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Final Report

2024 Drop Camera Survey of Benthic Communities and Substrate in the 522 Study Area and Cumulative Six-Year Comparison

Submitted to:
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Final Report

2024 Drop Camera Survey of Benthic Communities and Substrate in the 522 Study Area

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Project Summary: The University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) conducted drop camera surveys to examine the benthic community and substrate in Vineyard Offshore LLC's (Vineyard Offshore's) Lease Area OCS-A 0522 (the "522 Study Area"). The primary goal of this project was to collect preliminary data to help determine the sampling intensity needed to collect enough baseline data for an environmental assessment of wind farm development impacts. Our objectives were to provide:

1) Distribution and density estimates of dominant benthic megafauna and,
2) Classify substrate across the survey domain

A centric systematic grid sampling design was used to sample 22 stations in the 522 Study Area. Stations were located 5.6 kilometers (km) apart. A sampling pyramid mounted with a high-resolution camera was deployed at each station and used to take four quadrat (2.3 square meter [m^2] images) samples. The area was surveyed on May 3rd and 4th ("summer") and September 4th and 5th ("fall") of 2024 using a commercial scallop fishing vessel to deploy the sampling pyramid. Twenty-one different benthic animal groups were observed in the 522 Study Area during 2024. Increases in common animal group densities, frequencies, and spatial distributions occurred between the summer and fall surveys. The animals appeared randomly distributed across the 522 Study Area. Sand, silt, and shell debris were the most common substrates found at stations in both seasons.

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Introduction

In 2019, Vineyard Offshore affiliate Vineyard Wind LLC leased a 516 square kilometer (km^2) area for renewable energy development on the United States (US) Atlantic outer continental shelf, referred to as Lease Area OCS-A 0522, which is located south of Nantucket, Massachusetts. Vineyard Offshore is conducting fisheries surveys in the 522 Study Area to gain preliminary baseline data on the substrate and benthic megafauna, which is the focus of this report. Additional fisheries studies are being conducted in Lease Area OCS-A 0501 and Lease Area OCS-A 0534; these studies are reported separately.

SMAST has developed an image-based drop camera survey that allows for sampling of the epibenthic community with minimum disturbance to the seafloor. The SMAST drop camera survey can be used to better understand benthic macrofaunal community characteristics, substrate habitats, and the spatial and temporal scales of potential impacts on these communities and habitats. The survey techniques were developed collaboratively with scallop fishers and use quadrat sampling methods based on diving studies (Stokesbury and Himmelman, 1993;1995). Initial surveys in the early 2000s focused on estimating density of scallops within closed portions of the US Georges Bank fishery and the survey approach has since expanded to cover most of the scallop resource in eastern US and Canadian waters (approximately 100,000 km^2; Figure 1). Information from the survey has been incorporated into the scallop stock assessment through the Stock Assessment Workshop process and reliably provided to the New England Fisheries Management Council (NEFMC) to aid in annual scallop harvest allocation (NEFSC, 2010; 2018).

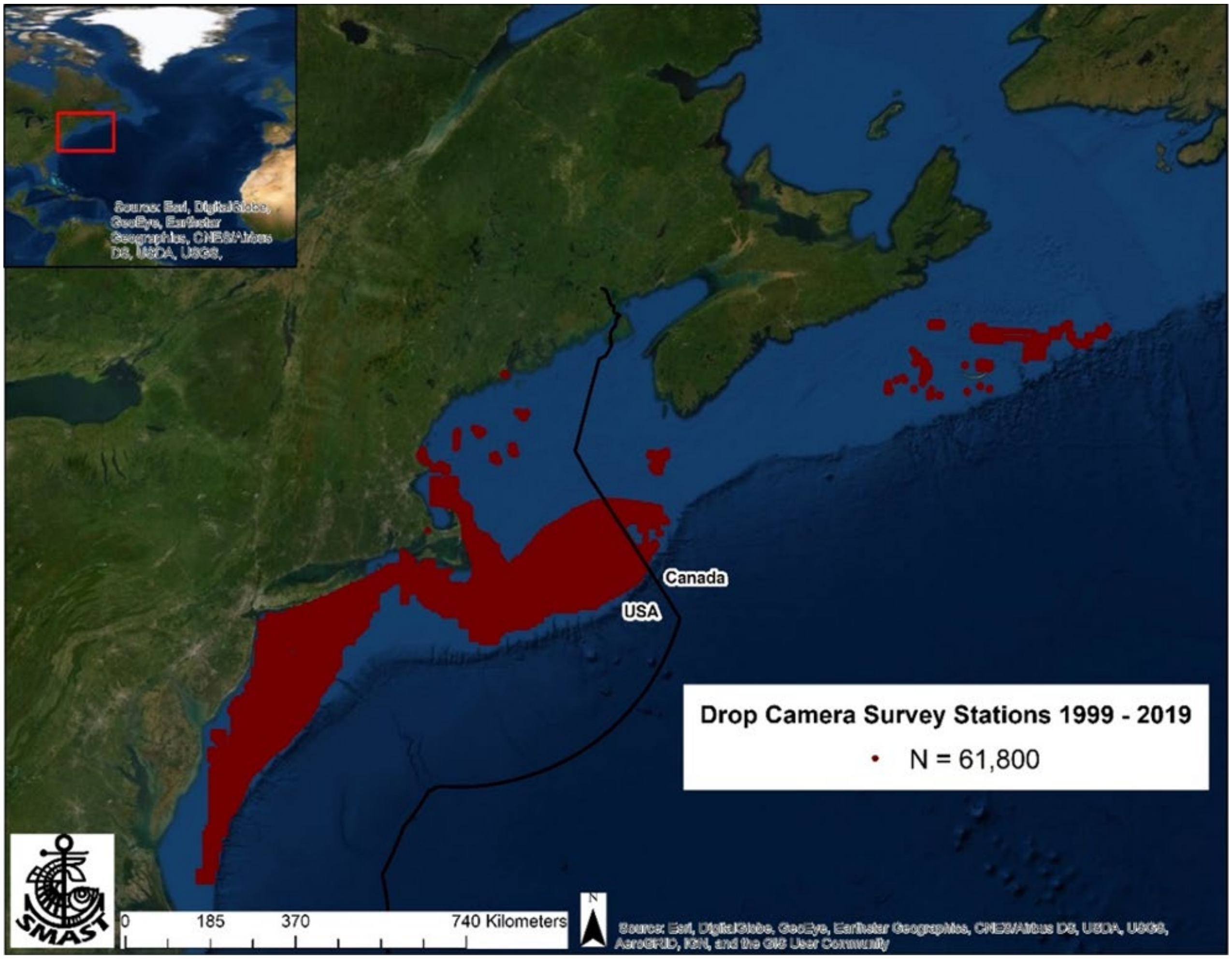


Figure 1. The spatial extent of SMAST drop camera surveys in eastern US and Canadian waters. All stations surveyed from 1999 to 2019 are displayed in red.

Data from the drop camera surveys have contributed in numerous ways to understanding the ecology of non-scallop species (Marino et al., 2009; MacDonald et al., 2010; Bethoney et al., 2017; Asci et al., 2018; Rosellon-Druker and Stokesbury, 2020) and the characterization of benthic habitat (Stokesbury and Harris, 2006; Harris and Stokesbury, 2010; NEFMC, 2011; Harris et al., 2012; Stokesbury et al., 2024). This work contributed to several ecosystem-based management activities, such as the NEFMC Swept Area Seabed Impact model (NEFMC, 2011). Drop camera surveys have also been used to define habitat characteristics and spatial distribution of benthic marine invertebrates in potential wind energy areas off the coasts of Maryland and southern New England (Guida et al., 2017) and accurately quantify ecologically and economically important species that would be difficult to sample with a net, including squid egg clusters or habitat-forming filamentous fauna (bryozoans or hydrozoans; Figure 2).

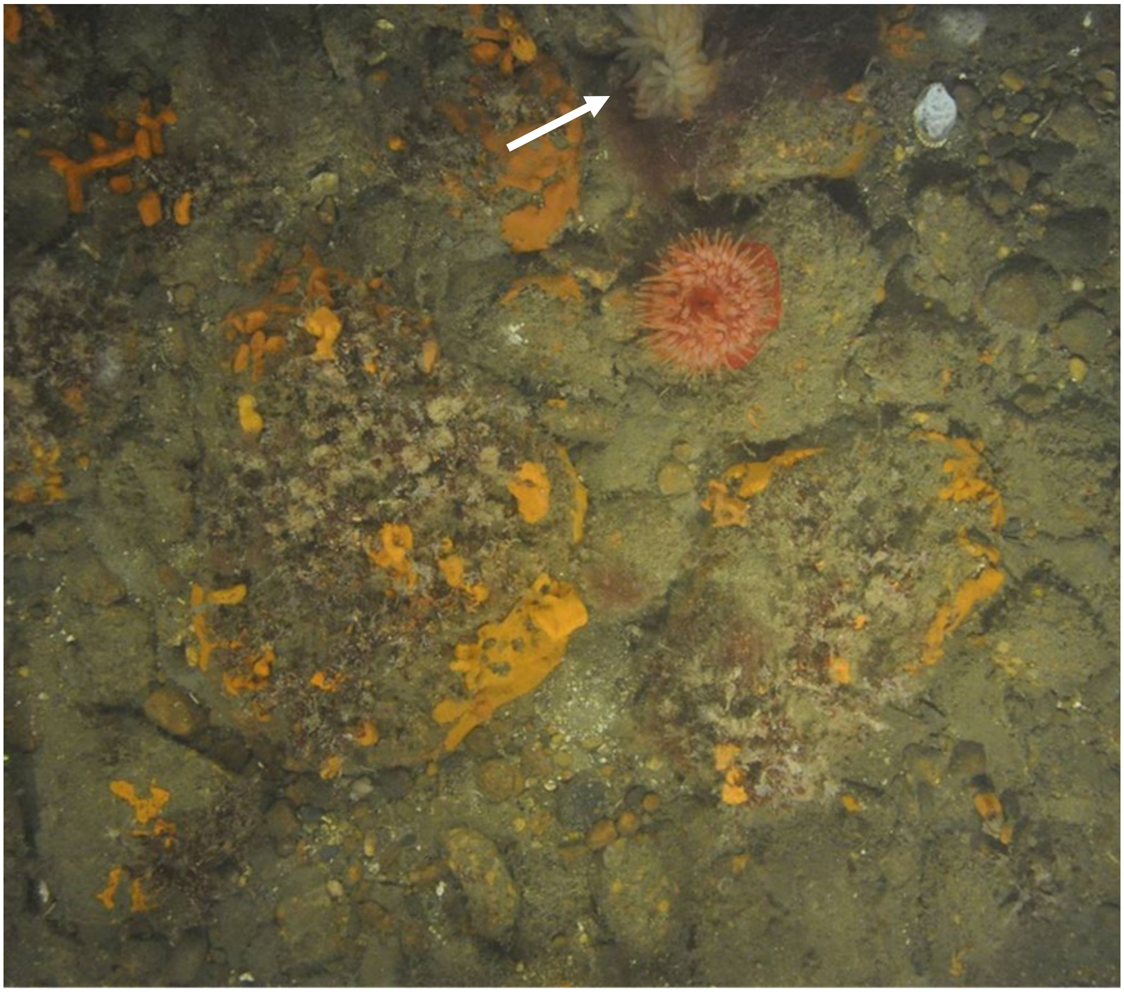


Figure 2. Example of a digital still image taken by the SMAST drop camera survey in complex habitat in the Rhode Island/Massachusetts Wind Energy Area on Cox's Ledge during a survey in 2013. A squid egg cluster was present (white arrow, top, middle).

The data collected by the drop camera surveys can be used in an impact assessment to determine whether a change to the environment occurred due to a specific stressor, such as offshore wind development, and to what extent benthic animals are affected (Smith, 2006). The Before-After Control-Impact (BACI) study is an experiment designed to assess anthropogenic impacts on natural habitats and is particularly useful in large-scale anthropogenic disturbances or environmental management (Green, 1979; Underwood, 1991; Kerr et al., 2020). To account for naturally fluctuating characteristics, a designated area outside of the impact area, that is comprised of similar environments and communities, is chosen as a control site (Eberhardt, 1976). This approach can be strengthened with an asymmetrical design that uses multiple control sites at different distances from the impact site, incorporating the concepts of Beyond BACI (Underwood, 1993) and Before-After-Gradient designs (Ellis and Scheider, 1997). The drop camera survey data can be used to compare epibenthic faunal distributions between impact and control sites over time. The drop camera surveys are used in many different projects and will aid in building a regional, standardized baseline dataset needed to assess development impacts on epibenthic communities and habitats. The data collected in this study can be used to provide preliminary estimates and facilitate analysis detailing the number of samples required to detect significant changes in density and distribution of the benthic community.

Goals and Objectives

The primary goal of this project is to collect preliminary data on the benthic community and substrate in the 522 Study Area. This data could be used to help determine the sampling intensity needed to collect enough baseline data for the environmental assessment of wind farm development in the 522 Study Area. The preliminary data were gathered using drop camera surveys in the 522 Study Area (Figure 3) to:

1) Map the distribution and estimate the density of dominant benthic megafauna, and
2) Classify substrate type

These two objectives document the primary epibenthic animals and habitats within the 522 Study Area, and these data could be used to identify the sampling intensity needed for future statistical tests and surveys. The objectives will also document seasonal and/or annual changes in distribution and density.

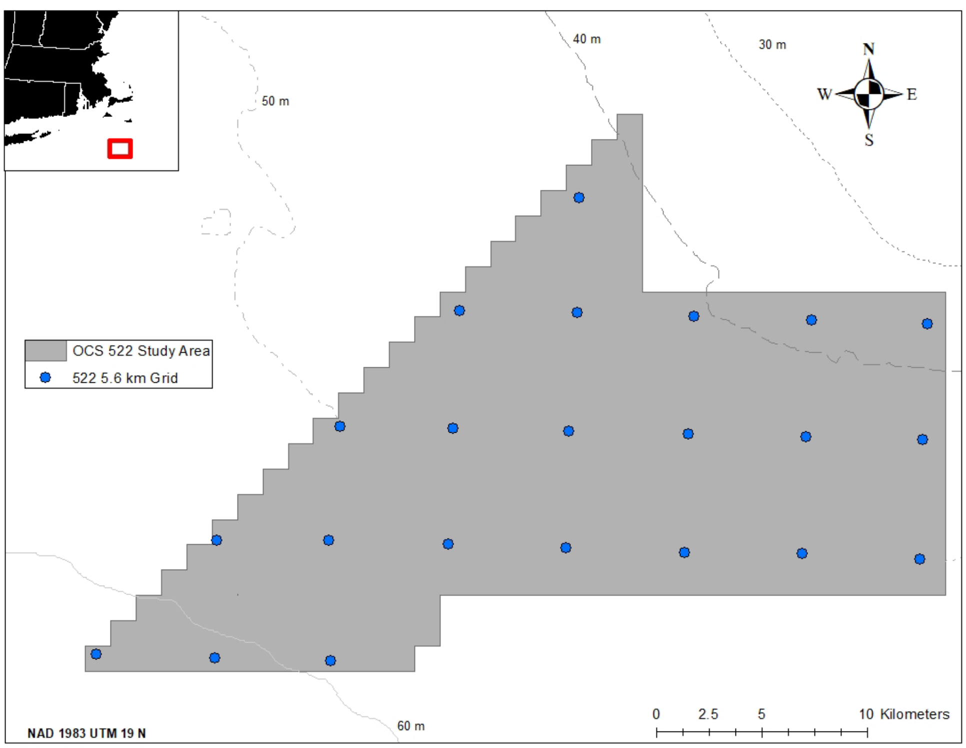


Figure 3. The 2024 drop camera survey station grid in the 522 Study Area.

Methods

A centric systematic grid design was used to sample stations in the 522 Study Area. Stations were placed 5.6 km apart (Figure 3). At each station, a sampling pyramid was deployed, and a high-resolution camera was used to take four quadrat samples (2.3 m^2 images) (Figure 4). This is the same sampling resolution used in the 2012 and 2013 drop camera surveys of the Massachusetts Wind Energy Areas (Stokesbury, 2014; 2021).

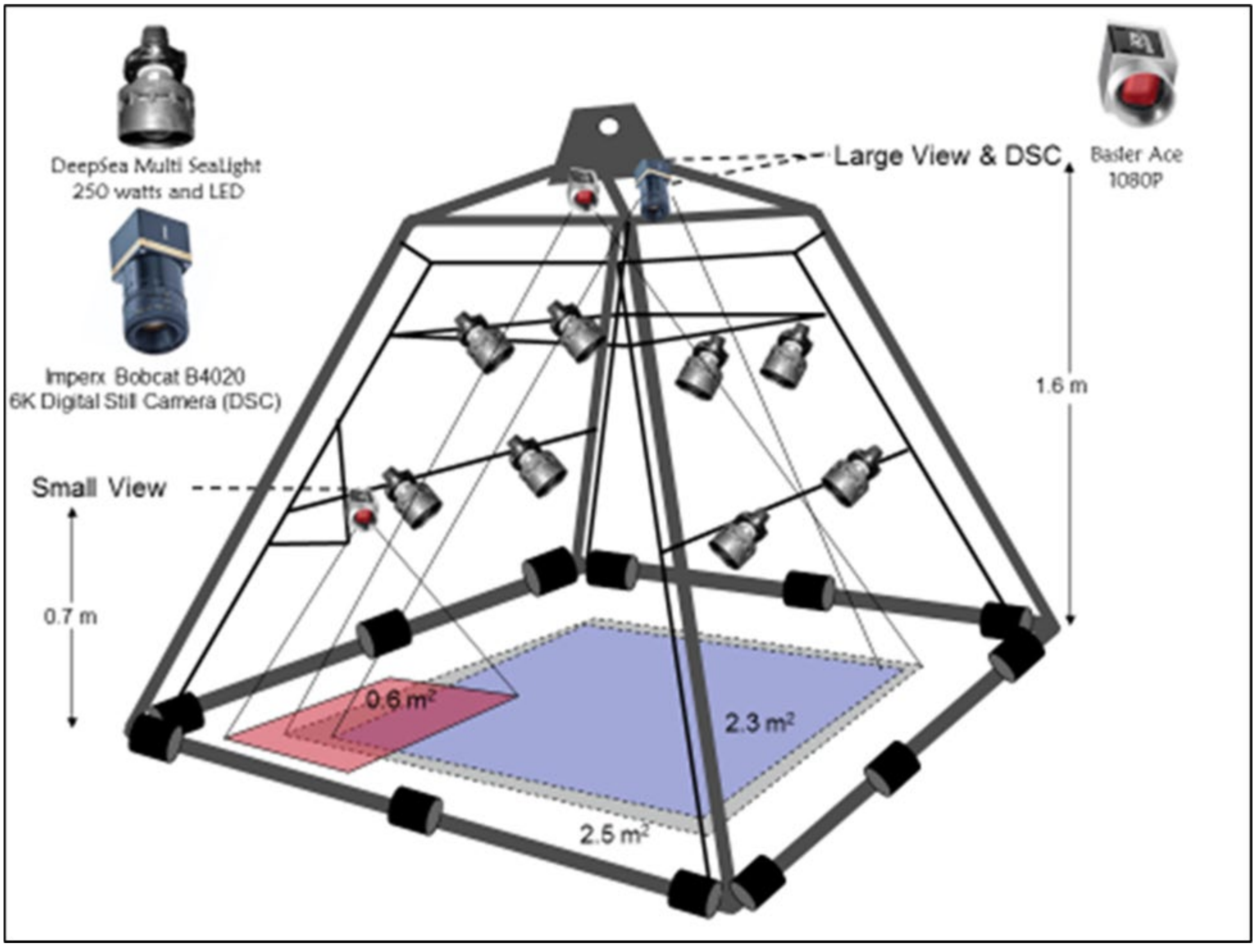


Figure 4. SMAST drop camera survey pyramid with cameras and lights used for data collection. The camera used for the small view was turned to the side to provide a view parallel to the seafloor for some stations.

A commercial scallop fishing vessel was used to deploy the pyramid (Stokesbury, 2002; Stokesbury et al., 2004; Bethoney and Stokesbury, 2018). A mobile studio including monitors, computers for image capturing and data entry, and survey navigation (software integrated with the differential global positioning system) was assembled in the wheelhouse of the vessel. Two downward-facing cameras mounted on the sampling pyramid provided 2.3 m^2 and 2.5 m^2 quadrat images of the seafloor for all stations. A third camera that provided a 0.6 m^2 view parallel to the seafloor was also deployed. Images from all cameras and video footage from the 2.5 m^2 camera of the first quadrat were saved and the pyramid was raised, so that the seafloor could no longer be seen. The vessel was allowed to drift approximately 50 meters (m), and the pyramid was lowered to the seafloor again to sample a second quadrat; this was repeated two additional times so that each station had four images from each camera. Onboard the survey vessel, scallop counts, station location, and depth were recorded and saved through a specialized field application for entry into an SQL Server Relational Database Management System.

After the survey, the images obtained by the high-resolution digital still camera were used as the primary data source. Other images and videos collected were used as digitizing aids. Within each quadrat, macrobenthos taxa were counted or noted as present, and the substrate was classified (Stokesbury, 2002; Stokesbury et al., 2004; Bethoney and Stokesbury, 2018). Fifty taxa of macrobenthos could have been identified if present in the sample (Appendix I). In addition, Atlantic longfin squid egg clusters were counted when observed. Sediments were classified from the images using the Wentworth particle grade scale, where the sediment particle size categories (in grain diameters) are based on a doubling or halving of the fixed reference point of 1 millimeter (mm): sand = 0.0625 to 2.0 mm, gravel = 2.0 to 256.0 mm, and boulders > 256.0 mm (Lincoln et al., 1992). Gravel was divided into two categories: granule/pebble = 2.0 to 64.0 mm and cobble = 64.0 to 256.0 mm (Lincoln et al., 1992). The presence of each sediment category was noted for each quadrat image. Maps and analysis focused on classifying stations by the largest sediment particle size observed in a digital still image from that station (Harris and Stokesbury, 2010). Shell debris was also identified. After the images were digitized, a quality assurance check was performed on each image to ensure the accuracy of counted and identified species and sediments. Note that this sediment classification was not the only method used in Lease Area OCS-A 0522. Other more comprehensive efforts have been completed by Vineyard Offshore to classify the benthic habitat in Lease Area OCS-A 0522 and are reported elsewhere.

Mean densities and standard errors of animals counted were calculated using equations for a two-stage sampling design where the mean of the total sample is (Cochran 1977):

$$\bar{\bar{x}} = \sum_{i=1}^{n} \left(\frac{\bar{x}_i}{n} \right)$$

where n is the number of stations and $\bar{x}_i$ is the mean of the four quadrats at station i. The SE of this two-stage mean was calculated as:

$$S.E.(\bar{x}) = \sqrt{\frac{1}{n}(s^2)}$$

where:

$$s^2 = \sum^{n} (\bar{x}_i - \bar{\bar{x}})^2 / (n-1)$$

According to Cochran (1977) and Krebs (1989), this simplified version of the two-stage variance is appropriate when the ratio of sample area to survey area (*n*/*N*) is small. In this case, thousands of square meters (*n*) are sampled compared with millions of square meters (*N*) in the 522 Study Area. A similar multi-stage approach was used to calculate mean presence values. Mean density or quadrats present per station of taxa and substrate within the 522 Study Area were mapped (Figures 8 to 26). This analysis focused on the benthic animal groups in the 522 Study Area that were detected at high enough rates for statistical analysis (Bethoney et al., 2017). Densities for each animal group were compared by graphing mean estimates with their associated 95% confidence intervals (Sokal and Rohlf, 2012). Density categories (or class intervals) for distribution maps were divided up based on quantiles of observed data. Quantiles distribute the observations equally across the class interval which gives unequal class widths but the same frequency of observations per class. Class intervals were chosen based on the variability of densities at each station (i.e. if there were only two different densities observed then the data was distributed into two class intervals with a maximum of four intervals chosen).

Results and Discussion

The two drop camera surveys of the 522 Study Area were conducted between May 3 to 4, 2024, and September 4 to 5, 2024. All images and videos collected were shared with Vineyard Offshore. All 22 stations were surveyed in both seasons. Twenty-onedifferent benthic animal groups were observed in the 522 Study Area, with the most common displayed in Table 1. Fourteen of the common animal groups were found in both seasons; dogfish and brittle stars were only found in the summer while squid and sculpin were only found in the fall (Figures 5 and 6). The abundances and densities of animal groups found in both seasons did not all exhibit the same seasonal patterns. While sea star, crab, silver hake, skate, and hake abundances and densities were higher in the fall than summer (Figures 8, 9, 11, 12, 15), hermit crab, flatfish, sea robin, buccinum (whelk) and moon snail abundances and densities were higher in the summer than fall (Figures 10, 13, 14, 17, 29). Buccinum had wide confidence intervals around mean densities due to their large numbers at a few stations (Figures 5, 8, 17). Animals in presence/absence groups had higher frequencies per quadrat in the summer than in the fall, apart from the other crustacean category and euphausids (Figure 6). All animal distributions appeared to be randomly distributed in both seasons within the 522 Study Area (Figures 8 to 33). Sand, silt, and shell debris were the dominant substrates observed at each station throughout both seasons, with sand being the most frequently observed substrate (Figures 33 and 34), however some gravel was observed in the fall and not in the summer.

The 2024 summer survey was completed in May to mitigate poor visibility from turbidity in the water column, which has been problematic in previous surveys of this area (Stokesbury et al., 2022). There were no unusable quadrats in the summer survey (Figure I-1) and only three quadrats had visibility issues in the fall survey (Figure I-2). Visibility improved from prior fall surveys of this area (2019 and 2020) but was similar to 2023, with three quadrats also not visible in that fall survey. Future surveys will continue to be conducted during the same months to achieve maximum visibility.

Table 1. The most common benthic animal groups, in order of most to least quadrats present, during the summer (left) and fall (right) drop camera surveys of 522 Study Area in 2024. Groups left blank in the "counts" column are tracked as present or absent.

Summer			Fall		
Animal Group	**Quadrats Present**	**Counts**	**Animal Group**	**Quadrats Present**	**Counts**
Buccinum (whelk)	37	220	Holes (Burrowing Animals)	67	
Holes (burrowing Animals)	82		Silver Hake	17	51
Sea Stars	9	60	Crabs	23	28
Hermit Crabs	28	43	Other Crustaceans	19	
Sand Dollars	20		Sea Stars	7	14
Moon snail	10	20	Sand Dollars	14	
Crabs	7	15	Hermit Crabs	9	12
Other Crustaceans	8		Skate	10	10
Other Mollusks	6		Euphausids	6	
Skate	4	4	Hake	4	5
Sea Robin	3	3	Buccinum (whelk)	3	3
Euphausids	3		Clams	2	
Clams	2		Sea Robin	2	2
Brittle Stars	2		Sculpin	1	1
Flatfish	2	2	Flatfish	1	1
Silver Hake	2	2	Squid	1	
Hake	1	1	Moon snail	1	1
Ocean Pout	1	1	**Total Quadrats Sampled**	**87**	
Dogfish	1	1			
Total Quadrats Sampled	**88**				

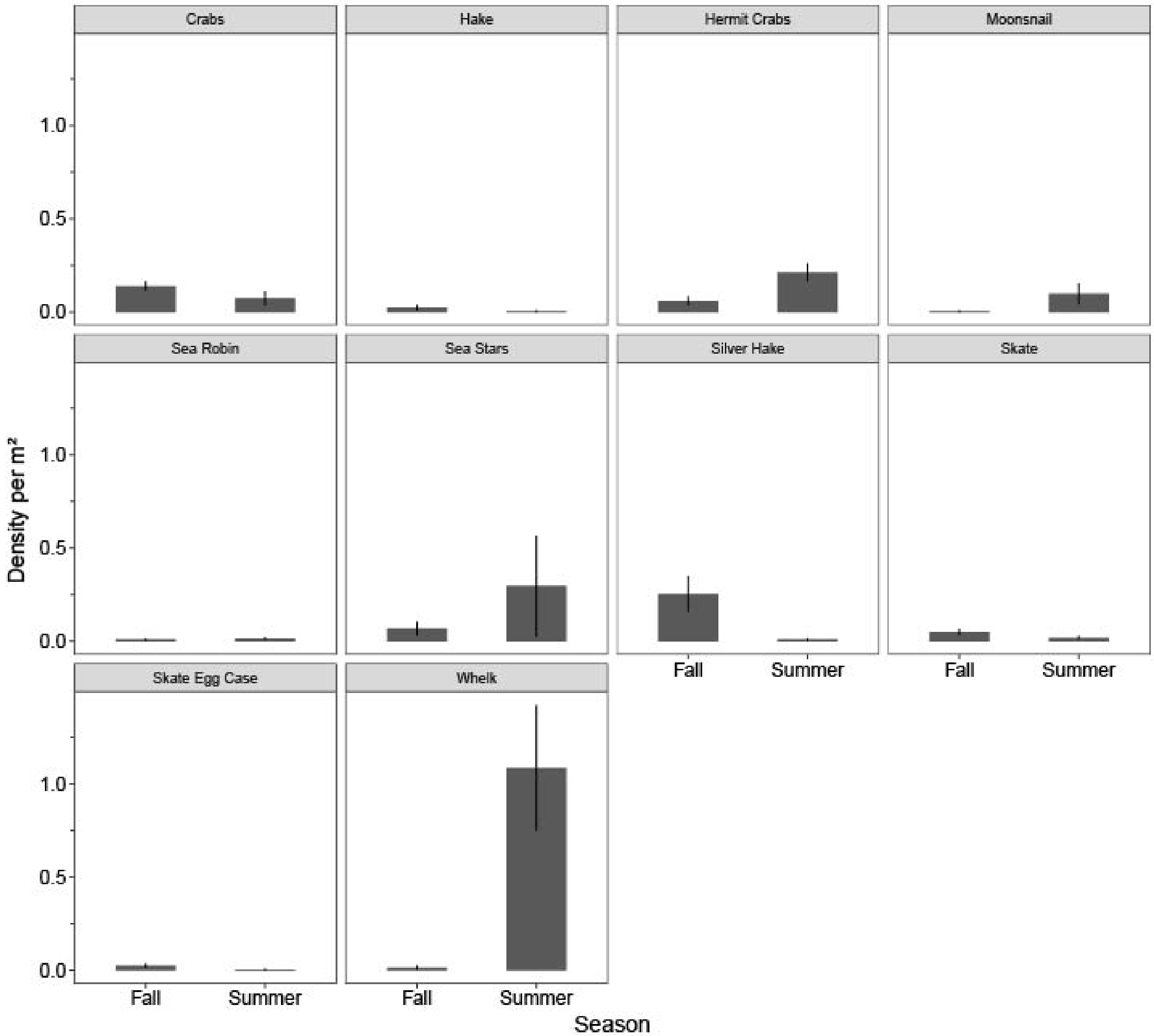


Figure 5. The mean densities (± SE) of common benthic animals from the summer 2024 and fall 2024 drop camera surveys of the 522 Study Area. In the case that a species density was < 0.05 for both seasons it was not plotted.

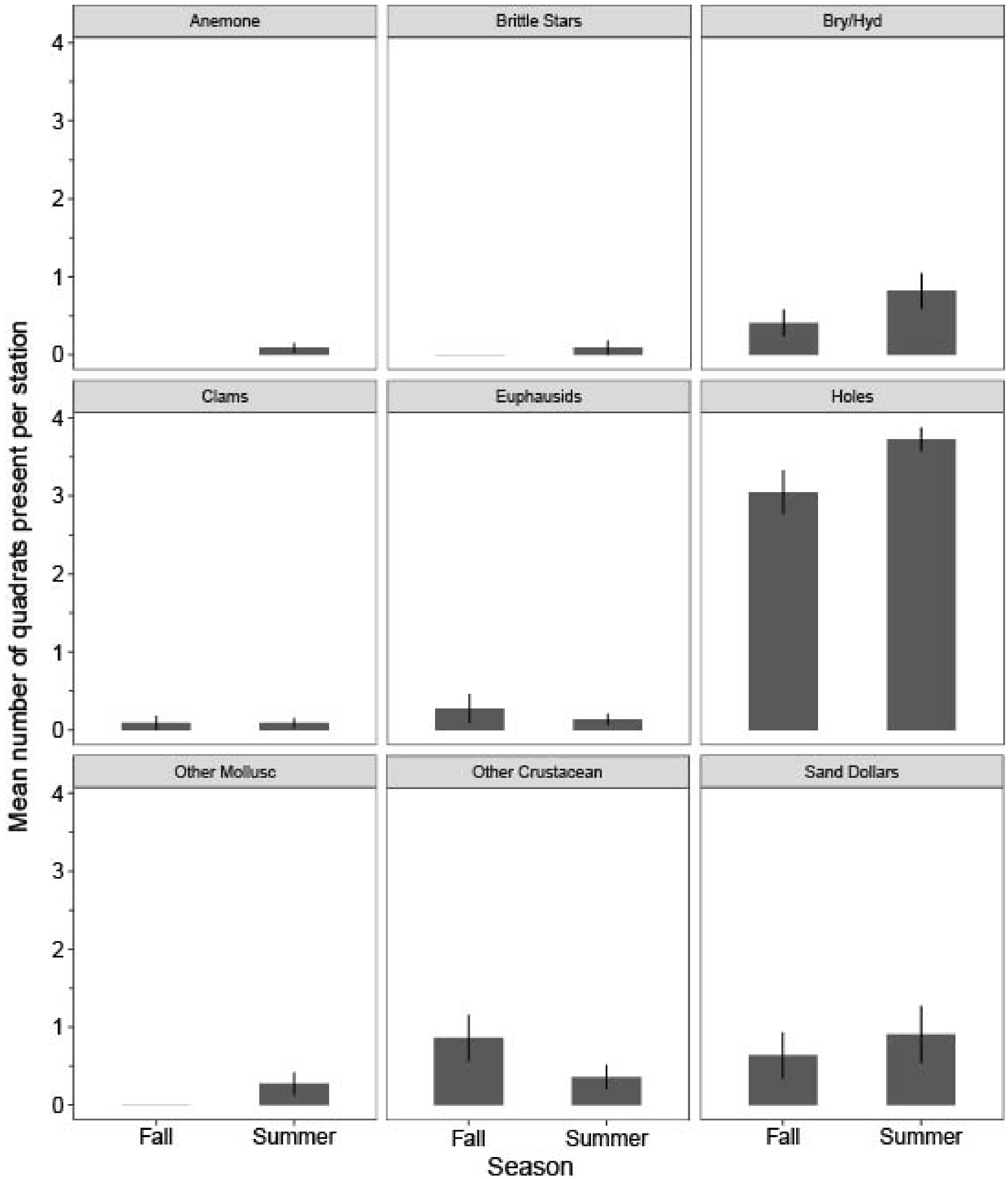


Figure 6. The average number (± SE) of quadrats where benthic animals were present per station during the summer 2024 and fall 2024 drop camera surveys of the 522 Study Area. Holes represent burrowing animals and Bry./Hyd. represents bryozoans and hydrozoans. Four quadrats (each consisting of 2.3 m^2 images) were observed at each station.

