Mahone Bay Living Shoreline Monitoring Summary 2021 – 2023

Prepared for Coastal Action

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The Mahone Bay Living Shoreline Project was built to protect against flooding and erosion along the vulnerable Edgewater Street, where the town's iconic Three Churches stand. TransCoastal Adaptations Centre for Nature-Based Solutions (TCA) at Saint Mary's University runs the monitoring program for the living shoreline project. This monitoring program analyzes the effectiveness of the shoreline at reducing the impacts of erosion, storm surges, flooding, and stormwater runoff on the Mahone Bay waterfront. Since the construction and planting of the shoreline in 2022, the living shoreline has performed very well. TCA staff have been collecting data on wave and water conditions, vegetation, sediment movement, erosion, and storms throughout 2023. Data collected and observations have shown the shoreline to be performing very well throughout the season and during storms, erosion and loss of vegetation has been minimal requiring minimal adaptive management.

Nature-Based Solutions Assessment:

The table below (Table 1) was adapted using information from the Monitoring Framework Matrix by the Science+ Resilience Institute, (2020). This framework includes additional considerations that are less relevant for the purposes of this project and for this location and were therefore excluded from our monitoring program however are useful to consider for future work. Table 1 provides the rationale behind each monitoring activity by defining what the indicators of success are for each performance parameter, and links them to the main goals that nature-based shoreline adaptations aim to achieve: in this case, ecological function, and hazard mitigation and structural integrity.

Table 1: Monitoring framework relevant to the Mahone Bay living shoreline (modified from Science + Resilience Institute, 2020).

Monitoring For:	**Performance Parameter:**	**Indicator(s):**	**Monitoring Activity:**
Ecological Function	Biological health and biodiversity	Plant species cover, abundance, richness, and composition	Vegetation surveys, observations
		Sessile organism presence, abundance, cover, richness, composition	Observations
		Distribution and abundance of wrack, debris	RPAS, observations
	Habitat creation	Change in species usage	Observations
Hazard Mitigation and Structural Integrity	Shoreline and topographic changes	Change in feature position/elevation	RPAS, GNSS RTK Surveys
	Coastal flooding	Change in wave conditions	Wave loggers
		Water levels	Water level loggers
	Structural integrity	Visible scour, erosion, escarpments, material degradation	RPAS, observations

Monitoring Methods

Prior to the shoreline construction, TCA completed a variety of surveys in the spring and summer of 2022 to understand the site conditions, this included completing drone flights, deploying wave and water level loggers, and elevation surveys using both GPS equipment and a bathymetric survey. Construction of the

shoreline began in June of 2022 and the planting of marsh grasses and shrubs that are currently present on the shoreline occurred that summer.

Since construction has been completed, TCA has been using a variety of methods to measure the effectiveness of the shoreline project. This has included deploying wave loggers during every major storm and completing post-storm assessments. Post-storm assessments involve examining the shoreline for any vegetation loss, erosion, or storm debris. This activity is supported by The Maritime Provinces Spatial Analysis Research Centre (MP_SpARC) at Saint Mary's University which has completed drone flights after every major storm and every spring to monitor changes in elevation, and to map any movement of the vegetation, wrack, and storm debris onsite.

TCA uses a Sontek M9 river surveyor to map the ocean floor. This device moves through the water on a small floating board and emits acoustic frequencies to measure the surface of the ocean floor. This M9 can measure water depth and is paired with a GPS rover that sits on top of the instrument to provide precise location data to use for mapping. Bathymetric surveys were completed by towing the instrument with a kayak along the living shoreline before construction in June 2021, and 1-year post-construction in July 2023.

