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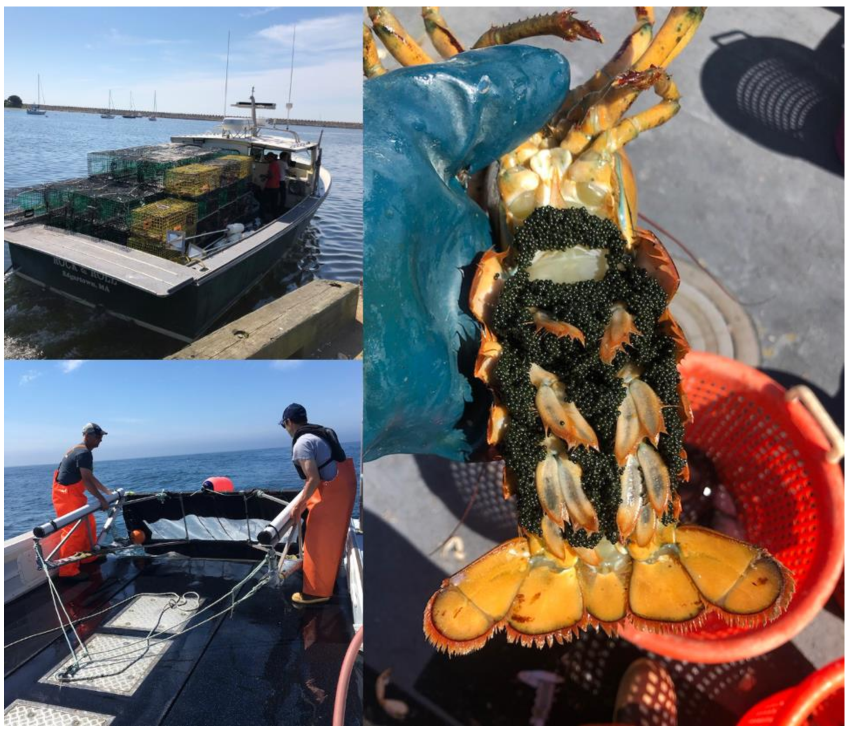
2019 Survey Season Annual Report
June Through October 2019

American Lobster, Black Sea Bass, Larval Lobster Abundance Survey, And Lobster Tagging Study of the 501N Study Area



VINEYARD WIND

Submitted to:
Vineyard Wind LLC
700 Pleasant Street
New Bedford, MA 02740

2019 Survey Season Annual Report

June Through October 2019

Project Title:	American Lobster, Black Sea Bass, Larval Lobster Abundance Survey, And Lobster Tagging Study of the 501N Study Area
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Report Date:	May 1, 2020
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PROJECT SUMMARY

The University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) and Massachusetts Lobstermen's Association (MLA), conducted a standardized ventless lobster trap survey and tagging study in Vineyard Wind's Lease Area OCS-A 0501, on the Outer Continental Shelf (OCS). In northern portion of the Lease Area, termed the 501 North (501N) Study Area, populations of adult lobster, larval lobster, and black sea bass were sampled and compared to those in the easterly adjacent Control Area (see Figure 1).

The primary goal of this project was to identify baseline conditions in the 501N Study Area and adjacent Control Area, to then compare potential impacts on several marine species of proposed wind development activities in the 501N Study Area to the Control Area. To establish a first-year baseline, a Before-After-Control-Impact (BACI) design was employed to detect eventual patterns of sustained difference. Our primary objectives for this project were to:

1) Estimate the size and distribution of lobster and black sea bass populations in the 501N Study Area and adjacent Control Area;

2) Classify population dynamics of these two species such as length, sex, reproductivity success, age, diet, and disease;

3) Estimate the relative abundance and distribution of planktonic species such as larval lobster in the neustonic layer of each area, using a towed ichthyoplankton net at each survey location; and

4) Obtain movement patterns of adult lobsters through a tagging study.

For the lobster, black sea bass, and planktonic sampling locations, we employed a random sampling design by stratifying the area of interest using existing lease blocks. Lease blocks within the two study areas, (the 501N Study Area and adjacent Control Area) were identified and divided into smaller sub-areas called aliquots. An aliquot (within each lease block) was randomly selected and served as a sampling location that held constant throughout the survey. There were 15 sampling sites selected in the 501N Study Area and 15 in the Control Area, for a total of 30 stations. Each location was sampled two times per month from July to October 2019 using a string of traps. Ventless traps were alternated with standard vented traps to compare differences in catch rates and size selectivity of both trap types. A single, unbaited sea bass pot was also attached to one end of a string. Surface plankton tows were conducted twice per month from June to August, then once per month in September and October due to equipment issues and weather restrictions.

A total of 351 lobsters were sampled between both study areas and trap types: 214 in the 501N Study Area, with an average size of 90.75 ± 2.2 millimeter (mm), and 137 in the Control Area, with an average size of 91.25 ± 2.4 mm. The 501N Study Area yielded an overall male: female ratio of 1.6:1, and the Control Area ratio was 2.4:1. A total of 264 black sea bass were sampled from commercial sized sea bass pots at each location; 99 in the 501N Study Area and 165 in the Control Area. Larval lobster samples were collected at each location with a neuston net; for the season we collected 23 total lobster larvae ranging from stages two to four. The average larval lobster density was 0.07 larvae / 1000m^3 in the development area and 0.04 larvae / 1000m^3 in the Control area.

Jonah crab were reported independently of other bycatch due their existence as commercially important target species. Overall catch during the survey was 1,918 crabs, with 1,160 sampled in the 501N Study Area and 758 in the Control Area. Jonah crab data are presented in Appendix 1, while counts of additional bycaught species are presented in Appendix II.

The substrate and habitat classification were determined from data collected by a separate SMAST Drop Camera Survey of Benthic Communities and Substrate in Vineyard Wind Lease Area OCS-A 0501 and Control Area. Dominant substrate in these areas were shown to be sand with a few areas of gravel in both the 501N Study Area and Control Areas (Appendix III, Figure 1)

INTRODUCTION

The Vineyard Wind Lease Area OCS-A 0501 is approximately 14 miles from the southeast corner of Martha's Vineyard. The Lease Area is within the Massachusetts Wind Energy Area (MA WEA), which was established on the Outer Continental Shelf (OCS) for offshore wind energy development and ranges from approximately 37 to 49.5 meters (m) in depth (Vineyard Wind, 2018). As part of extensive pre- and post-construction research initiatives, SMAST surveyed populations of commercially target species of concern in the northern portion of Vineyard Wind's Lease Area, (501N) and an easterly adjacent Control Area. The surveys used traps (for bottom dwelling species) and towed planktonic nets (for larval species) to begin assessing potential impacts of offshore wind development activities in the 501N Study Area using BACI protocol. The design of this experiment assumes that the 501N Study Area and Control Area have similar environments and over time would change at the same levels in the absence of planned development activities (Underwood, 1991) in the Lease Area .The Vineyard Wind monitoring plan developed by SMAST after considerable stakeholder and agency input, called for research on adult and larval lobster populations in 501N as well as reef-structure associated finfish; this study satisfied all components. Black sea bass monitoring was conducted also at the request of the Massachusetts Division of Marine Fisheries (MA DMF) as part of their recommendation for environmental assessment in the 501N Study Area (MA DMF, 2018; Cadrin et al., 2019). This first year of study provided a baseline on American lobster and black sea bass abundance through a trap survey, as well as temporal abundance and distribution of lobster larvae in the upper layer of the water column.

Ventless trap surveys are a widely accepted method for assessing populations relatively (Courchene and Stokesbury, 2011). This methodology is used widely by the MA DMF and Rhode Island Department of Environmental Management (RIDEM) to assess the status of the American lobster in southern New England (ASMFC, 2015). This survey design was also implemented in several graduate student projects at SMAST ((Courchene and Stokesbury, 2011; Cassidy, 2018). Ventless trap surveys were previously used with success in the pre-construction monitoring of the Rhode Island/Massachusetts wind energy area (RI/MA WEA), located on Cox's Ledge (Collie and King, 2016), in the United Kingdom (Roach et al., 2018), and to assess the impact of the Block Island Wind Farm (BIWF) on American lobster abundance from 2013 through 2018 (Griffin et al, 2019).

PROJECT GOALS AND OBJECTIVES

The goal of this project is to provide baseline relative abundance data for several species of concern to help inform the environmental impact assessment of wind energy development in the 501N Study Area and the adjacent Control Area (Figure 1). Our primary objectives are to:

1) Estimate the size and distribution of lobster and black sea bass populations in the 501N Study Area and adjacent Control Area;

2) Classify population dynamics of these two species such as length, sex, reproductivity success, age, diet, and disease;

3) Estimate the relative abundance and distribution of planktonic species such as larval lobster in the neustonic layer of each area, using a towed ichthyoplankton net at each survey location; and

4) Obtain movement patterns of adult lobsters through a tagging study.

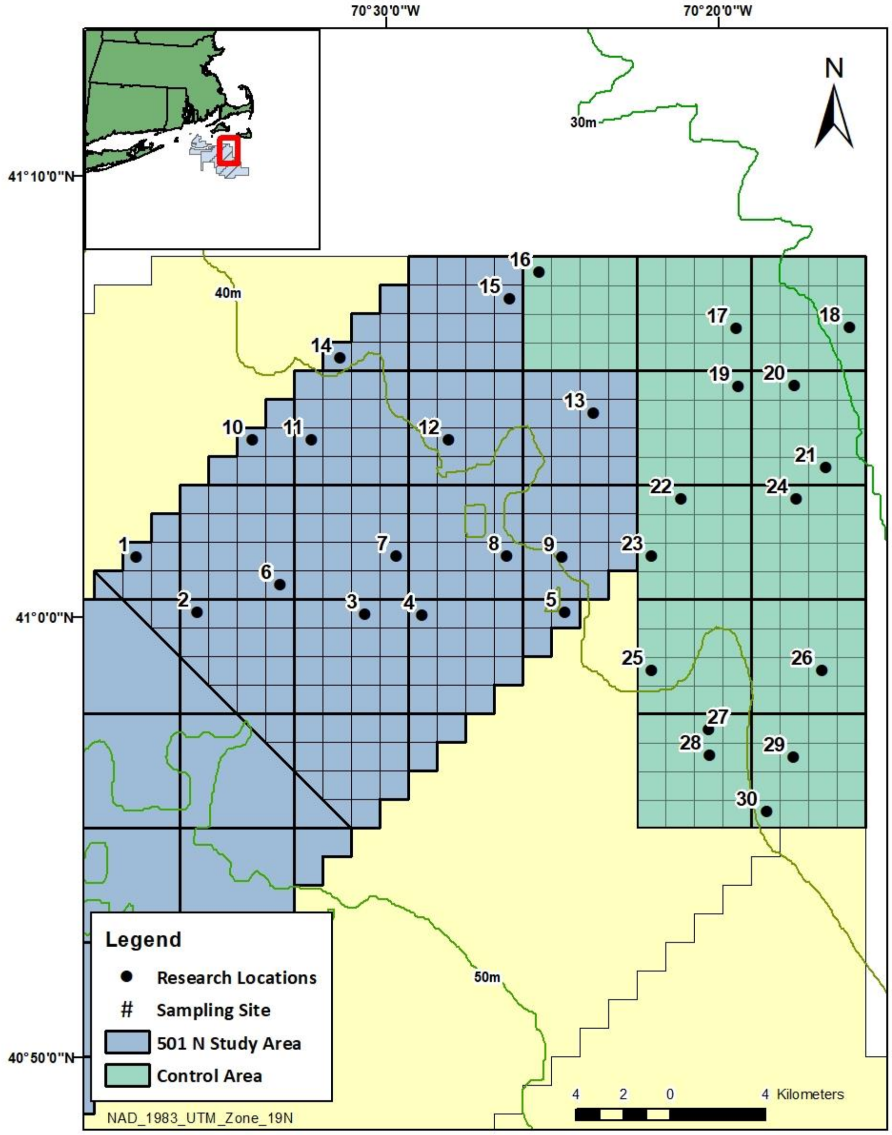

Figure 1. 501N Study Area (blue) and Control Area (green) with randomly selected sampling sites (research locations)

METHODS

Ventless Trap Survey

Fisheries-dependent trap sampling data historically has been used selectively to aid in relative abundance indices for American lobster (*Homarus americanus*) because of substantial spatial biases associated with the way these data are collected (ASMFC, 2015). The non-random fashion in which commercial traps are fished introduces a potential source of bias to catch per unit effort (CPUE) estimates, as the fishery actively targets lobster. Instead, trawl survey relative abundance indices have been used for lobster stock assessment purposes, because of the randomized sampling design and non-selective nature of trawl gear. However, trawl surveys have potential biases associated with their inability to fish in all productive lobster habitats, such as rock and ledge bottom, and in areas where static fishing gear is deployed (traps, gillnets, and bottom longlines) due to gear conflict (ASMFC, 2015).

