Monitoring Coastal Dune Resilience
A Contract with City of Tybee Island
Final Report

P.I. Dr. Lissa M. Leege, Department of Biology
Graduate Assistant: Skyler Fox

BACKGROUND AND STUDY OBJECTIVES

To aid with natural sediment accumulation and increase storm protection, Tybee Island constructed a half-mile long, eight-foot-tall dune and vegetated it with six native dune species in 2020. The goal of this contract with the City of Tybee Island and researchers at Georgia Southern University was to evaluate the success of this restored dune by comparing it to more natural, previously established dunes on the island. Additionally, we wanted to identify and analyze possible threats to the success of the restored dune, including beach access pathways. To do this, the specific initial objectives of this contract with the City of Tybee Island were to:

1) implement and adapt dune monitoring protocols,
2) collect data on impacts of beach access pathways, and
3) analyze the area of historical dune footpaths using Geographic Information Systems (GIS).

However, the initial graduate assistant who had been assigned to this project had to step down from his position due to health issues, and a new graduate assistant (Skyler Fox) joined this project as a replacement in Fall 2023. Because of this, the project was slightly modified to fit the scope of Skyler's master's thesis project. Instead of collecting data on both footpaths and bridge crossovers, we shifted our focus to just footpaths since they have been shown to cause more damage to dunes than bridge crossovers (Findlay, 2022; Purvis et al., 2015). Therefore, the modified goals of the project were to:

1) implement and adapt dune monitoring protocols and
2) evaluate impacts of pedestrian traffic on footpaths on dune resiliency by:
    a) measuring characteristics of dune vegetation, soil, and sand accumulation along footpaths and comparing these to adjacent undisturbed dune areas,
    b) measuring the rate and extent of dune recovery following restricting pedestrian traffic,
    c) measuring the rate and severity of damage to dunes after adding new footpaths to previously undisturbed areas, and
    d) creating an ArcGIS Story Map for public viewing showing the impacts of footpaths and the importance of limiting disturbance on dunes.

METHODS

1) Implement and adapt dune monitoring protocols

We used the protocol previously developed for a Coastal Incentive Grant (CIG) that includes quarterly sand and vegetation measurements. We have made one modification to the protocol since its development for the CIG. In 2022-2023, we identified the plant species present and counted the number of "clumps" of each species in our 1m x 1m plots. However, we determined that the number of clumps, while relevant immediately after planting, is no longer particularly informative since individual plants have spread, and is also somewhat subjective, meaning that volunteers could be counting clumps in different ways so that these measurements would be inconsistent. Because of this, we modified our protocol in 2024; instead of counting the number of clumps, we estimated the percent cover of each plant species. Although this protocol could still be considered subjective to some extent, it is more relevant in vegetation monitoring. We also provided volunteers with a "cover card" (see photo in linked protocol) to minimize inconsistency in measurements. We will continue to visually assess percent cover class in 2024

as a way to compare our previous measurements across the years of monitoring, although this is a less precise way of measuring percent cover. Each cover class is converted into the "midpoint" of the cover class range so that we have a numerical variable to include in statistical analyses. For example, because cover class 4 is 25-50%, the midpoint of that cover class is 37.5. Additional details of the updated protocol can be found at the following links: https://drive.google.com/file/d/1kSIdXvOLg7F71uu0DHbprVs9V2r_aBxu/view and https://docs.google.com/document/d/1ay8qgSrY0W_U1We3ZxjXtcR6tsKmrAe3dxnI-ycC09E/edit?usp=sharing.

2) Evaluate impacts of pedestrian traffic on footpaths on dune resiliency

Detailed methods can be found in our approved Georgia DNRCRD Research Application Proposal (Appendix A). For the purposes of this report, we analyzed and reported a subset of data that was collected. For example, we took height and chlorophyll measurements on *Uniola paniculata* (sea oats) each month as described in the research application. These analyses and others will be included in Skyler's Master's thesis.

RESULTS AND DISCUSSION

1) Implement and adapt dune monitoring protocols

Storm protection provided by Tybee's dunes

- Between September 24 and October 11, 2022, 1.5 years after dune restoration, Tybee's dunes accumulated an average of 9.24 cm of sand from Hurricane Ian. The established dune accreted 2.4 times more sand than the restored dune, and the toe (the base of the dune facing the ocean) accreted 3.4 times more sand than the crest (the top of the dune; Figure 1).
- Between September 13 and October 6, 2024, 3.5 years after dune restoration, Tybee's dunes accumulated an average of 3.07 cm of sand during Hurricane Helene. While there was no difference in sand accretion between the dune toe and crest, the established dune accreted 5.4 times more sand than the restored dune (Figure 2).
- These results suggest that while overall, the restored dune is accumulating sand, it is not performing quite as well as the established dune during hurricanes. The restored dune crest is most at risk because of its limited ability to accumulate sand. Additionally, the difference in accumulation between the established and restored dune was larger in Hurricane Helene than Ian, which is interesting since Helene occurred two years later after dune restoration; however, these differences could be partially due to differences in intensities between the two hurricanes. For example, the maximum wind speed at the Hilton Head Airport Station (18 mi from Tybee Island) was 38 mph for Ian on September 30, 2022 and 30 mph for Helene on September 27, 2024 (Weather Underground). It will be necessary to continue monitoring sand movement throughout hurricane seasons to see if this pattern continues.

