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Final Report

2023 Drop Camera Survey of Benthic Communities and Substrate in the 522 Study Area

Submitted to:
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Final Report

2023 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 the 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 in May and September of 2023 using a commercial scallop fishing vessel to deploy the sampling pyramid. Twenty-three different benthic animal groups were observed in the 522 Study Area during 2023. 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.

Table of Contents

List of Tables 5
List of Figures 6
Introduction 8
Goal and Objectives 11
Methods 12
Results and Discussion 14
References 39
Appendix I 42

List of Tables

Table 1. The most frequently observed benthic animal groups, in order of most to least quadrats present, during the 2023 SMAST drop camera surveys of the 522 Study Area 15

Appendix I: Table I-1. Georges Bank species are grouped into taxonomic categories............. 42

List of Figures

Figure 1. Spatial extent of SMAST drop camera surveys in eastern US and Canadian waters..... 9

Figure 2. Example of a digital still image taken by the SMAST drop camera survey in complex habitat of the Rhode Island Wind Energy Lease Area on Cox's Ledge during a survey in 2013 10

Figure 3. Drop camera survey station grid in the 522 Study Area for 2023 surveys.................. 11

Figure 4. SMAST drop camera survey pyramid with cameras and lights used for data collection 12

Figure 5. Density of common benthic animals and associated 95% confidence intervals from the summer 2023 and fall 2023 drop camera survey of the 522 Study Area..................................... 15

Figure 6. The average number of quadrats benthic animals were present in at each station during the summer 2023 and fall 2023 drop camera survey of the 522 Study Area............................... 16

Figure 7. Substrate composition, defined by the most common substrate type observed at a station, during summer and fall drop camera surveys of the 522 Study Area in 2023................ 17

Figure 8. The distribution of sea stars in the summer 2023 and fall 2023 drop camera surveys of the 522 Study Area... 18

Figure 9. The distribution of crabs in the fall 2023 drop camera survey of the 522 Study Area. 19

Figure 10. The distribution of hermit crabs in the summer 2023 and fall 2023 drop camera surveys of the 522 Study Area 20

Figure 11. The distribution of scallops in the summer 2023 drop camera survey of the 522 Study Area... 21

Figure 12. The distribution of silver hake in the summer 2023 and fall 2023 drop camera surveys of the 522 Study Area 22

Figure 13. The distribution of hake in the summer 2023 and fall 2023 drop camera surveys of the 522 Study Area... 23

Figure 14. The distribution of moon snails in the summer 2023 drop camera survey of the 522 Study Area 24

Figure 15. The distribution of skates in the fall 2023 drop camera surveys of the 522 Study Area 25

Figure 16. The distribution of squid in the fall 2023 drop camera surveys of the 522 Study Area 26

Figure 17. The distribution of other fish in the fall 2023 drop camera surveys of the 522 Study Area... 27

Figure 18. The distribution of flat fish in the fall 2023 drop camera survey of the 522 Study Area 28

Figure 19 The distribution of ocean pout in the fall 2023 drop camera surveys of the 522 Study Area... 29

Figure 20. The distribution of whelk in the summer 2023 and fall 2023 drop camera surveys of the 522 Study Area... 30

Figure 21. The distribution of sea robin in the fall 2023 drop camera survey of the 522 Study Area 31

Figure 22. The distribution of sand dollars in the summer 2023 and fall 2023 drop camera surveys of the 522 Study Area 32

Figure 23. The distribution of holes (burrowing animals) in the summer 2023 and fall 2023 drop camera surveys of the 522 Study Area 33

Figure 24. The distribution of brittle stars in the fall 2023 drop camera survey of the 522 Study Area 34

Figure 25. The distribution of bryozoans and hydrozoans in the summer 2023 and fall 2023 drop camera surveys drop camera survey of the 522 Study Area 35

Figure 26. The distribution of clams in the fall 2023 drop camera survey of the 522 Study Area 36

Figure 27. The distribution of substrate types in the summer 2023 drop camera survey of the 522 Study Area 39

Figure 28. The distribution of substrate types in the fall 2023 drop camera survey of the 522 Study Area 40

Appendix I: Figure I-1. The distribution of image visibility per station for the summer 2023 drop camera survey of the 522 Study Area 43

Appendix I: Figure I-1. The distribution of image visibility per station for the fall 2023 drop camera survey of the 522 Study Area 43

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 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 the 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 is regularly provided to the New England Fisheries Management Council (NEFMC) to aid in annual scallop harvest allocation (NEFSC, 2010; 2018).

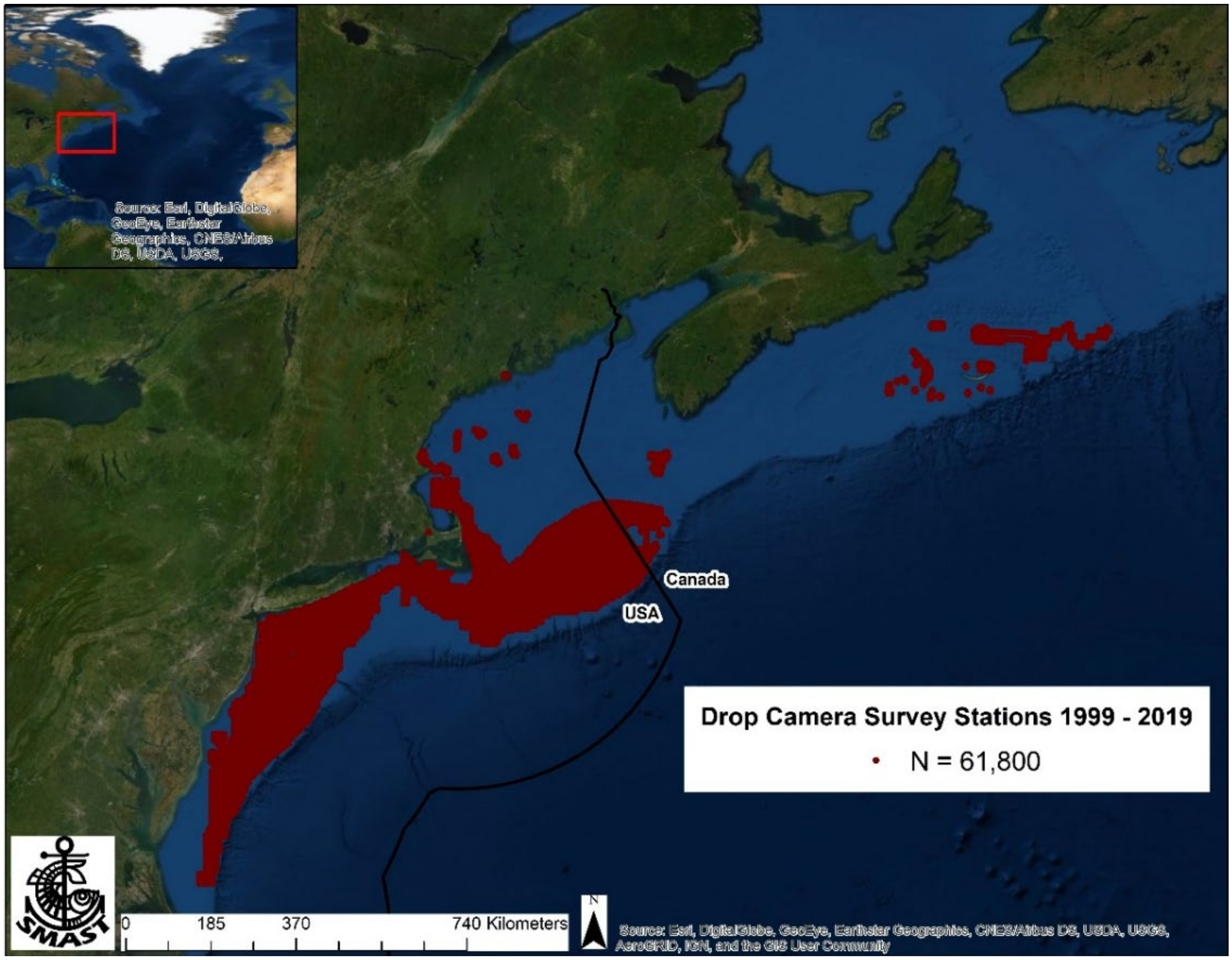


Figure 1. The spatial extent of SMAST drop camera surveys in eastern US and Canadian waters. All stations surveyed from 1999 to 2019 are displayed in red.

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). 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). Ecologically and economically important species that would be difficult to sample with a net or dredge, such as squid egg clusters or habitat-forming filamentous fauna (bryozoans or hydrozoans), can be counted using drop camera surveys (Figure 2).

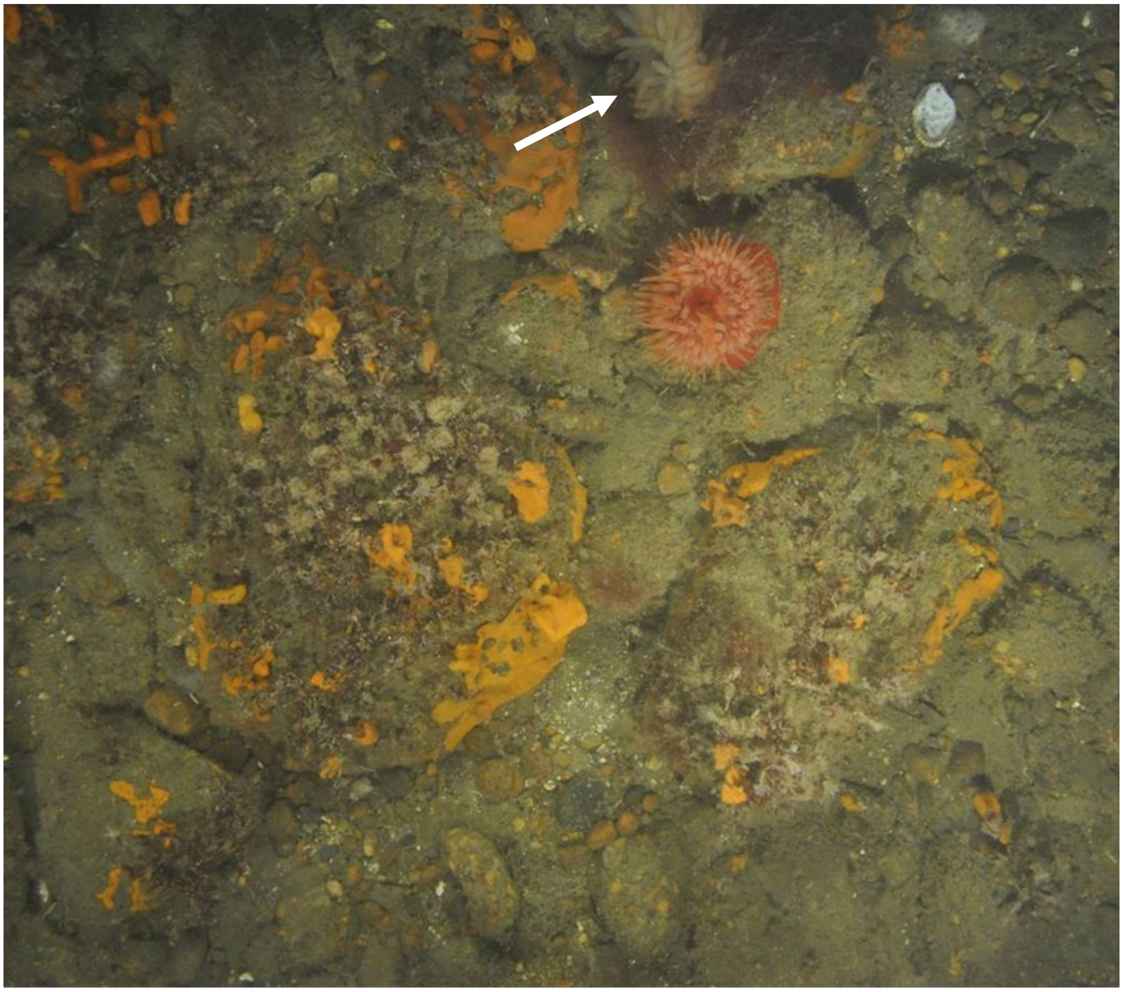


Figure 2. Example of a digital still image taken by the SMAST drop camera survey in complex habitat in the Rhode Island/Massachusetts Wind Energy Area on Cox's Ledge during a survey in 2013. An Atlantic longfin squid egg cluster was present (top, middle).

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 (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 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 with a specific level of precision. This will enable a precisely designed control-impact experiment prior to the development of the area.

Goal and Objectives

The primary goal of this project is to collect preliminary data on the benthic community and substrate in the 522 Study Area. These 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 types.

These two objectives document the primary epibenthic animals and habitats within the 522 Study Area, which 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.

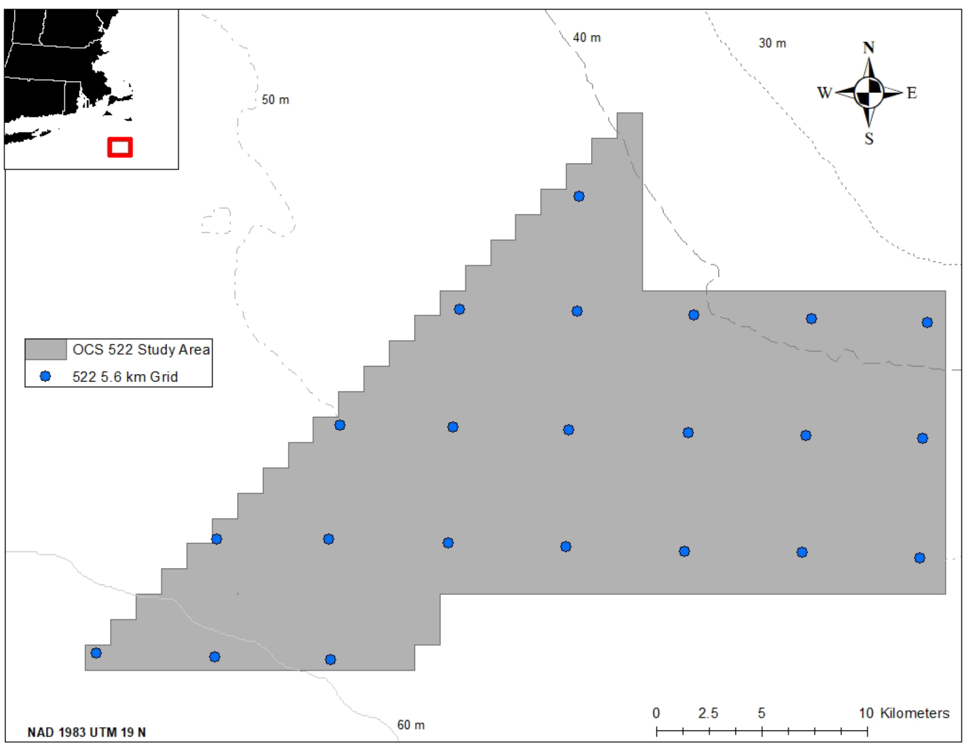


Figure 3. The 2023 drop camera survey station grid in the 522 Study Area.

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 (2.3 m^2 images) samples (Figure 4). This is the same sampling resolution used in the 2012 and 2013 drop camera surveys of the Rhode Island/Massachusetts Wind Energy Area.