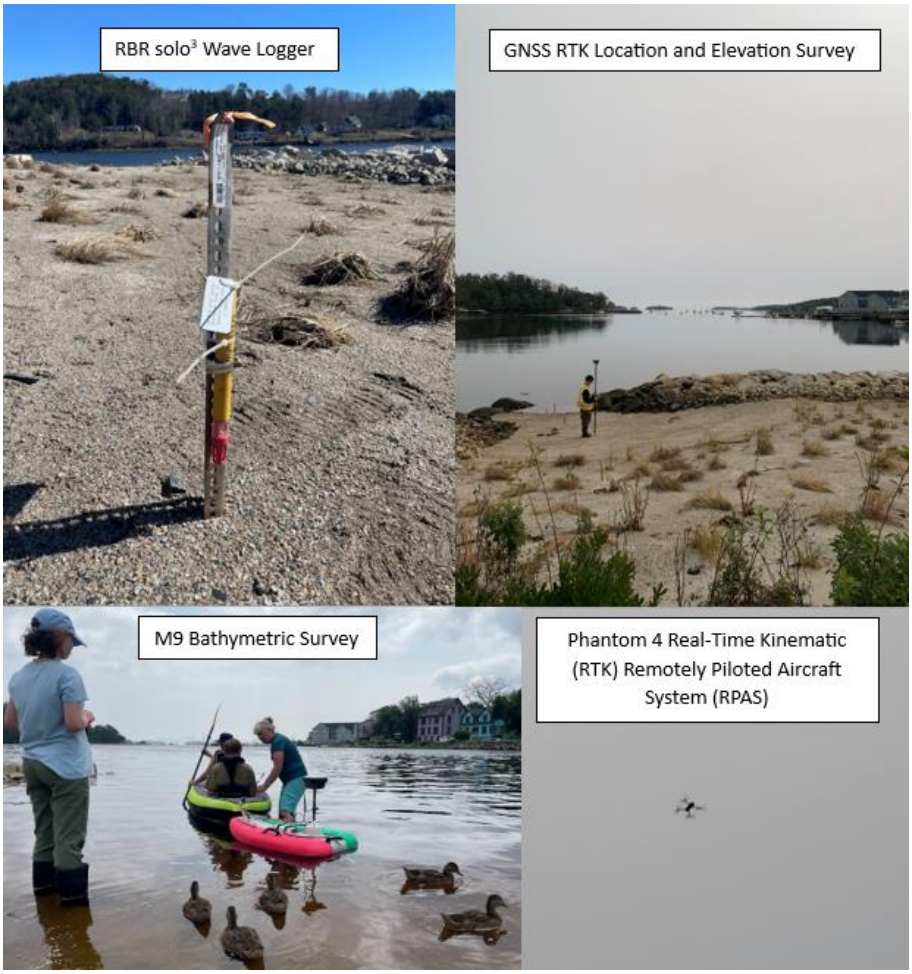


Figure 1: Instruments used to monitor the Living Shoreline.

TCA used two different types of loggers to measure water level and waves on the living shoreline; these small loggers were deployed on stakes at various elevations on the shoreline to collect data on wave height, energy, wave period, and water level. These loggers were deployed during major storms to measure waves associated with storm surges and high wind and rain events. Loggers were also deployed in the spring of 2022 and the summer of 2023 to capture a full spring and neap tidal cycles and classify normal/baseline wave conditions.

Fall and Winter 2022/2023

On September 24, 2022 hurricane Fiona reached Nova Scotia, causing major damage throughout the province and Atlantic Canada. To record the wave energy, wave height, and water level during the storm TCA staff placed a wave logger on the centre of the shoreline before the storm made landfall. Fortunately, the impacts on Mahone Bay Harbour were not as harsh as what was observed in other areas of the province. The storm reached Mahone Bay during a low tide and the direction of winds were offshore, therefore water levels were low, and waves that developed from the storm did not reach the newly planted vegetation.

Following Fiona, the 2022 winter was unseasonably warm. Temperatures mostly stayed above freezing with some occasional cold snaps, because of this the ground was not able to stay frozen. Newly planted vegetation had not had time for their roots to spread leaving the shoreline at risk of erosion from wind and rain. Thankfully erosion was minimal, and any damage was addressed by repurposing Christmas trees, by weaving them into the vegetated bank they provided the necessary protection and stability.

Spring and Summer 2023

In the spring of 2023, the marsh grasses planted in the fall came back to life and shrubs on the vegetation bank started to bud and eventually bloom. Native honeybees were noticed to be attracted to the vegetated bank and the shoreline became quite lush and beautiful by mid-summer.

Figure 2: Vegetation growth in the spring/summer of 2023.