To minimize the potential biases associated with standard abundance indices we modified Collie and King's (2016) cooperative, random stratified ventless trap survey of the Rhode Island/Massachusetts Wind Energy Area (RI/MA WEA). Just as it did in Collie and King (2016), this will generate robust estimates of lobster relative abundance and juvenile lobster population estimates in the 501N Study Area and Control Area. Sampling sites were determined by dividing our area into lease blocks (larger grid cells in Figure 1) that were 23km^2 each. Each block was divided into 16 "aliquots" and one randomly selected aliquot (1.4km^2) within each block served as a sampling site for the duration of the survey. This survey design combines the best aspects of both fishery dependent and independent surveys; random stratified sampling design and static fishing gear that can be deployed on any substrate type.

SMAST worked in cooperation with Capt. Jarett Drake and Capt. Mohawk Bolin on the project, who allowed the scientists on board and deployed and maintained the gear used in the surveys. A total of 30 strings of traps were deployed from their vessels at the sampling sites on July 8, 2019 and split equally between the 501N Study Area and Control Areas. The strings in each area are designed using the standard protocols demonstrated in previous SMAST, MA DMF, and coastwide ventless trap studies (ASFMC, 2015; Courchene and Stokesbury, 2011). Each string contained 6 lobster pots, alternating between vented and ventless traps to obtain information on catch rates of lobsters both above and below the minimum landing size (MLS). A single, unbaited commercial sized sea bass pot was attached at one end of each string (Figure 2) to collect information on this hard-structure associated finfish species. The dimensions for all lobster traps were standardized (40" x 21" x 16") throughout all survey areas and contained a single kitchen, parlor, and rectangular vent in the parlor of vented traps (size 1 $^{15}/_{16}$" x 5 ¾"). All traps were spaced 150ft apart and the gear followed federal rigging regulations; the downlines of each string utilized new weak link technology to deter whale entanglements. A Tidbit v2™ Temperature Logger was placed on the first trap of each string to compare CPUE and bottom water temperature (Cassidy, 2018).

Trap deployment, maintenance, and hauling was contracted to commercial lobstermen, but sampling was always conducted by an SMAST researcher on board each fishing vessel. To the degree possible, survey gear was hauled on a three-day soak time, in the attempt to standardize catchability among trips. All strings were reset in the same assigned location after each haul. SMAST researchers accompanied fishermen on each sampling trip to record CPUE and biological data using the standard MA DMF and RI DEM lobster trap sampling protocol, which enumerate lobsters per trap, number of trap hauls, soak time, trap and bait type, carapace length (to the nearest mm), sex, shell hardness, number of claws or shell damage, presence of shell disease, and egg stages on ovigerous females (ASMFC, 2015). American lobster and Jonah crab CPUE refer to the number of animals collected per each string hauled. A subset of these data (carapace width (mm) and sex) were collected from the majority of Jonah crabs in each string. In addition, other bycaught species were recorded and described in Appendix I and II. String locations were confirmed with the station's original coordinates after each haul via GPS and some within aliquot modifications to the sampling sites were made at the instruction of commercial fisherman to avoid user conflicts with other fishing gear types. Depth at mean low water for each trawl location was recorded from NOAA navigational charts as a survey standard to avoid variability from tidal fluctuations.

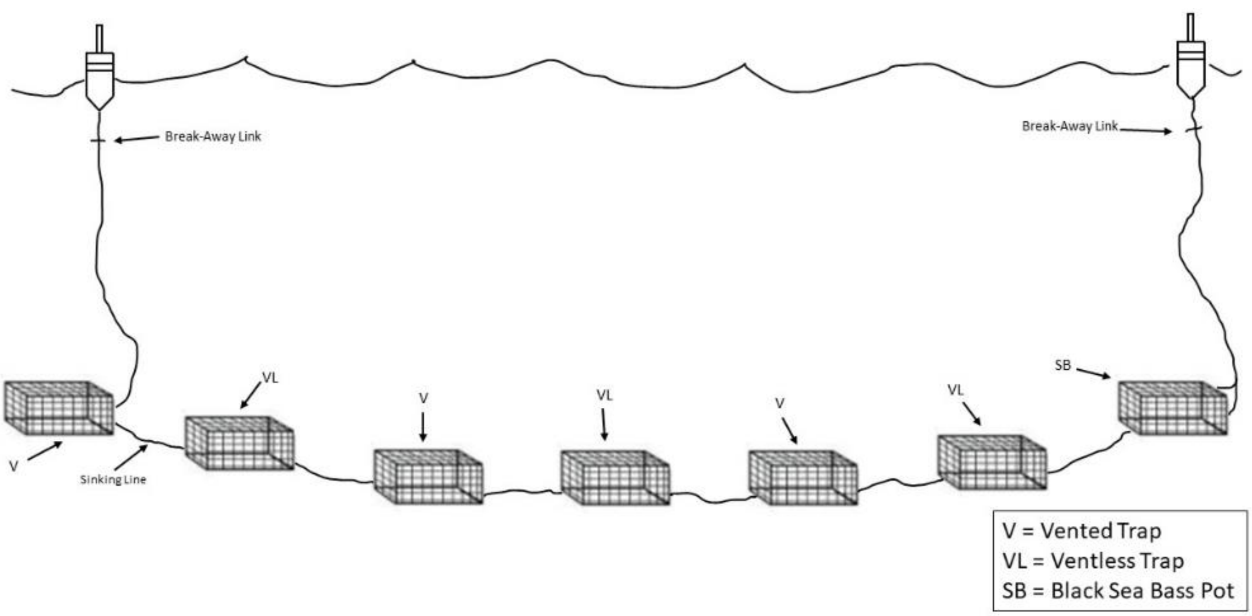

Figure 2. Diagram of a string of traps (three vented, three ventless, and one sea bass pot) placed at each sampling site

Lobster Tagging Study

A lobster tagging study was also conducted using the methods described in Courchene and Stokesbury (2011). Lobsters with a carapace length greater than 40mm were tagged using Floy™ anchor tags inserted with a hypodermic needle. The tags were inserted into the arthral muscle of the animal, so it is retained during molting. Each tag displayed an individual identification number and included a phone number for reporting of recaptures by fishermen (Cassidy, 2018). Each tagged lobster was released at the aliquot of capture, allowing for the spatial assessment of lobster within and outside the development area. Tagging data has also been useful for recapture information by commercial fishermen to determine the average velocity of recaptured individuals (Cooper and Uzmann, 1971; Geraldi et al., 2009).

Black Sea Bass

This survey assessed the black sea bass population at the 15 strings in each study area. To achieve this, one un-baited black sea bass pot was set at the far end of each string of lobster traps and was allowed to naturally saturate over the soaking period. The sampling for black sea bass occurred simultaneously with lobster trap hauling and all black sea bass caught in sea bass pots were counted and measured to the total length in centimeters (cm). Black sea bass CPUE refers to the number of black sea bass captured per each sea bass pot haul. A subset of these fish were taken at each hauling period for biological analysis (aging, diet, and fecundity), with a goal of two specimens from each sampling site; or thirty fish from each area for a total of sixty fish per sampling period. Stomach content analyses were conducted on all sea bass collected throughout the study, as this species preys on lobster (Wahle, et al, 2013). Otolith samples were taken from those fish collected and were stored for potential future analysis. These analyses were important for collecting general information on this species in a previously undescribed location.

Larval Lobster Study

A towed neuston net collected samples from the same sampling sites as the traps. This occurred on the days set aside for baiting and setting gear from June through October, 2019 and predated the trap portion of the survey by a month. The sampling net was deployed off the stern of the commercial fishing vessels; the net opens to 2.4m x 0.6m x 6m in size and is made of a 1320 micrometer mesh. The net, when towed, samples the top 0.5 m of the water column. One 10 minute tow at approximately 4 knots was conducted at each location. The contents from each tow were washed into tubs, sorted, and stored in a mixture of 10% formalin: 90% seawater, as described by Milligan (2010). Once back in the lab, samples were transferred into 70% ethanol for preservation and lobster larvae were staged according to Herrick (1911).

RESULTS AND DISCUSSION

Lobster Trap Survey

Individual trap hauls in the 501N Study Area totaled 251 vented traps, and 294 ventless traps. These numbers were slightly lower in the Control Area, where 262 vented traps and 281 ventless traps were sampled. One hundred separate strings were hauled in the 501N Study Area, while 95 strings were hauled in the Control Area. Accounting for strings containing less than 6 traps lobster traps, an average of 11.3±0.68 strings were hauled per sampling period in the Control Area. The 501N Study Area averaged 11.4±0.66 lobster string hauls during each sampling period, with no difference in the number of individual lobster traps hauls between areas (Wilcoxon signed rank, W = 39, p-value = 0.49). The number of black sea bass pot hauls between the both areas did not vary either (Wilcoxon signed rank, V = 2.5, p = 0.06) as 92 and 78 pot hauls occurred in the 501N Study Area and Control Area, respectively. Gear loss throughout the survey explains the discrepancy between total, individual trap hauls per area. This was attributed to transiting vessels, and fishing activity that occurs in the area.

A total of 351 American lobsters were collected from both lobster trap types combined: 137 were caught in the Control Area, while 214 in the 501N Study Area. American lobster counts were the lowest in the beginning of July during the first sampling period (n=13) and reached a high in September during the sixth sampling period (n=85). Lobster catch fluctuated monthly and by area (Figure 3). The aliquots in the 501N Study Area that experienced the highest lobster totals were Aliquots 2, 3, and 4 (n=33, n=24, and n=28). In the Control Area, Aliquot 27 dominated total catch. Forty-two lobsters, or 30.7% of all lobsters caught in the Control Area came from this aliquot. The next highest total catches were observed on Aliquots 17, 22, and 28, which each produced 12 lobsters per site (Figure 4). Overall, 229 males and 122 females were observed between both areas. The Control Area produced 97 males and 40 females, while 132 males and 82 females originated from the 501N Study Area This resulted in a 2.4:1 ratio in the Control Area, 1.6:1 ratio in the 501N Study Area, and a 1.9:1 overall ratio. Overall, Male:Female sex ratios ranged between 0.9:1 to 2.5:1 in the 501N Study Area and 0.8:1 to 8.0:1 in the Control Area (Table 1).

