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Final Report

2021/2022 Drop Camera Surveys of Benthic Communities and Substrate in the Vineyard Wind 1 Lease Area OCS-A 0501 and a Control Area

Submitted to:
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Final Report

2021/2022 Drop Camera Surveys of Benthic Communities and Substrate in the Vineyard Wind 1 Lease Area OCS-A 0501 and a Control 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 Wind 1 LLC's (Vineyard Wind) Lease Area OCS-A 0501 and a Control Area adjacent to the lease area. The primary goal of this project was to collect baseline data for future environmental assessment of wind farm development impacts. Our objectives were to provide:

1) distribution and density estimates of dominant benthic megafauna,
2) classify substrate types at drop camera stations across the survey domain,
3) compare benthic communities and substrate types between the development area, Control Area, and broader regions of the United States (US) Atlantic Outer Continental Shelf (OCS), and
4) classify substrate within aliquots sampled by the American Lobster, Black Sea Bass, Larval Lobster Abundance Survey, And Lobster Tagging Study (an associated SMAST trap survey also conducted for Vineyard Wind). These aliquots coincided with a subset of the drop camera stations.

A centric systematic sampling design was used to survey stations with the drop camera in Lease Area OCS-A 0501 (termed the "VW1 Study Area") and an adjacent Control Area.[1] Stations in the two areas were placed 1.5 kilometers (km) apart following a grid design. At each station, a sampling pyramid was deployed and a high-resolution camera was used to take four quadrat (2.3 square meter [m^2] images) samples. Both areas were surveyed in May 2021 and May 2022 using a commercial scallop fishing vessel to deploy the sampling pyramid.

The benthic community of the VW1 Study Area and Control Area in 2021 and 2022 continued to be dominated by benthic invertebrates such as sand dollars, hermit crabs, waved whelks (*Buccinum undatum*, not the commercially harvested channeled whelk, *Busycotypus canaliculatus*), anemones, crabs (cancer spp.), and burrowing species. The vertebrates included in the dominant benthic community were skates, silver hake, and red hake. The density of the dominant benthic animals found in the VW1 Study Area and Control Area was similar in both years except for hermit crabs, which had a higher density in the VW1 Study Area in 2021 and a higher density in the Control Area in 2022. By contrast, most of the taxa recorded as present or absent in a quadrat were observed in more quadrats per station in the VW1 Study Area in 2021 and 2022 (aside from bryozoans, hydrozoans, and anemones). Overall, there was an increase in the amount and frequency of all animal taxa from 2021 to 2022. The confidence intervals associated with the estimates of dominant benthic megafauna prevalence and the ability to detect significant differences show this sampling intensity is adequate for statistical comparison of variance between study and control sites over time.

The drop camera survey results indicated the substrates in the VW1 Study Area and Control Area were dominated by sand in 2021 with sparse gravel; no cobble or boulders were

[1] The Bureau of Ocean Energy Management segregated Lease Area OCS-A 0501 into two lease areas – OCS-A 0501 and OCS-A 0534 – in June 2021. The VW1 Study Area, which is in the area designated as Lease Area OCS-A 0501, is referred to as the "501N Study Area" in SMAST fisheries survey reports compiled prior to the lease area segregation. Similarly, the 534 Study Area, which is designated as Lease Area OCS-A 0534, is referred to as the 501S Study Area in SMAST fisheries survey reports compiled prior to the lease area segregation.

observed. By 2022, the substrates were still dominated by sand, but some gravel, cobble, and boulders were observed. The benthic community of the VW1 Study Area and Control Area were most like each other, compared to the selected broader control regions of the US Atlantic OCS in both 2021 and 2022. Benthic communities and substrates became more similar from 2021 to 2022 in the VW1 Study Area and Control Area. The similarity of control areas to the VW1 Study Area decreased within increasing distance between the areas. The substrate within designated lobster trap survey aliquots was also assessed by the drop camera and was entirely comprised of sand in 2021 and sand, gravel, or cobble in 2022.

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Introduction

In 2015, Vineyard Wind leased a 675 square kilometer (km^2) area for renewable energy development on the US Atlantic OCS, referred to as Lease Area OCS-A 0501. This lease area is located approximately 14 miles south of Martha's Vineyard in Massachusetts. Vineyard Wind is developing Lease Area OCS-A 0501 and fisheries studies are being conducted in a 250 km^2 area referred to as the "VW1 Study Area", which is the focus of this report. Vineyard Wind is also conducting lobster trap and larval studies in the VW1 Study Area and Control Area. Additional fisheries studies are being conducted in Lease Area OCS-A 0522 and Lease Area OCS-A 0534; these studies are reported separately.

The SMAST drop camera system was used for fisheries studies in the VW1 Study Area and Control Area. This system is an image-based drop camera survey that allows for optical sampling of the epibenthic community with minimum disturbance to the seafloor. The 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 scallop fishery and the survey 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 reliably provided to the New England Fisheries Management Council to aid in annual scallop quota harvest allocation (NEFSC, 2010; 2018).

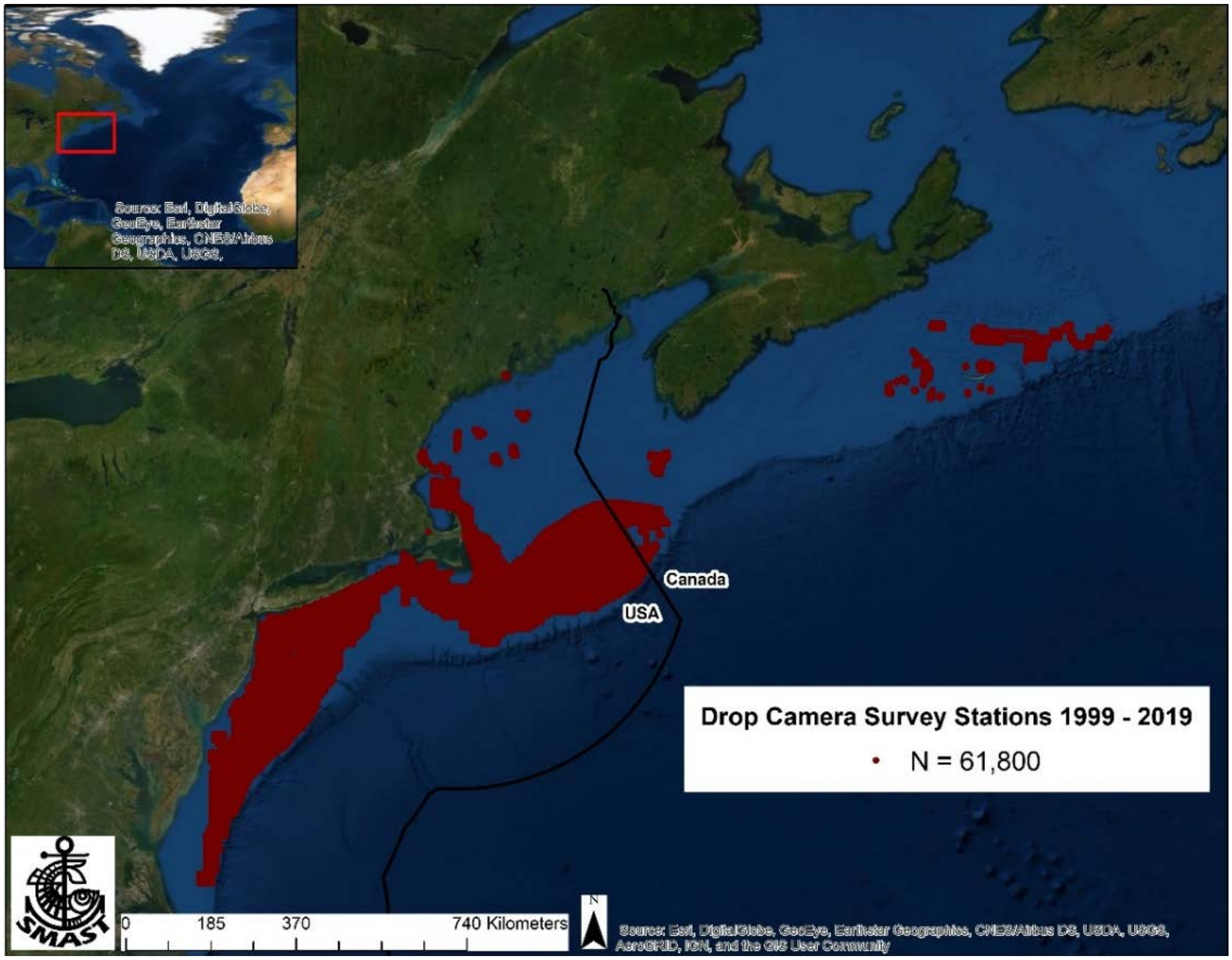


Figure 1. The spatial extent of SMAST drop camera surveys in eastern US and Canadian waters. All stations surveyed from 1999 to 2019 are displayed in red.

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). Survey data have contributed to several ecosystem-based management activities, such as the New England Fisheries Management Council Swept Area Seabed Study 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 Atlantic longfin squid (*Doryteuthis pealeii*) egg clusters or habitat-forming filamentous fauna (bryozoans or hydrozoans), can be identified and counted using drop camera surveys (Figure 2).

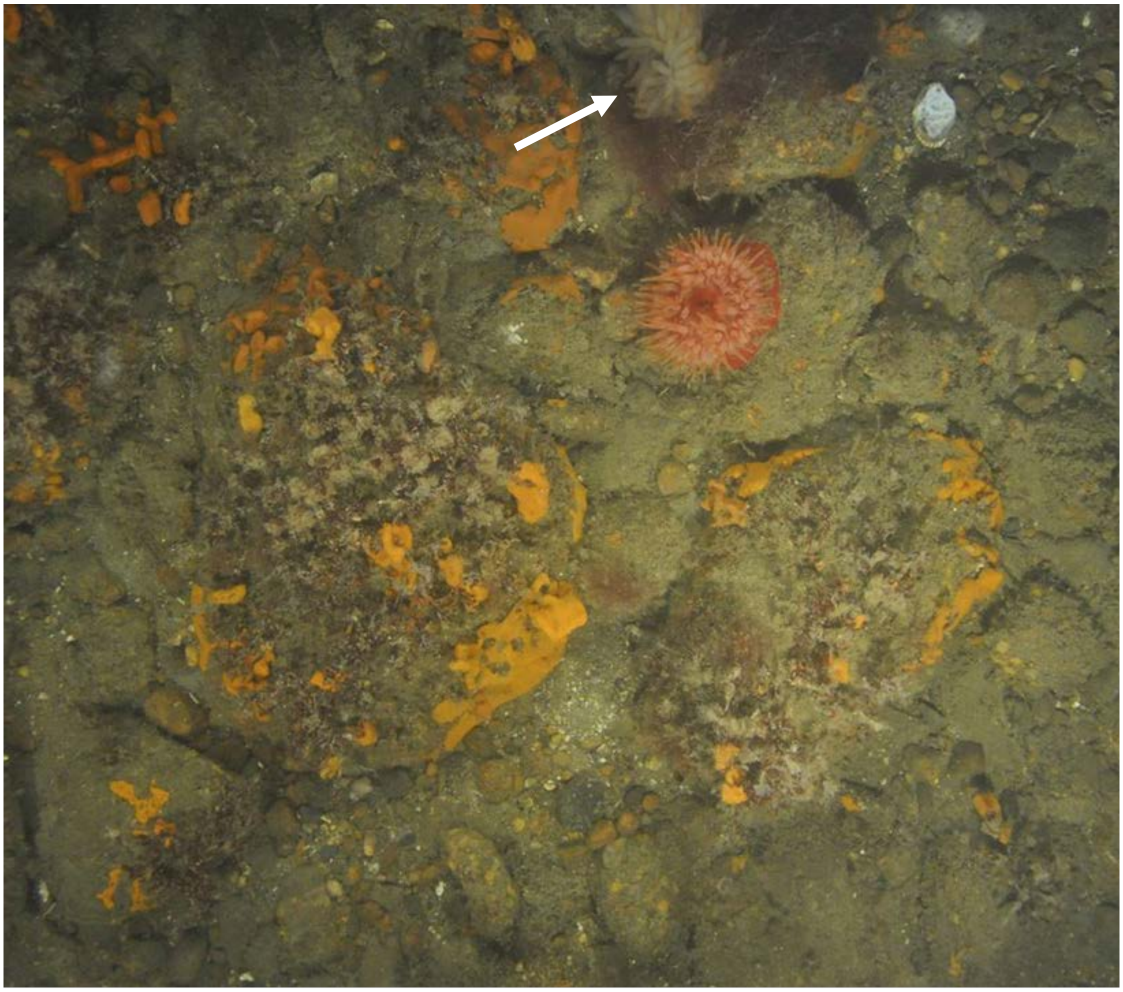


Figure 2. Example of a digital still image taken by the SMAST drop camera survey in complex habitat of the Rhode Island Wind Energy Lease Area on Cox's Ledge during a survey in 2013. An Atlantic longfin squid egg cluster was present (top, middle).

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 wind development, and to what extent the ecological components were affected (Smith, 2006). The Before-After Control-Impact (BACI) approach is an experimental design for assessing 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 VW1 Study Area, but containing similar environments and communities, was 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 study site, incorporating the concepts of Beyond BACI (Underwood, 1993) and Before After Gradient (Ellis and Schneider, 1997). The drop camera survey data can be used to compare epibenthic faunal distributions between study and control sites over time. The drop camera surveys will aid in building a regional, standardized baseline dataset needed to address development impacts on epibenthic communities and habitats. From this study, the data collected can be used to provide preliminary estimates of density and distributions and enable 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 monitoring the development of the area.

Goal and Objectives

The primary goal of this project is to provide baseline epibenthic faunal and substrate habitat data for future environmental assessment of wind development in the VW1 Study Area (Figure 3). The preliminary data were gathered using drop camera surveys in the VW1 Study Area (development area) and a nearby Control Area during two different time periods 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 VW1 Study Area and Control Area and this helped identify the sampling intensity needed for future statistical tests and surveys. These objectives will also document seasonal and/or annual changes in distribution and density.

3) Compare benthic communities and substrate types between the development area, control area, and broader control regions on the US Atlantic OCS.

This objective is related to identifying multiple control areas at differing distances from the development area.

4) Classify substrate within aliquots sampled by SMAST's associated American Lobster, Black Sea Bass, Larval Lobster Abundance Survey, and Lobster Tagging Study (trap survey) of the Study and the Control Areas.

This objective leverages drop camera data to provide habitat information for the trap survey.

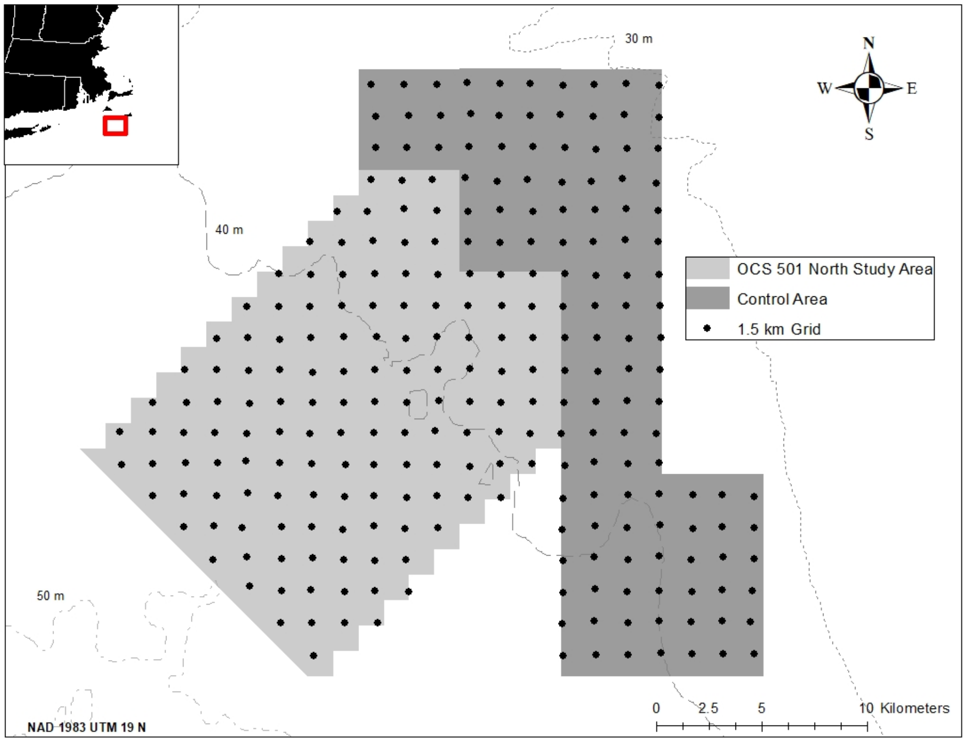


Figure 3. The 2021 and 2022 drop camera survey station grid in the VW1 Study Area and an adjacent Control Area.

Methods

A centric systematic grid design was used to sample survey stations in the VW1 Study Area and Control Area. Stations in the two areas were situated 1.5 km apart (Figure 3). A sampling pyramid was deployed at each station and a high-resolution camera was used to take four quadrat samples (Figure 4). Both areas were surveyed in May 2021 and May 2022 using a commercial scallop vessel to deploy the sampling pyramid. The Control Area was defined as an adjacent area with the same latitude boundaries (40.93 to 41.14 decimal degrees) as the VW1 Study Area in waters deeper than 30 meters (m) that did not overlap with wind lease areas (Figure 3). This resulted in water depths in the VW1 Study Area potentially being deeper than the Control Area, but the Control Area offered the best location for a control site near the development area. The Control Area could have been moved further away to achieve similar depths but results from the 2012 and 2013 drop camera surveys of the Massachusetts Wind Energy Areas that provided preliminary data on this area indicated that a control area needed to be near the development site to ensure a similar assemblage of animals. The grid resolution was determined after an analysis of the variability of the dominant benthic invertebrates observed in the 2012 and 2013 surveys that suggested at least 60 stations, but ideally close to 200, were needed to provide an adequate sample size for a reliable analysis of variance (Krebs, 1989).

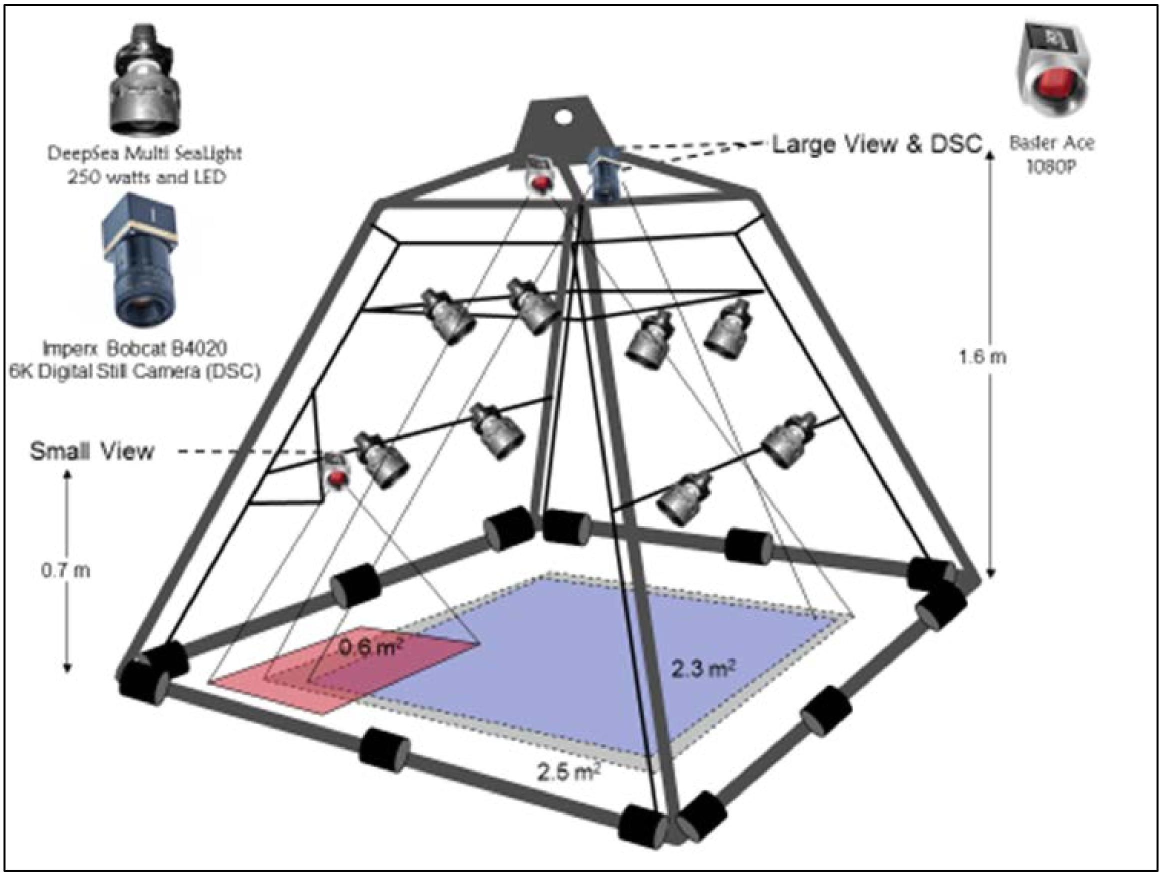


Figure 4. The SMAST drop camera survey pyramid with cameras and lights used for data collection. The camera used for the small view was turned to the side to provide a view parallel to the seafloor for some stations.

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 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. Additionally, a third camera providing 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 view 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 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 high-resolution digital still images were used as the primary data source (Figure 2). The other images and videos collected were used as digitizing aids to assist with the identification and counting of species. Within each quadrat, macrobenthos 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 counted or noted as present in the images (see Appendix I). In addition, Atlantic longfin squid egg clusters were counted when observed. Sediments were classified following the Wentworth particle grade scale from images, 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 analyses 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 as present or absent. 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.

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 VW1 Study Area and adjacent Control Area. A similar multi-stage approach was used to calculate mean presence values. Mean density or quadrats present per station of taxa and substrate were mapped and statistically compared between the development and control sites. This analysis focused on the most observed benthic animal groups in the VW1 Study Area and Control Area as these were detected at high enough rates for statistical analysis (Bethoney et al., 2017). Densities for animal groups were compared by graphing mean estimates with their associated 95% confidence intervals (Sokal and Rohlf, 2012).

A percent similarity index (Renkonen, 1938) was used to quantify the similarity between benthic community and substrate types between the VW1 Study Area, Control Area, and broader control areas (BCAs) on the US Atlantic OCS. This index compares relative proportions of taxonomic categories present in each area standardized as a percentage of the total categories observed. The approach uses species occurrence to assess the spatial dominance of species categories as opposed to the number of individuals observed as abundance comparisons will do. This allows for a more comprehensive model of the benthic communities, as rarer species will not be excluded due to the extraordinarily high abundance of the few dominant species. This comparison will include only species from Asci et al. (2018). These animals were sessile or exhibited locally mobile behavior and were identified in previous drop camera surveys for this comparison. Drop camera data from four areas similar in size and depth to the VW1 Study Area, but at increasing distances away, were used as BCAs. For 2021 and 2022 these BCA's were the Nantucket Lightship, the Great South Channel, Closed Area II Access Area and the Northern Edge (Figure 5). Surveys of these areas were conducted for sea scallop assessment in 2021 and 2022 and followed the same design and protocols as described above (Bethoney and Stokesbury, 2018). Comparisons were made between survey results on an annual basis (2021 and 2022) since the VW1 Study Area and Control Areawere surveyed only in May in both years (Figure 5). The BCAs are not in areas slated for wind energy development and could be used as BCA going forward depending on similarity index results.

