Assessing the Water Quality, Habitat, and Social Benefits of Green Riprap

STAC Workshop Report
September 15, 2021
Virtual

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About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at http://www.chesapeake.org/stac.

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Cover graphic from: Picture from the U.S. Fish and Wildlife Service Green Riprap site at Round Bay, Maryland. The installation was completed in 2013 and image taken in September 2020. Image courtesy of Meg Cole, Chesapeake Research Consortium.

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Meg Cole, Chesapeake Bay Program Scientific & Technical Advisory Committee Coordinator, Chesapeake Research Consortium

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Executive Summary

Shoreline alterations in the Chesapeake Bay have led to a loss of native tidal and shallow water habitats throughout the waterways of the Bay. Efforts to reduce the proliferation of shoreline hardening through the use of Living Shorelines and similar restoration practices have slowed the loss of native habitats, but do not address areas that have already been hardened. Green Riprap is a low cost, simple restoration technique to improve the water quality, habitat, and aesthetics of shorelines previously hardened with rock revetments by planting marsh vegetation in the voids between riprap rocks. However, Green Riprap techniques are new to the Chesapeake Bay and before widespread use is encouraged, a synthesis of the science and identification of research gaps are needed. This workshop was developed to provide the foundation to evaluate the state of the science on Green Riprap and its potential for providing enhanced water quality, increased near shore biodiversity, and improved aesthetic functions of previously hardened tidal shorelines.

The workshop brought together scientists, practitioners, and NGOs to share aspects of shoreline systems that Green Riprap could contribute to and elucidate the best practices for their construction. The workshop was a single-day online meeting with an optional field trip to example Green Riprap projects. The workshop convened experts from multiple disciplines to evaluate the state of the science for Green Riprap, including estuarine scientists that study tidal wetlands and tidal shorelines, shoreline engineers, physical modelers, and social scientists. Several Green Riprap projects built by the U.S. Fish and Wildlife Service and other groups were shared through talks, a virtual field trip, and an in-person field trip. The talks were followed by discussion on the next steps forward. Results were a prioritized list of research questions related to: site criteria; plant species most effective for Green Riprap use; water quality criteria that could be used to assess project success; ecological benefits, including increased biodiversity; and social benefits, including increased recreational/aesthetic values made possible by Green Riprap habitats.

Key recommendations from the workshop include:

1. Additional research to help understand both the best design of these shorelines and their benefits;
2. Increased visibility of the technique through the creation of public pilot projects; and
3. Additional outreach to all the involved parties, including property owners, contractors, and regulators to ensure clear definitions and that the projects are sited and designed correctly.

Potential partners for addressing these recommendations include the Chesapeake Bay Program's Wetland and Fish Habitat Workgroups and the U.S. Fish and Wildlife Service.

Introduction

Shoreline conditions have declined in the Chesapeake Bay as a result of pressures from coastal populations, particularly shoreline modifications (armoring) that harm important coastal habitats including marshes and submerged aquatic vegetation (SAV). Shifts in preferences for shoreline management practices to nature-based approaches (Living Shorelines) have been underway for about 20 years. More of these projects are being implemented each year, likely due to new incentives, legislation, and training of marine contractors. Innovations in shoreline restoration are continuing at a rapid pace and there is growing interest in 'greening' existing armored (riprap) shorelines to achieve an ecological uplift.

Green Riprap is a low cost, simple restoration technique used to improve the water quality, habitat, and aesthetics of shorelines hardened with rock revetments. Green Riprap involves planting marsh vegetation in the voids between riprap rocks. Green Riprap provides another tool for waterfront homeowners and river groups to improve water quality in the Bay or river while creating a more natural look along their shoreline. **Green Riprap is not a substitute for or a type of living shoreline. Rather, Green Riprap is an enhancement of a structural shoreline solution and should be limited to areas that are already hardened or where Living Shorelines are not practicable. In addition, planting marsh grass into a riprap structure is not considered a form of tidal marsh compensation.**

Green Riprap projects have the potential to enhance water quality, increase near shore biodiversity, and improve aesthetic functions of tidal shorelines. However, Green Riprap techniques are new to the Chesapeake Bay and before widespread use is encouraged, a synthesis of the science and identification of research gaps are needed. There is interest in using this as a Best Management Practice (BMP) and this workshop was developed to provide the foundation to evaluate the BMP potential.

Green Riprap adds habitat to hardened shorelines and helps improve water quality through the reduction of nearshore erosion associated with hardened shorelines. Therefore, this workshop addressed several CBP goals, including: Sustainable Fisheries GIT Fish Habitat Goal: Identifying and improving our understanding about important fish habitat will help target our conservation and restoration efforts; Habitat GIT Goal: Restore, enhance and protect a network of land and water habitats to support fish and wildlife and to afford other public benefits, including water quality, recreational uses and scenic value across the watershed; and Water Quality GIT Goal: By 2025, have all practices and controls installed to achieve the Bay's dissolved oxygen, water clarity/submerged aquatic vegetation and chlorophyll a standards as articulated in the Chesapeake Bay TMDL document.

Objectives and Workshop Format

Workshop objectives were to synthesize the state of the science on green techniques for riprap revetments and identify research needs. Specific workshop components included:

- Convening experts from multiple disciplines to evaluate the state of the science for Green Riprap, including estuarine scientists that study tidal wetlands and tidal shorelines, shoreline engineers, physical modelers, and social scientists.
- Sharing the results from several Green Riprap projects that the U.S. Fish and Wildlife Service and other groups have completed.
- Developing a prioritized list of research questions related to: site criteria; plant species that are most effective for use in Green Riprap habitats; water quality criteria that could be used to assess project success; ecological benefits, including increased biodiversity; and social benefits, including increased recreational/aesthetic values made possible by Green Riprap habitats.
- Challenging shoreline designers to help develop design standards for incorporating Green Riprap into new revetment designs.
- Identifying challenges related to establishment of non-native plants and animals in Green Riprap habitats that compete with native plants and animals.

The workshop was a one-day event held in September 2021 and gathered experts in Living Shorelines, Green Riprap, and shoreline/marsh ecology. Due to COVID-19 related constraints, the workshop was held virtually; however, there was an optional in-person field trip held on a different day. Workshop outcomes included lessons learned from recent case studies and recommendations for next steps to evaluate the potential for these projects as a new, creditable Best Management Practice (BMP) for nutrient/sediment load reduction and/or encouraged community practices to mitigate shoreline hardening.

