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SeagrassNet Monitoring in the Great Bay Estuary, NH/MEField Season 2020

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Introduction

Eelgrass (*Zostera marina* L.) forms a critical habitat in the Great Bay Estuary, and is valued not only for the functions it provides but also as an indicator of water quality. A global monitoring protocol called SeagrassNet was started in 2001 by Dr. Fred Short and designed to scientifically detect and document seagrass habitat change (Short et al. 2015). Since Dr. Short's retirement, SeagrassNet (seagrassnet.org) is currently in the process of being transferred to the Smithsonian Institute. Annual monitoring (3-4 times a year) of eelgrass in the Great Bay Estuary using the SeagrassNet protocol was conducted in Portsmouth Harbor between 2001 and 2009 (Short et al 2006b, Rivers and Short 2007). This site was discontinued after eelgrass failed to recover from grazing by Canada Geese in the winter of 2003. SeagrassNet monitoring in Great Bay started in 2007 (Short et al. 2009); that site is referred to as "NH 9.2, Great Bay." In July 2019, a new site was established in Portsmouth Harbor, approximately 1,000 meters from the previous site and designated "NH 9.3, Fort Foster." Results from SeagrassNet 2020, conducted in Great Bay and at Fort Foster, are described in this report.

Sites

The two sites were established following the standard SeagrassNet protocol (Short et al. 2015) used worldwide. Details are noted in "Methods" and further details and context can be found in the Quality Assurance Project Plan for the Great Bay Estuary (Matso and Short 2019). For SeagrassNet, a "site" consists of three permanent, parallel, 50 m transects, referred to as A, B and C. For all SeagrassNet sites, transect A is closest to shore and shallowest; C is furthest from shore and deepest (Figures 1 through 4). See figure captions for water depths at each transect.

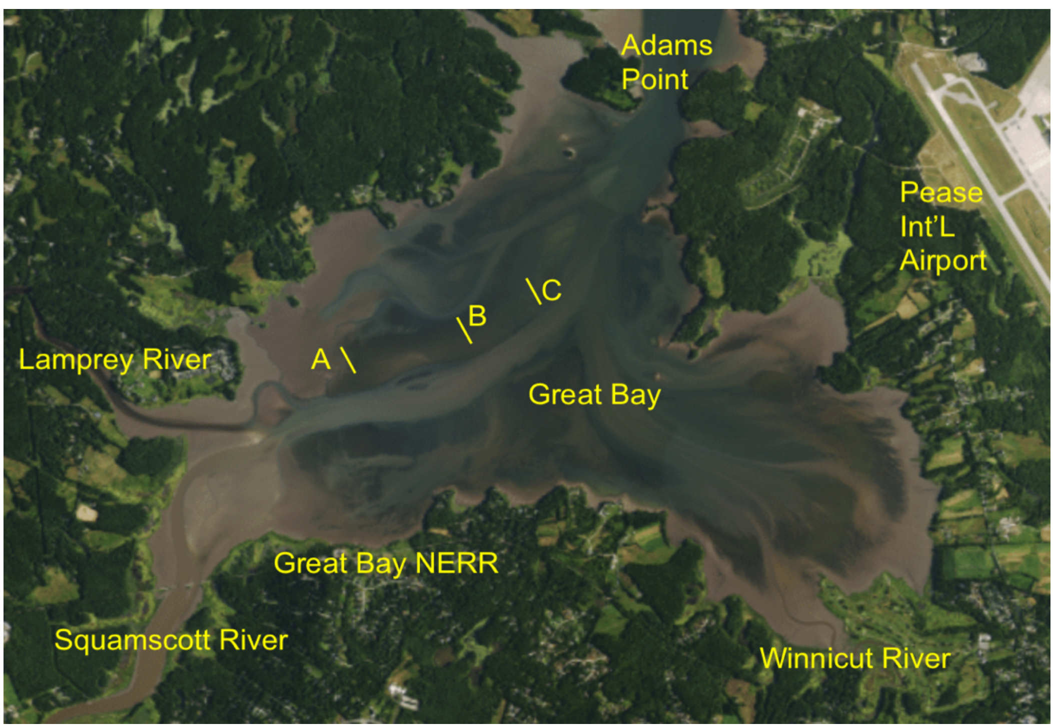


Figure 1. SeagrassNet monitoring site, NH 9.2, with Transects A, B and C in Great Bay, New Hampshire. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Lines showing transects are not to scale. Transect depth estimates (Mean Low Lower Water) are: A = 0 m; B = 0.3 m; C = 0.6 m.

Figure 2. SeagrassNet monitoring transects, using GPS-identified points for each end and the midpoint of permanent Transects A, B, and C in Great Bay, New Hampshire. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Distances between transect points are not to scale.

Figure 3. SeagrassNet monitoring site, NH 9.3, with Transects A, B, and C in Portsmouth Harbor, NH/ME, at Fort Foster. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Distances between transect points are not to scale. Transect depth estimates (Mean Low Lower Water) are: A = 1.2 m; B = 1.8 m; C = 3.7 m.

Figure 4. SeagrassNet monitoring transects, using GPS-identified points for each end and the midpoint of permanent Transects A, B, and C in Portsmouth Harbor, NH/ME, at Fort Foster. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Distances between transect points are not to scale.

Sampling

In 2020, SeagrassNet sites were sampled once in the summer. Previously, sampling occurred 3 to 4 times a year. However, PREP's Technical Advisory Committee agreed that the frequency should be reduced from 2020 forward in order to allocate resources to other seagrass monitoring priorities. The Great Bay site was sampled by a team using snorkel at low tide on July 22 and July 23. The newly established site, Fort Foster, was sampled August 1 and 2 by SCUBA.

During the Fort Foster sampling, the divers were unable to locate Transect C which had been established in 2019. The anchors and floats were likely displaced during winter storms. Therefore, it was necessary to set up a new transect line. It was placed at the same waypoints as the original line although the surveyed quadrats would not have corresponded with those from 2019.

Quadrats are $0.25m^2$ and placed at specific random locations (Figure 5). SeagrassNet sampling parameters for each quadrat include: photographic record; percent cover; canopy height; biomass (above and below-ground combined); shoot density; and sexual reproduction (number of flowering shoots). Biomass assessments focus on the type of shoots (non-reproductive versus reproductive) that are dominant in the quadrat; this is almost always the non-reproductive shoots. Note that the biomass sampling procedure in the SeagrassNet Manual (Short et al. 2015) advises an alternative method for assessing biomass for "large seagrass species" like eelgrass. Instead of taking a core, the field team collects an individual shoot of similar height to representative plants in the quadrat, including at least 7 cm of rhizome, approximately 0.5 m landward of each quadrat. In the lab, the plant height is measured and the shoot divided into blade, meristem, and rhizome sections. The plant is dried for 24 hours in an oven and the total dried shoot weight is multiplied by density to obtain biomass. Seaweed percent cover is also assessed for each 0.25m^2 quadrat.

The position of the quadrats (Figure 5) along each transect was assigned during the development of the SeagrassNet protocol using a random number generator and does not change, providing repeated measure assessment of specific parts of each eelgrass bed over time.

The SeagrassNet protocol includes other parameters that are not quadrat specific, but rather apply to the site or to particular transects at the site; these include temperature, salinity, and light penetration. For light penetration, HOBO sensors (without wipers) from Onset (HOBO Pendant Temperature/Light 8K Data Logger; Model #UA-002-08) were deployed for at least two-weeks as part of each sampling event. The sensors for light also measure water temperature. In Great Bay, the sensors were attached to a 0.5 meter PVC pipe and placed approximately one meter away from the end of the transects, ideally in an area not shaded by eelgrass. The loggers were about 0.25 meters off the bottom. At Fort Foster, the sensors were attached to the anchors marking the end of the transects, at a height above the top of the eelgrass. Salinity was measured with a separate sensor (HOBO Conductivity Logger, Model #U24-002-C.

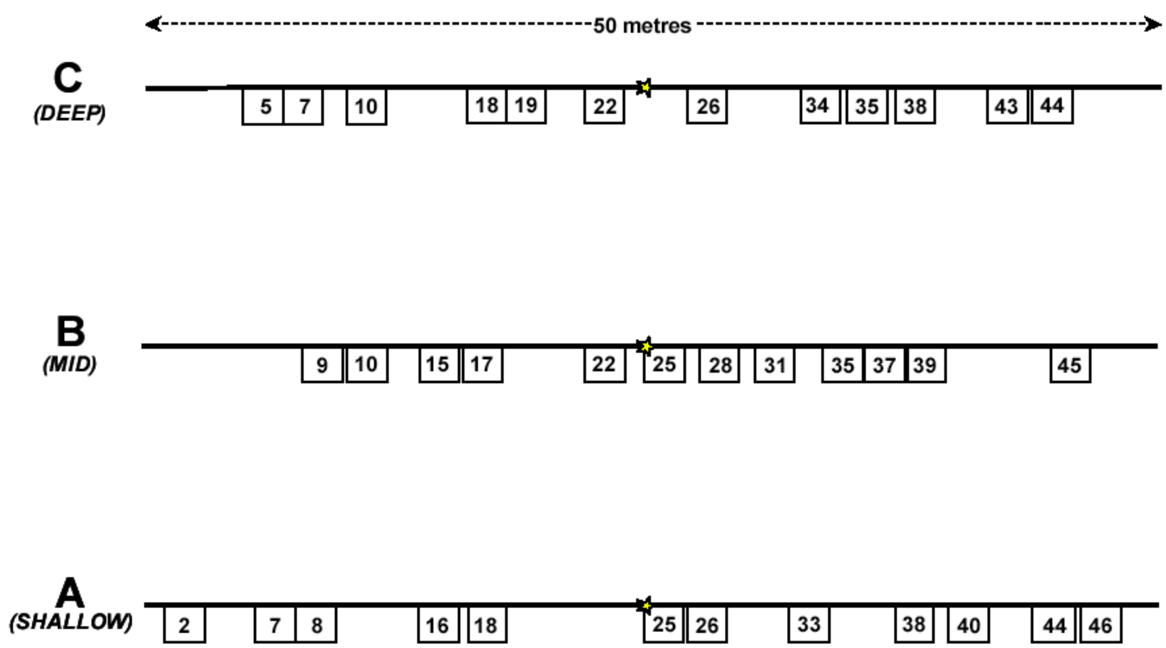


Figure 5. Location of the 12 SeagrassNet quadrats along the three 50 m transects. Each square represents a quadrat. Numbers indicate the meter distance along each transect where the quadrats are positioned for sampling (Distances are not drawn to scale). The stars represent the midpoint of each transect.

For the light analysis, only the data between 10 a.m. and 2 p.m. are analyzed in order to avoid the effects of low sun angle on the light data. Values collected every 10 minutes during the 4-hour period are compared with land-based values in order to produce percent light penetration. These values are then used to produce a daily average. We define 'Percent in situ surface light' as the amount of light reaching the plants compared to the amount of light at the water surface. This is calculated by dividing the amount of light reaching the plants underwater by the amount of light at the water surface and multiplying the quotient by 100 to produce a percentage. The land-based light reaching the water surface is obtained from a Hobo sensor located on the roof at Jackson Estuarine Laboratory. Complete SeagrassNet protocols for this project are found in the project QAPP (Matso and Short 2019).

Cross-transect Measurements

The SeagrassNet protocol suggests doing cross-transect measurements once each field season. This entails measuring out to the edge of the continuous eelgrass meadow and then to the last plant. These distances are measured at Transect C (deepest site) and Transect A (shallowest site). A tape is run out perpendicularly from the 0, 25, and 50 meter points on each transect. For Transect C, the distance is measured out towards deeper water and for Transect A, towards the shoreline, typically shallower. On September 24, 2020, these measurements were completed at NH9.3, Fort Foster, on SCUBA (Table 1). To clarify, "continuous" eelgrass means that the seagrass plants are less than 1 m apart. Eelgrass plants greater than a meter apart are considered outside the continuous seagrass bed, in other words, sporadic or sparse (F. Short personal communication, Sept 2020).

Table 1: Distances measured from each transect point to edge of the continuous bed and then to the last eelgrass shoot at NH9.3 Fort Foster.

Transect Point	Edge of Continuous Bed (m)	Last Shoot (m)
A00	29.1	35.3
A25	28.3	30.5
A50	21.8	32.6
C00	21.1	26.1
C25	10.1	18.1
C50	0.70	42.3

Cross transect measurements were attempted at NH9.2, Great Bay, although they proved to be difficult. At Transect C, the distances between the transect line and the edges of the continuous bed were >100 meters. It was challenging to run a transect tape over that distance, especially by snorkel. In addition, visibility was limited and it was difficult to determine where the last plant was located. At Transect A, the eelgrass was very sporadic. Overall, there was not a consistent continuous bed.

