

# Site Report: Pine Knoll Shores

*Original restoration completed in 2002*

This living shoreline project involved a collaboration between The North Carolina Aquarium at Pine Knoll Shores and the North Carolina Coastal Federation with funding from NOAA's Community Based Restoration Program, Restore America's Estuaries and the FishAmerica Foundation.

## Where, What, Why

Construction of the Pine Knoll Shores living shoreline involved the placement of a low sill of granite boulders along 100m (~430 feet) of eroding marsh shoreline. The goal of this project was **to demonstrate the value of marsh sills for defending against shoreline erosion.**



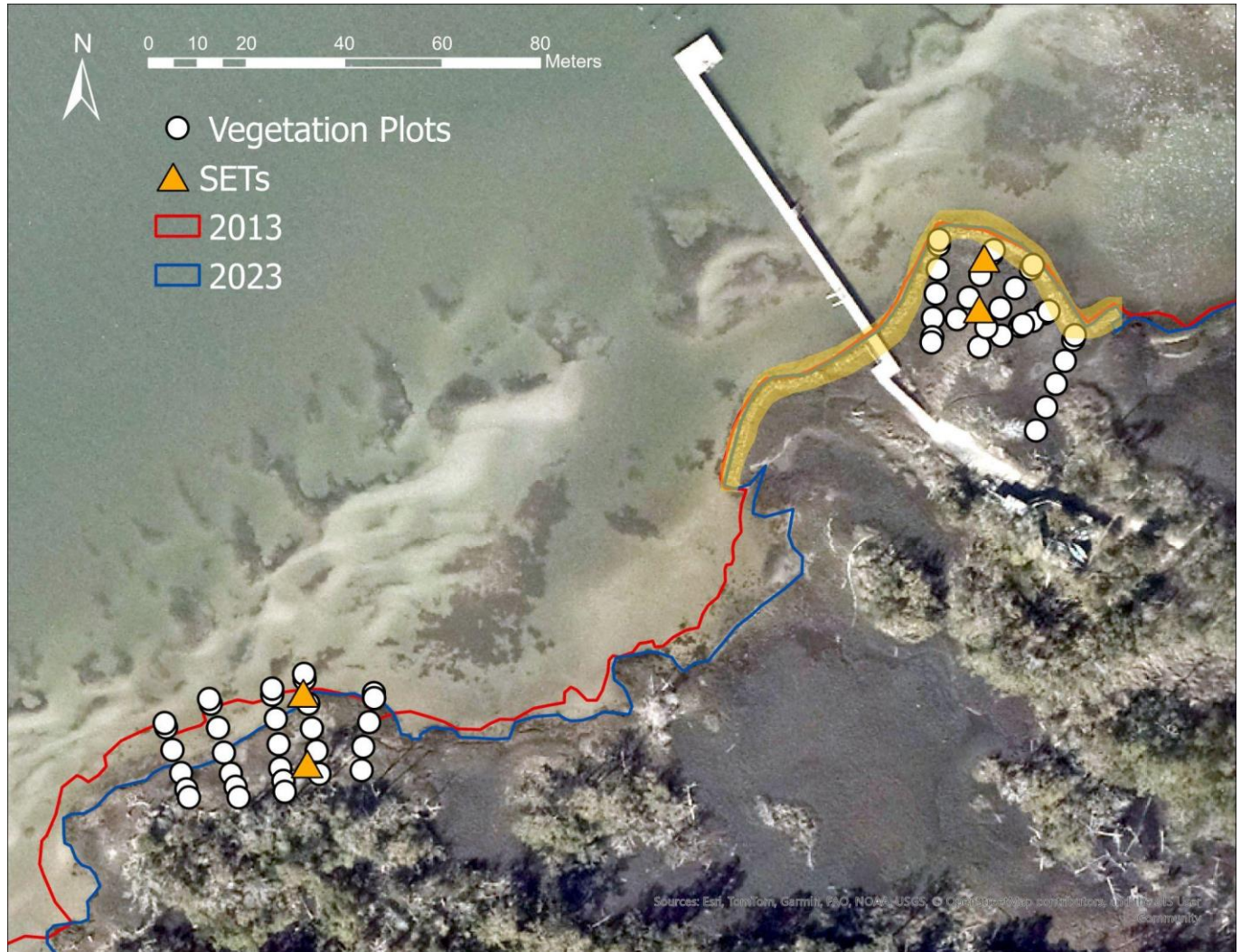
**Figure 1.** Pine Knoll Shores marsh sill living shoreline (2016).

