Barnegat Bay Submerged Aquatic Vegetation Monitoring Program

2021 Final Report

Dr. Elizabeth A. Lacey
Elizabeth.Lacey@stockton.edu
Stockton University
School of Natural Science and Mathematics
101 Vera King Farris Drive
Galloway, New Jersey 08205

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SUMMARY

The objective of this monitoring program is to provide ongoing quantitative measures on the health of the primary indicator submerged aquatic vegetation (SAV), which provides water quality enhancement, shoreline stabilization and habitat provisioning for economically and ecologically important fish and invertebrates. Barnegat Bay has experienced a decline in *Zostera marina* habitat over the past 15 years and based on results from this study, has yet to experience a significant recovery. The northern region continues to be dominated by *Ruppia maritima* and the southern region by *Zostera.* Trends in *Zostera* indicate an overall decline in percent cover and an increase in aboveground biomass, most likely due to an increase in leaf number or etiolation but not shoot density. Trends in *Ruppia* were less consistent with northernmost sites declining percent cover and either increasing or remaining relatively the same in biomass. While epiphytic cover and macroalgae biomass do give insights into environmental conditions, there are no direct models relating these parameters to seagrass health, which is the primary objective of this monitoring program. Therefore, it is suggested these parameters no longer be measured quantitatively. Continued monitoring is suggested for parameters indicative and important for SAV health (percent cover and biomass) to elucidate trends and it is suggested that monitoring be conducted yearly to capture the stochastic nature of SAV growth more fully. Future work is scheduled for the 2022 and 2023 growing season to determine the strength of the competitive interactions between *Ruppia* and *Zostera* and if *Ruppia* can provide equivalent habitat and ecosystem services as *Zostera*. Linkages between these basal primary producers and upper trophic levels is well documented and the future state of Barnegat Bay fauna will be determined by the resilience of this vegetation in the face of those stressors it faces.

PROJECT DESCRIPTION

Seagrass beds provide a diverse suite of services which increase the diversity and productivity of coastal ecosystems (Larkum et al., 2006; Moore, 2009). Seagrasses are also considered indicators of ecosystem decline (Orth et al., 2006; Burkholder et al., 2007) and recent losses of this essential fish habitat have been attributed to degradation of water quality. Since 2004, there has been a well-documented decline in *Zostera marina* within Barnegat Bay due to eutrophication (Kennish et al. 2008, 2010, 2012; Fertig et al., 2013). Aboveground and belowground biomass decreased by 50-88% over the 2004-2006 period (Kennish et al. 2007b, 2008, 2010) and results subsequent to 2006 indicated continued decline, with 2009 having the lowest seagrass biomass values recorded in the estuary since comprehensive in situ sampling of seagrass beds commenced in 2004. While efforts have been made to decrease nutrient loading in Barnegat Bay (e.g., Governor's 10-point Barnegat Bay Action Plan), monitoring these important SAV ecosystems after management strategies are implemented is necessary to assess the efficacy of these strategies and adapt them, as necessary. Monitoring information, including those abiotic and biotic parameters indicative of SAV health, are necessary to more accurately predict future trends in SAV bed coverage and therefore their contributions to ecosystem functioning.

The objective of this program was to provide ongoing quantitative measures on the health of the primary indicators, submerged aquatic vegetation, at multiple sites throughout northern, central and southern Barnegat Bay. These quantitative parameters included above and belowground biomass, canopy complexity, microalgal (or epiphytic) cover, and macroalgal biomass. Results from this survey were compared to previous survey results from 2004-2019 in order to evaluate the status and trends of submerged aquatic vegetation within the Barnegat Bay estuary.

METHODOLOGY

Site Information

Sampling was conducted at the same nine sites as were sampled in 2015 and taken from a previously established set of 15 studied by Kennish et al. from 2004 – 2011 within Barnegat Bay

(Kennish et al. 2013; Figure 1, Table 1). The subset of sites selected span the salinity, temperature, and nutrient gradients known to exist in Barnegat Bay, as well as represent the major submerged aquatic vegetation habitat (*Ruppia maritima* and *Zostera marina*) found in the northern, central and southern sections of the estuary. Sampling was completed in June and October of 2021 to document annual and inter-annual changes in submerged aquatic vegetation demographics.

Biomass

To collect aboveground and belowground submerged aquatic vegetation biomass, ten 11 cm diameter cores were taken within 50 m of the original site coordinates at each site, using those GPS coordinates provided by Kennish et al. (2013). Each core was sieved through 1.0 cm mesh and washed clean of sediment before transport back to the Stockton Marine Field Station for continued processing. Vegetation was first separated by species and leaves separated from rhizomes and root hairs. Samples were dried in an air circulating oven at 50°C for a minimum of 24 hours before aboveground and belowground biomass was recorded as grams dry weight (DW) per m^{-2}. Macroalgal biomass was collected from ten haphazardly placed 0.25 m^2 quadrats within a 50 m radius at each sampling site. Samples were separated by macroalgal functional group and placed in an air circulating oven at 50°C to dry for a minimum of 24 hours before biomass of each identified genus was recorded as grams dry weight (g DW) per m^{-2} (Sidik et al., 2001).

Habitat Visual Census

To determine areal coverage of each benthic cover (*Zostera marina*, *Ruppia maritima*, macroalgae, other) a visual census was completed using a m^2 quadrat haphazardly placed within a 50 m radius at each sampling site (n = 10). The percent cover of seagrass, macroalgae, or other was estimated in situ by a diver using a scale of 0 to 100 in increments of 5.

Epiphytic Load

To determine epiphyte load, 15 individual *Z. marina* shoots were haphazardly collected within a 50 m radius at each sampling site. Each shoot was separated into individual blades, blade number, length, and width recorded, and epiphytes removed from both sides of each blade via razor blade held 90° to the leaf surface. All samples were placed in an air circulating oven at 50°C for a minimum of 24 hours and weighed to calculate biomass as g dry weight (g DW) per m^{-2} (Kendrick and Lavery, 2001).

Statistical Analyses

To address seagrass trends in Barnegat Bay, all biomass and percent cover data were tested for normality and variance. With all non-normal data, nonparametric Mood's Median or Kruskal Wallis tests with Dunn two-tailed post hoc were run to test for significant differences at one site across all biennial sampling years (2015, 2017, 2019, and 2021). Time series analysis was run to determine overall trends in percent cover of both *Ruppia* and *Zostera*.

RESULTS

All monitoring sites were 1-2 m in depth along a gradient of decreasing salinity BB 01 to BB 15. At those sites with lower salinities, mainly *Ruppia maritima* was present while sites with higher salinities had only *Zostera marina*. Overall percent cover of both species has declined from 2015 to 2021 (Figure 2 & 3).

Zostera sites

At those sites containing a higher percentage of *Zostera* over *Ruppia* (01, 03, 06, 08), percent cover by *Zostera* in June ranged from 10-80% and in October ranged from 10-30%. A seasonal decline in *Zostera* occurred at Site 03 & 08 and an increase occurred at Site 06, overall providing stable percent cover of *Zostera marina* through the season (29%, average of spring and fall at all four *Zostera* sites; Figure 4a). Trend analyses of *Zostera* percent cover at each site indicated overall declines at sites 01, 03, and 06 (Figure 5). While site 08 trend analysis indicated a recovery (Figure 5d), percent cover in 2021 was significantly lower than 2015. At these four sites, *Ruppia* cover was 0% for both sampling events (Figure 4b). Percent cover of macroalgae was high in Spring at these sites, ranging from 10-60% and overall decreasing significantly at most sites with season (Figure 4c). For *Zostera*, overall mean aboveground biomass was high in the southern region (BB 01, 03, 06 and 08), with a maximum over 640 g dry weight/m^2 at Site 08 (Figure 6a). In the Fall, a significant reduction in aboveground biomass occurred at all sites as did a decrease in belowground biomass.

