<u>A Marsh Under Stress:</u>
<u>What's Driving Changes in the Chase Garden Creek Salt Marsh?</u>

Year 2 Annual Report: February 2024 – January 2025

Prepared by: Jordan Mora & Molly Autery
Association to Preserve Cape Cod

Funded by the Lavori Sterling Foundation and APCC Private Foundation Funds

Photo of Chase Garden Creek salt marsh (Section A study area) showing erosion that resulted in collapse of marsh edge along the main channel (photo credit: APCC).

<u>Summary of Year 2 Tasks</u>

The focus of the Chase Garden Creek salt marsh assessment project in Year 2 was twofold: 1) pursue public outreach to increase awareness in the surrounding community of the importance of the Chase Garden Creek salt marsh ecosystem and the research undertaken by the Association to Preserve Cape Cod (APCC) to inform future restoration strategies, and 2) understand the drivers behind the erosion and subsidence in the most vulnerable sections of the salt marsh. These two objectives came out of several stakeholder engagement efforts in 2023 which included members of Dennis and Yarmouth town staff, state and federal agencies (including but not limited to USDA Natural Resources Conservation Service, Coastal Zone Management, Division of Ecological Restoration, Department of Fish and Game), project funders, and other regional groups (Aquacultural Research Corporation, Cape Cod Conservation District, Cape Cod Commission, and the Cape Cod Cooperative Extension).

For the first piece of the Year 2 mission, APCC held a public meeting in July 2024 via Zoom to engage the neighboring communities in Yarmouth and Dennis. APCC was interested in receiving stories and concerns from homeowners and other community members regarding the state of Chase Garden Creek salt marsh. Additionally, APCC took the opportunity to teach about the importance of salt marshes in protecting coastal communities, including homes and other infrastructure. APCC continued to share information about the goals and work accomplished in Chase Garden Creek through several e-newsletter articles. These articles were published in August 2024 and January 2025, and the messages, respectively, related to the rationale behind measuring sediments in salt marshes and the importance of building partnerships and connections across Cape Cod for scientific research. Chase Garden Creek was also noted in one of the October and December 2024 e-newsletters thanking our summer interns and reflecting on work completed by the Ecosystem Restoration Program team in 2024.

In order to obtain our second Year 2 goal of better understanding the salt marsh dynamics (i.e., tidal regime, sediment movement, and marsh platform integrity), APCC partnered with the Center for Coastal Studies (CCS) to complete a sediment study within three sections of the Chase Garden Creek salt marsh. The CCS contract was funded through a private foundation interested in supporting early phases of restoration projects on Cape Cod, and APCC's time and expense was covered by the Lavori Sterling Foundation, whose generous donations made the whole project possible. The details of the sediment study methods and preliminary findings are provided in this report. The main question pursued was: How do different parts of the marsh (selected based on differing levels of vulnerability derived from the Year 1 assessment) vary in terms of flooding regime, plant community, and sediment accumulation rates? Does the growing shoal at the Chase Garden Creek inlet limit sediment supply or tidal range within the salt marsh system?

Sediment Study Methods

Site orientation: To best investigate the driving forces behind the erosion observed at Chase Garden Creek, APCC studied water levels, vegetation cover, and sediment deposition in three sections of marsh. These three sections were chosen based on accessibility and representation across the full range of sea level rise vulnerability, determined using an analysis of unvegetated to vegetated ratio (UVVR) in Year 1. Figure 1 shows the locations of the three sections: Section C (highest vulnerability and lowest vegetated cover), Section A (lowest vulnerability and highest proportion of vegetated cover), and Section B (moderate vulnerability and vegetation cover). Section C is closest to the Cape Cod Bay inlet (~650 m), Section A is the second closest to the inlet (~850 m) and bordered on the landward side by the backbarrier dune, Chapin Memorial Beach, and Section B is farthest from the inlet (~1000 m) (Figure 1). The sections will be listed in this order (C, A, B) to reflect proximity to the inlet throughout the report.

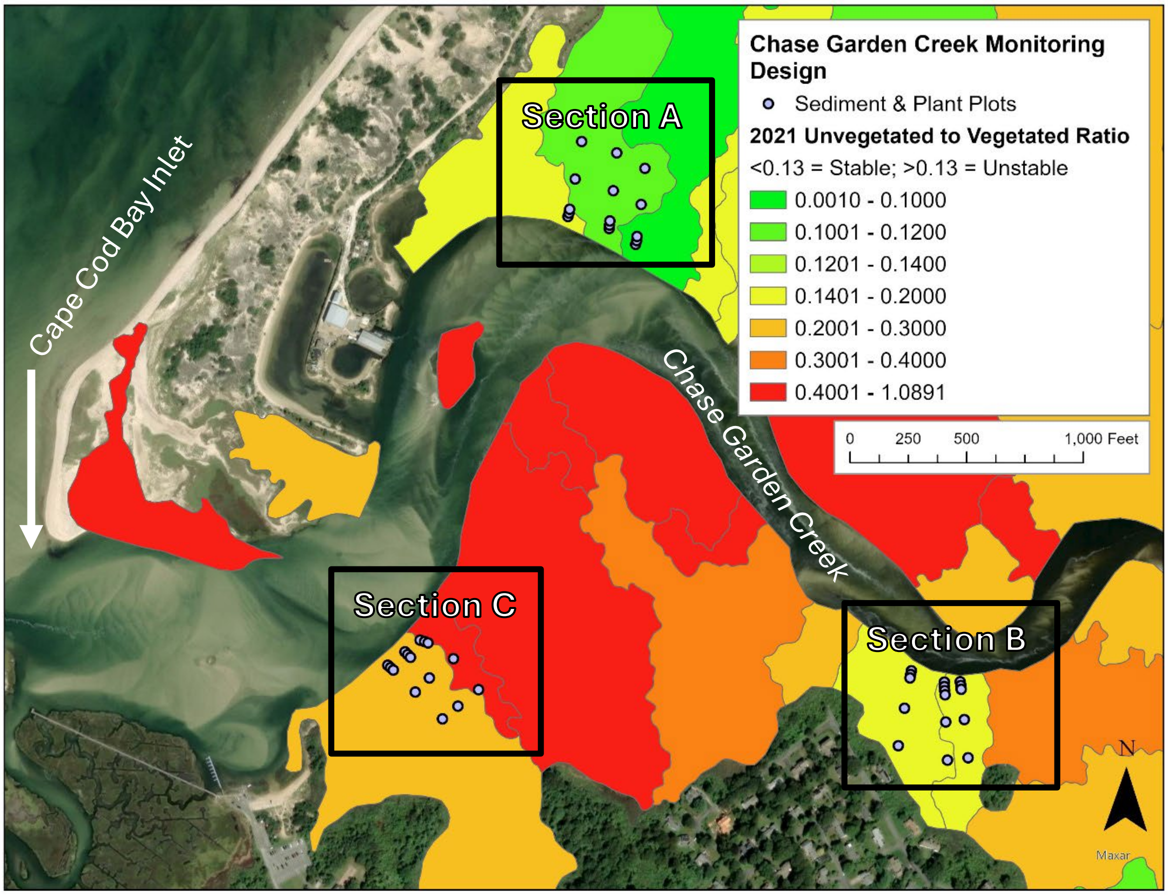

Figure 1: Chase Garden Creek salt marsh located on the north side of Cape Cod. The main channel acts as the border between Yarmouth, MA (to the south) and Dennis, MA (to the north). The three study sections are indicated by bolded black rectangles and were chosen to compare factors impacting marsh resilience across the vulnerability spectrum. The 2021 Unvegetated to Vegetated Ratio, completed by APCC in Year 1 of the project scope, indicates differences in vulnerability with increasing sea levels (areas with warmer colors are less stable, cooler colors show more resilience against rising seas).

Water level and salinity: Water level monitoring helps us understand the tidal regime at Chase Garden Creek, including how tidal inundation varies at different areas in the marsh, and how tidal range impacts sediment delivery and accumulation. The goal of this water level monitoring was to establish baseline measurements of surface water and groundwater levels for an entire lunar cycle (30 days).

Six water level and salinity loggers (Solinst Levelogger 5, Model 3001) were deployed for one lunar cycle (August 23, 2024 – September 23, 2024) in order to capture at least two full neap (i.e., lower gravitational pull from the moon and spring (i.e., highest gravitational pull from the moon and sun) tides. There were two loggers measuring groundwater levels at Sections A and C, three measuring surface water levels in the creek at Sections A, B, and C, and one reference logger measuring surface water levels near the inlet leading to Cape Cod Bay (Figure 2). During the last week of deployment, the reference station logger was lost during a heavy storm event which eroded the bank where the instrument was deployed, so there is no data from the inlet.