Results

Note that the primary focus of this report is on 2020 results. Inter-year comparisons and more detailed discussions will be featured in other publications, such as future State of Our Estuaries reports. In addition, please note that wasting disease was not assessed in 2020 although it is part of the SeagrassNet protocol. "Evidence of grazing" was assessed but no evidence was seen at any of the sampling events.

Results are reported without determination of significant differences between sites or transects using parametric statistics.

Table 2: Mean values for SeagrassNet parameters; standard deviation in parentheses. The median is given for reproductive shoots because of the skewed distribution of values. Canopy heights for each quadrat are an average of 5 measured plants. These averages were used to calculate the mean values. Great Bay was sampled on July 21 and 22, 2020; Fort Foster was sampled on August 1 and 2, 2020.

	Great Bay Site			Fort Foster Site		
	Transect A	**Transect B**	**Transect C**	**Transect A**	**Transect B**	**Transect C**
Biomass (g/m2)	4 (5)	38 (26)	189 (99)	196 (119)	215 (91)	155 (83)
Eelgrass % Cover	12 (17)	48 (21)	77 (15)	65 (28)	84 (15)	75 (25)
Density (shoots/m2)	33 (37)	149 (59)	300 (83)	148 (75)	139 (31)	103 (47)
Canopy Height (cm)	34 (8)	70 (13)	119 (9)	105 (28)	130 (24)	130 (25)
Repro Shoots (#/m2)	4 (7))	20 (7)	0 (16)	14 (11)	8 (4)	6 (5)
Seaweed % Cover	4 (3)	45 (27)	4 (2)	12 (16)	5 (6)	6 (6)

Eelgrass Biomass

Biomass refers to the weight of eelgrass plant tissue per square meter, e.g., grams/m^2. In this case, biomass includes a combined measure of both below-ground and above-ground plant tissue. Biomass is considered very dependent on light and is therefore an important metric (Krause-Jensen et al. 2004).

At the Great Bay site, Transect C had the highest biomass in July with 189 g/m^2. Transects A and B had substantially less biomass, with 4 g/m^2 and 38 g/m^2, respectively (Table 1; Figure 6). At the Fort Foster site, Transect B had the highest biomass in August with 215 g/m^2, followed by Transects A and C with 196 g/m^2 and 155 g/m^2, respectively (Table 1; Figure 7).

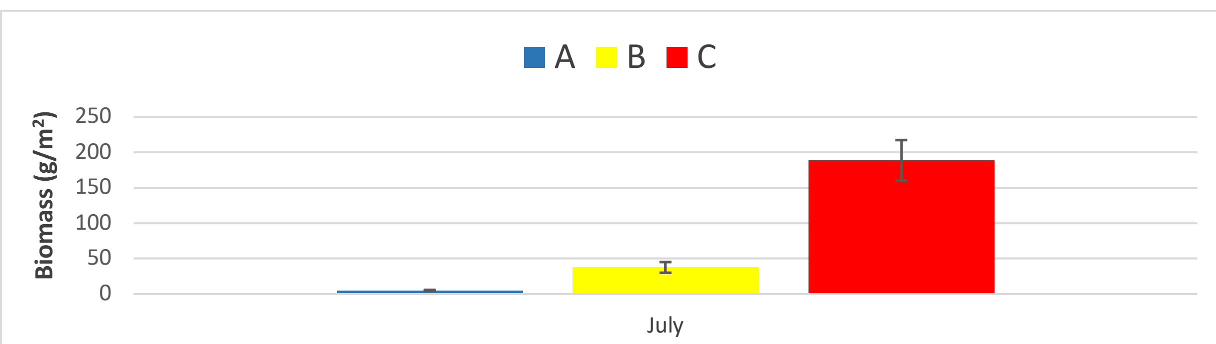


Figure 6. Eelgrass biomass at SeagrassNet site NH9.2 (Great Bay), Transects A, B, and C for 2020. Error bars indicate Standard Error.

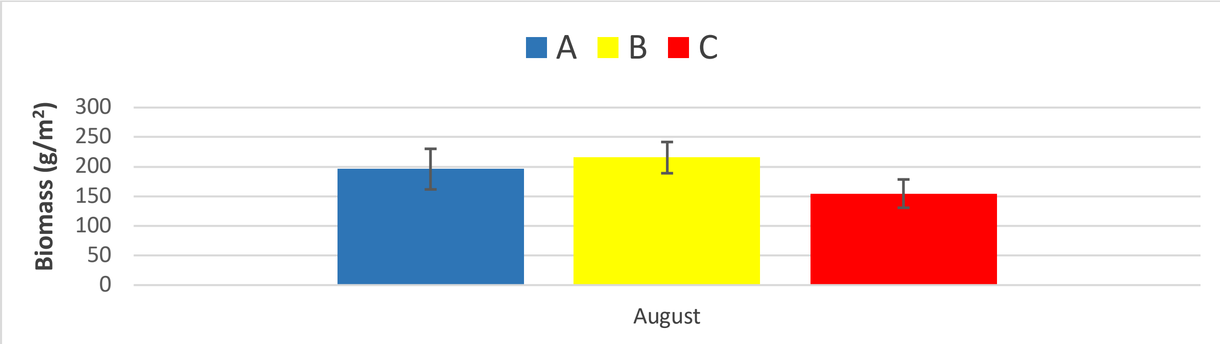


Figure 7. Eelgrass biomass at SeagrassNet site NH9.3 (Fort Foster), Transects A, B, and C for 2020. Error bars indicate Standard Error.

Eelgrass Percent Cover

Percent cover is a visual measure, looking straight down, of how much of the substrata within the quadrat is covered by seagrass on a scale of 0 – 100%. Each person on the team is trained using a percent cover guide, a standard scientific field technique for vegetation measurements.

At Great Bay, Transect C had the highest percent cover in July with 77%. Transects A and B had 12% and 48%, respectively (Table 1; Figure 8). At the Fort Foster site, Transect B had the highest percent cover in August with 84%, followed by Transects A and C with 65% and 75%, respectively (Table 1; Figure 9).

Eelgrass Shoot Density

Shoot density is the number of shoots in a given space, e.g., square meters. Density is considered more sensitive to changes in light than percent cover, which can also be impacted by leaf length (Krause-Jensen et al. 2004). When using density as an indicator of eelgrass health, it is important to also consider canopy height, since eelgrass can grow more densely but with much shorter shoots, depending on light. In that case, without considering other parameters, one could misinterpret a change in density for a change in overall biomass.

To determine shoot density, the total number of eelgrass shoots within each $0.25m^2$ quadrat was counted. If the eelgrass was very dense, a $0.0625m^2$ quadrat was placed in the lower right-hand corner of the larger quadrat and shoots within counted instead. To calculate density in square meters, the total number of shoots in each $0.25m^2$ or $0.0625m^2$ quadrat was multiplied by 4 or 16, respectively.

In Great Bay, Transect C had the highest shoot density in July, with a mean shoot density of 300 shoots/m^2. Transect B had a mean shoot density of 149 shoots/m^2, and Transect A had the lowest value, with a mean shoot density of 33 shoots/m^2 (Table 1; Figure 8). At Fort Foster, Transect A had the highest value in August with 148 shoots/m^2. Transect B had 139 shoots/m^2, and Transect C had the lowest density at 103 shoots/m^2 (Table 1; Figure 9).

Eelgrass Canopy Height

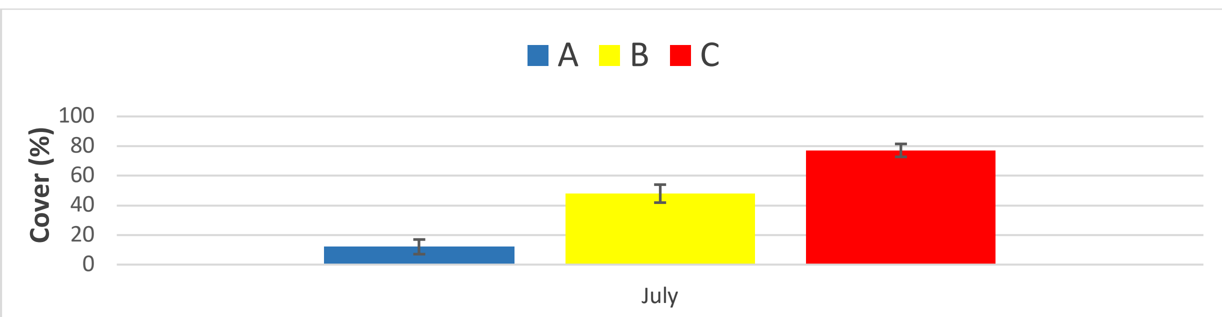
Canopy height is a useful metric, especially when combined with other indicators (e.g., density and percent cover) to achieve a proxy for biomass. Biomass can be a very time-consuming metric to achieve. If a relationship can be established between biomass and a combination of percent cover, density and canopy height, one can use a model approach to predicting biomass across the estuary (Neckles et al. 2012).

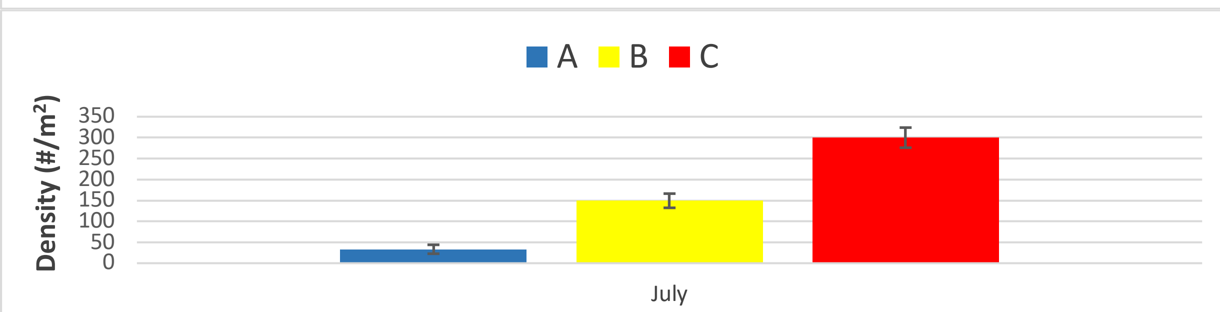
To determine canopy height, in each 0.25m^2 quadrat, the heights of 5 representative plants were measured. Plants were randomly selected from different parts of the quadrat. The plants were held up straight and a folding ruler used to measure height to the nearest centimeter. The mean of these five heights equals canopy height.

In Great Bay, Transect C had the tallest plants in July, with a mean canopy height of 119 cm. For Transect B, mean canopy height was 70 cm, while Transect A had the shortest leaves, with a mean canopy height of only 34 cm (Table 1; Figure 8). At Fort Foster, like in Great Bay, the deeper transects had longer leaves. In August, Transects B and C had mean canopy heights of 130 cm, while Transect A had the shortest plants, with an average canopy height of 105 cm (Table 1; Figure 9).

Eelgrass Flowering
Counting the number of flowering shoots per square meter helps to assess eelgrass sexual reproduction, which can play a critical role in eelgrass resilience, via the plant's response to stress (Jarvis et al. 2014). Below, the median number of reproductive shoots, rather than the mean, are given for each site due to the skewed distribution of the values.

In Great Bay, Transect B had the most reproductive shoots with a median of 20 per quadrat, while Transect A had a median of 4 per quadrat. Transect C had a median of 0 reproductive shoots per quadrat (Table 1; Figure 8). At Fort Foster, Transect A had the highest median reproductive shoots at 14 per quadrat. Transect B had a median of 8 reproductive shoots per quadrat, and Transect C had a median of 6 per quadrat (Table 1; Figure 9).