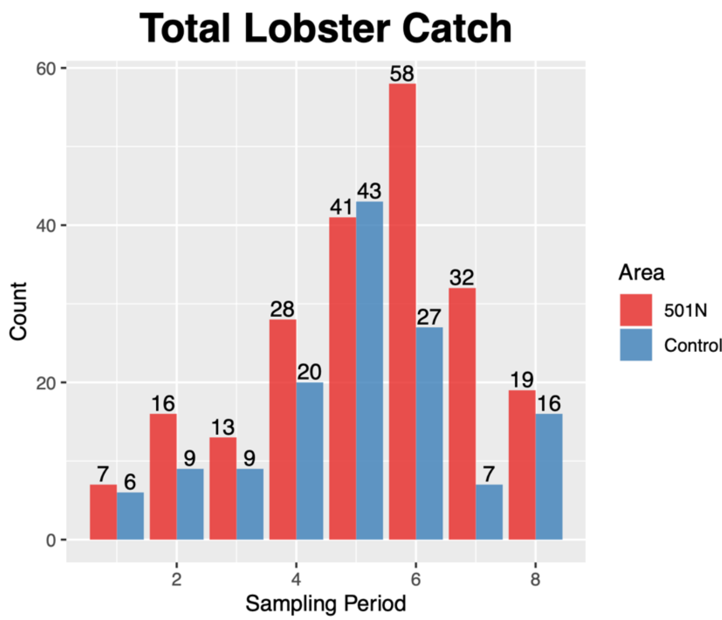

Figure 3. Total lobster catches by sampling period for the 501N Study Area (red) and Control Area (blue).

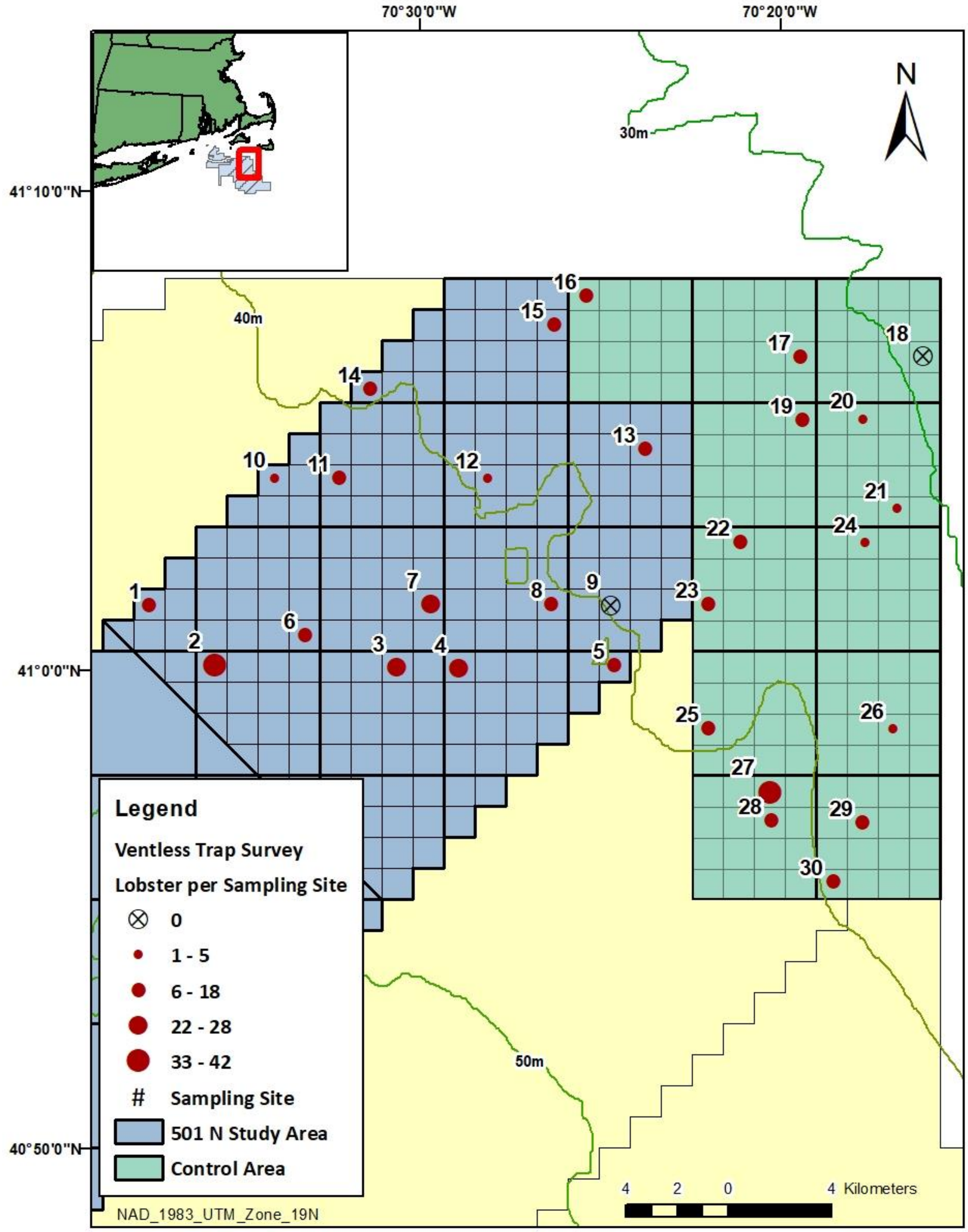

Figure 4. Total lobster catch at each aliquot over the duration of the field season, numbers next to each dot are the station numbers.

CPUE was used to compare catches of American lobster between areas and over time and refers to the average number of organisms caught on a per string basis. To evaluate CPUE, a value of 1 was added to all raw lobster count data and transformed using the natural log of the raw value. The residuals of the natural log transformed count data fit a Gaussian error distribution and were therefore able to be evaluated using statistical tests assuming a normal distribution. Normality was confirmed through a Shapiro-Wilk Normality Test ($W = 0.99$, $p = 0.13$), with 95% confidence intervals for CPUE reported assuming a Poisson distribution.

The average CPUE recorded throughout the survey was 1.80±0.188 lobsters/string. Average area level comparisons showed lobster CPUE was higher in the 501N Study Area (2.14±0.287 lobsters/string) than in the Control Area (1.44±0.241 lobsters/string) (Table 1) and this difference was significant (Two Sample T-test, -2.58, df = 192, $p = 0.01$). Differences are visualized in Figure 5a, as higher relative abundances were observed in the 501N Study Area.

CPUE also varied with respect to area and sampling period. In the Control Area, sampling period 1 in early July produced 0.46±0.369 lobsters/string, the minimum CPUE observed in either area throughout the season. Observations of average CPUE >1.0 lobster/string were seen during sampling periods 4, 5, 6, and 8 in late summer and fall, while the remaining sampling periods demonstrated values <1.0 lobster/string. The highest average catches seen in the Control Area occurred during sampling periods 5 and 6 (2.45±1.024 and 4.78±1.292 lobsters/string, respectively). In the 501N Study Area, the lowest CPUE recorded was also observed during sampling period 1 (0.47±0.346 lobsters/string). Similar to the Control, the highest average catches recorded in the 501N Study Area were also during sampling periods 5 and 6 (3.73±1.141 and 4.83±1.244 lobsters/string) in September. However, CPUE in the 501N Study Area fell below 1.0 lobsters/string only during sampling periods 1 and 3 (Table 1). Results suggest lobster relative abundance was seasonal with greater CPUE estimates observed later in the survey.

Table 1. Summary of results from the ventless trap survey conducted for each sampling period in the 501N Study Area and Control Area including the month sampled, the average bottom temperature, the number of lobsters collected, the catch per unit effort (for a 6 pot string), the mean carapace length, and the sex ration.

Sampling Period	Area	Month	Temp (^oC)	Number Caught	CPUE	Mean CL (mm)	Sex Ratio (M:F)
1	Control	July	12.01	6	0.46	96.50	1.0
2	Control	July	11.84	9	0.64	91.44	8.0
3	Control	August	13.07	9	0.64	94.67	0.8
4	Control	August	13.36	20	1.67	84.40	4.0
5	Control	September	16.28	43	4.78	89.40	2.9
6	Control	September	17.85	27	2.45	93.37	2.0
7	Control	October	15.14	7	0.64	90.71	2.5
8	Control	October	14.87	16	1.45	97.44	2.2
1	501N	July	9.66	7	0.47	98.14	2.5
2	501N	July	10.62	16	1.07	81.69	2.2
3	501N	August	11.06	13	0.93	86.85	0.9
4	501N	August	11.39	28	2.33	87.70	2.1
5	501N	September	13.6	41	3.73	89.71	2.2
6	501N	September	17.81	58	4.83	93.33	2.1
7	501N	October	15.88	32	2.91	93.47	0.9
8	501N	October	15.47	19	1.90	92.65	0.9
Average	Control	All	14.52±0.45	137	1.44±0.24	91.25±2.38	2.4
Average	501N	All	13.33±0.60	214	2.14±0.29	90.75±2.15	1.6
Average	Both	All	13.90±0.39	351	1.80±0.19	90.95±1.60	1.9

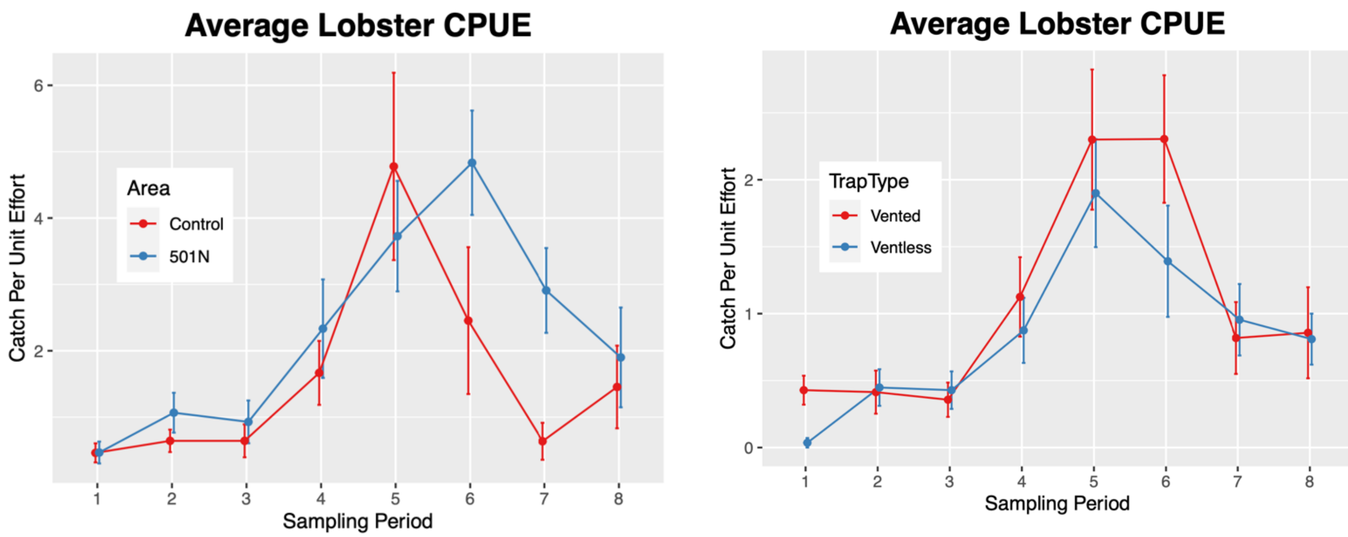

Figure 5a. CPUE (catch per string of six pots) results with standard error bars for the Study Areas (left). Figure 5b. Estimates of trap type performance over the duration of the survey (right) with standard error bars.

Comparing only differences between the two different trap types showed vented traps outperformed ventless traps, catching 196 lobsters compared to 155. This difference was also reflected in average catch rates, but CPUE between the two trap types did not vary significantly (Two Sample T-test, 1.30, df = 385, p = 0.19) (Figure 5b). An average of 1.01±0.141 lobsters were caught in vented traps on each string, while CPUE estimates for ventless traps on each string were 0.80±0.125 lobsters. The size distribution of lobsters captured in vented traps were significantly greater than ventless traps (K-S test, D = 0.30, p = 1.24e-07). The average size of lobsters caught in vented traps (95.50±2.119mm) was greater than that of ventless traps (85.14±2.122mm) (Two Sample T-test, 6.82, df = 341, p = 2.06e-11). When compared to the minimum landing size (MLS) of 85.7mm, ventless traps nearly averaged a commercially legal sized lobster while vented traps contained lobsters were well above the MLS.

