60-180 seconds which allowed for a battery life of up to 4.5 years, 2.5 years for high power tags, and 1.5 years for tags equipped with sensors (i.e., V13TP).

In addition to tag detections recorded from tags deployed as part of the SABMPA project, this report also includes data from detections of fish tagged by other projects. This data was collected opportunistically and at the discretion of the project authority. There is mixed and currently often minimal information available on tagging methods for projects other than SABMPA, which also vary depending on species and location of tagging.

DATA PRE-PROCESSING AND ANALYSIS

a. Acoustic telemetry

a. Ocean Tracking Network pre-processing

To examine how acoustic telemetry can be used for long term monitoring as part of a global collaborative network, this report primarily uses detections that were uploaded to the Ocean Tracking Network (OTN) data portal and returned having undergone quality control by the OTN database team. OTN returns verified detections from receivers associated with the SABMPA project and, most crucially, detections for receivers and tags of other projects that upload their data to the portal that would otherwise not be accessible to the SABMPA project. The steps that the Ocean Tracking Network (OTN) uses to pre-process and provide reports of detections is described in full at this weblink: OTN Data Workflows — Ocean Tracking Network Data Portal, "https://members.oceantrack.org/data/otn-workflows" (last access 28 Jul 2025). In brief, tagging, receiver deployment, and detection data is pulled from project data repositories and quality controlled to address or remove errors and blanks. Tag and receiver metadata is then linked to detections on receivers using the unique tag and receiver identifier numbers. Matched data are split by year and quality controlled, for example to address duplicate entries and detections that did not match to a receiver, and the detections are shared with researchers. This report summarizes data obtained up to August 2023.

b. Pre-processing

Detections were filtered for possible false detections based on the detection ID of the tagged individual and the timing of each detection relative to the previous or following detections of the same individual (i.e., speed filter, 'glatos::false_detections()', Holbrook et al. 2017). Detection filters applied to detections matched to SABMPA project tags resulted in the removal of 1170 detections based on the timing between successive detections, whereby the distance between receivers associated with detections resulted in improbable movement events. Improbable single detections were also flagged as false and removed. The data was then examined using the 'glatos' package in R for detection summaries. Possible mortalities or tag expulsions were examined using the 'mort' function in glatos which highlights detections that repeat in one location indicating a tag that remains unnaturally stationary after an initial period of activity post-release.

a. Detection summaries and movement pathways

The filtered detection data was first converted to the appropriate format for 'glatos' using the function 'read_otn_detections()' followed by the function 'detection_events()' to break the detections down into 12-hour detection bins and provide the timing of detection within each bin. Detection event data was then summarised by location or individual tagged using the function 'summarize_detections()'. Summary data was then split by species for plotting, reporting in tables and statistical analysis. A Receiver Efficiency Index (REI) was also run using the function 'REI()' to identify the receiver stations most efficient at detecting species and individuals. REI is a number between 0 and 1 that represents the relative detection frequency of tagged animals at each receiver station compared to all receivers. Unique tag IDs and species are used in the calculation of efficiency (Ellis et al. 2019). The following equation describes REI:

$$REI = \frac{T_r}{T_a} \times \frac{S_r}{S_a} \times \frac{DD_r}{DD_a} \times \frac{D_a}{D_r}$$

Whereby *T* refers to tags, *S* to species, DD the number of unique days with detections, D number of days the array was active. Subscript *r* refers to detected on a single receiver, subscript *a* refers to detections on all receivers. REI was run independently for each array configuration (i.e., pre and post 2021).

b. Statistical comparisons

The data was then checked for normality and heteroscedasticity. Analysis of Variance (ANOVA) with post-hoc multiple comparisons tests were used to examine how movement and residency varies throughout the receiver array. Bonferonni correction was used to account for multiple tests. Welch's t-test with Games-Howell post-hoc was used for data that failed assumptions of normality using the 'onewaytests' package.

b. Linear models

Linear models were used to examine potential drivers of variation in seasonal residency for each species separately using the R package 'lmer'. Month and year were included as fixed effects as were the following parameters recorded at each station: depth, bottom temperature, and benthoscape classification (i.e., habitat type). Individual ID was included as a random effect. Only species with a sample size (individuals detected) of five or greater were included. All analyses were conducted with R 4.3.1 in Rstudio 2023.09.1.

OPEN DATA AVAILABILITY

Raw acoustic telemetry receiver data and metadata are available open access on the Ocean Tracking Network (OTN) datal portal ("https://members.oceantrack.org/project?ccode=SABMPA"). The data and code used in this report are available on GitHub ("https://github.com/dfo-mar-mpas/stannsbank_mpa"). Project metadata and species detections for SABMPA project tags updated seasonally are available on the Ocean Biodiversity Information System (OBIS) data portal ("https://doi.org/10.14286/txzmn8"). Bottom temperature data are available on the Open Government Portal (Pettitt-Wade et al. 2024, https://open.canada.ca/data/en/dataset/910b8e22-2fd1-4ba1-8db6-d16763c7a625). All links last accessed 28 July 2025. Please contact the authors of this Tech Report for further information and to ensure appropriate data use.

RESULTS

Detections of tagged fish on the acoustic telemetry receivers are broken down by detections from animals tagged by other projects, and animals tagged within the SAB MPA by the SABMPA project. Note that the acronym without a space refers to the project code on the OTN database and with a space refers to the MPA in general.

DETECTIONS OF SABMPA PROJECT TAGS

Total detections relative to tagging conducted

After filters were applied, 51,655 detections of SABMPA project tags were logged across all receivers since the first deployment in 2015 to the data offload in August 2023. A total of 170 individuals and seven species were tagged by the SABMPA project in the MPA and all tagged fish had at least one detection event in the MPA (i.e., >2 receiver detections within 12hours, Table 1). Due to proximity to Cape Breton Island and ports used by chartered fishermen, the majority of tags were deployed in the southwest of St. Anns Bank MPA, near the current western line of receivers (Figure 1b). With the exception of 14 Atlantic Striped Wolfish, 7 Snow Crab, and 1 Shorthorn Sculpin (*Myoxocephalus 8anada8s*) tagged in 2016, the majority of individuals (i.e., Atlantic Cod and Atlantic Halibut) were tagged and detected from 2018 onwards (Table 1, Figure 3). All 47 Atlantic Cod tagged in 2018 were detected on the array in that year and 13-18 individuals continued to be detected each year until the next tagging effort in 2022. Body length measured during tagging showed an increase in maximum size of Atlantic Cod tagged in 2022 and detected 2022-2023 relative to previous years (Figure 2).

Tagging effort for Atlantic Cod and Atlantic Halibut increased in fall 2022 with a corresponding increase in individuals detected (Table 1, Figure 3). Tagging also occurred in fall 2023 for Atlantic Cod and Atlantic Halibut (68 and 16 tagged, respectively) with V13 and the longer life V16 tags with detections expected to return in data offloads in subsequent years. An additional 58 Atlantic Cod were tagged and released in St. Anns Bank MPA in 2016 by the SABMPA project with tags donated from a project partner and, therefore, are included in the next section: 'Detections of Other Project Tags'.

Several tag types and programming were used depending on the target species body size and expected swim speed and some tags were donated to MPA research from other projects, which meant they varied in battery life. All tags allowed observations of individuals returning annually or seasonally (1.5 to 4.5 years, Table 2). Several Atlantic Striped Wolffish were detected for two subsequent years and one for an additional two years after that, which was a tag with a longer lifespan (Table 1 & 2, Figure 3). After tagging commenced on Snow Crab in 2018, five individuals were detected but only one of these tags had a multi-year life span and was detected in subsequent years (Table 1, Figure 3). Shorthorn Sculpin (2), Atlantic Tomcod (*Microgadus tomcod*, 3), and Thorny Skate (*Amblyraja radiata*, 1) were also tagged and detected on the SABMPA array. Tomcod and Sculpin tagged in 2022 were also detected the following year.

Atlantic Cod

Many individuals tagged by the SABMPA project in the MPA exhibited movements to and from the MPA array to other arrays in the region managed by other projects (Figure 3, Table 3). Most detections were matched to Atlantic Cod tags and distributed among arrays associated with 8 projects, including SABMPA (Figure 3). After tagging release in SAB MPA in 2018, Atlantic Cod were detected repeatedly making seasonal movements between SAB MPA and the Gulf of St.

Lawrence via the Cabot Strait until mid-2020 (i.e., CBS array; Figure 3, Figure 4, Table 3), congruent with SAB being a migratory habitat. Similar movements were captured by different arrays in the Gulf of St. Lawrence for the Atlantic Cod tagged more recently (Figure 3, Table 3). Several Atlantic Cod tagged in SAB MPA during fall 2022 were detected on arrays in the Gulf during winter/spring, whereas others remained in SAB MPA throughout the year (Figure 3, Figure 5). Atlantic Cod that were tagged and released in SAB MPA generally spent winter months at higher latitudes and lower longitudes (~47° N, -60° W, respectively; i.e., Cabot Strait, Gulf of St. Lawrence) and summer-fall months were more frequently spent at lower latitudes and higher longitudes (~46° N, -59° W, respectively; i.e., SABMPA, Figure 5, Figure 6, Table 3).

Atlantic Halibut

Halibut tagged in SABMPA during Nov 2022 were initially detected on receives near release, then were detected on receivers to the northwest (higher latitude and longitude) during winter months, and returned to the array in April-May 2023 (Figure 7). One project other than SABMPA detected SABMPA tagged Atlantic Halibut with receivers around Scatarie Island, ~3 km west of and adjacent to the MPA (project NSWS; Table 3 & 4, Figures 1 & 3). These receivers sit at a similar latitude to some of the SABMPA receivers and a slightly lower latitude and indicated a seasonal offshore-inshore migration during winter-summer, respectively (Figure 6 & 7). The Scatarie Island receivers only detected one individual, but the detection frequency indicated that the individual remained in the area for two weeks during mid-July (15 – 28th July 2022) after being released in the MPA in Aug 2021 and detected moving westwards in the MPA in December 2021 (Figure 7). Atlantic Halibut also exhibited higher maximum residency time and on fewer SABMPA receivers relative to Atlantic Cod tagged in the MPA (Figure 6). Altogether, these findings show the potential to detect seasonal inshore/offshore movements of Atlantic Halibut beyond the boundaries of the MPA (Figure 8). Future data offloads should provide greater insights on these multi-year tags and for tags deployed after the Aug 2023 data offload.

Atlantic Striped Wolffish

All fourteen Wolffish tagged in 2016 in SAB MPA were detected within SAB MPA on June 12 2016 on the south array near their release location (Figures 8 & 9, Table 4). Seventeen days later, one Wolffish was detected moving east past two receivers on the south array for another seventeen days before settling (29th June to 17th July 2016,Table 3). On the 5 Sept 2016, this same individual was then detected further west past its original location, before its final detection on the north array just one day later (Sept 6 2016 Figure 8, Figure 9). There were no further detections of the tagged wolfish on the SABMPA array. However, one individual that hadn't been detected since initial release in Zone 1 of the MPA on 12 June 2016 was detected by OTN Wave gliders (project GDL) south of the fixed array in Zone 2 on June 21 2017, Oct 30 2018, and Nov 2, 2019 (Figure 8 and 9, Table 3).

DETECTIONS OF OTHER PROJECT TAGS

As of the latest receiver offload in August 2023, a total of 330 individuals from 33 distinct external research projects and 13 species have been detected on these receiver lines (includes Canadian and International projects, Table 4). This does not include two single detections, one from a project based on Atlantic Herring in the northern Gulf of St. Lawrence and one on multiple tropical species in Florida, USA, that were flagged as false given the unlikelihood of single detections and the distance for the species tagged by the associated projects. Atlantic Salmon had the most individuals detected at 102 associated with 11 distinct OTN research projects, which was also the highest. This was followed by Bluefin Tuna (78 individuals, three projects), White Shark (*Carcharodon carcharias*, 65, four projects), and Atlantic Cod (47, two projects, (Table 4, Figure 10a). A total of 18 Blue Shark (*Prionace glauca*) were detected from two projects, six Porbeagle shark (*Lamna nasus*), and five American Eel (*Anguilla rostrata*) both from two projects each. The array has also detected two Snow Crab and Atlantic Halibut, and one Atlantic Sturgeon (*Acipenser oxyrinchus*), Grey Seal (*Halichoerus grypus*), Shortfin Mako (*Isurus oxyrinchus*), and a Leatherback Turtle (Figure 10a). In addition, one tagged individual detected on the array has been associated with a project assessing shark and tuna movement in relation to offshore wind turbines. This individual unfortunately was not identified to the species level at the time of this analysis but is one of four species associated with that project (Figure 10a).

SEASONAL RESIDENCY AND ANNUAL RETURNS

The seasonal presence of tagged species in St. Anns Bank MPA was evident in the periods of detection with most individuals of most species absent during winter months (i.e., Dec-May; Figure 10b). Atlantic Salmon (*Salmo salar*) had the highest number of individuals detected at one time with brief occurrences each year during spring/early summer (i.e., May-June; Figure 10b & 10c). American Eel were detected transiting through in the fall (Oct-Nov). Pelagic sharks, Bluefin Tuna, and Atlantic Cod had peak occurrences during early summer and early fall. Atlantic Cod and Atlantic Halibut were among the only species present during winter months (Figure 5, 7, 10b & 10c), but the majority of individuals for these species also exhibited absence during winter months. This includes Atlantic Cod tagged in the MPA that continued to be detected in the MPA for multiple years, returning to the MPA after spending winter/spring in the Gulf of St. Lawrence and Cabot Straight (Table 5), and several Atlantic Halibut tagged in 2022 that returned and remained resident to the SABMPA array after absence during winter (from ~Dec/Jan to April/May, Figure 7).

In total we detected 39 individuals from other projects that have at least one annual return since the first array was deployed in St. Anns Bank in 2015 (Table 5). Six species were detected returning in at least one subsequent year with 12 Bluefin Tuna detected for up to three years, two Porbeagle Sharks for two years (2017-2018), 13 Atlantic Cod for up to three years (2016-2019), six White Sharks for up to two years (2019-2022), four Blue Sharks for two years (2015-2017 or 2022-2023), and one Snow Crab (2019-2020). Most recent annually returning individuals (i.e., 2021-2023) were among Bluefin Tuna, White Sharks, and Blue Sharks due to the recent or ongoing tagging programs and the highly migratory behaviour for these species. The possibility of detecting individuals over multiple seasons or years is dependent on the lifespan of the tag used and longer battery life is limited to the larger tag sizes, which are only deployed on larger growing species. For example, Atlantic Salmon are often tagged as smolts or kelts, which require small tags with low battery life lasting weeks to months as opposed to years (Figure 12).

REGIONAL MOVEMENTS AND CONNECTIVITY

The culmination of SABMPA detection data collected from other projects tags on a wide range of migratory and seasonally resident species informs on the location and timing of shifts in occurrence for these species in the MPA (Figure 11). Interpolated tracks of sequential detections on receivers also indicated common latitudinal pathways of movement across species (Figure 13).

Freshwater ecosystems

Connectivity between freshwater ecosystems in the Northwest Atlantic and the offshore marine SAB MPA was evidenced by Atlantic Salmon that were detected in SAB MPA after being released from 11 different freshwater systems located across Atlantic Canada and the USA (Table 4, Figure 14). The majority of individuals were released from one of the most distance locations; Penobscot River in Maine, USA (32 individuals) with a minimum migration distance of 1000km. The second highest count of individuals detected were released from one of the closest locations; various stretches of St. Mary's River in Nova Scotia (26 individuals) with a minimum migration distance of 240km to SABMPA receivers (Table 4). Atlantic Salmon detected on the SABMPA array were also released from LaHave River, NS (9) and West River in Sheet Harbour, NS (7), transiting through the Eastern Shore Islands AOI. Of note, individuals from West River detected in SAB were tagged as part of a collaboration with DFO Science Marine Conservation Targets Program and the Nova Scotia Salmon Association (NSSA). The remaining individuals in this list include the longest migration distances we observed for Atlantic Salmon by current estimates of release locations with one individual making the journey from Cascapedia River, QC (minimum distance of 600km), one from far up the Kennebec River, Maine (minimum 1200km), and three that were tagged far up the Tobique River, NB (minimum 1000km, Figure 14). Note that eleven additional Atlantic Salmon currently have unspecified release locations from throughout Atlantic Canada (Table 4). Perhaps of most striking contrast, and an example of freshwater-marine connectivity, was evidenced by detections of American Eel in SAB MPA with one near and one distant release location. Three American Eels detected in SAB MPA were released in the Bras d'Or Lake, Cape Breton, a minimum migration distance of 200km, whereas two others were released in the Bay of Quinte, Lake Ontario, Canada, a minimum migration distance of 1700km (Figure 14, Table 4).

Gulf of St. Lawrence

In addition to evidence provided by detections of anadromous or catadromous species, connectivity between the Gulf of St. Lawrence and SAB MPA was also represented by detections of Atlantic Sturgeon, Grey Seal (Magdalen Islands), and Atlantic Cod that were tagged in the Gulf of St. Lawrence (Table 4, Figure 14). Two Atlantic Cod detected in SAB MPA were tagged in the southern Gulf of St. Lawrence. However, Atlantic Cod were primarily tagged in southern St. Anns Bank, NS, in 2016 and 2017 as part of a collaborative by Dalhousie University and DFO to use animal-borne transceivers and gps bio-loggers to track seal and prey movement, habitat use in the region, and connectivity with the Gulf of St, Lawrence (i.e., SGS – Sable Island Grey Seal Bioprobes project, Table 4, Baker et al. 2015). This partly accounts for the high proportion of cod detections in SAB MPA in 2016-2017 relative to other species and projects (Figure 10b and 10c). The majority of Bluefin Tuna detected in SAB MPA (76 individuals) were also tagged in the Northumberland Straight and St. Georges Bay, NS (Figure 14).

Nova scotia south shore and the Scotian shelf

In addition to the aforementioned movements of Atlantic Salmon released from Nova Scotian rivers, connectivity between the south shore of Nova Scotia and SAB MPA was also provided by detections of Blue Sharks tagged near Halifax, NS (10 individuals), White Sharks released near Lunenburg (2), West Ironbound Island (4), and Kejimkujik Park, NS (1), and a Porbeagle Shark released in the Emerald Basin (Table 4 and Figure 14). In addition to the connectivity these species provide in migrations to SAB and en route, the latitudinal and longitudinal spread of detections on SABMPA project receivers demonstrate the broad connectivity exhibited by these oceanic predators within the MPA boundaries (Figure 11).

Southern Newfoundland

Detections of Blue Sharks highlighted the connectivity between the coast of Newfoundland and SAB MPA, with two individuals released in St. john's, two in St. Mary's Bay, and four in

Conception Bay, NL. Two Porbeagle sharks were also released in Hermitage Bay, NL and later detected in SAB MPA (Table 4, Figure 14).

South of the Canadian EEZ

In addition to Atlantic Salmon that migrated from rivers in Maine, USA, detections of several other species in SAB MPA provide ample evidence of transboundary connectivity with ecosystems south of the Canadian EEZ (Figure 14). This includes many White Sharks that were released along the Atlantic coast from South Carolina to Cape Cod, MA (at least 50 confirmed. Seven additional individuals tagged either in Nova Scotia or South Carolina). Two Bluefin Tuna were released on the North Carolina shelf near Hatteras, USA, one Shortfin Mako released in New England, two Atlantic Halibut released in the Gulf of Maine, USA, and three Porbeagle Sharks released off Georges Bank, USA. One of the most impressive migrations was of a Leatherback Turtle released in Costa Rica, an estimated 4600km away (Table 4, Figure 10, Figure 14).