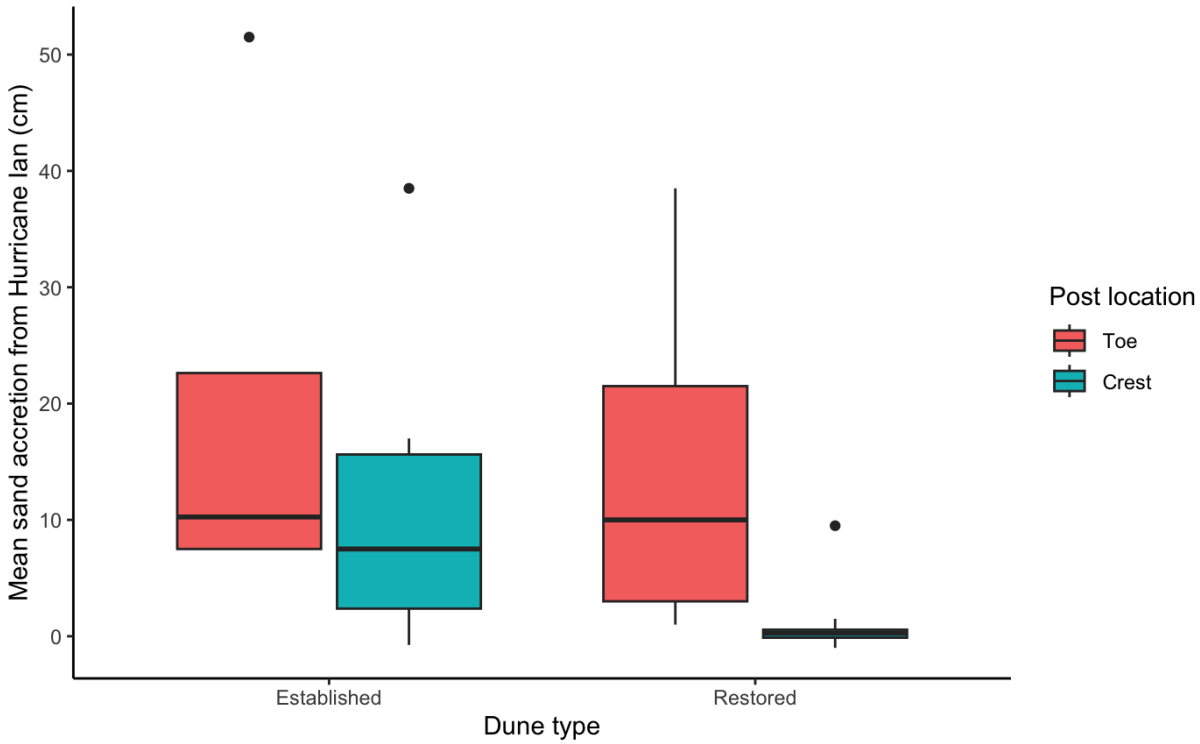

Figure 1. Sand accretion (cm) occurring between September 24 and October 11, 2022, from Hurricane Ian. A Scheirer-Ray-Hare test showed effects of dune type ($H_{1,27}$ = 4.65, p = 0.031) and post location ($H_{1,27}$ = 9.63 , p = 0.0019). There was no significant interaction between effects of dune type or post location ($H_{1,27}$ = 1.3, p = 0.25).