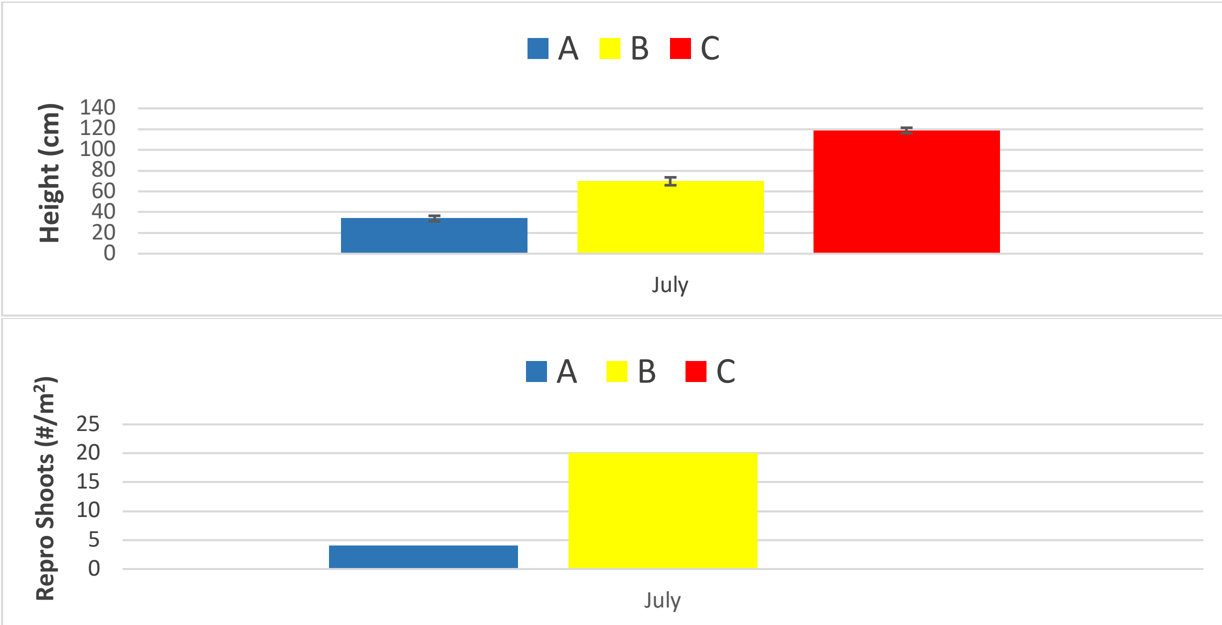


Figure 8. Eelgrass percent cover, shoot density, canopy height, and number of reproductive shoots at SeagrassNet site NH9.2, Transects A, B, and C in Great Bay for 2020. All values are averages except for number of reproductive shoots, which are medians. Error bars indicate Standard Error of the means.

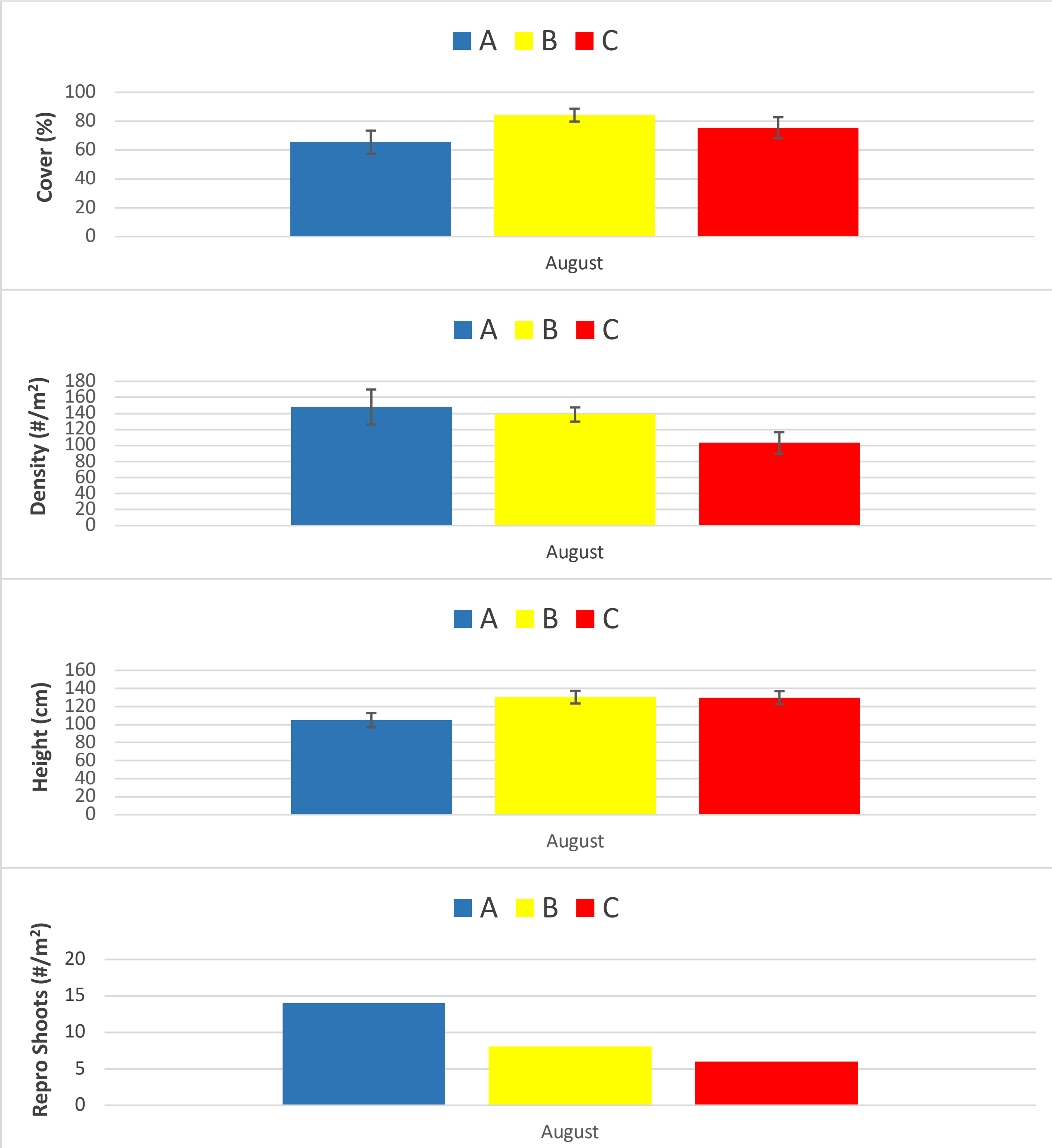


Figure 9. Eelgrass percent cover, shoot density, canopy height, and number of reproductive shoots at SeagrassNet site NH9.3, Transects A, B, and C at Fort Foster. All values are averages except for number of reproductive shoots, which are medians. Error bars indicate Standard Error of the means.

Percent Cover of Seaweeds

While many factors impact seaweed abundance, it is well established that changes in subtidal seaweed biomass and species composition can be a reflection of eutrophication status and, furthermore, that relatively well-flushed estuaries are more likely to see eelgrass degradation from seaweeds than from plankton (Valiela et al. 1997; van den Heuvel et al. 2019). For more on seaweeds in the Great Bay Estuary, including biomass and listing of different seaweed species, see the 2020 seaweed report at: https://scholars.unh.edu/prep/442/

In Great Bay, seaweed percent cover was substantially higher at Transect B than at Transects A and C in late July 2020. Transect B had 45% seaweed cover, whereas Transects A and C both had 4% cover (Table 1; Figure 10).

At Fort Foster, seaweed percent cover was higher at Transect A than at Transects B and C in early August 2020. Transect A had 12% seaweed cover while Transects B and C had similar cover measurements, 5% and 6%, respectively (Table 1; Figure 11).

At Fort Foster, the seaweed was predominantly confined to the area near the water-sediment interface and so did not seem to interfere with light for seagrass plants. In contrast, the seaweed in Great Bay was often found higher in the water column where it could interfere with light.

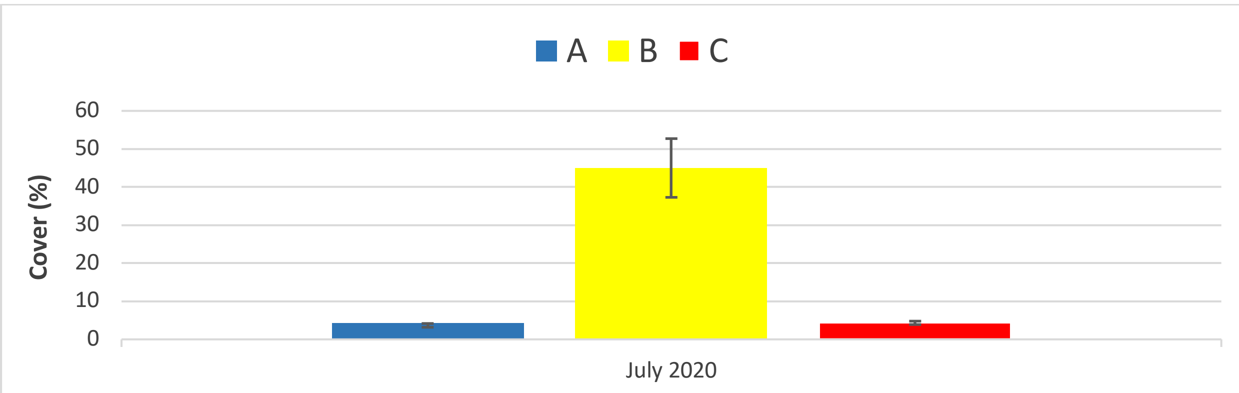


Figure 10. Seaweed percent cover at site NH9.2 (Great Bay), Transects A, B, and C for July 2020. Error bars indicate Standard Error of the means.

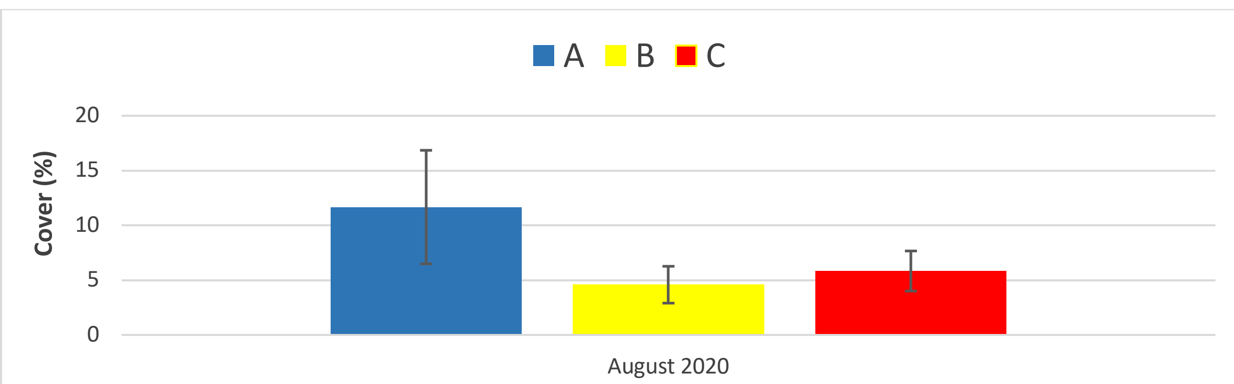


Figure 11. Seaweed percent cover at site NH9.3 (Fort Foster), Transects A, B, and C for August 2020. Error bars indicate Standard Error of the means.

Temperature

Eelgrass can tolerate wide ranges for both temperature and salinity but studies indicate that optimal levels are narrower. Lee et al. (2007) report an optimal range of 13° to 24° C. Temperatures warmer than 24° can be associated with factors that degrade eelgrass (Burdick et al. 1993; Kaldy 2014). In the Great Bay, especially at the shallowest transect (A), summer temperatures in excess of 30° have been observed; temperatures this high can result in eelgrass mortality due to increased metabolic demands, which in turn requires higher water clarity to maintain carbon balance and growth.

In Great Bay, between 7/22/2020 and 8/11/2020, temperatures ranged from below 20° to over 35° C (Figure 12). Transect A, the shallowest transect where plants are frequently exposed at low tide, had the greatest extremes, with temperatures frequently between 30° and 35° throughout July and early August.Transect B, the medium-depth transect, experienced lower temperatures overall, although there were frequent excursions above 30°. At Transect C, temperatures rose above 25° on several occasions in late July. Note that most of the high temperature spikes were at low tide. At low tide, the Hobo sensors at Transects A and B can be exposed to air temperatures and/or very close to the surface, causing exposure to direct sunlight.

At Fort Foster, data were available between 8/2/2020 and 8/27/2020 for Transects A and C (Figure 13). In that period, the temperature ranged from 11.3° to 20.9° C. In general, the temperature difference between the two transects, which are much closer together than the Great Bay transects, was almost always less than 3º. The greatest differences between the transects usually amounted to less than 6°, but this was rare.