POTENTIAL DRIVERS OF VARIATION IN DETECTIONS

MPA zone, bottom temperature, depth, and habitat type were examined as potential drivers of variation in other project tag detections and residency on receivers in SAB (Table 7). The majority of species and detections occurred in Zone 1. This is largely due to most receivers occurring in Zone 1 (84 receiver stations including the two array designs 2015-2023) compared to two in Zone 2b, and six in Zone 2c (only in the 2021-2023 array). Atlantic Salmon, Grey Seal, and White Shark were the only species that occurred in Zone 2b. Whereas Atlantic Salmon, Bluefin Tuna, and White Shark were the only species that occurred in Zone 2c. Grey Seal only occurred in Zone 2b (1 individual, Table 7).

For benthoscape habitat classifications, the majority of species and detections occurred over mud and till > 50% cobbles/gravel habitat. Atlantic Cod, Snow Crab, Blue Shark, and Bluefin Tuna were primarily detected over till >50% cobbles/gravel. Atlantic Sturgeon and Snow Crab were only detected over till >50% cobbles/gravel (note low number of individuals detected overall, Figure 10a). Bluefin Tuna, Atlantic Salmon, and White Shark were the only species detected in all habitat classifications (Table 7). Note these findings are also partly driven by the number of receivers in each habitat type (47, 5, 29, 8, 1; A-E classifications, respectively), and pelagic species such as Bluefin Tuna may not be expected to have strong habitat associations.

Bottom temperature recorded on receivers in SAB MPA was found to vary throughout the year with a low in winter and gradual increase until late fall (Figure 15, Figure 16). The 2021 single gate array (i.e., OTN2021) recorded higher temperatures during late summer and fall than the previous double gate array (i.e. North South – Figure 16), likely owing to the change in location and shallower overall depth. Data from Atlantic Cod, Atlantic Salmon, Bluefin Tuna, and White Shark tagged by other projects was sufficient to examine possible trends over time. Detections of Atlantic Cod in SAB MPA from winter 2015 to fall 2018 had a negative relationship with mean daily bottom temperature, although exhibited high variation. Detections of Bluefin Tuna and Atlantic Salmon from summer 2015 to summer 2023, and White Sharks detected primarily from summer 2019 to summer 2023 had positive relationships (Figure 17).

Trends were also apparent for bottom depth at receiver locations and detections of fish tagged by other projects. Atlantic Salmon were detected over greater depths in more recent years (i.e., negative relationship, Figure 18). In contrast, oceanic predators Bluefin Tuna and White Shark were detected over shallower depths but with high variation (i.e., Figure 18). Note that the range in possible depth also increased with the change in array design in 2021.

DISCUSSION

The St. Anns Bank MPA embodies a diverse and productive ecosystem within the Eastern Scotian Shelf and serves as an important component of the evolving Scotian Shelf-Bay of Fundy bioregional conservation network. While primarily chosen for its *in situ* conservation features, such as areas of high diversity and productivity, the representation of habitat features is equally significant in this location. Understanding how animals utilize habitat within the MPA and the broader bioregion is crucial for understanding and contextualizing trends in biodiversity within the MPA overtime. It is evident that the ecosystems and habitats within SAB are interconnected with external areas through the movement of migratory animals that utilize the MPA throughout the year as part of their regular movements in and out of the Gulf of St. Lawrence. Detections of tagged migratory species, including sharks and turtles, have revealed connectivity between the MPA and areas as far as Costa Rica, some 4,600 km away. Many of the species detected within the MPA, both resident and migratory, are of significant regional and national conservation focus (DFO 2012). The application and analysis of acoustic telemetry data offers an important opportunity to assess these macro-scale ecosystem properties of this distinctive regional ecosystem.

The telemetry program in SAB represents the longest continuous dataset for the MPA, with its origins tracing to a question surrounding assumed patterns of crab movement through this ecosystem (Cote et al. 2019; Zisserson and Cameron 2016). Indeed, understanding the movement ecology of animals permanently or transiently inhabiting the MPA is integral to the site's identity. Maintenance of acoustic receiver arrays in the MPA since 2015, along with subsequent tagging programs, has generated a wealth of information about the SAB ecosystem and its connections to surrounding areas. In total, the SAB MPA telemetry program has produced a large volume of open access data, building a long-term dataset on fish presence/absence, migration, habitat use, and seasonal residency in relation to bottom temperature. In addition to those tagged as part of the SAB MPA program, a wide range of species tagged as part of other marine movement ecology investigations have been detected to date. By providing all data as open access through the OTN platform, acoustic telemetry research in SAB has contributed to at least 40 telemetry projects, many of which are based in the Northwest Atlantic, whose tagged animals were recorded in the MPA and/or for whose receivers detected the presence of animals tagged in the MPA in their study location. Monitoring species movement within, adjacent to, and in connection with SAB MPA helps to illustrate the importance of the MPA for mobile species in the region. Moreover, the protective capacity of the MPA can be examined by monitoring fish movement relative to fishing practices and habitats adjacent the MPA.

A MIGRATION CORRIDOR WITH REGIONAL CONNECTIVITY

Metadata on where tagging took place and detections of those individuals on receivers in SABMPA and throughout the region provided direct evidence of many species using the MPA as a migratory corridor and exhibiting connectivity between SAB MPA and the Gulf of St. Lawrence, freshwater systems throughout the Northwest Atlantic, and the eastern coast of USA. This contributes to several conservation objectives and our understanding of Indicator 21 from Kenchington (2014) on the "*Fluxes of nekton across the boundaries of the MPA*". Although they are present in the MPA for shorter periods compared to less migratory resident species, these migrants are often large oceanic predators that are critical in shaping local biodiversity and are there presence provides an indicator of the habitat conditions of the area. Additionally, there are smaller forage species that migrate in large numbers, both of which contribute to seasonal fluxes in biomass in the MPA. For example, detections in SAB of species tagged by projects other than SABMPA includes White Sharks, Blue Sharks, and Porbeagle Shark released on the Nova Scotia south shore and eastern seaboard of the USA, and Bluefin Tuna tagged in the Northumberland straight that may have been travelling to spawning grounds in the Gulf of Mexico (Wilson et al. 2015).

From tagging work completed by the SABMPA acoustic telemetry project, Atlantic Cod were shown to move into and through SAB for summer-fall residency and back to the Gulf of St. Lawrence for winter, a behaviour that is most likely associated with spawning in the Gulf, overwintering in the deep areas of the Laurentian channel, and feeding on the Scotia Shelf (Comeau et al. 2002). Atlantic Halibut were shown to spend the summer in SAB and move near the coast (Scatarie Island) during the fall.

The detection of animals tagged by other projects has provided a major contribution to our understanding of the use of SAB as a migration corridor and the scale of connections between the MPA and outside areas. Additionally, this report provides information on the repeat movements over multiple years, which provides an opportunity to track changes in individual behaviour and migratory routes through the MPA over long time scales.

Detections on the SAB array highlight its importance as a migratory habitat for anadromous Atlantic Salmon and also provide researchers information on movement and mortality from at least 11 different freshwater systems through the OTN open data system. Salmon smolts emerge from their natal rivers into the marine environment during spring, where they start their northern migration to the Labrador Sea, Canadian Arctic, and Greenland (Lacroix 2013). Of interest, was the detection of Salmon smolts leaving the West River, Sheet Harbour ecosystem. Here, smolts enter the marine environment into the Eastern Shore Islands archipelago (Halfyard et al. 2012; Halfyard et al. 2013), which has been designated as an Area of Interest (AOI) for the establishment of a MPA. Protection of the smolts during this transition to a marine life history phase was identified as a conservation priority for this area, motivating a tagging and marine acoustic receiver program for the AOI by the Marine Conservation Targets Science program and the Nova Scotia Salmon Association ("https://members.oceantrack.org/project?ccode=ESIAOI", last accessed 25th July 2024). Detection of Salmon in SAB provides information on the movement rates of Salmon after they leave the Eastern Shore and provides evidence of connectivity between conservation areas. Likewise, detections of American Eel in SAB MPA contributes to studies investigating potential changes in the seasonal timing of migration from freshwater to the Sargasso Sea, and in the case of our detections, in relation to donor rivers in the Maritimes versus translocations in Lake Ontario and St. Lawrence River (Stahl et al. 2023, Twardek et al. 2021).

Adjacent to SAB is Cape Breton Island, which contains the Bras d'Or lake ecosystem, a unique 'inland sea' that was designated as a Biosphere Reserve by UNESCO in 2011 ("https://www.unesco.org/en/mab/bras-dor-lake", last accessed 25th July 2024). The estuarine ecosystem of the Bras d'Or lakes is host to a diversity of flora and fauna that have long supported Mi'kmaw communities of Unama'ki (Cape Breton Island). Understanding movements and the ecology of Atlantic Salmon and American Eel is of particular importance to these communities. The Unama'ki Institute of Natural Resources (UINR), in collaboration with Dalhousie University, Ocean Tracking Network, and DFO, have an acoustic tagging program to understand migratory behaviour and habitat use of Striped Bass (*Morone saxatilis*) and American Eel in Pitu'paq (Bras d'Or lakes), which is an emerging species of interest for acoustic telemetry research in the region given potential distribution shifts. Akin to juvenile Salmon leaving the Eastern Shore Islands AOI, acoustic receiver coverage in the MPA will provide important information on freshwater-marine transitions for anadromous species, in particular recording data used for estimating movement rates and at-sea mortality for species of Pitu'paq.

Moreover, detection of acoustically tagged animals from Pitu'paq in the MPA provides important information on connectivity to this regionally and globally significant ecosystem.

HABITAT ASSOCIATIONS

This study examined various factors such as MPA zone, bottom temperature, depth, and habitat type as potential drivers influencing the variation in other project tag detections and residency on receivers in SAB. The majority of species and detections were observed in Zone 1, mainly due to the higher number of receivers stationed there compared to Zones 2b and 2c, which were only covered since 2020, with the revised array configuration. Atlantic Salmon, Grey Seal, and White Shark were found only in Zone 2b, while Atlantic Salmon, Bluefin Tuna, and White Shark were detected in Zone 2c. Notably, Grey Seals that were released in the Gulf of St. Lawrence were singularly detected in Zone 2b, although only two individuals have been detected to date.

Regarding habitat classifications, most species and detections occurred over mud and till, particularly with over 50% cobbles/gravel habitat. Note that the majority of stations were in mud habitat in all years and secondarily >50% cobbles/gravel habitat until 2021. Atlantic Cod, Snow Crab, Blue Shark, and Bluefin Tuna were primarily detected over the 50% cobbles/gravel habitat, with Atlantic Sturgeon and Snow Crab exclusively detected in it as well. Bluefin Tuna, Atlantic Salmon, and White Shark were the only species detected across all habitat classifications. There also appeared to be some affinity for animal detections near shallow rocky banks which was demonstrated by the Receiver Efficiency Index showing higher values over Scatarie Bank (Figure 19). We found that these banks had the highest residency for species that spent the majority of the year in SAB MPA (Atlantic Cod, Atlantic Halibut, Atlantic Striped Wolffish) and species generally only present during summer/fall months (e.g., White Sharks, Bluefin Tuna). Likely in the shelf component of the MPA, where depth transitions are subtle until the Laurentian Channel break, these banks represent transitions between habitat types and commensurately areas of higher species turnover. Indeed, preliminary reviews of fish and invertebrate community patterns conducted during the site establishment process noted that depth transitions were linked to patterns of community compositional shifts (Ford and Serdynska, 2013). Residency near these areas of high species turnover is likely associated with higher productivity and prey availability due to the proximity to the surface and potential for upwelling driven by wind and coastal eddies relative to the deeper and less bathymetrically dynamic areas of the MPA (Smith and Sandrom 1988, Kenchington 2014).

In analysis of diet compositional richness, Jeffery et al. (2025) noted that, on average, diet richness was highest over muddy bottoms amongst all predatory species. These findings mirror our observation based on fish detections that there appeared to be habitat preference towards muddy bottoms. However, both analyses are influenced by sampling distribution (i.e., enhanced crab survey stations and receivers, partly due to mud covering the largest area) and thus more balanced sampling across habitat types may be required to assign habitat preference. Nonetheless, these results suggest that areas within the MPA associated with depth transitions (i.e., Scatarie Bank in our analysis) may be of particular importance for resident and migratory animals in the MPA and thus should be prioritized for monitoring going forward. These findings also agree with benthic imagery surveys conducted in 2023 in SAB, where fish and invertebrate richness appeared to be highest in association with transitions to shallow banks. In particular, the benthic imagery survey found relative high fish diversity in association with Curdo bank (~ 12m depth) in Zone 2a, approximately 20 km from Scatarie Island. Note that this bank is not near any acoustic receivers currently deployed as part of the SAB MPA program, but is near some of the most successful fish tagging sites for the program (i.e., release locations) and may be a priority location for future deployments.

NETWORK INDICATORS AND CONSERVATION MONITORING

Acoustic telemetry offers a powerful tool for monitoring MPA networks, providing valuable insights into biodiversity dynamics and space utilization across spatiotemporal scales (Balbar et al. 2020). This technology enables the monitoring of MPA and conservation network design effectiveness and conservation objectives by informing on animal abundance, distribution, and movement patterns collected *in situ* that can be used to calculate residence, migration pathways, and habitat associations. Such data has been instrumental in identifying stock mixing, mortality, and migration patterns, aiding in the refinement of MPA boundaries and adjacent fishing activities (e.g., Lea et al. 2016, Nielsen et al. 2014). Our analysis demonstrated the importance of SAB as a seasonal migratory habitat for a variety of taxa, and year-round residence for some taxa. As the Scotian Shelf-Bay of Fundy bioregional conservation network is developed with a long-term monitoring plan, information on species movement between sites will be important and connectivity has been identified as a design priority for the regional network (King et al. 2021). Acoustic telemetry offers an opportunity to collect and track this information directly instead of relying on model-based approaches (e.g., biophysical dispersal models). Observations of juvenile Salmon movement between the ESI AOI and SAB provides direct evidence of the conservation value of SAB relative to the (proposed) objectives of another site. With climate change posing increasing challenges, the integration of visual identification programs (e.g., marine mammal monitoring programs in the Gully MPA) and animal telemetry becomes crucial for directly monitoring species response to evolving environmental conditions and ultimately the efficacy of the regional network of conservation measures.

Since Kenchington (2014) recommended Indicator 21 as a placeholder for the emerging utility of acoustic telemetry and data access via the OTN, the technology and capacity of OTN has advanced considerably (Lennox et al. 2023). Although the initial cost of establishing an acoustic telemetry monitoring program can be extensive, equipment loans and collaborative maintenance through OTN and research partners facilitates projects in the early stages (including SAB MPA and the Gully MPA) and can help maintain projects in the long run. With appropriate study design, acoustic telemetry could be applied towards any of the four main categories of indicators identified in Kenchington (2014) (i.e. Background, Effectiveness, Anthropogenic pressures, and Socio-economic).

Background indicators are among the most typical to examine using this technology and demonstrated herein, for example, species daily residency and counts of occurrence in relation to co-located bottom temperature, depth, and habitat type. High levels of data sharing among telemetry projects in the region provides an opportunity to examine effectiveness indicators more closely. For example, detections and residency relative to total individuals, date, and location tagged allow the computation of additional movement metrics such as distance travelled over time to reach SAB and expected metabolic energy budgets, and energy metabolism can be examined using accelerometer tags (e.g., Metcalfe et al. 2016). The themes of other projects with tags detected on the SABMPA array linked through a global network shed some light on potential indicators that can be applied towards conservation objectives and the value of long-term monitoring. This includes potential anthropogenic pressure and impact indicators, for example, to investigate the impacts of offshore wind (Reubens et al. 2013), vessel noise (Ivanova et al. 2020), and identify potential illegal fishing practices (Tickler et al. 2019).

Accurately quantifying spatial overlap may require a study design that allows for triangulation (e.g., grid design – Ivanova et al. 2020) from which positions can be calculated and used to generate Kernel Density Estimates (KDEs) of space use which is also applicable for measuring home range estimates. For less precise needs, such as characterization of habitat use over course scales, pseudo-positions (or Centres-of-Activity, Simpfendorfer et al. 2002) can be generated from sparse receiver coverage in a conservation area (Kraft et al. 2023).

In this report we detected a high number of large oceanic predators such as White Sharks. Given that these apex predators facilitate the maintenance of biodiversity through predator-prey dynamics, a background indicator could use space-use metrics such as KDEs to examine potential species interaction (or use predation tags, Weinz et al. 2020), or as an effectiveness indicator examining the effect of anthropogenic disturbances on natural predator-prey dynamics. We also present bottom temperature data as a potential parameter to examine alongside detections of SAB receivers (VR2AR's) that natively record hourly temperature and depth data. Although this data shows potential as a standard complement to animal detections, temperature data recorded on receivers requires calibration to account for the internal working temperature of the device (Innovasea, Pers. Comm. 2024). A current concern regarding climate change effects is potential for shifting or slowing down of ocean currents that help to maintain consistency in global weather cycles (Rahmstorf et al. 2015). Given that marine species travel via ocean currents and often have strong environmental cues that trigger the onset of migration (Winkler et al. 2014), tracking their movements concurrent with environmental data and the timing of arrival and departure on established migration routes, such as SAB, could provide the proverbial 'canary in the coal mine' of large scale change in ocean circulatory dynamics.

In this report we provided evidence of the same individuals returning to SAB over multiple years, which could be investigated more closely to examine intra-specific variation in migration timing, homing behaviour, and use of specific areas of SAB under different environmental conditions. Intra-specific variation in response to climate change effects could be examined more closely using tags with sensors such as temperature, depth, and acceleration. Such tags were used on some of the Bluefin Tuna detected over multiple years, but were not reported due to incomplete information on sensor specifications and data units. These tools facilitate the investigation of the primary drivers of spatial and temporal variation in occurrence and distribution and estimates of survival and population size under different future scenarios (e.g., Atlantic Salmon – Pardo et al. 2021, Chaput et al. 2018; White Sharks – Winton et al. 2023; Bluefin Tuna – Block et al. 2019). Moreover, indicators could be developed from sampling and measurements taken during the tagging process (Ivanova et al. 2025), for example, using stable isotope analysis of tissue samples to contribute to measurements of niche overlap (e.g., Matley et al. 2016), and examine lipid content to examine body condition and nutritional impacts of stressors in different MPA zones (Bordeleau et al. 2018), using cortisol to measure the role of stress hormones in migration timing (Birnie-Gauvin et al. 2019), or geomorphometric analysis from photographs of tagged fish to characterize distinct morphologies associated with migration, residency, and individual specialization (Burke et al. 2022).

CHALLENGES AND OPPORTUNITIES

There are a number of limitations inherent with acoustic telemetry that are important to consider in study design for research and monitoring. Fish detections provide a definitive measure of species presence and absence within the vicinity of an active receiver array. A tagged individual needs to be within the detection range of at least one receiver to be recorded, the tag needs to have an appropriate nominal delay between successive acoustic signals relative to the animals swim speed and vicinity to the receiver, and the signal must not be obstructed by physical obstacles (e.g., bathymetry, wrecks, boulders) or excessive ambient noise (e.g., shipping (Ivanova et al. 2020). Receiver deployment and animal tagging in SAB requires access to vessels that can operate offshore, ideally with capacity for spending several days at sea before returning to port. Fish tagging in the MPA has primarily occurred closer to land where it is easier to access, which presents an inherent bias in the data when attempting to determine species distribution in the MPA using this technology.