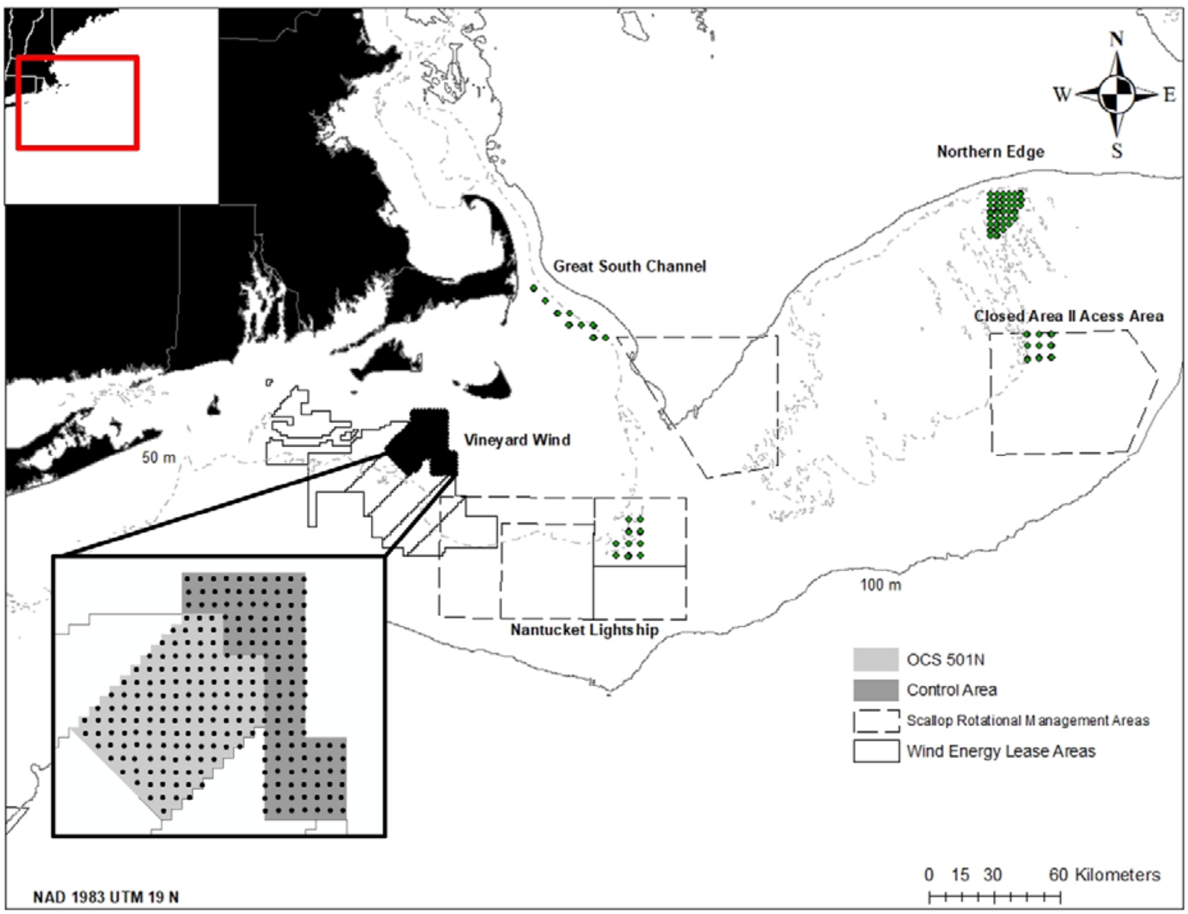


Figure 5. The locations of four broader control areas (BCAs) (green dots) that were compared to the VW1 Study Area and primary Control Area (black dots) to assess benthic community and substrate similarity using the drop camera survey. These areas include portions of the Nantucket Lightship, Great South Channel, Closed Area II Access Area, and the Norther Edge.

Results and Discussion

The two drop camera surveys of the VW1 Study Area and Control Area were conducted from May 18 – 23, 2021, and May 3 – 6, 2022. In each year, 124 stations were sampled in the Control Area and 131 stations were sampled in the VW1 Study Area. Due to high turbidity and silt in the water column, some stations within the southern portion of the Control Area were not visible in 2021. All images and videos collected were shared with Vineyard Wind. The results of this report primarily focused on the most observed benthic animals, as well as scallops, flat fish, and groundfish (Atlantic cod and haddock), due to their regional commercial importance. The substrate types observed are also detailed in this report. For general information on all categories tracked refer to Table 1 and Appendix I and II.

Table 1. The most frequently observed benthic animal groups and commercially important animal groups, in order of most to least quadrats present, during the May 2021 (left) and May 2022 (right) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Groups left blank in the "Counts" column are tracked as present or absent.

Animal Group	Quadrats Present	Counts	Animal Group	Quadrats Present	Counts
Sand Dollars	475		Holes (Burrowing Animals)	751	
Holes (Burrowing Animals)	213		Sand Dollars	555	
Hermit Crabs	109	145	Hermit Crabs	545	1634
Anemone	54		Whelk (Buccinum)	254	582
Sponges	34		Bryozoans/Hydrozoans	219	
Hake	29	29	Anemone	117	
Skates	19	19	Hake	80	94
Crabs	18	22	Silver Hake	80	105
Silver Hake	15	15	Moon snail	58	73
Bryozoans/Hydrozoans	13		Sponges	51	
Skate Egg Case	9	9	Crabs	39	42
Moon snail	8	8	Skates	36	36
Scallops	5	5	Flat Fish	34	35
Haddock	1	1	Scallops	10	10
Total Quadrats Sampled	1020		Total Quadrats Sampled	1020	

Visibility significantly improved from previous surveys in 2019 and 2020 (Bethoney et al., 2020; Stokesbury et al., 2022). Overall, 832 of the 1,020 quadrats sampled were visible in 2021 while 1,017 out of the 1,020 quadrats sampled were visible in 2022. An increase in the abundance or presence of animal groups occurred between 2021 and 2022 (Table 1; Figures 6 and 7). It is possible the better visibility during the 2022 survey increased our ability to quantify the organisms in images leading to the increase in total species observed. Future investigations are necessary to confirm the differences between seasonal and annual patterns detailed in this report and previous reports.

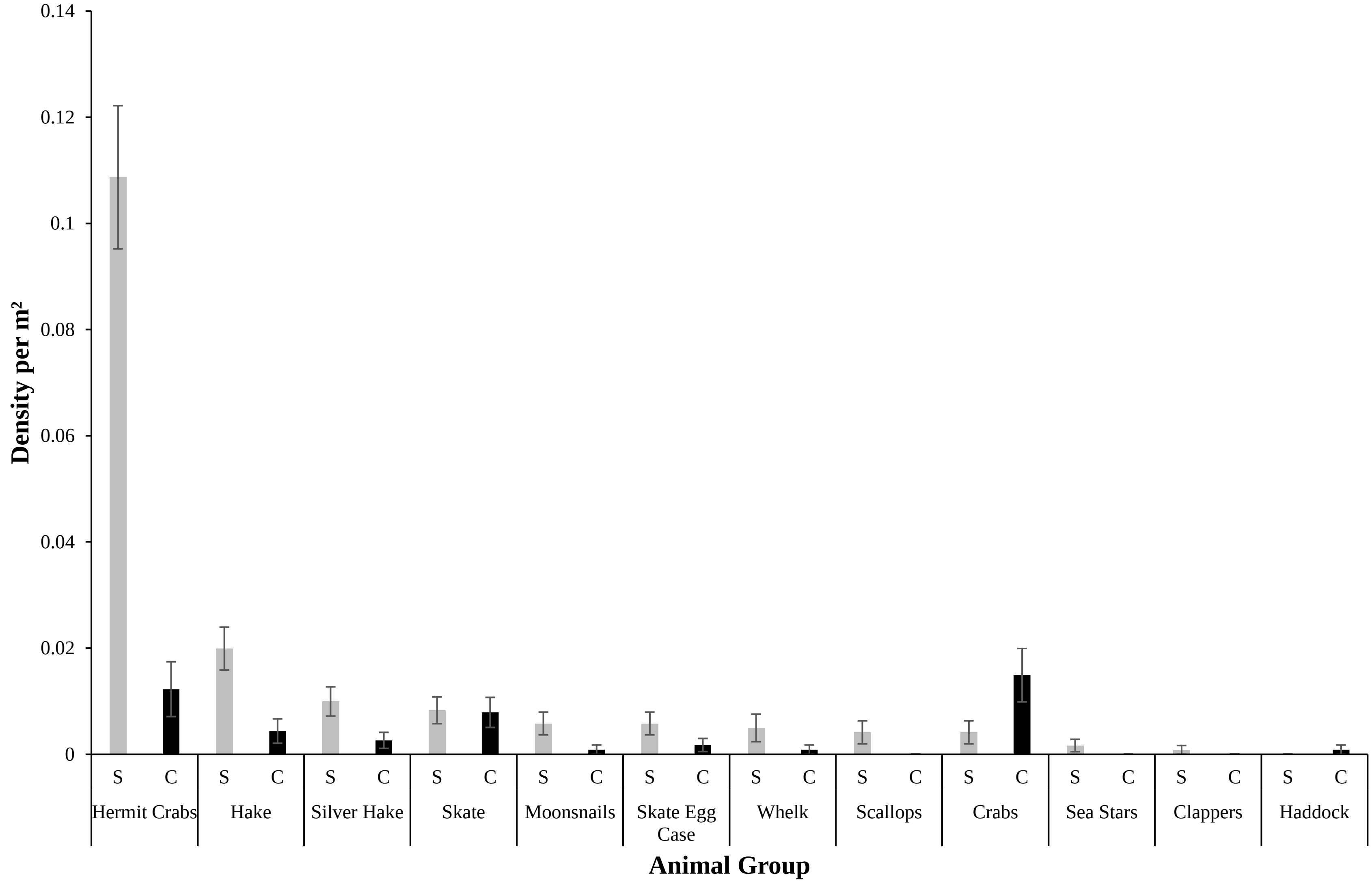


Figure 6. Densities of common or commercially important benthic animals in the May 2021 drop camera survey of the VW1 Study Area (S) and the adjacent Control Area (C). Error bars represent 95% confidence intervals.

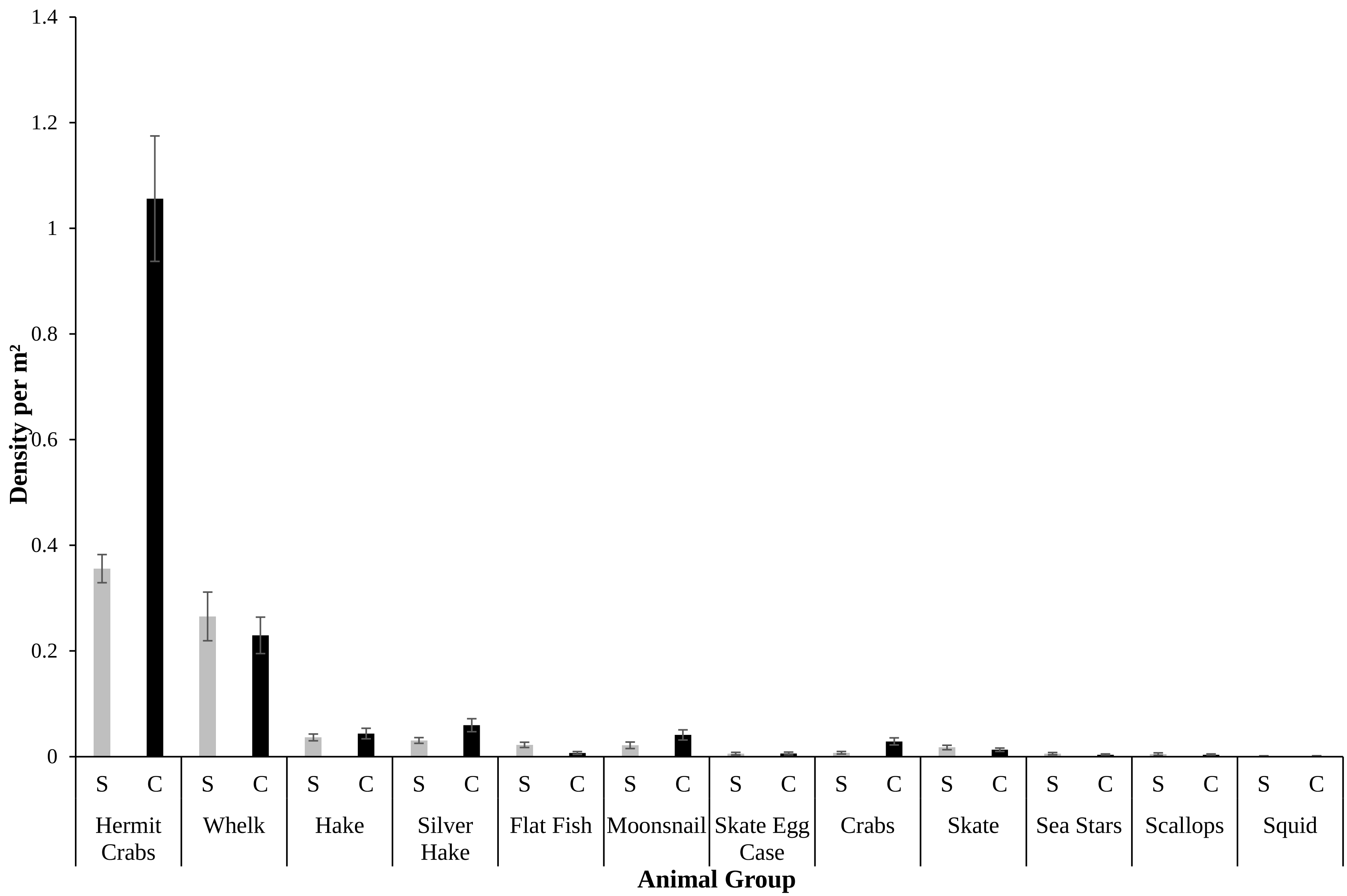


Figure 7. Densities of common or commercially important benthic animals in the May 2022 drop camera survey of the VW1 Study Area (S) and the adjacent Control Area (C). Error bars represent 95% confidence intervals.

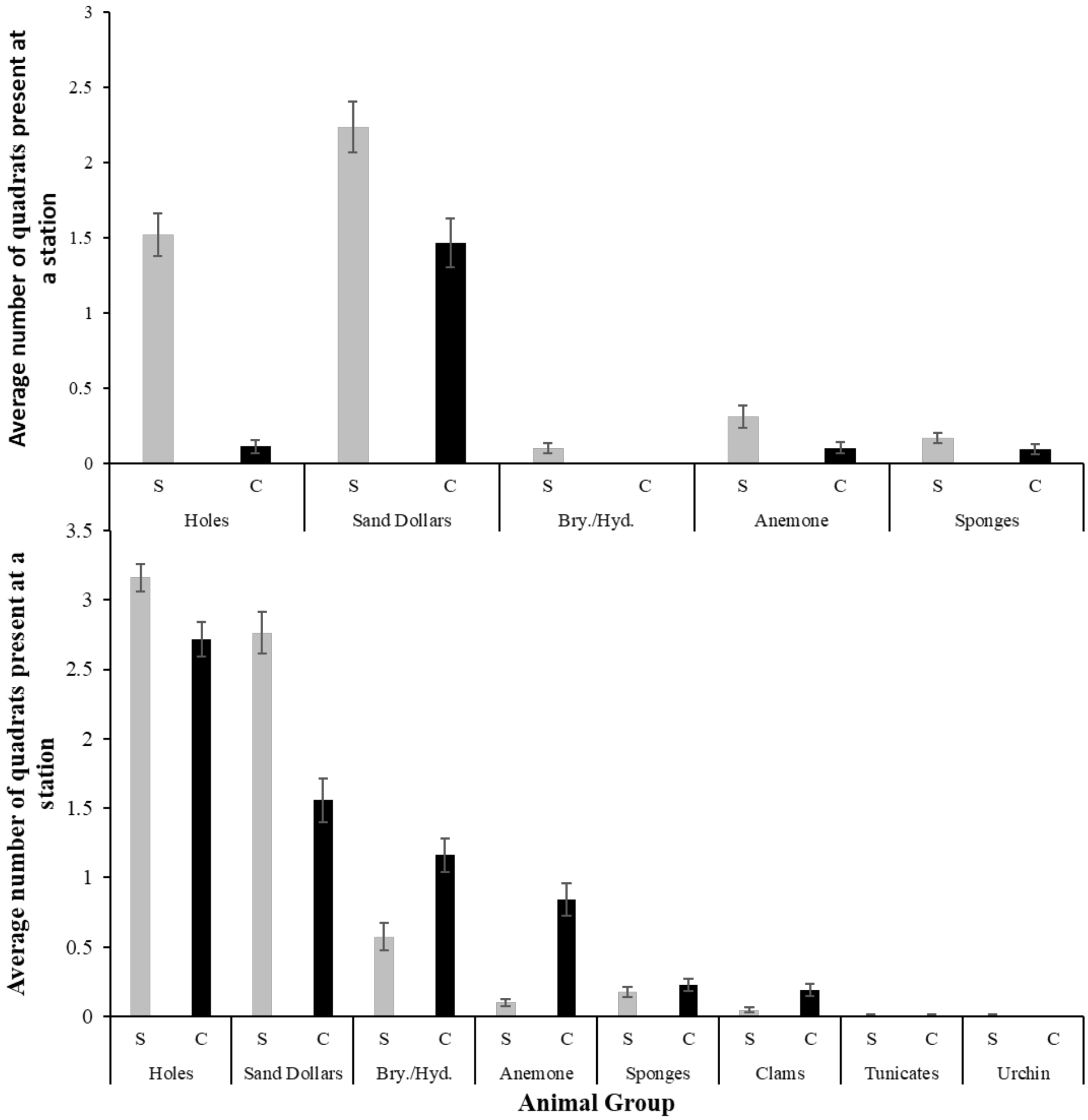


Figure 8. The average number of quadrats common benthic animals were present in at each station during the 2021 (top) and 2022 (bottom) drop camera surveys of the VW1 Study Area and adjacent Control Area. Four quadrats (2.3 m^2 in 2021 and 2022) were observed at each station. Holes represent burrowing animals and Bry./Hyd. indicates bryozoans and hydrozoans. Error bars represent 95% confidence intervals.

The densities of the most observed benthic animals found in the VW1 Study Area and Control Area were similar in both years (Figures 6 and 7). The one exception was hermit crabs *(Diogenidae spp. or Paguridae spp.*), which had a considerably higher density in the VW1 Study Area versus the Control Area in 2021 (Figure 6). However, the opposite was true in 2022 with hermit crab density higher in the Control Area compared to the VW1 Study Area (Figure 7). The species with the highest abundance in the May 2021 survey were crabs (Cancer spp.), skate (*Leucoraja* spp. or *Dipturus laevis*), red hake (*Urophycis chuss*), silver hake (*Merluccius bilinearis*), and hermit crabs (Figure 6). The species with the highest abundance in the May 2022 survey were hermit crabs, whelk (*Buccinum undatum)*, crabs, red hake, moon snail (*Euspira heros)*, and silver hake (Figure 7).

The distribution of all animals counted (estimated as individuals per m^2) changed between 2021 and 2022 (Figures 9 to 20). Density categories for animal distributions were divided into quartiles, if there were enough observed animals, where each category represents 25% of the observed data. If there were few observations per station (i.e., zero, one, or two animals) then these counts formed unique density categories. Silver hake, hermit crabs, whelk, red hake, and moon snails were distributed over a larger area in 2022 compared to 2021 (Figures 9, 12, 13, 14, and 18). Hermit crabs and whelk were distributed almost entirely over the whole survey domain in 2022.

There were more species observed in 2022 than in 2021. Clappers (recently dead *Placopecten magellanicus)* and haddock were observed in 2021 but not in 2022 (Figures 21 and 22). Monkfish (*Lophius americanus*), sculpin (*Myoxocephalus octodecemspinosus* or *Prionotus carolinus)*, sea robin (*Prionotus carolinus)*, squid, and flat fish were all observed in the 2022 survey but not in the 2021 survey (Figures 23 to 27). The visibility issues affected more stations in the southern portion of the Control Area in 2021, thereby limiting the value of the comparison in that area. Visibility was not an issue in 2022 with <1% of quadrats unusable. Overall, the results suggest similar benthic fauna occupied the VW1 Study Area and Control Area in 2021 and 2022, but with a notable increase in abundance and spatial distribution of these animal groups between the years. Several other organisms that drop camera surveys can quantify, including the American lobster (*Homarus americanus*) and squid eggs, were not observed in either survey (Appendix I).

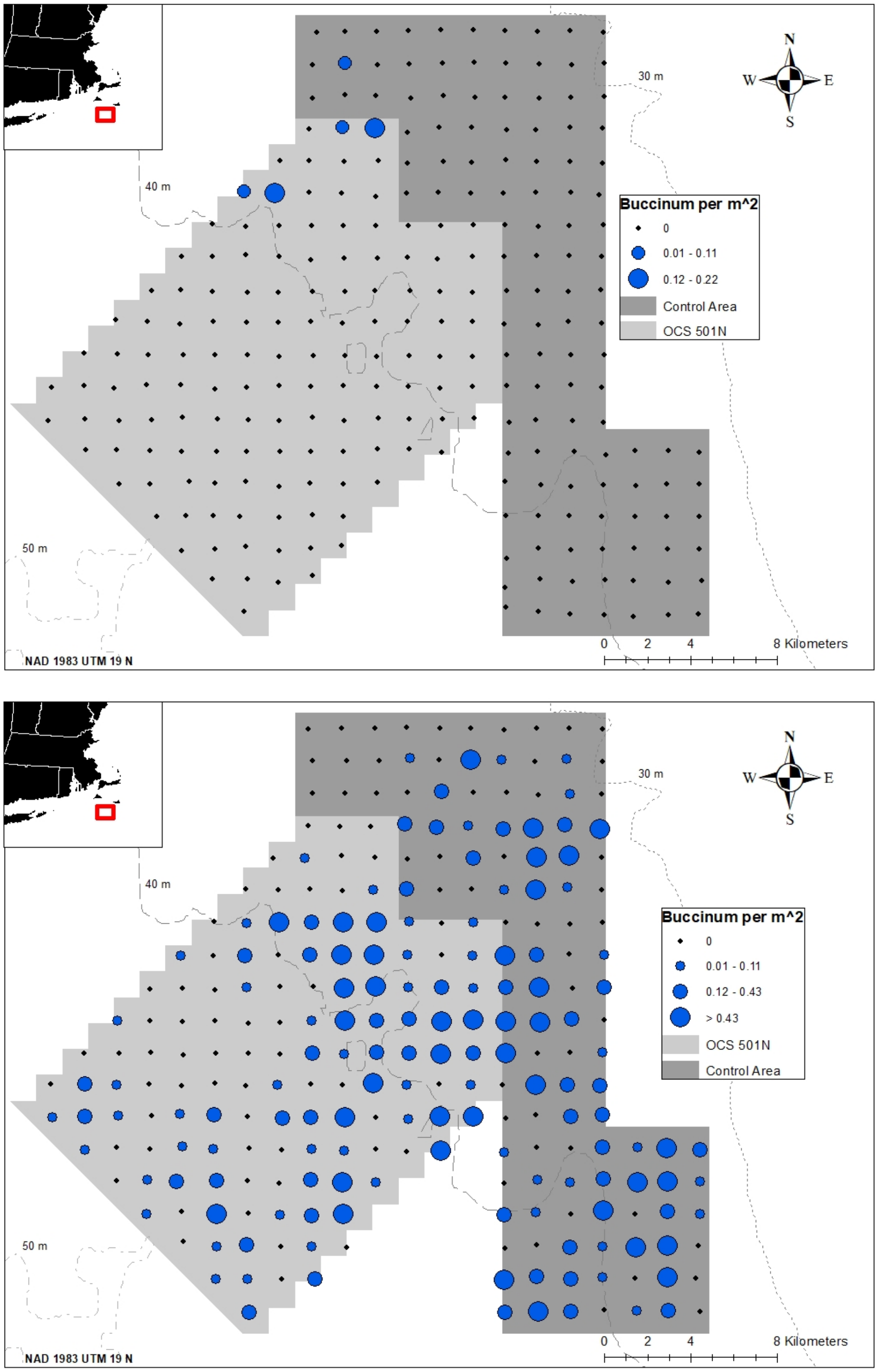
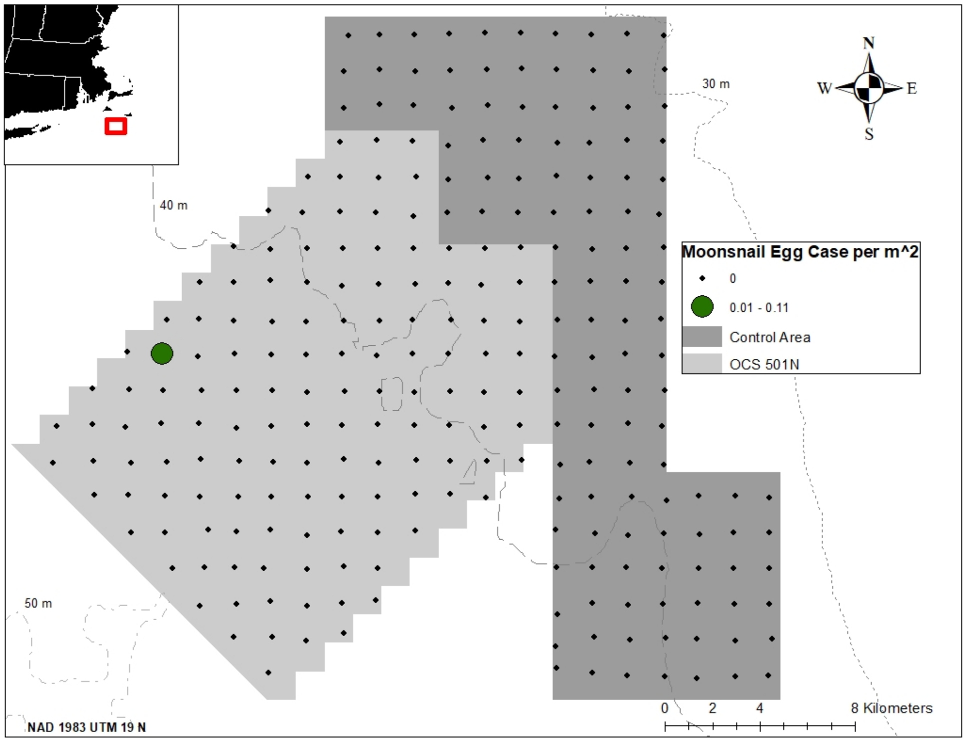


Figure 9. The distribution of whelk (*Buccinum undatum*) from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.



