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Summary report

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The presence, persistence, and movements of highly migratory pelagic fishes (HMS) in southern New England offshore wind lease areas from 2022-2023 determined by acoustic telemetry

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Abbreviations:

ACT: Atlantic Cooperative Telemetry Network
BW: Beacon Wind
DSA: data sharing addendum
FL: fork length
HMS: highly migratory species
MACEC: Massachusetts Clean Energy Center
MADMF: Massachusetts Division of Marine Fisheries
MATOS: Mid-Atlantic Acoustic Telemetry Observation System
MFW: Mayflower Wind/SouthCoast Wind
NMFS: National Marine Fisheries Service
NOAA: National Oceanic and Atmospheric Administration
OCS: outer continental shelf
REV: Revolution Wind
RI: residency index
SF: South Fork
SMAST: University of Massachusetts Dartmouth School for Marine Science and Technology
SNE: southern New England
SRW: Sunrise Wind
SST: sea surface temperature
WEA: Wind Energy Area

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Table of Contents

List of Tables

List of Figures

Preface

The intent of this draft report is to provide an update on the regional activities of the HMS acoustic telemetry monitoring project that was made possible by the signing of the data sharing addendum (DSA) by Equinor Wind, LLC; Beacon Wind, LLC; Mayflower Wind Energy, LLC; Vineyard Wind 1, LLC; Park City Wind, LLC; Vineyard Northeast, LLC; and Northeast Offshore, LLC in fall 2022. Accordingly, this report focuses on the regional project's activities and results during 2022 and 2023 and aims to provide DSA signees with a general overview of the project including species monitored; locations monitored; general and inter-annual patterns of HMS presence, residency, and movements; environmental correlates related to HMS presence; and environmental data measured by acoustic receivers. In-depth analysis of data trends across pre-, during, and post-construction periods will commence in a forthcoming report that incorporates newly obtained data from 2024. Feedback obtained from DSA signees on this draft report will also be considered when scoping the follow-up report that considers 2024 data.

Executive summary

Spatiotemporal use of the SNE WEA by HMS was studied with passive acoustic telemetry via an array of acoustic receivers deployed from January 1, 2022 to December 31, 2022 (n = 75 receivers) and from January 1, 2023 to December 31, 2023 (n = 73 receivers). A total of 259 acoustic transmitters were deployed on 10 species, including blue shark (n = 86), bluefin tuna (n = 70), common thresher shark (n = 3), dusky shark (n = 12), little tunny (n = 1), sandbar shark (n = 3), shortfin mako (n = 50), smooth hammerhead (n = 1), spinner shark (n = 2), and yellowfin tuna (n = 31) in and around the WEA during summer 2020 (n = 29), 2021 (n = 69), 2022 (n = 70), and 2023 (n = 91). During 2022 and 2023, 164 of the 259 total tagged individuals were detected by the receiver array, including 144 of the 199 individuals tagged by developer-funded efforts and 20 of the 60 individuals (4 blue sharks, 10 bluefin tuna, 5 shortfin mako, and 1 smooth hammerhead) tagged in 2020 and 2021 during a pilot study funded by MACEC. A total of 33,098 detections were recorded over all individuals with multiple cases of fish detected in years subsequent to tagging. Tagged HMS inhabited the WEA during the warmer months of the year; blue sharks, bluefin tuna, and shortfin mako were the earliest species to arrive in June of both years, while bluefin tuna were the last species to depart in January 2023 and December 2023. Complete emigration occurred by mid-winter as no detections were logged from January through May 2022 and February through May 2023.

Tagged HMS ranged widely throughout the WEA and were detected by 70 receivers in 2022 and 71 receivers in 2023. A total of 3,077 residence events were documented, including 1,347 in 2022 (88 transmitters detected) and 1,730 in 2023 (103 transmitters detected). Residences lasted from 1 to 2,994 minutes (49.9 hours), with blue sharks and yellowfin tuna having the longest mean residence durations in both 2022 and 2023. Monthly residency indices, calculated as the cumulative number of days individuals of a species were detected at a given station divided by the cumulative number of receiver deployment days when each detected individual (of that species) was available for detection, varied across time and receiver stations for each species but generally indicate that HMS are more transient in the array during arrival/departure in late-spring, fall, and early winter and are more residential during the summer. For species for which interannual comparisons were available, bluefin tuna, blue shark, dusky shark, and shortfin mako exhibited residency throughout the WEA, while yellowfin tuna residency was largely limited to the southeasternmost extent of the WEA. Movement networks constructed by mapping paths between consecutive detections for bluefin tuna, blue shark, shortfin mako, and yellowfin tuna suggest that concentrations and spreads of activity may shift and vary throughout the WEA among species and years. Monitoring of both abiotic and biotic factors (i.e., bottom and surface temperature, thermal stratification, chlorophyll concentration) revealed species-specific associations in densities of occurrence that could potentially link presence, residency, and/or movements to certain ranges of environmental conditions and aid in prediction of habitat that may be of particular importance to HMS within leases, although further modeling efforts are needed. Lastly, a relatively high number of unidentified transmitters (n = 930) were recorded in the array that were deployed by other scientific groups; data sharing is currently underway, when permitted, to match these detections to their owners. Additional monitoring will continue, and forthcoming analyses will include data collected during the 2024 monitoring season.

Background and justification

The offshore waters of southern New England (SNE) have long supported populations of highly migratory fish species (HMS; e.g., tunas, billfish, mahi mahi, sharks) and many fisheries that target them. In addition to serving as a migratory corridor for numerous HMS (Galuardi and Lutcavage, 2012; Vaudo et al., 2016; Kohler and Turner, 2019), SNE is ecologically-important and contains Essential Fish Habitat (i.e., the waters and substrate necessary for spawning, feeding, and growth to maturity) for at least 14 HMS including albacore (*Thunnus alalunga*), bluefin tuna (*Thunnus thynnus*), skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), basking shark (*Cetorhinus maximus*), blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), common thresher shark (*Alopias vulpinus*), porbeagle (*Lamna nasus*), white shark (*Carcharodon carcharias*), dusky shark (*Carcharhinus obscurus*), sandbar shark (*Carcharhinus plumbeus*), tiger shark (*Galeocerdo cuvier*), and sand tiger (*Carcharias taurus*) (NMFS, 2015). SNE also contains historical fishing grounds for iconic species such as swordfish (*Xiphias gladius*), bluefin tuna, white marlin (*Kajikia albida*), and shortfin mako, and supports an extensive contemporary recreational fishery for HMS in which hundreds of vessels participate each year. Of interest, a proportion of this recreational fishing effort for HMS occurs within popular fishing areas that have been leased for offshore wind development (Kneebone and Capizzano, 2020).

Given the ecological importance of SNE to HMS and the economic value of HMS in SNE, there is a need to monitor the potential impacts of offshore wind development on these species as well as any associated impacts on the large, directed recreational fishery they support within the Rhode Island/Massachusetts and Massachusetts Wind Energy Areas, which are collectively referred to as the "WEA" in this report (Figures 1a – b). At present, there is an incomplete understanding of how offshore wind development may impact recreational fishing activities (i.e., fishing methods, fishing locations, target species), including the extent to which fishing effort may be disrupted due to the displacement of target species or fishing vessels from popular areas that fall within the WEA (MADMF Research Priorities White Paper, November 2018). There is also an incomplete understanding of how offshore wind activities may affect species presence, distribution, and movement/migration through the WEA. The goal of this study was to use acoustic telemetry to monitor the spatial ecology characteristics of tagged HMS within each lease area and evaluate impacts on animal presence and movements from construction and operation across offshore wind lease areas in the region.

Objectives

The objective of this project was to use passive acoustic telemetry to monitor the location (presence), persistence (residency), and movements of HMS in the WEA while describing the environmental conditions potentially associated with their presence. Our specific objectives were to:

(1) Work cooperatively with commercial fishermen to deploy and maintain an array of acoustic receivers to monitor the presence and persistence of tagged HMS within the WEA.

(2) Conduct at-sea sampling trips within and adjacent to the WEA to deploy acoustic transmitters on HMS that are captured or targeted by the recreational fishery in southern New England, with particular focus on Atlantic bluefin tuna, shortfin mako, and blue shark.

(3) Analyze acoustic receiver 'detection' data to investigate patterns in animal presence, residency, and movements in relation to (a) environmental conditions, (b) local water depth, (c) season and year, and (d) offshore wind construction activities.

(4) Opportunistically monitor the presence and persistence of other acoustically tagged marine species within the acoustic receiver array and share data through the Atlantic Cooperative Telemetry (ACT) Network's Mid-Atlantic Acoustic Telemetry Observation System (MATOS).

Methods

Acoustic monitoring (Objective 1)

To achieve our objectives, VEMCO acoustic receivers (INNOVASEA Systems Inc., Halifax, Nova Scotia, Canada) were deployed to continuously monitor for the presence of tagged HMS at specific locations during both 2022 (n = 75 total receivers) and 2023 (n = 73 total receivers) in Revolution Wind (OCS-A 0486), South Fork Wind (OCS-A 0517), Sunrise Wind (OCS-A 0487), Bay State Wind (OCS-A 0500), Vineyard Wind 1 (OCS-A 0501), New England Wind (OCS-A 0534, OCS-A 0561), Beacon Wind (OCS-A 0520), SouthCoast Wind (formerly Mayflower Wind; OCS-A 0521), and Vineyard Northeast (OCS-A 0522) (Figures 1a – b). Acoustic receiver deployment and maintenance occurred in two separate manners: (A) in cooperation with for-hire commercial fishing vessels and (B) in cooperation with the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST). Details on the deployment location and duration of each receiver can be found in Tables 1a – h. Due to perpetual loss, receivers were not deployed at stations BW_01 and SRW_13 in 2023.

In (A), VEMCO VR2AR acoustic release receivers were deployed on the seafloor using a custom-designed pop-up mooring system (Mooring Systems, Inc., Bourne, MA) that could be reassembled and redeployed after being summoned to the surface (Figure 2). On demand receivers with no vertical lines were used to avoid interactions with protected species and to minimize the potential for interaction with developer activities (e.g., surveying and cable laying). Individual VR2AR receiver locations were selected based on the desire to minimize potential interaction with commercial fishing gear, particularly mobile fishing gear, and maximize the coverage of the popular recreational fishing area. Previously in 2021, all receivers were placed on LORAN TD lines ending in '0' or '5' according to a longstanding, informal agreement within the fishing industry designed to minimize interaction between fixed and mobile fishing gear. Based on extensive receiver loss incurred in 2021 (which was assumed to be due to mobile gear interactions), input was sought from the commercial fishing fleet to identify specific areas where there was a lower probability of interaction with mobile fishing gear (i.e., 'dragger hangs'). Where necessary, receivers were subsequently relocated to specific 'hangs' in 2022 and deployed in those locations consistently for the duration of the project. Due to extensive corrosion, all receivers in Revolution Wind, South Fork Wind, and Sunrise Wind were hauled in early May 2023, outfitted with new hardware, and redeployed later in the month.

Deployment intervals varied by lease. For Vineyard Wind 1, New England Wind, Beacon Wind, SouthCoast Wind, and Vineyard Northeast, receivers were deployed from roughly May/June to December each year and were hauled at the end of each season to prevent loss throughout the winter. For Revolution Wind, South Fork Wind, Sunrise Wind, and Bay State Wind, monitoring occurred year-round beginning in May/June 2022 due to collaboration on an Atlantic cod (*Gadus morhua*) study being conducted by SMAST. Additionally, receivers at stations REV_07, REV_08, REV_10, REV_16, and SF_02 were carried over from a pilot project funded by the Massachusetts Clean Energy Center (MACEC; Gervelis and Kneebone, 2022) and were already deployed in the array as of January 2022. At each download, receivers were cleaned, downloaded, and installed with new batteries as needed. The location of some acoustic receivers was adjusted slightly throughout the project period due to requests from the developers or prior interactions with commercial fishing gear and other offshore wind monitoring equipment. These relocations all occurred in close proximity to the assumed detection range of the acoustic receiver's initial deployment location and, thus, did not represent a significant disruption to the ability to monitor tagged HMS at the spatial scale necessary to achieve the monitoring objectives.

In (B), VR2W and VR2Tx acoustic receivers were deployed by SMAST in the Revolution Wind, South Fork Wind, and Sunrise Wind leases throughout 2022 for the aforementioned Atlantic cod study. Upon removal of these SMAST receivers in early 2023, three VR2AR stations originally deployed in 2022 were relocated to maintain coverage at the stations vacated by the SMAST receivers: REV_18, SF_01, and SRW_10 (Figures 1a – b); continuing to monitor at the vacated SMAST stations was deemed a higher priority than monitoring at the station in which the receiver was originally deployed in 2022. Detection data from SMAST receivers deployed at these stations in 2022 were used for analyses.

Environmental monitoring

In addition to logging 'detections' from acoustic transmitters, VR2AR and VR2Tx acoustic receivers recorded average ambient noise (mV at 69 kHz), water temperature (°C), tilt angle (degrees), and depth (m; VR2AR only) every hour throughout their deployment. For VR2Tx acoustic receivers and any missing stations, local depth was estimated using the ETOPO 2022 15 Arc-Second Global Relief Model database (NOAA National Centers for Environmental Information) queried via the R package *marmap* (Pante and Simon-Bouhet, 2013).

Acoustic receiver detection range testing

Acoustic receiver range testing was conducted at stations 501_02 (7/17/2023) and REV_18 (10/25/2023) to estimate the radius around the receiver in which V16 transmitters could be detected. During range testing, two V16-4H transmitters (fixed nominal delay = 60 s) were secured to a vertical line that was anchored to the bottom, with one transmitter positioned around 20 feet off the bottom and the other around 20 feet from the surface. This configuration was used to evaluate detection range both below and above the thermocline, respectively. The mooring line with attached transmitters was deployed at a series of fixed distances from the receiver (501_02: 250, 500, 750, 1000 m; REV_18: 100, 250, 500, 750 m) and left in place for a period of one hour at each distance. The time of deployment and removal was noted for each deployment. Upon receiver download, the number of detections logged independently by both the surface and bottom transmitters during the 1-hour deployment periods was divided by 60 (i.e., the total number of possible detections during the 1-hour period) to calculate the percentage of detections logged at each distance interval and respective position in the water column.

Acoustic tagging (Objective 2)

VEMCO acoustic transmitters (INNOVASEA Systems Inc., Halifax, Nova Scotia, Canada) were deployed on individual HMS during for-hire trips aboard charter sportfishing vessels in July to August of 2020 and 2021 and June to September of 2022 and 2023. Sixty of these transmitters were deployed as part of a pilot study funded by the MACEC (Gervelis and Kneebone 2022). The location of fishing/sampling during each trip was selected based on the target species and fishing method (e.g., sharks vs. bluefin tuna), and efforts were made to tag individuals with transmitters within or as close to the WEA as possible. All HMS were captured on hook-and-line (rod-and-reel) fishing gear using standard recreational sportfishing techniques. All capture and tagging activities were approved by the New England Aquarium's Institutional Animal Care and Use Committee (protocol #2020-07) and scientific research permits (SRP) HMS-SRP-21-33 (2021), HMS-SRP-22-34 (2022), and HMS-SRP-23-31 (2023) issued by the NOAA HMS Management Division.

Internal tagging

Acoustic transmitters (models V16-4H: 16 mm diameter; nominal transmission delay = 60 – 120 seconds and 80 – 160 seconds; expected longevity = 1,975 – 2,435 days; and V16P-4H: 16 mm diameter; nominal transmission delay = 40 – 80; expected longevity = 1,222 – 1,266 days; max depth = 204 meters; accuracy = ± 10 meters; resolution = 0.9 meters) were surgically implanted into tunas and sharks using standard techniques. Pressure sensing (V16P) transmitters encoded the swimming depth of the tagged animal at the time of the acoustic transmission, thereby permitting the monitoring of depth distribution and vertical movements. Tunas were brought aboard the vessel using a knotless, rubber dip net and placed on their side on a cool, wet, rubber mat. A wet towel was also placed over the eyes to calm the fish during the procedure. The vessel's raw seawater deck hose was then positioned anterior to the mouth or above the gill arch opening to deliver ambient seawater to the gills during surgery. Upon retrieval to the side of the vessel, sharks that could safely be handled were tail roped and secured by applying pressure to the tail rope and leader on which they were caught. The sharks were then placed in tonic immobility alongside the vessel, the head and gills always remaining in the water. Once the animals were secured, a local anesthetic (lidocaine; dose = 2 mg kg^{-1}) was administered subcutaneously and allowed to react 1 minute before incising. Using a fresh scalpel, an initial incision was made traversing only the dermis, and a 15-mm trocar was used to penetrate the body cavity. The acoustic transmitter was then inserted, and the wound was closed with one to three interrupted, monofilament, absorbable sutures. For tunas, the fork length (FL) was measured (cm) from the tip of the snout to the fork in the tail over the body prior to the animal being released. For sharks, the FL was estimated, and sex determinations were made via the presence/absence of claspers (male). All surgical tools were disinfected and rinsed with freshwater prior to and after each surgery.

External tagging

Acoustic transmitters (model V16-4H; 16 mm diameter; nominal transmission delay = 40 – 80 and 80 – 160 seconds; expected longevity = 1,365 – 2,435 days) were externally attached to larger tunas and sharks. External V16-4H transmitters were encapsulated in a polyvinyl chloride 'shark' case and were rigged with multi-strand stainless cable covered in heat shrink tubing and a titanium anchor (Jepsen et al. 2015). The overall length of the tether ranged from 8 to 15 cm and was scaled based on the size of the animal to be tagged. During tagging, fish were brought alongside the vessel, and the tag was applied in the dorsal musculature using a tagging pole equipped with a stainless-steel applicator needle. Following tagging, the FL of the fish was estimated, the sex was noted for sharks, and the hook was either removed or cut in half using bolt cutters. Some sharks were tagged while they were free swimming next to the tagging vessel; FL was estimated for each of these individuals, and sex was assessed via visual observation of claspers when possible.

Data analysis (Objective 3)

Raw acoustic detections and archived environmental data downloaded from acoustic receivers were compiled into a database for analysis. Due to high mobility of HMS and the relatively large distance between individual acoustic receivers, single detection events were considered valid and retained for analysis. All analyses were performed in R (version 4.3.1; R Core Team, 2023), primarily with *tidyverse* packages (Wickham et al., 2019).

Presence and persistence

To evaluate the presence and persistence of tagged HMS at each acoustic receiver station, as well as within the full receiver array, periods of residence were calculated. A residence event was defined as any time an individual was detected at least once at a receiver station. Residences ended when individuals were not detected (i.e., absent) for at least 24 hours or if that individual was detected on another receiver, whichever occurred first. To examine the amount of time individuals were detected during a residence event, the duration of each residence was calculated as the time between the first and last detection. The total number and duration of residence events were then summarized by species in each year.

Annual residency index (RI) was calculated by species across all receiver stations by dividing the cumulative number of days individuals of a species were detected at a given station from June through November by the cumulative number of days that station (receiver) was deployed when each detected individual of that species was available for detection. Monthly RI was calculated for bluefin tuna, blue shark, shortfin mako, and yellowfin tuna similarly across each month from June through December. For both indices, individuals that were not detected by the receiver during the time period of interest were excluded from analysis. RI values were multiplied by 100 to prevent comparison of small decimal values and can thus range from 0 (no individuals of the species were detected by the receiver in the timeframe) to 100 (all detected individuals of the species were detected every day by the receiver in the timeframe). Detection histories were also created to visually demonstrate the presence of each individual and all tagged species over time and in relation to acoustic receiver stations.

Movement patterns (Network analysis)

Network analysis was employed to describe occupancy and connectivity of tagged HMS among acoustic receiver stations (hereafter referred to as “nodes”) throughout the WEA and to assess shifts in transit and activity centers over time. Annual movement networks were created for the four species with the largest number of tagged individuals (bluefin tuna, blue shark, shortfin mako, and yellowfin tuna) using the *igraph* package (v2.0.2, Csardi and Nepusz, 2006). “Edges” between nodes were created when sequential detections at two different receiver stations occurred within 72 hours. This time step was selected based on the duration of residence periods documented by this study as well as the anticipated movement rates of the tagged species and the overall area of the acoustic receiver array (Gervelis and Kneebone 2022). Edges were then weighted to reflect the number of unique transmitters that traveled between nodes to highlight areas of high traffic in the network. In addition to creating network overviews of movement, network metrics of density, degree centrality, eigenvector centrality, and strength were calculated for each species using functions within the *igraph* package and in base R (v4.3.0). To maximize effective comparison of networks between years, data were only used from stations that were present for the entire deployment period in 2022 and 2023 (n = 67).

Network density was calculated by dividing the total number of existing edges between nodes by the number of possible edges (i.e., if all nodes with detections were connected to all other nodes with detections, excluding self-connections). The resulting proportion is a measure of network utilization, with lower densities possibly indicating more localized movements and higher densities associated with broad use of the potential network (Farine and Whitehead, 2015). Strength was calculated for each node as the sum of the weights of immediate (i.e., directly connected) edges and is a measure of connectivity with adjacent nodes (Farine and Whitehead, 2015). Strength is a measure of repeated movements, with higher strength values indicating larger numbers of individuals moving through that node.

Degree centrality is the total number of direct connections that a node has to other nodes in the network without factoring in edge weight. Well-connected nodes will have higher degree centrality and may act as a “hub” for movement in the network or possibly as an area of greater activity (Farine and Whitehead, 2015). Eigenvector centrality expands upon degree centrality by factoring in degrees of connectivity among nodes. It is calculated by first assigning an initial eigenvector score of 1 to all nodes in an adjacency matrix; nodes with no connection to other receivers are then down weighted. Scores are then summed for each node and a new adjacency matrix is created with each node’s sum assigned as the new eigenvector centrality score for each connection. The process repeats itself until scores begin to stabilize across nodes, at which time they are then normalized on a 0–100 scale. As a result, well-connected stations with immediate connections to *other* well-connected stations receive higher eigenvector centrality scores. Nodes with large eigenvector centrality values are considered the most influential in the network and help highlight high-use areas (Csardi and Butts, 2006).

Once all network metrics were calculated, a series of tests were run to examine distribution of the metric data for each species by year using boxplots and the Shapiro-Wilks test, excluding network density because it is a singular value for each species’ whole network each year. The Brown-Forsythe test was then used to assess significant differences across each metric’s distributions of variance between years. Because stations were not all paired between years (i.e., not all stations had detections for a given species each year), and distribution and variance for all but a few yearly metrics were non-normal, a two-tailed Wilcoxon Rank-Sum test was used to quantitatively compare distribution of metric values between years for each species. Values for each metric were sorted into percentiles for each species and year to highlight nodes with the greatest influence on their networks, and comparisons were made between species and year using the 90^{th} percentile since it provides a good balance between considering too many nodes as influential (e.g., 80^{th} percentile) or too few (e.g., 95^{th} percentile), which might exclude otherwise important nodes. All maps were created using the *sf* (Pebesma, 2018) package.

Depth distribution

The distribution of swimming depth at the time of detection was examined for each species tagged with V16P transmitters. Histograms were constructed to describe the number of detections logged within 2-meter depth bins from the surface (0 meters) to the maximum swimming depth (72 meters) observed over all tagged species. The percentage of time individual species were detected at specific depth intervals or ranges was qualitatively compared to examine trends.

Environmental conditions

To establish the environmental conditions under which HMS were present in the study area, bottom water temperature, sea surface temperature (SST), and surface chlorophyll a concentration were identified or estimated at the time and location of each acoustic detection. Bottom water temperature data were sourced from the hourly water temperature data measured and logged by each VR2AR or VR2Tx acoustic receiver. Each detection was assigned a bottom temperature that was measured at the nearest hour interval by the detecting receiver. Daily Multi-scale Ultra-high Resolution (MUR) SST Analysis fv04.1 data (jplMURSST441) at 0.01° (decimal degrees) resolution provided by NASA JPL under support from NASA MEaSUREs program were downloaded using the *rerddap* package (Chamberlain, 2021), and an SST was assigned to each detection based on the SST interpolated at the location of the detecting receiver on that calendar date. To examine animal presence in relation to thermal stratification, the difference between the bottom water temperature and SST was calculated (ΔT) at the time of each detection. Chlorophyll a data were obtained from the NOAA NESDIS Ocean Color Science Team and the NOAA CoastWatch program (noaacwNPPN20S3ASCIDINEOF2kmDaily gap filled at 2km resolution; https://coastwatch.noaa.gov) accessed via *rerddap*. Kernel density plots were created using the geom_density function in package *ggplot2* (Wickham, 2016) to describe the range of environmental conditions in which each species was detected over the study period.

Data sharing (Objective 4)

Metadata from deployed acoustic receivers and raw acoustic detection data downloaded from receivers were uploaded to the ACT Network's MATOS data sharing portal periodically as permitted by data sharing agreements signed by individual developers.

Results

Acoustic receiver deployments and maintenance (Objective 1)

Seventy of the 75 VR2AR and VR2Tx acoustic receivers deployed in 2022 were recovered and downloaded (Tables 1a – h). Five receivers (SRW_10, SRW_13, MFW_02, 522_02, and 522_05; Figure 1a) were not present during recovery trips and presumed lost. Note that the receiver at SRW_10 was in a different position in 2022 than is shown in Figure 1; data from the SMAST receiver deployed at the SRW_10 location shown in Figure 1 were used in 2022. Five receivers (BW_01, BW_06, MFW_01, 522_07, and 522_10; Figure 1a) were caught by commercial fishermen and recovered during the season; BW_06 was redeployed midseason at a new location approximately 1 nautical mile away from its original location. The receiver at station SRW_11 was recovered but malfunctioned and did not record any detection data during its deployment. In 2023, 71 of the 73 VR2AR receivers were recovered and downloaded (Tables 1a – h). Two receivers (522_05 and 522_07; Figure 1b) were not present during December recovery trips and presumed lost. Two receivers (SF_01 and MFW_01; Figure 1b) were caught by commercial fishermen and recovered during the season; SF_01 was redeployed midseason at a nearby location (to stay clear of other survey equipment) while MFW_01 was not redeployed.

Range testing

Results of range tests indicated that detection range (50% probability of detection) for V16-4H transmitters at stations 501_02 and REV_18 is approximately 200 to 400 m (Table 2). Detection efficiency was also greater for the transmitter moored approximately 20 feet (7 meters) from the surface than for the transmitter moored around 20 feet (7 meters) from the bottom.

Acoustic tagging (Objective 2)

A total of 259 acoustic transmitters were deployed on blue sharks (n = 86), bluefin tuna (n = 70), common thresher sharks (n = 3), dusky sharks (n = 12), little tunny (n = 1), sandbar sharks (n = 3), shortfin mako (n = 50), smooth hammerhead (n = 1), spinner sharks (n = 2), and yellowfin tuna (n = 31) during 2020 (n = 29), 2021 (n = 69), 2022 (n = 70), and 2023 (n = 91) (Tables 3, 4; Figure 3). A summary of metadata for all transmitter deployments, including those deployed for the MACEC project, can be found in Table 3.

Presence, persistence, and movements of tagged HMS (Objective 3)

The single common thresher shark tagged in 2022 was not detected and confirmed to be a post-release mortality based on its repeated detection near the release location by acoustic receiver equipped gliders. Detection data from a shortfin mako tagged in 2023 indicated that the shark traveled to station BW_02 approximately 11 days after tagging at which point the transmitter was shed or a mortality event occurred based on prolonged and repeated detections; all data for this transmitter were censored beyond the first detection at this station. A yellowfin tuna tagged in 2023 was caught and kept by an angler on October 6, 2023, after it had emigrated out of the receiver array; no data were censored for this transmitter. Both the shortfin mako and yellowfin tuna were removed from calculations of annual residency indices due to truncation of days available for detection but were kept for calculations of monthly residency indices as this issue is negligible on shorter time scales.

Presence and residency

Of the 259 HMS tagged from 2020 to 2023, 164 (63%) individuals were detected (33,098 total detections) by the receiver array across 2022 (17,833 detections; 88 individual transmitters) and 2023 (15,265 detections; 103 individual transmitters) (Table 4; Figures 4a – b, 5a – b). Of the 94 transmitters that were not detected in 2022 or 2023 (accounting for the single common thresher that experienced post-release mortality), 58 (61.7%; including 31 blue shark, 16 bluefin tuna, 1 dusky shark, 2 sandbar shark, 6 shortfin mako, and 2 yellowfin tuna) were detected either by the pilot MACEC study in 2020 or 2021 or by acoustic receivers in ACT Network whose data were shared from 2020 to 2025. Thirty-six transmitters were not detected at any point in time (6 blue shark, 9 bluefin tuna, 1 dusky shark, 8 shortfin mako, and 12 yellowfin tuna). Of the 70 transmitters deployed in 2022, 56 (80%) were detected during the 2022 season, while 69 (76%) of the 91 transmitters deployed in 2023 were detected during that same year. In the year in which they were tagged in 2022 and 2023, HMS were first detected from 0.7 to 128.1 (Mean ± SD: 12.4 ± 20.9) days after release; two individuals (both yellowfin tuna) tagged in 2022 were not detected until 2023, 343 and 359 days after tagging. Fifty-eight (35%) of the 167 individuals tagged during 2020 – 2022 that were at large (and presumably available for potential detection, assuming no tag shedding) in years subsequent to tagging were detected in 2022 or 2023, including 6 (of 29; 21%) individuals tagged in 2020 (2 blue shark, 2 bluefin tuna, 2 shortfin mako), 31 (of 69; 45%) individuals tagged in 2021 (13 blue shark, 12 bluefin tuna, 1 dusky shark, 4 shortfin mako, 1 smooth hammerhead), and 21 (of 69; 30%) individuals tagged in 2022 (10 blue shark, 1 bluefin tuna, 4 dusky shark, 2 shortfin mako, 4 yellowfin tuna). Twenty-seven (16%) of the 167 individuals tagged during 2020 to 2022 (excluding the one common thresher shark that suffered post-release mortality) were detected in both 2022 and 2023 including 12 (of 82; 15%) blue shark, 5 (of 35; 14%) bluefin tuna, 5 (of 10; 50%) dusky shark, 3 (of 22; 14%) shortfin mako, 2 (of 12; 17%) yellowfin tuna.

Tagged HMS were detected by all recovered, functional receivers in 2022 (n = 70) and 2023 (n = 71). Overall, blue sharks, bluefin tuna, and shortfin mako exhibited the broadest temporal use of the WEA and were documented in at least half of the calendar months, with bluefin tuna being the only species recorded in either December or January. Collectively over both years of monitoring, blue sharks were detected between June 3 and November 1, bluefin tuna between June 15 and January 9, common thresher sharks between August 29 and November 19, dusky sharks between July 19 and October 3, sandbar sharks between July 30 and October 2, shortfin mako between June 6 and November 13, smooth hammerhead between July 5 and July 27, spinner sharks between August 6 and September 9, and yellowfin tuna between July 22 and September 25 (Figures 4a – b). The single little tunny tagged in 2023 was detected solely on September 9. A total of 3,077 residence events were documented, including 1,347 in 2022 (88 transmitters detected) and 1,730 in 2023 (103 transmitters detected) (Tables 5, 6, 7). Residences lasted from 1 to 2,994 minutes (49.9 hours), with blue sharks and yellowfin tuna having the longest mean residence durations in both 2022 and 2023 (Table 6). Little tunny, smooth hammerhead, and spinner sharks exhibited the shortest mean residence times.