Changes and gaps in array design can complicate analyses and the ability to examine long-term trends. The previous SABMPA array had two gates designed to examine directional movements. The current array provides capacity to examine presence/absence over a wider area, but is less capable of examining directional movement given that it is one line of receivers. Two receivers in this gate failed to receive communications from the surface and were not recovered in 2022, which results in a gap in possible detections at these locations. There remain large areas of the MPA where no receivers (fixed or mobile) have been placed. This includes the deepest areas in the Laurentian Channel, and shallow areas in the northwest of the MPA towards Cape Breton Island. The edges of the MPA are also not permanently monitored with regards to fixed acoustic telemetry receivers, thus it is not possible to examine how species use these areas or how long individuals spend in the MPA overall. Bordering an MPA of this size (~290 km perimeter) with ~ 800 m spacing (distance used in the current design to minimize detection gaps across the array) would require a significant deployment of receivers, requiring upwards of 364 receivers deployed. However, the current limitations of the array design and scale of the MPA could be addressed by capitalizing on advances in the technology and array design. For example, tagging large predators with animal-borne mobile transceivers to detect other tagged animals and study species interactions (e.g., Lidgard et al., 2013, Barkley et al., 2020), using wave gliders to expand detection coverage during peak seasons and offload data from receivers remotely outside of deploy/recovery windows, and using random walk models to determine the efficacy of more sparse array designs (e.g., Carlisle et al. 2019, Kraus et al. 2018). OTN has previously deployed several wave gliders with tracks over much of SAB MPA (Coastal Environmental Observation Technology and Research (CEOTR), "https://ceotr.ocean.dal.ca/gliders/home", last accessed 23 Feb 2024) and this contributed to presence/absence data in this report within and outside the MPA, and outside the range of SABMPA project receivers. These wave gliders have also been used for annual data offloads of the Gully MPA acoustic telemetry project (GULMPA) from VR4 acoustic moorings, designed to be deployed for 4-5 years. Incorporation of acoustic receivers into Slocum gliders operated by the Maritimes Region glider program could also be used to expand coverage of detections, while simultaneously collecting data on water column properties.

Current array designs in SAB can be modified to focus more on conservation objectives and explore specific indicators directly, while maintaining long-term monitoring effort. Study design is critical from choosing the right tags, tag programming, capture and tagging locations, to array design, which receivers to use, and what other concurrent data to collect (e.g., oceanographic, biological, benthic mapping). There is no one design that is ideal for monitoring every conservation objective, but exploring alternative designs could facilitate addressing different questions and objectives to gain a more complete understanding over time. For example, a widely spaced grid array could have more gaps in detection for species passing directly through than the current receiver array, while providing more insights on how species move throughout the MPA, and pass through the array in different directions. Similar designs have been deployed as part of the Great Lakes Acoustic Telemetry Observation System (GLATOS) providing detailed information on species movement and behaviour as part of a long-term monitoring program (Krueger et al. 2018, Kraus et al. 2018).

In this report we presented benthoscape habitat classification as a potential paired-indicator with acoustic telemetry to examine spatial-temporal patterns of habitat use associated with different benthoscape, substrate, or depth classes. Timing of habitat use and associated fine-scale behaviours could be examined using grids of receivers that cover entire patches of habitat in the MPA, which is similar to how this technology has been used to study the connectivity and habitat use exhibited by reef-associated sharks among MPAs in the Great Barrier Reef (Espinoza et al. 2015, 2021).

For individuals tagged by other projects, most of the evidence of connectivity is for movement to the MPA, whereby we are provided a release location for detections we have received in SAB. One of the major benefits of using acoustic telemetry is the large network of researchers and technology deployed that has potential to detect our tagged individuals, and individuals tagged by other projects that our receivers have the potential to detect. However, not all projects share their data on receiver locations and tags that are detected and there are various levels of data sharing (e.g., species ID and general region of release only vs full biological, tag specifications, release location, and release date/time). Moreover, each project has different objectives, study design, data sharing agreements, and other nuances that take time to understand for projects that opportunistically detect their tags.

Increased collaboration and data sharing between research groups including across international borders will help facilitate our understanding of migration routes between release location and detection in SAB from individuals tagged by other projects. This includes incorporating information from detections on other arrays in the region that also detected individuals that we detected from other projects. Collaborative networks such as the OTN, the European Tracking Network (ETN), and similar networks in the United Sates (e.g., Atlantic Cooperative Telemetry (ACT) and FACT) are leading the way in providing platforms for data sharing, support for field operations (e.g., tagging or receiver deployments), equipment sharing or loans, and data analysis assistance and training (Bangley et al. 2020, Lennox et al. 2024). DFO has made recent efforts to increase data open access and several groups have made their data fully open access (e.g., PBSM on OTN). The Marine Conservation science program in the Maritimes Region has worked extensively with the OTN to make its data openly available and ensure MPA project data for the Scotian Shelf-Bay of Fundy Bioregion are connected through the OTN data portal under the designation "*Maritimes Conservation Network*". These include deployments in St Anns Bank (SABMPA), the Eastern Shore Islands (ESIAOI), Musquash Estuary MPA (MUSQMPA), and the Gully MPA (GULMPA).

Maintaining ongoing tagging programs alongside receiver stations provides the most value in data returned given that data access rights stem from the tag that is deployed. Currently annual tagging programs are in place for Atlantic Cod and Atlantic Halibut. Once tagging metadata is uploaded to OTN, detections are returned for all stations available on the OTN global repository. Detections of other project tags are often returned with data gaps given various data access rights and commitment to uploading complete data. However, the collaborative global network of acoustic telemetry researchers is expanding and heading towards greater open access and data sharing given the common goal of understanding aquatic animal movement and associated impacts. Collaborative networks also bring together diversity in expertise that can facilitate pairing information from acoustic telemetry with other established and emerging tools for a more robust approach to monitoring (e.g., fisheries surveys, eDNA, stable isotopes: Verhelst et al. 2023). With the ongoing expansion of acoustic telemetry networks and collaborative data sharing (Lennox et al., 2024), the study of aquatic animal movement is enhancing opportunities for understanding connectivity and energy transfer throughout the world's aquatic ecosystems.

This includes working more closely with Indigenous partners and knowledge systems, such as the ’Apoqnmatultik two-eyed seeing acoustic telemetry project in the Bras d’or Lake’ (“https://www.apoqnmatultik.ca”, last accessed June 5, 2024). Although monitoring in SAB has yet to fully implement a ‘two-eyed seeing’ approach, the need for Mi’kmaq involvement has been increasingly recognised and shared monitoring is currently underway between DFO and UINR (Mancion and Jeffery 2025; DFO 2024).

CONCLUSIONS AND RECOMMENDATIONS

Acoustic telemetry data collected in St. Anns Bank MPA from 2015 to 2023 provides direct evidence of the seasonality and habitat use of many aquatic species that enter and are resident in the MPA. This is one of the longest running datasets for the MPA and the potential contribution of this data towards conservation network monitoring has expanded considerably through open data access with the Ocean Tracking Network. Animals tagged by the SABMPA project, and by numerous other projects elsewhere, demonstrated the importance of SAB as a migration corridor and a hub for connectivity throughout the region. Among detections in this report are fisheries monitoring studies focussed on species of commercial (e.g., Atlantic Halibut, Atlantic Cod) or conservation interest (e.g., Leatherback Turtles in Costa Rica), species interaction (e.g., White Sharks and Grey Seals) and studies focussed on predicting species response to environment change (e.g., Bluefin Tuna and Blue Sharks). At-sea survival and marine habitat use were key questions for researchers trying to evaluate population trends in threatened or endangered species that may find refuge in conservation areas. This includes Atlantic Salmon and American Eel travelling from freshwater ecosystems throughout the Maritimes, Gulf region, and Northeastern USA, Atlantic Cod and Bluefin Tuna from the Gulf of St. Lawrence, and White Sharks and other pelagic sharks from eastern USA. Many of these species were only detected in the MPA during summer and fall months, whereas some species were resident for much of the year. Most detections occurred over shallow banks in the MPA (e.g., Scatarie Bank), which indicates the unique value these habitats provide for migratory and resident aquatic species. Partly due to the challenges of tagging far offshore, SABMPA project tags were primarily detected in the western part of the MPA, therefore, less information was gathered for the deeper areas of the MPA in the east.

The current findings highlight potential modifications that could be made to array design to better characterize species residency throughout the MPA, focus more on core migratory pathways and shallow banks, and monitor different fisheries zones, habitat types, depths, and overlap with vessel activity. Positioning receivers to allow triangulation (i.e., grids) would open up a long list of other possible indicators for monitoring including more specific measures of space use and behavioral shifts. Grid designs have been found to provide great benefits in understanding space use at large and fine scales, however, any design changes come with pros and cons. Modifications should consider the implications of changing or removing gates of receivers for understanding temporal variation in detections, monitoring long-term trends, the contribution to tagging projects outside the MPA including within DFO, and logistical constraints for deployment and recovery. Retaining some of the same receiver positions for as long as possible in key areas would maximise the feasibility of examining long-term trends. Having an array in the water with a tagging program brings access to a whole suit of other tools (e.g., data and collaborations, co-located environmental and biological data) that can be applied towards monitoring efforts and help to inform managers, policy makers, and the public on what happens in conservation areas and the connections beyond their boundaries. Moreover, applying these tools in migration corridors such as SAB help monitor potential changes in animal behavior related to emerging threats, including climate change effects and shifts in ocean currents with potential for far reach implications for fisheries, conservation, and socio-economic processes.

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TABLES

Table 1 SABMPA project tags: Total tagged individuals detected annually by receivers in St. Anns Bank MPA relative to individuals tagged and released (in parentheses) by the SABMPA project until August 2023. All tagged individuals have had at least one detection event (>2 detections) since release. Estimated tag battery life is provided in Table 2.

Species	2016	2017	2018	2019	2020	2021	2022	2023	All years
Atlantic Cod			47 (47)	13	14	18	63 (59)	40	106 (106)
Atlantic Halibut						2 (2)	36 (35)	19	37 (37)
Striped Wolffish	14 (14)	5	2	1	1				14 (14)
Atlantic Tomcod			2 (2)				1 (1)	1	3 (3)
Shorthorn Sculpin	1 (1)						1 (1)	1	2 (2)
Snow Crab	7 (7)		5		1	1	1		7 (7)
Thorny Skate			1 (1)						1 (1)
Total annually	22 (22)	5	57 (50)	14	16	21 (2)	102 (96)	61	170 (170)

Table 2 SABMPA project tags. Total counts of tagged animals up to August 2023 by species, body length (mean ± S.D.), acoustic telemetry tag type, and the individual counts with corresponding estimated tag lives depending on tag type and programming. TP in tag type are temperature and pressure sensor tags.

Species tagged	*n*	Total Length (m)	Tag type	*n* with estimated tag life (days)		
				500	900	1580
Atlantic Cod	106	0.50 ± 0.07	V13		59	47
Atlantic Halibut	37	1.30 ± 0.29	V13TP	35	2	
Striped Wolffish	14	0.52 ± 0.07	V13			14
Atlantic Tomcod	3	0.37 ± 0.01	V13		1	2
Shorthorn Sculpin	2	0.35 ± 0.04	V13		1	1
Thorny Skate	1	0.46	V13			1

Table 3 SABMPA project tags. Total fish counts and detections between 2015 and 2023, first and last detections, and mean latitude and longitude for Atlantic Cod, Atlantic Halibut, and Atlantic Striped Wolffish by array detected after release in St. Anns Bank MPA by the SABMPA tagging project.

Species	Array*	Fish count	Detections	First detection (Y-M-D) UTC	Last detection (Y-M-D) UTC	Mean latitude (DD)	Mean longitude (DD)
Atlantic Cod	BOOGSL	2	5	2018-11-18 05:10:30	2019-05-26 05:51:52	48.04083	-61.16233
	CBS	11	1285	2018-05-07 02:23:17	2020-06-12 23:02:58	47.23778	-60.06786
	CBTSC	3	361	2023-05-07 10:25:46	2023-06-15 19:49:44	46.70382	-61.10605
	GDL	7	66	2018-10-30 10:41:53	2023-07-03 07:39:45	46.23519	-59.40149
	NSWS	1	4	2022-12-22 06:47:56	2022-12-22 06:54:33	46.00596	-59.68604
	SABMPA	106	11143	2018-04-23 10:21:00	2023-08-15 04:40:53	46.03081	-59.11792
	V2LEMERA	1	3	2019-05-06 20:59:47	2019-05-06 21:35:55	46.54681	-60.19643
	ZSC	1	20	2018-06-07 12:43:47	2018-06-08 14:31:50	47.03150	-60.65098
Atlantic Halibut	NSWS	1	23	2022-07-15 21:07:39	2022-07-28 13:00:05	46.04097	-59.70979
	SABMPA	37	34953	2021-08-30 16:00:00	2023-08-16 18:01:01	45.9898	-59.20308
Striped Wolfish	GDL	1	13	2017-06-21 02:00:37	2019-11-02 20:05:25	46.02831	-59.16994
	SABMPA	14	195	2016-06-11 12:32:00	2016-09-06 20:51:14	46.01241	-59.09851

*Array project codes are as follows: Buoys of Opportunity - Gulf of St. Lawrence (BOOGSL), Cabo Strait Line (CBS), Glider Operations (GDL), Nova Scotia White Shark Monitoring (NSWS), St. Anns Bank MPA acoustic tracking (SABMPA), Emera Snow Crab and American Lobster (V2LEMERA), Scotian Shelf Snow Crab Tagging (ZSC). See the Ocean Tracking Network website for more details on each array ("https://members.oceantrack.org/data/discovery/bypublic.htm", last accessed 1st May 2024).

Table 4 Other project tags: Total individual species counts and detections by project and general release location for detections in St Anns Bank Marine Protected Area. This does not include individuals tagged by the SABMPA project.

Species	Project	Release Location	Individuals	Dets
American Eel			5	167
	BDLSPG - Apoqnmatulti'k - Bras D'Or Lake	Amaguadee's Pond, Bras d'Or Lake, NS, CA	1	7
		Bras d'Or Lakes, NS, CA	2	47
	BQEEL - Bay of Quinte Eel Tracking	Bay of Quinte, Lake Ontario, ON, CA	2	113
Atlantic Cod			47	14,719
	SGS - Sable Island Grey Seal Bioprobes	East Scotian Shelf, NS, CA	4	267
		Southern St.Anns Bank, NS, CA	41	14404
	SPI - Shippagan, NB: Cod tagging	Southern Gulf of St. Lawrence, CA	2	48
Atlantic Halibut	MEHAL - Maine Atlantic Halibut Tagging	Gulf of Maine, USA	2	47
Atlantic Salmon			102	2,068
	ASF - Atlantic Salmon Federation Tagging	Gulf of St. Lawrence, CA* Saint Andrews, NB, CA*	2	81
	BDK - Overwinter Bras d'Or Atlantic Salmon	Bras d'Or Lakes, NS, CA	2	378
	ESRF - Atlantic Salmon Offshore Tracking Project	Cascapedia River, Gulf of St. Lawrence, CA	1	10
		LeHave River, NS, CA	9	54
		Morell River, PEI, CA	2	89
		St. Mary's River, NS, CA	12	344
		Western Atlantic, CA	11	465
	KNE - NOAA Kennebec Salmon Tracking	Kennebec River, Maine, USA	1	15
	MARSS - Maritimes Atlantic Salmon marine survival	St Mary's River, NS, CA	8	89

Species	Project	Release Location	Individuals	Dets
Atlantic Salmon	NARR - Smolts in the Narraguagus River, Maine , U.S.A.	Milbridge, Narraguagus River, Maine, USA	2	11
	PBN - NOAA Penobscot Salmon Tracking	Penobscot River, Maine, USA	6	156
	PBSM_QRPT - Quoddy Region Salmon Tracking	Magaguadavic Basin, St. George, NB, CA	4	37
	PBU – USGS: Salmon tagging	Bucksport, Maine, USA	26	294
	TNGS - Tobique Narrows Generation Station efficiency	Tobique River, NB, CA	3	7
	V2LNSSA - Nova Scotia Salmon Association, Sheet Harbour	West River, Sheet Harbour, NS, CA	7	38
Atlantic Sturgeon	QSLR - St. Lawrence River Fish Monitoring	Gulf of St. Lawrence, CA	1	9
Blue Shark			18	579
	MFSAR - Shark Spatial Ecology and life history in NL	Conception Bay, NL, CA	4	140
		St. Johns, NL, CA	2	13
		St. Mary's Bay, NL, CA	2	32
	NSBS - OTN NS Blue Shark Tracking	Halifax, NS, CA	10	394
Blue Shark OR Shortfin Mako OR Bluefin Tuna	ACT.HMSWEA - INSPIRE/NEAQ - Offshore Wind Telemetry	South Fork Wind Farm, Rhode Island, NE, USA	1	3
Bluefin Tuna			78	989
	BFTTAG - Bluefin Tuna multi-beam and tagging	Gulf of St. Lawrence, PEI, CA	14	79
	DFOBFT - Long-term monitoring of Atlantic Bluefin Tuna and Swordfish	Port Hood, NS, CA	6	105
	TAG - Tag-A-Giant Foundation: Bluefin Tuna Tracking	North Carolina shelf, Hatteras, USA	2	168
		Northumberland Straight, CA*	56	637
		St. Georges Bay, NS, CA*		
Grey Seal	GSFP - Grey seal foraging pressure	Magdalen Islands, Gulf of St. Lawrence, CA	1	2

Species	Project	Release Location	Individuals	Dets
Leatherback Turtle	MIGRAMAR / LBTPCR - Leatherback Turtle in Pacuare Wildlife Reserve, CR	Pacuare Wildlife Reserve, Costa Rica	1	41
Porbeagle Shark			6	74
	JPBS - DFO: Porbeagle and Blue Sharks	Emerald Basin, NS, CA	1	16
		Georges Bank, USA	3	56
	MFSAR - Shark Spatial Ecology and life history in NL	Hermitage Bay, NL, CA	2	2
Shortfin Mako	ACT.PROJ130 / RICSS RIDEM DMF Coastal Shark Tagging	Block Island, New England, USA	1	29
Snow Crab	ZSC - Scotian Shelf Snow Crab Tagging	Scotian Shelf, NS, CA	2	371
White Shark			65	867
	ACT.NYSHARKS/ PROJ129 - New York Juvenile White Shark	Long Island, NY, USA	5	33
	ACT.PROJ179/ MSRPWS - Massachusetts White Shark Research Program	Cape cod, MA, USA* South Carolina, USA*	44	672
	FACT.CCOCE - Sharks on the shelf, Western North Atlantic Ocean	Hilton Head, South Carolina, USA	1	9
		Lunenburg, NS, CA	2	25
		South shore, NS, CA* South Carolina, USA*	7	47
	FACT.CCOCE - Sharks on the shelf, Western North Atlantic Ocean	Scatarie Island, CB, NS, CA	1	37
		W. Ironbound I., NS, CA	4	38
	V2LWSAMP - White Shark Acoustic Monitoring Program	Kejimkujik Park, NS, CA	1	6

*Multiple possible locations are stated where specific locations are yet to be sourced from other projects.

Table 5 Other project tags: Annual detections in St. Anns Bank MPA of annually returning individuals (Tag ID) tagged by projects external to the SABMPA tagging project (including DFO) shown by species and associated project ID.