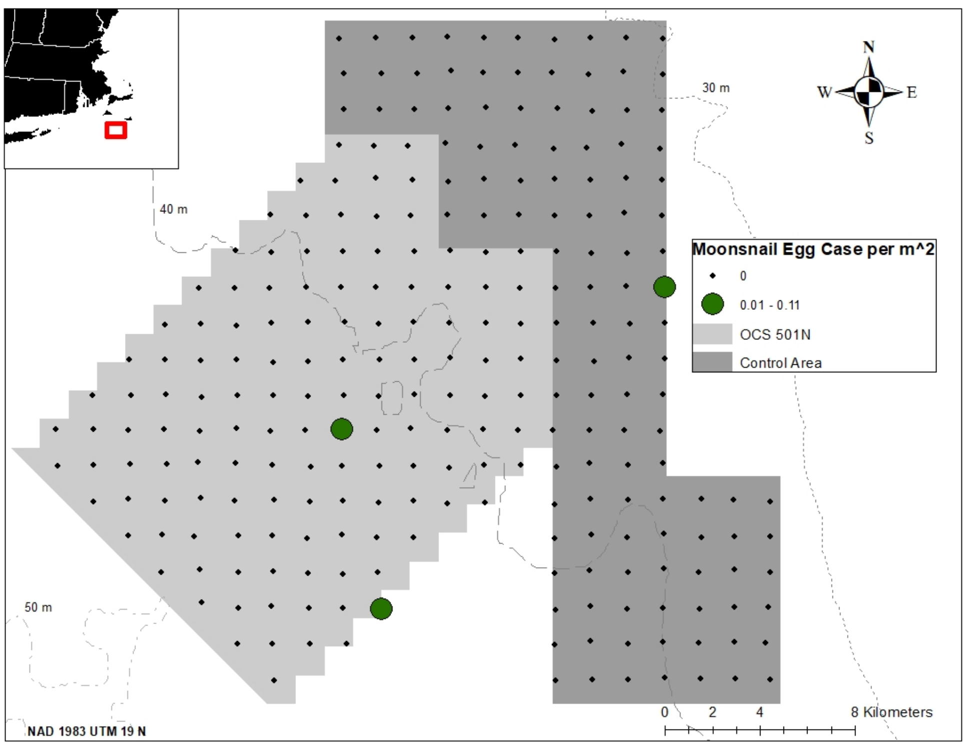
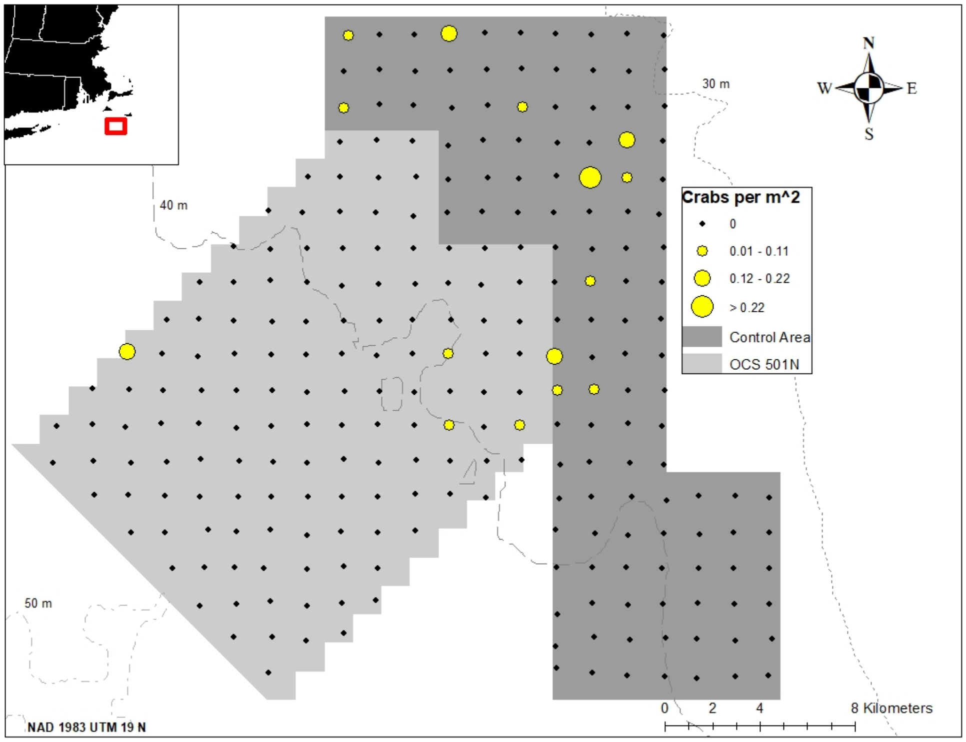


Figure 10. The distribution of collars (moon snail egg cases) from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one collar observed at a station in May of both years.



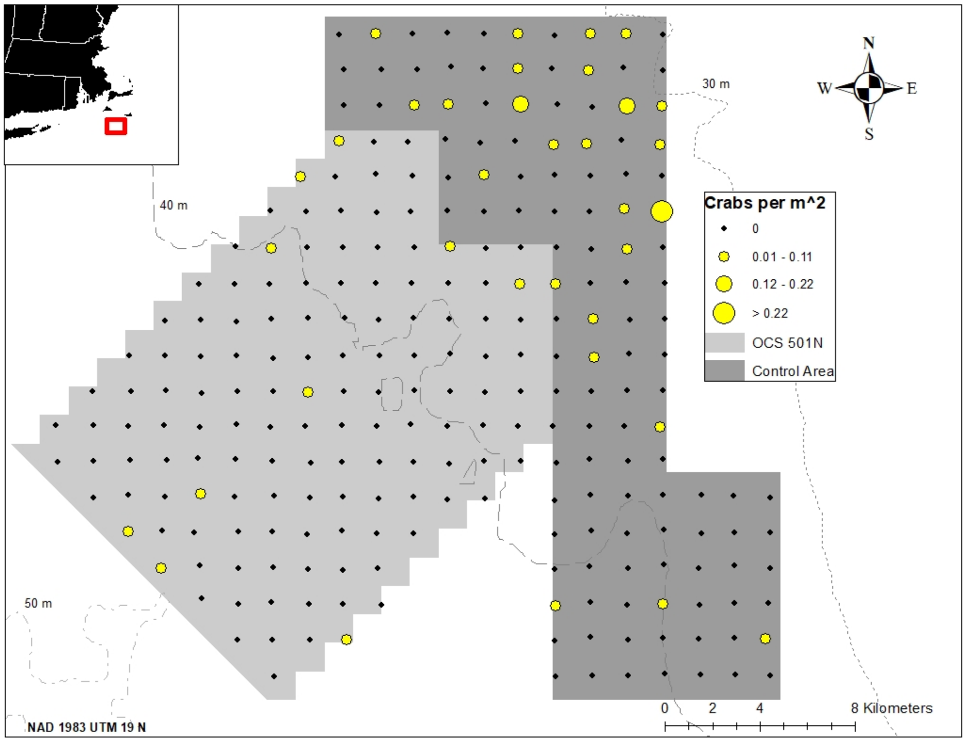
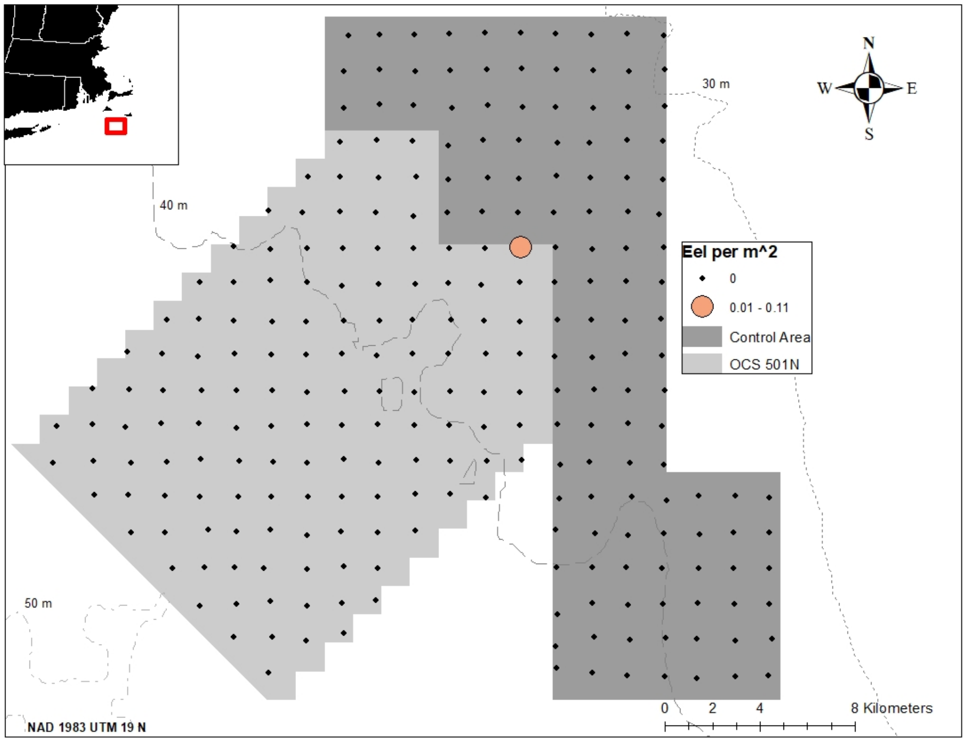


Figure 11. The distribution of crabs from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.



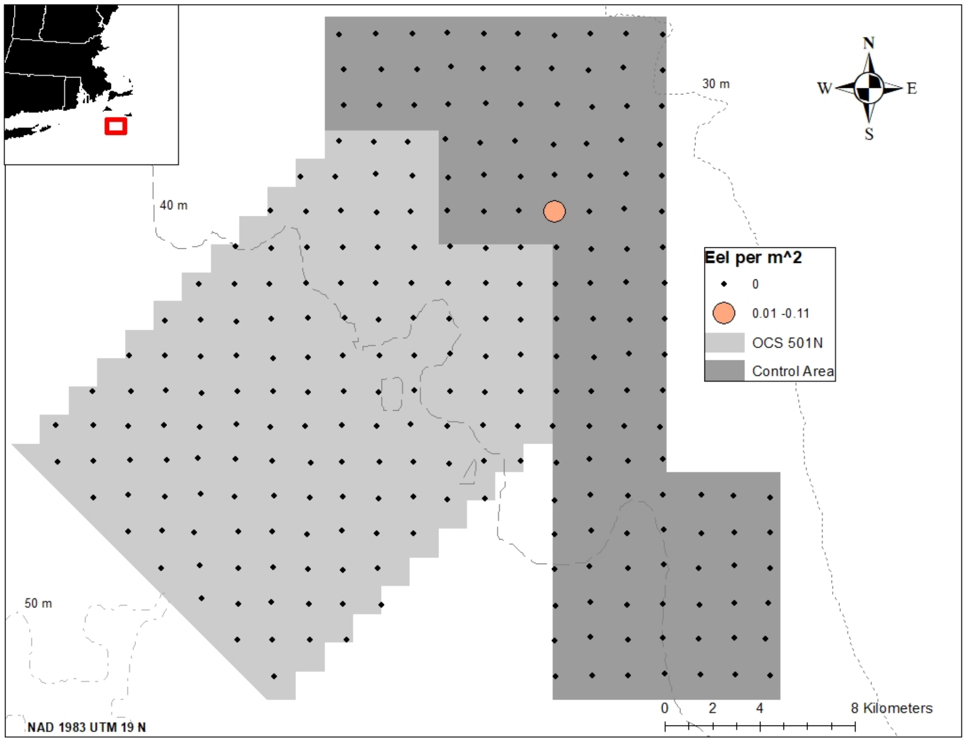
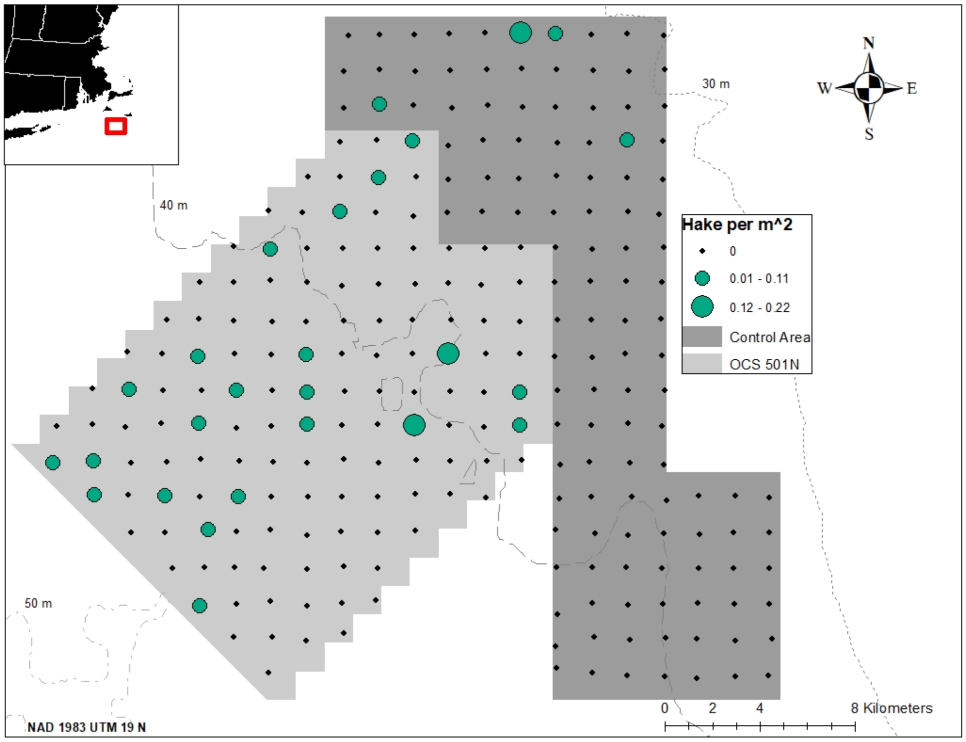


Figure 12. The distribution of eels from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one eel observed at a station in May of both years.



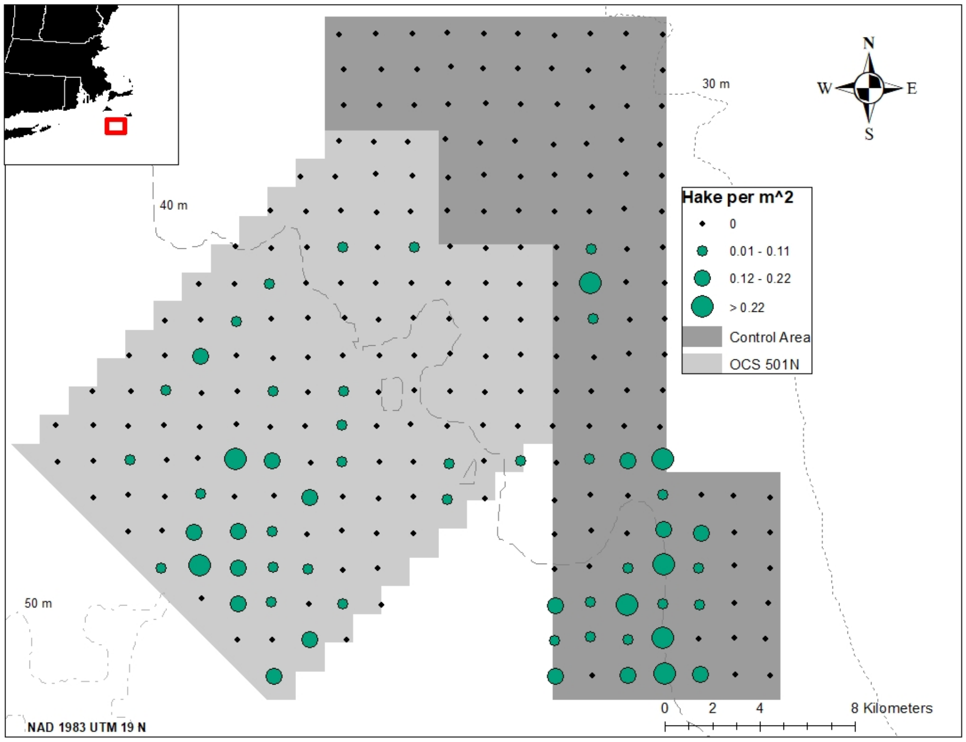


Figure 13. The distribution of hake from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.

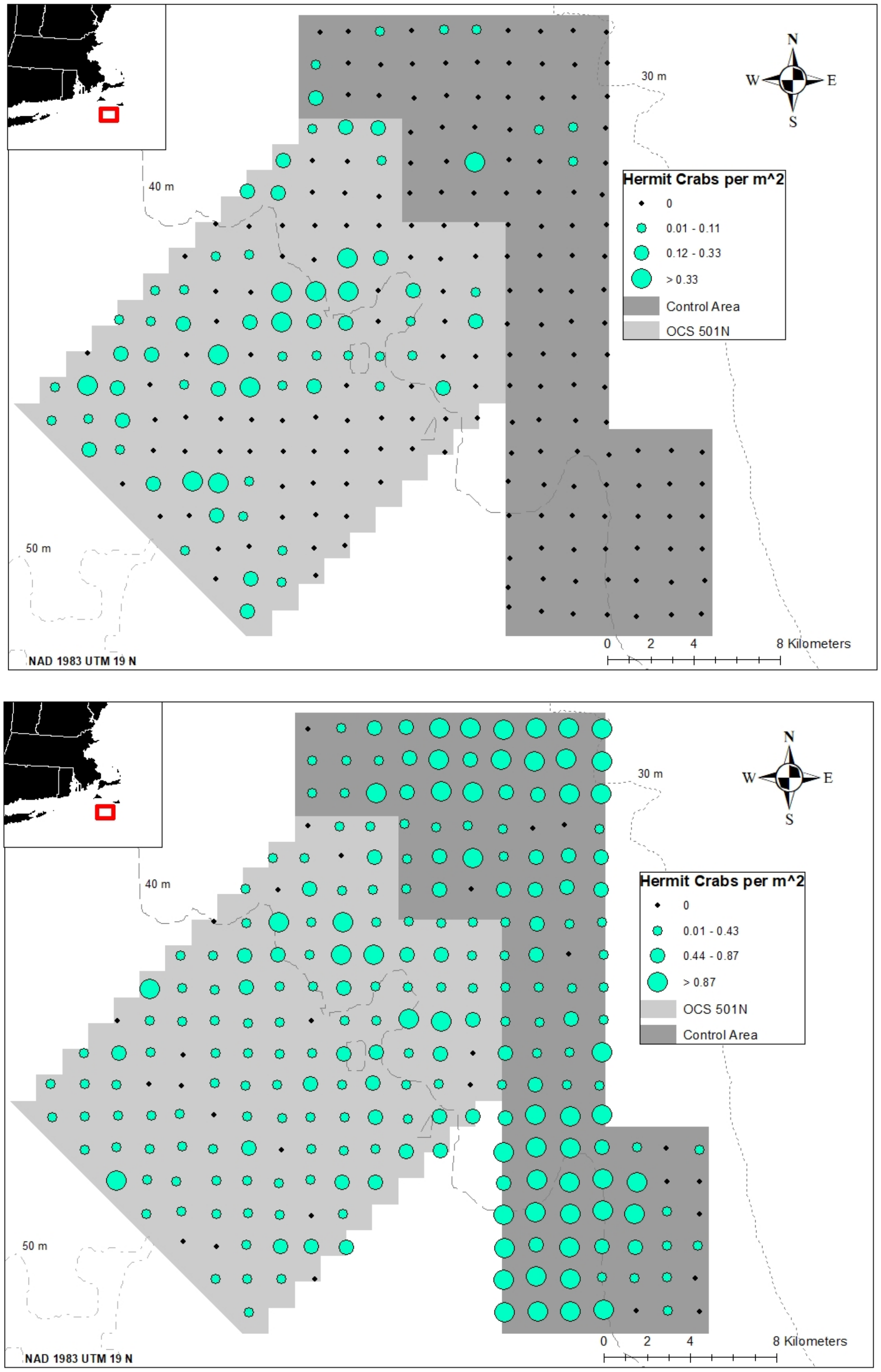


Figure 14. The distribution of hermit crabs from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.

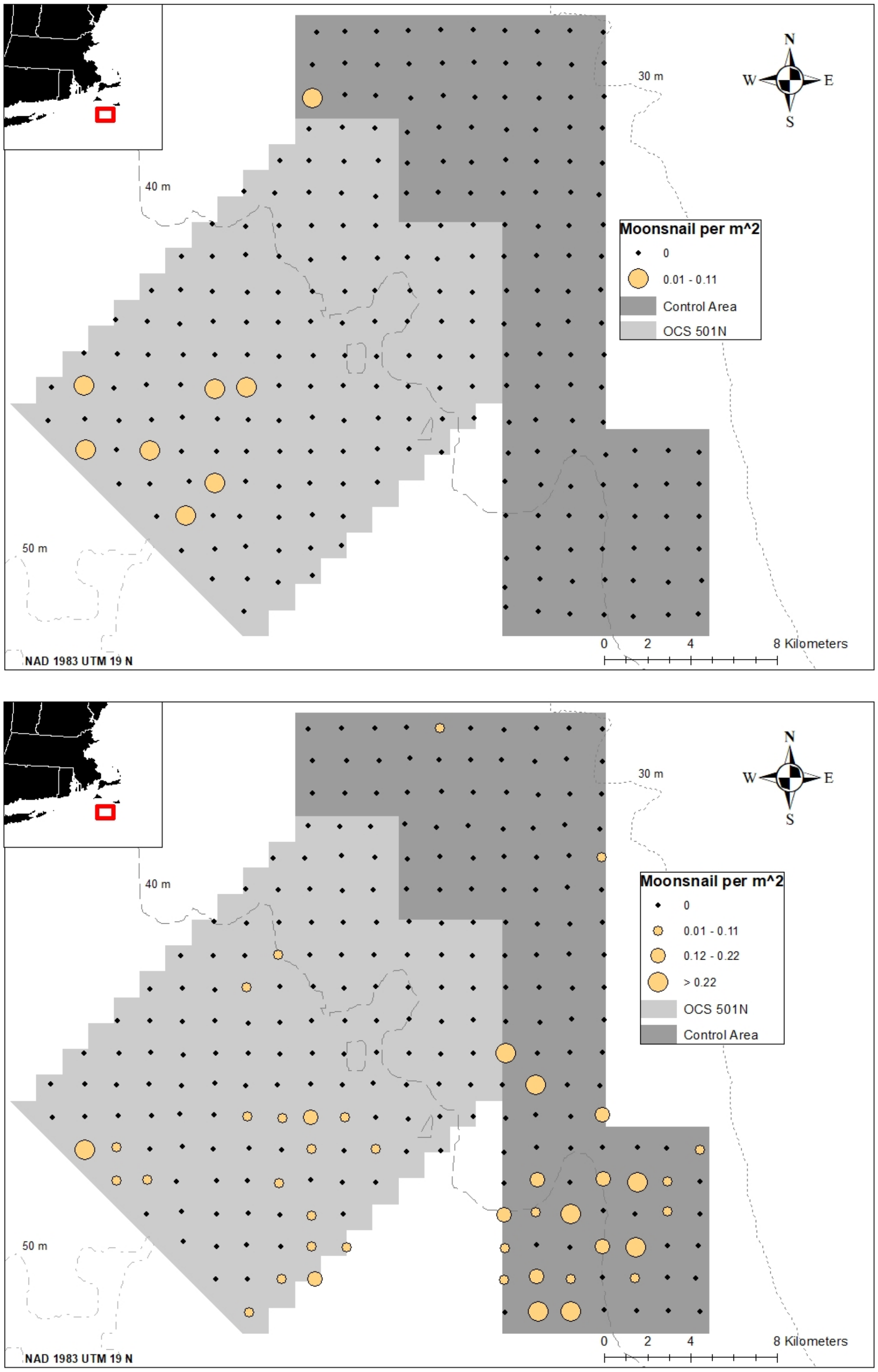


Figure 15. The distribution of moon snails from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.

