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Sarah Stafford
Dept. of Economics, William & Mary

Amanda Guthrie
Virginia Institute of Marine Science

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What Drives Property Owners to Modify their Shorelines?

A Case Study of Gloucester County, Virginia

Sarah Stafford*, Professor of Economics, William & Mary, 241 Tyler Hall, Williamsburg, VA 23187

Amanda G. Guthrie, Doctoral Student, Virginia Institute of Marine Science, William & Mary, Davis Hall, Gloucester Point, VA 23062

Abstract: This analysis uses data from a survey of shoreline property owners combined with data on shoreline modification permits to examine whether and how property owners modify their estuarine shorelines. We find that shoreline armoring is very popular among property owners that choose to modify their shoreline. While living shorelines are less common, applications for them are increasing both in absolute numbers and as a percentage of all shoreline modification requests. A number of different issues factor into the shoreline modification decision including effectiveness, cost, aesthetics, and property values. More valuable parcels are more likely to be modified, as are parcels that have been owned longer. Parcels with a high percentage of natural cover or agricultural use are less likely to be modified. Parcels with primary structures that are closer to the shoreline are more likely to have some sort of armoring. Regardless of their choice of shoreline modification, almost all survey respondents believe that their choices have had a neutral or positive impact on erosion and the health of the Chesapeake Bay.

Keywords: Shoreline Armoring, Living Shorelines, Erosion, Survey, Property Owner

* Corresponding Author: slstaf@wm.edu, 757-221-1317

1. Introduction

Coasts have long been locations of human settlement due to the resources and opportunities they provide. Expanding urbanization and increasing population density along coasts have been negatively impacting coastal ecosystems across the globe for decades, if not centuries, as humans modify the shoreline to serve their needs (Dugan et al. 2011). Climate change and accompanying sea level rise (SLR) are exacerbating these impacts, which has resulted in increased erosion, shoreline retreat, and habitat loss (Gopalakrishnan et al. 2018). In response to these to these changing conditions, humans continue to modify the shoreline to protect existing development and to allow for new development. In areas with strong individual property rights, shoreline property owners can choose from a number of different management options to mitigate erosion and shoreline loss. These individual choices can have significant implications not only for the property owners' property but also for neighboring properties and the larger ecosystem in which the property lies (Dugan et al. 2011).

This paper focuses on the modification decisions of shoreline property owners in coastal Virginia. Over the past 80 years the sea level in coastal Virginia has risen more than 0.3 m and it is projected to rise an 0.5 m by 2050 (Boon and Mitchell 2015). As a result of this and increasing severity and frequency of storm events due to climate change (Webster et al. 2005), coastal Virginia has experienced significant shoreline loss and will continue to do so in the future. The area is also home to a large population with significant investments in real estate. One recent estimate found that over 50,000 homes, totaling over $17 billion in property value, sit on land less than 1.5 m above the current

high tide line (Strauss et al. 2014). To protect their property, many property owners have or will modify their shorelines.

Under the Virginia Tidal Wetlands Act (Va. Code §28.2-1300 et seq.), Virginia protects wetlands and shallow water habitat due to the numerous ecosystem services they provide. Therefore, shoreline property owners must obtain approval from the Virginia Marine Resources Commission (VMRC) before undertaking any shoreline modifications. This analysis uses information from a survey of shoreline property owners as well as VMRC permit applications to analyze property owners' shoreline modification choices.

We focus our analysis on Gloucester County, Virginia, located at the mouth of the York River as it flows into the Chesapeake Bay about 40 miles northwest of Norfolk, Virginia. Gloucester has over 600 miles of shoreline on tidal creeks, rivers, and the Bay with various shoreline modifications that have been implemented over the last 30 years (VIMS 2016). Empirical and policy insights from this study should have relevance for other similar locations within the Chesapeake Bay as well as estuarine settings with strong individual property rights in the U.S. and other countries.

The remainder of the paper is organized as follows: Section 2 provides background on shoreline management choices and the related literature; Section 3 describes the survey and permit data that we use to examine the factors that drive property owners to choose various shoreline modifications; Section 4 presents the results of the survey and our analysis of the drivers of the modification choice; and Section 5 provides and discussion of these results and concludes.

2. Shoreline Modifications

66 Shoreline recession and loss in the Chesapeake Bay is affected by natural and
67 anthropogenic coastal erosion and SLR (Hardaway and Byrne 1999, Sallenger et al.
68 2012). Gradual shoreline erosion is due to wave action – either from wind-driven waves
69 or boat wakes (Leonardi et al. 2016, Bilkovic et al. 2017a). Shoreline erosion can also
70 occur during hurricanes or Nor'easters resulting in immediate changes to the shoreline
71 (Leonardi et al. 2016). In response to both gradual and sudden shoreline erosion, property
72 owners may undertake some form of shoreline management to mitigate further shoreline
73 loss.
74 Armored shorelines, such as bulkheads or riprap revetment, are engineered
75 infrastructure that hardens the shoreline to prevent erosion.[1] Bulkheads are vertical
76 structures that run along the shoreline and are often backfilled to create a flat surface
77 leading up to the structure. Although bulkheads are perceived as durable structures, they
78 can be damaged in large storm events (Smith et al. 2017). Moreover, they often increase
79 the rate of coastal erosion locally and decrease habitat quality for estuarine species
80 (Bilkovic et al. 2006, Dugan et al. 2011, Ells and Murray 2012). Riprap revetments are
81 typically sloping structures along the shoreline made of stone and used in conjunction
82 with a graded bank to withstand waves, dissipate wave energy, and reduce wave scour.
83 They have also been shown to reduce fish habitat quality (Balouskus and Targett 2018).
84 Other potential shoreline modifications include groins (wooden structures perpendicular
85 to the shoreline) and breakwaters (high-profile rock sills offshore). Such structures do not

[1] Examples of the various types of shoreline modifications are presented in the On-Line Supplemental Material.

directly harden the shoreline, but disrupt wave energy patterns and may increase erosion downstream of the structures (Komar 1983).

In contrast to those shoreline management options, living shorelines stabilize the shore through restoration of natural shoreline habitats, and can utilize both non-structural and structural elements (Bilkovic and Mitchell 2017b). Non-structural elements can include bank grading and planting marsh cord grasses, such as *Spartina alterniflora* and *S. patens*. Low-profile structural elements can be used in conjunction with the non-structural elements, and are often comprised of rock or oyster shells that are placed parallel to the shore in front of a marsh edge or vegetated area. Often added plants are used to augment existing or establish new vegetation (VIMS 2005). Living shorelines are not expected to significantly impair natural processes occurring at the land-water interface and they have been shown to attenuate wave energy better than armored shoreline structures (Gittman et al. 2014).

In Virginia property owners must obtain approval from the VMRC before undertaking any shoreline modifications. Additionally, the Virginia Tidal Wetlands Act allows local governments located in the coastal zone to voluntarily assume the primary responsibility for approving shoreline modification applications through a citizen wetlands board overseen by VMRC. Currently, 34 counties and cities and two towns have created local wetland boards to review permit applications. In the twelve localities that have not created such boards, the VMRC acts as the permitting authority. Because other entities may have jurisdiction over particular parcels and/or types of modifications, property owners submit a Joint Permit Application (JPA) to VMRC who forwards it to the local wetlands board and to the Virginia Department of Environmental Quality

(VDEQ) and the U.S. Army Corps of Engineers if necessary.[2] The local wetlands board and staff members (or VMRC, depending on the jurisdiction) review the proposed activities and conduct a site visit. Once the application has been examined, the board holds a public hearing before making its decision to approve the project as requested, to approve the project with modifications, or to deny the application.

