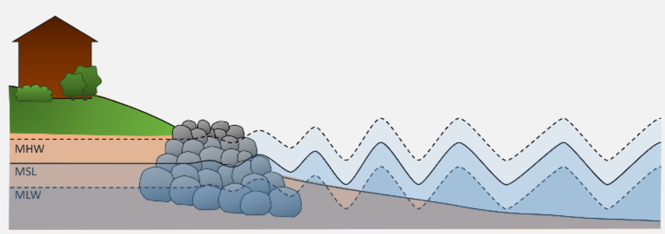
Purpose

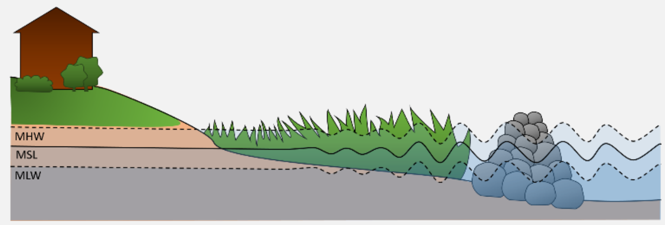
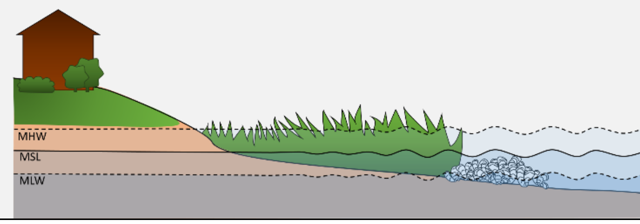
Living shorelines are an erosion control strategy that incorporate native wetland vegetation either alone, or in combination with structural elements like natural fiber logs, bagged oyster shell, rock, or wooden sills parallel to shore to provide an initial wave break. Living shorelines that include both natural and structural elements are commonly referred to as Hybrid Living Shorelines. Site-specific living shoreline design is largely a function of wave energy. The Living Shoreline application (app) allows users to visualize shoreline wave energy conditions to determine which living shoreline approach is most suitable. The tool's areal coverage extends north from the New River Estuary through Bogue, Back, and Core Sounds in eastern NC. The data included in this tool are: 1) Shoreline Wind Wave Energy, 2) Shoreline Boat Wake Energy, 3) Distribution of Natural Shoreline Marsh and, 4) Living Shoreline Suitability.

Disclaimer: This tool predicts the most appropriate shoreline stabilization strategy for a given shoreline based on wave energy conditions. Additional local factors like nearshore land use, bathymetry, topography and salinity are also important to consider when designing a living shoreline. Consult with local regulatory experts/engineers to determine site-specific design options and permitting requirements.

How It Works

A shoreline shape file available through the [North Carolina Division of Coastal Management] was converted to points with a spacing of 50 m. At each of these 50 m points (> 45,00 in study area), the shoreline wave energy inputs from wind waves and boat wakes as well as distance to the nearest natural shoreline marsh were evaluated. For each of the wave energy parameters, a given shoreline point received a value of 0, 5, or 10 depending on the specific criteria described below. Each site received a proximity to natural marsh shoreline score of 0 or 10. The scores for each layer were then summed to provide a cumulative value ranging from 0-30. The cumulative score determines the living shoreline suitability for that site as follows: living shorelines are not recommended for points with a score of 0-5 (red points on map), hybrid living shorelines are suitable for sites with a score of 10, 15, or 20 (yellow points) and marsh vegetation alone or marsh with oyster are suitable when scores are 25 or 30 (green points).

Wind	Boat	Marsh	Cumulative	Suitability Score	Suitable Shoreline Stabilization Type Examples
0	0	0	0	0 – 5 Living Shorelines not suitable	
0	5	0	5		
5	0	0	5		

Wind	Boat	Marsh	Cumulative	Suitability Score	Suitable Shoreline Stabilization Type Examples
0	10	0	10	10 – 20 Hybrid Living Shoreline	
5	5	0	10		
10	0	0	10		
0	0	10	10		
0	5	10	15		
5	10	0	15		
10	5	0	15		
5	0	10	15		
0	10	10	20		
5	5	10	20		
10	10	0	20		
10	0	10	20		
5	10	10	25	25 – 30 Marsh alone or with oyster reef	
10	5	10	25		
10	10	10	30		