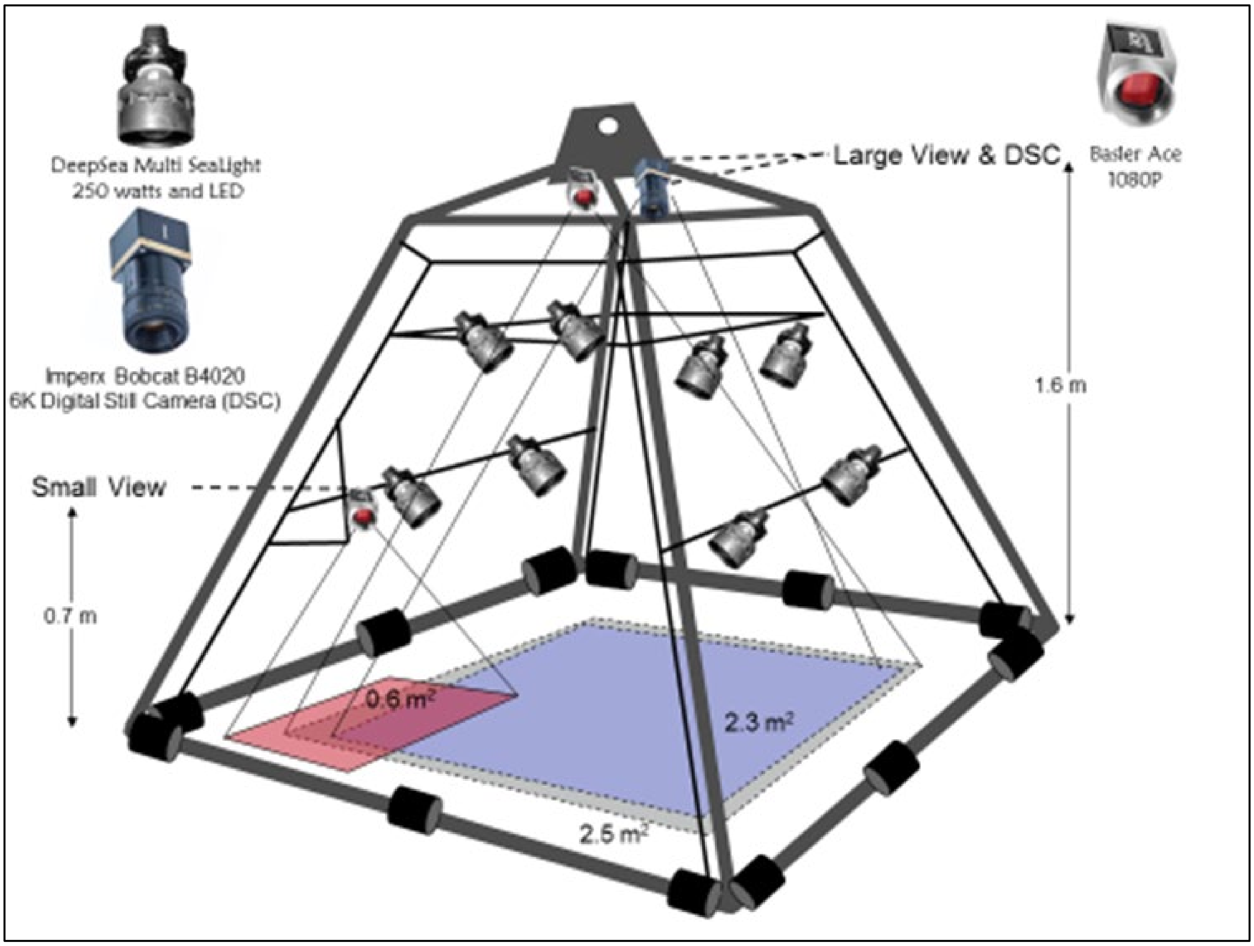


Figure 4. SMAST drop camera survey pyramid with cameras and lights used for data collection. The camera used for the small view was turned to the side to provide a view parallel to the seafloor for some stations.

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 vessel's wheelhouse. 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 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 (Figure 2). 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 most observed benthic animal groups in the 522 Study Area as these 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).

Results and Discussion

The two drop camera surveys of the 522 Study Area were conducted on May 5, 2023, and October 1, 2023. All images and videos collected were shared with Vineyard Offshore. All 22 stations were surveyed in both seasons. Twenty-two different benthic animal groups were observed in the 522 Study Area, with the most common displayed in Table 1. Nine of the common animal groups were found in both seasons. Crabs, skates, flounder, squid, ocean pout, clams, brittle stars, and euphausiids were not observed in the summer but were observed in the fall (Figures 5 and 6). Scallops and moon snails were observed in the summer but not in the fall (Figures 5 and 6). All animal groups that were present in both seasons were found in higher abundances and densities in the fall than in the summer. Sea stars had wide confidence intervals around mean densities due to their large numbers at a few stations (Figures 5 and 8). Animals in presence/absence groups had higher frequencies per quadrat in the fall than in the summer as well, besides bryozoans/hydrozoans (Figure 6). Substrates remained relatively unchanged from season to season (Figure 7). Sand, silt, and shell debris were the dominant substrates observed at each station through both seasons, but some gravel was observed in the fall and not in the summer. The animals appeared to be randomly distributed from year to year within the 522 Study Area (Figures 8 to 28). Sand was the most frequently observed largest substrate over both years, but some gravel was observed in the fall at two stations (Figures 27 and 28).

The summer survey was completed in May in an effort to mitigate the 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 two quadrats had visibility issues in the fall survey (Figure I-2). Surveys were not completed in this area in the fall during the two previous years due to contractual issues and delays, but we were able to successfully survey in the fall of 2023 (Lego et al., 2023). The visibility was an improvement from the prior years (2019 and 2020) and future surveys will be conducted during the same months to achieve maximum visibility. In the fall, we attempted to survey the 522 Study Area in September but were one day late, hence the October 1, 2023, survey date. Though visibility was not a major issue throughout the 2023 survey season, two quadrats were not visible in the fall survey. Hence, we will aim to survey this area in September going forward.

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 the 522 Study Area in 2023. Groups left blank in the "Counts" column are tracked as present or absent. Note that 10 common benthic animal groups are listed for the survey and 12 are listed for the fall survey.

Animal Group	Quadrats Present	Counts	Animal Group	Quadrats Present	Counts
Holes (Burrowing Animals)	18		Holes (Burrowing Animals)	57	
Sea Stars	6	62	Buccinum (whelk)	35	126
Sand Dollars	6		Hermit Crabs	33	53
Hermit Crabs	4	8	Sand Dollars	16	
Bryozoans/Hydrozoans	3		Sea Stars	8	65
Moon Snail	2	2	Silver Hake	6	6
Hake	2	2	Crabs	5	8
Scallops	1	1	Clams	3	
Buccinum (whelk)	1	2	Squid	3	17
Silver Hake	1	1	Hake	3	4
Total Quadrats Sampled	**88**		Skate	3	3
			Flounder	1	1
			Total Quadrats Sampled	**88**	

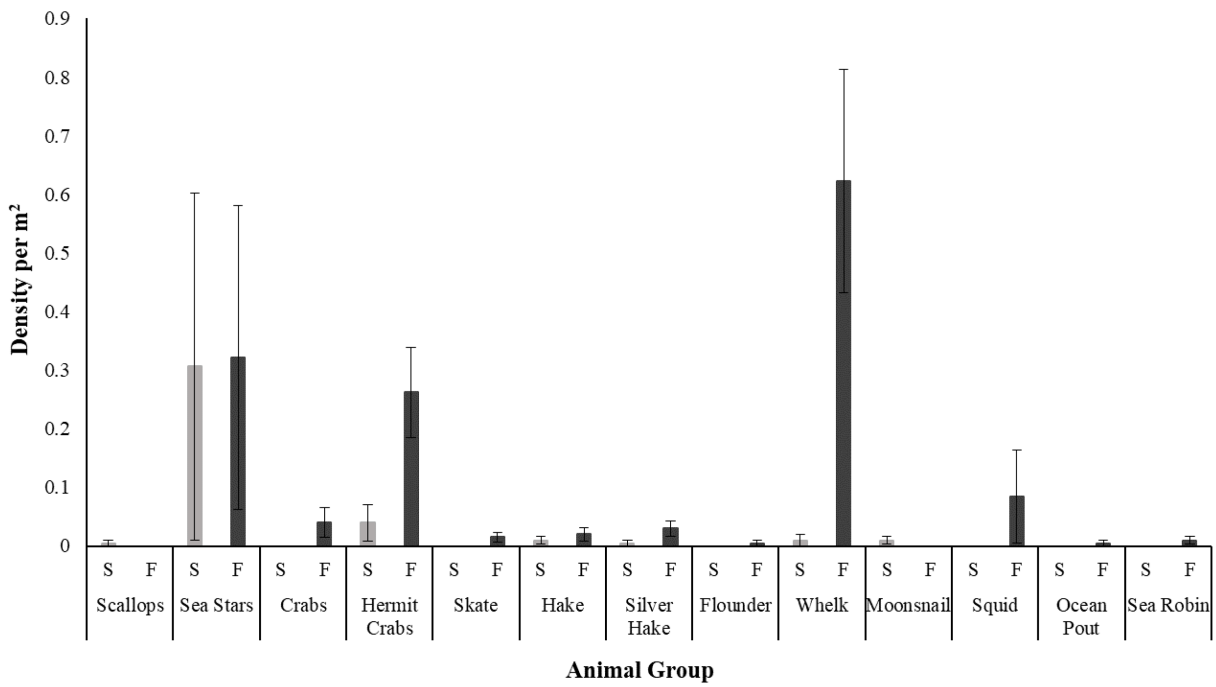


Figure 5. The mean densities of common benthic animals from the summer 2023 (S) and fall 2023 (F) drop camera surveys of the 522 Study Area. Error bars represent 95% confidence intervals.

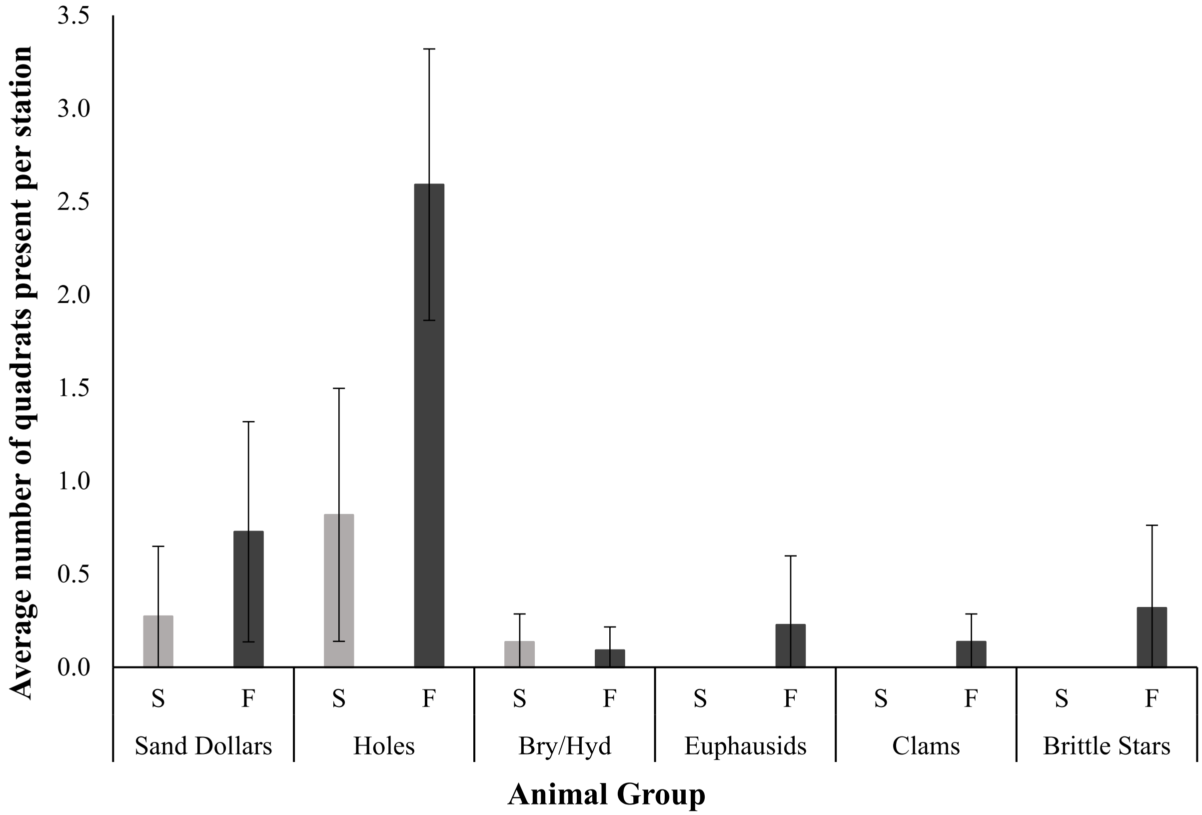


Figure 6. The average number of quadrats where benthic animals were present per station during the summer 2023 (S) and fall 2023 (F) drop camera surveys of the 522 Study Area. Holes represent burrowing animals and Bry./Hyd. represents bryozoans and hydrozoans. Four quadrats (each consisting of 2.3 m^2 images) were observed at each station.

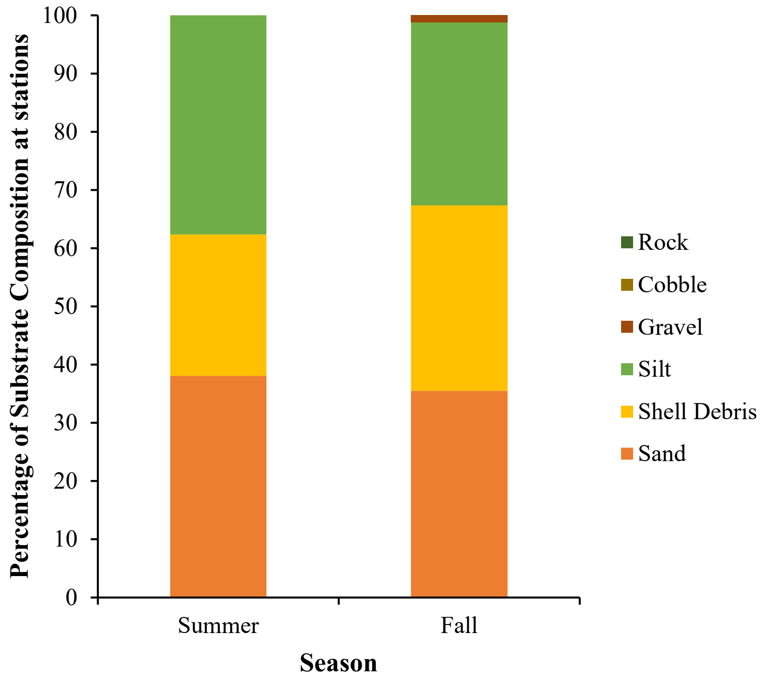
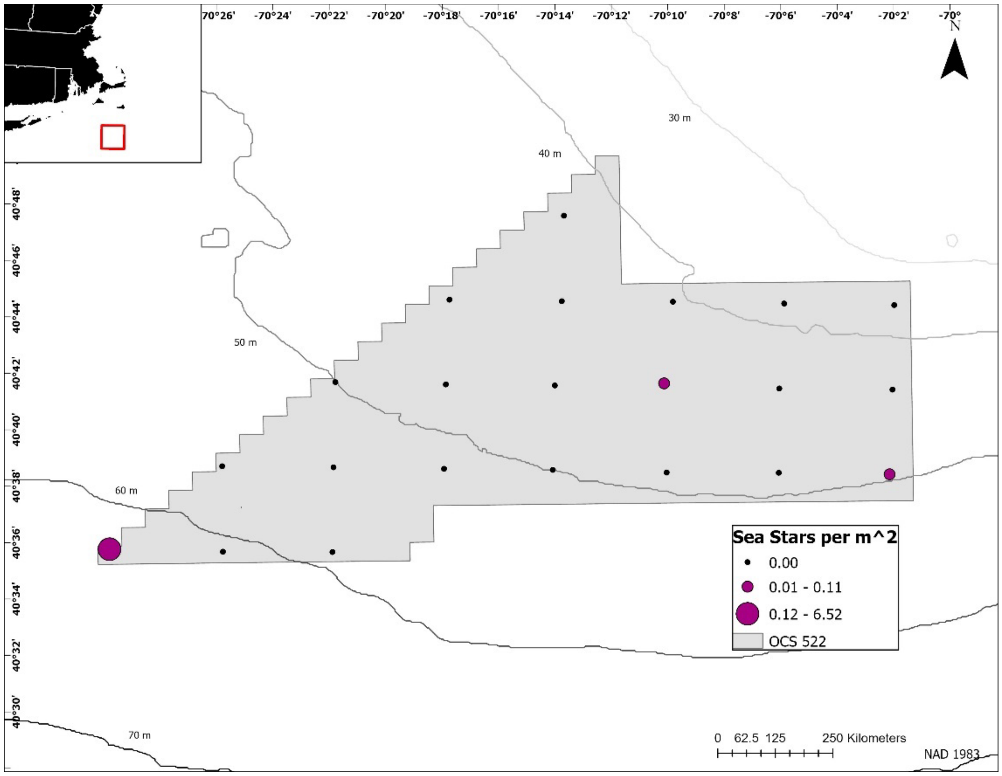


Figure 7. Substrate composition, defined by the most common substrate type observed at a station, during the summer and fall drop camera surveys of the 522 Study Area in 2023. Cobble and rock were not observed at any station.