Species	Project ID	Tag ID	2015	2016	2017	2018	2019	2020	2021	2022	2023
Atlantic Cod*	SGS	COD_SGS_1		205	98						
		COD_SGS_12			51	16					
		COD_SGS_14			55	5					
		COD_SGS_17		698	138						
		COD_SGS_21		8	526						
		COD_SGS_22		15	30						
		COD_SGS_28				11	2				
		COD_SGS_32		105	49						
		COD_SGS_38			24	18					
		COD_SGS_4		1534	9						
		COD_SGS_41		52	32						
		COD_SGS_7		337	531						
		COD_SGS_9		1039	302	135					
Blue Shark	NSBS	BLUESH_NSBS_1		21	34						
		BLUESH_NSBS_2	73	13							
		BLUESH_NSBS_3	10	101							
		BLUESH_NSBS_9								9	8
Bluefin Tuna	BFTTAG	BLUEFIN_BFTTAG_2					1		5		
	DFOBFT	BLUEFIN_DFOBFT_2							21		13
		BLUEFIN_DFOBFT_3								14	7
	TAG	BLUEFIN_TAG_10				1	1				
		BLUEFIN_TAG_11			7			2			

Species	Project ID	Tag ID	2015	2016	2017	2018	2019	2020	2021	2022	2023
		BLUEFIN_TAG_20					5	6			
		BLUEFIN_TAG_30							26	2	
		BLUEFIN_TAG_35						6	166	13	
		BLUEFIN_TAG_4	1		12	3					
		BLUEFIN_TAG_53								3	7
		BLUEFIN_TAG_6	3		1						
		BLUEFIN_TAG_7	15	38							
Porbeagle Shark	JPBS	PORB_JPBS_1			13	3					
		PORB_JPBS_2			3	3					
Snow Crab	ZSC	CRAB_ZSC_1					28	33			
White Shark	ACT.MSRPWS	WHITE_MSRPWS_25						3			28
		WHITE_MSRPWS_33						2	5		
		WHITE_MSRPWS_37						6		8	
	ACT.NYSHARKS	WHITE_NY_14						7	6		
	FACT.CCOCE	WHITE_CCOCE_7						8	2		
		WHITE_CCOCE_8						19	18		

*Annually returning Atlantic Cod are all associated with the Sable Island Grey Seal and Atlantic Cod project (SGS) that released the fish either near Canso or the Scotian Shelf (i.e. near or within the current MPA boundaries est. 2017)

Table 6 Other project tags: Annual detections in St. Anns Bank MPA of animals tagged by projects external to the SABMPA tagging project (including DFO) shown by species and station detected. Bottom depth (m) and MPA Zone are shown for each station.

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
Atlantic Cod	N1	78	1		381	83						
	N2	76	1		55	75	42					
	N3	81	1		20	171						
	N4	83	1			54	9					
	N5	85	1		41	41	8					
	N6	86	1		164	31	1					
	N7	90	1	22	262	73	28					
	N8	96	1	10	97	60						
	N9	104	1	3	51	83	16					
	N10	110	1	7	75	77						
	N11	114	1		13	13						
	N12	119	1		39	43						
	N13	121	1		96	227						
	N14	125	1		257	54						
	N15	104	1		293	28						
	N16	128	1		417	86						
	N17	127	1		20	19						
	N18	128	1		73	100						
	N19	130	1		58	18						
	N20	132	1		6	73						
	N21	131	1		81	70						

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
Atlantic Cod	S4	115	1		27	16						
	S6	131	1		25	20						
	S8	138	1		13	59						
	S9	127	1		17	32						
	S10	138	1		83	20						
	S11	148	1		27	27						
	S12	150	1		133	58						
	S13	153	1		7	76						
	S14	114	1		1238	34						
	S15	114	1		2495	12						
	S16	120	1		1508	9						
	S17	128	1		1005	31	70					
	S18	129	1		404	38						
	S19	117	1		172	43						
	S22	132	1		351		11					
	S23	140	1		494	9		2				
Atlantic Salmon	2021_010	34	1								3	3
	2021_019	34	1								11	29
	2021_020	110	1								6	6
	2021_021	112	1								33	18
	2021_025	117	2b								4	9
	2021_026	119	1								14	6
	2021_027	120	1								1	6

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
Atlantic Salmon	2021_028	143	1								22	5
	2021_034	133	1								5	2
	2021_035	116	1								3	4
	2021_038	157	1								4	50
	2021_039	163	1								15	63
	2021_040	150	1								19	29
	2021_041	152	2c								4	45
	2021_043	144	2c								12	12
	2021_044	150	2c								3	8
	2021_045	155	2c								40	31
	2021_046	155	2c								22	4
	N1	78	1	15				1				
	N2	76	1	91						1		
	N8	96	1	40						4		
	N11	114	1	18					1	9		
	N14	125	1			3	5					
	N17	127	1				8			14		
	N18	128	1			14				2		
	N19	130	1			33			2			
	N20	132	1			10		4		3		
	N21	131	1			3		3		2		
	N23	141	1			1		5				
	S1	104	1	5				9		9		

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
Atlantic Salmon	S2	103	1	3				33		35		
	S3	107	1	4						20		
	S4	115	1	12						35		
	S5	123	1	20		14	1			33		
	S6	131	1	15			40	17		46		
	S7	133	1	18			15			13		
	S8	138	1	22				1		14		
	S9	127	1	12				2		6		
	S10	138	1	1				17		21		
	S11	148	1	23						17		
	S12	150	1	26		28				5		
	S13	153	1	15						4		
	S14	114	1					1		9		
	S15	114	1					25	3	4		
	S16	120	1					1		1		
	S17	128	1			5		3				
	S18	129	1			13	9	6		4		
	S20	125	1				6	18		9		
	S21	125	1			3				5		
	S23	140	1			9	24	1				
Blue Shark	N2	76	1	5	13							
	N3	81	1	4	33							

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
Blue Shark	N7	90	1	17	16							
	N10	110	1		4			1				
	N11	114	1	5				3				
	N12	119	1	19		10						
	N18	128	1		12		7	3				
	S1	104	1	1		1						
	S3	107	1		18			2				
	S7	133	1	4			8					
	S8	138	1	6				1				
	S9	127	1	7				1				
	S10	138	1	17		12						
	S11	148	1	7				2				
	S12	150	1	2	6							
	S21	125	1			7		12				
	S22	132	1		2			2				
Bluefin Tuna	2021_001	87	1							13	6	
	2021_003	78	1							11	8	2
	2021_004	83	1							37	15	
	2021_005	75	1							52	4	
	2021_008	45	1							22	4	
	2021_009	36	1							30	8	
	2021_010	34	1							4	10	
	2021_011	34	1							2	9	4

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
Bluefin Tuna	2021_012	39	1							2	5	3
	2021_020	110	1							6	10	
	2021_034	133	1								10	5
	2021_035	116	1								3	8
	2021_036	130	1							5	6	4
	2021_037	145	1							7	5	
	2021_041	152	2b							2	14	
	N1	78	1	12				8		5		
	N2	76	1	1				7	4	3		
	N3	81	1	3	7			6	6	5		
	N4	83	1	6	11	1	6	11		1		
	N5	85	1	24	12		2			4		
	N6	86	1	11	8		1	2				
	N9	104	1	11				1				
	N10	110	1	25				3				
	N11	114	1	19			5					
	N13	121	1	13			3	2				
	N21	131	1					5		3		
	N22	137	1					6		7		
	S1	104	1	4						3		
	S2	103	1	1		1	6					
	S3	107	1	7		2	1	1				
	S8	138	1	2				1	3			

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
Bluefin Tuna	S9	127	1	6			2		3			
	S10	138	1	7			1	2				
	S11	148	1	9			1					
	S12	150	1			6	1	1	2			
	S16	120	1				5	1				
	S18	129	1					8	1			
	S19	117	1				2		1			
Porbeagle Shark	N21	131	1			1	3					
Snow Crab	S2	103	1					28	33			
White Shark	2021_001	87	1							5	12	7
	2021_002	84	1							5	1	
	2021_003	78	1								16	9
	2021_004	83	1								13	18
	2021_005	75	1							10	16	8
	2021_006	66	1								4	8
	2021_008	45	1							5	9	2
	2021_010	34	1								1	1
	2021_012	39	1								2	2
	2021_013	60	1							8	4	9
	2021_014	57	1							1	7	10
	2021_016	66	1							4		5
	2021_017	88	1								6	12
	2021_018	104	1								7	6

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
White Shark	2021_019	104	1							3	15	
	2021_020	110	1							9	2	
	2021_021	112	1							1	4	4
	2021_023	118	1								5	10
	2021_024	118	2b								3	9
	2021_025	117	2b								1	13
	2021_026	119	1							3		21
	2021_027	120	1							4		4
	2021_034	133	1								24	5
	2021_035	116	1								6	11
	2021_036	130	1								6	11
	2021_037	145	1								7	5
	2021_038	157	1								6	6
	2021_039	163	1							6	7	
	2021_040	150	1								7	4
	2021_041	152	2b								21	11
	2021_043	144	2b							7	18	
	2021_044	150	2b							7	10	
	N1	78	1					6	5			
	N16	128	1						17	7		
	N17	127	1					2	8			
	S3	107	1		1				2			
	S5	123	1						4	7		

Species	Station*	Bottom depth (m)	MPA Zone	2015	2016	2017	2018	2019	2020	2021	2022	2023
White Shark	S6	131	1						7	11		
	S7	133	1					1	2			
	S8	138	1					7	2			
	S9	127	1					8		5		
	S12	150	1		7			3				
	S13	153	1		7			7	6			
	S14	114	1					4	2			

*Station IDs beginning '2021' are the redesigned array from 2021 onwards, N stations are the previous North array gate, and S are the previous South array gate. Only stations with detections are listed.

Table 7 Other project tags: Summary of species detections on SABMPA receivers by benthoscape habitat classification, MPA Zone, mean depth (meters), and the maximum number of years the species was detected on the same receiver.

Species	Benthoscape habitat classification					MPA Zone			Mean depth (m)	Max years detected
	A - Mud	B - Gravelly sand/mud <50% cobbles/gravel	C - Till >50% cobbles / gravel	D - Till with coraline algae	E - Gravel with crinoids	Zone 1	Zone 2b	Zone 2c		
American Eel	117	15	34		1	167			126	1
Atlantic Cod	3802		10917			14719			116	4
Atlantic Halibut	36	11				47			148	1
Atlantic Salmon	1253	75	701	32	7	1858	29	181	121	4
Atlantic Sturgeon			9			9			77	1
Blue Shark	233	36	302	8		579			120	3
Bluefin Tuna	346	37	400	191	15	947		42	107	6
Grey Seal	2						2		118	1
Leatherback Turtle	41					41			141	1
Porbeagle Shark	45	2	27			74			123	2
Shortfin Mako	8		11	10		29			59	1
Snow Crab			371			371			101	2
White Shark	477	76	184	101	29	757	26	84	109	3
Total detections	6360	252	12956	342	52	19598	57	307		

FIGURES

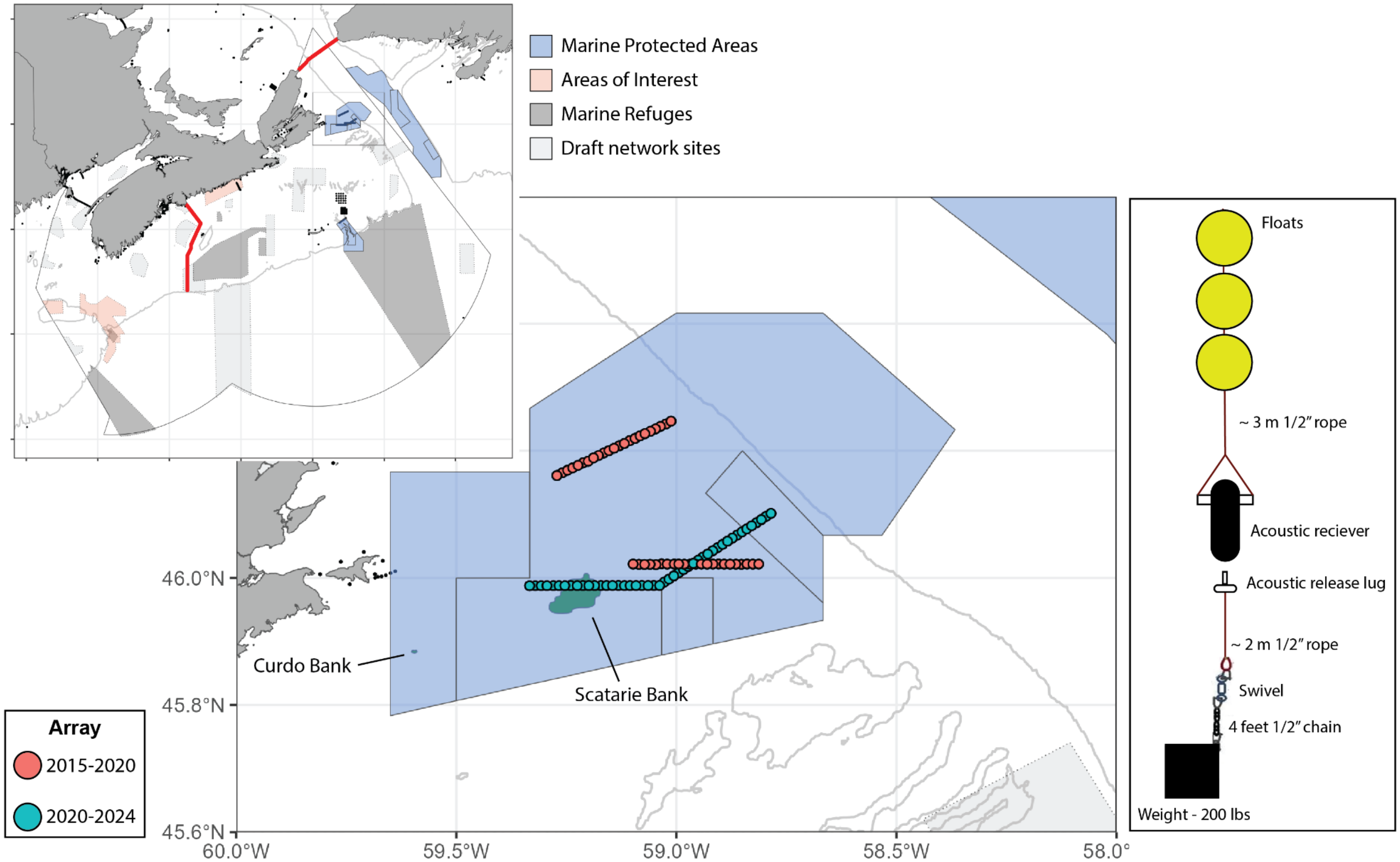
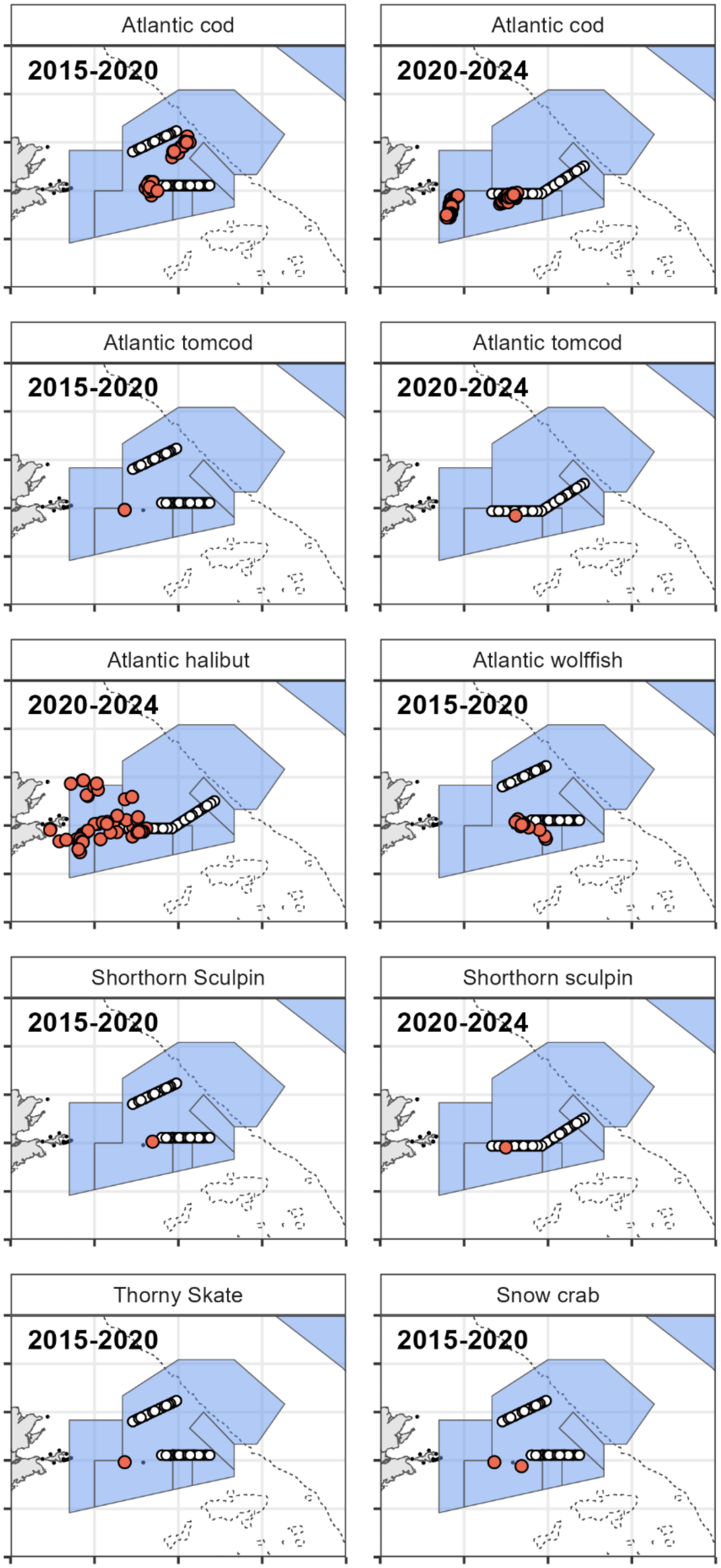


Figure 1 Map depicting St. Anns Bank MPA boundaries and acoustic telemetry receiver positions as part of the previous double gate (2015-2020) and the modified single gate (2020-2024). Dashed line shows the 250m isobath. Inset shows SAB array relative to bioregional OTN arrays acoustic receiver deployment locations inclusive of 2015-2023. Red lines depict the core OTN receiver arrays of the Halifax Line (HFX) and Cape Breton Strait (CBS) and black dots show the location of other acoustic receiver stations in the region. Shaded polygons on the Scotian-Shelf Bioregional Conservation Network. Acoustic receiver mooring configuration shown on the right. (b) showing tag release for each species by time period and the gates that were in place when they were released.