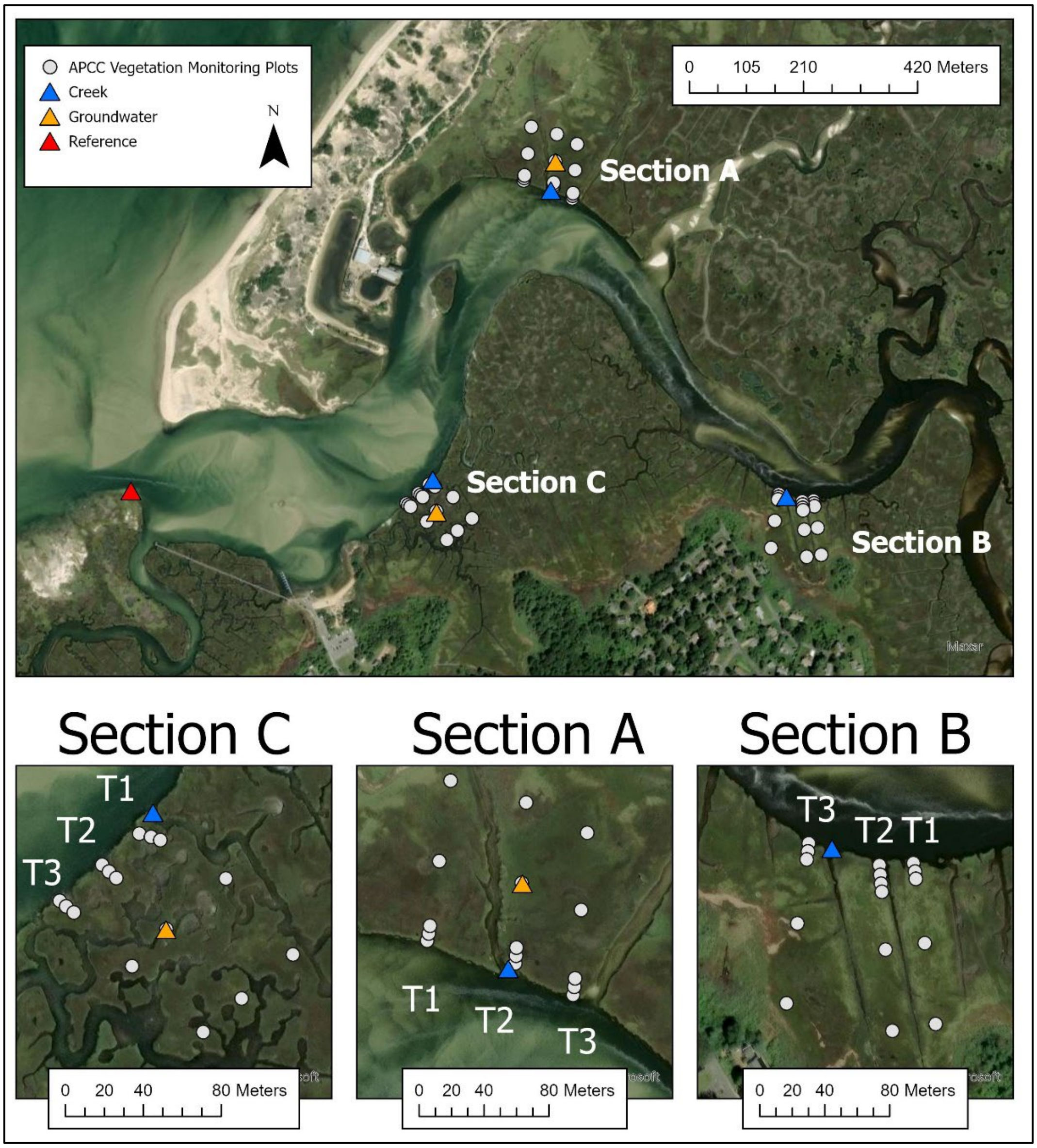

Figure 2: Vegetation and sediment trap monitoring plots (gray circles) and water level logger stations (blue triangles indicate surface water, orange triangles indicate groundwater, and red indicates the reference station) at Chase Garden Creek.

All loggers were calibrated using saltwater standards for salinity prior to deployment and set to record water depth and salinity at 6-minute intervals. The loggers at the surface water stations in the creeks were affixed to metal stakes that were driven ~2 feet deep into the sediment bed. The groundwater wells (or piezometers) were designed to prevent clogging and encourage drainage. The piezometers were secured by drilling 1/8- and 1/4-inch holes roughly 1/2- to 1-inch apart throughout the lower 60 cm of the 1-meter PCV. The holes were covered with garden mesh fabric, and they were installed roughly 60 cm deep. The elevation of the groundwater wells and creek stakes was surveyed using a Spectra 85 Real-Time Kinematic (RTK) GPS device with 1-2 cm accuracy.

A barometric pressure logger (Solinst Barologger, Model 3001) was deployed during the same period as the water level loggers (August 23, 2024 – September 23, 2024) in a tree at the upland edge of the action marsh, placed roughly 1.5 meters above the marsh to minimize the chance of flooding damage. Barometric pressure data was used to convert absolute pressure collected by the water level loggers to water depth. Creek water levels were used to calculate inundation time at the vegetation monitoring plots, or the percentage of time the monitoring plots were flooded over a 1-month period.

Sediment traps: Sediment traps provide measurements of sediment accumulation on the marsh surface. This information is used to assess how sediment accumulation varies within the overall marsh system and across the elevation gradient. In particular, APCC was interested in how the sandy shoal near the inlet impacts sediment delivery and accumulation at the three study sections. APCC contracted Dr. Katie Castagno from the Center for Coastal Studies (CCS) to manage the sediment trap design, deployment, collection, and laboratory processing.

Sediment traps were placed along three transects running perpendicular to the creek edge and extending towards the upland border within each marsh study section, (Figure B). Five monitoring stations were spaced along the transects at 0 m, 5 m, 10 m, 50 m, and 100 m from the creek or channel edge (Figure B). Wooden stakes were placed in the marsh in June 2024 to mark the location of each monitoring station. Marsh elevation of each station was measured using a Spectra 85 Real-Time Kinematic (RTK) GPS.

The sediment traps were constructed from 50 mL plastic centrifuge tubes (Figure 3). A small piece of aquarium netting was placed over the opening of the tube and secured with a rubber band to prevent bioturbation from marine life (i.e., crabs and snails) entering the trap. Each sediment trap was set in the marsh surface such that marsh surface aligned with the top 0.5 inches of the tube. Four tubes, or replicates, were deployed at each monitoring station to prevent data loss and lessen the influence of outliers. The sediment traps were left in place for 1-month intervals. At the end of each month, the traps were collected and replaced by new, empty traps. Sediment trap deployments started in June 2024 and will continue through April 2025.

Figure 3: Example of a sediment trap pre-deployment at Chase Garden Creek.

The collected sediment traps are transported to CCS for analysis. Dr. Castagno and staff first decant the salt water from the traps and re-fill the tubes with tap water. This step helps to remove salt from the sediment in the tube to prevent erroneous measurements of sediment mass. The tubes are left standing upright for 24 hours so the sediment can settle from the water and collect at the bottom. The water is then poured off from the tube and the sediment is transferred to crucibles for further measurement. The sediment in the crucibles is dried, weighed to calculate dry mass (g), combusted in a furnace in a process known as loss-on-ignition (LOI), and weighed again to calculate the post-combustion mass (g). The pre- and post-combustion masses are used to calculate the organic content of the sediment. Sediment accumulation rates (g/day) are calculated by dividing the dry mass by the number of days the sediment traps were deployed on the marsh. Accumulation rates and organic content were analyzed using graphing tools in Excel and spatial analysis tools in ArcGIS Pro, in conjunction with water level and vegetation data.

Vegetation monitoring: Vegetation monitoring in salt marshes helps to identify what plant communities are present throughout the marsh. The composition and distribution of plant species provides information regarding patterns of flooding, sediment deposition, and marsh resiliency. This vegetation data will help to further characterize the three sections of marsh beyond the

Unvegetated/Vegetated (UVVR) ratio and MarshRAM surveys conducted for this site by APCC in 2023, improving our understanding of marsh vulnerability and resiliency in a spatial context.

To establish baseline observations of vegetation cover, vegetation was monitored at the peak of the growing season in August 2024. The locations of vegetation monitoring plots correspond with the sediment trap stations at 0 m, 5 m, 10 m, 50 m, and 100 m (Figures 2 and 4). In the field, 1m^2 PVC quadrats were placed 1 meter from the sediment traps (consistent distance from the traps was obtained by flipping the 1m^2-quadrat once) to avoid areas disturbed during sediment trap deployment and collection. Where necessary, the location of the vegetation plot was adjusted slightly to avoid surveying an area of marsh that was not comparable to the sediment trap (e.g., in a creek, pool, or disturbed area). Within each vegetation plot, plants were measured using ocular (or visual) estimates of percent cover by species. Where *Spartina alterniflora* was present, the height of the five tallest stems was recorded. In addition, each plot was documented by taking a labeled photo.

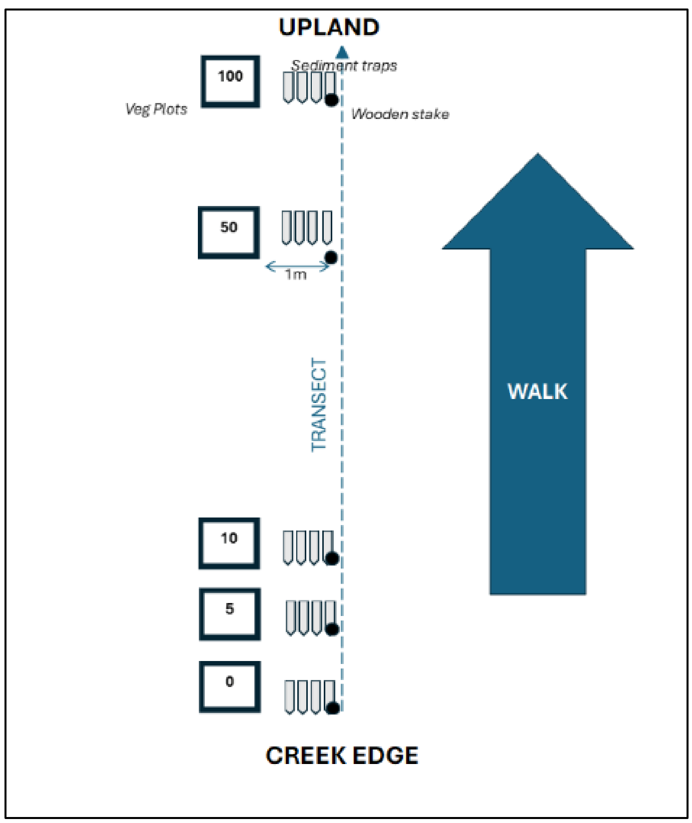

Figure 4: Schematic representation of vegetation monitoring plot and sediment trap transects.

After fieldwork was completed, the field data sheets were scanned and uploaded to a digital project folder. The data was transferred into an Excel spreadsheet where each row represents a monitoring plot, including plot identification information (plot ID, northing, easting, and RTK elevation). The data then underwent a quality assurance process to check the accuracy and correctness of the entered data. Plant percent cover and *S. alterniflora* heights were analyzed using graphing tools in Excel (i.e., bar plots and scatter plots) and spatial analysis tools in ArcGIS Pro, in conjunction with water level and available sediment data.