HMS presence and residency across individual receiver stations was somewhat variable both within and between years (Tables 7, 8a – h; Figures 6a – b). Over 2022 and 2023 combined, station

501_04 logged the most detections and residences and detected the greatest number of individual fish (Table 7). Annual RI values varied between receiver stations and across years for each species and ranged from 0.5 to 4.0 (Mean ± SD: 1.0 ± 0.4) in aggregate for stations with non-zero values (Figures 6a – b). However, relatively consistent trends in overall presence and residency were evident between 2022 and 2023 for blue shark, shortfin mako, and dusky shark. Bluefin tuna and yellowfin tuna exhibited somewhat consistent patterns of RI by station between years but had residency at considerably more receiver stations in 2023. Sandbar shark, smooth hammerhead, common thresher shark, spinner shark, and little tunny were only detected in one of the two years thereby precluding interannual comparison. Monthly RI values were highly variable between species and between years within species, ranging from 3.2 to 50.0 (Mean ± SD: 4.5 ± 2.8) in aggregate for stations with non-zero values, but were highest from July to September for bluefin tuna; June to September for blue shark; July, August, and October for shortfin mako; and July and August for yellowfin tuna (Tables 8a – h).

Movements

Tagged HMS exhibited extensive movements throughout the WEA, both from release locations into the receiver array and between individual stations within the receiver array. In many instances, individuals were first detected by receivers that were closest to the tagging location. However, some individuals were first detected on more distant receivers (on the other side of the array) weeks to months after release, indicating that they moved through the array undetected or traversed around the periphery of the array before arriving at the receiver.

Bluefin tuna

In 2022, bluefin tuna (n = 11) exhibited a sparse but expansive network across 49 receivers (nodes) and eight different lease areas (Tables 9, 11a; Figure 7a). Stations within SouthCoast Wind appeared to be an area of concentrated activity with the highest eigenvector centrality (EC) of the network occurring at MFW_06 (Table 11a; Figure 8b). Nodes within Sunrise Wind, New England Wind, and Beacon Wind exhibited degree centrality (DC) and strength (S) values in the 90th percentile (Table 9; Figures 8a, 8c). In 2023, the bluefin tuna network included more than three times as many individuals (n = 38), was nearly tripled in density (0.14), and expanded to all 67 nodes included in the analysis (Table 9). Nodes within Revolution Wind, South Fork Wind, and Sunrise Wind exhibited DC, S, and EC values in the 90th percentile (Table 11a).

Median distributions of all metrics were higher in 2023 (n = 67) than in 2022 (n = 49) (Figure 9). The Brown-Forsythe test also confirmed that variance distribution significantly differed in DC (F = 35.008, p < 0.001), S (F = 31.247, p = <0.001), and EC (F = 5.457, p = 0.021) between years (Table 12). The Wilcoxon Rank-Sum test confirmed significant differences in the overall distribution of DC ($W = 0$, $n_1 = 49$, $n_2 = 67$, $p < 0.001$), S ($W = 1$, $n_1 = 49$, $n_2 = 67$, $p < 0.001$), and EC ($W = 670.5$, $n_1 = 49$, $n_2 = 67$, $p < 0.001$) between years, with higher median values observed consistently in 2023 than in 2022.

Blue shark

The blue shark network in 2022 was comprised of 45 individuals and included every node (n = 67; Table 9). Activity was highest in Vineyard Wind 1, where at least 21 individual sharks visited and yielded high S values indicative of repeated movements by several animals (Table 11b; Figure 8f). Four of the seven EC scores in the 90th percentile occurred in Vineyard Wind 1, with station 501_04 having the highest EC value (100.00). (Table 11b; Figure 8e). In 2023, the network was constructed from fewer detected animals (n = 16) and had a lower network density (0.05) involving 58 of the 67 available nodes (Table 9). Vineyard Wind 1 nodes still retained high activity, with stations 501_01 and 501_04 exhibiting DC, S, and EC values in the 90th percentile (Table 11b; Figures 8d, 8e, 8f). Station BW_02 also scored highly across all metrics likely due to its proximity and connectivity to the nodes in Vineyard Wind 1 (Figures 7b, 8e).

Boxplots showed higher median distribution of degree centrality and strength in 2022 (n = 67) than in 2023 (n = 58), but lower median EC (Figure 9). Distribution of variance for all metrics were found to be significantly different between years via the Brown-Forsythe test (Table 12). Wilcoxon Rank-Sum results confirmed distribution of DC (W = 3,706.5, n_1 = 67, n_2 = 58, p < 0.001), S (W = 3,692.5, n_1 = 67, n_2 = 58, p < 0.001), and EC (W = 1,389.5, n_1 = 67, n_2 = 58, p < 0.001) were significantly different between 2022 and 2023 (Table 12).

Shortfin mako

Shortfin makos (n=13) maintained a large, but low-density (0.04) network involving 57 nodes in 2022 (Table 9). Three nodes in the Sunrise Wind lease (SRW_05, 07, 09) and two nodes in Revolution Wind (REV_12, 16) exhibited high DC, S, and EC scores in the 90th percentile (Table 11c; Figures 8g, 8i). In 2023, the network included twice as many individuals detected (n = 26) and more nodes (n = 61), though the density remained low (0.06; Table 9). Activity was centered in the same general location (as 2022) and all DC, S, and EC scores in the 90th percentile occurred at nodes within Revolution, South Fork, or Sunrise Wind (Table 11c; Figures 8g, 8h, 8i). This concentration of activity is evidenced by large edges representing movements of multiple individuals between nodes in Sunrise Wind and Revolution Wind (Figure 7c).

Median metric values were slightly higher in 2023 than in 2022, with the largest difference evident in EC (Figure 9). The Brown-Forsythe test revealed that the variance distribution was significantly different between years for DC and S, but not EC (Table 12). The Wilcoxon Rank-Sum test found significant differences between years for DC (W = 982, n_1 = 57, n_2 = 61, p < 0.001), S (W = 995.1, n_1 = 51, n_2 = 61, p < 0.001), and EC (W = 1,088, n_1 = 57, n_2 = 61, p < 0.001) (Table 12).

Yellowfin tuna

Yellowfin tuna formed the smallest network (density = 0.17) of the four major species in 2022, as 7 individuals were detected across 9 nodes in the Beacon Wind, SouthCoast Wind, and Vineyard Northeast lease areas (Tables 9, 11d; Figure 7d). The highest number of fish detected (n = 2) in addition to the highest degree centrality (DC = 2) and strength (S = 2) values were recorded at station 522_10 (Table 11d; Figures 7d, 8j, 8l). In 2023, the network comprised movements of ten individuals and expanded more than four-fold (n = 38 nodes), with a density of 0.08 (Table 9). Presence and movements also expanded to include all lease areas except South Fork, with stations in Beacon Wind and SouthCoast Wind comprising all metric values in the 90th percentile (Table 11d; Figure 7d, 8k).

Median values of DC and S were higher in 2023 than in 2022, but median EC was higher in 2022 than in 2023 (Figure 9). Brown-Forsythe tests found significantly different distributions of variance in DC and S, but not EC (Table 12). The Wilcoxon Rank-Sum test found significant differences in distribution of DC ($W = 31.5$ $n_1 = 9$, $n_2 = 38$, $p < 0.001$) and S ($W = 31.5$, $n_1 = 9$, $n_2 = 38$, $p < 0.001$), but not EC ($W = 144$, $n_1 = 9$, $n_2 = 38$, $p = 0.473$; Table 12).

<u>Depth distribution</u>

Swimming depth was characterized based on detection data obtained for blue shark (n = 5 individuals), bluefin tuna (n = 25 individuals), dusky shark (n = 1), shortfin mako (n = 2), and yellowfin tuna (n = 9). Tagged individuals across all species were detected when swimming at depths of 0 (the surface) down to 72 meters, with 86.4% of all depth observations occurring shallower than 30 meters (Figure 10). Bluefin and yellowfin tuna were detected most frequently when swimming at depths of <10 meters, while blue and shortfin mako sharks were detected by far the most frequently when swimming at the surface (0 to 2 meters depth). The single detected dusky shark was detected most frequently between the depths of 6 to 16 meters.

<u>Environmental conditions and correlates</u>

Tagged HMS were detected over a range of environmental conditions that are typically evident in SNE during the summer and fall (Table 13). Since the depth of the animal (in the water column) could not be determined at the time of acoustic detection, it was not possible to assign an exact temperature to each record. Thus, bottom and sea surface temperatures place bounds on the conditions in which HMS were observed in the study area. Density plots (Figure 11) revealed that HMS were typically observed in bottom temperatures from 9 to 17 °C. These species were also observed most frequently in waters with SSTs ranging from 15 to 25 °C and chlorophyll a concentrations ranging from 0.3 to 2.1 mg ml^{-1}. Most species were observed frequently in heavily stratified waters (surface warmer than the bottom) except for common thresher sharks, which were most common in thermally uniform waters.

Bottom water temperature recorded hourly at each receiver station demonstrated typical seasonal trends evident in SNE (Table 14; Figure 12). The highest bottom temperatures in each year occurred from the beginning of September to the end of November. Thermal stratification was highest in mid-summer and was positive (i.e., surface water warmer than the bottom) at nearly all leases until the end of September, after which reverse stratification (i.e., bottom warmer than the surface) became evident in several leases (Figure 13). Average noise (mV) was variable by lease throughout each year of the study but appeared to show concentrations from June through August in 2022 and August through October in 2023 (Table 14; Figure 14).

<u>*Other transmitter data collected (Objective 4)*</u>

After removal of detections from SMAST receivers, a total of 888,205 detections were recorded for 930 unique transmitters not deployed by this project, including 467 in 2022 (215,459 detections) and 671 in 2023 (672,746 detections); 222 transmitters were detected in both 2022 and 2023. Detections occurred in every calendar month and peaked dramatically from June through August before declining from fall through spring. When permitted, these data have been shared through ACT/MATOS.

Synthesis and conclusions

The data presented in this report constitute the beginning of a regional investigation into the effects of offshore wind activity on the presence, persistence, and movements of HMS in the WEA. To this end, this report summarizes the spatiotemporal distributions and characteristics of HMS (blue shark, bluefin tuna, common thresher shark, dusky shark, little tunny, sandbar shark, shortfin mako, smooth hammerhead, spinner shark, and yellowfin tuna) tagged and detected in the first two years of the regional study (i.e., when receiver coverage was achieved throughout all lease areas in SNE). Focus was placed on bluefin tuna, blue shark, shortfin mako, and yellowfin tuna as these species composed the largest number of individuals tagged during 2022 and 2023. Additional data collected in 2024 will be incorporated in future versions of this regional report and ongoing monitoring will continue pending funding.

Seasonal distributions of HMS across both 2022 and 2023 corroborate the anticipated habitation of the WEA in warmer months (June to October) and the gradual departure of animals with progression towards cooler months (November to January). Among species for which there were sufficient data to examine distributions, blue sharks, bluefin tuna, and shortfin mako were documented as the earliest to arrive in June, which is similar to findings from previous efforts following the MACEC project tags in the WEA (Gervelis and Kneebone, 2022); observations for dusky shark and yellowfin tuna suggest appearance later in the summer in July. Bluefin tuna were recorded as the last remaining species in January and persisted much longer than blue sharks, common thresher sharks, and shortfin mako, which were all last detected in November. Lastly, although the array was greatly reduced for the entirety of the winter, the scarcity of detections at those receivers that did remain out during the winter months substantiates universal emigration from the region and reimmigration circa June.

Numerous tagged individuals returned to the WEA and were detected in years subsequent to tagging thereby implying the importance of SNE to HMS. Considering acoustic detection data reported herein (for 2022 and 2023) as well as data collected in 2020 and 2021 by pilot monitoring studies funded by the MACEC and specific developers, 63 tagged individuals returned to the receiver array in years after tagging, including 43 individuals (22 blue shark, 9 bluefin tuna, 4 dusky shark, 6 shortfin mako, and 2 yellowfin tuna) that were detected over two years, 11 individuals (1 blue shark, 6 bluefin tuna, 1 dusky shark, and 3 shortfin mako) that were detected over three years, and one blue shark that was detected for four consecutive years. Accounting for potential losses of tagged animals due to external tag shedding, natural mortality, and fishing mortality, the consistent, repeated annual detection of many individuals is notable, particularly given that several of the species monitored (e.g., bluefin tuna, yellowfin tuna, shortfin mako, blue shark) occupy vast regions of the Atlantic Ocean and undertake trans-oceanic seasonal migrations (Vaudo et al. 2017; Kohler and Turner 2019; Galuardi and Lutcavage 2012).

Residency index scores varied across species, months, years, and receiver stations indicating that HMS presence and persistence in WEA is impacted by many factors. Lower residency index values were generally evident in June and October/November concomitant with the arrival and departure of HMS from the region, respectively, while higher residency index scores were generally prevalent during the peak of summer in July, August, and September. In addition to this temporal variation, there is some evidence that residency can be site-specific within the confines of each lease. In both 2022 and 2023, yellowfin tuna exhibited concentrated residency and movements in the southernmost extent of the WEA, likely due to the existence of environmental conditions that were more conducive to their preferences relative to those conditions evident in the northern portions of the WEA. In contrast, species such as blue shark, bluefin tuna, dusky shark, and shortfin mako generally exhibited residency and movements throughout each lease area and did not show distinct areas of habitation within enclaves of the WEA. Additional years of data are required to better understand spatiotemporal patterns in HMS residency throughout the WEA/SNE region.

Movements within and around the WEA illustrate the extent of the spatiotemporal scale that HMS traverse across SNE. Tagging events often necessarily occurred outside of the WEA/acoustic receiver array due to the availability of the target species at the time of the sampling trip. However, many fish tagged outside the confines of the WEA were detected from days to months post-release, highlighting their ability to travel protracted distances at varying rates as well as the overall connectivity of areas both inside and outside of the WEA in the SNE region. Tagged HMS collectively ranged across all monitored areas in both 2022 and 2023, and networks created for the four most tagged species (bluefin tuna, blue shark, shortfin mako, yellowfin tuna) revealed patterns in species-specific use of the WEA. For example, in 2022 bluefin tuna activity was concentrated in the southeastern portion of the WEA, but more widespread use of the entire WEA occurred in 2023. Yellowfin tuna networks similarly expanded to involve more nodes in the northwestern portion of the WEA in 2023 but were primarily focused in the southeastern portion of the WEA in both years. Blue shark and shortfin mako networks were relatively consistent between years, with the highest activity occurring in the vicinity of Vineyard Wind 1 and eastern Sunrise and Revolution, respectively, in each year. Interannual differences in species' networks were also highly influenced by the number of individuals monitored in each year, as exemplified by the large difference in network density for bluefin tuna between 2022 and 2023. Efforts were made to evenly distribute transmitters across species in each year, but the availability of specific species varied, sometimes greatly, between years. For example, in 2022 extensive sampling efforts resulted in the tagging of only five bluefin tuna, two of which were tagged east of Cape Cod, and sparse networks due to the lack of activity in the WEA. In contrast, seven times more bluefin were tagged in 2023, which resulted in a more extensive and denser network. Receiver loss also adversely impacted networks, especially when lost receivers were well-connected to others or frequently visited by target species. For example, the receiver at SRW_11 experienced a malfunction in 2022 that resulted in the complete loss of detection data that year, and SRW_11 was not included in either the 2022 or 2023 network analysis to maintain a consistent comparison between years. However, when SRW_11 was included in exploratory 2023 network analyses, the station was found to be an important node for bluefin tuna, blue sharks, and shortfin makos. As additional years of data become available, receivers lost in only one year may not need to be excluded thereby yielding a more comprehensive assessment of animal movements between pre- and post-construction periods.

Although residence durations were often brief (averaging 72 minutes), HMS undoubtedly spent longer periods of time in the lease area than were documented by acoustic receivers. During peak periods of monitoring when all acoustic receivers were deployed in the array, <2% of the total area of the WEA was being monitored for active transmitters, assuming an average receiver detection range of 300 m (0.3 km) (based on range testing). Accordingly, the duration of residence events reported herein should be viewed as minimums, with actual residence durations of individual HMS in the WEA likely being far greater than what was monitored by acoustic receivers.

Tagged HMS occurred in the WEA over a range of temperatures and chlorophyll concentrations, with species-specific density peaks providing insight into their respective environmental preferences. These associations are not unexpected given previous correlations of HMS movements along distinct regimes of temperature and primary productivity (Queiroz et al., 2012; Vaudo et al., 2017; Walli et al., 2009). Further modeling efforts (e.g., generalized additive models, species distribution models) of species with sufficient sample sizes and detection data will be undertaken in future reports to allow further determination of the relative effect and importance of each of these environmental variables and facilitate predictions about species presence. Such endeavors are critical due to the breadth of conditions typically encountered from spring through fall across the geographical expanse of the WEA. Furthermore, the inherently dynamic characteristics of offshore bodies of water connotes possibilities for ephemeral, fine-scale differences along areas as small as individual leases that could very well explain any interannual variability seen in the distribution and movements of tagged HMS in the WEA, especially given that overarching seasonal trends in bottom water temperature and stratification were largely mirrored between years but with fluctuations of as much as several degrees Celsius in certain leases at corresponding timepoints throughout the year. Accordingly, thorough *in situ* monitoring by the acoustic receiver array and subsequent further analysis of the environmental data will be essential in distinguishing the impacts of upcoming wind development from the influence of background environmental conditions. Thus, future implementation of environmental modeling in the context of ongoing offshore wind construction and operation remains a priority.

Receivers that were caught and/or lost presumably because of entanglement with fishing gear posed complications over the course of the study. Locations of the VR2AR moorings caught in both years indicate that commercial fishing activity is a risk to deployed receivers throughout the coverage of the WEA, particularly in Vineyard Northeast, Beacon Wind, and SouthCoast Wind. Relocation of receivers to ‘hangs’ in 2022 following extensive receiver loss in 2021 markedly reduced receiver loss but did not eliminate interactions altogether. While receiver loss may be difficult or even impossible to eliminate completely (due to the intrinsic uncertainty involved in working in an area with multiple competing interests from the fishing, energy, and scientific communities), the improved efficacy of the current receiver network, especially given the relatively minimal loss experienced in 2023, should allow for the collection of more consistent and comparable data in future years. Moving forward, receiver stations BW_01, MFW_01, 522_02, 522_05, and 522_07 will not be deployed due to perpetual interactions or loss across two or more monitoring seasons and the implications of missing years of data on spatial analysis.

Acoustic receiver range testing at two stations (501_02, REV_18) revealed consistent trends indicative of a 50% detection range at a radius of 200 – 400 m from acoustic receivers and greater detection efficiency when transmitters are above the thermocline. This overall detection range is smaller than what has been documented for V16H transmitters in similar oceanic environments (e.g., comparable depths). Interestingly, detection range was greater for transmitters positioned above the thermocline and nearer to the surface, a result that is unexpected given that such transition layers may interfere with the propagation of pulse trains to the VR2AR receivers moored (below the thermocline) on the bottom. While previous studies have demonstrated that thermal stratification reduces detection range, with more severe reductions evident with increasing strength and depth of stratification (Huveneers et al. 2016), increased detection efficiency has been documented when acoustic transmissions propagate on the same side of the thermocline as the receiver (O'Brien and Secor, 2021). In both 2022 and 2023, strong thermal stratification existed at the majority of receiver stations. Thus, it is unknown why detection range was greater for transmitters placed above rather than below the thermocline; the opposite result is expected given the results of O'Brien and Secor (2021). Observations at two spatially disparate stations in the northeast and northwest quadrants of the WEA further suggest that this phenomenon may not be localized and that other physical processes may be pervasive across the WEA that enable its occurrence. Additional testing is required to determine if this pattern persists at additional locations and to better understand the overall dynamics of acoustic receiver performance in the WEA.

Next steps

Data from acoustic monitoring performed in 2024 will be compiled, analyzed in accordance with the methods outlined in this report, and synthesized into a forthcoming report that will follow the format presented herein. Additional analyses focused on time periods coincident with pre-construction, construction, and operations activities will be explored as appropriate. Acoustic telemetry monitoring in the WEA will continue in 2025 in accordance with individual developer contracts; developer participation in the DSA will be re-evaluated if monitoring efforts are curtailed in specific lease areas.

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Table 1a – Metadata for acoustic receivers deployed in the Revolution Wind (OCS-A 0486) lease area during 2022 and 2023. In 2022, station REV_18 was maintained by the University of Massachusetts-Dartmouth School for Marine Science & Technology. REV = Revolution Wind.

Station	2022							2023						
	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed
REV_01	41.28	-71.13	38	VR2AR	5/14/22	12/31/22	232	41.28	-71.13	38	VR2AR	1/1/23	5/3/23	123
								41.28	-71.13	38	VR2AR	5/31/23	12/31/23	215
REV_02	41.22	-71.15	35	VR2AR	5/14/22	12/31/22	232	41.22	-71.15	36	VR2AR	1/1/23	5/3/23	123
								41.22	-71.15	36	VR2AR	5/31/23	12/31/23	215
REV_03	41.21	-71.12	36	VR2AR	5/14/22	12/31/22	232	41.21	-71.12	40	VR2AR	1/1/23	5/3/23	123
								41.21	-71.12	40	VR2AR	5/31/23	12/31/23	215
REV_04	41.21	-71.07	34	VR2AR	5/14/22	12/31/22	232	41.21	-71.07	35	VR2AR	1/1/23	5/3/23	123
								41.21	-71.07	35	VR2AR	5/31/23	12/31/23	215
REV_05	41.20	-71.20	40	VR2AR	5/14/22	12/31/22	232	41.20	-71.20	40	VR2AR	1/1/23	5/3/23	123
								41.20	-71.20	40	VR2AR	5/31/23	12/31/23	215
REV_06	41.19	-71.15	37	VR2AR	5/14/22	12/31/22	232	41.19	-71.15	39	VR2AR	1/1/23	5/3/23	123
								41.19	-71.15	39	VR2AR	5/31/23	12/31/23	215
REV_07	41.16	-71.24	40	VR2AR	1/1/22	12/31/22	365	41.16	-71.24	42	VR2AR	1/1/23	5/4/23	124
								41.16	-71.24	42	VR2AR	5/31/23	12/31/23	215
REV_08	41.16	-71.17	39	VR2AR	1/1/22	12/31/22	365	41.16	-71.17	39	VR2AR	1/1/23	5/4/23	124
								41.16	-71.17	39	VR2AR	5/31/23	12/31/23	215
REV_09	41.16	-71.12	36	VR2AR	5/14/22	12/31/22	232	41.16	-71.12	37	VR2AR	1/1/23	5/4/23	124
								41.16	-71.12	37	VR2AR	5/31/23	12/31/23	215
REV_10	41.11	-71.25	35	VR2AR	1/1/22	12/31/22	365	41.11	-71.25	35	VR2AR	1/1/23	5/4/23	124
								41.11	-71.25	35	VR2AR	5/31/23	12/31/23	215
REV_11	41.10	-71.20	34	VR2AR	5/14/22	12/31/22	232	41.10	-71.20	36	VR2AR	1/1/23	5/4/23	124
								41.10	-71.20	36	VR2AR	5/31/23	12/31/23	215
REV_12	41.16	-71.00	34	VR2AR	5/14/22	12/31/22	232	41.16	-71.00	34	VR2AR	1/1/23	5/3/23	123
								41.16	-71.00	34	VR2AR	5/31/23	12/31/23	215
REV_13	41.12	-71.04	34	VR2AR	5/14/22	12/31/22	232	41.12	-71.04	34	VR2AR	1/1/23	5/3/23	123
								41.12	-71.04	34	VR2AR	5/31/23	12/31/23	215
REV_14	41.13	-70.97	30	VR2AR	5/14/22	12/31/22	232	41.13	-70.97	30	VR2AR	1/1/23	5/3/23	123
								41.13	-70.97	30	VR2AR	5/31/23	11/20/23	174
REV_15	41.12	-70.89	36	VR2AR	5/14/22	12/31/22	232	41.12	-70.89	37	VR2AR	1/1/23	5/3/23	123
								41.12	-70.89	37	VR2AR	5/31/23	12/31/23	215
REV_16	41.08	-71.02	35	VR2AR	1/1/22	12/31/22	365	41.08	-71.02	37	VR2AR	1/1/23	5/3/23	123
								41.08	-71.02	37	VR2AR	5/31/23	12/31/23	215
REV_17	41.09	-70.96	36	VR2AR	5/14/22	12/31/22	232	41.09	-70.96	37	VR2AR	1/1/23	5/3/23	123
								41.09	-70.96	37	VR2AR	5/31/23	12/31/23	215
REV_18	41.14	-71.11	31	VR2Tx	1/1/22	12/27/22	361	41.13	-71.11	31	VR2AR	5/31/23	12/31/23	215

Table 1b – Metadata for acoustic receivers deployed in the South Fork Wind (OCS-A 0517) lease area during 2022 and 2023. In 2022, station SF_01 was maintained by the University of Massachusetts-Dartmouth School for Marine Science & Technology. SF = South Fork Wind.

Station	2022							2023						
	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed
SF_01	41.08	-71.17	35	VR2Tx	1/1/22	11/21/22	325	41.09	-71.18	34	VR2AR	5/31/23	9/5/23	98
								41.09	-71.18	34	VR2AR	9/21/23	12/31/23	102
SF_02	41.09	-71.09	33	VR2AR	1/1/22	12/31/22	365	41.09	-71.09	35	VR2AR	1/1/23	5/4/23	124
								41.09	-71.09	35	VR2AR	5/31/23	12/31/23	215

Table 1c – Metadata for acoustic receivers deployed in the Sunrise Wind (OCS-A 0487) lease area during 2022 and 2023. Dashes denote that the receiver was missing at the end of the field season. *NA* entries denote stations that were not carried over from the previous year. In 2022, station SRW_10 was maintained by the University of Massachusetts-Dartmouth School for Marine Science & Technology. SRW = Sunrise Wind.

Station	2022							2023						
	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed
SRW_01	40.96	-71.26	53	VR2AR	6/1/22	12/31/22	214	40.96	-71.26	53	VR2AR	1/1/23	5/4/23	124
								40.96	-71.26	53	VR2AR	5/31/23	12/31/23	215
SRW_02	40.98	-71.18	52	VR2AR	6/1/22	12/31/22	214	40.98	-71.18	53	VR2AR	1/1/23	5/4/23	124
								40.98	-71.18	53	VR2AR	5/31/23	12/31/23	215
SRW_03	40.97	-71.13	49	VR2AR	6/1/22	12/31/22	214	40.97	-71.13	48	VR2AR	1/1/23	5/4/23	124
								40.97	-71.13	51	VR2AR	5/31/23	12/31/23	215
SRW_04	41.00	-71.00	46	VR2AR	6/1/22	12/31/22	214	41.00	-71.00	46	VR2AR	1/1/23	5/3/23	123
								41.00	-71.00	46	VR2AR	5/31/23	11/20/23	174
SRW_05	41.01	-70.94	45	VR2AR	6/1/22	12/31/22	214	41.01	-70.94	45	VR2AR	1/1/23	5/3/23	123
								41.01	-70.94	45	VR2AR	5/31/23	12/31/23	215
SRW_06	40.99	-70.91	49	VR2AR	6/1/22	12/31/22	214	40.99	-70.91	51	VR2AR	1/1/23	5/3/23	123
								40.99	-70.91	51	VR2AR	5/31/23	12/31/23	215
SRW_07	41.00	-70.87	47	VR2AR	6/1/22	12/31/22	214	41.00	-70.87	48	VR2AR	1/1/23	5/3/23	123
								41.00	-70.87	48	VR2AR	5/31/23	11/21/23	175
SRW_08	41.00	-70.82	48	VR2AR	6/1/22	12/31/22	214	41.00	-70.82	49	VR2AR	1/1/23	5/3/23	123
								41.00	-70.82	49	VR2AR	5/31/23	12/31/23	215
SRW_09	40.94	-70.96	50	VR2AR	6/1/22	12/31/22	214	40.94	-70.96	50	VR2AR	1/1/23	5/3/23	123
								40.94	-70.96	50	VR2AR	5/31/23	11/21/23	175
SRW_10	41.03	-71.20	46	VR2Tx	1/1/22	11/21/22	325	41.03	-71.22	48	VR2AR	5/31/23	12/31/23	215
SRW_11	40.89	-71.01	58	VR2AR	6/1/22	12/31/22	214	40.89	-71.01	58	VR2AR	1/1/23	5/31/23	151
								40.89	-71.01	58	VR2AR	5/31/23	12/31/23	215
SRW_12	40.91	-70.91	51	VR2AR	6/1/22	12/31/22	214	40.91	-70.91	51	VR2AR	1/1/23	5/31/23	151
								40.91	-70.91	53	VR2AR	5/31/23	12/31/23	215
SRW_13	40.90	-70.85	54	VR2AR	6/1/22	-	-	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*

Table 1d – Metadata for acoustic receivers deployed in the Vineyard Wind 1 (OCS-A 0501) lease area during 2022 and 2023.

Station	2022							2023						
	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed
501_01	41.12	-70.50	38	VR2AR	6/3/22	12/2/22	183	41.12	-70.50	37	VR2AR	5/12/23	12/2/23	205
501_02	41.09	-70.50	40	VR2AR	6/3/22	12/2/22	183	41.09	-70.50	40	VR2AR	5/12/23	12/2/23	205
501_03	41.01	-70.40	40	VR2AR	6/3/22	12/2/22	183	41.01	-70.40	40	VR2AR	5/12/23	12/2/23	205
501_04	41.00	-70.45	42	VR2AR	6/3/22	12/2/22	183	41.00	-70.45	42	VR2AR	5/12/23	12/2/23	205

Table 1e – Metadata for acoustic receivers deployed in the New England Wind (OCS-A 0534) lease area during 2022 and 2023.