The Virginia legislature also tasked the Virginia Institute of Marine Science (VIMS) with providing technical assistance to help the boards effectively balance public and private interests. However, this assistance is advisory only and in practice boards tend to favor allowing the property owner to protect his or her property with the approach requested rather than the approach recommended by VIMS. For example, a 2012 study of the decisions made by wetlands boards and the VMRC between 2009 and 2010 revealed that while slightly less than half of all applications were consistent with VIMS recommended management option, less than three percent of all applications were denied by wetland boards or VMRC (VIMS 2012).

There are a number of existing empirical studies that examine shoreline property owners' management choices due to SLR, although to our knowledge, no other papers have focused on Virginia shorelines. Many of the existing studies use economic analyses to determine the impact of management choice on property values (Landry et al. 2003, Dundas and Lewis 2018, Walsh et al. 2019). In contrast, the focus of our study is the examination of the owner's management choice itself, not the consequences of that choice. There are a handful of existing studies that also examine the shoreline

[2] The VDEQ addresses activities that may be regulated by the Federal Clean Water Act. The U.S. Army Corp of Engineers addresses dredge and fill operations in wetlands and activities affecting navigation.

management decision of owners including Scyphers et al. (2015), Beasley and Dundas (2019), and Peterson et al. (2019).

Scyphers et al. (2015) study owners' shoreline management choices in an estuarine environment – Mobile Bay, Alabama – based on a survey of waterfront property owners. The survey had a 36 percent response rate, but given a lack of available data on the universe of property owners from which their survey sample was drawn, the authors were not able to determine the extent to which their survey suffers from non-response bias. Among survey respondents, over 80 percent had a shoreline modification and the most common type of modification was a bulkhead, which was present at over 70 percent of respondents' properties. Revetments, the next most common structure, were present at just over 6 percent of all properties. Bulkheads were perceived as the most "effective and durable" option but were also believed to be the most environmentally harmful. Natural shorelines were considered to be the most attractive but also to require the most annual maintenance. Interestingly, based on the respondents' answers to questions about the cost of their modifications, the authors found that in practice, bulkheads were the most expensive option. The authors also found that the factor that best predicted a respondent's shoreline modification was the type of modification at the neighboring property.

Beasley and Dundas (2019) examine property owners' decisions to modify oceanfront coastlines in Oregon. Their study uses data on oceanfront parcels including type of shoreline modification, parcel value, lot size, elevation, erosion rates and other geomorphological characteristics but does not include survey responses from owners. The authors construct an annual panel of data from 1990-2015 and find that, as expected,

parcels at lower elevation and parcels with higher levels of erosion are more likely to armor. The authors also find that the value of the parcel affects the modification decision as more valuable parcels are more likely to be protected by armoring. Additionally, echoing the findings of Schyphers et al. (2015), they find that owners are more likely to armor if their neighbors have done so and that the neighbor's decisions tend to dominate the other factors in their model.

Peterson et al. (2019) study the environmental and socioeconomic factors that drive armoring along the Georgia coastline. The authors use data from a census of armoring along the Georgia coast, environmental and cadastral data, and surrounding housing and population density data to conduct their analysis. They find that larger properties, properties with shallower slopes, properties with higher erosions rates, properties with shorter shorelines and properties with higher building values are more likely to armor. Like Schyphers et al. (2016) and Beasley and Dundas (2019), the authors also find that the presence of armoring at neighboring parcels is an important predictor of armoring. The authors estimate that continued SLR and population growth will trigger additional hard armoring in the future.

This paper builds on the contributions of these existing studies by combining survey responses with geomorphological and cadastral data to examine the choice of shoreline modifications in an estuarine setting. Our analysis confirms some results of these existing studies and provides some new contributions. Importantly, our examination provides new insights into the factors that drive adoption of living shorelines as a modification choice – something which the earlier studies were unable to do.

3. Data Used in the Analysis

One of the primary sources of data on shoreline modifications in Virginia is the VMRC permit database which provides information on all shoreline modification permit applications from 1972-2017, including the owner's modification choice, the application date, and the decision of the wetlands board and/or VMRC. [3] We combine this information with cadastral data provided by Gloucester County (which includes property assessments and building information) using the location of the property covered by each permit. Unfortunately, the permit application does not require the applicant to explicitly identify the latitude and longitude of the proposed work. Thus, some applications had to be linked to specific parcels using a range of information on the applications such as the name of the applicant or the name of adjacent property owners. Of the 1,167 permits, we were able to geolocate 1,012 or about 85 percent.

Given the geolocation of each property, we determined the name of the current property owner, the zoning classification, the size of the lot, the current assessed value of the land and any improvements, and the coordinates of the primary building on the parcel (Wilson 2017 unpublished data, Gloucester County 2017 unpublished data). Combining this data with the Shoreline Management Model constructed by the Center for Coastal Resources Management, and a road and parcel flooding assessment (Berman et al. 2017, Braff 2017 unpublished data), we determined the distance from the closest building to the shoreline, the land elevation for the closest building, the type of land cover on the parcel, the length of the shoreline, the fetch of the shoreline, hours of inundation, and the height of the bank.

[3] These data are available on-line at https://webapps.mrc.virginia.gov/public/habitat/.

198 We combined this objective data with data from a survey we conducted in 2018 of
199 shoreline property owners.[4] The survey asked property owners basic information about
200 the use of the property, how long the property has been owned, the owner's experience
201 with erosion and flooding on the property, and the owner's expectations about future
202 changes in flooding and erosion. We also asked owners about the types of shoreline
203 modifications in place on their property, the reasons for making (or not making) a
204 modification, and the factors they considered in choosing a modification. Finally, we
205 asked the owners of their opinion as to the impact of their shoreline modification choice
206 on the neighboring shoreline and the health of the Chesapeake Bay. The survey achieved
207 a response rate of 26 percent, with 276 surveys completed by the property owner. To
208 extrapolate our results to the overall survey universe, we created a set of survey weights
209 that account for differences in the sampling rates and responses rates for parcels in the
210 survey. To assess the potential for non-response bias, we examined whether there are
211 statistically significant differences between respondents and the overall universe. As
212 discussed in detail in the on-line supplemental materials the results suggest no
213 statistically significant difference with respect to critical variables such as property value,
214 size, acreage, elevation and land use. However, there are statistically significant
215 differences ($p<0.05$) for three variables, hurricane storm surge category, parcels that
216 experience fewer annual hours of inundation, and parcels that have been more recently
217 purchased, which could potentially bias some of our findings. Unfortunately, we do not
218 have demographic data on either the survey universe, that is shoreline property owners,

[4]A detailed description of the survey design and a copy of the survey is included in the On-Line Supplemental Material.

219 or on the survey respondents. Existing data sources do not provide such data at the level
220 required to identify shoreline property owners due to privacy concerns. Sine we did not
221 have the data to compare the survey respondents to the overall universe with respect to
222 demographics and we were concerned that requesting such data might discourage some
223 from completing the survey, we did not ask respondents to provide such information.
224
225 **4. Survey and Analysis Results**
226 The survey asked property owners to identify the types of shoreline modifications
227 in place on their property. Because we deliberately oversampled living shorelines, we
228 used weights to extrapolate the survey responses to the survey universe of shoreline
229 properties to estimate expected shoreline.[5] As shown in the top bar of Figure 1, the
230 percentage of properties expected to have unmodified shorelines is just over 51 percent
231 and the percentage of properties expected to have living shorelines either alone or in
232 combination with other modifications is 11 percent. The expected percentage of
233 properties with some form of armoring is about 45 percent including the 7 percent of
234 properties with both armoring and living shorelines. These results differ from those of
235 Scyphers et al. (2015) who found that just under 20 percent of their Mobile Bay,
236 Alabama respondents reported unmodified shorelines and over 70 percent of respondents
237 had bulkheads. While revetments are the most common type of stand-alone modification
238 reported in Gloucester, only around 7 percent of the Mobile Bay respondents reported
239 revetments.

