FINAL REPORT – Assessment of 2020 SOAR Project for The Nature Conservancy, New Hampshire

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Oyster farmers in New Hampshire and Maine participating in the Supporting Oyster Aquaculture and Restoration (SOAR) project in 2020 deployed 318,670 farm-raised oysters onto a 1-acre restoration site near Nannie Island in Great Bay (Fig. 1) in late November and early December 2020. The University of New Hampshire (UNH) portion of the overall SOAR project consisted of three tasks. Each is briefly described below, followed by results, discussion, and references. Appendix A contains the raw data for oyster metrics.

Task 1: Characterize SOAR restoration area

The 2020 SOAR site was mapped on August 27, 2021 using towed underwater video methods as described in previous projects. About 13 transects were imaged across the restoration area (Fig. 1).

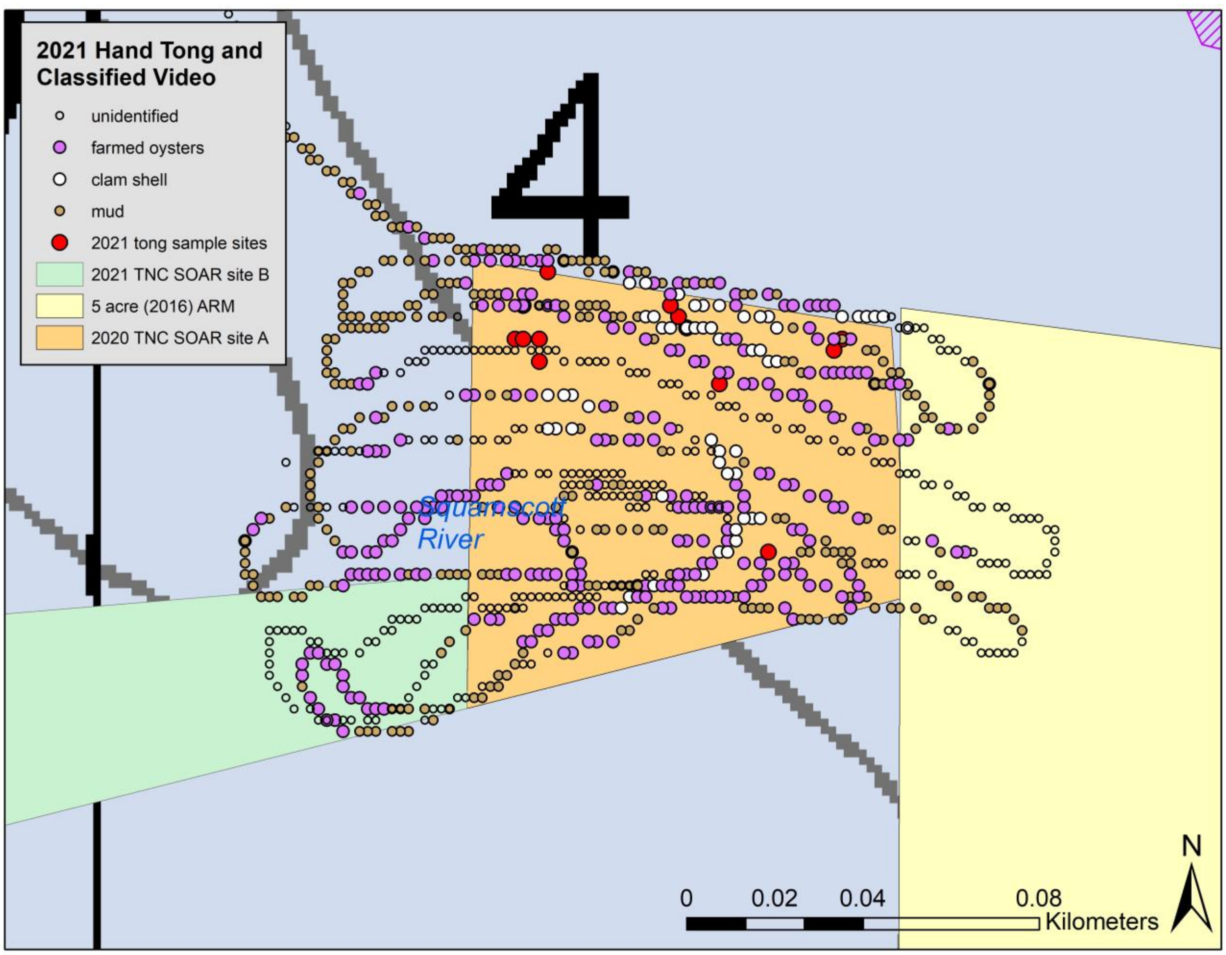

Fig. 1. Classified shiptracks of towed underwater video showing locations of farmed oysters (purple circles), clam shell used to construct reef base (white; includes sparse and dense clam cover), and mud (brown) bottoms. Note substantial number of video images that could not be classified ("unidentified") due to poor visibility or other issues.