The workshop began with a virtual field trip (video) to different sites where Green Riprap practices have been implemented and was followed by a series of talks given by subject matter experts (see summary of presentations below). This video was completed in order to provide all participants with a field experience.. Green Riprap sites highlighted were Round Bay, West Severna Park, Gibson Island Marina, and Gibson Island Causeway. Aside from Committee members, Alison Milligan (Round Bay resident and Anne Arundel Watershed Steward) and Ellen Kleinknect (Round Bay resident) are featured discussing the benefits of a Green Riprap installation in their community.

Figure 1. Screenshot of the virtual field trip created by the Steering Committee with technical assistance from Severn Media. Steering Committee members and featured community members discuss the benefits of retrofitting existing stone riprap with native plants to improve habitat and water quality. Link to video.

After the invited speaker presentations, there were breakout group discussions about research needs, barriers and opportunities to implementation, and actions and incentives needed to increase the use of Green Riprap. These discussions were led by team members using interactive Jamboards. Additional feedback was solicited through Mentimeter. Participant responses to both the Mentimeter (Figure 7) and Jamboard exercises (Figure 8, Figure 9) can be found in Appendix E. An in-person field trip was conducted a week later for those in the area who wanted to see a subset of project sites in person. Sites visited were Ulmstead Marina, Round Bay Main Beach, West Severna Park Marina, and Gibson Island. Interested participants were able to take part in a small demonstration planting at Ulmstead Marina.

Figure 2. Photos from the in-person field trip to U.S. Fish and Wildlife Service Green Riprap projects on September 20th, 2021. On the left, participants discuss a Green Riprap installation at Round Bay. In the image on the right, Leah Franzluebbers (USFWS) demonstrates planting *Spartina patens* in between a rock void.

Workshop Summary

Brief Summary of Presentations

Workshop presentation slides are available on the corresponding STAC workshop webpage here.

Introductory Talks

The first part of the workshop included introductory talks designed to provide background on Green Riprap, distinguish it from other shoreline modification or restoration techniques, and give context for its utility and need.

Objectives of the Workshop: 'What is Green Riprap?'

– Leah Franzluebbers (USFWS), Rich Mason (USFWS)

Leah Franzluebbers, a U.S. Fish and Wildlife biologist at the Chesapeake Bay Field Office, gave an overview of how to define Green Riprap, a new strategy for greening existing rock revetments.

Shoreline hardening in the Chesapeake Bay is a widespread and growing problem. Many residential coastal landowners have installed rock on their shorelines for stabilization, whether needed or not. When shoreline hardening eliminates tidal fringe marsh, many important ecosystem functions are lost. Among the options already available for shoreline restoration, there is opportunity for additional techniques. Green Riprap is a small-scale, low-cost restoration technique for retrofitting existing riprap shorelines. It involves planting the riprap with marsh grasses to improve the ecological and aesthetic value of the shoreline. The current process for Green Riprap projects is fairly simple: grow marsh grasses in coconut fiber coir pots for 4to 6 weeks, until the plants are well established. Plant according to their inundation requirements in the riprap by wedging the pots in the voids of the rock – depending on the size of the riprap, some rearranging of the rock may be necessary.

Franzluebbers ended by emphasizing that the technique is, in most cases, a retrofit to existing riprap revetments. Green Riprap is not a replacement of Living Shorelines, nor is it a way to justify the construction of revetments in areas where they are unnecessary and detrimental. It is simply another technique to be considered among all those that landowners and practitioners consider when they assess restoration for hardened shorelines.

Rich Mason, another biologist at the Chesapeake Bay Field Office, then spoke about the genesis of the idea of greening revetments. Living near the water in Anne Arundel County, a county in the Chesapeake Bay with highly developed shorelines, he started noticing many areas where tidal marsh grasses had naturally colonized the riprap in landowners' revetments. This observation prompted the idea of deliberately planting grasses within existing riprap structures – ample opportunity exists in Anne Arundel County, as around 45 percent of shorelines in that county is hardened, whether by bulkhead or revetment (Nunez et al, 2021). The high level of hardening in this county, reflected by other high percentage hardened counties in the Bay, shows a crucial need for additional strategies for restoring functioning to hardened shorelines. There is a gap in shoreline restoration techniques for shorter, privately owned shorelines with existing structures, one that can be filled by the implementation of Green Riprap.

Ecological Aspect of Green Riprap and Natural Shorelines

Ecological Aspects of Green Riprap and Natural Shorelines Restoring and Preserving the Shoreline Ecotone – *Donna Bilkovic (VIMS)*

Donna Bilkovic provided an overview on the importance of the shoreline ecotone to the Chesapeake Bay and how nature-based shore protection can help preserve those critical habitats. She provided background on the extent of tidal shoreline that are armored (15 percent) or characterized by marshes (60 percent) throughout the Chesapeake Bay. She described the scientific understanding of the value of fringing shoreline marshes as habitat for fish and invertebrates as well as other important ecosystem services, including wave attenuation, trapping sediment, nutrient removal, and carbon storage. She then detailed the documented adverse effects of shoreline armoring on shoreline ecotone habitats and described the continuum of shoreline protection approaches options being used in Chesapeake Bay and other sheltered estuaries depending on the condition of the shoreline, depth of the nearshore waters, and energy setting – from Conserving Natural Habitat to Living Shorelines to Greening Armoring to Armoring.

To facilitate workshop goals to identify where there are knowledge gaps for shoreline armoring enhancement techniques such as Green Riprap, she described findings from a large-scale multi-year field evaluation of ecosystem function equivalency between Living Shorelines (*created marsh with stone sill wave break seaward of marsh*) and natural fringing marsh on the basis of nutrient cycling, primary production, and habitat provisioning for benthic and epifaunal invertebrates, nekton, and their predators (i.e., herons, and diamondback terrapins), throughout Virginia's Chesapeake Bay. This work provided encouraging support that Living Shorelines are capable of providing the same ecosystem services that natural fringing marshes have provided historically in both rural and urban settings. While a Living Shoreline is a different technique than enhancing an existing hardened shore with vegetation (e.g. Green Riprap), there may be lessons that can be learned from successful Living Shorelines and many of the research questions previously posed for Living Shorelines are likely to be questions that will need to be examined for greening an armored feature before its widespread use.

To end and place the potential for use of *Green Riprap* into a broader context, she used output from a Shoreline Management Model (CCRM-VIMS, SMM v5.1; https://www.vims.edu/ccrm/ccrmp/bmp/smm/index.php) to identify the extent of shoreline in Virginia for which Living Shorelines may be suitable and where shoreline enhancement techniques could be applied to existing armoring. In Virginia alone over 10,000 kilometers (km) (6,500 miles) of tidal shoreline are potential locations to restore and enhance shoreline marshes. Some of those shorelines are currently armored for which enhancement techniques such as Green Riprap may be a transitional approach or a means to provide ecological uplift through the placement of marsh plants which may provide some measure of marsh ecosystem services.