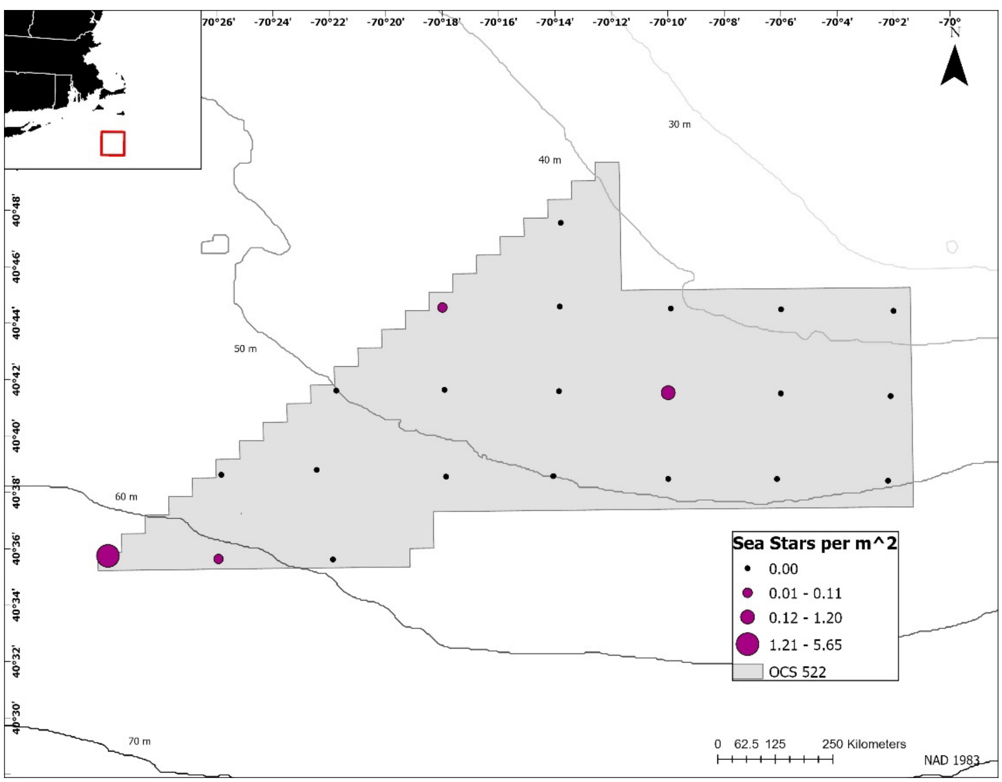


Figure 8. The distribution of sea stars from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Density categories equally divide the data into quartiles above zero based on observations for both seasons.

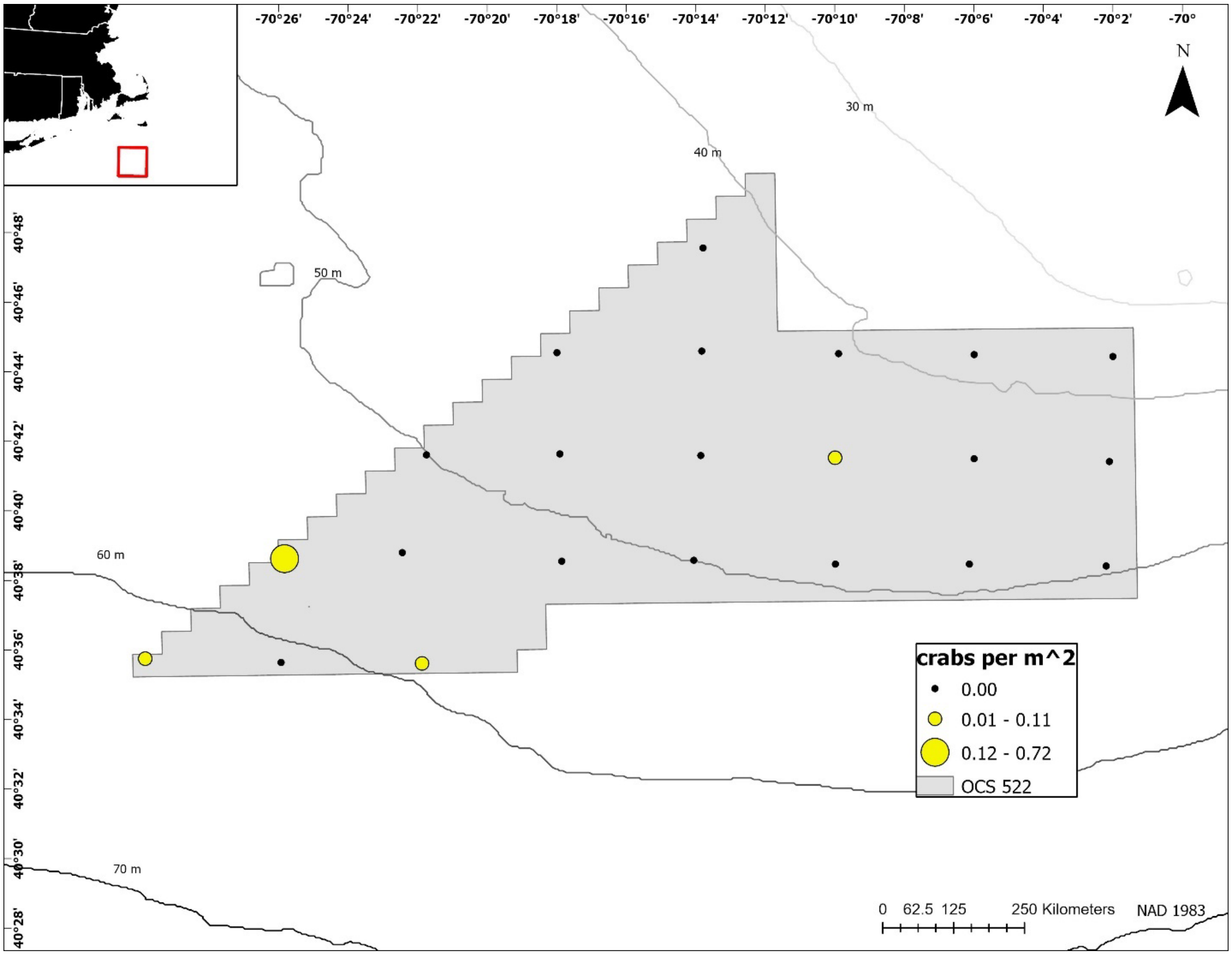


Figure 9. The distribution of crabs from the fall 2023 drop camera survey of the 522 Study Area. No crabs were observed in the summer 2023 survey period. Density categories divide the data into quartiles above zero based on observations in the fall 2023 survey period.

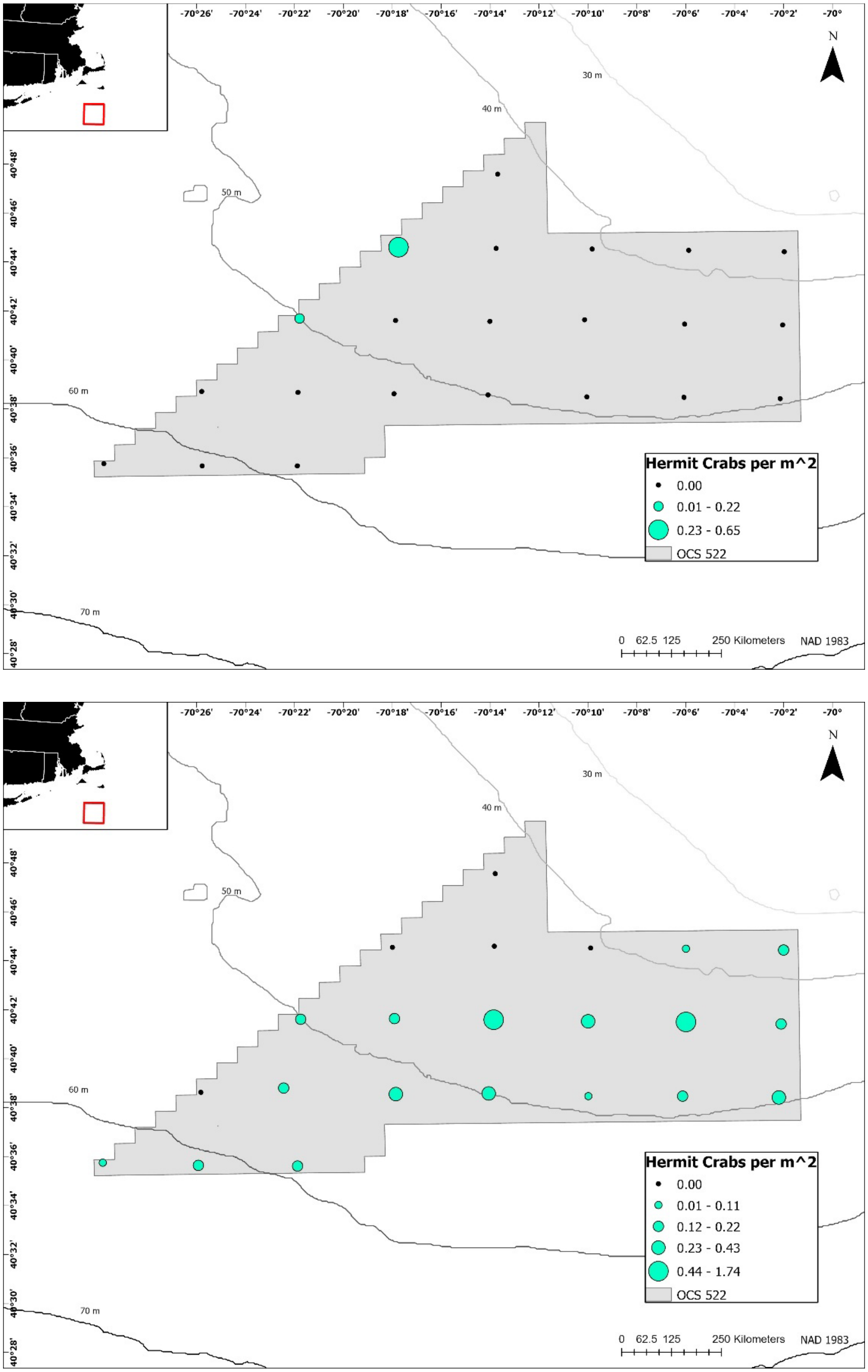


Figure 10. The distribution of hermit crabs from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Density categories divide the data into quartiles above zero based on observations for both seasons.

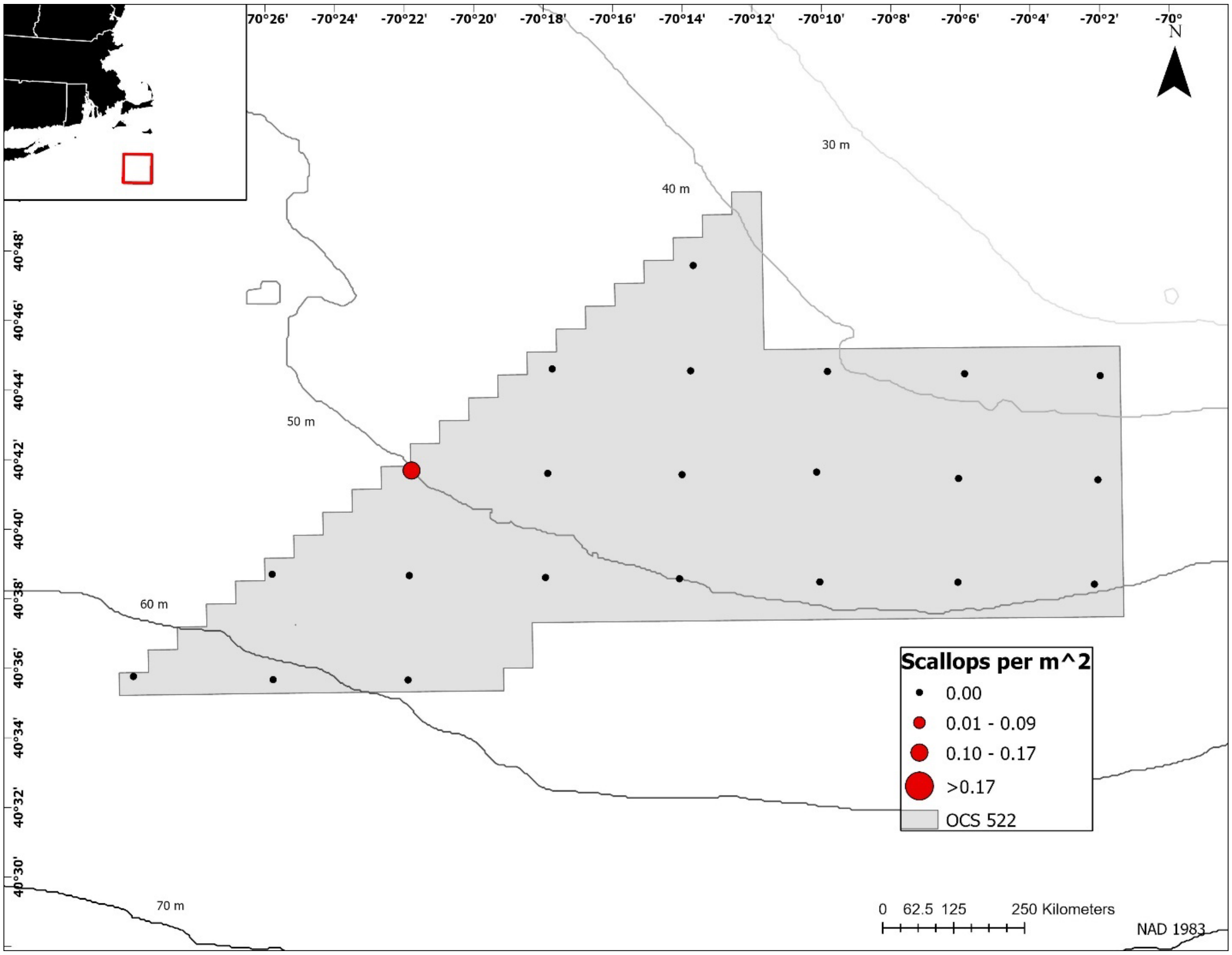


Figure 11. The distribution of scallops from the summer 2023 drop camera survey of the 522 Study Area. No scallops were observed in the fall 2023 survey period. Density categories divide the data into quartiles above zero based on observations in the summer 2023 survey period.