The imagery was classified in the laboratory at 2-second intervals into three classes: (1) SOAR oysters visible; (2) clam shell (sparse or dense) used to construct reef base; and (3) mud sediments. Areal coverage was determined by calculating the percentage of the total images that could be classified represented by each class. Reef height was estimated from the imagery using shell height data from Task 2 for approximate scaling.

The oysters transplanted from farm sites covered about 0.19 ha (= 1,965 m^2) of bottom area, or 48.6% (355 of 731 classified images) of the overall 0.4-hectare (1-acre) restoration site (Table 1; Fig. 2). Note that ~60% of the video could not be classified ("unidentified" in Fig. 2) and these images were not included in the calculations for areal coverage. Clam shell used to construct the reef base covered 8.3% (336 m^2) of the 1-acre area, and the remainder of the area (43.1%; 1744 m^2) was mud (Table 1). We know of no method for assigning error terms to these estimates, but it should be noted that most (60.6%) of video images could not be classified. This limitation, as well as the presence of farmed oysters outside the restoration area (Fig. 1), likely contributed to the wide range of estimates of survival of the farmed oysters (see below). Based on the imagery and oysters measured in Task 2, the farmed oysters protruded on average about 5 cm above the bottom.

Table 1. Metrics for reef formed by farmed oysters deployed onto the restoration site.

Sampling Date	Sampling Method	Overall Restoration Area (ha)	Area with Oysters (ha)	Reef Height (cm)	Area With Clam Shell (ha)	Mud Bottom Area (ha)
September 30, 2021	UNH underwater video	0.4	0.19	~5	0.03	0.17