Elevation: In order to explore relationships between elevation, flooding, and sediment deposition on a landscape scale, a LiDAR (Light Detection and Ranging) raster was downloaded from the National Oceanic and Atmospheric Administration's online portal, the Data Access Viewer. Elevation from the LiDAR raster supplements the elevation collected in the field via RTK and allows for the observation of broader spatial patterns. The geographical extent was set to include the Chase Garden Creek salt marsh and surrounding area to ensure complete coverage of the field sites. The dataset used in this report was collected and processed by the USGS (2021 USGS LiDAR: Central Eastern Massachusetts). The point cloud data has an estimated vertical accuracy of 3.7 cm, an estimated horizontal accuracy of 11 cm, and an estimated point spacing of 0.2 m. The full metadata can be found here: https://www.fisheries.noaa.gov/inport/item/69417.

Findings

Morphology: The marsh study sections show notable differences in morphology (i.e., shape and structure). Section C is highly channelized with dense ditching, or creeks, of various sizes running throughout the marsh (Figure 5). Sections A and B are far less channelized and show higher elevation (Figure 5). A large depression is visible in Section A; field observations note that this depression is much lower than the surrounding marsh surface. Section B is highest in elevation and has the most consistent morphology from the seaward marsh edge to the upland (Figure 5).

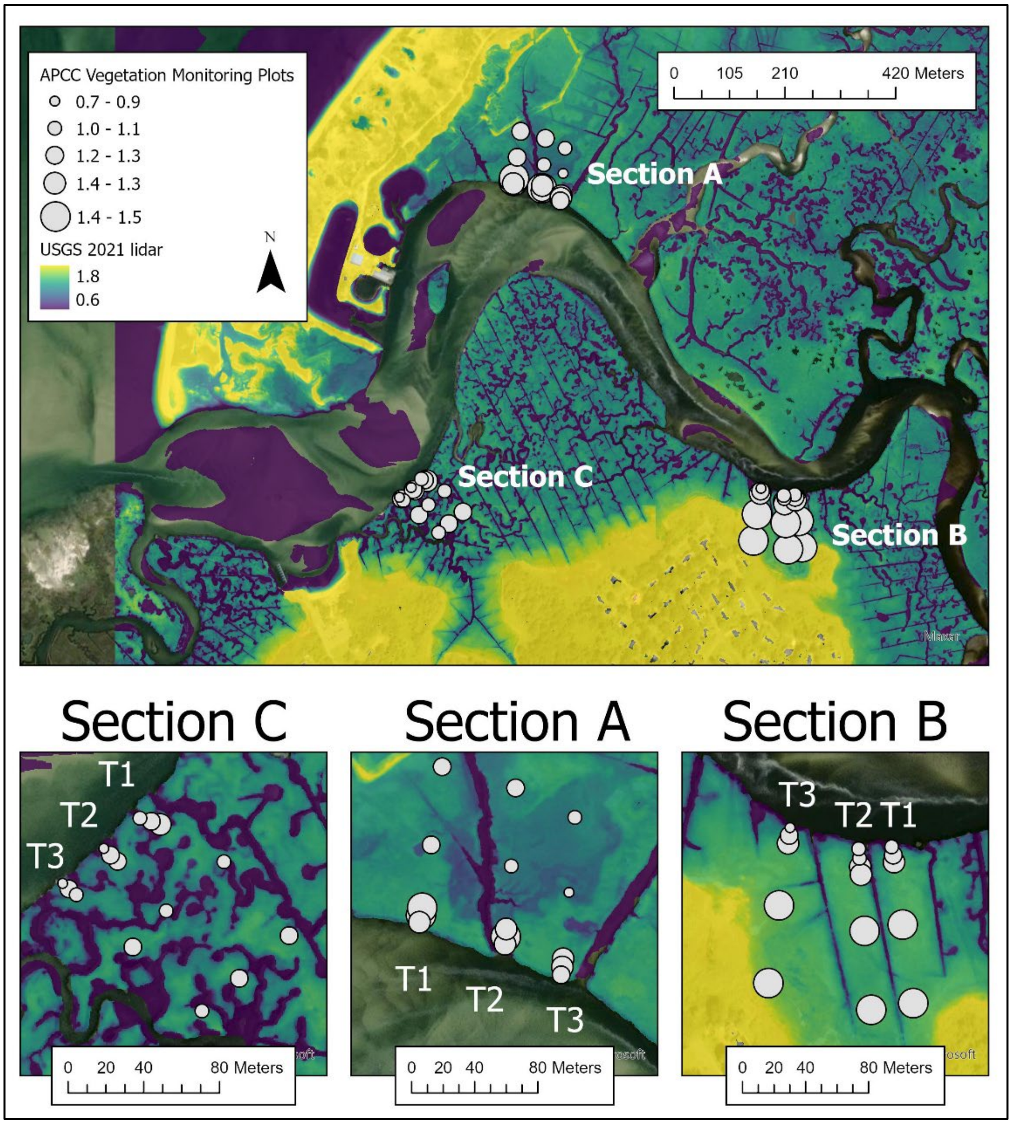

Figure 5: An overview of Chase Garden Creek elevations (USGS LiDAR raster and APCC-measured RTK points) showing differences in morphology between Sections C, A, and B.

Water Level and Salinity: The surface water level data collected from the creeks of the three study sections shows that the area closest to the inlet (Section C) has the greatest tidal range due to the lower elevation of the channel. In other words, because the main channel of Chase Garden Creek gets lower in elevation towards the inlet (a normal structure for estuarine systems), there is greater drainage and lower water levels during low tide at Section C compared to Section A and B (Figure 6). This was the only major difference in surface water level among the three sections.

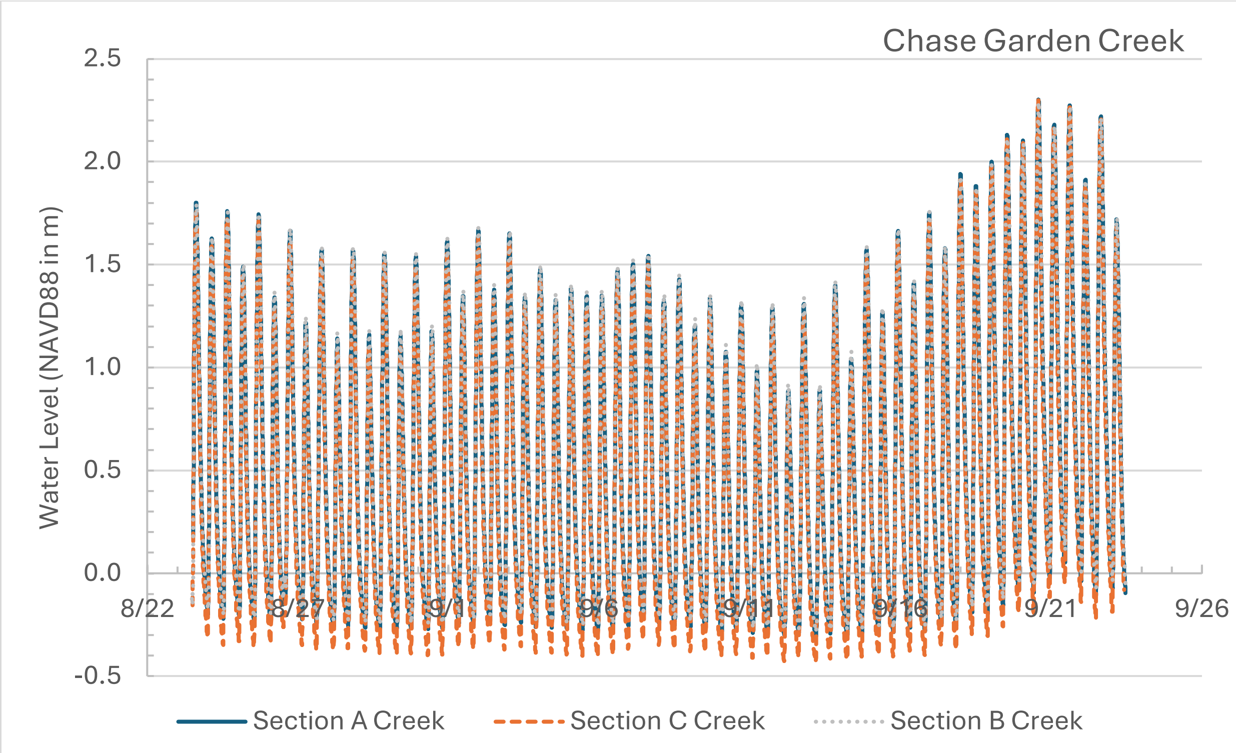

Figure 6: Water level recordings from automatic continuous data loggers deployed for one complete lunar cycle (30 days) in creeks within three study sections of Chase Garden Creek.

The salinity data from the loggers showed much more variability across the study sections than the water level data (Figure 7). The impact of the rain event on August 26th, 2024, was much more pronounced at Section C than the other two sections. Salinity ranges were high (~30 ppt), showed very little fluctuation with the tide (2-3 ppt), and were very similar across the three sections leading up to the rain event (first three days of deployment). However, after the rain event, the salinity at Section C showed greater fluctuation with each tidal cycle and the salinity was lower, on average, than the other two sites. Section B showed the greatest range in salinity within a single tide event with the fastest recovery following storm events. At Section A, the salinity rebounded quickly after the first rain event, but the rainstorm at the end of the deployment (September 19-22, 2024) had a greater impact, dropping salinities by 5-10 ppt for an extended period of time. The September storm had much higher northeastern winds with gusts over 30 mph whereas the wind during the August storm only reached 13 mph, indicating that the wind has a significant impact on salinities across the marsh system. The drop in salinities around September 10th appears to be solely due to high winds.