Station	2022							2023						
	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed
534_01	40.98	-70.60	48	VR2AR	6/3/22	12/2/22	183	40.98	-70.60	48	VR2AR	5/12/23	12/2/23	205
534_02	40.91	-70.63	50	VR2AR	6/3/22	12/2/22	183	40.91	-70.63	50	VR2AR	5/12/23	12/2/23	205
534_03	40.85	-70.80	53	VR2AR	6/3/22	12/2/22	183	40.85	-70.80	53	VR2AR	5/12/23	12/2/23	205
534_04	40.91	-70.56	49	VR2AR	6/3/22	12/2/22	183	40.91	-70.56	49	VR2AR	5/12/23	12/2/23	205
534_05	40.86	-70.62	52	VR2AR	6/3/22	12/2/22	183	40.86	-70.62	52	VR2AR	5/12/23	12/2/23	205
534_06	40.85	-70.67	54	VR2AR	6/3/22	12/2/22	183	40.85	-70.67	54	VR2AR	5/12/23	12/2/23	205

Table 1f – Metadata for acoustic receivers deployed in the Beacon Wind (OCS-A 0520) lease area during 2022 and 2023. *NA* entries denote stations were not carried over from the previous year. BW = Beacon Wind

Station	2022							2023						
	Latitude	**Longitude**	**Depth (m)**	**Receiver type**	**Deploy start**	**Deploy end**	**Days deployed**	**Latitude**	**Longitude**	**Depth (m)**	**Receiver type**	**Deploy start**	**Deploy end**	**Days deployed**
BW_01	40.97	-70.38	41	VR2AR	6/3/22	8/15/22	74	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
BW_02	40.93	-70.43	44	VR2AR	6/3/22	12/5/22	186	40.93	-70.43	44	VR2AR	5/12/23	12/2/23	205
BW_03	40.79	-70.59	55	VR2AR	6/3/22	12/5/22	186	40.79	-70.59	55	VR2AR	5/12/23	12/2/23	205
BW_04	40.76	-70.66	58	VR2AR	6/3/22	12/5/22	186	40.76	-70.66	58	VR2AR	5/12/23	12/2/23	205
BW_05	40.67	-70.66	60	VR2AR	6/3/22	12/5/22	186	40.67	-70.66	60	VR2AR	5/12/23	12/2/23	205
BW_06	40.73	-70.57	54	VR2AR	6/3/22	6/14/22	12	40.74	-70.58	54	VR2AR	5/12/23	12/2/23	205
	40.74	-70.58	55	VR2AR	6/25/22	12/5/22	164							
BW_07	40.79	-70.52	53	VR2AR	6/3/22	12/5/22	186	40.79	-70.52	52	VR2AR	5/12/23	12/2/23	205
BW_08	40.83	-70.49	53	VR2AR	6/3/22	12/5/22	186	40.83	-70.49	53	VR2AR	5/12/23	12/2/23	205
BW_09	40.81	-70.45	53	VR2AR	6/3/22	12/5/22	186	40.81	-70.45	53	VR2AR	5/12/23	12/2/23	205
BW_10	40.89	-70.41	46	VR2AR	6/3/22	12/5/22	186	40.89	-70.41	47	VR2AR	5/12/23	12/2/23	205

Table 1g – Metadata for acoustic receivers deployed in the SouthCoast Wind (OCS-A 0521) lease area during 2022 and 2023. Dashes denote that the receiver was missing at the end of the field season. MFW = Mayflower Wind (station names were derived from the previous name designated to OCS-A 0521).

Station	2022							2023						
	Latitude	**Longitude**	**Depth (m)**	**Receiver type**	**Deploy start**	**Deploy end**	**Days deployed**	**Latitude**	**Longitude**	**Depth (m)**	**Receiver type**	**Deploy start**	**Deploy end**	**Days deployed**
MFW_01	40.90	-70.27	41	VR2AR	6/6/22	9/17/22	104	40.90	-70.27	40	VR2AR	6/1/23	10/4/23	126
MFW_02	40.84	-70.35	50	VR2AR	6/6/22	-	-	40.84	-70.35	48	VR2AR	6/1/23	12/2/23	185
MFW_03	40.82	-70.42	48	VR2AR	6/6/22	12/5/22	183	40.82	-70.42	49	VR2AR	6/1/23	12/2/23	185
MFW_04	40.79	-70.43	49	VR2AR	6/6/22	12/5/22	183	40.79	-70.43	50	VR2AR	6/1/23	12/2/23	185
MFW_05	40.70	-70.51	56	VR2AR	6/6/22	12/7/22	185	40.70	-70.51	55	VR2AR	6/1/23	12/2/23	185
MFW_06	40.63	-70.57	61	VR2AR	6/6/22	12/7/22	185	40.63	-70.57	60	VR2AR	6/1/23	12/2/23	185
MFW_07	40.65	-70.47	57	VR2AR	6/6/22	12/7/22	185	40.65	-70.47	58	VR2AR	6/1/23	12/2/23	185
MFW_08	40.70	-70.40	49	VR2AR	6/6/22	12/7/22	185	40.70	-70.40	49	VR2AR	6/1/23	12/2/23	185
MFW_09	40.74	-70.33	47	VR2AR	6/6/22	12/7/22	185	40.74	-70.33	48	VR2AR	6/1/23	12/2/23	185
MFW_10	40.79	-70.27	42	VR2AR	6/6/22	12/7/22	185	40.79	-70.27	43	VR2AR	6/1/23	12/2/23	185

Table 1h – Metadata for acoustic receivers deployed in the Vineyard Northeast (OCS-A 0522) lease area during 2022 and 2023. Dashes denote that the receiver was missing at the end of the field season.

Station	2022							2023						
	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed	Latitude	Longitude	Depth (m)	Receiver type	Deploy start	Deploy end	Days deployed
522_01	40.78	-70.22	43	VR2AR	6/6/22	12/7/22	185	40.78	-70.22	42	VR2AR	6/1/23	12/2/23	185
522_02	40.72	-70.29	48	VR2AR	6/6/22	-	-	40.72	-70.29	47	VR2AR	6/1/23	12/2/23	185
522_03	40.73	-70.21	44	VR2AR	6/6/22	12/7/22	185	40.73	-70.21	43	VR2AR	6/1/23	12/2/23	185
522_04	40.72	-70.11	41	VR2AR	6/6/22	12/7/22	185	40.72	-70.11	41	VR2AR	6/1/23	12/2/23	185
522_05	40.71	-70.05	43	VR2AR	6/6/22	-	-	40.71	-70.05	43	VR2AR	6/1/23	-	-
522_06	40.66	-70.05	48	VR2AR	6/6/22	12/7/22	185	40.66	-70.05	48	VR2AR	6/1/23	12/2/23	185
522_07	40.67	-70.12	45	VR2AR	6/6/22	10/22/22	139	40.67	-70.12	46	VR2AR	6/1/23	-	-
522_08	40.66	-70.22	48	VR2AR	6/6/22	12/7/22	185	40.66	-70.22	47	VR2AR	6/1/23	12/2/23	185
522_09	40.66	-70.28	49	VR2AR	6/6/22	12/7/22	185	40.66	-70.28	49	VR2AR	6/1/23	12/2/23	185
522_10	40.69	-70.37	51	VR2AR	6/6/22	10/17/22	134	40.69	-70.37	51	VR2AR	6/1/23	12/2/23	185
522_11	40.61	-70.42	60	VR2AR	6/6/22	12/7/22	185	40.61	-70.42	60	VR2AR	6/1/23	12/2/23	185
522_12	40.61	-70.32	57	VR2AR	6/6/22	12/7/22	185	40.61	-70.32	57	VR2AR	6/1/23	12/2/23	185

Table 2 – Results of acoustic receiver range tests performed at stations 501_02 and REV_18 in 2023. Transmitters with a fixed, 60 s nominal delay were moored at varying distances from the receiver and left in place for 1 hour (60 minutes). Transmitters were deployed at around 20 feet (7 meters) from the surface and around 20 feet (7 meters) off the bottom to examine detection range above and below the thermocline. Percentages represent the number of detections that were logged relative to the 60 total transmissions that each transmitter emitted over the 60 minutes it was deployed at each distance.

Distance (m)	**501_02**		**REV_18**	
	Surface	**Bottom**	**Surface**	**Bottom**
100	-	-	58.3%	65.0%
250	41.7%	36.7%	61.7%	63.3%
500	38.3%	33.3%	43.3%	20.0%
750	33.3%	5.0%	0.0%	0.0%
1000	0.0%	0.0%	-	-

Table 3 – Metadata from the 259 highly migratory species (HMS) that were tagged from 2020 to 2023. FL = fork length.

Species	# Tagged	Sex			Size	Tag placement	
		Male	Female	Unknown	FL (cm)	External	Internal
Blue shark	86	80	6	0	120 - 259	78	8
Bluefin tuna	70	-	-	70	61 - 254	1	69
Common thresher shark	3	0	3	0	152 - 183	3	0
Dusky shark	12	4	7	1	100 - 183	9	3
Little tunny	1	-	-	1	72	0	1
Sandbar shark	3	2	1	0	122 - 152	3	0
Shortfin mako	50	11	23	16	85 - 244	37	13
Smooth hammerhead	1	0	1	0	183	1	0
Spinner shark	2	2	0	0	168 - 168	2	0
Yellowfin tuna	31	-	-	31	71 - 121	0	31

Table 4 – Summary of the number of transmitters that were deployed and/or detected for each species from 2020 to 2023. In the “Detected” columns, numbers outside parentheses represent the total number of transmitters detected in that year, and numbers in parentheses represent the number of detected individuals that were tagged in previous years. The single common thresher shark tagged in 2022 was confirmed as a post-release mortality.

Species	**2020**	**2021**	**2022**		**2023**		**Total**	
	Tagged	**Tagged**	**Tagged**	**Detected**	**Tagged**	**Detected**	**Tagged**	**Detected**
Blue shark	13	36	33	45(15)	4	16(12)	86	49(25)
Bluefin tuna	8	22	5	11(9)	35	39(10)	70	45(15)
Common thresher shark	0	0	1	-	2	2	3	2
Dusky shark	0	2	8	8(1)	2	7(5)	12	10(5)
Little tunny	0	0	0	-	1	1	1	1
Sandbar shark	0	2	1	1	0	0	3	1
Shortfin mako	8	6	8	13(6)	28	26(3)	50	36(8)
Smooth hammerhead	0	1	0	1(1)	0	0	1	1(1)
Spinner shark	0	0	2	2	0	0	2	2
Yellowfin tuna	0	0	12	7	19	12(4)	31	17(4)
Total	29	69	70	88(32)	91	103(34)	259	164(58)

Table 5 – Summary of the number of detections (Dtx), residences (Res), and unique transmitters (Tx) observed at each lease area by species and year. In the “Tx” columns, numbers outside parentheses represent the total number of transmitters detected in that year, and numbers in parentheses represent the number of detected individuals that were tagged in a previous year. Dashes denote that no tags were deployed and/or available for detection in the given year.

Lease	Blue shark						Bluefin tuna						Common thresher shark						Dusky shark						Little tunny					
	2022			2023			2022			2023			2022			2023			2022			2023			2022			2023		
	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx
Revolution Wind	3352	192	27	727	45	7	43	11	4	2032	290	22	-	-	-	114	9	2	439	23	5	183	17	5	-	-	-	0	0	0
South Fork Wind	165	14	9	46	3	3	2	2	2	206	35	13	-	-	-	0	0	0	46	3	2	0	0	0	-	-	-	0	0	0
Sunrise Wind	1321	111	28	436	35	9	43	14	4	1105	254	29	-	-	-	263	13	2	147	15	4	97	12	5	-	-	-	0	0	0
Vineyard Wind 1	2960	185	30	524	42	7	32	5	1	208	35	16	-	-	-	223	12	2	62	7	5	139	10	4	-	-	-	3	2	1
New England Wind	995	91	32	138	12	7	48	15	4	357	63	21	-	-	-	27	3	1	80	8	5	90	8	3	-	-	-	0	0	0
Beacon Wind	1815	127	31	271	20	8	100	18	6	784	105	26	-	-	-	127	8	2	203	15	5	324	20	5	-	-	-	0	0	0
SouthCoast Wind	1384	89	29	396	24	8	99	19	7	977	121	25	-	-	-	8	2	2	486	28	4	278	18	3	-	-	-	0	0	0
Vineyard Northeast	1465	119	29	279	19	8	63	15	8	1038	128	25	-	-	-	37	3	1	390	22	5	65	7	2	-	-	-	0	0	0
Total	13457	928	45(15)	2817	200	16(12)	430	99	11(9)	6707	1031	39(10)	-	-	-	799	50	2	1853	121	8(1)	1176	92	7(5)	-	-	-	3	2	1

Lease	Sandbar shark						Shortfin mako						Smooth hammerhead						Spinner shark						Yellowfin tuna					
	2022			2023			2022			2023			2022			2023			2022			2023			2022			2023		
	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx	Dtx	Res	Tx
Revolution Wind	23	2	1	0	0	0	263	29	6	1228	76	15	0	0	0	0	0	0	94	11	2	0	0	0	0	0	0	26	3	2
South Fork Wind	0	0	0	0	0	0	4	1	1	89	11	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sunrise Wind	65	4	1	0	0	0	218	31	7	718	72	17	6	2	1	0	0	0	46	4	1	0	0	0	0	0	0	68	9	6
Vineyard Wind 1	0	0	0	0	0	0	14	3	3	25	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81	6	2
New England Wind	0	0	0	0	0	0	99	12	6	180	20	11	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	147	13	6
Beacon Wind	142	11	1	0	0	0	211	18	5	131	17	10	0	0	0	0	0	0	9	1	1	0	0	0	47	4	4	312	39	9
SouthCoast Wind	210	10	1	0	0	0	160	15	7	253	20	9	0	0	0	0	0	0	0	0	0	0	0	0	10	1	1	242	33	6
Vineyard Northeast	104	5	1	0	0	0	244	25	8	146	20	10	3	1	1	0	0	0	0	0	0	0	0	0	120	8	4	117	13	4
Total	544	32	1	0	0	0	1213	134	13(6)	2770	239	26(3)	9	3	1(1)	0	0	0	150	17	2	0	0	0	177	13	7	993	116	12(4)

Table 6 – Summary of the number and duration of residences documented for each species in each year of the study. Tx = unique transmitters.

Species	Tx	Residences	Duration (minutes)			
			Minimum	Maximum	Mean	Standard deviation
2022						
Blue shark	45	928	1	2952	95	289
Bluefin tuna	11	99	2	1432	65	210
Common thresher shark	0	-	-	-	-	-
Dusky shark	8	121	1	1101	65	152
Sandbar shark	1	32	2	809	68	148
Shortfin mako	13	134	1	1258	48	145
Smooth hammerhead	1	3	2	5	4	2
Spinner shark	2	17	2	37	14	10
Yellowfin tuna	7	13	2	359	88	148
2023						
Blue shark	16	200	1	1931	77	246
Bluefin tuna	39	1031	1	1795	58	204
Common thresher shark	2	50	1	841	54	151
Dusky shark	7	92	1	1252	43	139
Little tunny	1	2	2	2	2	-
Sandbar shark	0	-	-	-	-	-
Shortfin mako	26	239	1	1487	70	207
Smooth hammerhead	0	-	-	-	-	-
Spinner shark	0	-	-	-	-	-
Yellowfin tuna	12	116	1	2994	86	322

Table 7 – Summary of the number of total detections, residence events, and transmitters detected by receiver station by year. Dashes denote instances when no data were collected because of receiver loss, malfunction, or removal from the receiver array.

Station	Detections		Residences		Transmitters detected	
	2022	2023	2022	2023	2022	2023
REV_01	180	145	10	17	6	11
REV_02	185	164	10	24	8	17
REV_03	235	237	21	26	14	14
REV_04	214	595	13	39	8	17
REV_05	422	119	21	14	11	12
REV_06	226	102	12	18	7	15
REV_07	286	107	22	17	16	15
REV_08	155	85	11	14	6	12
REV_09	246	159	15	18	9	14
REV_10	99	248	9	24	8	15
REV_11	109	139	9	16	7	11
REV_12	579	199	18	31	11	20
REV_13	210	370	13	30	12	17
REV_14	183	227	18	25	13	18
REV_15	356	162	22	19	17	15
REV_16	271	518	23	50	21	20
REV_17	239	395	16	38	13	25
REV_18	19	339	5	20	5	14
SF_01	100	143	11	15	9	10
SF_02	117	198	9	34	7	19
SRW_01	78	212	10	29	9	21
SRW_02	85	72	12	22	10	15
SRW_03	68	110	12	20	8	12
SRW_04	206	174	18	38	13	23
SRW_05	449	303	22	41	19	27
SRW_06	89	325	13	34	10	24
SRW_07	246	303	21	44	16	30
SRW_08	205	316	24	23	17	19
SRW_09	247	288	21	44	15	27
SRW_10	50	114	8	21	6	16
SRW_11	-	279	-	49	-	23
SRW_12	123	191	20	30	15	22
501_01	369	308	30	24	17	13
501_02	453	219	36	20	19	10
501_03	987	240	64	25	25	17
501_04	1259	436	70	41	24	24
534_01	287	124	29	16	25	11

534_02	239	205	21	17	16	15
534_03	149	145	14	24	11	20
534_04	257	191	24	23	17	19
534_05	167	141	18	24	13	20
534_06	124	133	21	15	14	12
BW_01	406	-	24	-	15	-
BW_02	388	248	31	24	17	20
BW_03	152	203	13	24	11	19
BW_04	209	111	14	12	12	10
BW_05	136	296	12	22	11	16
BW_06	89	190	12	24	6	17
BW_07	201	139	17	22	14	15
BW_08	360	257	21	22	17	17
BW_09	157	216	17	32	15	26
BW_10	429	289	33	27	17	18
MFW_01	344	262	24	12	19	9
MFW_02	-	319	-	26	-	19
MFW_03	247	248	20	25	12	18
MFW_04	311	220	16	30	11	23
MFW_05	152	179	11	21	10	17
MFW_06	88	136	10	19	10	15
MFW_07	108	133	14	20	11	16
MFW_08	339	172	16	19	11	14
MFW_09	234	358	22	31	15	21
MFW_10	526	127	29	15	23	11
522_01	404	216	30	22	21	14
522_02	-	158	-	19	-	12
522_03	291	219	28	27	15	18
522_04	194	159	21	19	18	16
522_05	-	-	-	-	-	-
522_06	298	193	19	21	17	17
522_07	192	-	21	-	17	-
522_08	206	228	17	22	14	17
522_09	227	209	15	21	13	18
522_10	363	56	20	12	15	10
522_11	102	100	14	12	12	10
522_12	112	144	10	15	10	11

Table 8a – Monthly blue shark residency index (RI) by station in the Revolution Wind (OCS-A 0486), South Fork Wind (OCS-A 0517), and Sunrise Wind (OCS-A 0487) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind.

Station	June		July		August		September		October		November		December	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
REV_01	5.0	3.3	5.3	3.2	0	0	0	0	0	0	0	0	0	0
REV_02	3.3	3.3	6.7	0	3.6	0	0	0	0	0	0	0	0	0
REV_03	3.3	0	5.9	9.7	0	0	3.3	0	0	0	0	0	0	0
REV_04	6.7	0	4.2	3.2	0	0	3.3	0	0	0	0	0	0	0
REV_05	3.3	0	9.0	3.2	6.5	0	3.3	0	0	0	0	0	0	0
REV_06	3.3	0	6.7	3.2	0	0	0	0	0	0	0	0	0	0
REV_07	8.9	0	6.6	4.8	0	0	3.3	0	0	3.2	0	0	0	0
REV_08	6.3	0	5.2	3.2	0	0	0	0	0	3.2	0	0	0	0
REV_09	5.0	0	7.6	3.2	3.4	0	0	0	0	0	0	0	0	0
REV_10	6.7	3.3	3.8	6.5	0	6.5	0	0	0	0	0	0	0	0
REV_11	0	6.7	5.5	6.5	3.4	0	0	0	0	0	0	0	0	0
REV_12	8.9	3.3	4.8	3.2	0	0	0	0	0	0	0	0	0	0
REV_13	5.0	0	3.2	0	0	3.2	3.3	0	0	0	0	0	0	0
REV_14	13.3	3.3	5.8	3.2	3.6	0	3.3	0	0	0	0	0	0	-
REV_15	4.4	0	4.0	3.2	3.4	0	3.3	0	0	0	0	0	0	0
REV_16	3.3	0	5.7	8.1	3.3	0	3.3	0	0	0	0	0	0	0
REV_17	6.7	3.3	4.1	3.2	3.2	0	3.3	0	0	0	0	0	0	0
REV_18	3.3	3.3	3.8	0	3.4	0	0	0	0	0	0	0	0	0
SF_01	3.3	0	4.8	3.2	3.2	3.2	0	0	0	0	0	0	-	0
SF_02	3.3	0	3.6	0	3.2	0	0	0	0	3.2	0	0	0	0
SRW_01	0	0	3.8	0	3.4	0	3.3	0	3.2	0	0	0	0	0
SRW_02	5.7	0	0	0	3.4	0	5.0	0	0	0	0	0	0	0
SRW_03	0	0	0	0	3.6	3.2	5.0	3.3	6.5	0	0	0	0	0
SRW_04	3.3	0	0	0	3.5	0	3.3	3.3	0	0	0	0	0	-
SRW_05	3.3	12.5	3.2	0	5.0	0	3.3	6.7	3.2	0	0	0	0	0
SRW_06	0	0	3.2	3.2	8.3	3.2	3.3	3.3	0	0	0	0	0	0
SRW_07	3.3	12.5	3.6	3.2	5.9	9.7	3.3	0	0	0	0	0	0	-
SRW_08	3.3	0	3.8	3.2	5.1	3.2	3.8	7.7	3.2	0	0	0	0	0
SRW_09	3.3	0	0	3.2	4.5	3.2	3.3	13.3	6.5	3.2	0	0	0	-
SRW_10	3.3	3.3	4.8	0	3.6	0	6.7	0	0	0	0	0	-	0
SRW_11	-	0	-	3.2	-	0	-	0	-	0	-	0	-	0
SRW_12	3.3	0	0	5.3	3.4	0	4.2	6.7	9.7	3.2	0	0	0	0

Table 8b – Monthly blue shark residency index (RI) by station in the Vineyard Wind 1 (OCS-A 0501), New England Wind (OCS-A 0534), Beacon Wind (OCS-A 0520), SouthCoast Wind (OCS-A 0521), and Vineyard Northeast (OCS-A 0522) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. BW = Beacon Wind, MFW = Mayflower Wind (station names were derived from the previous name designated to OCS-A 0521).

Station	June		July		August		September		October		November		December	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
501_01	1.7	3.3	3.6	7.5	6.0	4.8	3.3	0	0	0	0	0	0	0
501_02	7.1	0	7.2	8.1	5.9	9.7	3.3	0	0	0	0	0	0	0
501_03	3.6	12.5	4.4	3.2	9.2	7.5	7.2	0	0	0	0	0	0	0
501_04	0	6.7	3.2	4.3	1.1	29	5.8	3.8	0	0	0	0	0	0
534_01	3.6	0	3.6	0	3.8	0	4.0	3.8	0	3.2	0	0	0	0
534_02	3.6	25.0	6.8	0	3.5	0	5.0	3.3	0	3.2	0	0	0	0
534_03	3.6	0	3.2	0	3.2	0	3.3	3.3	3.2	0	3.3	0	0	0
534_04	0	0	4.8	3.2	3.9	0	3.8	3.8	0	0	0	0	0	0
534_05	3.6	12.5	3.8	0	4.3	3.2	5.0	3.3	0	0	0	0	0	0
534_06	0	3.3	0	0	4.1	0	6.7	0	0	0	0	0	0	0
BW_01	7.1	-	5.5	-	1.0	-	-	-	-	-	-	-	-	-
BW_02	3.6	0	3.2	3.2	7.8	4.8	3.3	3.8	0	0	0	0	0	0
BW_03	3.6	0	3.8	0	3.4	0	0	3.6	3.2	3.2	0	0	0	0
BW_04	3.6	0	3.2	0	3.4	0	3.3	0	0	0	0	0	0	0
BW_05	0	0	4.5	0	0	0	3.3	0	3.2	0	0	0	0	0
BW_06	0	0	0	0	6.9	6.5	0	0	3.2	0	0	0	0	0
BW_07	3.6	0	3.8	0	3.4	0	3.3	0	0	0	0	0	0	0
BW_08	3.6	0	3.8	0	3.4	3.2	3.3	3.3	0	0	0	0	0	0
BW_09	0	5.0	3.2	0	3.4	3.2	3.3	3.3	0	0	0	0	0	0
BW_10	3.6	0	3.8	0	5.6	3.2	5.8	3.3	0	0	0	0	0	0
MFW_01	4.0	0	4.8	3.2	3.3	4.3	7.8	6.7	-	0	-	-	-	-
MFW_02	-	3.3	-	0	-	3.2	-	3.3	-	0	-	0	-	0
MFW_03	0	3.3	3.6	3.2	4.4	0	5.6	3.3	0	0	0	0	0	0
MFW_04	0	12.5	3.2	0	0	4.8	5.0	0	3.2	0	0	0	0	0
MFW_05	0	0	0	0	3.2	3.2	4.4	0	3.2	0	0	0	0	0
MFW_06	2.0	0	0	0	0	0	3.3	0	0	0	0	0	0	0
MFW_07	0	0	0	0	3.4	0	5.0	0	9.7	3.2	0	0	0	0
MFW_08	4.0	0	0	3.2	3.3	0	4.7	0	0	0	0	0	0	0
MFW_09	0	3.3	4.8	3.2	3.4	3.2	6.7	0	0	0	0	0	0	0
MFW_10	4.0	0	4.2	0	4.6	0	4.2	0	0	0	0	0	0	0
522_01	0	0	4.8	3.2	4.1	0	3.3	3.3	0	0	0	0	0	0
522_02	-	0	-	3.2	-	0	-	0	-	0	-	0	-	0
522_03	0	0	4.8	3.2	4.0	3.2	1.0	0	0	0	0	0	0	0
522_04	0	3.3	3.2	4.8	3.8	3.2	5.6	0	0	0	0	0	0	0
522_06	4.0	0	4.8	6.5	3.3	3.2	3.3	0	0	0	0	0	0	0
522_07	0	-	3.2	-	4.0	-	4.4	-	0	-	-	-	-	-
522_08	0	0	3.2	3.2	4.1	0	3.3	0	0	0	0	0	0	0
522_09	4.0	0	3.2	3.2	3.4	0	4.4	0	0	0	0	0	0	0
522_10	0	0	0	0	3.2	0	6.7	0	0	0	-	0	-	0
522_11	0	0	0	0	4.5	0	4.2	0	0	0	0	0	0	0
522_12	0	3.3	0	0	3.3	0	4.2	0	0	0	0	0	0	0

Table 8c – Monthly bluefin tuna residency index (RI) by station in the Revolution Wind (OCS-A 0486), South Fork Wind (OCS-A 0517), and Sunrise Wind (OCS-A 0487) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind.

Station	June		July		August		September		October		November		December	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
REV_01	0	0	0	0	0	4.8	0	3.3	0	6.5	0	3.3	0	0
REV_02	0	0	0	5.0	0	4.3	0	3.3	0	4.0	0	3.3	0	0
REV_03	0	0	0	0	0	4.4	0	3.3	0	5.4	0	0	0	0
REV_04	0	0	0	6.5	0	6.9	0	5.0	0	5.6	0	0	0	0
REV_05	0	0	0	3.8	3.2	3.2	0	3.3	0	3.2	0	3.3	0	0
REV_06	0	0	0	5.0	0	3.7	0	3.3	0	3.2	0	0	0	0
REV_07	0	0	0	3.8	3.2	4.8	0	3.3	0	4.8	0	3.3	0	0
REV_08	0	0	0	3.9	0	3.2	0	3.3	0	3.2	0	0	0	0
REV_09	0	0	0	4.3	0	4.0	0	3.3	0	0	0	0	0	0
REV_10	0	0	0	3.2	3.2	3.2	0	3.3	0	3.2	0	6.7	0	0
REV_11	0	0	0	0	6.5	4.8	0	3.3	0	4.3	0	0	0	0
REV_12	0	0	0	5.3	0	4.6	0	3.3	0	3.2	0	0	0	0
REV_13	0	0	0	3.6	3.2	6.0	0	3.3	0	3.2	0	0	0	3.2
REV_14	0	0	0	4.0	0	3.9	0	0	0	3.2	0	0	3.2	-
REV_15	0	6.7	0	0	0	4.8	0	0	0	3.2	0	0	0	0
REV_16	0	0	0	7.1	3.2	10.0	3.3	3.3	0	3.2	0	0	0	0
REV_17	0	3.3	0	5.4	0	4.9	0	3.3	0	0	0	0	3.2	0
REV_18	0	0	0	0	3.2	3.8	0	3.3	0	3.2	0	0	0	0
SF_01	0	0	0	0	3.2	4.3	0	0	0	3.2	0	0	-	0
SF_02	0	0	0	3.6	0	6.5	0	3.3	0	3.2	0	0	3.2	0
SRW_01	0	0	0	3.2	0	4.8	0	3.3	0	3.2	0	3.3	0	0
SRW_02	0	0	0	5.0	4.8	3.2	3.3	3.3	0	4.8	0	3.3	0	0
SRW_03	0	0	0	3.2	3.2	5.2	3.3	3.3	3.2	3.2	0	3.3	0	0
SRW_04	0	0	0	0	0	6.4	0	3.3	0	3.2	0	0	0	-
SRW_05	0	3.3	0	3.7	0	5.6	0	3.3	0	3.2	0	3.3	0	0
SRW_06	0	0	0	6.5	3.2	3.7	0	0	0	3.2	0	3.3	0	0
SRW_07	0	0	0	5.3	0	6.0	0	3.3	0	3.2	0	0	0	-
SRW_08	0	0	3.2	0	0	4.0	0	3.3	0	3.2	0	0	0	0
SRW_09	0	0	0	3.2	3.2	5.4	0	0	0	3.8	0	4.8	0	-
SRW_10	0	0	0	3.2	6.5	3.2	0	0	0	3.2	0	3.3	-	3.2
SRW_11	-	0	-	3.9	-	6.7	-	6.7	-	3.9	-	5.0	-	0
SRW_12	0	5.3	0	3.2	3.2	5.2	0	3.3	3.2	3.2	0	0	0	0

Table 8d – Monthly bluefin tuna residency index (RI) by station in the Vineyard Wind 1 (OCS-A 0501), New England Wind (OCS-A 0534), Beacon Wind (OCS-A 0520), SouthCoast Wind (OCS-A 0521), and Vineyard Northeast (OCS-A 0522) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. BW = Beacon Wind, MFW = Mayflower Wind (station names were derived from the previous name designated to OCS-A 0521).