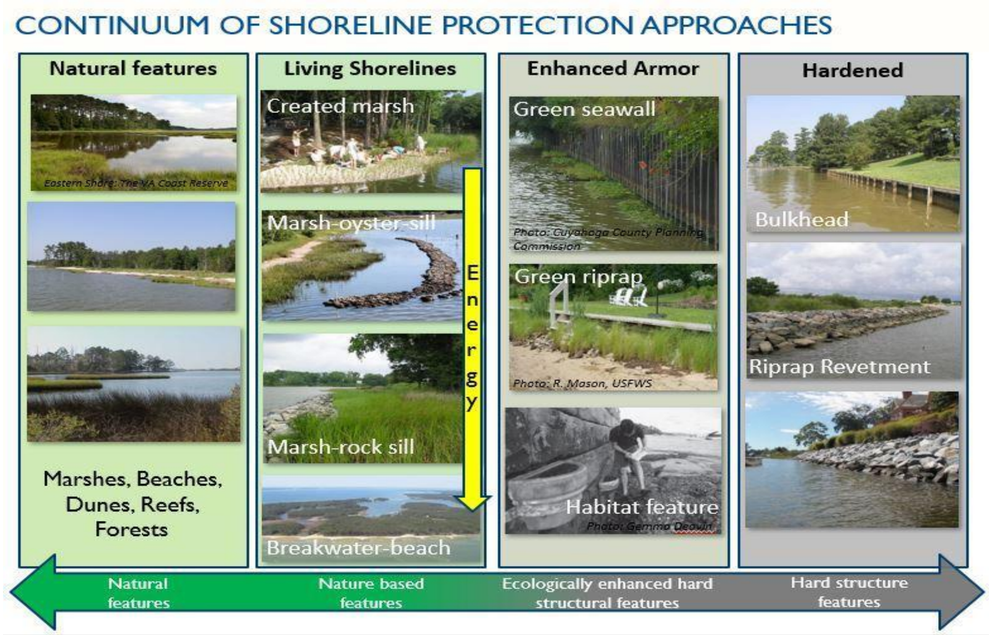

Figure 3**.** Shoreline protection approaches in Chesapeake Bay include conserving natural features, creating living shorelines, enhancing armoring with ecological features, and armoring. Figure by Donna Bilkovic, VIMS.

Above the Rock: Options for Landscaping or Naturalization

– Doug DeBerry (College of William and Mary)

Doug DeBerry, professor at the College of William and Mary, discussed native landscaping in the riparian buffer zone. Beginning first with an overview, DeBerry reviewed the distinction between a functional and degraded system while building on the concept of an 'ecotone' addressed in a previous presentation by Donna Bilkovic (VIMS). Ecotones are often abrupt partitions or transitions between ecosystems, but within this context, the ecotone is the shoreline ecosystem. A functional riparian buffer is one in which the physical, chemical, and biological processes in residence contribute to the self-maintenance of the ecosystem through time. Emergent properties of such a system are nutrient cycling, primary productivity, biodiversity, and carbon sequestration. Specific functions of upland riparian buffers are erosion reduction, sediment and pollution filtration, water temperature moderation, habitat provision for wildlife, water storage, and flood reduction. To note, forests provide substantially more ecosystem functions in riparian zones than turfgrass due to an expansive root zone and other structural components of the system (tree biomass, greater soil cohesiveness, etc.). Buffer width depends on desired function – under 100 meters (m) width is adequate for sediment removal or water temperature moderation purposes, whereas species diversity or habitat for specific target organisms require much larger buffers (Castelle et al. 1994).

When planting above the rock, it is strongly recommended to utilize native species. Using diverse natives can build contingency into a project, as these species have a higher ability for survival since they are adapted to local environmental conditions. Additionally, natives increase pollinator services for ecotones with surrounding agricultural lands nearby, of which there are many in both Virginia and Maryland. As presented by Dennis Whigham (SERC), non-natives may have allelopathic properties – secondary compounds in their tissues that oftentimes exude into the soil – causing them to function as herbicides and prevent other plants from being able to take up nutrients.

Regarding the costs of native landscaping, there is not an expansive amount of research completed on this topic. DeBerry is taking part in current study examining pollinator systems in solar facilities and there is related literature published on public parks and by the Department of Transportation (DOT) on highway and transportation Research shows the return on investment with native plant diversity seed mixes is 3 years for low diversity mixes and 5 to 7 years for high diversity mixes. Money saved is mostly from decreased maintenance costs such as mowing.

The concept of Integrated Vegetation Management (IVM) is a helpful technique to practice with successful native landscaping as it promotes stable low growing plant communities to resist invasion. This practice maintains a vibrant ecosystem while not compromising the view of an inspirational setting and minimizes its own use over time. The goal of planting native species is to put in work upfront, and have the system maintain itself in the long run. To address biological invasion in wetland and stream environments, applying IVM maximizes the potential for native species richness by exploiting the stress-disturbance dynamics. IVM can manipulate this dynamic for the benefit of native diversity. DeBerry shared a case study of a project site on the Anacostia River in downtown DC. The brownfield was transitioned into a tall grass prairie using IVM and invasion ecology techniques. After 2 years, there were over 90 percent native species and after 3 years, the project maintenance tasks were negligible and mostly used for monitoring.

Managing Phragmites – *Dennis Whigham (SERC), Kirk Havens (VIMS)*
A non-native haplotype of *Phragmites australis* has become a major invasive species in the U.S. and Canada, primarily in wetland habitats. In estuarine habitats in Chesapeake Bay, *Phragmites* has invaded wetlands and is now widespread and so common and abundant that management is likely no longer possible in many areas. *Phragmites* management can be considered in areas where the shoreline has been altered by the placement of bulkheads, riprap, and the establishment of Living Shorelines. Melissa McCormick (Smithsonian Environmental Research Center) and colleagues found that all of the patches of *Phragmites* that they examined in association with riprap contained multiple genotypes (McCormick et. al. 2010. Journal of Ecology 98: 1369-1378).

Figure 4. Images relating to the ‘Managing Phragmites’ discussion presented by Dennis Whigham (Smithsonian Environmental Research Center). On the left, Whigham holds up a *Phragmites australis* shoot. On the right, phragmites growth along a riprap shoreline. Images provided by Dennis Whigham.

