# COMPARING BELOWGROUND CHARACTERISTICS OF NATURAL AND RESTORED COASTAL DUNES ALONG THE NORTHEAST FLORIDA (USA) COAST

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## INTRODUCTION

Highly developed coasts often comprise nature-based constructed and restored dune systems to protect critical infrastructure and support ecosystem benefits (Nordstrom et al., 2000). Yet, we often fail to capture how the below-ground properties (i.e., biomass/roots, geology, and geotechnical properties) of these reconstructed dunes vary from their natural counterparts. This is critical to understand because differences in belowground properties can result in contrasting morphodynamic behaviors and responses (i.e., erosion rates, dune recovery trajectories) (Bryant et al., 2019). The objective of this work is to quantify dune ecological, geotechnical, and geologic properties across a range of natural to recently reconstructed dunes along the northeast Florida coast. While the overall project evaluates five dune sites, this presentation will focus on two sites six (6) kilometers apart on adjacent barrier island beach-dune systems (Fig 1).

## STUDY SITES AND METHODS

The "natural" site is located within a National Estuarine Research Reserve, while the "restored" site is located along a developed coastal reach south of the reserve (Fig 1). The natural site contains a tall (6+ m above MSL) relict dune with mature vegetation (e.g., trees, shrubs, tall grasses) fronted by a shorter (3 to 4 m above MSL) vegetated incipient dune (Fig 1a). The focus of this study is on the dynamic incipient dune. The restored site was constructed in two phases. The first was a small-scale emergency dune restoration following decimation by storms in 2016 and 2017, while the second phase included a complete dune and berm restoration and vegetation planting in 2022. The current morphology is a crested dune with a stepped berm (Fig 1b).

At each site, we conducted ground penetrating radar (GPR) surveys, collected vibracores (sub-sample grain size measured from camera RGB images), used shallow soil cores (30 cm deep) to sample for below ground biomass (samples sieved, dried, and weighed), and performed dynamic cone penetrometer (DCP) tests.

## RESULTS

Grain diameter and sorting varies within and between each beach-dune system. The incipient dune at the natural site comprises poorly sorted mixed to interbedded coquina and quartz sand. The topmost layer of all cores at the natural site contained a coarse shelly lag deposit. On average, the median ($D_{50}$) grain size and sorting of samples from vibracores of the berm and upper dune at the natural site were similar (0.6 mm). By contrast, the mid-dune samples were more well-sorted and had a finer average $D_{50}$ (0.5 mm) (Fig 2).

At the restored site, the berm and mid dune comprise a mix of quartz sand and coquina similar to the natural site, but core samples from the upper dune are dominated by clean fine to medium quartz sand. The average $D_{50}$ grain size of vibracore samples of the berm and mid-dune at the restored site is 0.7 mm and 0.8 mm, respectively, while samples from the upper dune at the restored site are more well-sorted and have an average $D_{50}$ grain size of 0.3 mm.

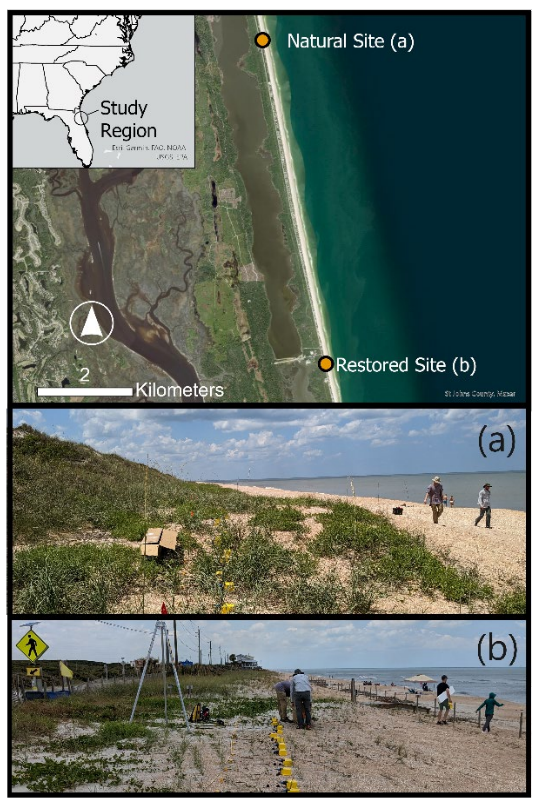


Figure 1 – Map of the study sites along the northeast Florida coast. a) The natural dune site and b) the restored dune site.