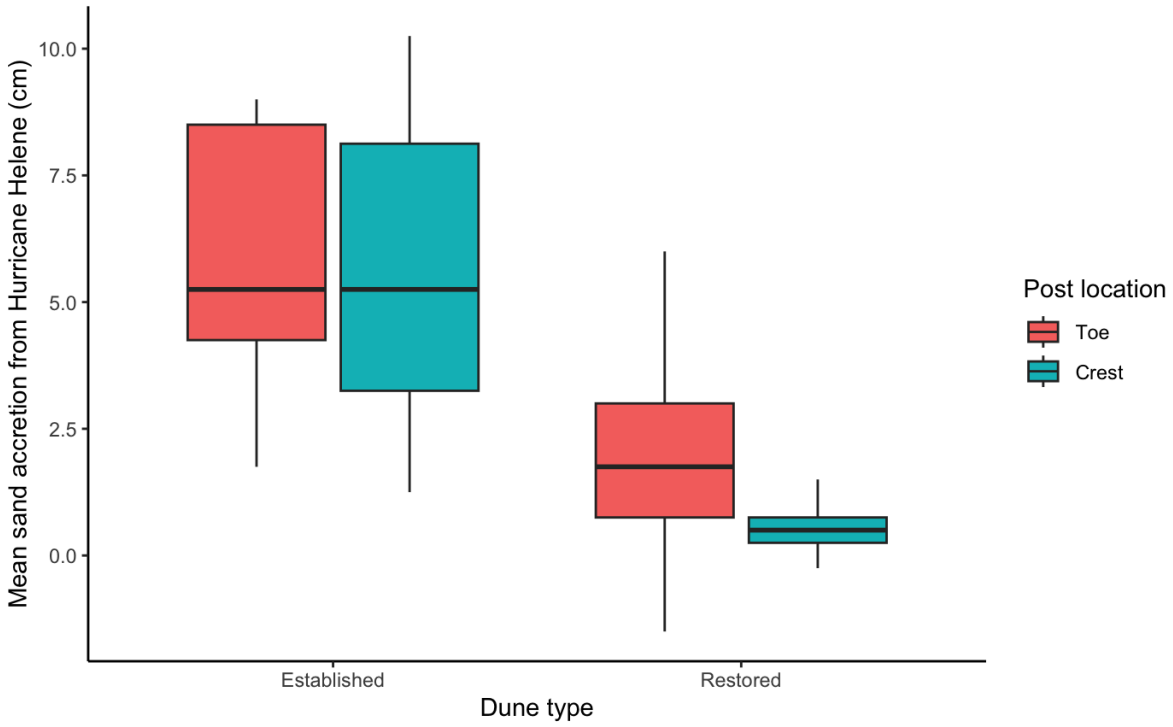

Figure 2. Sand accretion (cm) occurring between September 13 and October 6, 2024, from Hurricane Helene. A Scheirer-Ray-Hare test showed a significant effect of dune type ($H_{1,29}$ = 16.9, p = 0.00004) but not of post location ($H_{1,29}$ = 1.51, p = 0.22). There was no significant interaction between effects of dune type or post location ($H_{1,29}$ = 0.5, p = 0.48).

Sand accretion overtime

- Since 2022, over a two-year period, significantly more sand has accumulated in the established dune compared to the restored dune. By September 2024, the established crest had the highest mean sand accretion (48.43 cm), while the restored crest had the lowest (6.59 cm) (Figure 3).
- Because the restored dune crest is not accreting much sand, it is not increasing in height, especially compared to the established crest. Dune height is important because a taller dune can provide increased protection from storm surge.
- The established and restored toes are accumulating sand over time at a similar rate, which may be influenced by the sand fences in place at the dune toe.
- Future research should focus on finding ways to stimulate vertical growth of the restored dune to maximize storm protection.