The average carapace length of lobsters sampled in the 501N Study Area was 90.75±2.152 and 91.25±2.376mm in the Control Area. (Table 1). There was no difference in size distribution of lobsters caught within both areas (K-S test, D = 0.09, p = 0.57) (Figure 6A). Average size did not vary significantly either (Two Sample T-test, 0.31, df = 314, p = 0.76). When factoring in a time component, average lobster carapace length also never varied throughout the survey. A Two-Way ANOVA using month and area as independent variables showed no significant differences in average lobster size between months (F = 2.3, df = 3, p = 0.07) or areas (F = 0.2, df = 1, p = 0.65).

A difference in carapace length distribution (K-S test, D = 0.17, p = 0.02) and average size (Two Sample T-test, 3.21, df = 230, p = 0.001) was observed between male and female lobsters when all survey data was examined as an aggregate (Figure 6B). When these data were compared on an area level, there was no difference in size distribution between sexes in the Control Area (K-S test, D = 0.24, p = 0.07) or 501N Study Area (K-S test, D = 0.19, p = 0.06). Female lobsters were on average larger than males (94.56±2.81mm compared to 89.0±1.91mm). However, the average size of male lobsters was not different between Control and 501N Study Area (Two Sample T-test, 0.54, df = 210, p = 0.59); the same was true for females (Two Sample T-test, 0.31, df = 101, p = 0.76).

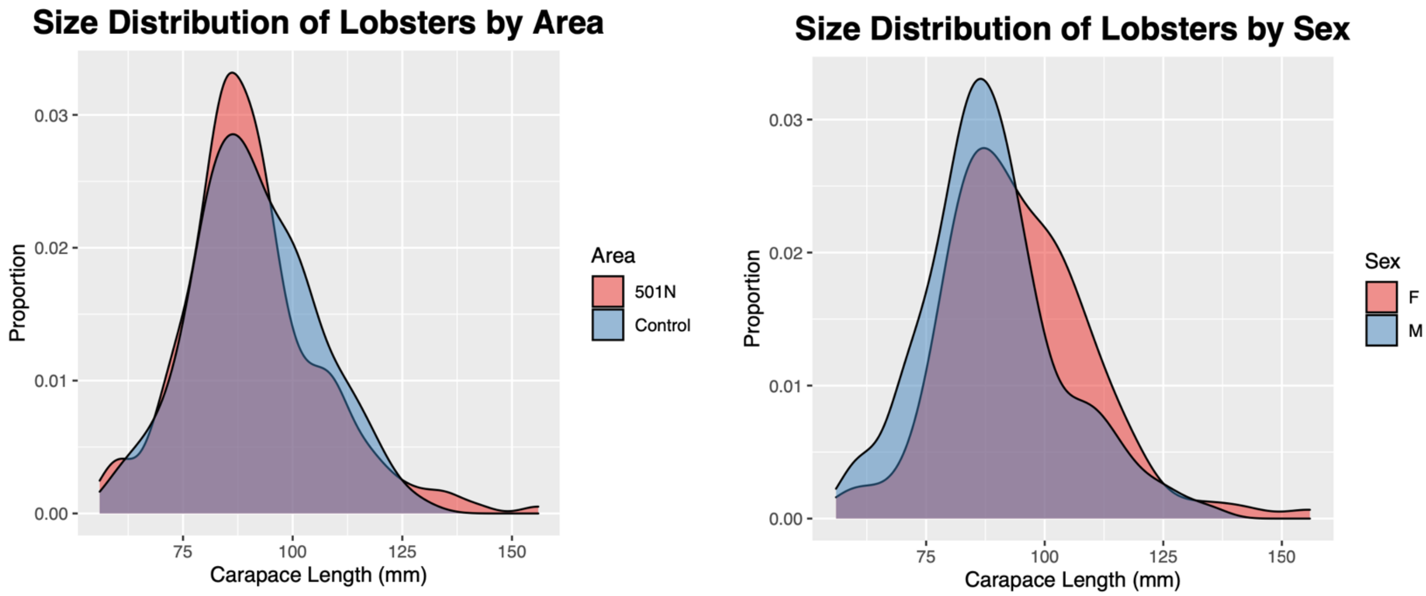

Figure 6a. Proportional distribution of carapace lengths by area (left) Figure 6b. Proportional distribution of carapace lengths by sex (right)

As shown on Table 2, of the 122 females sampled in both trap types, 45% (n=18) from the Control Area and 35% (n=29) from the 501N Study Area had some level of egg development, with more females sampled overall in the second half of the survey (n=86) than in the first half (n=36). The highest proportion of egg presence occurred in both areas during July in sampling period 1 (67% in the Control and 100% in the 501N Study Area), but sample sizes of female lobsters were low (n=3 and n=2, respectively) during this time (Table 2). The lowest proportions of females with eggs occurred in August, when a combined 8% of females showed visual level of egg development. The majority of egg bearing females were observed in deeper water between the 40m and 50m isobaths (Figure 7).

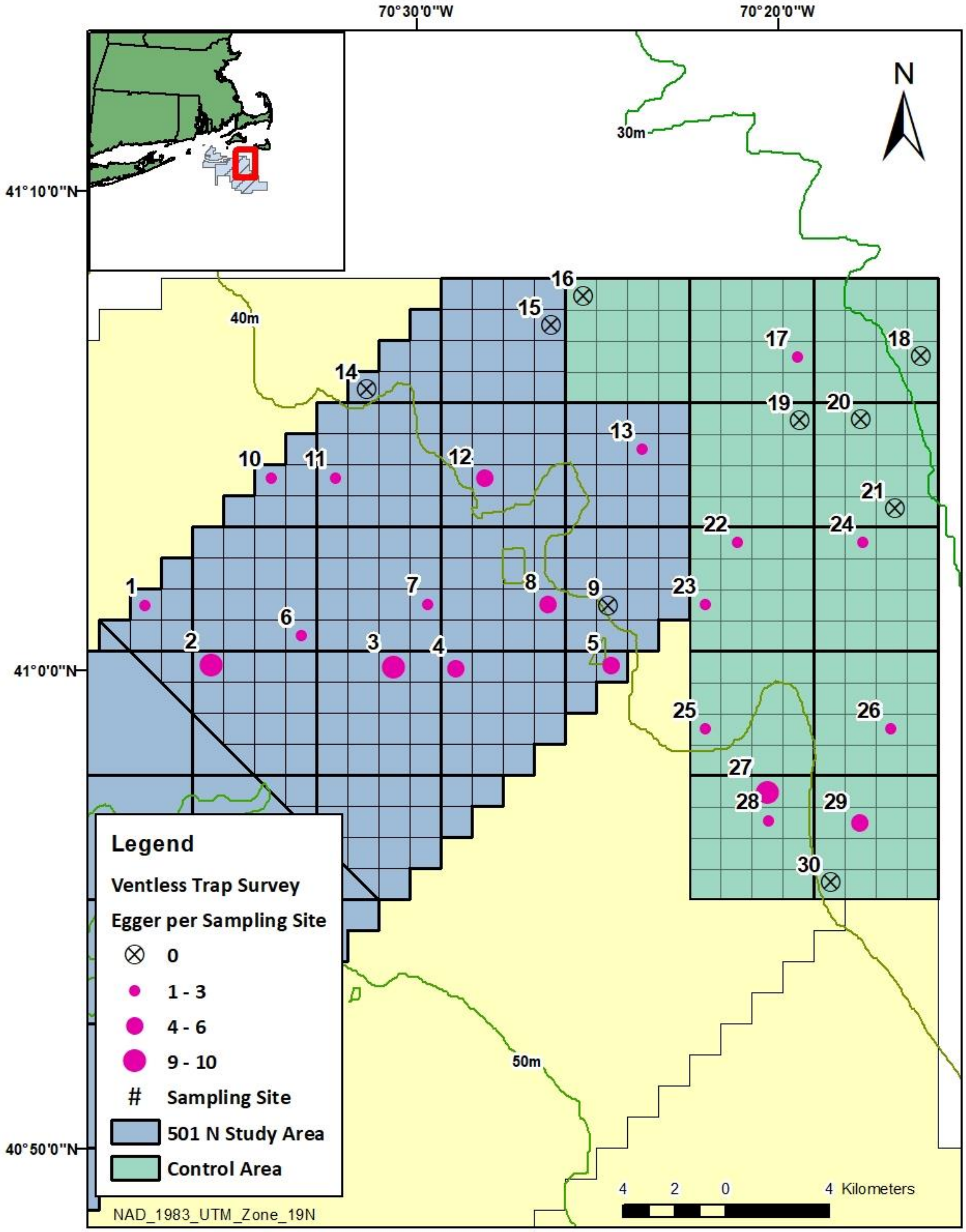

Figure 7. Map depicting the total number of egg bearing females sampled in the ventless trap throughout the duration of the Study Areas

Table 2. Summary of lobster egg bearing females samples throughout all sampling periods during the survey in both the Control and 501N Study Areas

Sampling Period	Area	Month	Number of Females	Number with eggs	Eggers (%)
1	Control	July	3	2	67%
2	Control	July	1	0	0%
3	Control	August	5	1	20%
4	Control	August	4	1	25%
5	Control	September	11	5	45%
6	Control	September	9	6	67%
7	Control	October	2	1	50%
8	Control	October	5	2	40%
1	501N	July	2	2	100%
2	501N	July	5	0	0%
3	501N	August	7	0	0%
4	501N	August	9	0	0%
5	501N	September	13	1	8%
6	501N	September	19	12	63%
7	501N	October	17	7	41%
8	501N	October	10	7	70%
Average	Control	All	40	18	45%
Average	501N	All	82	29	35%
Average	Both	All	122	47	39%

The proportion of lobsters containing any level of epizootic shell disease was low. As shown on Table 3, from the Control Area, the rate of infected individuals ranged from 0% to 22%, with an overall infection rate of 7% (n=9) (Table3). In the 501N Study Area infection rates ranged from 0% to 43% with an overall infection rate of 6% (n=13) (Table 3). Combined, a 6% (n=22) infection rate was observed for the duration of the study (Table 3)

Table 3. Summary of lobsters sampled in the ventless trap survey that were infected with epizootic shell disease from both the 501N Study Area and Control Area.