The presence of multiple genotypes in the same patch means that cross-pollination between flowers on ramets that are genetically different can occur and the patch will be a source of seeds for the potential establishment of additional patches in the subestuary. *Phragmites* in riprap also reproduces asexually, resulting in continued spread and an increased abundance of flowering ramets that can produce more seeds. Given the increased abundance of shoreline modification in the Chesapeake Bay, management of new and established riprap areas should focus on the elimination of *Phragmites* from areas where it is already established and management of new shoreline and adjacent upland disturbance sites to preclude the establishment of additional *Phragmites* patches.

Bioengineering Aspects of Green Riprap and Natural Shorelines

This session focused on the “how-to” of Green Riprap: site selection, planting process, and case studies.

Techniques and Case Studies – *Leah Franzluebbers (USFWS), Rich Mason (USFWS)*
Franzluebbers explained the current process for planting marsh grasses in riprap. After a site has been identified and selected, a plant list must be assembled. Appropriate vegetation will vary based on location within the watershed and goals for specific sites. It is key to have the nursery grow the grasses out in coconut fiber pots (3 to 4 inches in diameter) for about 4 to 6 weeks, which gives the plant an immediate source of soil when it is planted into the riprap. The time grown out in the nursery allows the plant’s roots to be well established, so that once the grass is placed into the rock, it can have a higher chance of survival. It is crucial that the pots be made with natural materials, so that they can biodegrade once installed in the rock. Plastic materials should not be used. Once you have your grasses sufficiently grown out, plant them in the riprap by wedging the plants in the voids between the rock. This often involves doing some re-arranging, making sure that the pot is covered with rock and will not float away when the tide comes in. Planting should ideally occur as early in the growing season as possible, to give the vegetation ample time to establish in the rock before dormancy. After a few growing seasons, the fiber pot will have biodegraded and the plant should have established within the rock well enough to survive on its own and begin building soil.

Eventually, the grasses will spread and further colonize the rock. One key to success is planting in the correct zones – often the discoloration on the rock can give an indication where the tide zones are (see Figure 5). Some sites will have existing vegetation that can provide biological benchmarks as to where best to plant.

Figure 5. Image of rock discoloration indicating different tidal zones. The upper, darker zone is the high tide zone, the lower, lighter zone is the mid-tide zone, and the zone directly adjacent to the water is the low-tide zone.

Case Studies: Projects Completed by U.S. Fish and Wildlife Service

Ulmstead Community Marina (2013)

- Site Conditions:
  - Location: Magothy River (Anne Arundel County, MD)
  - Wave energy: maximum fetch of 1.3 miles to NW; significant boat wake
  - Nearshore water: Shallow bench off rock (not exposed at normal low tide)
  - Sediment: Very little sediment accretion in rock. Most adjacent shorelines have bulkheads. Upland area gentle slope, likely provides some sediment.
  - Aspect and Shade: NW facing. One small tree, otherwise full sun
  - Existing plants: *Spartina patens*, high tide bush, and groundsel tree
- Process:
  - Direct planting (plants grown in coir pots for 6 weeks, no sand added)
  - Species planted: *Spartina patens*, *Spartina alterniflora*, and *Panicum amarum*
- Results:
  - Good *S. patens* growth, failure of *S. alterniflora* (planted too low)

Post Planting (2013) After (2018) After (2020)

Round Bay Community Beach (2013)

- Site Conditions:
    - Location: Severn River (Anne Arundel County, MD)
    - Wave energy: maximum fetch of 2 miles to the SSW; significant boat wake
    - Nearshore water: Some of the area has exposed beach off the rock, other areas have gently sloping shallow bench that is not exposed at normal low tide
    - Sediment: Less than 1in of sediment accreted in rock. The swimming beach is to the east, otherwise most adjacent areas have bulkheads or revetment. Upland area varies, likely providing some sediment.
    - Aspect and Shade: South facing, full sun
    - Existing plants: none
    - Unique feature: A sill was installed in part of the project area as part of a previous project
- Process:
    - Direct planting (plants grown in coir pots for 6 weeks, no sand added)
    - Species planted: *Spartina patens*, *Spartina alterniflora*, and *Panicum amarum*
- Results:
    - Excellent growth of all plants in the main planting area. In certain areas, rock is no longer visible.

Before Planting (2013)

After 4 Years (2017)

After 8 Years (2021)

West Severna Park Marina, Severna Park (2013)

- Site Conditions:
    - Location: Severn River (Anne Arundel County, MD)
    - Wave energy: Fetch of 0.3 miles to the SSW. Protected Cove, no boat wake
    - Nearshore water: Bottom is not exposed at normal low tide
    - Sediment: Less than 1 inch of silty sediment accretion in rock. Upland area varies but mostly lawn, likely provides some sediment input
    - Aspect and Shade: South facing, some areas shaded by existing bushes
    - Existing plants: High tide bush, Hibiscus
- Process:
    - Direct planting (plants grown in coir pots for 6 weeks, no sand added)
    - Species planted: *Spartina patens*, *S. alterniflora*, and *Panicum amarum*
- Results:
    - Good growth of all plants

Post Planting (2013)

After 5 Years (2018)

Private Residence, Severna Park (2015)

- Site Conditions:
  - Location: Magothy River (Anne Arundel County, MD)
  - Wave Energy: Quiet cove, maximum fetch of 0.3 miles to the ESE. No significant boat wake
  - Nearshore water: Shallow bench off rock (exposed at normal low tide)
  - Sediment: Very little sediment accretion in rock. Small natural marsh is adjacent. All other adjacent shorelines have bulkheads or riprap. Upland area is forested with steep slope. Likely provides some sediment.
  - Aspect and Shade: ESE facing. Shading from trees, partial sun
  - Existing plants: Nothing in rock. English ivy was removed prior to planting
- Process:
  - Rock filled with sand before planting plugs
  - Species planted: *Hibiscus moscheutos*, *Solidago sempervirens*, *Panicum amarum*, *Spartina patens*, *Spartina alterniflora*, *Schoenoplectus pungens*
- Results:
  - Sand washed out soon after planting, taking most of the plants with it
  - Some difficulty planting given large rock. Good *S. patens* and *S. sempervirens* survival and growth
  - *S. alterniflora* mostly failed but three to four living stems remain
  - Some natural colonization has occurred

Before Planting (2015)

After 2 Years (2017)

Gibson Island, FWS Project (2015)

- Site Conditions:
    - Location: Magothy River (Anne Arundel County, MD)
    - Wave energy: maximum fetch of 0.56 miles to the WNW; pier in front of site provides some wave attenuation
    - Sediment: Little to no accretion in rocks, minimal potential for upland erosion
    - Aspect and shade: WNW facing, full sun
    - Existing plants: Adjacent fringe marsh grasses and shrubs
- Process:
    - Rock filled with sand and washed in with pumped water before planting. Plants were first grown out in coir pots for 6 weeks
    - Species planted: *Spartina alterniflora*, *Solidago sempervirens*, *Panicum virgatum*, *Spartina patens*
- Results:
    - Initially the sand washed out and it appeared that most of the plants were gone
    - Some of the upper zone plants were planted too high
    - Summer 2021: some bare patches of rock, but good survival in high marsh species and natural colonization