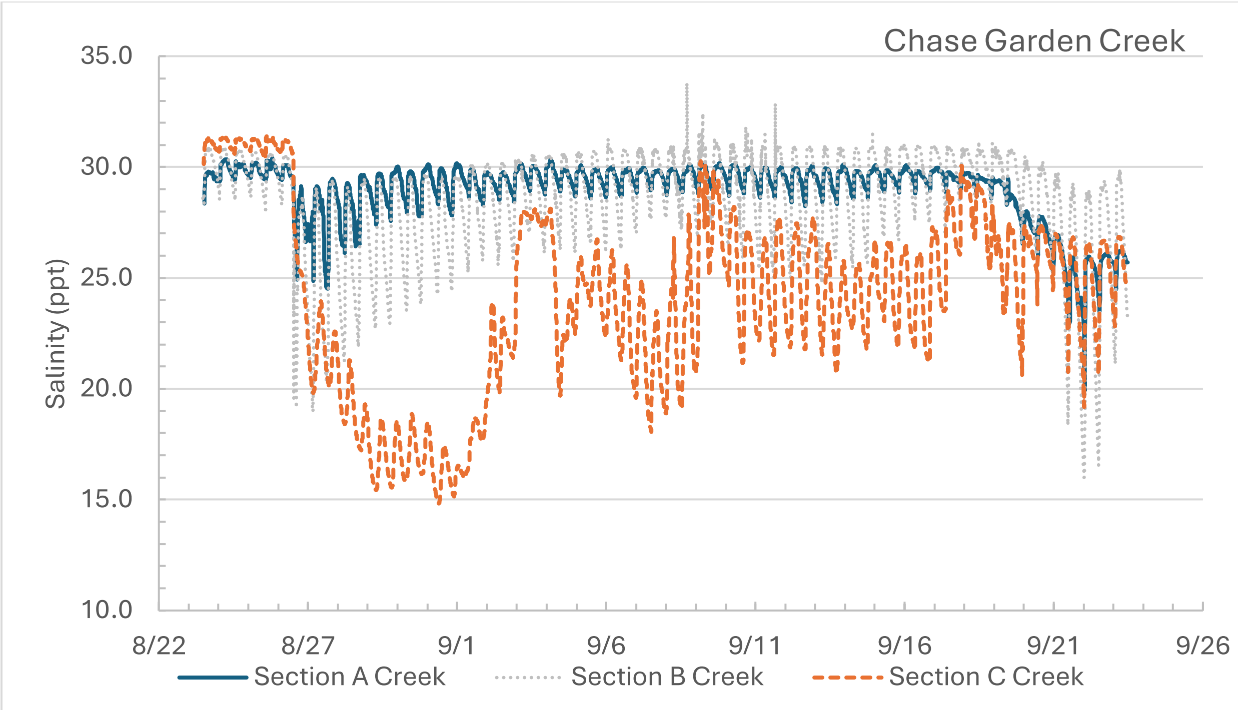

Figure 7: Salinity recordings from continuous data loggers deployed within creeks at three study sections of the Chase Garden Creek salt marsh. Note the rain event on August 26, 2024, and during the last week of deployment (September 19-22).

The groundwater level data collected at Section A and Section C showed very different drainage rates across the two areas of salt marsh (Figure 8). Section A drains much faster with a lower groundwater table depth at low tide. Groundwater depth reaches an elevation of 0.5 m (NAVD88) during spring tides. In contrast, the groundwater table at Section C rarely falls below 1.0 m (NAVD88). These data indicate that Section C stays much more waterlogged during low tides compared to Section A. This constant water saturation at Section C can stress the plants due to low oxygen in the root zone resulting in shorter growth forms and bare, or unvegetated, area.

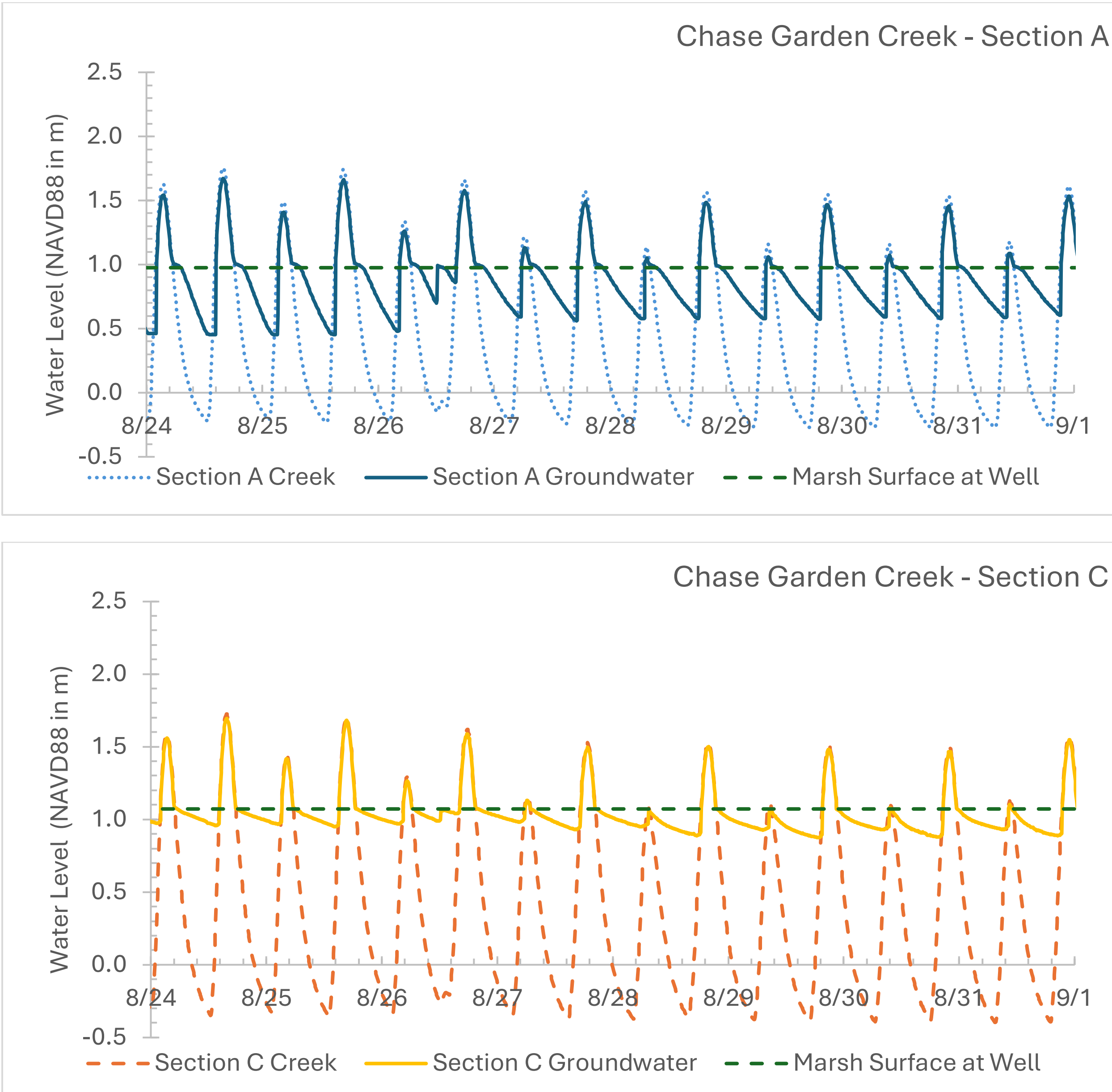

Figure 8: Groundwater level data against the surface water level data collected at Section A and Section C of the Chase Garden Creek salt marsh study areas for one week of spring tides. Note the rain event on August 26, 2024, which increased the groundwater table before the next flood tide.

Average inundation (or percent time flooded) generally decreases from the channel edge towards the upland in Sections C and B (Figures 9 and 10). The steadiest decrease in average inundation occurs in Section B, while inundation trends vary more in Section C. In Section A, the 50 m and 100 m plots in transect 3 and the 50 m plot in transect 2 are in a depression, which is likely flooded more frequently and for longer durations due to its lower elevation (Figure 9). Average inundation in Section A sharply increases at the 50 m plot, where average % time flooded rises from ~13% at the 10 m plot to ~23% at the 50 m plot (Figure 10).

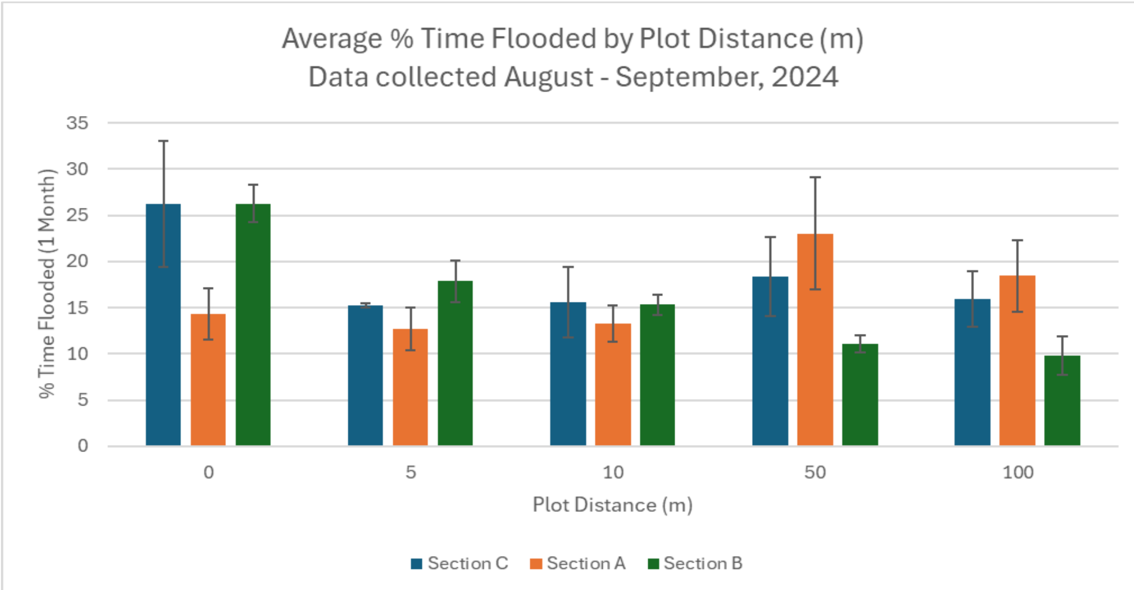

Figure 9: Average inundation (percent time flooded) in August to September 2024 at sediment and vegetation monitoring stations. Plot distance indicates distance from inundation source, or creek. Error bars represent one standard deviation of the mean.