Wave conditions measured between April 14th- May 23rd and June 12th- July 20th of 2023 showed the relatively calm wave conditions that are typically observed on the shoreline. Significant wave height is defined as the average wave height of the highest third of the waves, this is defined in a way that it can correspond to what a mariner observed when visually estimating the average wave height. In the spring significant wave height conditions range between 0.01 – 0.14 meters, and typical wave energy is under 5 Joules. A joule (J) is the energy needed to lift 1 kilogram of matter 1 meter at sea level, significant wave height conditions were slightly lower in the summer months compared to the spring, they ranged between 0.01m – 0.07m, the maximum wave height recorded during this time was 0.14m. The following figures show the significant wave height and energy captured from a logger placed in the centre of the shoreline.

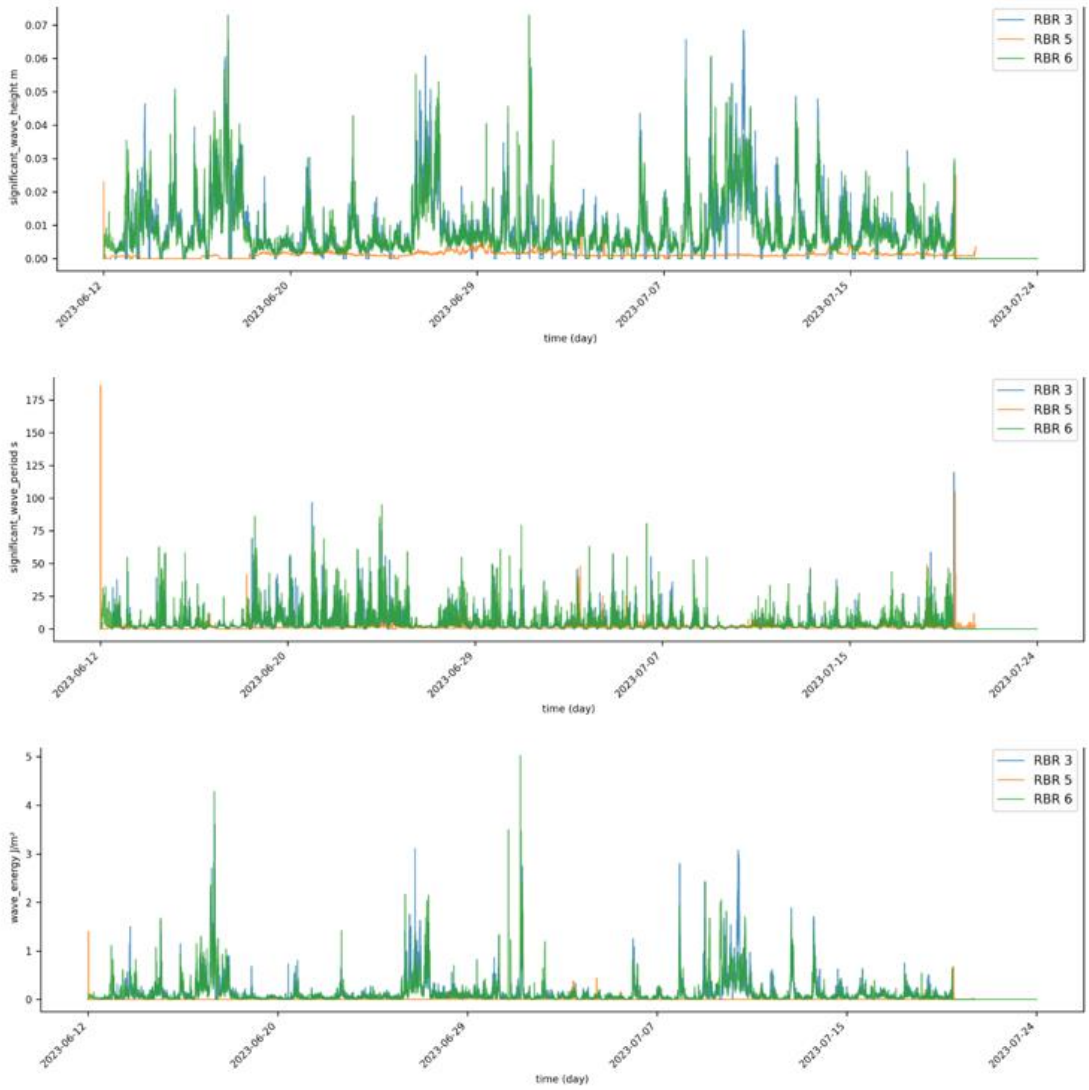
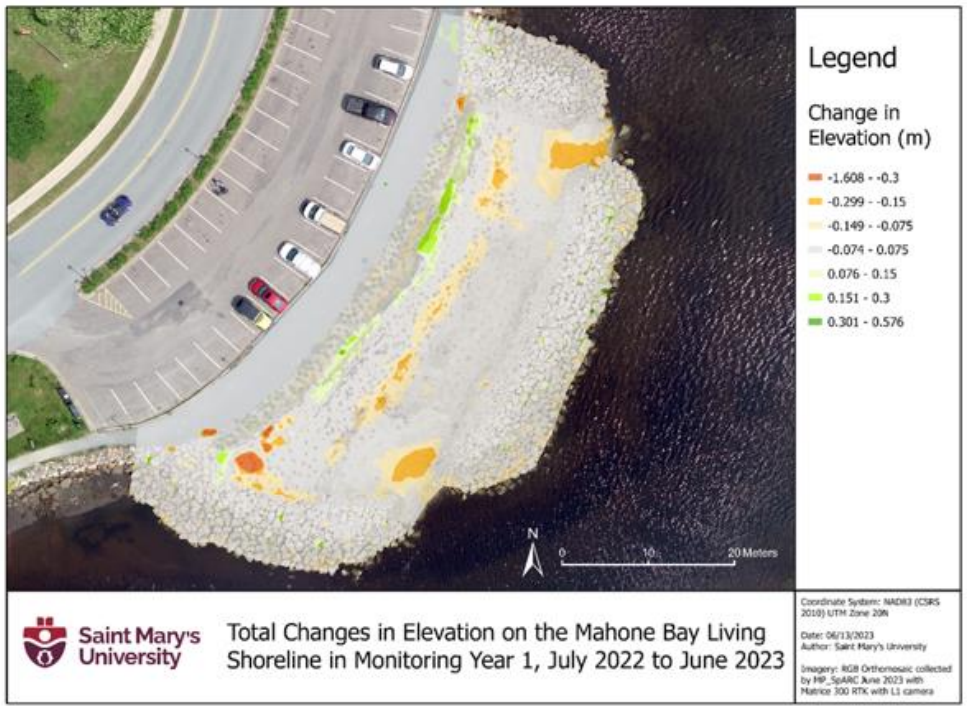