[5] The weights used to extrapolate our estimates are presented in the On-Line Supplemental Material.

We asked owners with unmodified shorelines to identify the reasons that they had not modified their shoreline. About half of the 106 respondents with unmodified shorelines stated that shoreline modification was not necessary for their property, even though almost one fifth of them stated that they had experienced erosion on their property. About one-quarter stated that the cost of modifications had prevented them from making changes while about 8 percent stated that they didn't have the time to make modifications and 8 percent cited the permit process as an impediment to making modifications.[6] However almost 15 percent stated that they planned to make modifications to their shorelines in the near future – all of these respondents indicated that they had experienced erosion on their property.[7]

For the 170 respondents whose shoreline have been modified, we asked whether the modifications were in place when the property was bought or whether the owner made the modifications. Figure 2 shows the unweighted responses to this question by modification type. Almost 70 percent of the respondents with living shorelines on site (either alone or in conjunction with some other modification) added the living shoreline themselves. In contrast, about 75 percent of owners with stand-alone bulkheads on their properties bought the property with an existing bulkhead compared to only 25 percent who added a bulkhead to an unmodified shoreline. Approximately 60 percent of respondents with stand-alone revetments were responsible for adding them to unmodified shorelines and almost 80 percent of owners with stand-alone breakwaters added them. This is consistent with the trends in shoreline modifications permits across time in

[6] Owners could identify multiple reasons for not making modifications.
[7] About 15 percent of the owners without modifications chose not to provide any reasons for why they had not made any shoreline modifications to date.

Gloucester. As shown in figure 3, in the 1970s most of the permit applications were for bulkheads but by the late 1980s less than half were. In the mid to later 1990s revetments were the most popular type of modification with living shorelines only entering the mix in the early 2000s. In more recent years, living shorelines have typically accounted for about one-third of permit requests.

The survey asked property owners who had modified their own shoreline to provide additional details about their most recent modification including why they had chosen the modification that they did. The options included cost, aesthetics, effectiveness, increased property value, preserving access to the water, similarity to the neighbors' shoreline, and restoring the shoreline and respondents could select more than one explanation. Of the 127 respondents who had made modifications to their property, 104 provided answers to this question. Figure 4 shows their answers broken out by the most recent modification made.

Across the board the most commonly cited explanation for choosing a particular modification type was effectiveness. For all modifications other than stand-alone living shorelines, effectiveness was the most popular reason for picking that modification choice. While about 70 percent of stand-alone living shoreline owners also cited effectiveness as a critical factor, the most popular reason for putting in a stand-alone living shoreline was to restore the shoreline with about 90 percent of respondents citing that factor. Restoring the shoreline was also popular for owners with living shorelines combined with armoring and for mixed armoring, but was less popular with owners of stand-alone bulkheads, revetments, and breakwaters. Aesthetics were more important for owners with living shorelines than owners with other types of modifications. Finally, for

all modifications other than breakwaters, between 30 and 45 percent of owners cited cost as an important factor.

One consistent funding of existing studies of shoreline modifications is that a neighbor's modification choice is highly correlated with an owner's modification choice (Scyphers et al. 2015, Beasley and Dundas 2019, and Peterson et al. 2019). Using data from a shoreline modification inventory conducted between 2009 and 2011 (Berman et al. 2017), we examine the relationship between the modifications on the survey respondent's property and modifications at neighboring properties and find that this pattern holds true for armoring in our survey as well, as about two-thirds of properties with bulkheads have neighbors with bulkheads and just under two-thirds of properties with revetments have neighbors with revetments. This relationship is less strong for groins and breakwaters where fewer than one-third of properties have neighbors with the same modification. However, for living shorelines, none of the survey respondents have neighbors with inventoried living shoreline. This may be due to the fact that living shoreline do not show up on aerial surveys as well as other modifications or that the inventory was conducted in 2011 prior to most living shorelines being installed. Although there is a statistical correlation between neighboring shoreline modifications, interestingly, only 20 percent of respondents cited a neighbor's modification as an important factor in their decision. This suggests that there may be other factors that are driving the statistical correlation between neighboring modifications such as underling geophysical conditions or shared information networks which independently lead to the same choice.

306 The final part of the survey asked respondents to respond to two questions, first
307 whether they thought their shoreline management choices had made a difference in
308 erosion in their area and second whether they thought their shoreline management
309 choices had made a difference in the health of the shoreline and the Chesapeake Bay.
310 The purpose behind these two questions was to determine whether respondents believe
311 that their personal decisions have a positive or negative impact on the larger system.[8]
312 Figure 5 presents their answers, broken out by shoreline modifications, in the top two
313 panels. For each type of modification, at least half of the respondents stated that their
314 modification(s) had mitigated erosion in the area and had positively impacted the health
315 of the bay. The least positive group was those respondents who have stand-alone
316 bulkheads on their properties. Almost no owners believe that their actions have a negative
317 impact on erosion and/or the health of the bay: the few that do have revetments or
318 bulkheads.
319 There are, however, substantial differences in the answer to this question based on
320 the role that the owner played in the modification decision, as shown in the bottom panels
321 of Figure 5. Of those that had made all of the modification themselves, about 90 percent
322 believe that their modification has improved erosion in the area and the health of the bay.
323 Those who made only some of the shoreline modifications on their properties are
324 somewhat less optimistic, with about 80 percent stating that their decisions had improved
325 erosion and just under 60 percent stating that their decisions had improved the health of
326 the bay. About 40 percent of owners who purchased their properties with modifications

[8] While the second question in particular mixes scales (shoreline and the bay as a whole) respondents in the pre-test did not have trouble answering the question.

but have not made any themselves stated that their choices (presumably to not add additional modifications) had a positive impact on both erosion and shoreline/bay health. For owners with no shoreline modifications, about 70 percent did not provide an answer to these questions. Those that did were much less likely to state that their choices (presumably to not modify the shoreline) made either the shoreline health or the level of erosion better. Instead, they were much more likely to state that their choices had no effect. While still a small percentage, owners with unmodified shorelines were the most likely to state that their choice had made erosion in their area worse.

To examine more robustly what factors can empirically be linked to a property owner's decision to modify their shoreline, we link the survey responses to the cadastral and geomorphological data for that owners' property. Our initial econometric analysis focuses on the decision to modify the shoreline but does not distinguish between the types of modifications. For this analysis, we assume that property owners will modify their shoreline if the expected benefits from the modification exceed the expected costs of the modification, that is, if the net benefit is positive. The net benefit of shoreline modification can be written as

$$Y_i^* = f(X_i) + \epsilon_i$$

where X_i is a vector of property and owner characteristics and ϵ_i is an unobserved individual-specific disturbance term.[9] We assume that whenever the net benefit, Y*, is positive, the owner will make a shoreline modification. Thus Y* is a latent variable that corresponds with an observable variable Y which indicates whether or not a shoreline

[9] The survey asked owners to provide answers with respect to a specific parcel indicated on the survey form. Owners with multiple properties were only surveyed once.