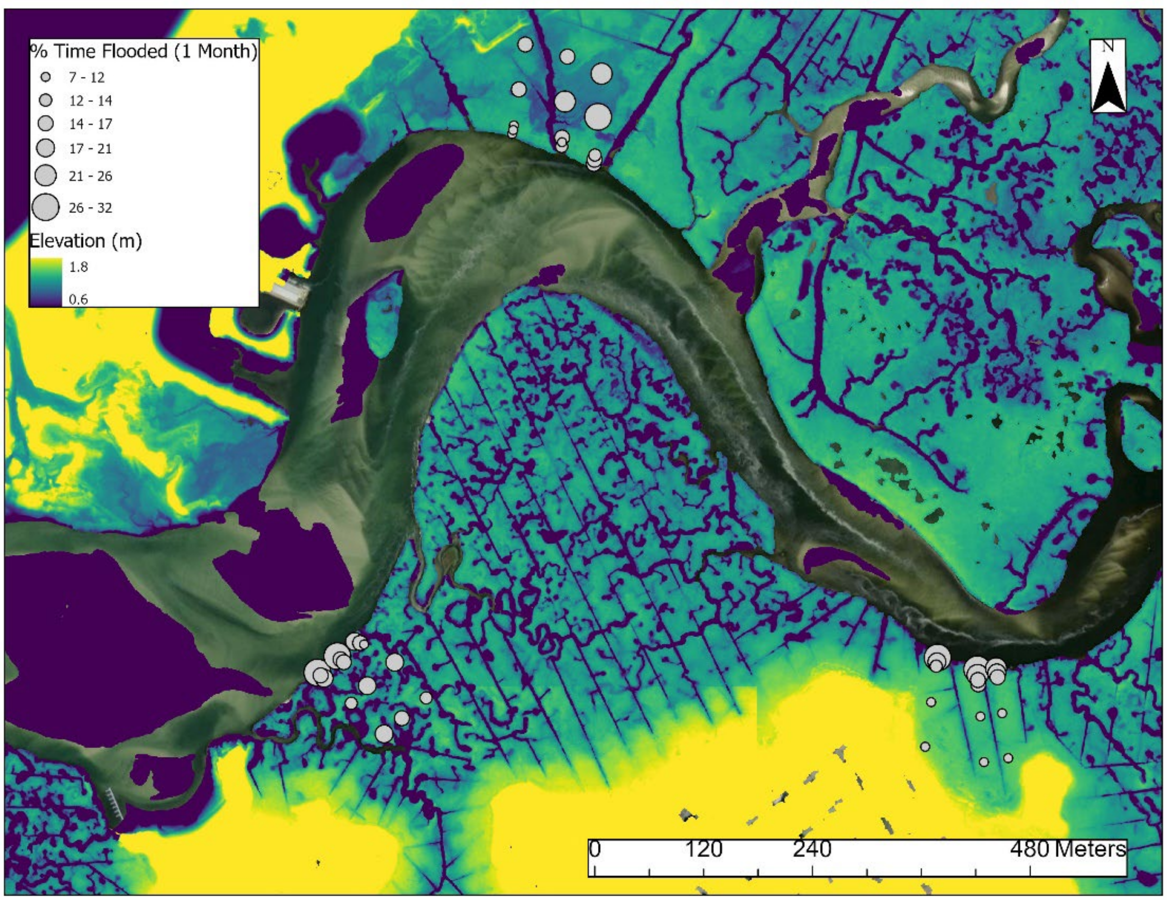

Figure 10: A map showing percent time flooded (August – September 2024) along vegetation monitoring transects represented by size (larger circles indicate greater time flooded).

Plant species richness: Species richness, or number of different plant species present, increases with distance from the Cape Cod Bay tidal channel inlet. At Section C (~650 m from the inlet), only two species were observed: *Spartina alterniflora*, a species commonly associated with low marsh environments, and *Salicornia (sp.)*, a species commonly associated with saline, shallow depressions (Figure 11a). At Section A (~850 m from the inlet), *Spartina patens*, *Distichlis spicata*, and *Limonium (sp.)* were observed in addition to *S. alterniflora* and *Salicornia (sp.)* (Figure 11b). *S. patens*, *D. spicata*, and *Limonium (sp.)* are associated with high marsh environments. Plant species richness is greatest at Section B (~1,000 m from the inlet), where groupings of plant species shows community zonation typical of low marsh, high marsh, pannes (hypersaline, shallow depressions), and upland borders (Figure 11c).

S. alterniflora and unvegetated cover: Average *S. alterniflora* cover generally increases from the channel edge to the upland in Sections C and A. In Section C, *S. alterniflora* cover increases from 0 m to 10 m and remains just above 60% at 50 m and 100 m (Figure 12a). In Section A, *S. alterniflora* cover increases from 0 m to 10 m before slightly decreasing towards the upland (Figure 12a). In Section B, *S. alterniflora* cover is greatest at 0 m and 5 m and generally decreases towards the upland, in contrast to Sections C and A (Figure 12a).

Average *S. alterniflora* stem height remains around 60-80 cm in Section C and generally decreases from 0 m to 100 m in Section B (Figure 12b). In Section A, average *S. alterniflora* stem height is just below 80 cm at 0 m, 5 m, and 10 m; average stem height sharply increases to 50 m before decreasing (but remaining relatively high) at 100 m (Figure 12b). In Section A, the 50 m and 100 m plots in transect 3 and the 50 m plot in transect 2 are in a depression (Figure 13).

The proportion of unvegetated to vegetated plot cover varies across plot distances. At Sections C, A, and B, there is no clear increase or decrease in unvegetated plot area from the channel edge to the upland (Figure 12c). The most unvegetated plots are found in Sections C and A, while plots in Section B tend to be more vegetated (Figure 12c). Plots located near channels or in a depression, as is the case in Sections C and A, are generally more unvegetated (Figure 14).

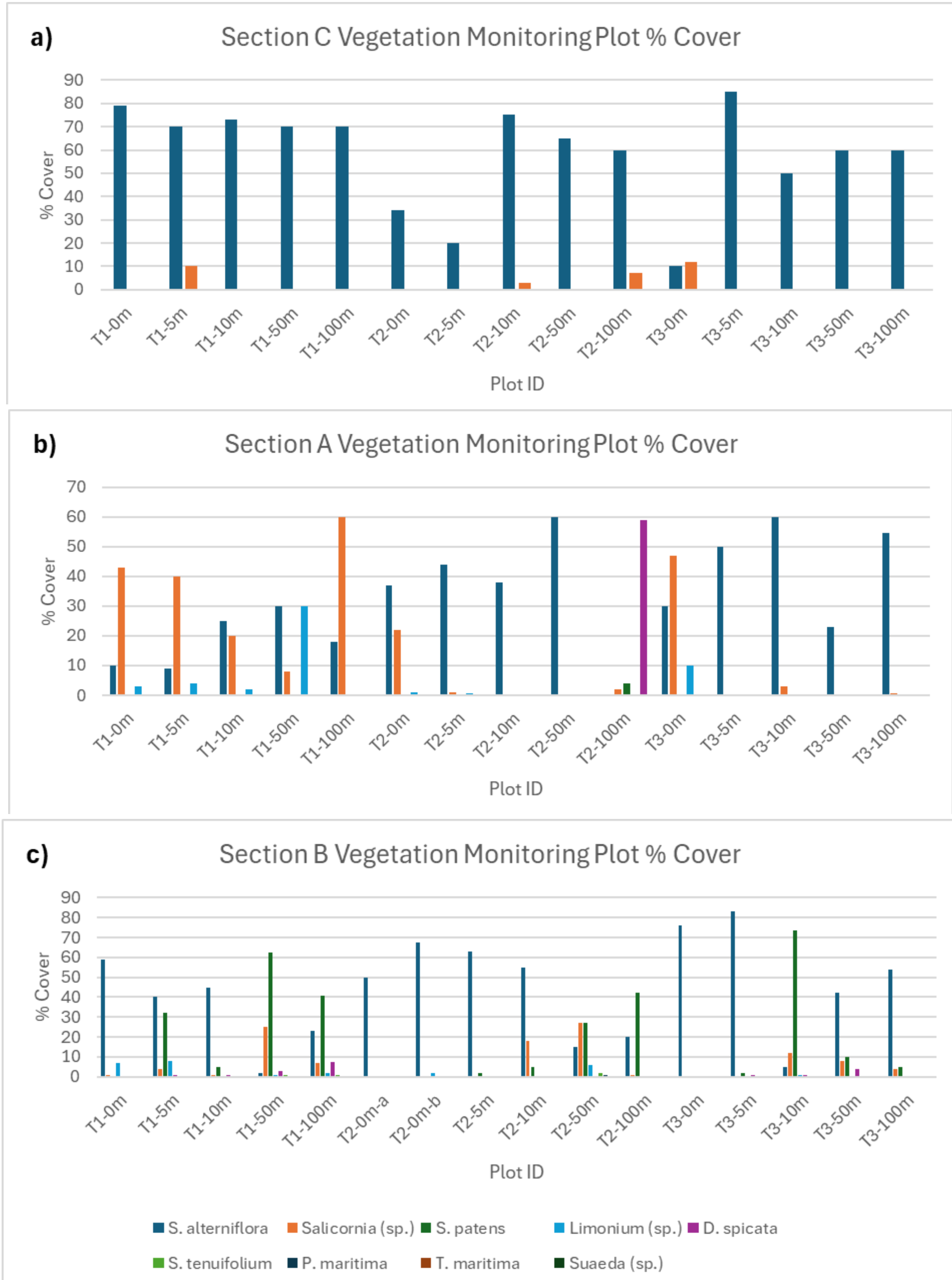

Figure 11: Percent cover of plant species observed at Sections C (panel a), A (panel b), and B (panel c).