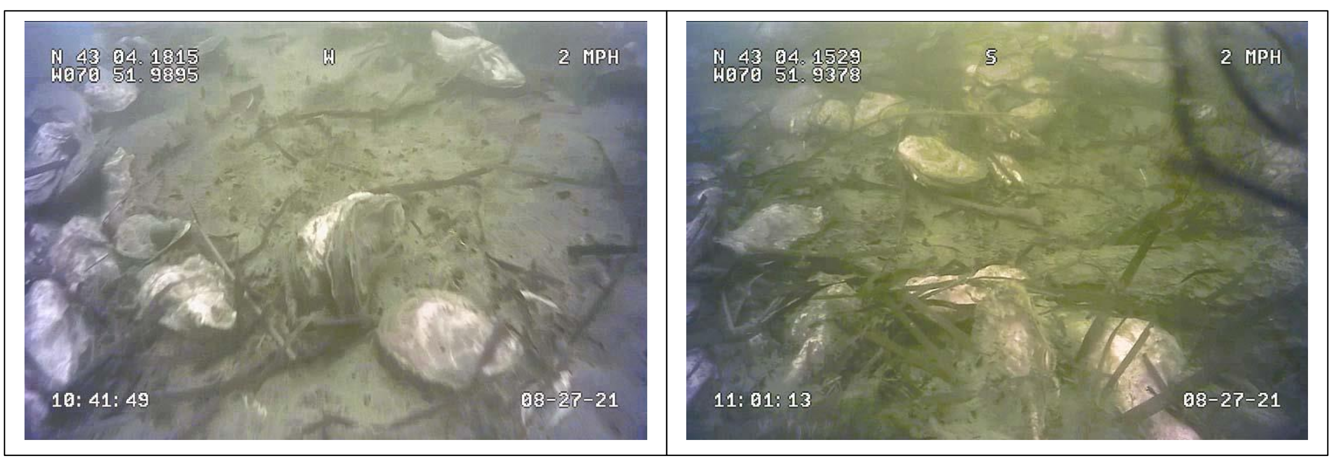

Fig. 2. Video stills showing typical condition and positions of farmed oysters on the mud bottom areas of the restoration site.

Task 2: Assess oyster demographics

Oyster demographics included three metrics, each treated separately below: growth, density, survival, and recruitment. Farmed oysters on the restoration site were sampled using two methods: divers (NH Fish & Game Department) removing all oysters from five haphazardly placed replicate 0.25 m^2 quadrats and returning them to the laboratory for measurement of shell height (to nearest mm using a ruler) of live and box (recently died, both valves intact); and qualitative sampling with handheld tongs (12 replicates), counting, and measuring in the field all live and box oysters retrieved (Appendix A). Size-frequency plots were constructed for all live oysters, farmed and spat, collected.

Growth was evident based on thin shell layers along the lower lip of some of the farmed oysters when sampled in October 2021, about 1 year after they had been deployed to the restoration area. However, no size measurements were made when the oysters were deployed to the site so calculating an average for growth is not possible. Nonetheless, wild spat that had likely recruited to the farmed oysters indicated growth rates typical of those for wild oysters in Great Bay (see more below). Mean live oyster shell height data was 125 mm for tong data and 123 mm for quadrat data, and 106 mm for tong data and 109 mm for quadrat data for box oysters (Table 2). These data can be used to estimate average growth using future measurements.

Density was calculated for live and dead (box) adult oysters and spat using the NHF&G quadrat data (Table 2). Adult live farmed oyster density averaged 12.6 individuals/m^2 (±2.6, 1 SE) and live spat averaged <1 individuals/m^2. These averages are low compared to typical healthy reefs in New Hampshire. However, the natural Nannie Island reef adjacent to the restoration area had not received a spat set for the past 3 years and was essentially dead with no live adult oysters (see more discussion in Recruitment section below).

Survival of the farmed oysters was estimated in two ways. The first, compared the density and areal coverage data in Table 2 with deployed live oysters. This was only possible with the NH F&G quadrat data as the area of each tong grab cannot be consistently translated into an area, meaning a density is not available:

If it was assumed that the NHF&G quadrat data represented the entire restoration site (4,046 m^2):

Total live oysters in the restoration area: 4,046 m^2 with live oysters x 12.6 oysters/m^2 = 50,992

Percent survival: (50,992/318,670) x 100 = 16.0%

This survival is extremely low. Even if it is assumed that the NHF&G data represented the entire study area (1 acre = 4,047 m^2), and an average of 19.4 oysters (live and dead)/m^2 were collected, then only ~78,000 oysters were in the restoration area. This suggests that all the oysters were not sampled. Additionally, although the error terms around both density means were high (averaging about 40%; Table 2), they do not bring either density estimate close to the number deployed. Possible explanations include:

- A portion of the oysters were deployed outside the 1-acre plot. However, while this is inevitably the case, and is indicated by the positive video quadrats outside the deployment area, it is unlikely that the area seeded was so large as to account for the entire difference between mortality estimates.
- Many of the deployed oysters were lost by sinking into the mud bottom (Fig. 3).

The most likely scenario is a combination of the two. The quadrat data collected by Jenn Dijkstra and associates might yield a better density estimate?