Ruppia sites

In the regions categorized as *Ruppia*-dominated habitat for the previous studies (13, 14, 15), *Zostera* was absent with the exception of Site 15, where *Zostera* was only present in the spring (Figure 4a). Over the survey period percent cover of *Ruppia* in June ranged from 28 -40% and in October ranged from to 17 - 26% (Figure 4b). The majority of sites experienced a seasonal decline, with an average 19% *Ruppia* cover across all seasons at all three *Ruppia* sites. Trend analyses of *Ruppia* percent cover indicated overall declines at all three sites (Figure 7). Macroalgae was not present at the three *Ruppia*-dominated sites (Figure 4c). For *Ruppia*, the mean aboveground biomass for all three sites in both seasons averaged 27g DW/m^2 (Figure 6b). Seasonally, only site 14 experienced a significant change as biomass increased through the growing season. Belowground biomass trends were not consistent with some sites experiencing an increase in belowground biomass (14 and 15) while others did not significantly change (13).

Transitional Sites

At BB 10 & 12, the two sites classified as transitional between *Zostera* and *Ruppia* during the 2015, 2017, and 2019 surveys, *Zostera* percent cover did not significantly change over the season (12% averaged across both sites all season; Figure 4a) while *Ruppia* significantly increased from Spring (17%) to Fall (48%; Figure 4b). Trend analyses indicated a decline in *Zostera* at both sites while *Ruppia* declined at site 12 and appears to be recovering at site 10, although there was no significant difference between percent cover 2015 to 2021 (Figure 8 & 9). For aboveground biomass, *Ruppia* significantly increased seasonally while *Zostera* biomass decreased seasonally (Figure 6). *Zostera* belowground biomass decreased significantly from Spring to Fall at site 10 and did not significantly change at site 12. *Ruppia* belowground biomass significantly increased at both sites.

CONCLUSIONS

Barnegat Bay experienced a noticeable decline in underwater vegetated habitat over the past 15 years and has yet to experience a recovery (Figure 10; Kennish et al. 2008, 2010, 2012; Fertig et al., 2013). Overall trends in *Zostera* percent cover do indicate a decrease in spatial footprint while increases in *Zostera* biomass may indicate an investment by the plant in new leaves or etiolation and not new shoots (Ralph et al., 2007), which would have increased percent cover. Various factors (anthropogenic and natural) can be attributed to the heterogenous decline across the Bay (Kennish et al. 2008, 2010, 2012; Fertig et al., 2013) and can also be attributed to the changing species compositions within the bay. While the central region was previously considered a transitional area, overall trends indicate declines in both *Z. marina* and *R. maritima.*

Overall, *Ruppia* aboveground biomass was low for all sites, but similar to previously reported biomass in the region (Kennish 2011). Previous studies (Lacey, 2015, 2017, 2019) identified both sites BB 10 and 12 as transitional areas but trend analyses indicated an overall decline in both species, indicating this transition may not be permanent. Because of the boom-bust growth patterns in *Ruppia*, biennial sampling may not be frequent enough to capture and track these trends. As part of a yearly monitoring program at Stockton University, a comparison of trend analyses between yearly and biennially at one site in Barnegat Bay indicated that while biennial sampling captured overall *Zostera* trends adequately (Figure 11a, 11b), *Ruppia* trends were more accurately captured with yearly sampling (Figure 11c, 11d). For this reason, an increase in sampling frequency is recommended. The stability of any shift is unknown and can only be elucidated through continued studies, particularly on the dynamics between these two species as they interact within the Barnegat Bay environment in comparison to other studied locations. Implications of this species shift on habitat provisioning, shoreline buffering, water quality improvement and other ecosystem services have also yet to be determined but warrant further research.

As further studies focus on the services provided by the submerged aquatic vegetation, additional studies on the role of macroalgae and epiphytic microalgae on seagrass health are necessary. No models exist which relate macroalgae biomass and epiphytic coverage to seagrass health. While recording qualitatively the presence or absence of either parameter may provide some details, it is suggested that further quantitative assessment cease. Altering the sampling strategy to maintain biomass and percent cover records is more directly in line with the goals of a monitoring program as these are the parameters that can be predictive of seagrass declines rather than parameters of algae. While studies suggest that in some natural and bare areas, drift macroalgae can form alternative habitats which support important, diverse invertebrate communities (Hernandez Cordero and Seitz 2014; Hernandez Cordero *et al.* 2012), monitoring only macroalgal biomass does not provide information on this potential habitat. Future research efforts should experimentally manipulate densities of drift macroalgae in conjunction with parameters important to seagrass health (e.g, growth rate).

Throughout Barnegat Bay, results from this and previous studies indicate that seagrass distribution continues to be patchy within the Bay and no significant recovery has occurred in any region. While some regions have maintained consistent coverage by SAV, it is unclear the extent of coverage with limited funding for monitoring and no current funding for mapping current distributions. Continued monitoring in conjunction with regular mapping is necessary to track any potential recovery and the impact of any returning, favorable water conditions. Current water quality monitoring is limited and when considering temperature, a major factor impacting SAV growth, trends vary per region (Figure 12). Efforts should be made to expand the monitoring program to include additional stations for both water quality and seagrass health, particularly within transitional areas, and increase seagrass sampling frequency to yearly to detect trends in the more stochastic *Ruppia maritima* population. Linkages between these basal primary producers and upper trophic levels is well documented and the future state of Barnegat Bay fauna, including recreationally and commercially important fish and invertebrate species, will be determined by the resilience of this vegetation in the face of changing water quality parameters.