348 modification has been implemented at the property. We estimate this model for the 276
349 survey responses using a logistic regression given that the dependent variable, *Modified*,
350 in our model is binary.[10] More specifically, *Modified* is equal to 1 if the owner reports
351 that there is a shoreline modification on the property and 0 otherwise. The logistic
352 regression identifies the statistical relationship between *Modified* and the vector of
353 property and owner characteristic variables, which are listed in Table 1.[11] To correct for
354 the potential for non-response bias, we estimate the regression using the survey weights.
355 Significance level was set at 0.1.

356 Table 2 presents the results of this logistic regression. The first two explanatory
357 variables measure the *Value of Improvements* to the parcel and the *Land Value* itself
358 based on 2017 county tax assessments. The coefficients on both *Value of Improvements*
359 and *Land Value* are positive although only the latter is statistically significant ($p<0.1$).
360 This is consistent with more valuable properties having a higher net value of protection
361 and with the results of Beasley and Dundas (2019) who found that the total market value
362 of the property positively affected the probability of armoring on the Oregon coast.
363 Recalling that values of improvements and land are similar in scale, note that the relative
364 size of the coefficient on *Land Value* as well as its statistical significance suggests that
365 land value is the more important factor. However, one might be concerned that the value
366 of the land and/or improvements may to some extent reflect existing modifications as
367 some shoreline modifications such as bulkheads have been shown to increase property
368 values (Landry et al. 2003, Dundas and Lewis 2018, Walsh et al. 2019). While this may

[10] All regressions reported in this paper were estimated using Stata Version 15.1.
[11] There is no significant autocorrelation among these variables, so we are not concerned with issues of multicollinearity.

369 be less of a concern for tax assessment values – which are generally based on basic
370 information such as lot size, house size and number of bedrooms and bathrooms –
371 compared to market prices, we also run the analysis without these two variables to ensure
372 that the results are robust to their exclusion. Overall, there is very little qualitative
373 difference in the results when these two variables are excluded.[12] While the absolute size
374 of many of the coefficients changes, only one variable (*Distance to Shore*) changes in
375 significance and is no longer considered significant ($p>0.1$)

376 The results for *Years Owned* indicate that the longer the current owner has had the
377 property, the more likely it is that the property has some sort of shoreline modification
378 ($p<0.01$). However, whether the property is zoned for conservation does not have a
379 significant effect on the likelihood of a shoreline modification, as shown by the
380 insignificant coefficient on *Conservation* in Table 2. The negative and significant
381 coefficient on *Structure Distance to Shore* ($p<0.05$) shows that the farther the primary
382 structure is from the shoreline, the less likely it is to be modified. While we also expected
383 *Total Shoreline* to have a negative coefficient, since the longer the shoreline, the more
384 expensive it is to prevent erosion and thus the lower the net benefit from modification,
385 the coefficient on this variable is insignificant, suggesting that the length of the shoreline
386 by itself was not detected to have any impact on the likelihood of modification.

387 *Percent Moderate Wave Energy* and *Percent High Wave Energy* measure the
388 percentage of the parcel for which wave energy is considered to be moderate or high,
389 respectively and is based the fetch of the shoreline, that is the distance of open water over
390 which waves can blow and generate waves. *Percent Low Bank* measures the portion of

[12] These results are provided in the On-Line Supplemental Materials.

391 the shoreline that has a bank that is less than 5 feet above mean low water level. These
392 variables were included in the analysis to assess how differences in environmental
393 conditions affect the decision to modify, but none of the coefficients on these variables
394 are statistically significant suggesting that there is no specific impact of these conditions
395 on shoreline modification. The two land use variables, *Percent Natural Cover* and
396 *Percent Agricultural Use*, both have a negative and statistically significant impact
397 ($p<0.01$) on the likelihood that the property's shoreline has been modified.
398 The last three variables come from the property owner survey. *Used as a Primary*
399 *Residence* is a binary variable indicating whether the property is the owner's primary
400 residence as opposed to a second home, rental property, or undeveloped land. We also
401 include *Reported Flooding* and *Reported Erosion* to indicate whether the owner reported
402 having experienced flooding or erosion on the parcel in our survey. We expected all three
403 variables to be positively related to the likelihood that a property has a modified shoreline
404 and while all three variables do have the expected positive coefficient, none of them are
405 statistically significant.
406 While these results do provide some interesting insights into the factors driving
407 shoreline modification overall, we also wanted to examine the extent to which we could
408 tease out factors that lead to specific types of shoreline modifications, particularly factors
409 that lead to living shorelines as opposed to various types of shoreline armoring. To
410 conduct this analysis, we use a multinomial logistic regression. The underlying
411 framework is the same as the logistic analysis presented above except that instead of one
412 latent variable representing the net benefit of any shoreline modification, there are
413 multiple latent variables representing the net benefit of different types of shoreline

414 modification and the individual's response is assumed to correspond to the modification
415 that has the maximum net benefit for them. Since shorelines can be modified in numerous
416 ways or combinations of ways, we simplify the analysis and consider five different types
417 of modifications: stand-alone living shorelines, living shorelines combined with
418 armoring, mixed armoring, stand-alone revetments, and stand-alone bulkheads. The
419 choice of no modification is considered to be the baseline for the analysis, thus the
420 regression estimates the likelihood of adopting specific type of modification compared to
421 the baseline of not modifying the shoreline. As we did with the logistic model, we use
422 survey weights to correct for potential non-response bias.

423 The results of the multinomial logistic analysis are presented in Table 3.[13] In
424 contrast to the results presented in Table 2, in this analysis *Value of Improvements* and
425 *Land Value* have moderately significant coefficients for the two modifications categories
426 that contain living shorelines ($p<0.1$). This suggests that the value of the property is a
427 statistically significant driver only for living shorelines. For stand-alone living shorelines,
428 both coefficients are positive, although only the coefficient on improvement value is
429 moderately significant ($p<0.01$). For living shorelines with armoring, both improvement
430 value and land value are significant ($p<0.1$ and $p<0.01$, respectively) although the
431 coefficient on improvement value is negative and land value is positive. However, the
432 size of the coefficient on land value is more than double that of the coefficient on
433 improvements and is more statistically significant. Combined together, in almost all cases
434 this leads to a positive net impact of value on the likelihood of choosing living shorelines

[13] We did not include variables capturing the existence of shoreline modifications at neighboring properties because we do not know which modifications were adopted first and thus were concerned about introducing endogeneity into the analysis.

435 combined with mixed armoring compared to no modification. Since living shorelines are
436 much less likely to be monetized into tax assessments than any other type of armoring,
437 we feel confident that these results suggest that the value of a property drives the decision
438 to add a living shoreline, not the opposite.

439 The positive relationship between *Years Owned* and the probability of choosing a
440 specific type of modification holds for both mixed armoring and stand-alone revetments,
441 with positive and significant coefficients for both ($p<0.05$). While the coefficients on
442 *Years Owned* are not significant for stand-alone bulkheads and living shorelines with
443 mixed armoring, both have positive coefficients that are of similar size to the coefficient
444 on this variable in the logistic regression. Note, however, that the coefficient on this
445 variable for stand-alone shorelines is much smaller and is insignificant. Whether a parcel
446 is zoned for conservation does not have a significant effect on the likelihood of any type
447 shoreline modification nor does the length of the shorelines, as shown by the insignificant
448 coefficients on *Conservation* and *Total Shoreline*. However, *Structure Distance to Shore*
449 has a negative and significant coefficients ($p<0.01$) for the three modification choices that
450 do not involve living shorelines – thus homes that are closer to the shore are more likely
451 to implement some sort of armoring on their properties, all other things being equal, but
452 are no more likely to build a living shoreline. With respect to wave energy, only stand-
453 alone living shorelines appear to be systematically related to wave energy ($p<0.01$). As
454 was the case with the logistic analysis, *Percent Low Bank* does not appear to be a driver
455 of any particular type of shoreline modification. Higher percentages of natural cover on a
456 parcel are negatively and significantly correlated with the adoption of mixed armoring,
457 stand-alone revetments, and stand-alone bulkheads ($p<0.05$, $p<0.1$, and $p<0.01$,

458 respectively) while higher percentages of agricultural use are negatively related to the
459 adoption of living shorelines combined with armoring and stand-alone revetments ($p<0.1$,
460 for both).