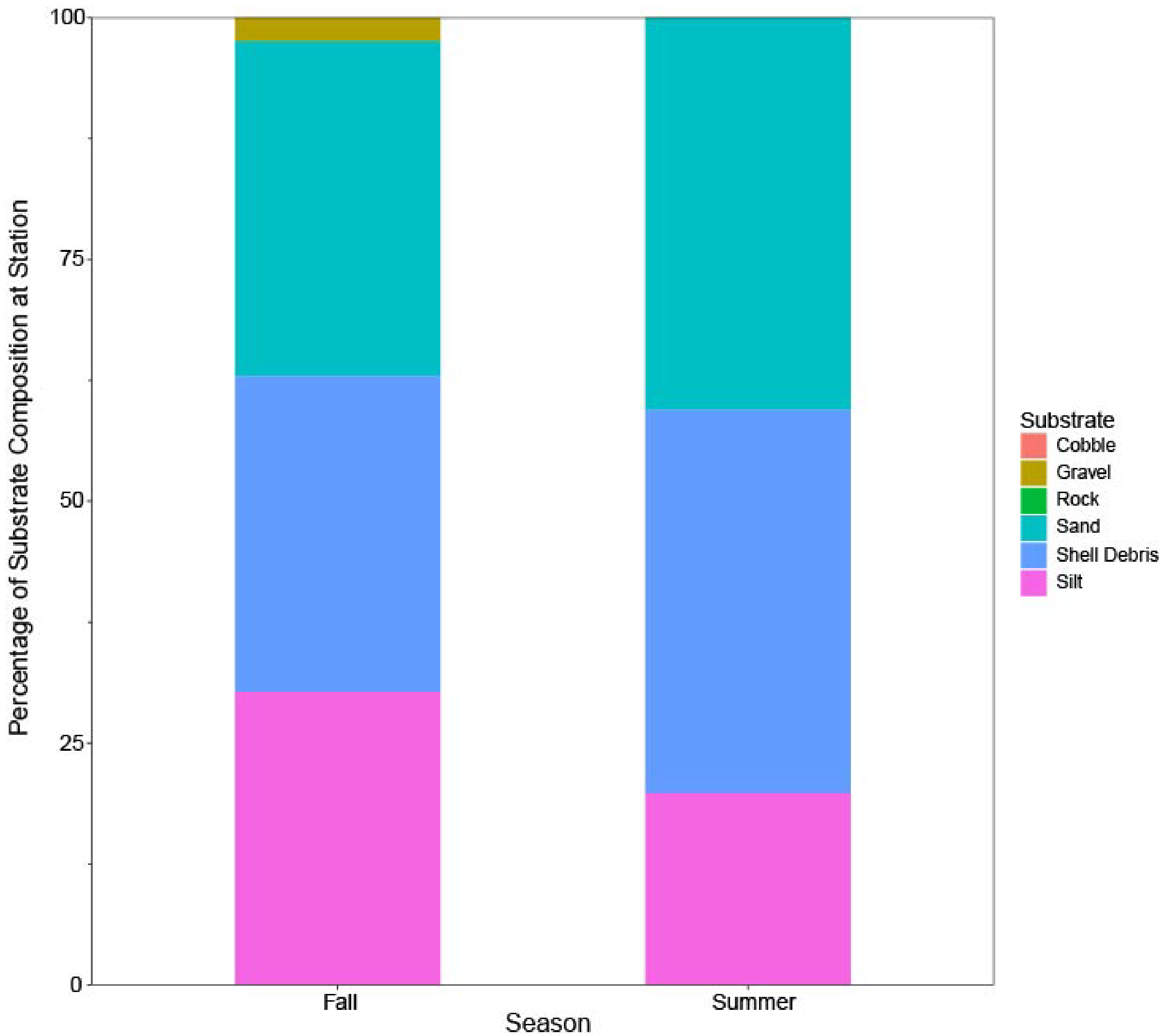


Figure 7. Substrate composition, defined as the percentage of the most common substrate type observed at a station, during the summer 2024 and fall 2024 drop camera surveys of the 522 Study Area. Cobble and rock were not observed at any station.

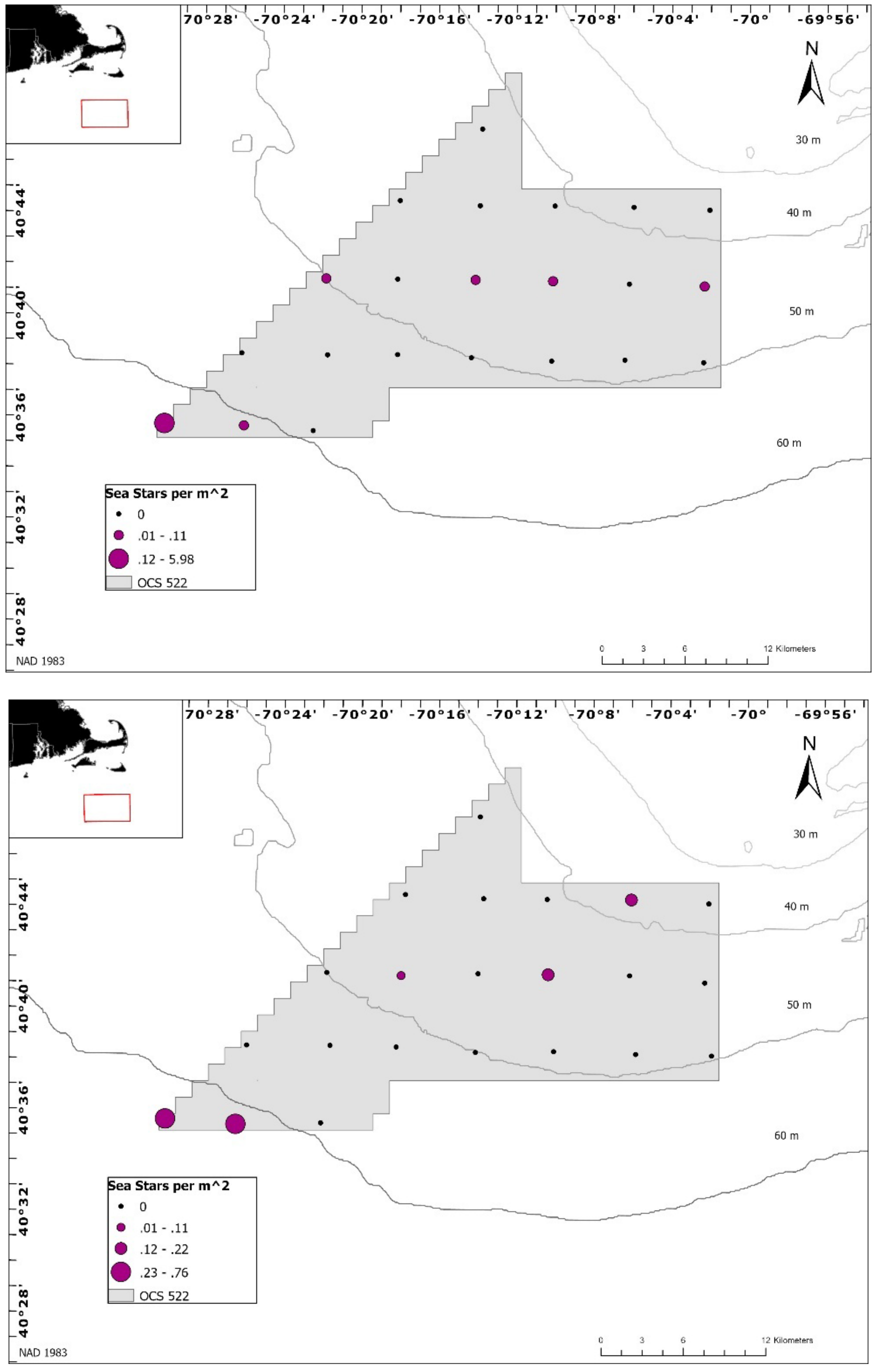


Figure 8. The distribution of sea stars from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area

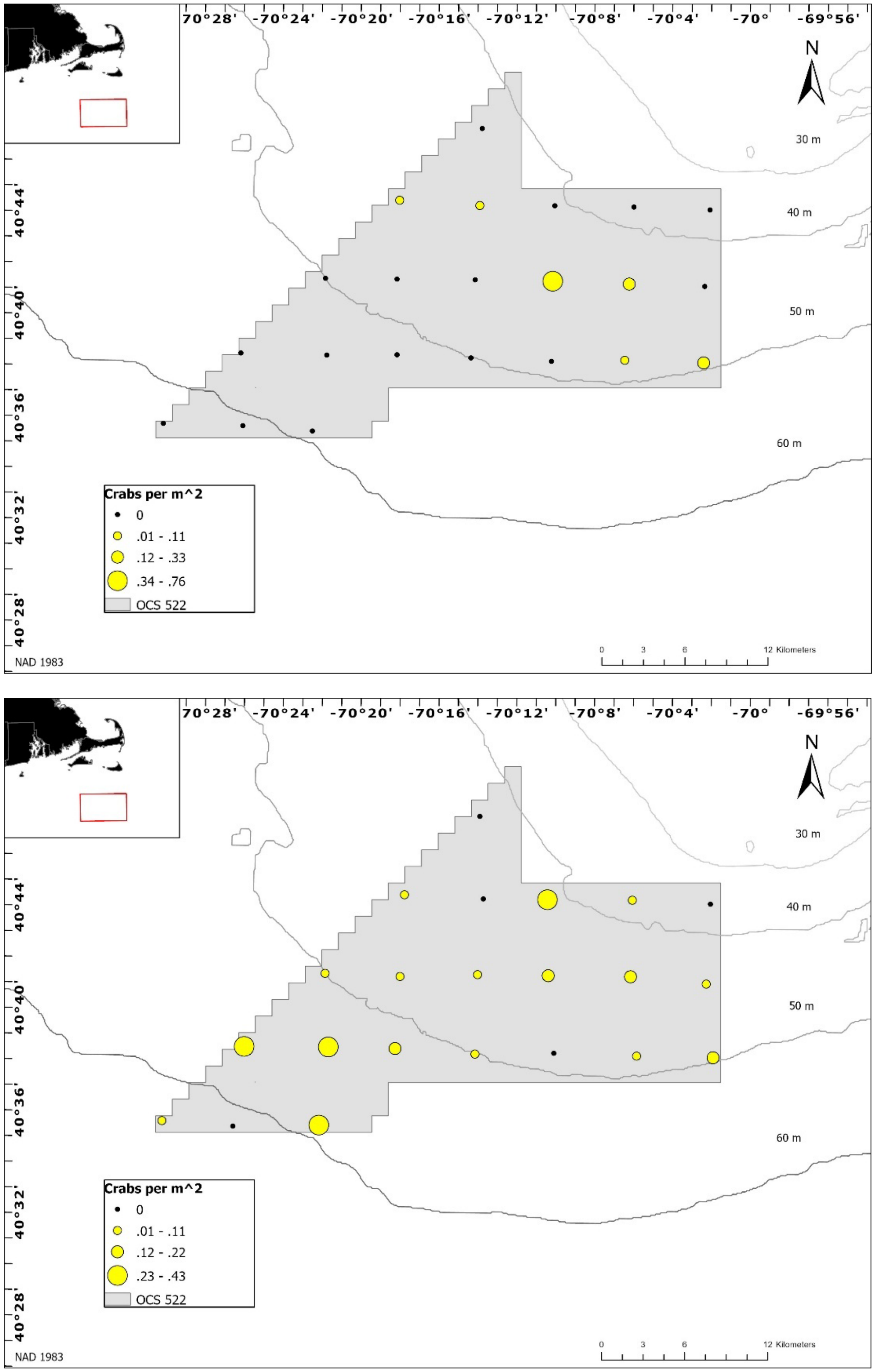


Figure 9. The distribution of crabs from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

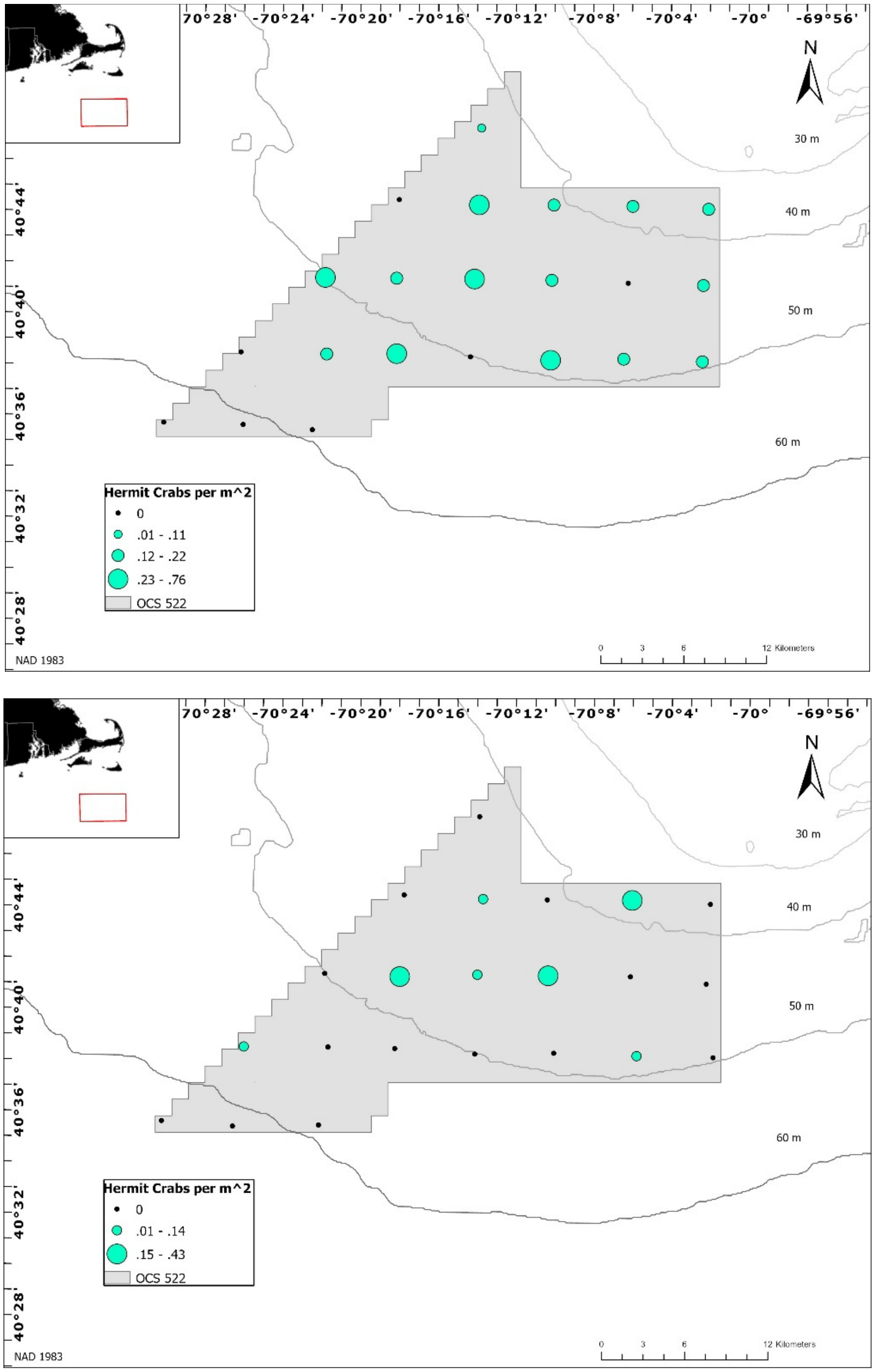


Figure 10. The distribution of hermit crabs from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

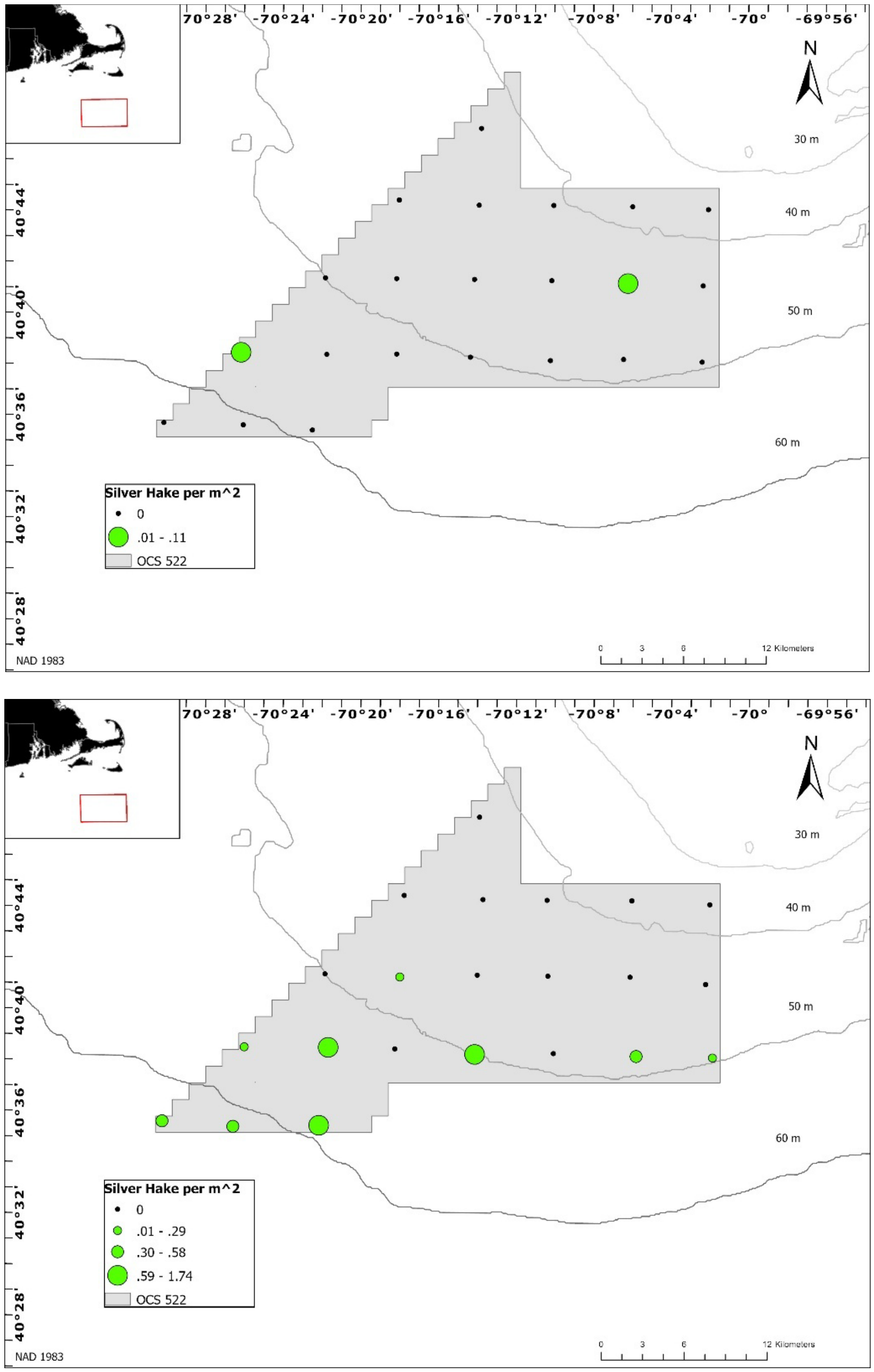


Figure 11. The distribution of silver hake from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

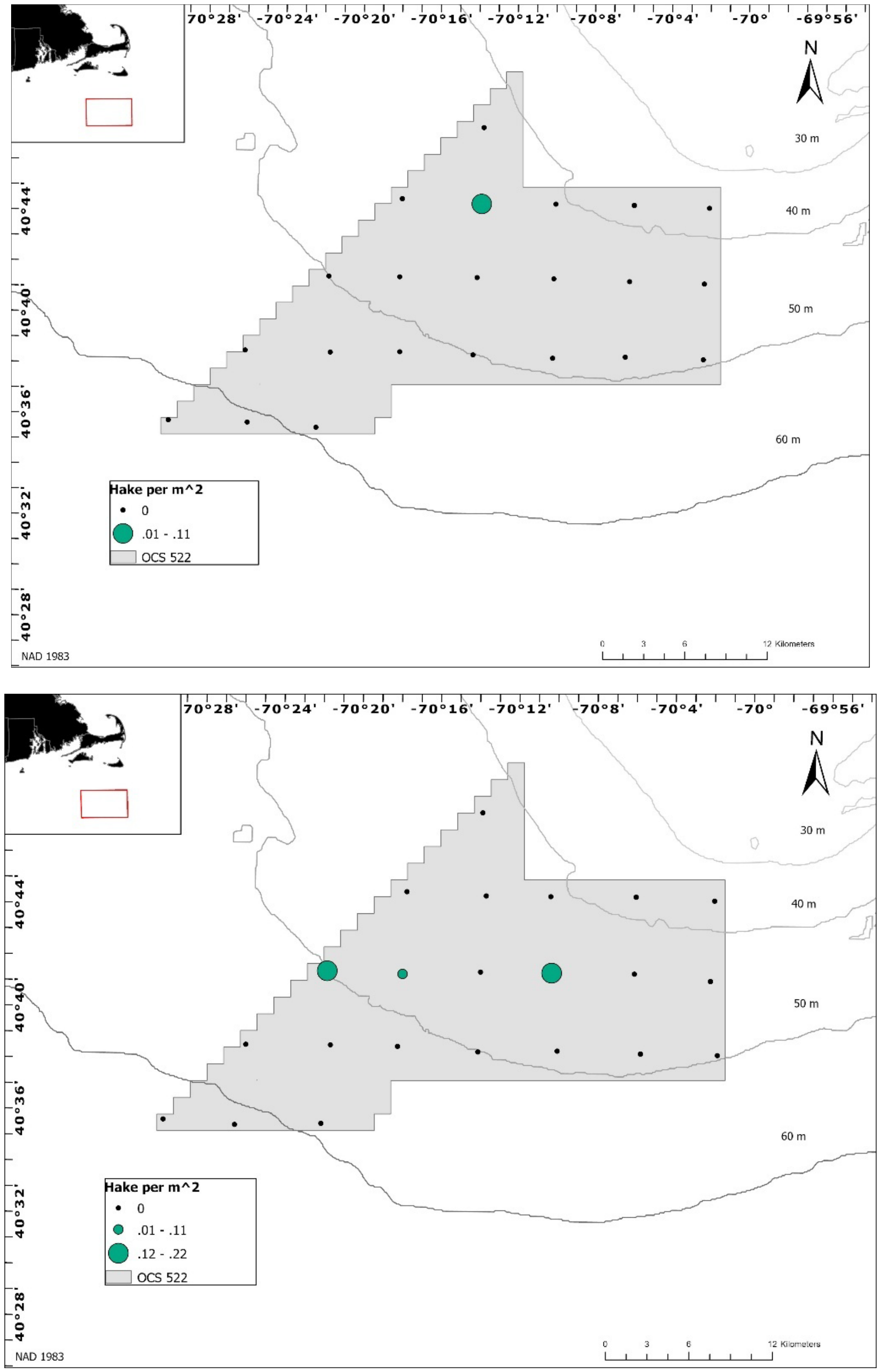


Figure 12. The distribution of hake from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

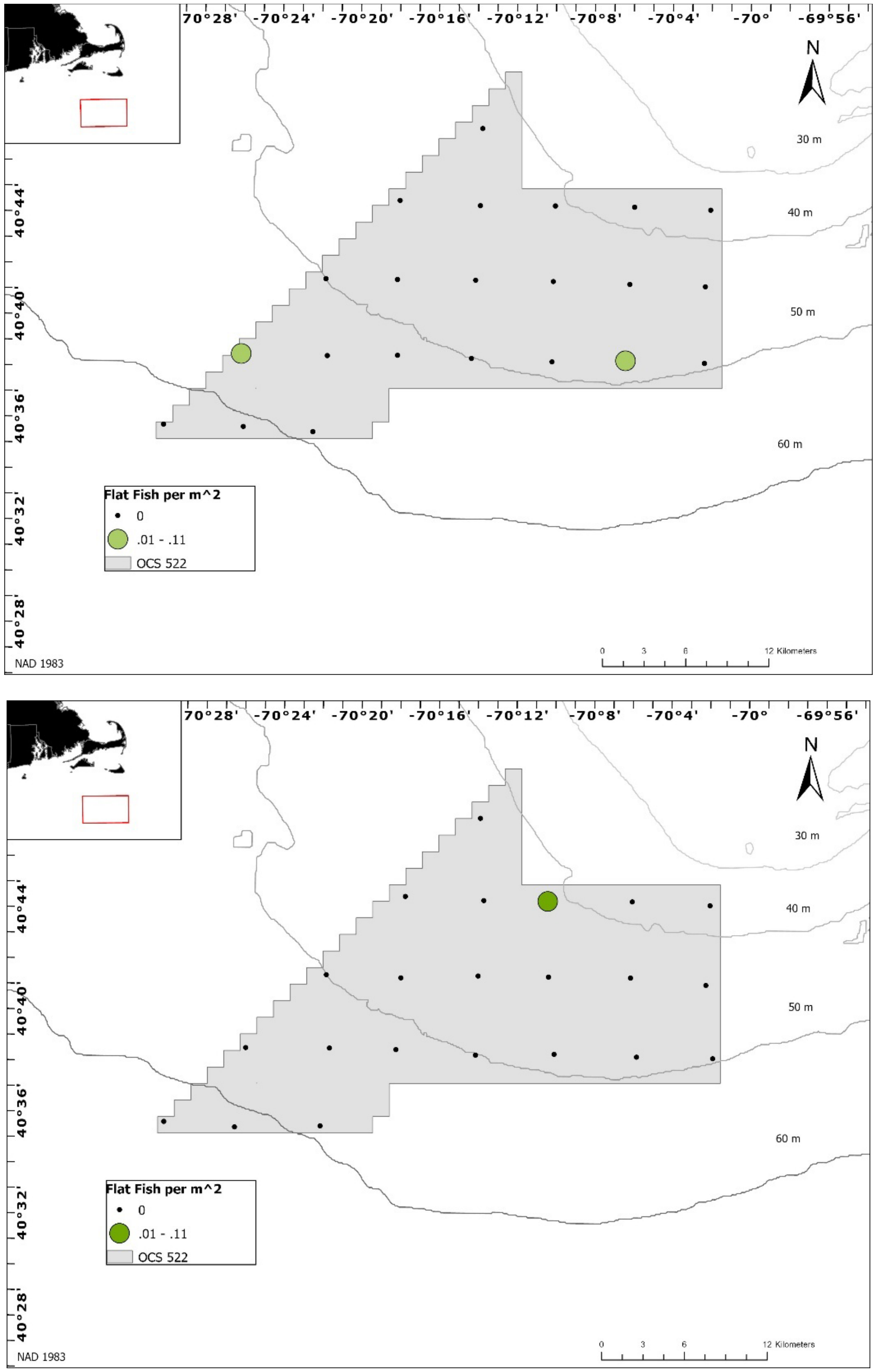
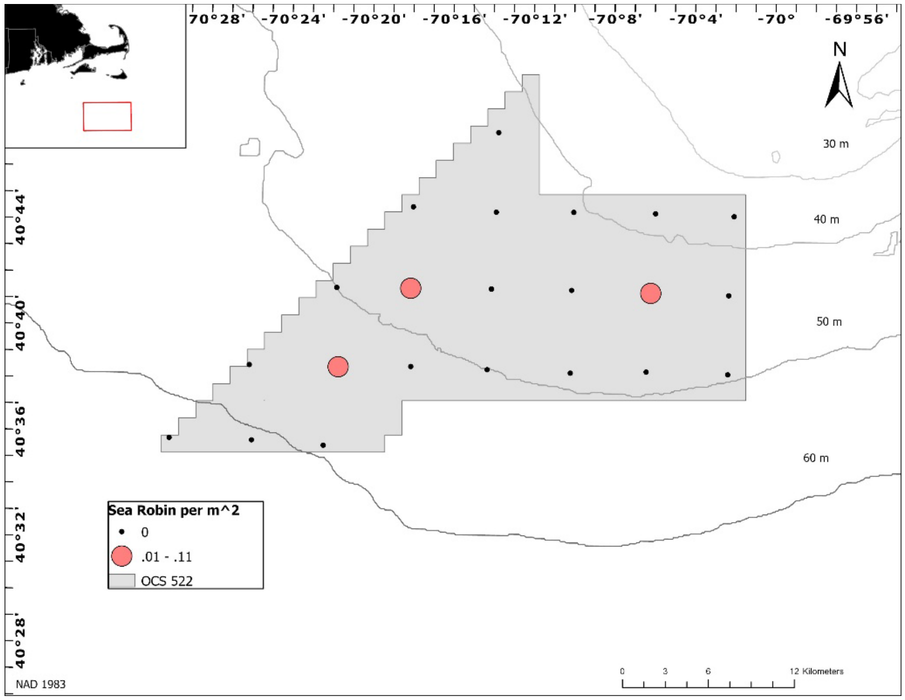


Figure 13. The distribution of flatfish species from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.



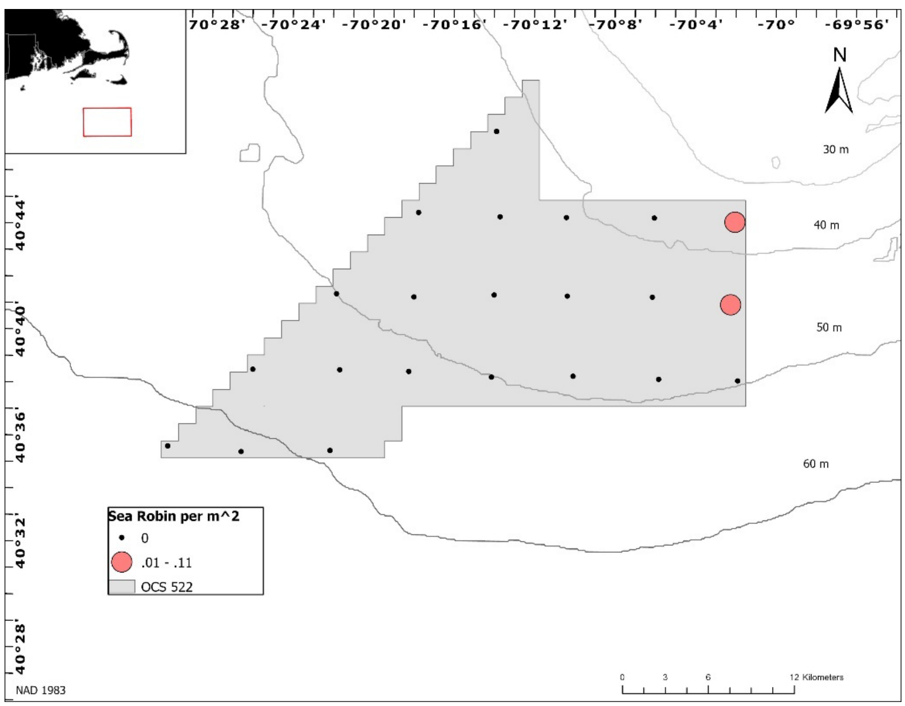


Figure 14. The distribution of sea robin from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

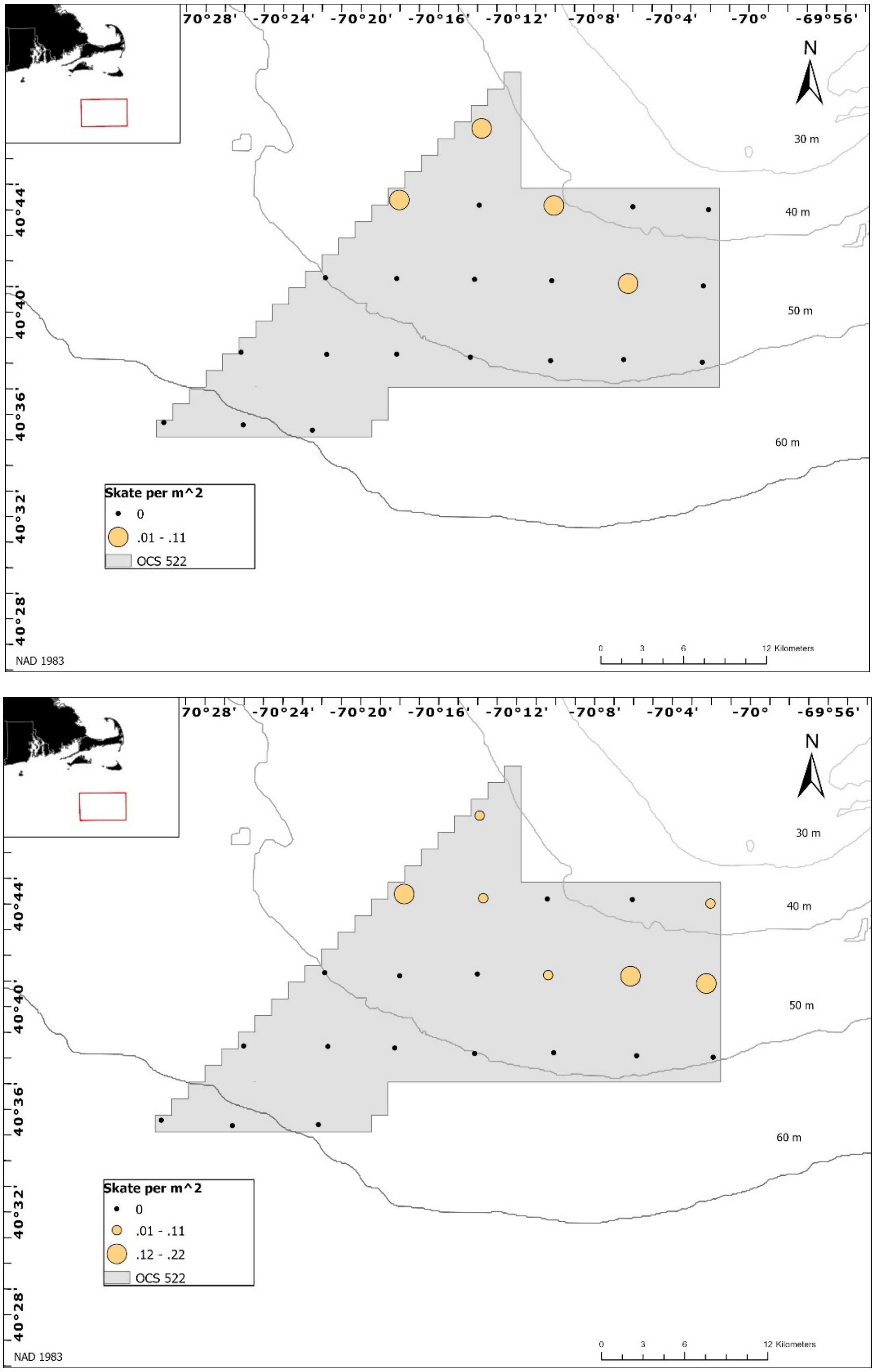


Figure 15. The distribution of skate species from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