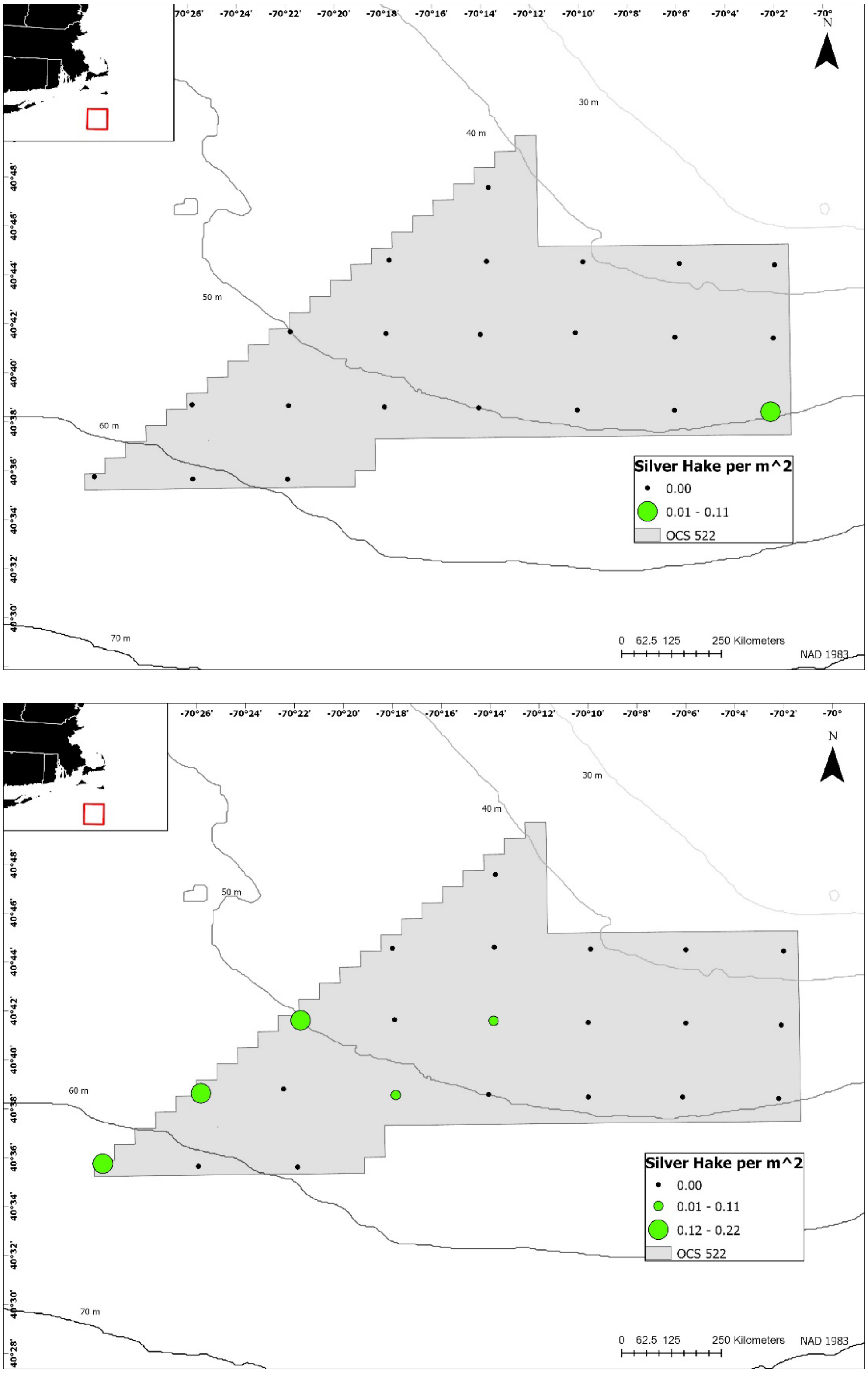
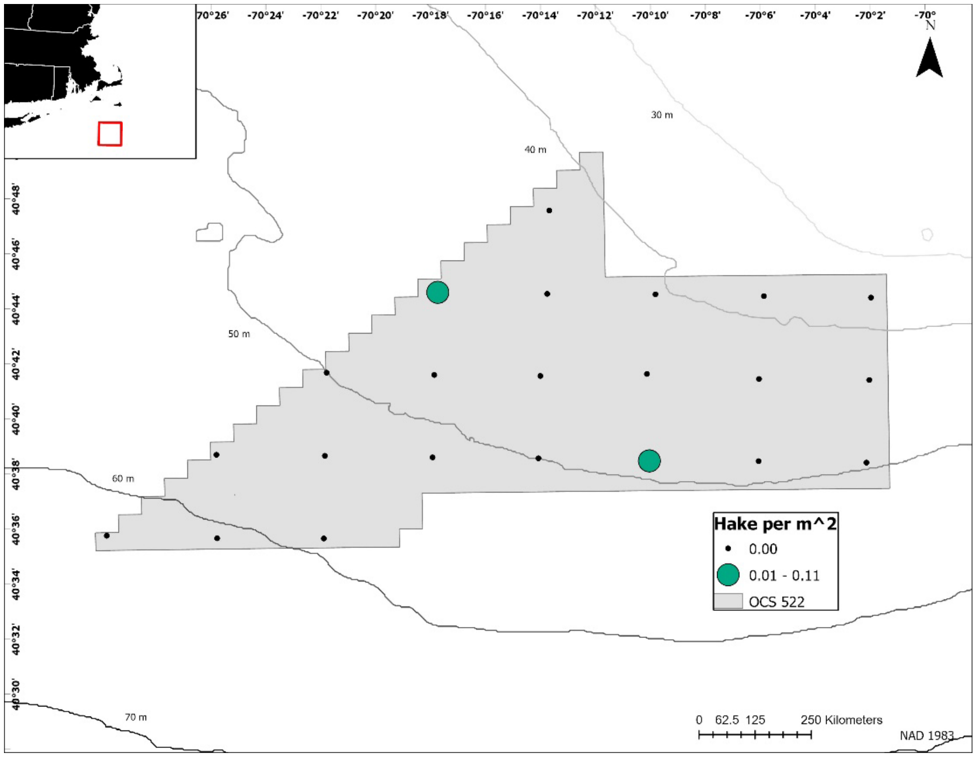


Figure 12. The distribution of silver hake from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Density categories represent zero, one, or two silver hake observed at a station in both seasons.



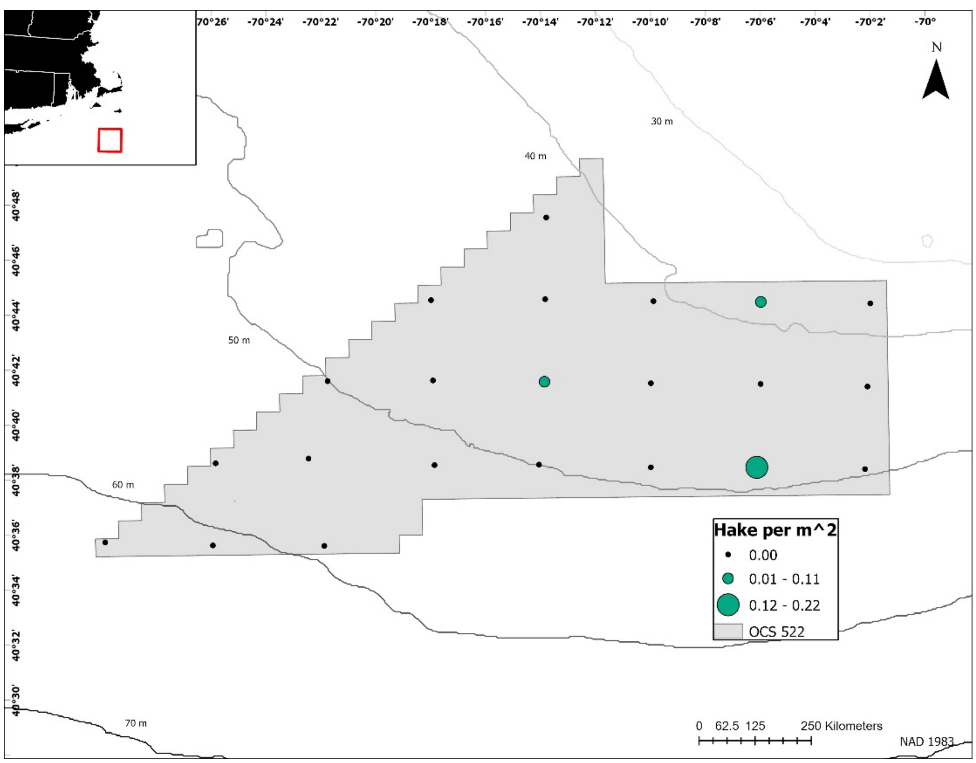


Figure 13. The distribution of hake from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Density categories represent zero, one, or two hake observed at a station in both seasons.

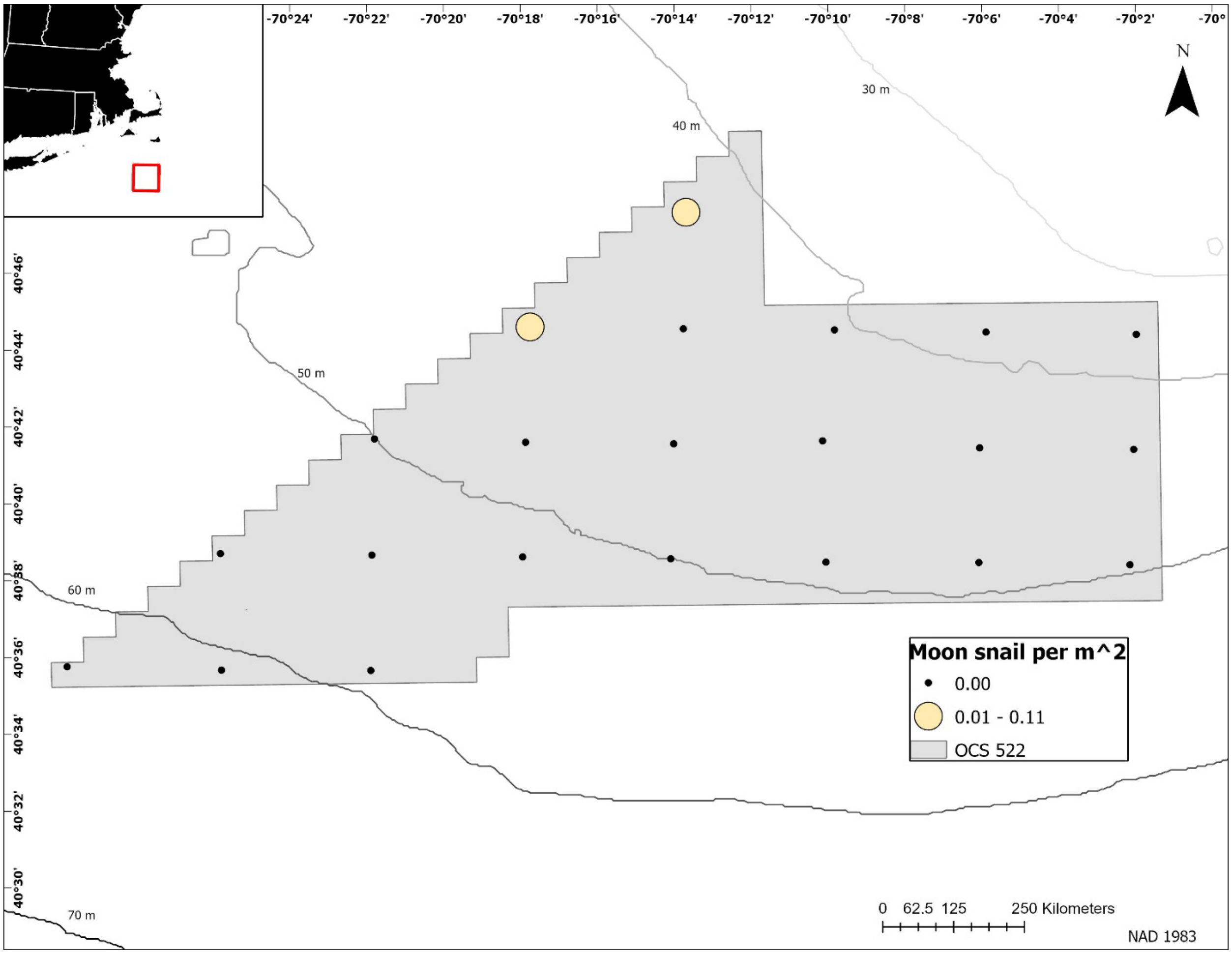


Figure 14. The distribution of moon snails from the summer 2023 drop camera survey of the 522 Study Area. No moon snails were observed in the fall 2023 survey period. Density categories represent zero or one moon snail observed at a station in the summer 2023 survey period.

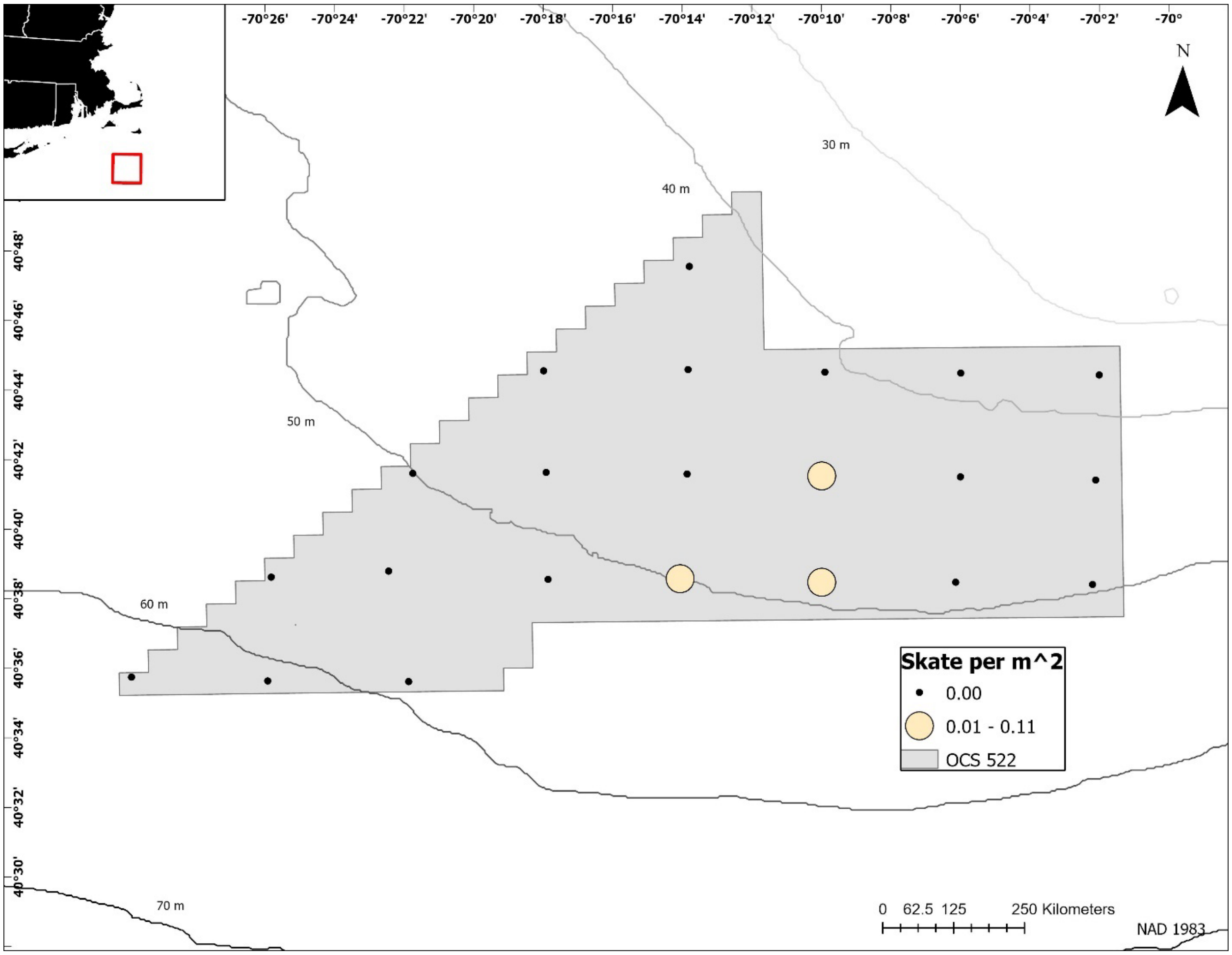


Figure 15. The distribution of skates from the fall 2023 drop camera survey of the 522 Study Area. No skates were observed in the summer 2023 survey period. Density categories represent zero or one skate observed at a station in the fall 2023 survey period.