Interpretations of GPR profiles from the natural system indicate a wave-built platform with landward-dipping beds (likely a former beach cusp) overlain by a thin, vegetated aeolian cap with chaotic bedding. By contrast, GPR profiles from the restored system reveal evidence of the multi-phase construction projects. The landward-most section of the restored dune contains evidence of concave down beds possibly resulting from dumping and sculpting with an excavator. The bedding in the seaward section largely follows the angle of the surface topography, with occasional chaotic bedding.

Cone tip resistance (a proxy for shear strength) reflects these stratigraphic differences: cone tip resistance measurements in the natural berm, natural dune, restored berm, and seaward portion of the restored dune vary from 1 to 5 MPa over 10 to 20 cm increments in response to observed and inferred geological changes. In contrast, cone tip resistance in the landward (older) section of the restored dune is largely invariable (1 to 2 MPa) over 50-100 cm increments.

Below ground biomass samples from the restored site contained less biomass both by total biomass (g) and weight percent (%). On average, soil cores from the natural beach-dune system contained 0.47% (26 g) of biomass versus 0.1% (6 g) of biomass at the restored site. Within each site, we categorized samples as belonging to either the berm, mid dune, or upper dune. For the natural site, the biomass of the uppermost 30 cm was spatially distributed as follows: the berm contained 0.13% (7.3 g total), the mid dune contained 0.05% (2.2 g total), and the upper dune contained 0.38% (24.3 g total). For the restored site, the biomass of the uppermost 30 cm was spatially distributed as follows: the berm contained 0.00% (0.2 g total), the mid dune contained 0.02% (1.0 g total), and the upper dune contained 0.27% (18.3 g total)

## DISCUSSION AND CONCLUSIONS

Study results indicate key geological and geotechnical differences among the restored dune and natural dune, despite similar overall morphologies and berm sediment composition. These differences can be ascribed to their differing formational mechanisms. We infer from GPR, sediment cores, and DCP tests that the natural incipient dune formed on a former beach cusp through a mix of marine (i.e., overwash) and aeolian processes facilitated by wrack deposition and plant growth. The resulting stratigraphy is complex and multi-layered with highly-variable grain sizes. The landward portion of the restored dune, however, was constructed using fine to medium sand and any layering is attributable to anthropogenic construction methods. The seaward portion of the restored dune reflects efforts by St. John's County to select grain mineralogy and sizes more similar to the natural berm and provide for a steeper berm that tapers landward into short, flat dune similar to the adjacent beaches in the reserve.

Future work from this project will consider how differences in belowground biomass (e.g., roots) further influence the geotechnical and geological properties of natural and engineered dunes. Additional monitoring should evaluate the responses of the natural and restored dunes to the same storm event.

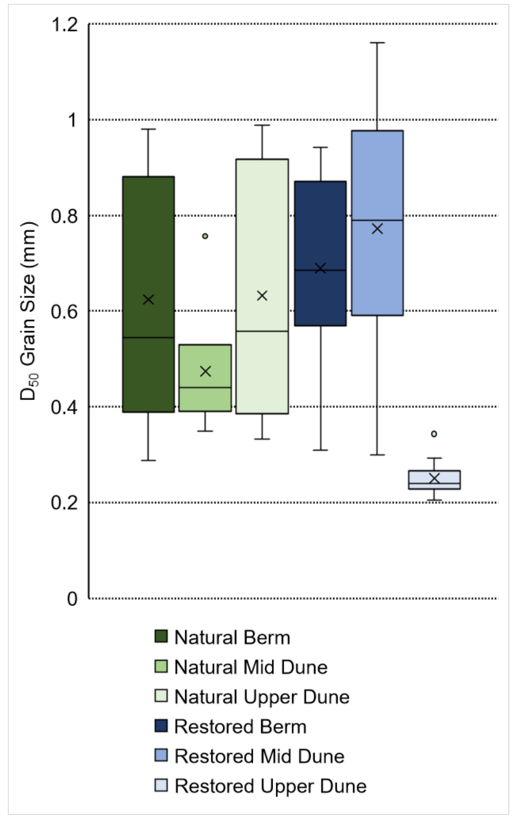


Figure 2 – Boxplots of grain size ($D_{50}$) samples from cores from the berm, mid dune, and upper dune at a natural (green) and restored (blue) beach-dune system. 'X' marks indicate the mean grain size of the samples and small dots are outliers.

## REFERENCES

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