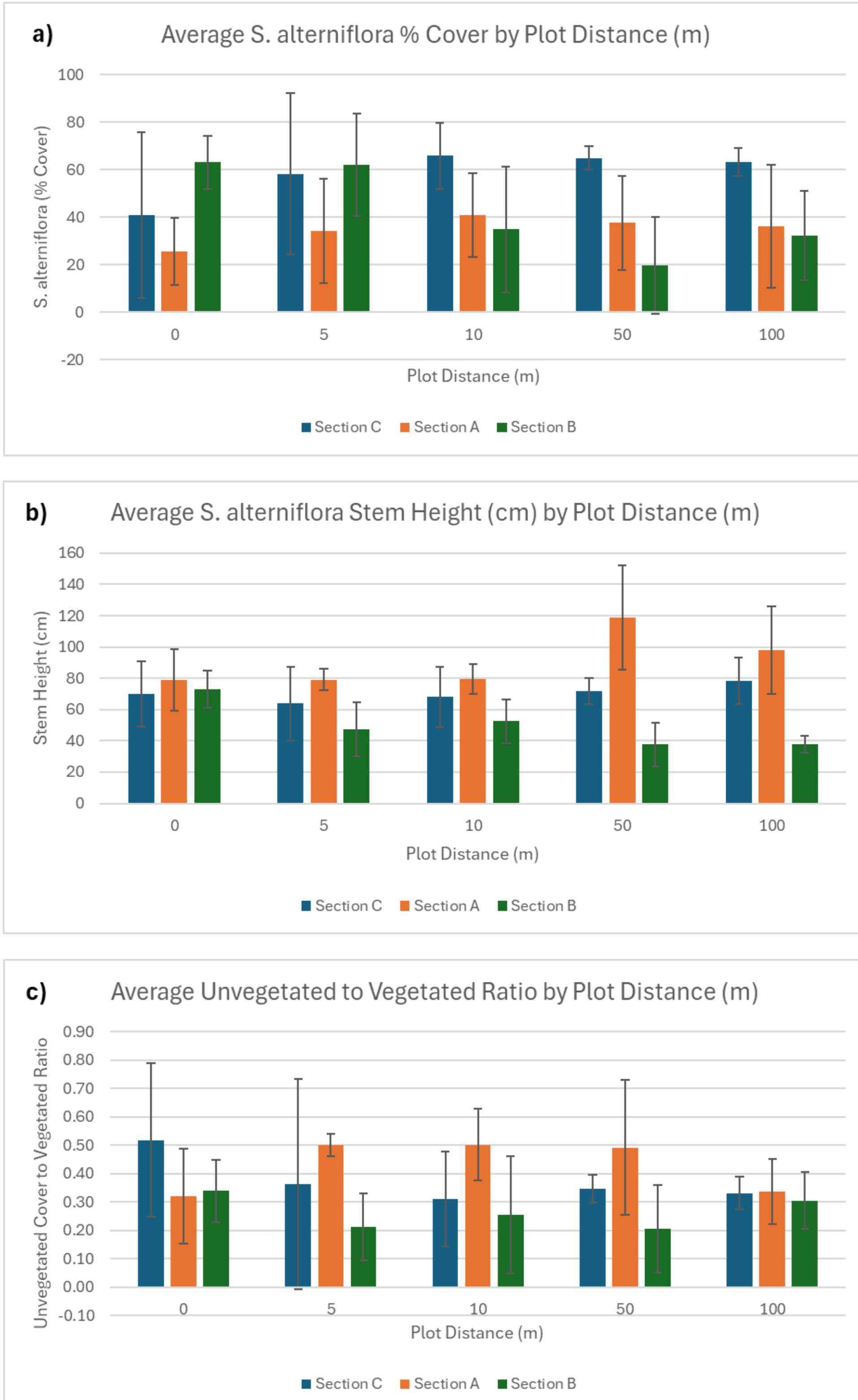

Figure 12: Average *Spartina alterniflora* cover (a), *S. alterniflora* stem heights (cm) (b), and unvegetated/vegetated cover (c) for three study sections of Chase Garden Creek salt marsh. For the unvegetated/vegetated cover, higher numbers indicate greater unvegetated area within the survey plots. Plot distance represents the distance from the creek edge or inundations source. Error bars represent one standard deviation of the mean.

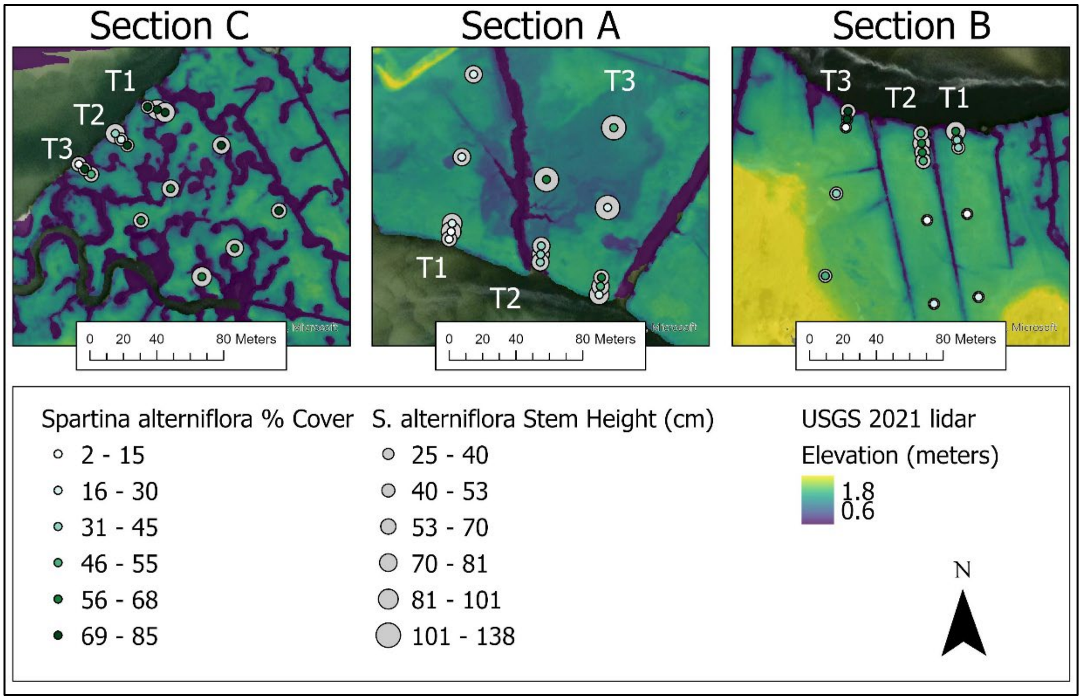

Figure 13: A map of *Spartina alterniflora* stem heights (cm) represented by size (larger circles indicate greater stem heights) and *S. alterniflora* % cover represented by color (darker green indicates greater *S. alterniflora* % cover) along vegetation monitoring transects within Chase Garden Creek salt marsh.

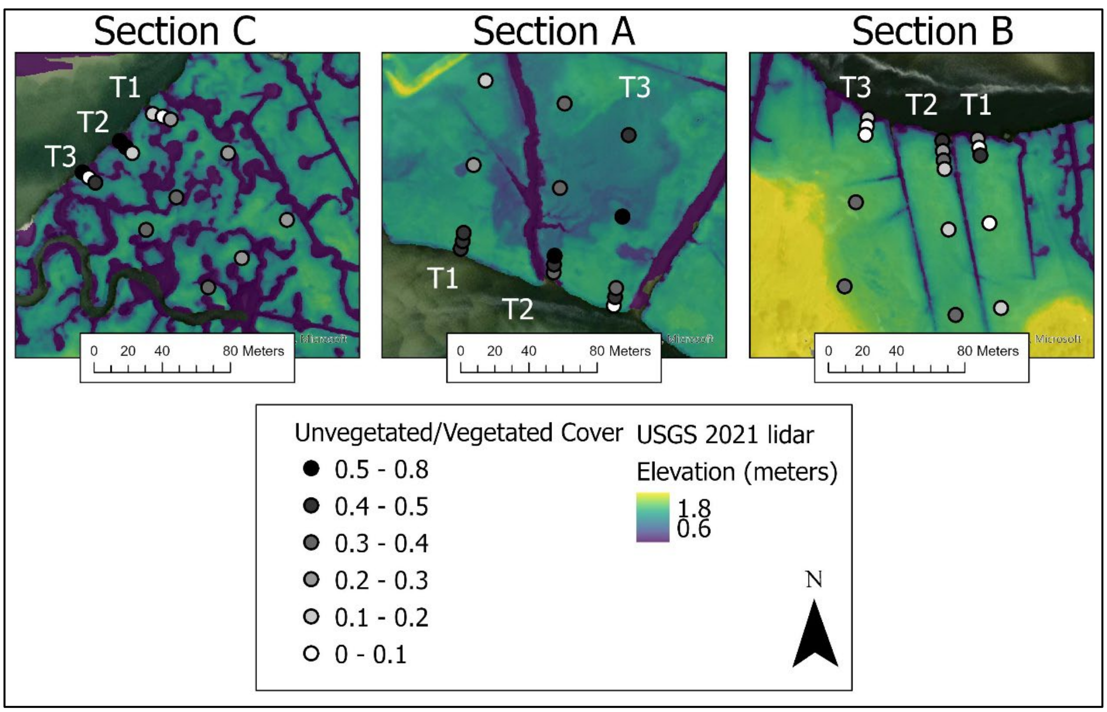

Figure 14: A map of the unvegetated/vegetated cover ratio represented by color (darker colors indicate more unvegetated area) along vegetation monitoring transects.

Sediment trap organic content and accumulation rates: Organic content and accumulation rates (g/day) measured from the sediment traps provides insights into what kinds of sediment, and how much, is being deposited on the marsh surface at Chase Garden Creek during high tides. The sediment trap data discussed here was collected in September and represents conditions during early August to mid-September. Data collected from Sections A and B was deployed from August 5th, 2024 - September 12th, 2024, and data from Section C was deployed from August 6th, 2024 – September 12th, 2024. This period of data collection was selected due to the overlap in deployment time with vegetation monitoring and water level logger deployment.

Average organic content generally increases from 0 m to 100 m in Sections C and B. This increase is most pronounced in Section B (Figure 15a). In Section A, average organic content increases from 0 m to 10 m, decreases at 50 m, and increases again at 100 m (Figure 15a). Average accumulation decreases from 0 m to 100 m in Sections C and B (Figure 15b). In Section A, the average accumulation decreases from 0 m to 10 m, increases dramatically at 50 m, then decreases (but remains relatively high) at 100 m (Figure Hb). The trend in average accumulation observed in Sections C, A, and B are opposite to the trend in average organic content (Figure 15).