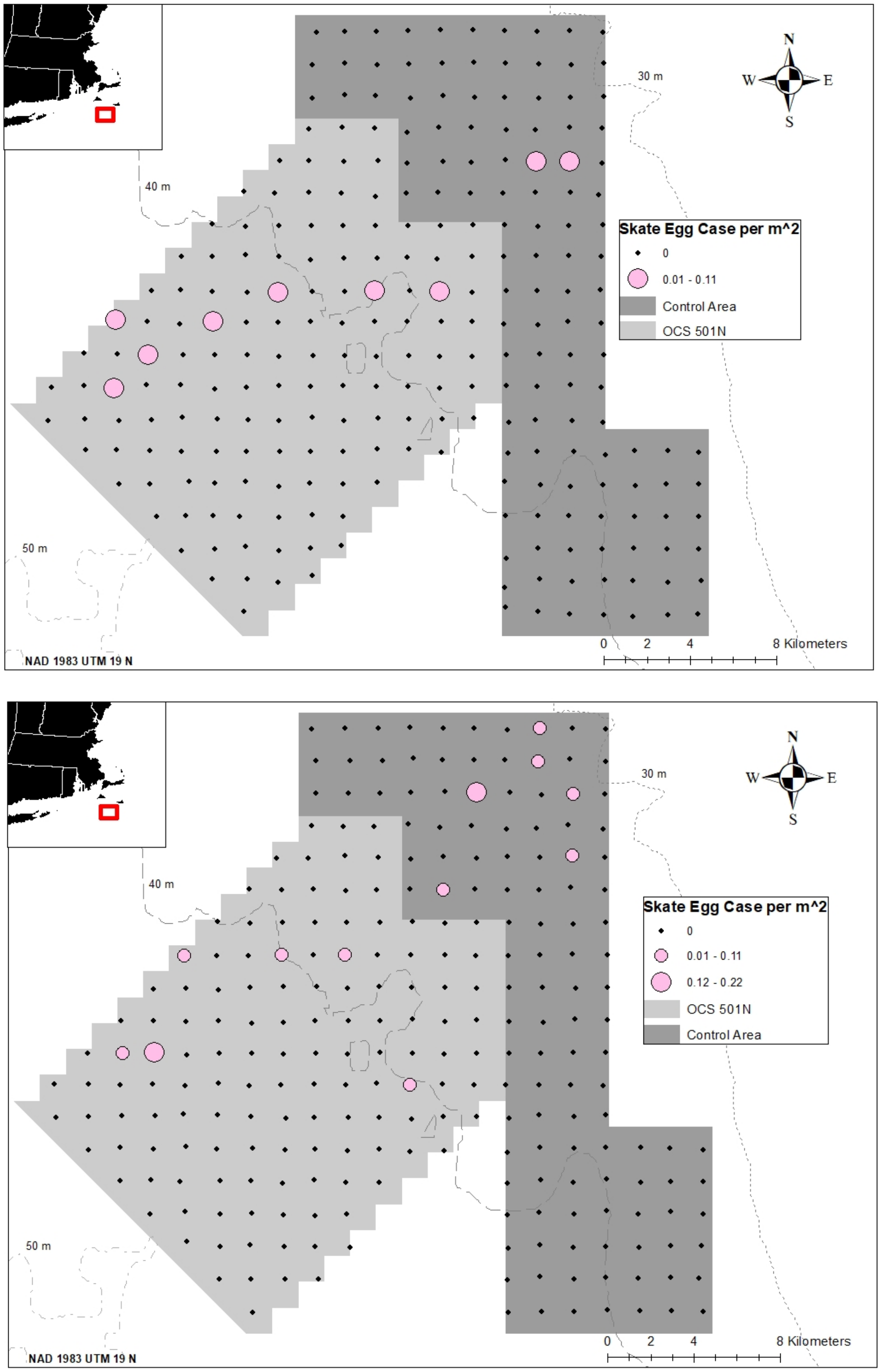


Figure 16. The distribution of purses (skate egg cases) from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.

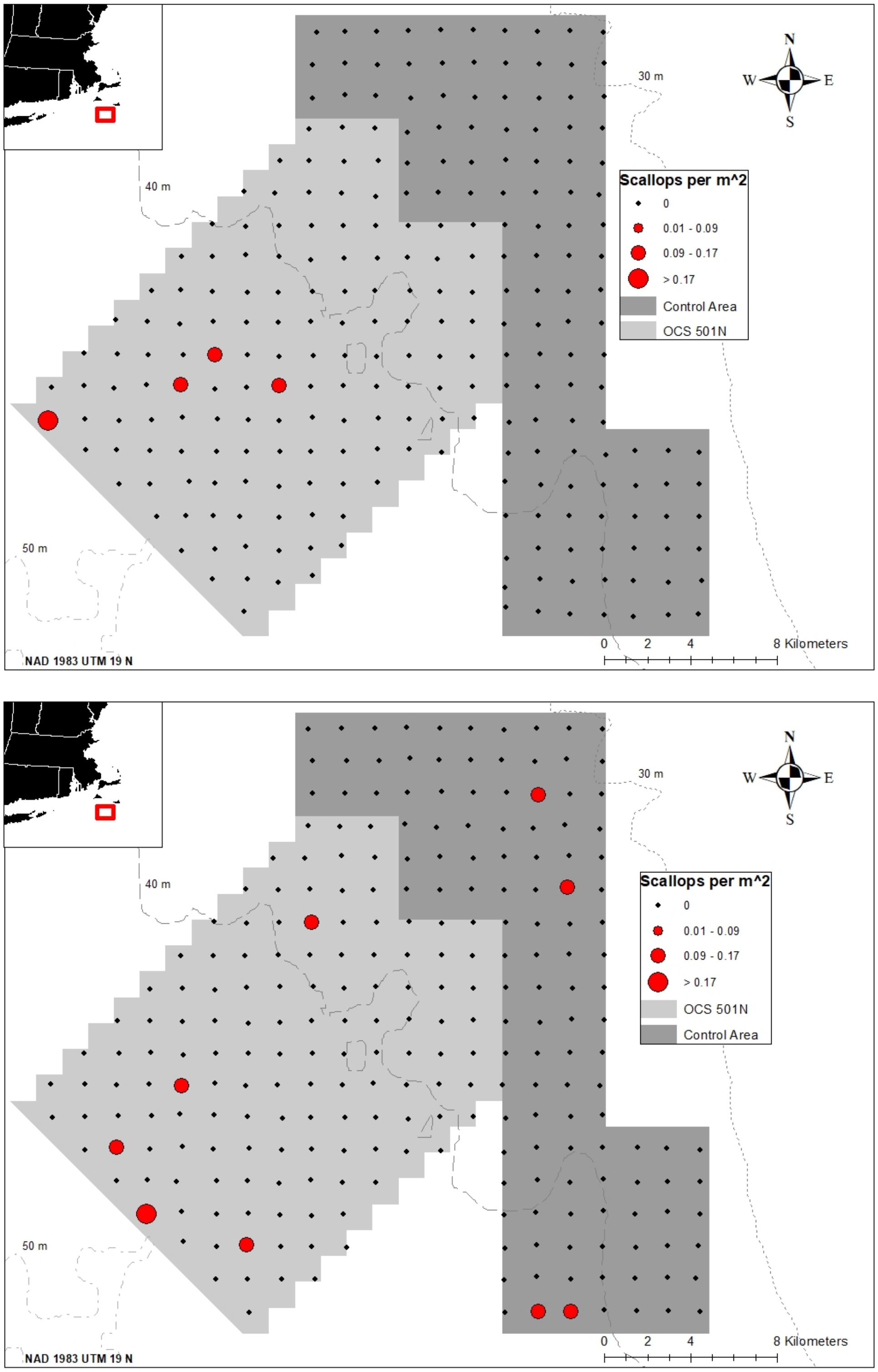
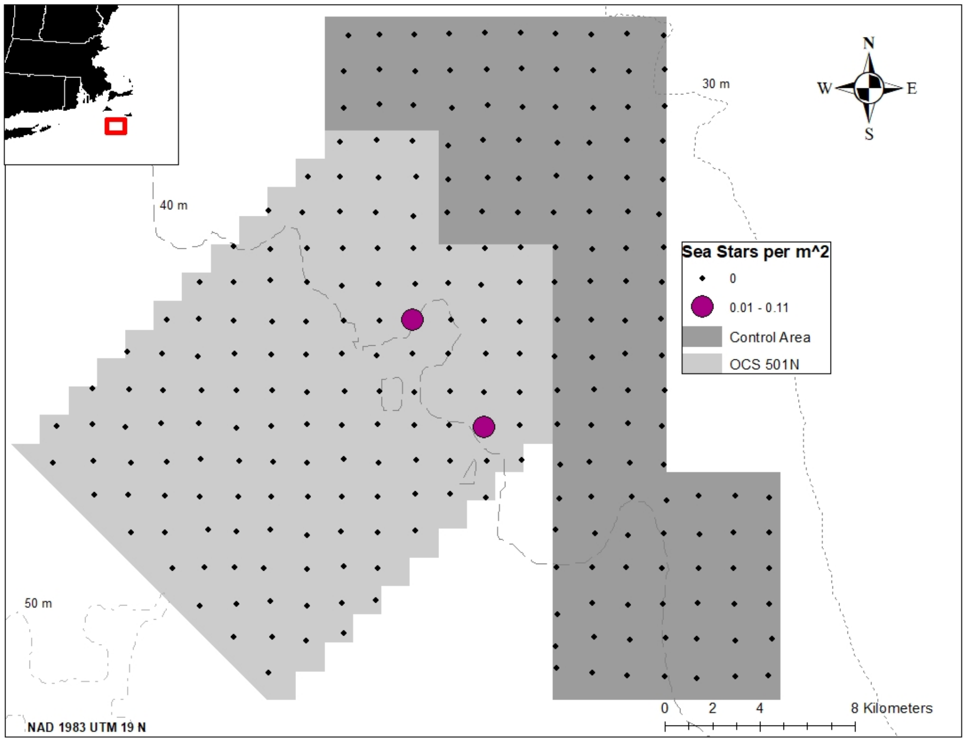


Figure 17. The distribution of scallops from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.



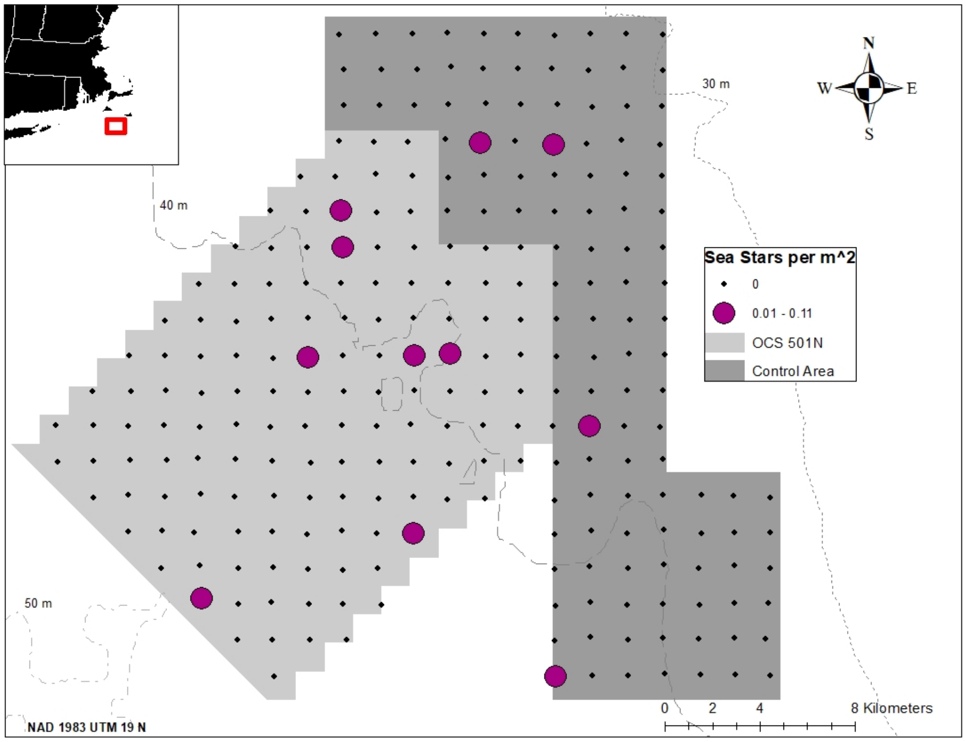


Figure 18. The distribution of sea stars from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one sea star observed at a station in May of both years.

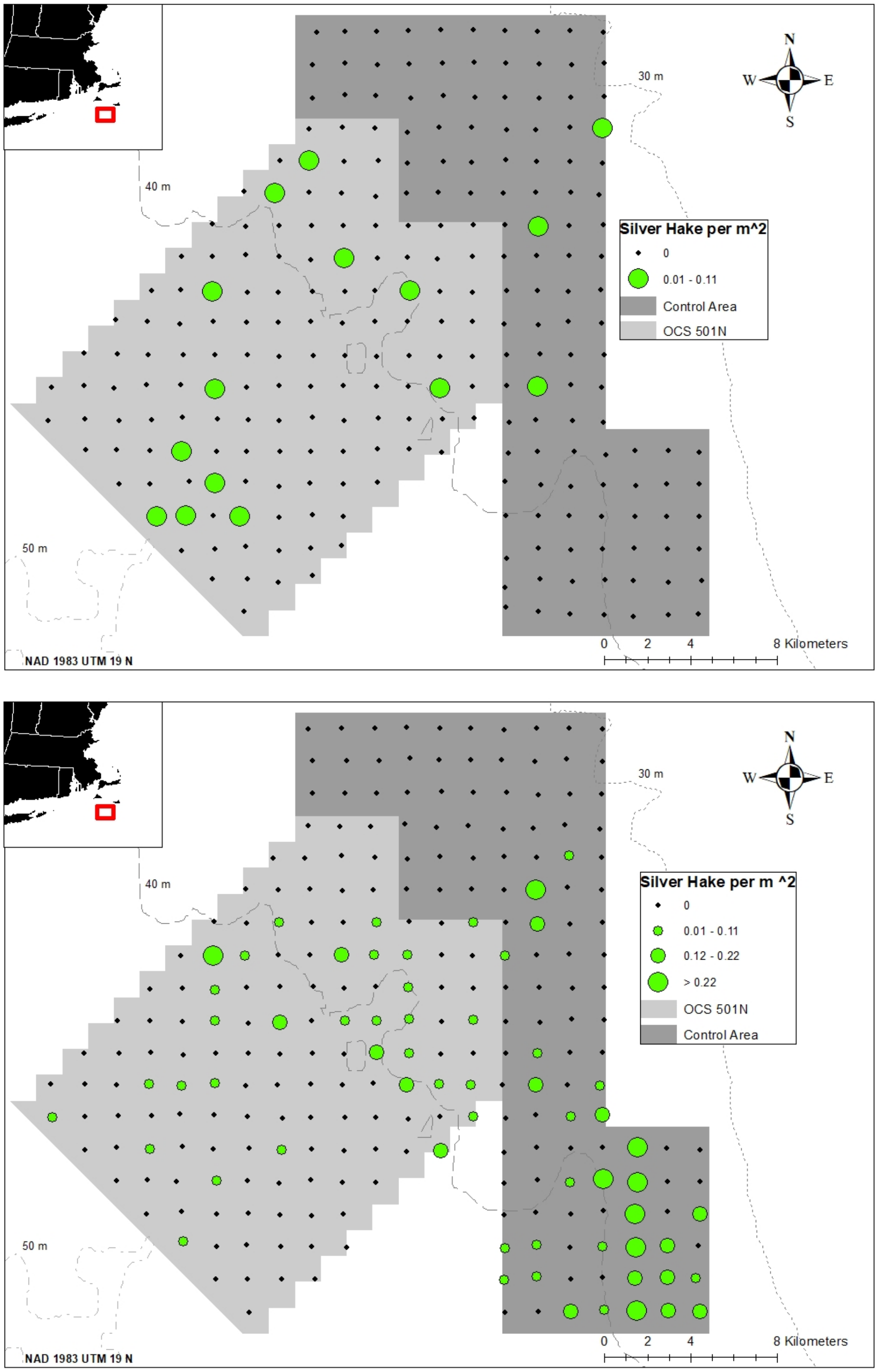


Figure 19. The distribution of silver hake from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.

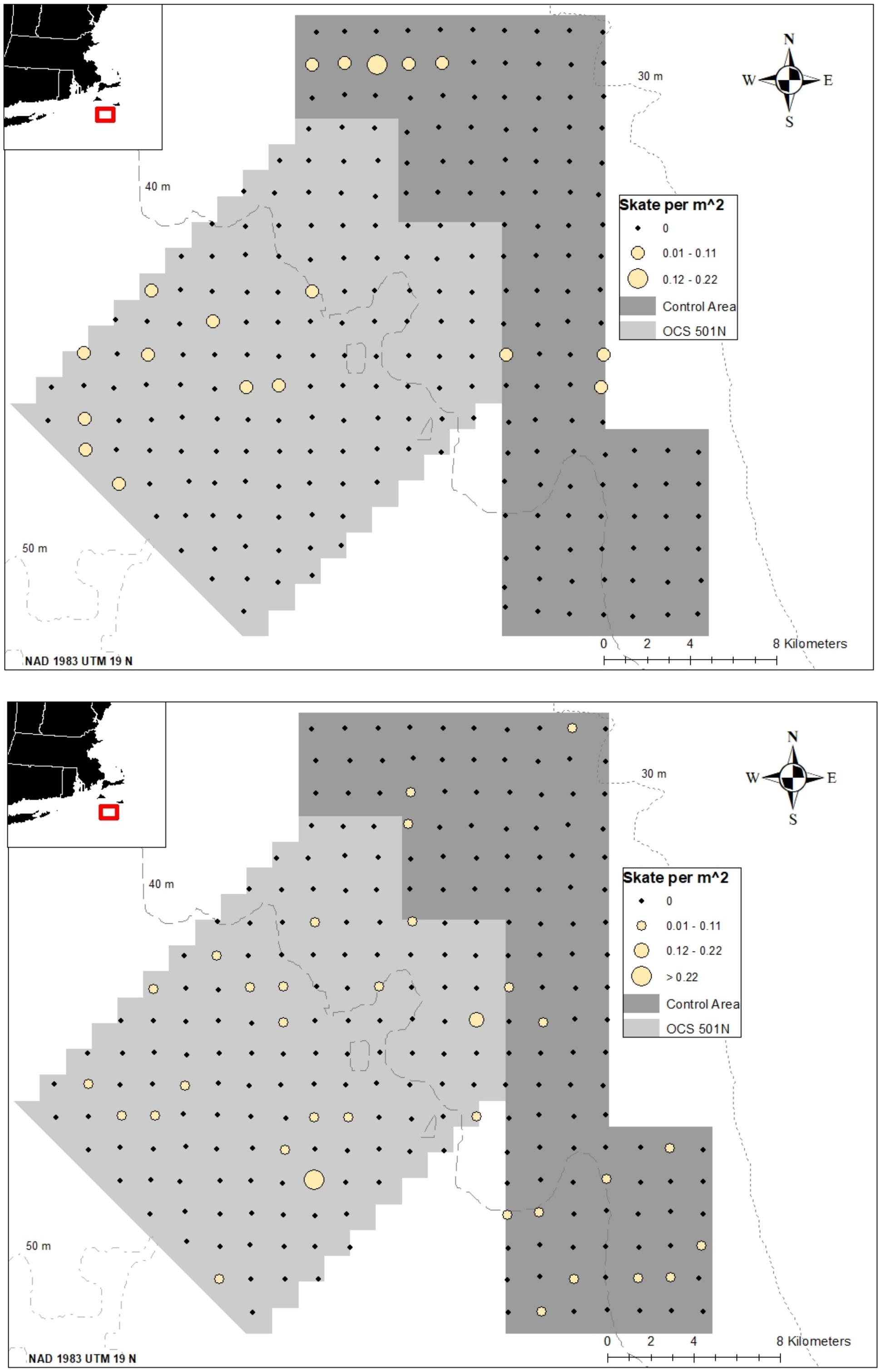


Figure 20. The distribution of skates from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May of both years.

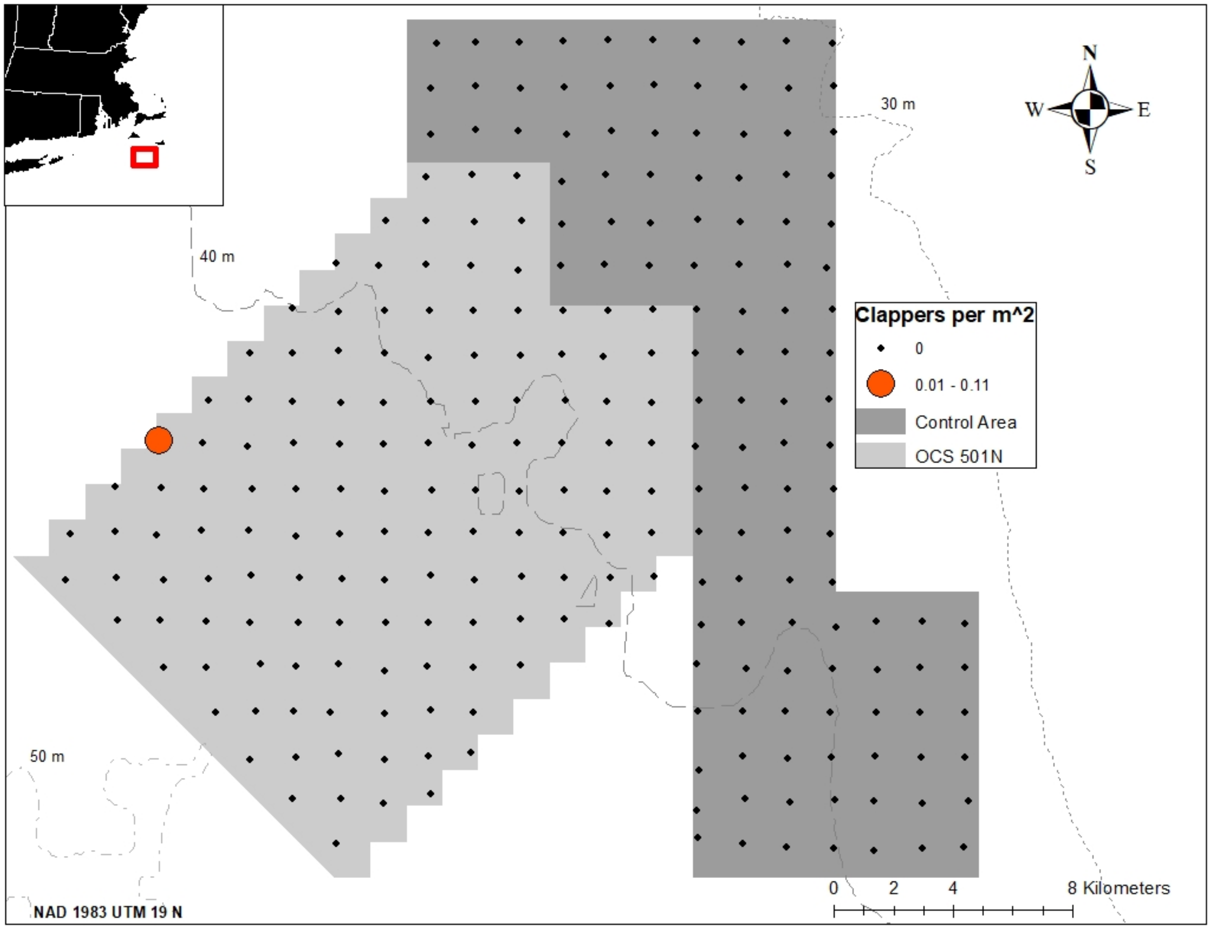


Figure 21. The distribution of clappers (dead scallops) from the May 2021 drop camera survey of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one clapper observed at a station in May of 2021. No clappers were observed in the May 2022 survey.

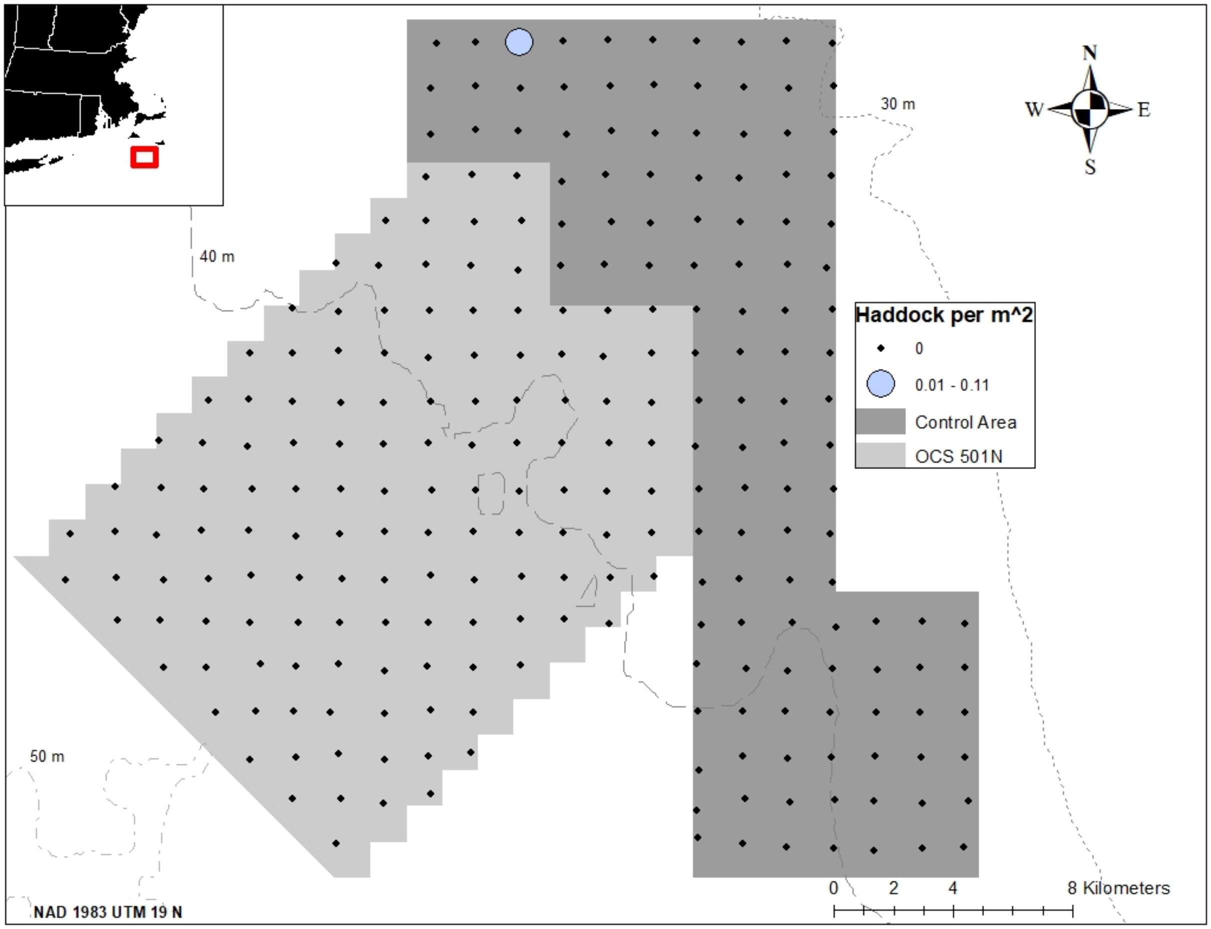


Figure 22. The distribution of haddock from the May 2021 drop camera survey of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one haddock observed at a station in May 2021. No haddock were observed in the May 2022 survey.