Station	**June**		**July**		**August**		**September**		**October**		**November**		**December**	
	2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
501_01	0	0	0	5.4	0	3.2	0	0	0	4.0	10.0	0	0	0
501_02	0	0	0	7.1	0	0	0	0	0	3.2	0	0	0	0
501_03	0	3.3	0	4.0	0	3.2	0	3.3	0	0	3.3	0	0	0
501_04	0	3.3	0	0	0	3.2	0	4.0	0	4.0	6.7	0	0	0
534_01	0	0	0	10.0	0	3.2	3.3	3.3	0	6.5	3.3	0	0	0
534_02	0	3.3	3.2	0	0	0	3.3	3.3	0	0	3.3	0	0	0
534_03	0	7.9	0	3.6	0	3.2	0	3.3	6.5	3.2	0	3.3	0	0
534_04	0	0	0	6.0	0	3.2	0	3.3	0	4.8	3.3	3.3	0	0
534_05	0	0	3.2	3.6	0	3.2	0	3.3	0	3.2	0	3.3	0	0
534_06	0	0	3.2	3.2	0	0	6.7	3.3	0	5.4	3.3	3.3	0	0
BW_01	0	-	4.2	-	0	-	-	-	-	-	-	-	-	-
BW_02	0	0	0	3.2	0	3.6	0	3.3	0	6.5	0	3.3	20.0	0
BW_03	0	0	0	3.2	0	0	3.3	5.0	0	3.2	0	3.3	0	0
BW_04	0	0	3.2	3.4	0	0	0	5.0	0	3.2	3.3	3.3	0	0
BW_05	0	3.3	0	3.2	0	0	0	0	3.2	5.4	0	3.3	0	0
BW_06	0	0	0	0	0	3.2	6.7	3.3	3.2	4.8	3.3	0	0	0
BW_07	0	50.0	3.2	0	0	0	3.3	3.3	0	3.2	3.3	3.3	0	0
BW_08	0	6.7	0	0	0	0	0	3.3	0	3.2	0	3.3	0	0
BW_09	0	6.3	0	3.2	0	3.4	3.3	4.0	0	3.2	6.7	3.3	0	0
BW_10	0	0	0	3.2	0	0	3.3	6.7	0	3.2	0	3.3	0	0
MFW_01	0	0	4.2	0	0	3.2	0	3.3	-	0	-	-	-	-
MFW_02	-	3.3	-	0	-	3.4	-	4.2	-	3.2	-	3.3	-	0
MFW_03	0	3.3	0	3.6	0	7.0	3.3	3.3	0	4.0	3.3	3.3	0	0
MFW_04	0	12.5	0	3.2	0	3.2	3.3	4.3	0	3.2	3.3	3.3	0	0
MFW_05	0	0	0	6.5	0	0	3.3	4.0	0	3.9	3.3	3.3	0	0
MFW_06	0	0	4.2	5.4	0	0	0	3.3	0	4.5	3.3	0	0	0
MFW_07	0	0	0	3.2	0	0	3.3	4.0	0	4.8	0	0	0	0
MFW_08	0	0	0	0	0	3.2	3.3	4.0	0	3.2	3.3	3.3	0	0
MFW_09	0	0	0	3.2	0	5.4	0	8.6	0	3.2	3.3	0	28.6	0
MFW_10	0	3.3	0	3.6	0	3.2	0	6.7	0	3.2	3.3	0	0	0
522_01	0	0	0	7.1	0	3.2	0	4.0	0	4.3	3.3	0	0	0
522_02	-	0	-	6.5	-	3.2	-	4.8	-	3.2	-	0	-	0
522_03	0	0	0	3.6	0	3.2	0	5.6	0	3.2	0	3.3	0	0
522_04	0	3.3	4.2	3.6	0	0	0	3.3	0	4.0	0	3.3	0	0
522_06	4.0	3.3	4.2	0	0	3.2	0	6.7	6.5	3.2	3.3	0	0	0
522_07	0	-	3.2	-	0	-	0	-	0	-	-	-	-	-
522_08	0	3.3	3.2	3.2	0	3.2	0	4.2	3.2	4.3	0	3.3	0	0
522_09	0	0	0	6.5	0	3.2	0	3.3	0	3.2	0	3.3	14.3	0
522_10	0	0	0	0	0	3.5	3.3	3.3	0	3.2	-	3.3	-	0
522_11	0	3.3	0	0	0	4.0	3.3	3.3	0	3.2	3.3	3.3	0	0
522_12	0	0	0	3.2	0	0	0	5.0	0	4.0	0	0	0	0

Table 8e – Monthly shortfin mako residency index (RI) by station in the Revolution Wind (OCS-A 0486), South Fork Wind (OCS-A 0517), and Sunrise Wind (OCS-A 0487) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind.

Station	June		July		August		September		October		November		December	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
REV_01	0	0	0	14.3	0	3.2	0	3.3	0	0	0	0	0	0
REV_02	0	3.3	0	4.0	0	0	4.8	3.3	0	0	0	0	0	0
REV_03	0	0	0	0	0	0	4.8	0	3.2	0	0	0	0	0
REV_04	0	0	0	4.0	0	0	0	0	0	3.2	0	0	0	0
REV_05	0	0	3.2	0	0	3.2	0	3.3	0	0	0	0	0	0
REV_06	0	0	3.2	4.0	0	0	0	6.7	0	0	0	0	0	0
REV_07	0	0	3.2	6.1	3.2	3.2	4.8	0	0	0	0	0	0	0
REV_08	0	3.3	0	0	0	3.2	0	3.3	0	0	0	0	0	0
REV_09	0	0	3.2	5.1	0	3.3	0	0	0	0	0	0	0	0
REV_10	0	0	0	0	4.8	3.3	0	0	0	6.5	0	0	0	0
REV_11	0	3.3	0	0	3.2	0	0	0	0	0	0	0	0	0
REV_12	0	0	4.8	0	3.2	3.3	4.8	3.3	0	3.2	0	0	0	0
REV_13	0	0	3.2	12.8	3.2	3.3	0	0	0	0	0	0	0	0
REV_14	0	0	3.2	16.7	0	0	4.8	3.3	0	0	0	0	0	-
REV_15	0	3.3	9.7	7.7	3.2	0	3.3	0	0	0	0	0	0	0
REV_16	0	0	3.2	10.3	3.2	6.6	0	0	0	0	0	0	0	0
REV_17	0	0	3.2	10.4	0	3.2	0	3.3	0	3.2	0	0	0	0
REV_18	0	0	0	4.0	0	6.6	0	3.3	0	0	0	0	0	0
SF_01	0	0	0	3.2	0	0	0	0	0	9.7	0	0	-	0
SF_02	0	0	3.2	5.1	0	6.6	0	3.3	0	0	0	0	0	0
SRW_01	3.3	0	0	7.1	0	3.2	4.8	0	0	6.5	0	6.7	0	0
SRW_02	0	0	3.2	7.1	0	0	0	0	0	6.5	0	0	0	0
SRW_03	0	0	0	7.1	0	0	3.3	0	3.2	3.2	0	0	0	0
SRW_04	0	3.3	0	4.2	0	0	0	0	6.5	3.2	0	0	0	-
SRW_05	0	0	3.2	10.3	3.2	0	0	0	0	3.2	3.3	0	0	0
SRW_06	0	3.3	0	10.3	3.2	0	0	3.3	3.2	4.3	0	0	0	0
SRW_07	0	3.3	4.5	6.0	3.2	3.2	0	0	4.8	6.5	0	0	0	-
SRW_08	0	0	4.8	3.7	0	0	0	3.3	0	6.5	0	0	0	0
SRW_09	0	0	0	5	0	0	0	0	6.5	6.5	3.3	0	0	-
SRW_10	0	0	0	0	0	0	4.8	0	0	6.5	0	0	-	0
SRW_11	-	3.3	-	3.2	-	0	-	0	-	0	-	3.3	-	0
SRW_12	0	0	0	7.1	0	0	0	0	3.2	3.2	5.0	0	0	0

Table 8f – Monthly shortfin mako residency index (RI) by station in the Vineyard Wind 1 (OCS-A 0501), New England Wind (OCS-A 0534), Beacon Wind (OCS-A 0520), SouthCoast Wind (OCS-A 0521), and Vineyard Northeast (OCS-A 0522) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. BW = Beacon Wind, MFW = Mayflower Wind (station names were derived from the previous name designated to OCS-A 0521).

Station	June		July		August		September		October		November		December	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
501_01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
501_02	0	0	3.2	0	0	3.2	0	0	0	0	0	0	0	0
501_03	0	0	0	0	0	0	0	0	0	3.2	0	0	0	0
501_04	0	0	0	0	3.2	3.2	0	0	0	0	0	0	0	0
534_01	0	0	4.8	7.1	0	0	0	0	0	0	0	0	0	0
534_02	0	0	0	7.1	0	3.2	0	3.8	3.2	9.7	0	0	0	0
534_03	0	0	4.8	4.7	0	3.2	0	0	3.2	3.2	0	0	0	0
534_04	0	0	0	0	0	0	0	3.8	3.2	3.2	0	0	0	0
534_05	0	0	0	5.1	0	3.2	0	0	9.7	0	0	0	0	0
534_06	0	0	4.5	0	0	3.3	0	0	3.2	0	0	0	0	0
BW_01	0	-	0	-	0	-	-	-	-	-	-	-	-	-
BW_02	0	0	0	5.3	3.2	3.2	0	0	0	0	0	0	0	0
BW_03	0	0	4.8	4.4	0	0	0	0	6.5	0	0	0	0	0
BW_04	0	0	3.2	7.1	0	0	0	0	6.5	0	0	0	0	0
BW_05	0	0	0	14.3	0	0	0	0	3.2	0	0	0	0	0
BW_06	0	0	0	7.1	0	0	0	0	0	0	0	3.3	0	0
BW_07	0	0	3.2	0	0	0	0	0	6.5	3.2	0	0	0	0
BW_08	0	0	0	0	0	0	0	0	6.5	0	0	0	0	0
BW_09	0	0	0	7.1	0	6.7	0	0	6.5	3.2	0	0	0	0
BW_10	0	0	0	0	6.5	0	0	0	0	6.5	0	0	0	0
MFW_01	0	0	3.8	0	6.5	0	5.9	0	-	0	-	-	-	-
MFW_02	-	0	-	7.1	-	3.2	-	0	-	3.2	-	0	-	0
MFW_03	0	0	0	7.7	0	0	0	0	0	0	0	0	0	0
MFW_04	0	0	0	7.7	0	6.7	0	3.8	6.5	3.2	0	0	0	0
MFW_05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MFW_06	0	0	0	7.1	0	0	0	0	3.2	0	0	0	0	0
MFW_07	0	0	4.8	8.3	0	0	0	0	0	0	0	3.3	0	0
MFW_08	0	0	4.8	3.2	0	4.3	0	0	0	0	0	0	0	0
MFW_09	0	0	3.2	7.1	0	0	3.3	0	0	0	0	0	0	0
MFW_10	0	0	6.5	0	3.2	3.2	6.7	0	0	6.5	0	0	0	0
522_01	0	0	3.2	0	6.3	3.2	3.3	0	0	0	0	0	0	0
522_02	-	0	-	4.0	-	0	-	3.8	-	0	-	0	-	0
522_03	0	0	3.2	0	0	3.2	0	0	0	0	0	0	0	0
522_04	0	0	3.2	7.1	3.2	0	0	0	0	0	0	0	0	0
522_06	0	0	0	5.1	0	3.2	3.3	5.0	3.2	0	0	0	0	0
522_07	0	-	3.2	-	0	-	6.7	-	0	-	-	-	-	-
522_08	0	0	4.8	0	0	0	6.7	3.3	3.2	0	0	0	0	0
522_09	0	0	0	4.0	0	0	0	3.3	3.2	3.2	0	0	0	0
522_10	0	0	0	8.3	5.9	4.3	0	0	0	0	-	0	-	0
522_11	0	0	0	0	0	0	0	0	3.2	0	0	3.3	0	0
522_12	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0

Table 8g – Monthly yellowfin tuna residency index (RI) by station in the Revolution Wind (OCS-A 0486), South Fork Wind (OCS-A 0517), and Sunrise Wind (OCS-A 0487) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. *NA* entries denote that no tags were deployed and/or available for detection at that time. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind.

Station	June		July		August		September		October		November		December	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
REV_01	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_02	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_03	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_04	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_05	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_06	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_07	*NA*	0	0	4.0	0	0	0	0	0	0	0	0	0	0
REV_08	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_09	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_10	*NA*	0	0	3.2	0	0	0	0	0	0	0	0	0	0
REV_11	*NA*	0	0	4.0	0	0	0	0	0	0	0	0	0	0
REV_12	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_13	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_14	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	-
REV_15	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_16	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_17	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
REV_18	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
SF_01	*NA*	0	0	0	0	0	0	0	0	0	0	0	-	0
SF_02	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
SRW_01	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	0	0
SRW_02	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
SRW_03	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
SRW_04	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	-
SRW_05	*NA*	0	0	0	0	0	0	3.3	0	0	0	0	0	0
SRW_06	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
SRW_07	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	-
SRW_08	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
SRW_09	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	-
SRW_10	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	-	0
SRW_11	-	0	-	0	-	3.2	-	0	-	0	-	0	-	0
SRW_12	*NA*	0	0	0	0	4.8	0	3.3	0	0	0	0	0	0

Table 8h – Monthly yellowfin tuna residency index (RI) by station in the Vineyard Wind 1 (OCS-A 0501), New England Wind (OCS-A 0534), Beacon Wind (OCS-A 0520), SouthCoast Wind (OCS-A 0521), and Vineyard Northeast (OCS-A 0522) lease areas in each year of the study. Dashes and omitted stations denote that receivers were not deployed or malfunctioned at that time. *NA* entries denote that no tags were deployed and/or available for detection at that time. BW = Beacon Wind, MFW = Mayflower Wind (station names were derived from the previous name designated to OCS-A 0521).

Station	June		July		August		September		October		November		December	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
501_01	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
501_02	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
501_03	*NA*	0	0	0	0	6.5	0	0	0	0	0	0	0	0
501_04	*NA*	0	0	0	0	11.3	0	0	0	0	0	0	0	0
534_01	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	0	0
534_02	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	0	0
534_03	*NA*	0	0	3.2	0	3.2	0	0	0	0	0	0	0	0
534_04	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	0	0
534_05	*NA*	0	0	0	0	3.2	0	3.3	0	0	0	0	0	0
534_06	*NA*	0	0	0	0	3.2	0	3.3	0	0	0	0	0	0
BW_01	*NA*	-	0	-	0	-	-	-	-	-	-	-	-	-
BW_02	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
BW_03	*NA*	0	0	7.7	0	4.8	0	5.0	0	0	0	0	0	0
BW_04	*NA*	0	0	7.7	0	4.8	0	0	0	0	0	0	0	0
BW_05	*NA*	0	0	7.7	0	3.2	3.3	3.3	0	0	0	0	0	0
BW_06	*NA*	0	0	12.9	0	3.2	3.3	3.3	0	0	0	0	0	0
BW_07	*NA*	0	0	3.2	0	6.5	0	0	0	0	0	0	0	0
BW_08	*NA*	0	0	6.5	5.9	3.2	0	3.3	0	0	0	0	0	0
BW_09	*NA*	0	0	4.5	0	0	0	10.0	0	0	0	0	0	0
BW_10	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	0	0
MFW_01	*NA*	0	0	0	0	0	0	0	-	0	-	-	-	-
MFW_02	-	0	-	3.2	-	0	-	3.3	-	0	-	0	-	0
MFW_03	*NA*	0	0	9.7	0	0	0	3.3	0	0	0	0	0	0
MFW_04	*NA*	0	0	3.2	0	3.2	0	6.7	0	0	0	0	0	0
MFW_05	*NA*	0	0	3.2	0	3.2	0	5.0	0	0	0	0	0	0
MFW_06	*NA*	0	0	3.2	0	4.3	0	3.3	0	0	0	0	0	0
MFW_07	*NA*	0	0	0	0	4.8	0	0	0	0	0	0	0	0
MFW_08	*NA*	0	0	0	0	4.8	0	0	0	0	0	0	0	0
MFW_09	*NA*	0	0	0	5.6	3.2	0	0	0	0	0	0	0	0
MFW_10	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	0	0
522_01	*NA*	0	0	0	0	3.2	0	0	0	0	0	0	0	0
522_02	-	0	-	0	-	3.2	-	0	-	0	-	0	-	0
522_03	*NA*	0	0	0	0	4.8	0	0	0	0	0	0	0	0
522_04	*NA*	0	0	0	0	0	0	0	0	0	0	0	0	0
522_06	*NA*	0	0	0	11.1	0	0	0	0	0	0	0	0	0
522_07	*NA*	-	0	-	0	-	3.3	-	0	-	-	-	-	-
522_08	*NA*	0	0	0	0	6.5	0	0	0	0	0	0	0	0
522_09	*NA*	0	0	0	0	3.2	3.3	0	0	0	0	0	0	0
522_10	*NA*	0	0	0	5.6	0	0	3.3	0	0	-	0	-	0
522_11	*NA*	0	0	3.2	0	3.2	3.3	0	0	0	0	0	0	0
522_12	*NA*	0	0	0	5.6	3.2	0	0	0	0	0	0	0	0

Table 9 – Network density by species and year. Tx = total number of individual fish that make up the network for a given year, n = total number of nodes (stations) within the network, Network Density = the proportion of connections (edges) between nodes to all possible connections (excluding self-connections) between nodes.

Species	**2022**			**2023**		
	Tx	**n**	**Network Density**	**Tx**	**n**	**Network Density**
Bluefin tuna	11	49	0.05	38	67	0.14
Blue shark	45	67	0.12	16	58	0.05
Shortfin mako	13	57	0.04	26	61	0.06
Yellowfin tuna	7	9	0.17	10	38	0.08

Table 10 – 90th percentile thresholds for each quantified metric by species and year.

Species	Network Metric	90th Percentile Threshold 2022	90th Percentile Threshold 2023
Bluefin tuna	Degree Centrality	5.2	24.6
	Strength	5.2	40
	Eigenvector Centrality	26.62	71.35
Blue shark	Degree Centrality	22	8.3
	Strength	33.4	9.3
	Eigenvector Centrality	20.08	63.2
Shortfin mako	Degree Centrality	5	10
	Strength	6	11
	Eigenvector Centrality	31.14	44.6
Yellowfin tuna	Degree Centrality	1.2	8.3
	Strength	1.2	10.3
	Eigenvector Centrality	100	76.72

Table 11a – Bluefin tuna network metadata from 2022 and 2023. *NA* denotes that no metric data exist due to the lack of detections. Asterisks denote metric values that fall within the 90th percentile in that year (see Table 10 for threshold values). Stations SRW_11, SRW_13, BW_01, MFW_01, MFW_02, 522_02, 522_05, and 522_07 were not included due to receiver loss or discontinuation in one or both years. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind, BW = Beacon Wind, MFW = Mayflower (SouthCoast) Wind, Tx = total unique transmitters detected, DC = Degree Centrality, STR = Strength, EC = Eigenvector Centrality.

Station	2022				2023			
	Tx	DC	STR	EC	Tx	DC	STR	EC
REV_01	0	*NA*	*NA*	*NA*	7	15	20	18.46
REV_02	0	*NA*	*NA*	*NA*	11	17	33	33.57
REV_03	0	*NA*	*NA*	*NA*	11	20	40*	53.59
REV_04	0	*NA*	*NA*	*NA*	10	27*	49*	59.52
REV_05	1	1	1	0.05	7	10	13	9.33
REV_06	0	*NA*	*NA*	*NA*	12	18	28	23.8
REV_07	1	2	2	0.01	8	11	14	6.55
REV_08	0	*NA*	*NA*	*NA*	7	13	15	10.87
REV_09	0	*NA*	*NA*	*NA*	9	17	24	27.92
REV_10	1	2	2	0.02	9	13	18	7.68
REV_11	1	4	4	0.16	7	13	15	11.07
REV_12	0	*NA*	*NA*	*NA*	11	23	39	61.64
REV_13	1	2	2	0.05	12	23	37	76.01
REV_14	1	2	2	40.89*	7	11	17	36.14
REV_15	0	*NA*	*NA*	*NA*	7	15	19	29.21
REV_16	2	3	3	0.24	13	27*	62*	94.60*
REV_17	1	1	1	14.72	15	22	40*	74.18*
REV_18	1	2	2	0.16	9	18	23	19.41
SF_01	1	2	2	0	6	14	17	16.83
SF_02	1	1	1	0	13	30*	44*	69.46
SRW_01	0	*NA*	*NA*	*NA*	13	13	14	21.44
SRW_02	3	6*	7*	0.49	13	19	25	30.98
SRW_03	2	4	5	0.38	8	17	19	22.35
SRW_04	0	*NA*	*NA*	*NA*	15	27*	47*	100.00*
SRW_05	0	*NA*	*NA*	*NA*	17	30*	49*	89.86*
SRW_06	1	2	2	0.01	10	13	19	33.97
SRW_07	0	*NA*	*NA*	*NA*	16	27*	36	75.31*
SRW_08	1	1	1	0.07	6	10	11	10.04
SRW_09	1	1	1	0	15	27*	46*	92.64*
SRW_10	1	4	4	0.05	10	18	22	20.26
SRW_12	2	4	4	0.72	11	23	25	27.42
501_01	1	4	4	0	7	11	11	12.54

501_02	0	*NA*	*NA*	*NA*	5	7	7	1.03
501_03	1	2	2	23.05	5	8	10	6.76
501_04	1	2	2	7.97	11	17	20	10.71
534_01	2	4	4	0	6	13	15	7.09
534_02	3	4	4	7.59	4	7	7	0.45
534_03	1	2	2	1.25	11	11	14	4.89
534_04	1	2	2	0	10	15	19	2.64
534_05	1	2	2	0.21	9	18	20	2
534_06	2	6*	6*	0	6	14	14	5.34
BW_02	1	2	2	0	7	14	15	14.79
BW_03	1	2	2	0.21	8	14	15	0.99
BW_04	2	3	3	0	7	12	12	1.99
BW_05	0	*NA*	*NA*	*NA*	10	14	14	5.27
BW_06	1	6*	6*	1.72	9	16	17	2.19
BW_07	2	5	5	0.64	9	16	20	1.33
BW_08	0	*NA*	*NA*	*NA*	7	11	13	1.48
BW_09	2	6*	6*	6.44	14	21	30	2.9
BW_10	1	2	2	0	10	17	23	4.33
MFW_03	2	4	4	3.77	11	21	25	3.09
MFW_04	2	6*	6*	4.98	12	19	27	2.74
MFW_05	2	3	3	0.84	11	17	22	2.63
MFW_06	4	5	5	100.00*	8	11	13	1.61
MFW_07	1	1	1	0.57	10	13	17	0.6
MFW_08	1	2	2	0	7	14	18	1.53
MFW_09	2	4	4	0	12	21	31	7.13
MFW_10	1	2	2	23.05	7	14	19	2.66
522_01	2	4	4	61.22*	10	17	25	10.65
522_03	0	*NA*	*NA*	*NA*	11	20	28	3.09
522_04	1	2	2	40.89*	10	13	15	2.39
522_06	4	2	2	41.87*	10	10	11	1.46
522_08	2	2	2	3.75	11	19	23	6.45
522_09	1	2	2	0	9	13	21	2.17
522_10	1	2	2	0	5	9	13	0.61
522_11	3	3	3	11.7	6	9	9	0.69
522_12	0	*NA*	*NA*	*NA*	8	13	17	1.03

Table 11b – Blue shark network metadata from 2022 and 2023. *NA* denotes that no metric data exist due to the lack of detections. Asterisks denote metric values that fall within the 90th percentile in that year (see Table 10 for threshold values. Stations SRW_11, SRW_13, BW_01, MFW_01, MFW_02, 522_02, 522_05, and 522_07 were not included due to receiver loss or discontinuation in one or both years. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind, BW = Beacon Wind, MFW = Mayflower (SouthCoast) Wind, Tx = total unique transmitters detected, DC = Degree Centrality, STR = Strength, EC = Eigenvector Centrality.

Station	2022				2023			
	Tx	DC	STR	EC	Tx	DC	STR	EC
REV_01	5	11	12	0.11	1	1	1	0
REV_02	7	10	14	0.06	1	1	1	1.63
REV_03	11	18	26	0.47	1	4	4	5.01
REV_04	7	14	16	0.3	1	1	1	3.38
REV_05	8	15	25	0.13	2	4	4	4.08
REV_06	5	9	15	0.05	1	2	2	0.32
REV_07	10	12	21	0.09	3	5	5	14.69
REV_08	6	14	19	0.07	2	4	4	12.63
REV_09	7	20	24	0.33	1	2	2	2.19
REV_10	3	6	6	0.19	3	10*	12*	41.36
REV_11	4	9	9	0.2	2	6	8	19.1
REV_12	5	18	21	2.68	4	6	6	9.47
REV_13	5	9	10	0.66	1	2	2	7.81
REV_14	7	17	21	0.77	3	5	5	3.52
REV_15	10	17	19	9.98	1	2	2	0
REV_16	12	18	24	1.03	2	5	5	24.14
REV_17	7	13	14	0.32	2	4	4	4.3
REV_18	4	8	8	0.52	1	2	2	1.63
SF_01	7	13	14	4.84	2	3	3	1.6
SF_02	4	9	10	0.22	1	2	2	16.7
SRW_01	6	6	6	0.02	0	*NA*	*NA*	*NA*
SRW_02	5	9	9	0.66	0	*NA*	*NA*	*NA*
SRW_03	3	7	8	0.55	1	2	2	0
SRW_04	10	12	16	2.94	1	2	2	16.7
SRW_05	11	14	21	7.41	2	3	3	21.32
SRW_06	5	8	9	1.81	2	4	5	8.24
SRW_07	9	18	22	15.95	4	11*	12*	36.97
SRW_08	13	24*	31	12.75	4	5	5	58.19
SRW_09	9	14	16	5.73	4	9*	10*	79.31*
SRW_10	4	7	7	0.04	1	1	1	0
SRW_12	8	11	12	1.21	4	6	7	47.12
501_01	15	17	34*	52.77*	4	13*	15*	92.99*

501_02	16	20	37*	58.62*	2	6	9	74.89*
501_03	21	24*	59*	95.57*	5	8	8	85.62*
501_04	21	30*	75*	100.00*	4	12*	14*	81.42*
534_01	20	24	36*	26.13*	2	3	3	9.68
534_02	11	20	25	9.29	3	5	5	30.15
534_03	5	7	7	0.75	1	1	1	0
534_04	15	25*	34*	17.68	2	3	4	38.42
534_05	9	14	17	11.22	3	4	4	11.29
534_06	7	11	13	10.2	1	0	0	0
BW_02	12	22	33	35.64*	5	10*	10*	100.00*
BW_03	6	10	11	2.18	3	5	5	15.38
BW_04	5	5	5	0.32	0	*NA*	*NA*	*NA*
BW_05	5	7	7	0.44	0	*NA*	*NA*	*NA*
BW_06	2	6	6	0.38	1	4	4	7.81
BW_07	9	13	15	3.4	0	*NA*	*NA*	*NA*
BW_08	13	22	29	16.13	3	4	4	15.14
BW_09	10	17	18	4.44	4	6	6	17.07
BW_10	11	25	36*	23.67*	1	4	4	19.1
MFW_03	9	20	25	6.81	2	5	5	11.99
MFW_04	5	11	11	1.34	3	7	7	33.63
MFW_05	6	10	11	0.66	1	2	2	0
MFW_06	4	6	6	0.63	0	*NA*	*NA*	*NA*
MFW_07	6	13	13	1.87	1	1	1	1.67
MFW_08	7	13	15	0.94	1	1	1	18.36
MFW_09	6	14	16	2.1	3	2	2	0
MFW_10	14	19	23	10.21	0	*NA*	*NA*	*NA*
522_01	10	17	23	12.95	2	4	4	29.45
522_03	9	17	26	4.99	2	2	2	0
522_04	12	18	23	8.92	4	4	4	52.81
522_06	7	7	7	5.66	2	1	1	0
522_08	7	12	15	9.5	3	2	2	4.81
522_09	7	10	12	1.5	2	3	3	18.2
522_10	8	18	21	7.8	0	*NA*	*NA*	*NA*
522_11	7	11	14	1.72	0	*NA*	*NA*	*NA*
522_12	6	7	7	0.77	1	0	0	0

Table 11c – Shortfin mako network metadata from 2022 and 2023. *NA* denotes that no metric data exist due to the lack of detections. Asterisks denote metric values that fall within the 90th percentile in that year (see Table 10 for threshold values). Stations SRW_11, SRW_13, BW_01, MFW_01, MFW_02, 522_02, 522_05, and 522_07 were not included due to receiver loss or discontinuation in one or both years. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind, BW = Beacon Wind, MFW = Mayflower (SouthCoast) Wind, Tx = total unique transmitters detected, DC = Degree Centrality, STR = Strength, EC = Eigenvector Centrality.

Station	**2022**				**2023**			
	Tx	**DC**	**STR**	**EC**	**Tx**	**DC**	**STR**	**EC**
REV_01	0	*NA*	*NA*	*NA*	2	4	4	12.5
REV_02	1	1	1	5.54	3	4	4	19.33
REV_03	2	3	3	25.09	0	*NA*	*NA*	*NA*
REV_04	0	*NA*	*NA*	*NA*	2	3	3	2.63
REV_05	1	1	1	0	2	3	3	1.67
REV_06	1	1	1	5.54	2	5	5	15.87
REV_07	3	3	3	0	3	3	3	0.25
REV_08	0	*NA*	*NA*	*NA*	2	4	4	2.84
REV_09	1	2	2	25.09	4	7	8	29.45
REV_10	2	1	1	0	2	6	6	4.87
REV_11	1	2	2	0	1	1	1	1.62
REV_12	4	8*	8*	94.19*	4	5	5	4.74
REV_13	2	4	4	54.99*	3	7	8	26.16
REV_14	2	3	3	30.95	5	10*	13*	76.96*
REV_15	3	1	1	0	3	5	5	13.63
REV_16	3	5*	6*	89.90*	4	10*	12*	15.46
REV_17	1	1	1	23.68	7	13*	16*	100.00*
REV_18	0	*NA*	*NA*	*NA*	4	9	11*	27.59
SF_01	0	*NA*	*NA*	*NA*	2	8	8	2.94
SF_02	1	2	2	0	5	10*	12*	24.37
SRW_01	2	1	1	0	6	6	6	5.17
SRW_02	1	1	1	0	2	5	5	14.19
SRW_03	2	0	0	0	3	5	5	8.65
SRW_04	1	1	1	4.62	7	11*	11*	56.95*
SRW_05	4	7*	8*	100.00*	5	11*	11*	44.60*
SRW_06	2	4	6*	42.42	7	11*	12*	73.50*
SRW_07	3	6*	7*	21.14	6	13*	13*	64.09*
SRW_08	1	1	1	0	5	11*	11*	57.08*
SRW_09	2	6*	7*	31.43*	6	5	6	43.4
SRW_10	1	1	1	0	2	7	7	8.74
SRW_12	2	4	4	8.84	3	5	5	10.52
501_01	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*

501_02	1	1	1	0	1	2	2	14.04
501_03	0	*NA*	*NA*	*NA*	1	2	2	7.76
501_04	2	3	3	0	1	2	2	0.03
534_01	1	1	1	0.11	1	2	2	1.24
534_02	2	4	4	0.01	4	9	10	5.16
534_03	3	3	3	3.17	5	7	7	40.54
534_04	1	2	2	0.01	3	3	4	10.69
534_05	1	2	2	0.03	3	4	4	6.11
534_06	2	2	2	0	0	*NA*	*NA*	*NA*
BW_02	1	1	1	0	3	4	4	0.29
BW_03	2	4	4	0.14	2	2	2	0
BW_04	3	4	5	1.31	1	2	2	2.99
BW_05	1	1	1	0.27	1	3	3	7.74
BW_06	0	*NA*	*NA*	*NA*	2	1	1	0
BW_07	2	5*	6*	0.54	1	2	2	0.34
BW_08	1	4	4	0.01	0	*NA*	*NA*	*NA*
BW_09	1	4	4	0.04	3	4	5	1.97
BW_10	1	1	1	0	1	3	3	0.04
MFW_03	0	*NA*	*NA*	*NA*	2	3	3	1.02
MFW_04	1	2	2	0	5	6	7	2.95
MFW_05	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
MFW_06	1	2	2	7.06	1	1	1	0
MFW_07	1	1	1	0	2	2	2	0.38
MFW_08	1	2	2	0	3	3	4	0.77
MFW_09	2	3	4	0.09	1	2	2	0
MFW_10	3	5*	6*	0.21	2	2	2	0
522_01	4	8*	8*	0.05	1	1	1	0
522_03	2	2	2	0.04	2	1	1	0
522_04	2	2	2	0.01	1	2	2	0.03
522_06	2	1	1	0	4	4	4	3.8
522_08	3	4	4	0.54	1	2	2	0.44
522_09	1	2	2	1.49	3	5	5	7.34
522_10	1	1	1	0.01	3	1	2	0.23
522_11	1	1	1	0	1	2	2	0
522_12	2	2	2	0	0	*NA*	*NA*	*NA*

Table 11d – Yellowfin tuna network metadata from 2022 and 2023. *NA* denotes that no metric data exist due to the lack of detections. Asterisks denote metric values that fall within the 90th percentile in that year (see Table 10 for threshold values). Stations SRW_11, SRW_13, BW_01, MFW_01, MFW_02, 522_02, 522_05, and 522_07 were not included due to receiver loss or discontinuation in one or both years. REV = Revolution Wind, SF = South Fork Wind, SRW = Sunrise Wind, BW = Beacon Wind, MFW = Mayflower (SouthCoast) Wind, Tx = total unique transmitters detected, DC = Degree Centrality, STR = Strength, EC = Eigenvector Centrality.