461 Interestingly, properties that are used as primary residences are more likely to
462 adopt stand-alone living shorelines ($p<0.05$) which is not the case for any type or
463 combination of shoreline armoring. Looking at this result from the opposite perspective,
464 this means that owners who do not reside primarily at a particular property are unlikely to
465 install a living shoreline, perhaps because they believe that it requires more oversight or
466 maintenance than armored structures. Finally, while reporting erosion does not make
467 adoption of any particular type of modification more likely, reporting flooding is
468 positively correlated with adopting a living shoreline ($p<0.1$).

469

470 **5. Discussion and Conclusion**

471 The results of our survey indicate that shoreline armoring is very popular among
472 property owners that choose to modify their shoreline – an estimated 90 percent of the
473 modified shorelines in Gloucester, Virginia have some sort of armoring in place. Living
474 shorelines are much less likely – only about 20 percent of modified shorelines include a
475 living shoreline, half of which are in conjunction with some sort of shoreline armoring.
476 However, a review of the permit applications for shoreline modifications indicates that
477 living shorelines applications are increasing both in absolute numbers and as a percentage
478 of all shoreline modification requests while shoreline armoring requests are decreasing
479 both in absolute and relative terms. The survey indicates that a number of different issues
480 factor into the decision of which shoreline modification to implement. While the

481 effectiveness of the modification is the most frequently cited factor, cost, aesthetics, and
482 increasing property values are also important factors. Interestingly, although other
483 studies have found that a neighbors' modification choice is one of the best predictors of
484 the type of modification that a property owner installs, owners do not cite this as an
485 important factor in their decisions., suggesting other factors driving the statistical
486 correlation between neighboring modifications such as underling geophysical conditions
487 or shared information networks which independently lead neighbors to make the same
488 modification choice.

489 Looking empirically at the factors driving the modification decision, many of the
490 results are consistent with our expectations – that more valuable parcels are more likely
491 to be modified, as are parcels that have been owned longer and parcels with primary
492 structures closer to the shoreline. Similarly, parcels with a high percentage of natural
493 cover or agricultural use are less likely to be modified. The empirical analysis also
494 reveals some interesting, and perhaps less intuitive, findings about the drivers of different
495 types of modifications. While more valuable parcels are more likely to install living
496 shorelines, property value does not appear to be a significant factor in the decision to
497 choose shoreline armoring, while the length of ownership is a significant factor for
498 armored shorelines, but not for living shorelines. We also find that parcels with primary
499 structures that are closer to the shoreline are more likely to have some sort of armoring,
500 but that this is not the case for living shorelines. We find that owners are significantly
501 less likely to implement living shorelines on properties that are not used as primary
502 residences or at properties that are exposed to moderate and high fetch.

Based on the survey results, just over 50 percent of the shoreline of Gloucester County is estimated to be unmodified. For about half of these properties, owners stated that shoreline modification is unnecessary. With sea level rise and accompanying increase in erosion, this may change and the owners of these properties may make modifications in the future. For some owners of unmodified properties, cost and permit requirements are currently impediments to shoreline modification, but as SLR continues, we are likely to see at least some of these owners seek to modify their shoreline. Perhaps more pressing is the fact that just under one-third of owners of currently unmodified shorelines in Gloucester indicated that they intended to modify their shoreline in the near future. Since owners indicate that they are influenced by a range of factors, it may be possible to implement different policies or programs to increase the adoption of modifications such as living shorelines, which have the smallest negative impact on the environment. The finding that almost all survey respondents believe that their choices have had a neutral or positive impact on erosion in their area and the health of the Chesapeake Bay – regardless of the type of modification they have implemented – suggests that education about the true impacts of various modification choices on erosion and the health of the bay may help to persuade owners of unmodified shorelines to choose options that are more beneficial in these regards.

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Data Availability Statement

The datasets generated during and analyzed during the current study are not publicly available due to survey participant privacy concerns but are available from the corresponding author on reasonable request.

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612 Table 1. Variables Used in the Econometrics Analysis of Shoreline Modifications

Variable	Description	Weighted Mean	Weighted Standard Deviation
Value of Improvements	Assessed value of improvements on parcel in 2017 (million$).	0.25	0.22
Land Value	Assessed value of land in 2017 (million$).	0.24	0.15
Years Owned	Number of decades parcel owned, right censored at 10 decades.	1.25	1.11
Conservation	Binary variable indicating whether parcel is in conservation zoning district.	0.47	0.50
Structure Distance to Shore	Distance between primary building and shoreline (hundred feet).	1.29	10.20
Total Shoreline	Length of shoreline (thousand feet).	0.74	1.63
Percent Moderate Wave Energy	Percent of shoreline with moderate wave energy (exposures of 1 to 5 nautical miles of fetch).	0.32	0.42
Percent High Wave Energy	Percent of shoreline with high wave energy (exposures of more that 5 nautical miles of fetch).	0.31	0.41
Percent Low Bank	Percent of shoreline with a bank less than 1.52m above mean high tide line.	0.80	0.38
Percent Natural Cover	Percent of parcel covered by forest, timber, scrub or grass.	0.10	0.24
Percent Agriculture Use	Percent of parcel used for agriculture.	0.02	0.10
Used as Primary Residence	Binary variable indicating parcel is owner's primary residence.	0.61	0.49
Reported Flooding	Parcel owner reports flooding during previous year.	0.60	0.49
Reported Erosion	Parcel owner reports erosion during previous year.	0.64	0.48

613

614

615 Table 2. Results of the Logistic Analysis of Shoreline Modification
616

Variable	Coefficient	Standard Error
Value of Improvements	0.15	1.06
Land Value	3.32*	1.98
Years Owned	0.33**	0.15
Conservation	0.25	0.47
Structure Distance to Shore	-0.43**	0.22
Total Shoreline	0.03	0.15
Percent Moderate Wave Energy	-0.26	0.46
Percent High Wave Energy	0.10	0.52
Percent Low Bank	-0.66	0.56
Percent Natural Cover	-2.34***	0.69
Percent Agriculture Use	-4.33***	1.47
Used as Primary Residence	0.21	0.37
Reported Flooding	0.31	0.40
Reported Erosion	0.06	0.38
Constant	1.03*	0.54

617 *Indicates significance at 90% level, **Indicates significance at 95% level, ***Indicates
618 significance at 99% level.
619