Figure 3: Significant wave height, significant wave period, and wave energy (J/m^2) for the RBR's deployed from June 12th – July 20th, 2023. Loggers were deployed at low tide, RBR 3 and RBR 5 were located in the water where at each gap in the bulkhead where the tide enters the shoreline. RBR 5 was located in the centre of the shoreline.

Using a Digital Elevation Model (DEM) and various modelling techniques, TCA mapped the changes in both elevation and structure of the shoreline that happened between each flight. As expected, some sand redistribution occurred between the construction and summer of 2023, driven by high tides and waves creating a more natural topography. Some small scour was visible on the landward side of the marsh sill but this filled in over time. Some rocks were observed to have been physically re-arranged in patterns on the beach and this activity should be discouraged as it creates scour. Changes in elevation and the shoreline structure between July 2022 and June 2023 are shown in figure 4.



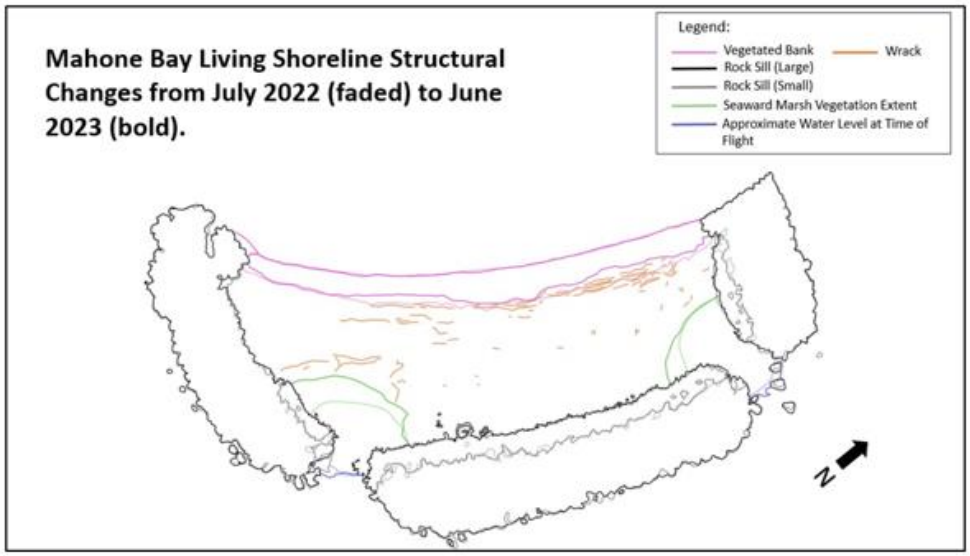


Figure 4: Left: Changes in elevation between July 2022 and June 2023. Right: Shoreline structural changes from June 2023 to October 2023; Figures created by Kelly Umlah and Greg Baker. Note, most of the changes reflect growth of vegetation.

The image below (Figure 5) shows the results from the 2023 bathymetric survey. The pink-purple shading shows the entire survey area, and the darker purple areas represent deeper water, such as the outflowing channel of Ernst Brook. Combined with visual observations on site, the data indicate that some sand was removed from the eastern 'beach' between the rock sill and this was deposited in a small lobe at the base of the opening. No scour was recorded at the base of the rock sill. Subsequent visual observations indicate that this material was transported landward and returned to the beach by wave action during normal conditions.

Figure 5: Left: Sontek M9 river surveyor being towed by TCA staff, picture taken by Leah Rudderham. Right: visualization of M9 survey results completed by Christian Hart.

Fall 2023

TCA visited the shoreline before Port-Tropical Storm Lee which made landfall on September 16th, 2023 to deploy loggers to record the wave energy and height associated with the storm surge. Three wave loggers were deployed one day prior to Lee with the intent of characterizing wave conditions and if the living shoreline reduced wave heights.

Tropical storm Lee brought high winds, rain, waves, and a storm surge to Mahone Bay, on the living shoreline significant wave height peaked just above 0.3m and wave energy reached 60 $J \cdot m^{-3}$. Wave height reached a maximum of 0.33m. Photos captured by a community member showed the rough water conditions that submerged the whole shoreline, at the peak of the storm water level was level with the vegetation bank and flooded areas of the walking path along the waterfront. The storm left a dock as well as other woody debris on the shoreline, some vegetation plugs were ripped out but minimal erosion occurred within the site.

Figure 6: Images of the living shoreline on September 16th during the post-tropical storm Lee.