Station	**2022**				**2023**			
	Tx	**DC**	**STR**	**EC**	**Tx**	**DC**	**STR**	**EC**
REV_01	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_02	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_03	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_04	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_05	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_06	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_07	0	*NA*	*NA*	*NA*	1	1	1	0
REV_08	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_09	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_10	0	*NA*	*NA*	*NA*	1	0	0	0
REV_11	0	*NA*	*NA*	*NA*	1	1	1	0
REV_12	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_13	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_14	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_15	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_16	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_17	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
REV_18	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SF_01	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SF_02	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_01	0	*NA*	*NA*	*NA*	2	1	1	0
SRW_02	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_03	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_04	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_05	0	*NA*	*NA*	*NA*	1	1	1	5.07
SRW_06	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_07	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_08	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_09	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
SRW_10	0	*NA*	*NA*	*NA*	2	1	1	0
SRW_12	0	*NA*	*NA*	*NA*	3	4	4	29.97
501_01	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*

501_02	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
501_03	0	*NA*	*NA*	*NA*	1	2	2	0.22
501_04	0	*NA*	*NA*	*NA*	2	5	5	1.4
534_01	0	*NA*	*NA*	*NA*	1	1	1	6.71
534_02	0	*NA*	*NA*	*NA*	3	5	6	38.64
534_03	0	*NA*	*NA*	*NA*	1	4	4	11.21
534_04	0	*NA*	*NA*	*NA*	1	2	2	0.22
534_05	0	*NA*	*NA*	*NA*	3	4	5	24.33
534_06	0	*NA*	*NA*	*NA*	3	4	4	19.58
BW_02	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
BW_03	0	*NA*	*NA*	*NA*	5	11*	11*	100.00*
BW_04	0	*NA*	*NA*	*NA*	2	5	5	32.47
BW_05	2	0	0	58.49	3	3	3	7.96
BW_06	1	0	0	0	3	9*	11*	80.44*
BW_07	0	*NA*	*NA*	*NA*	3	10*	13*	96.14*
BW_08	1	0	0	0	3	7	10	77.16*
BW_09	0	*NA*	*NA*	*NA*	3	8	8	49.29
BW_10	0	*NA*	*NA*	*NA*	1	2	2	3.42
MFW_03	0	*NA*	*NA*	*NA*	2	6	6	42.22
MFW_04	0	*NA*	*NA*	*NA*	2	7	7	28.02
MFW_05	0	*NA*	*NA*	*NA*	4	10*	11*	76.54
MFW_06	0	*NA*	*NA*	*NA*	3	7	8	50.73
MFW_07	0	*NA*	*NA*	*NA*	2	6	6	20.14
MFW_08	0	*NA*	*NA*	*NA*	2	6	6	37.04
MFW_09	1	1	1	0	3	5	5	3.93
MFW_10	0	*NA*	*NA*	*NA*	2	4	4	23.73
522_01	0	*NA*	*NA*	*NA*	1	2	2	0.14
522_03	0	*NA*	*NA*	*NA*	2	5	5	0.89
522_04	0	*NA*	*NA*	*NA*	0	*NA*	*NA*	*NA*
522_06	1	1	1	0	0	*NA*	*NA*	*NA*
522_08	0	*NA*	*NA*	*NA*	1	2	2	0.73
522_09	1	1	1	0	1	2	2	0.12
522_10	2	2*	2*	100.00*	1	2	2	1.26
522_11	1	0	0	0	2	4	4	4.66
522_12	1	1	1	100.00*	1	1	1	0

Table 12 – Statistical results of both the Brown-Forsythe test of variance distribution and the Wilcoxon Rank-Sum test (i.e., Mann-Whitney U Test) of overall distribution of metric data from 2022 and 2023. Asterisks denote a significant difference was found ($p < 0.05$) between years.

Species	**Metric**	**Distribution of variance (Brown-Forsythe Test)**		**Distribution of metric values (Wilcoxon Rank-Sum Test)**	
		F-Value	**p-Value**	**W-Value**	**p-Value**
Bluefin tuna	Degree centrality	35.008	<0.001*	0	<0.001*
	Strength	31.247	<0.001*	1	<0.001*
	Eigenvector centrality	5.457	0.021*	670.5	<0.001*
Blue shark	Degree centrality	24.451	<0.001*	3706.5	<0.001*
	Strength	22.592	<0.001*	3692.5	<0.001*
	Eigenvector centrality	6.459	0.012*	1389.5	0.006*
Shortfin mako	Degree Centrality	11.025	0.001*	982	<0.001*
	Strength	8.815	0.004*	991.5	<0.001*
	Eigenvector centrality	0.638	0.426	1088	<0.001*
Yellowfin tuna	Degree centrality	9.024	0.004*	31.5	<0.001*
	Strength	8.155	0.006*	31.5	<0.001*
	Eigenvector centrality	0.429	0.516	144	0.473

Table 13 – Environmental conditions in which tagged species were detected/observed during the study period. The SST value for little tunny was reported as a single number due to limited detection data. SST = sea surface temperature, T = temperature, ΔT = SST – bottom T, Chl a = chlorophyll a.

Species	**SST (ºC)**	**Bottom T (ºC)**	**ΔT (ºC)**	**Chl a (mg/mL)**
Blue shark	14.7 - 25.2	7.9 - 19.2	-0.5 - 13.8	0.24 - 2.33
Bluefin tuna	7.8 - 24.9	8.6 - 17.7	-1.5 - 14.2	0.27 - 2.17
Common thresher shark	13.3 - 20.7	12.4 - 16.3	-1.0 - 8.1	0.65 - 2.10
Dusky shark	17.5 - 25.4	9.6 - 19.8	0.1 - 13.2	0.31 - 1.33
Little tunny	21.7 - 21.7	13.6 - 13.8	7.9 - 8.1	0.68 - 0.74
Sandbar shark	18.8 - 24.2	11.1 - 17.6	1.3 - 12.2	0.32 - 1.75
Shortfin mako	13.1 - 24.6	8.7 - 17.0	-0.7 - 14.1	0.30 - 2.16
Smooth hammerhead	20.3 - 22.7	9.5 - 13.1	9.0 - 11.8	0.49 - 0.78
Spinner shark	22.1 - 24.9	12.1 - 15.3	6.9 - 12.8	0.29 - 0.95
Yellowfin tuna	19.0 - 24.7	9.4 - 13.4	5.8 - 14.6	0.27 - 2.03

Table 14 – Summary of hourly (bottom) temperature and average noise measured by VR2AR and VR2Tx acoustic receivers deployed at each lease in each year of the study. Asterisks by dates indicate that receiver deployment was not continuous at one or more stations in the lease throughout the range of dates. Refer to tables 1a – 1h for dates of all deployment periods for each station.

Lease	2022			2023		
	Dates	**Temperature (°C)**	**Noise (mV)**	**Dates**	**Temperature (°C)**	**Noise (mV)**
Revolution Wind	1/1 - 12/31*	3.1 - 22.4 (12.0 ± 3.4)	147.7 - 985.0 (220.9 ± 59.3)	1/1 - 12/31*	3.4 - 17.7 (10.5 ± 3.6)	146.2 - 983.8 (223.2 ± 67.4)
South Fork Wind	1/1 - 12/31*	5.0 - 23.4 (11.6 ± 3.9)	149.8 - 731.6 (235.6 ± 63.7)	1/1 - 12/31*	5.9 - 18.5 (11.9 ± 3.0)	155.9 - 821.9 (254.4 ± 85.5)
Sunrise Wind	1/1 - 12/31*	4.2 - 20.6 (12.0 ± 2.6)	142.2 - 844.5 (206.9 ± 56.2)	1/1 - 12/31*	3.9 - 16.8 (9.9 ± 3.2)	140.8 - 744.2 (200.8 ± 43.1)
Vineyard Wind 1	6/3 - 12/2	8.7 - 17.0 (13.5 ± 2.1)	146.8 - 833.9 (207.3 ± 55.8)	5/12 - 12/2	8.5 - 16.1 (12.6 ± 1.9)	145.5 - 945.5 (212.1 ± 61.0)
New England Wind	6/3 - 12/2	8.0 - 16.3 (12.6 ± 2.3)	146.1 - 870.7 (200.5 ± 45.3)	5/12 - 12/2	7.1 - 15.8 (11.7 ± 2.2)	146.1 - 746.9 (194.4 ± 36.5)
Beacon Wind	6/3 - 12/5*	8.1 - 16.4 (12.7 ± 2.0)	149.2 - 818.0 (195.2 ± 33.8)	5/12 - 12/2	7.3 - 16.1 (11.6 ± 2.2)	148.6 - 589.9 (192.1 ± 33.0)
SouthCoast Wind	6/6 - 12/7*	8.2 - 17.4 (13.0 ± 1.9)	151.1 - 910.7 (197.6 ± 34.6)	6/1 - 12/2*	7.8 - 17.0 (12.2 ± 2.0)	150.6 - 570.5 (194.8 ± 35.1)
Vineyard Northeast	6/6 - 12/7*	8.5 - 17.6 (13.4 ± 1.9)	148.7 - 722.9 (201.3 ± 43.8)	6/1 - 12/2	8.1 - 17.0 (12.5 ± 1.9)	148.4 - 689.2 (195.9 ± 41.5)
All leases	1/1 - 12/31*	3.1 - 23.4 (12.5 ± 2.8)	142.2 - 985.0 (209.3 ± 52.7)	1/1 - 12/31*	3.4 - 18.5 (11.1 ± 3.1)	140.8 - 983.8 (207.9 ± 55.0)

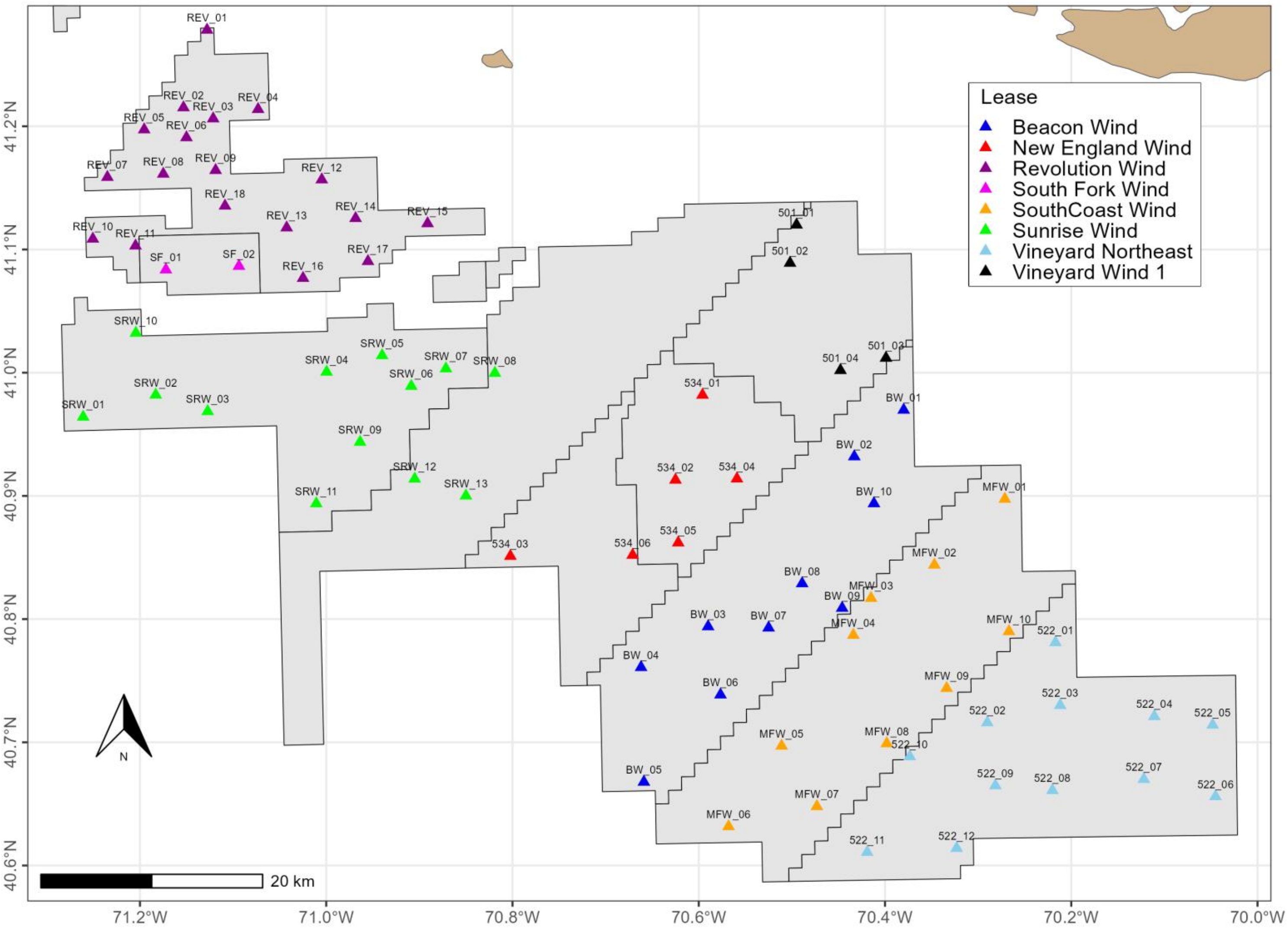


Figure 1a – Map showing the locations of 75 acoustic receiver stations (colored triangles) deployed in the MA/RI wind energy area in 2022. Abbreviations for each station are indicated above each triangle.

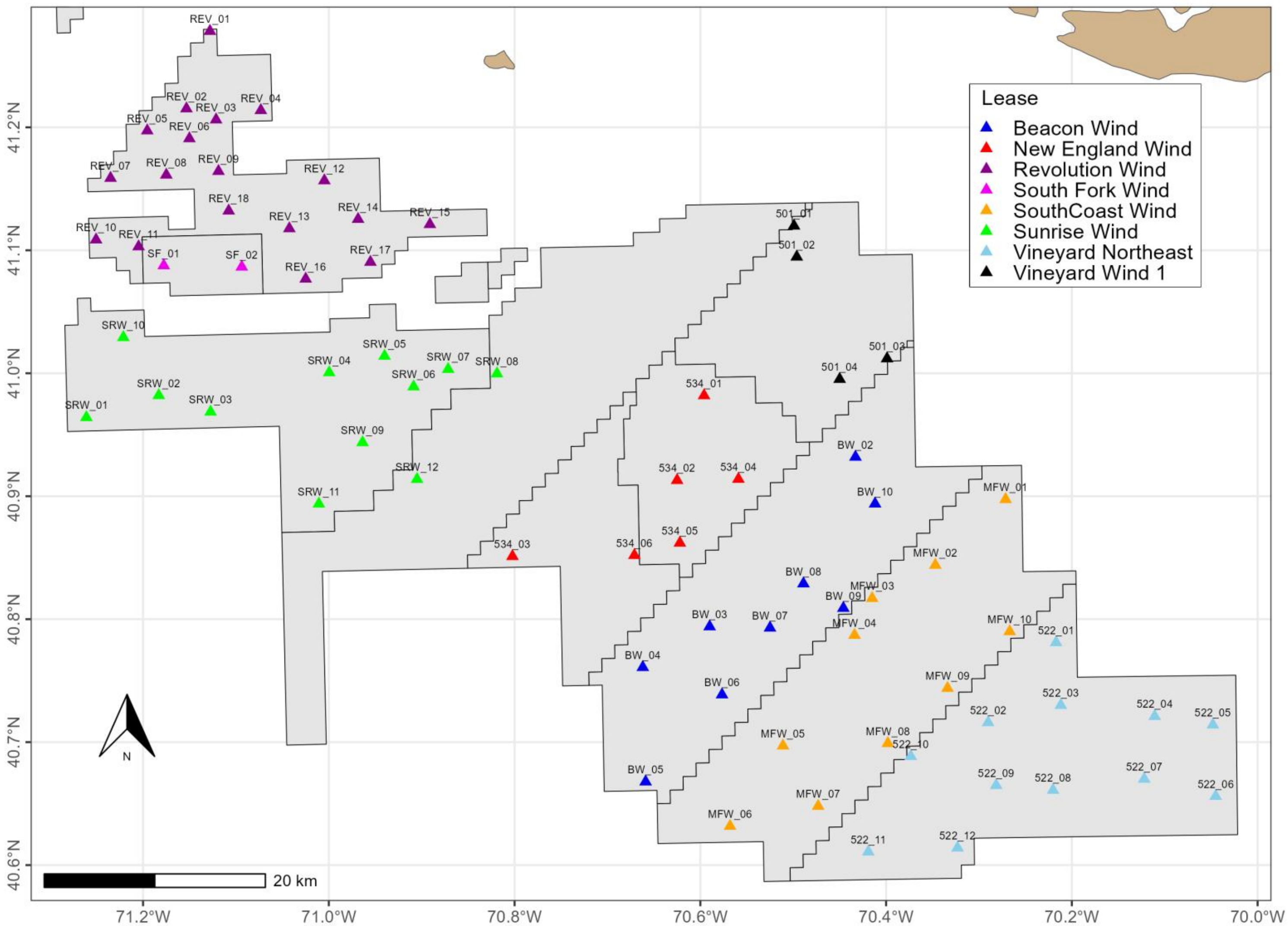


Figure 1b – Map showing the locations of 73 acoustic receiver stations (colored triangles) deployed in the MA/RI wind energy area in 2023. Abbreviations for each station are indicated above each triangle. The receivers at SRW_13 and BW_01 were lost in 2022, and the stations were not redeployed in 2023.

Figure 2 – Recoverable and reusable mooring configurations used to deploy VEMCO VR2AR acoustic receivers.

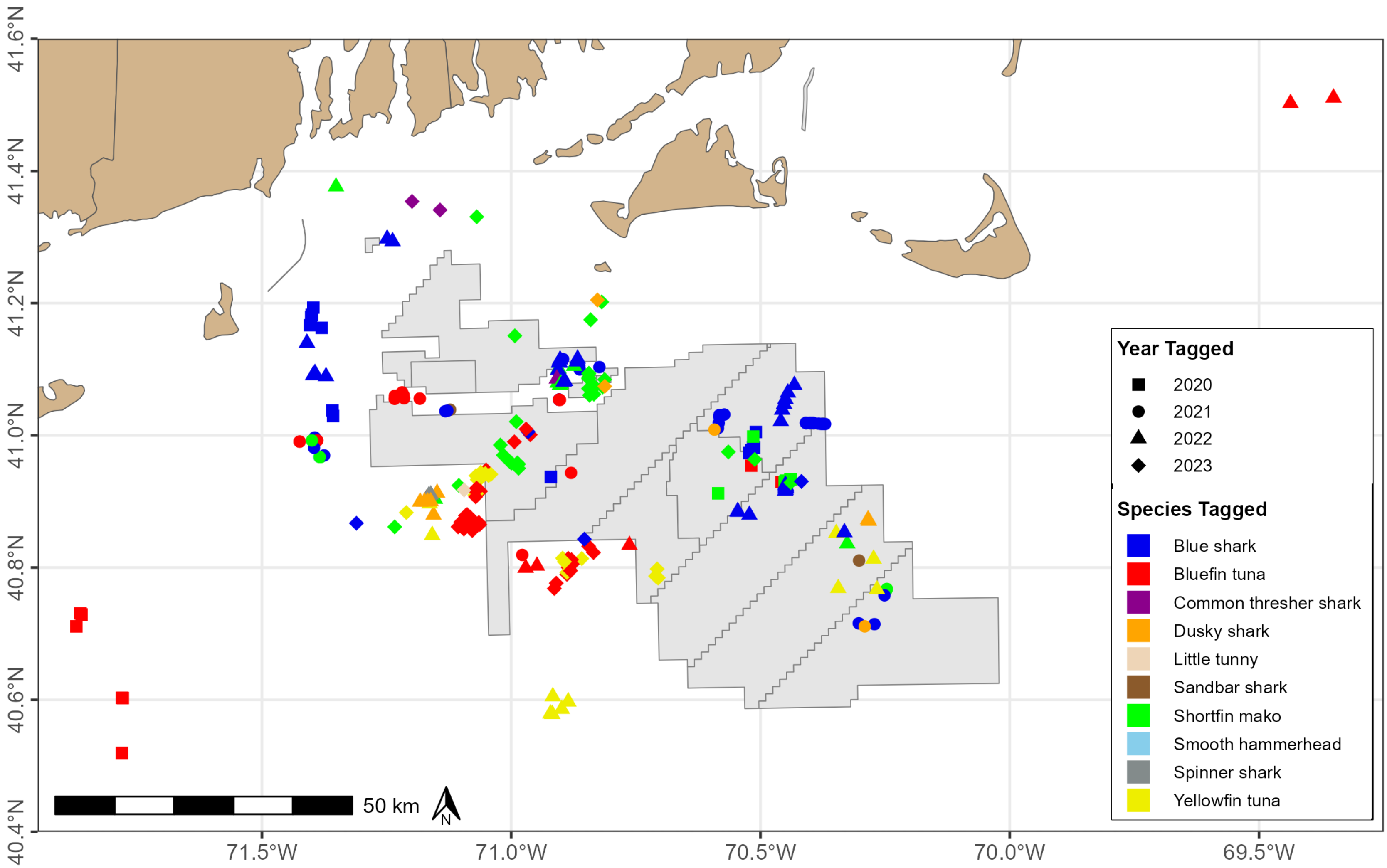


Figure 3 – Locations of tagging relative to the lease areas for the 259 individuals tagged since 2020.

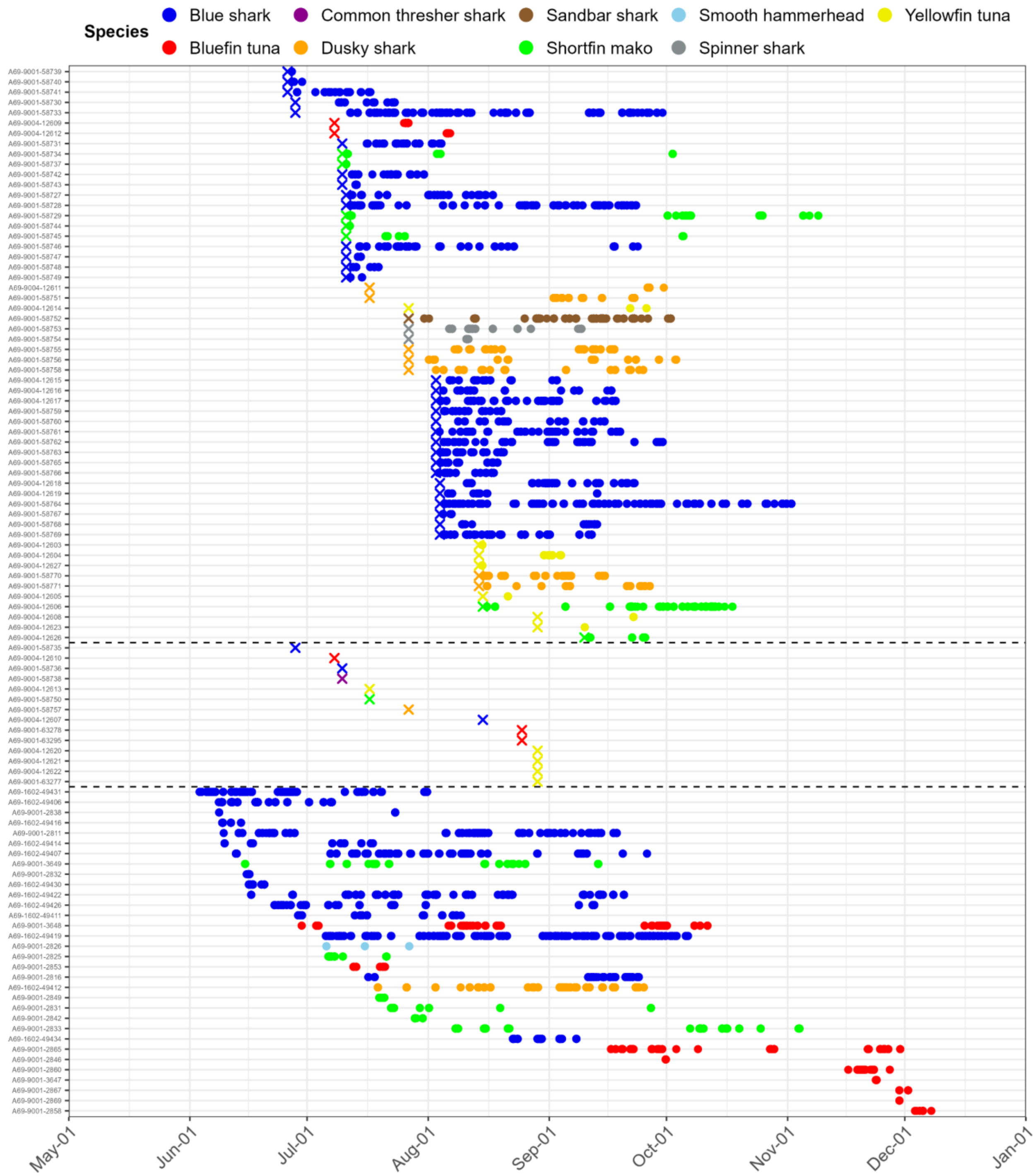


Figure 4a – Detection histories for 88 individuals that were monitored in 2022. Each dot represents a detection on one of the acoustic receivers. Colored ‘Xs’ represent the time of tagging for each individual. Detected individuals that were tagged in previous years have no ‘X’ in their detection history. Dashed lines separate fish tagged and detected in 2022 (n = 56; top), fish tagged but not detected in 2022 (n = 14; middle), and returning fish tagged in previous years (n = 32; bottom).

Figure 4b – Detection histories for 103 individuals that were monitored in 2023. Each dot represents a detection on one of the acoustic receivers. Colored 'Xs' represent the time of tagging for each individual. Detected individuals that were tagged in previous years have no 'X' in their detection history. Dashed lines separate fish tagged and detected in 2023 (n = 69; top), fish tagged but not detected in 2023 (n = 22; middle), and returning fish tagged in previous years (n = 34; bottom).

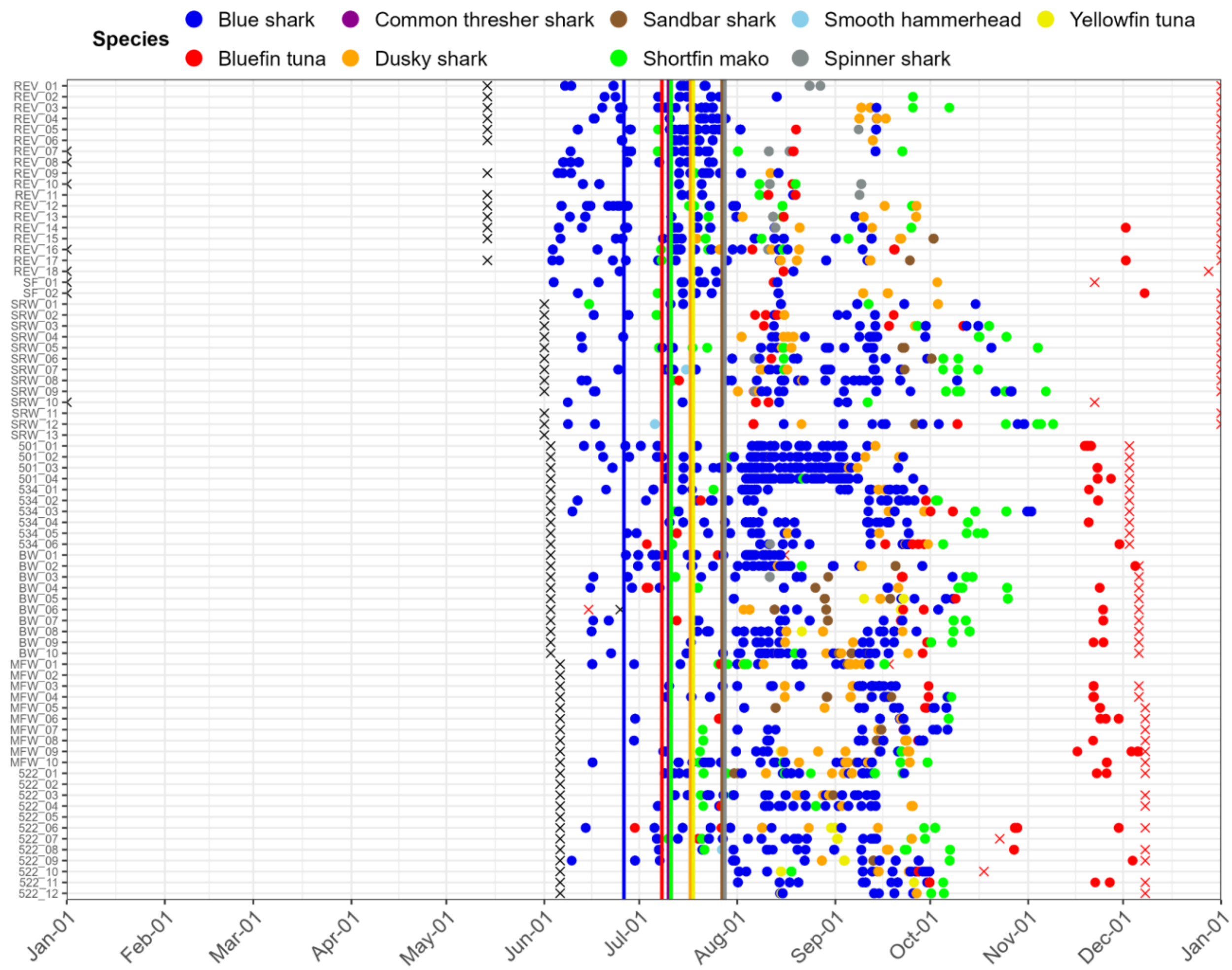


Figure 5a – Detection histories of each species on each receiver station in 2022. Colored circles indicate when that species was observed at a given station. Colored vertical lines represent the time individuals of each species were first tagged in 2022. Black 'Xs' represent the time when the receiver was deployed, and red 'Xs' represent the time it was removed or caught via interaction with fishing gear. Note that receivers at SRW_13, MFW_02, 522_02, and 522_05 were lost during the field season. The receiver at SRW_11 malfunctioned, and no data were retrieved from this station.