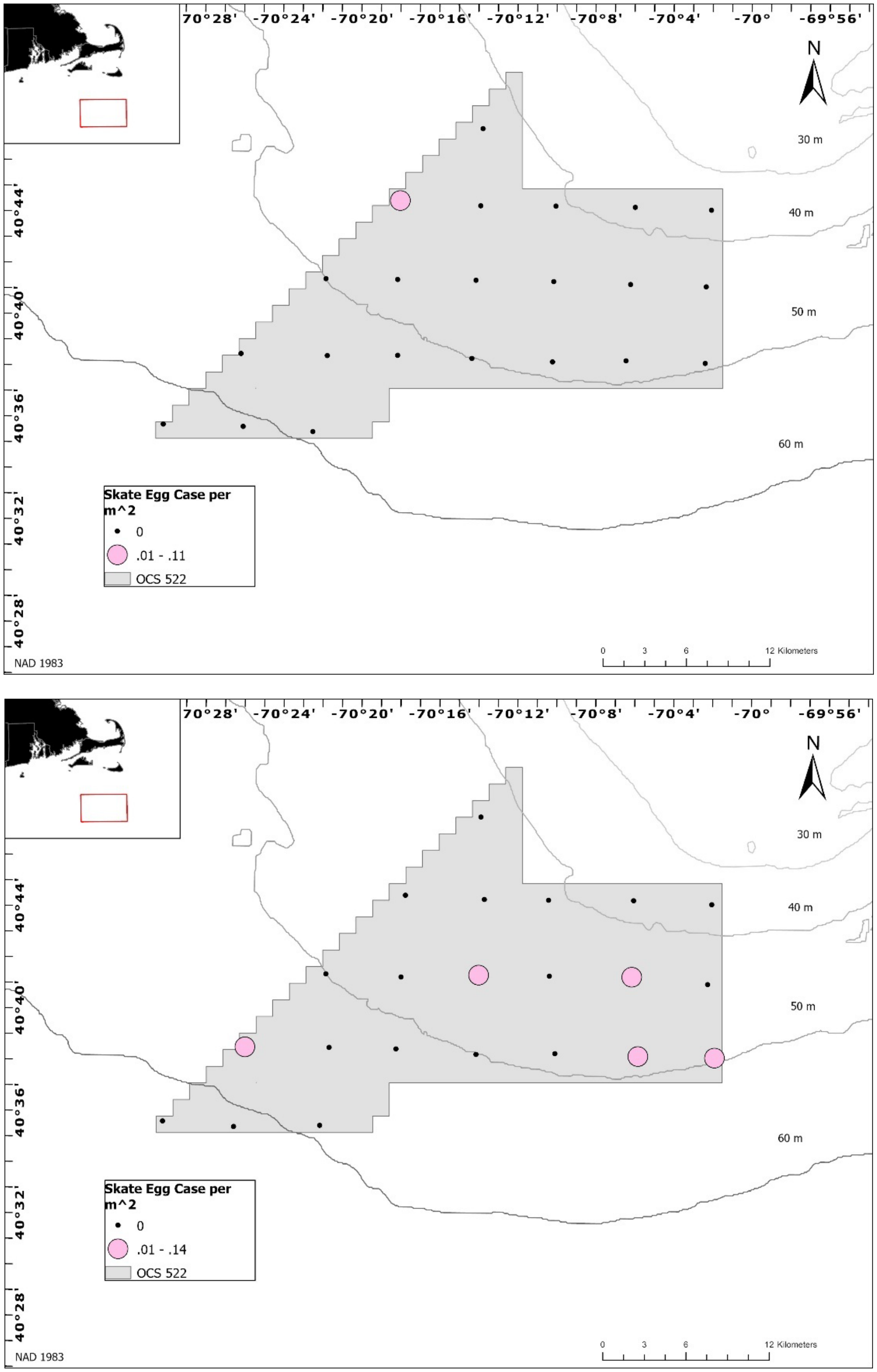


Figure 16. The distribution of skate egg cases from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

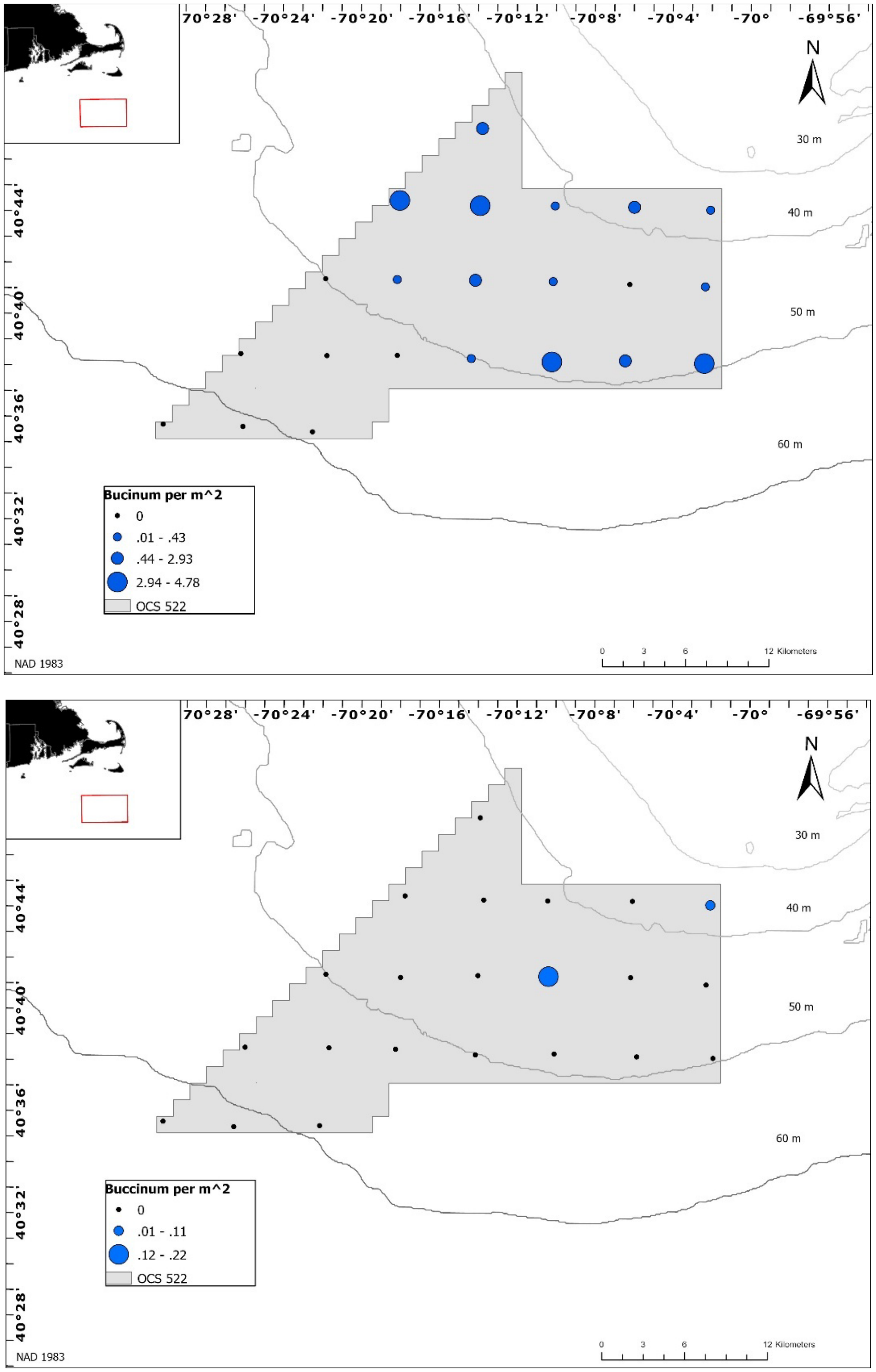


Figure 17. The distribution of Buccinum (whelk) from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area.

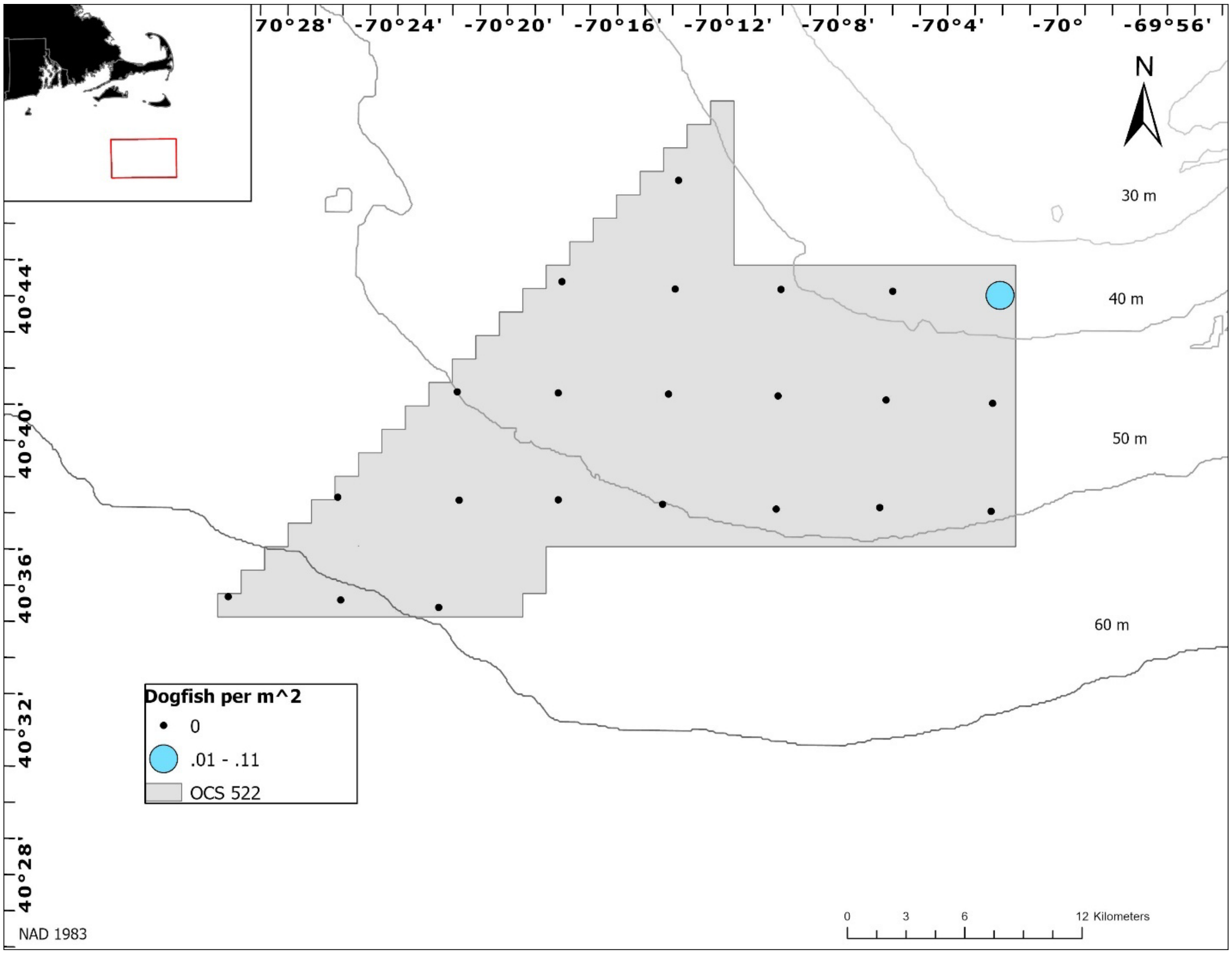


Figure 18. The distribution of dogfish from the summer 2024 drop camera survey of the 522 Study Area.

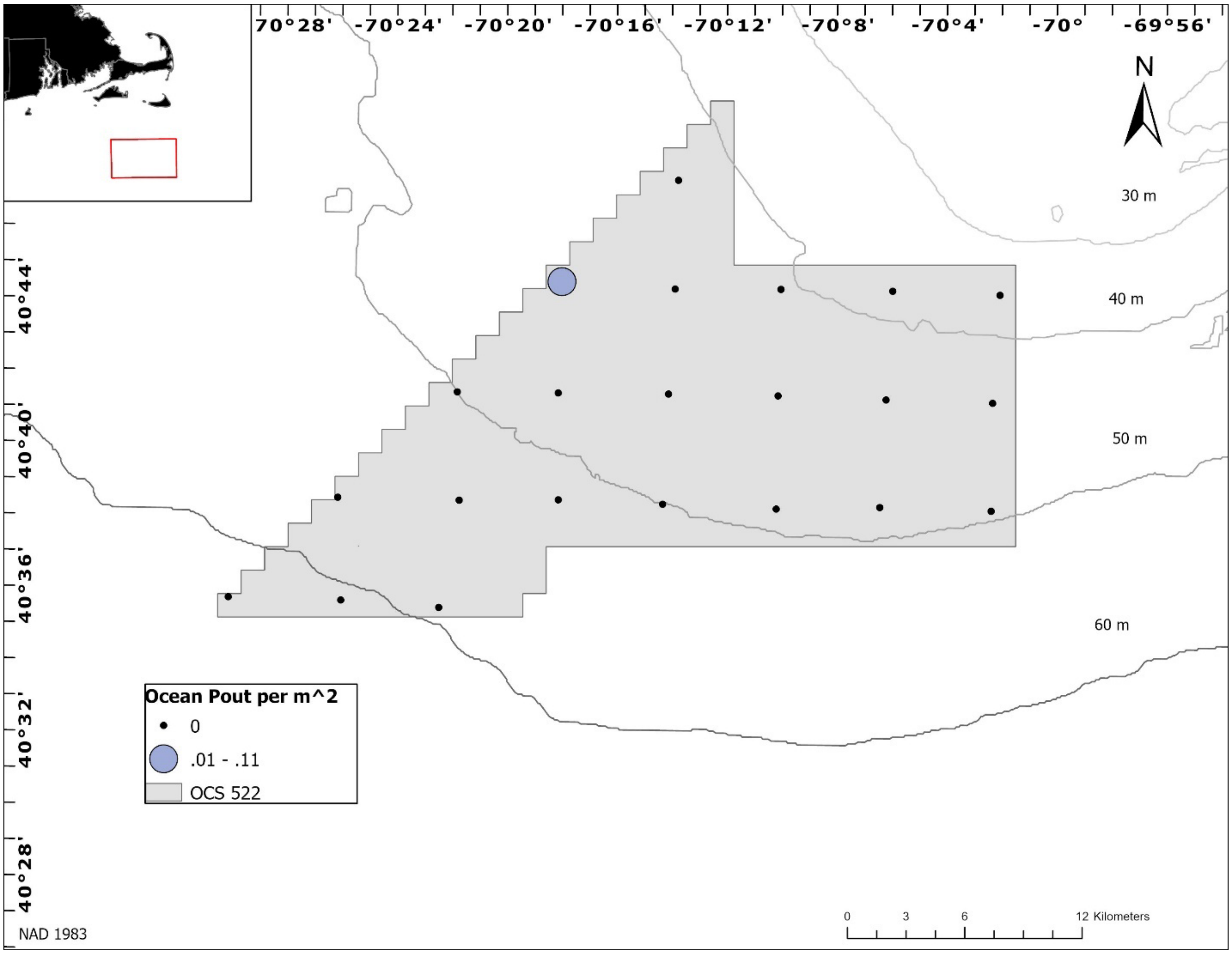


Figure 19. The distribution of ocean pout from the summer 2024 drop camera survey of the 522 Study Area.

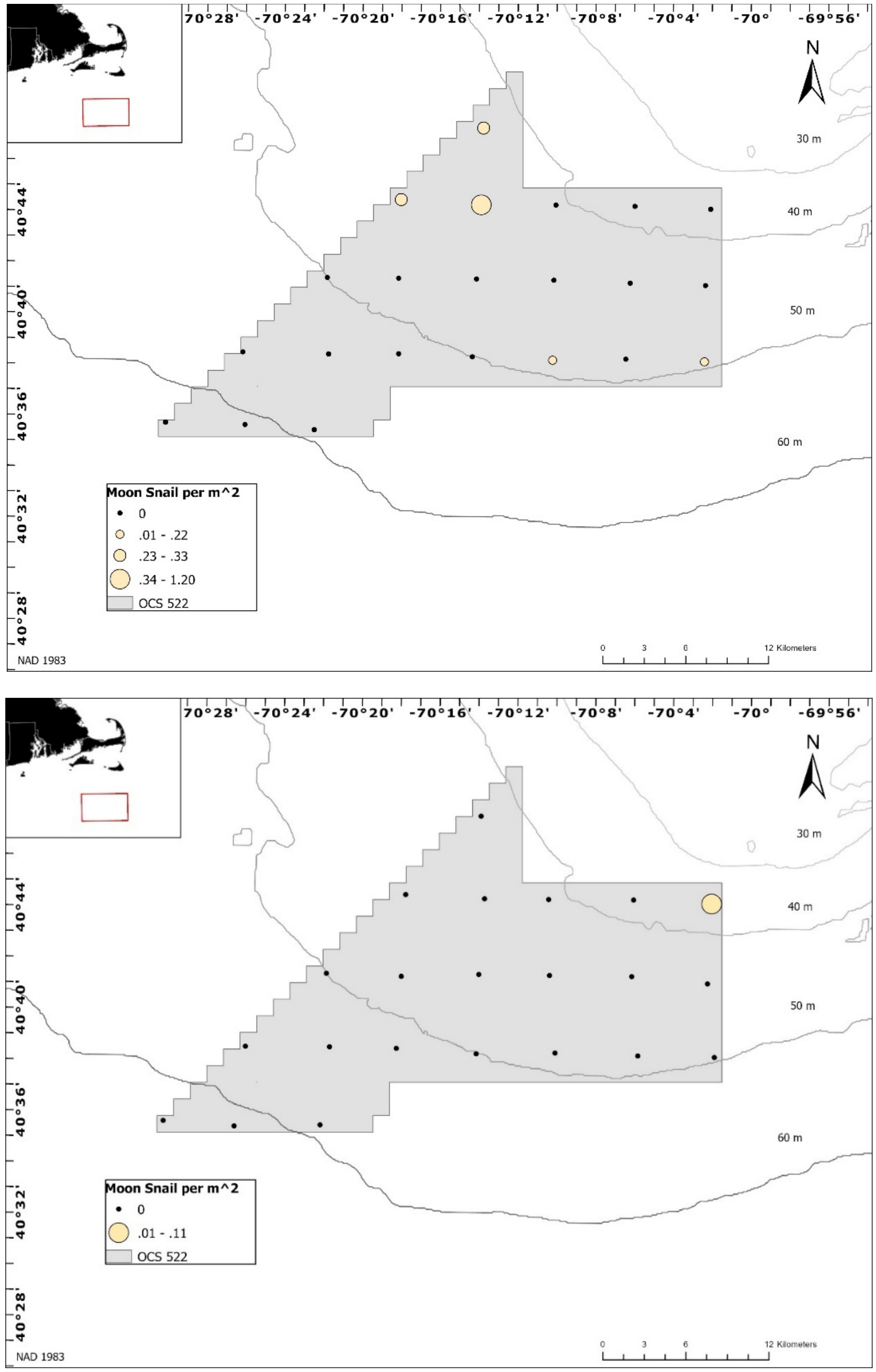


Figure 20. The distribution of moon snails from the summer 2024 (top) and fall 2024 (bottom) drop camera survey of the 522 Study Area.

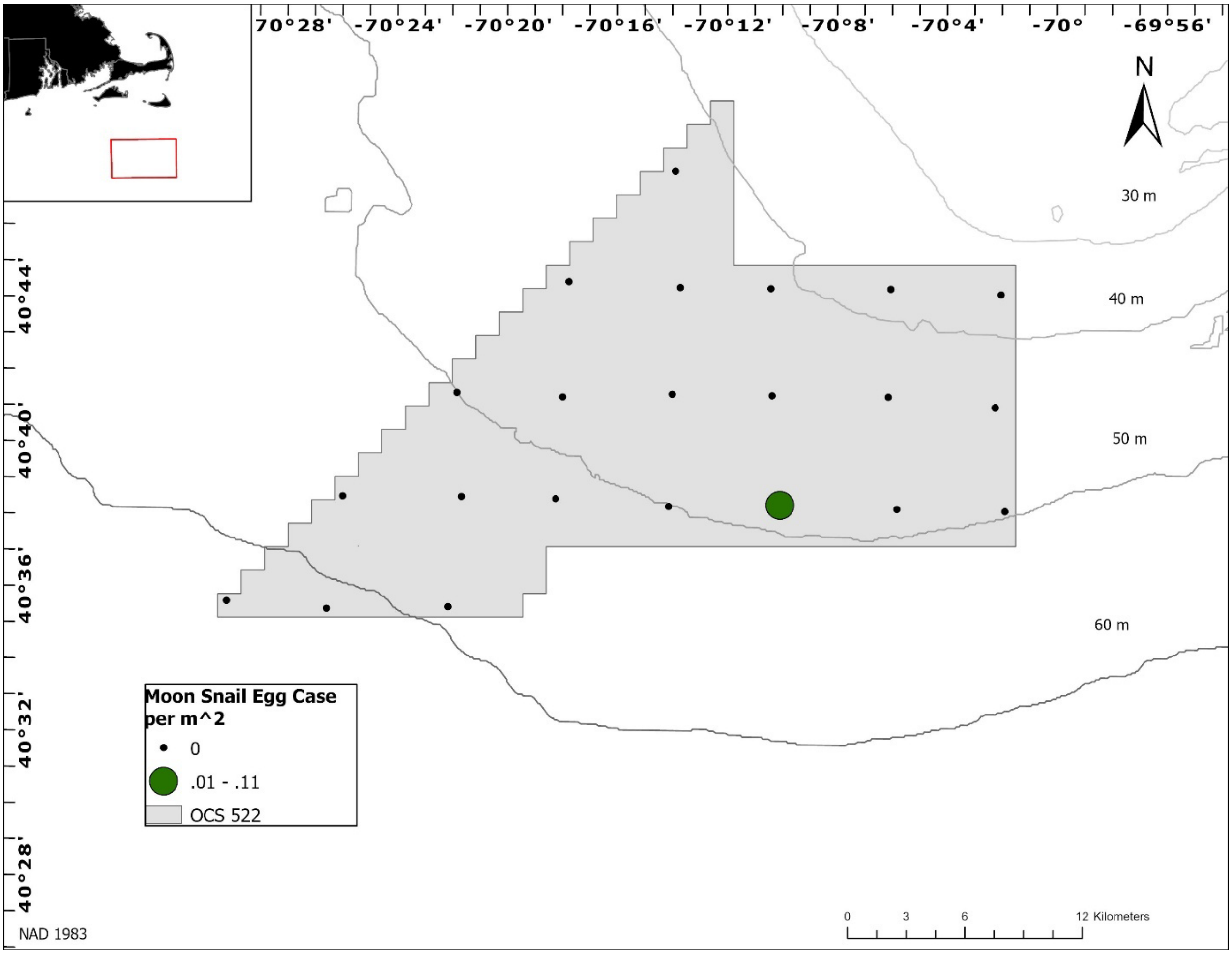


Figure 21. The distribution of moon snail egg cases from the fall 2024 drop camera survey of the 522 Study Area.

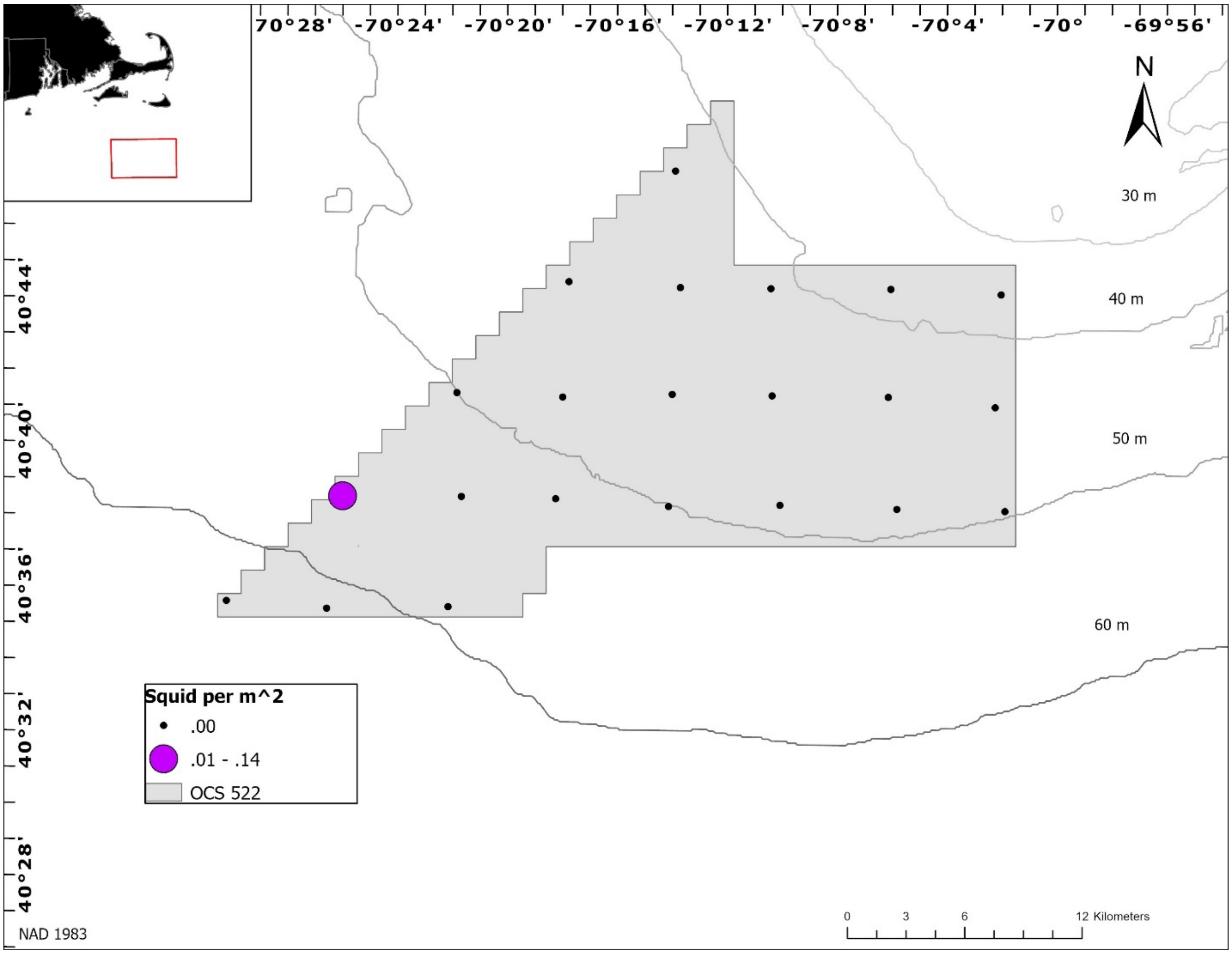


Figure 22. The distribution of squid from the fall 2024 drop camera survey of the 522 Study Area.

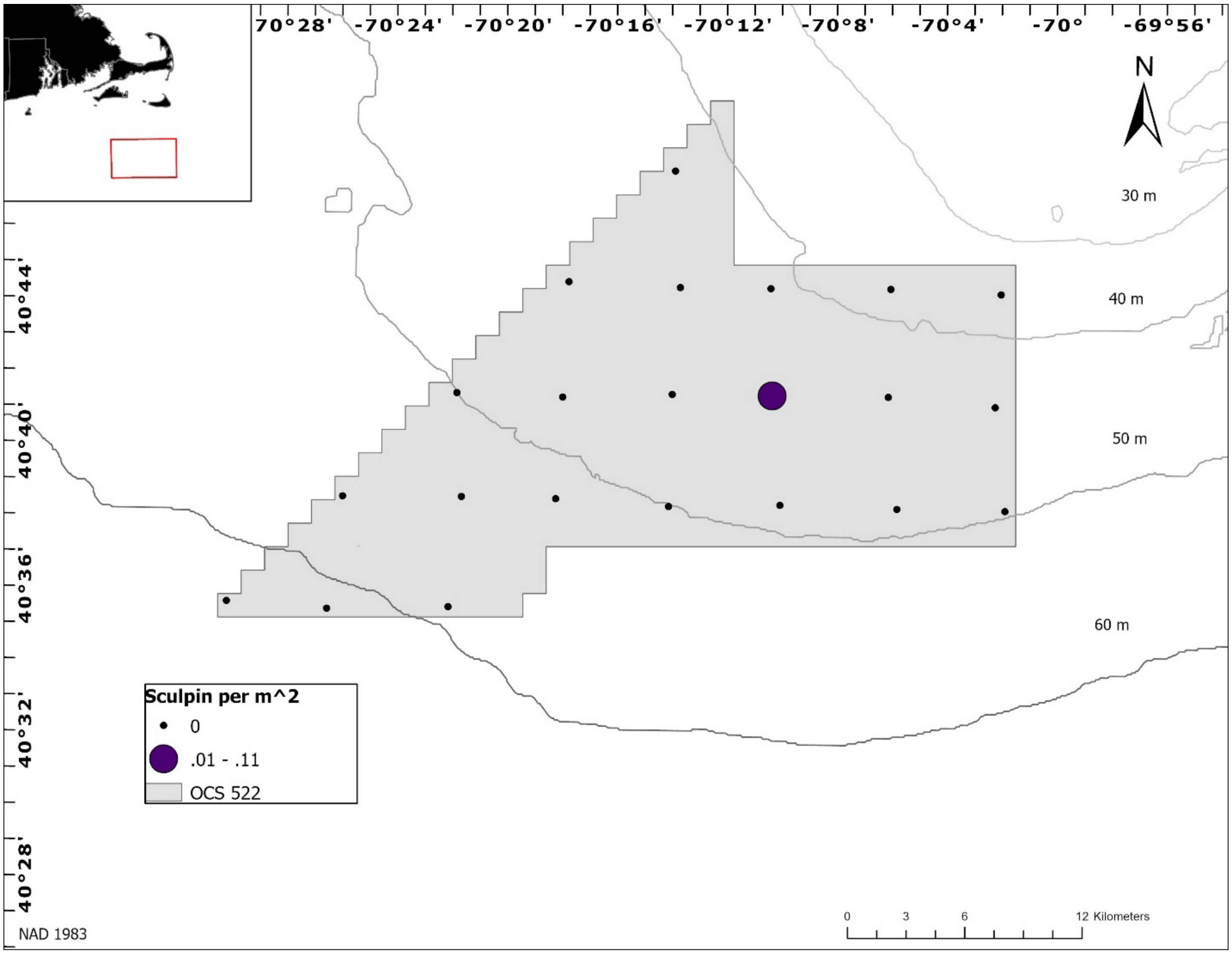


Figure 23. The distribution of sculpin from the fall 2024 drop camera survey of the 522 Study Area.