The second approach to estimating survival was based on the mean number or density of box oysters in tong (R. Grizzle data) and quadrat samples (F&G diver data) compared to density of live oysters, assuming that all oysters on the site were adequately sampled (which would not have been the case if some were completely buried and not sampled):

Percent survival = 1 – (density of boxes/(density of boxes + density of live oysters)) x 100:

Tong Data = 1 - (5.0/(5.0+10.8)) x 100 = 68%
Quadrat data = 1 – (6.8/(6.8+12.6)) x 100 = 65%

Survival from the proportion of dead farm oysters (Boxes) compared to the total farm oysters sampled is remarkably consistent. This is in contrast to the survival estimated using the two different techniques. Survival estimates of such a wide range (16% to 68%) for the two methods of estimation suggest that better methods are needed if useful estimates are to be made for the total population of live oysters deployed. Survival and its converse mortality are useful metrics. However, accurate estimation will always be problematic unless marked animals are deployed, or all oysters that were initially deployed are adequately sampled. More useful metrics may simply be abundance and density of live oysters because they are major factors in spawning success and subsequent recruitment. We need to better understand how many live oysters and at what density are needed to enhance reef restoration success. Both may be strongly affected by site conditions such as sediment type, whether a hard substrate base was initially constructed, or other environmental metrics. This project documented some amount of burial of the deployed oysters (Figs. 2 and 3), but future sampling will be needed to better characterize survival, live oyster density, and their relation to restoration success.

Table 2. Metrics for farmed oysters and wild oyster spat recruited in 2021 to the oysters deployed in 2020.

		Farmed Oysters					Wild Oysters Recruited to Farmed Oysters in 2021	
Sampling Date	**Sampling Method**	**Mean Live SOAR Oysters (#/tong-Grizzle, #/m^2 -NHF&G)**	**Mean Live SOAR Oyster Height (mm)**	**Mean No. SOAR Boxes (#/tong-Grizzle, #/m^2-NHF&G)**	**Mean Box Height (mm)**	**Survival$^+$ (%)**	**Mean Spat (#/tong-Grizzle, #/m^2 -NHF&G)**	**Mean Spat Height (mm)**
Oct 7-8 2021	UNH Hand-Held Tongs	10.8	125.1	5.0	105.8	68.4	4.1	12.5
	± SE	9.4	8.4	4.4	6.7		3.7	1.6
Oct 25 2021	NH F&G diver quadrats	12.6	123.0	6.8	109.0	64.9	<1	17.0
	± SE	2.6	5.6	4.0	10.8		<1	3.0

$^+$ Survival for tong data = (1-(#Box/(#Box + #Live)))x100. For quadrat data = (1-(density Box/(density Box + density Live)))x100

Fig. 3. Farmed oysters illustrating range of condition when sampled on October 6 & 8, 2021: A: Left to right - completely buried (black shell), half buried, no burial. B: small spat on farmed oyster.

Recruitment was estimated by counting and measuring recently set spat collect by tongs and quadrats (Table 2). Larvae produced by wild oysters in the Bay or the farmed oysters could have recruited onto the farmed oysters during the summer 2021 spawning season. All live oysters <40 mm shell height (the maximum size for recent spat in New Hampshire) were considered spat resulting from "natural recruitment" regardless of their source.

A size-frequency plot of all live oysters collected using handheld tongs clearly separated the spat (mean: 12.5 mm shell height) from the farmed oysters (mean: 125.1 mm) with a maximum height of 24 mm for spat (Fig. 4). These size data compare well with the annual monitoring data from NH Fish & Game Department and other studies in Great Bay. All of the live spat had recruited onto live farmed oysters. None were on clam shell used to construct the reef bases, or on box farmed oysters. It should also be noted that the maximum size of the farmed oysters (199 mm) was about 50 mm greater than the largest wild oysters typically collected in recent years from Great Bay.