Sampling Period	Area	Month	Number Caught	Number w/Shell Disease	Shell Disease (%)
1	Control	July	6	1	17%
2	Control	July	9	0	0%
3	Control	August	9	2	22%
4	Control	August	20	1	5%
5	Control	September	43	0	0%
6	Control	September	27	1	4%
7	Control	October	7	1	14%
8	Control	October	16	3	19%
1	501N	July	7	3	43%
2	501N	July	16	3	19%
3	501N	August	13	2	15%
4	501N	August	28	2	7%
5	501N	September	41	0	0%
6	501N	September	58	2	3%
7	501N	October	32	1	3%
8	501N	October	19	0	0%
Average	Control	All	137	9	7%
Average	501N	All	214	13	6%
Average	Both	All	351	22	6%

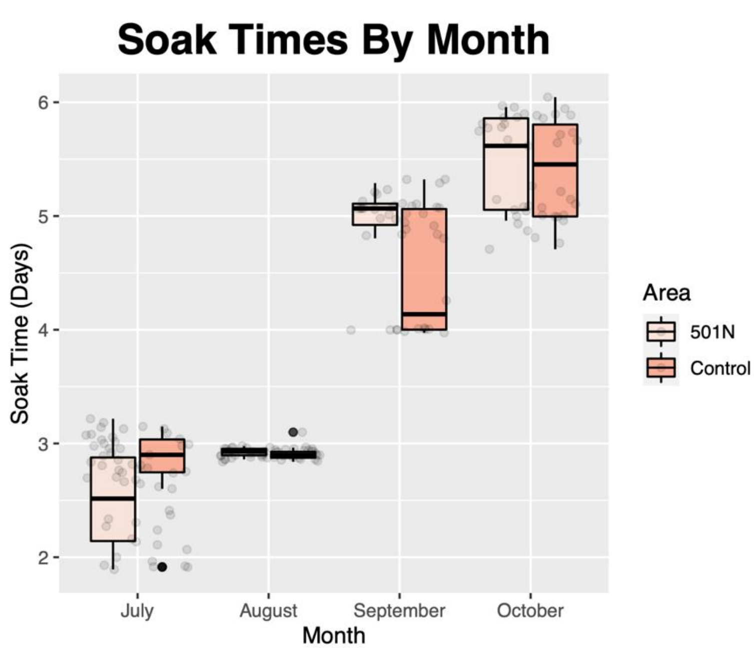

Figure 8. Average soak times by month for both the Control and 501N Study Area over the duration of the survey season

Average soak times throughout the sampling season ranged from 2.1 to 5.5 days in the 501N Study Area and 2.7 to 5.8 days in the Control Area. Soak times varied significantly between sampling periods (Kruskal Wallis, chi-squared = 160.35, df = 7, p < 2.2e-16), as the survey deviated from the 3-night soak schedule based on the need to stagger setting days at the beginning of the survey and more frequent inclement weather events in later months (Figure 8). The average overall soak times were 2.7±0.11 days in July, 2.9±0.01 days in August, 4.8±0.15 days in September, and 5.4±0.13 days in October.

Bottom water temperature varied significantly throughout the course of the survey season (Kruskal-Wallis, chi-squared = 6580.9, df = 48, p < 2.2e-16), with minimum and maximum temperatures of 9.04°C and 18.4°C recorded during the first and sixth sampling periods (in July and September), respectively. The average temperatures in the 501N Study Area fluctuated from 10.17°C in July, to 11.21°C in August, 15.71°C in September, and 15.69°C in October. In the Control Area, average temperatures also deviated monthly from 11.90°C in July, to 13.20°C in August, 17.14°C in September, and dropped to 15.68°C during October (Figure 9). The variability in temperature between areas is likely attributed to depth and the time in which the samples were taken. Sites in the 501N Study Area were on average, 42.4±0.59m while the Control Area sites were 37.6±0.59m. Depth was highly correlated with temperature (Pearson, t = -4.13, df = 161, p = 5.805e-05). While some temperature fluctuations can be explained by time and depth, the month of July lacks 31/57 bottom temperature data points due to multiple sensor failure, therefore those observations were removed from the temperature analysis.

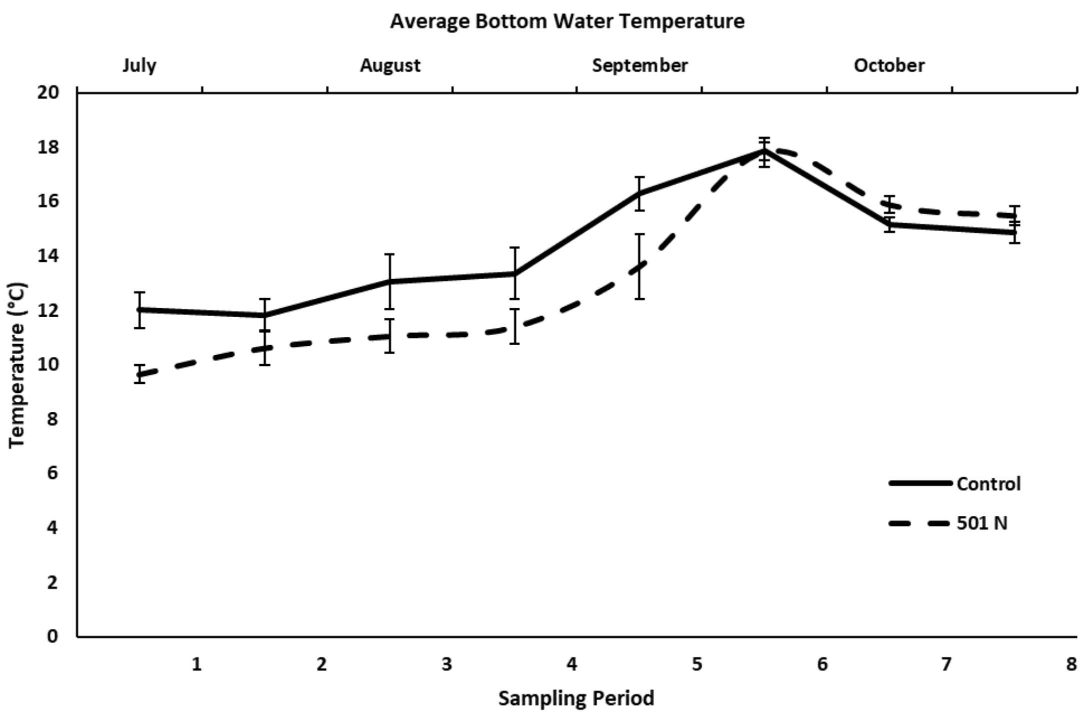

Figure 9. Average temperature and standard deviation by sampling period for both the 501N Study Area and Control Area of the ventless trap survey

Lobster Tagging Study

Of the 351 lobsters captured, 320 were tagged and released, while the remaining did not receive a tag. As of January 24, 2020, six different recaptures have been reported; five lobsters were re-released while 1 was landed. One occurred during the survey, four were reported by Capt. Mohawk Bolin, and one by Capt. Tim Fields during commercial fishing activities, and one recapture occurred during survey activities. All recorded recaptures have been males that range from 77mm to 129mm carapace length. Days at large ranged from 5 to 75 days. Three lobsters were recaptured within 0.35km of where tagging occurred, while the remaining three lobsters moved distances of 35.24km, 17.39km, and 36.34km. Movement rates were estimated for these lobsters to be 0.52km/day, 0.40km/day, and 0.58km/day. All reported recaptures by commercial fishermen were initially tagged during sampling periods 5, 6, or 8; n=1 and n=5 lobsters originated from the 501N Study Area and Control Areas, respectively.

To confirm that there was no significant tag loss or mortality due to tagging, a tank experiment was conducted at the SMAST seawater lab facility. For this experiment 23 lobsters were tagged and mixed with 28 untagged lobsters to simulate the effect of Floy Anchor tags applied to lobsters by SMAST researchers in the field. The animals were held in two flow-through sea water tanks for 39 days, each maintained between 10-12°C. Lobsters held were allowed to acclimate for up to two weeks before the experiment begin. Lobsters were held in seawater in water temperatures fluctuating from 10-12°C, while regularly being checked and fed. At the conclusion of the experiment, lobsters were individually examined for tag-related mortality and loss. No tagged lobsters died during the 39-day trial. One lobster lost a tag, and a single untagged lobster died during this time period.

Black Sea Bass

In total, n=264 black sea bass were collected from 170 individual black sea bass pots over the duration of the study; n=99 originated from the 501N Study Area, while n=165 sea bass stemmed from the Control Area (Table 4, Figure 10). Comparatively, more sea bass were captured in sea bass pots (n=254) than in vented or ventless traps (n=236), especially given there were n=513 vented and n=575 ventless individual trap hauls. CPUE by individual traps were 1.55± 0.68 fish/trap for sea bass pots, 0.33± 0.047 fish/trap in ventless pots, and 0.09± 0.027 fish/trap in vented pots. On average, sea bass pots in the 501N Study Area were 1.08± 0.60 fish/trap , while the Control Area yielded 2.12± 1.31 fish/trap (Table 4). The difference in CPUE between areas was not significant (Wilcoxon Rank Sum, $W = 3748$, $p = 0.54$). Sea bass CPUE showed strong seasonality, with 85.2% (n=225) of sea bass observed during September in both areas. This was reflected in CPUE; the average catch rate for September was 6.25± 0.817 fish/trap. This was

Table 4. Summary of black sea bass collected from sea bass specific sampling pots

Sampling Period	Area	Month	Temp (°C)	Number (Caught)	Number (Measured)	CPUE	Length (cm)
1	Control	July	12.01	0	0	0.00	0.00
2	Control	July	11.84	1	0	0.08	0.00
3	Control	August	13.07	1	1	0.08	32.00
4	Control	August	13.36	7	7	0.70	32.43
5	Control	September	16.28	20	20	2.43	33.90
6	Control	September	17.85	126	125	15.75	34.08
7	Control	October	15.14	5	5	0.71	30.20
8	Control	October	14.87	5	5	0.57	28.40
1	501N	July	9.66	0	0	0.00	0.00
2	501N	July	10.62	1	1	0.07	35.00
3	501N	August	11.06	0	0	0.00	0.00
4	501N	August	11.39	0	0	0.00	0.00
5	501N	September	13.6	4	4	0.40	32.00
6	501N	September	17.81	75	75	5.91	33.29
7	501N	October	15.88	14	12	1.27	32.83
8	501N	October	15.47	5	5	0.50	31.60
Average	Control	All	14.52±0.45	165	163	2.12±1.31	33.68±0.53
Average	501N	All	13.33±0.60	99	97	1.08±0.60	33.11±0.88
Average	Both	All	13.90±0.39	264	260	1.55±0.68	33.47±0.46

significantly different (Wilcoxon Rank Sum, W = 3936, p = 4.96e-13) than the CPUE recorded for all other months (0.29± 0.091 fish/trap) (Figure 11). Of the n=264 black sea bass observed throughout the survey, lengths were not taken on n=4 fish. The average total length of sea bass caught in the 501N Study Area was 33.11± 0.88cm and 33.68±0.0.53cm in the Control Area (Table 4)