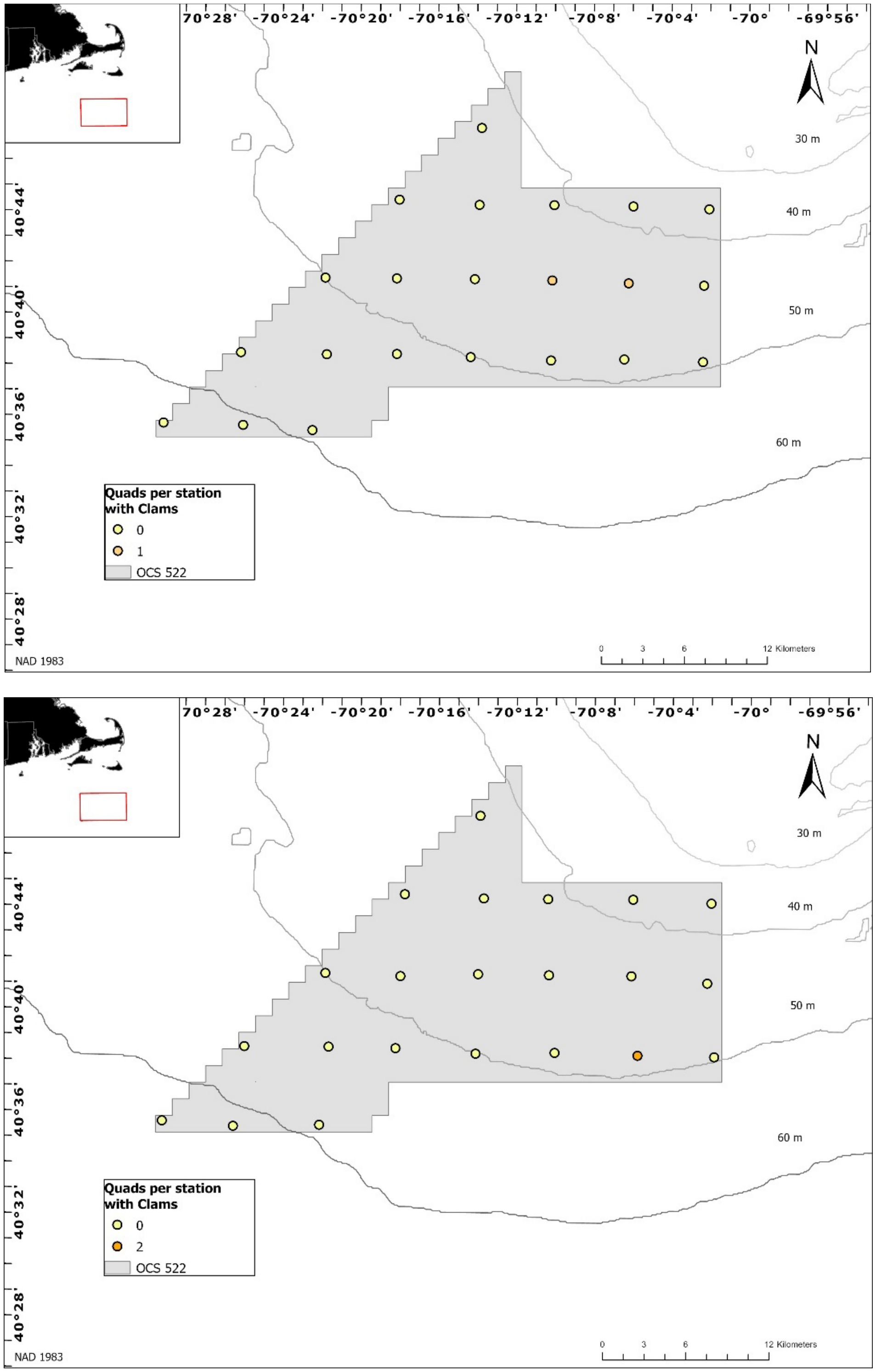


Figure 24. The distribution of clams from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed at, as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

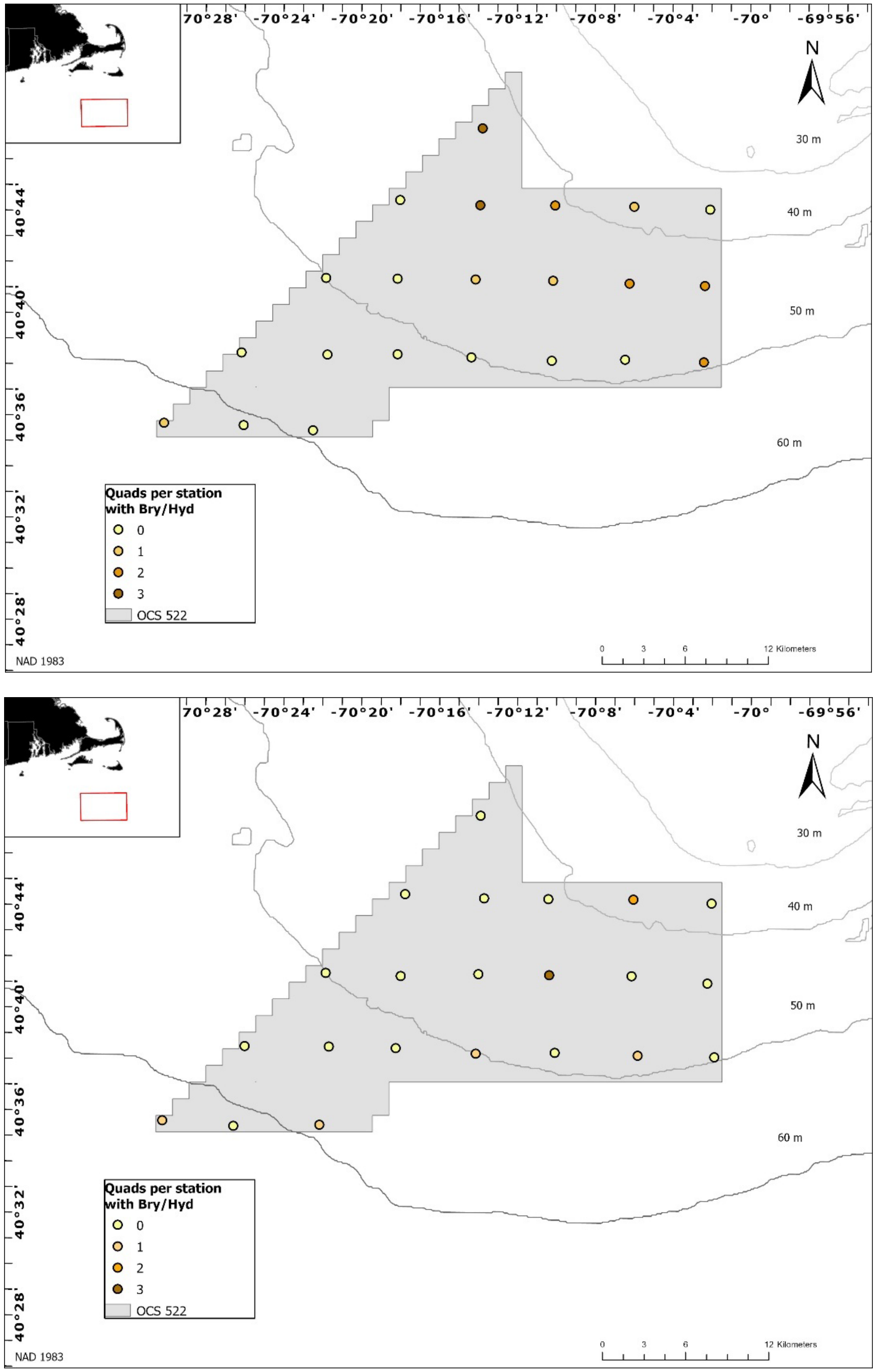
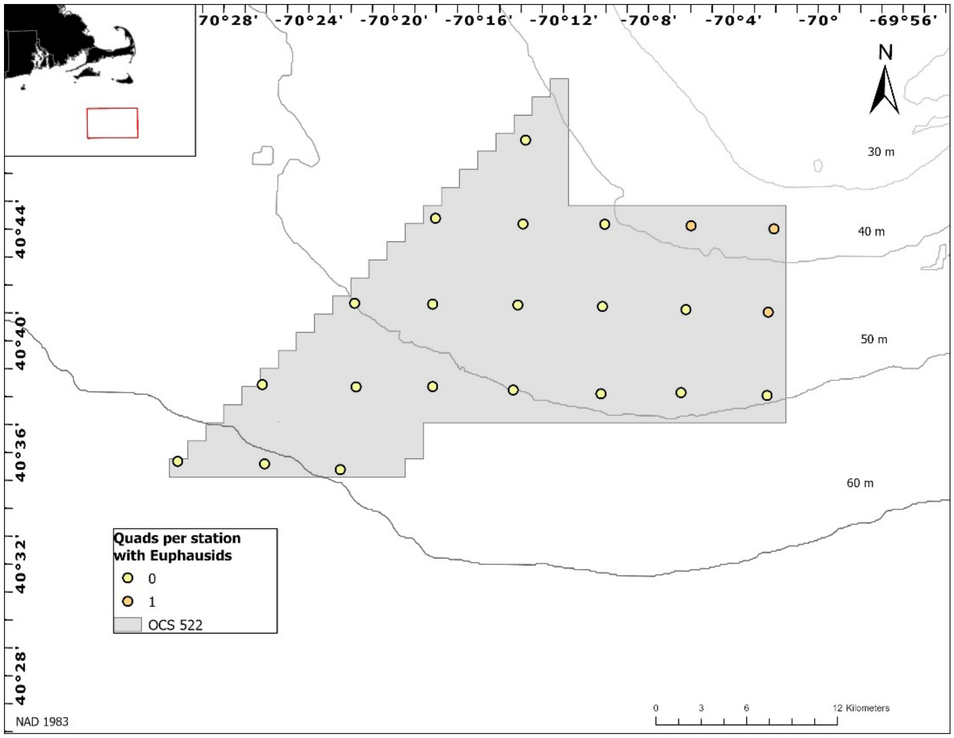


Figure 25. The distribution of Bry/Hyd (bryozoans and hydrozoans) from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.



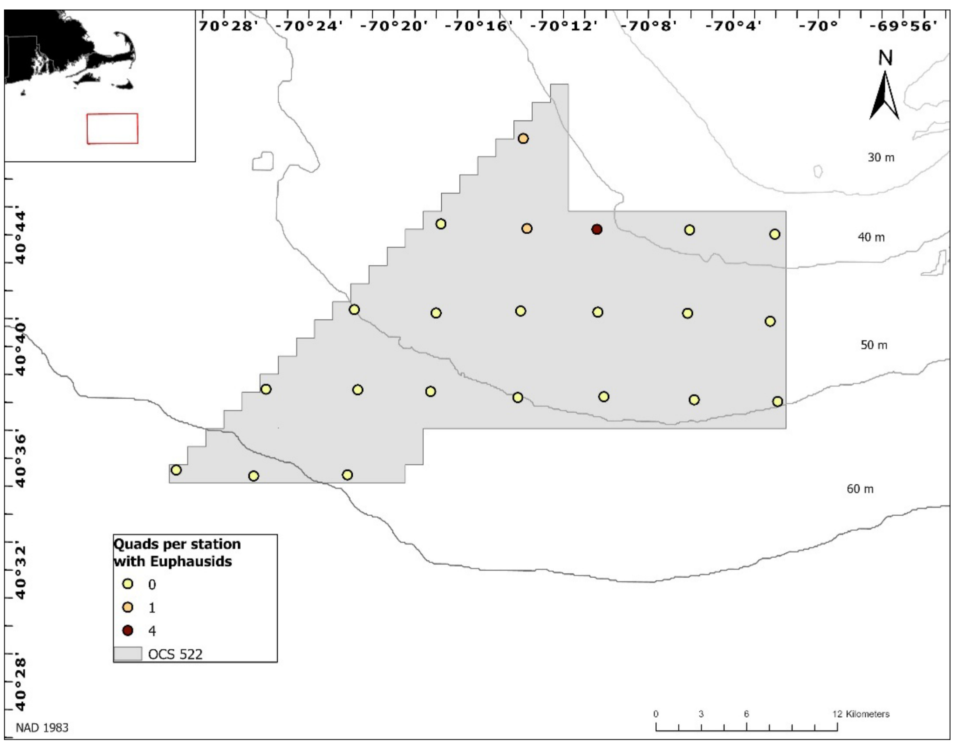
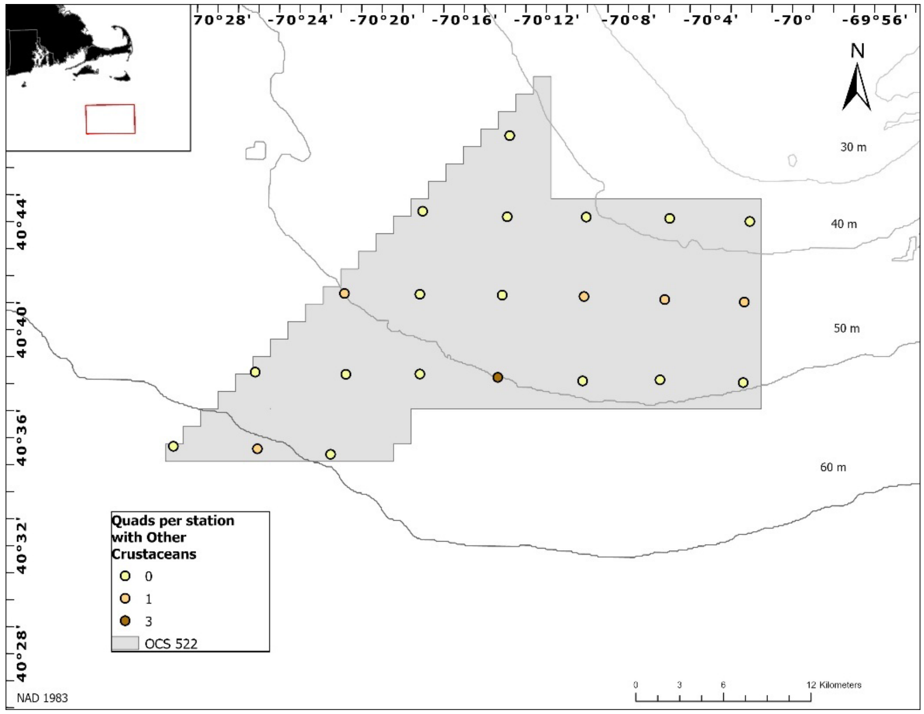


Figure 26. The distribution of euphausids from the summer2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.



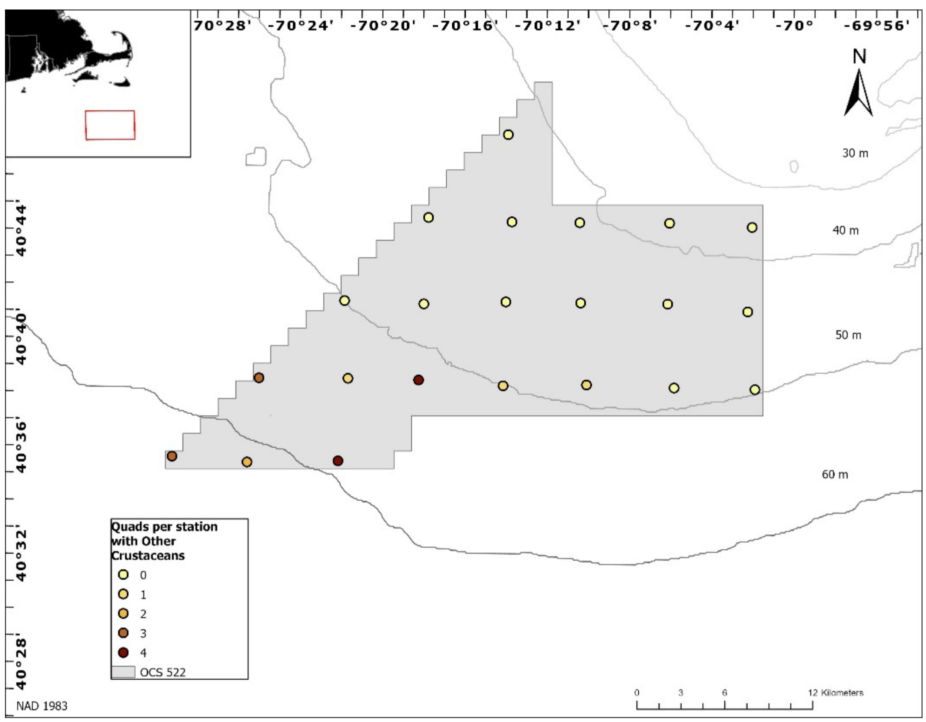
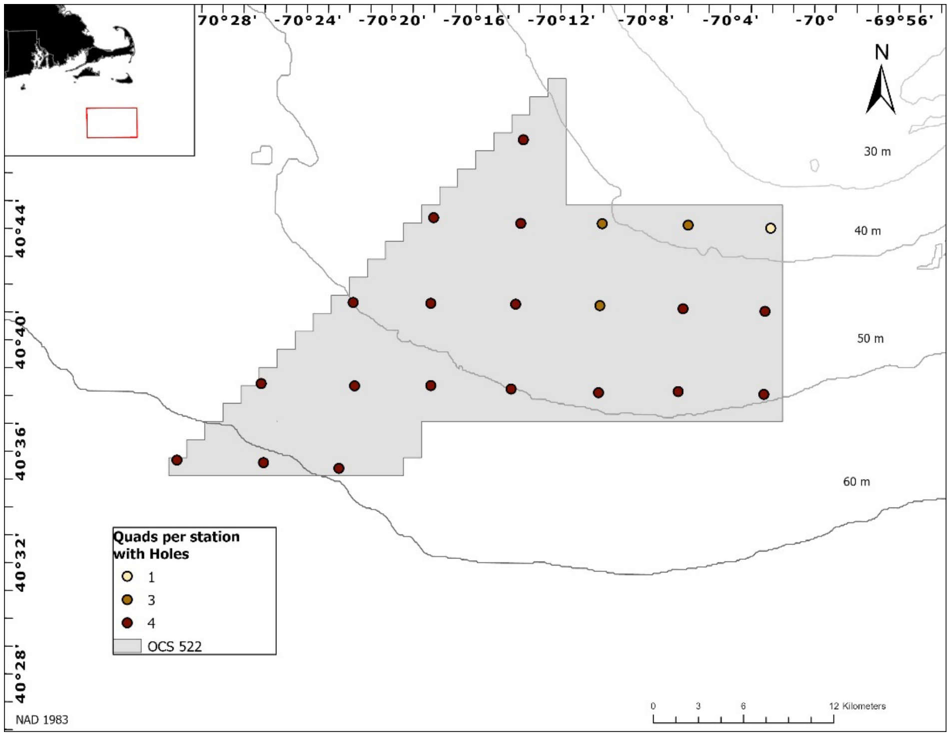


Figure 27. The distribution of other crustaceans from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.



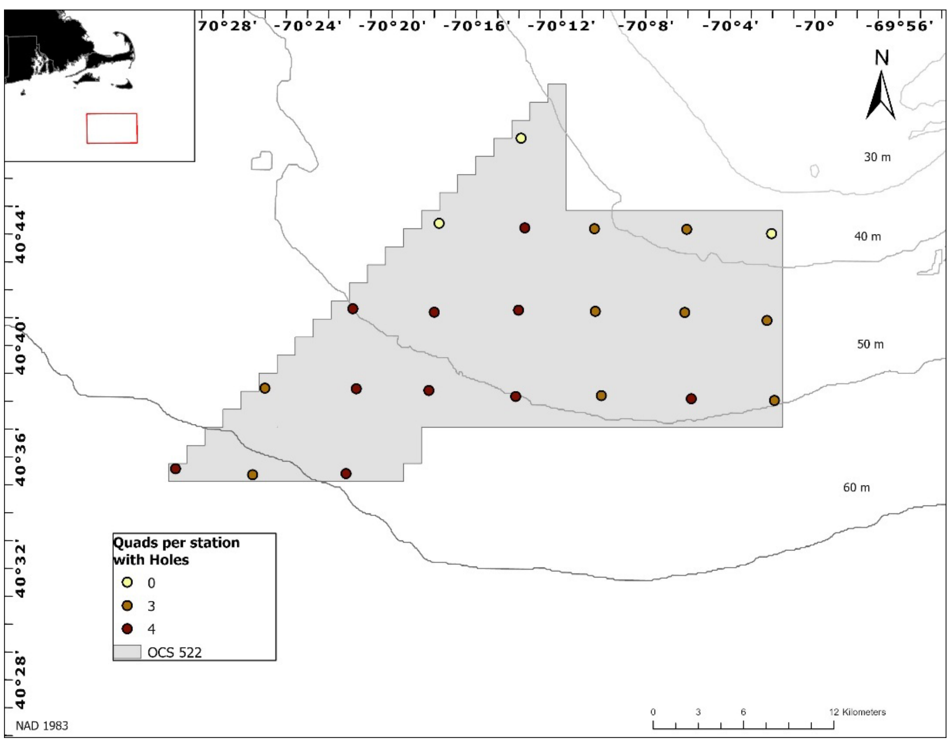


Figure 28. The distribution of holes (burrowing animals) from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

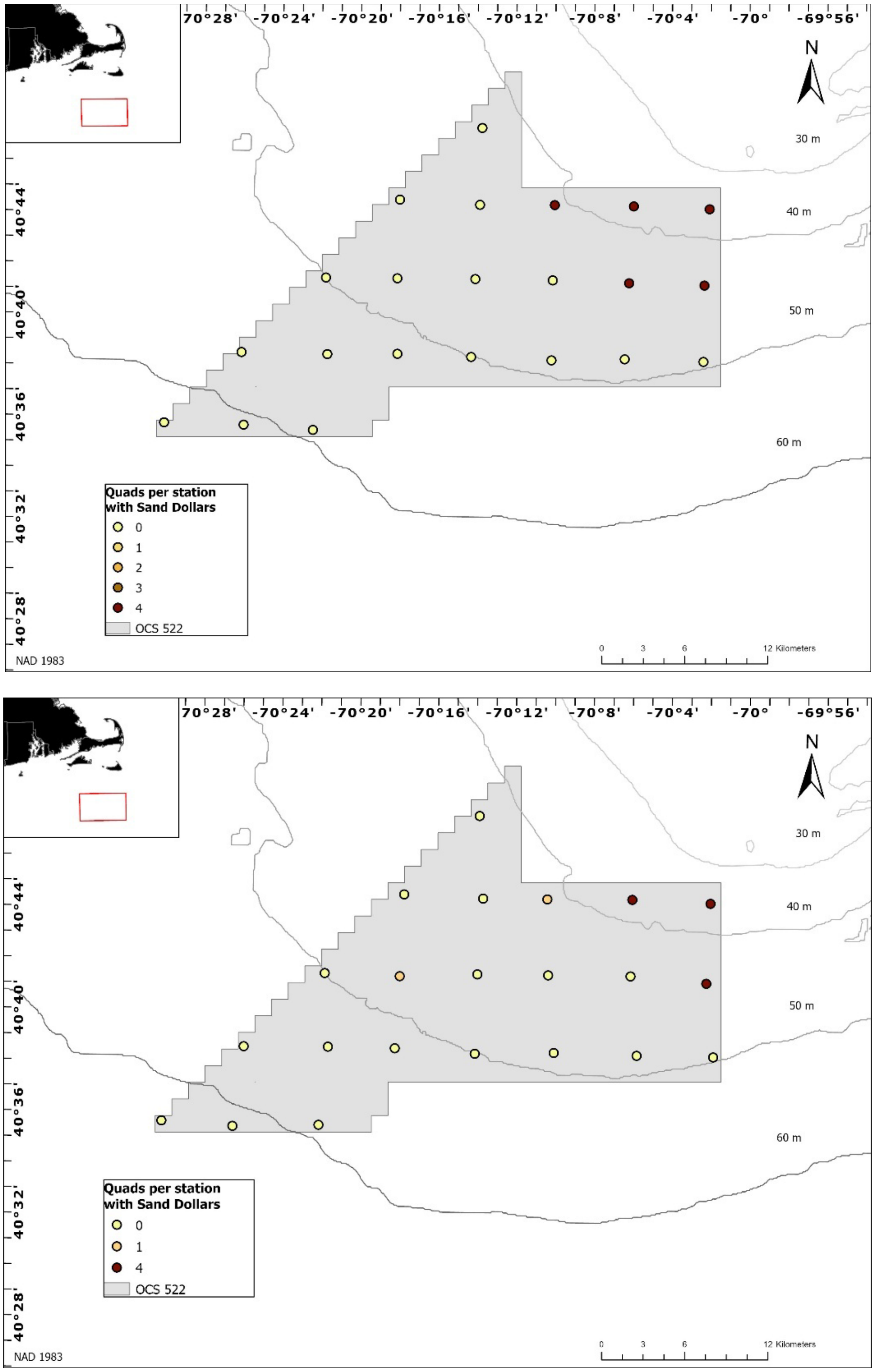


Figure 29. The distribution of sand dollars from the summer 2024 (top) and fall 2024 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

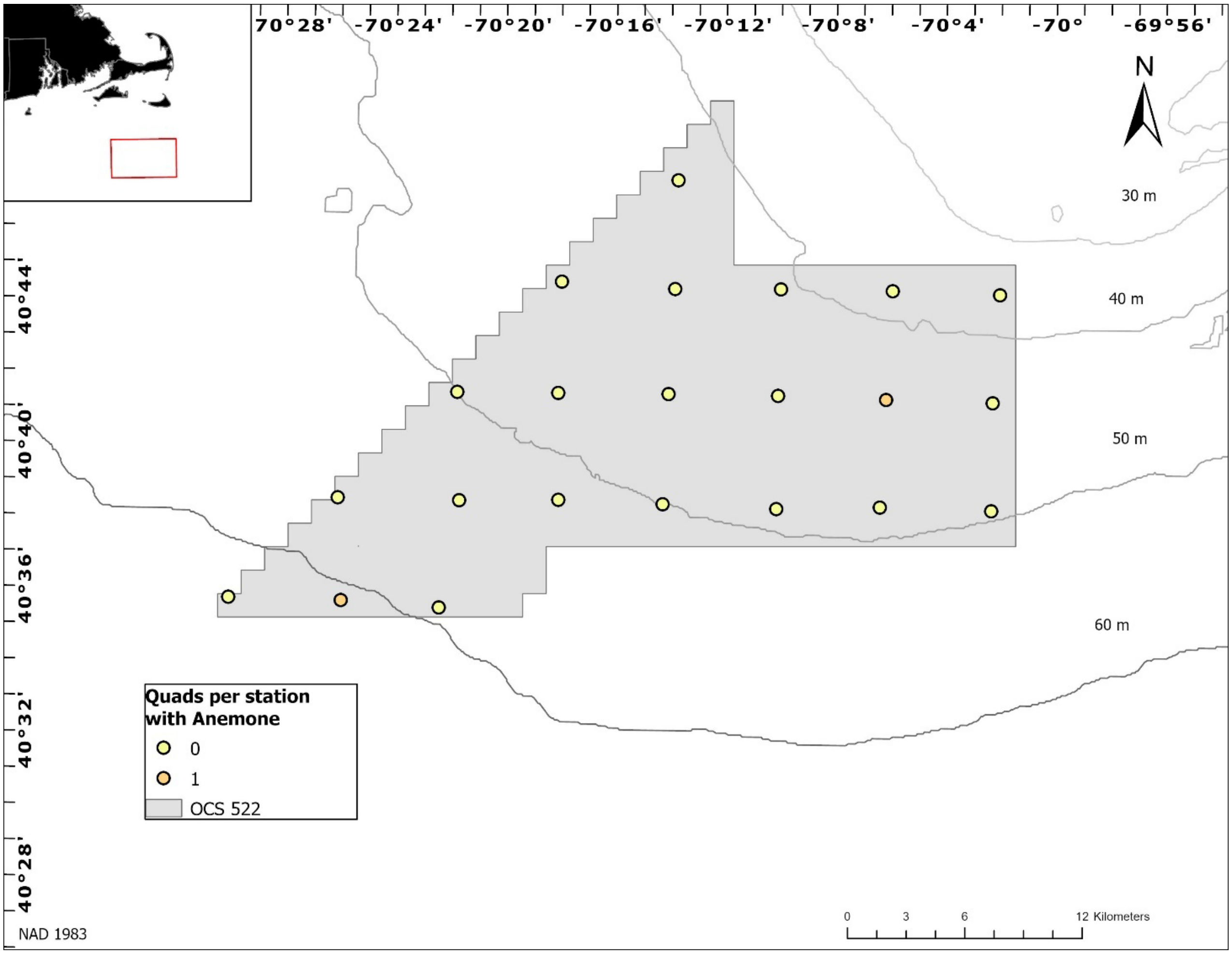


Figure 30. The distribution of anemones from the summer 2024 drop camera survey of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

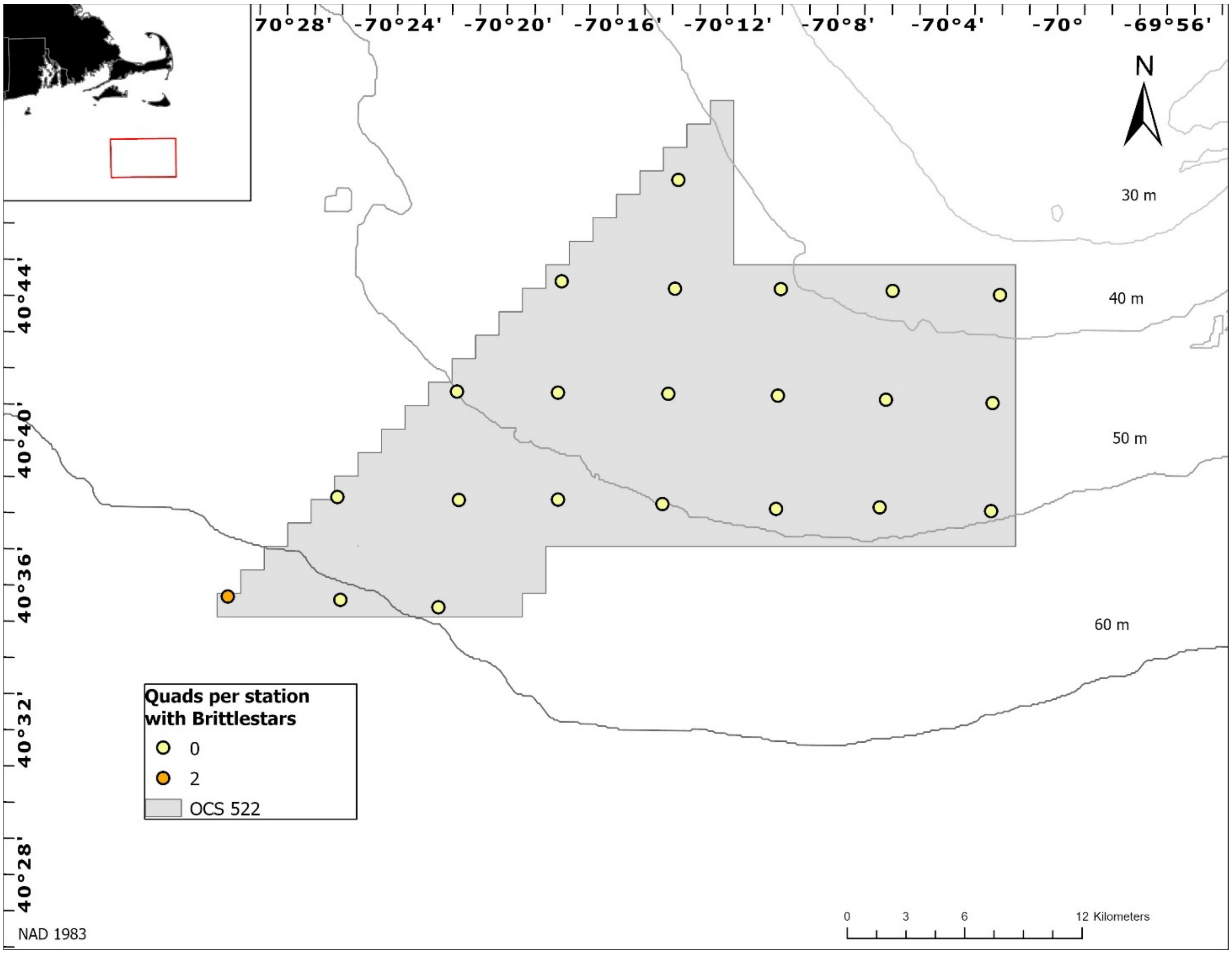


Figure 31. The distribution of brittle stars from the summer 2024 drop camera survey of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

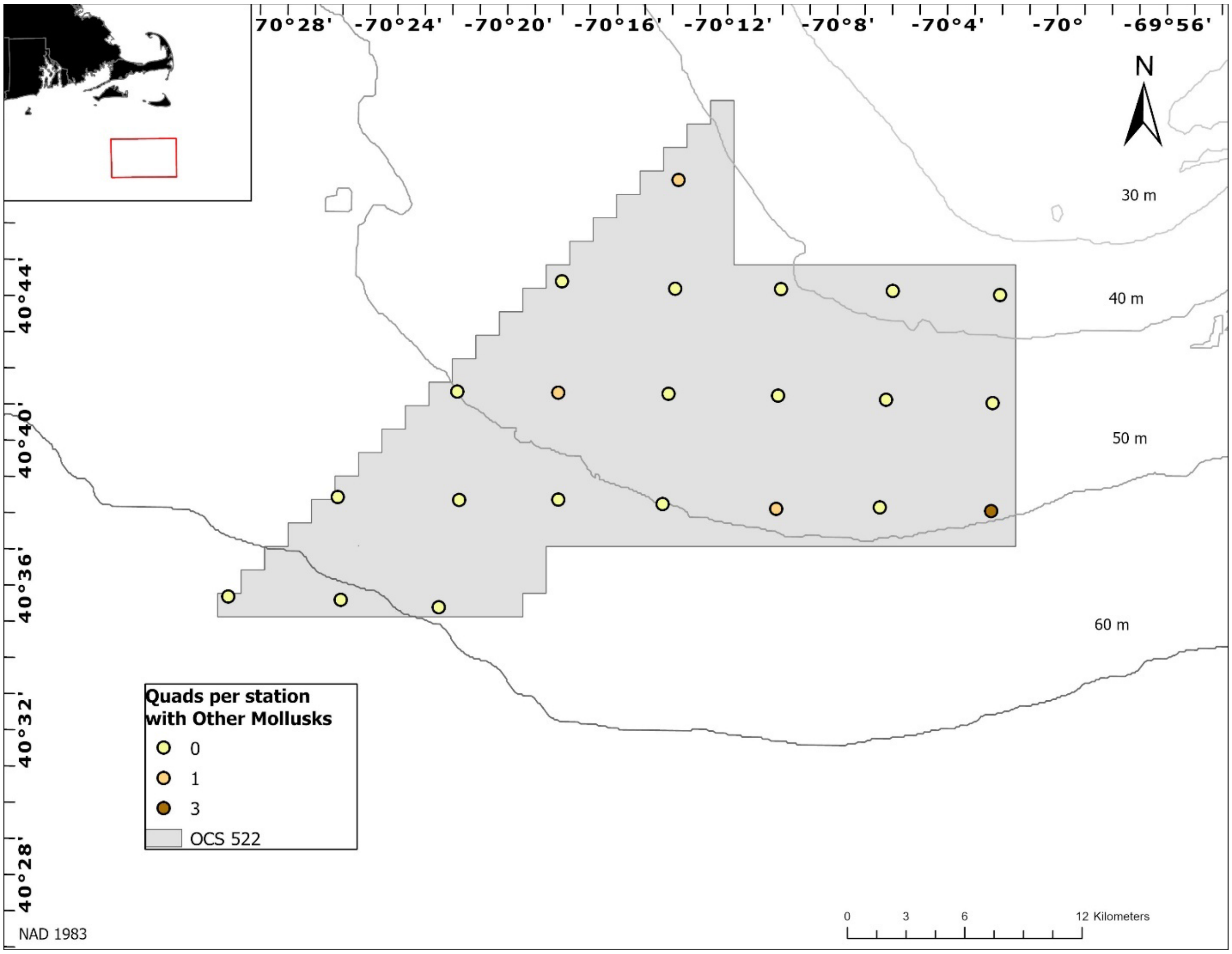


Figure 32. The distribution of other mollusks from the summer 2024 drop camera survey of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated by the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

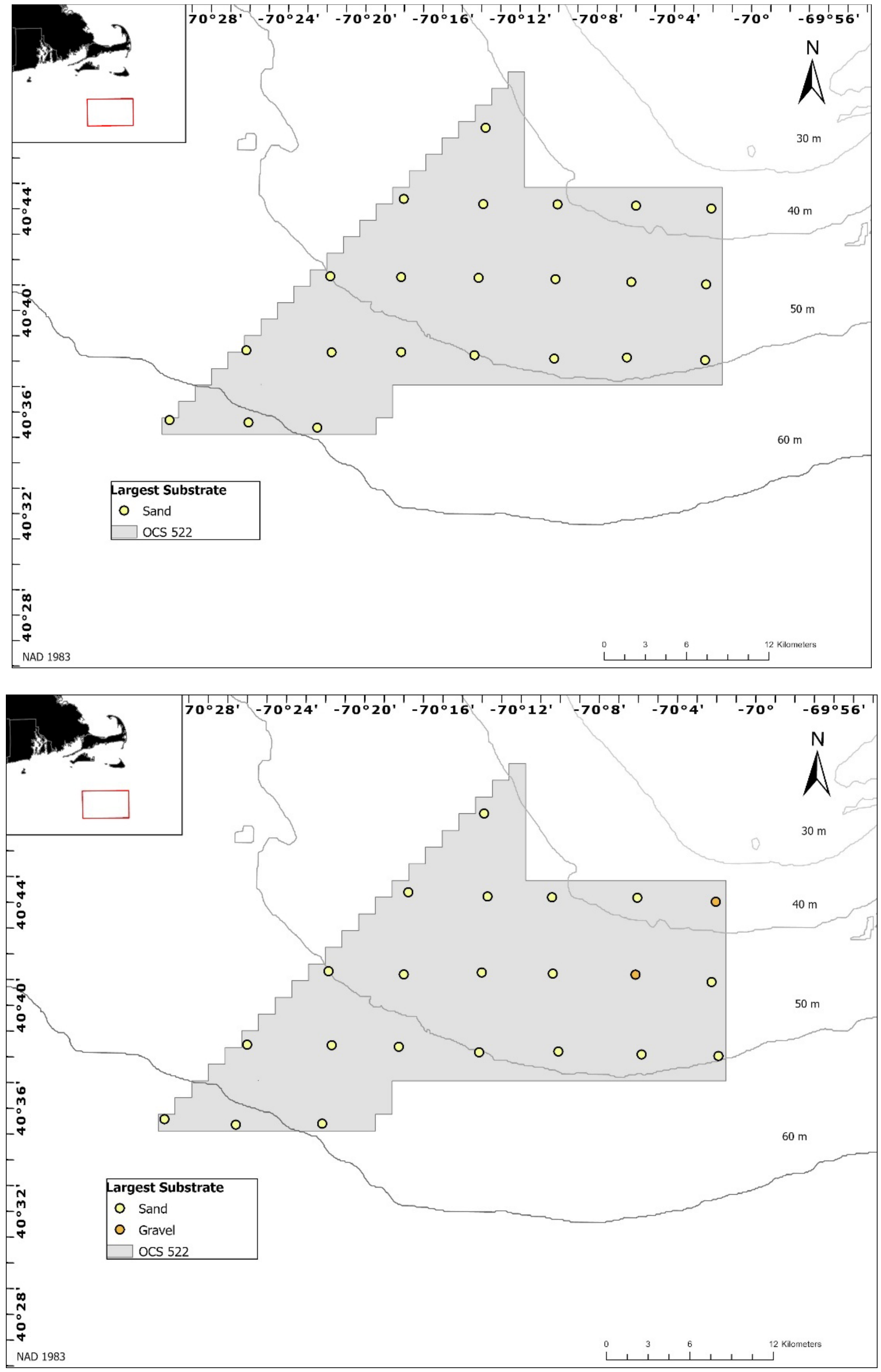


Figure 33. The distribution of the largest substrate type from the summer 2024 (top) and fall 2024 (bottom) drop camera survey of the 522 Study Area.