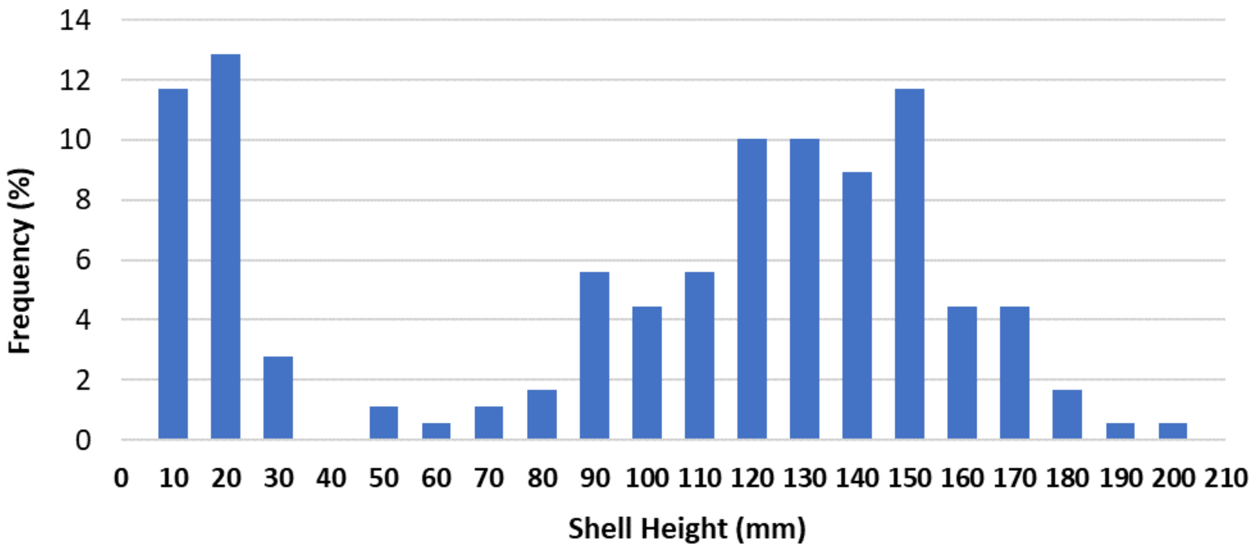

Fig. 4. Size-frequency plots for farmed oysters collected using handheld tongs (Table 2).

Size-frequency data were also assessed for the NH Fish & Game quadrat sampling data (Fig. 5). These data showed trends similar to the handheld tong data, with a clear separation of 2021 spat from the farmed oysters deployed to the site.

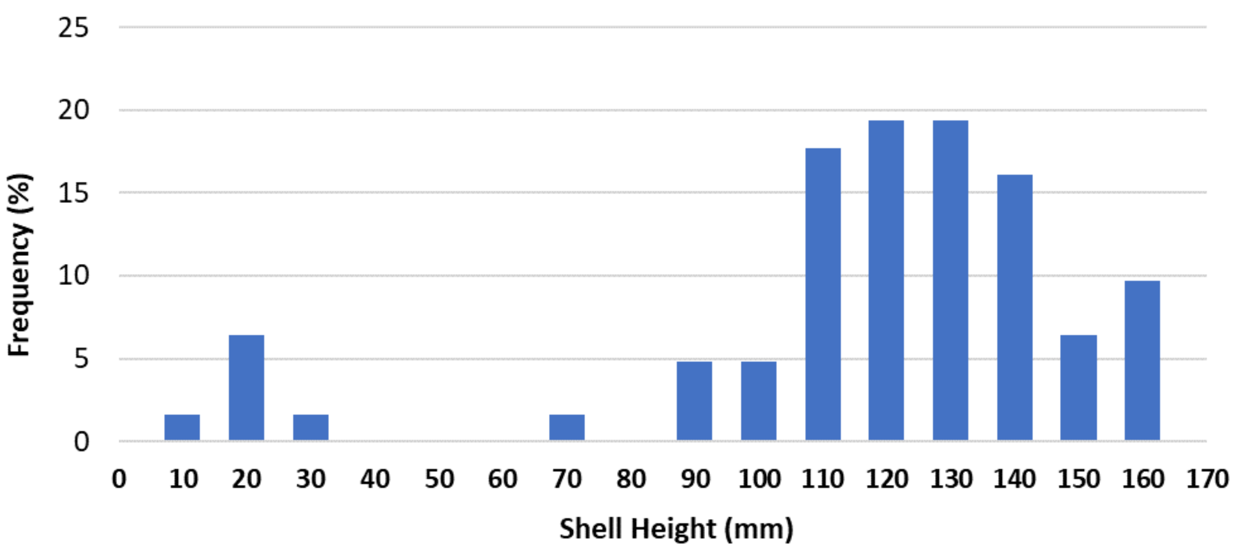

Fig. 5. Size-frequency plots for farmed oysters collected by NHF&G divers from quadrats (Table 2).