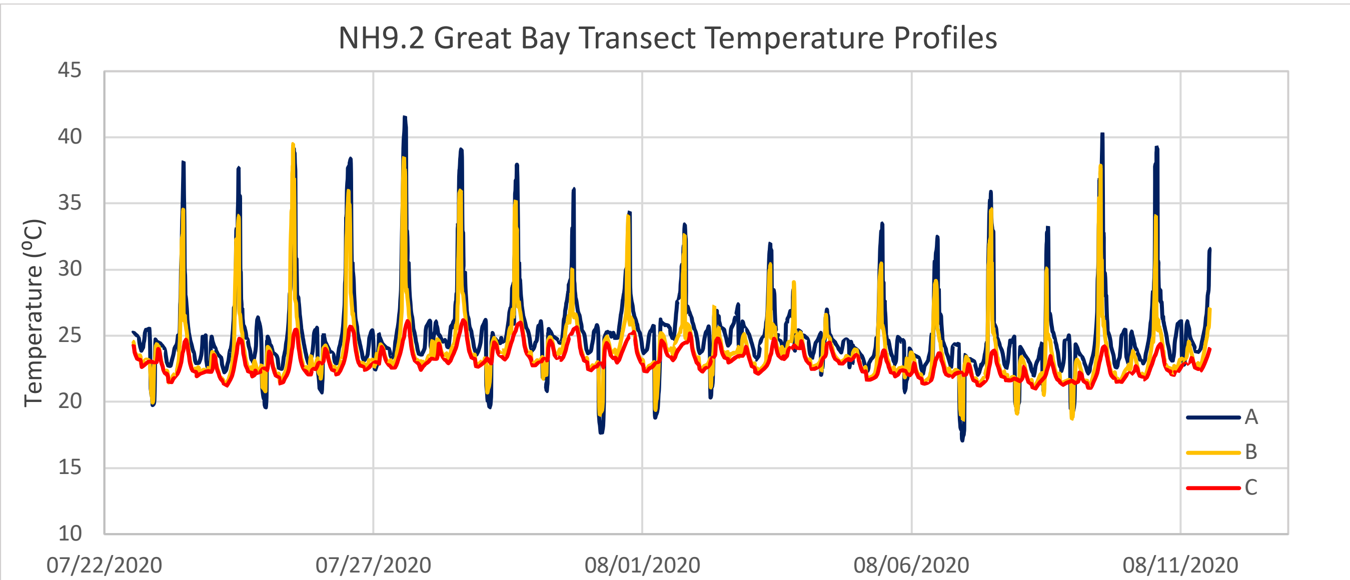


Figure 12. Temperature data collected by HOBO sensors (every 10 minutes) at each of the three transects at site NH9.2 (Great Bay), 7/22/2020 – 8/11/2020. Note that the vertical axis starts at 10º C.

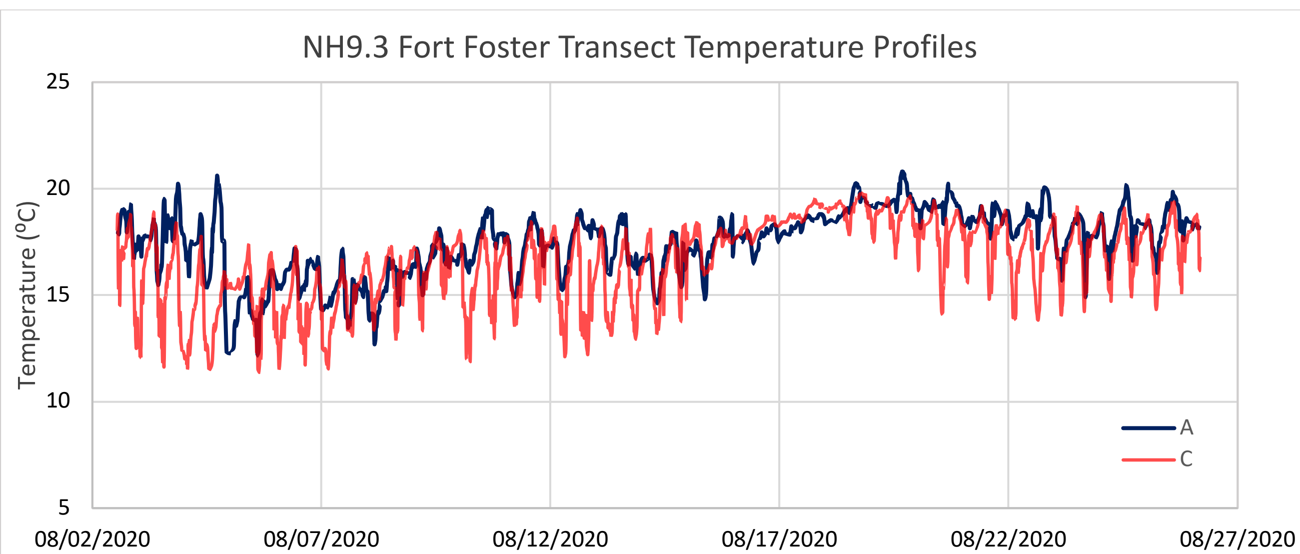


Figure 13. Temperature data collected by HOBO sensors (every 10 minutes) at Transects A and C at site NH9.3 (Fort Foster), 8/2/2020 – 8/27/2020. Note that the vertical axis starts at 5° C.

Salinity
Eelgrass can tolerate virtually all salinities from 0 to 35 ppt for limited times. In general, however, higher salinity is beneficial to eelgrass, with salinities below 15 ppt negatively affecting eelgrass health indicators (Nejrup and Pederson 2008). However, if eelgrass is experiencing a wasting disease epidemic, salinity excursions below 12 ppt can halt the progression of the disease (Burdick et al. 1993).

In Great Bay, salinity can be highly variable. It is impacted by water depth and proximity to the mouths of the three rivers that feed the Bay, as well as the main channel (Figures 1 and 2). The only salinity data collected in 2020 was at Great Bay Transect B. Data were collected from the end of July to mid-October (Figure 14). The data indicate that salinity began and ended the period at just above 25 ppt, with a dip that began in mid-August and extended through September.

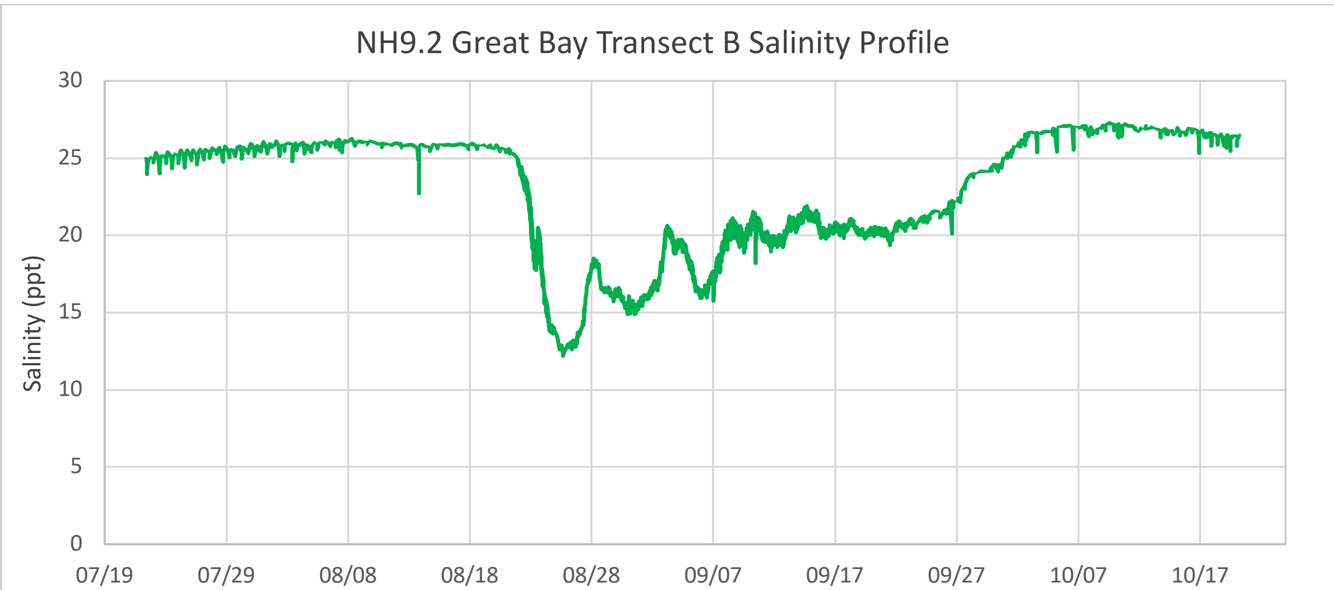


Figure 14. Salinity data collected by a HOBO sensor (every 10 minutes) at Transect B, site NH9.2 (Great Bay), 7/22/2020 – 10/20/2020.

At Fort Foster, salinity values from the HOBO are not reported due to a malfunction with the sensor. At the UNH Coastal Marine Laboratory, across the harbor from the monitoring site, salinities over the time period ranged between 30 and 33 ppt. This small variation relative to Great Bay salinity is expected since this site is adjacent to the Atlantic Ocean and much less susceptible to declines in salinity caused by precipitation and watershed inputs from freshwater tributaries.

Light
Seagrasses require more light than other marine primary producers because of their need to support growth and respiration of below-ground structures (roots and rhizomes), which exist in an environment of low (if any) oxygen levels (Lefcheck et al. 2017). Therefore, light availability is often but not always the most important factor governing eelgrass growth rates (Ochieng et al. 2010). Previously, 11% in situ Surface Irradiation (SI) — the amount of light reaching the plants compared to the amount of light at the surface — was noted as the minimum threshold for eelgrass survival; however, subsequent research (e.g., Short et al. 1995; Ocheing et al. 2010) indicate that long-term eelgrass health can be negatively impacted when SI levels are consistently below 34%. Kenworthy et al. (2014) note that light requirements at Massachusetts study areas varied from 9.5% to 29.7%, with the central tendency between 15% and 22%. Moreover, the Massachusetts study agreed with previous research indicating that light requirements tend to increase in areas with poorer water clarity and higher levels of organic matter.

Here, we focus on light results for the July/August timeframe. Additionally, for Great Bay, we focus on Transect C. In Great Bay, Transect C, the highest mean percent light values were between 65% and 78% (Figure 15). As expected, higher light values occurred on those days when the tide heights were lowest; lower tides result in less difference between the surface versus underwater light levels at a fixed height above the sediment surface because there is less water to absorb the sunlight.

At Fort Foster, percent light levels were lower overall than at Great Bay, most likely due to the plants growing in much deeper water (See Discussion below). The highest mean levels at Transect A were between 20% and 28% (Figure 16), whereas at Transect C, the highest mean levels were between 5% and 8% (Figure 17). Transect A had the highest percent light values at Fort Foster, which is expected since it is in shallower water. Note that the differences in percent light values between A and C most likely reflect differences in water depth (Figures 16 and 17). Historical weather data were checked to see if there were wind and/or precipitation events that could have affected light penetration, but none were found.

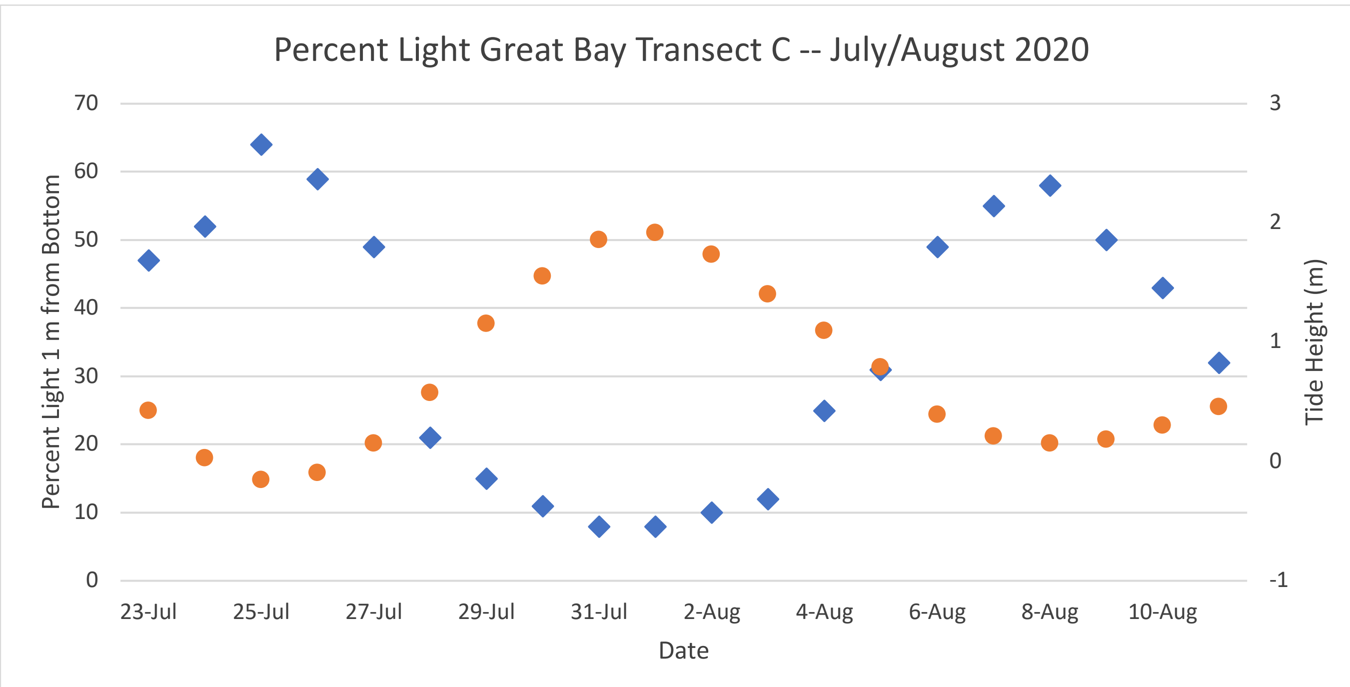


Figure 15. Mean values (blue diamonds) of percent light at 1 m from the bottom at Transect C, site NH9.2 (Great Bay), 7/23/2020 – 8/11/2020. Values represent means from data collected by HOBO sensors every 10 minutes, between 10 a.m. and 2 p.m. Tide height at noon in meters (orange circles) is plotted on the secondary axis. Only data for Transect C are plotted since Transects A and B experience less than 1 m depth at low tide.