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Appendix I: Species list and visibility information

Table. I-1. A list of George's Bank species that can be quantified using drop camera surveys and are grouped into taxonomic categories (Stokesbury and Harris 2006).

Category	**Scientific name**	**Common name**
Scallop	*Placopecten magellanicus*	Sea scallop
Starfishes	*Solaster endeca*	Purple sunstar
	Crossaster papposus	Spiny sunstar
	Leptasterias Polaris	Polar sea star
	Asterias spp.	Sea stars
	Henricia spp	Blood star
Sand dollars	*Echinarachnius parma*	Sand dollar
Bryozoans/hydrozoans	*Flustra foliacea*	Bryozoans
	Callopora aurita	Bryozoans
	Electra monostachys	Bryozoans
	Cribrilina punctate	Bryozoans
	Eucratea loricate	Bryozoans
	Tricellaria ternate	Bryozoans
	Eudendrium capillare	Hydrozoans
	Sertularia cupressina	Sea cypress hydroid
	Sertularia argentea	Squirrel's tail hydroid
	Diphasia fallax	Hydrozoans
	Filograna implexa	Lacy tube worm
Sponges	*Suberites ficus*	Fig sponge
	Haliclona oculata	Finger sponge
	Halichondria panacea	Crumb of bread sponge
	Cliona celata Grant	Boring sponge

	Polymastia robusta	Encrusting sponge
	Isodictya palmate	Palmate sponge
	Microciona prolifera	Red beard sponge
Lobster	*Homarus americanus*	American lobster
Crabs	*Cancer irroratus Say*	Atlantic rock crab
	Cancer borealis Stimpson	Jonah crab
Hermit crabs	*Diogenidae*	Left-handed hermit crabs
	Paguridae	Right-handed hermit crabs
	Parapaguridae	Deep water hermit crabs
Eel pout	*Zoarces americanus*	Ocean pout
Flounder	*Paralichthys dentatus*	Summer flounder
	Paralichthys oblongus	Fourspot flounder
	Scophthalmus aquosus	Windowpane flounder
	Pseudopleuronectes americanus	Winter flounder
	Limanda ferruginea	Yellowtail flounder
	Glyptocephalus cynoglossus	Witch flounder
	Trinectes maculatus	Hogchoaker
Haddock	*Melanogrammus aeglefinus*	Haddock
Hake	*Merluccius bilinearis*	Silver hake
	Urophycis spp.	Red and white hake
Sculpins	*Myoxocephalus octodecemspinosus*	Longhorn sculpin
	Prionotus carolinus	Northern sea robin
Skates	*Leucoraja erinacea*	Little skate
	Leucoraja ocellata	Winter skate
	Dipturus laevis	Barndoor skate

Other fish	*Myxine glutinosa*	Atlantic hagfish
	Scyliorhinus rotifer	Chain dogfish
	Squalus acanthias	Spiny dogfish
	Anguilla rostrate	American eel
	Conger oceanicus	Conger eel
	Clupea harengus	Atlantic herring
	Brosme brosme	Cusk
	Gadus morhua	Atlantic cod
	Lophius americanus	Goosefish
	Ammodytes dubius	Northern sand lance
	Scomber scombrus	Atlantic mackerel
	Sebastes fasciatus	Acadian refish
	Anarhichas lupus	Atlantic wolfish
Shell debris	*Buccinum undatum*	Waved whelk
	Euspira heros	Northern moonsnail
	Mercenaria mercenaria	Northern quahog
	Modiolus modiolus	Northern horse mussel
	Ensis directus	Atlantic jackknife
	Placopecten magellanicus	Sea scallops

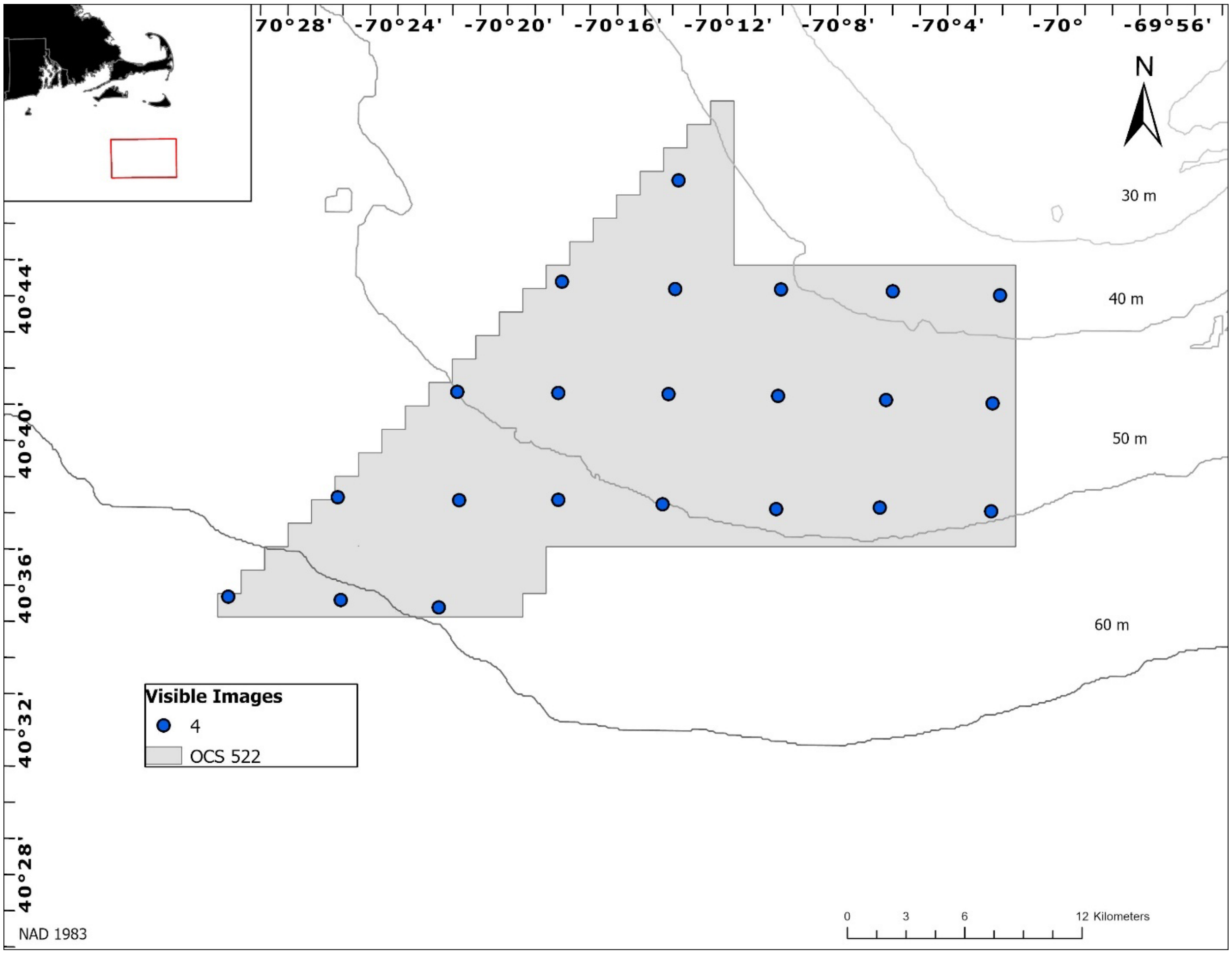

Figure I-1. The distribution of digital still camera image visibility per station for the summer 2024 drop camera survey of the 522 Study Area. The color of the station represents the number of quadrats that were visible as indicated in the figure legend.

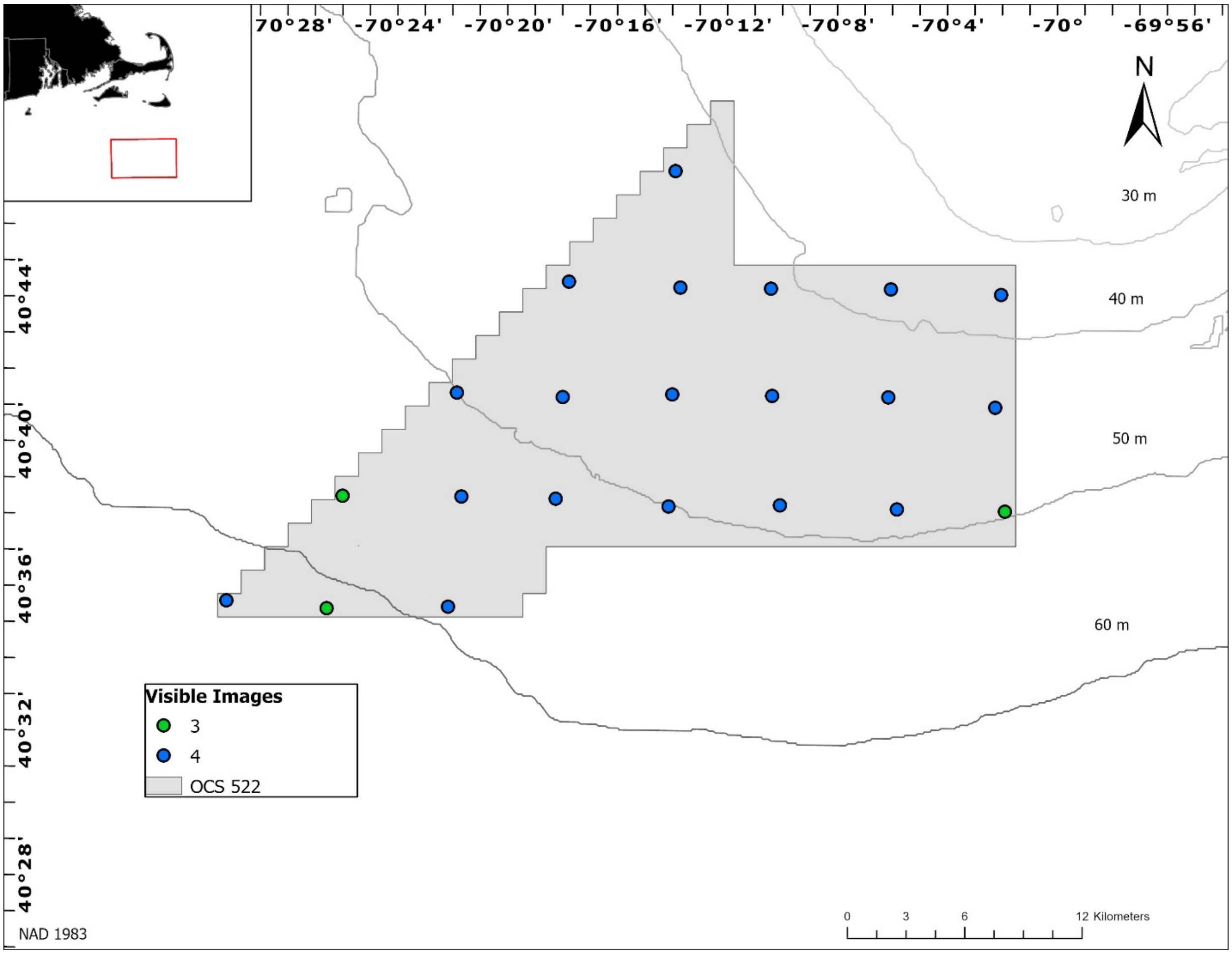

Figure I-2. The distribution of digital still camera image visibility per station for the fall 2024 drop camera survey of the 522 Study Area. The color of the station represents the number of quadrats that were visible as indicated in the figure legend.

Appendix II: Cumulative Six Year Comparison

Executive Summary

- The power analysis of the top three taxa (sea stars, crab, and silver hakes) suggests that 72 to 97 stations need to be surveyed per season (144 to 194 stations per year) to detect a 100% effect size change at least 80% of the time.
- A minimum sampling grid of 2.8 km between stations is recommended, but to increase the number of species detections and power a 1.5 km grid would be optimal. Further, a 1.5 km grid is the same spacing used in the Vineyard Wind 501N Drop Camera surveys.

Methods

The data from all surveys of the 522 Study Area conducted since summer 2019 were analyzed and compared. In addition to some of the analyses described in this report for the 2024 surveys, statistical modelling was used to assess whether there were significant changes in drop camera counts of the most abundant species groups by year or season. For each counted species group, the counts were modelled using a negative binomial generalized linear mixed effects model. Counts were used because all surveys used the same camera with the same field of view. The negative binomial distribution was chosen to better account for overdispersion in the observed counts than the Poisson distribution (both are designed for count data). Each model contained year, season, and a spatial smoother to account for spatial autocorrelation, as fixed covariates. Year was treated as a categorical variable rather than a numerical time series as it was suspected that there could be large changes in species counts in individual years rather than trends through time. Spatial autocorrelation was included because the grid design of the drop camera does not place the stations randomly through space and stations closer to each other may be more likely to have a similar species composition. Additionally, the likely high probability of zero counts for species groups at stations was accounted for using a zero-inflation component where the frequency of zeros was allowed to vary by season. Allowing zero inflation to vary by season was included to reflect differences in the presence/absence of species at different times of the year and to reflect differences in detectability of the drop camera between seasons. The models (identical for each species group) were fit using the *glmmTMB* package (Brooks et al 2017) in R (R Core Team 2024). The residual fits of all models were assessed graphically, and model convergence was assessed using feedback from the software regarding the ability of each model to define a hessian matrix. For the models that converged and had reasonable residual plots, the significance of each covariate was assessed using *p*-values and a 0.05 significance threshold.

The power of each model was assessed by deriving new datasets for each species from each species model and then fitting the same models to each simulated species dataset to see how often a significant effect was detected over 100 iterations for a range of power analysis scenarios (Johnson et al 2015; Pargent et al 2024). This custom approach to power analysis allowed for appropriate capture of overdispersion and high frequencies of zero in the count data, and the spatial autocorrelation structure included in the models. The power analysis examined four different sample sizes of 22, 47, 72, and 97 stations in each of the 10 surveys, and considered whether the model could detect changes with different combinations of percent increase in the effect size of each of season and year. The 22 stations were used because this was the amount deployed in the observed data, and 72 stations per survey is approximately the amount that would be done if using a 1.5 nautical mile (nmi) grid (which is commonly used by the drop camera survey in other projects). The remaining station counts (47 and 97) were selected as an evenly spaced number between 22 and 72, and then that same spacing greater than 72. The percentage changes of effect size considered were 25, 50, and 100% for each of the variables (year and season), while holding the other variable at 0 effect size (representing no change in population density). The null hypothesis, where there is no change in counts driven by either variable, was implemented by setting the effect size of both variables to 0. The null hypothesis was run to assess the general performance of the power analysis, as around 5% power is expected for the null hypothesis when using a significance threshold of 0.05 (i.e., a false positive significant result will occur around 5% of the time even when there is no difference). The four sample sizes were run for each of the three effect size percentages for the two variables (year and season) and the null hypothesis was also run, so for each species there were 28 unique power scenarios computed (3 effect sizes for year + 3 effect sizes for season + the null hypothesis = 7, then 7 x 4 sample sizes = 28 scenarios). For each of these 28 power scenarios, the model was simulated with 100 unique datasets. This was conducted for each of the species with converged statistical models.

The output for each of the 28 power scenarios for each species group was a power value for either year or season, depending on which variable was held constant at 0 and which varied. For season (with only two levels) power was calculated as the percentage of the 100 repetitions where a significant effect was detected for season using a *p*-value less than 0.05 as the threshold of significance (Johnson et al 2015; Pargent et al 2024). For year (with six levels) power was calculated by refitting a reduced version of the model not including year and then conducting a likelihood ratio test to assess whether the inclusion of year in the full model significantly improved model performance relative to the reduced model, again using a 0.05 threshold of significance. Power was then the percentage of the 100 repetitions that resulted in a significant difference between the full and reduced model. The power calculation for year was handled this way to avoid expansive complexity that would be caused by defining an effect size change for each of the six years individually and then to avoid having substantially more power scenarios to analyze as a result. Therefore, the interpretation of the power of year in the power analysis is the power of year collectively rather than any specific two years.

Results and Discussion

From 2019 through 2024 there were 10 surveys conducted by the drop camera in the 522 Study Area. Seasonal summer and fall surveys were conducted in 2019, 2020, 2023, and 2024, and only summer surveys were conducted in 2021 and 2022. All surveys used the same grid design and placed 22 stations spaced 5.6 km (3 nmi) apart throughout the 522 Study Area.

The counts of species groups observed varied among species and through time (Table II-3; Figures II-4 to II-19). The mean species density for each seasonal survey was estimated and compared for species that had at least one survey where the mean density was greater than 0.05 individuals per m^2 (Figure 34). The most counted species group was sea stars; however, these were often concentrated at a small number of stations (Figure II-15). Sea stars were significantly lower in 2020 compared to other years (p-value = 0.001), where sea stars were observed at one station in total across the 2020 surveys (Table II-3). No significant difference with season was detected for the sea star counts (p-value = 0.538). Whelk were the next most common species; however, these were largely driven by the fall 2023 and the summer 2024 surveys (Figure II-19). The statistical model for whelk was unable to converge; hence the model results were unviable and not reported. Lack of convergence for this species group was most likely due to having extremely few non-zero observations in most of the surveys and then having two surveys with extremely high counts. This can cause numerical scaling issues in models, leading to convergence issues. Crabs were identified in relatively high numbers in some of the surveys (summer 2019, 2020, 2024, and fall 2024), and then rarely observed in the other surveys (Table II-1; Figure II-4). The combined relatively high counts of crabs in 2024 were significantly higher than any other year (p-value = 0.026). No significant difference with season was detected for the crab counts (p-value = 0.889). Hermit crab had annual variation in observations and slightly higher counts in the summer compared to the fall (Table II-1; Figure II-9), however the statistical model was unable to converge. Of the remaining species groups, silver hake achieved statistical model convergence but no significant differences among years or seasons were detected (p-values > 0.1) (Table II-1; Figure II-16). The remaining countable species groups did not have sufficient non-zero observations for statistical modelling (Table II-1).

The mean number of quadrats where presence/absence species were identified per station also varied among species groups and through surveys (Table II-2; Figures II-2 and II-20 to 29). Holes (representing burrowing animals) were the most observed and had the highest percentage of observations (Table II-2; Figure II-2 and II-25). Sand dollars and euphausiids were the next two most observed presence/absence species groups, and the remaining species groups were either infrequently present across most surveys or commonly observed during a single survey (Table II-2). Substrate composition across surveys mostly consisted of silt and sand, with shell debris prominent in some years and gravel occasionally observed in fewer years (Figure II-3).

The three counted species groups that had good performing statistical models (sea stars, crabs, and silver hake) were included in the power analysis (Table II-3). As expected, power generally increased when trying to detect a greater effect size and with more samples. However, there was often minimal or no improvement in power between 72 stations and 97 stations for sea stars and silver hake. In most cases, power tended to be higher for detecting differences in season rather than year, when all else was equal. The exceptions to this were the results for crabs using 47 or 72 stations per survey (Table II-3). Under the number of stations used during the 10 surveys that have been conducted in the 522 Study Area so far (22 stations), the only scenario where power was greater than the common target of 80% was when detecting a difference among seasons when there was a 100% increase in sea star counts (Table II-3, 22 stations column). Most of the remaining scenarios for 22 stations had less than 50% power.

For crabs, 80% or greater power was only achieved in two scenarios, which was when attempting to detect a 100% increase in counts between years with 72 stations and when detecting a 100% increase in counts between seasons with 97 stations (Table II-3). The power analysis for silver hake demonstrated it was also rare to achieve 80% or greater power for this species group, however close to 80% power (76%) was achieved when attempting to detect a 100% increase in counts among seasons with 47 stations and 80% power was exceeded for this scenario with 72 and 97 stations (Table 4). Sea stars were the only species group to achieve 80% power or greater when attempting to detect a 50% increase in counts between seasons, which happened using 47, 72, and 97 stations.

Only one of the scenarios tested were able to achieve 80% power for detecting changes among years, which was for crabs when attempting to detect a 100% increase with 72 stations. This is indicative of the dataset being too noisy for a strong annual signal to have been detected by the models, and more surveys and increased sample size will likely help. The null hypothesis, which should have around 5% power to indicate reasonable performance of the power analysis, spanned 5% for most of the scenarios but did demonstrate potential higher power than 5% for silver hake with 97 stations and lower power than 5% for sea stars with 97 stations (Table II-3). However, as the range of null hypothesis results was still close to 5%, they can be considered reasonable but with some uncertainty.

The power results indicate that drop camera surveying of the 522 Study Area would benefit from an increase in stations conducted during each survey as 22 stations only resulted in 80% or greater power when trying to detect a large (100%) change in counts for one species group. An increase to around 47 stations would give 80% power to detect a 50% increase in sea stars and give 76% power to detect a 100% increase in silver hake, between seasons. An increase to 72 stations would increase power in all scenarios and provide 80% power for detecting a 100% change in crabs among years, in addition to 91% power silver hake when attempting to detect a 100% increase between seasons. Increasing to 47 stations each survey may represent a worthwhile improvement in statistical power without as big an effort increase required for 72 or 97 stations.

Many of the other counted species' groups that the drop camera recorded were detected in too low numbers for statistical analysis and may also benefit from increased sample sizes. Statistical modelling was used to guide the species groups that the power analysis was applied to, and many of the species' groups had model convergence issues using the selected model. More species groups may have had successfully converged models (and therefore included in a simpler version of the power analysis) if a simpler model structure was used, such as removing the spatial autocorrelation, zero-inflation component, or one of the season or year covariates, however these were each considered important things to account for in the model. Conversely, more complex model structure such as including an interaction between year and season was desirable to better capture changes in species throughout the time series, but all species models were unable to converge when fitted to the observations and increased sample sizes could help this.

Table II-1. The number of animals counted during each seasonal drop camera survey. This table only includes animals that are counted during the drop camera surveys and excludes species groups that are marked as present or absent only. All counted species with at least one observation in any survey are included. The '#' columns refer to the total number of each species group counted during each seasonal survey, and the % columns refer to the percentage of images that each species group was present during each seasonal survey. All seasonal surveys had 88 quadrats apart from the summer 2024 survey, which had 87 quadrats. Percentages were rounded to the nearest integer. The table is arranged from the most counted species group to the least.

	Fall 2019		Fall 2020		Fall 2023		Fall 2024		Summer 2019		Summer 2020		Summer 2021		Summer 2022		Summer 2023		Summer 2024	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Sea stars	54	6	0	0	65	9	14	8	87	6	1	1	36	5	96	10	62	7	60	10
Buccinum (whelk)	0	0	0	0	126	40	3	3	3	1	0	0	0	0	1	1	2	1	220	43
Crabs	2	2	0	0	8	6	28	28	91	36	73	30	4	3	8	5	0	0	15	8
Hermit crabs	1	1	0	0	53	38	12	10	21	19	2	2	29	20	10	10	8	5	43	33
Silver hake	0	0	0	0	6	7	51	20	13	15	10	10	1	1	2	2	1	1	2	2
Hake	3	3	0	0	4	3	5	5	18	11	11	13	1	1	25	24	2	2	1	1
Moonsnail	0	0	0	0	0	0	0	1	6	6	1	1	6	6	8	8	2	2	20	12
Skate	2	2	0	0	3	3	10	11	4	5	4	5	1	1	5	6	0	0	4	5
Squid	0	0	0	0	17	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Flounder	1	1	0	0	1	1	1	1	2	2	1	1	0	0	2	2	0	0	2	2
Sea robin	0	0	0	0	2	2	2	2	0	0	0	0	0	0	1	1	0	0	3	3
Other fish	0	0	0	0	3	3	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Dogfish	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Scallops	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
Ocean pout	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1
Eel	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
Sculpin	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Sea cucumber	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

Table II-2. The percentage (%) of quadrats that the animal groups recorded as present or absent were present during drop camera surveys, by season and year. All species groups with at least one observation in any survey are included. All seasonal surveys had 88 quadrats apart from the 2024 surveys, which had 86 quadrats each. The table is arranged from the most encountered species group to the least.

	Fall 2019	Fall 2020	Fall 2023	Fall 2024	Summer 2019	Summer 2020	Summer 2021	Summer 2022	Summer 2023	Summer 2024
Holes (burrowing animals)	13.6	0.0	64.8	77.0	48.9	29.5	2.3	54.5	20.5	93.2
Sand dollars	9.1	4.5	18.2	16.1	10.2	13.6	19.3	26.1	6.8	22.7
Euphausiids	86.4	0.0	5.7	6.9	34.1	0.0	0.0	3.4	0.0	3.4
Other mollusks	0.0	0.0	1.1	0.0	8.0	0.0	5.7	26.1	8.0	6.8
Other crustaceans	0.0	0.0	5.7	21.8	14.8	0.0	1.1	0.0	1.1	9.1
Bryozoans/ Hydrozoans	0.0	0.0	2.3	10.3	4.5	0.0	0.0	10.2	3.4	20.5
Clams	0.0	0.0	3.4	2.3	0.0	0.0	0.0	8.0	0.0	2.3
Brittle stars	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3
Anemone	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0	2.3
Sand lance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0
Ctenophores	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

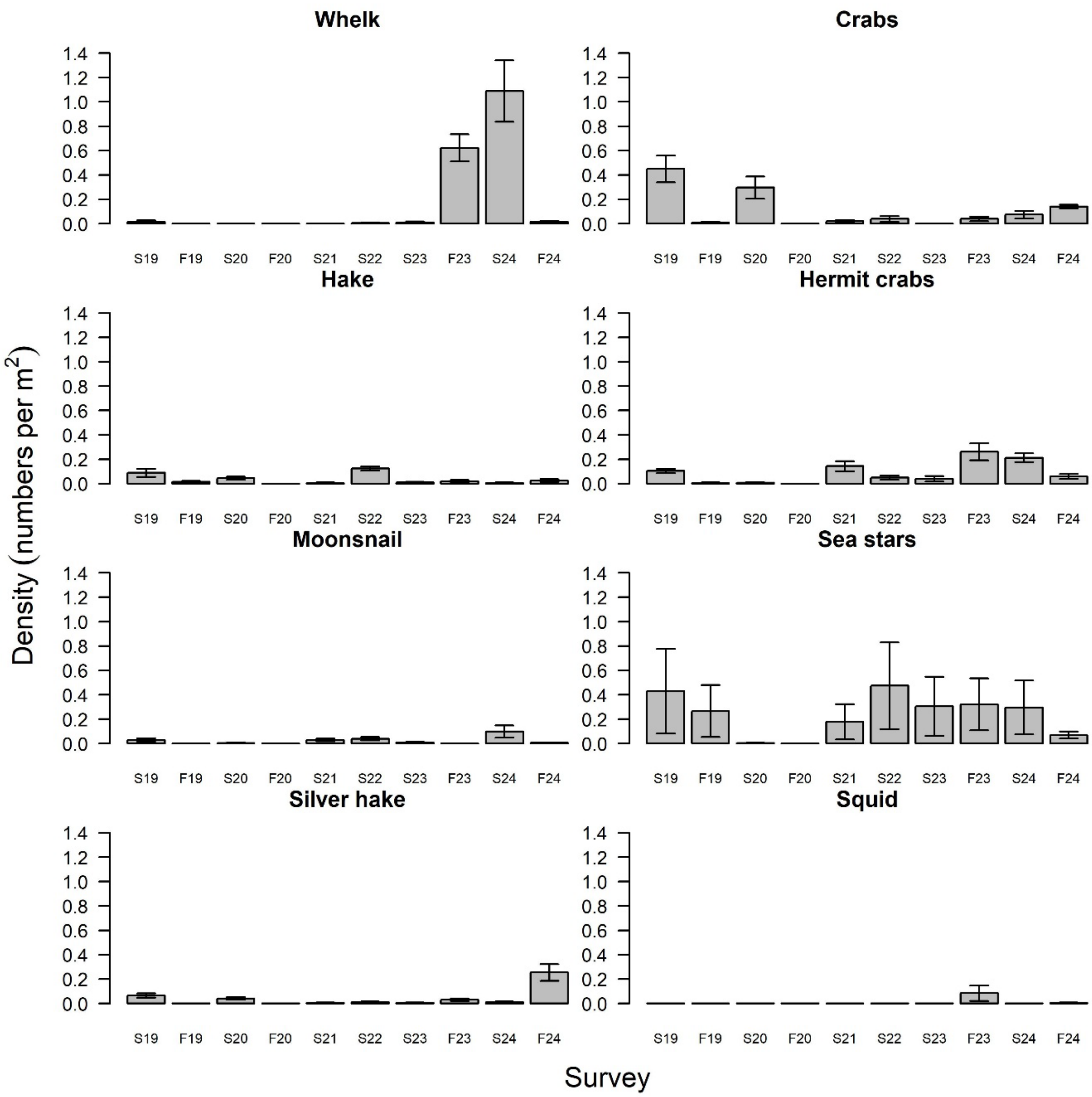

Figure II-1. The mean density (numbers per m^2) of species counted during drop camera surveys each season and year in the 522 Study Area. The standard error around the mean density is also displayed using error bars. On the x-axis F19 stands for Fall 2019, S19 stands for Summer 2019, and so forth. The species depicted are only those where the density was at least 0.05 per m^2 during at least one survey.

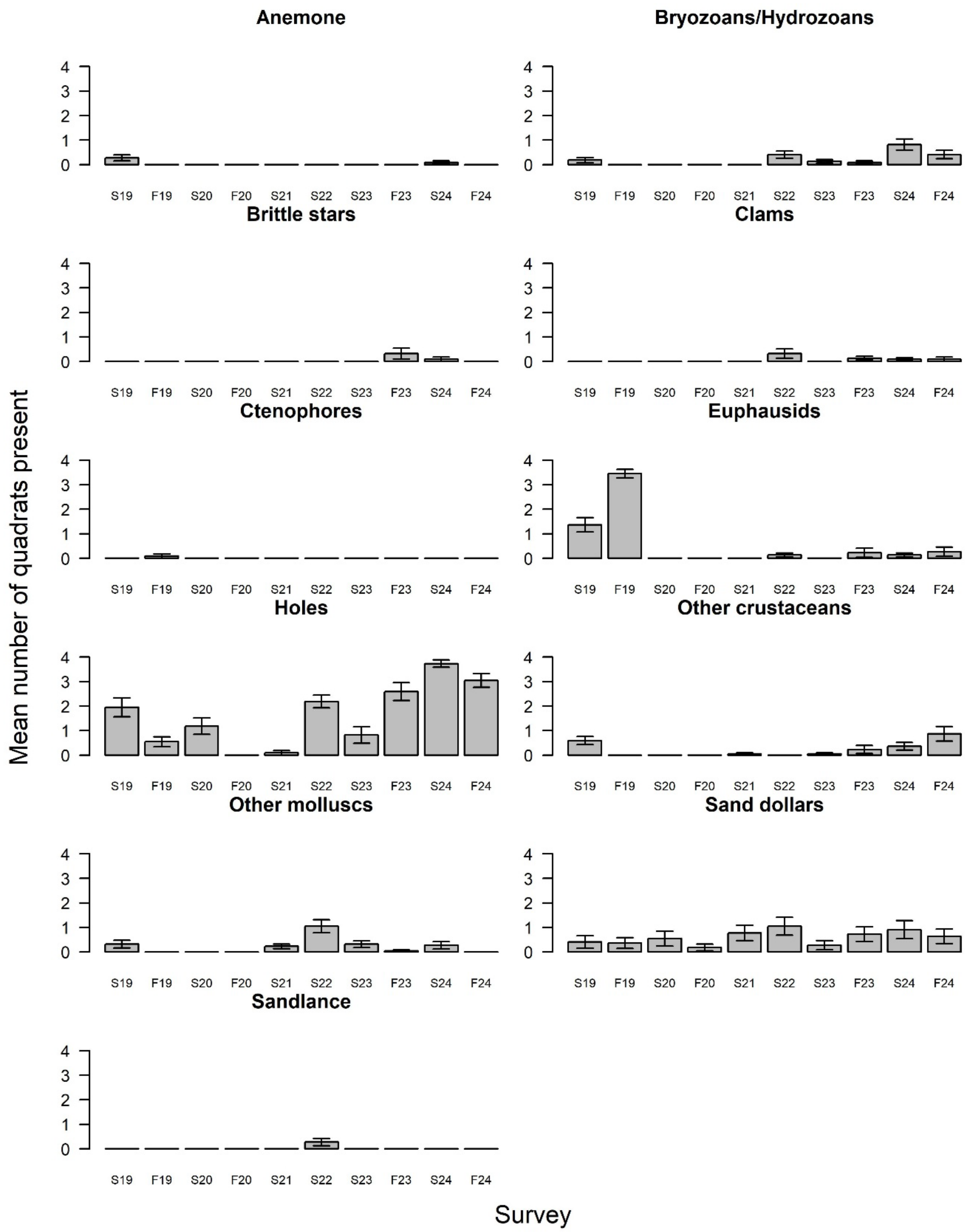

Figure II-2. The mean number of quadrats where species groups were present per station during seasonal drop cameras surveys in the 522 Study Area. The maximum is four. The standard error around the mean density is also displayed using error bars. On the x-axis F19 stands for Fall

2019, S19 stands for Summer 2019, and so forth. The species depicted are only those that were observed during at least one seasonal survey.