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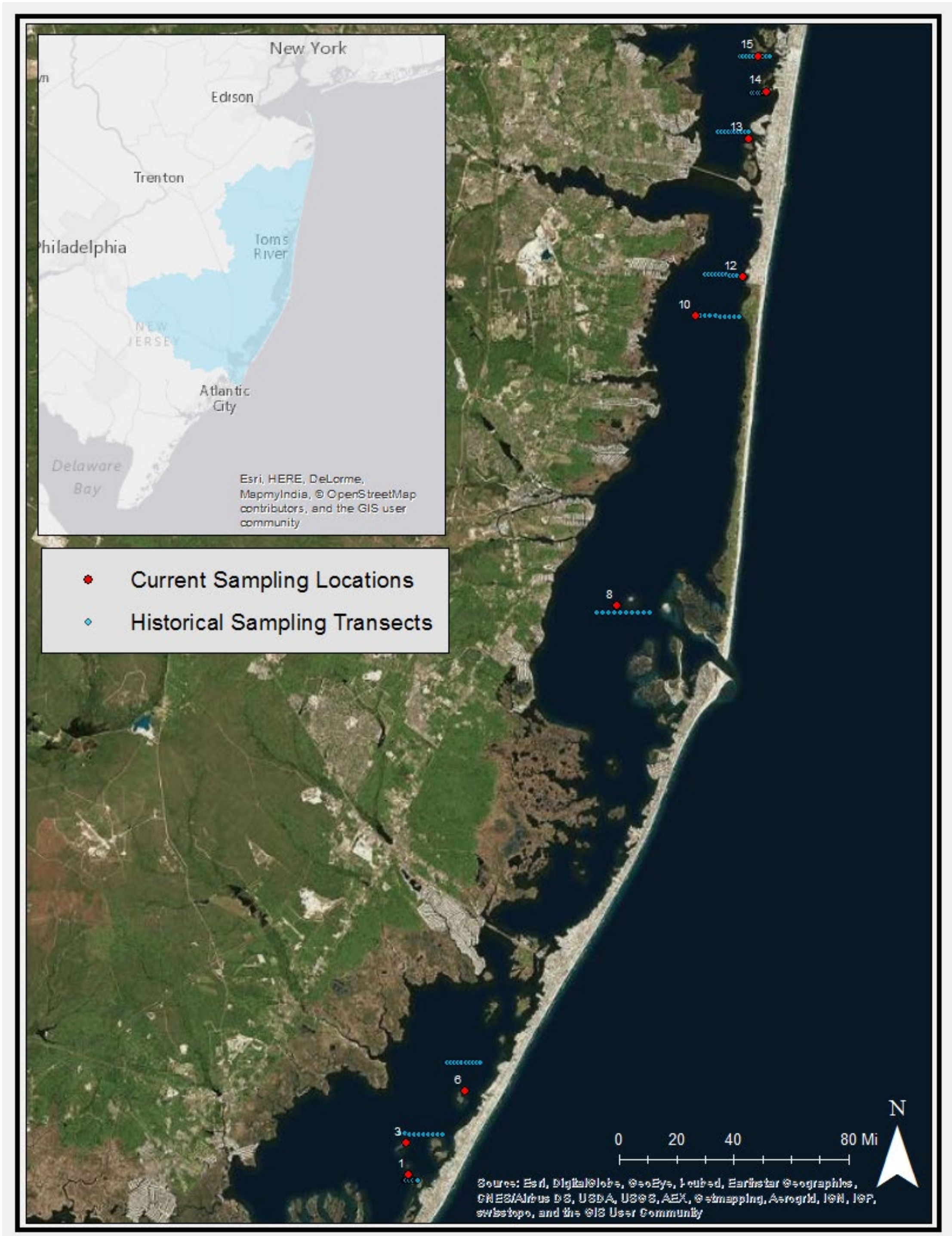


Figure 1. Barnegat Bay-Little Egg Harbor Estuary showing previously established transects (blue dots from Kennish et al 2013) and current sampling locations (red dots).

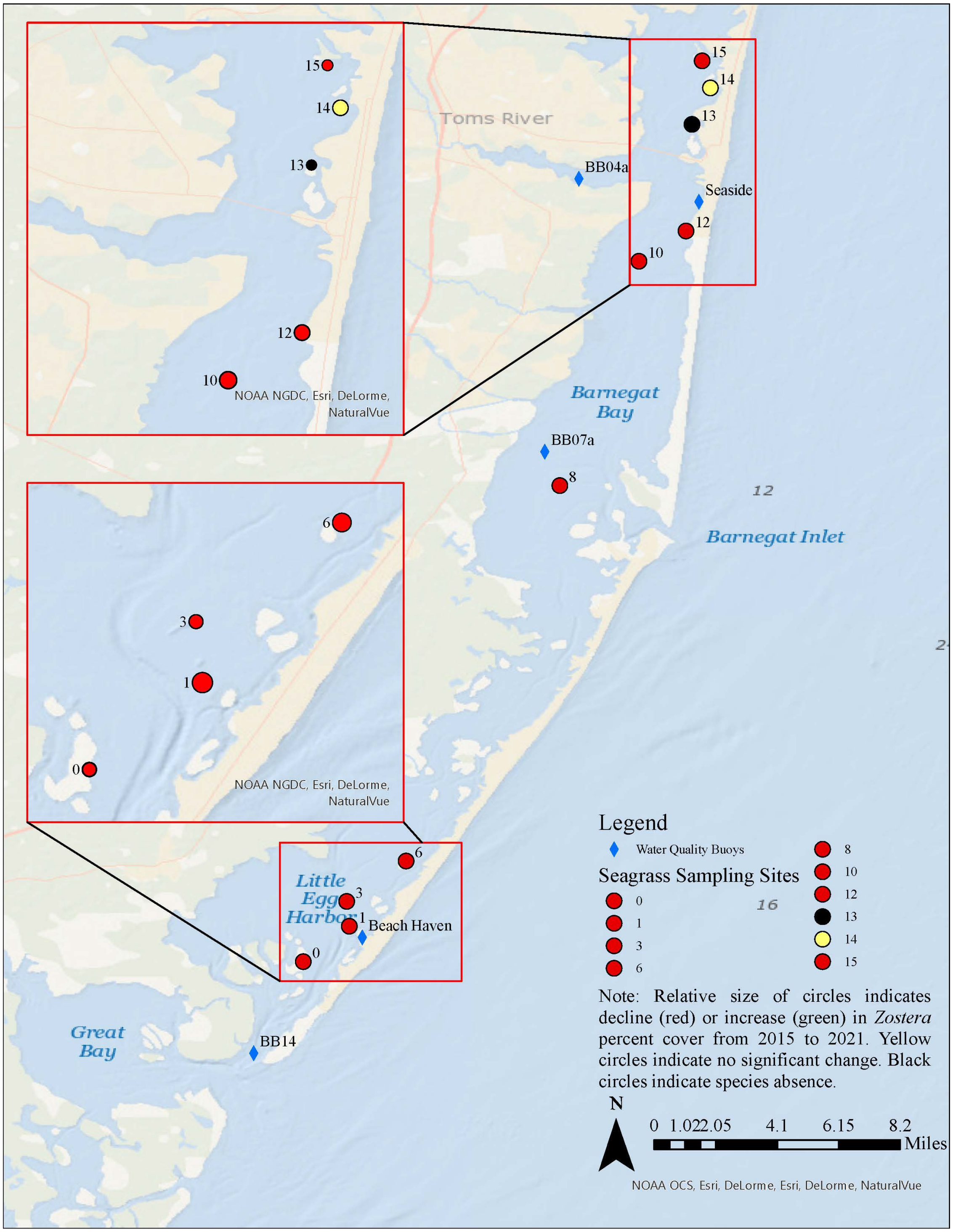


Figure 2. Trends in *Zostera marina* percent cover from 2015 – 2021 at Barnegat Bay-Little Egg Harbor Estuary. Site 0 is one of the Marine Ecosystem Research Lab long-term monitoring sites. Figure created by D. Dyson.