620

621 Table 3. Results of Multinomial Logit of Modification Choice

Variable	**Stand-Alone Living Shoreline** Coefficient (SE)	**Living Shoreline and Armoring** Coefficient (SE)	**Mixed Armoring** Coefficient (SE)	**Stand-Alone Revetment** Coefficient (SE)	**Stand-Alone Bulkhead** Coefficient (SE)
Value of Improvements	2.78* (1.54)	-3.03* (1.70)	1.13 (1.86)	0.76 (1.41)	-0.21 (1.99)
Land Value	1.38 (2.73)	7.85*** (2.36)	2.59 (2.96)	3.28 (3.31)	4.81 (3.52)
Years Owned	0.04 (0.24)	0.31 (0.24)	0.52** (0.23)	0.55** (0.25)	0.38 (0.29)
Conservation	0.95 (0.73)	0.87 (0.70)	0.37 (0.60)	0.52 (0.56)	-0.16 (0.85)
Structure Distance to Shore	-0.04 (0.25)	-0.27 (0.28)	-0.91*** (0.33)	-0.77*** (0.33)	-1.01*** (0.38)
Total Shoreline	-0.31 (0.40)	0.34 (0.61)	0.44 (0.67)	-0.57 (0.47)	-3.30 (2.89)
Percent Moderate Wave Energy	-3.94*** (1.37)	-0.45 (0.85)	1.00 (0.75)	0.21 (0.69)	0.77 (0.77)
Percent High Wave Energy	-1.59** (0.79)	0.52 (0.95)	1.23 (0.84)	0.42 (0.81)	0.18 (0.84)
Percent Low Bank	-0.69 (0.89)	-1.27 (0.91)	-0.71 (0.76)	-0.58 (0.73)	-0.16 (0.89)
Percent Natural Cover	-0.78 (1.51)	-2.67 (1.64)	-4.87** (2.22)	-2.03* (1.12)	-14.03*** (2.14)
Percent Agriculture Use	-0.37 (1.55)	-11.53* (4.55)	-27.51 (16.98)	-6.56* (3.36)	-32.26 (25.32)
Used as Primary Residence	1.72** (0.70)	0.21 (0.55)	-0.48 (0.58)	0.28 (0.51)	-0.75 (0.66)
Reported Flooding	1.21* (0.73)	0.62 (0.65)	0.49 (0.63)	-0.31 (0.57)	-0.05 (0.64)
Reported Erosion	0.85 (0.68)	0.01 (0.59)	0.01 (0.57)	-0.38 (0.49)	-0.90 (0.68)
Constant	-1.92** (0.97)	-1.15 (0.99)	-0.74 (086)	-0.20 (0.69)	0.50 (0.79)

622 Base outcome is Natural Shoreline. *Indicates significance at 90% level, **Indicates significance at 95% level, ***Indicates
623 significance at 99% level.
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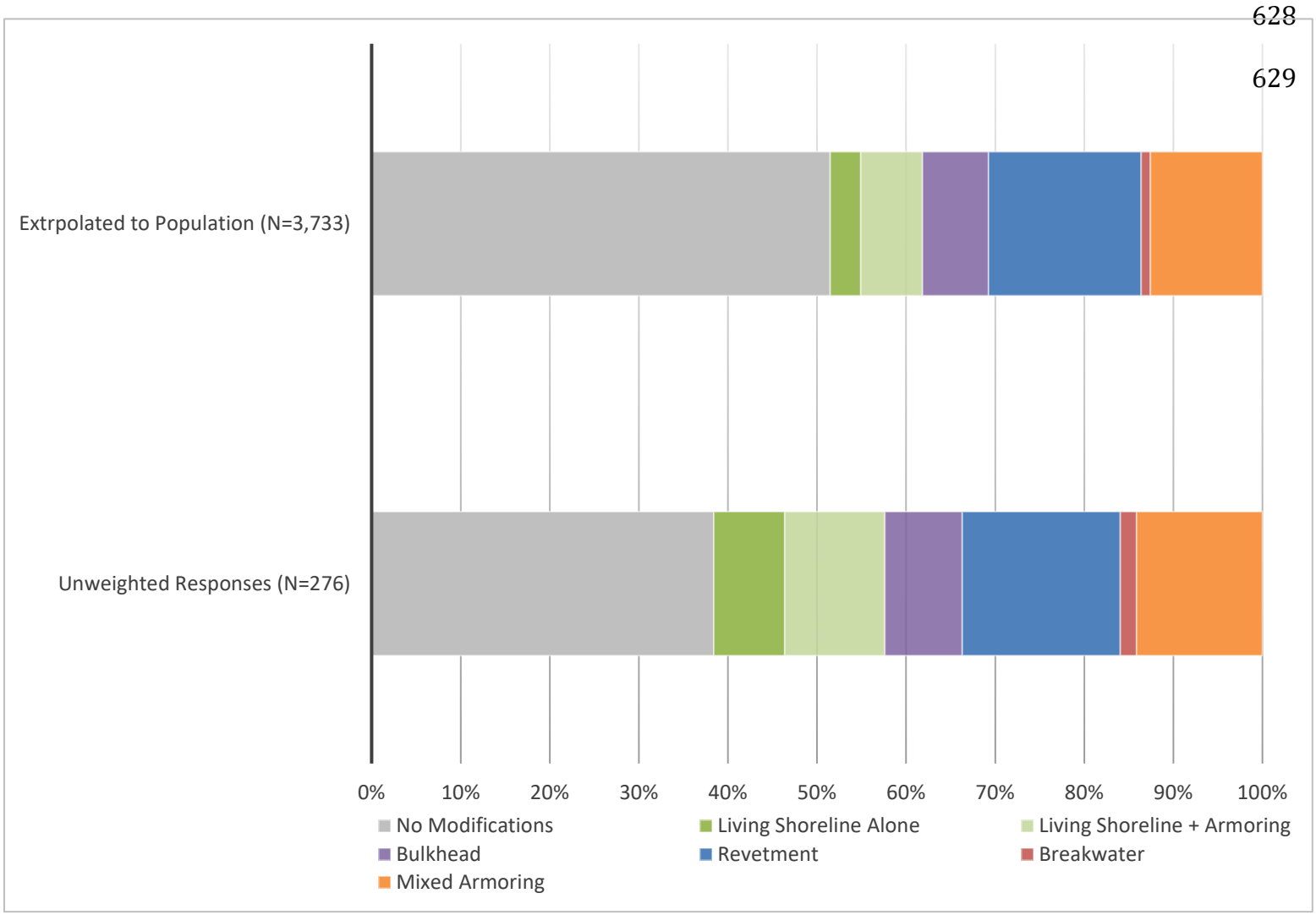
627 Figure 1: Shoreline Modifications in Gloucester County, Virginia



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630 Figure 2: Implementation of Modification by Modification Type

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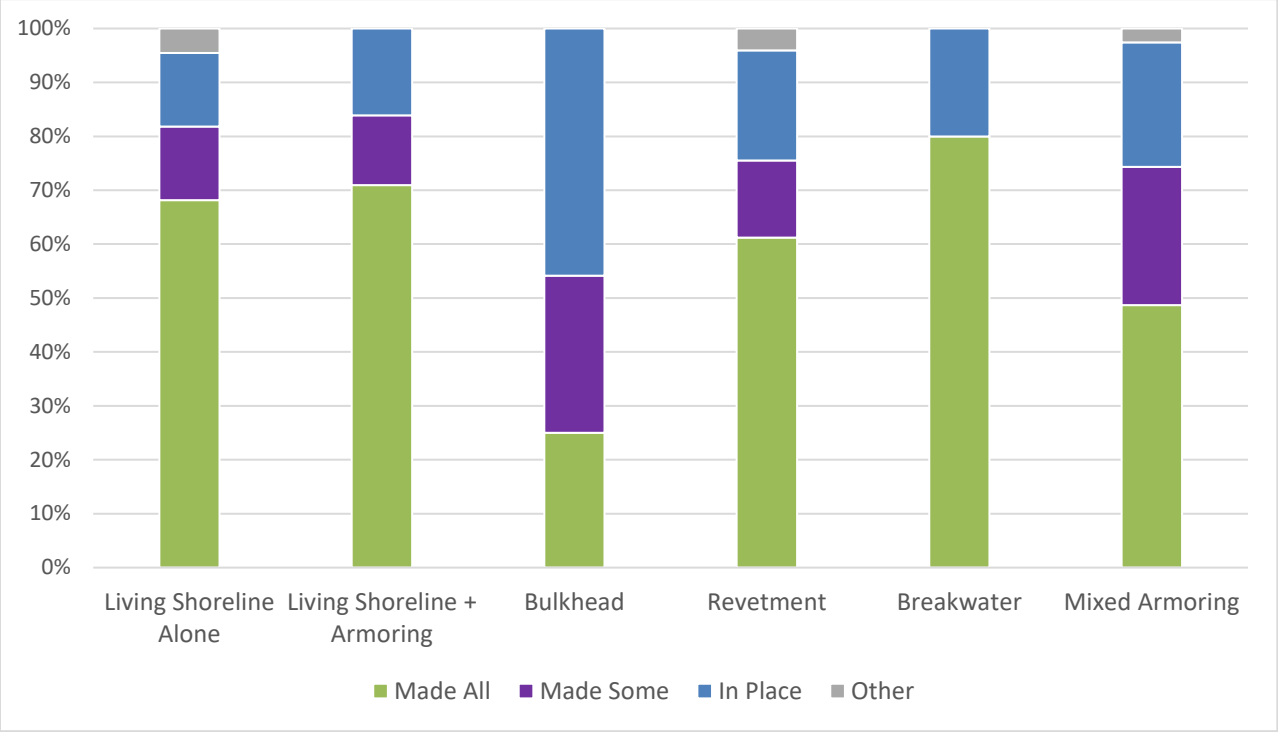