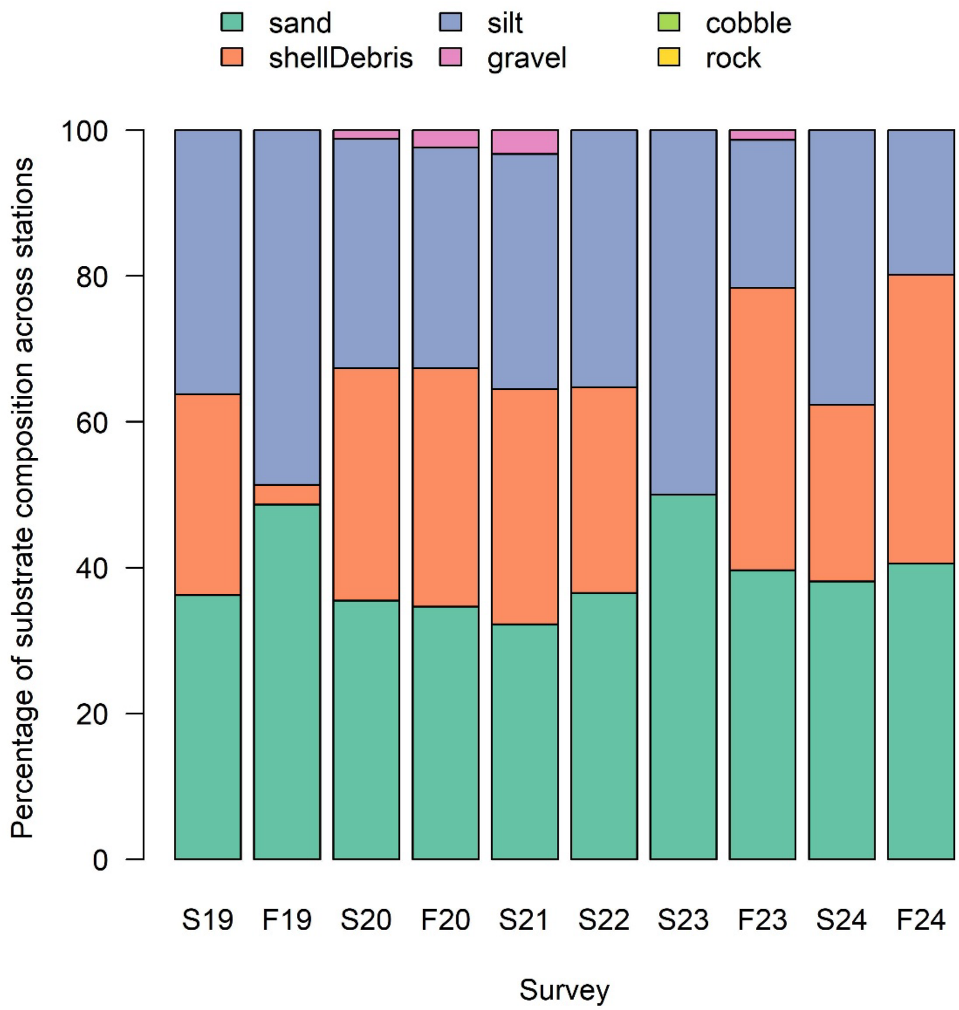

Figure II-3. Substrate composition for each seasonal drop camera survey in the 522 Study Area. Substrate composition expressed as the percentage composition of the frequency that each sediment type was detected relative to the other sediment classifications. Cobble and rock were not present in any of the seasonal surveys. F19 stands for Fall 2019, S19 stands for Summer 2019, and so forth.

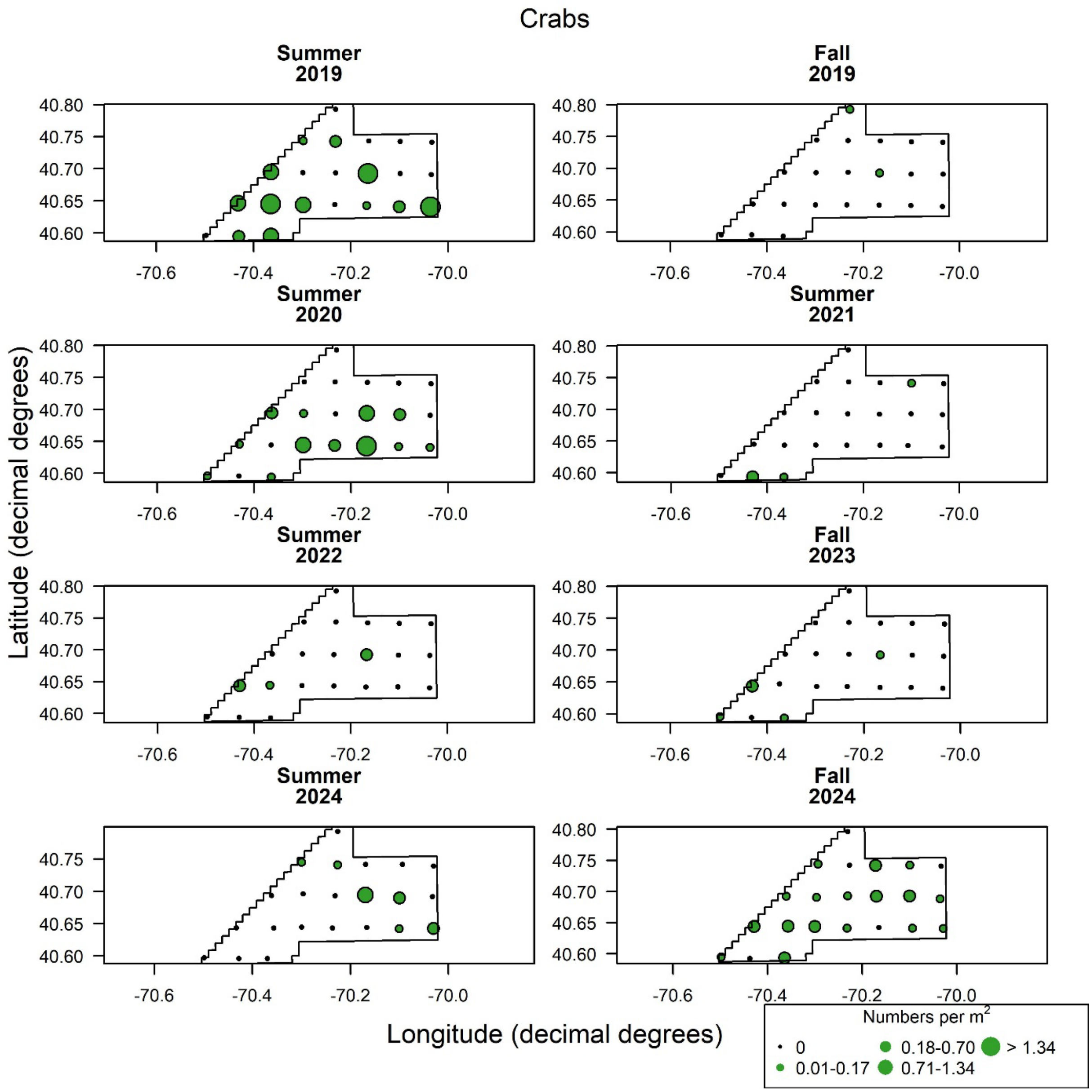

Figure II-4. Seasonal density plots of crabs at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

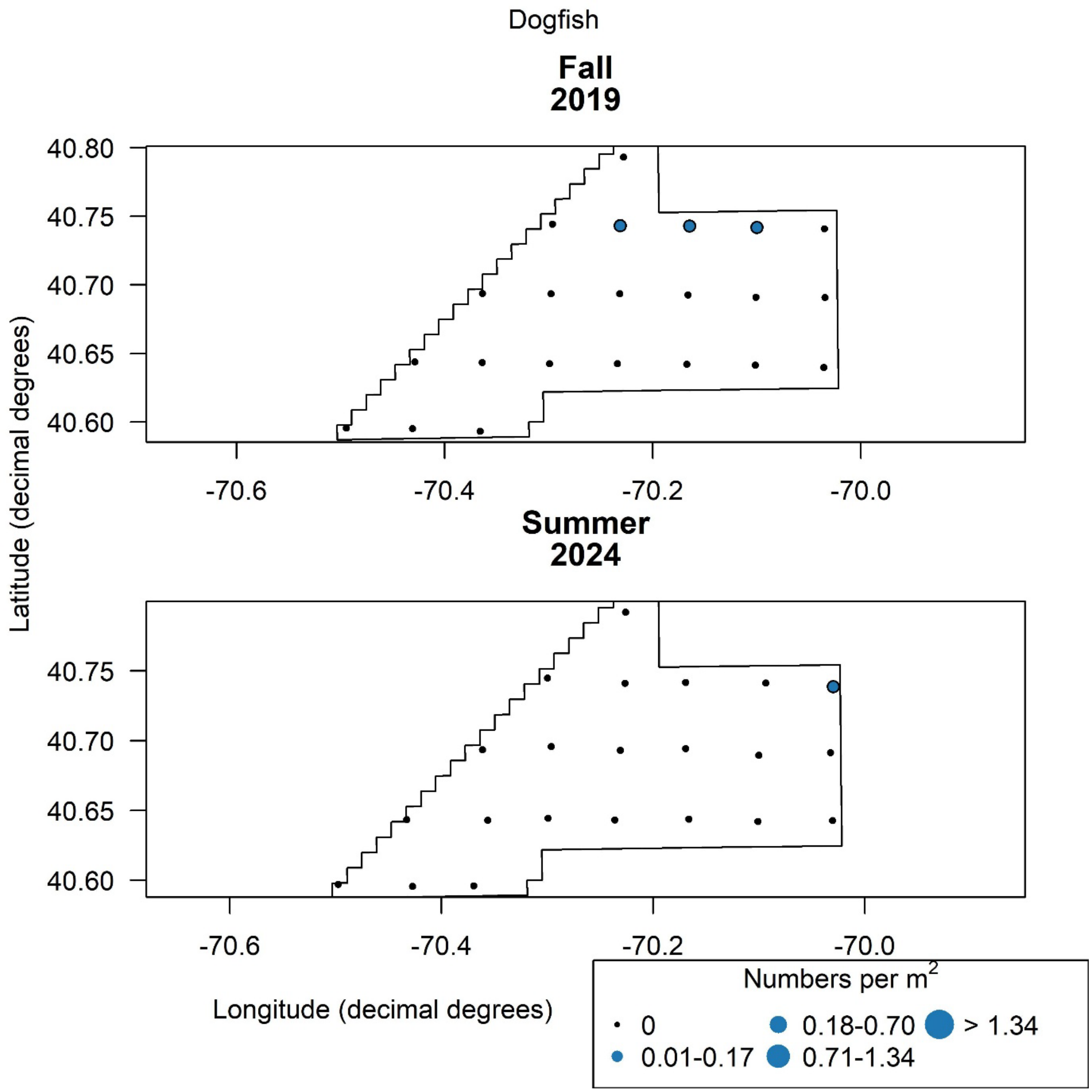

Figure II-5. Seasonal density plots of dogfish at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

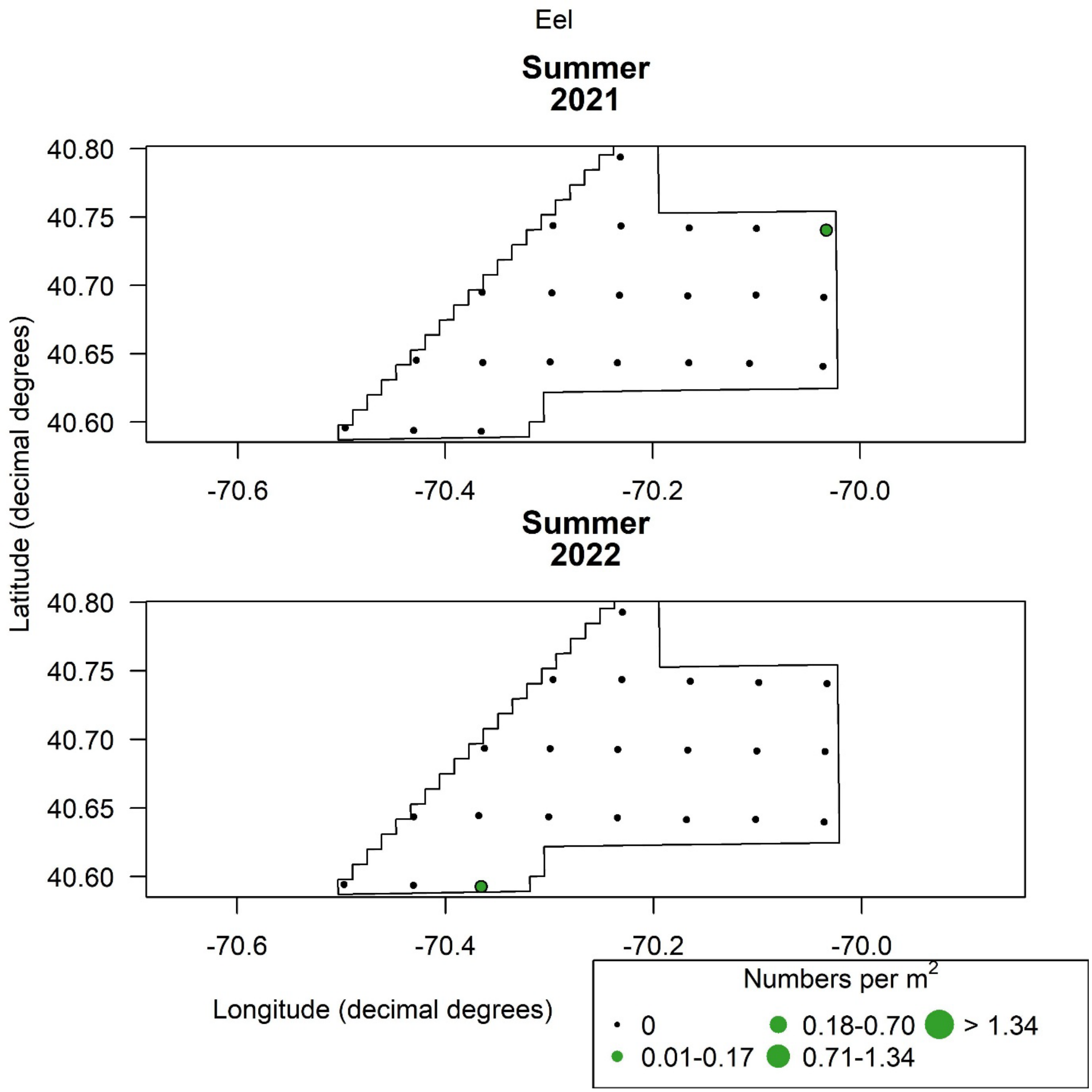

Figure II-6. Seasonal density plots of eel at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

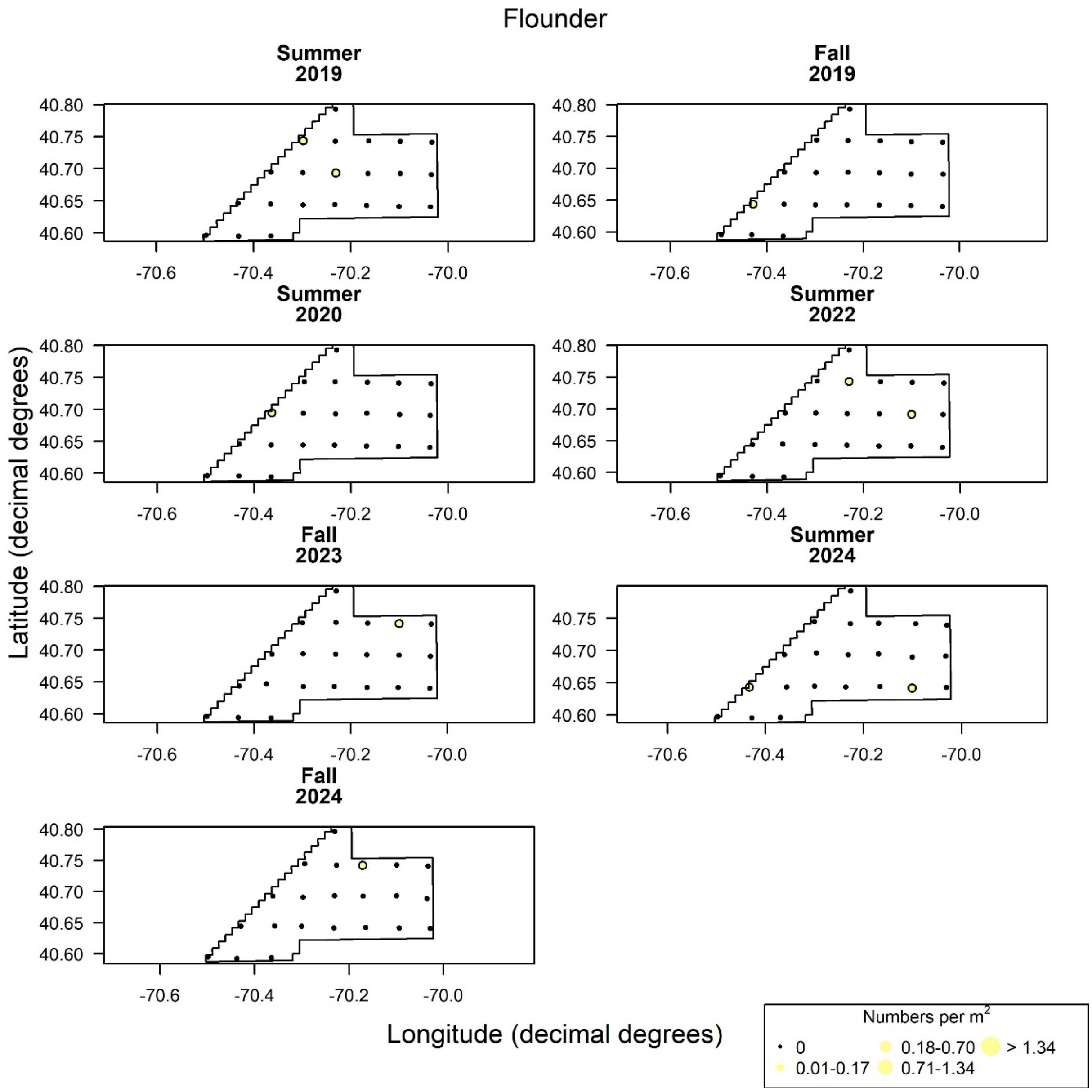

Figure II-7. Seasonal density plots of flounder at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

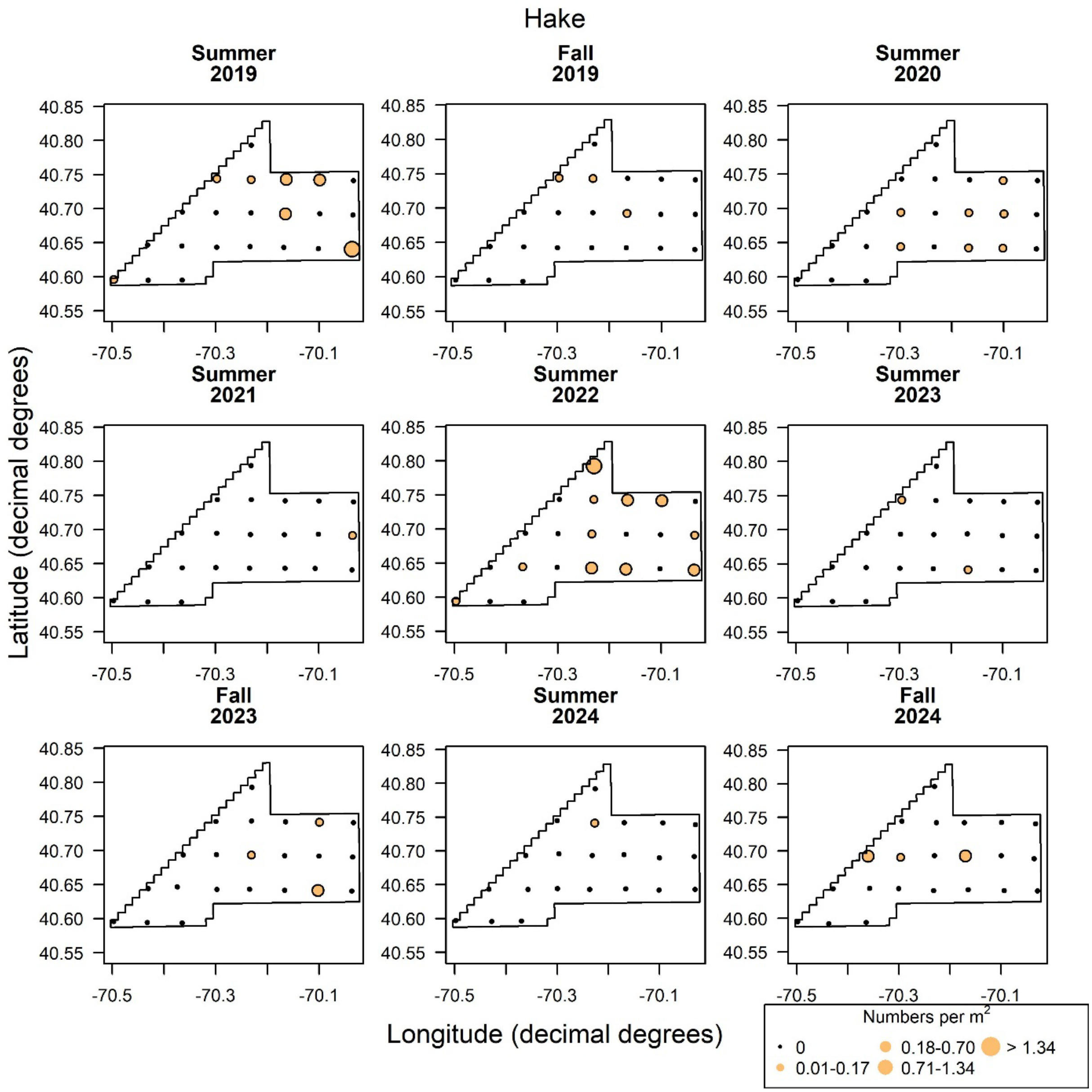

Figure II-8. Seasonal density plots of hake at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

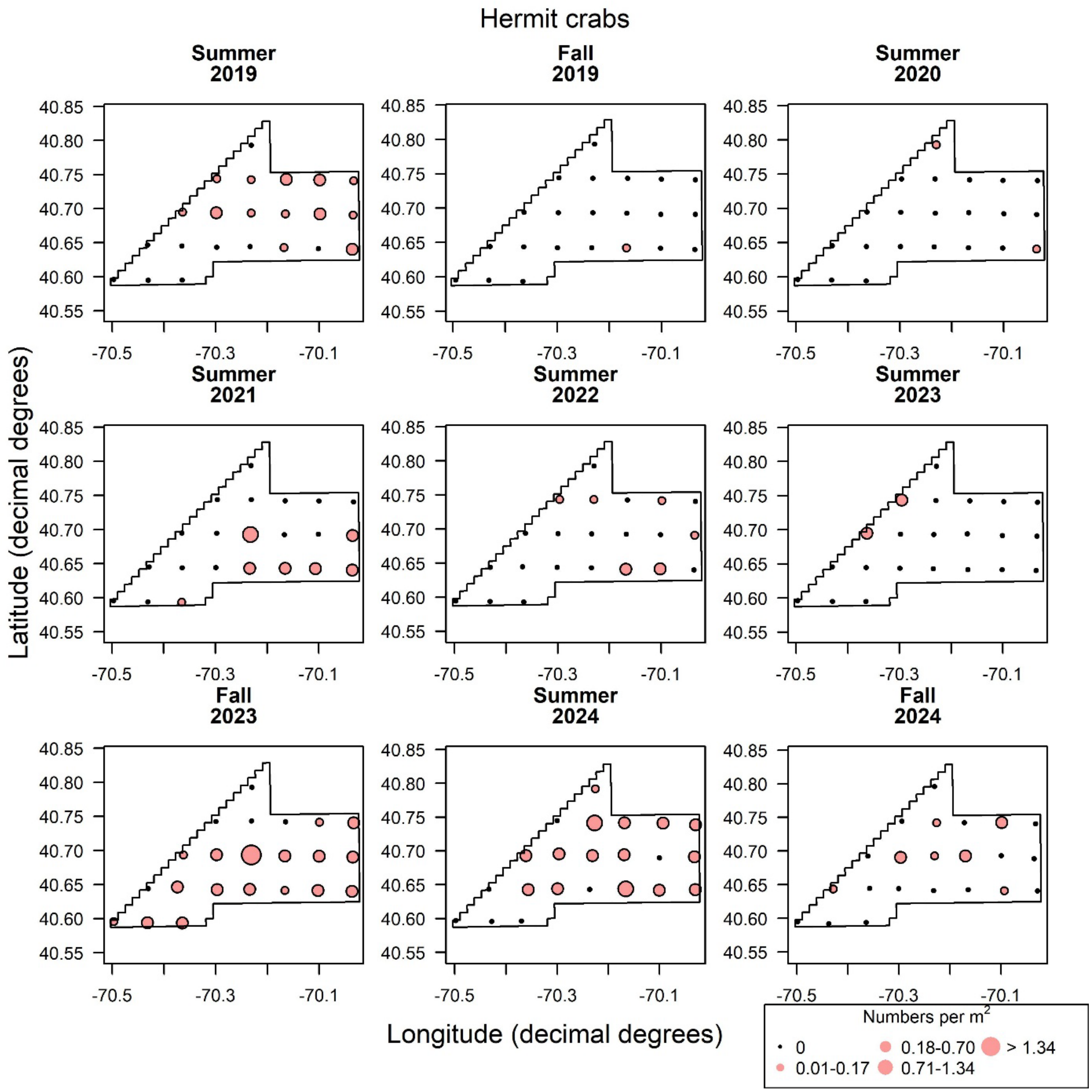

Figure II-9. Seasonal density plots of hermit crabs at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

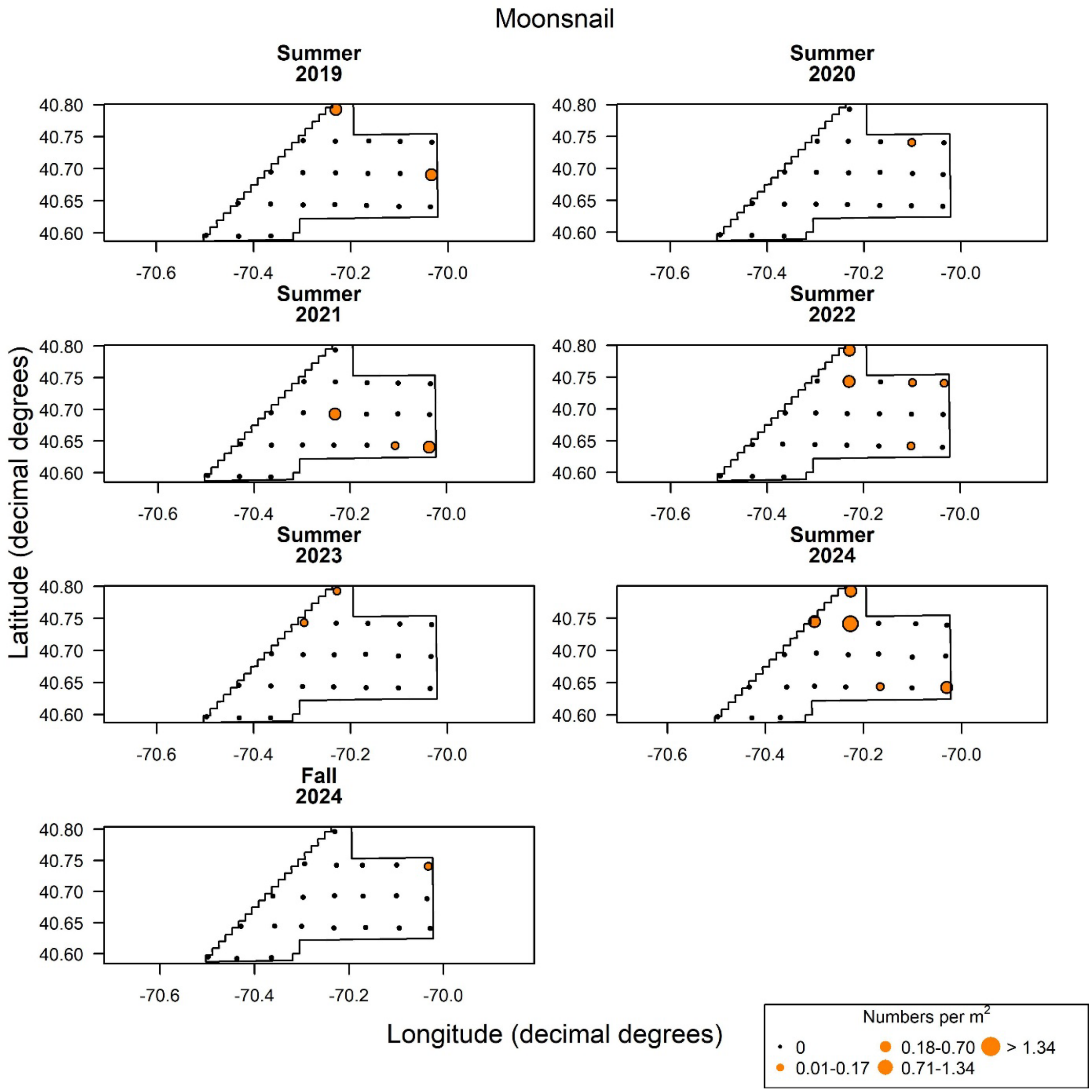

Figure II-10. Seasonal density plots of moon snail at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

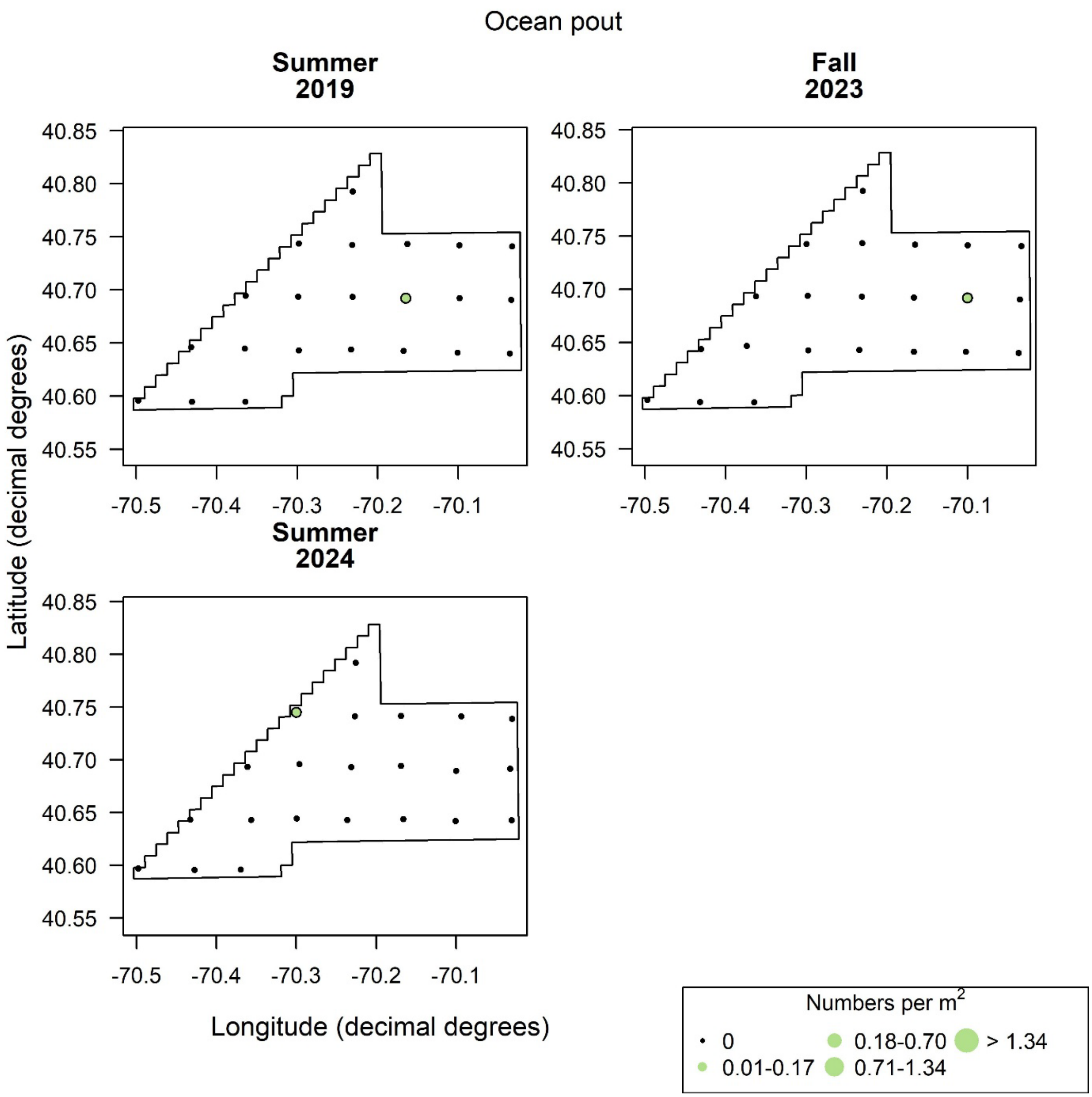

Figure II-11. Seasonal density plots of ocean pout at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