Photo Credit: Meg Cole

6 Years After Planting (2021)

Shipwright Harbor Marina - Deale, MD (2019)

- Site Conditions:
    - Location: confluence of Tracys Creek and Rockhold Creek in Herring Bay (Anne Arundel County, MD)
    - Wave energy: maximum fetch of 0.76 miles to the SE
    - Sediment: Little to no accretion in rocks, low potential for upland erosion
    - Aspect and shade: east- and west-facing
    - Existing plants: various shrubs and trees just upland (in some areas, shading the rock); *Spartina patens, S. alterniflora* and phragmites present in occasional patches
- Process:
    - Direct planting (plants grown in coir pots for 6 weeks, no sand added)
    - Species planted: *Spartina alterniflora*, *Solidago sempervirens*, *Panicum virgatum*, and *Spartina patens*
- Results:
    - Most of the *S. alterniflora* appears to have washed away and some of the upper zone plants were planted too high by volunteers
    - Good survival of *S. patens, P. virgatum*, and *S. sempervirens*


Post Planting (2019)


After 3 Months (2019)


After 1 Year (2020)


Post Planting (2019)


After 3 Months (2019)


After 1 Year (2020)

Poplar Island, Cell 4D (2019)

- Site Conditions:
  - Location: within Cell 4D on Poplar Island
  - 65 foot groin with *S. alterniflora* marsh behind it
  - Wave energy: while not completely exposed to the Bay, there is a significant amount of wave energy coming into contact with the groin. It was designed to dissipate wave energy before it reaches the marsh behind it.
- Process:
  - Direct planting (plants grown in coir pots for 6 weeks, no sand added)
  - Rock is much larger here, so plants were wedged into good spaces rather than moving the rocks around
  - Species planted: *Spartina alterniflora*
- Results:
  - Site was planted late in the summer (3rd week of August 2019), so the grasses had much less time to establish
  - Good survival considering late planting and large rock size

Post-Planting (2019)

After 1 Year (2020)

After 2 Years (2021)

Hillsmere Community Marina (2020)

- Site Conditions:
  - Location: mouth of the South River (Anne Arundel County, MD)
  - Rock groin for controlling wave energy at the marina
  - Larger rock size (10to 14 inch average)
- Process
  - Direct planting (plants grown in coir pots for 6 weeks, no sand added)
  - Species: *Spartina alterniflora, Spartina patens, Panicum virgatum, Solidago sempervirens, Kosteletzkya virginica*
- Results
  - After a year, most plants gone (~10 percent remain)
  - Failure most likely a result of too much energy at the site, preventing vegetation from staying secure in the larger rock voids
    - Some likely planted too high due to volunteer involvement
    - Planting occurred in late August due to the pandemic, so not enough time for roots to grow and establish in the rock

Before Planting (2020)

Post-Planting (2020)

After 1 Year (2021)

Gibson Island Case Study – *Sepehr Baharlou (BayLand Consultants and Designers, Inc.)*
Sepehr Baharlou, from BayLand Consultants and Designers, Inc., spoke to the group about a project the firm had completed in 2011 on Gibson Island, Maryland. The community on Gibson Island relies on a single road for access to their homes. Roughly 500 feet of the causeway had been threatened by erosion on both sides, as storms that come through often over top the road. The community approached BayLand to come up with a solution that would protect the roadway from erosion while retaining the character of the neighborhood and being aesthetically pleasing. The presence of submerged aquatic vegetation (SAV) in the protected cove on the western side of the road precluded a living shoreline design, so the company had to consider other options. The solution implemented was a modified stone revetment that integrated vegetation into the hardened structure. The structure was a traditional revetment; however, they filled the voids between the riprap with a pea gravel and sand mixture, topping the structure off with an additional 4 inches. This provided growing media for the vegetation. In the high marsh elevations, *Spartina patens* was planted, and in the low elevations, *Spartina alterniflora*. BayLand constructed about 100 feet to test the technique in 2005 and after assessing success, completed the rest in 2011.

The finished shoreline structure protected the roadway from erosion, allowed SAV to continue flourishing in the cove, and met the aesthetic desires of the community. Ten years after the construction, the vegetation at the site is robust. Some of the gravel and sand mixture did migrate downslope, but this allowed some area for the marsh to grow. Though BayLand planted only *S. patens* and *S. alterniflora*, years later there are at least 8 to10 species present due to natural colonization, including high tide bush. BayLand and the community are both pleased with the results of the project, which have implications for the broader success of integrating vegetation into existing rock shoreline structures.

Figure 6. Pictures of the BayLand Engineering Green Riprap installation at Gibson Island at various stages of completion. From left to right, the images show the after riprap construction (2004), after filling and planting (2011), and one year after planting (2012). Images provided by BayLand Consultants & Designers, Inc.

Nurseries – *Tom Wheeler (Providence Center)*
Tom Wheeler, Greenhouse Manager for Providence Center, was unable to give his presentation as scheduled, but planned on speaking about how nurseries fit into the process for Green Riprap projects.

Nurseries like Providence Center in Arnold, MD, are a necessary aspect of a successful Green Riprap planting. Because Providence Center has provided plants for Green Riprap projects in the past, they are prepared for orders of marsh grasses grown for a month in coconut fiber pots. If a nursery has not done so before, it is important to contact them well over a month in advance of the intended plant date to allow them to source the coconut fiber pots. If the nursery has enough notice, they can plant the seed directly in the coconut fiber pot, otherwise the grasses will be transplanted later into the pots.

Social Aspects of Green Riprap and Natural Shorelines
This section focused on the social aspects of Green Riprap and related green infrastructure projects that affect implementation.