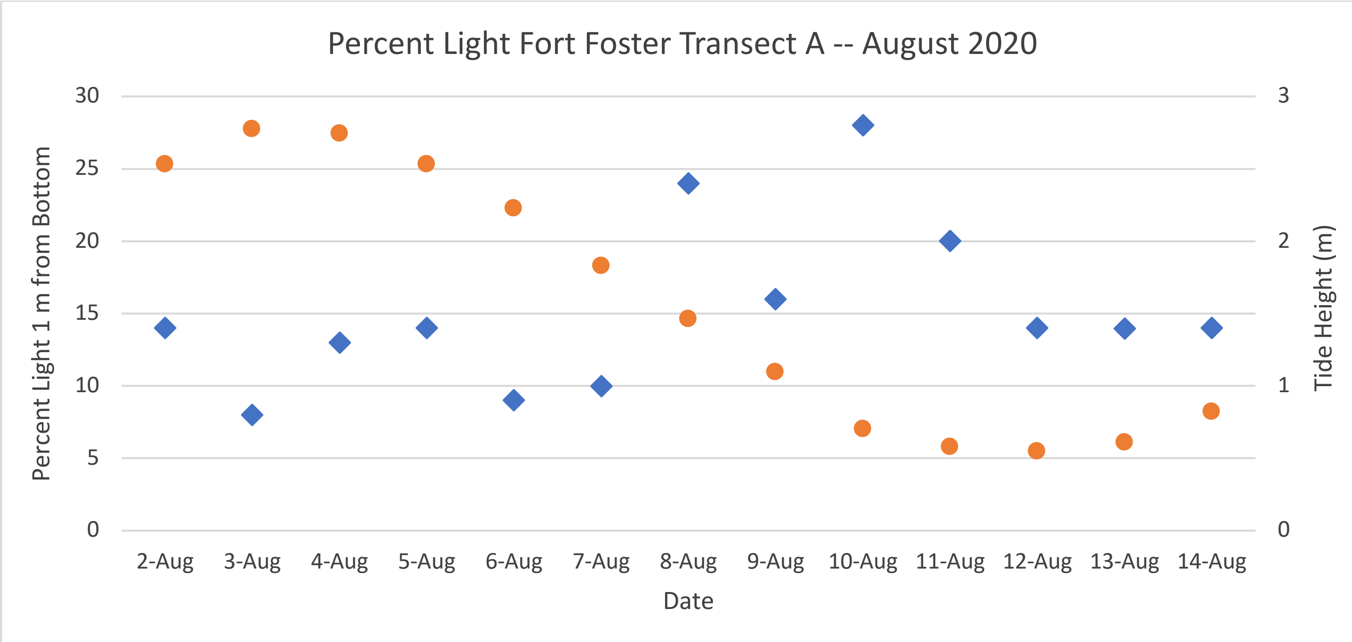


Figure 16. Mean values (blue diamonds) of percent light at 1 m from the bottom at Transect A, site NH9.3 (Fort Foster), 8/2/2020 – 8/14/2020. Values represent means from data collected by HOBO sensors every 10 minutes, between 10 a.m. and 2 p.m. Tide height at noon in meters (orange circles) is plotted on the secondary axis

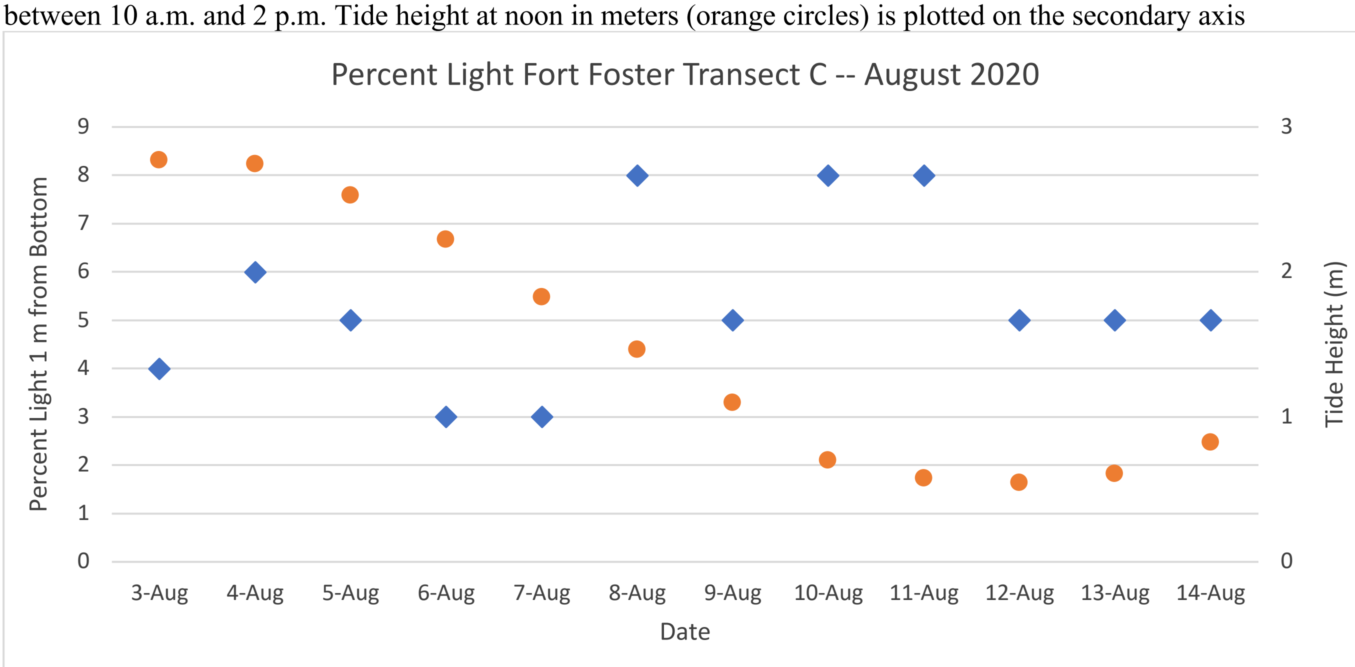


Figure 17. Mean values (blue diamonds) of percent light at 1 m from the bottom at Transect C, site NH9.3 (Fort Foster), 8/3/2020 – 8/14/2020. Values represent means from data collected by HOBO sensors every 10 minutes, between 10 a.m. and 2 p.m. Tide height at noon in meters (orange circles) is plotted on the secondary axis.

Discussion

In 2020, for the areas where the SeagrassNet sites are located (west portion of Great Bay and the Maine side of Portsmouth Harbor), eelgrass abundance remains lower than levels from the 1980s. Short et al. (1993) report 1987-88 biomass levels in Great Bay (near Transect C) of 263 g/m^2. In 2020, in contrast, peak biomass levels in Great Bay were just under 200 g/m^2. Similarly, in 1988, eelgrass density in Great

Bay near Transect C was 427 shoots/m^2 (Short et al. 1993) compared with approximately 300 shoots/m^2 in 2020. The same 1993 report notes biomass levels at Fishing Island in Portsmouth Harbor (near the Fort Foster SeagrassNet site) of 506 g/m^2 supported by a shoot density averaging over 800 shoots/m2. In 2020, in contrast, peak biomass levels at Fort Foster were 215 g/m^2, much lower than 1980s levels and density levels were only 139 shoots/m^2 (Table 1; Figure 9). Whereas the temporal comparisons for the sites in Great Bay are justified by the consistency of the meadows there, the Fishing Island site was largely intertidal, with minimal self-shading to allow for very high biomass and shoot density compared to the subtidal meadow at Fort Foster, so these two sites cannot be compared.

Results from SeagrassNet in 2020 show contrasting conditions, both between the two sites (Great Bay and Fort Foster) overall, as well as between the Great Bay transects. The difference in conditions at the three Great Bay transects are much greater than at the Fort Foster transects, which are much closer together and are more similar in terms of depth profile. It is important to note that Great Bay's Transect A is completely exposed at low tide, making the eelgrass there very susceptible to wind and wave effects as well as impacts from ice, warm water, and desiccation, both in the summer and winter. Overall, these results emphasize the more stressful conditions affecting the Great Bay eelgrass, which experiences greater fluctuations in light, temperature, and salinity (Figures 12 - 18) than the eelgrass at Fort Foster. Also, results show that summer water temperaturess in Great Bay are frequently above 25°C. In contrast, conditions at Fort Foster during the sampling period remained well below 25°.

With regard to light, according to data for Transect C at Great Bay over the sampled two-week period, eelgrass plants experienced conditions below the 15%-22% range indicated in the Kenworthy et al. (2014) study for four out of the 20 sampling days (Figure 15); all four days occurred when high tide corresponded to the 10 a.m. to 2 p.m. sampling window. The eelgrass at Fort Foster experienced peak mean light levels of over 25% (Transect A; Figure 16). At the deepest Transect (C), peak mean light levels were below 10% (Figure 17). This may seem surprising given the clearer water in Portsmouth Harbor (see photographs in Appendix 2). Several points are important in interpreting these data. First, the metric being discussed is percent light, not light attenuation (Kd). Light attenuation tends to increase as one moves up river, so Great Bay would have more light attenuation than Portsmouth Harbor. Percent light, on the other hand, represents the proportion of light from the surface that makes it to the eelgrass beds. Therefore, the depth of the eelgrass may have a significant impact, and the Fort Foster eelgrass beds are in much deeper water than the Great Bay eelgrass meadows. For example, at low tide at Transect C in Great Bay, the water depth can be as low as 1.5 ft. At Fort Foster's Transect C, the lowest water is closer to 12 ft. Despite lower levels of light reaching eelgrass at Fort Foster, the beds have comparable or greater biomass than the meadows in Great Bay, where the percent light reaching plants is much greater. These results are in agreement with previous work showing that high temperatures can impact carbon balance and biomass as well as the conclusions from Kenworthy et al. (2014) that eelgrass growing in coarser sediment with less organic content will have lower light requirements.

Note also that the Great Bay Hobo was deployed 7/23/2020 – 8/11/2020 and Fort Foster's 8/3/2020 – 8/14/2020 which could contribute to differences in light. In the 11 days that only the Great Bay Hobo was deployed, there were no notable wind or rain events. In addition, as noted earlier, there could be issues related to using a land-based reference for Fort Foster that is 8.5 miles away, versus only 1.8 miles away for the Great Bay transects, but with 24 measurements averaged for each day and 2-3 weeks of measurements, it is unlikely.

More in-depth inter-year comparisons for eelgrass, seaweed, temperature, salinity, and light will be forthcoming in the State of Our Estuaries Report, which will be released in December of 2022.

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Appendix 1

Eelgrass data for biomass, percent cover, shoot density, canopy height and reproductive shoots and percent cover seaweed at SeagrassNet site NH9.2 (Great Bay), Transects A, B, and C in July 2020.