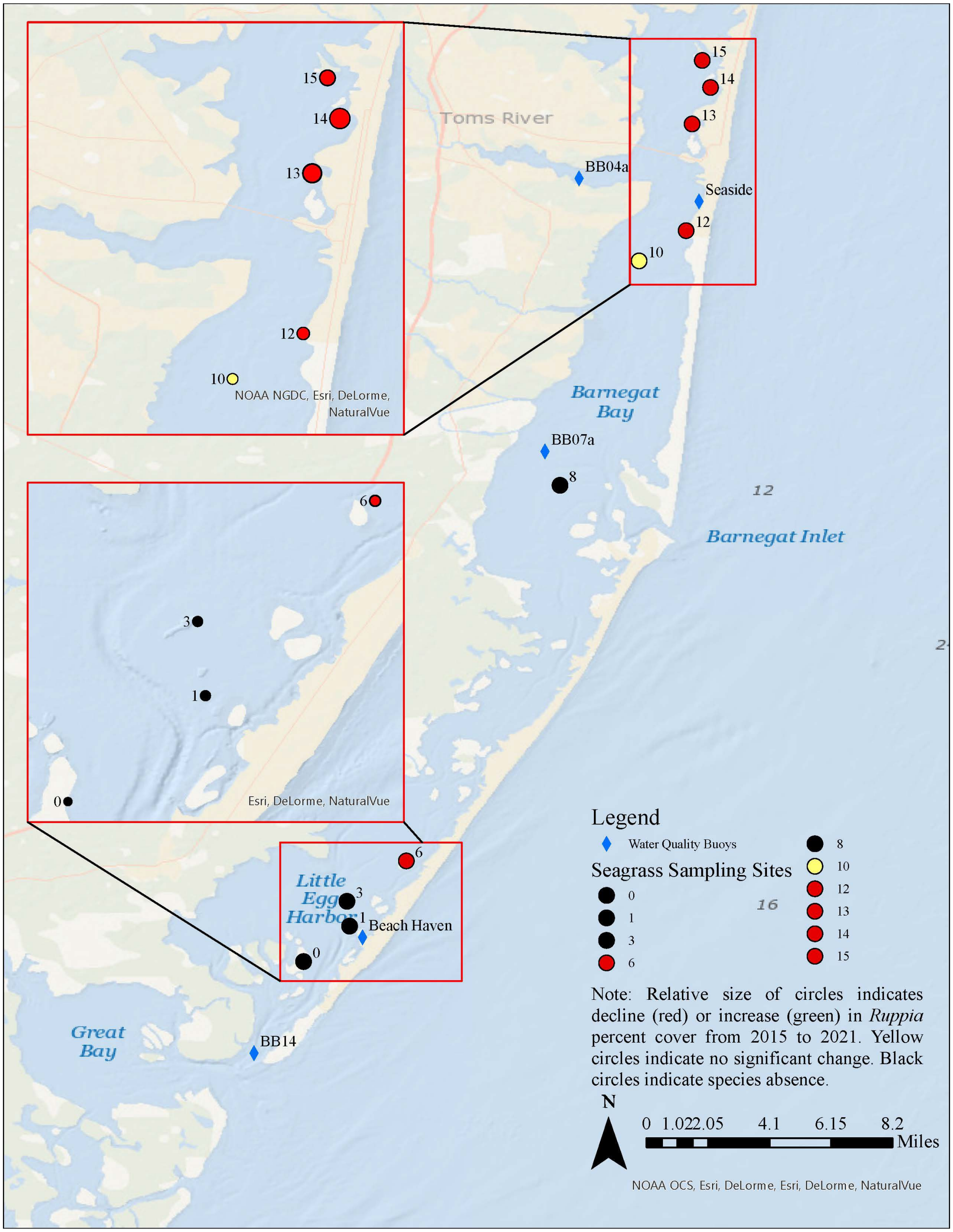
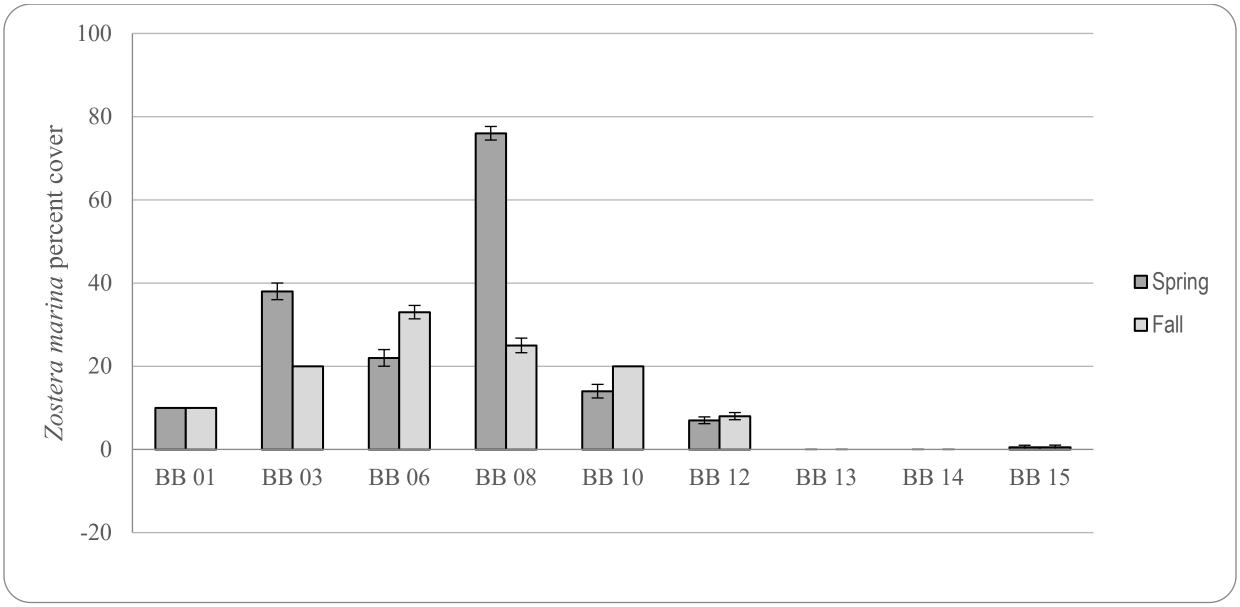
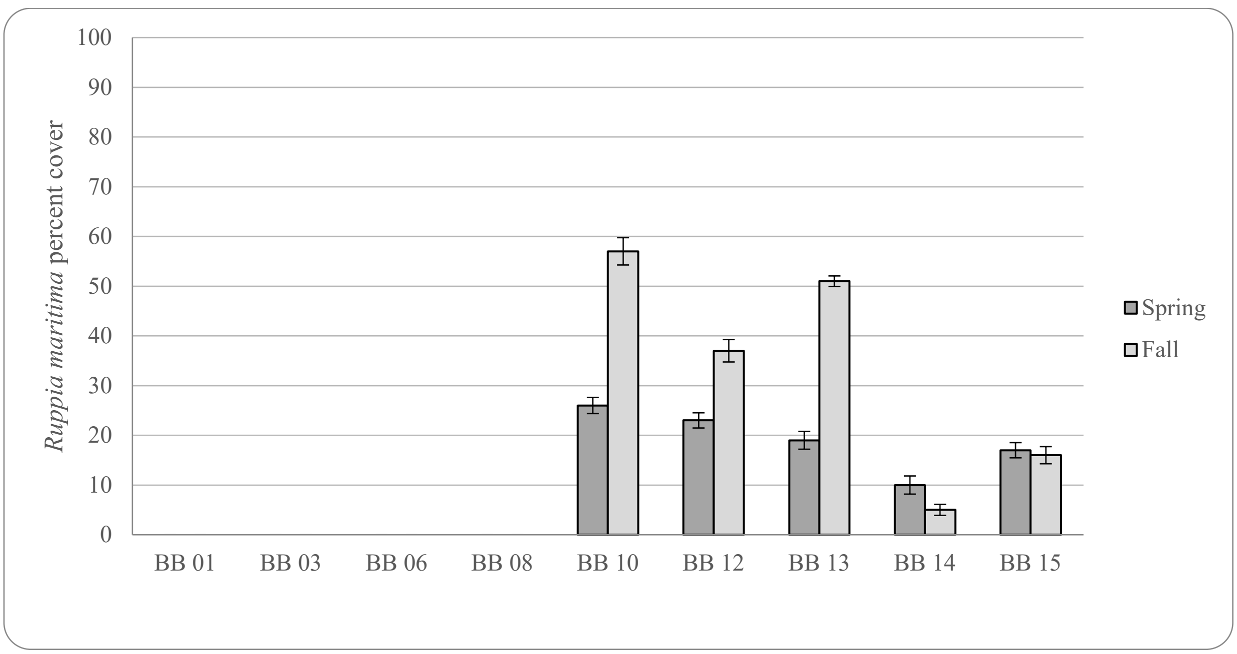