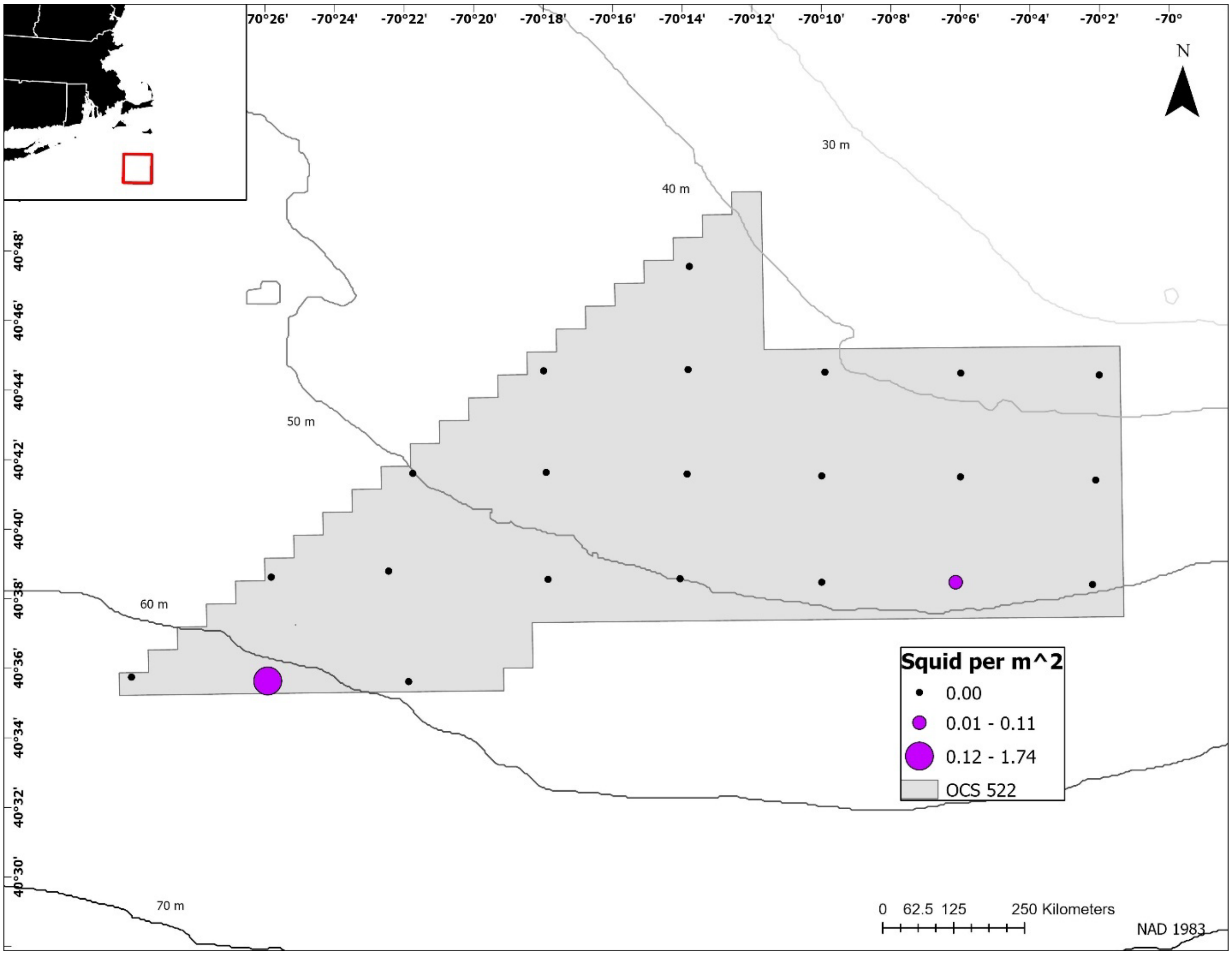


Figure 16. The distribution of squid from the fall 2023 drop camera survey of the 522 Study Area. No squid were observed in the summer 2023 survey period. Density categories divide the data into quartiles above zero based on observations in the fall 2023 survey period.

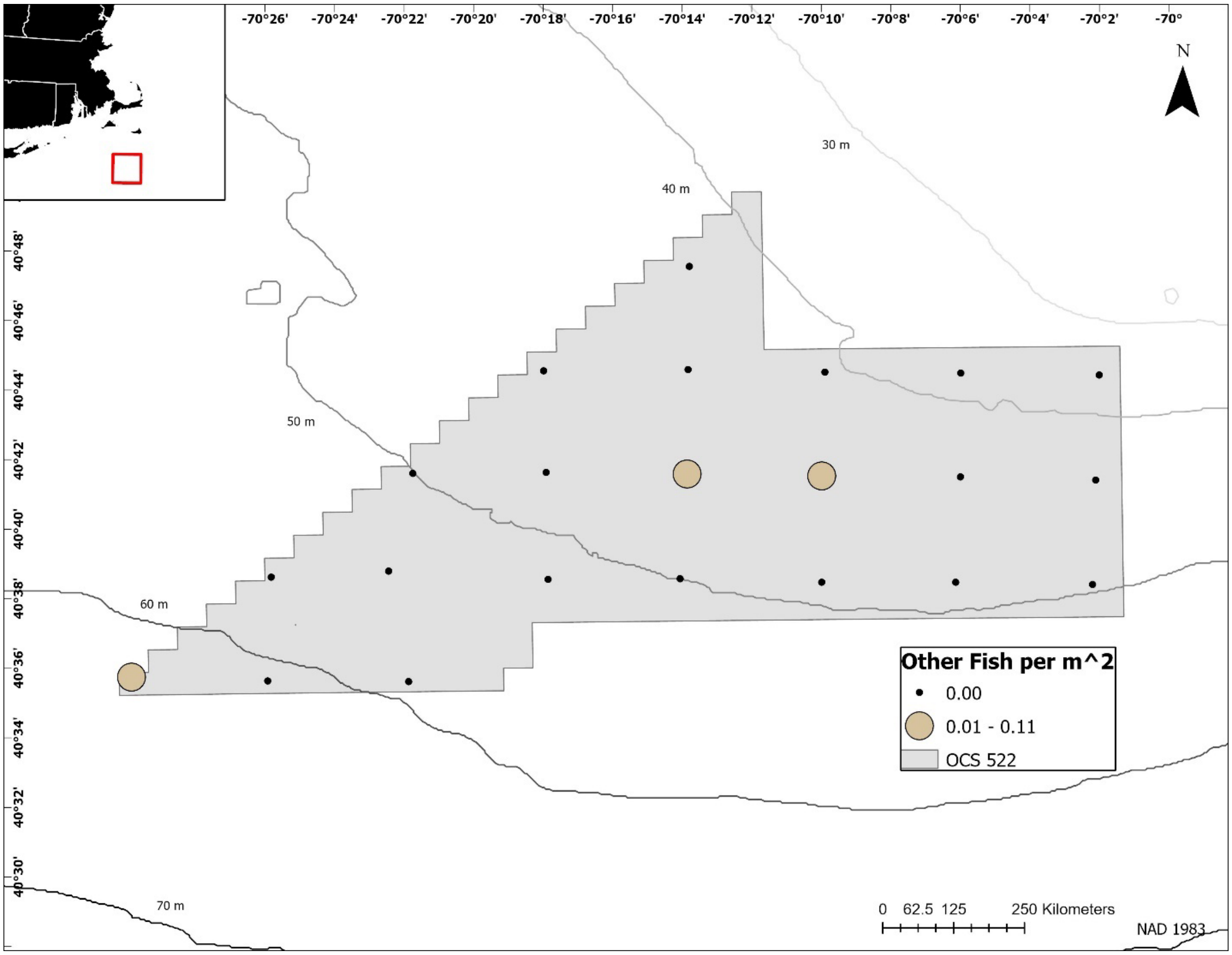


Figure 17. The distribution of other fish from the fall 2023 drop camera survey of the 522 Study Area. No other fish were observed in the summer 2023 survey period. Density categories represent zero or one other fish observed per station in the fall 2023 survey period.

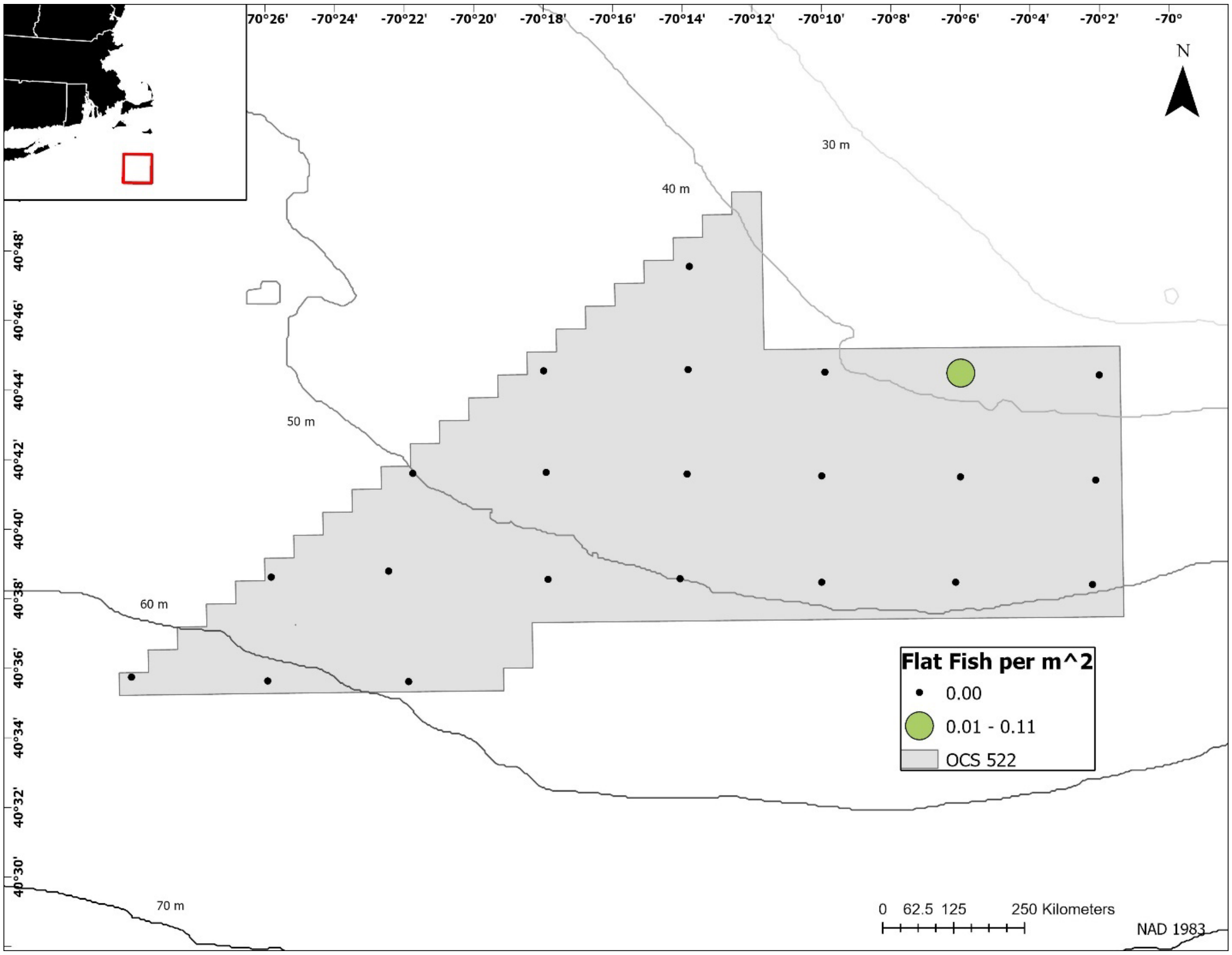


Figure 18. The distribution of flat fish (flounder) from the fall 2023 drop camera survey of the 522 Study Area. No flat fish were observed in the summer 2023 survey period. Density categories represent zero or one flat fish observed per station in the fall 2023 survey period.

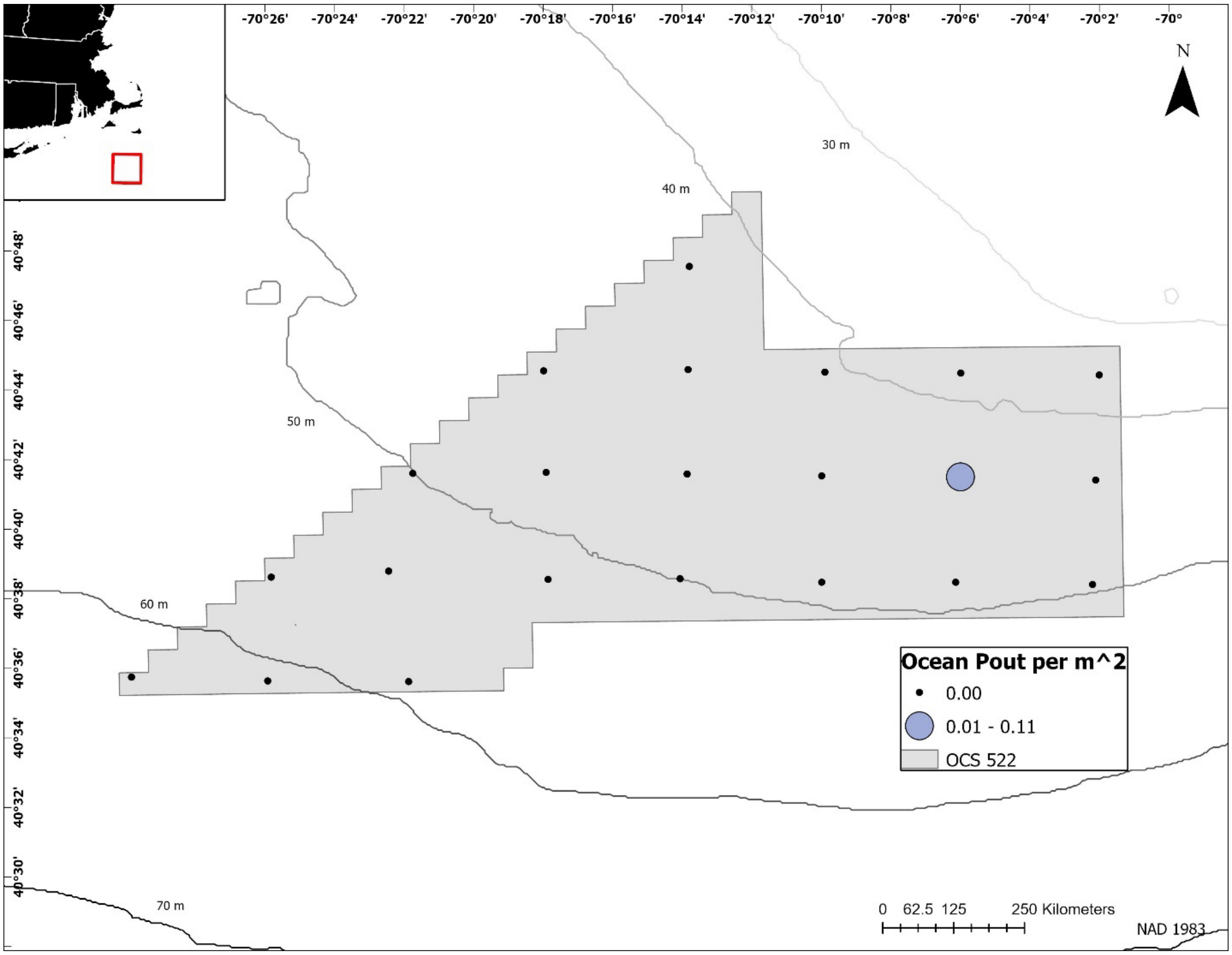
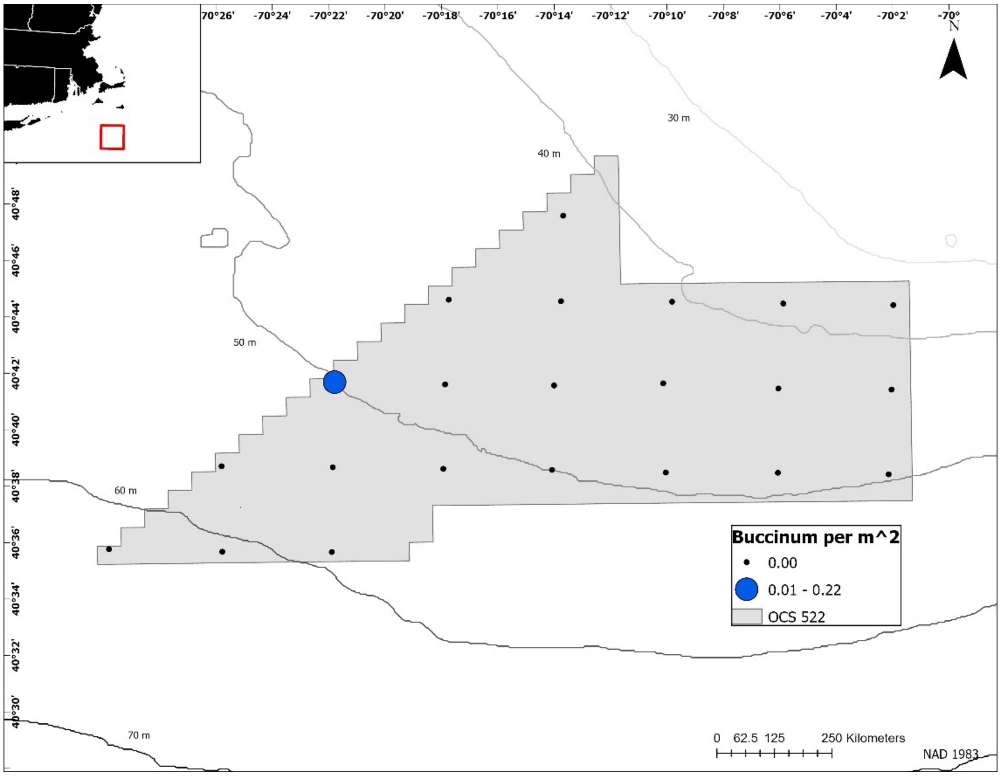


