

Supplemental Material

Description of the Property Owners Survey Design

In the fall of 2018, we conducted a survey of shoreline property owners in Gloucester County, Virginia. To develop our survey sample, we used property data from the county to identify a total of 3,733 privately owned waterfront parcels. We stratified these parcels along three dimensions: current type of shoreline modification, fetch, and connectivity. With respect to the first dimension, current shoreline modification, we separate properties into three categories, properties with a living shoreline, properties with another type of shoreline modification (breakwater, groin, revetment, or bulkhead), and properties with no known modification. We did this to make sure that the survey covered both those who have chosen to modify their shorelines and those who have chosen not to. Additionally, given the limited data on living shoreline adoption and the fact that they are less common than other types of modifications, we wanted to make sure that a sufficient number of properties with living shorelines were included in the survey. The shoreline modification groups were based on a review of the VMRC permit database and a 2009-2011 VIMS shoreline inventory conducted using aerial photographs and observations by boat. Figure 1 provides a description and example of the various types of shoreline modifications.

The next dimension for stratification is fetch, a proxy for wave energy, as it is the distance of open water over which wind can blow and generate waves. The amount of wave energy can affect whether shoreline modifications are necessary and the most effective modification type. For this survey, we classified parcels as high, moderate, or low fetch using the Shoreline Management Model from VIMS (Berman et al. 2017). The last stratification

dimension is ecosystem connectivity which is a measure of ability of various species to move through an environment, and is a proxy for the amount of shoreline modification in the surrounding area. For this survey, we classified parcels as high, moderate, or low connectivity based on surrounding habitat features (e.g., distance to marshes and shoreline armoring). Given these three dimensions, we have 27 strata. For the 10 strata with less than 20 parcels, all 20 parcels were included in the survey sample. For the 16 strata with between 20 and 200 parcels, we randomly selected 20 parcels to receive the survey. For the one stratum where there are more than 200 parcels, we randomly selected 10 percent of the parcels to receive a survey. Overall our survey sample consisted of 1,059 parcels.

Ideally the randomly selected sample should be roughly representative of the universe from which it is drawn. To check this, we compared the universe of the analysis to the sample universe based on the cadastral and geographic data that we have available for the entire survey. These means are presented in Table 1. For the sample, we calculated the weighted mean which adjusts for differences across the localities and strata. Of the 20 variables included, the weighted sample means are statistically different from the universe mean for only three variables, the distance from the primary structure to the shoreline, the percentage of parcels in Hurricane Storm Surge Category 1, and the years the parcel has been owned by the current owner. The means for land and improvements value, acreage, elevation, shoreline length, percent of the shoreline with a low bank, zoning, land use, number of neighbors, and the average annual hours the property is estimated to be inundated are not statistically different between the sample and the universe.

Of the 1,059 surveys sent out to property owners, 23 were returned to us by the Post Office. Of the remaining surveys, 291 were returned to us by the recipient. The majority of these, 276, were completed in whole or in part by the property owner. There were 15 surveys that

were returned to us uncompleted – typically because the intended recipient was deceased or no longer owned the property in question. Thus the survey achieved a 26 percent response rate. The lowest response rate for an individual stratum was 12 percent and two additional strata had response rates below 20 percent. However, each stratum had at least two completed surveys returned. To extrapolate our results to the overall survey universe, we created a set of survey weights that account for both the differences in the sampling rates across strata as well as the differential response rate in the various strata. More specifically, the survey weight for a returned survey is equal to the total number of sampled parcels in its strata divided by the number of properties in that strata. These weights can be used to extrapolate from the completed surveys to the sample, assuming that the completed surveys are generally representative of the strata, that is there is not a non-response bias in the completed surveys. The survey weights used in the analysis are presented in Table 2.

To determine whether the completed surveys are generally representative of the universe, as shown in Table 1 we compared the weighted means for the completed surveys to the universe means. Note that the weighted means for the completed surveys are statistically different for only three variables: percent of parcels in Hurricane Storm Surge Category 1, annual hours of inundation, and years owned. Thus there is the potential for the results from the survey to be biased towards parcels in the most affected hurricane storm surge category, parcels that experience fewer annual hours of inundation, and parcels that have been more recently purchased. However, with respect to critical variables such as property value, size, acreage, elevation and land use we have no reason to expect non-response bias.