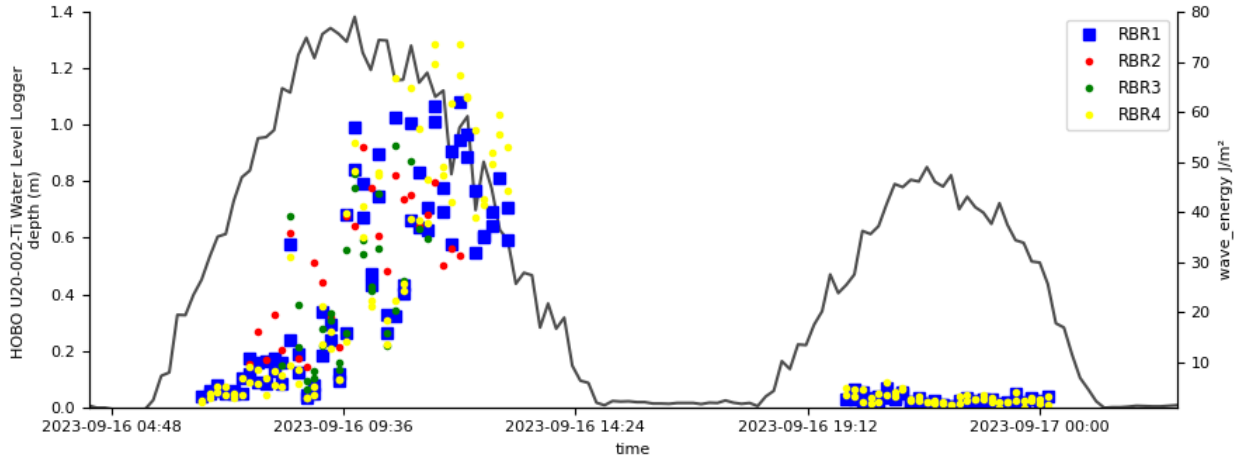


Figure 7: Water level and wave energy conditions observed during post-tropical storm Lee. Water depth is shown on the left axis and is represented by the solid black line, the first "hump" being the tide that occurred during the storm. The colored boxes refer to the wave energy on the right axis that was captured by various wave loggers. Maximum wave energy peaked just after high tide at just over 60J.RBR 1 was located at the lowest elevation, RBR 2 and RBR 3 were in a transect with RBR 1, RBR 4 was located in the middle of the marsh sill. Figure produced by Christian Hart.

TCA visited the shoreline the week after to record damage and complete a drone survey. Tropical storm Lee really tested the shoreline's ability to weather storms, overall damage on the shoreline was very minimal it proved to be very effective at protecting the walking path alongside it. After the storm other areas of the waterfront appeared more battered with debris and areas of erosion and scour were noted along the path, above the rock armour stone along the waterfront.

Figure 8: Debris left on the living shoreline after post-tropical storm Lee, photos taken by Leah Rudderham.

In October 2023, TCA staff tested a Sofar wave buoy, this was anchored just offshore from October 13th to December 1st. This buoy appears like any other small buoy floating in the harbour but is equipped with solar panels and can take consistent measurements on wave and weather conditions over long time periods. The wave buoy was anchored just offshore of the living shoreline for a little over a month in the fall. Significant wave height collected from the buoy typically ranged from 0.01 – 0.07 with occasional peaks near 0.10. This is very similar to what has been observed directly on the shoreline. Other measurements recorded included wave period, wind direction, wave direction, and surface temperature.