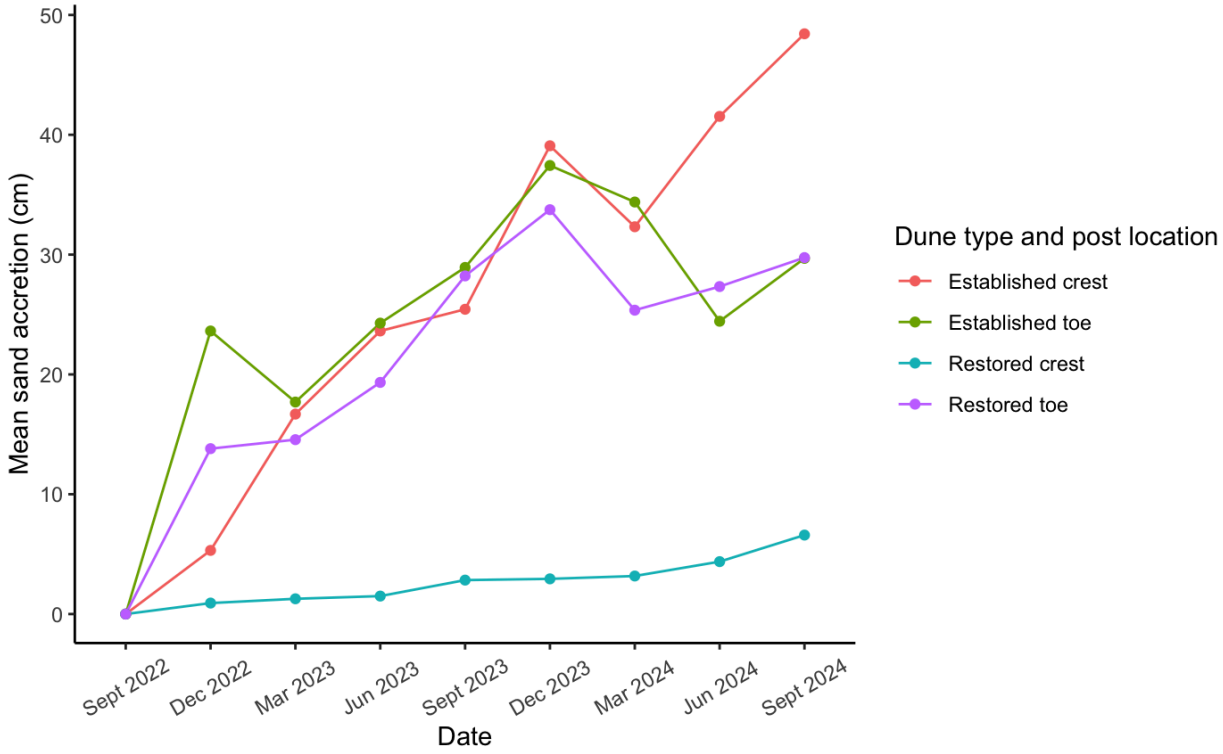

Figure 3. Cumulative mean sand accreted (cm) across the two-year monitoring period. A Scheirer-Ray-Hare test showed a significant effect of dune type ($H_{1,29}$ = 7.43, p = 0.0064). There was no effect of post location ($H_{1,29}$ = 3.16, p = 0.076), but a significant interaction between effects of dune type and post location ($H_{1,29}$ = 5.19, p = 0.023).

Vegetation

June 2023:

- In the plots adjacent to the established posts, there were no significant differences in species richness or the cover class midpoint by dune type (i.e., established or restored) or plot location (i.e., toe or crest).

- In the plots five meters from the posts, the established dune had significantly higher species richness compared to the restored dune. The established crest had the highest species richness (2.5 species per square meter), while the restored crest had the lowest (0.56 species per square meter) (Figure 4).
- This suggests that three years following dune restoration, the restored crest may not be supporting vegetation and species diversity to the same extent as the established crest.
- The cover class midpoint was also significantly higher in the established dune (38.6) compared to the restored dune (in the plots five meters from the posts).
- Although the cover class midpoint is a less precise measurement than total percent cover which we started measuring in 2024, this information still serves as a baseline for the future and tells us that the established dune supported more vegetation than the restored dune in 2023.

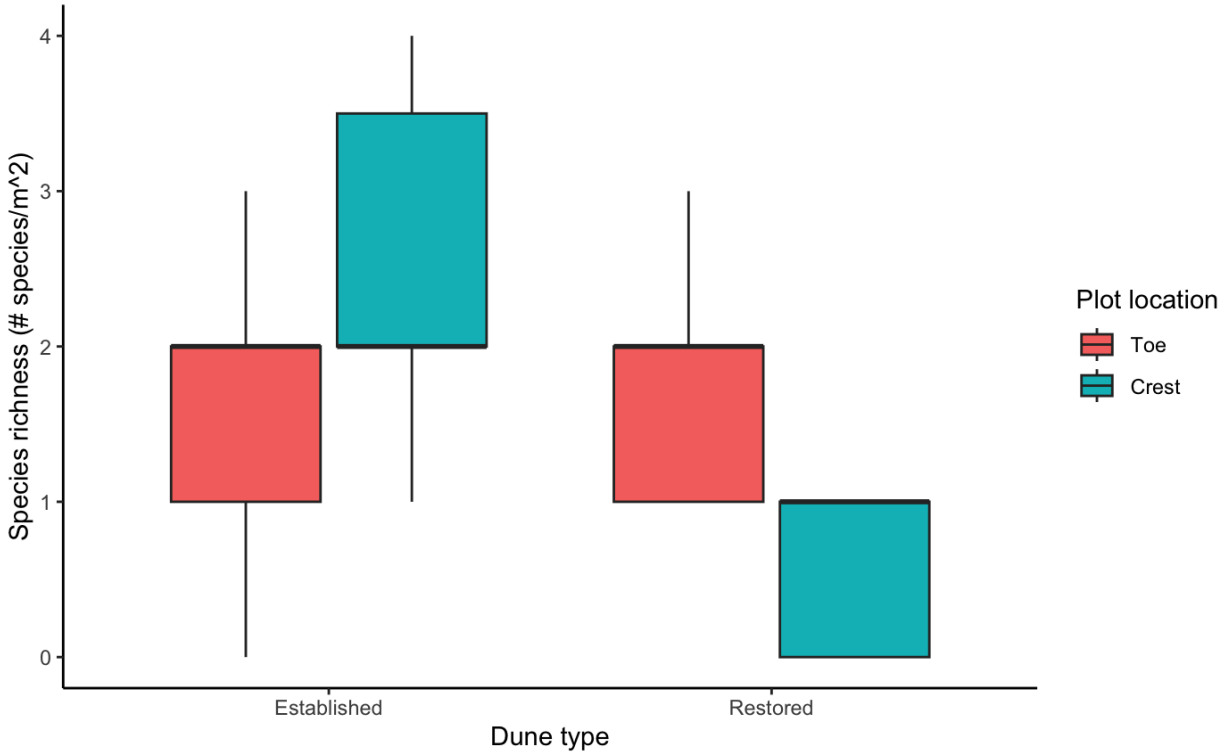

Figure 4. Species richness (# species/m^2) on June 13, 2023. A Scheirer-Ray-Hare test showed a significant effect of dune type ($H_{1,30}$ = 4.15, p = 0.042). There was no effect of plot location ($H_{1,30}$ = 2.26, p = 0.13), but a significant interaction between effects of dune type and plot location ($H_{1,30}$ = 7.77, p = 0.0053).