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634 Figure 3. Distribution of Shoreline Modification Applications over Time

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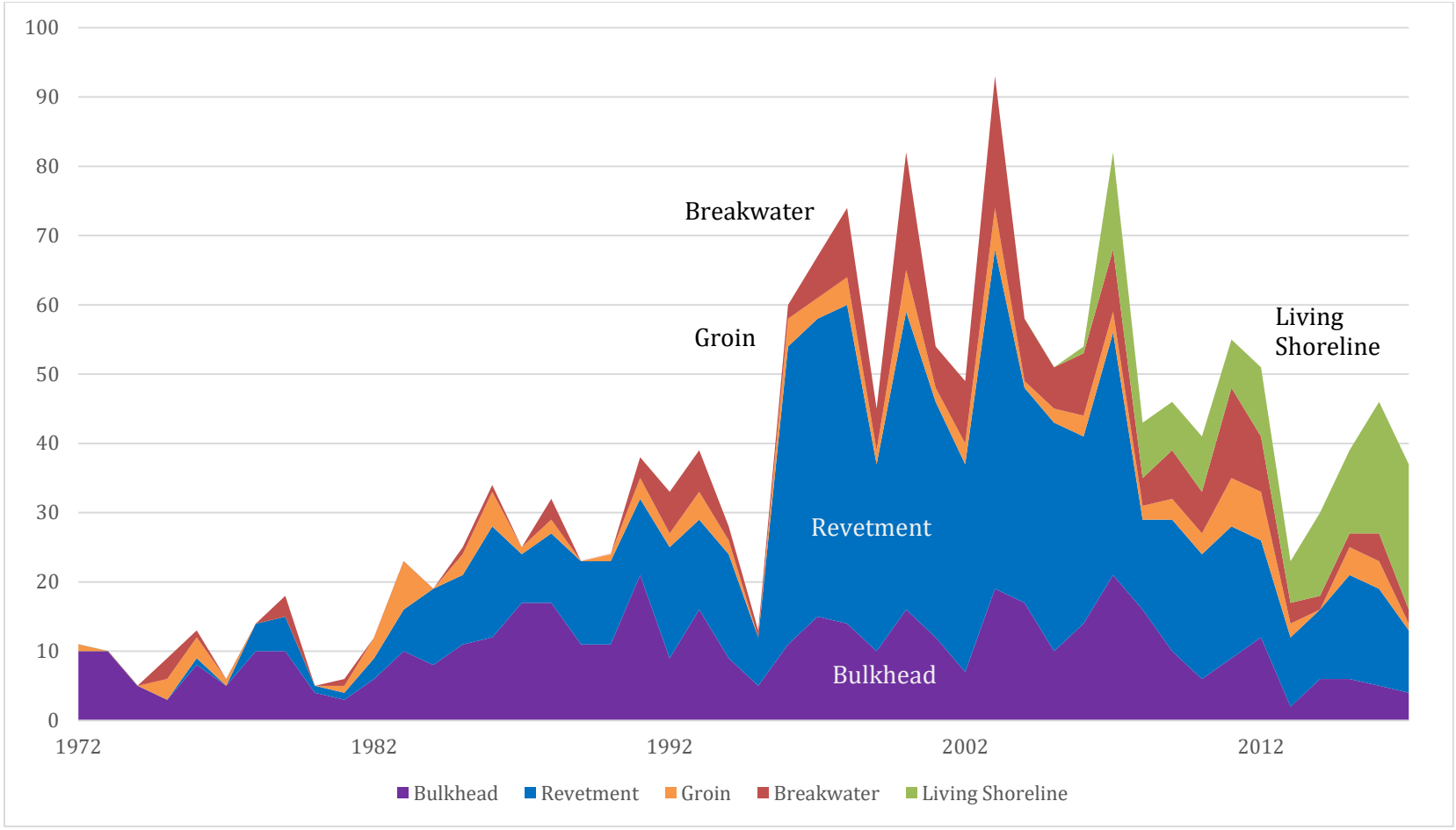

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637 Figure 4: Factors Influencing the Most Recent Modification Decision

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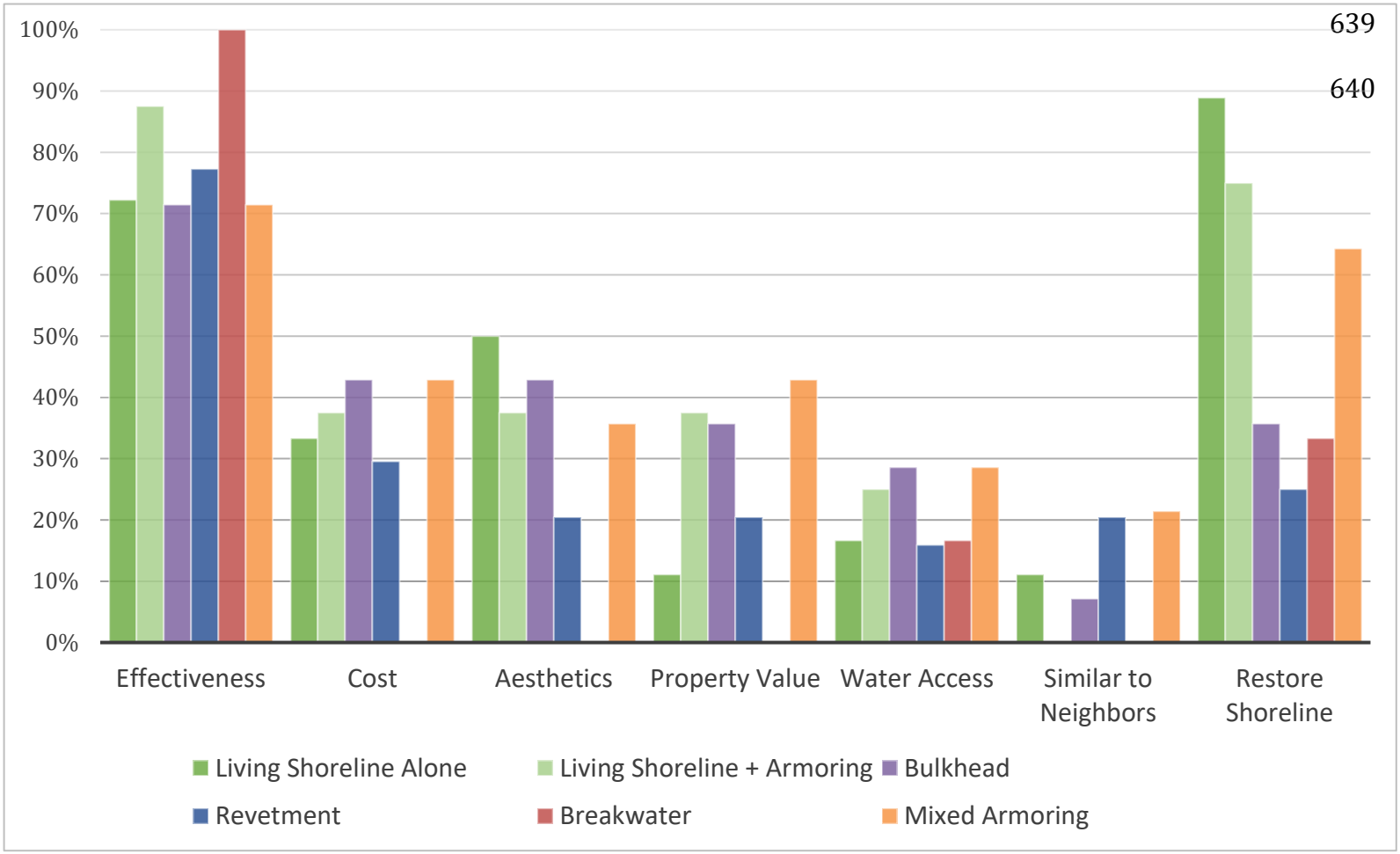