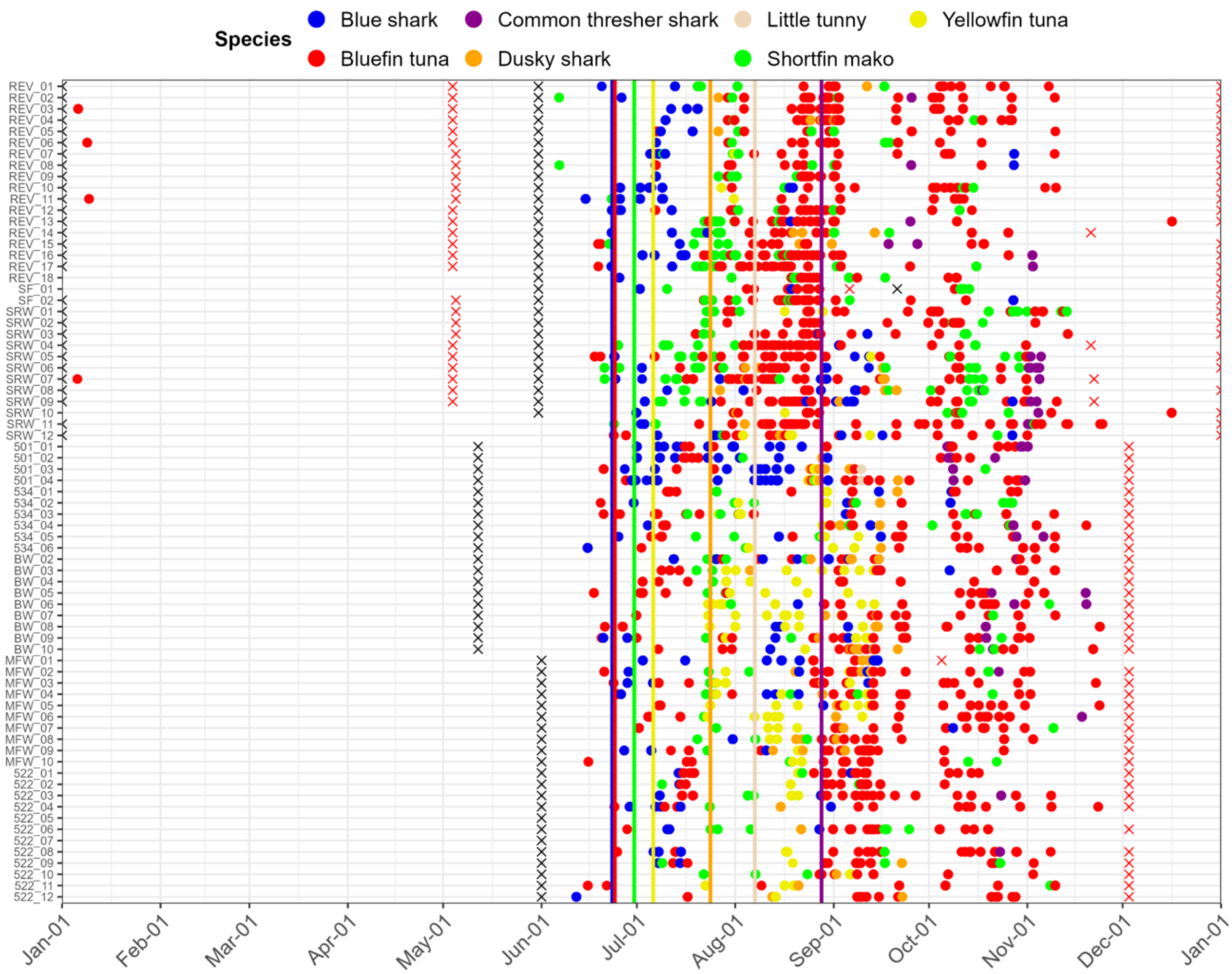


Figure 5b – Detection histories of each species on each receiver station in 2023. Colored circles indicate when that species was observed at a given station. Colored vertical lines represent the time individuals of each species were first tagged in 2023. Black 'Xs' represent the time when the receiver was deployed, and red 'Xs' represent the time it was removed or caught via interaction with fishing gear. Note that receivers at 522_05 and 522_07 were lost during the field season.

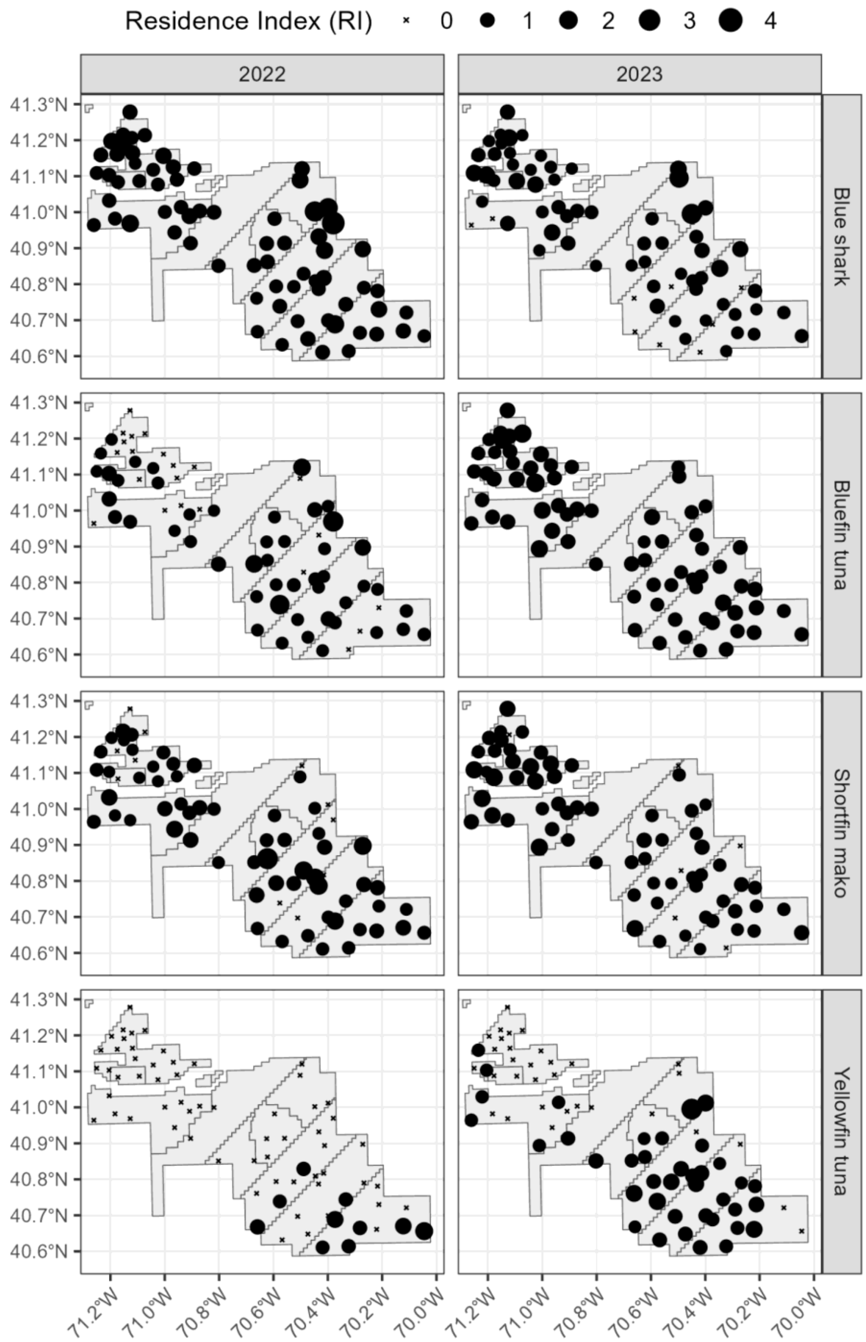


Figure 6a – Residency index (RI) calculated at each receiver station for blue shark, bluefin tuna, shortfin mako, and yellowfin tuna during 2022 and 2023. Note that receivers at SRW_13. MFW_02, 522_02, and 522_05 were lost in 2022, and receivers at 522_05 and 522_07 were lost in 2023. The receiver at SRW_11 malfunctioned in 2022, and no data were retrieved from this station. Values of RI for stations BW_01, MFW_01, 522_07, and 522_10 in 2022 and station MFW_01 in 2023 were calculated across subsets of months from June to November; refer to tables 1a - 1h for deployment intervals.

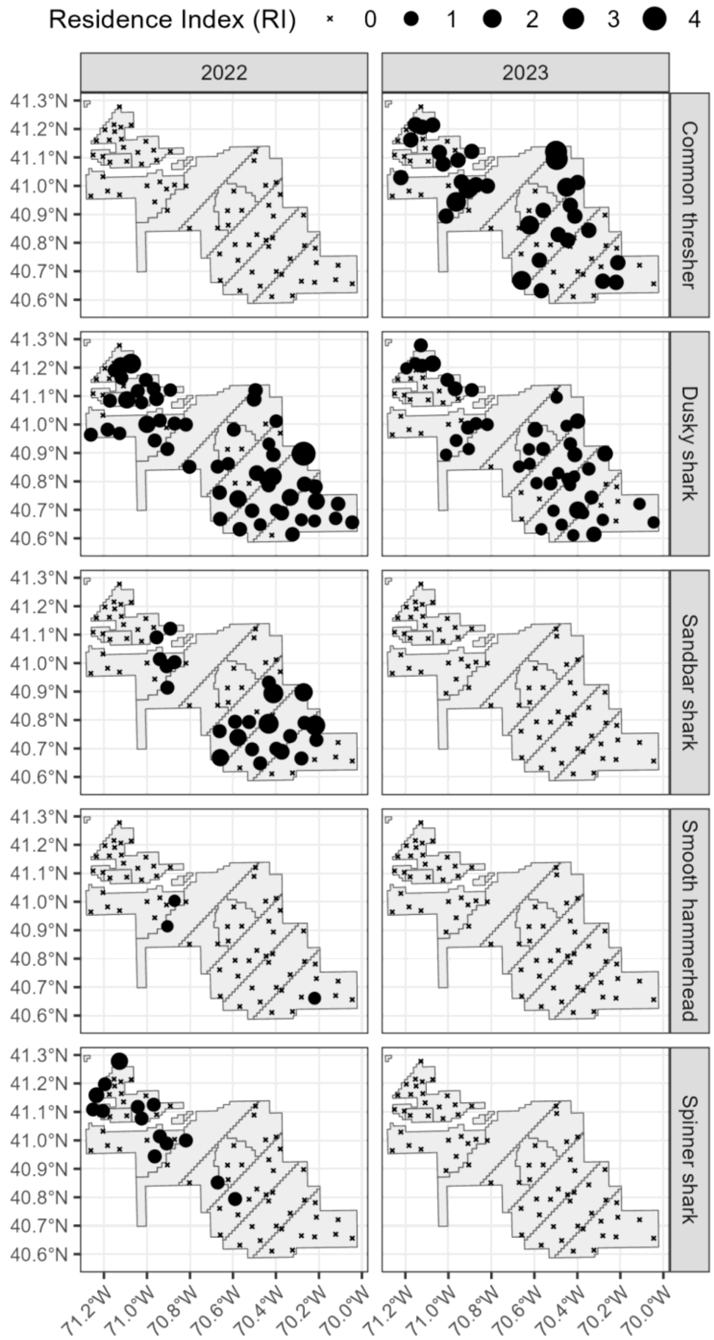


Figure 6b – Residency index (RI) calculated at each receiver station for common thresher, dusky, shark, sandbar shark, smooth hammerhead, and spinner shark during 2022 and 2023. Note that receivers at SRW_13, MFW_02, 522_02, and 522_05 were lost in 2022, and receivers at 522_05 and 522_07 were lost in 2023. The receiver at SRW_11 malfunctioned in 2022, and no data were retrieved from this station. Values of RI for stations BW_01, MFW_01, 522_07, and 522_10 in 2022 and station MFW_01 in 2023 were calculated across subsets of months from June to November; refer to tables 1a - 1h for deployment intervals.

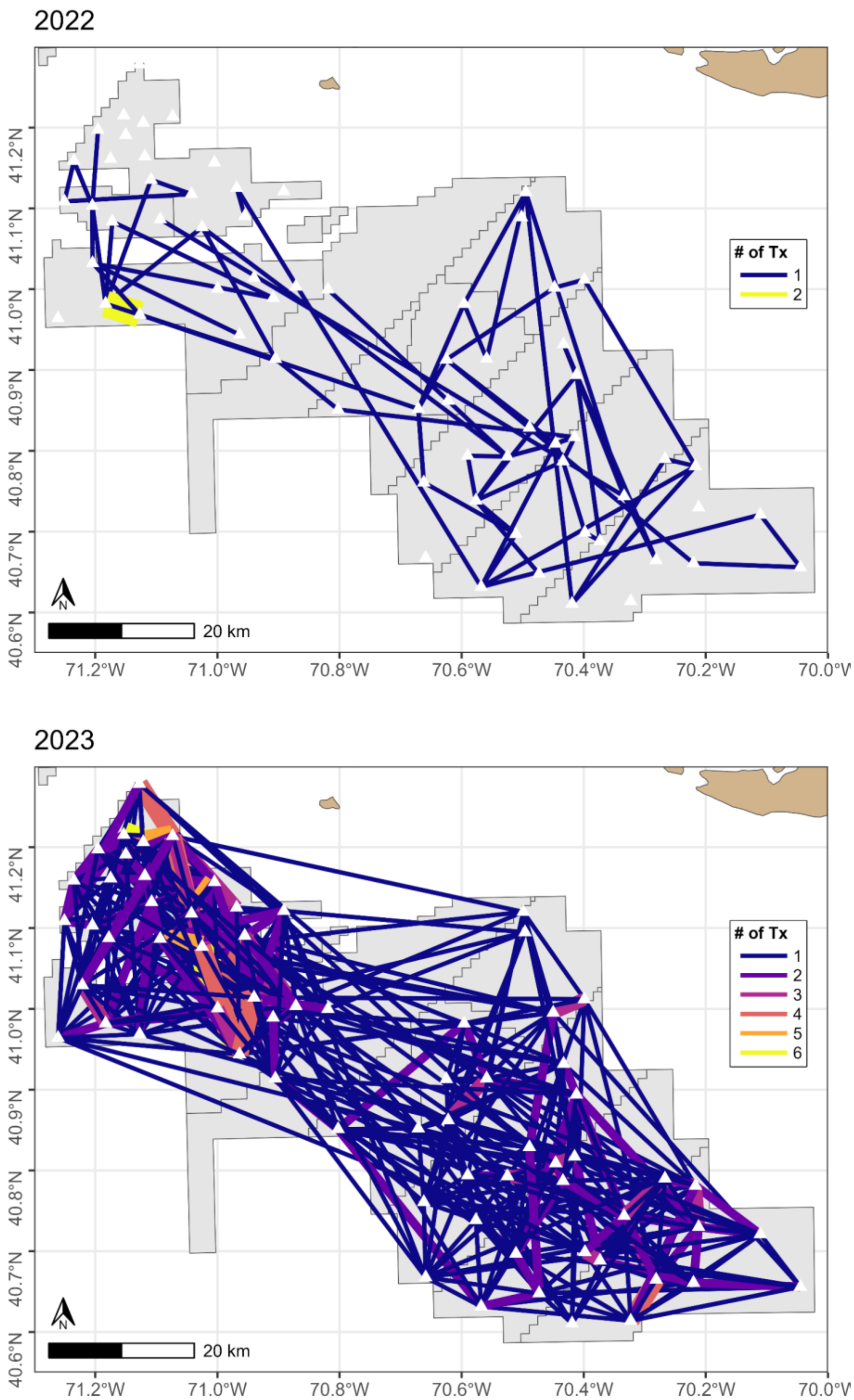


Figure 7a – Maps of the 2022 (top) and 2023 (bottom) bluefin tuna movement networks. Edges are weighted by the number of transmitters (Tx) that traveled between nodes (receiver stations).

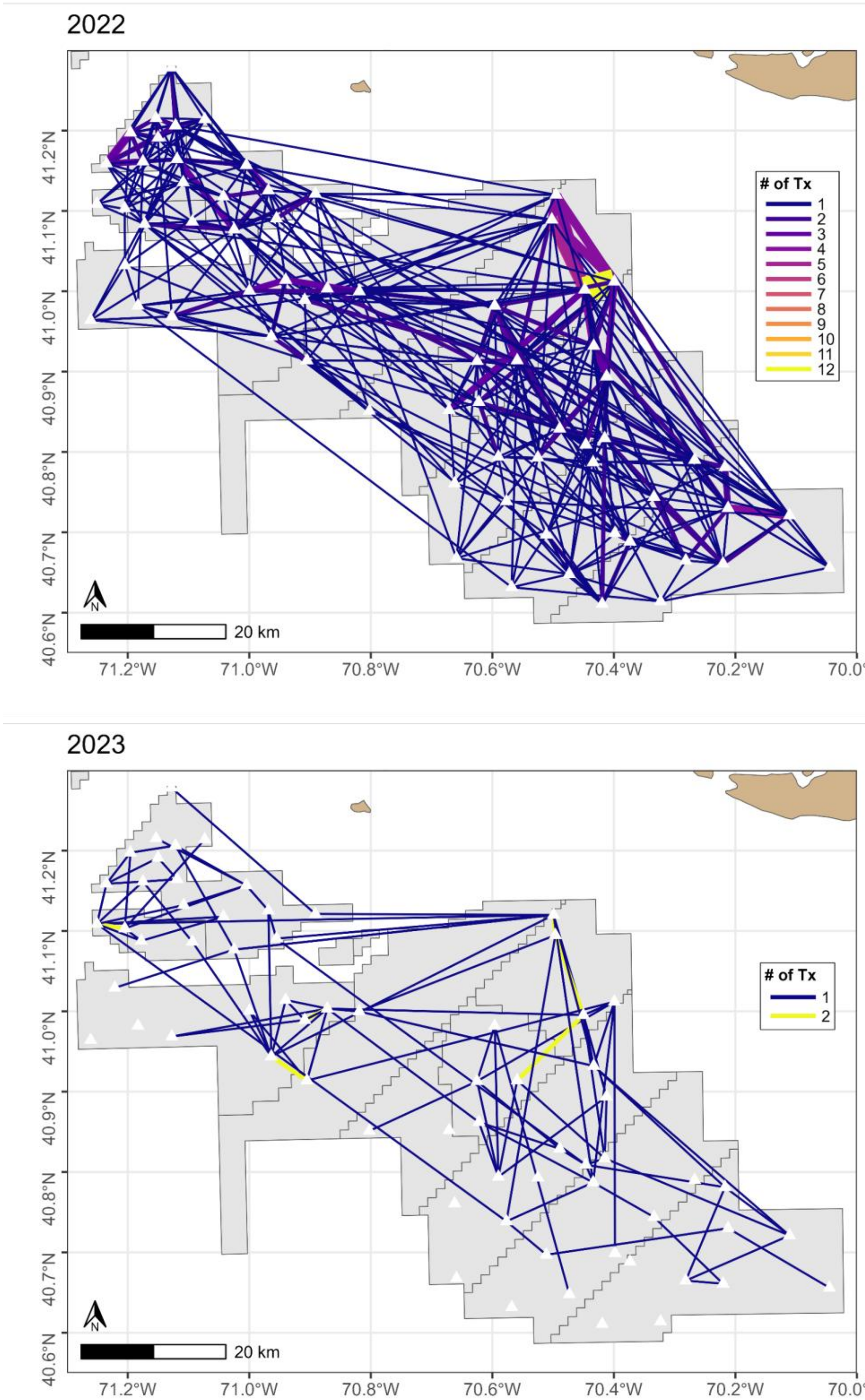


Figure 7b – Maps of the 2022 (top) and 2023 (bottom) blue shark movement networks. Edges are weighted by the number of transmitters (Tx) that traveled between nodes (receiver stations).

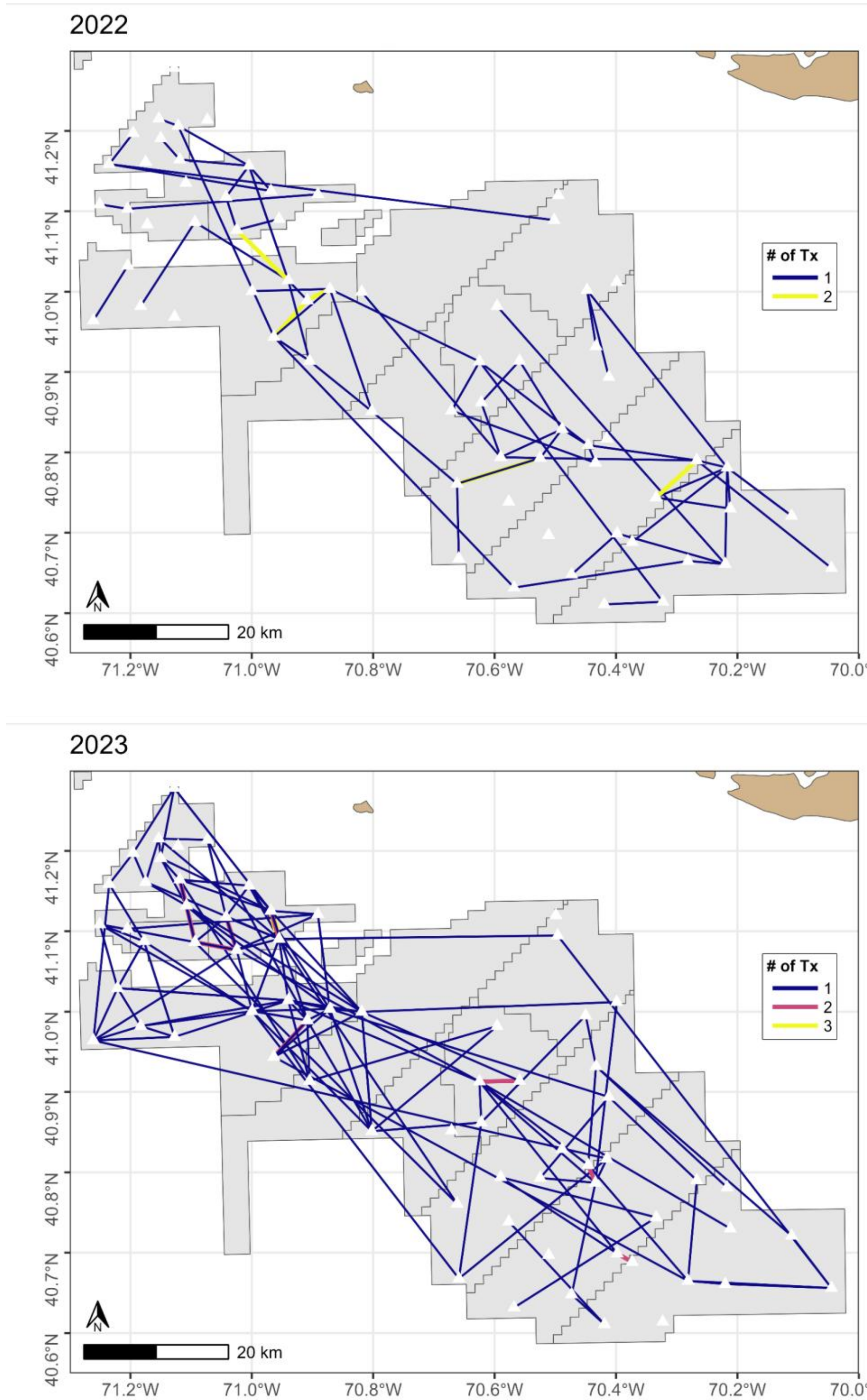
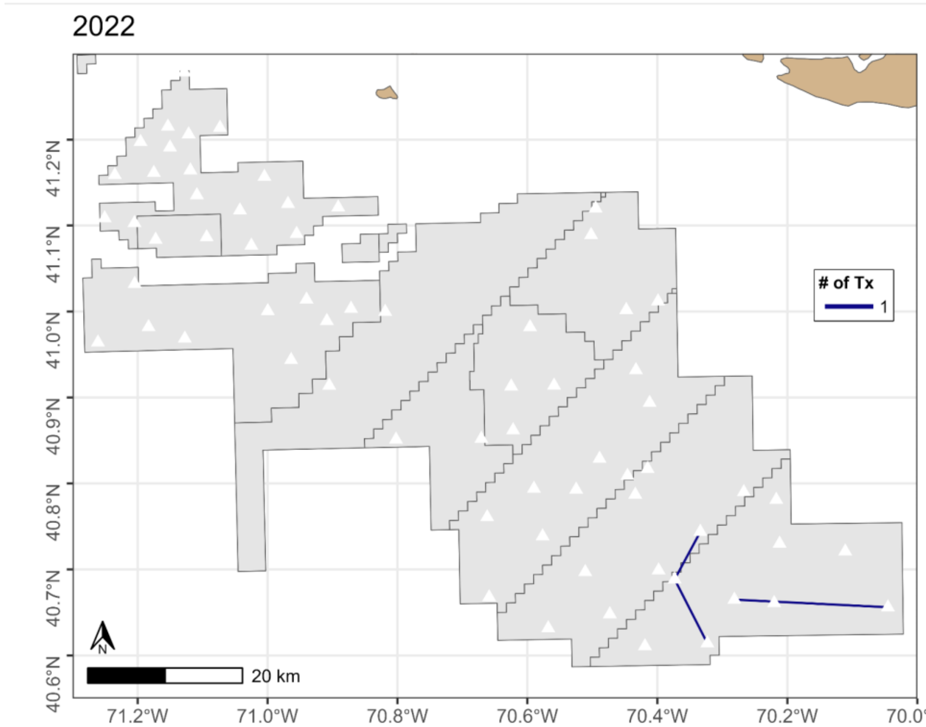


Figure 7c – Maps of the 2022 (top) and 2023 (bottom) shortfin mako movement networks. Edges are weighted by the number of transmitters (Tx) that traveled between nodes (receiver stations).



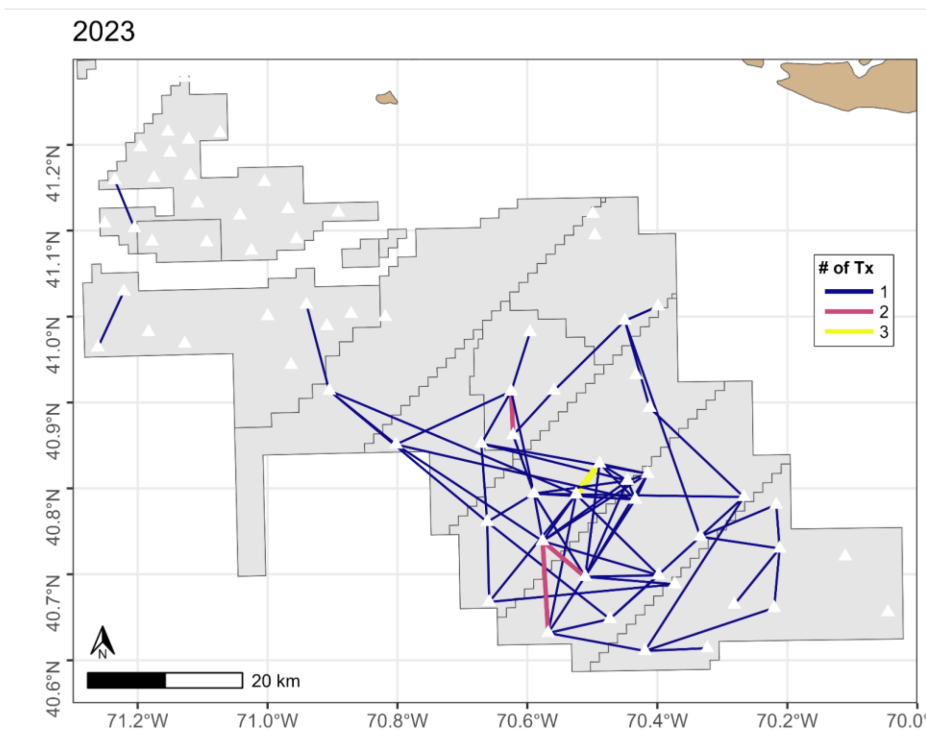


Figure 7d – Maps of the 2022 (top) and 2023 (bottom) yellowfin tuna movement networks. Edges are weighted by the number of transmitters (Tx) that traveled between nodes (receiver stations).