June 2024:

- In the plots adjacent to the established posts, the crest had nearly twice the species richness as the toe (which is expected), but there were no differences in species richness by dune type. In the plots five meters away from the posts, species richness did not differ by dune type.
- In the plots adjacent to the established posts, dune type and plot location did not differ in total percent vegetation cover. In the plots five meters from the posts, percent vegetation cover was dependent on the interaction between dune type and plot location. The established crest had the highest vegetation cover (56.29%), while the established toe had the lowest (17.86%) (Figure 5).

- Again, there were no significant differences in the cover class midpoint in the plots adjacent to the posts, but cover class midpoint was dependent on plot location in the plots five meters from the posts. Because the same results hold true using the less precise measurement of cover class midpoint, this metric can still be used as a relatively reliable comparison across years of monitoring.
- These results suggest that four years following restoration, the restored dune is supporting vegetation to the same extent as the established dune. This is important because vegetation builds and stabilizes dunes, allowing for lateral and vertical growth.

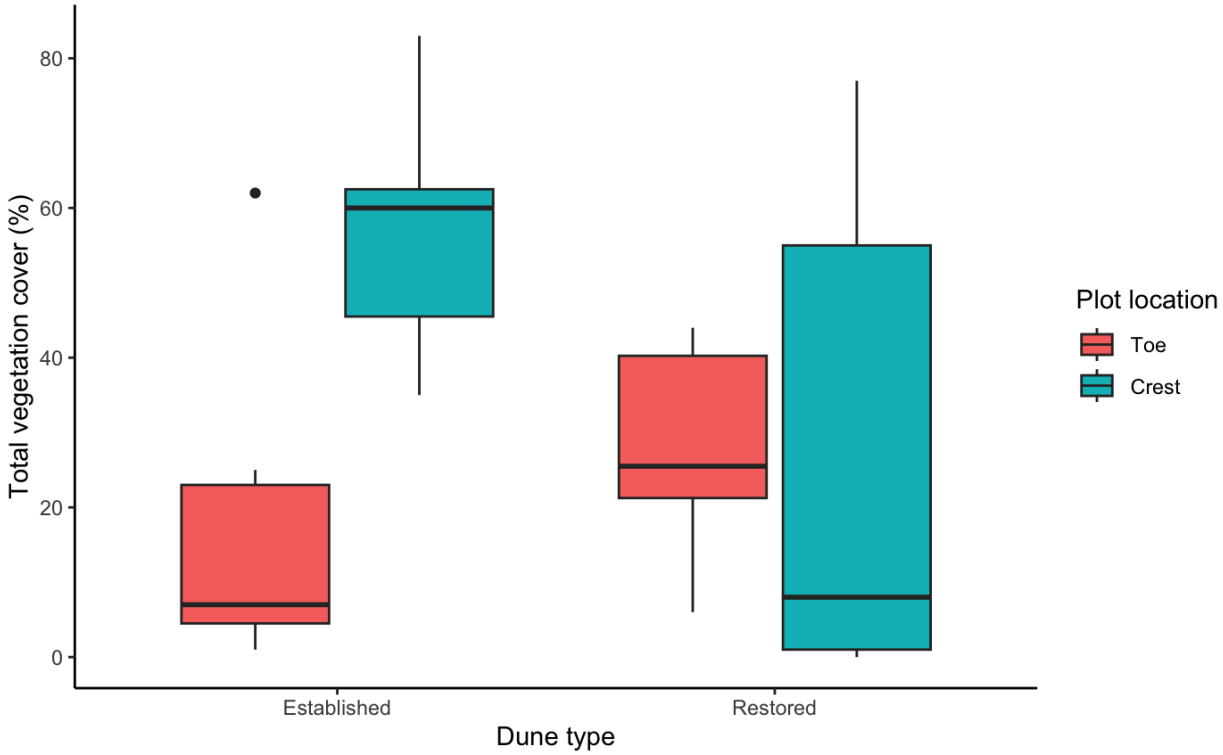

Figure 5. Total vegetation cover (%) of Tybee's dunes on June 14, 2024. A Scheirer-Ray-Hare test showed no significant effects of dune type ($H_{1,31}$ = 0.99, p = 0.32) or plot location ($H_{1,31}$ = 2.01, p = 0.16), but a significant interaction between effects of dune type and plot location ($H_{1,31}$ = 6.96, p = 0.0084).