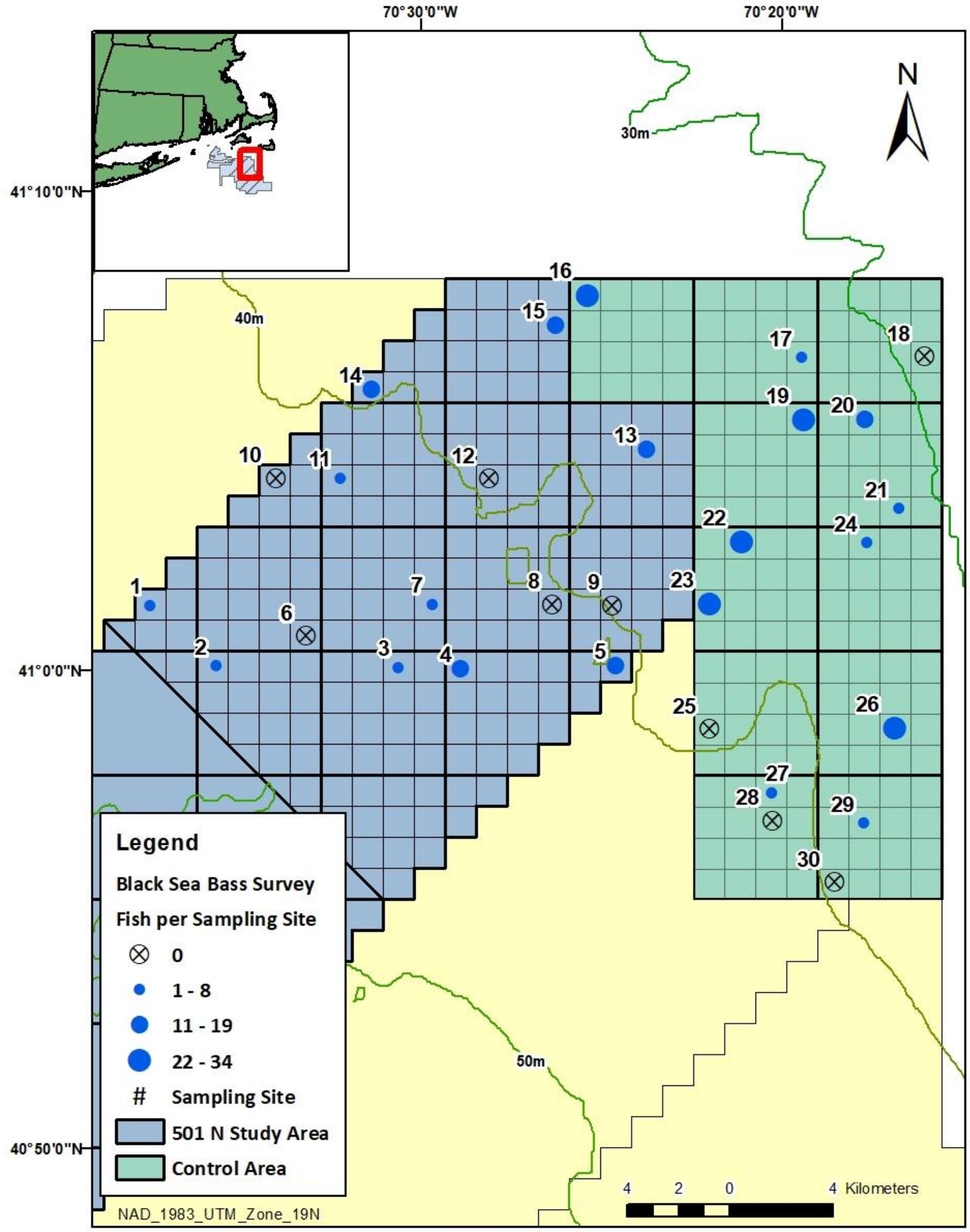

Figure 10. Map depicting the total number of Black sea bass sampled in sea bass specific pots at each location over the duration of the study

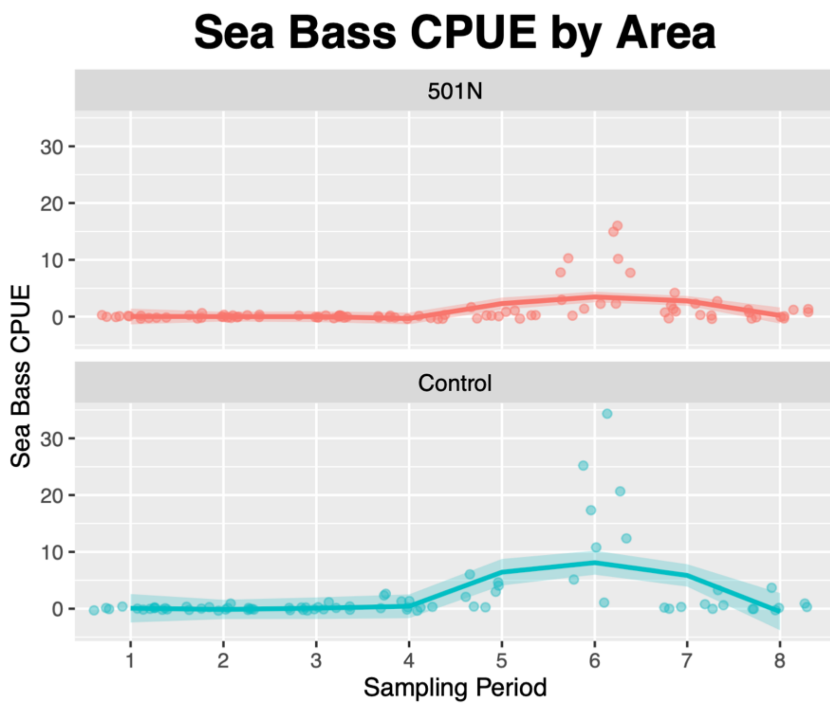

Figure 11. Black sea bass CPUE trends in both Study Areas throughout the survey fit with a smoothing curve

During the study, n=37 black sea bass were dissected from the Control Area an n=35 in the 501N Study Area (Table 5). Of the fish dissected, 17% (n=6) from the 501N Study Area and 24% (n=9) from the Control Area contained food. Of the 15 fish with stomach contents, 93% (n=14) contained some level of visually identifiable crab. Other prey items observed were fish, clam, common whelk, and shrimp. Otoliths were extracted from sampled sea bass and saved for future analysis.

Table 5. Summary of results from stomach content analysis of black sea bass sampled

Sampling Period	Area	Number Sampled	Number With Contents	Contents (%)	Contents (% crab)
3	Control	1	1	100%	100%
4	Control	5	3	60%	67%
5	Control	10	1	10%	100%
6	Control	17	2	12%	100%
7	Control	3	1	33%	100%
8	Control	1	1	100%	100%
2	501N	1	1	100%	100%
5	501N	5	2	40%	100%
6	501N	16	0	0%	0%
7	501N	10	2	20%	100%
8	501N	3	1	33%	100%
Average	Control	37	9	24%	89%
Average	501N	35	6	17%	100%
Average	Both	72	15	21%	93%

Larval Lobster Study

Each vessel utilized standardized tow durations of 10 minutes, a net sampling opening to 1.75 m^2, and average tow speeds ranging from 2.2 to 4.0 knots depending on the sea state. This translated to an average 1797.2 ± 524 m^3 of water sampled at each tow location. In total n=23 lobster larvae were captured during the larval study, with n=13 (Table 6, Figure 12) in the 501N Study Area and n=10 in the Control Area . Catches per sampling period ranged from n=0 to n=7 larval lobsters of life stages two, three, and four, with no stage one lobsters observed (Table 6). Larval lobster counts per sampling period ranged from 0 to 0.29±0.6 lobster larvae per 1000 m^3 of seawater sampled. Combined there was an estimated 0.05±0.2 larvae / 1000 m^3, with a slightly higher density in the 501N Study Area than in the Control Area, 0.07±0.3 and 0.04±0.2 larvae / 1000 m^3 respectively (Table 7). While other species were also observed and collected during the larval towing periods, such as fish, crabs, shrimp, jellyfish, and various isopods, we did not classify these samples further. However, all samples were stored and preserved for possible future analysis.

Table 6. Summary of the counts of lobster larvae by stage during the survey.

Total Lobster Larvae Sampled						
Area	Sampling Period	Larval Stage				
		I	II	III	IV	Total
Control	1	0	4	0	0	4
Control	2	0	1	0	0	1
Control	3	0	3	1	0	4
Control	4	0	0	0	0	0
Control	5	0	0	1	0	1
Control	6	0	0	0	0	0
Control	7	0	0	0	0	0
Control	8	0	0	0	0	0
501N	1	0	0	0	0	0
501N	2	0	3	0	0	3
501N	3	0	3	4	0	7
501N	4	0	0	1	1	2
501N	5	0	0	0	0	0
501N	6	0	0	0	1	1
501N	7	0	0	0	0	0
501N	8	0	0	0	0	0
Control	All	0	8	2	0	10
501N	All	0	6	5	2	13
Both	All	0	14	7	2	23

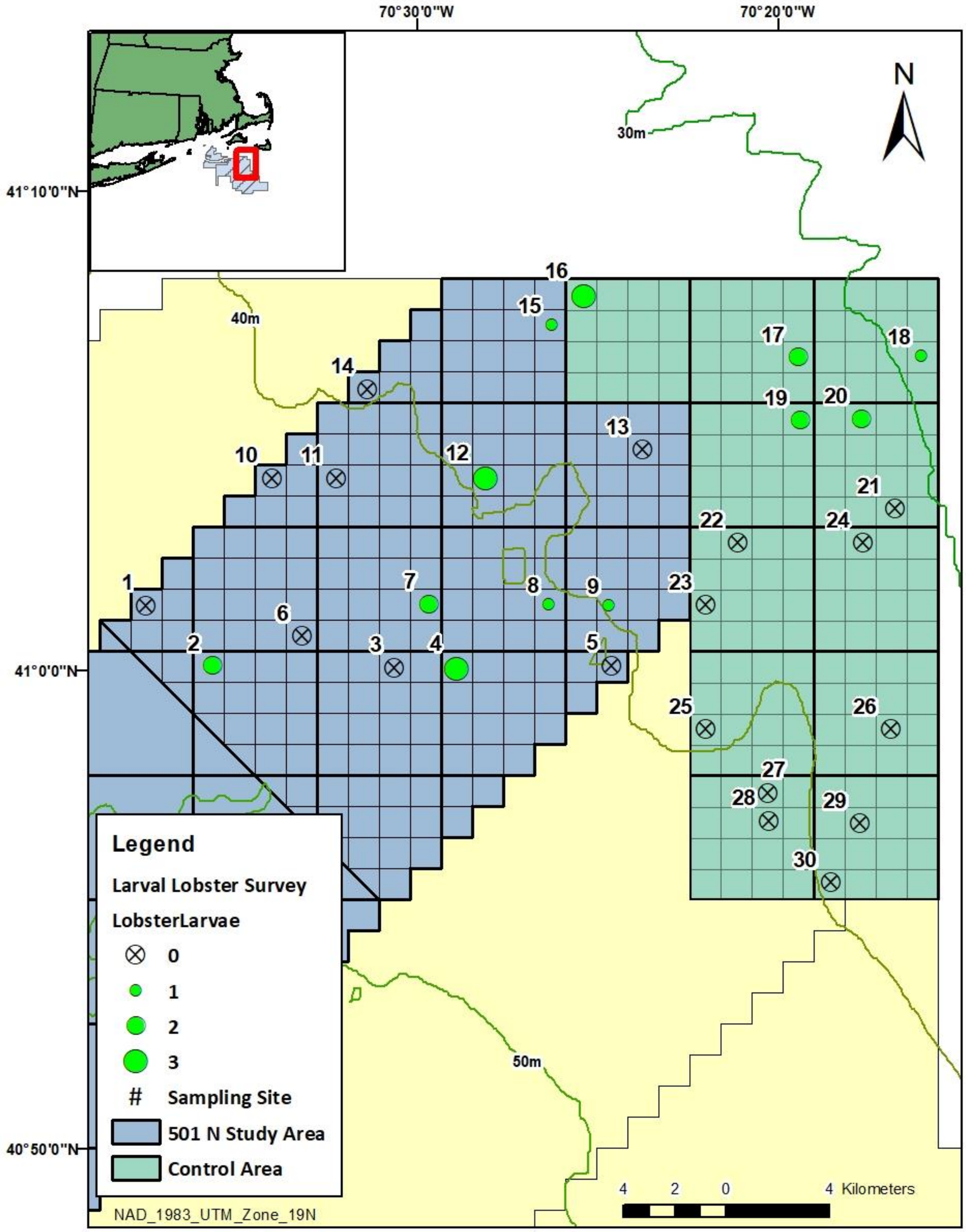

Figure 12. Map depicting the total number of lobster larvae sampled during neuston net tows at each location over the duration of the study.

Table 7. Summary of the mean density of lobster larvae estimated for each area over the duration of the study.

Mean Lobster Larvae / 1000 m³						
Area	Sampling Period	Larval Stage				
		I	II	III	IV	Total
Control	1	0	0.12	0	0	0.12
Control	2	0	0.03	0	0	0.03
Control	3	0	0.09	0.03	0	0.12
Control	4	0	0	0	0	0
Control	5	0	0	0.03	0	0.03
Control	6	0	0	0	0	0
Control	7	0	0	0	0	0
Control	8	0	0	0	0	0
501N	1	0	0	0	0	0
501N	2	0	0.11	0	0	0.11
501N	3	0	0.12	0.16	0	0.29
501N	4	0	0	0.05	0.04	0.08
501N	5	0	0	0	0	0
501N	6	0	0	0	0.05	0.05
501N	7	0	0	0	0	0
501N	8	0	0	0	0	0
Control	All	0	0.03±0.14	0.01±0.06	0	0.04±0.17
501N	All	0	0.03±0.17	0.03±0.13	0.01±0.09	0.07±0.27
Both	All	0	0.03±0.16	0.02±0.10	0.01±0.06	0.05±0.22

LITERATURE CITED

Atlantic States Marine Fisheries Commission (ASMFC). (2019). American Lobster. Retrieved February 7, 2019, from http://www.asmfc.org/species/american-lobster

ASMFC American Lobster Stock Assessment Review Panel. (2015). *American Lobster Benchmark Stock Assessment for Peer Review Report* (Accepted for Management Use, pp. 31-493, Rep. No. NA10NMF4740016). ASMFC.