Atlantic cod
2015-2020
Atlantic cod
2020-2024
Atlantic tomcod
2015-2020
Atlantic tomcod
2020-2024
Atlantic halibut
2020-2024
Atlantic wolffish
2015-2020
Shorthorn Sculpin
2015-2020
Shorthorn sculpin
2020-2024
Thorny Skate
2015-2020
Snow crab
2015-2020

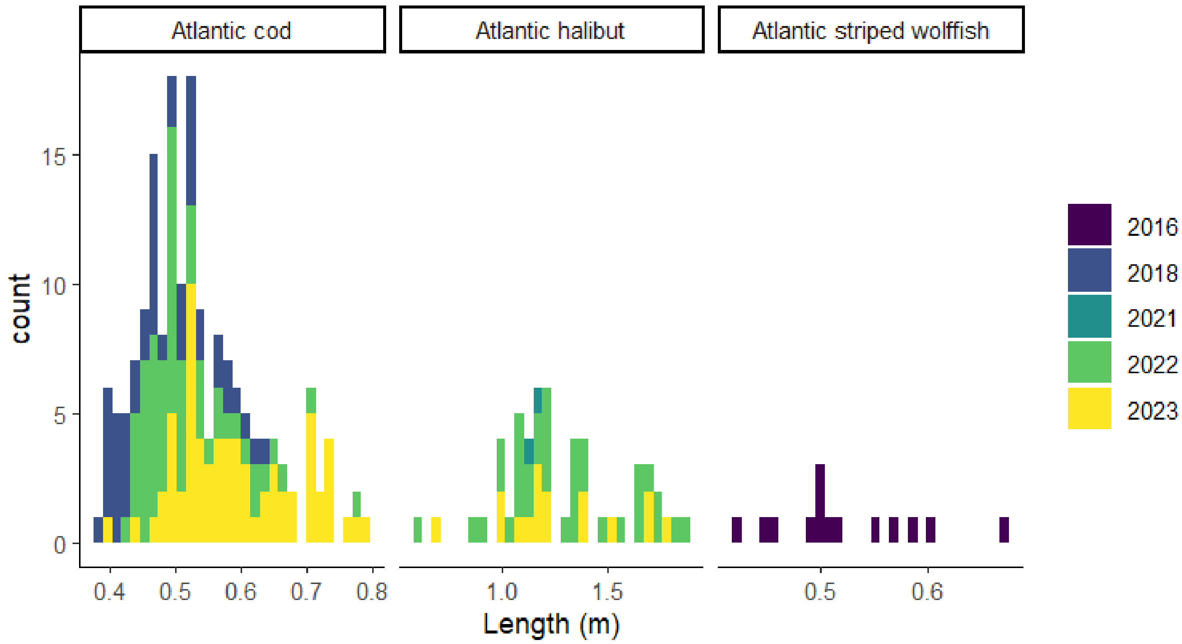


Figure 2 SABMPA project tags. Total length (m) frequency of Atlantic Cod, Atlantic Halibut, and Atlantic Striped Wolffish that were tagged and released in St. Anns Bank MPA by the SABMPA project from 2016 to 2023. Colour denotes year tagged. Note different x axis scale for each species. Species with >5 individuals tagged were included.

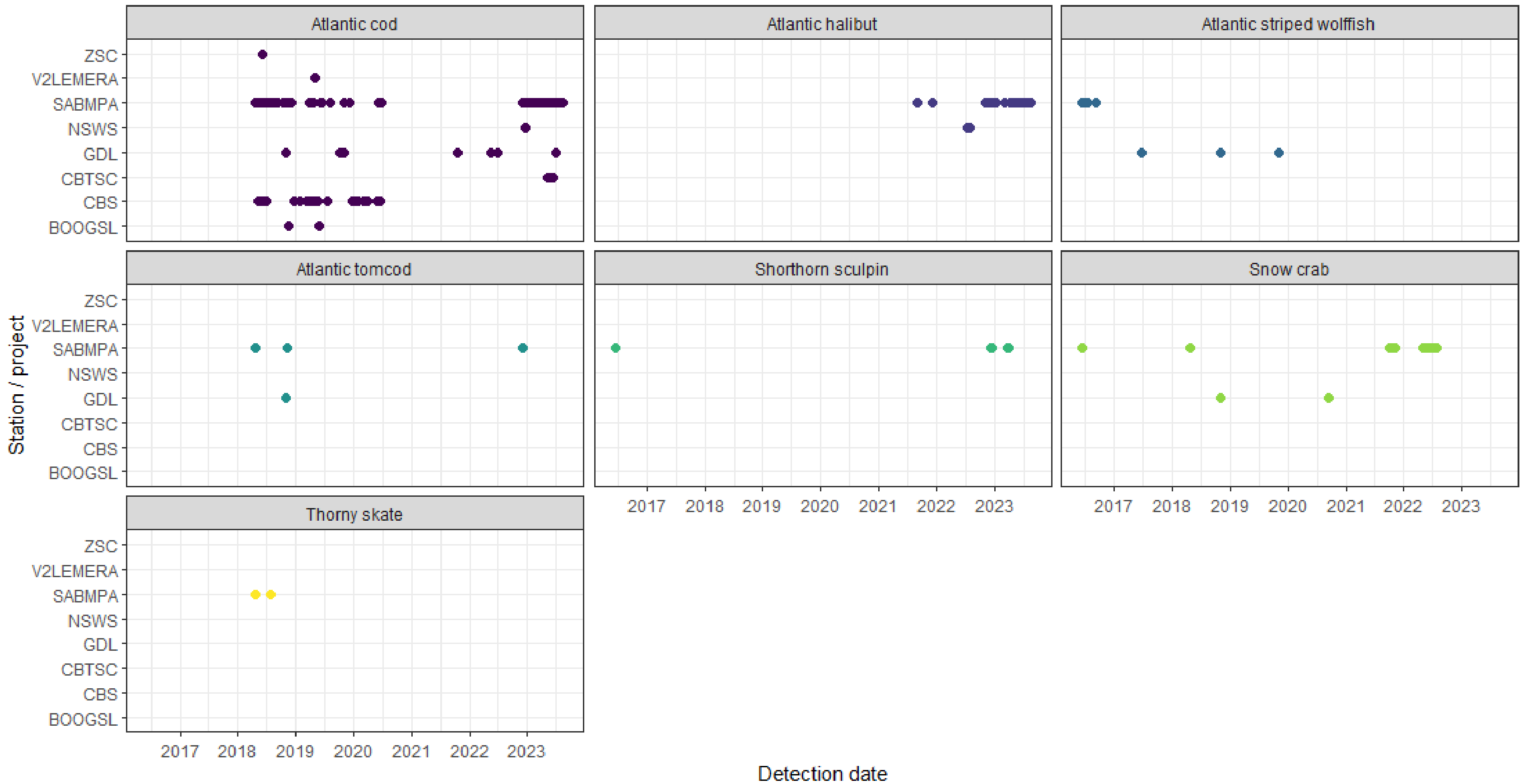


Figure 3 SABMPA project tags: Detections over time for individuals tagged and released in St Anns Bank Marine Protected Area (SAB MPA) by the project that recorded the detections. Fish tagged and released in SAB MPA have been detected by 8 projects based along the western coast of the Atlantic Ocean. Data shown are after filters applied including removal of single detections.

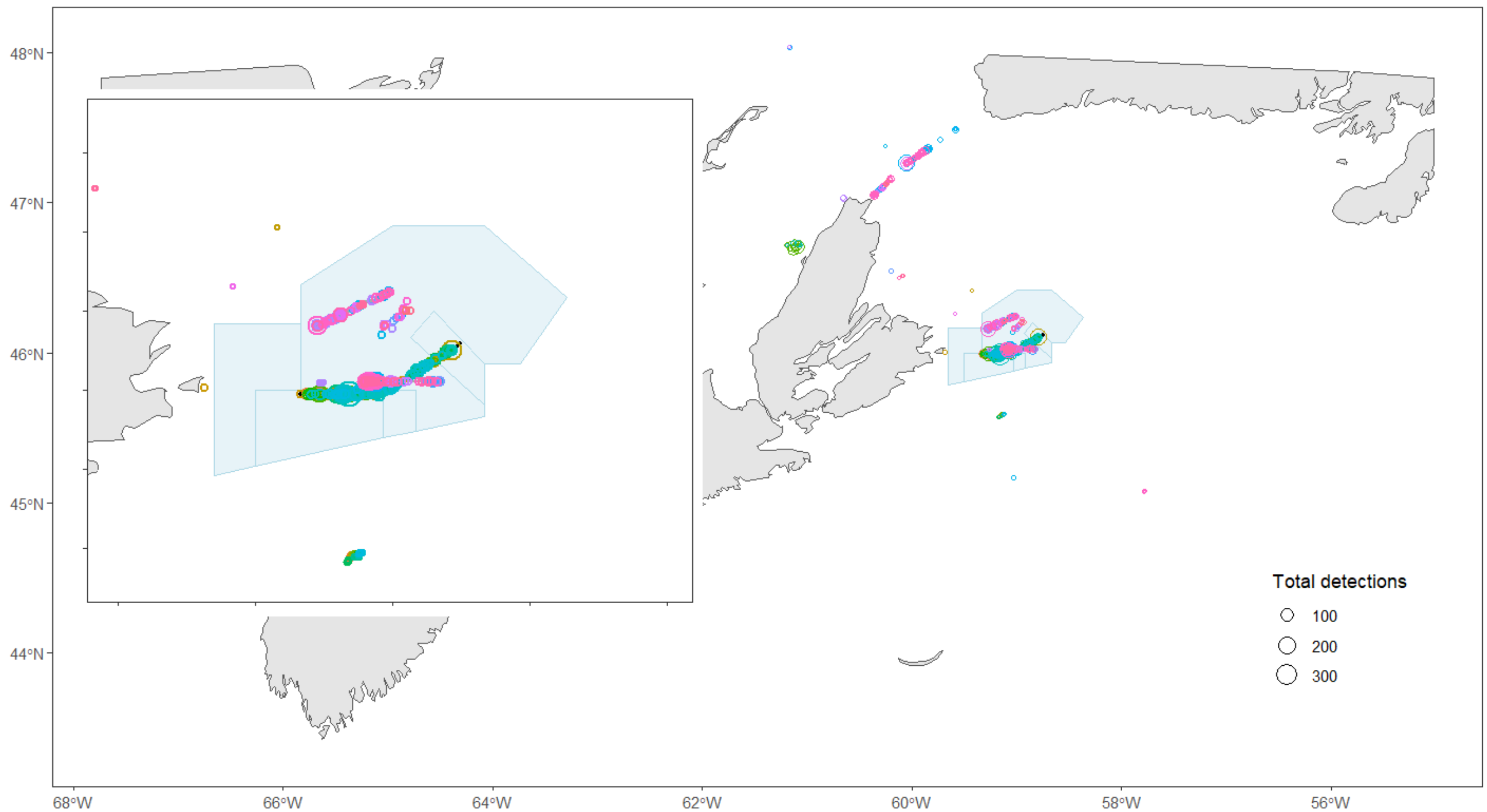


Figure 4 SABMPA project tags: Atlantic Cod detection bubbles for Atlantic Cod tagged in SAB MPA since 2018 that passed detection filters. Inset box shows a close up of detections in and around SAB MPA. Bubble size denotes the number of detections and colour indicates different individuals detected. Total detections are after detection filters were applied.

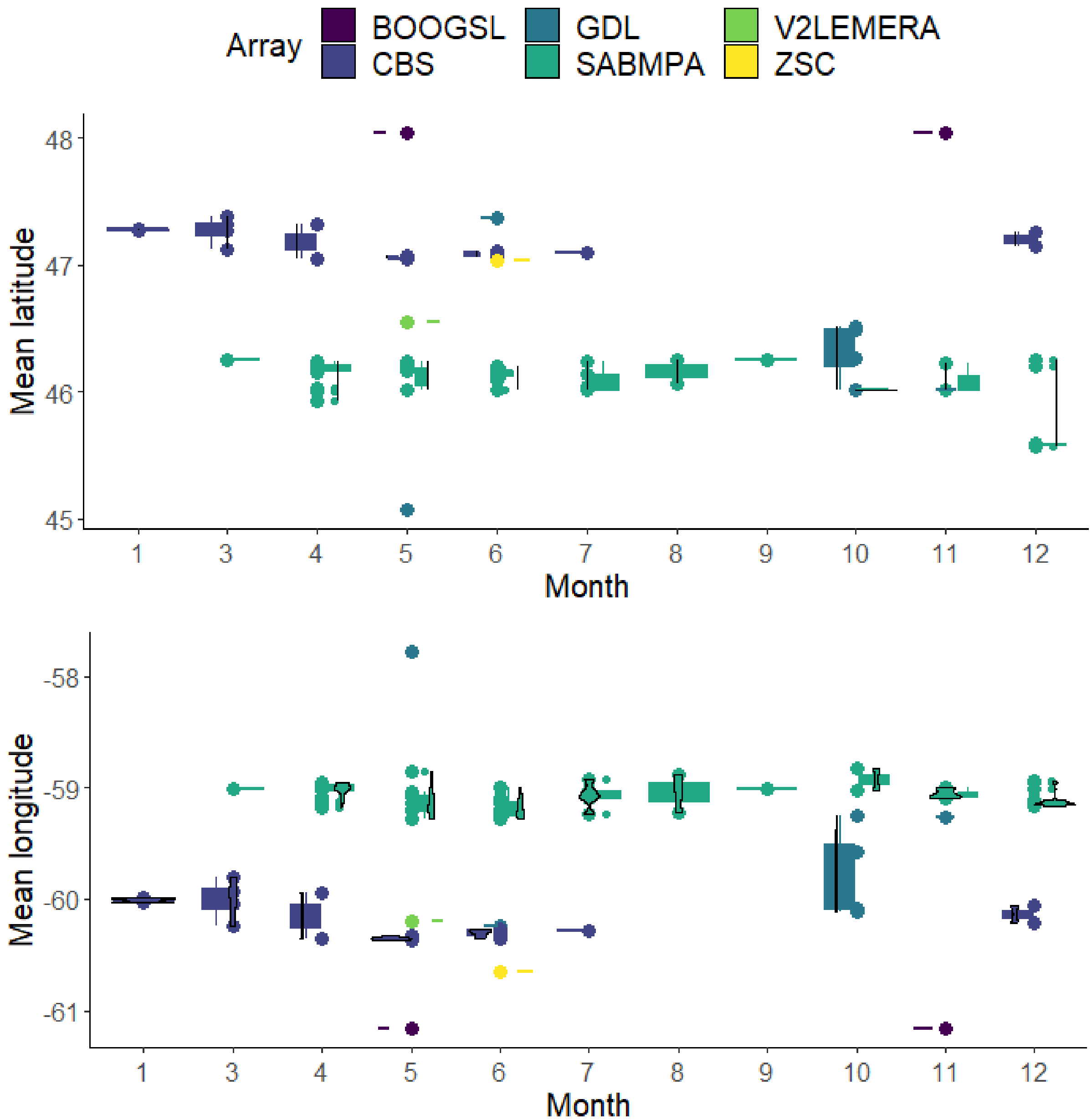


Figure 5 SABMPA project tags: Monthly detection wine plots for Atlantic Cod tagged in St. Anns Bank MPA 2018 to 2023 by latitude (a), and longitude (b). Colors indicate the acoustic arrays that detected tagged individuals; SABMPA, Scotian Shelf Snow Crab Tagging (ZSC), OTN Glider Operations (GDL), Buoys of Opportunity – Gulf of St. Lawrence (BOOGSL), and the Cabot Strait line (CBS). Data shown are after filters were applied.

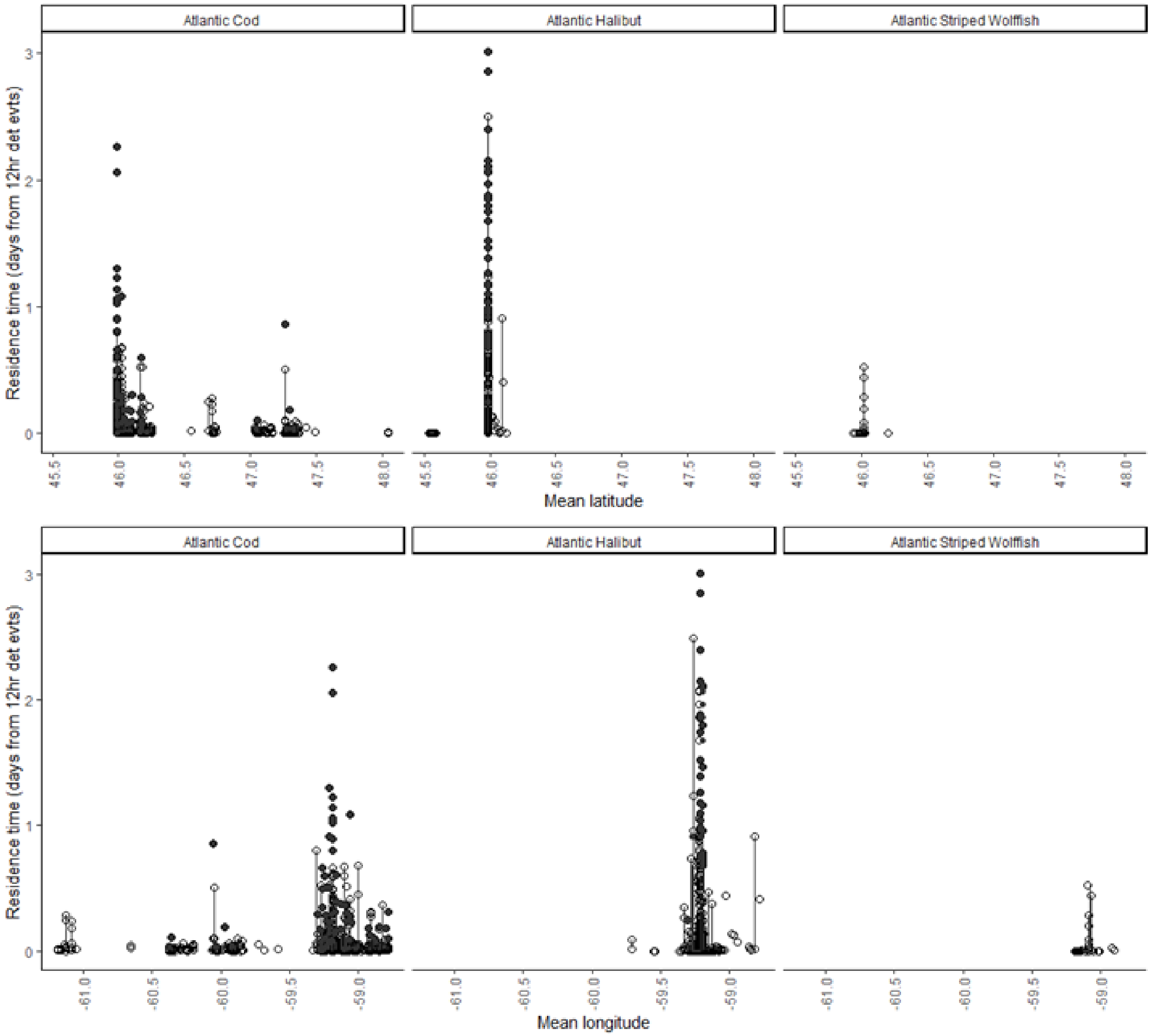


Figure 6 SABMPA project tags: Residence time in days from 12hr detection event bins of sequential detections by mean latitude and longitude detected for Atlantic Cod, Atlantic Halibut, and Atlantic Striped Wolffish tagged in St. Anns Bank MPA 2018 to 2023. Detections include SABMPA project receivers and all detections from receivers outside the MPA shared via the Ocean Tracking Network.

Figure 7 SABMPA project tags. Detections by latitude and longitude over time of Atlantic Halibut that were released in St. Anns Bank MPA. Colour denotes the OTN project that detected the tags.