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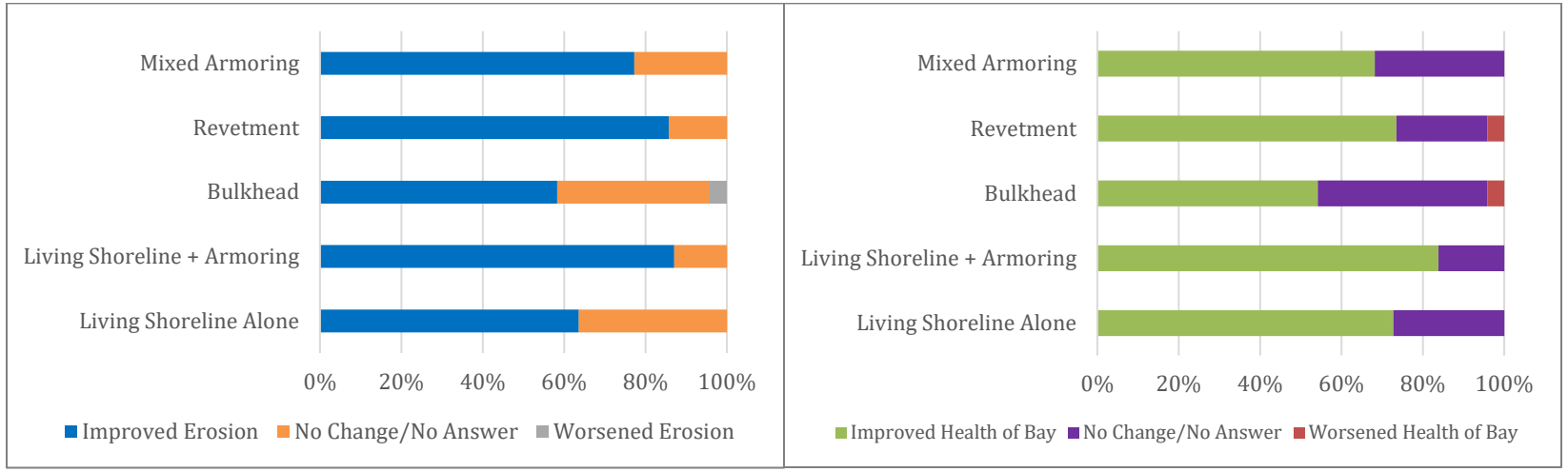
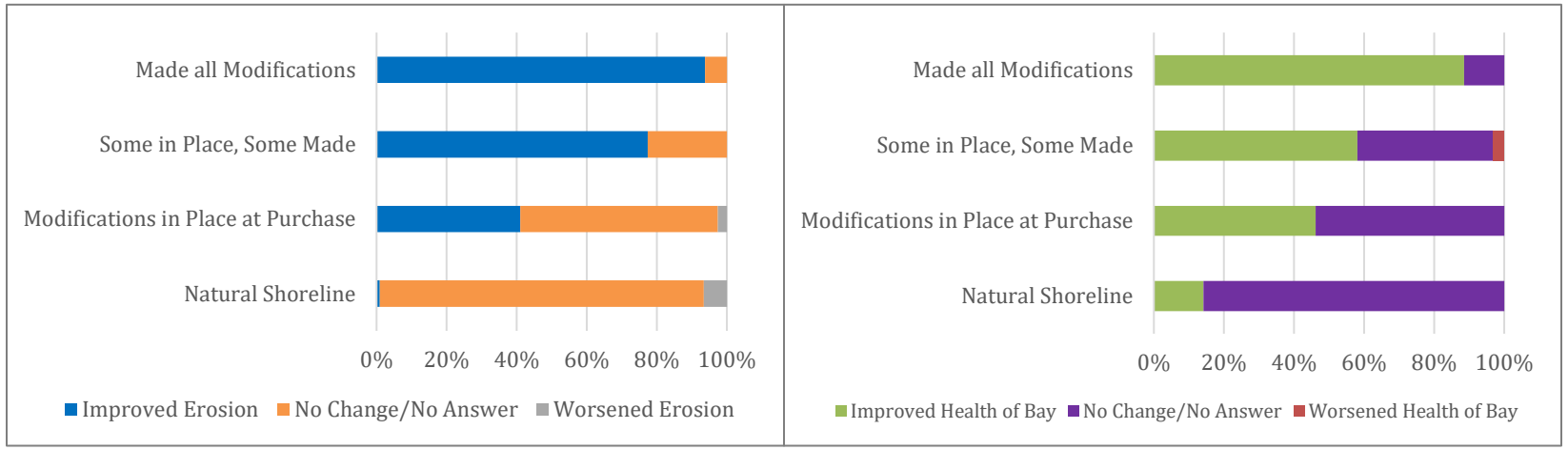
Figure 5: Owner Perceptions of Modification Impacts





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

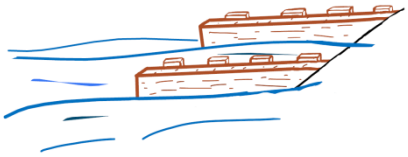
*Indicates significance at 90% level, **Indicates significance at 95% level, ***Indicates significance at 99% level.

Figure 1: Shoreline Modification Options

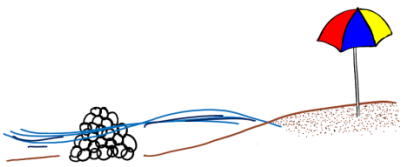
Bulkhead
A wall placed along the shoreline between the land and the water. The plants and land above the wall do not often get wet.

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

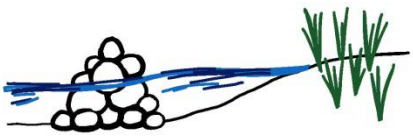
Groin
A wall that is perpendicular from the land, and goes into the water.



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.