Cadrin, S., Stokesbury, K., & Zygmunt, A. (2019). Recommendations for Planning Pre- and Post- Construction Assessments of Fisheries in the Vineyard Wind Lease Area (Final Report). University of Massachusetts Dartmouth.

Cassidy, K.S. (2018). *Decline of American Lobster, Homarus americanus, Abundance in Buzzards Bay, Massachusetts, USA Between 2005-2006 and 2013-2104* (Unpublished master's thesis). University of Massachusetts Dartmouth.

Collie, J.S. and King, J.W. 2016. Spatial and Temporal Distributions of Lobsters and Crabs in the Rhode Island Massachusetts Wind Energy Area. US Dept. of the Interior, Bureau of Ocean Energy Management, Atlantic OCS Region, Sterling, Virginia. OCS Study BOEM BOEM 2016-073. 48 pp.

Cooper, R. A., & Uzmann, J. R. (1971). Migrations and Growth of Deep-Sea Lobsters, Homarus americanus. Science, 171(3968), 288–290. doi: 10.1126/science.171.3968.288

Courchene, B., & Stokesbury, K. D. E. (2011). Comparison of Vented and Ventless and trap Catches of American Lobster with SCUBA Transect Surveys. *Journal of Shellfish Research,30*(2), 389-401. doi:10.2983/035.030.0227

Geraldi, N. R., Wahle, R. A., & Dunnington, M. (2009). Habitat effects on American lobster (Homarus americanus) movement and density: insights from georeferenced trap arrays, seabed mapping, and tagging. *Canadian Journal of Fisheries and Aquatic Sciences*, 66(3), 460–470. doi: 10.1139/f09-011

Griffin, M., Read, L., Carey, D. A. (2019). Block Island Wind Farm Annual Report May 2018-October 2018. *INSPIRE Environmental* (Final Report).

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, Bureau of Ocean Energy Management. OCS Study BOEM 2017-088. 312 p.

Herrick, F. H. (1911). *Natural History of the American Lobster* (Document No. 747). Washington D.C.: United States Bureau of Fisheries

Le Bris, A., Mills, K. E., Wahle, R. A., Chen, Y., Alexander, M. A., Allyn, A. J., Schuetz, J. G., Scott, J.D., & Pershing, A. J. (2018). Climate vulnerability and resilience in the most valuable North American fishery. *Proceedings of the National Academy of Sciences, 115*(8), 1831-1836. doi:10.1073/pnas.1711122115

Massachusetts Division of Marine Fisheries (MA DMF). (2018). *Recommended regional scale studies related to fisheries in the Massachusetts and Rhode Island-Massachusetts offshore Wind Energy Areas*(Rep.). Retrieved http://lobstermen.com/wp-content/uploads/2018/11/Offshore-Wind-Regional-Fisheries-Studies-11-5-18.pdf

Milligan, P. J. (2010). *Abundance, distribution and size of American lobster (Homarus Americanus) larvae in Buzzards Bay, Massachusetts: a thesis in marine science and technology- living marine resources management.* University of Massachusetts Dartmouth School of Marine Sciences. Unpublished Master's Thesis

Roach, M., Cohen, M., Forster, R., Revill, A. S., & Johnson, M. (2018). The effects of temporary exclusion of activity due to wind farm construction on a lobster (Homarus gammarus) fishery suggests a potential management approach. *ICES Journal of Marine Science, 75*(4), 1416-1426. doi:10.1093/icesjms/fsy006

Vineyard Wind. (2018). *Construction and Operations Plan* (Vol. 1, Rep.). MA. Retrieved from https://www.boem.gov/Vineyard-Wind-COP-VolumeI-Complete/.

Wahle, R.A., Brown, C., and Hovel, K. (2013). The Geography and Body Size Dependence of Top-Down Forcing in New England's Lobster-Groundfish Interaction. Bulletin of Marine Science. 89(1): 189 – 212. http://dx.doi.org/10.5343/bms.2011.1131

Wahle, R.A., Dellinger, L., Olszewski, S., and Jekielek, P. (2015). American lobster nurseries of southern New England receding in the face of climate change. Journal of Marine Science.

Appendix I

Jonah Crab

A total of 1918 Jonah crabs were collected from lobster traps in both study areas: 60.5% (n=1160) in the 501N Study Area and 39.5% (n=758) in the Control Area (Table 1, Figure 1). Total counts of Jonah crab fluctuated throughout the survey and the highest catches occurred in October. Average Jonah crab string CPUE in both study areas throughout the survey was 9.84±1.53 crab/string. Average CPUE in the Control Area was 7.98±1.84 crabs/string, and 11.60±2.39 crabs/string in the 501N Study Area (Table 2, Figure 2a).

Of the 1918 Jonah crab counted throughout the survey duration, 1888 were sexed and 1697 were measured. Contrary to lobster results, ventless traps outperformed vented traps and caught 79.0% (n=1515) of Jonah crab compared to 21.0% (n=403) caught in vented traps (Table 2, Figure 2b). Vented traps tended to capture larger crabs compared to ventless traps. Jonah crabs captured in ventless and vented traps had average carapace widths of 115.71±0.58 mm and 121.12± 1.14 mm, respectively. Jonah crab carapace width varied by area: on average animals caught in the Control Area were larger than in the 501N Study Area. Carapace width estimates of 118.98± 0.78mm were recorded in the Control Area, and 115.18± 0.68mm in the 501N Study Area (Table 1).

Jonah crab sex ratio remained consistently male-skewed throughout all sampling periods. Of the 1888 crabs sexed, 95.6% (n=1804) were males and 4.5% (n=84) were females. The highest occurrence of female Jonah crab in both areas was in October. Overall, October produced 76.2% of all females recorded for all months: n=43 in the 501N Study Area and n=13 in the Control Area. Average male: female sex ratios over the survey duration were 32.8:1 and 17.5:1 from the 501N Study Area and Control Areas, respectively. This resulted in a combined sex ratio of 21.5 males for every one female. No females were observed to have any level of external egg development.

Table 1. Summary of area level Jonah crab data collected throughout the duration of the study.

Sampling Period	Area	Month	Temp (^oC)	Number Caught	Number Sexed	Number Measured	CPUE	Mean CW (mm)	Males	Females	Sex Ratio (M:F)
1	Control	July	12.01	26	26	26	2.00	124.50	26	0	-
2	Control	July	11.79	60	57	57	4.29	124.74	56	1	56.0
3	Control	August	13.09	54	54	54	3.86	125.85	54	0	-
4	Control	August	13.40	59	57	57	4.92	123.18	55	2	27.5
5	Control	September	16.30	68	66	66	7.56	118.62	63	3	21.0
6	Control	September	17.83	70	69	69	6.36	117.07	66	3	22.0
7	Control	October	15.14	194	192	192	17.64	112.97	184	8	23.0
8	Control	October	14.89	227	223	223	20.64	120.01	218	5	43.6
1	501N	July	9.62	63	63	63	4.20	121.17	62	1	62.0
2	501N	July	10.62	76	75	75	5.07	119.88	74	1	74.0
3	501N	August	11.06	99	99	99	7.07	116.20	98	1	98.0
4	501N	August	11.40	64	63	63	5.33	119.37	62	1	62.0
5	501N	September	13.62	103	103	103	9.36	120.99	102	1	102.0
6	501N	September	17.81	94	94	94	7.83	109.84	88	6	14.7
7	501N	October	15.88	326	325	134	29.64	103.84	288	37	7.8
8	501N	October	15.41	335	322	322	33.50	116.20	308	14	22.0
Average	Control	All	14.47±0.26	758	744	744	7.98±1.84	118.98± 0.78	722	22	32.8
Average	501N	All	13.39±0.35	1160	1144	953	11.60±2.39	115.18± 0.68	1082	62	17.5
Average	Both	All	13.9±0.23	1918	1888	1697	9.84±1.53	116.85±0.92	1804	84	21.5

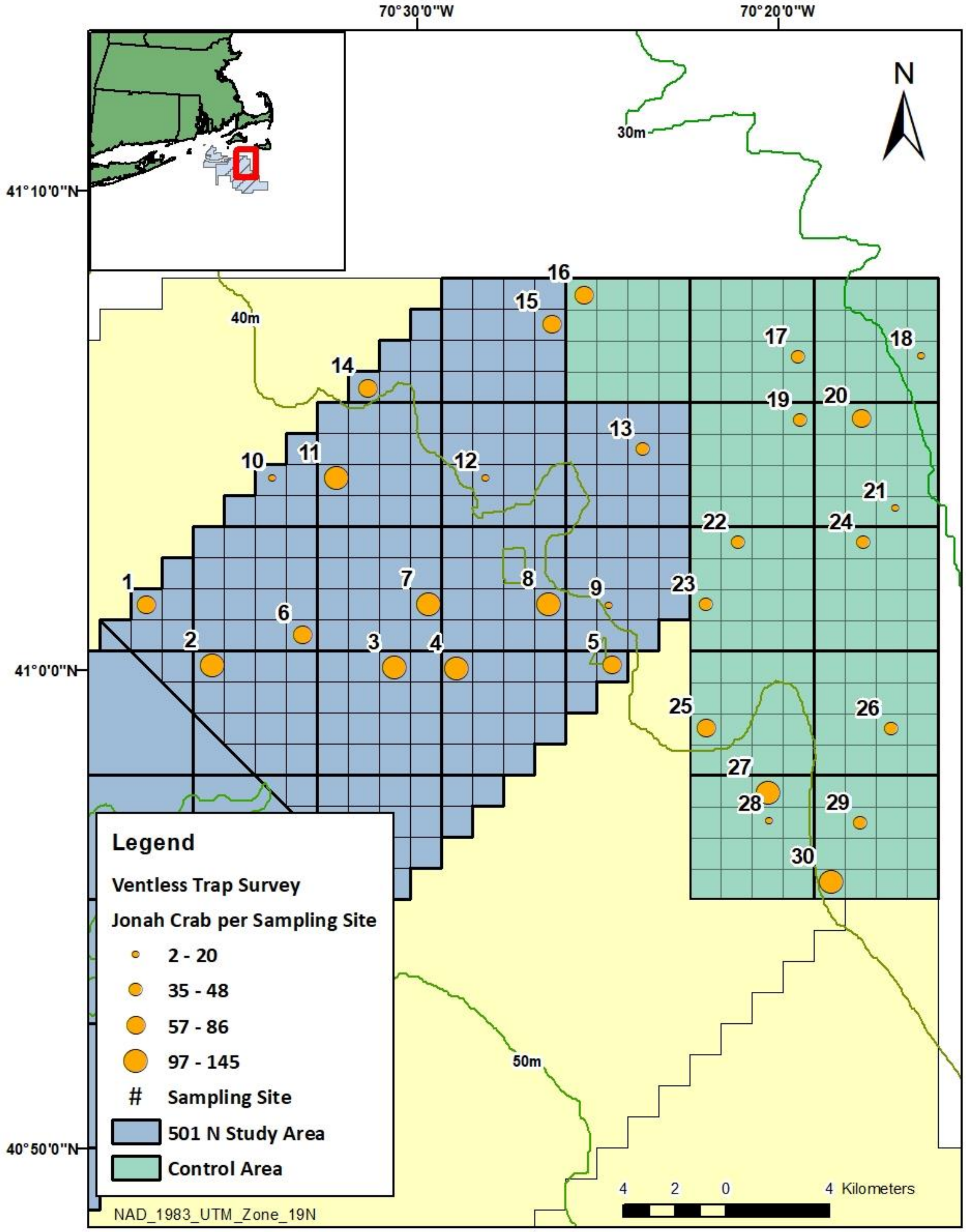

Figure 1. The distribution of Jonah crab sampled at all locations over the course of the study

Table 2. A summary of Jonah crab data organized by trap type.