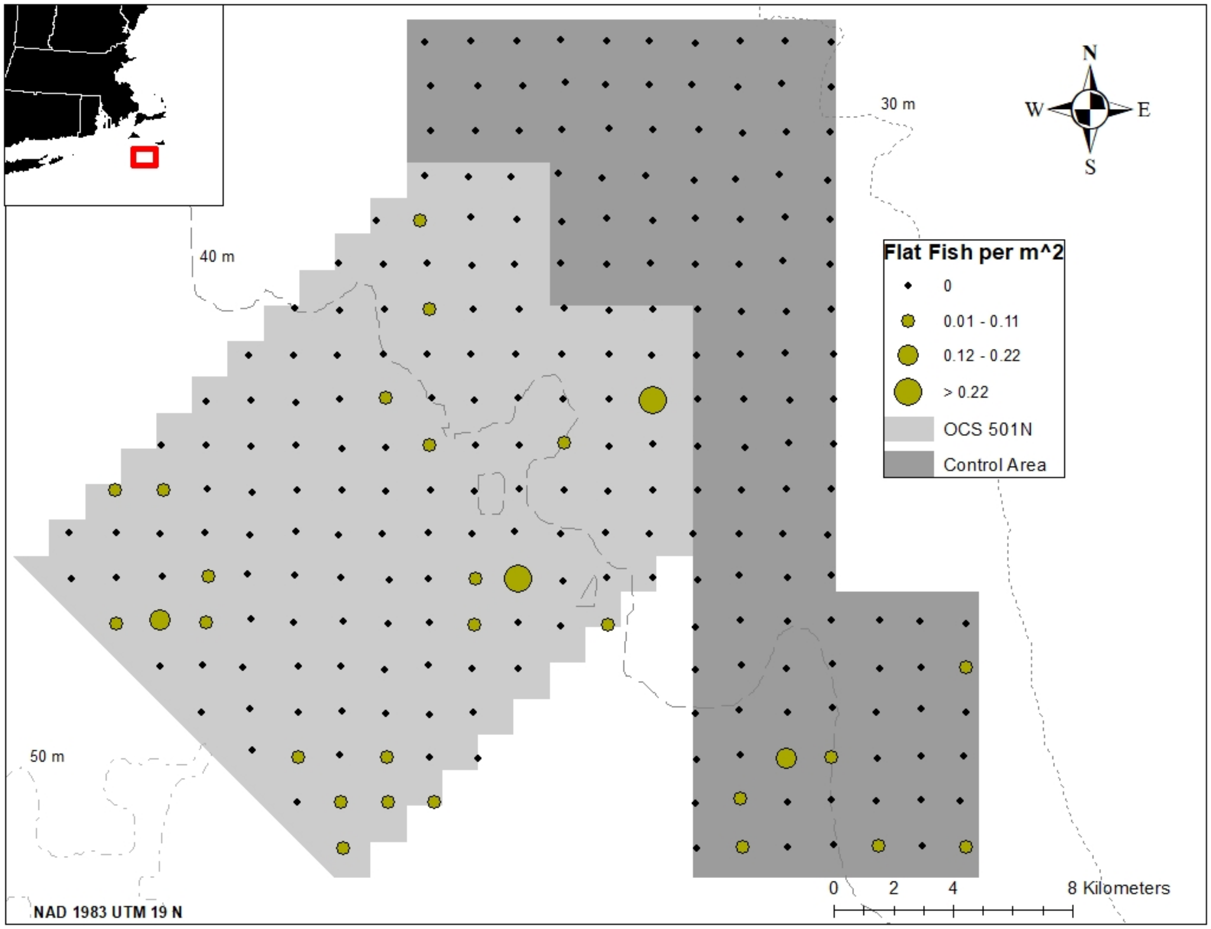


Figure 23. The distribution of flat fishes from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May 2022. No flat fishes were observed in the May 2021 survey.

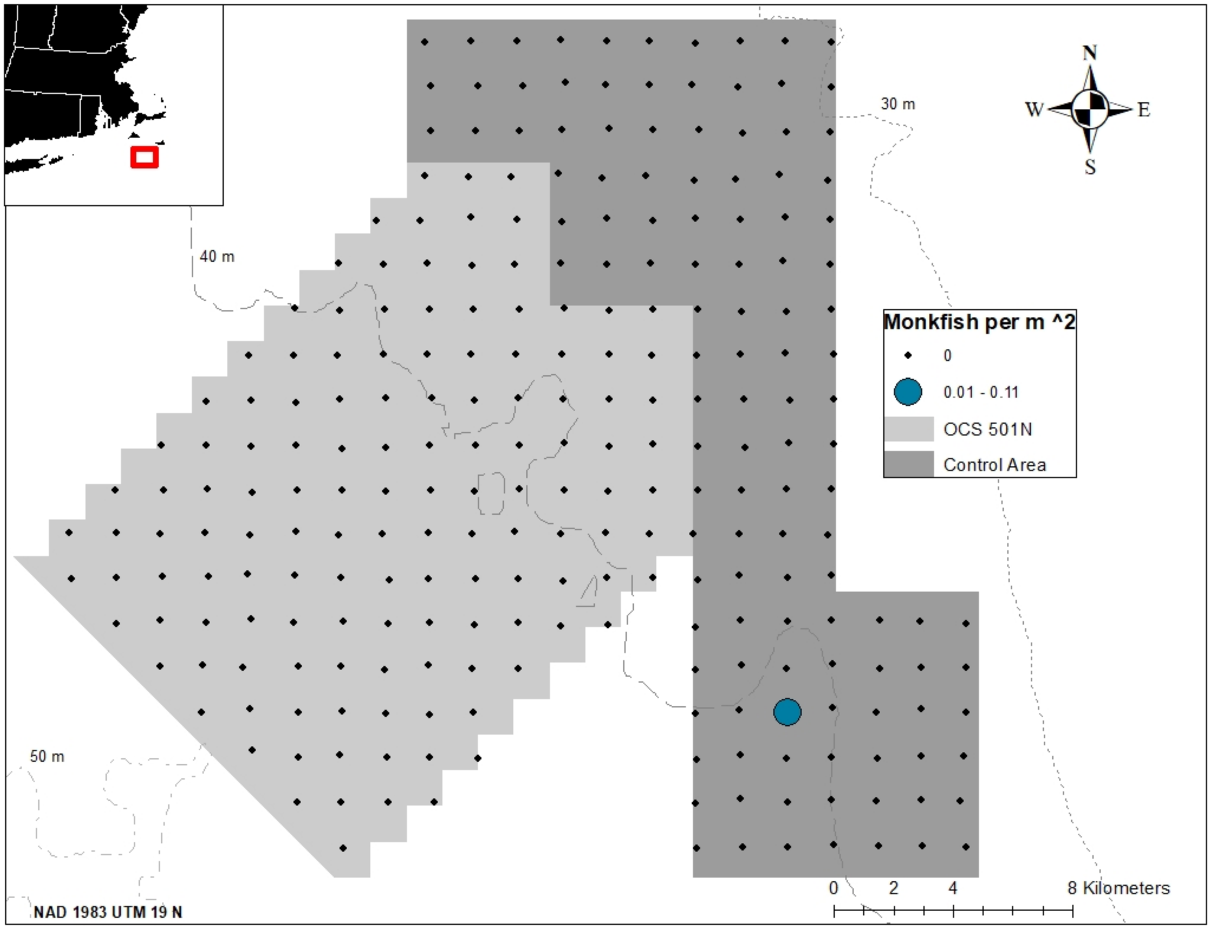


Figure 24. The distribution of monkfish from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one monkfish observed at a station in May 2022. No monkfish were observed in the May 2021 survey.

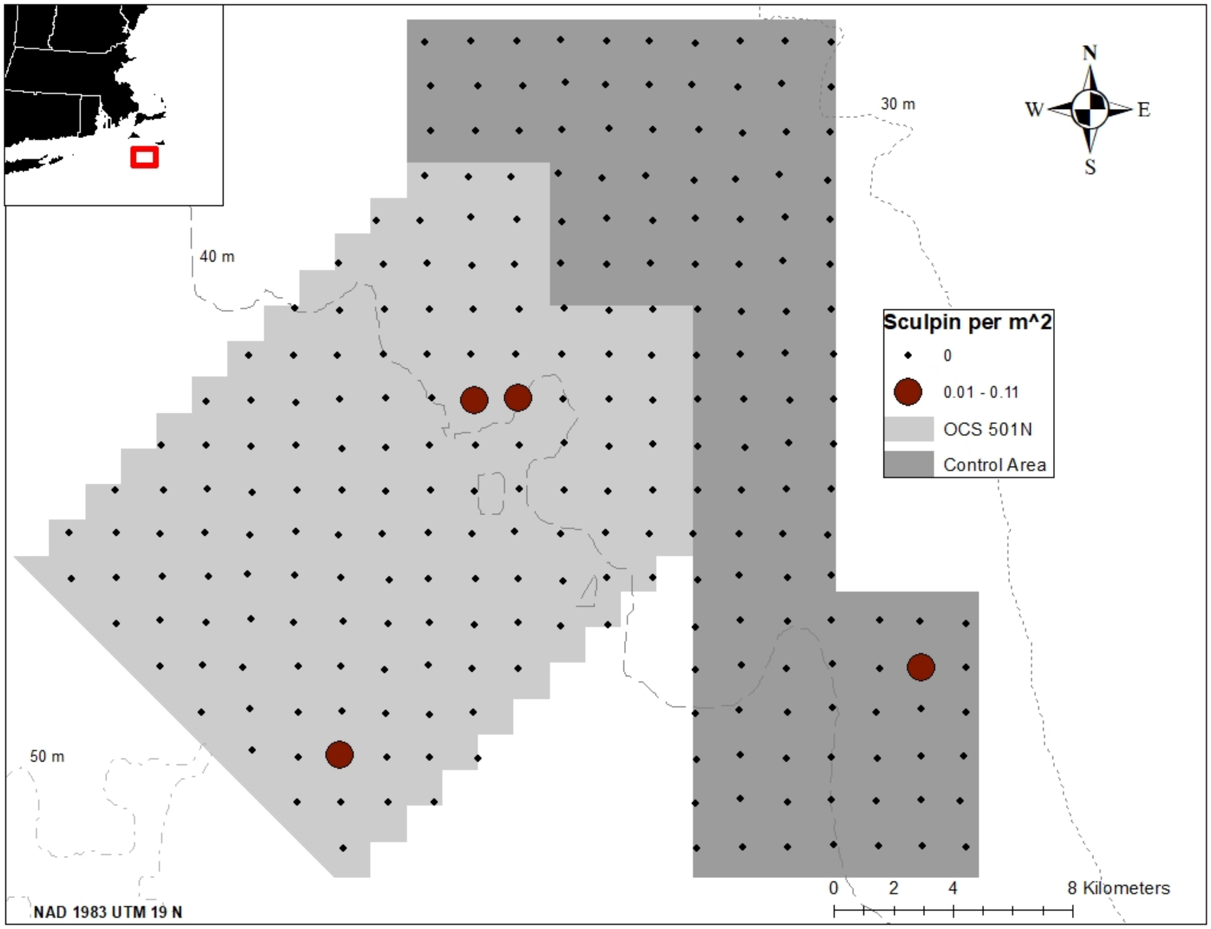


Figure 25. The distribution of sculpin from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one sculpin observed at a station in May 2022. No sculpin were observed in the May 2021 survey.

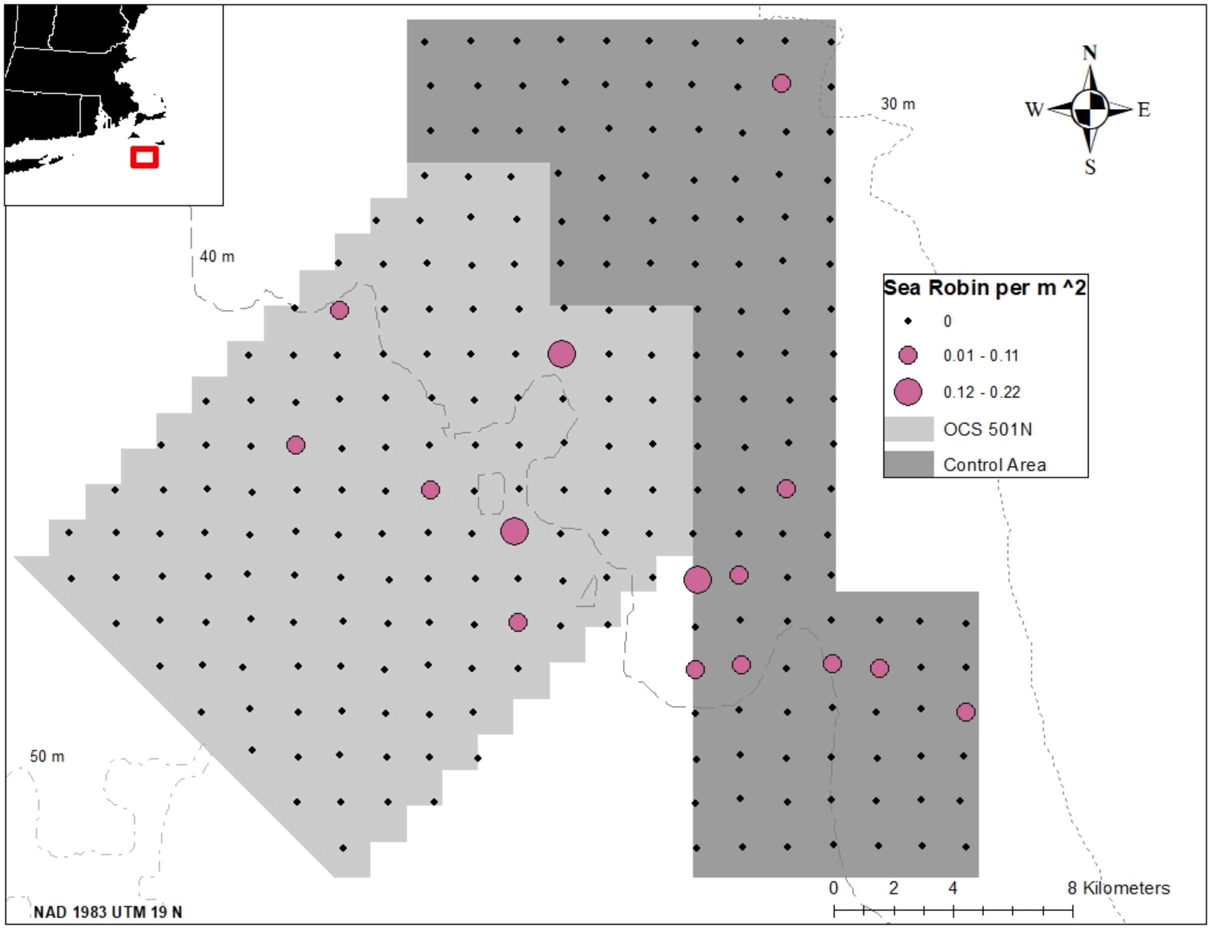


Figure 26. The distribution of sea robin from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Density categories divide the data into quantiles above zero based on observations in May 2022. No sea robins were observed in there May 2021 survey.

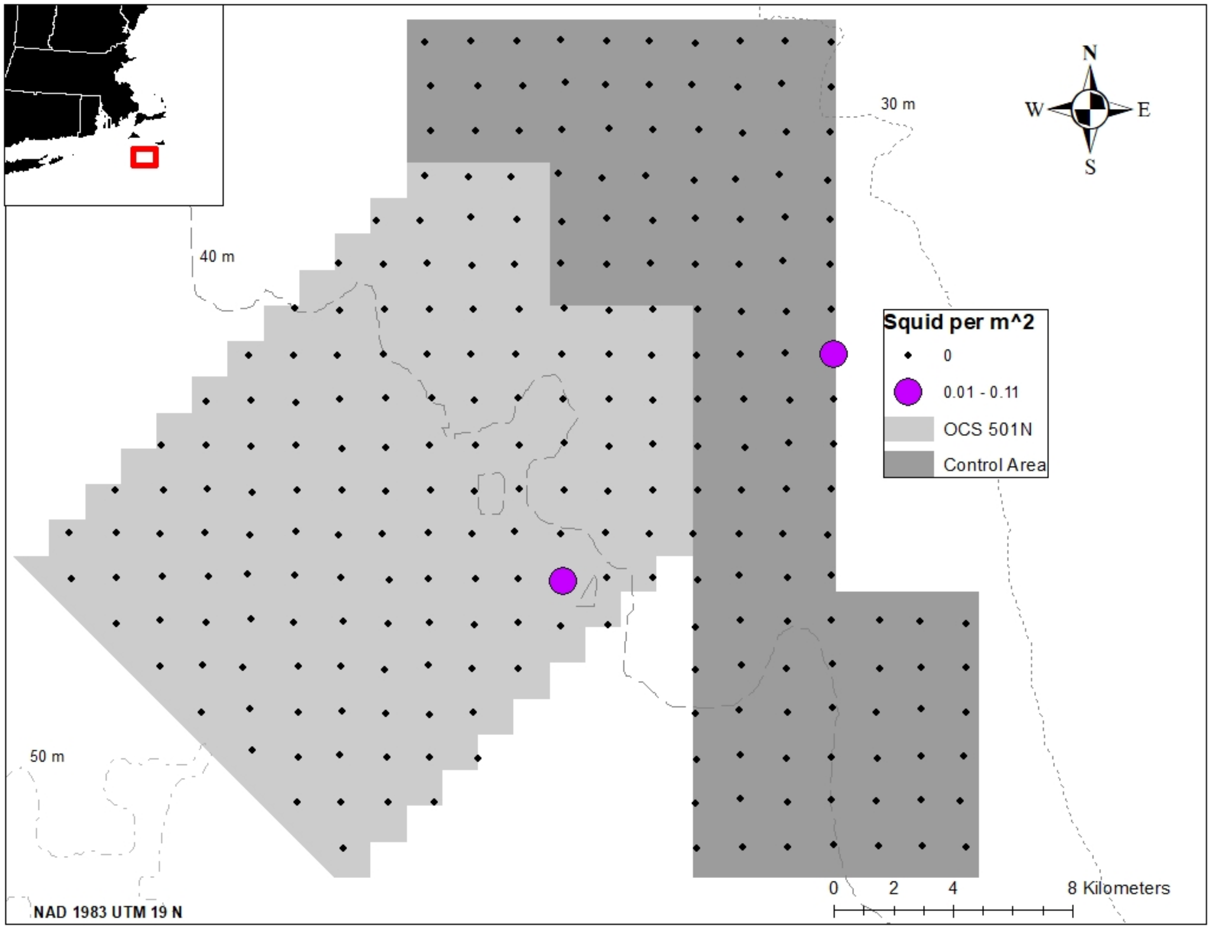


Figure 27. The distribution of squid from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Density categories represent zero or one squid observed at a station in May 2022. No squid were observed in the May 2021 survey.

The most common benthic taxa noted as present or absent included holes (burrowing animals), sand dollars, anemones, bryozoans/hydrozoans, and sponges for both years. All the animal groups were observed in more quadrats per station in the VW1 Study Area compared to the Control Area in 2021 (Figure 8). Holes (burrowing animals) and sand dollars were found in significantly more quadrats in the VW1 Study Area than in the Control Area in 2022. However, bryozoans/hydrozoans, anemones, sponges, and clams were found in more quadrats in the Control Area than in the Study Area in 2022. More presence/absence animal groups were observed in the 2022 survey, and these included clams, tunicates, and urchins (Figure 8). The spatial distributions of animal groups varied annually. Anemones were found more frequently in shallower depths in 2022 compared to 2021 (Figure 28). The opposite is true for bryozoans /hydrozoans, which were found more frequently in deeper water in 2022 than in 2021 (Figure 29). The spatial distribution of holes (burrowing animals) increased at all depths over the survey area from 2021 to 2022 (Figure 30). Sand dollars and sponges were found in similar spatial distributions in both years (Figure 31). Clams, tunicates, and urchins were only observed in 2022 but with a limited spatial distribution in the survey areas (Figures 32 to 34).

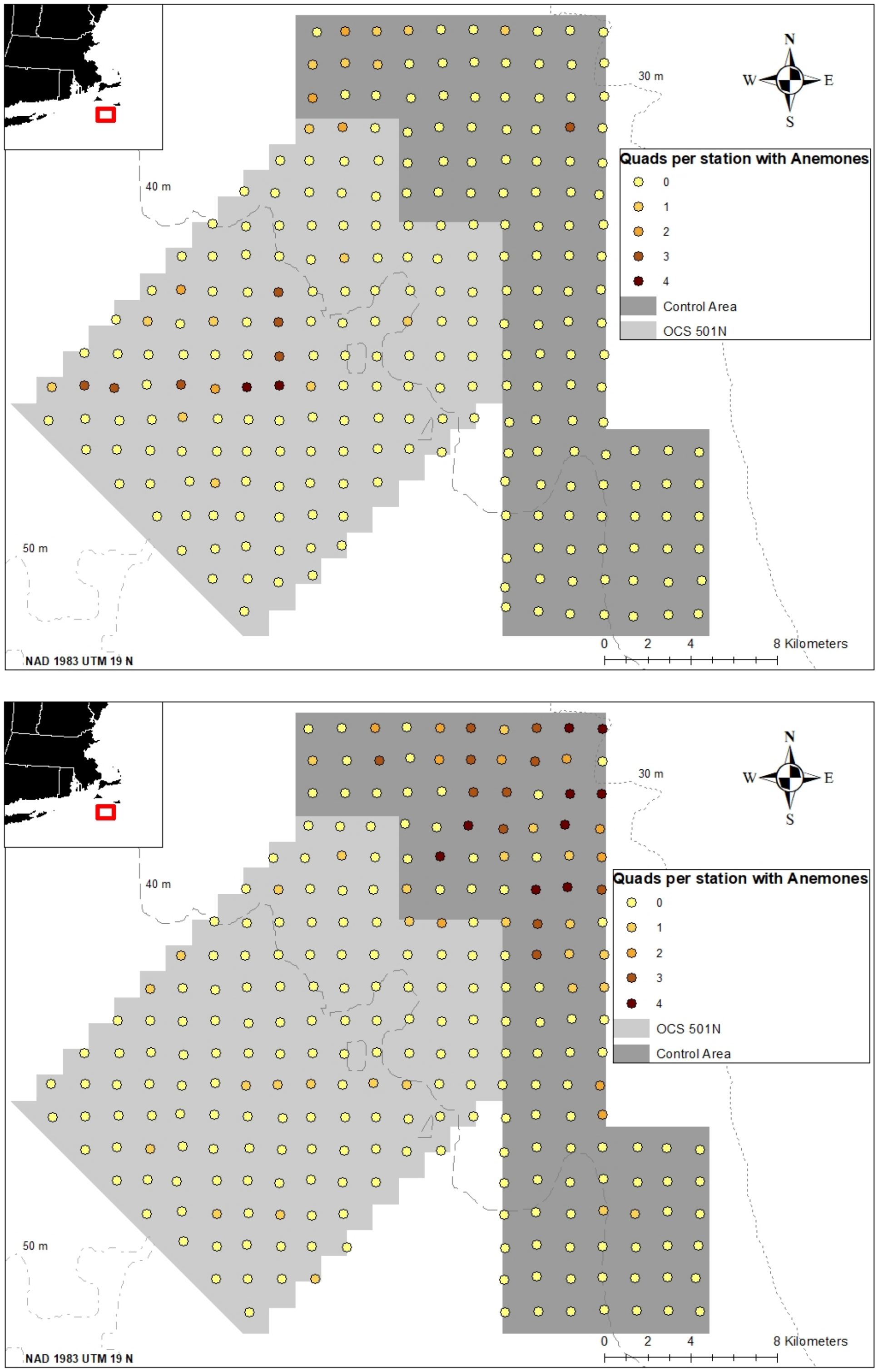


Figure 28. The distribution of anemones from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that anemones were observed in as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