Figure 19. The distribution of ocean pout from the fall 2023 drop camera survey of the 522 Study Area. No ocean pout were observed in the summer 2023 survey period. Density categories represent zero or one ocean pout observed per station in the fall 2023 survey period.



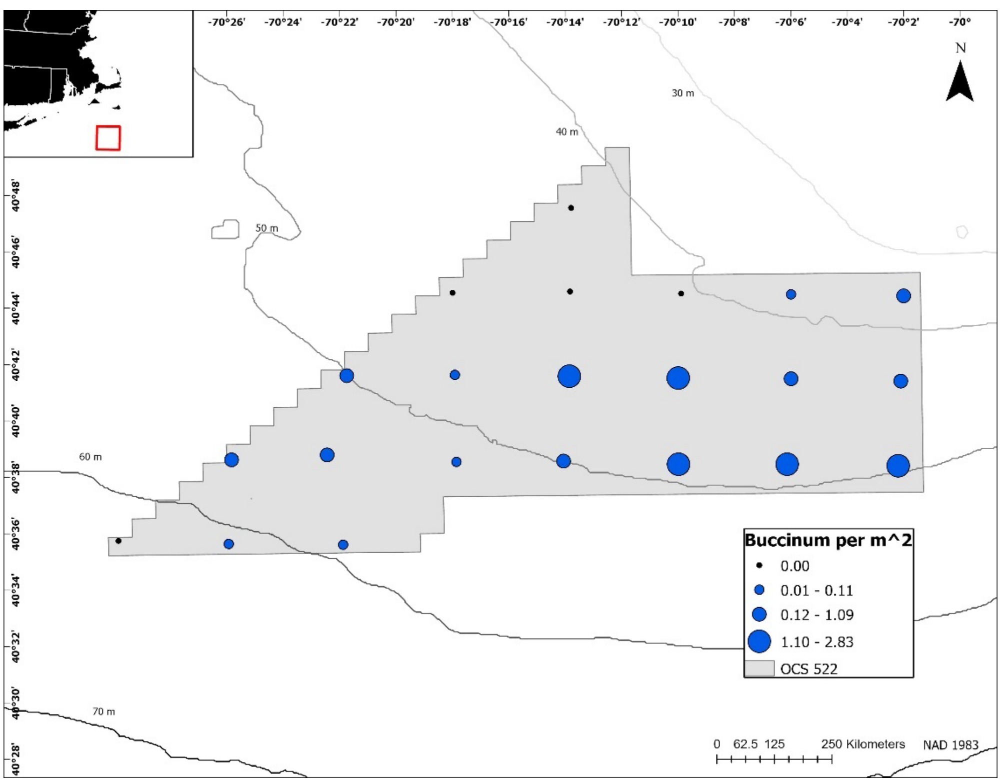


Figure 20. The distribution of whelk from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Density categories divide the data into quartiles based on observations in both seasons.

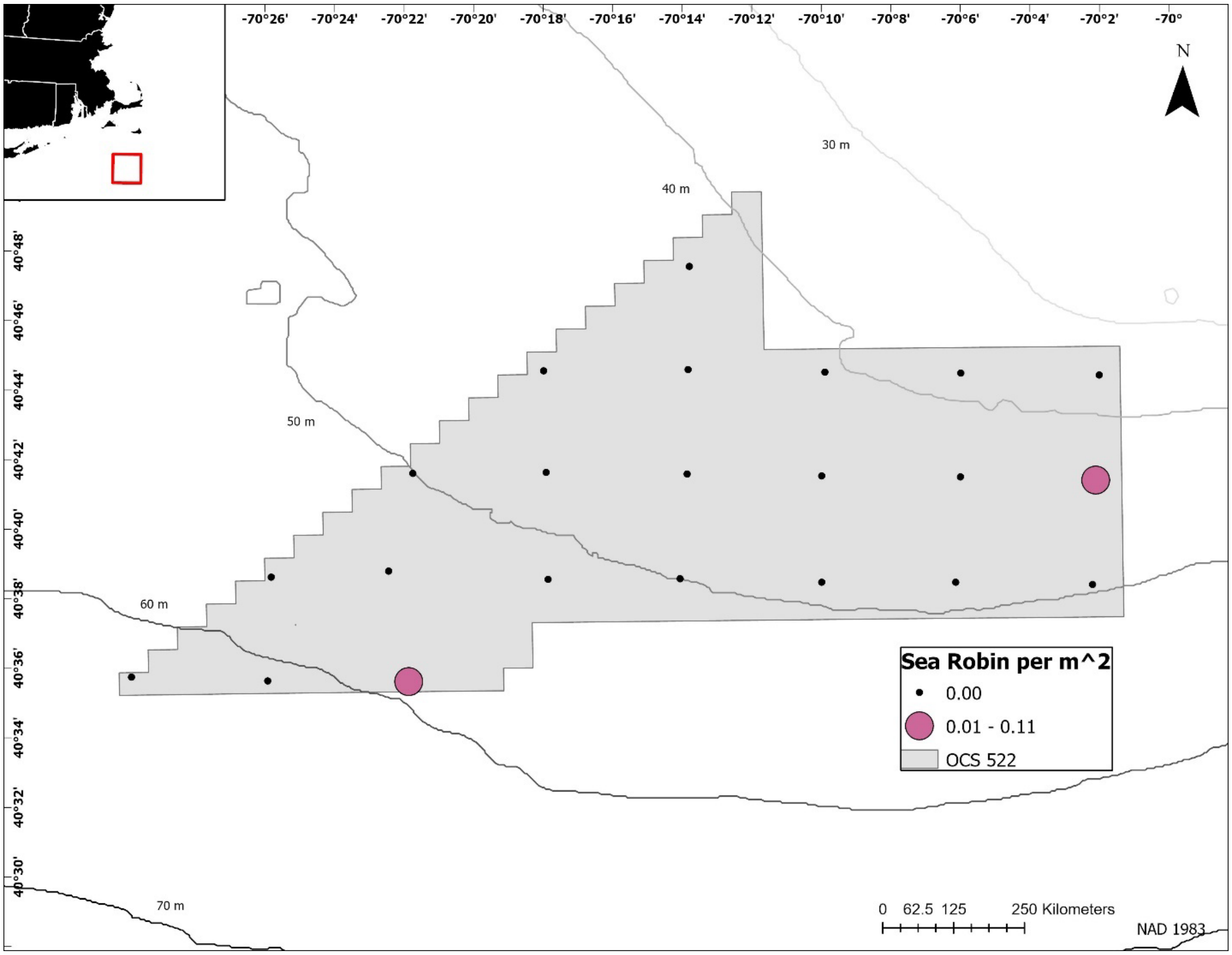


Figure 21. The distribution of sea robin from the fall 2023 drop camera survey of the 522 Study Area. No sea robins were observed in the summer 2023 survey period. Density categories represent zero or one sea robin observed per station in the fall 2023 survey period.

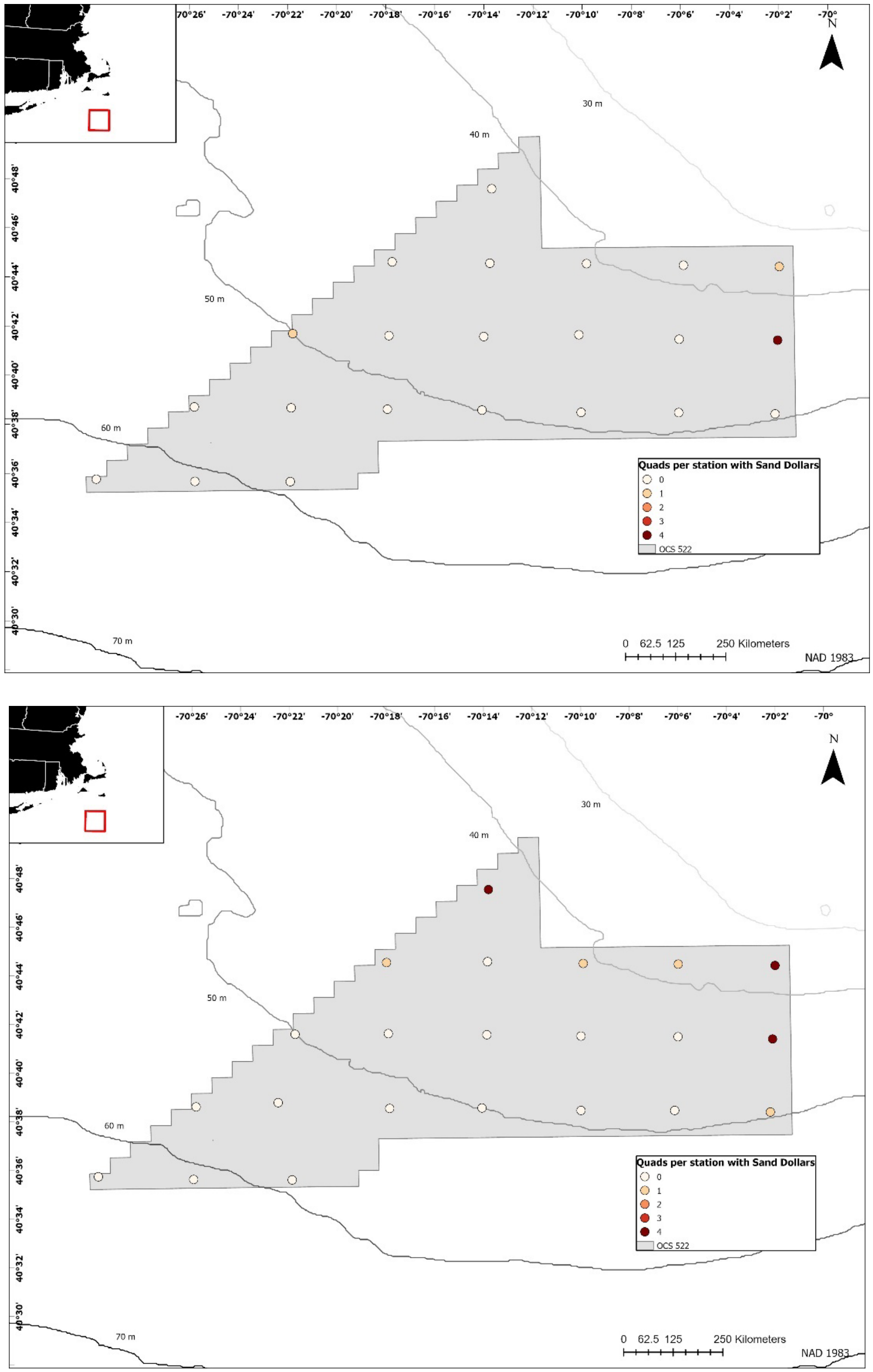


Figure 22. The distribution of sand dollars from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that sand dollars were observed as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

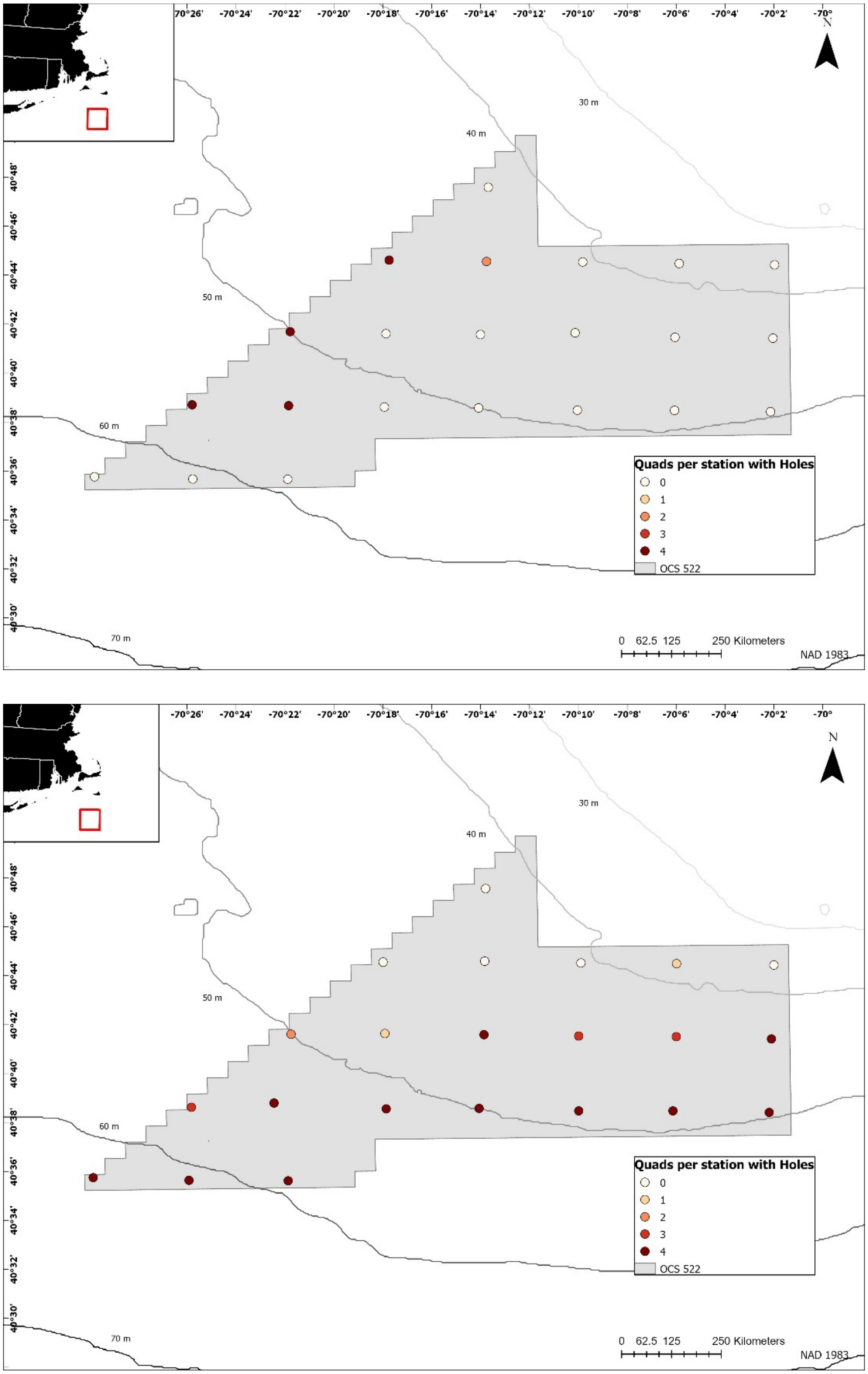


Figure 23. The distribution of holes (burrowing animals) from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that holes (burrowing animals) were observed as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

