ASSESSING SHORELINE CHANGE AND VEGETATION COVER ADJACENT TO BACK-BARRIER SHORELINE STABILIZATION STRUCTURES IN GEORGIA ESTUARIES

Katherine Wakefield[1]

AUTHOR: [1]Post-Master's Research Associate, Oak Ridge National Laboratory, 1 Bethel Valley Road, Oak Ridge, Tennessee 37830
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Abstract. Anthropogenic stabilization of erosional shorelines by hard-armoring structures (including bulkheads and riprap structures) is used for protection of property, especially if buildings, historical monuments, cultural resources, or other infrastructure are present. The post-installation effects of shoreline stabilization structures on adjacent shorelines in the back-barrier marshes of coastal Georgia are a concern, and interest in living shorelines (soft-armoring structures) as erosion control devices has increased because of their use of natural materials and vegetation.

AMBUR shoreline analysis software was used to calculate post-installation shoreline change rates of shorelines adjacent to riprap and bulkhead structures (riprap: -0.003 m/yr, bulkhead: -0.17 m/yr; negative=erosion, positive=accretion). There was no significant difference between the post-installation shoreline change rates of the structures (Wilcoxon Rank Sum, $p=0.4$), but individually there was erosion immediately adjacent to four of the structures after installation (the end-around effect).

The shoreline change rates adjacent to riprap structures showed site-specific accretion of the shoreline adjacent to the structure and needs more study to determine if this is a representative trend for this structure type. Vegetation percent cover, stem height, and stem densities were measured in addition to shoreline change rates. There were significant differences among the mean ranks of the groups (vegetation percent cover: Kruskal-Wallis chi-squared=16.274, df=3, $p=0.0010$; vegetation stem height: Kruskal-Wallis chi-squared=21.207, df=3, $p<0.0001$; vegetation stem density: Kruskal-Wallis chi-squared=8.8625, df=3, $p=0.03118$). Analysis of vegetation showed similarities between shorelines adjacent to living shorelines and control sites. There are significant differences in vegetation cover between riprap structures and the control sites, and these results showed that installation of riprap structures significantly changes the vegetation cover of the adjacent, unprotected shorelines.

These results provide novel methodologies and initial data for determining the influence of erosion control structures on back-barrier shorelines, but it is unclear how much influence historical anthropogenic activities such as boat traffic have had on shoreline erosion in the study sites. The researcher identified limitations with available data sets so they may be changed moving forward to improve future research on back-barrier shoreline study. The results from these studies may allow for better-informed decision making about the effects of shoreline stabilization structures on adjacent shorelines.

INTRODUCTION

Coastal areas are popular places to live and are frequented by people for a number of recreational and commercial activities. Shoreline property owners sometimes face land loss due to erosion and often place structures like seawalls or other erosion control devices to reduce the threat of erosion. Shoreline stabilization structures can be used on erosive shorelines to prevent property loss and protect structures, to keep waterways open for navigation, and to prevent loss of recreational beaches. While the influence of erosion control devices on beachfront shorelines is well documented, the influence of these stabilization structures on back-barrier marshes and upland shorelines is not.

The first objective was to determine the shoreline change rates adjacent to shoreline stabilizations structures on estuarine shorelines in Georgia and determine if the artificial stabilization efforts had a significant impact on the shoreline change rates of adjacent shorelines. Shoreline stabilization structures on the oceanfront can negatively influence the shoreline change rates of the adjacent shorelines, and it has been assumed with little quantitative evidence that shoreline stabilization structures on back-barrier shorelines function the same way.

The second part of the project was to determine how the installation of shoreline stabilization structures influence the presence of vegetation on the adjacent shorelines. Back-barrier shorelines are stabilized by vegetation, and the vegetation was expected to differ between the structures and the control sites due to the end-around effect that changed the natural erosion rates of the shorelines.