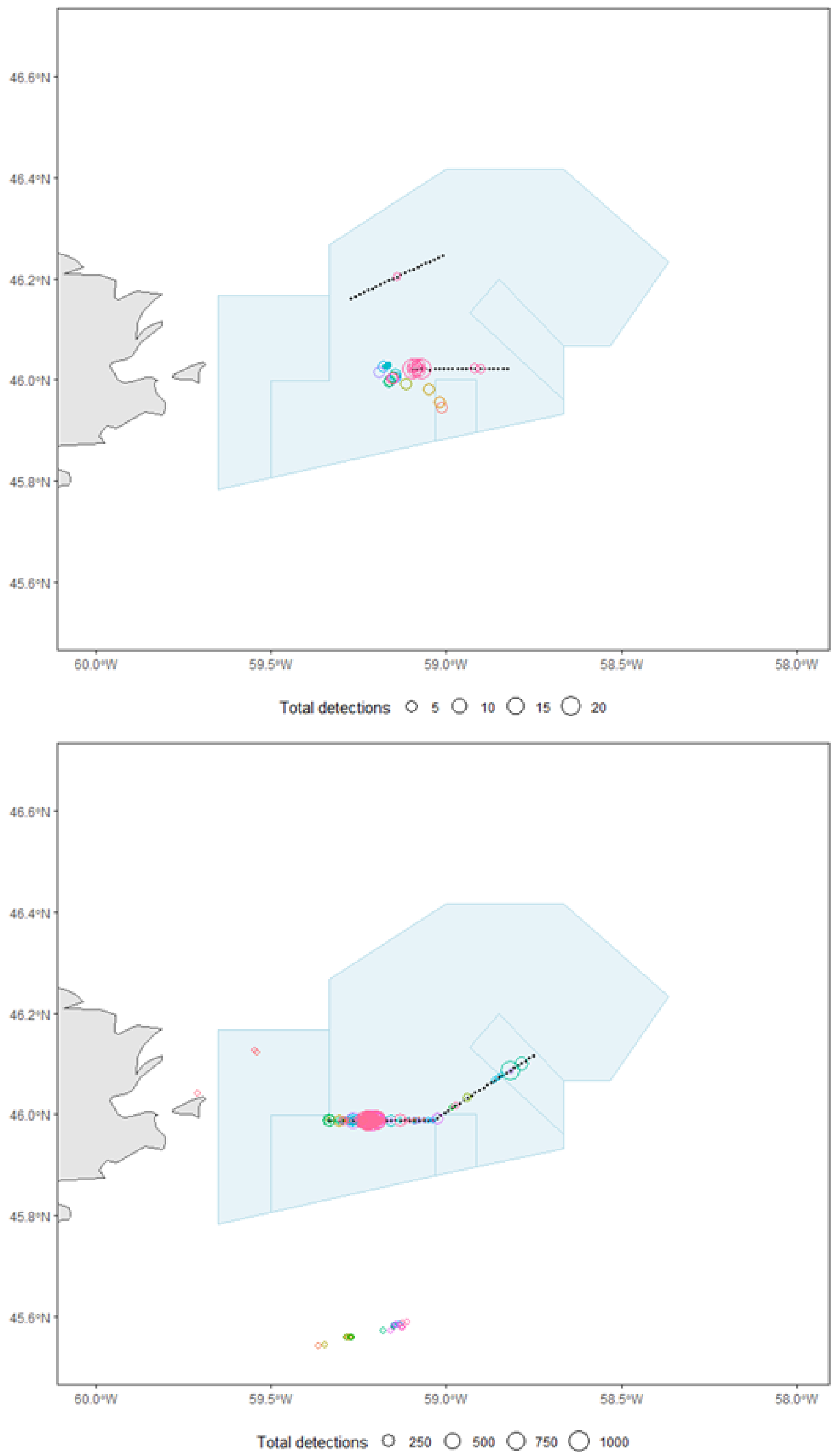


Figure 8 SABMPA project tags. Detection bubble plots for Atlantic Striped Wolffish (top) and Atlantic Halibut (bottom) tagged in St. Anns Bank MPA and detected by SABMPA project receivers, OTN wave gliders, and receivers by Scatarie Island (Halibut only for the latter). Colour denotes the individual detected and point size increases with detections. The receiver array in place at that time is shown as black points (2016-2019 for Wolffish, 2021-2023 for Halibut).

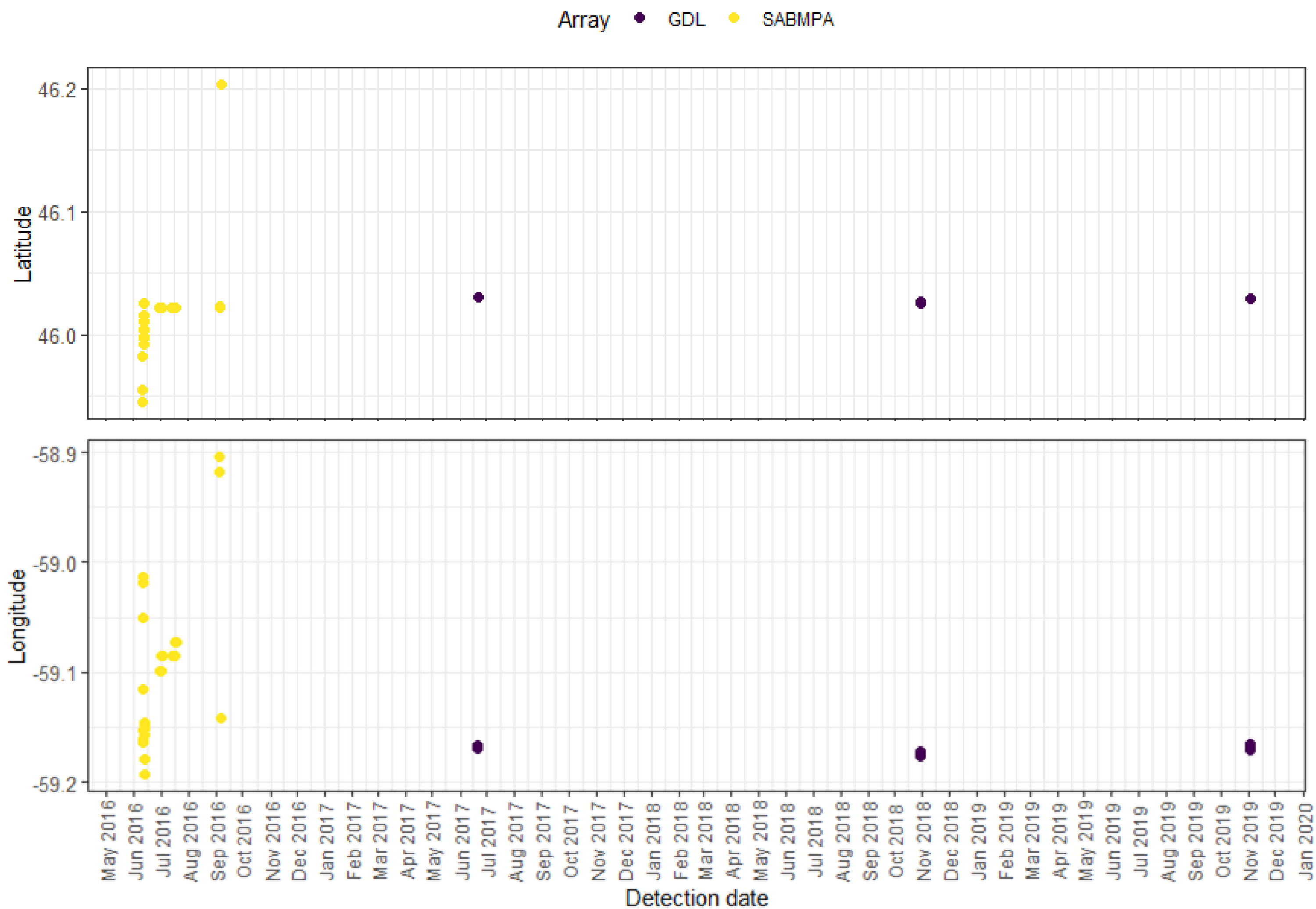


Figure 9 SABMPA project tags. Detections by latitude and longitude over time for Atlantic Striped Wolffish individuals tagged in St. Anns Bank MPA and detected by SABMPA receivers and OTN wave gliders (GDL). Note detections across latitude and longitude on the SABMPA array occurred for one individual and detections by wave gliders were also for one individual and should therefore be interpreted with caution.

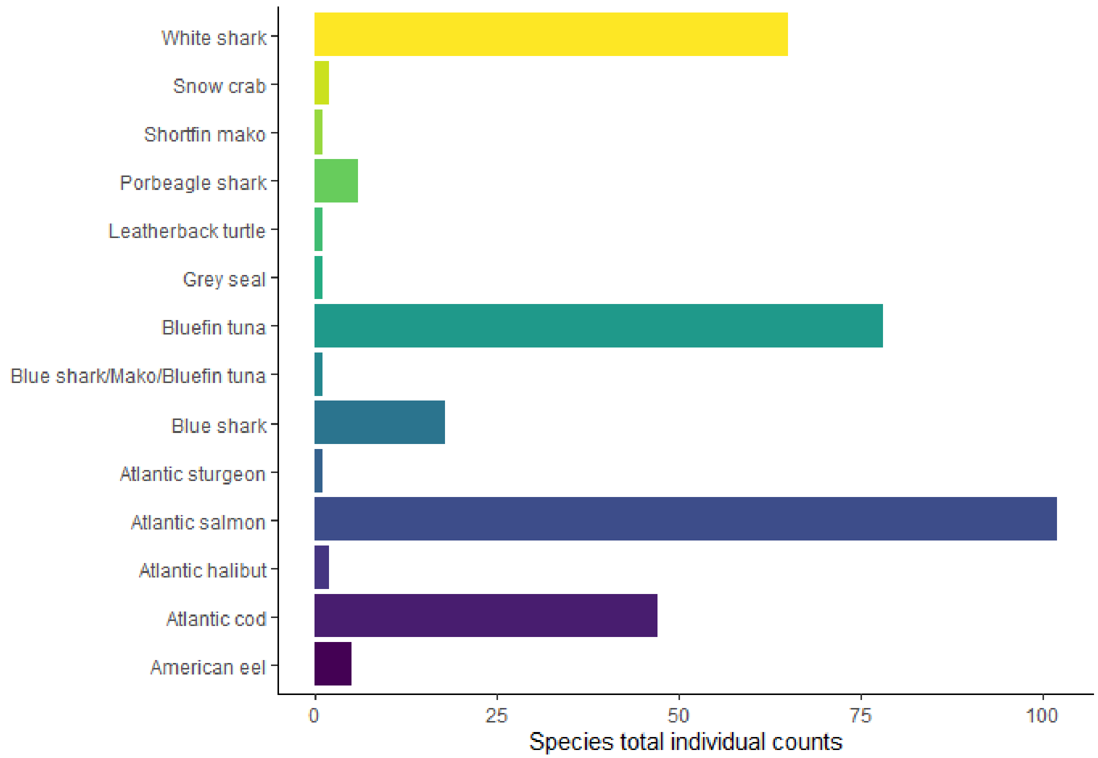


Figure 10 (a) Other project tags: Total individual counts for species detected in St. Anns Bank Marine Protected Area that were tagged and released by projects other than the SABMPA tagging project (2015-2023)

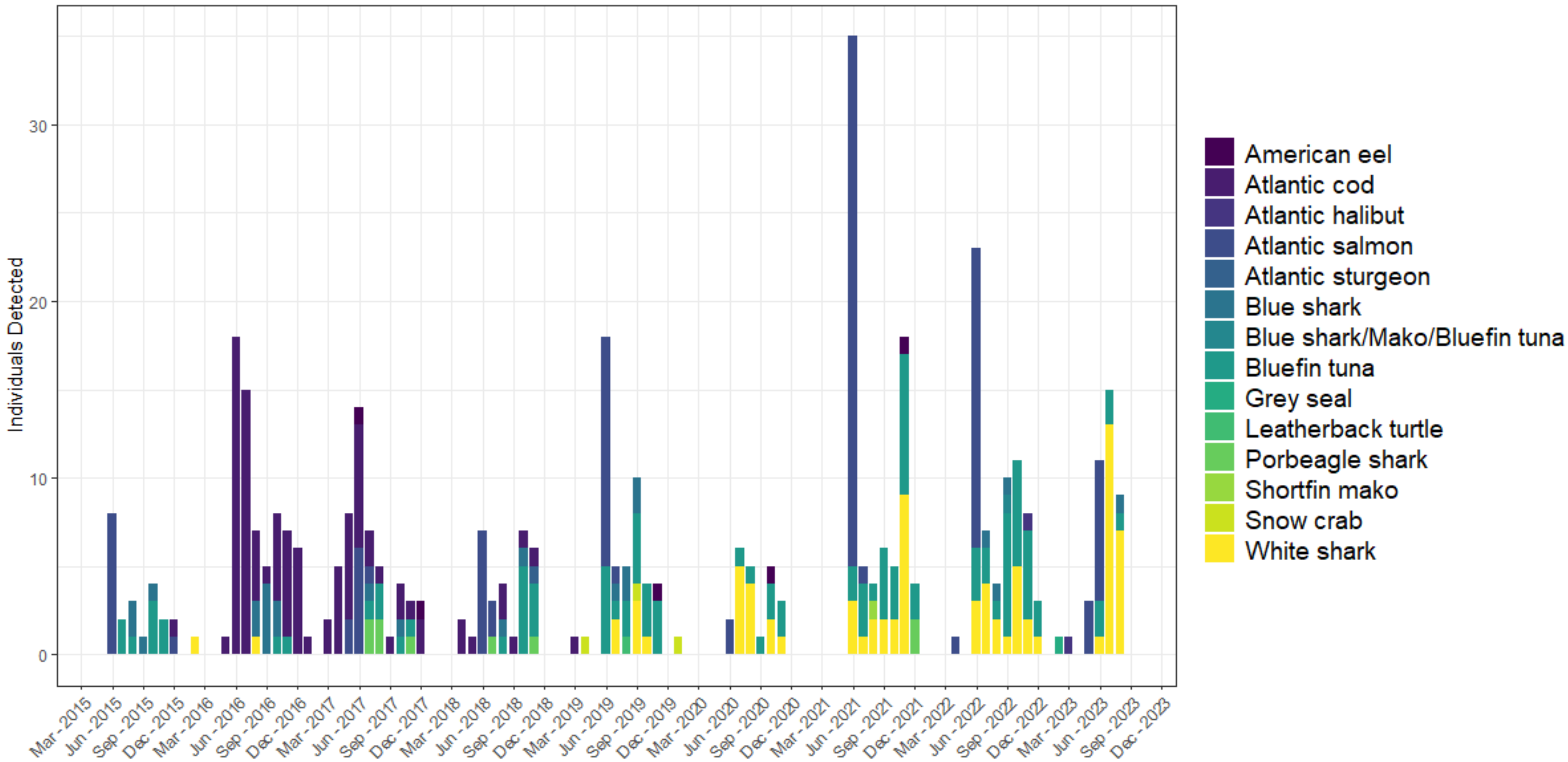


Figure 10 (b) Other project tags: Individual counts for species detected over time in St. Anns Bank MPA that were tagged and released by projects other than the SABMPA tagging project.

Figure 10 (c) Other project tags: Individual counts for species detected over time in St. Anns Bank MPA that were tagged and released by projects other than the SABMPA project shown on separate panels for each species.

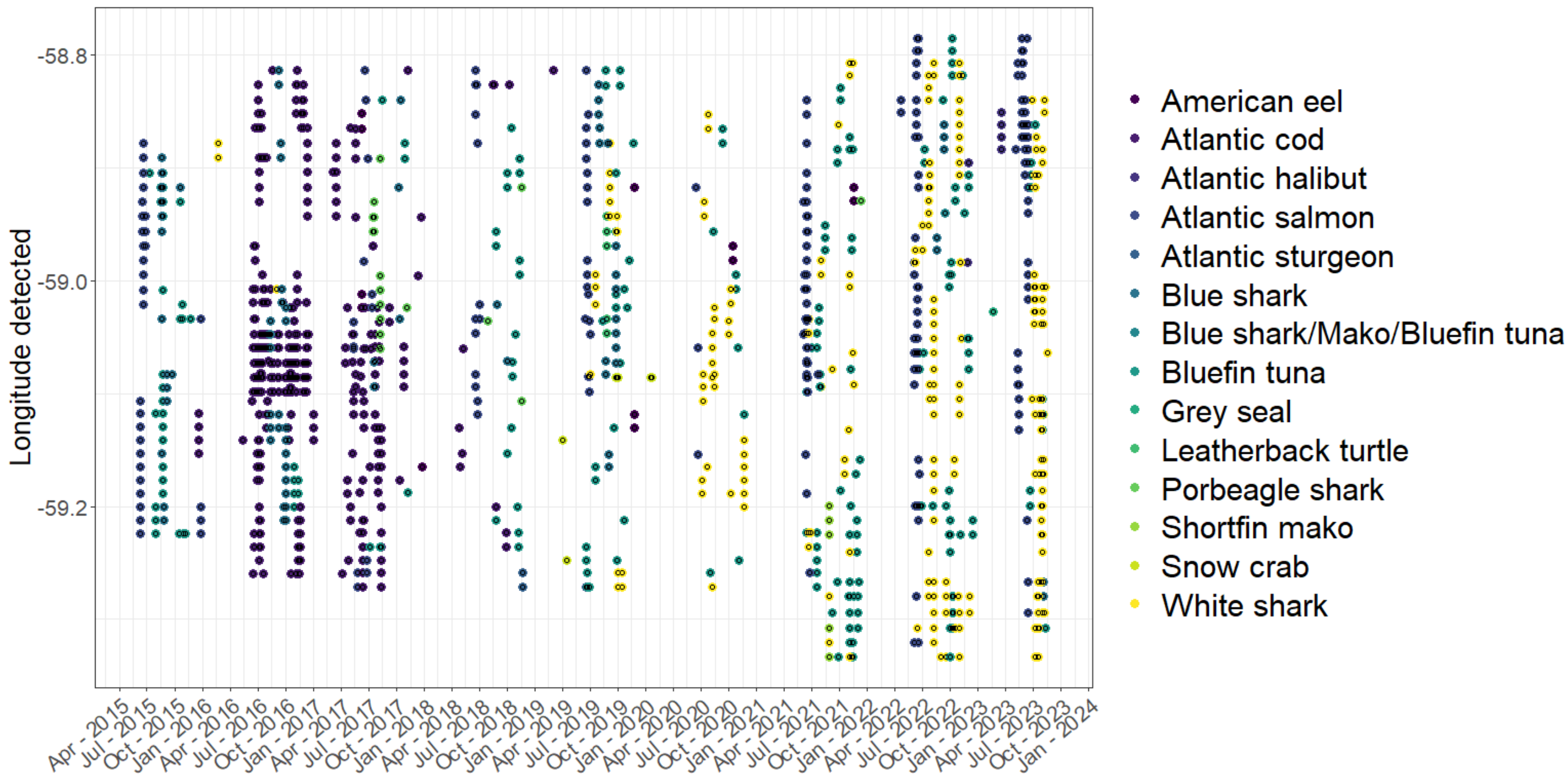


Figure 11 Other project tags: Detections of individuals over time by (a) longitude and (b) latitude in St. Anns Bank MPA that were tagged by projects other than SABMPA. Color indicates the species detected and each dot represents a detection of one individual. Note the high frequency of White Shark detections during summer 2020 and 2023 reflecting the increase in White Shark tagging in the region and seasonal occurrence of the species in the array. The longitudinal range of possible detection increased in 2021 after the array was re-designed as one long line.