Figure 3. Trends in *Ruppia maritima* percent cover from 2015 – 2021 at Barnegat Bay-Little Egg Harbor Estuary. Site 0 is one of the Marine Ecosystem Research Lab long-term monitoring sites. Figure created by D. Dyson.



Zostera marina percent cover
100
80
60
40
20
0
-20
BB 01
BB 03
BB 06
BB 08
BB 10
BB 12
BB 13
BB 14
BB 15
Spring
Fall



Ruppia maritima percent cover
100
90
80
70
60
50
40
30
20
10
0
BB 01
BB 03
BB 06
BB 08
BB 10
BB 12
BB 13
BB 14
BB 15
Spring
Fall

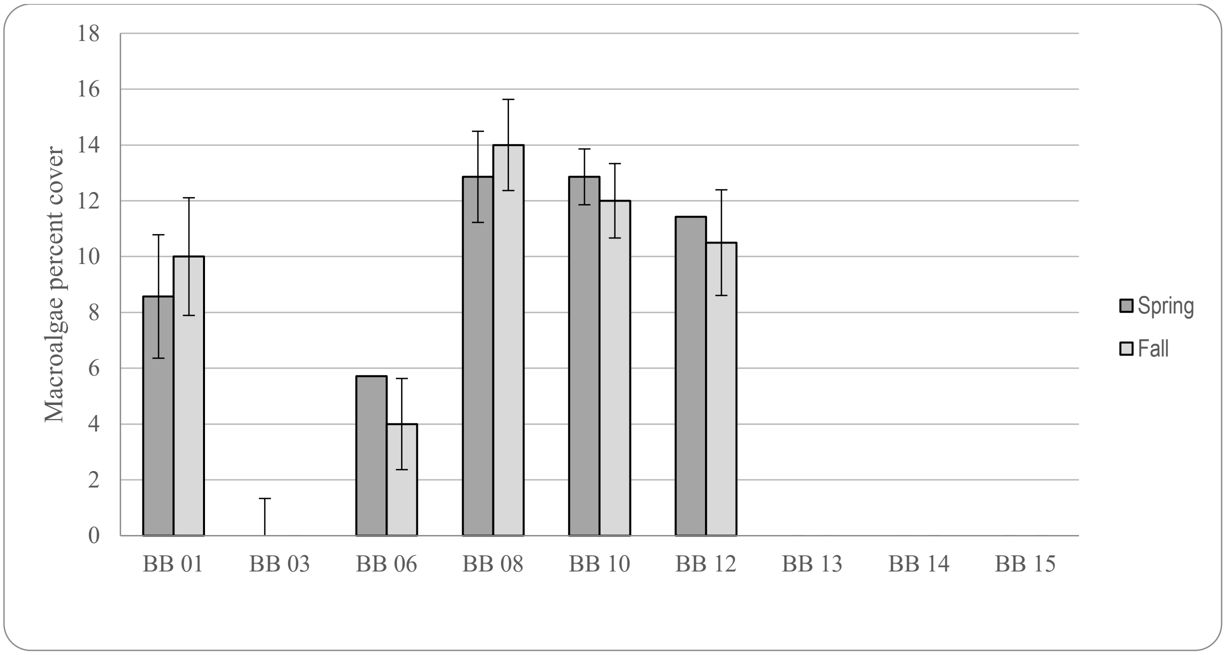


Figure 4: Percent cover (±SE) of (a) *Zostera marina*, (b) *Ruppia maritima*, and (c) macroalgae in Spring and Fall.

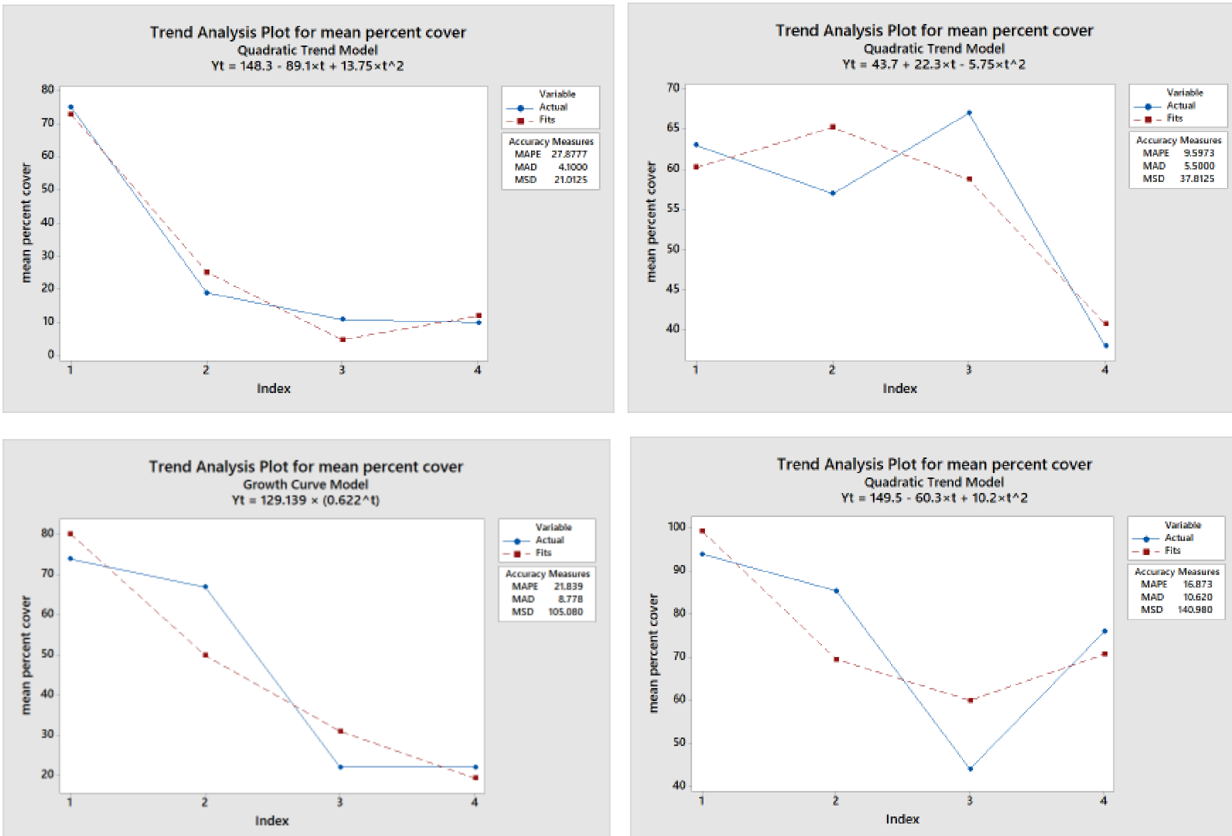
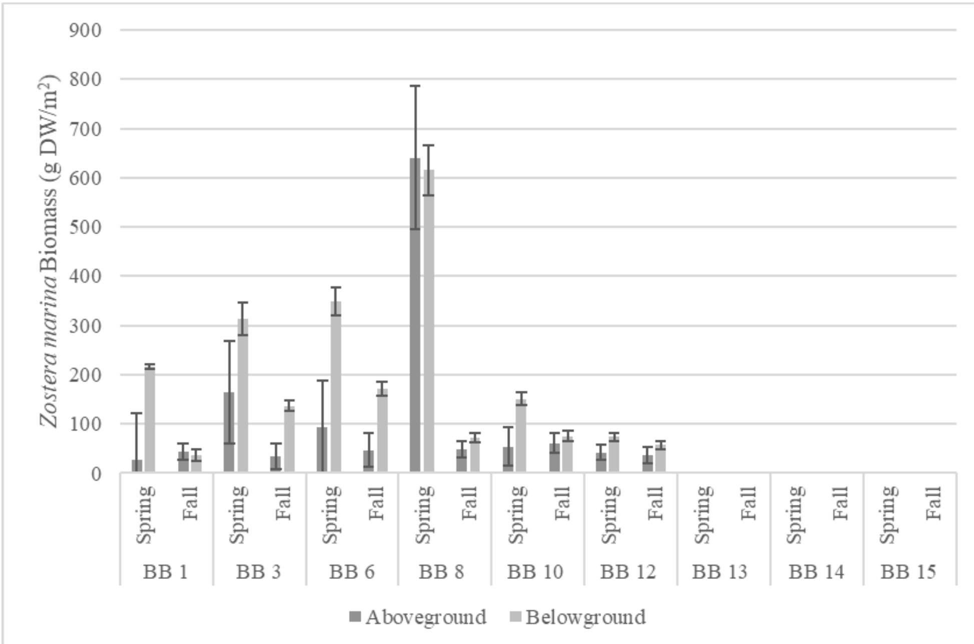