Location	Transect	Quadrat #	Sample Date	Biomass (g/m2)	Eelgrass % Cover	Algae % Cover	Shoot Density (#/m2)	Canopy Height (cm) Average	ReproShoot (#/m^2)
NH9.2 Great Bay	A	1	7/22/2020	0	0	5	0	NA	NA
NH9.2 Great Bay	A	2	7/22/2020	3	5	1	28	36	16
NH9.2 Great Bay	A	3	7/22/2020	0	0	5	0	NA	NA
NH9.2 Great Bay	A	4	7/22/2020	2	1	5	16	31	0
NH9.2 Great Bay	A	5	7/22/2020	3	1	1	16	28	0
NH9.2 Great Bay	A	6	7/22/2020	3	1	10	20	41	0
NH9.2 Great Bay	A	7	7/22/2020	6	20	1	40	33	12
NH9.2 Great Bay	A	8	7/22/2020	11	40	5	100	44	16
NH9.2 Great Bay	A	9	7/22/2020	14	30	10	96	31	12
NH9.2 Great Bay	A	10	7/22/2020	11	45	5	76	42	4
NH9.2 Great Bay	A	11	7/22/2020	0	0	1	0	NA	NA
NH9.2 Great Bay	A	12	7/22/2020	1	1	1	8	19	0
NH9.2 Great Bay	B	1	7/23/2020	19	75	5	128	103	0
NH9.2 Great Bay	B	2	7/23/2020	27	50	15	128	70	12
NH9.2 Great Bay	B	3	7/23/2020	68	65	20	224	80	12
NH9.2 Great Bay	B	4	7/23/2020	28	55	40	96	71	20
NH9.2 Great Bay	B	5	7/23/2020	46	70	30	160	59	28
NH9.2 Great Bay	B	6	7/23/2020	14	25	75	96	63	20
NH9.2 Great Bay	B	7	7/23/2020	32	15	80	128	58	20
NH9.2 Great Bay	B	8	7/23/2020	20	15	85	96	56	12
NH9.2 Great Bay	B	9	7/23/2020	35	45	55	128	68	12
NH9.2 Great Bay	B	10	7/23/2020	21	60	40	112	60	20
NH9.2 Great Bay	B	11	7/23/2020	34	65	30	224	69	20
NH9.2 Great Bay	B	12	7/23/2020	107	35	65	272	80	20
NH9.2 Great Bay	C	1	7/22/2020	231	75	1	304	119	0
NH9.2 Great Bay	C	2	7/22/2020	70	50	5	176	127	0
NH9.2 Great Bay	C	3	7/22/2020	253	95	5	432	103	0
NH9.2 Great Bay	C	4	7/22/2020	155	75	5	256	112	0
NH9.2 Great Bay	C	5	7/22/2020	239	90	5	368	110	16
NH9.2 Great Bay	C	6	7/22/2020	88	65	5	240	126	16
NH9.2 Great Bay	C	7	7/22/2020	76	80	5	288	103	0
NH9.2 Great Bay	C	8	7/22/2020	66	50	5	176	123	32
NH9.2 Great Bay	C	9	7/22/2020	328	90	5	304	123	48
NH9.2 Great Bay	C	10	7/22/2020	346	85	5	384	126	16
NH9.2 Great Bay	C	11	7/22/2020	236	90	5	400	124	0
NH9.2 Great Bay	C	12	7/22/2020	180	80	1	272	128	0

Eelgrass data for biomass, percent cover, shoot density, canopy height and reproductive shoots and percent cover seaweed at SeagrassNet site NH9.3 (Fort Foster), Transects A, B, and C in August 2020.

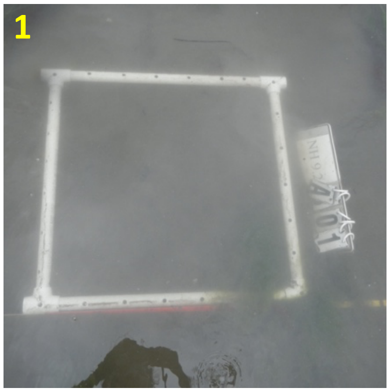
Location	Transect	Quadrat #	Sample Date	Biomass (g/m2)	Eelgrass % Cover	Algae % Cover	Shoot Density (#/m^2)	Canopy Height (cm) Average	ReproShoot (#/m^2)
NH9.3 Fort Foster	A	1	8/1/2020	136	10	10	16	106	0
NH9.3 Fort Foster	A	2	8/1/2020	315	70	10	176	129	4
NH9.3 Fort Foster	A	3	8/1/2020	397	80	0	208	114	20
NH9.3 Fort Foster	A	4	8/1/2020	181	95	5	272	122	32
NH9.3 Fort Foster	A	5	8/1/2020	383	90	5	208	104	16
NH9.3 Fort Foster	A	6	8/1/2020	51	25	5	64	53	0
NH9.3 Fort Foster	A	7	8/1/2020	234	70	0	128	97	12
NH9.3 Fort Foster	A	8	8/1/2020	73	70	10	144	62	20
NH9.3 Fort Foster	A	9	8/1/2020	101	60	20	112	83	0
NH9.3 Fort Foster	A	10	8/1/2020	88	40	60	64	113	4
NH9.3 Fort Foster	A	11	8/1/2020	155	100	0	224	145	28
NH9.3 Fort Foster	A	12	8/1/2020	238	75	15	160	130	20
NH9.3 Fort Foster	B	1	8/1/2020	228	95	0	144	118	8
NH9.3 Fort Foster	B	2	8/1/2020	238	75	15	176	117	8
NH9.3 Fort Foster	B	3	8/1/2020	170	60	15	144	110	4
NH9.3 Fort Foster	B	4	8/1/2020	189	55	5	112	75	8
NH9.3 Fort Foster	B	5	8/1/2020	108	75	10	112	124	4
NH9.3 Fort Foster	B	6	8/1/2020	249	95	0	144	140	12
NH9.3 Fort Foster	B	7	8/1/2020	159	85	5	112	133	4
NH9.3 Fort Foster	B	8	8/1/2020	221	90	0	112	134	16
NH9.3 Fort Foster	B	9	8/1/2020	252	100	0	208	137	8
NH9.3 Fort Foster	B	10	8/1/2020	467	100	0	160	162	8
NH9.3 Fort Foster	B	11	8/1/2020	151	80	5	112	161	4
NH9.3 Fort Foster	B	12	8/1/2020	154	100	0	128	152	4
NH9.3 Fort Foster	C	1	8/2/2020	234	85	5	128	145	16
NH9.3 Fort Foster	C	2	8/2/2020	225	90	5	144	165	0
NH9.3 Fort Foster	C	3	8/2/2020	235	90	5	112	144	4
NH9.3 Fort Foster	C	4	8/2/2020	148	90	5	112	141	12
NH9.3 Fort Foster	C	5	8/2/2020	197	90	5	128	127	8
NH9.3 Fort Foster	C	6	8/2/2020	142	95	0	96	155	4
NH9.3 Fort Foster	C	7	8/2/2020	257	95	0	128	122	0
NH9.3 Fort Foster	C	8	8/2/2020	203	90	5	192	153	12
NH9.3 Fort Foster	C	9	8/2/2020	89	55	5	68	97	4
NH9.3 Fort Foster	C	10	8/2/2020	45	15	25	24	89	0
NH9.3 Fort Foster	C	11	8/2/2020	23	45	5	48	119	8
NH9.3 Fort Foster	C	12	8/2/2020	57	65	5	56	102	8

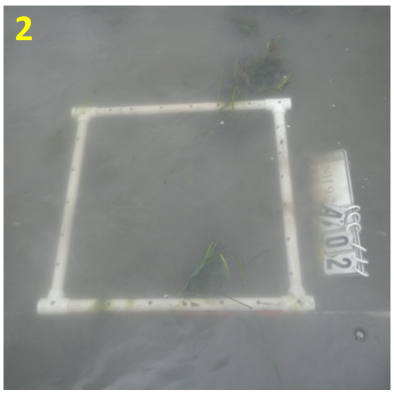
Appendix 2

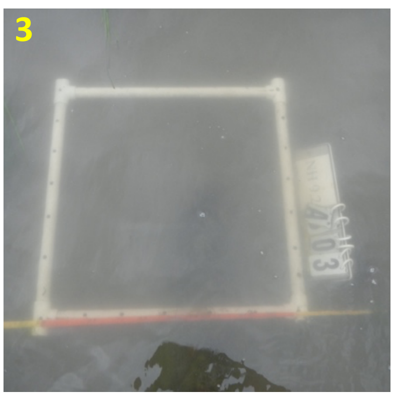
Photo mosaic of quadrat photos from the 3 SeagrassNet transects (A, B, and C) taken during the July 2020 survey in Great Bay, New Hampshire and the August 2020 survey at Fort Foster, Portsmouth Harbor. Each photo mosaic represents a single transect (A, B, or C) and photos are organized into 3 columns showing Quadrats 1-4, Quadrats 5-8, and Quadrats 9-12. Some photos from Transect A in Great Bay are difficult to interpret due to enhanced turbidity from the shallow water.

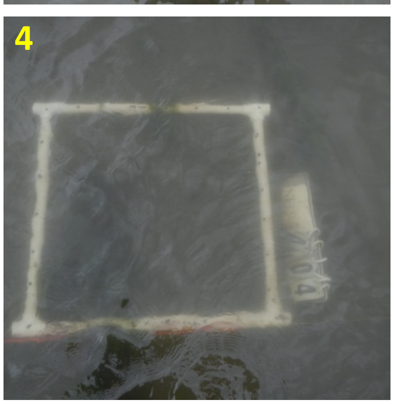
Site NH9.2 (Great Bay), Transect A, July 2020