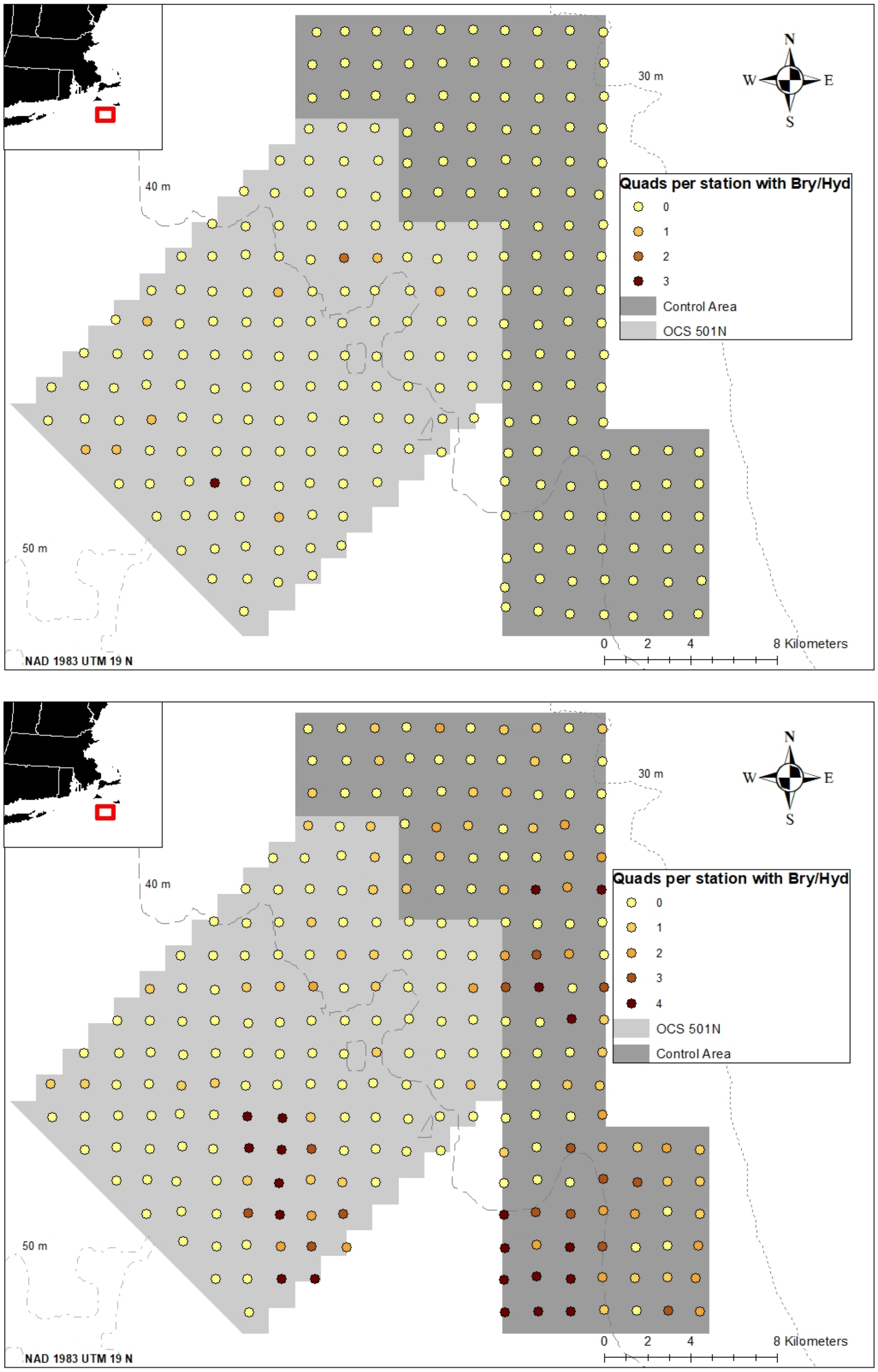


Figure 29. The distribution of bryozoans and hydrozoans from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that bryozoans and hydrozoans were observed in as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

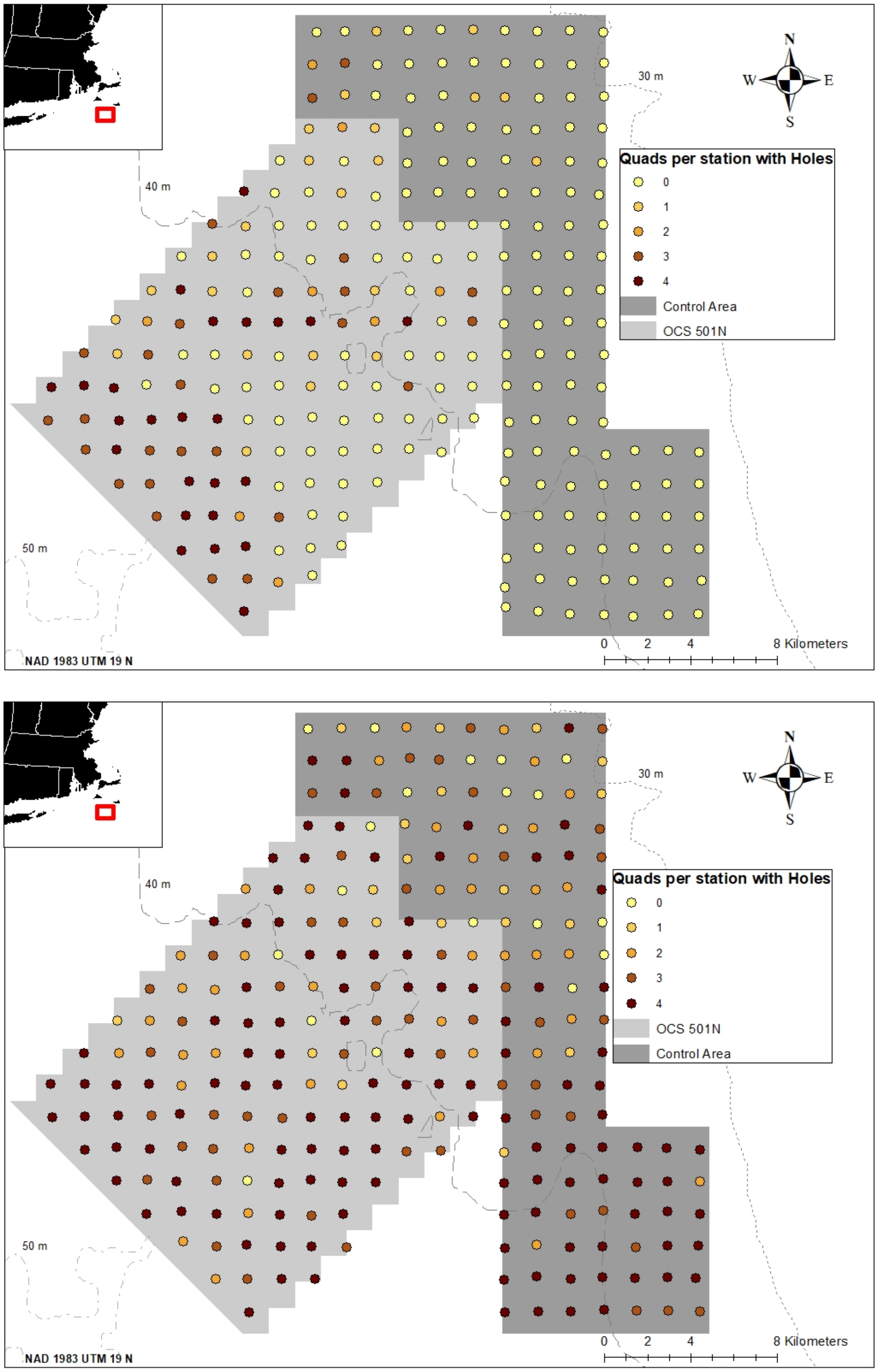


Figure 30. The distribution of holes (burrowing animals) from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that holes were observed in as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

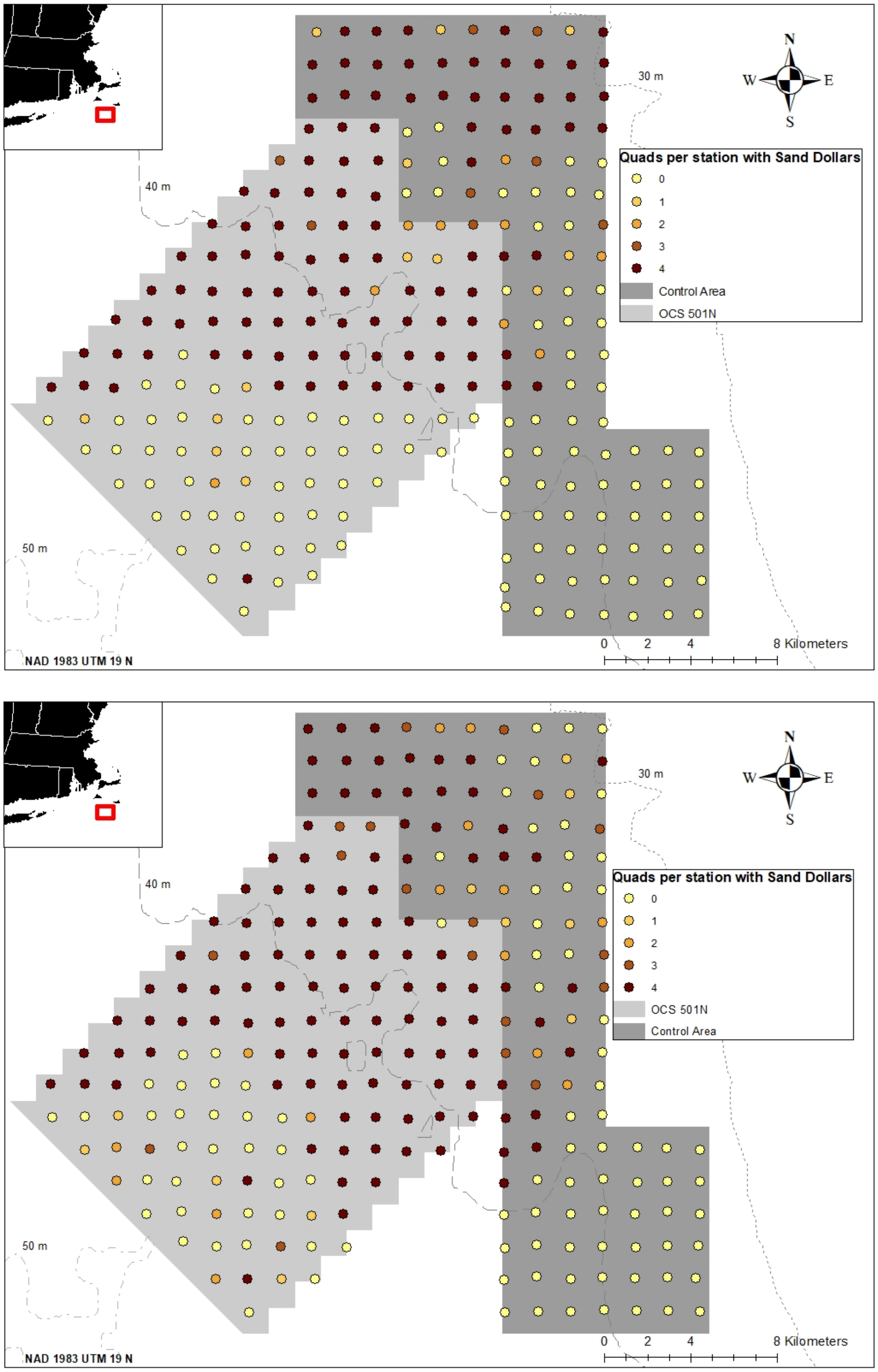


Figure 31. The distribution of sand dollars from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that sand dollars were observed in as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

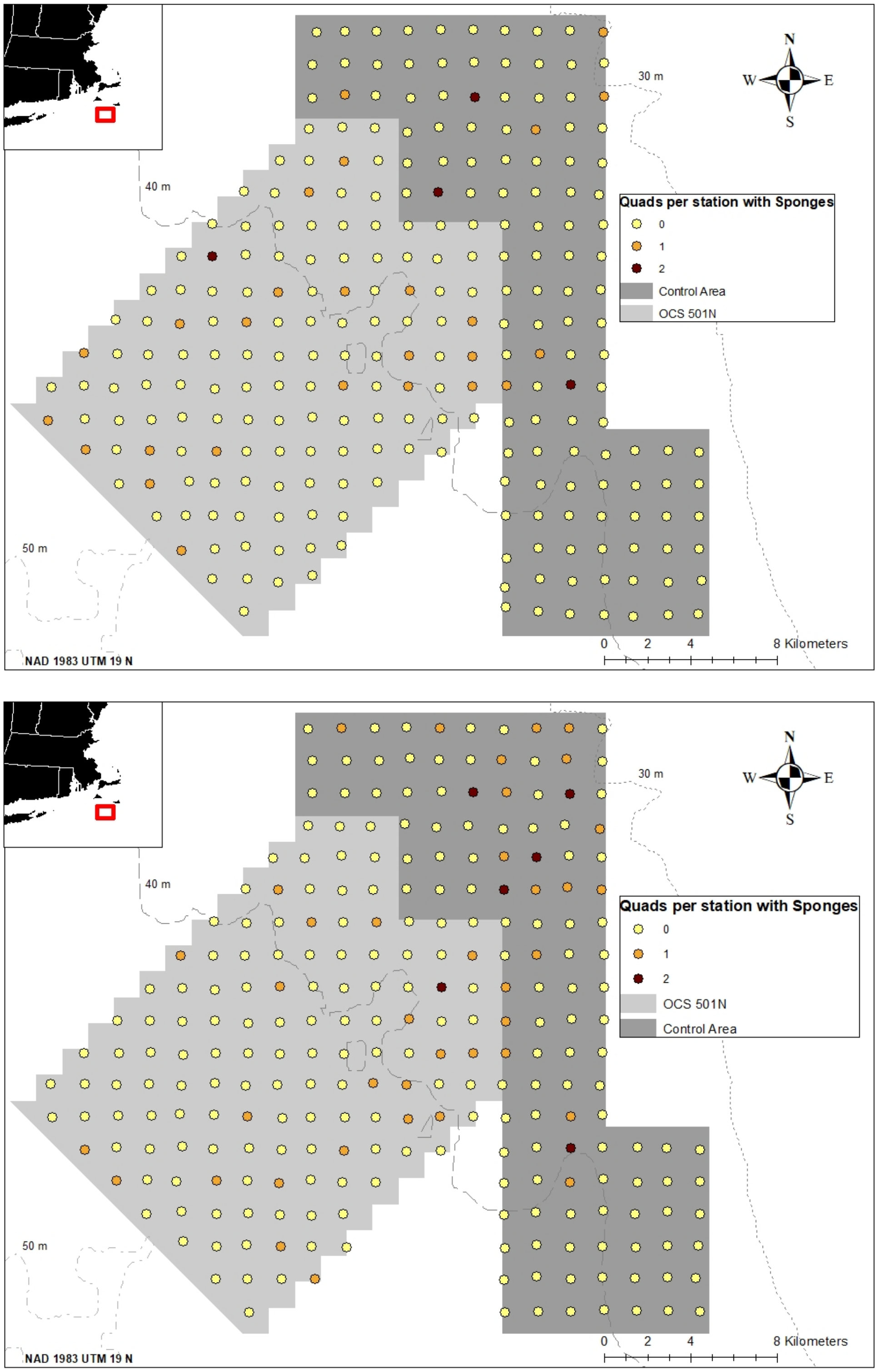


Figure 32. The distribution of sponges from the May 2021 (top) and May 2022 (bottom) drop camera surveys of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that sponges were observed in as indicated in the figure legend. Four quadrats (2.3 m^2 images) were observed at each station.

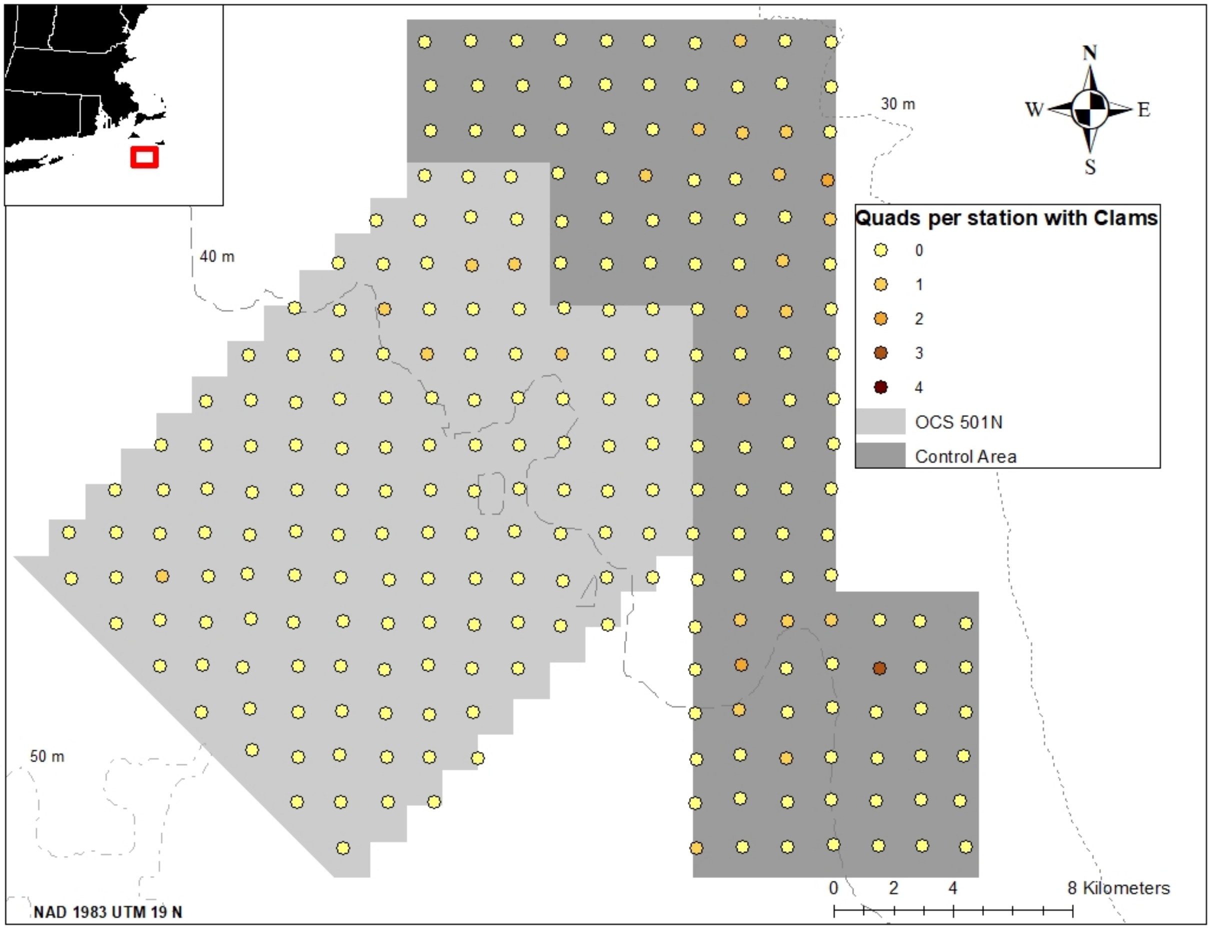


Figure 33. The distribution of clams from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that clams were observed in as indicated in the figure legend. No clams were observed in the May 2021 survey. Four quadrats (2.3 m^2 images) were observed at each station.

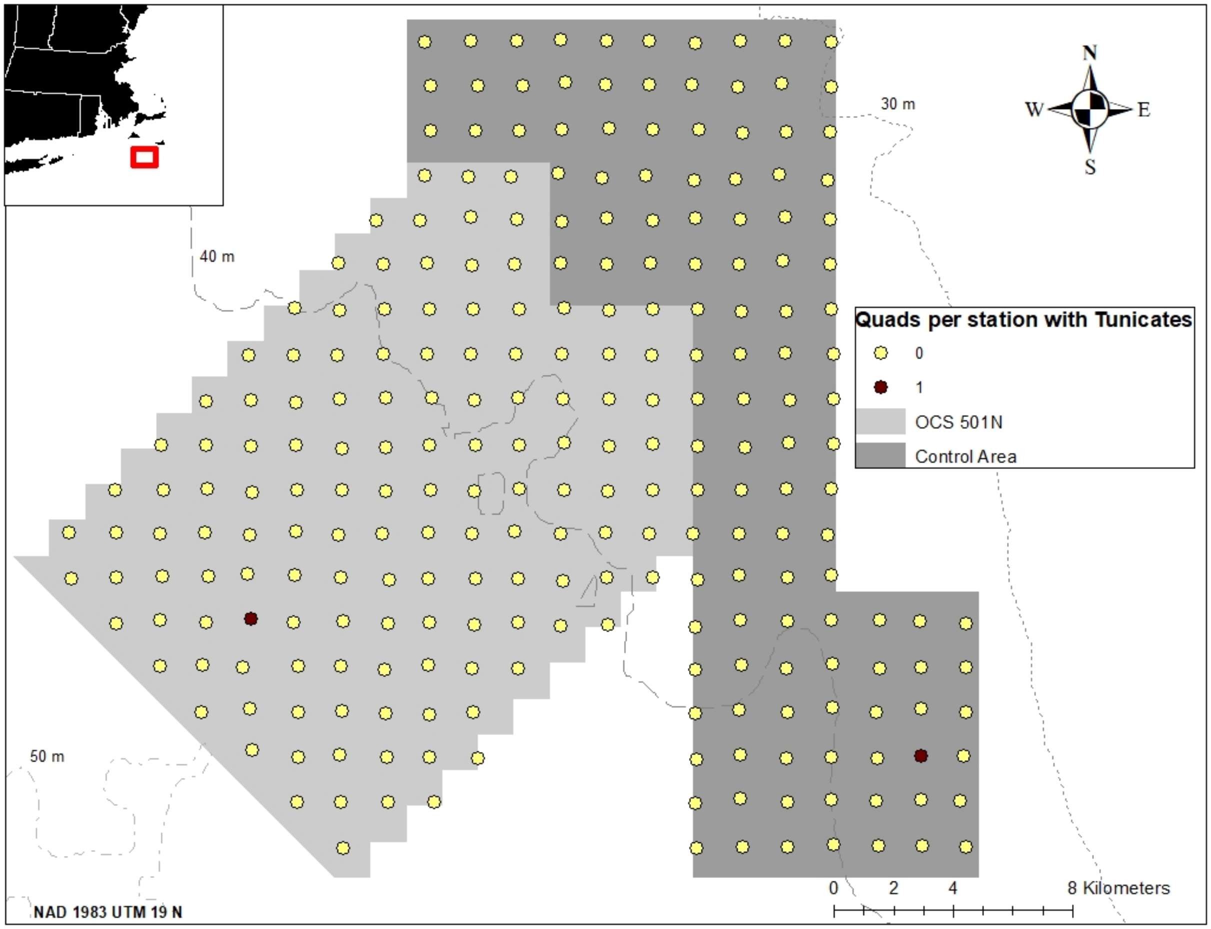


Figure 34. The distribution of tunicates from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that tunicates were observed in as indicated in the figure legend. No tunicates were observed in the May 2021 survey. Four quadrats (2.3 m^2 images) were observed at each station.