Figure 5: Trend analyses for *Zostera* percent cover at sites BB01 (a), BB03 (b), BB06 (c), and BB08 (d). Years are represented along the x-axis as 2015 (1), 2017 (2), 2019 (3), and 2021 (4).



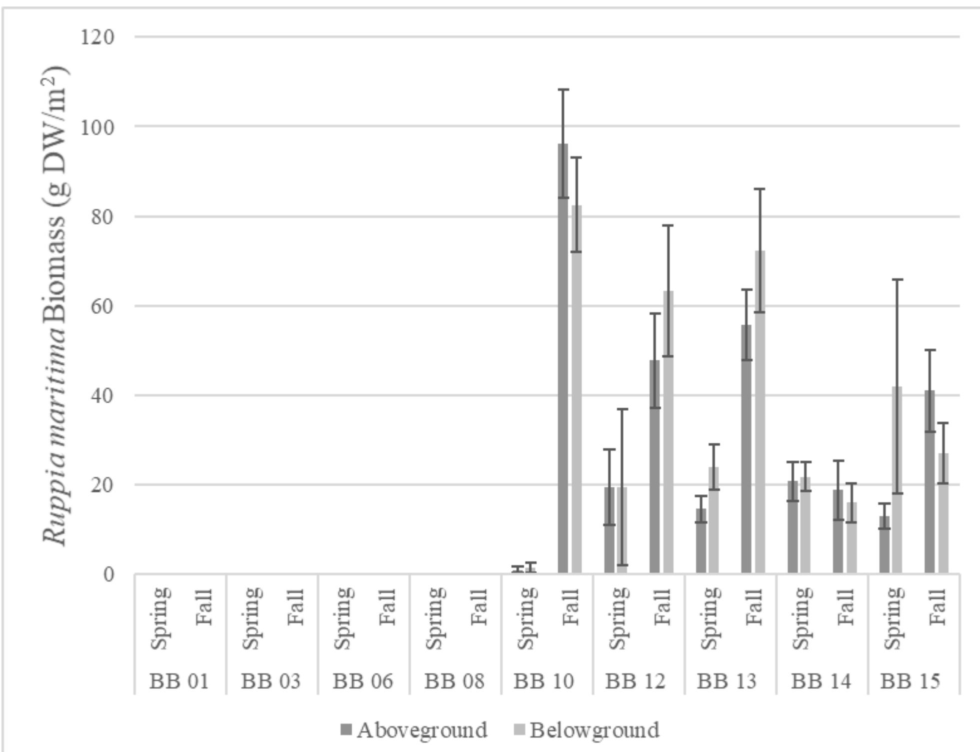


Figure 6: Aboveground and belowground biomass (g DW/m^2) ± SE of (a) *Zostera marina* and (b) *Ruppia maritima* (note difference in y-axis) in Spring and Fall.

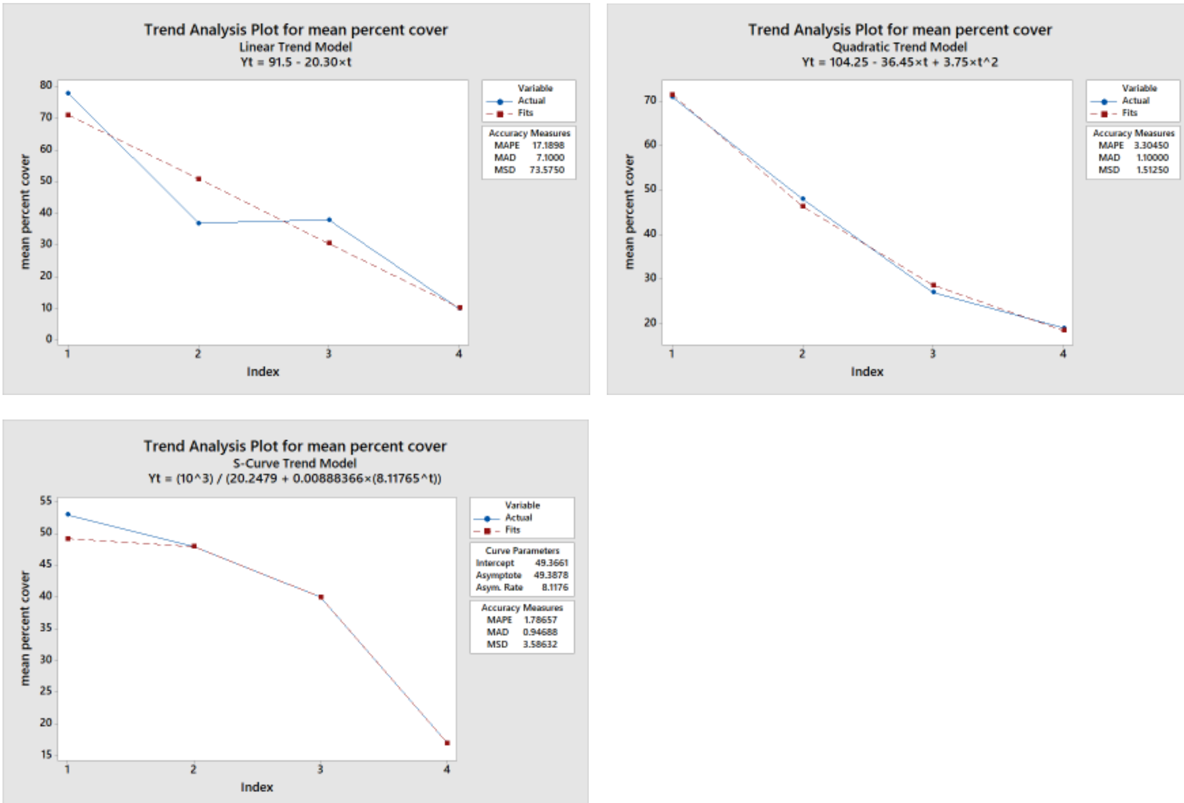


Figure 7: Trend analyses for *Ruppia* percent cover at sites 13 (a), 14 (b), and 15 (c). Years are represented along the x-axis as 2015 (1), 2017 (2), 2019 (3), and 2021 (4).