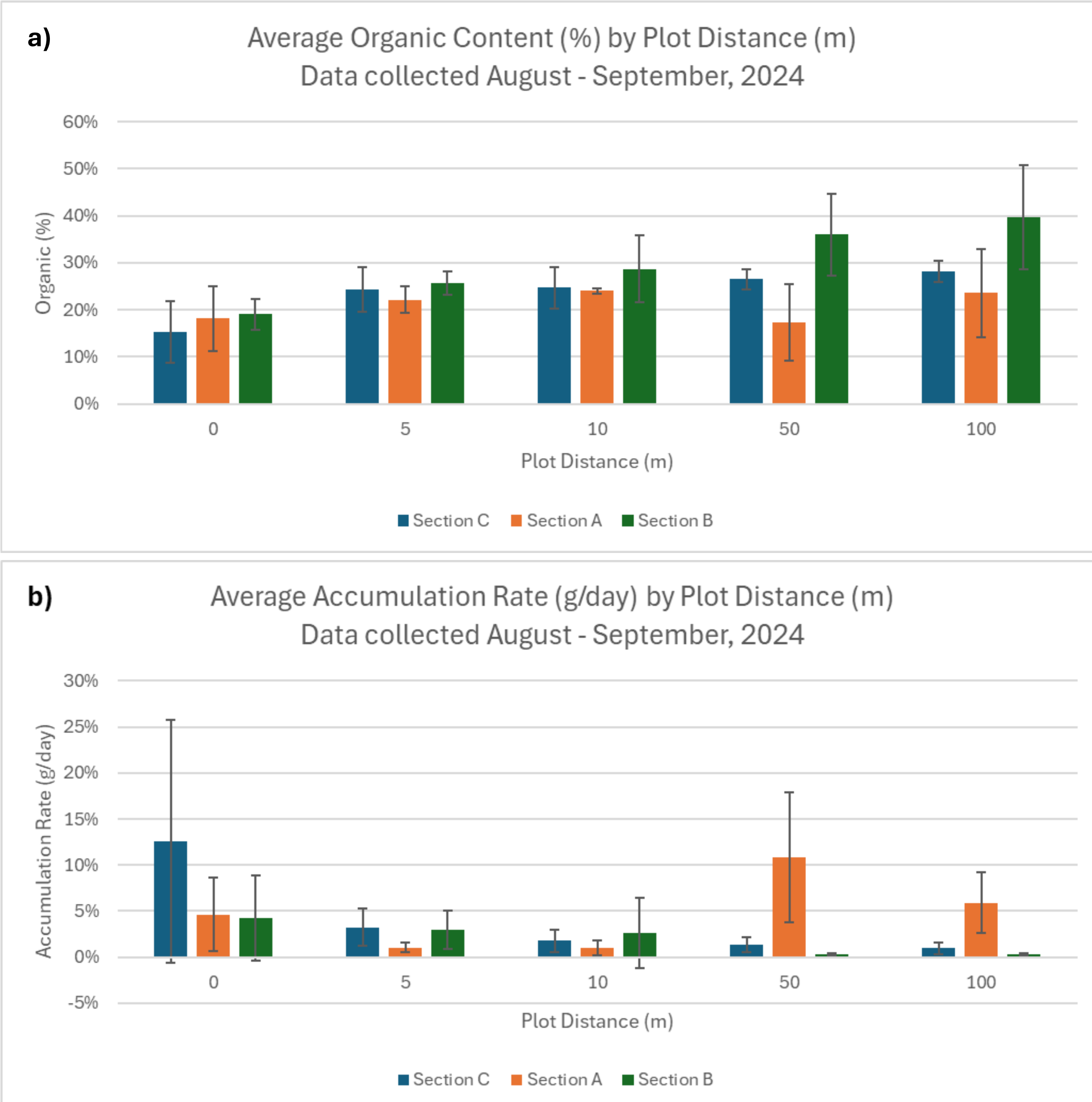

Figure 15: Average organic content (a) and accumulation rates (b) collected at monitoring stations during one month of data collection (August-September) in 2024 within three sections of the Chase Garden Creek salt marsh. Plot distance indicates distance from creek edge. Error bars represent one standard deviation of the mean.

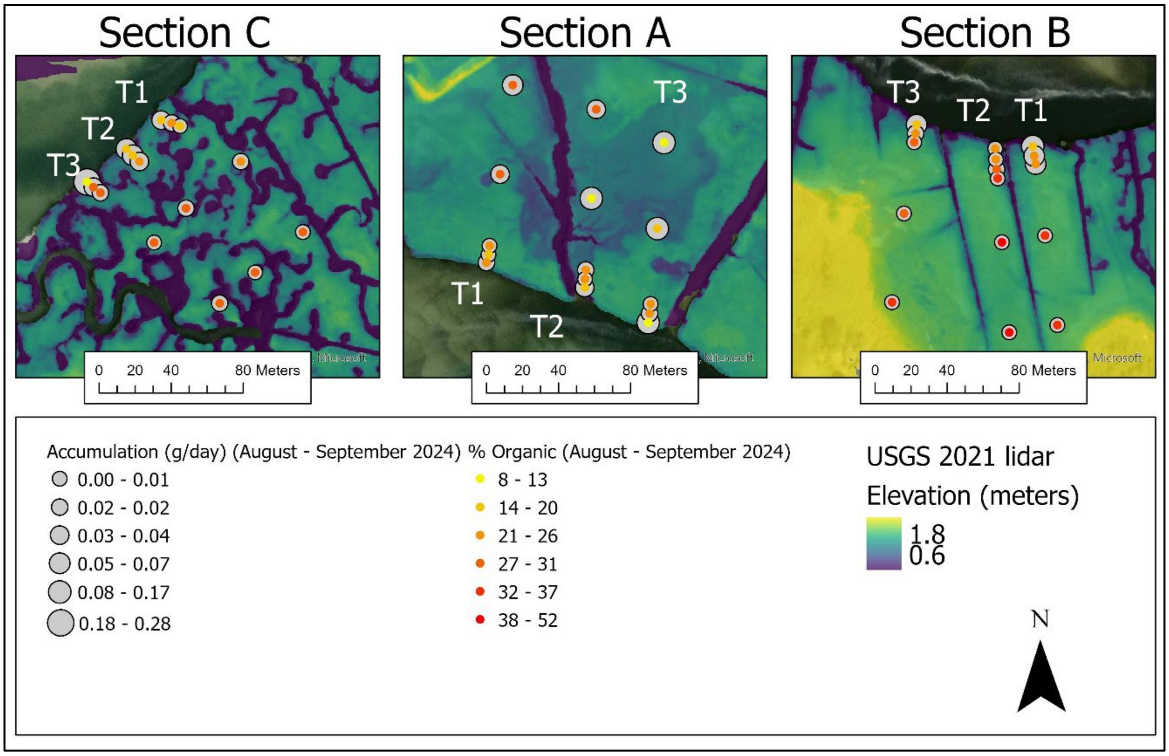

Figure 16: A map showing sediment accumulation rates represented by size (larger circles indicate greater accumulation) and organic content represented by color (darker orange/red indicates higher organic content) from one month of data collection (August-September) in 2024 within three sections of the Chase Garden Creek salt marsh.

Comparing elevation with inundation time, vegetation cover, and sediment: Inundation (% time flooded) is inversely related to elevation, i.e., as marsh surface elevation increases, the amount of time a section of marsh is inundated decreases (Figure 17a). Similarly, sediment accumulation rate seems to decrease as elevation increases (Figure 17c). In contrast, organic content has a positive correlation with elevation; where marsh surface elevation increases, the organic content of the sediment deposited in a section of marsh increases (Figure 17b). Thus, marsh surface elevation appears to be an influential factor in determining the inundation time, the composition, and amount of sediment deposited at a certain distance within the marsh. A large range in *S. alterniflora* cover exists between accumulation rates of 0 g/day and 0.05 g/day (Figure 17d). Outside of this cluster, *S. alterniflora* cover seems to decrease as accumulation rate increases (Figure 17d). Similarly, a wide range in *S. alterniflora* stem heights exists between accumulation rates of 0 g/day and 0.05 g/day (Figure 17e). Outside of this cluster, accumulation rate increases with increasing *S. alterniflora* stem height (Figure 17e).