Robustness of Results of Logistic Regressions of Shoreline Modifications Excluding Value Variables

In the paper we present the results of the logistic regression of shoreline modifications. This regression included in the paper includes two explanatory variables that measure the *Value of Improvements* to the parcel and the *Land Value* itself for 2017 based on county tax assessments. The coefficients on both *Value of Improvements* and *Land Value* are positive although only the latter is statistically significant ($p < 0.1$) which is consistent with more valuable properties having a higher net value of protection. However, as noted in the paper, one might be concerned that the value of the land and/or improvements may to some extent reflect existing modifications as some shoreline modifications such as bulkheads have been shown to increase property values. To address this concern, we also run the analysis without these two variables and present those results in Table 3. Overall, there is very little qualitative difference in the results when these two variables are excluded. While the absolute size of some of the coefficients changes, for the most part, the sign and the significance of the coefficients are unchanged. The one exception is the Structure Distance to Shore which is not statistically significant when the value variables are excluded.

Table 1: Means for the Survey Universe, Sample, and Response

	Overall Universe (N = 3,733)		Sample ¹ (N = 1059)		Responses ² (N= 276)	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Land Value	\$ 166,367	\$ 258,657	\$ 174,430	\$ 217,272	\$ 186,881	\$ 159,590
Value of Improvements	\$ 152,761	\$ 338,426	\$ 161,827	\$ 229,939	\$ 185,009	\$ 212,828
Acreage	9.5	37.3	10.3	41.7	11.5	45.1
Special Flood Hazard Area	0.97	0.17	0.97	0.18	0.97	0.18
Structure Elevation	7.5	9.5	7.9	9.5	9.2	10.5
Structure Distance to Shore	109	169	122*	170	125	162
Total Shoreline	799	3,793	745	2,812	857	3,548
Percent Low Bank	0.82	0.37	0.84	0.36	0.84	0.36
Hurricane Storm Surge Category 1	0.37	0.00	0.42*	0.49	0.44*	0.50
Hurricane Storm Surge Category 2	0.09	0.29	0.10	0.30	0.09	0.29
Hurricane Storm Surge Category 3	0.02	0.15	0.02	0.15	0.03	0.17
Hurricane Storm Surge Category 4	0.02	0.13	0.02	0.12	0.02	0.15
Conservation Zoning District	0.43	0.50	0.45	0.50	0.42	0.49
Rural Zoning District	0.04	0.20	0.04	0.19	0.03	0.16
Percent Agricultural Land Use	0.04	0.16	0.04	0.17	0.04	0.18
Percent Residential Land Use	0.72	0.42	0.72	0.41	0.73	0.39
Percent Paved	0.01	0.08	0.02	0.11	0.01	0.06
Number of Shorefront Neighbors	2.7	1.5	2.7	1.9	2.6	1.1
Average Annual Hours Inundated	437	1,175	381	1,028	285*	816
Years Owned	15.3	17.5	14.0*	14.6	12.8*	12.1
¹ Sample mean and standard deviation weighted by sample weights.						
² Responses mean and standard deviation weighted by response weights.						
*Difference between weighted mean and universe mean is statistically significant at the 95% confidence level.						

Table 2: Survey Weights Used in the Analysis, by Strata

Fetch and Connectivity Level	Living Shoreline	Armoring	No Modification
High Fetch/High Connectivity	2.00	9.42	5.14
High Fetch/Moderate Connectivity	2.83	13.93	10.00
High Fetch/Low Connectivity	5.33	15.37	10.50
Moderate Fetch/High Connectivity	2.25	4.00	10.36
Moderate Fetch/Moderate Connectivity	4.50	9.45	7.88
Moderate Fetch/Low Connectivity	3.50	5.54	6.67
Low Fetch/High Connectivity	2.13	23.33	26.96
Low Fetch/Moderate Connectivity	2.57	16.10	34.00
Low Fetch/Low Connectivity	7.50	14.73	12.93

Table 3. Results of the Logistic Analysis of Shoreline Modification Without Value Variables

Variable	Coefficient	Standard Error
Years Owned	0.31*	0.17
Conservation	0.60	0.39
Structure Distance to Shore	-0.27	0.20
Total Shoreline	0.14	0.35
Percent Moderate Wave Energy	-0.16	0.47
Percent High Wave Energy	0.10	0.55
Percent Low Bank	-0.72	0.57
Percent Natural Cover	-2.60***	0.88
Percent Agriculture Use	-3.11*	1.86
Used as Primary Residence	0.41	0.35
Reported Flooding	0.24	0.39
Reported Erosion	0.22	0.37
Constant	1.27**	0.52

*Indicates significance at 90% level, **Indicates significance at 95% level, ***Indicates significance at 99% level.