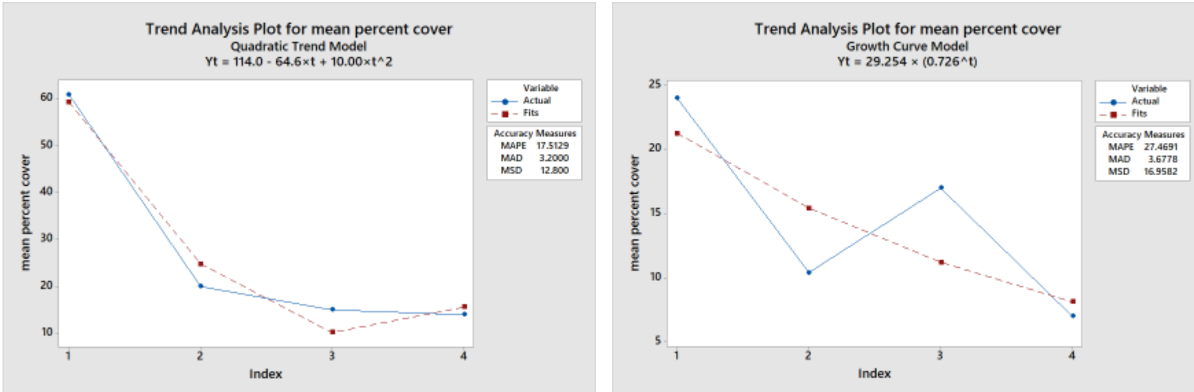


Figure 8: Trend analyses for *Zostera* percent cover at sites 10 (a) and 12 (b). Years are represented along the x-axis as 2015 (1), 2017 (2), 2019 (3), and 2021 (4).

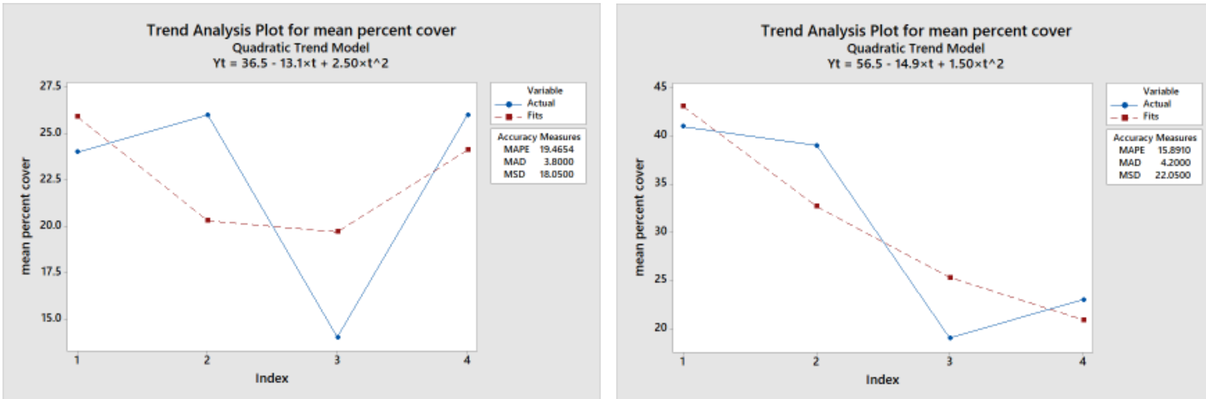


Figure 9: Trend analyses for *Ruppia* percent cover at sites 10 (a) and 12 (b). Years are represented along the x-axis as 2015 (1), 2017 (2), 2019 (3), and 2021 (4).

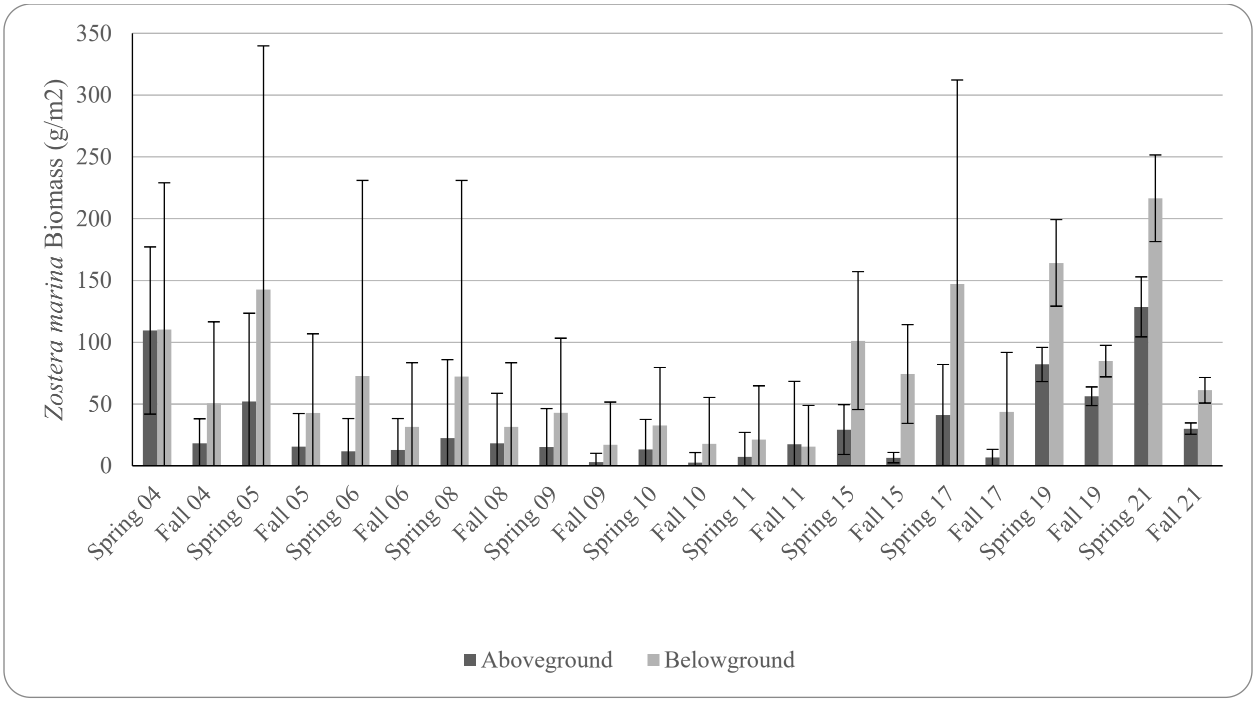


Figure 10: Average *Zostera marina* aboveground and belowground biomass (g DW/$m^2 \pm$ SD) for Spring and Fall throughout Barnegat Bay (data taken from NEIWPCC and the 2015 - 2019 BBP studies).