The finding of natural recruitment to the adult farm-raised oysters is important. Perhaps more importantly, our sampling and F&G sampling on the adjacent natural reef (Nannie Island) which had not received a set in about 3 years, turned up a lot of newly set spat. Together these data suggest a positive result of the farm oyster deployments on recruitment and strongly indicate more assessment is needed.

Deployment of adult oysters to restoration sites is not a new idea, but the use of farmed oysters for deployment may be. In any case, the efficacy of deploying adult oysters to restoration sites has not to our knowledge been widely tested. We are aware of no literature on the topic. Interestingly, the literature on probably the most widely used (for decades in some areas, including New Hampshire) comparable method, “spat seeding” that involves deploying laboratory-reared juvenile oysters, is meager and does not demonstrate its value for long-term restoration success. The present project at least indicates that deploying adult oysters to restoration sites likely enhances short-term reef restoration success, but longer-term assessments are needed.

Finally, we are finishing this year a NRCS-funded project adjacent to the SOAR site that should result in ~100,000 adult oysters from a range of size classes being deployed. Deployment will be on two of four constructed clam shell mounds. The aim will be to compare survival with the SOAR oysters as well as potential recruitment to the farmed oysters and adjacent shell mounds.

Task 3: Determine farmed oyster filtration capacity

The overall aim of this task was to determine filtration capacity by the live oysters collected in the restoration area using TNC’s online “Oyster Calculator” (https://oceanwealth.org/tools/oyster-calculator/). Based on the data in Table 2 above, <1% of the Bay’s volume was filtered daily under average environmental conditions by the live oysters on the restoration site when sampled. This number is not surprising because the restoration site was only 0.4 ha (1 acre) in size.

APPENDIX A - Handheld tong samples of SOAR oysters ("uglies") put out in 2020 in 1-acre area on TNC 2017 restoration site near Nannie Island

sampling date	lat_DD	long_DD	waypoint	tong #	# live oysters/ tong	live oyster height (mm)	2021 live spat	# "box" oysters/ tong	"box" oyster height (mm)
10/6/2021	43.06982	-70.86547	1278	1	4	140	0	3	129
10/6/2021						129			108
10/6/2021						165			114
10/6/2021						86			
10/6/2021	43.06983	-70.86548	1279	2	5	133	0	1	141
10/6/2021						172			
10/6/2021						151			
10/6/2021						186			
10/6/2021						141			
10/6/2021	43.06985	-70.86550	1280	3	7	124	0	6	147
10/6/2021						174			99
10/6/2021						111			134
10/6/2021						97			114
10/6/2021						124			127
10/6/2021						114			113
10/6/2021						136			
10/6/2021						154			
10/6/2021	43.06973	-70.86540	1281	4	16	6	3	8	195
10/6/2021						7			116
10/6/2021						7			179
10/6/2021						152			87
10/6/2021						145			139
10/6/2021						169			126
10/6/2021						141			129
10/6/2021						199			119
10/6/2021						94			
10/6/2021						130			
10/6/2021						145			
10/6/2021						131			
10/6/2021						177			
10/6/2021						138			
10/6/2021						170			
10/6/2021						162			
10/6/2021	43.06978	-70.86517	1283	5	40	12	14	4	127
10/6/2021						16			117
10/6/2021						6			94
10/6/2021						7			116
10/6/2021						6			
10/6/2021						4			
10/6/2021						4			
10/6/2021						5			
10/6/2021						4			
10/6/2021						15			
10/6/2021						9			
10/6/2021						10			
10/6/2021						9			
10/6/2021						19			
10/6/2021						49			
10/6/2021						55			
10/6/2021						73			
10/6/2021						61			
10/6/2021						101			
10/6/2021						83			
10/6/2021						73			
10/6/2021						61			
10/6/2021						78			
10/6/2021						121			
10/6/2021						160			
10/6/2021						165			
10/6/2021						144			
10/6/2021						113			
10/6/2021						110			
10/6/2021						150			
10/6/2021						101			
10/6/2021						83			
10/6/2021						137			
10/6/2021						112			
10/6/2021						92			
10/6/2021						115			
10/6/2021						104			
10/6/2021						112			
10/6/2021						127			
10/6/2021						113			
10/6/2021						149			
10/6/2021						128			
10/6/2021						129			
10/6/2021	43.06948	-70.86530	1285	6	13	8	4	1	98
10/6/2021						9			
10/6/2021						12			
10/6/2021						21			
10/6/2021						116			
10/6/2021						84			
10/6/2021						87			
10/6/2021						98			
10/6/2021						94			
10/6/2021						147			
10/6/2021						113			
10/6/2021						89			
10/6/2021						124			