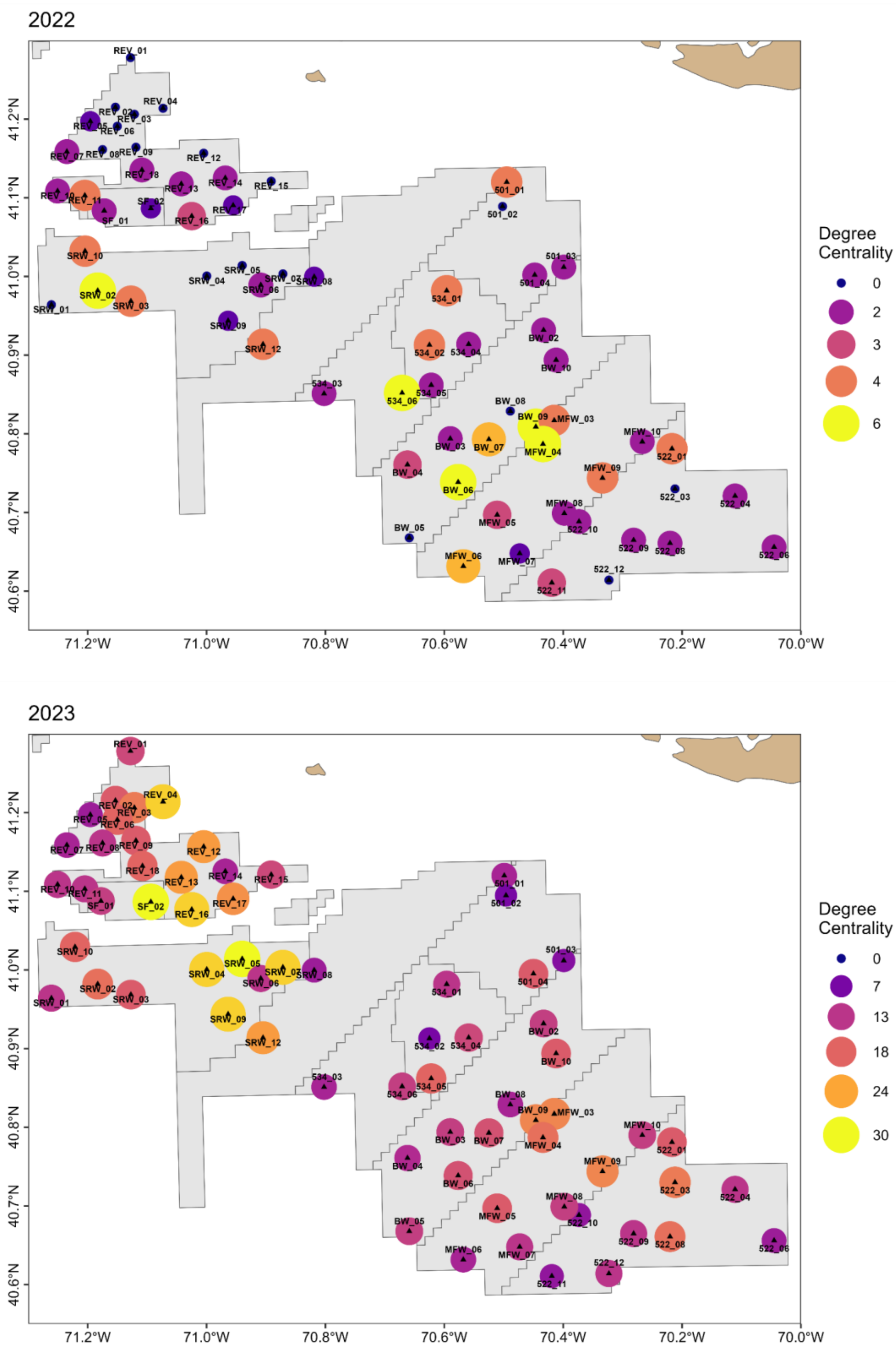


Figure 8a – Maps of 2022 (top) and 2023 (bottom) bluefin tuna node degree centrality values.

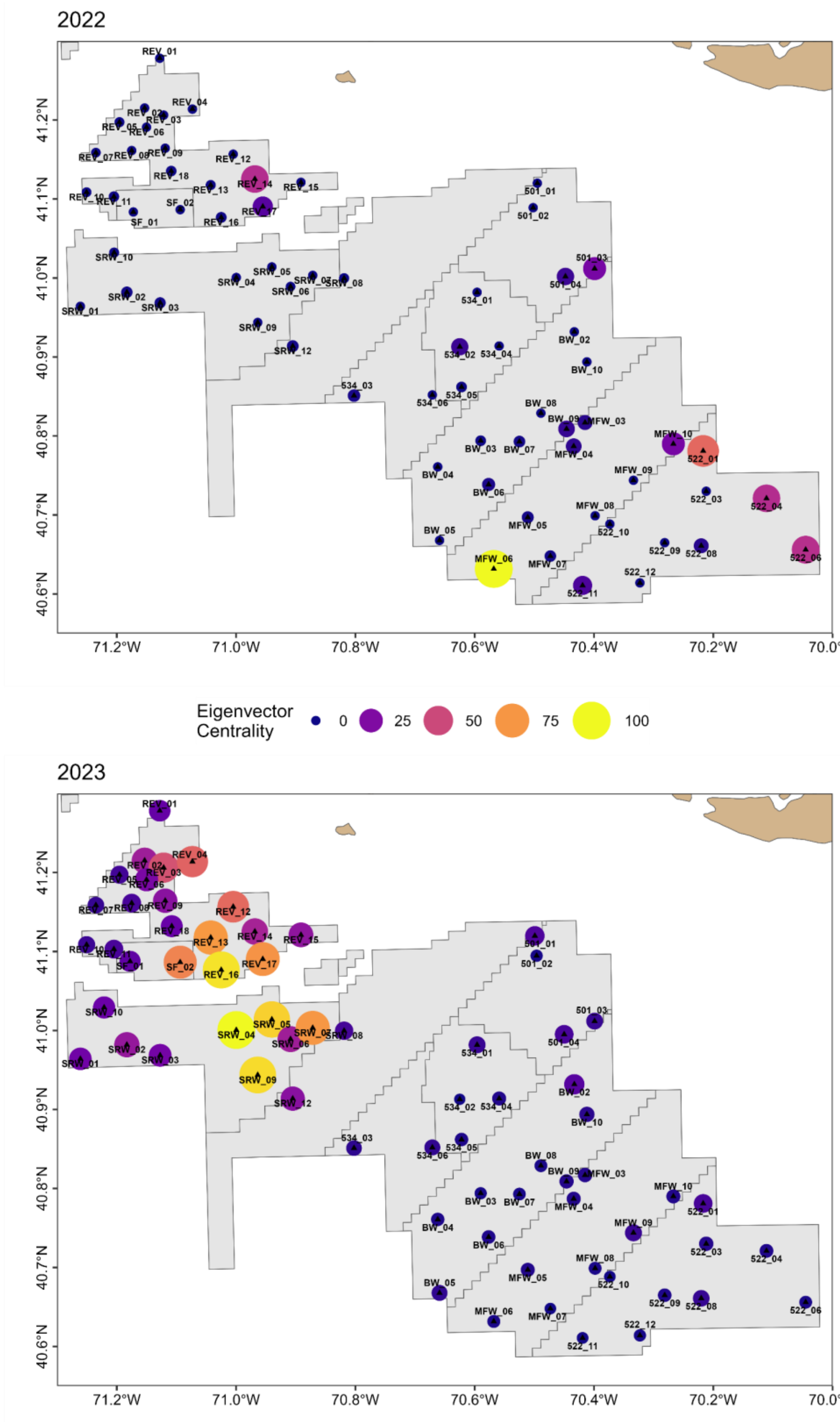


Figure 8b – Maps of 2022 (top) and 2023 (bottom) bluefin tuna node eigenvector centrality values.

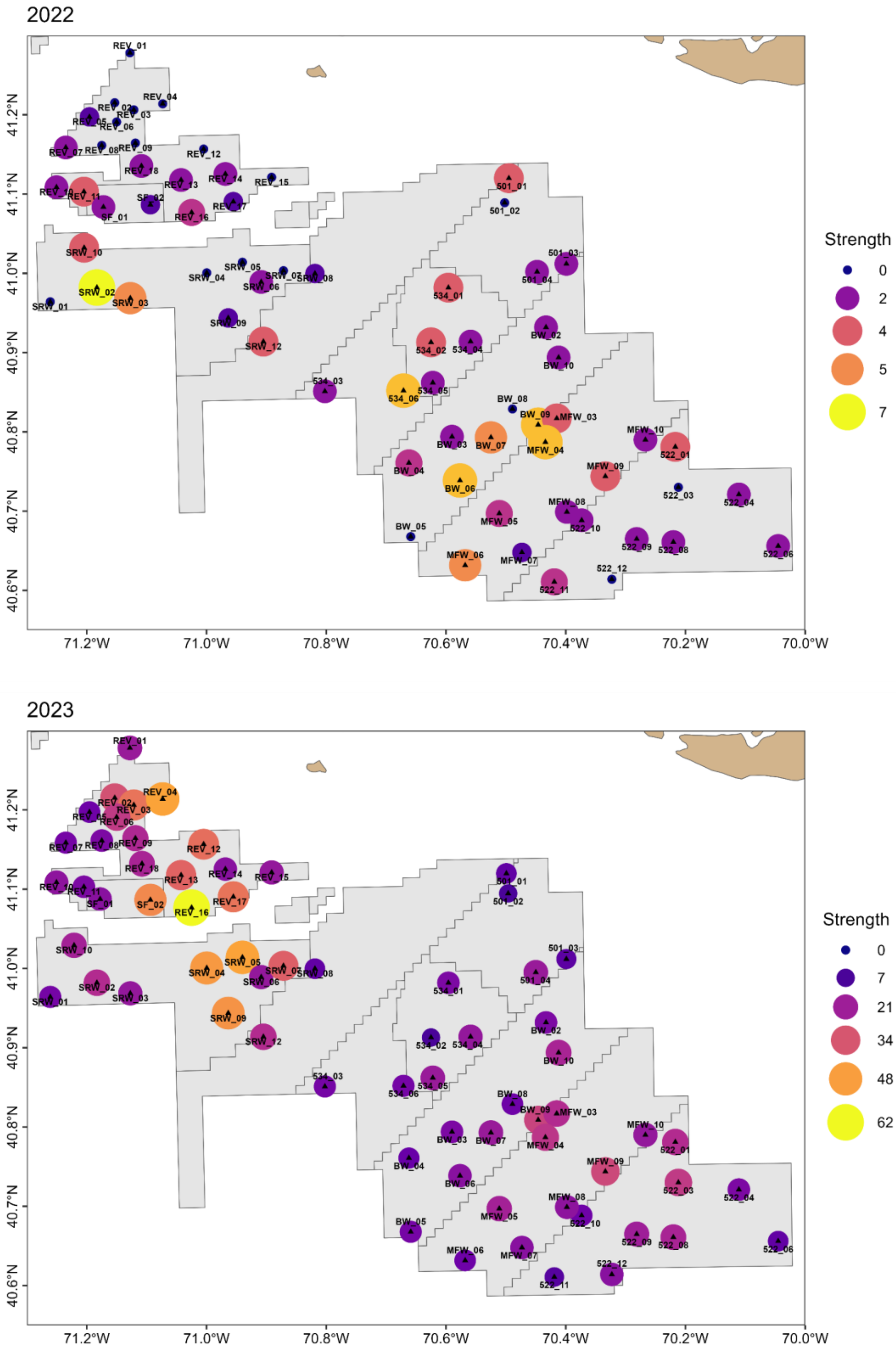
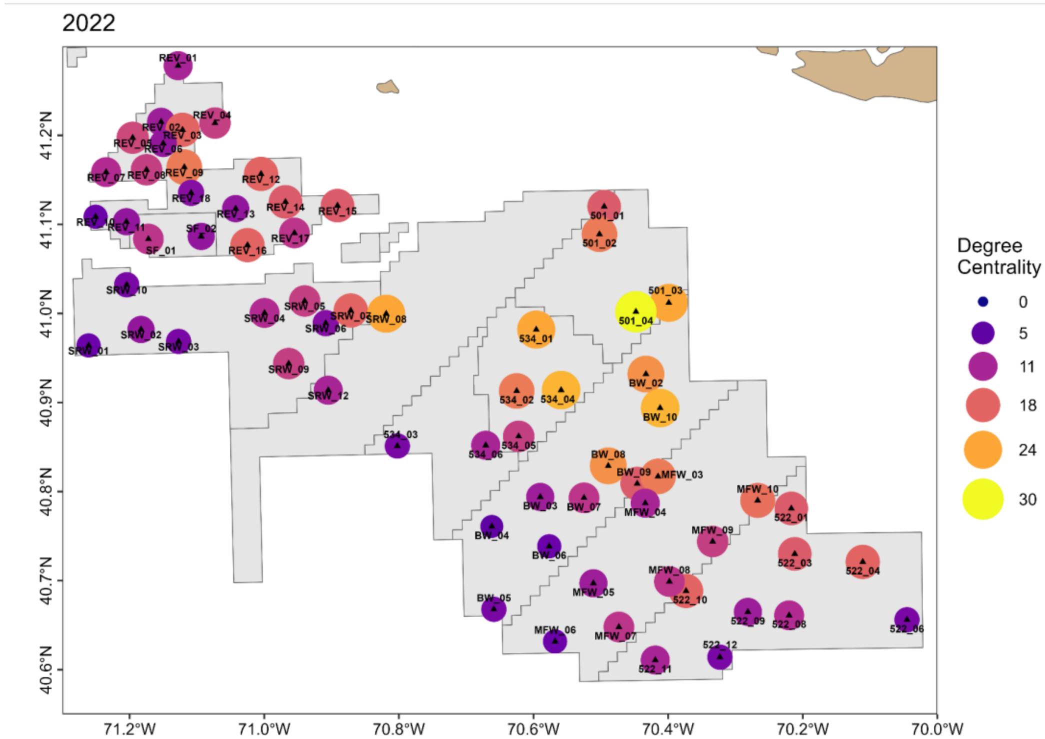


Figure 8c – Maps of 2022 (top) and 2023 (bottom) bluefin tuna node strength values.



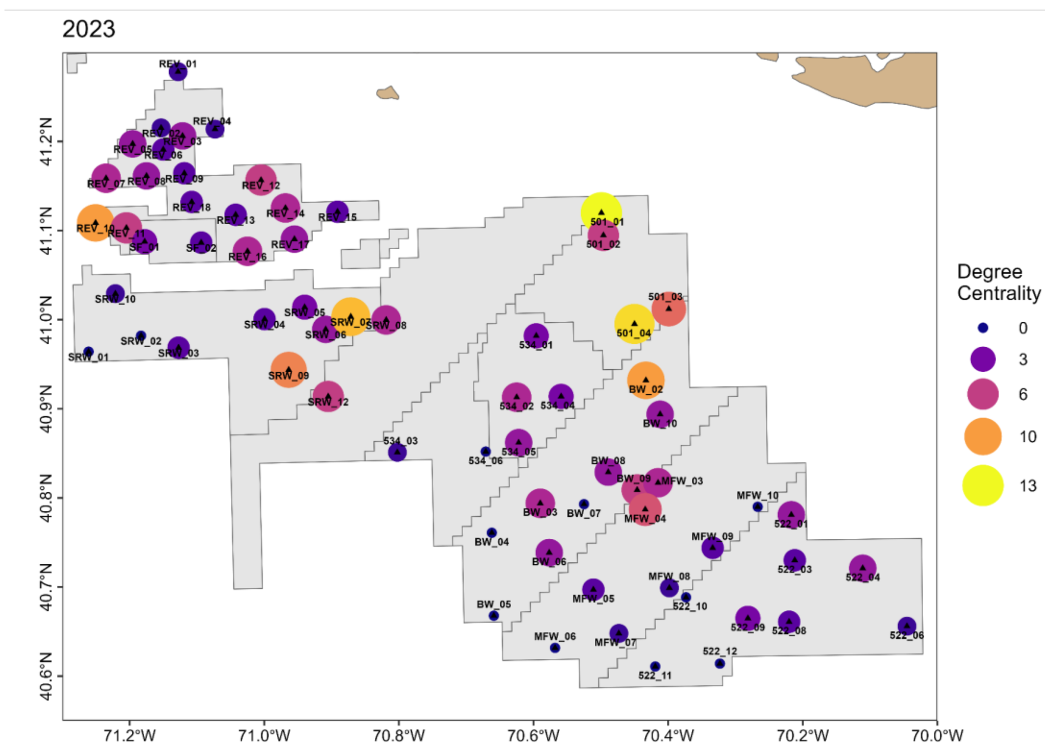


Figure 8d – Maps of 2022 (top) and 2023 (bottom) blue shark node degree centrality values.

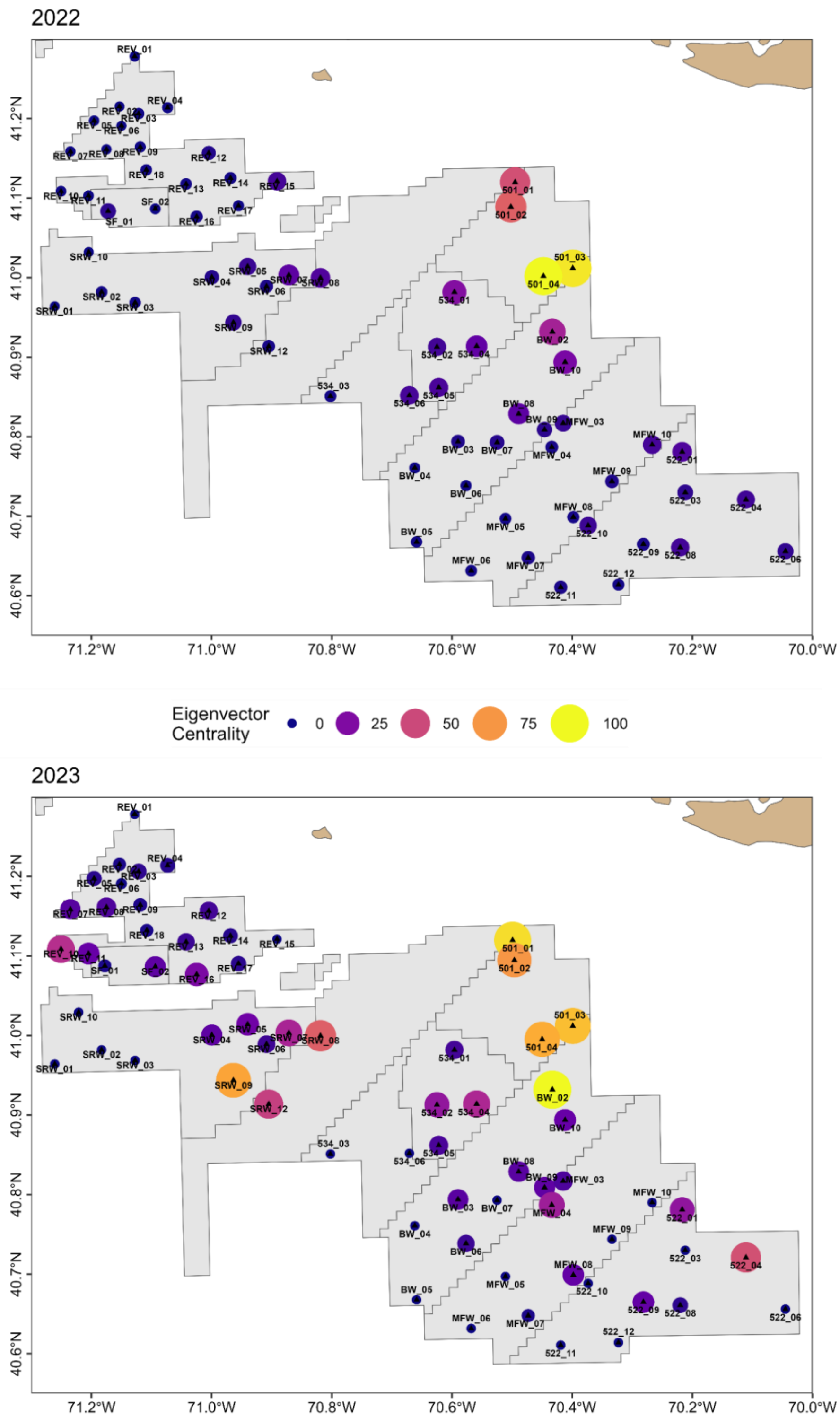


Figure 8e – Maps of 2022 (top) and 2023 (bottom) blue shark node eigenvector centrality values.

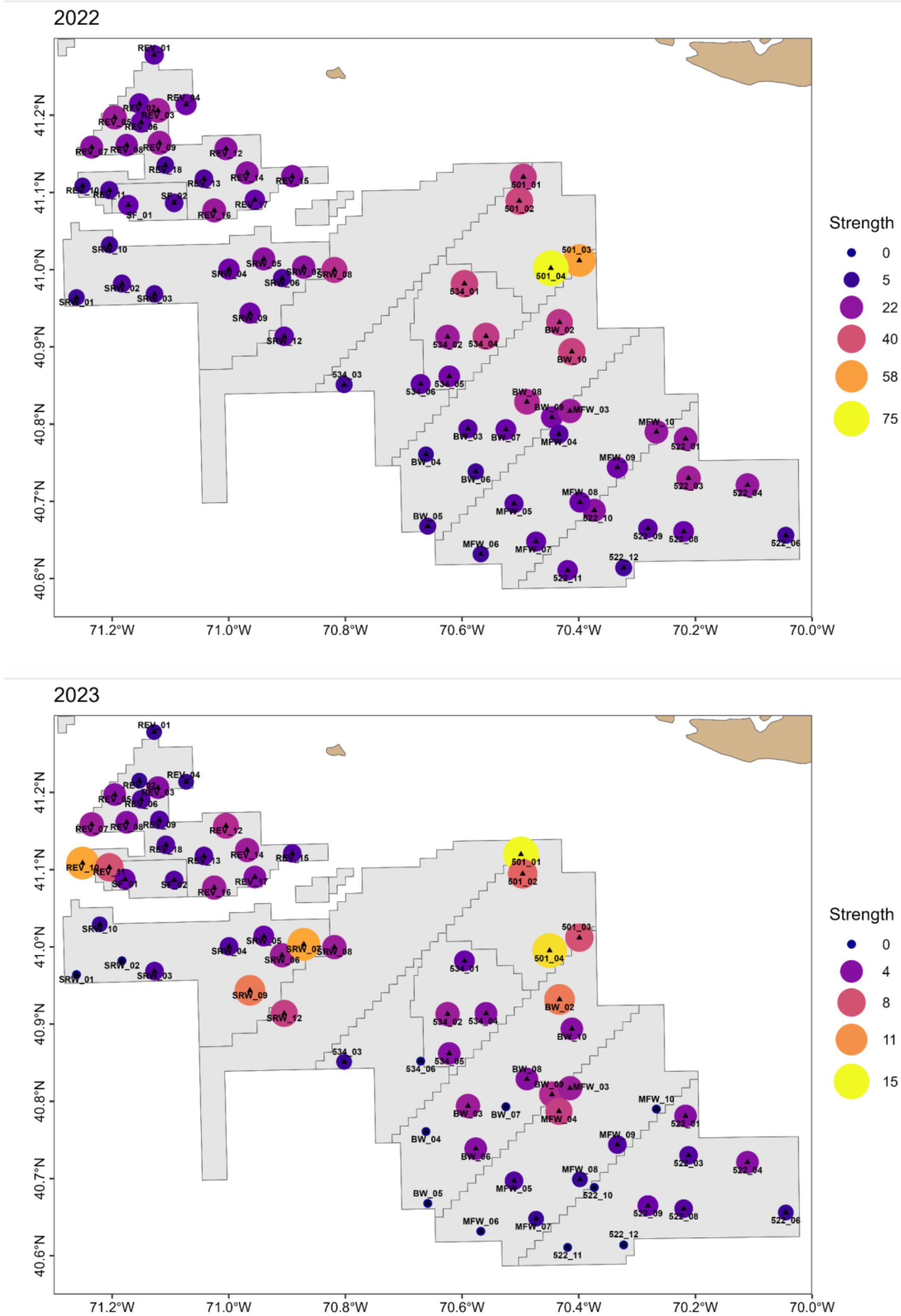


Figure 8f – Maps of 2022 (top) and 2023 (bottom) blue shark node strength values.

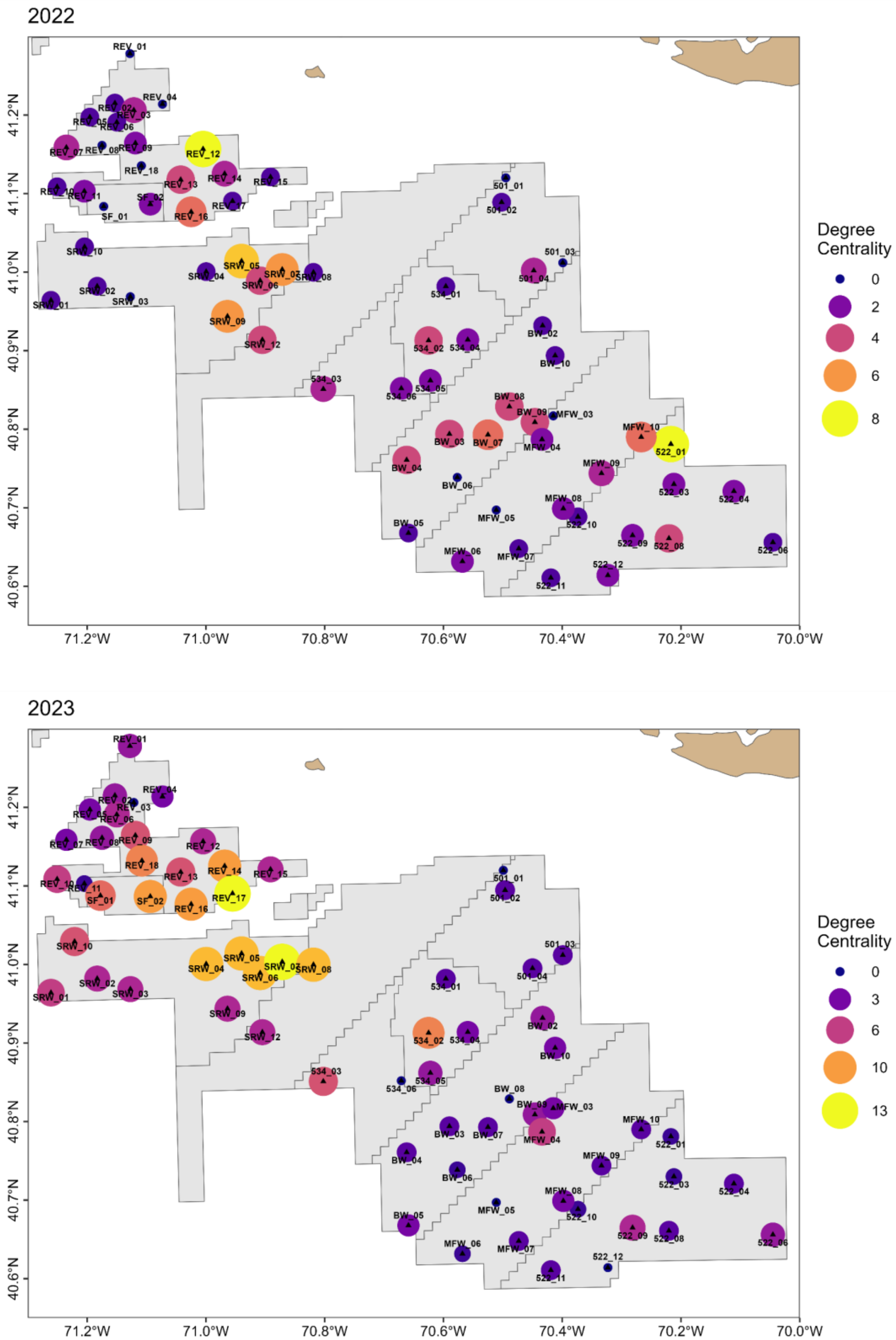


Figure 8g – Maps of 2022 (top) and 2023 (bottom) shortfin mako node degree centrality values.

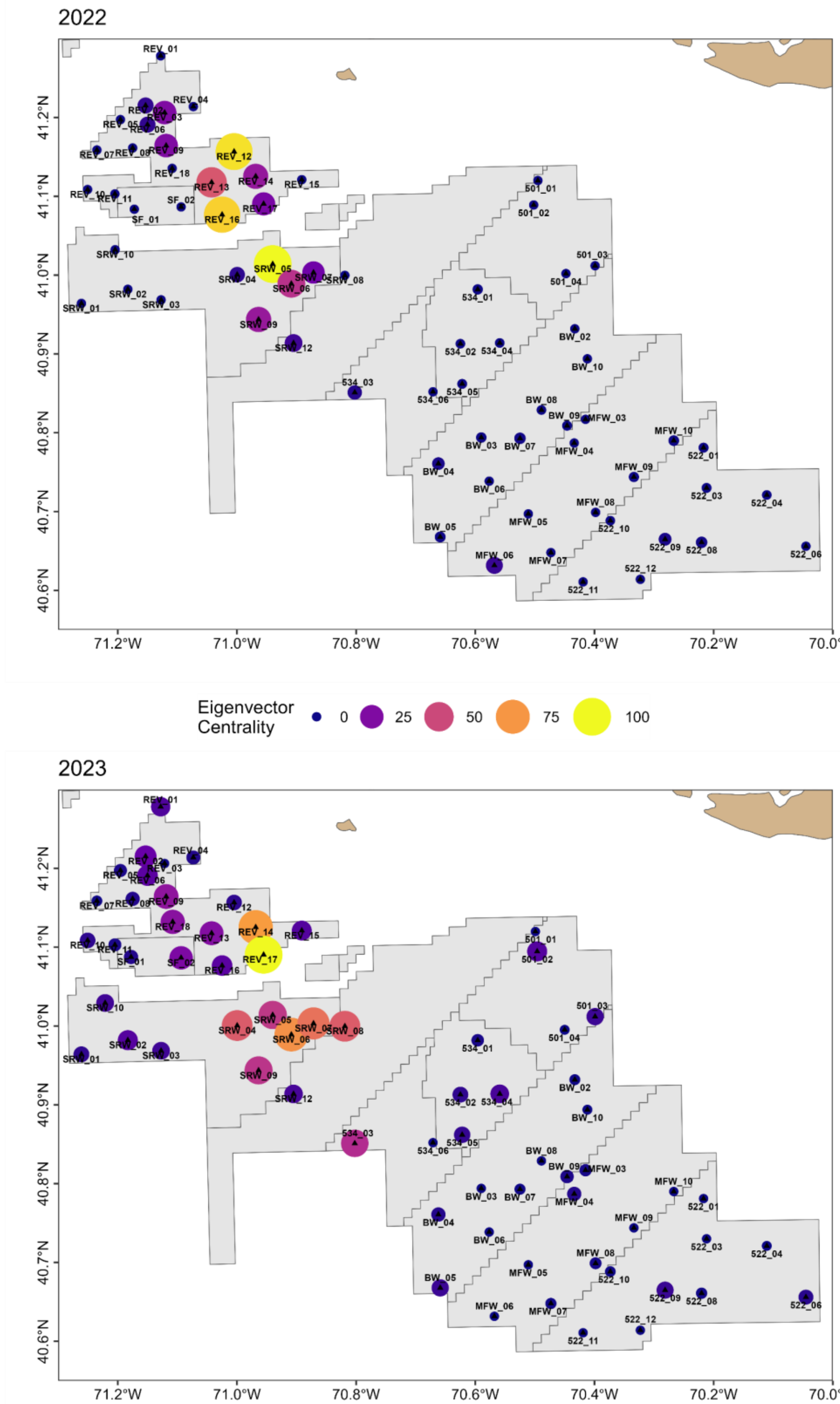


Figure 8h – Maps of 2022 (top) and 2023 (bottom) shortfin mako node eigenvector centrality values.