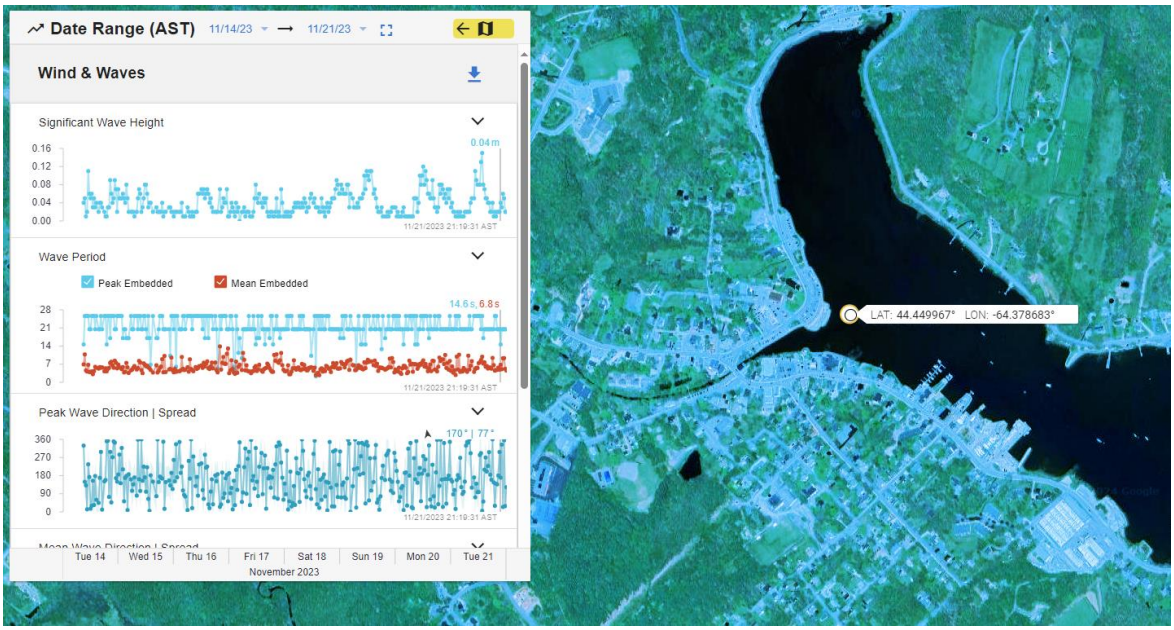


Figure 9: Conditions reported from the Sofar wave buoy from November 14th - 21st, 2023. Located just offshore from the living shoreline, significant wave height ranged from 0.01 - 0.13m. Wave period ranged from 14 - 27s. The buoy also reported on wave direction, wind direction, wind speed, and surface temperature.

Winter 2024

Heavy rainfall and winter storms battered the shoreline in December and January, combined with multiple freeze/thaw periods, some areas of the vegetated bank that already had some erosion lost more sediment; leaving the roots of some of the vegetation exposed to cold temperatures and winter conditions. Three consecutive storms at very high tide levels caused erosion along an approximate 3 m section of the vegetated bank on the eastern side of the site. This location is most exposed to higher waves travelling through the gap in the sill. To attempt to protect the bank from further erosion, Christmas trees and pine branches were woven between the standing vegetation. Further work to add more sediment and replace vegetation that may not survive the winter due to root exposure will be planned in the spring.

Figure 10: Erosion due to winter storms (left and centre), adaptive management using branches and Christmas trees to protect the bank from future winter storms (right).

Observations/Conclusions:

TCA's analysis of the shoreline focuses on the changes in structure and elevation, wave conditions, water levels, and erosion, flooding, and stormwater runoff. All measurements taken in 2023 indicate that the living shoreline is performing as expected, meaning that the shoreline has been successful at reducing the impacts of wave energy from storms on the infrastructure behind the shoreline. By simply walking along the gravel path next to Edgewater Street, you can observe areas where the path has washed out and eroded in other sections but remains in excellent condition behind the living shoreline.

TCA staff have also recorded observational data during site visits, including notes on vegetation growth during the 2023 summer, areas where erosion has occurred, plant successes or failures, and indications of species that use the marsh. Species observed on the shoreline include Great Blue Heron (*Ardea Herodias*), Mallard (*Anas platyrhynchos*), American Black Duck (*Anas rubripes*), and Honeybees (*Apis mellifera*). These species are common around Mahone Bay, but their use of the living shoreline is a positive indicator that in addition to reducing the impacts of erosion, flooding, and stormwater runoff,

the site is also a functional habitat for species who are experiencing rapid declines in available habitat throughout the province.

Figure 11: Great Blue Heron (Ardea herodias) footprints on the Mahone Bay living shoreline (left), Native honeybee spotted resting near the vegetation bank (right), June 2023. Mallards resting along the shoreline (bottom, September 2023).

Continued Monitoring:

TCA plans to continue and expand the monitoring program for the Living Shoreline. In the summer of 2024, plans are in place to complete additional bathymetric surveys and deploy wave loggers to examine the adjacent 100 meters of shoreline where the project will be expanded. Post-storm assessments and drone flights will also continue. Additionally, vegetation surveys will be added to the monitoring plan to research the survival and growth of the vegetation on living shorelines in temperate climates such as this.

Citizen science and community participation provides valuable information that can help us monitor changes to the shoreline. We ask that community members do **not** venture onto the constructed portion of the shoreline (on rock, sand, or bank) - pictures and observations can be taken from the walking path. If you notice any wildlife using the shoreline, or major changes (particularly after a storm) to the vegetation, storm debris, or erosion of the bank, please submit your photos and descriptive observations to transcoastaladaptations@smu.ca.

Figure 12: Photos captured by Leah Rudderham of the Mahone Bay Living Shoreline.

A more detailed description of the monitoring program and results can be found in the "Mahone Bay Living Shoreline Monitoring Report 2021 – 2023" which is available by request.

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