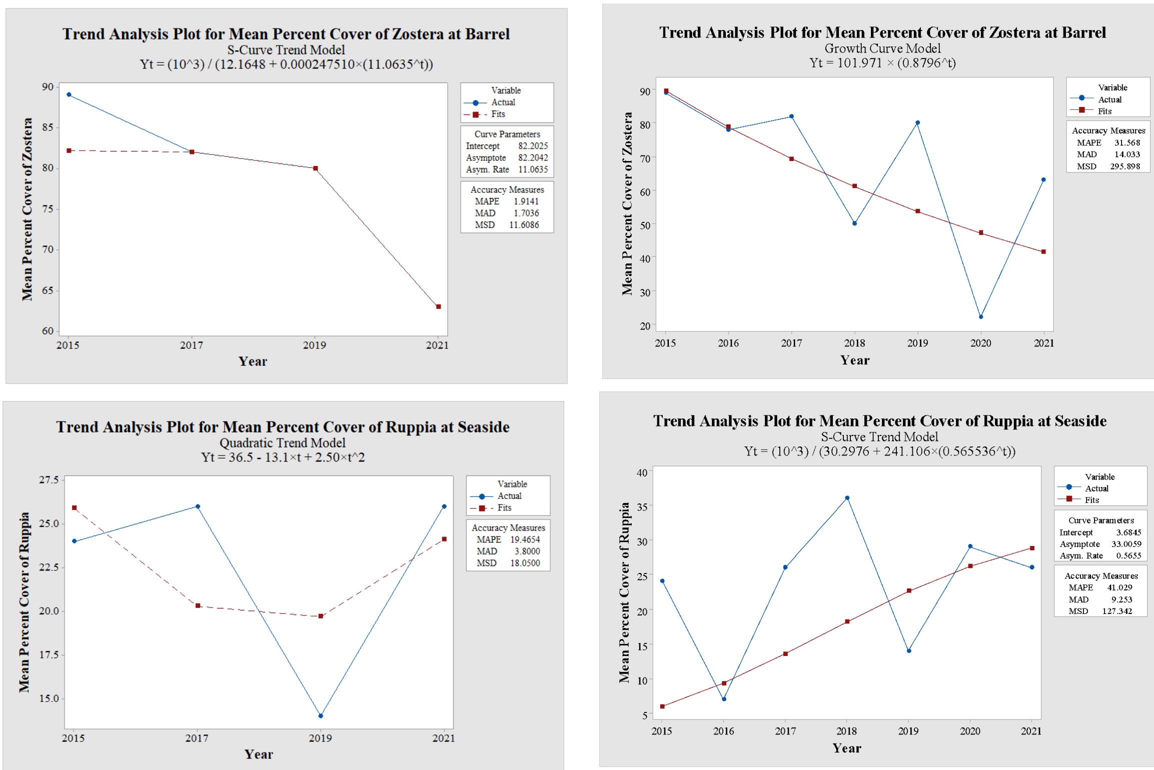


Figure 11. Trend analyses for *Zostera* percent cover during biennial (a) and yearly (b) sampling and *Ruppia* percent cover during biennial (c) and yearly (d) sampling.

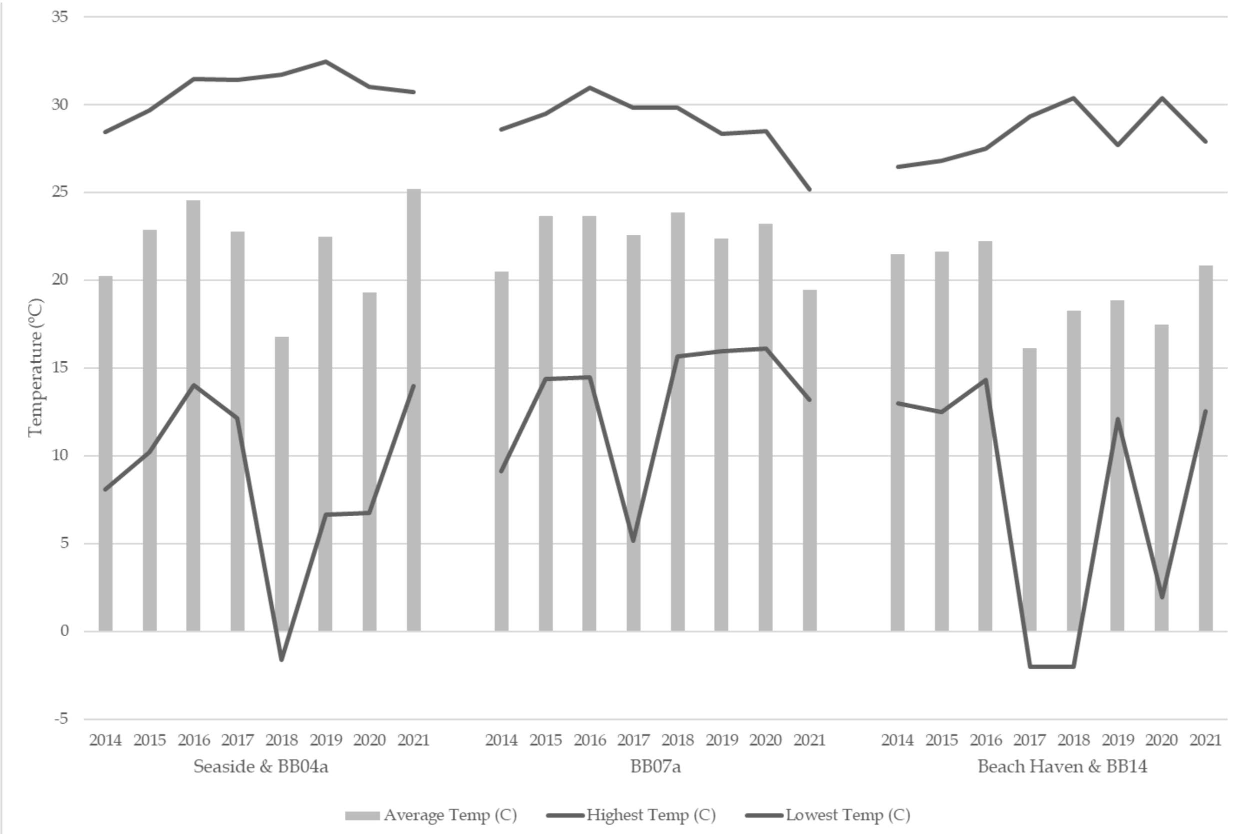


Figure 12. Average, maximum, and minimum temperatures at buoys in the southern, central, and northern portions of Barnegat Bay (locations in Figure 1). Figure created by D. Dyson.

Table 1: Coordinates (Decimal degrees) of sampling stations. Site number refers to location in relationship to previously established research transects. See Figure 1 for representation of all transects and current sampling sites.

Latitude	Longitude	Site #
39.57246	74.25129	1
39.58443	74.25255	3
39.6039	74.22392	6
39.78495	74.14985	8
39.89312	74.11174	10
39.90771	74.08906	12
39.95913	74.08618	13
39.9767	74.0773	14
39.98976	74.08128	15