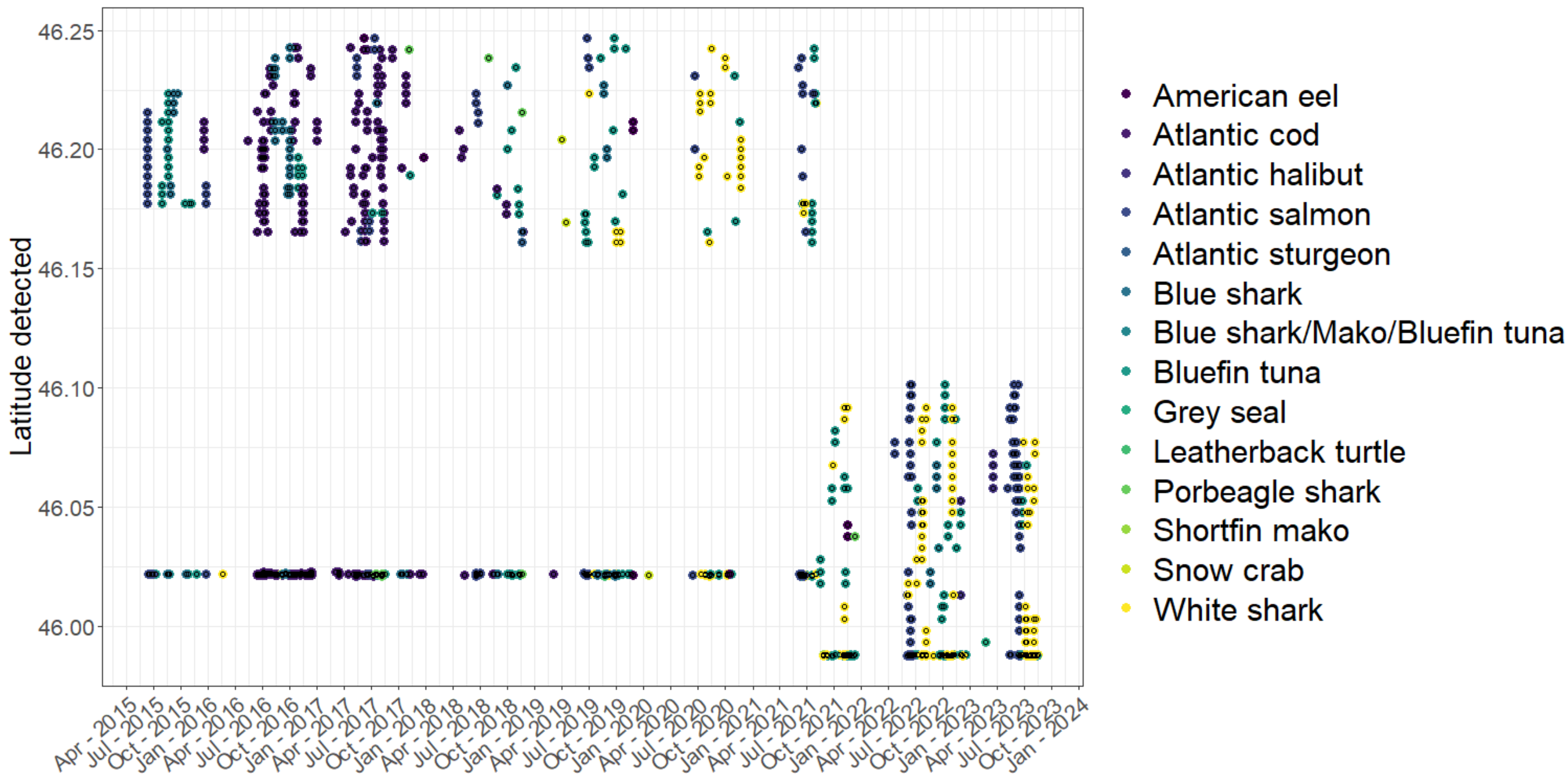


Figure 11 (b) Other project tags: Detections of individuals over time by (a) longitude and (b) latitude in St. Anns Bank MPA that were tagged by projects other than SABMPA. Color indicates the species detected and each dot represents a detection of one individual. Note the high frequency of White Shark detections during summer 2020 and 2023 reflecting the increase in White Shark tagging in the region and seasonal occurrence of the species in the array. The longitudinal range of possible detection increased in 2021 after the array was re-designed as one long line.

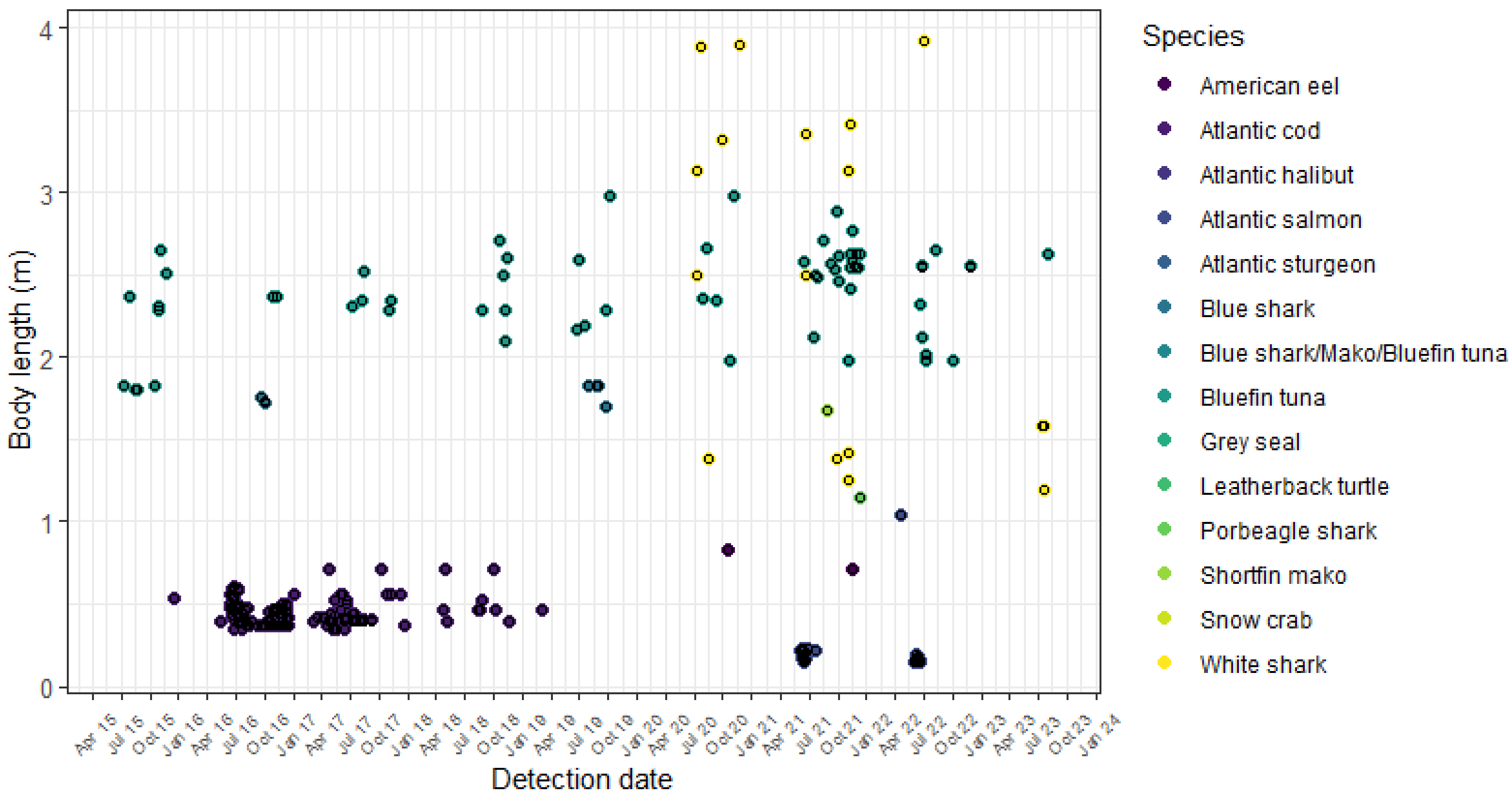


Figure 12 Other project tags: Detections of individuals over time by body length (m) in St. Anns Bank Marine Protected Area where length was provided by taggers. Note the increase in body length range of tagged species entering the array from 2020 onwards due to the tagging effort on White Sharks while programs have also continued on Bluefin Tuna and Atlantic Cod.

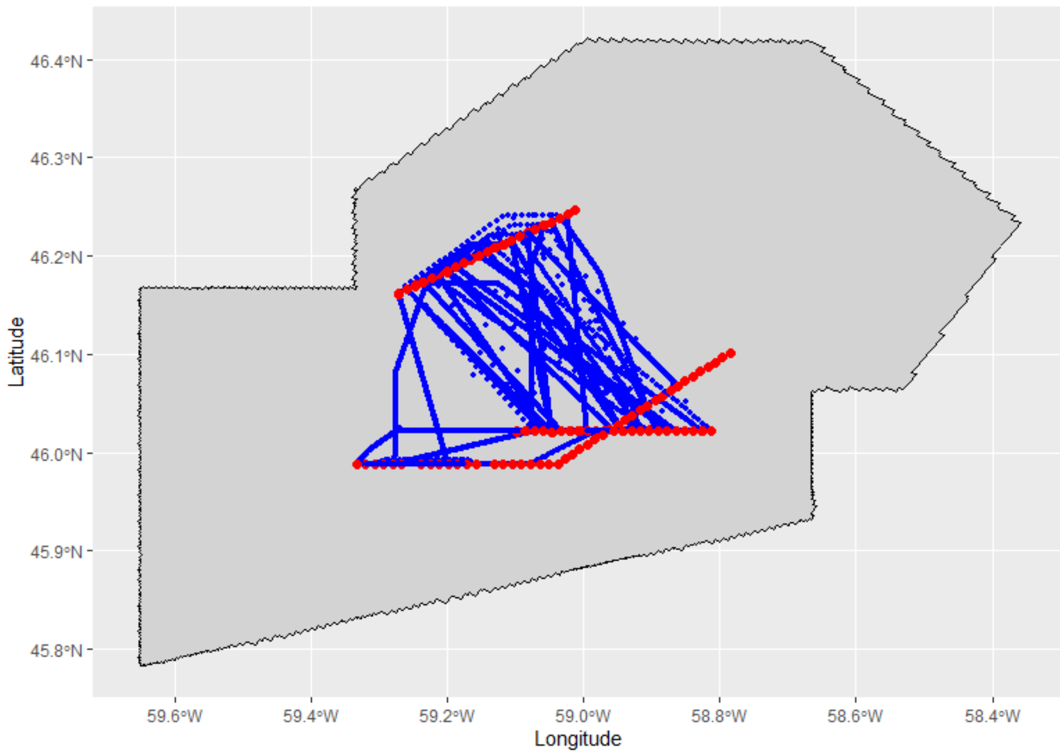


Figure 13 Other project tags: Interpolated pathways (blue) of all tagged fish generated from consecutive detections on receivers (red) in St. Anns Bank MPA for all filtered data collected 2015-2023. Note that interpolated pathways are limited by receiver positions and do not account for exploratory movements between receivers.

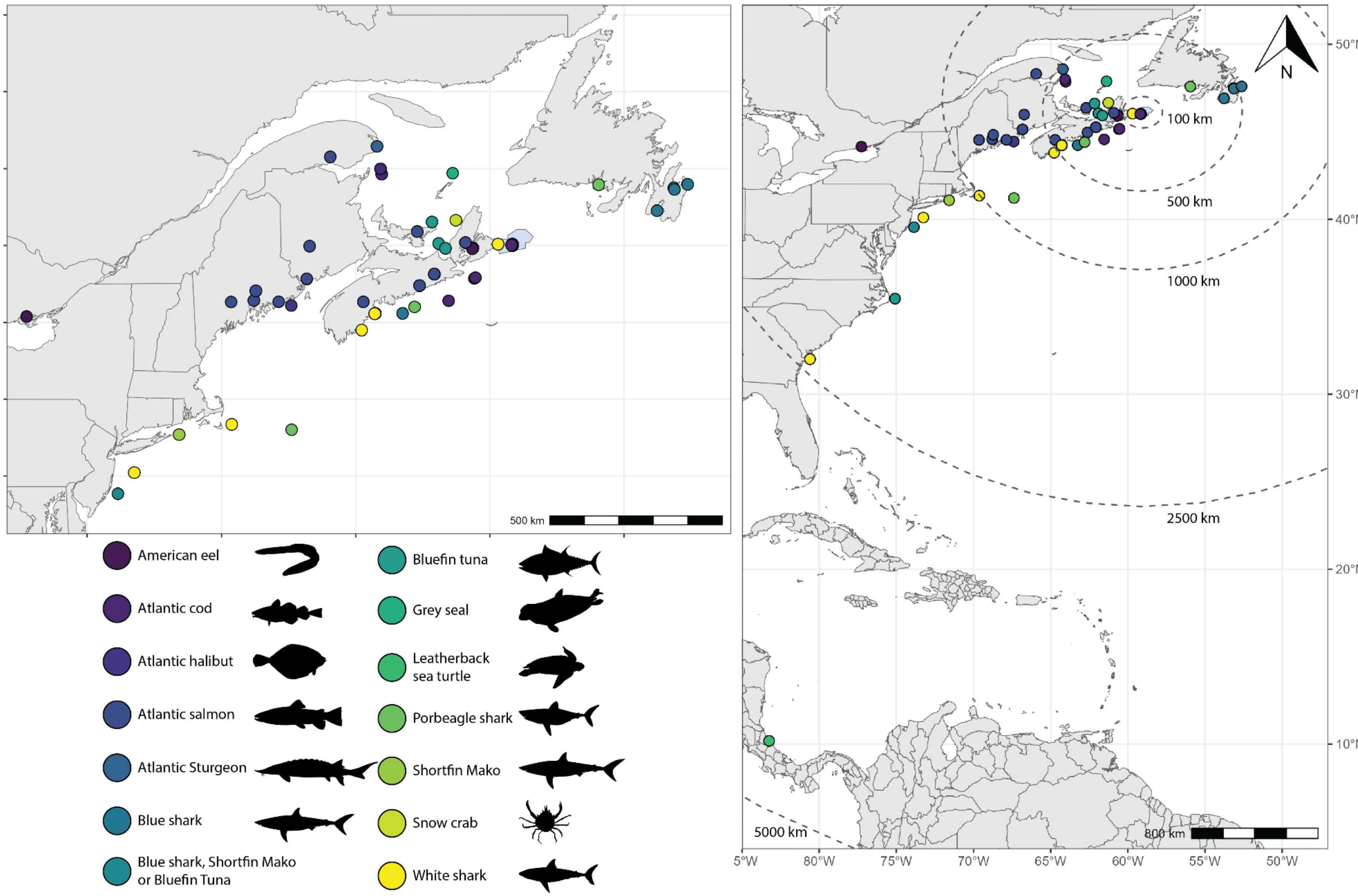


Figure 14 Other project tags: Map showing the release locations of tags detected in St. Anns Bank MPA in 2015 to 2023 that were tagged by projects other than the SABMPA project. Colour denotes the species tagged. Note some locations are specific from latitude and longitude provided by researchers and some are best estimates based on the region where tagging took place.

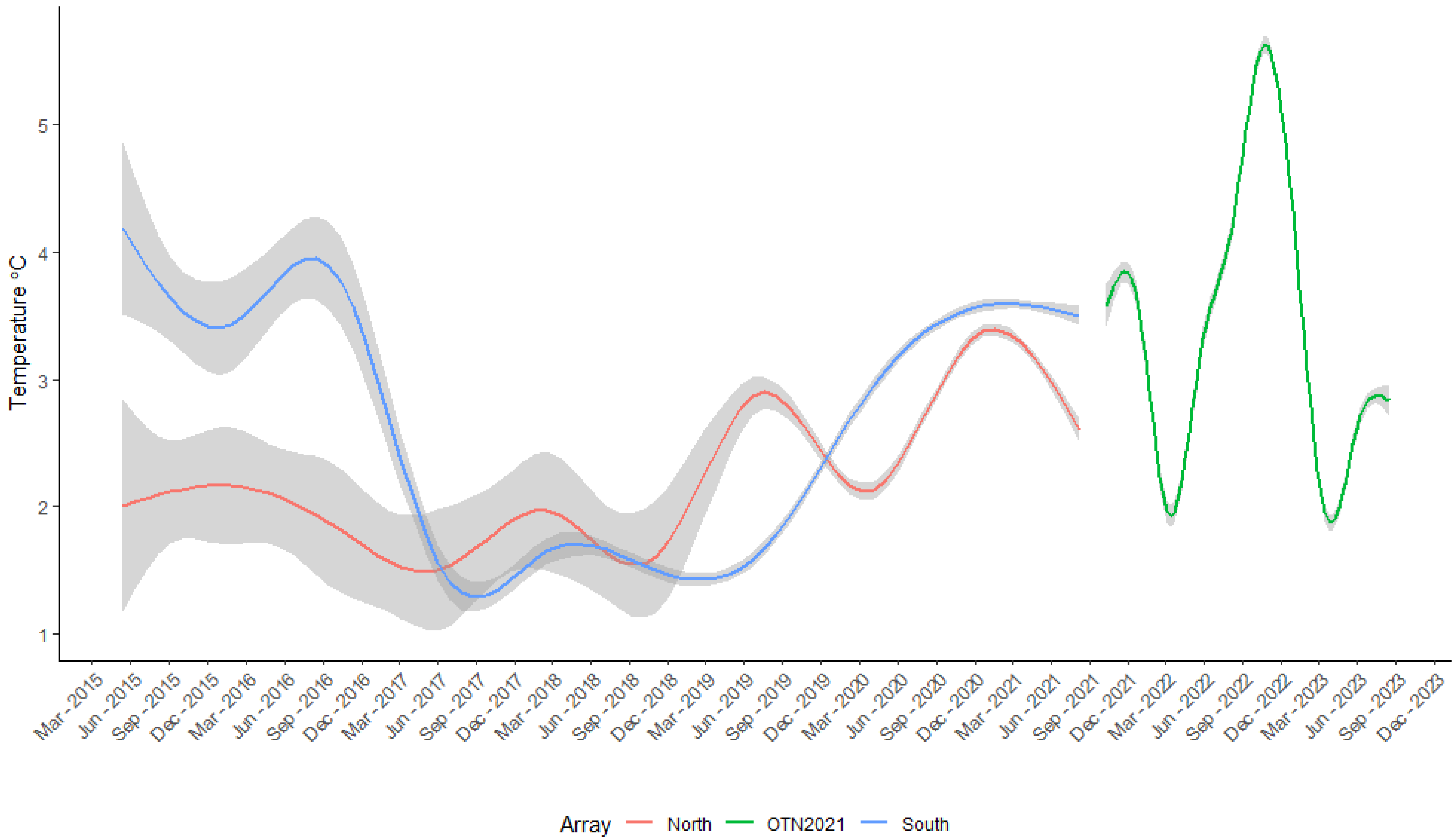


Figure 15 Daily temperature ± 95% confidence intervals recorded on receiver stations in St. Anns Bank MPA from 2015 to 2023. Receivers were deployed in two lines (North and South) 2015 to 2021 and one line 2021 to 2023 (OTN2021) with different locations in the MPA. Note higher confidence interval in early years are partly due to less receivers deployed. North and South total stations gradually increased until 2019 (13-23 stations each) and remained consistent with OTN2021 from 2019-2023 (46 stations).