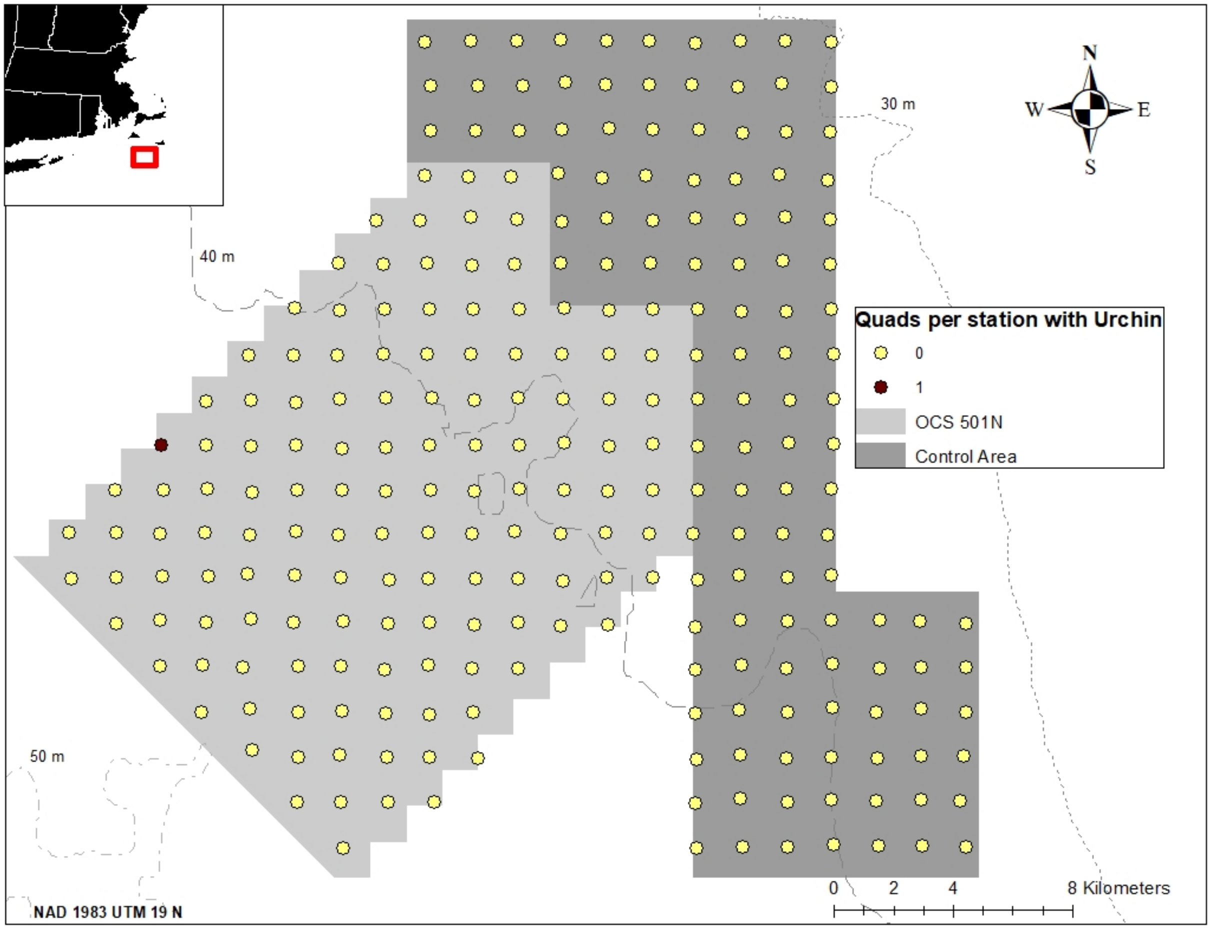


Figure 35. The distribution of urchins from the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Each station is colored by the number of quadrats that urchins were observed in as indicated in the figure legend. No urchin were observed in the May 2021 survey. Four quadrats (2.3 m^2 images) were observed at each station.

Sand comprised most of the surficial substrate at the stations surveyed in both years (Figures 36 to 38). Gravel was the largest particle size present in the VW1 Study Area and Control Areas during the 2021 survey (present at only two stations), and no cobble, rock, or boulders were observed. Boulder was the largest substrate observed in the 2022 survey but both cobble and gravel were also observed (boulder was only observed at one station) (Figures 36 to 38). Silt was common at most stations in both years, with only 10% and 29% of stations having no silt in 2021 and 2022, respectively. An increase in gravel and larger diameter substrates was noted in the time between the 2021 and 2022 surveys. Substrates shifted from a silt/sand/shell debris mix to a silt/sand/gravel/shell debris mix from 2021 to 2022. Substrates within aliquots sampled by the American Lobster, Black Sea Bass, Larval Lobster Abundance Survey, and Lobster Tagging Study of this area is predominately comprised of sand in 2021 and sand or gravel in 2022 (Figures 37 and 38).

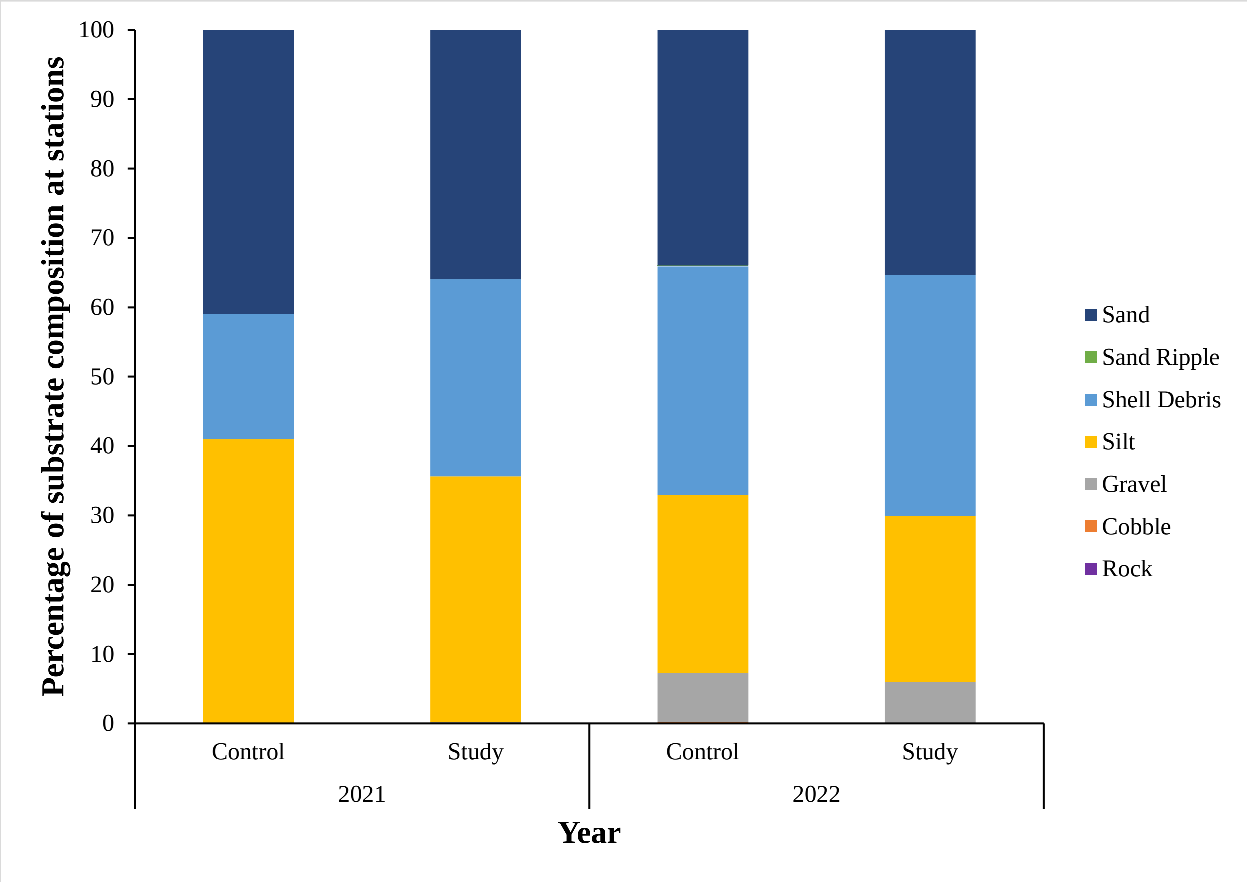


Figure 36. Substrate composition, defined by the most common substrate type observed at a station, during the May 2021 and 2022 drop camera surveys of the VW1 Study Area and an adjacent Control Area.

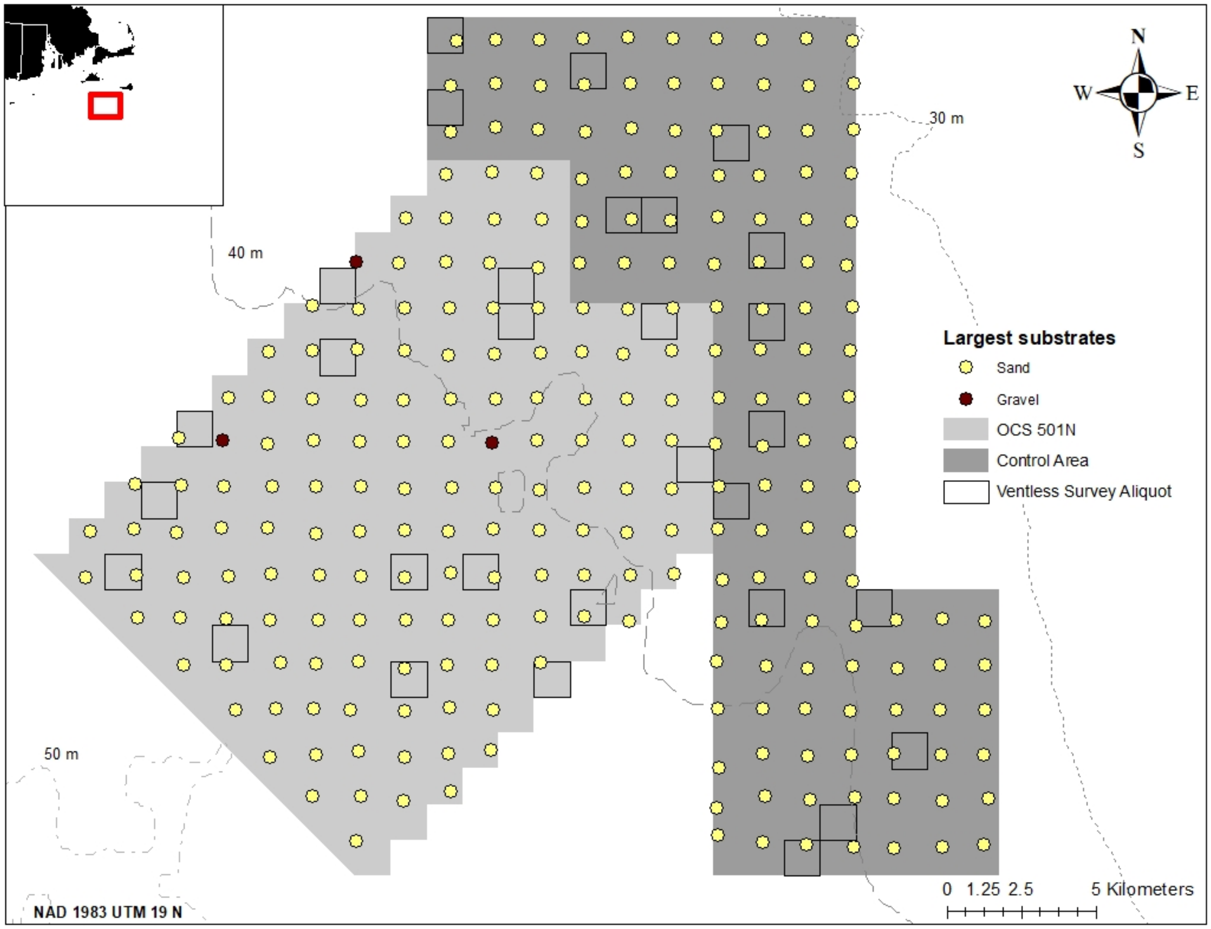


Figure 37. The largest substrate identified at each station in the May 2021 drop camera survey of the VW1 Study Area and an adjacent Control Area. Four quadrats (2.3 m^2 images) were observed at each station.

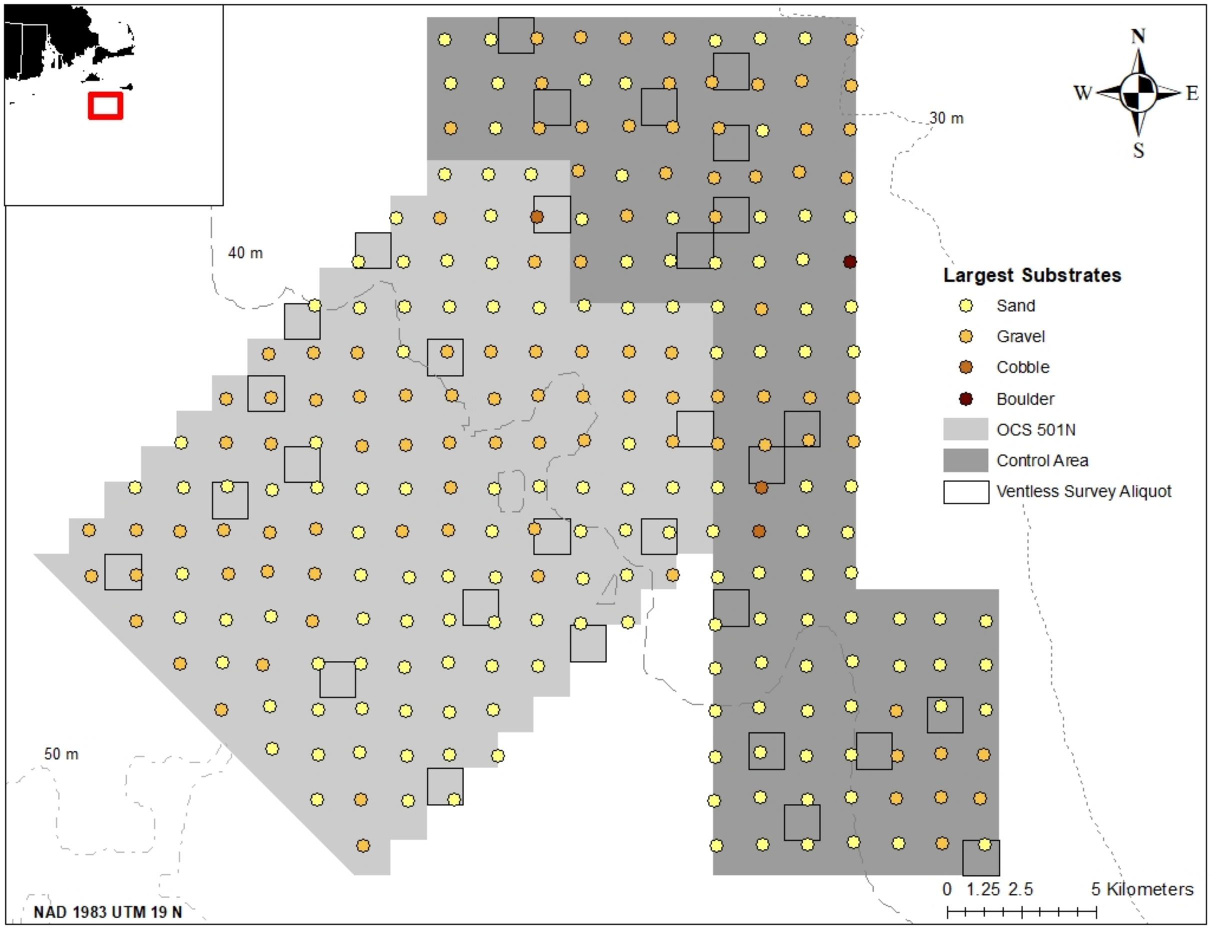


Figure 38. The largest substrate identified at each station in the May 2022 drop camera survey of the VW1 Study Area and an adjacent Control Area. Four quadrats (2.3 m^2 images) were observed at each station.

The composition of the benthic community in the VW1 Study Area and Control Area was most similar to each other when compared to the BCAs in both years (Tables 2 and 3). The two areas were 75% and 78% similar for 2021 and 2022, respectively, which was a slight decrease in similarity from 2020 when the two areas were 87% similar (Stokesbury et al., 2022). When compared to the BCAs (see Figure 5), the VW1 Study Area was most similar to the Nantucket Lightship area for both years with 75% and 76% similarity (Tables 2 and 3), which may correlate with the proximity to the VW1 Study Area. As the areas increased in distance from the VW1 Study Area, the similarity tended to decrease with the Great South Channel having 34% similarity and the Northern Edge having 34% similarity in 2021 and 36% and 27% similarity in 2022 to the VW1 Study Area. Interestingly, Closed Area II was 69% similar to the VW1 Study Area in both 2021 and 2022, but was the third furthest BCA, and closer to the Northern Edge than any other BCA.

The adjacent Control Area had the highest similarity of substrates compared to the VW1 Study Area, with the Nantucket Lightship and Closed Area II the next two most similar for both years (Tables 4 and 5). However, from 2020 to 2021, the similarity slightly decreased from 97%

to 91% (Stokesbury et al., 2022). The Great South Channel was the least like the VW1 Study Area in both years at 57% and 62% similarity for 2021 and 2022, respectively. The Northern Edge decreased in similarity to the VW1 Study Area from 33% in 2021 to 27% in 2022. The shifts in similarities on an annual basis may reflect highly dynamic environments in these areas.

Table 2. The percent similarity index between benthic communities in the VW1 Study Area, an adjacent Control Area, the Nantucket Lightship (NL), the Great South Channel (GSC), Closed Area II (CAII), and the Northern Edge (NE) areas surveyed in May 2021 by the drop camera.

Animal Group	Study	Control	NL	GSC	CAII	NE
Scallops	0.93	0.00	4.17	8.85	0.00	15.92
Sea Stars	0.37	0.00	2.08	23.89	0.00	12.44
Crabs (cancer spp.)	0.93	5.20	0.00	0.88	0.00	7.71
Hermit Crabs	18.28	4.40	29.17	9.73	30.43	15.92
Sand Dollars	54.66	72.80	52.08	7.08	44.93	0.50
Anemone	7.65	5.20	0.00	4.42	0.00	5.97
Bryozoans/Hydrozoans	2.43	0.00	10.42	24.78	17.39	27.86
Waved Whelk	0.75	0.40	2.08	1.77	1.45	2.49
Moonsnails	1.31	0.40	0.00	0.00	4.35	2.74
Sponges	4.10	4.80	0.00	15.04	0.00	7.71
Flat Fish	0.00	0.00	0.00	0.00	0.00	0.25
Red Hake	4.48	2.00	0.00	2.65	0.00	0.25
Skate	1.87	3.60	0.00	0.00	1.45	0.25
Silver Hake	2.24	1.20	0.00	0.88	0.00	0.00
Percent Similarity Index						
	75.17	___				
	74.84		___			
	34.25			___		
	69.14				___	
	33.71					___

Table 3. The percent similarity index between benthic communities in the VW1 Study Area, an adjacent Control Area, the Nantucket Lightship (NL), the Great South Channel (GSC), Closed Area II (CAII), and the Northern Edge (NE) areas surveyed in May 2022 by the drop camera.

Animal Group	Study	Control	NL	GSC	CAII	NE
Scallops	0.60	0.37	0.00	13.58	0.00	20.37
Sea Stars	0.70	0.37	8.93	27.16	0.00	11.11
Crabs (cancer spp.)	0.89	2.78	0.00	2.47	0.00	12.65
Hermit Crabs	23.86	28.12	21.43	3.70	30.77	10.80
Sand Dollars	35.88	17.85	41.07	12.35	57.69	0.31
Anemone	1.29	9.62	3.57	1.23	0.00	0.31
Bryozoans/Hydrozoans	7.46	13.32	10.71	24.69	9.62	32.10
Waved Whelk	12.72	11.66	3.57	0.00	0.00	0.00
Moonsnails	2.09	3.42	0.00	0.00	0.00	0.93
Sponges	2.29	2.59	5.36	7.41	0.00	8.64
Flat Fish	2.58	0.74	0.00	0.00	0.00	0.31
Red Hake	3.98	3.70	0.00	3.70	1.92	0.31
Skate	2.09	1.39	3.57	0.00	0.00	1.54
Silver Hake	3.58	4.07	1.79	3.70	0.00	0.62
Percent Similarity Index						
	77.53					
	76.49					
	36.49					
	69.12					
	27.05					

Table 4. The percent similarity index between substrate types in the VW1 Study Area, an adjacent Control Area, the Nantucket Lightship (NL), the Great South Channel (GSC), Closed Area II (CAII), and the Northern Edge (NE) areas surveyed in May 2021 by the drop camera.

Animal Group	Study	Control	NL	GSC	CAII	NE
Sand	35.48	39.41	31.30	27.48	39.13	28.92
Sand Ripple	0.00	0.00	1.74	0.00	7.61	0.60
Shell Debris	29.39	21.18	29.57	27.48	39.13	28.92
Silt	34.92	39.41	16.52	1.53	9.78	9.84
Gravel	0.21	0.00	20.00	26.72	4.35	28.71
Cobble	0.00	0.00	0.87	10.69	0.00	3.01
Boulder	0.00	0.00	0.00	6.11	0.00	0.00
Percent Similarity Index						
	91.58					
	77.43					
	56.70					
	74.87					
	67.88					

Table 5. The percent similarity index between substrate types in the VW1 Study Area, an adjacent Control Area, the Nantucket Lightship (NL), the Great South Channel (GSC), Closed Area II (CAII), and the Northern Edge (NE) areas surveyed in May 2022 by the drop camera.

Animal Group	Study	Control	NL	GSC	CAII	NE
Sand	35.36	33.93	35.64	27.48	44.44	32.21
Sand Ripple	0.00	0.14	5.94	0.00	0.00	0.00
Shell Debris	34.75	33.04	35.64	27.48	44.44	32.21
Silt	24.00	25.60	0.00	0.76	0.00	4.47
Gravel	5.81	7.09	22.77	27.48	11.11	29.31
Cobble	0.07	0.14	0.00	15.27	0.00	1.79
Boulder	0.00	0.07	0.00	1.53	0.00	0.00
Percent Similarity Index						
	96.85					
	75.93					
	61.61					
	75.93					
	74.79					

In previous reports, recommendations were made to try to mitigate the visibility issues encountered in 2019 and 2020 by advancing survey deployment to earlier in the summer and fall rather than July/August and October (Bethoney et al., 2020; Stokesbury et al., 2022). Early May and September were proposed as alternatives. Surveys were not conducted in the fall of 2021 or 2022 due to contract delays so we cannot determine whether surveying in September would improve visibility; however, surveying in May 2021 and 2022 did increase visibility, although some issues with visibility remained in 2021 with silt in the water column in the southern portion of the Control Area. This means the reliability of comparisons involving the Control Area in 2021 is decreased. Further analysis would be required to determine if the time of the year made a difference to the visibility of the images and the consequent data obtained. Future "summer" surveys will be conducted in May and the fall survey will be conducted in September in 2023.

As the 2021 and 2022 surveys were only conducted in the early summer, and not in the fall, temporal trends were restricted to the summer portion of the two years examined in this report and the other two prior years reports (Bethoney et al., 2020; Stokesbury et al., 2022). In general, the density and spatial data seem reflective of annual fluctuations as there is no clear trend of decreases or increases. Additional years of data are required to fully assess any temporal trends in species densities. Many animal groups were consistently observed in the VW1 Study Area and adjacent Control Area over the four years. The top twelve frequently observed animal groups that were counted were hermit crabs, crabs, waved whelk, skate, red hake, silver hake, skate egg cases, moon snails, flat fish, sea robins, scallops, and sea stars. The most commercially important species observed were scallops and flat fish. The most common presence/absence animal groups included holes (burrowing animals), sand dollars, anemones, and sponges. The 2022 survey saw a large increase in hermit crab abundance compared to 2021, the reason for which is unknown. Percent similarity indexes for benthic communities saw slight decreases from 2019 and 2020 to 2021 and 2022, which means that species compositions became slightly more different over time (Bethoney et al., 2020; Stokesbury et al., 2022). Although visibility could have played a role. Percent similarity indexes for substrates remained relatively unchanged suggesting similar fluctuations in areas over time.

The results of this survey provided a third and fourth year of baseline information on the benthic community and substrate in the VW1 Study Area and an adjacent Control Area prior to wind farm construction. Continuing this standardized systematic sampling approach will allow the data from annual drop camera surveys to be leveraged and combined for a comprehensive analysis. Each drop camera survey can be viewed as a potential dataset that can be integrated to conduct an asymmetrical analysis of variance to evaluate impacts (Underwood, 1993). With this analytical approach, a continuation of the SMAST drop camera surveys within and near offshore wind lease areas will aid in building a regional, standardized baseline dataset to (1) address the management objectives and research priorities for fisheries along the US East Coast, and (2) conduct a cumulative analysis of potential wind energy impacts along the US East Coast.

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Appendix I: Information on all categories tracked by the 2021 and 2022 Drop Camera Surveys in the VW1 Study Area and an adjacent Control Area

The main body of this report focused on the most common benthic megafauna and two commercially important animal groups observed in the VW1 Study Area and the adjacent Control Area. This appendix provides additional information about all animals tracked, including the number of quadrats in which animals were observed (Table 1), the density of all animals counted (Figure 1), and the average number of quadrats for all categories tracked as present or absent (Figure 2).

Table I-1. All animal groups observed during the 2021 and 2022 drop camera surveys of the VW1 Study Area and an adjacent Control Area. Groups left blank in the “Counts” column are tracked as present or absent (below).