Site Selection and Best Options to Incorporate
– Leah Franzluebbers (USFWS), Rich Mason (USFWS)
Mason emphasized that because there are a limited number of pilot projects completed, it is difficult to draw definite conclusions about which site conditions are best for the success of Green Riprap plantings, but gave an overview of variables that anecdotally have produced more success. Aspect does not seem to matter, but it is important for the site to have full sun exposure, as the fringe marsh plants are adapted for more sunlight. Higher fetch can make plantings difficult because it can dislodge plants, but some projects have been completed with longest fetch as high as 2 miles. Boat wake introduces similar issues as high fetch, but projects can still succeed even with high boat wake. A.3:1 ratio or shallower slope of the revetment and gradual nearshore slope are best, because shallower slopes allow more opportunity for sediment to be trapped. Planting in smaller rock has been preferable. It is easier to plant when revetments contain smaller rock sizes because the rock can be more easily moved around in order to wedge the plants successfully. Because the plants will be closer together in revetments with smaller rock, spread of the vegetation enough to cover the rock will occur faster. Gradual natural sediment input through littoral drift or runoff from upland is useful to increase the spread of vegetation over the riprap structure. Existing plants at or nearby the site are useful as biological benchmarks to ensure planting in the proper tidal zones. Consult Table 1 in Appendix D for a summary of these site characteristics.

There is still room for experimenting with site conditions when planting riprap with vegetation. If one is unsure about the conditions of a site, one option is to conduct a test planting of a small number of plants and assess survival over time. With landowners it is important to communicate that the success of the technique is not guaranteed, and that there may be some loss of plants and some need for a follow up planting in the future. Additionally, the grasses do take some time to fully establish and completely overrun the riprap with vegetation. Altogether, managing expectations is key – there is a lot of potential for success with Green Riprap but as with all restoration nothing is guaranteed.

Shoreline Property Owner Decision-Making: Motivations and Drivers

– Amanda Guthrie (Virginia Institute of Marine Science)

All Virginian property owners that applied for a shoreline erosion permit in 2019 were mailed a survey about the factors they considered during the shoreline modification decision-making process. Property owners that are modifying their shoreline for erosion control are often receiving the modification they requested from a contractor, indicating that they are already aware of some of the modification options, and that contractors may be a key point to affirm or redirect their preferences. Bulkheads and riprap are often being installed as repairs, which can provide an opportunity to add more green elements. Generally, property owners perceive bulkheads and riprap as more effective at erosion control and withstanding storms, whereas they generally perceive Living Shorelines as suitable species habitat and more aesthetically pleasing. As expected, the ability of a modification to provide shoreline protection (i.e., erosion and storm protection) is key in property owner decision-making, yet there are misperceptions about the protection benefits of each modification. Therefore, future messaging could focus on the protection benefits of Living Shorelines rather than the ecological value as property owners are not persuaded by Living Shorelines ecological benefits. As property owners may have decided which modification to install before they talk with contractors, the contractors are a key messenger that has potential to sway property owners' modification choice.

Marketing to Property Owners: Social Marketing to Improve Shoreline Management

– Jennifer Tabanico (Action Research), Lori Large (Action Research)

The goal of this project was to enhance the use of Living Shorelines to improve the health of the Chesapeake Bay and its tributaries by building resilient infrastructure, reducing excessive shoreline erosion, and preventing sediment, nitrogen, and phosphorus pollution, thereby creating healthier ecosystems, protecting communities, and mitigating the impacts of climate change. A key component of this project is for shoreline property owners to increase adoption of Living Shorelines or keep existing shorelines natural.

The project used a behavior-based data-driven approach called community-based social marketing. The process utilized the following data sources to identify the challenges faced by property owners when making decisions about their shorelines: a literature review; a survey of shoreline management experts; focus groups and a survey of Maryland and Virginia shoreline property owners. In addition, a steering committee of shoreline and communication experts was assembled to provide oversight and expertise.

The research results were used to design strategies and materials to help shoreline property owners in the Chesapeake Bay better manage their shorelines. Conducting a barrier and benefit mail survey was an essential step to understanding how to market the program to shoreline property owners. The survey was conducted in February and March 2020 with 1,600 shoreline property owners in Maryland and Virginia. Since shoreline aesthetics and management practices were found to be highly influenced by neighbors, f ocus groups were conducted with shoreline residents to explore how they communicate with one another.

- Mail Survey: The primary benefits to installing a Living Shoreline identified by property owners were: (1) I want to protect the health of the Bay; (2) I like how Living Shorelines look; (3) I want to provide habitat for fish; and (4) It's the right thing to do. The primary barriers to installing a Living Shoreline were: (1) Do not want to apply for a permit; (2) Living Shorelines are too expensive; and (3) Skepticism about Living Shorelines as an erosion control measure.

- Focus Groups: Neighbors regularly talk to each other about their shorelines and activities connected to the Bay, such as crabbing and boating. Residents check out each other's shorelines from the water. Many neighborhoods have online social media groups (e.g., Facebook and Nextdoor) where they share news and events. In addition, they read local newsletters. When seeking information about their shorelines, residents identified VIMS and Master Gardeners as credible sources. Interestingly, residents stated that the Bay area is made up of two groups – the *from here's* (i.e., have been in the region for decades or generations) and the *come here's* (i.e., own a vacation home or have newly arrived to the region). If a program relies on voices from residents to assist with outreach activities, it may be important to identify representatives from each group.

  Conclusions: Installing a living shoreline can be challenging for property owners to pursue on their own. The process involves collaboration with local, county and state government agencies, hiring of contractors or other technical experts as well as financial resources. Therefore, a program was designed to provide guidance to community members and non-profit agencies assisting property owners to take crucial steps towards protecting their shoreline and the health of the Bay. The overarching program message is that keeping a natural shoreline or installing a living shoreline protects your property and the health of the Bay. Importantly, education alone is not likely to influence adoption of complex behaviors. How program materials are presented to property owners, and by whom, are vitally important in piquing interest in living shorelines. In addition, seeing what their neighbors have done, and knowing there are others in the community who support living shorelines, are influential forces for engaging residents in this highly visible behavior.

Key Discussion Points

Research Needs

Breakout groups first discussed what research needs participants felt were most pressing in regard to the technique. Suggestions tended to coalesce around two categories: 1) research that would inform project design parameters and 2) research that would increase knowledge about the ecological functioning of greening riprap structures.

Design parameters discussed were the type and size of riprap, best planting methods, hardiest plant species based on salinity and location, timing of planting, limits of fetch, water regime requirements, and elevational placement of plants. Research needs regarding the ecological performance of Green Riprap projects included water quality and the extent to which greened riprap would remove nutrients and sediment or capture them before they enter the water. Participants also wondered about the use of greened riprap shorelines by organisms, as well as the habitat value and level of biodiversity present. Finally, to what extent greening riprap would attenuate waves and reduce scour was of interest. Research regarding ecological functioning should incorporate comparisons between greened riprap and other shoreline conditions.