2) Evaluate impacts of pedestrian traffic on footpaths on dune resiliency

a) Measure characteristics of dune vegetation, soil, and sand accumulation along footpaths and comparing these to adjacent undisturbed dune areas

- In August 2024, there was no significant effect of treatment (i.e., footpath edges vs. undisturbed areas) on species richness or sand movement.
- However, total percent vegetation cover was 1.25 times higher at footpath edges than in undisturbed dune areas. This is a surprising result and not consistent with a previous study, in which vegetation cover increased further away from footpaths (i.e., in less disturbed areas) (Purvis et al., 2015). A possible explanation is that dune areas that have experienced disturbance for years through the presence of a footpath have

somewhat adapted to that disturbance. In other words, the vegetation at previously established footpaths experiencing consistent trampling may not be as impacted as vegetation at newly established footpaths that had limited to no previous disturbance.
- I will conduct additional analyses to assess differences in total percent cover between treatments, specifically to see if differences exist in vegetation cover by species.

b) Measure the rate and extent of dune recovery following restricting pedestrian traffic

- There has been minimal recovery observed five months after footpaths were closed from pedestrian access. The average total percent vegetation cover at the center of closed-off footpaths is very similar to that of footpaths that were not closed off (Figure 6).
- Four months after footpath closure, there was no difference in species richness, total percent vegetation, or sand movement by treatment (i.e., control footpath edges, closed-off footpath edges, vs. undisturbed areas).
- Although it is necessary to continue taking measurements on the closed-off paths, my results over the period of observation indicate that closing paths does not necessarily promote dune recovery to the state of an undisturbed site.

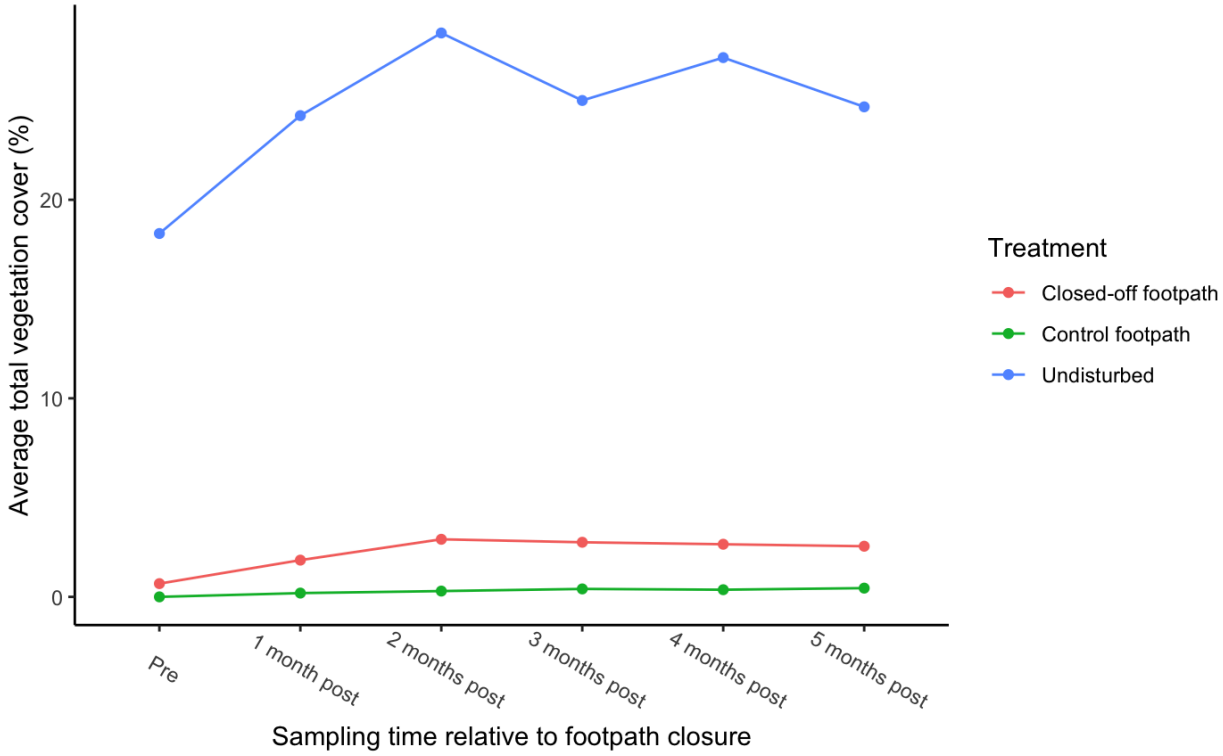

Figure 6. Average total percent vegetation cover in the center of closed-off footpaths, control footpaths, and undisturbed areas across the study period.

c) Measure the rate and severity of damage to dunes after adding new footpaths to previously undisturbed areas

- Trampling at newly created footpaths has had a significant impact on total percent vegetation cover. Figure 7 shows the change in average total percent vegetation cover in trampled and undisturbed areas as the number of tramples increased.
- After 2,000 tramples, there was no difference in species richness or sand movement by treatment (i.e., trampled and undisturbed).