## How

Construction involved installation of a 100 m long granite sill at the shoreward edge of the eroding marsh. The sill was built as a pyramid of granite rubble reaching just above mean sea level and included two drop downs (sections where the max sill height is ~ 1 foot lower than the rest of structure) to facilitate fish utilization of the marsh. The adjacent marsh shoreline was already vegetated, but additional plantings (1300 *Spartina alterniflora* plugs) were added as part of the construction effort.

The long-term monitoring plan for this site involves documenting vegetative community composition and total vegetative cover at 17 sampling plots behind the sill and another 19 plots in a nearby

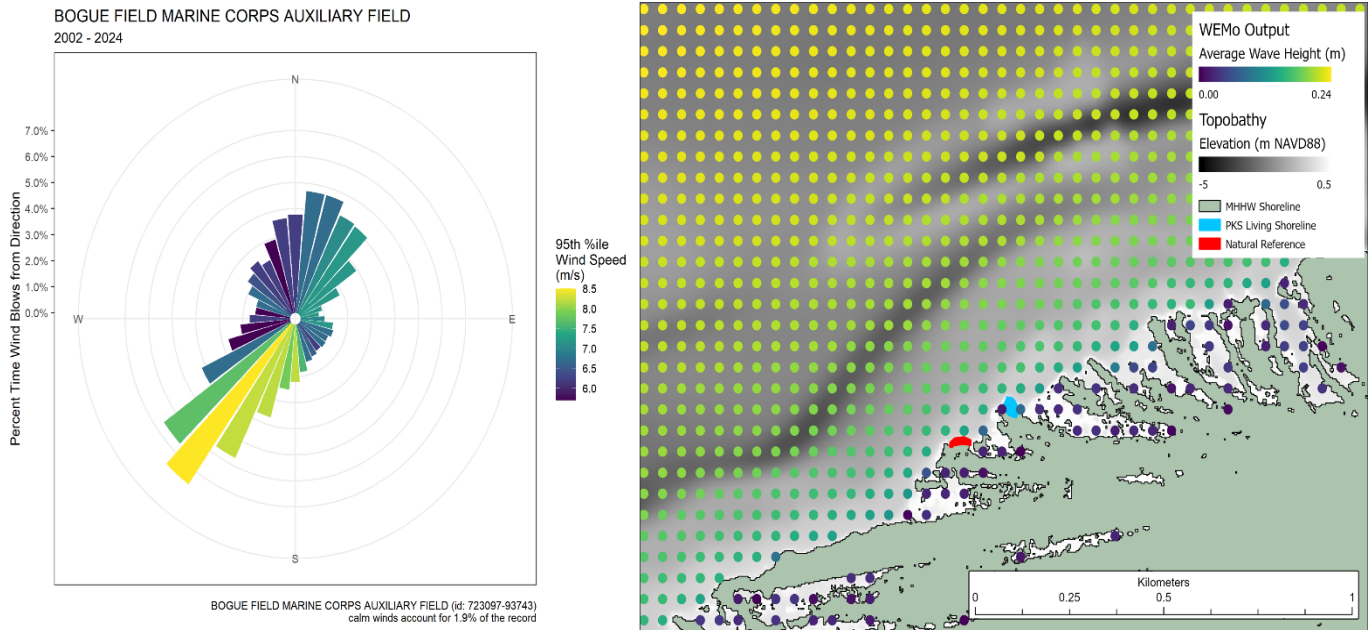
unaltered ('natural') reference site (Figure 2). In addition, four surface elevation tables (SETs) installed at this site (2 in the sill-marsh and 2 more in the reference marsh) provide the ability to track changes in elevation over time with mm scale resolution. The SET data collection began in 2004 and the vegetation data collection began in 2008.



**Figure 2.** Monitoring at PKS Sill and Natural shoreline reference sites. Red and blue lines depict the shoreline position in 2013 and 2023, respectively. White circles represent fixed locations where changes in total vegetative cover and vegetative community composition have been tracked over time. Orange triangles indicate locations of surface elevation tables (SETs). The rock sill structure is highlighted in yellow.