sampling date	lat_DD	long_DD	waypoint	tong #	# live oysters/ tong	live oyster height (mm)	2021 live spat	# "box" oysters/ tong	"box" oyster height (mm)
10/6/2021	43.06990	-70.86575	1286	7	4	111	0	0	
10/6/2021						123			
10/6/2021						113			
10/6/2021						101			
10/8/2021	43.06985	-70.86580	1316	8	16	18	8	6	88
10/8/2021						16			77
10/8/2021						12			83
10/8/2021						8			110
10/8/2021						12			98
10/8/2021						9			90
10/8/2021						7			
10/8/2021						20			
10/8/2021						160			
10/8/2021						150			
10/8/2021						140			
10/8/2021						130			
10/8/2021						136			
10/8/2021						130			
10/8/2021						110			
10/8/2021						125			
10/8/2021	43.06980	-70.86582	1317	9	8	10	1	4	75
10/8/2021						110			70
10/8/2021						142			93
10/8/2021						150			94
10/8/2021						50			
10/8/2021						170			
10/8/2021						142			
10/8/2021						120			
10/8/2021	43.06980	-70.86577	1318	10	23	11	6	7	98
10/8/2021						24			97
10/8/2021						22			101
10/8/2021						20			90
10/8/2021						9			90
10/8/2021						15			92
10/8/2021						122			98
10/8/2021						140			
10/8/2021						115			
10/8/2021						140			
10/8/2021						140			
10/8/2021						155			
10/8/2021						142			
10/8/2021						170			
10/8/2021						90			
10/8/2021						142			
10/8/2021						132			
10/8/2021						100			
10/8/2021						136			
10/8/2021						116			
10/8/2021						170			
10/8/2021						142			
10/8/2021						142			
10/8/2021	43.06980	-70.86580	1319	11	31	22	9	16	93
10/8/2021						18			110
10/8/2021						17			128
10/8/2021						17			98
10/8/2021						23			100
10/8/2021						11			70
10/8/2021						4			95
10/8/2021						15			98
10/8/2021						12			92
10/8/2021						116			98
10/8/2021						130			90
10/8/2021						140			95
10/8/2021						115			105
10/8/2021						109			95
10/8/2021						102			100
10/8/2021						130			100
10/8/2021						145			
10/8/2021						122			
10/8/2021						142			
10/8/2021						132			
10/8/2021						96			
10/8/2021						148			
10/8/2021						90			
10/8/2021						160			
10/8/2021						119			
10/8/2021						108			
10/8/2021						155			
10/8/2021						144			
10/8/2021						137			
10/8/2021						120			
10/8/2021						90			
10/8/2021	43.06977	-70.86577	1320	12	5	15	4	4	85
10/8/2021						20			80
10/8/2021						14			76
10/8/2021						15			125
10/8/2021						125			
10/8/2021						90			
10/8/2021						100			
10/8/2021						148			
				MEAN:	**14.2**	**95.9**	**3.5**	**3.8**	**124.7**
				1 SE:	**3.9**	**4.2**	**1.6**	**0.8**	**3.1**