- However, undisturbed dune areas had 1.58 times greater vegetation cover than trampled areas (Figure 8), suggesting that dunes in newly disturbed areas may be negatively impacted by the loss of vegetation.

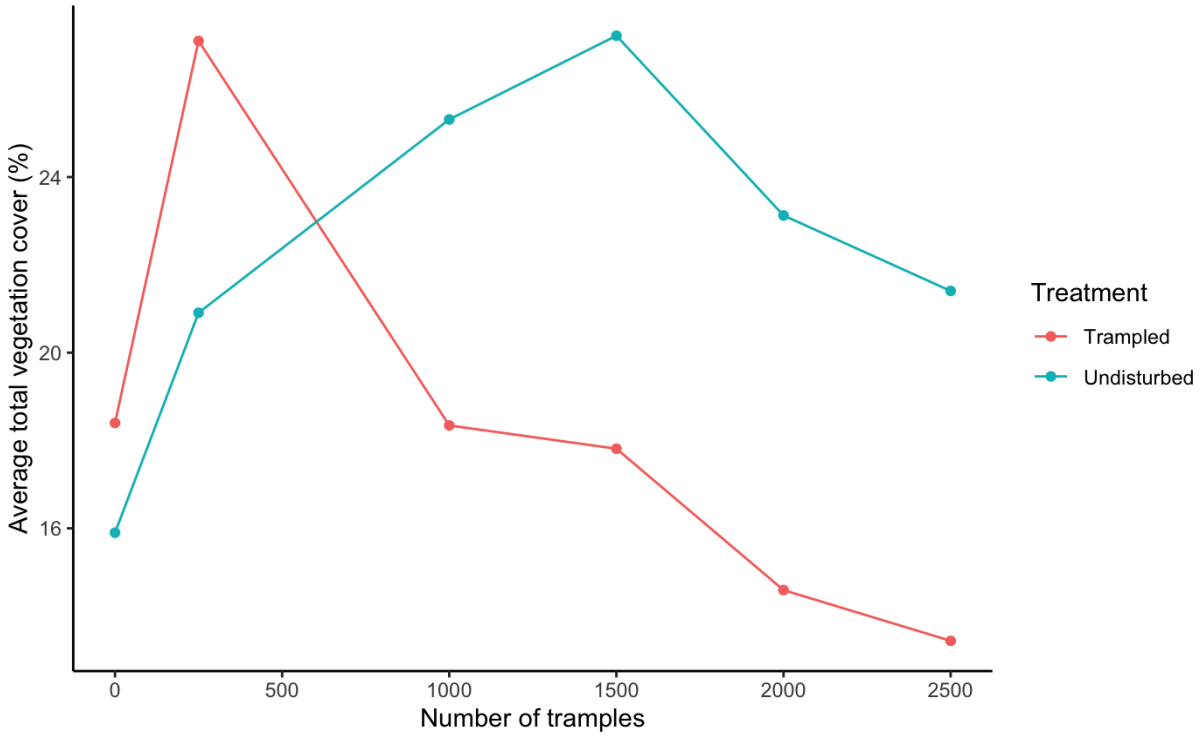

Figure 7. Average total percent vegetation cover of trampled and undisturbed areas by number of tramples across the study period.