## Site Physical Characteristics

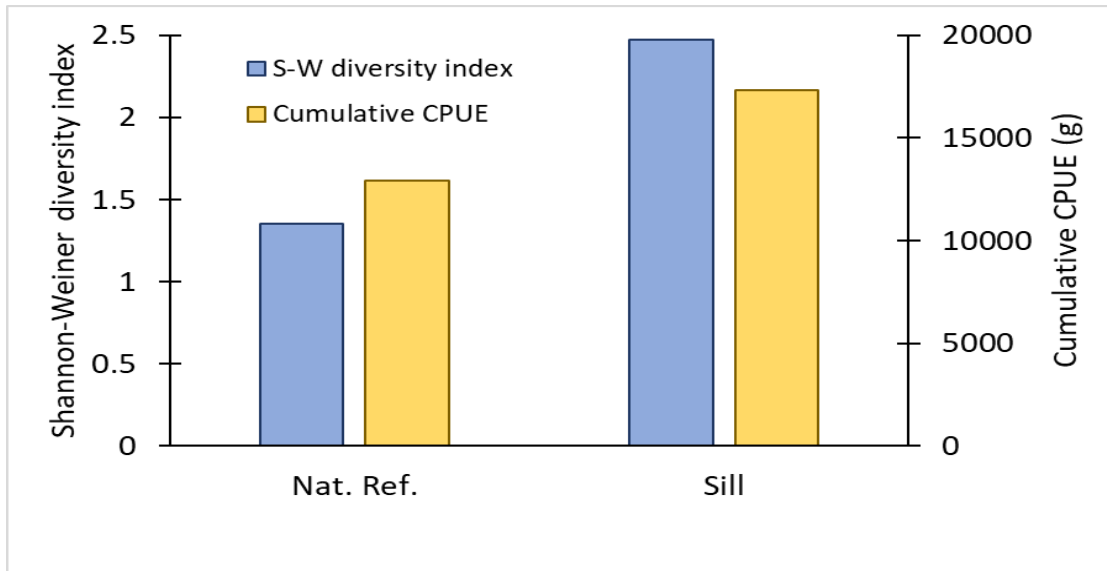
The Pine Knoll Shores project sites are on the sound side, north-facing shoreline of Bogue Sound. This location is relatively sheltered from the strongest winds which blow from the south west in this region, particularly during summer months (Figure 3). Despite this relatively sheltered position, average nearshore wave heights, modeled over the lifespan of the sill, range between 15 and 17 cm (~6 inches). The site is characterized by a tide range of 0.58 m (~23 inches) and has experienced 9 cm (3.5 inches) of sea level rise over the life of the sill (22 years).



**Figure 3.** Average recorded wind conditions over the project lifespan (left) were used to model wave heights in the vicinity of each project area using the Wave Exposure Model (WEMo, right). Colored points represent modeled wave heights within a 2 x 2 km area surrounding the project site. The Pine Knoll Shores sill is represented by the blue polygon; the natural reference site is represented by the red polygon. Gridded points are spaced 50 m apart.

## Habitat Value

A total of 24 and 18 fish and crustacean species were collected along the marsh platform and in the nearshore region of the living shoreline and natural reference marsh, respectively. Nekton sampling was conducted using multiple gear types including seines, fyke nets, and minnow traps during summer months of 2010, 2011, and 2017. The total abundance of nekton, measured as cumulative catch per unit effort (CPUE) among all gear types, as well as the diversity of species present were comparable between the sill and natural reference marsh (Figure 4). Generally, abundance of blue crab, pinfish and killifish were considerably higher at the sill, whereas abundance of anchovy was higher at the natural reference marsh.



**Figure 4.** Comparison of nekton present at the Pine Knoll Shores living shoreline (sill) and nearby natural reference marsh (Nat.Ref.). Blue bars indicate Shannon-weiner diversity index values; yellow bars indicate catch per unit effort in total grams of catch summed across sampling gears and dates.

## Performance Over Time

The marsh sill at Pine Knoll Shores aquarium has effectively held the line against erosion for the past 22 years. Wave gauges deployed waterward and landward of the sill suggest that incident waves are attenuated by up to 93%, with an average wave attenuation of 43%. At dropdowns in the sill that allow nekton passage, wave attenuation still occurs, but is reduced to an average of 30%. In addition to defending against shoreline erosion and reducing wave energy, the sill seems to be enhancing elevation gain; since 2004 when SETs were first installed at this site, the sill-protected marsh has gained elevation at an average rate of 9 mm/yr, while the reference marsh has gained at 0.5 mm/yr. Summed over the 20 years represented by the SET record (2004-2024) that results in a total elevation difference of 17 cm (~ 7 inches). Over the same time period, local mean sea level has increased at a rate of 4.5 cm/yr.

Vegetation monitoring data from this site show that the vegetative communities in the marsh sill living shoreline and natural reference marsh have tracked each other closely over time in terms of total vegetative cover and relative abundance of species present (Figure 4). In all years, total vegetative density appeared to be greater in the sill marsh than the reference marsh. This trend is partially driven by a greater relative abundance of *Spartina alterniflora*, which was planted in the sill marsh just after the sill was constructed, and partly by erosion of the vegetated edge of the reference marsh. Vegetative density declined sharply in both marsh types after 2018, the reason for this drop is currently being investigated.