Sampling Period	Trap Type	Month	Number (Trap Type)	% Caught	CPUE	Carapace Width (mm)
1	Vented	July	27	30%	0.93	118.74
2	Vented	July	26	19%	0.90	128.48
3	Vented	August	25	16%	0.89	123.81
4	Vented	August	24	20%	1.00	126.00
5	Vented	September	46	27%	2.30	126.98
6	Vented	September	36	22%	1.57	115.39
7	Vented	October	104	20%	4.73	110.58
8	Vented	October	115	20%	5.48	123.96
1	Ventless	July	62	70%	2.25	123.63
2	Ventless	July	110	81%	3.79	120.46
3	Ventless	August	128	84%	4.61	118.71
4	Ventless	August	99	80%	4.13	120.15
5	Ventless	September	125	73%	6.25	117.56
6	Ventless	September	128	78%	5.57	112.20
7	Ventless	October	416	80%	18.91	108.85
8	Ventless	October	447	80%	21.29	116.19
Average	Vented	All	403	21%	2.07±0.202	121.12± 1.140
Average	Ventless	All	1515	79%	7.77±0.391	115.71±0.576

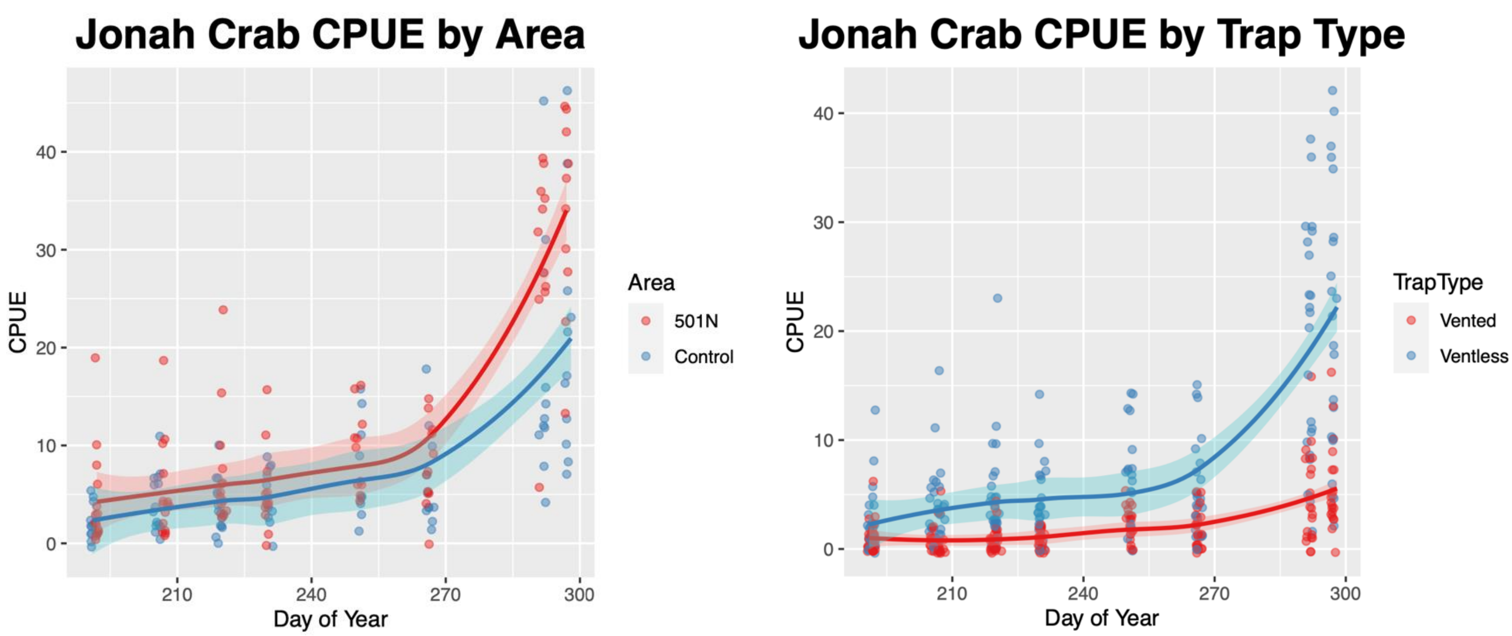

Figure 2a. Jonah crab CPUE from each Study Area (left). Figure 2b. A comparison of Jonah crab vented and ventless trap performance throughout the study (right).

APPENDIX II

Bycaught Species

Rock crabs were the most abundant species observed in both study areas throughout the duration of the survey: n=3722 and n=10543 were collected in lobster traps from the 501N Study and Control Areas, respectively. In the 501N Study Area, red hake (n=667), ocean pout (n=109), and black sea bass (n=104) were observed, while red hake (n=400), black sea bass (n=132), and scup (n=107) produced the next highest counts in the Control Area (Table 1). Commonly observed bycatch from un-baited sea bass pots located in the Control Area were rock crab (n=181), Jonah crab (n=53), and scup (n=24). This differed slightly within the 501N Study Area, as rock crab (n=192), Jonah crab (n=109), and red hake (n=56) were most regularly observed as bycatch in sea bass pots. Overall, rock crab (n=14638) was the most frequently encountered species across all trap configurations in both areas.

Table 1. Break down of total counts for bycaught species in each area.

Species	Lobster Traps (Both Types)		Sea Bass Pots		Total
	501N	Control Area	501N	Control Area	
Cod	0	0	2	0	**2**
Conger	83	94	1	1	**179**
Cunner	1	5	0	33	**39**
FourSpot	2	0	0	0	**2**
Hermit	88	90	4	2	**184**
HorshoeCrab	6	2	0	1	**9**
JonahCrab	1160	758	109	53	**2080**
Lobster	214	137	1	3	**355**
Menhaden	0	1	0	0	**1**
Monkfish	2	1	0	0	**3**
MoonSnail	6	8	0	0	**14**
Pout	109	6	12	0	**127**
Raven	18	21	2	1	**42**
RedHake	667	400	56	15	**1138**
RockCrab	3722	10543	192	181	**14638**
Scallop	1	0	0	0	**1**
Sculpin	7	2	1	0	**10**
Scup	52	107	29	24	**212**
Seabass	104	132	99	165	**500**
SeaRobin	2	2	0	0	**4**
SeaStar	2	3	0	0	**5**
SilverHake	6	0	1	0	**7**
Skate	8	21	0	0	**29**
SnowyGrouper	0	1	0	0	**1**
SpiderCrab	5	43	0	2	**50**
SpinyDog	17	22	1	0	**40**
SpottedHake	73	105	2	4	**184**
SummerFlounder	1	0	0	0	**1**
Tautog	1	1	0	0	**2**
Common Whelk	0	2	0	0	**2**
Windowpane	3	8	1	2	**14**
Totals	**6360**	**12515**	**513**	**487**	**19875**

APPENDIX III

Substrate Composition

The substrate composition was mostly sand across both areas; with small amounts of gravel were detected near several sampling aliquots (Figure 1). These results were gathered from the SMAST Drop Camera Survey of Benthic Communities and Substrate in Vineyard Wind Lease Area OCS-A 0501 and a Control Area that was conducted once in July and again in October, 2019.

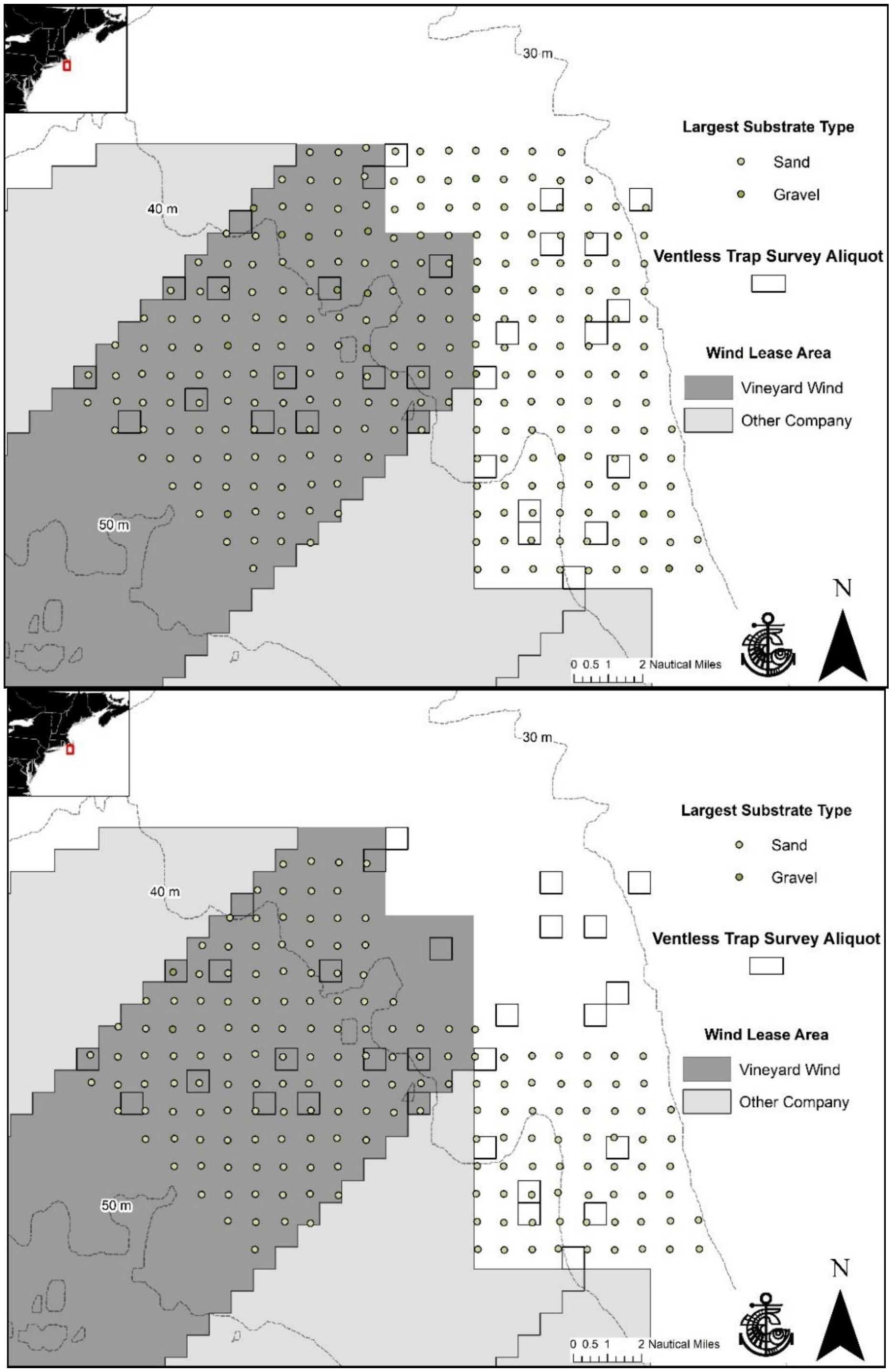

Figure 1. Results from the SMAST Drop Camera Survey of Benthic Communities and Substrate in Vineyard Wind Lease Area OCS-A 0501 and a Control Area showing the largest substrate type present at each sampling aliquot from the July (top) survey and the October survey (bottom)