Opportunities and Barriers

When discussing opportunities and barriers, participants expressed the importance of effectively communicating that greening riprap is a retrofit technique and not intended as a replacement for Living Shorelines or as justification to put in riprap structures. It will be important to understand the differences in ecological benefit between greening riprap and other natural and green shoreline options. Practitioners will have to understand where greening riprap fits in among other shoreline techniques and how to determine whether Green Riprap is the best option at a specific site. Finally, there should be mechanisms implemented to prevent property owners from using Green Riprap as a justification for adding hardened structures where a Living Shoreline is possible and preferred or for skirting mitigation requirements.

Results of several pilot projects revealed plants grown in coir pots approximately 1 quart in size are the best plant stock option. Standard plugs and plants grown in quart plastic pots were tried and did not perform nearly as well. The coir fiber protects the roots from wave energy and retains moisture helping the plants establish a robust root system. The coir pots can also be flattened and molded to fit into different size rock voids while maintaining protection of the roots. Native wetland nurseries typically do not grow plants in coir pots so coordination with nurseries several months in advance of the planting day is necessary.

Discussion then focused on homeowner motivations. At the moment, awareness is a barrier for homeowners, as there is not widespread knowledge about the technique and where it can be used. Homeowners are also deeply motivated by aesthetic considerations. Riprap and bulkhead have become the cultural norm for shorelines, so homeowners may desire what they view as a “clean” or “stronger” shoreline structure, even if those perceptions are not completely true. Finally, with all projects, there is a possibility for failure, with plants failing to survive or being washed away, and not all homeowners are able or willing to take on risk in that way.

One aspect of homeowner awareness of Green Riprap discussed was the opportunity for more demonstration sites, especially in highly visible areas, like public parks. This is discussed more in the Actions and Incentives section. Additionally, because homeowners are highly influenced by their neighbors and peers, participants suggested that outreach to other homeowners could be done by those who have already completed a successful Green Riprap planting on their property.

Finally, participants considered what shoreline owners will need in order to implement Green Riprap projects. Practitioners and homeowners will need all details about Green Riprap projects in one place for easy access, including parameter information mentioned in the Research Needs portion, (nurseries, contractors, etc). There was concern that expertise be readily available, which will mean practitioner groups integrating Green Riprap into their existing suite of shoreline options. Some landowners will not be able or willing to cover the costs themselves, which may necessitate grants or other funding sources.

Actions and Incentives

The final prompt for discussion was which actions or incentives could be put into place to encourage the use of these projects. Discussion focused around three topics: 1) possible policy change, 2) groups who could assist with outreach or implementation, and 3) technique selling points.

Policies suggested included a shoreline enhancement tax credit, which would include a range of shoreline enhancement and restoration techniques, including greening riprap, and would have an adjusted credit based on the ecological benefit of the technique. Funding opportunities were suggested, so that landowners and organizations could offset some or all of the cost of the project. This then raised the need for technical assistance for landowners, whether with grant writing, project planning, or planting. Finally, Total Maximum Daily Load (TMDL) credit was suggested, though many had reservations about that idea, as some worried adding a credit might incentivize the implementation of adding new hardened structures that happen to have vegetation integrated rather than Living Shorelines.

Discussion occurred around groups who could assist with incentivizing Green Riprap projects. Many suggestions were traditional environmental organizations, such as the Watershed Stewards Academy, local Riverkeepers, Master Naturalists, Master Gardeners, and the Chesapeake Bay Trust. Others suggested less traditional avenues, realtors and community groups, as good ways to reach more landowners. Forming relationships with volunteer groups, like the Maryland Conservation Corps, to carry out the planting work was suggested as well.

Finally, discussion turned to aspects of the technique that are most enticing to landowners who consider greening their riprap. Because they involve no sediment movement, projects do not require permitting. The cost is fairly low and a cost range per linear foot of revetment would give practitioners a tool to convince landowners of the ease of a Green Riprap project. Implementing a Green Riprap project in a high-use area like a public park would increase visibility and awareness of the technique, increasing the chance other community members try Green Riprap themselves. A project at a public area can be integrated into a larger plan of social marketing, where the public sees Green Riprap as a way to help their local environment, improve water access, and assist vulnerable or charismatic species. Overall, discussion emphasized the potential to fit this retrofit into an image of a desirable shoreline landowner lifestyle, decreasing the inclination towards maintaining bare riprap revetments.

Recommendations

There were three main categories of recommendations that came out of the workshop; 1) there is a clear need for additional research to help understand both the best design of these shorelines and their benefits; 2) there is a need for increased visibility of the technique through the creation of public pilot projects; and 3) there is a need for additional outreach to all the involved parties, including property owners, contractors, and regulators to ensure clear definitions and that the projects are sited and designed correctly. Specific recommended actions for each category are described below.

Research Needs

One of the pressing research needs is the development of clear design guidelines. Siting of Living Shoreline projects is key to their success and the same is anticipated to be true of Green Riprap projects. Key considerations that should be studied include the types/sizes of rock (and rock niches) that best support plant persistence, best planting practices (such as the best season for planting, whether to include substrates or fertilizers, etc), which plant species are most suited to the practice and how that might vary by location, the source and genetic make-up of the plant stock, tidal elevations most suited to each species of plant, and the limits of fetch under which a project is likely to thrive. An additional research question is how and when greening be integrated into Living Shoreline projects to add benefits to the projects. These questions can be answered through the study of existing projects and naturally colonized riprap sills, wave tank studies, and experimental construction of projects incorporating multiple different techniques or plant species.

The second pressing research need is to understand the ecological function and benefits of completed projects. Green Riprap projects are hypothesized to provide enhanced water quality improvements, nutrient and sediment removal, wave attenuation, and estuarine faunal habitat relative to riprap alone. However, these hypotheses are based on their similarity to the better-studied Living Shorelines since there is a paucity of current Green Riprap projects. Both the veracity of these hypotheses and size of the effect of enhancement provided by the planted riprap should be examined experimentally. Green Riprap has the potential to mitigate wave climates which could reduce the reflected wave scouring effect around the riprap structures, benefiting adjacent SAV beds and increasing the value of the nearshore habitat for benthic organisms. However, there are also concerns that the vegetation could affect the integrity of the riprap structure, leading to shorter lifespans. Since there is no data on either of these effects, they are prime research needs. Long-term monitoring of adjacent Green Riprap and standard riprap projects would help quantify these benefits/concerns.

Pilot Projects

A proliferation of pilot projects is an important step towards both quantifying Green Riprap services and expanding their visibility; therefore, this recommendation came up in multiple discussions. Pilot projects should use the best practices developed through research and/or contribute to the development of best practices. For research purposes, projects can be on public or private lands, but are best situated adjacent to riprap or Living Shoreline projects, allowing paired comparisons with the Green Riprap project of services. For enhanced visibility, Green Riprap projects are best situated on public lands, ideally paired with signage and other outreach materials.