Figure 1: Shoreline Modification Options

Bulkhead

A wall placed along the shoreline between the land and the water. The plants and land above the wall do not often get wet.



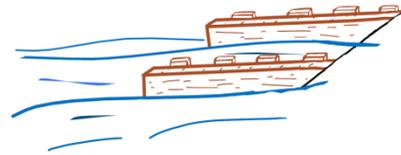
Revetment/Riprap

Rocks placed on a slope along the shoreline. The water does not often rise above the rocks.



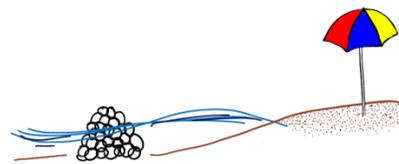
Groin

A wall that is perpendicular from the land, and goes into the water.



Breakwater

A pile (sill) of rocks placed in the water, away from the shore. The shore is a beach.



Living Shoreline

A pile (sill) of rocks, oyster bags, oyster reef structures, or fiber logs placed in front of a marsh, or in front of a planted marsh. The plants and land behind the sill get wet daily.



Shoreline Property Owner Survey

1. Please confirm that you are the owner of the property at _____.
- Yes No

If no, you do not need to complete the rest of the survey. Please send it back in the pre-addressed and stamped envelope included in your packet.

2. Is this your primary or a secondary residence? Primary Secondary

3. How long have you owned this property? Since _____.

4. Have you ever experienced flooding on your property? Yes No

If yes, was the flooding due to (check all that apply):

Storms
 "Sunny Day" Flooding

Has the flooding increased over the last year? Yes No

5. Have you noticed erosion of your shoreline? Yes No

If yes, was the erosion due to (check all that apply):

Storms Waves
 Boat Wakes

Has the erosion increased over the last 5 years? Yes No

6. What do you expect to experience in the next 5 years in terms of flooding (both storm-related and sunny-day) and erosion?
- No change
 Increase in floods and/or erosion
 Decrease in floods and/or erosion
 Don't have enough information

7. Has your shoreline been modified in any way – i.e., with a bulkhead, revetment or riprap, groin, breakwater, or living shoreline? Note that docks and boathouse are not considered to be shoreline modifications. Check all types of modifications on your property.

Bulkhead
 Revetment/Riprap
 Groin
 Breakwater
 Living Shoreline
 Other: _____

Did you add the modifications or were they in place when you bought the property?

- Made the modifications
- Some in place when we purchased, have added more
- In place when we purchased
- Modification decisions made by Condo/Homeowners Association

8. If you have not made any modifications, please indicate why not. Check all that apply. After you have answered this question, you may skip to the last question on the survey. If you have hired a contractor or made a shoreline modification, skip this question and go to question 10.

- Shoreline had already been modified and additional modifications are not necessary.
- All shoreline modification decisions are made by the Condo/Homeowners Association.
- Erosion is not a problem on this property.
- Too expensive to make the necessary modifications.
- Don't have the time to look into to options for making modifications.
- Permit process is too complicated.
- Plan to make a modification in the near future.

9. If you have hired a contractor or made a shoreline modification yourself, please list the type of modification and the approximate date it was built. (If you have made more than one, please answer for the most recent modification).

Type: _____ Year of Construction: _____

What other options did you consider (check all that apply)?

- Bulkhead
- Revetment/Riprap
- Groin
- Breakwater
- Living Shoreline
- Other: _____

Why did you make the choice that you did (check all that apply)?

- Cost
- Aesthetics
- Effectiveness
- Increase property value
- Preserve access to the water
- Similar to neighbors' shoreline
- Restore the shoreline

What factors did you consider when modifying your shoreline (check all that apply)?

- Cost
- Aesthetics
- Effectiveness
- Presence of wildlife
- Increase property value
- Preserve access to the water
- Similar to neighbors' shoreline

Did you use VMRC's General Permit? Yes No Not Sure

10. Do you think your shoreline management choices have made a difference in erosion in your area?

- No Yes, for the better Yes, for the worse.

11. Do you think your shoreline management choices have made a difference in the health of the shoreline and the Chesapeake Bay?

- No Yes, for the better Yes, for the worse.

12. If you have any other information or comments about your shoreline management decision that you would like to share with us, please so do in the space below. Thank you for your time. Your answers will help us to better understand shoreline modification and management in Virginia.