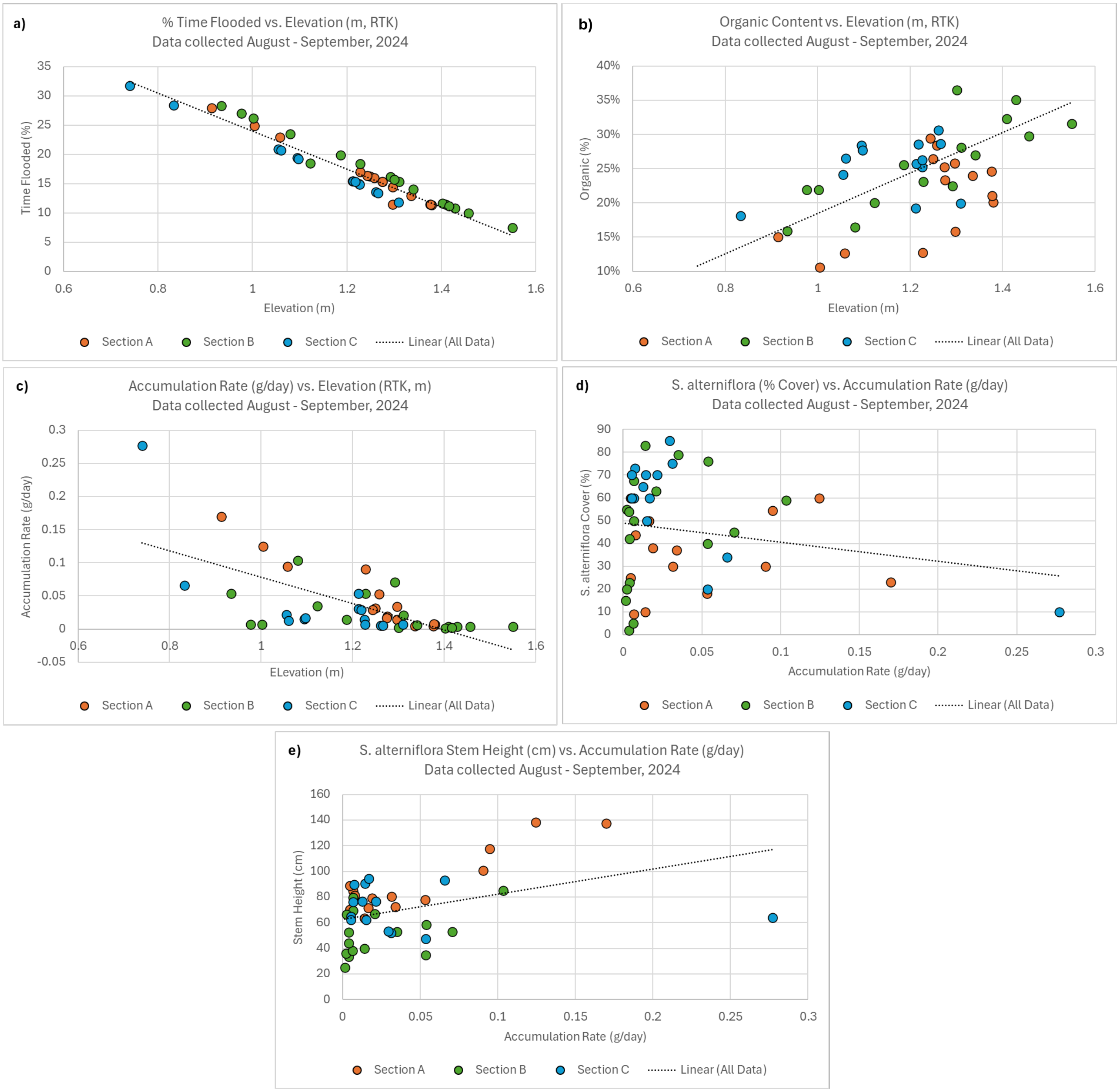

Figure 17: Scatter plots comparing marsh surface elevation (RTK, NAVD88) to inundation (% time flooded for 1 month) (a), percent organic content from sediment samples (b), and sediment accumulation (c). Figures 17d and 17e show relationships between sediment accumulation and *S. alterniflora* percent cover (d) as well as *S. alterniflora* stem height (e).

Discussion

The main research questions that APCC sought to answer with the Year 2 data collection were: How do different parts of the marsh (selected based on differing levels of vulnerability derived from the Year 1 assessment) vary in terms of flooding regime, plant community, and sediment accumulation rates? Does the growing shoal at the Chase Garden Creek inlet limit sediment supply or tidal range within the salt marsh system? The results from the Year 2 monitoring helped address both questions but also uncovered new questions which require further investigation before a restoration design can be developed for the marsh.

Water level and salinity: The water level data collected from the continuous loggers showed that the tidal range is very similar across the three study sections of the Chase Garden Creek salt marsh with Section C having the greatest range due to its proximity to the Cape Cod Bay inlet (i.e., the elevation of the creek bottom was lower than the other two creeks surveyed). These findings suggest that tidal range is not the main driver behind differences in marsh resilience among these three study sections.

However, the salinity readings from the loggers indicated more differentiation among the sites studied. Section C showed the lowest salinity levels even during high tides which indicates that freshwater (especially following rain events) is concentrating near this section of marsh. Given the deeper channel, one possibility is that freshwater pools here during the low tide diluting the saltwater on the incoming tide. In other words, following rain events, freshwater that originates from the groundwater and the headwaters of the system is held up on the inner/upstream side of the shoal. However, after a few tidal cycles, this freshwater pulse flushes out to the Cape Cod Bay and higher salinities resume near the inlet. Since the salinities never dropped below 15 ppt and were generally within 20-35 ppt (even during heavy rain events), the difference in salinity among the three marsh sections does not explain the difference in unvegetated to vegetated ratio (i.e., platform resilience) across these areas.

The other key finding from the continuous data loggers was related to the groundwater levels in Section A and Section C. Because of the lower elevation and higher ditch density, we expected to see lower groundwater tables during low tides at Section C compared to Section A. However, the opposite was true. Based on the data collected along with the plant community findings, the distinction in groundwater table and soil drainage may be one of the driving forces behind the degraded marsh integrity at Section C. Restoration activity should target reproducing the groundwater table depth seen at Section A as this produced taller *Spartina alterniflora* stems and less unvegetated cover. However, more groundwater wells should be deployed in all three sections of the marsh to confirm that the trends seen in 2024 are representative of the entire marsh area and not confined to the local conditions of the individual groundwater well placement.

Elevation: Although there was no significant difference among the tidal range of the three sections, the inundation (or percent time flooded during logger deployment), showed a measurable difference in how long the various parts of the marsh are underwater. The inundation time was inversely related to elevation such that lower marsh platforms or depressions were flooded for longer periods of time. Where the marsh plants are flooded for extended periods, these areas also tend to show greater unvegetated area and shorter stem heights caused by the added stress on the plants. Figure 5 shows how the three different sections varied in regard to elevation. Section C had the lowest elevation (on average), Section B had the highest elevation, and Section A had high elevation at the creek edge but lower elevation at longer distances from the creek edge. These findings suggest that Section C has experienced subsidence over time, but more information is needed to fully understand why the elevation at Section C is so reduced.

Plant community: The findings from the plant composition surveys corroborate the vulnerability assessment results from Year 1. Sections A and B contain much higher quality salt marsh habitat than Section C as seen by the increased species richness (especially in the higher elevations of Section B), taller stem heights at Section A, and greater vegetated cover. The sediment deposition also shows a weak but positive correlation with stem height which may be one of the contributing factors to why Section A showed greater revegetation between 2016 and 2021. The high stem heights in Section A might also explain the high sediment accumulation rates at plots located 50 and 100 meters from the creek edge in Transects 2 and 3.

Sediment dynamics: This report limited the analysis to sediment trap measurements collected between August and September because this set of data aligns most closely with the water level and plant data collected during the same time period. Although the sediment data analysis presented here was narrowly focused for this reason, there were a few key relationships worth noting. The first takeaway is that the *shoal does not appear to limit sediment supply* to the salt marsh, and in fact, it likely does the opposite by providing a large sediment source to the overall Chase Garden Creek system. Coarser grains of sand appear to accumulate on the edge of the marsh creek whereas finer, siltier sediments accumulate in the higher elevations of the marsh. Based on these findings, our assumption is that the sandier material is provided by the shoal, and the finer particles are derived from resuspension of decaying organic material in the marsh.

The second major takeaway from the sediment data analysis is that the strongest correlations among the marsh monitoring metrics included inundation, elevation, and sediment accumulation. In other words, the greatest factor in determining sediment accumulation was the elevation of the marsh surface. Where the marsh elevation was low the period of inundation was high, leading to the highest rates of sediment accumulation. Since Section C contains lower average elevation and showed comparable sediment accumulation as the other two sections, variation in sediment deposition does not drive the differences in marsh resiliency across the marsh sections.

Overall conclusions: Based on the monitoring data collected in 2024, we can eliminate the following from the list of possible contributing factors to the range of vulnerability seen at Chase Garden Creek salt marsh: tidal range, salinity, and sediment supply. The conditions that may explain the variation in habitat quality across the marsh include groundwater depth (or soil drainage) at low tide, elevation (including subsidence), and density of ditches. To further investigate the remaining factors that could be driving changes in the Chase Garden Creek salt marsh, APCC has proposed additional monitoring for Year 3 (2025) listed in the following section of this report. By pursuing these outstanding components, we can more effectively tailor future actions to restore or rebuild marsh integrity to improve the marsh's resilience to future sea level rise.

Year 3 Plan

Community Engagement: APCC is committed to maintaining community engagement through outreach opportunities over all five years of the Chase Garden Creek project. APCC will be presenting findings from the Year 2 study as part of collaborative restoration working group, referred to as the Cape and Islands Restoration Action Team, and at Mass Audubon's Cape Cod Natural History Conference in March 2025. Additionally, APCC is planning a second stakeholder meeting in summer or fall 2025 to update neighboring residents and other interested parties with information from Year 2 and Year 3 data collection.

Additional Field Monitoring: APCC proposes continued monitoring and data collection at the Chase Garden Creek salt marsh during Spring and Summer 2025. This data will supplement the baseline observations collected during Spring and Summer 2024 and inform future restoration techniques. Listed here are some data collection tasks APCC proposes completing at Chase Garden Creek:

1) ***Sediment cores:*** APCC proposes collecting several sediment cores from Sections C, A, and B. The locations of these cores are to be determined but will likely correspond to established vegetation monitoring plots and sediment trap sites. The method of gouge sediment coring allows for the collection of approximately 1 meter of sediment from below the marsh surface. Sediment cores allow us to measure long-term vertical accretion rates (the rate of change in marsh elevation), measure changes in sediment composition (i.e., organic content, grain size, and bulk density), and estimate the extent of past marsh zones (i.e., how the distribution of low marsh and high marsh area has changed) at particular locations in the marsh.
2) ***Surface sediment samples:*** In addition to several ~1-meter-long sediment cores, APCC proposes collecting surface samples (approximately 10 cm of sediment from below the marsh surface) from Sections C, A, and B. The locations of these surface samples will also

correspond to established vegetation monitoring plots and sediment trap sites. The benefit of collecting surface samples in addition to 1-meter-long sediment cores is the ability to sample more sections with less time and effort. The surface samples will allow us to measure organic content, bulk density, and grain size across a broader area of salt marsh. This data can be used to place the results from sediment cores in the larger context of the Chase Garden Creek salt marsh.

3) Water level: APCC proposes collecting additional surface water and groundwater levels. The data presented here represents 1 month of logging (August 23, 2024 – September 23, 2024) during late Summer 2024. Collecting additional periods of surface water and groundwater levels will provide more information about the tidal regime at Chase Garden Creek and allow for comparisons between months. The locations of the water level loggers are to be determined but will likely be deployed at the same stations used during Summer 2024.