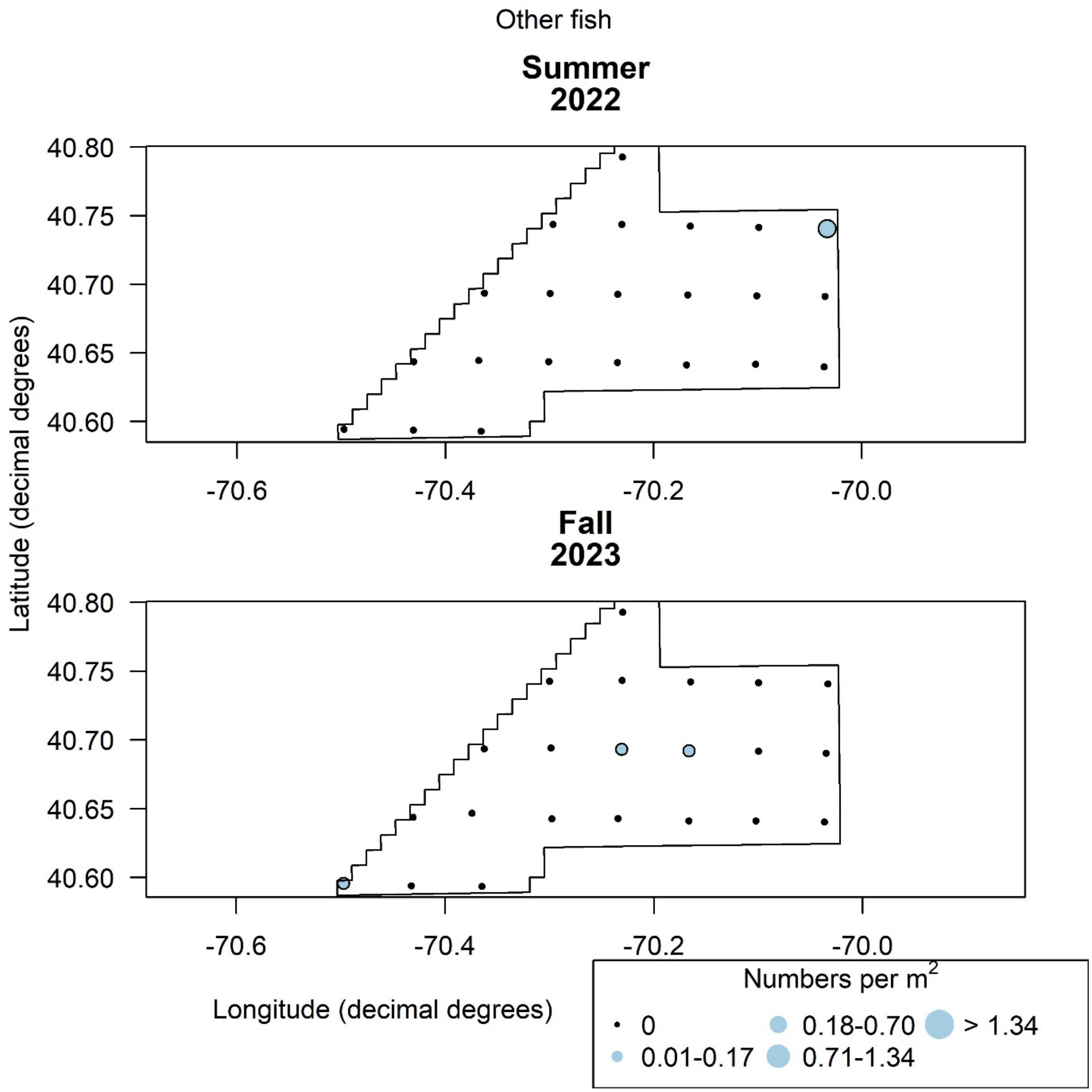

Figure II-12. Seasonal density plots of other fish at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

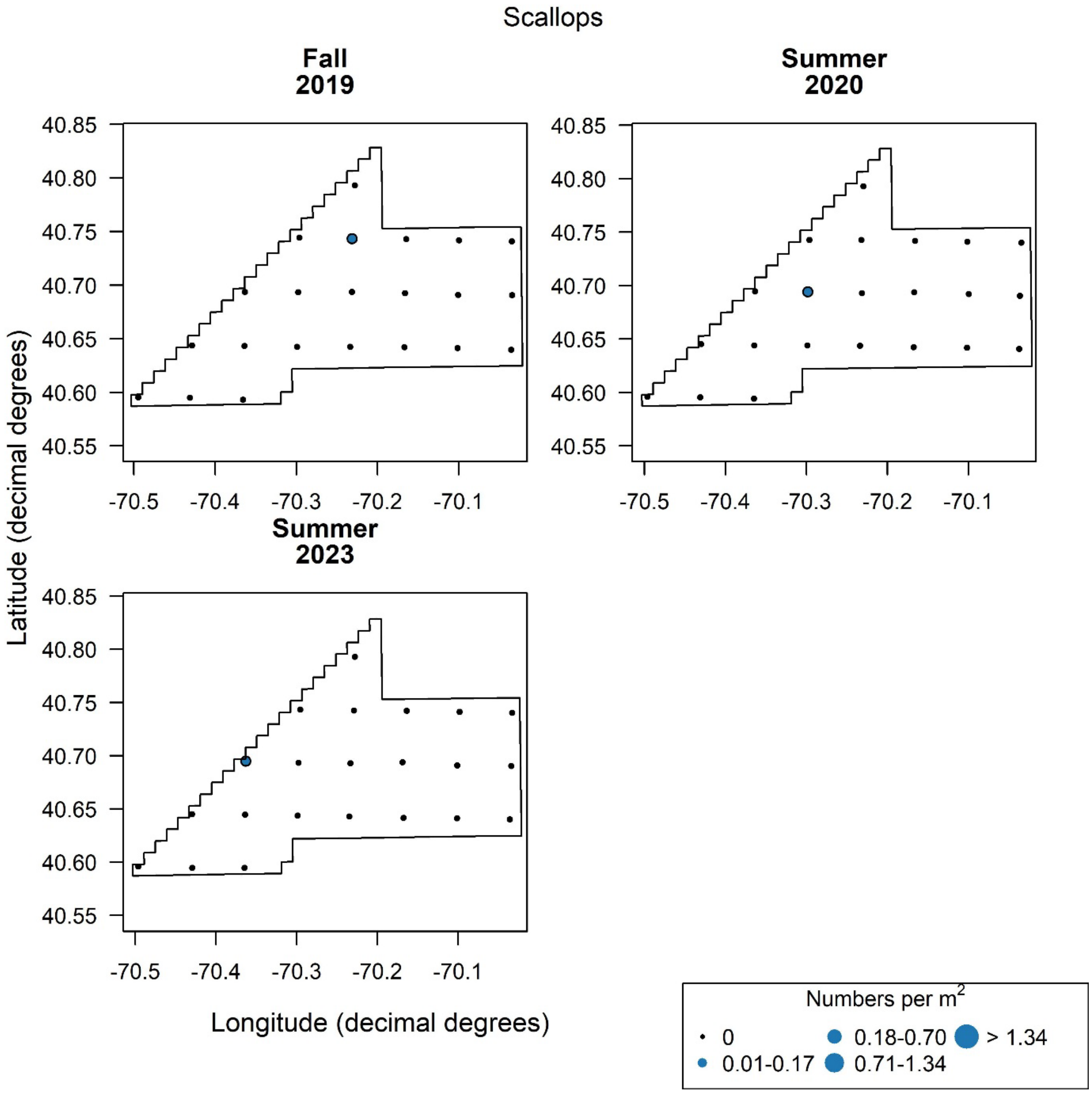

Figure II-13. Seasonal density plots of scallops at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

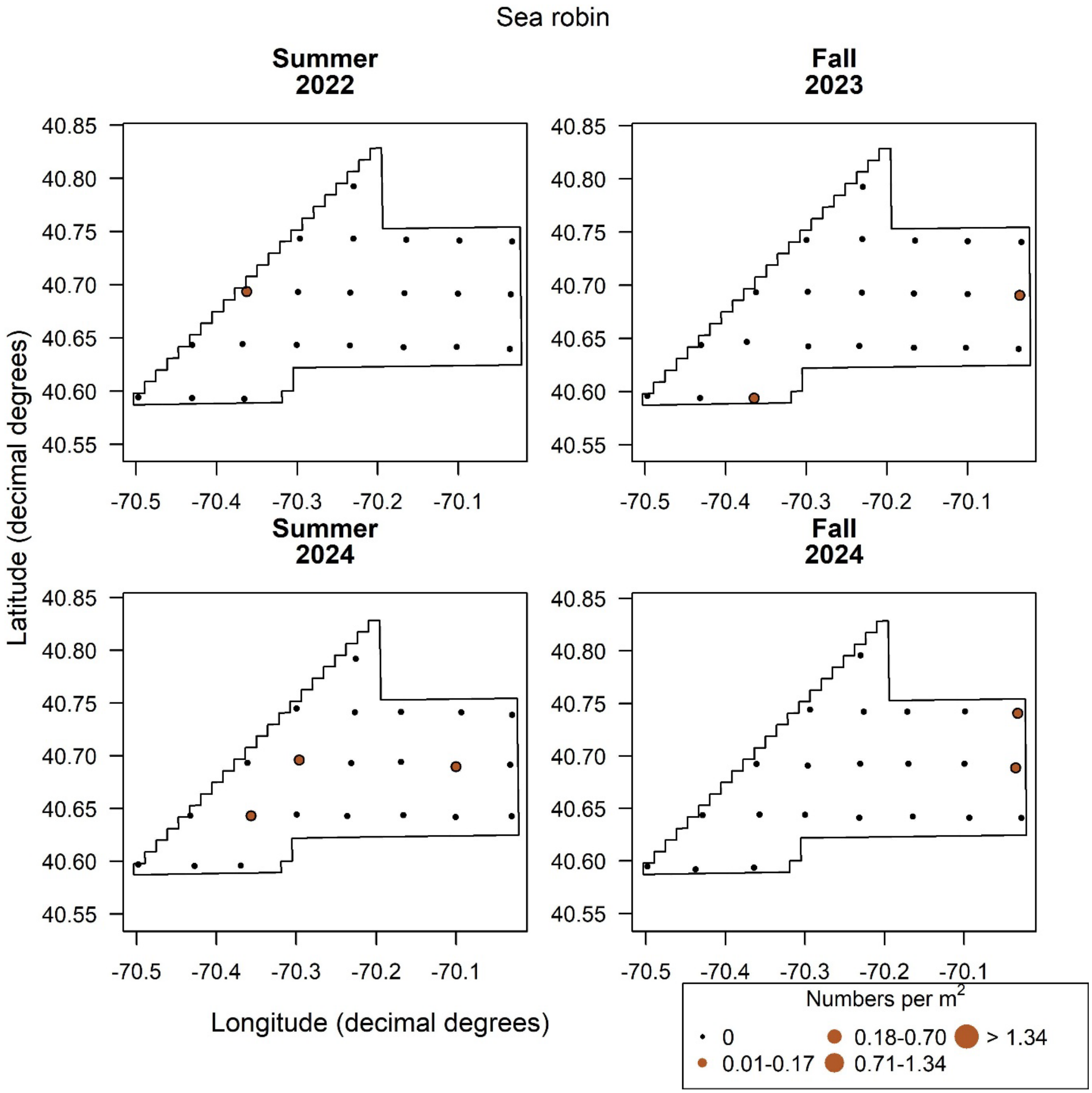

Figure II-14. Seasonal density plots of sea robin at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

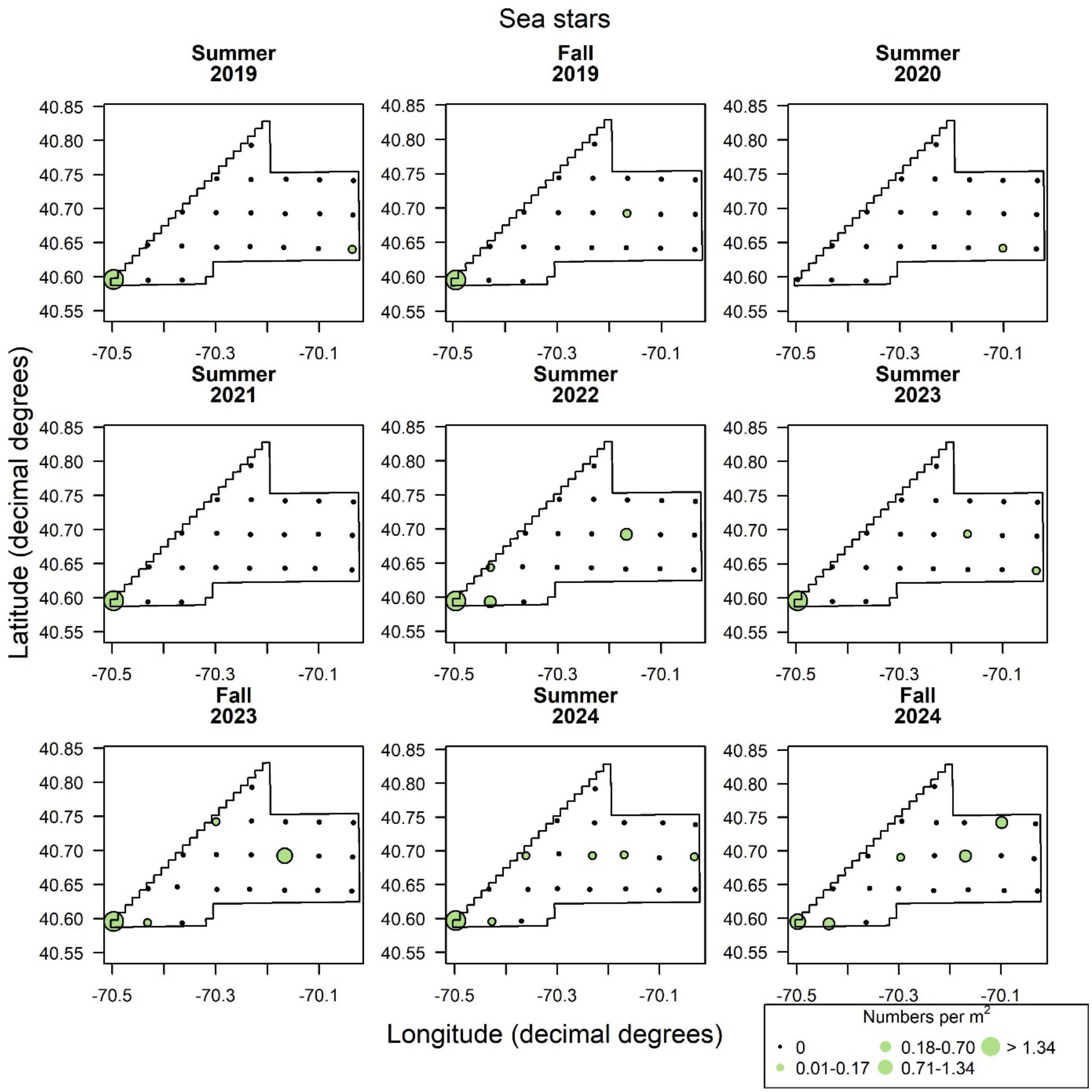

Figure II-15. Seasonal density plots of sea stars at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

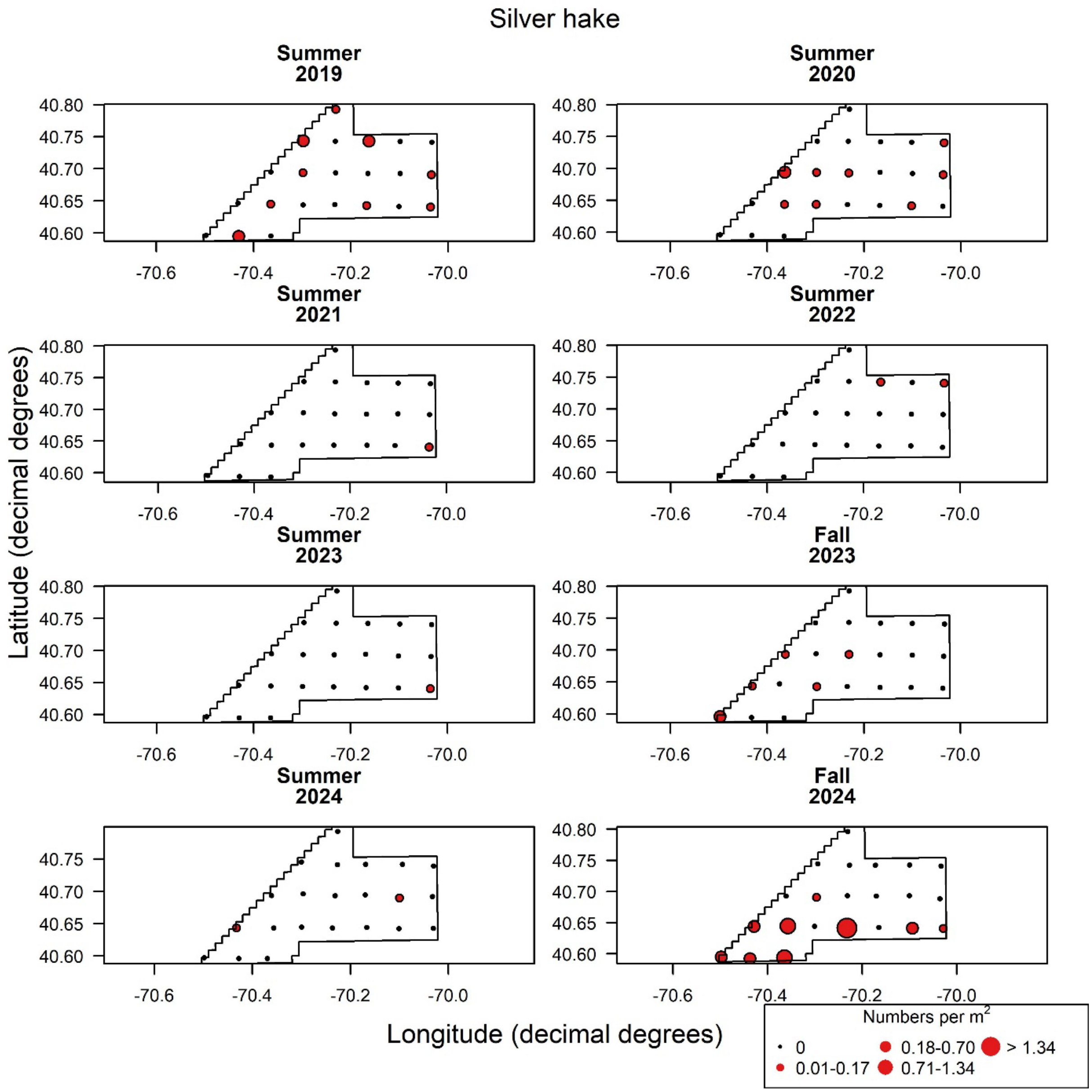

Figure II-16. Seasonal density plots of silver hake at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

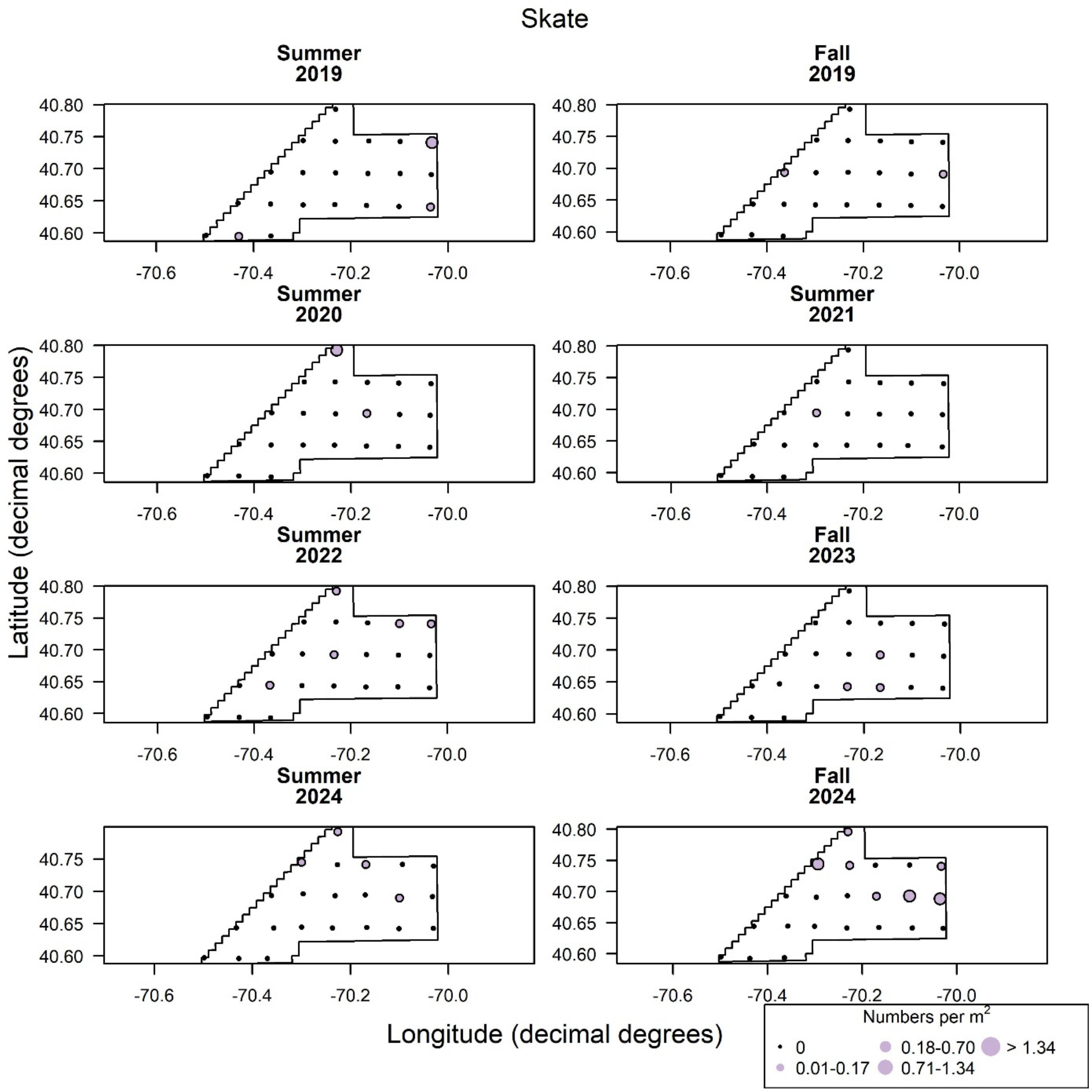

Figure II-17. Seasonal density plots of skates at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

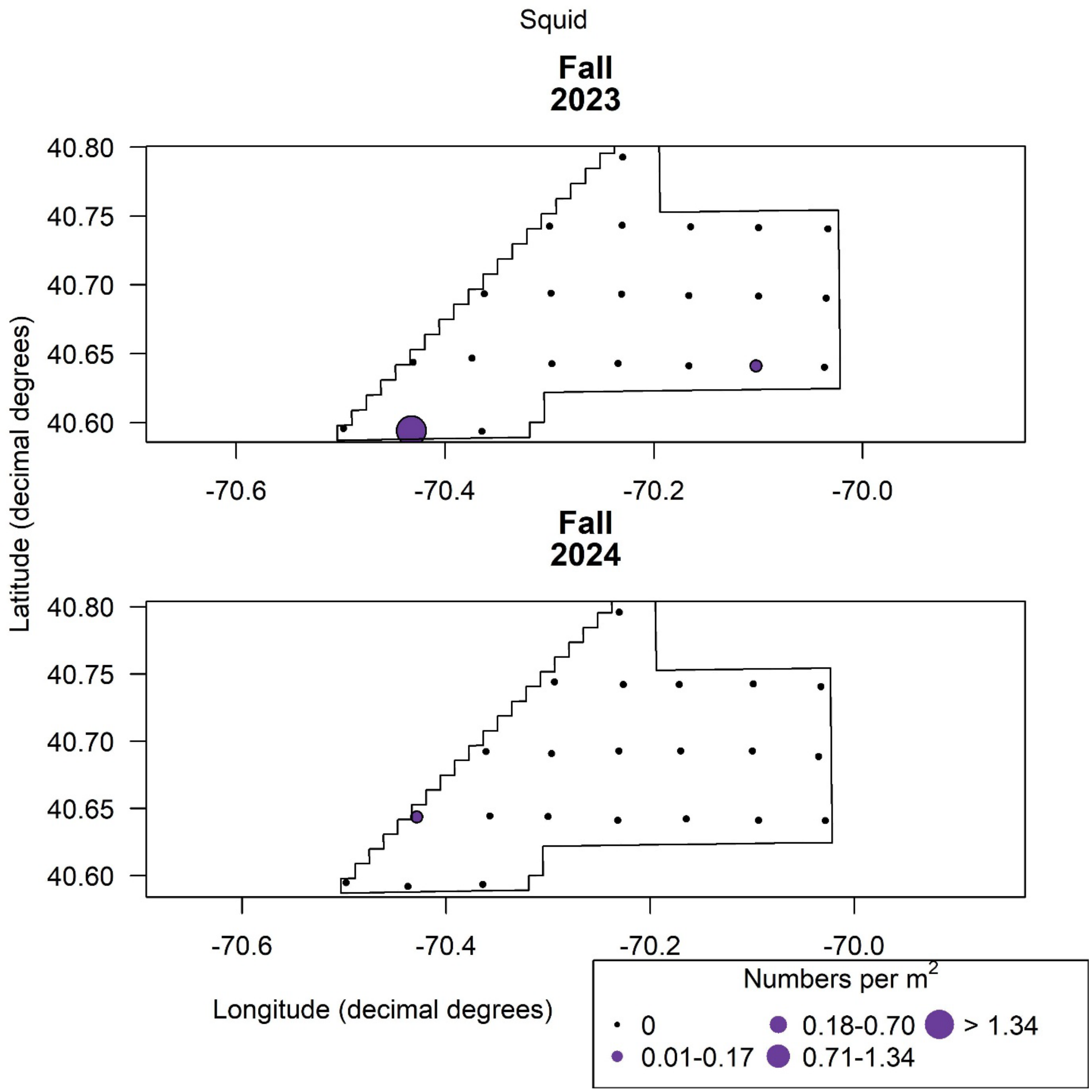

Figure II-18. Seasonal density plots of squid at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

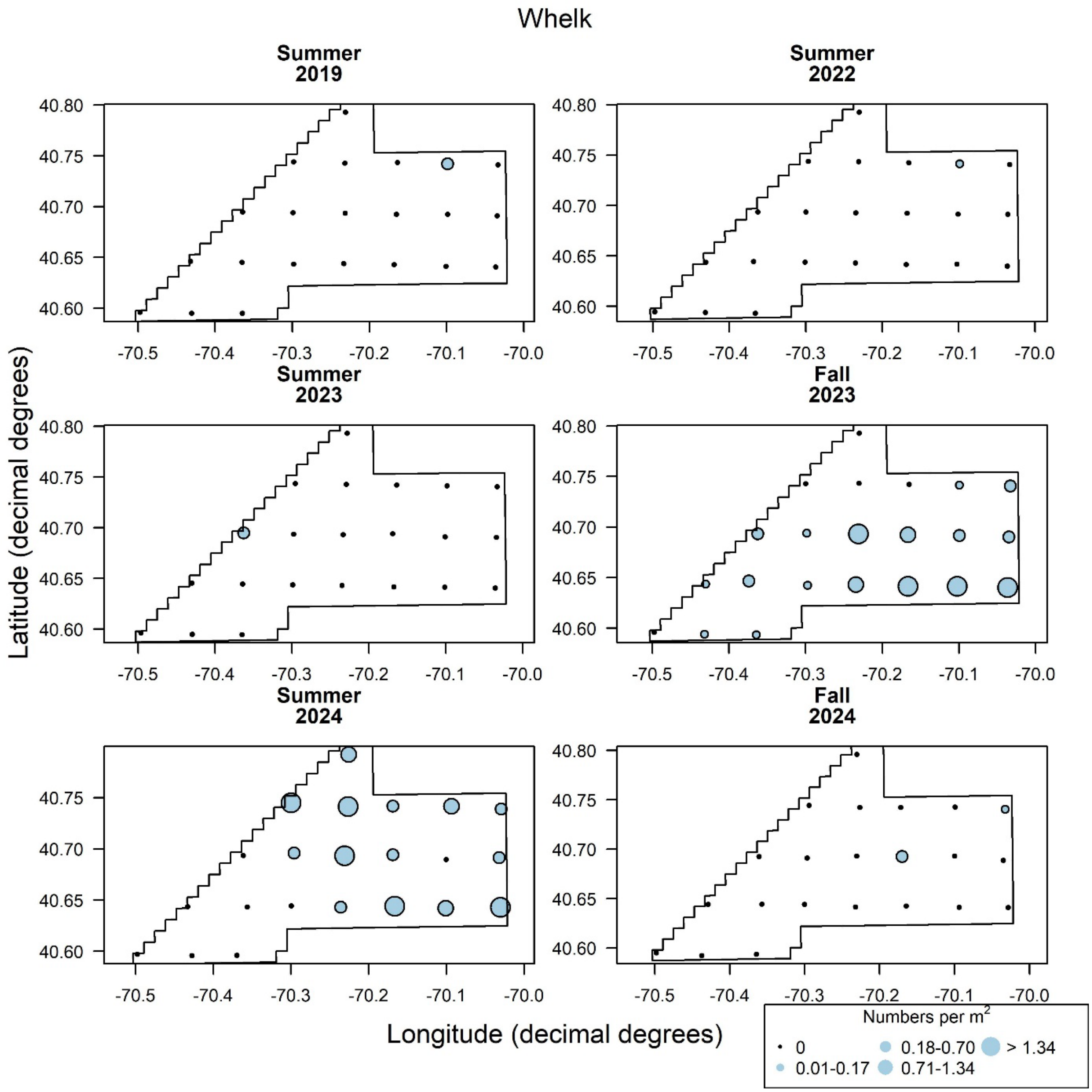

Figure II-19. Seasonal density plots of whelk at drop camera stations within 522 Study Area. All densities are expressed in numbers per m^2 and the points are scaled and colored by the magnitude of the density as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

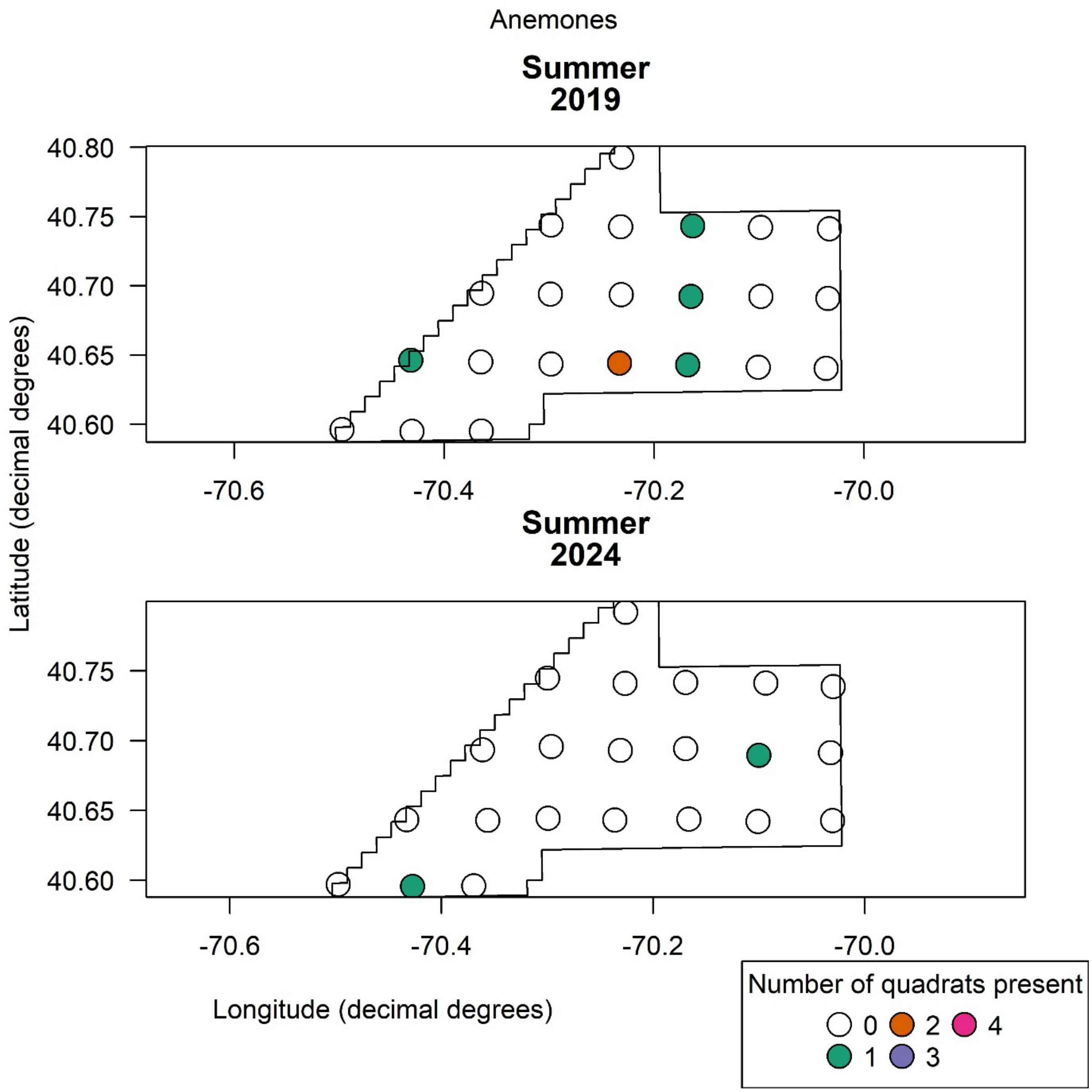

Figure II-20. Seasonal quadrat frequency plots of anemones at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