Quadrats 1-4

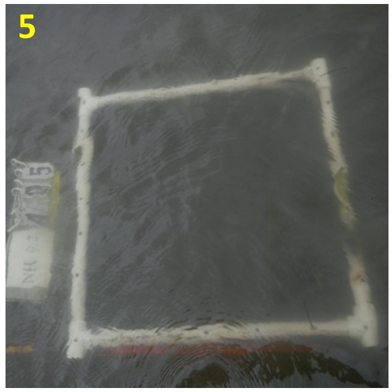


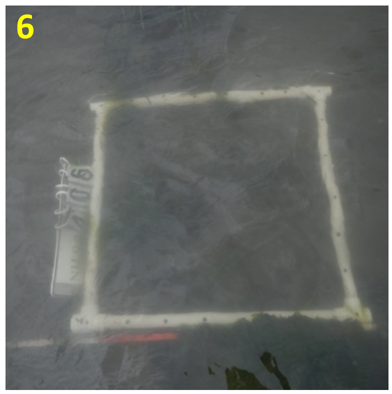


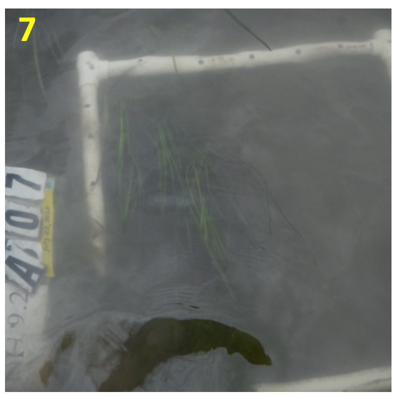


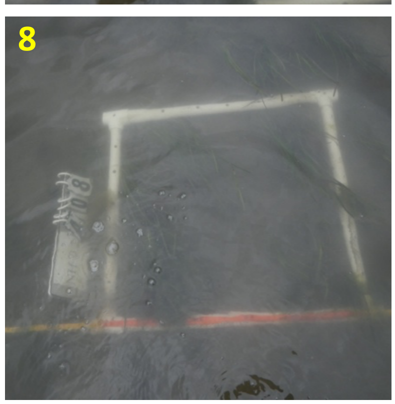


Quadrats 5-8

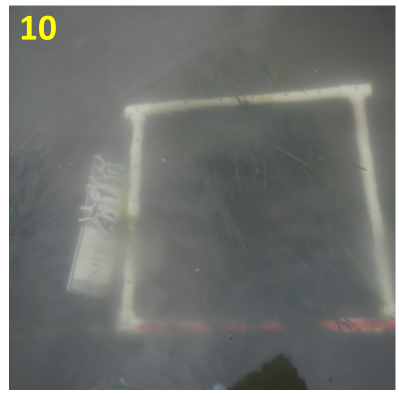


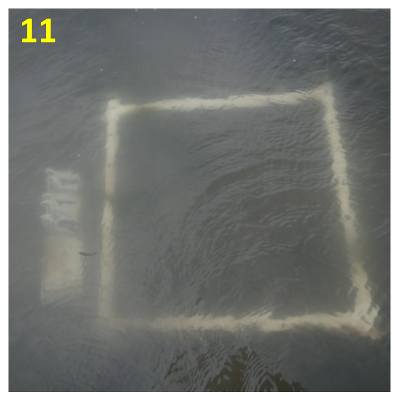






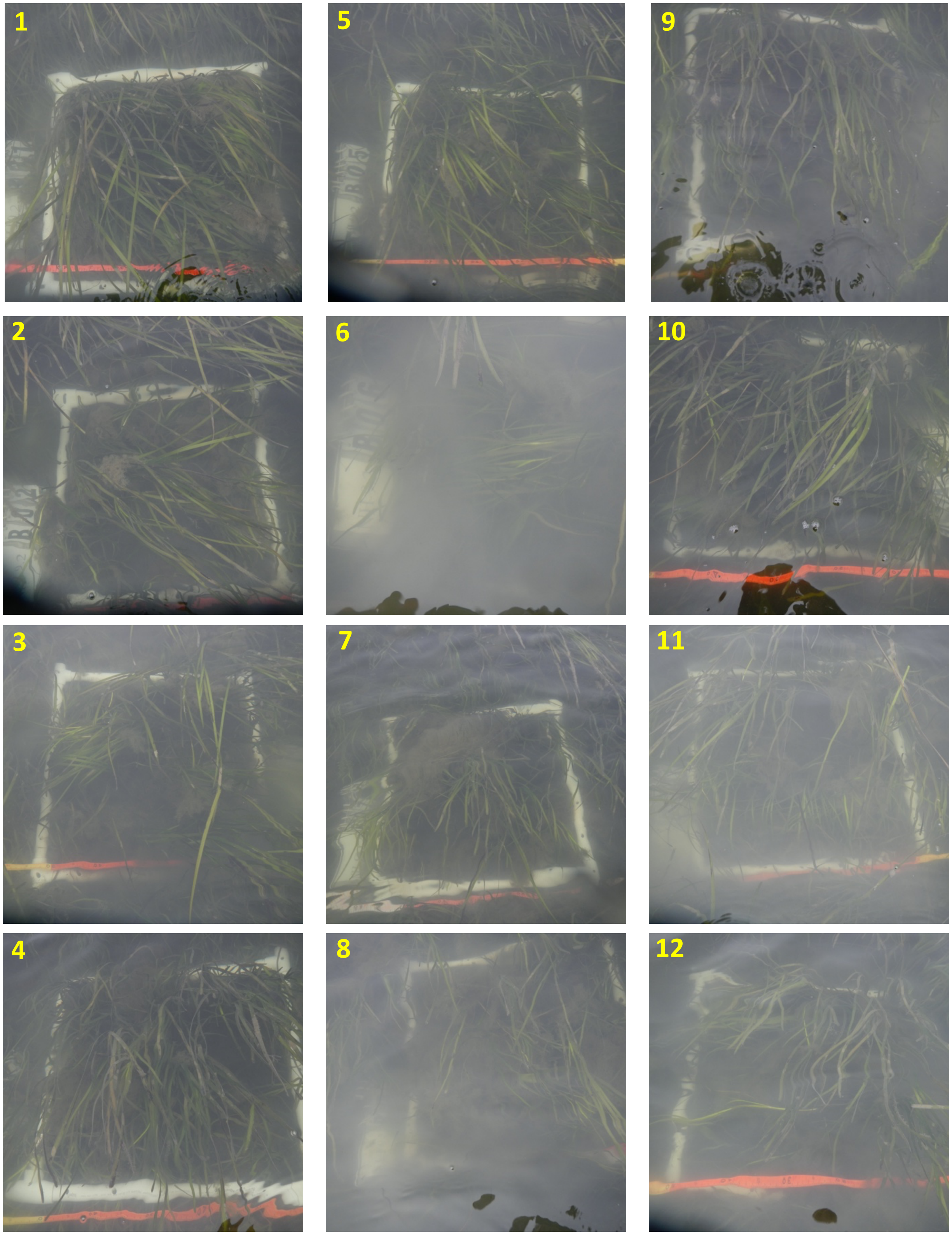
Quadrats 9-12





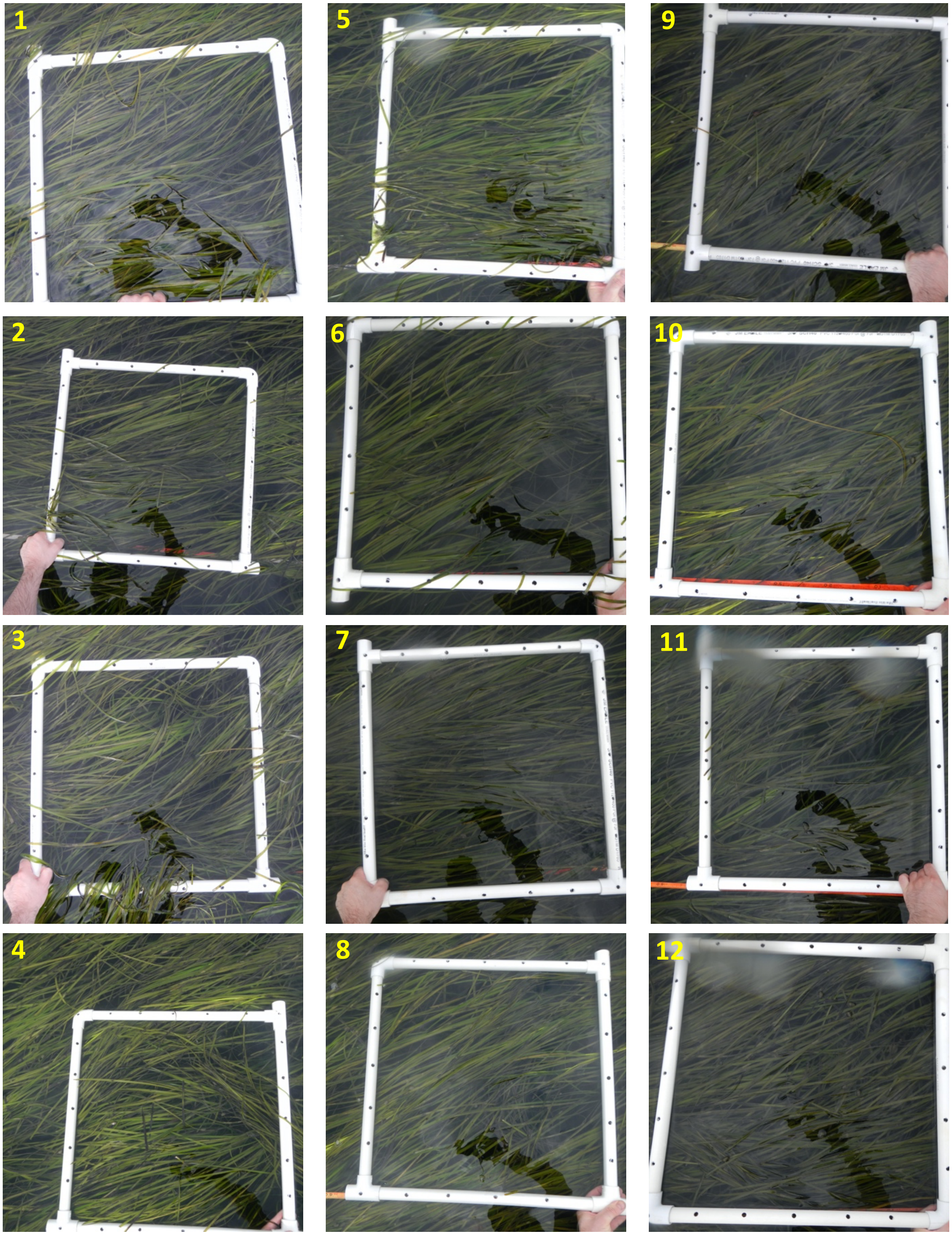
Site NH9.2 (Great Bay), Transect B, July 2020

<u>Quadrats 1-4</u> <u>Quadrats 5-8</u> <u>Quadrats 9-12</u>



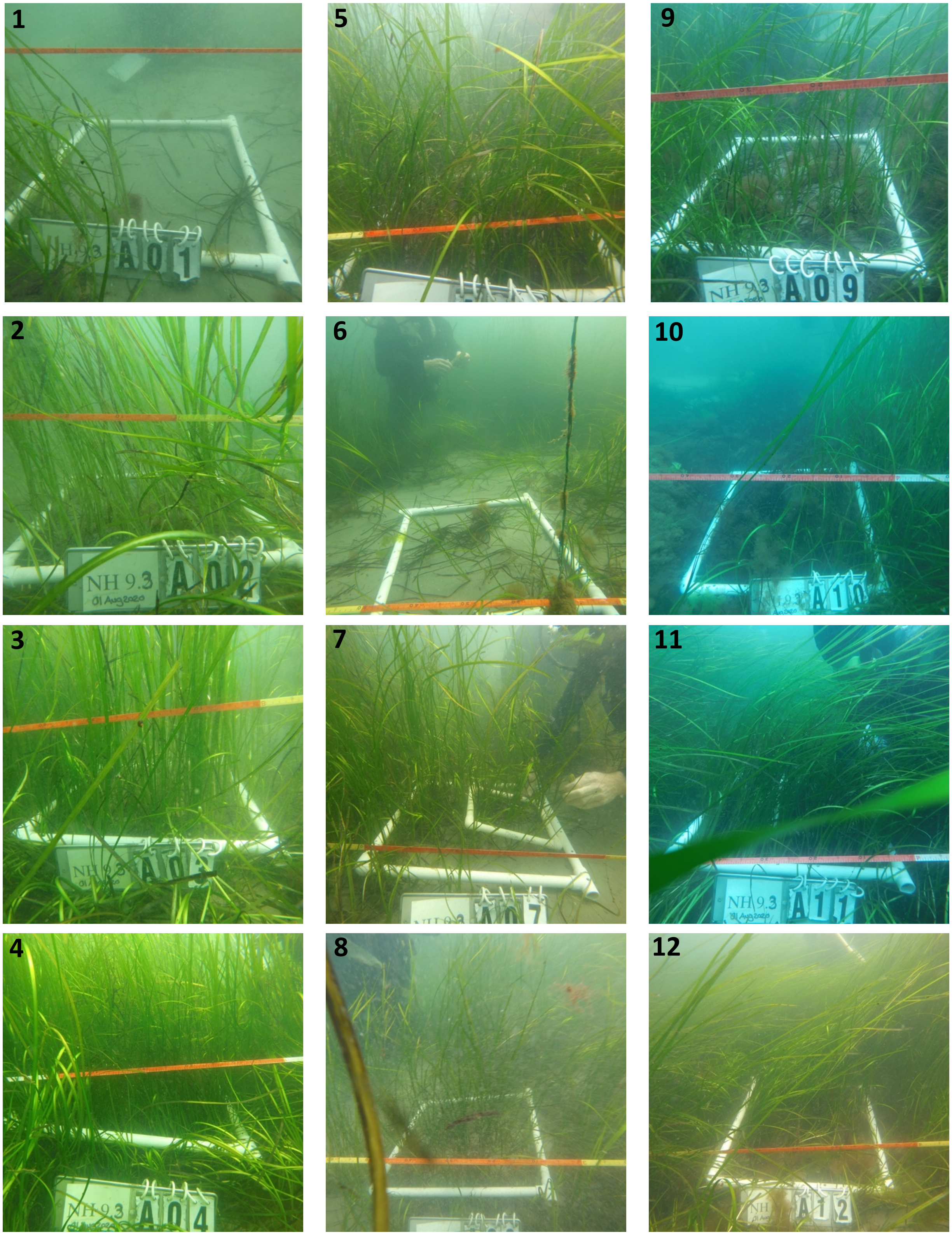
Site NH9.2 (Great Bay), Transect C, July 2020

<u>Quadrats 1-4</u> <u>Quadrats 5-8</u> <u>Quadrats 9-11</u>



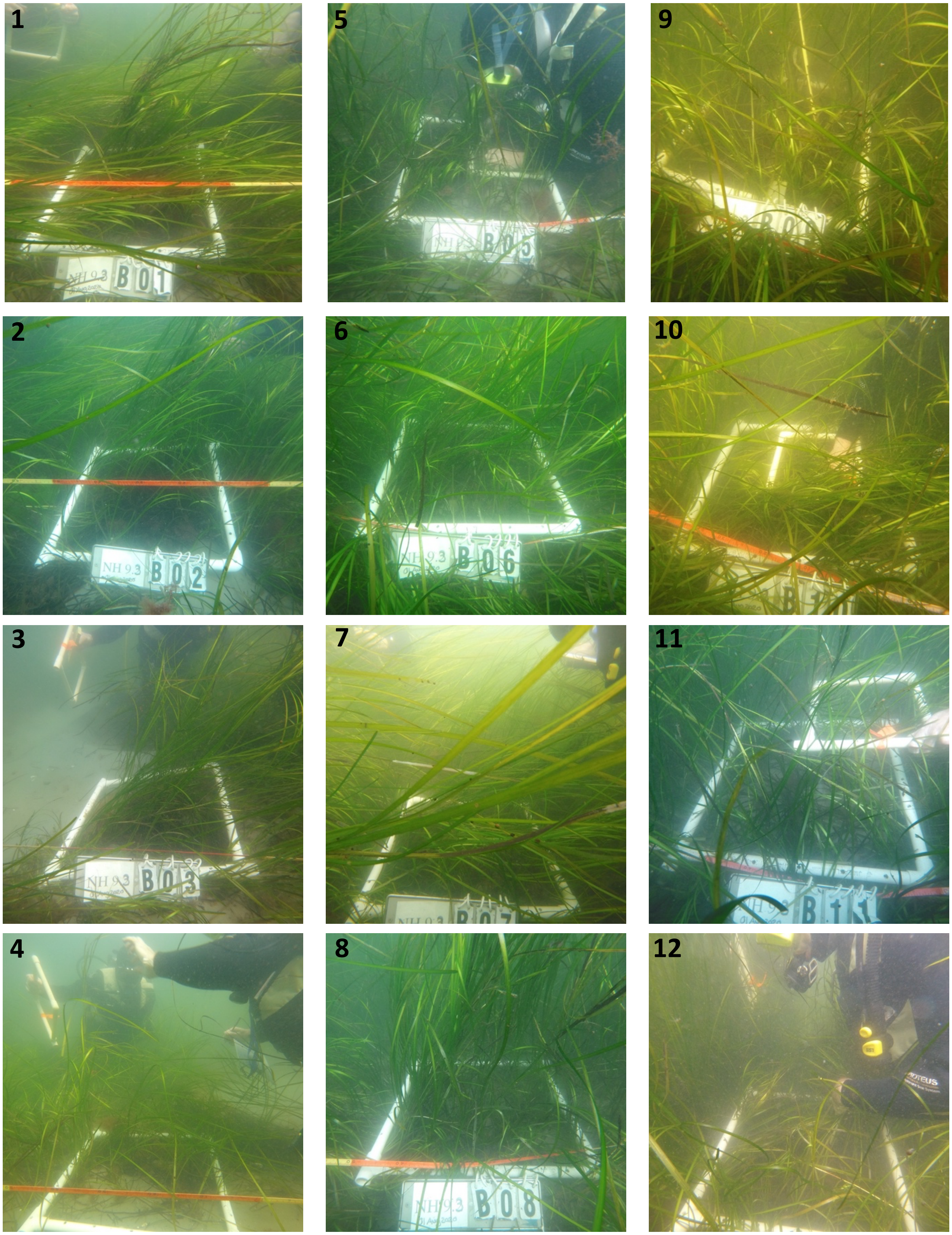
Site NH9.3 (Fort Foster), Transect A, August 2020