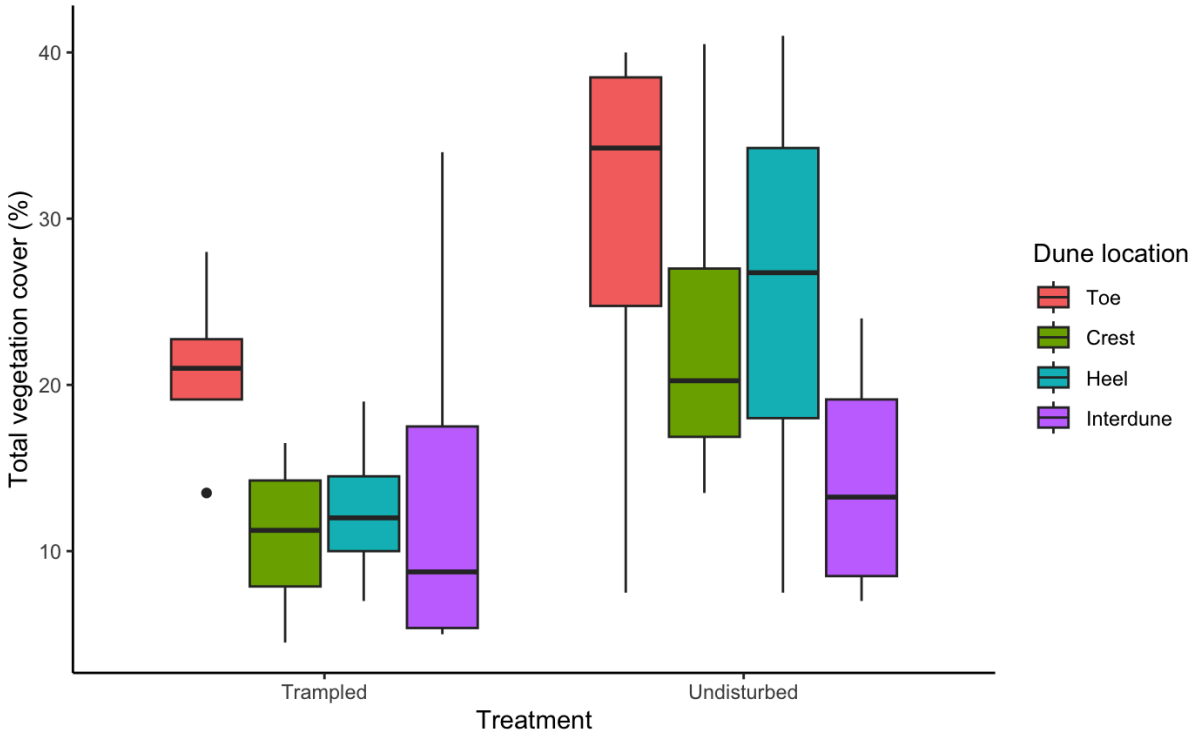

Figure 8. Total percent vegetation cover of trampled and undisturbed areas by dune location in August. A total of 2,000 tramples occurred in trampled areas prior to collecting measurements. A two-way ANOVA showed an effect of treatment ($F_{1,24}$ = 5.15, p = 0.033) but no effect of dune location ($F_{3,24}$ = 1.43, p = 0.26) and no significant interaction between effects of treatment or dune location ($F_{3,24}$ = 0.63, p = 0.6).

d) Create an ArcGIS Story Map for public viewing showing the impacts of footpaths and the importance of limiting disturbance on dunes

- Our ArcGIS Story Map is publicly available at this link: https://arcg.is/115zuy0. We would like to work with the City of Tybee to disseminate the story map on appropriate platforms.

RECOMMENDATIONS FOR MANAGEMENT

1) Implement and adapt dune monitoring protocols

- In June 2024, there were no significant differences in total percent vegetation cover or species richness by dune type. Therefore, we conclude that vegetation is being supported in the restored dune to the same extent as in the established dune. In addition to the results presented above, we have observed many new species present in the restored dune in 2024 compared to 2023, so much so that we added multiple plant species to our vegetation identification guide for our dune monitoring volunteers.
- The restored dune crest is accumulating only minimal sand, which means that it is not growing vertically. This is problematic because limited sand accumulation reduces the resilience of dunes following storm impacts and leaves these areas more vulnerable to damage.
- Since summer 2024, significant erosion has occurred in the restored dune, especially near 2nd Street. Hurricane Helene created a significant scarp on the dune, and the surf now comes all the way to the dune at high tide. Because there are still two more years until Tybee's next beach renourishment, it will be critical to continue to monitor the restored dune to determine its continued effectiveness in storm protection and natural

sand accumulation. To date, the dune has held up during two major hurricanes but was significantly negatively impacted by the second. As storm events are becoming more frequent because of climate change, it is essential that we continue to collect data to evaluate the ability of the restored dunes to provide ecosystem services.

- Because of this, we suggest that the City of Tybee continue to work with Georgia Southern University to host quarterly dune monitoring events. The two years of data collected thus far from these events have contributed to our understanding of the performance of the restored dune and will serve as a baseline for future measurements. Additionally, we have been able to engage local community members and students to help with this important initiative and educate them about dune health and Tybee's restoration project, and we would like to continue to provide these valuable volunteer opportunities to these citizens.

2) Evaluate impacts of pedestrian traffic on footpaths on dune resiliency

- Damage to dunes from pedestrian trampling and creation of new footpaths can occur relatively quickly, but it may take a longer period of time for recovery to occur.
- One reason the closed-off footpaths may not be recovering well is because people seem to be still using these paths, as evidenced by footprints in the paths when we perform our monthly data collection. Therefore, closing off footpaths and marking with signage and fencing does not completely eliminate pedestrian foot traffic. Therefore, if the City of Tybee chooses to eliminate certain footpaths, additional methods of redirecting the public will be necessary. Planting vegetation in addition to closing off the paths with signs and fencing may be more effective.
- The results reported here are preliminary, and the full project will be presented in Skyler's thesis in 2025 and shared with the City of Tybee.

REFERENCES

Findlay, A. O. (2022). *In the Face of Climate Change, Does Human Trampling Affect Dune Resilience and Alter Ecosystem Services?* (Publication No. 737) [Honors College thesis, Georgia Southern University]. Digital Commons. https://digitalcommons.georgiasouthern.edu/honors-theses/737

Purvis, K. G., Gramling, J. M., & Murren, C. J. (2015). Assessment of beach access paths on dune vegetation: diversity, abundance, and cover. *Journal of Coastal Research, 31*(5), 1222-1228.