METHODS

Historical aerial imagery and previously digitized historical shorelines were used to determine shoreline change rates of shorelines adjacent to six structures permitted between 1980 and 1990. The structures were chosen based on strict criteria regarding the ability to discern the structure from the imagery available and the consistent labeling of the structure among all of the data sets provided.

Area of interest plots were created to standardize the study area immediately adjacent to the structures. This allowed for consistent shoreline digitization and clipping from the shorelines and imagery available. Using Esri® ArcGIS™ version 10.2.1 and the freeware statistical program package AMBUR (Analyzing Moving Boundaries Using R), shoreline change rates were calculated for all of the area of interest plots adjacent to the 6 structures.

The vegetation analysis was field based, and vegetation data were collected from shoreline stabilization structures permitted between 1980 and 2010. A 50m by 30m grid of 5m by 5m squares was created adjacent to each shoreline stabilization structure parallel to the shoreline, and at each intersection point of the grid, percent cover, stem height, and stem density of the vegetation were recorded. These data were then grouped by shoreline stabilization structure and analyzed using Kruskal-Wallis and Wilcoxan rank sum tests.

RESULTS

The raw shoreline change rates and the associated p-values are given in Table 1. The riprap structure shoreline change regressions showed no significance as a group (R^2=0.007, p=0.159); however, the regression of riprap site Bryan S5P1 demonstrated a significant end-around effect; the rate of change immediately adjacent to the structure was more erosive than the rate of change 50 meters from the structure, and this pattern was significant (R^2=0.593, p=0.003, Figure 1a). The bulkhead structure regressions also did not show significance as a group (R^2=0.003, p=0.657). However, bulkhead site Chatham S2P2 regression showed a significant end-around effect (R^2=0.644, p=0.002, Figure 1b) as did bulkhead sites Chatham S4P1 (R^2=0.891, p<0.001, Figure 1c) and Chatham S4P2 (R^2=0. 0.527, p=0.007, Figure 1d).

There was a significant difference among the mean ranks of the structure types and controls regarding vegetation percent cover (Kruskal-Wallis χ^2=16.274, df=3, p=0.0010). The post hoc analysis of the percent cover data showed significant differences between the riprap structure and the other site types (Tables 2 and 3). There also was a significant difference among the mean ranks of the groups for stem height and for stem density (Kruskal-Wallis χ^2 =21.207, df=3, p<0.0001; Kruskal-Wallis χ^2 =8.8625, df=3, p=0.03118). Post hoc comparisons for the stem heights showed significant differences between the riprap and the control sites as well as between the riprap and the living shoreline sites. Post hoc comparisons of stem density showed no significant differences among any of the comparisons (Tables 2 and 3).

Table 1: The raw post-installation change rates (m/yr) for all transects in the shoreline change rate study. The mean shoreline change rate for all transects sampled was -0.08 (stdev=0.30), the mean of the riprap-only sites was -0.003 (stdev=0.24) and the mean of the bulkhead-only sites is -0.17 (stdev=0.33).

Transect	Bryan S5P1	Bryan S5P2	Camden S2P1	Camden S2P2	Chatham S2P1	Chatham S2P2	Chatham S4P1	Chatham S4P2	Chatham S5P1	Chatham S5P2	Glynn S1P1	Glynn S1P2
1	-0.24	-0.10	0.10	0.09	0.02	0.04	-0.90	-0.09	-0.03	-0.12	0.05	0.38
2	-0.33	-0.11	0.11	0.07	-0.01	0.07	-0.92	-0.03	-0.05	-0.15	0.02	0.38
3	-0.34	-0.12	0.07	0.08	0.07	0.07	-0.87	0.02	-0.08	-0.01	-0.05	0.48
4	-0.22	-0.16	0.08	0.05	0.02	0.10	-0.87	0.06	-0.21	0.02	-0.12	0.52
5	-0.19	-0.28	0.06	-0.03	-0.11	0.01	-0.85	0.05	-0.32	0.02	-0.25	0.52
6	-0.20	-0.28	0.05	-0.05	-0.05	0.01	-0.84	0.09	-0.52	0.04	-0.29	0.51
7	-0.22	-0.28	0.11	0.07	-0.12	0.12	-0.83	0.11	-0.41	0.04	-0.28	0.48
8	-0.19	-0.25	0.07	0.15	-0.10	0.12	-0.79	0.09	-0.39	-0.20	-0.24	0.37
9	-0.14	-0.35	0.04	0.18	-0.03	0.18	-0.71	0.04	-0.41	-0.24	-0.15	0.35
10	-0.02	-0.18	0.03	0.11	-0.08	0.17	-0.69	0.08	-0.42	-0.16	-0.16	0.33
11	-0.18	-0.18	0.02	0.16	-0.03	0.17	-0.63	0.08	-0.45	-0.16	-0.18	0.33
12	-0.13	-0.14				0.23		0.09				