<u>Wave Energy inputs in the Living Shoreline app:</u>

Wind Wave Energy Shoreline wind-wave energy was modeled using the National Oceanic and Atmospheric Administration's (NOAA) Wave Energy Model (WEMo). WEMo calculates representative wave energy (RWE = the average wave energy experienced at a site) using wind and bathymetric data. WEMo was run on a grid of points spaced at 50 m intervals and extending 200 m offshore using bathymetry data with a 20 m resolution bathymetric grid for the entire region. The 1 m tidal range in the study area was accounted for by lowering the bathymetry by 1 m (effectively raising the water level). The model was run using the top 20% (in terms of wind intensity) of hourly wind data from Cape Lookout (NDBC station CLKN7) spanning the period 2012-2015 to generate RWE_{20} values in units of J m^{-1} for each of the points in the 50 m grid. Shoreline wind-wave energy was determined from the average RWE_{20} value in a 75 m radius around each shoreline point. This approach results in a conservative estimate of the wind-wave energy experienced at a site during non-storm conditions.

Previous analyses of the RWE along stable natural marsh shorelines in the study region were used to determine the threshold range of WEMo values experienced by existing living shorelines within the study region (Currin et al., 2017). This analysis indicated that the width of natural shoreline marshes decreases dramatically in regions where shoreline RWE_{20} is > 300 J m^{-1} and further, that hybrid living shoreline approaches (that use vegetation with structural elements like natural fiber logs, bagged oyster shell, rock, or wooden sills parallel to shore to provide an initial wave break) are an effective means of shoreline stabilization at RW_{E20} values as high as 700.

Additional work by Theurkauf et al (2016) shows that settlement of oyster spat is limited along coastlines where RWE_5 values exceed 500 J m^{-1}. Based on these analysis, the scores for WEMo calculated RWE_{20} were set at:

Representative Wave Energy	Factor Score
≤ 300	10
300-700	5
> 700	0

Boat Wake Energy - Many previous research efforts have demonstrated the correlation between boat wake waves and shoreline erosion. While wind is often the dominant source of wave energy due to its more consistent nature, the impact of a single large boat wake can be substantial. It is therefore necessary to take both factors into consideration when determining the levels of wave energy that a shoreline experiences, and boat wake energy was incorporated into the tool's analysis of cumulative shoreline wave energy. Boat wake energy dissipates over distance from the vessel. Thus, the farther a boat travels from the shoreline, the less impact it has. For this tool, we weighted the impact of boat wakes on shorelines as a function of the proximity of the shoreline point to marked navigation channels.

Two primary types of boat channels exist in the study region: 1) Commercial Shipping channels like the Atlantic Intracoastal Water Way (ICW) which is frequented by large displacement hull vessels that create long period waves, and 2) Recreational channels that are too small to accommodate large vessels but are used by local boaters. Previous works have documented the height of waves at varying distances from the sailing line for vessels of a wide range of sizes (Zabawa and Ostrum 1980, Sorenson 1973). While the specific height of a wave at any distance from the sailing line is dependent on local bathymetry, these published values provide a reasonable baseline for establishing distance criteria. The analysis defined two categories of distance criteria based on these data:

Distance (m) to Recreational Channel	Distance (m) to Commercial Channel	Factor Score
< 100	< 200	0
100-200	200-500	5
>200	> 500	10

Each shoreline point was scored on proximity to the nearest recreational and commercial channel and the lowest (most conservative) of those two scores was used as the boat wake factor score for that site.

Proximity to Natural Marsh Shoreline – The presence of nearby existing marsh vegetation is a strong indicator of all of the factors that influence marsh stability. If marsh exists on a neighboring point, then there is a significant chance it will also be able to survive at the point in question barring any major differences in bathymetry or wind exposure between sites. It should be noted however that the lack of marsh nearby doesn't necessarily suggest that marsh vegetation isn't suited to the location in question, particularly along heavily modified shorelines. For this analysis, the proximity of each point to marsh was estimated using a shoreline habitat shape file from NCDCM. The marsh factor scores used in this tool are:

Proximity of Marsh Shoreline (m)	**Factor Score**
< 100	10
➢ 100	0