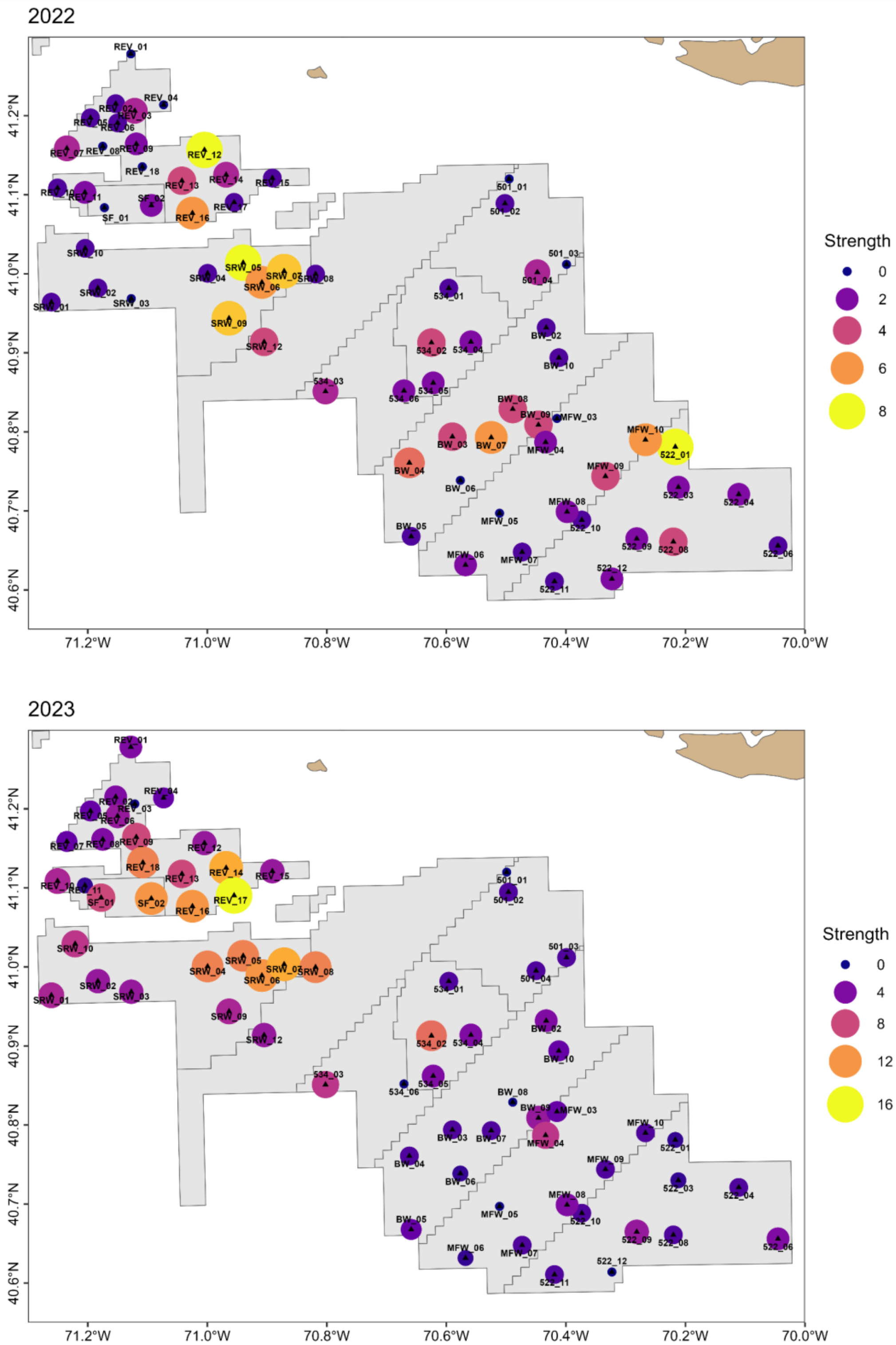


Figure 8i – Maps of 2022 (top) and 2023 (bottom) shortfin mako node strength values.

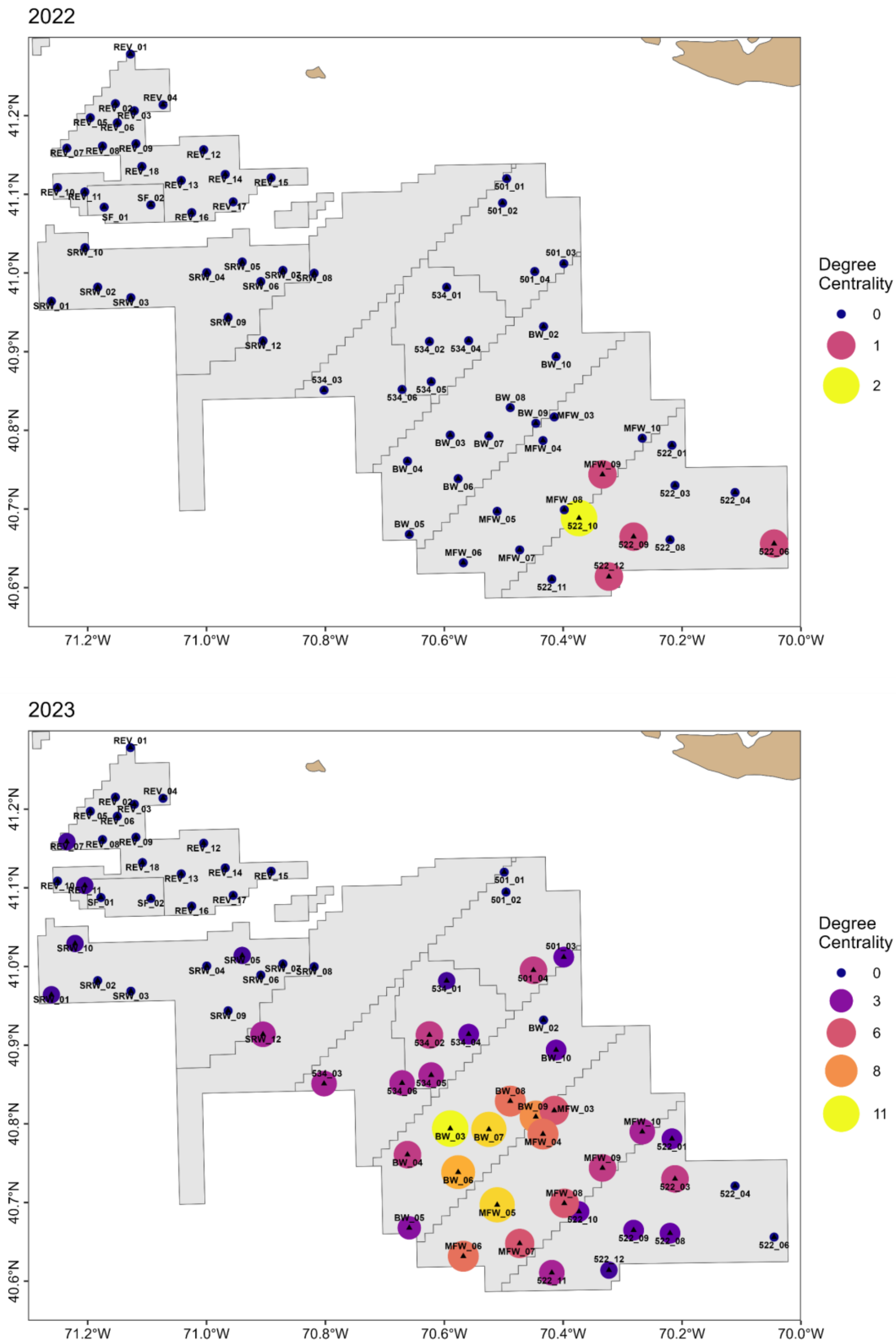


Figure 8j – Maps of 2022 (top) and 2023 (bottom) yellowfin tuna node degree centrality values.

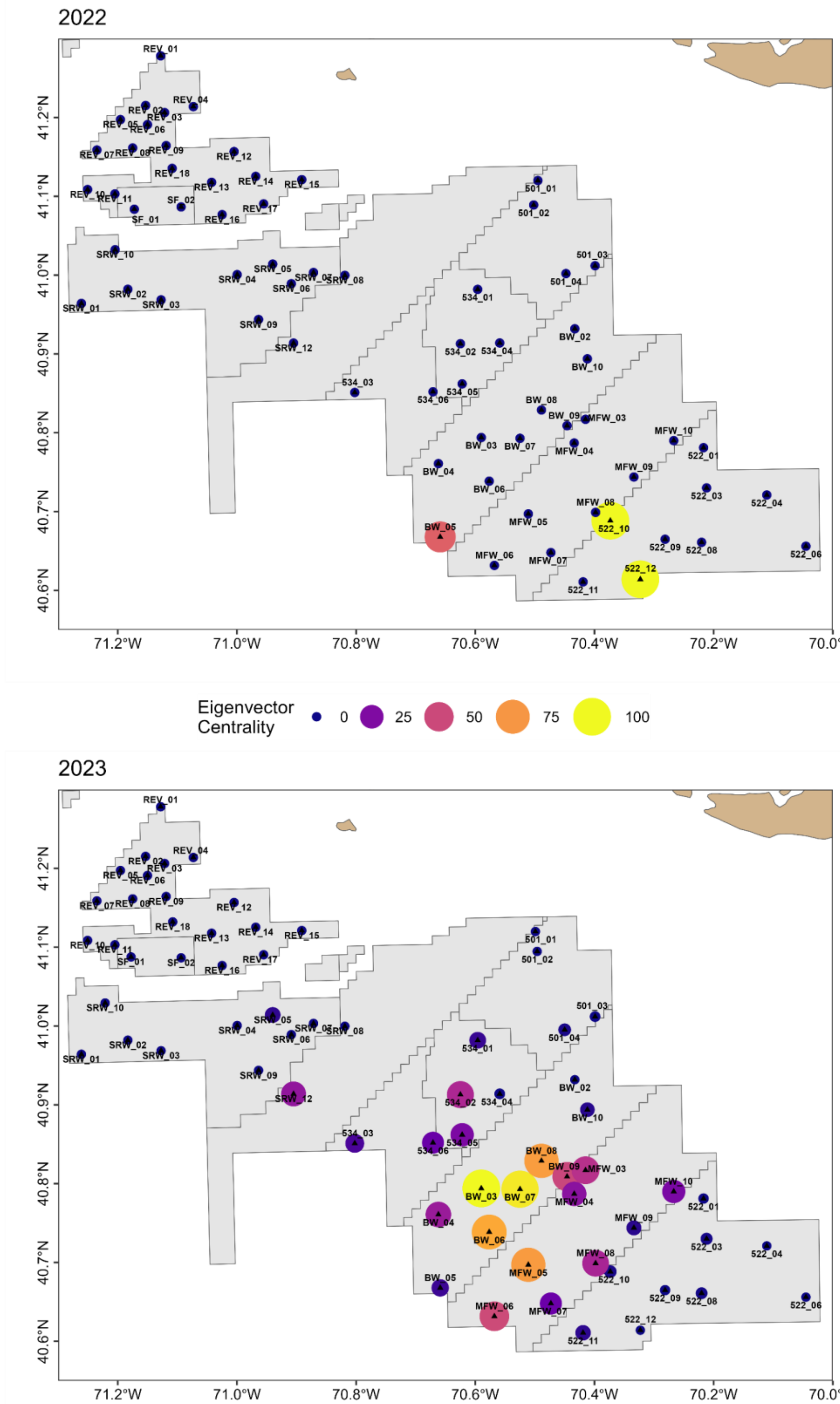


Figure 8k – Maps of 2022 (top) and 2023 (bottom) yellowfin tuna node eigenvector centrality values.

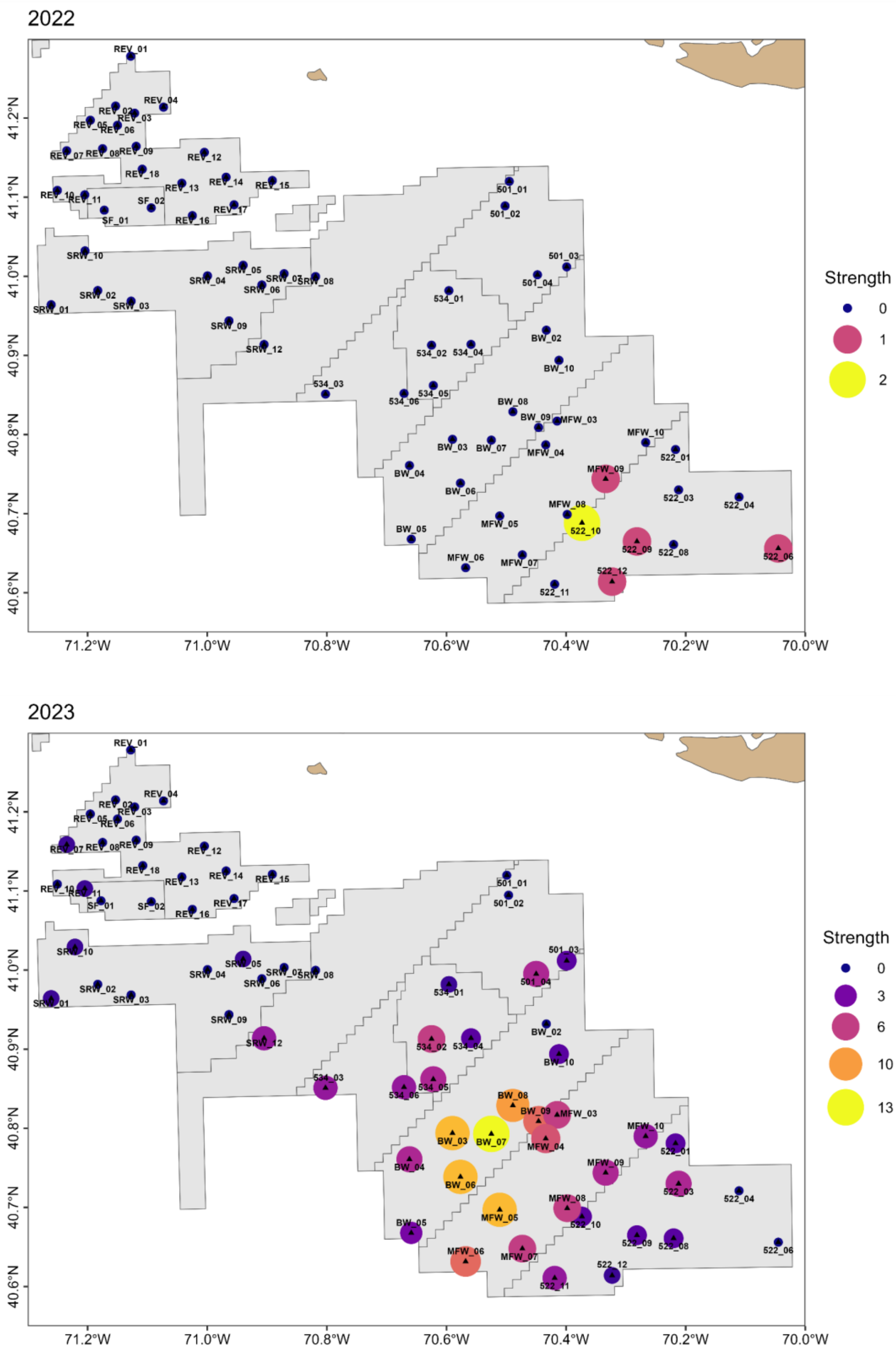


Figure 8l – Maps of 2022 (top) and 2023 (bottom) yellowfin tuna node strength values.

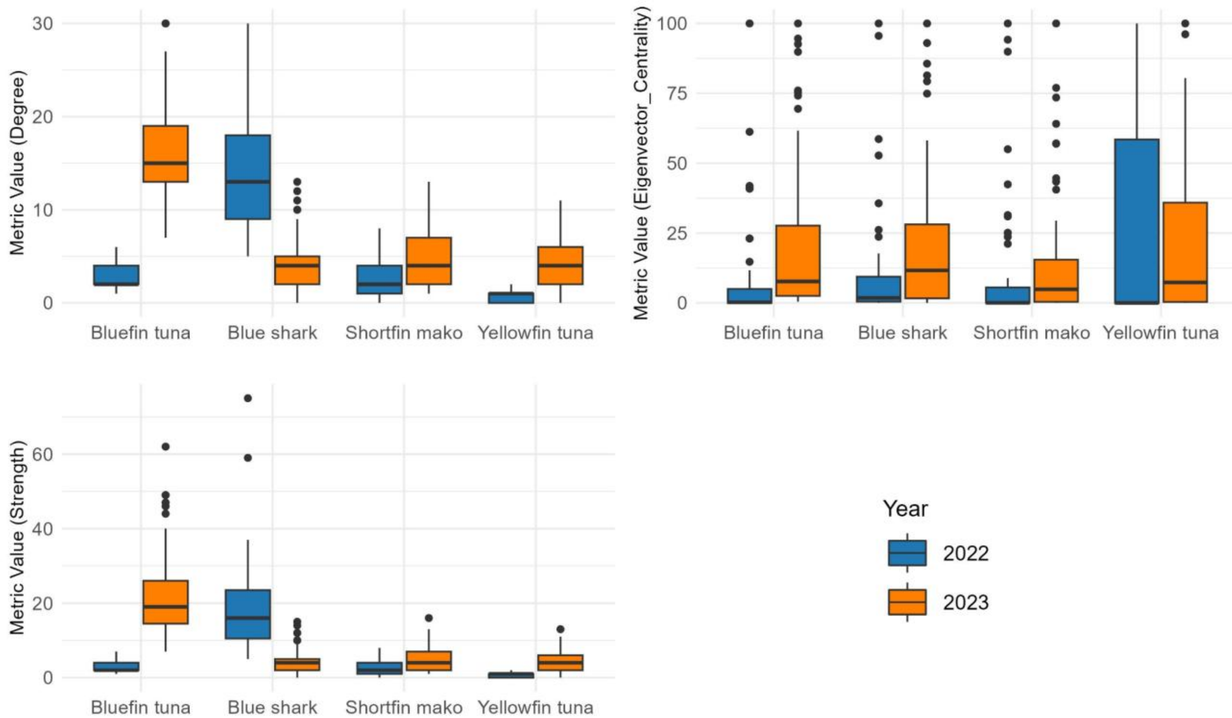


Figure 9 – Boxplots of metric distributions by species and year. Refer to Table 9 for respective sample sizes (number of nodes that recorded metric data each year for each species).

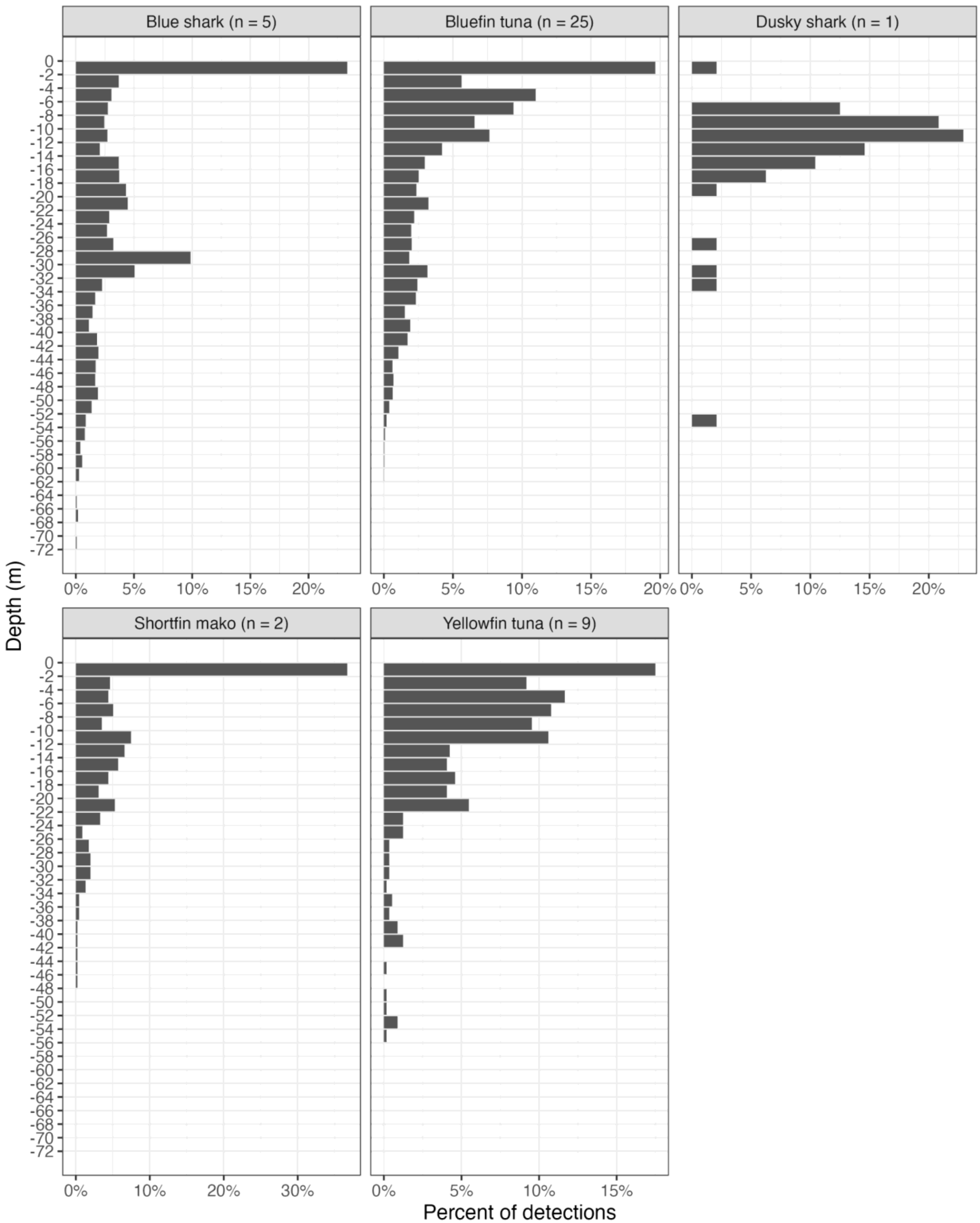


Figure 10 – Histogram of the proportion of detections obtained at 2-meter (m) depth intervals for each species that was tagged with V16P (pressure sensing) acoustic transmitters. The number of detected individuals is indicated for each species.

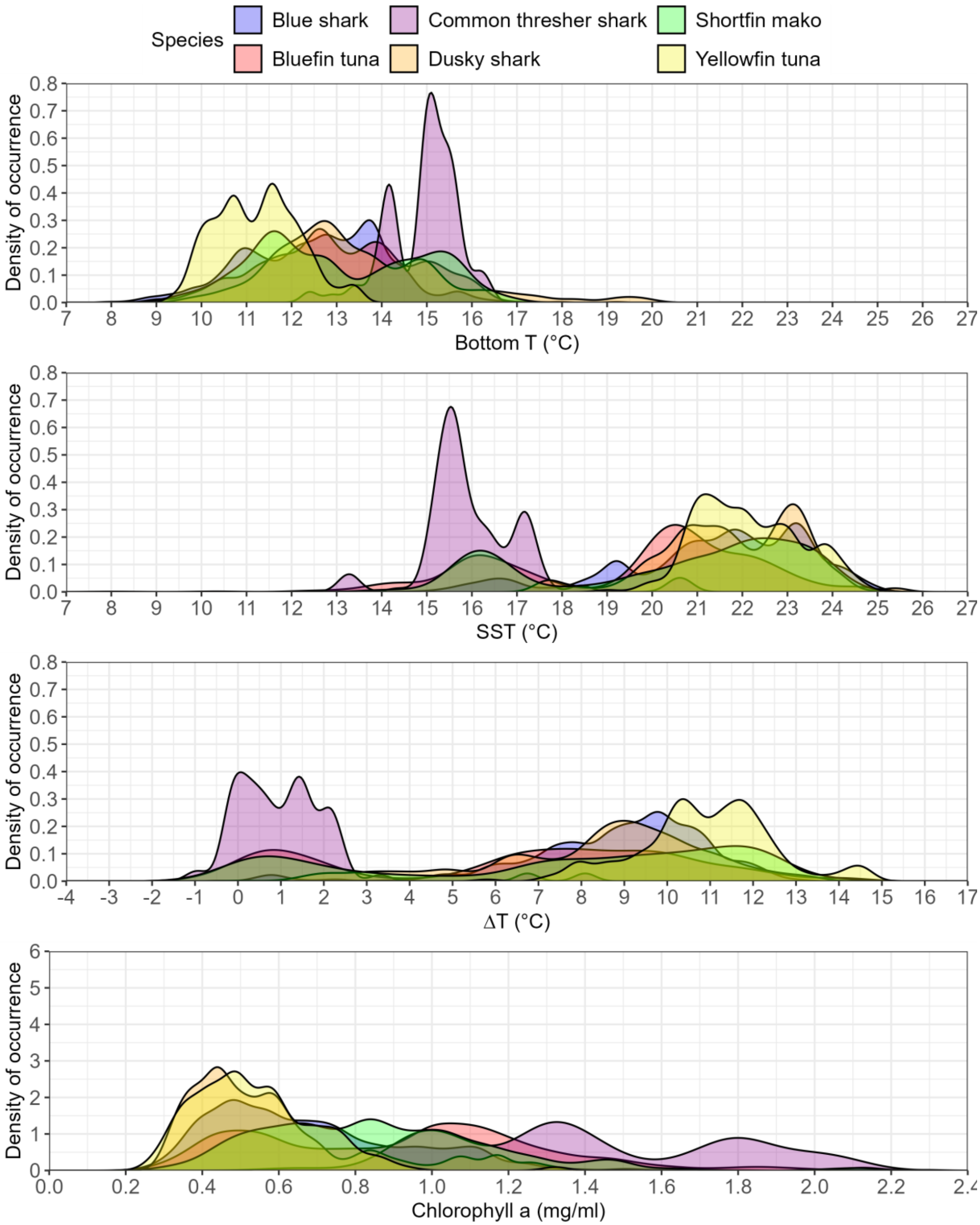


Figure 11 – Kernel density plots demonstrating the range of environmental conditions in which each species was detected/observed during the study period. Higher density values correspond to increased numbers of observations in those conditions. Little tunny, sandbar shark, smooth hammerhead, and spinner shark were omitted due to insufficient detection data. Bottom T = bottom temperature, SST = sea surface temperature, ΔT = SST – Bottom T.

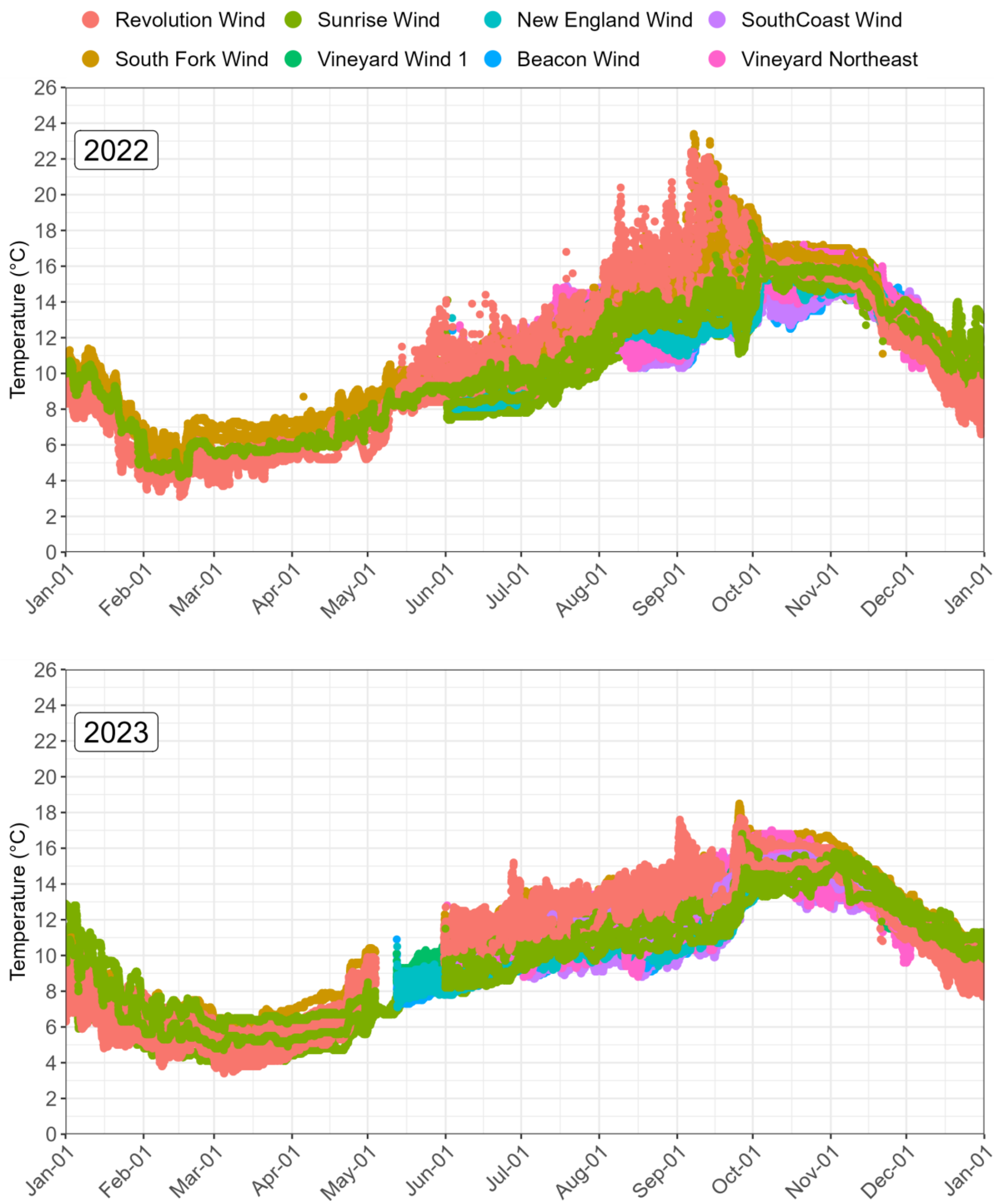


Figure 12 – Bottom water temperature measured hourly at each VR2AR and VR2Tx receiver station in each year of the study.

Figure 13 – Thermal stratification calculated hourly at each VR2AR and VR2Tx receiver station in each year of the study.

Figure 14 – Hourly average ambient noise (in 69 kHz) recorded at each VR2AR and VR2Tx receiver station in each year of the study.