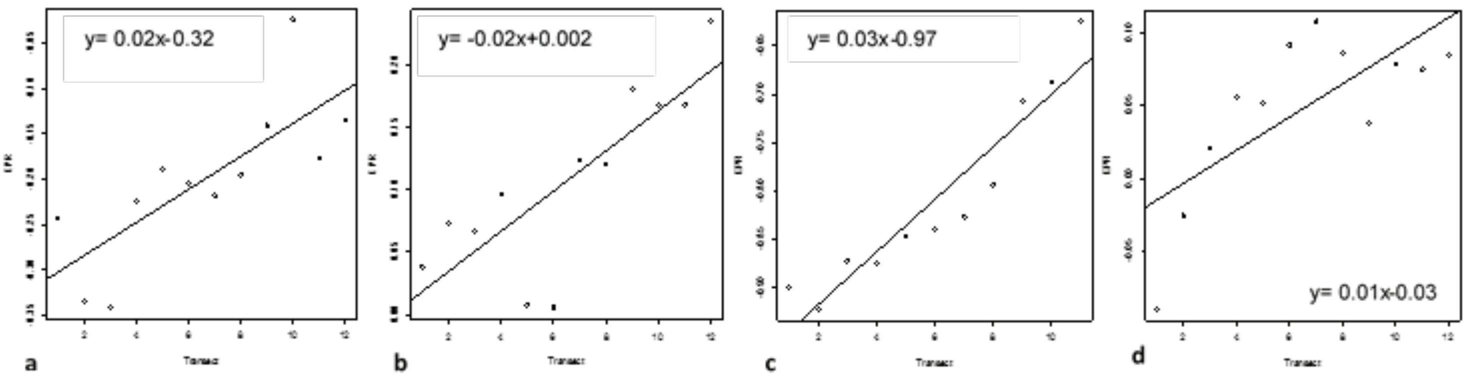

Figure 1: Selected regressions of the shorelines adjacent to the shoreline stabilization structures show four sites at which there was a significant end-around effect (a: riprap site Bryan S5P1, b: bulkhead site Chatham S2P2, c: bulkhead site Chatham S4P1, and d: bulkhead site Chatham S4P2).

Table 2: The average values and standard deviations for the vegetation percent cover, stem height, and stem density analyses. These values were collected from sample plots that were within 2 meters of the edge of the vegetation as it decreased to zero percent cover in the tidal creek.

Structure	% Cover (stdev)	Avg Stem Height (cm) (stdev)	Avg Stem Count (stems/m^2) (stdev)
Control	96.89 (8.81)	95.52 (32.18)	40.60 (24.92)
Living Shoreline	94.44 (10.49)	102.17 (46.46)	31.33 (16.42)
Bulkhead	98.38 (2.66)	74.70 (35.21)	49.23 (21.81)
Riprap Structure	70.83 (28.08)	42.00 (16.64)	56.33 (28.72)

Table 3: The p-values for the post-hoc Wilcoxan Rank Sum comparisons for the vegetation percent cover, stem height, and stem density analyses (control site n=5; living shoreline site n=2; bulkhead site n=3; riprap structure site n=3). The p-values reported have been corrected using the Bonferroni correction.