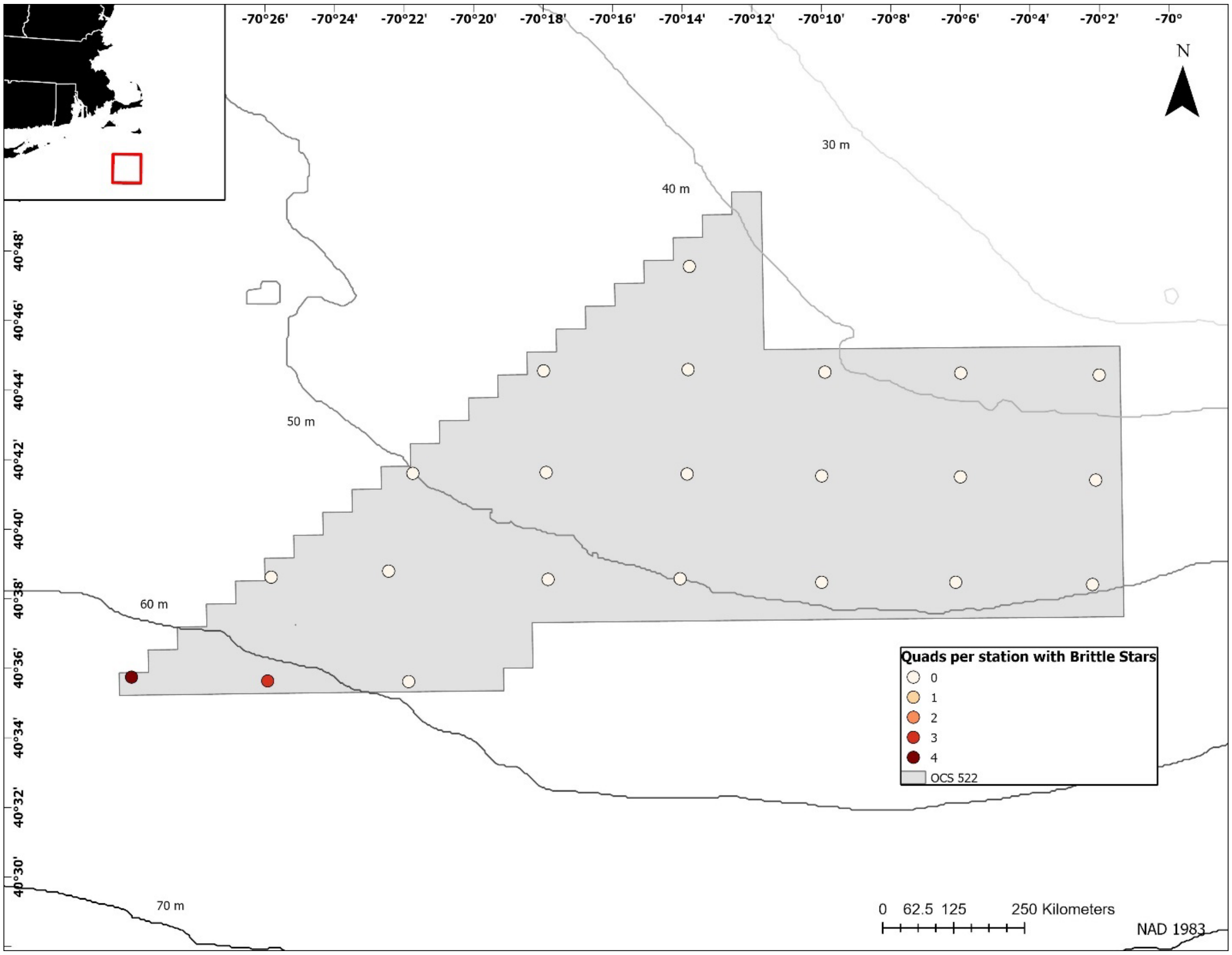


Figure 24. The distribution of brittle stars from the fall 2023 drop camera survey of the 522 Study Area. Each station is colored by the number of quadrats that brittle stars were observed as indicated in the figure legend. No brittle stars were observed in the summer 2023 survey period. Four quadrats (2.3 m^2 images) were observed at each station.

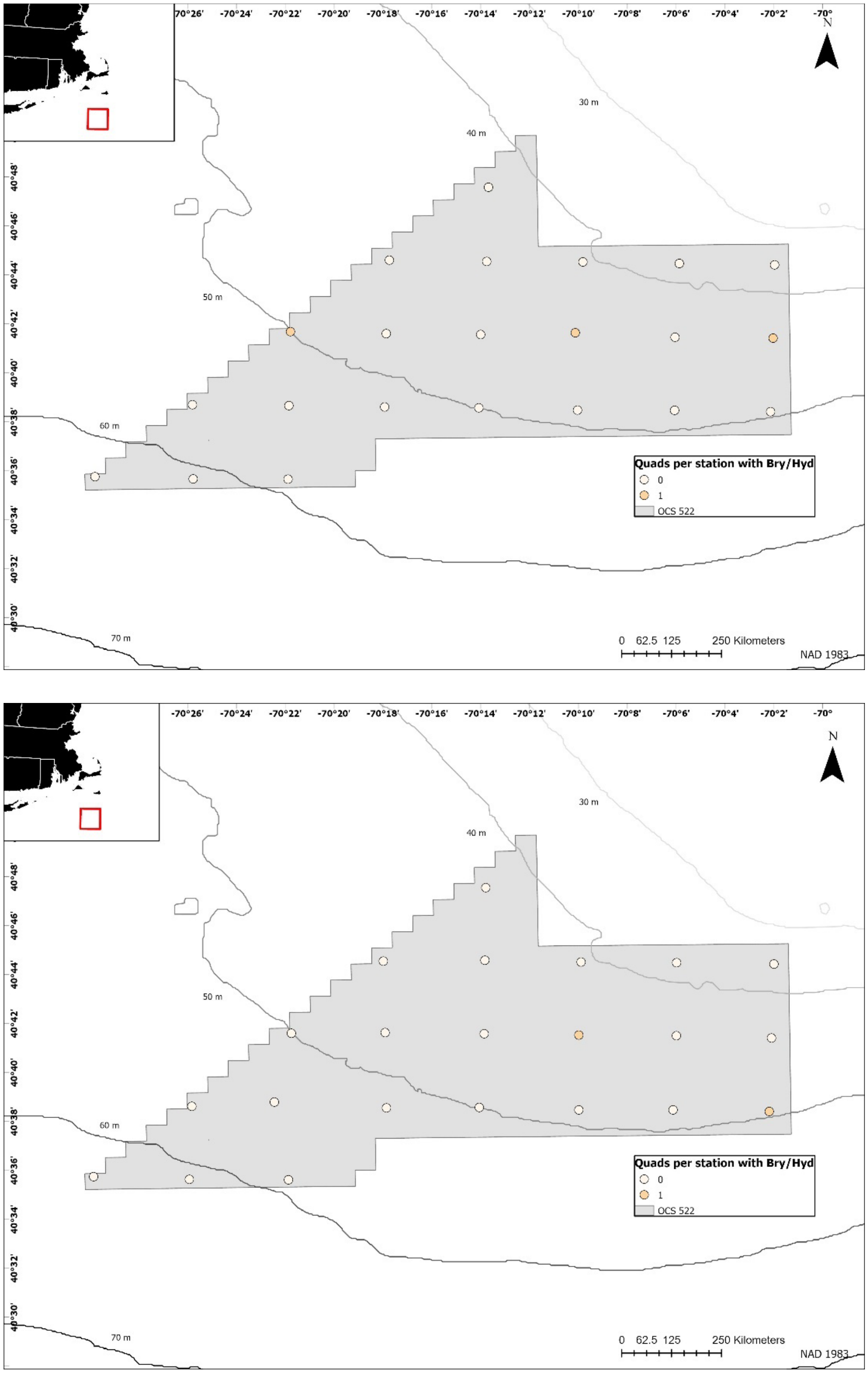


Figure 25. The distribution of bryozoans and hydrozoans from the summer 2023 (top) and fall 2023 (bottom) drop camera surveys of the 522 Study Area. Each station is colored by the number of quadrats that bryozoans and hydrozoans were observed as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

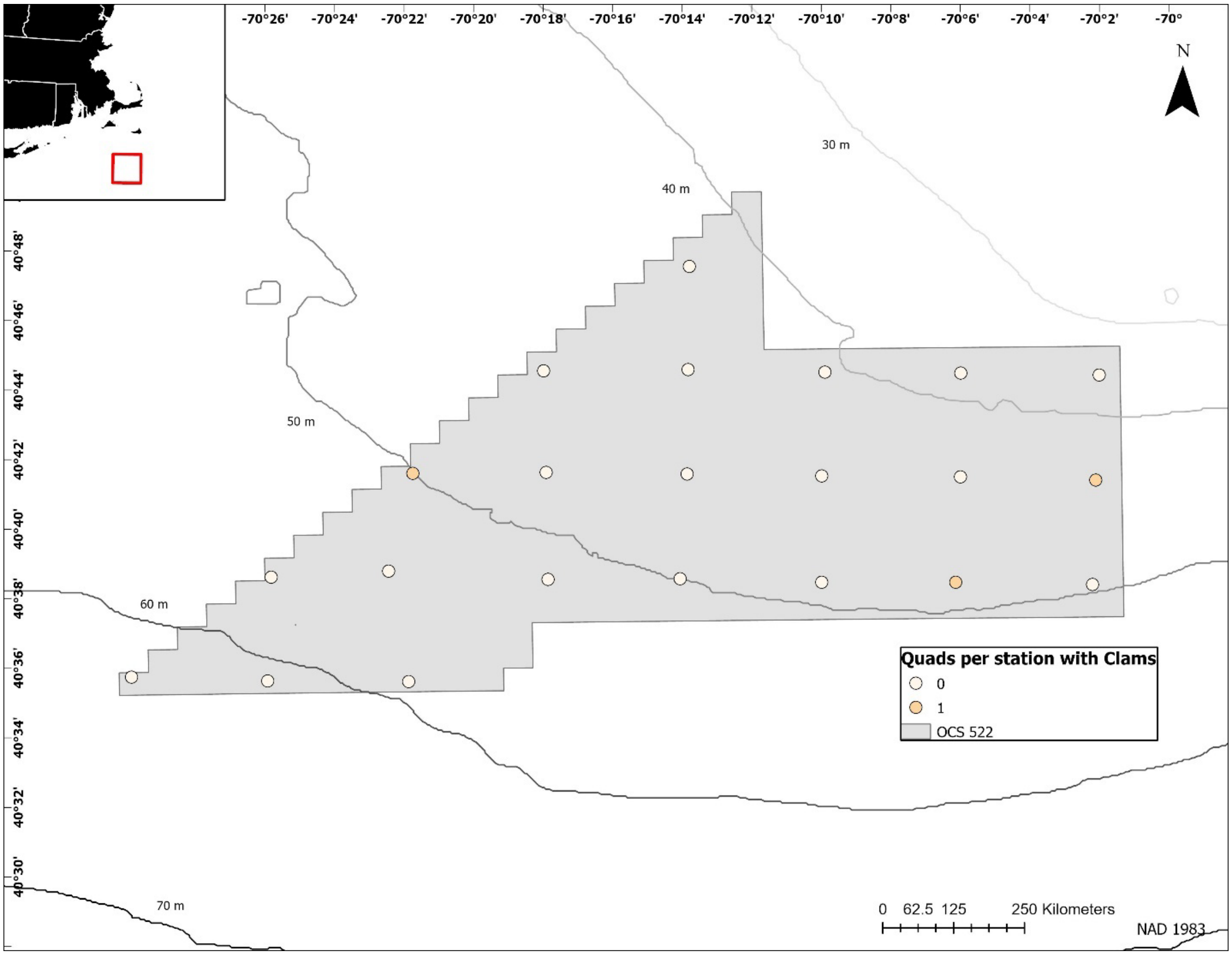


Figure 26. The distribution of clams from the fall 2023 drop camera survey of the 522 Study Area. Each station is colored by the number of quadrats that clams were observed as indicated in the figure legend. No clams were observed in the summer 2023 survey period. Four quadrats (2.3 m^2 images) were observed at each station.

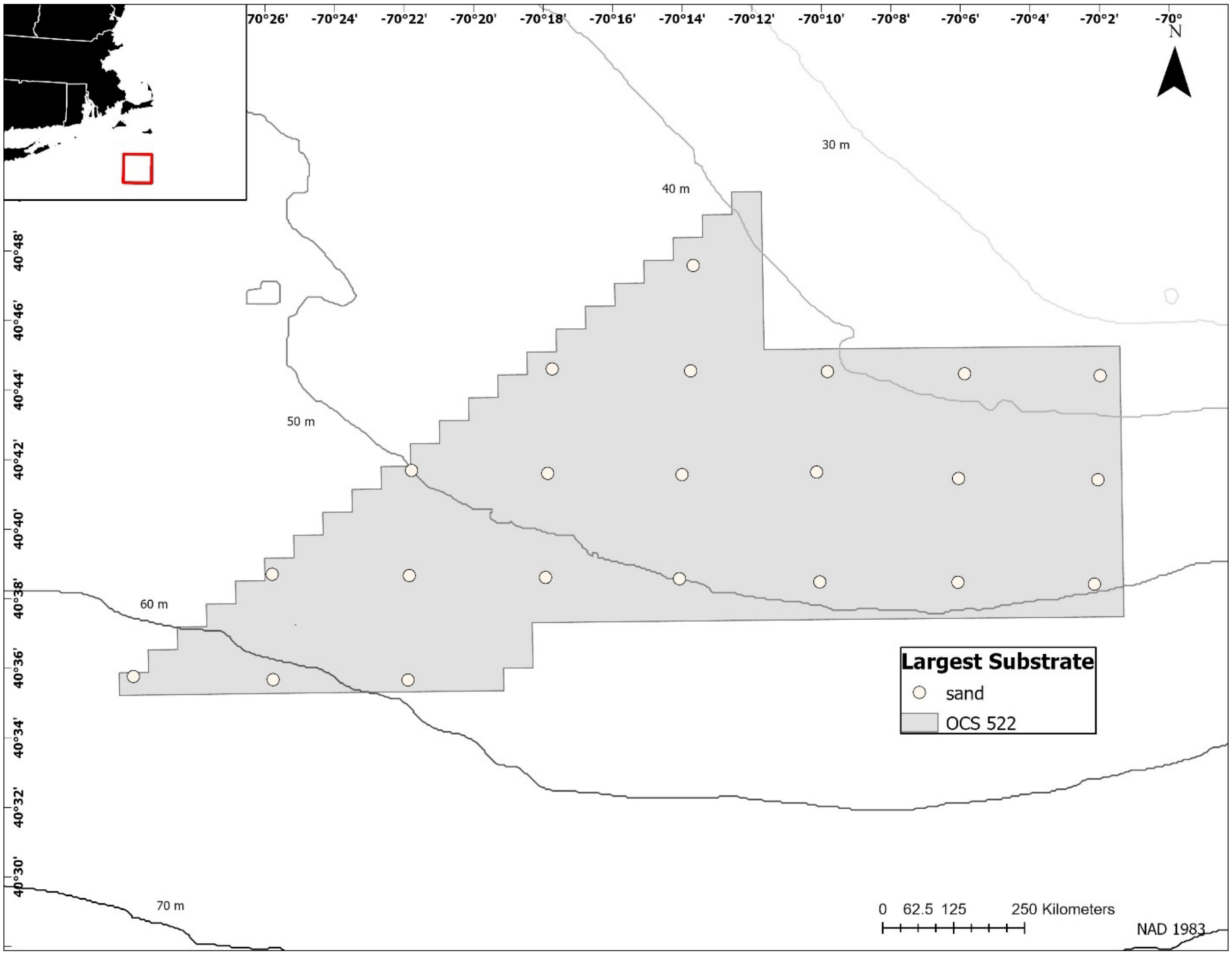


Figure 27. The distribution of the largest observed substrate type from the summer 2023 drop camera survey of the 522 Study Area. Four quadrats (2.3 m^2 images) were observed at each station. Note that more comprehensive efforts have been completed by Vineyard Offshore to classify the benthic habitat in Lease Area OCS-A 0522 and are reported elsewhere.