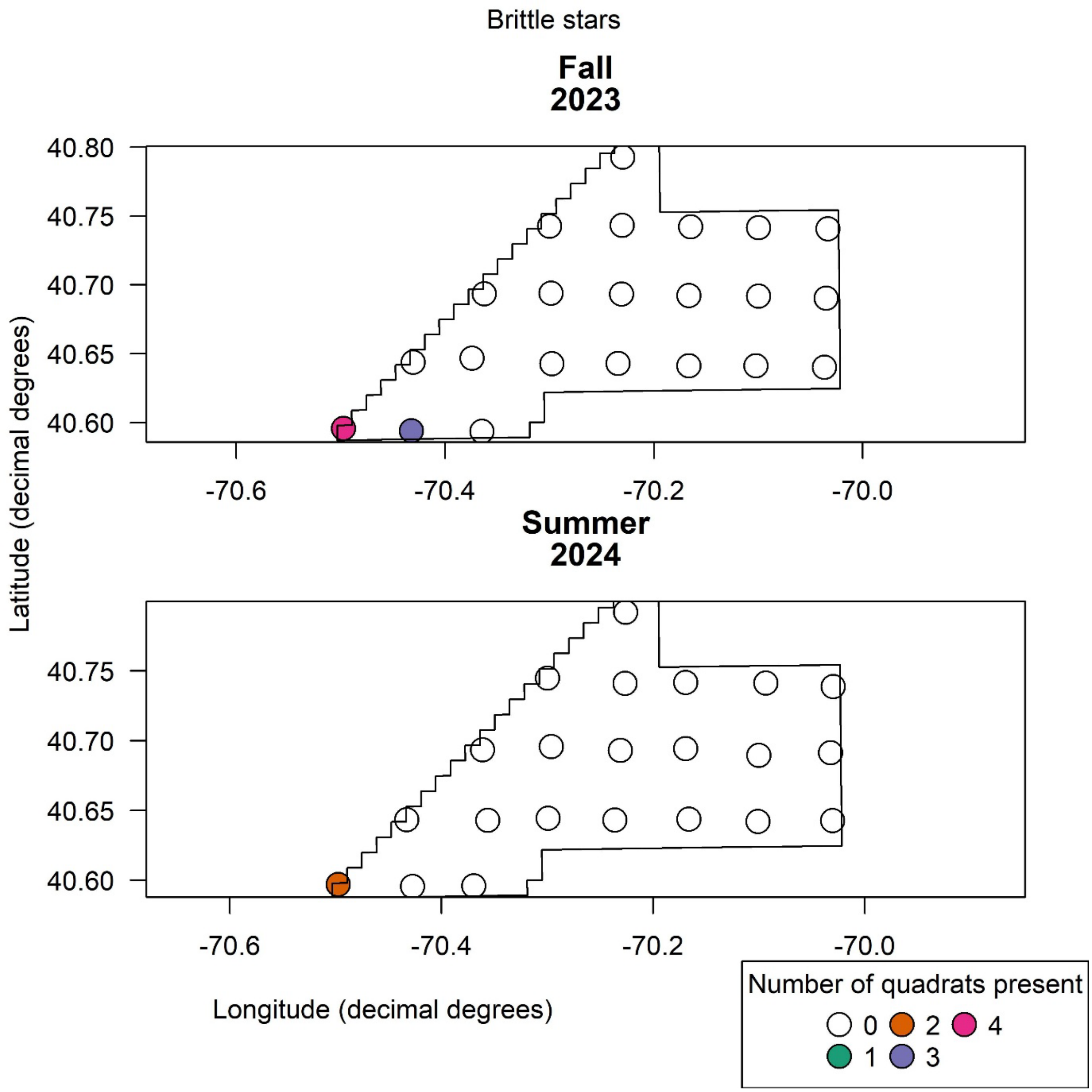

Figure II-21. Seasonal quadrat frequency plots of brittle stars at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

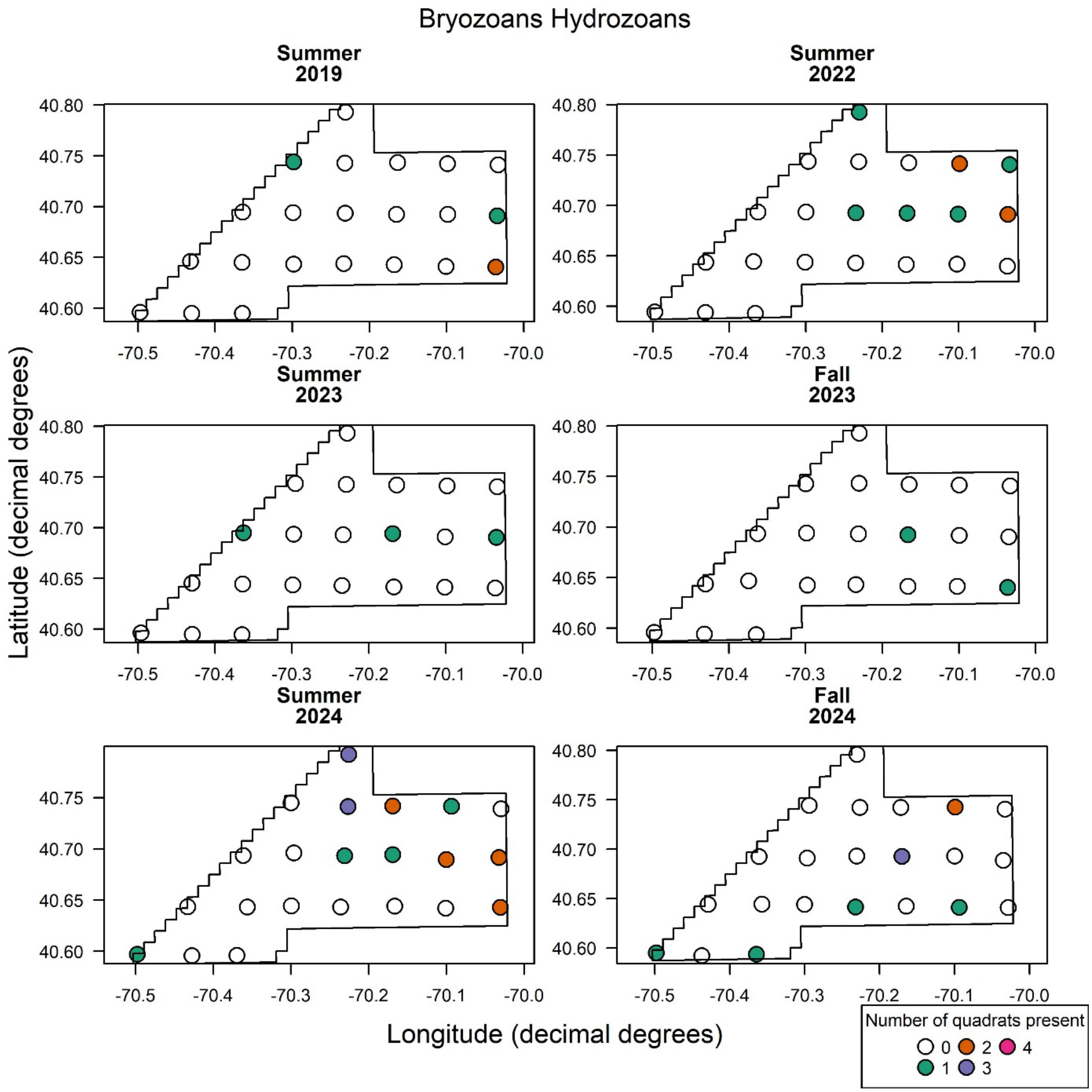

Figure II-22. Seasonal quadrat frequency plots of bryozoans and hydrozoans at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

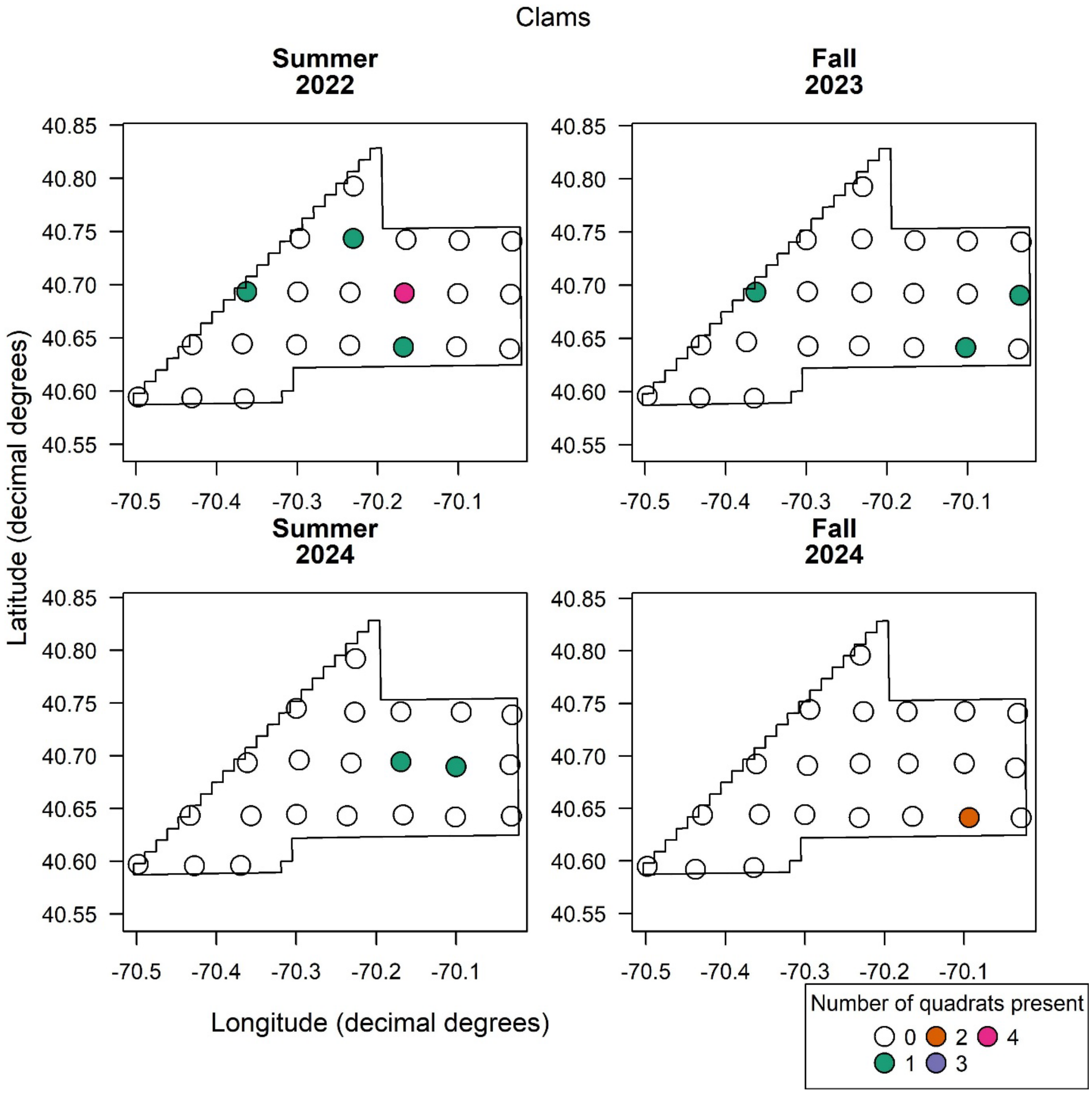

Figure II-23. Seasonal quadrat frequency plots of clams at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

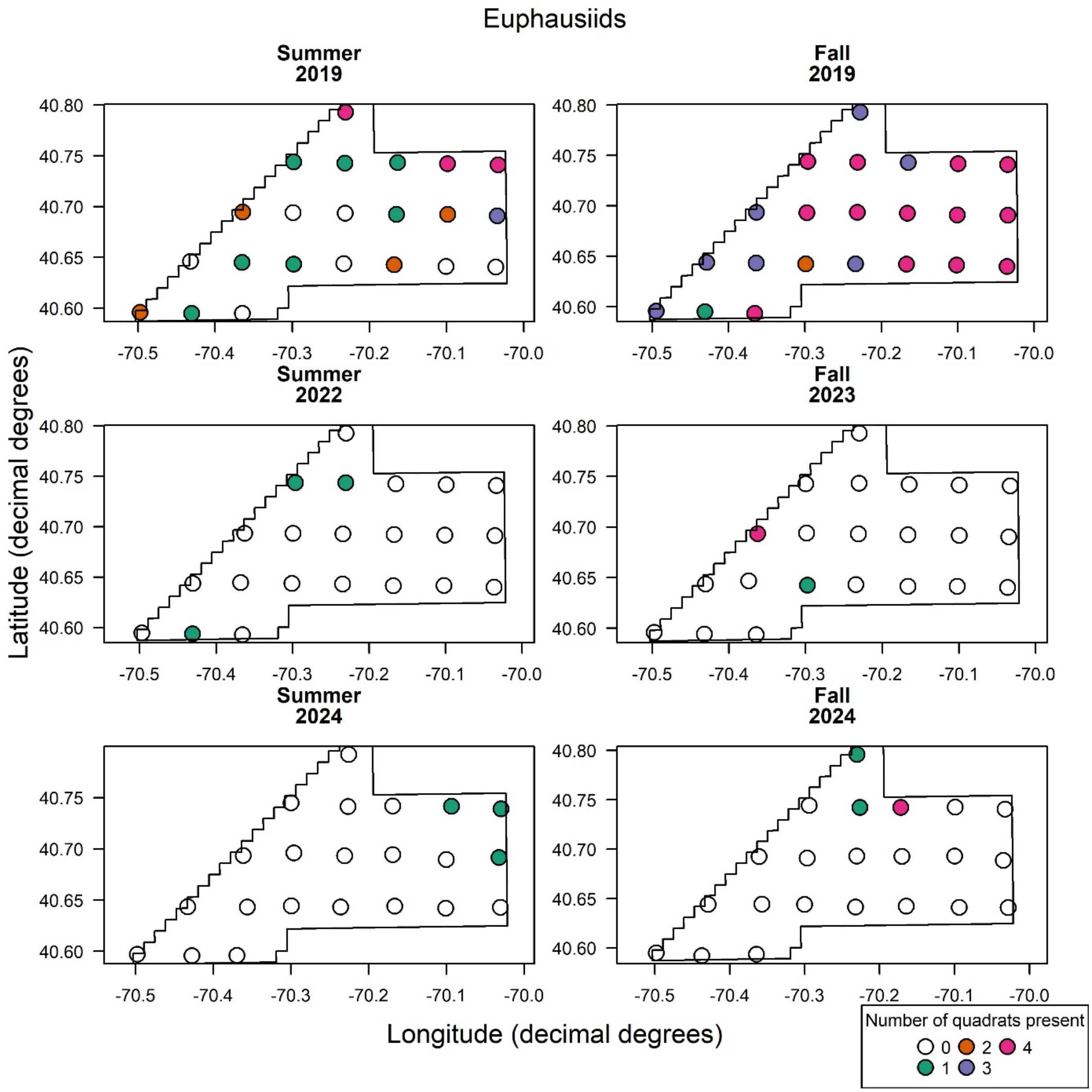

Figure II-24. Seasonal quadrat frequency plots of euphasiids at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

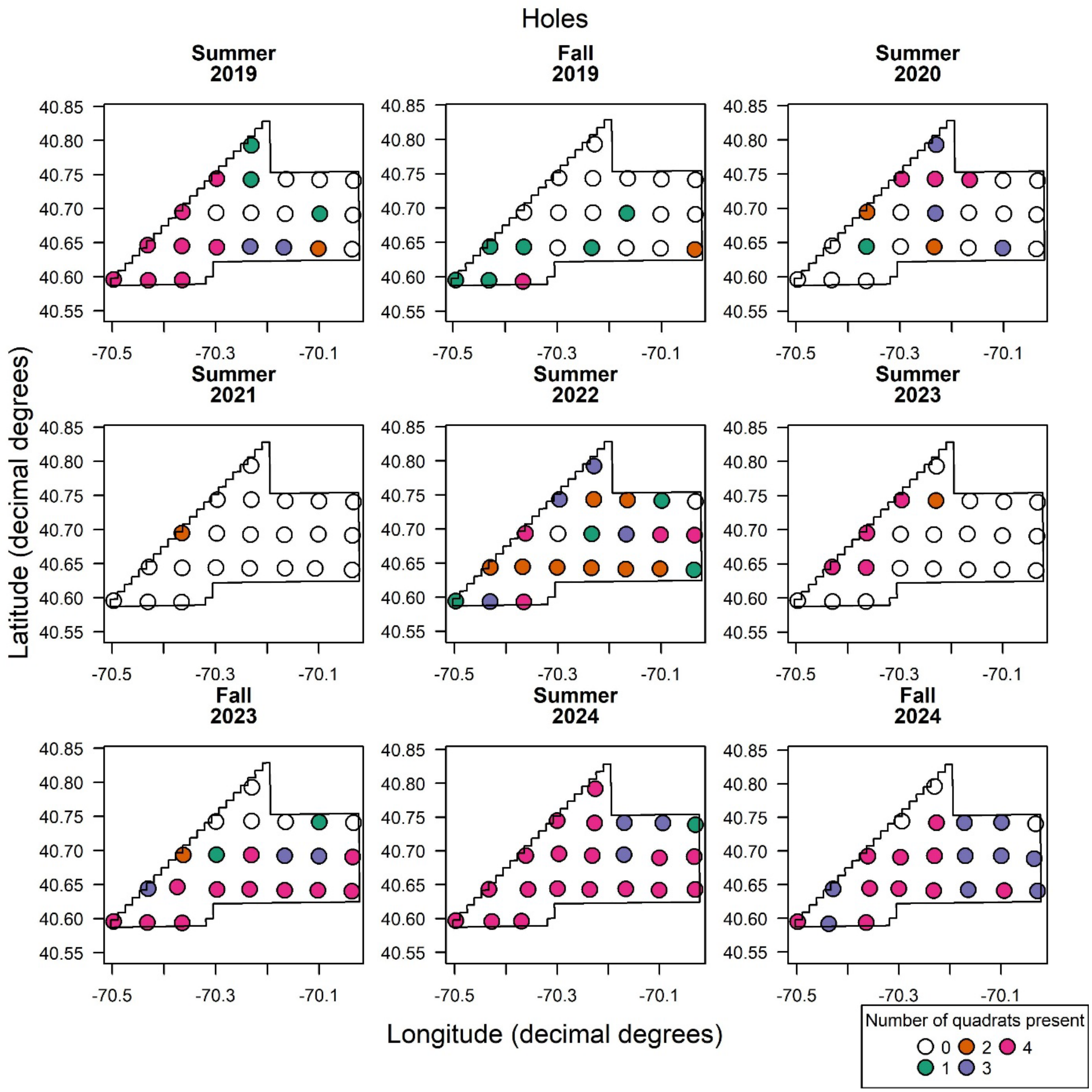

Figure II-25. Seasonal quadrat frequency plots of holes (indicating burrowing animals) at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

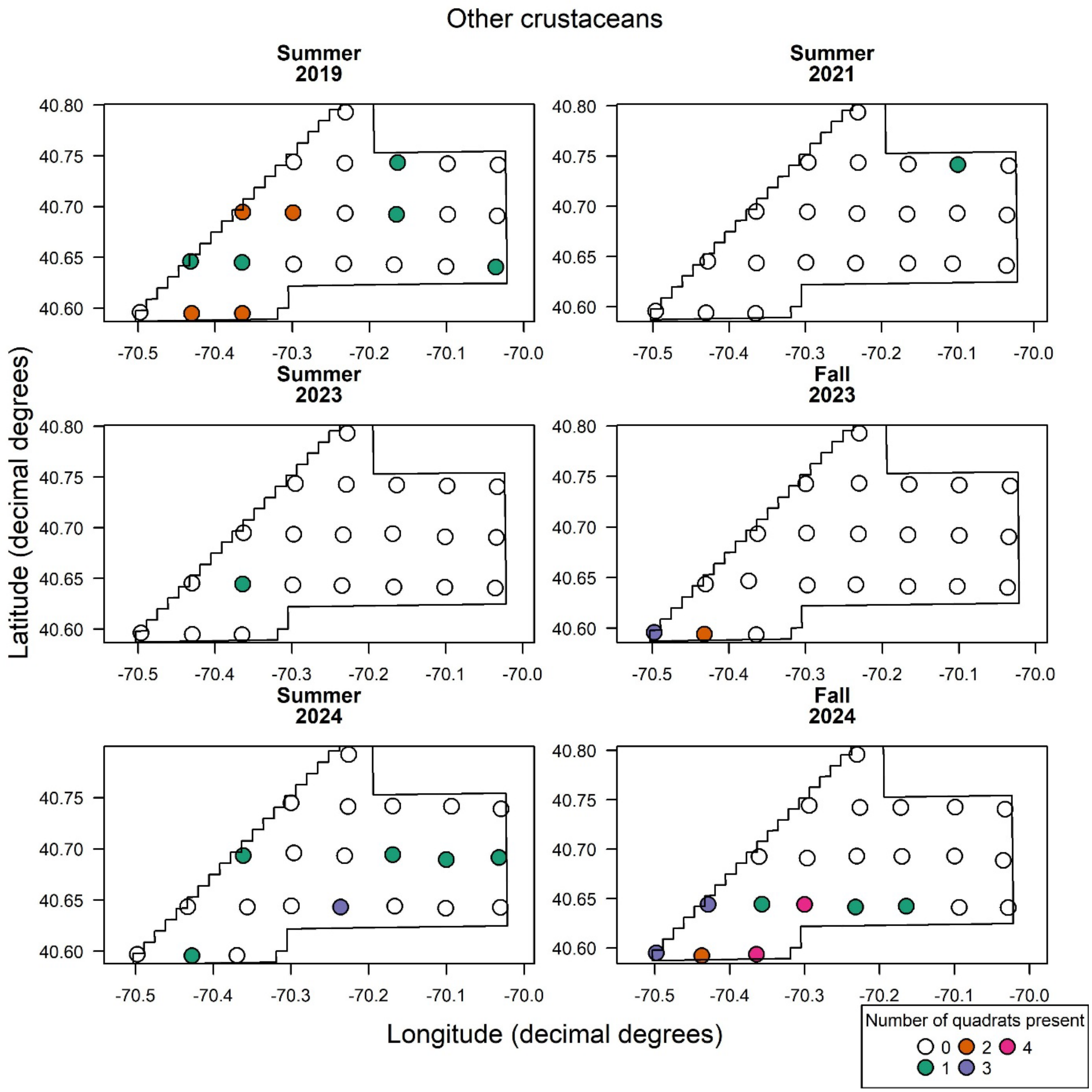

Figure II-26. Seasonal quadrat frequency plots of other crustaceans at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

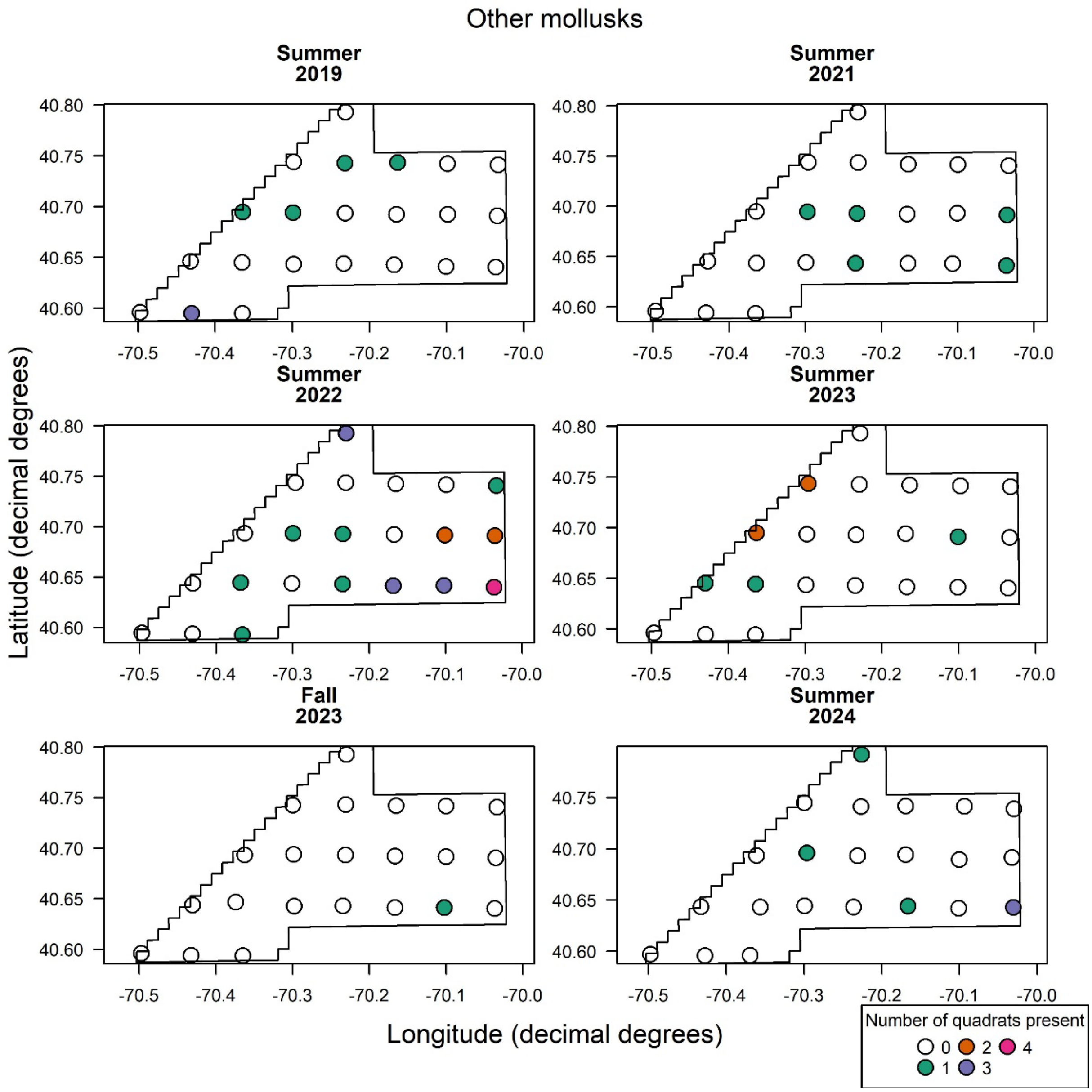

Figure II-27. Seasonal quadrat frequency plots of other mollusks at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

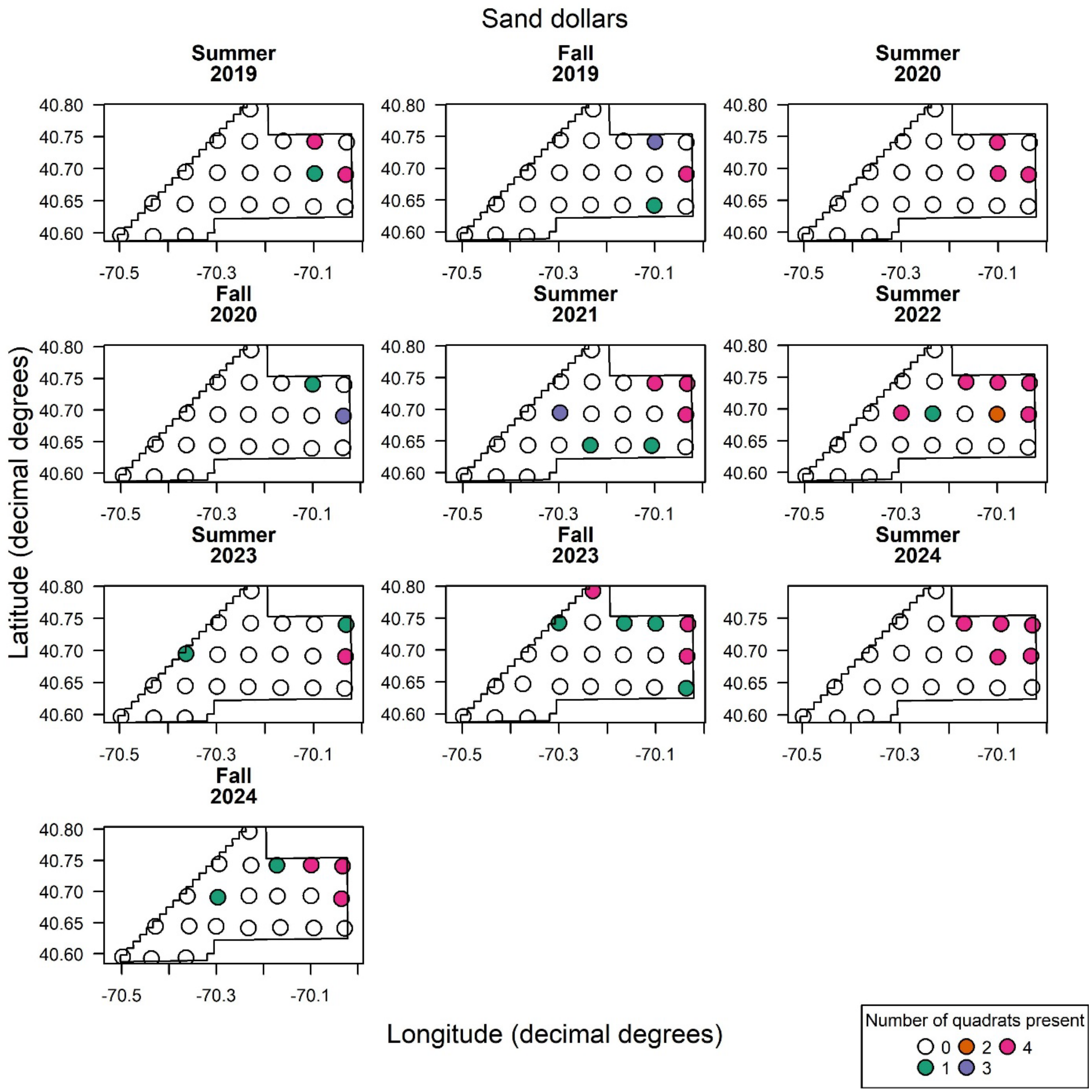

Figure II-28. Seasonal quadrat frequency plots of sand dollars at drop camera stations within 522 Study Area. The points are colored by the number of quadrats at each station where the species group was present, as indicated in the figure legend. Panels are not shown for seasons where no observations of the species group were made.

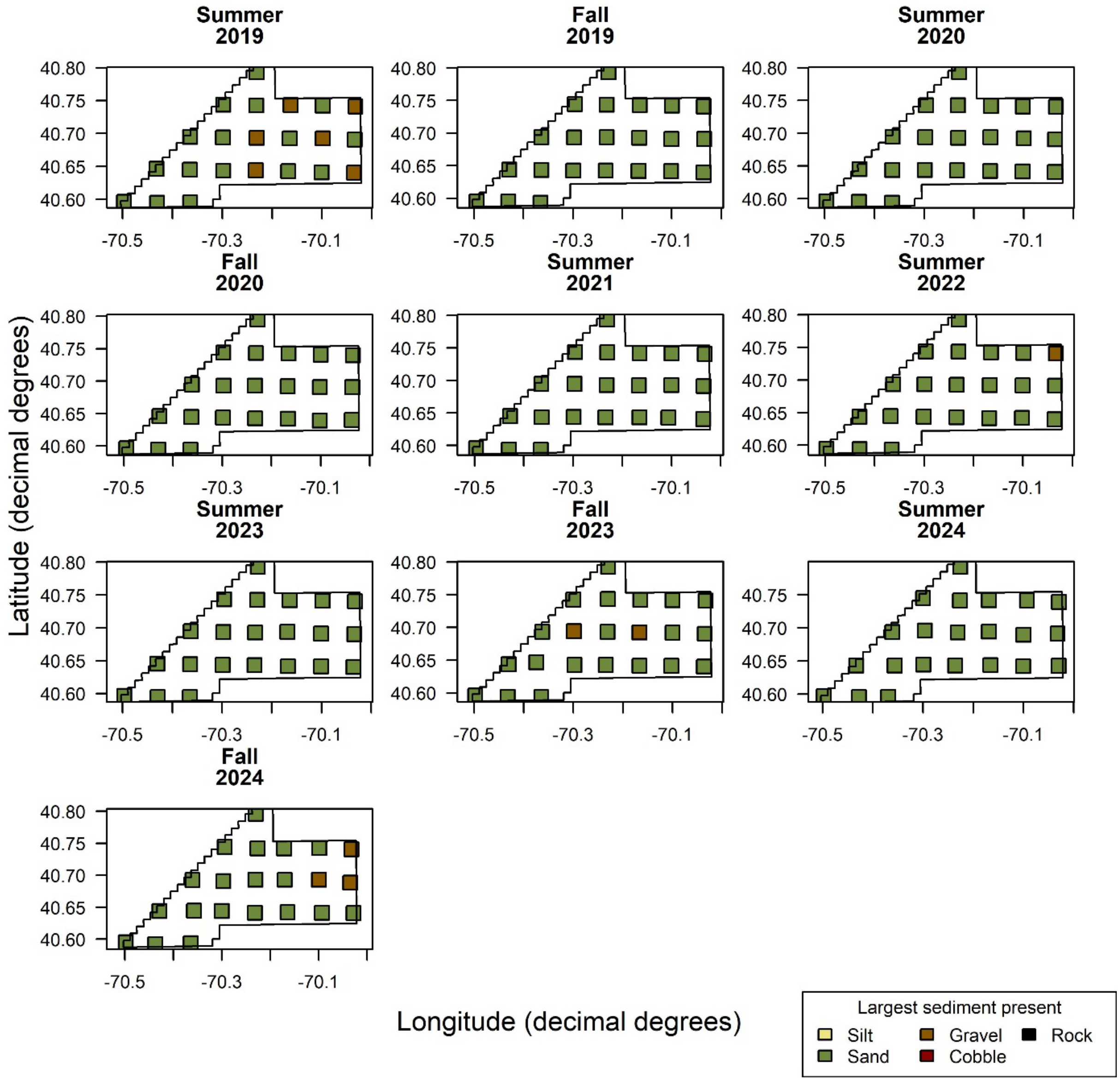

Figure II-29. The largest sediment type present at each drop camera station within 522 Study Area, during each seasonal survey. The largest sediment was determined for each station as the coarsest substrate type present in any of the quadrats at each station.

Table II-3. The percentage of 100 repetitions conducted to estimate statistical power for a range of scenarios from drop camera surveys in the 522 Study Area. The first three columns from left to right are used to arrange the scenarios into species group, variable being examined, and the percent change of effect size. The remaining columns present power estimates for each scenario indicated by the row and under different sample sizes, as indicated by the columns. Each cell in the power columns (rightmost four columns) is the statistical power (%) and is based on 100 unique repetitions each conducted by using the statistical model that was fitted to each species group observations to generate simulated data under a range of conditions (different effect size and sample size) and then refitting the model to the generated data. Note that null hypothesis, where effect size changes are 0 for both year and season, represents the Type I error rate of the model, and should sit around 5% when assessing significance using a 0.05 p value threshold.

Scenarios			Power (%)			
Species group	Variable	Effect size change (%)	22 Stations	47 Stations	72 Stations	97 Stations
Crabs	Null (both season and year at 0)	0	5-8	2-10	4-7	1-7
	Year	25	5.1	5	7	12
		50	8.1	16	29	44
		100	28	50	80	66
	Season	25	13	18	20.2	24
		50	17	29.3	32	43
		100	42	48	67	87
Sea stars	Null (both season and year at 0)	0	1-8	5-10	3-7	0-4
	Year	25	11	12	17	21
		50	29	29	54	55
		100	53	56	49	52
	Season	25	13	36	43	65
		50	56	86	95	95
		100	94	99	98	97
Silver hake	Null (both season and year at 0)	0	3-9	4-12	5	7-10
	Year	25	8	7	9	11
		50	18	13	21	42
		100	31	49.5	59	64
	Season	25	12	14	16	17
		50	19	42	55	63
		100	49	76	91	91

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Johnson, P.C., Barry, S.J., Ferguson, H.M. and Müller, P., 2015. Power analysis for generalized linear mixed models in ecology and evolution. *Methods in ecology and evolution*, *6*(2), pp.133-142. https://doi.org/10.1111/2041-210X.12306

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