Quadrats 1-4 | Quadrats 5-8 | Quadrats 9-12



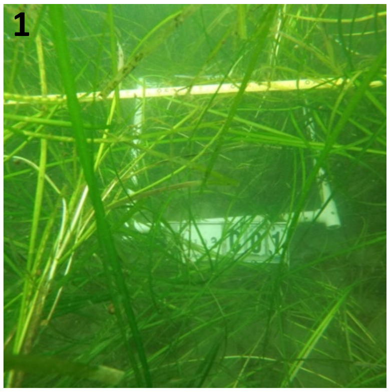
Site NH9.3 (Fort Foster), Transect B, August 2020

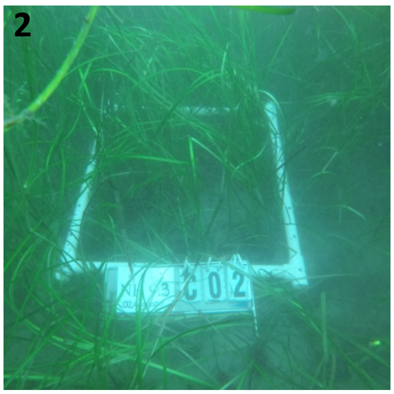
Quadrats 1-4 | Quadrats 5-8 | Quadrats 9-12

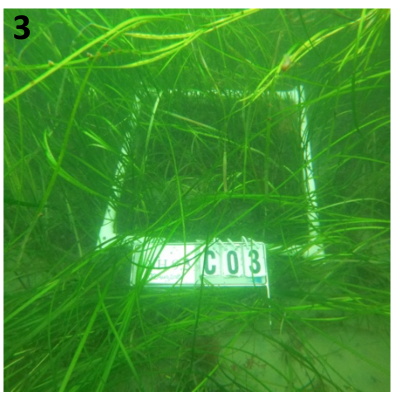


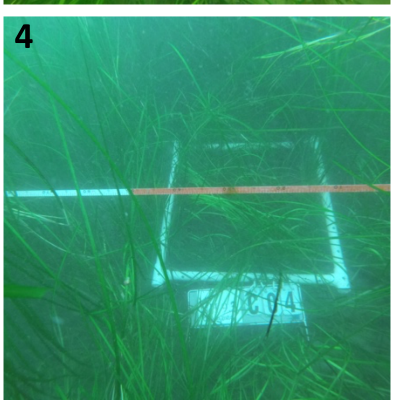
Site NH9.3 (Fort Foster), Transect C, August 2020

<u>Quadrats 1-4</u>

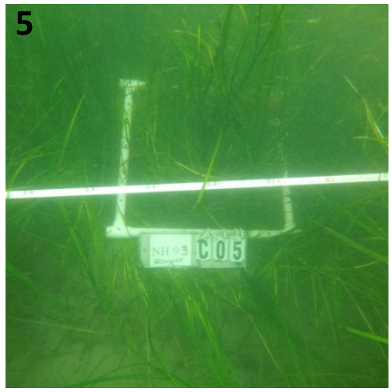


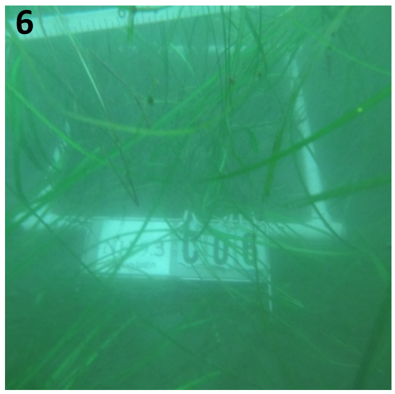


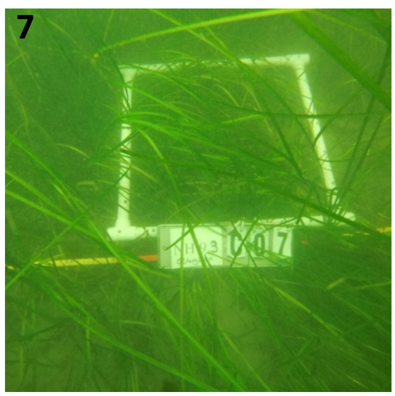


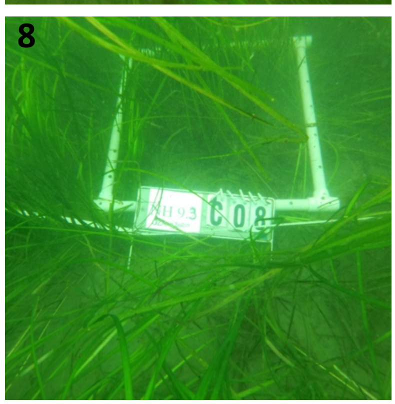


<u>Quadrats 5-8</u>

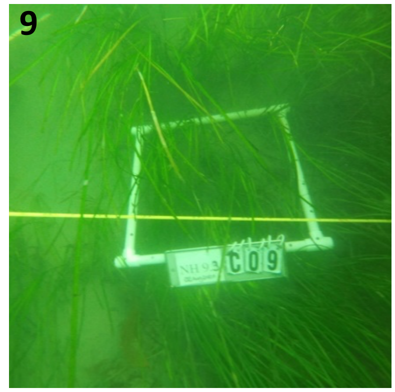


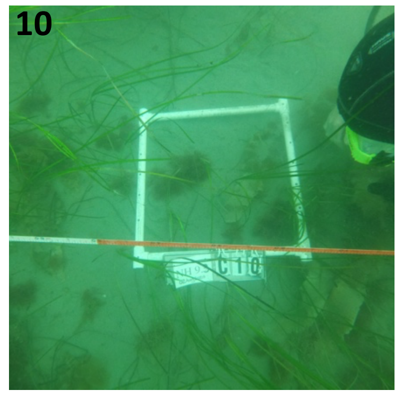


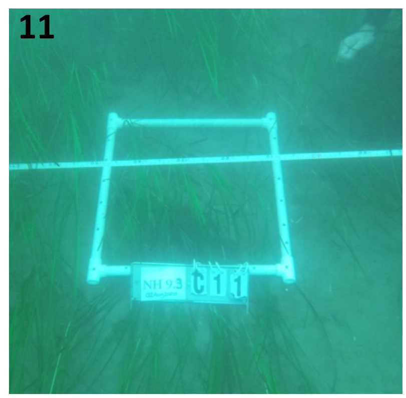


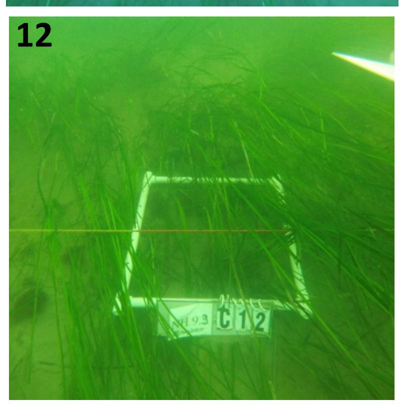


<u>Quadrats 9-12</u>









Appendix 3

QA/QC MEMORANDUM

To: Erik Beck, USEPA

From: Kalle Matso, PREP (Project QA Officer for SeagrassNet Monitoring)

Date: December 28, 2021

Re: Quality Assurance of 2020 SeagrassNet Monitoring Program

PURPOSE

The purpose of this memorandum is to document the results of quality assurance checks on the 2020 SeagrassNet monitoring program conducted by staff from UNH Jackson Estuarine Laboratory and PREP.

The project consisted of the continued monitoring and sampling of an established SeagrassNet site located in Great Bay, NH, as well as the establishment, monitoring, and sampling of a new SeagrassNet site located in Portsmouth Harbor at the site designated as "Fort Foster."

PREP reviewed these data with reference to the data quality objectives for the approved Quality Assurance Project Plan, available online: https://scholars.unh.edu/prep/420/

The following table contains assessments of the data quality objectives of the project. Supporting tables and figures are also provided below.

DATA QUALITY OBJECTIVE ASSESSMENTS

Data Quality Objective	Criteria	Protocol	Assessment of Criteria	Data Quality Objective Status
Precision	Biomass measurements should be maintained to 1/100 of a gram.	Laboratory analysis will measure biomass with a Sartorius Balance (Type = E2000D).	All of the biomass measurements were maintained to 1/100 of a gram and were measured using a Sartorius Balance (Type = E2000D).	**Achieved**
Bias	Percent cover, shoot density, canopy height, and grazing estimates should be comparable across members of the field assessment team within ±10%.	Field assessment team members will "calibrate" their assessments of percent cover, shoot density, canopy height, and grazing estimates prior to field work by reviewing published examples of visual representations of different percent covers (Short 2017). Field estimates will then be made by consensus of the field team. The field assessment team will also review photographs and associated percent cover estimates from previous years before the field season begins.	Field staff training included a "calibration" using published examples of visual representations of different percent covers prior to data collection, as well as a review of estimates to confirm a comparability across field staff members within ±10%. Field estimates were made by consensus of the field team. However, photographs and associated percent cover estimates from previous years were not reviewed prior to the field season.	**Achieved**
Spatial Accuracy	GPS units should have a reported accuracy less than or equal to 2 meters.	New transects will be established using a highly accurate, real-time kinematic (RTK) GPS. Transect locations will then be staked in the field using screw anchors. The minimum accuracy tolerance of the unit will be set to reject saving of waypoints with spatial accuracy less than 0.03m, thereby assuring spatial accuracy requirements are met or exceeded.	Field staff used GPS units that have a reported spatial accuracy of 3-5 meters under normal conditions. The Satellite Information screen was not used during field work, so the current spatial accuracy of the GPS units was not observed. Neither the Great Bay site nor the Portsmouth Harbor site were established using an RTK GPS. **This criterion and the method for georeferencing need to be reevaluated by PREP for future monitoring.**	**Partially Achieved**
Comparability	Field and laboratory data should be collected using standardized methods.	Check that protocols from the QAPP were used for field observations. The QA Manager should use filtering functions to check the field assessment team's spreadsheets for data entry errors. All percent cover values should fall into one of the categories specified in the sampling methods. All biomass values should be between 0 and 500 grams. A minimum of 10% of field observations should be checked against electronic spreadsheets.	Field staff collected data using a standardized field data sheet. The protocols in the QAPP were used for all field observations made (see Completeness below) except for Shoot Density. In some cases, it was not clear which of the two size quadrats was used for density counts. In those cases, counts were re-assessed and verified using photographs. Data entry errors were assessed and any anomalies were explainable when the field personnel were asked about the issue at hand.	**Achieved**

Data Quality Objective	Criteria	Protocol	Assessment of Criteria	Data Quality Objective Status
Completeness	Field observations should be made for percent cover, shoot density, canopy height, grazing, and wasting disease estimates. In addition, environmental data collection should include light levels, temperature, and salinity.	Check field observations for completeness. Document reasons for any deviations from sampling protocol.	Field observations were made during sampling events for percent cover, shoot density, and canopy height. Although considered during eelgrass processing, wasting disease data were not captured during sampling events. Note that wasting disease is not requested on current field data sheets (**QAPP Appendix A**). Per environmental data criteria, light levels, temperature, and salinity data were collected via HOBO data loggers.	**Partially Achieved**

Table 1: Field observations and environmental data collection performed.

Parameter Observed:	Completed	Pass or Fail
Percent Cover	Yes	Pass
Shoot Density	Yes	Pass
Canopy Height	Yes	Pass
Grazing	Yes	Pass
Wasting Disease	No	Fail
Light Levels	Yes	Pass
Temperature	Yes	Pass
Salinity	Yes	Pass