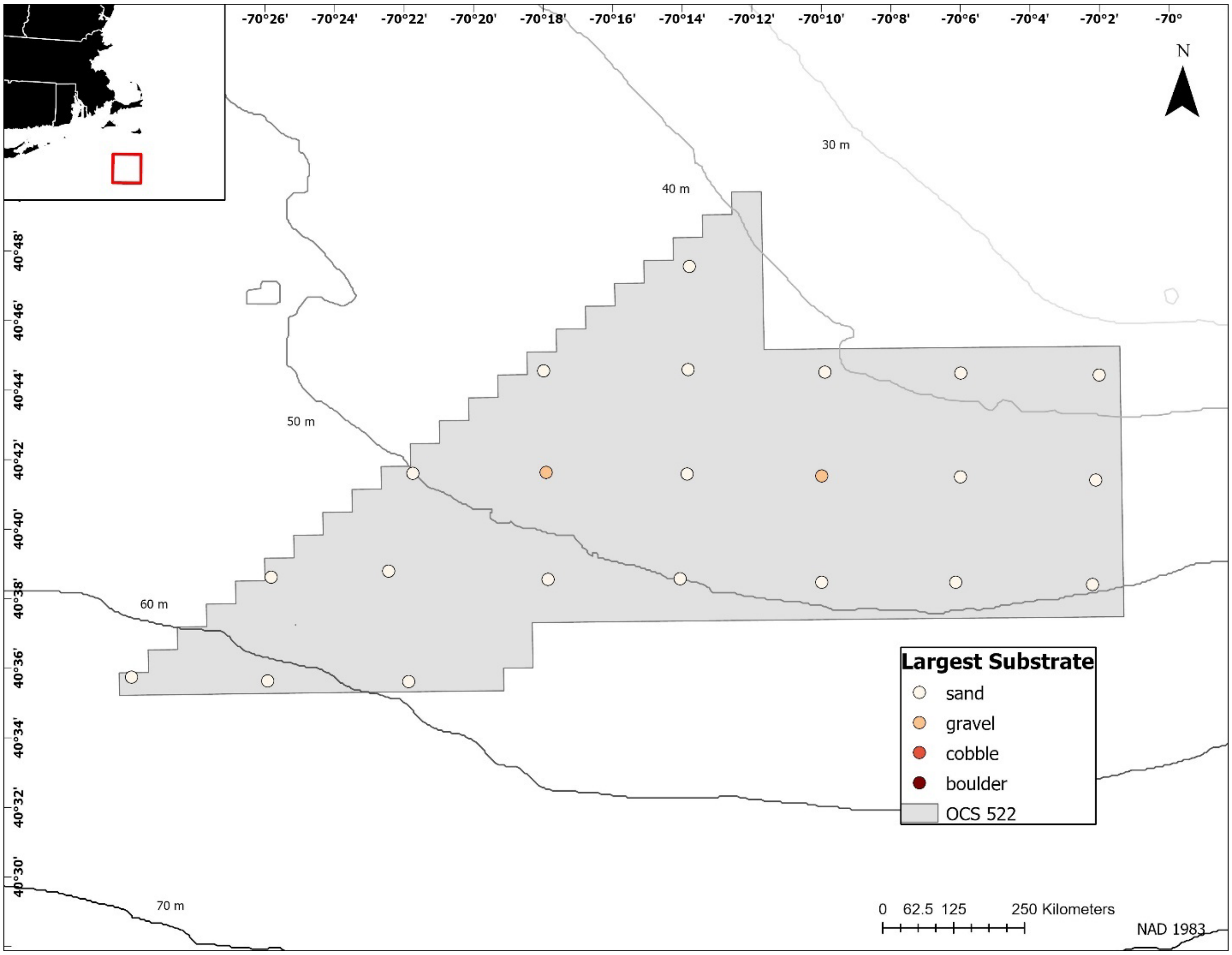


Figure 28. The distribution of the largest observed substrate type from the fall 2023 drop camera survey of the 522 Study Area. Four quadrats (2.3 m^2 images) were observed at each station. Note that more comprehensive efforts have been completed by Vineyard Offshore to classify the benthic habitat in Lease Area OCS-A 0522 and are reported elsewhere.

References

Asci SC, Langton RW, Stokesbury KDE (2018) Estimating similarity in benthic communities over decades and in areas open and closed to fishing in the central Gulf of Maine. *Mar. Ecol. Prog. Ser.* 595: 15-26.

Bethoney ND, Zhao L, Chen C, Stokesbury KDE (2017) Identification of persistent benthic assemblages in areas with different temperature variability patterns through broad-scale mapping. *PLoS ONE* 12 (5), e0177333. https://doi.org/10.1371/journal.pone.0177333.

Bethoney ND, Stokesbury K (2018) Methods for Image-based Surveys of Benthic Macroinvertebrates and Their Habitat Exemplified by the Drop Camera Survey for the Atlantic Sea Scallop. *J. Vis. Exp.* (137), 57493. doi:10.3791/57493.

Cochran WG (1977) Sampling Techniques 3rd Edition. John Wiley & Sons, New York.

Eberhardt LL (1976) Quantitative ecology and impact assessment. *J. Environ. Manage*. 4, 27–70.

Ellis JI, Schneider DC (1997) Evaluation of a gradient sampling design for environmental impact assessment. *Environ. Monit. Assess.* 48, 157 – 172.

Green RH (1979) Sampling Design and Statistical Methods for Environmental Biologists. Wiley, Chichester, UK.

Guida V, Drohan A, Welch H, McHenry J, Johnson D, Kentner V, Brink J, Timmons D, Estela-Gomez E (2017) Habitat Mapping and Assessment of Northeast Wind Energy Areas. Sterling, VA: US Department of the Interior, BOEM. OCS Study BOEM 2017-088. 312 p.

Harris BP, Stokesbury KDE (2010) The spatial structure of local surficial sediment characteristics on Georges Bank, USA. *Cont. Shelf. Res.* 30, 1840-1853.

Harris BP, Cowles GW, Stokesbury KDE (2012) Surficial sediment stability on Georges Bank in the Great South Channel and on eastern Nantucket Shoals. *Cont. Shelf. Res.* 49, 65-72.

Kerr LA, Kritzer JP, Cadrin SX (2020) Strengths and limitations of before–after–control–impact analysis for testing the effects of marine protected areas on managed populations, *ICES J. Mar. Sci.*, fsz014, https://doi.org/10.1093/icesjms/fsz014.

Krebs CJ (1989) Ecological methodology. Harper & Row, New York.

Lego, C, Morgan, B, Delargy, A, Stokesbury, KDE (2023) 2021/2022 Drop Camera Surveys of Benthic Communities and Substrate in Vineyard Wind 1 Lease Area OCS-A 0501 and a Control Area. University of Massachusetts Dartmouth - SMAST, New Bedford, MA. SMAST-CE-REP-2023-075. 68 pp.

Lincoln RJ, Boxshall GA, Clark PF (1992) A dictionary of ecology, evolution, and systematics. Cambridge University Press, Cambridge.

MacDonald AM, Adams CF, Stokesbury KDE (2010) Abundance estimates of skates (*Rajidae*) on the continental shelf of the northeastern USA using a video survey. *Trans. Am. Fish. Soc.* 139, 1415-1420.

Marino II MC, Juanes F, Stokesbury KDE (2009) Spatio-temporal variations of sea star *Asterias* spp. distributions between sea scallop *Placopecten magellanicus* beds on Georges Bank. *Mar. Ecol. Prog. Ser.* 382, 59–68.

NEFSC (Northeast Fisheries Science Center) (2010) Stock assessment for Atlantic sea scallops in 2014. In: 59th Northeast Regional Stock Assessment Workshop (59th SAW) Assessment Report. U.S. Dept. of Commerce, NEFSC Ref. Doc. 14-09.

NEFSC (2018) Sea scallop assessment summary for 2018. In: 65th Northeast Regional Stock Assessment Workshop (65th SAW) Assessment Summary Report. U.S. Dept of Commer, Northeast Fish Sci Cent Ref Doc 18-08, p 13-19.

Rosellon-Druker J, Stokesbury KDE (2020) Characterization and quantification of echinoderms (Echinodermata) on Georges Bank and the potential role of marine protected areas on these populations. *Invert. Biol.* 132(2): https://doi.org/10.1111/ivb.12243.

Sokal RR, Rohlf FJ (2012) Hypothesis testing and interval estimation. Pages 119–176 *in* M. Rolfes, editor. Biometry, 4th edition. Freeman, New York, New York.

Smith E (2006) BACI Design. Encyc. of Environmetrics. Vol. 1, pp141-148 https://doi.org/10.1002/9781118445112.stat07659.

Stokesbury KDE, Himmelman JH (1993) Spatial distribution of the giant scallop *Placopecten magellanicus* in unharvested beds in the Baie des Chaleurs, Québec. *Mar. Ecol. Prog. Ser.* 96, 159-168.

Stokesbury KDE, Himmelman JH (1995) Examination of orientation of the giant scallop, *Placopecten magellanicus*, in natural habitats. *Can. J. Zool.* 73, 1945-1950.

Stokesbury KDE (2002) Estimation of Sea Scallop Abundance in Closed Areas of Georges Bank, USA. *Trans. Am. Fish. Soc.* 131:1081–1092.

Stokesbury KDE, Harris BP (2006) Impact of limited short-term sea scallop fishery on epibenthic community of Georges Bank closed areas. *Mar. Ecol. Prog. Ser*. Vol 307: 85-100.

Stokesbury KDE, Harris BP, Marino MC, Nogueira JI (2004) Estimation of sea scallop abundance using a video survey in off-shore US waters. *J. Shellfish Res.* Vol 23, No. 1, 33-40.

Stokesbury KDE, Riley C, Lego C, Cassidy C (2022) 2020 Drop Camera Survey of Benthic Communities and Substrate in the 501N Study Area and a Control Area. University of Massachusetts Dartmouth - SMAST, New Bedford, MA. SMAST-CE-REP-2021-075. 61 pp.

Underwood AJ (1991) Beyond BACI: experimental designs for detecting human and environmental on temporal variations in natural populations. *Aust. J. Mar. Freshwater Res.* 42: 569–587.

Underwood AJ (1993) The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. *Australian J. Ecol.* 18: 99–116.

<u>Appendix I:</u> Species list and visibility information

Table I-1. A list of Georges 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

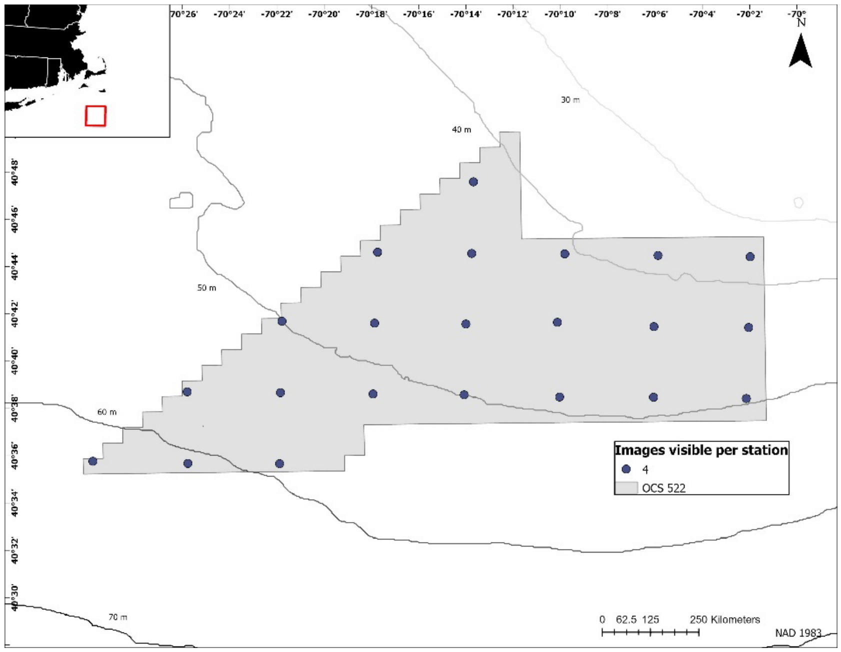


Figure I-1. The distribution of quadrat image visibility per station for the summer 2023 drop camera survey. The color of the stations represents the number of quadrats that were visible as indicated in the figure legend.

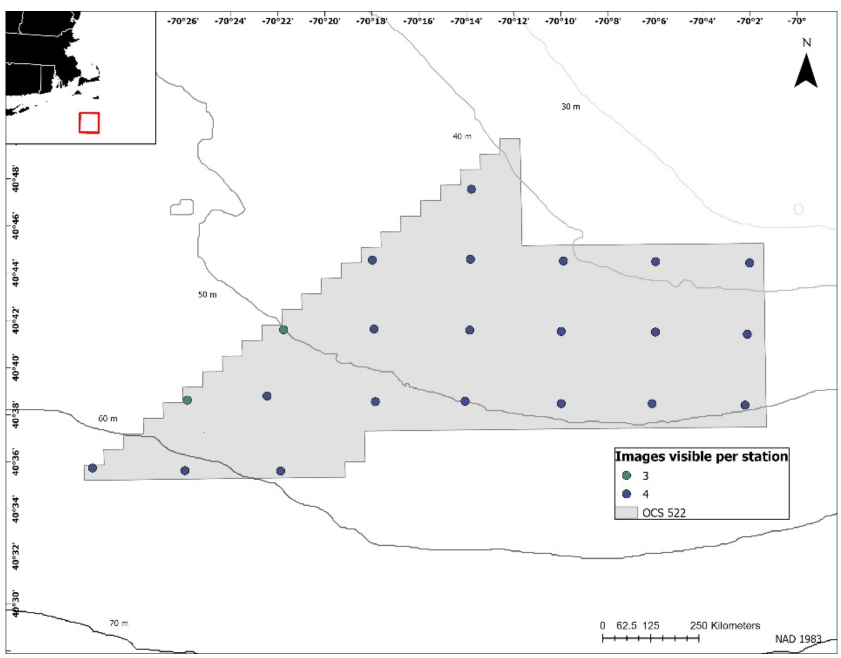


Figure I-2. The distribution of quadrat image visibility per station for the fall 2023 drop camera survey. The color of the stations represents the number of quadrats that were visible as indicated in the figure legend.