	2021				2022			
	Control		Study		Control		Study	
Animal Group	Present	Counts	Present	Counts	Present	Counts	Present	Counts
Sand dollar	182		293		193		361	
Detritus	52		216		255		379	
Holes	14		199		337		413	
Anemone	13		41		104		13	
Crab	13	17	5	5	30	33	9	9
Sponges	12		22		28		23	
Hermit crab	11	14	98	131	304	1205	240	428
Skate	9	9	10	10	15	15	21	21
Red hake	5	5	24	24	40	50	40	44
Silver hake	3	3	12	12	44	68	36	37
Skate eggcase	2	2	7	7	7	7	6	7
Euphausiids	2		4		4		15	
Unidentified fish	2	2	0	0	12	14	8	9
Moonsnail	1	1	7	7	37	47	21	26
Buccinum	1	1	4	6	126	262	128	320
Other crustaceans	1		2		7		17	
Eel	1	1	0		1	1	0	0
Haddock	1	1	0		0	0	0	0
Bry./Hydrozoans	0		13		144		75	
Sandlance	0		13		4		8	
Other mollusc	0		9		24		118	
Scallop	0	0	5	5	4	4	6	6
Sea star	0	0	2	2	4	4	7	7
Other fish	0	0	2	11	2	2	3	15
Seaweed	0		1		3		2	
Moonsnail eggcase	0	0	1	1	1	1	1	1
Clappers	0	0	1	1	0	0	0	0
Clams	0		0		24		6	
Sea robin	0	0	0	0	9	10	8	8
Flounder	0	0	0	0	8	8	26	27
Animal detritus	0		0		4		0	
Mouse	0	0	0	0	1	1	1	1
Squid	0	0	0	0	1	1	1	1
Tunicate	0		0		1		1	
Sculpin	0	0	0	0	1	1	3	3
Monkfish	0	0	0	0	1	1	0	0
Urchin	0		0		0		1	
Scallop seed	0		0		0		3	
Echinoderm	0		0		0		0	
Lobster	0	0	0	0	0	0	0	0
Brittlestar	0		0		0		0	
Coral	0		0		0		0	
Ctenophore	0		0		0		0	
Filo	0		0		0		0	
Jellyfish	0		0		0		0	
Mussels	0		0		0		0	
Cod	0	0	0	0	0	0	0	0
Dogfish	0	0	0	0	0	0	0	0
Oceanpout	0	0	0	0	0	0	0	0
Hagfish	0	0	0	0	0	0	0	0
Herring	0	0	0	0	0	0	0	0
Mackerel	0	0	0	0	0	0	0	0
Sea raven	0	0	0	0	0	0	0	0
# of Visible Quadrats	333		501		494		523	

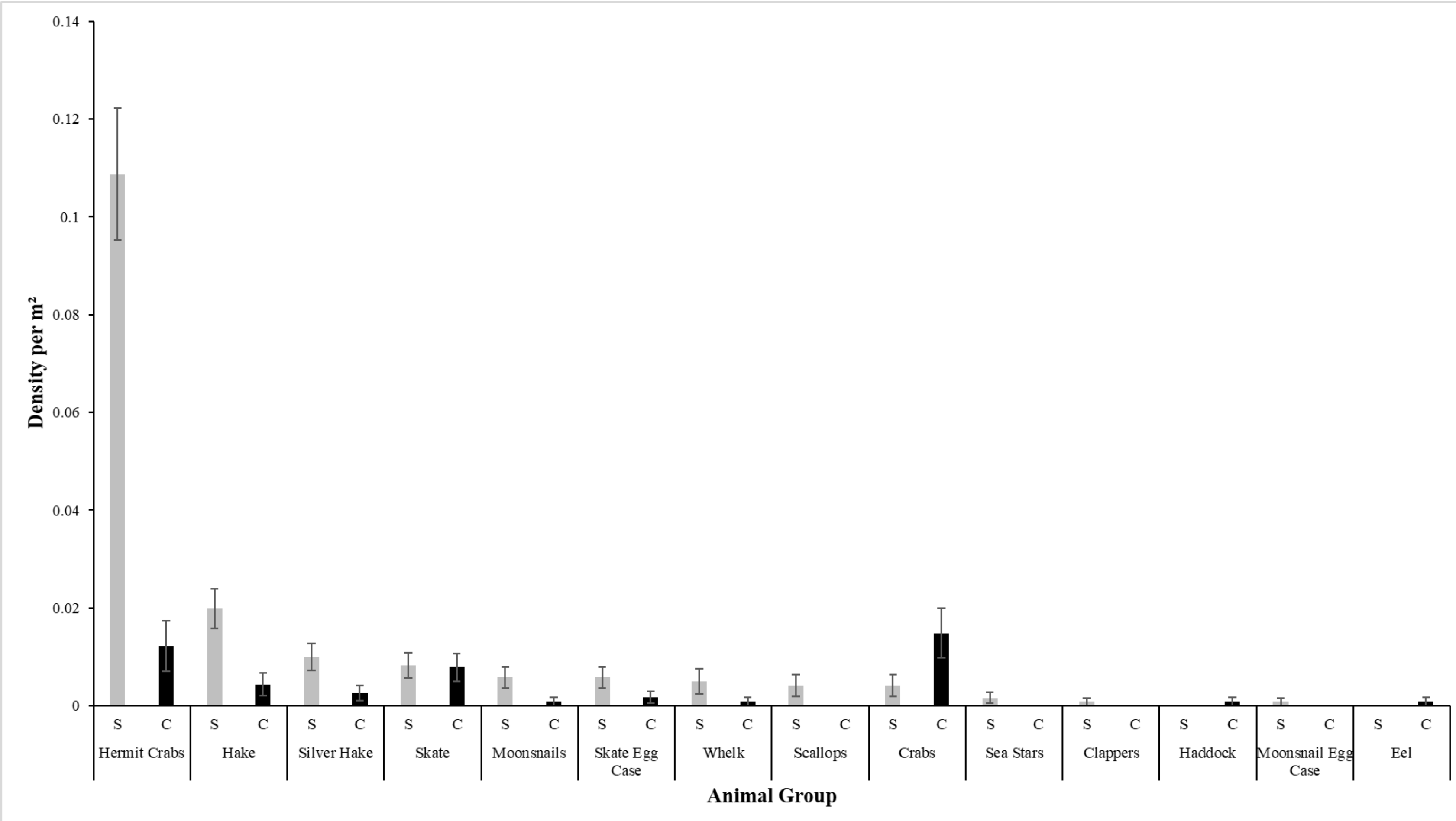

Figure I-1. Densities of animals in the May 2021 drop camera survey of the VW1 Study Area (S) and an adjacent Control Area (C).

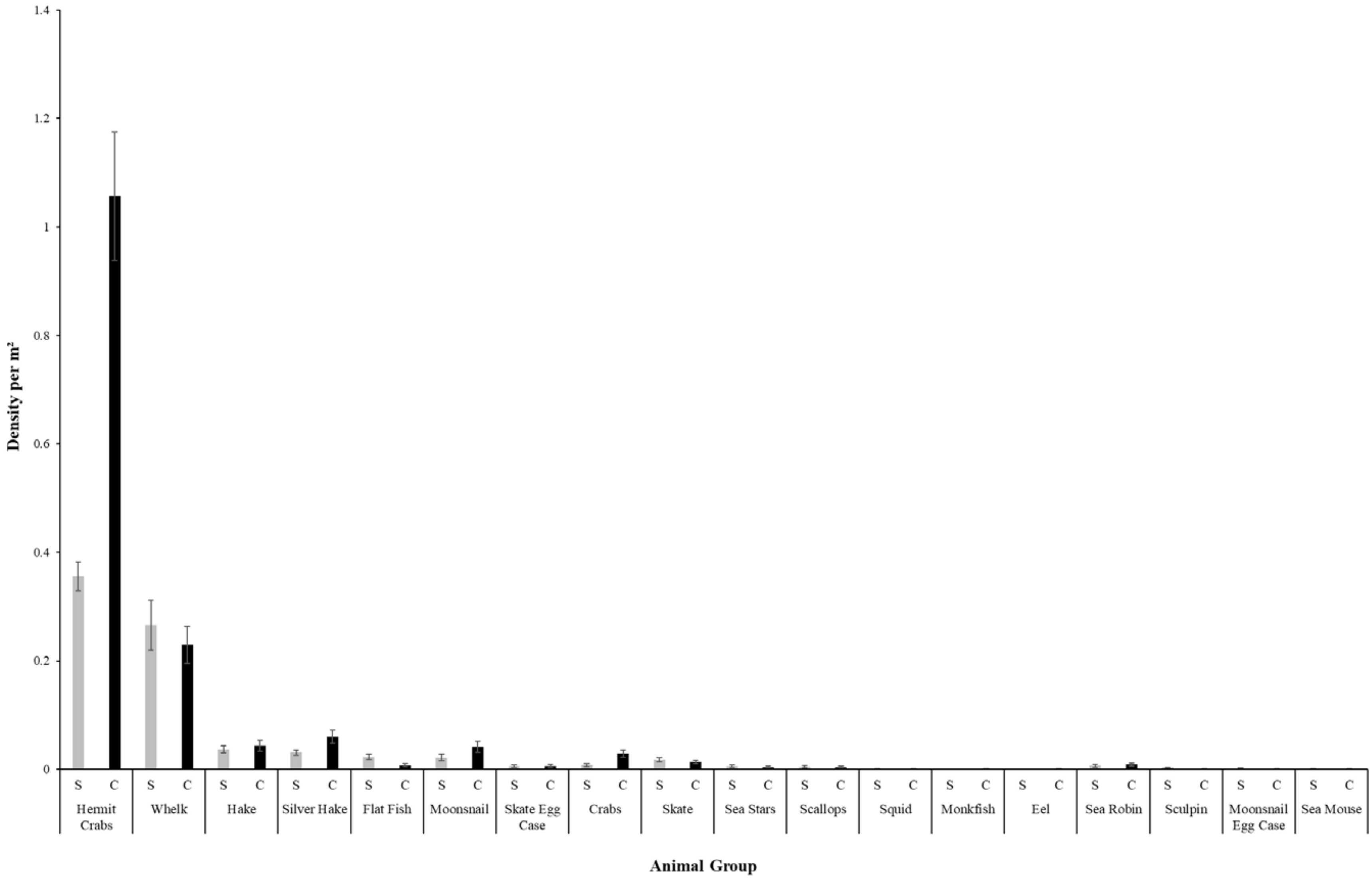

Figure I-2. Densities of animals in the May 2022 drop camera survey of the VW1 Study Area (S) and an adjacent Control Area (C).

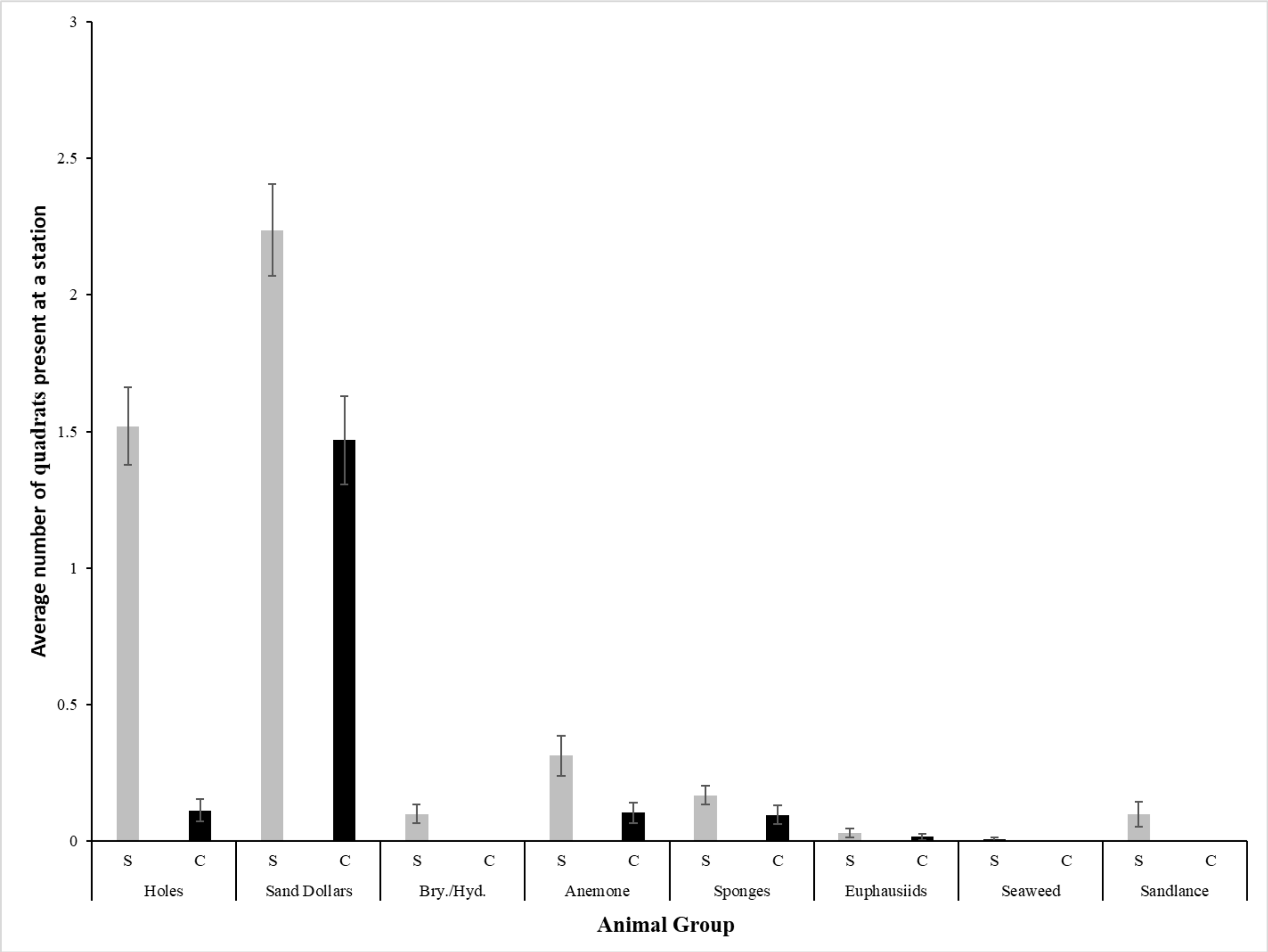

Figure I-3. Average number of quadrats animals were present in at each station in the May 2021 drop camera survey of the VW1 Study Area (S) and an adjacent Control Area (C). Four quadrats (2.3 m^2 in 2021 and 2022) were observed at each station.

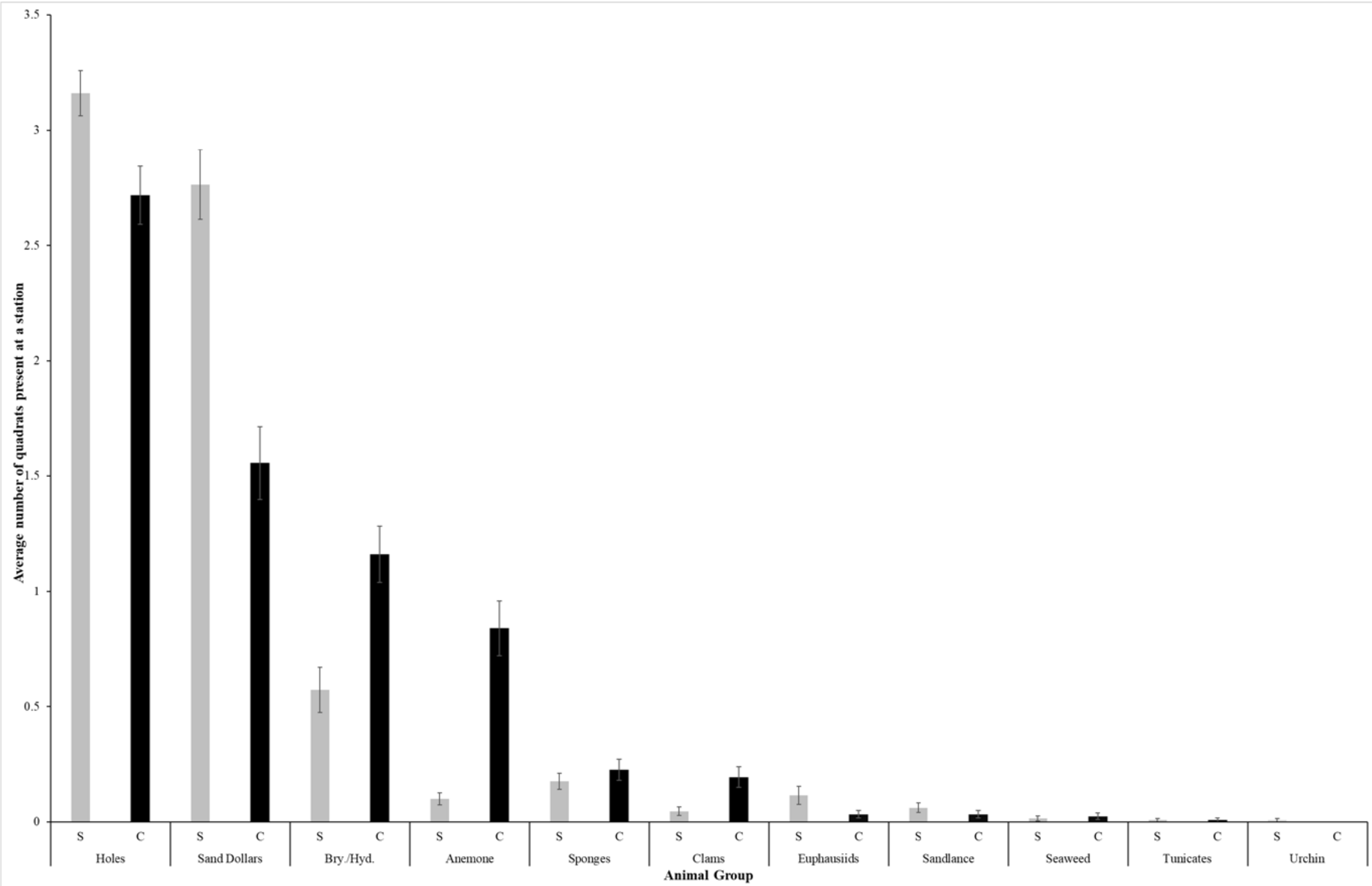

Figure I-4. Average number of quadrats animals were present in at each station in the May 2022 camera survey of the VW1 Study Area (S) and an adjacent Control Area (C). Four quadrats (2.3 m^2 in 2021 and 2022) were observed at each station.

<u>Appendix II</u>: Species list

Table II-1. A list of Georges Bank species that can be quantified by the drop camera survey, 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*	Atlantic rock crab
	Cancer borealis	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	Hog choker
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 redfish
	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

Appendix III: Quadrat Visibility

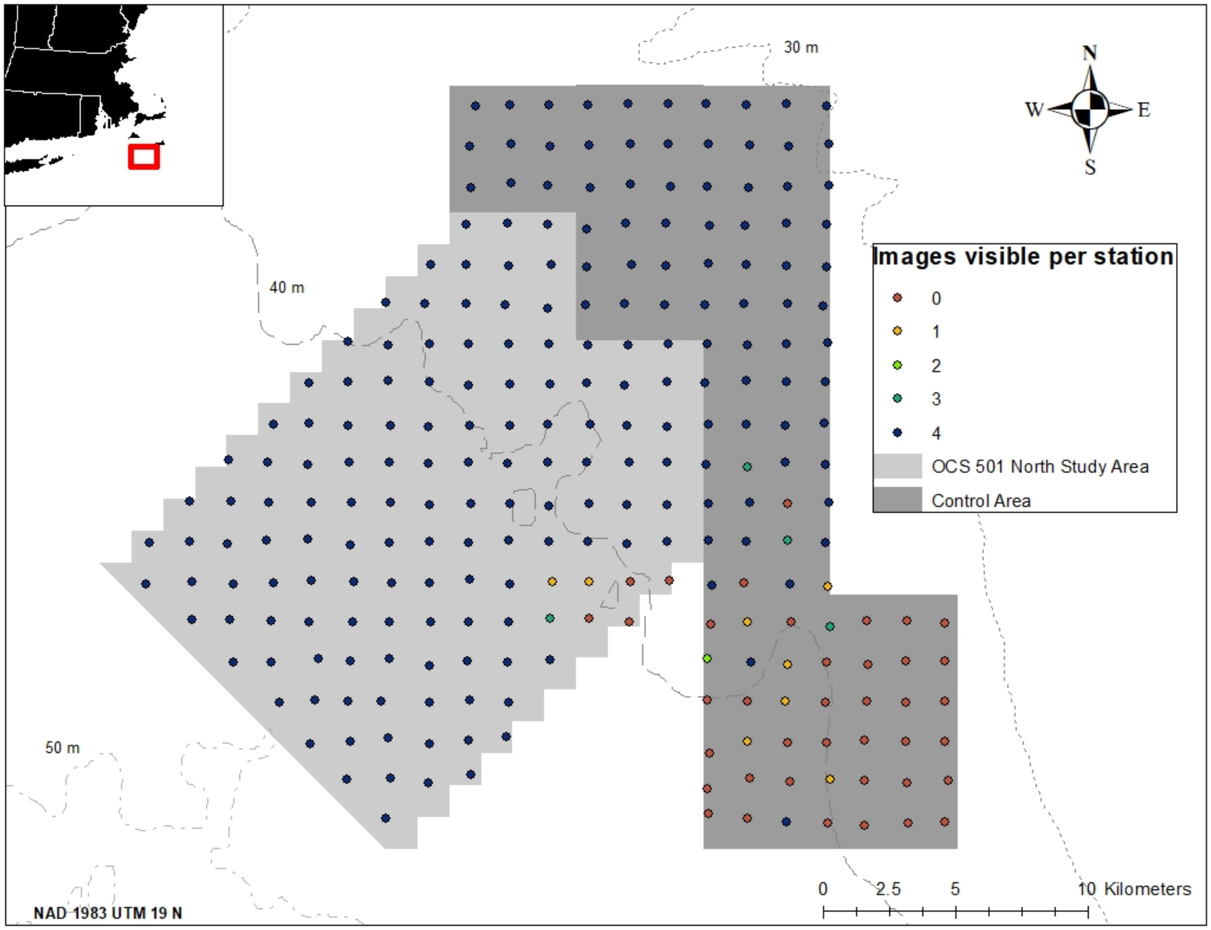

Figure III-1. The distribution of quadrat image visibility per station for the May 2021 drop camera survey of the VM1 Study Area and Control Area. The color of the stations represents the number of quadrats that were visible as indicated in the figure legend.

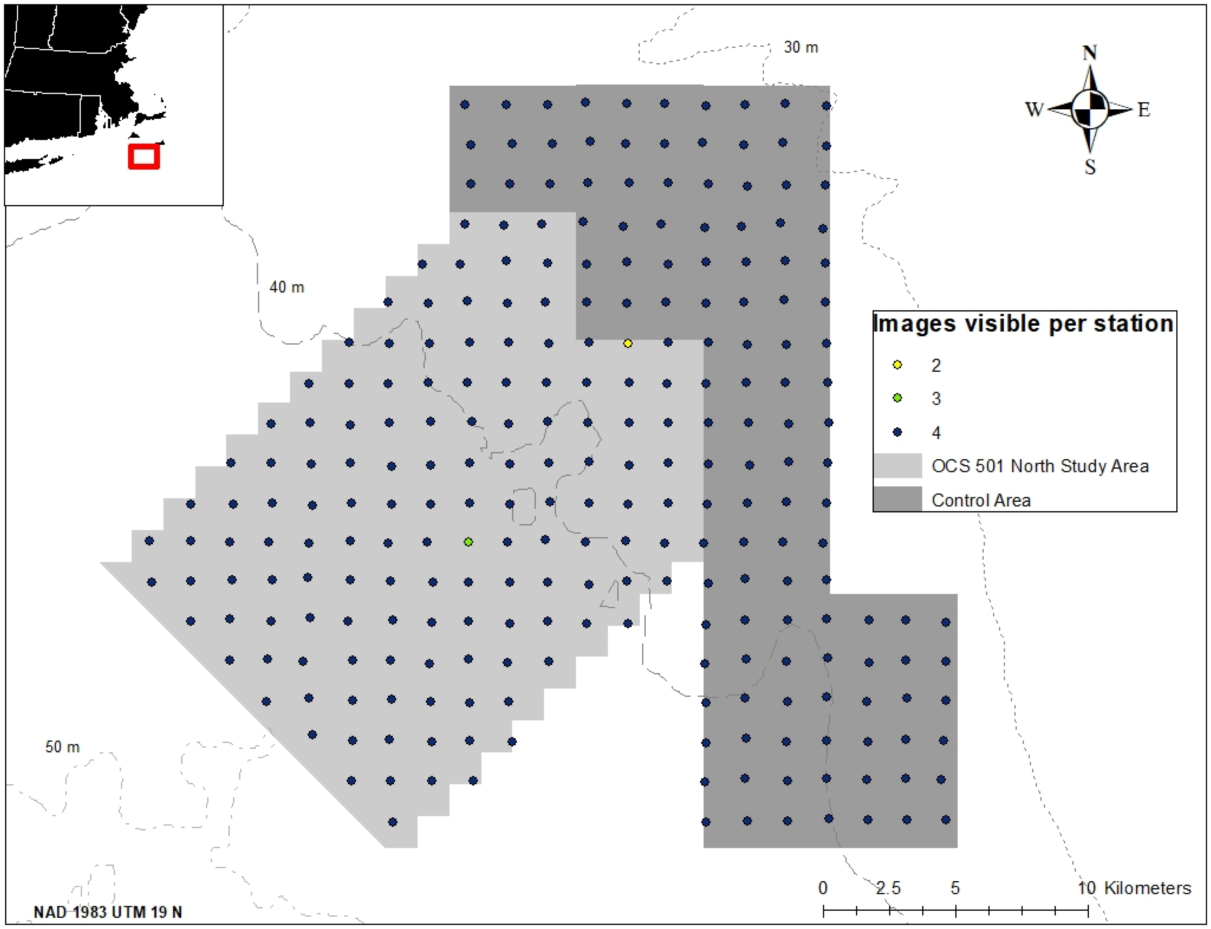

Figure III-2. The distribution of quadrat image visibility per station for the May 2022 drop camera survey of the VM1 Study Area and Control Area. The color of the stations represents the number of quadrats that were visible as indicated in the figure legend.