Comparison	% Cover	Stem Height	Stem Density
Riprap vs. Control	0.0018	0.0006	0.4932
Riprap vs. Living Shoreline	0.0246	0.0006	0.0960
Riprap vs. Bulkhead	0.0180	0.1128	2.6718
Living Shoreline vs. Control	2.7342	0.4440	1.6476
Living Shoreline vs. Bulkhead	4.6008	0.5820	0.1056
Control Vs. Bulkhead	4.1376	0.5634	1.0698

DISCUSSION

The installation of hard-armoring, shoreline parallel structures such as bulkheads and revetments often increases end-around erosion, the erosion of the shoreline immediately adjacent to the structure, especially on the downdrift or ebbdrift side of the structure (Jackson, 2010). The results of the shoreline change rate analysis show significant end around effects adjacent to individual structures: one riprap structures (Figure 1a) and three bulkhead structures (Figures b- d). The shorelines adjacent to the structures, if not structured themselves, are vital in protecting inland area from storm surge and sea-level rise because of the presence of marsh vegetation (Costanza et al., 2008; Moller and Spencer, 2002). These observations suggest that property owners and coastal managers should consider the implications of installing the structures and the potential for exacerbating erosion.

The vegetation percent cover on the shorelines adjacent to the riprap structures was significantly lower adjacent to riprap structures than adjacent to the other two structure types or the control plots. There were significant differences in the vegetation stem height measurements between riprap structures and both the control sites and the living shoreline sites, but there were no significant differences among the vegetation stem densities for any of the comparisons.

Riprap structures had the shortest overall stem heights as well as the highest stem density (Tables 2- 3). This shows an inverse relationship between stem height and stem density of *Spartina alterniflora* supported by previous research (Valiela et al., 1978). The shorelines adjacent to the riprap structures have a distinct lack of an erosional scarp adjacent them, and these results suggest that riprap structures could be contributing to settlement of sediment, providing more tidal-creek-adjacent area on which new *S. alterniflora* can grow (Gleason et al., 1979).

This project was intended to show the potential impacts on shoreline change with regard to the installation of shoreline stabilization structures and the subsequent influence on vegetation. Research so far has utilized remote sensing data on a large timescale, and this project focused on a smaller geographical scale within the same timeframe as well as incorporating field vegetation sampling methods. The shoreline change rate analyses suggest that the shorelines adjacent to riprap structures may be experiencing less erosion than those adjacent to bulkheads, and may even be experiencing accretion at some individual sites. These results also show that the shorelines adjacent to these hard-armoring structures are disturbed by an end-around effect on an individual basis, but the sample size is too small to make overall assumptions of the influence of the structures. The vegetation analysis shows that shorelines adjacent to the living shoreline structures are the most similar to the non-structured control sites with regard to vegetation cover. Shorelines adjacent to riprap structures have lower percent cover and higher stem densities, supporting the difference seen in the shoreline change rate analyses.

Although the structures used on the back-barrier shorelines are one of three types (bulkhead, riprap structure, or living shoreline), each shoreline stabilization structure is unique and overall patterns are difficult to discern. There is a new argument of whether soft-armoring structures (living shorelines) are a better alternative to shoreline stabilization than the hard-armoring structures that have been used for decades, and this project sets the groundwork for future study comparing the living shorelines to the hard-armoring structures. As research advances and the need for accurate shoreline change rate data increases, the influence of anthropogenic activities and erosion control devices cannot be ignored. Coastal populations continue to increase, and this necessitates the proper management and conservation of ecologically and economically important areas. Current and future researchers and managers now have a baseline for shoreline change rate data with regard to hard-armoring shoreline stabilization structures in the back-barrier of Georgia. The now-quantified effects of these hard-armoring structures provide another link between the utilization of coastal areas and anthropogenic influence on these areas.

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