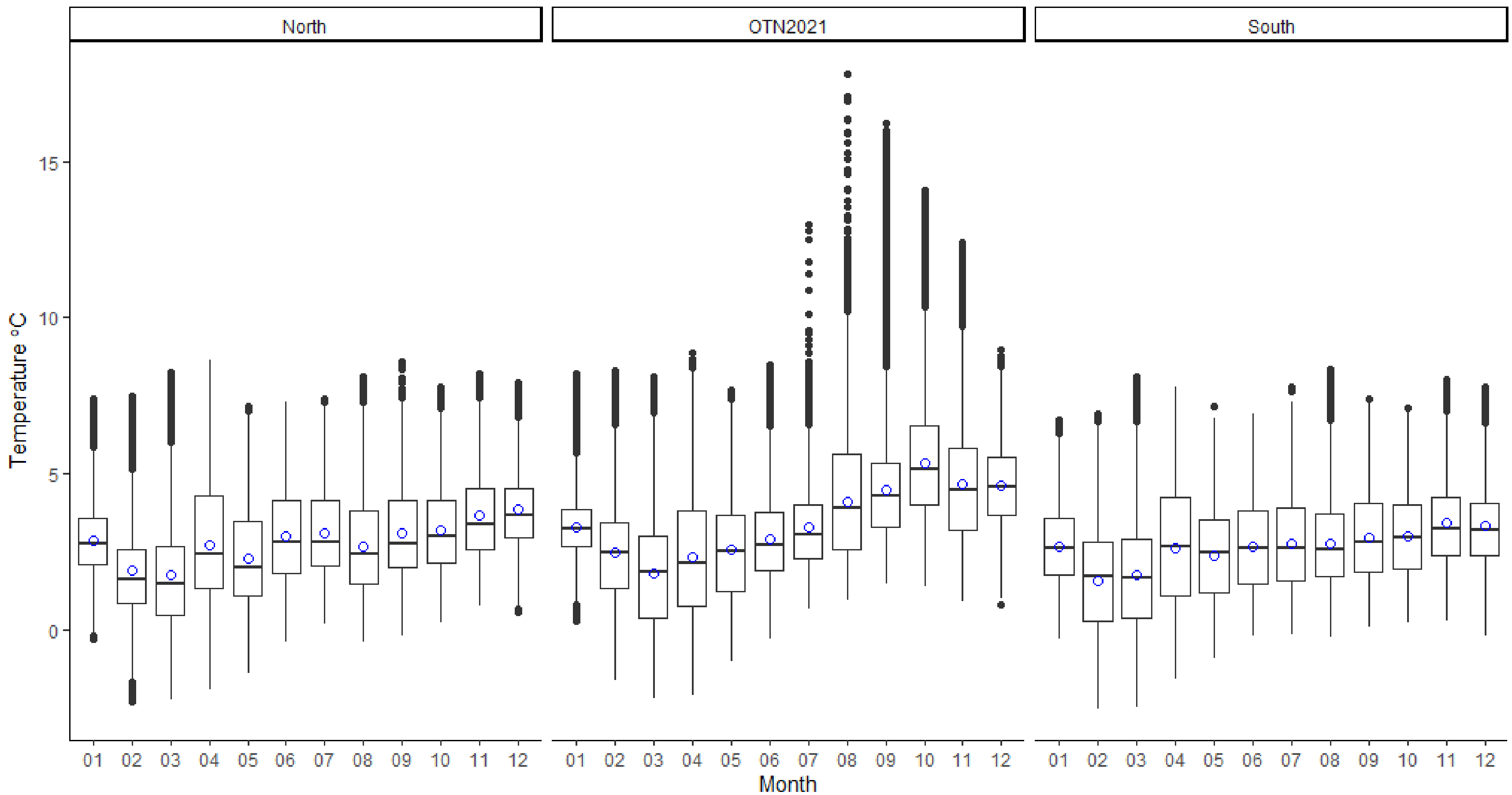


Figure 16 Box plots showing monthly average (blue point) bottom temperature recorded on receiver stations in St. Anns Bank MPA from 2015-2023 showing extreme data (black dots), min and max (vertical lines), interquartile range (boxes), and the median (middle horizontal line). Panels show data from different arrays with different positions in the MPA. North and South was a double line of stations in place 2015-2021 (13-23 stations each) and OTN2021 was single line in place 2021-2023 (46 stations).

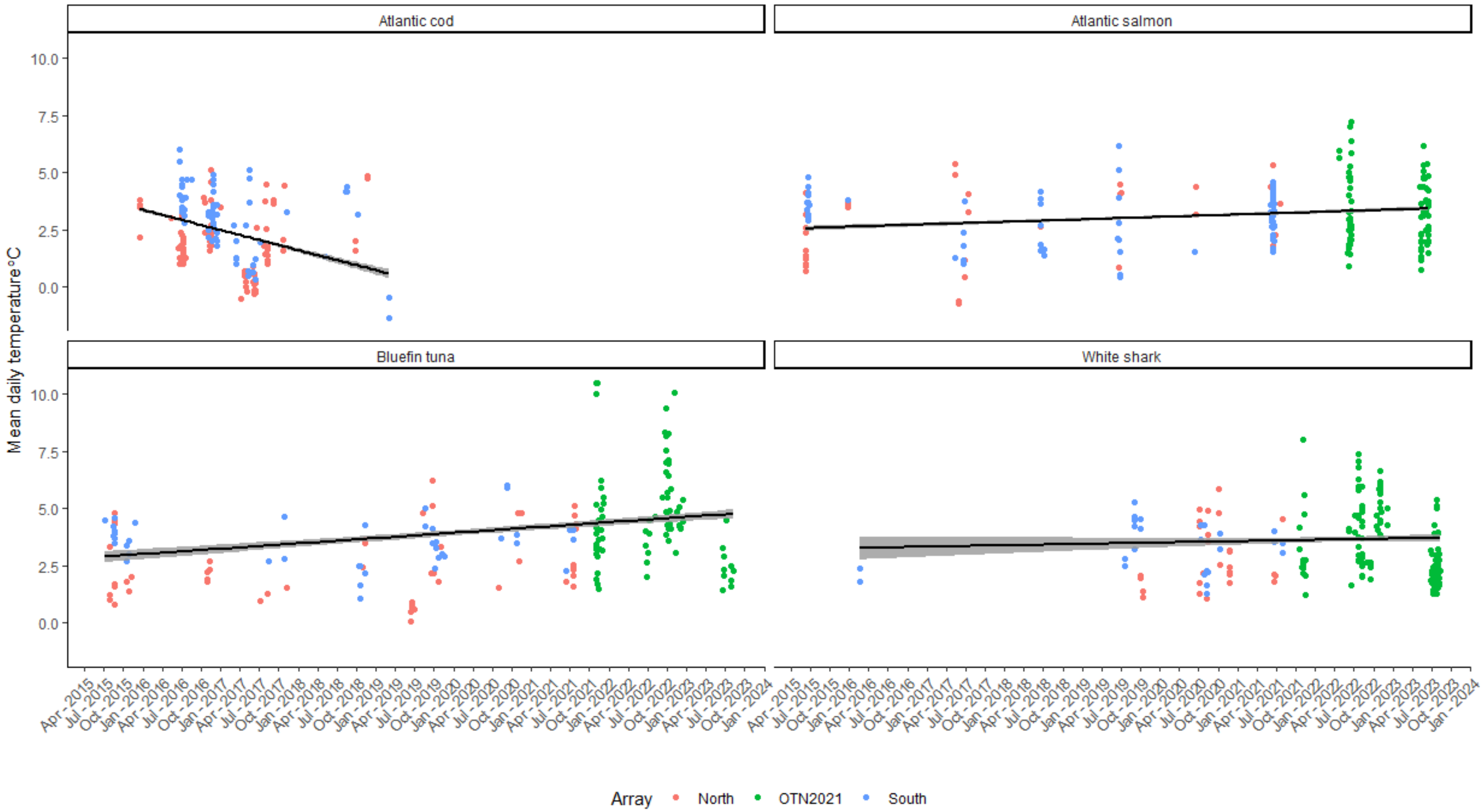


Figure 17 Other project tags: Mean daily bottom temperature recorded on receivers when detecting Atlantic Cod, Atlantic Salmon, Bluefin Tuna, and White Sharks in St. Anns Bank MPA 2015 to 2023. Different colours denote the different array designs. Linear model regression lines are shown with standard error.

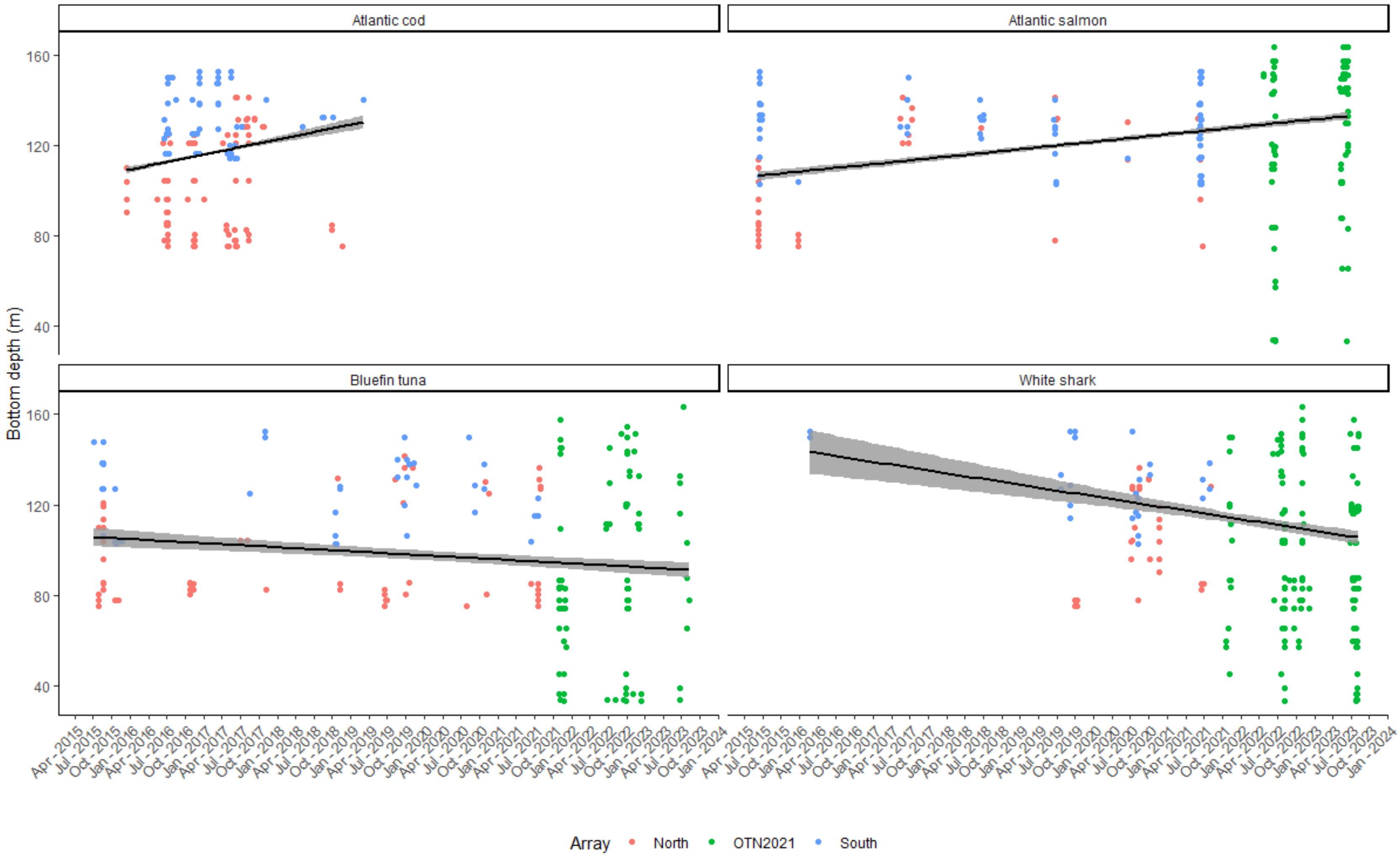


Figure 18 Other project tags: Bottom depth (m) at receiver locations when detecting Atlantic Cod, Atlantic Salmon, Bluefin Tuna, and White Sharks in St. Anns Bank MPA 2015 to 2023. Different colours denote the different array designs. Linear model regression lines are shown with standard error.

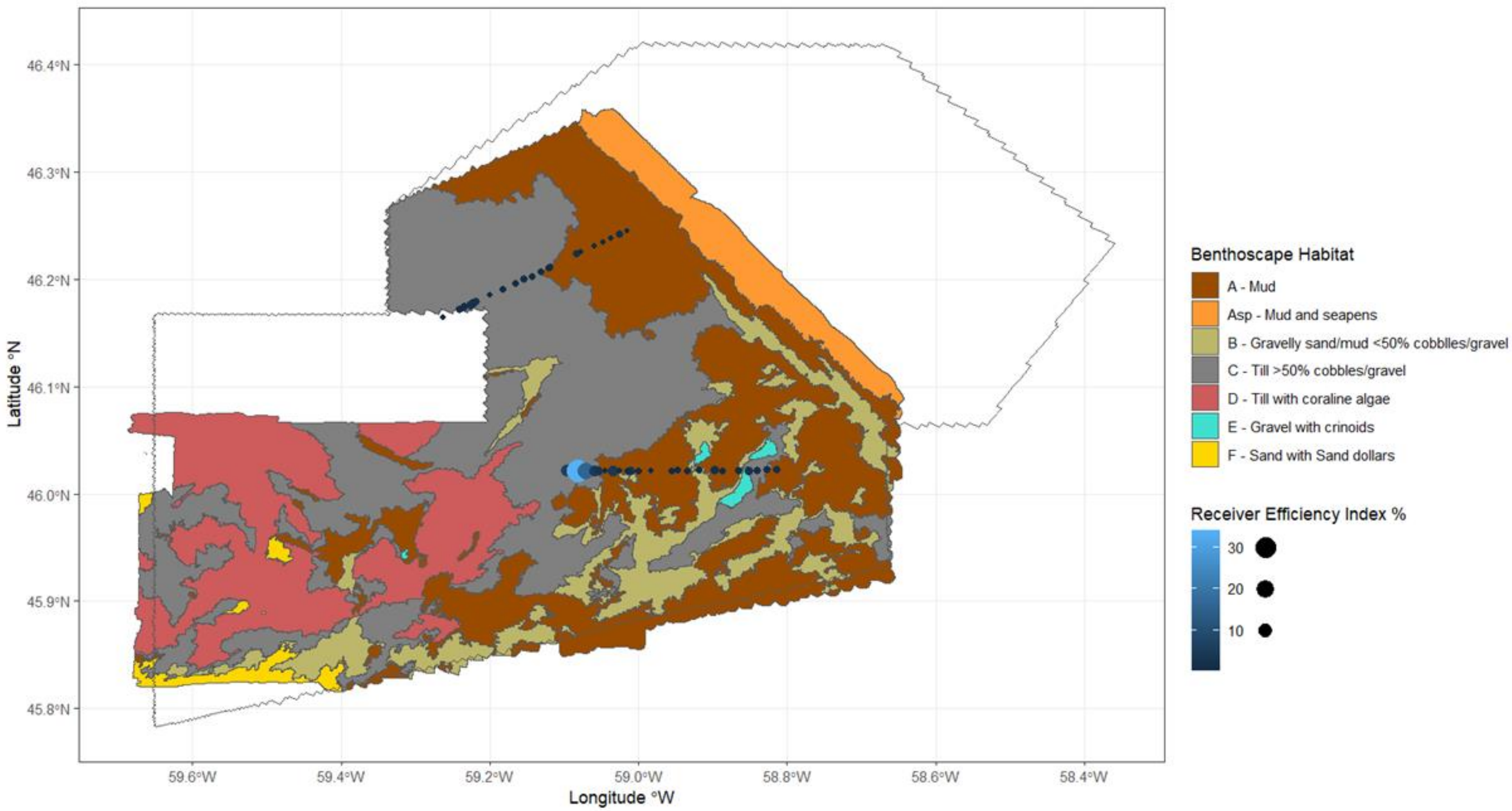


Figure 19 Other project tags: Receiver Efficiency Index (REI) bubble plot from all detections in St. Anns Bank Marine Protected Area on the North and South array (a) and (b) the 2021 array. Habitat classifications are shown from Benthoscape mapping. REI is a value ranging 0-1 calculated from the total species and individuals detected on each receiver station relative to the total species and individuals detected on the array (shown in %).

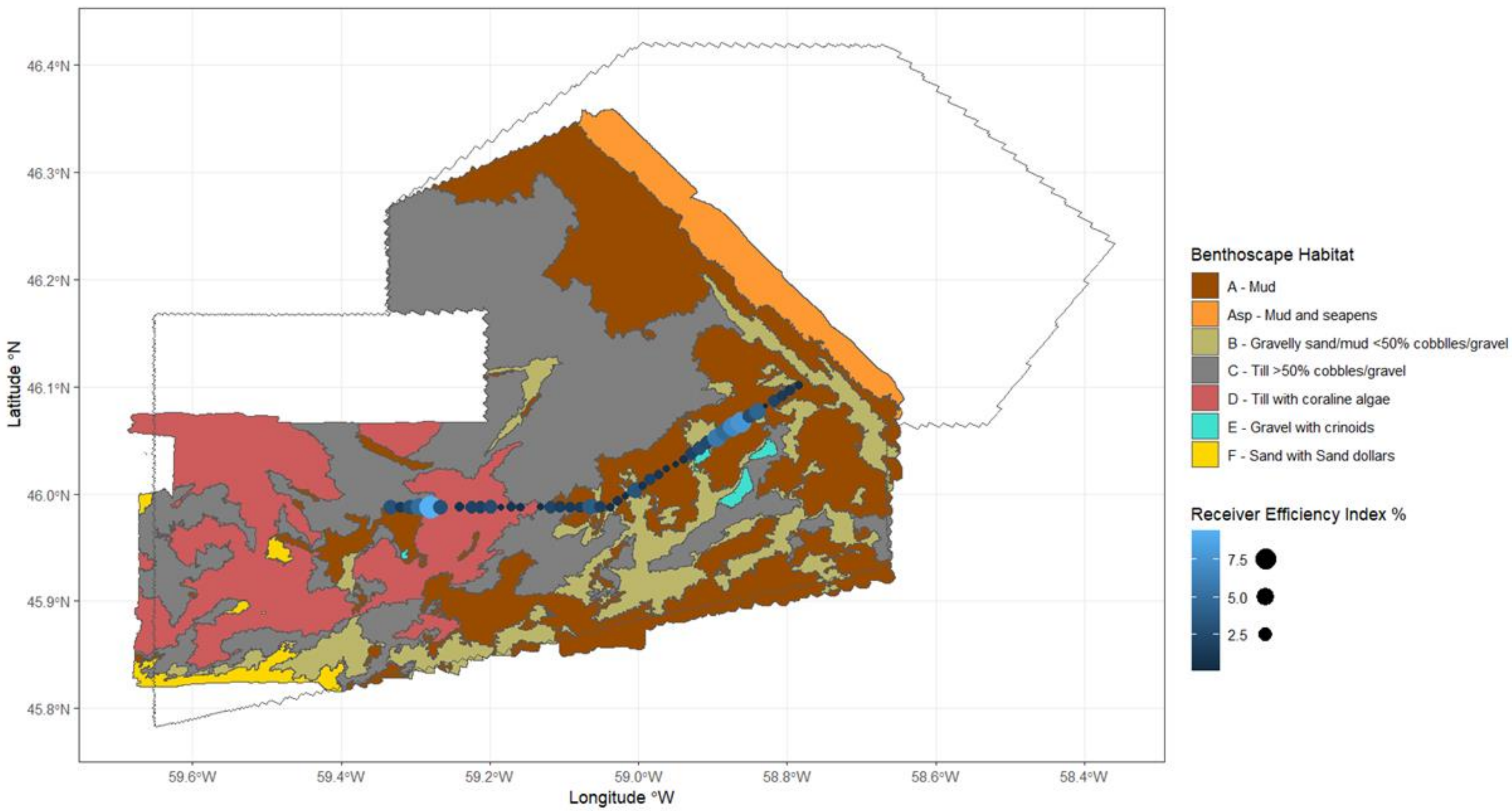


Figure 19 (b) Other project tags: Receiver Efficiency Index (REI) bubble plot from all detections in St. Anns Bank Marine Protected Area on the North and South array (a) and (b) the 2021 array. Habitat classifications are shown from Benthoscape mapping. REI is a value ranging 0-1 calculated from the total species and individuals detected on each receiver station relative to the total species and individuals detected on the array (shown in %).