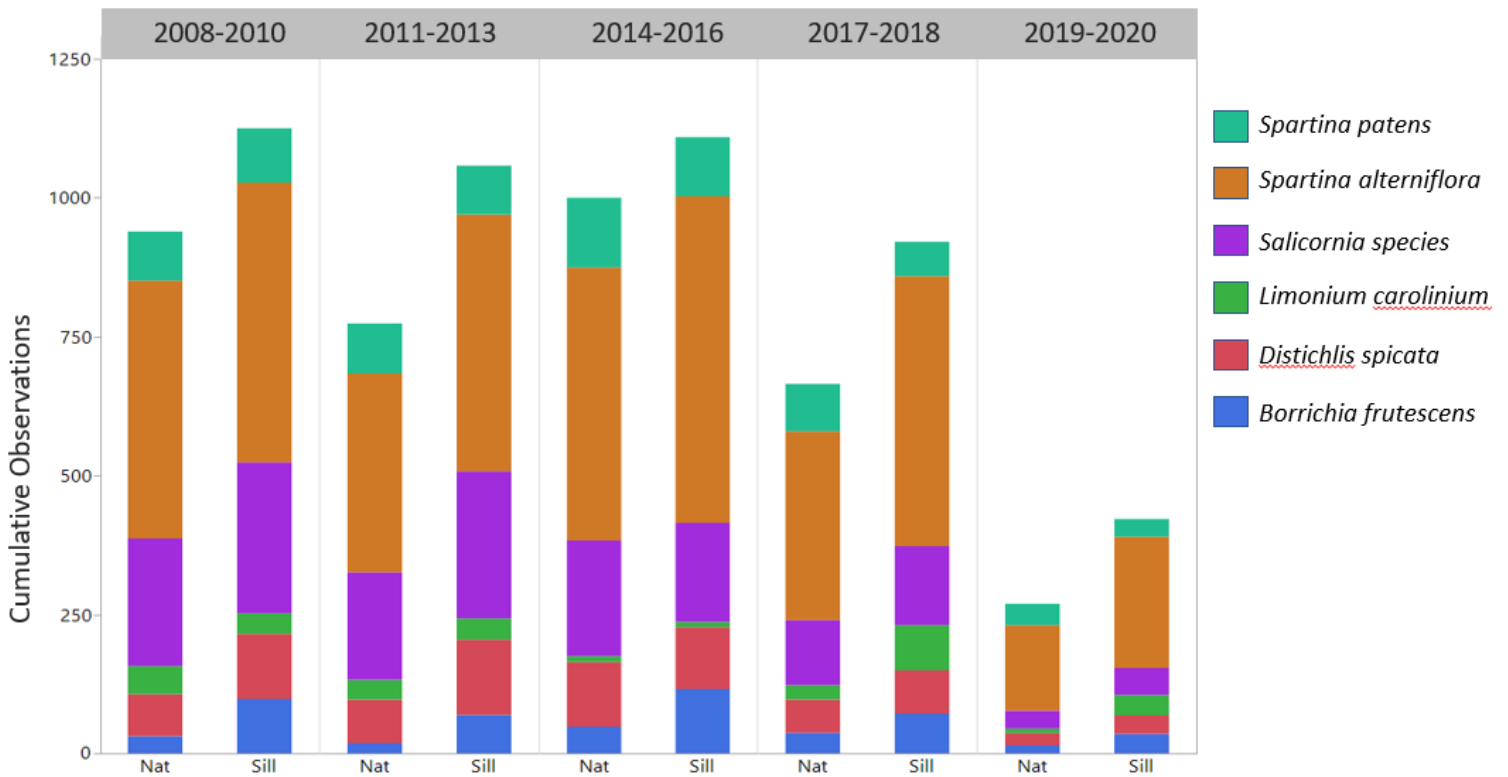


Figure 4. Vegetation monitoring data summed across all plots (28 per treatment) for each time period. Cumulative values represent the sum of recorded vegetation index (Carolina Vegetation Survey) scores and thus represent a relative measure of vegetative density.

## Performance Summary

The marsh sill living shoreline at Pine Knoll Shores has effectively attenuated wave energy and defended against erosion of the adjacent marsh for 22 years. The marsh that is protected by this sill has grown in elevation at a pace greater than that of local relative sea level rise. Presumably, this elevation gain has been fueled by resuspension of nearshore sediments by waves, and the subsequent trapping of those sediments by the sill during flood tides. The sill marsh has a vegetative community that has closely mirrored that of the natural reference marsh over time suggesting that the habitat value of the two marshes is comparable. Like other granite sills in the area, the Pine Knoll Shores sill is also heavily colonized by oysters.

Report Credit: Davis, J., Walker, Q., Puckett, B, LeClaire, A., Giannelli, R and Bost, M. (2024). Site Report: Pine Knoll Shores Original Living Shoreline. US DOC NOAA NOS National Centers for Coastal Ocean Science (NCCOS). Marsh Sill Living Shorelines.