Outreach and Messaging

The most important outreach recommendation is to ensure messaging about Green Riprap, as it fits into the continuum of shoreline practices, is consistent. It is important that homeowners, contractors, and regulators have the same understanding of when a Green Riprap project, rather than a Living Shoreline project, is appropriate to the site. In addition, since Green Riprap projects are ecologically more similar to riprap than a natural marsh, clear guidelines about how they fit into the regulatory structure are necessary. For example, in a project where natural marsh was lost and compensatory mitigation was required, **Green Riprap would not qualify as mitigation for the lost marsh**. This report should serve as a starting point for clear messaging, but development of state-specific BMP documents would be beneficial.

Other outreach recommendations included: leveraging groups that already work with landowners (such as non-profits and riverkeeper groups) and compiling resources for projects into a centralized location. The resources should be organized in the framework of a "step-by-step" process, including who can help design these projects, which plants to choose, and the typical cost range per linear foot of project. The resources should include a section for exchanges of Lessons Learned, for example, because most nurseries don't grow plants in the preferred quart-size containers, it is necessary to contact the nursery many months before the project is due to be planted.

Conclusion

Green Riprap is a relatively new technique for enhancing ecosystem services on already established riprap projects. Although there is little data on the efficacy of these projects, results from existing projects are promising. Their low cost and ease of permitting are key assets and should ensure interest in the practice if its benefits can be quantified. Research, increased visibility, and consistent messaging are all keys to ensuring that the practice moves forward and becomes more common.

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Appendix A: Agenda

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC) Workshop

Assessing the Water Quality, Habitat, and Social Benefits of Green Riprap
September 15th, 2021

9:00 am **Introduction**

- Welcome, expertise in the room; purpose of the workshop
- Objectives of the workshop – *Rich Mason (FWS), Leah Franzluebbers (FWS)*
    - Define Green Riprap vs. Living Shoreline

9:30 pm **Virtual Field trip to Green Riprap Sites** – *Severn Media*

9:45 am **Ecological, Social, and Bioengineering Aspects of Green Riprap and Natural Shorelines**

9:45 am **Ecological** –

- Restoring and preserving the shoreline ecotone– *Donna Bilkovic (VIMS)*
- Above the rock: options for landscaping or naturalization – *Doug DeBerry (William & Mary)*
- Managing phragmites – *Dennis Whigham (SERC), Kirk Havens (VIMS)*

10:45 am **15-minute Break**

11:00 am **Bioengineering** –

- Structural, "how to":
    - Case studies and techniques – *Rich Mason, Leah Franzluebbers (FWS)*
    - Gibson Island – *Sepehr Baharlou (BayLand Engineering)*
- Nurseries – *Tom Wheeler (Providence Center)*

11:45 am **Social** –

- Site selection – *Rich Mason (FWS), Leah Franzluebbers (FWS)*
    - Retrofitting existing Riprap structures
    - Best options to incorporate
- Shoreline modification decision making - *Amanda Guthrie (VIMS)*
- Marketing to homeowners – *Jennifer Tabanico, Lori Large (Action Research)*

12:45 pm **Lunch**

1:45 pm **Breakout Discussions: How can we get more of these pilot projects going?**

2:15 pm **Reconvene and Report-out**

2:45 pm **Whole Group Discussion**

3:15 pm **Adjourn**

Appendix B: Workshop Participants

Aaron Wendt, Virginia Department of Conservation and Recreation
Alexi Sanchez de Boado, Princeton Hydro
Amanda Guthrie, Virginia Institute of Marine Science
Antonija Mađerić , EcoMission
Ariel Woodworth, Cecil County Government
Cirse Gonzalez, Virginia Institute of Marine Science
Dan Gefell, U.S. Fish and Wildlife Service
Danielle McCulloch, U.S. Fish and Wildlife Service
Dennis Whigham, Smithsonian Environmental Research Center
Donna Marie Bilkovic, Virginia Institute of Marine Science
Doug DeBerry, William & Mary
Greg Noe, U.S. Geological Survey
Isabel Sanchez-Viruet, University of Maryland College of Environmental Science
Jane Cyphers, Community Members
Jennifer Tabanico, Action Research
Karinna Nunez, Virginia Institute of Marine Science
Katherine Stahl, U.S. Fish and Wildlife Service
Kerry Bray, Hazen and Sawyer
Kirk Havens, Virginia Institute of Marine Science
Lauren Taneyhill, National Oceanic and Atmospheric Administration
Leah Franzluebbers, U.S. Fish and Wildlife Service
Lew Linker, United States Environmental Protection Agency
Lori Large, Action Research
Lorie Staver, University of Maryland College of Environmental Science
Marija Hrgarek, EcoMission
Mary Bennett, Elizabeth River Project
Molly Mitchell, Virginia Institute of Marine Science
Nicole Carlozo, Maryland Department of Natural Resources
Rich Mason, U.S. Fish and Wildlife Service
Sarah Hilderbrand, Maryland Department of Natural Resources
Scott Macomber, Stormwater Maintenance LLC
Sepehr Baharlou, BayLand Consultants & Designers, Inc.
Ted Brown, Biohabitats
Thayer Young, Cicada Systems GIS Consulting
Tim Sullivan, U.S. Fish and Wildlife Service
Tom Ihde, Morgan State University
Tracey Harmon, Virginia Department of Transportation
William Nardin, University of Maryland College of Environmental Science

Appendix C: List of Figures

Appendix D: Tables

Green Riprap Site Conditions	
Variables	**Lessons Learned from Pilot Projects**
Aspect	Unimportant
Sun Exposure	Full sun preferable, but varies based on target plant species
Average Fetch (NM)	Lower fetch has higher chance of success
Longest Fetch	Sites with less than 2 miles are worth considering
Boat Wake (mph)	No-wake zone preferred. Sites with boat wake may work
Revetment Slope	3:1 or less is best. Shallower slopes preferable
Nearshore Slope	Gradual nearshore slope is best
Size of rock	Smaller rock is preferable for ease of planting and faster plant spread
Sediment Source	Sediment inputs (e.g. upslope sediment erosion) can speed up plant growth
Nearby Natural Marsh	Can be seed source for natural colonization
Presence of Exposed Mud/Sand Flat	Most successful sites have had exposed bottom at low tide, but other sites are worth considering
Soil Depth (Low-Mid)	Any soil or sediment in the rock voids is good
Soil Depth (Mid-High)	Any soil or sediment in the rock voids is good
Percent Cover Existing Vegetation (Low-Mid)	Natural colonization of rock structures indicates greater possibility of project success
Percent Cover Existing Vegetation (Mid-High)	Natural colonization of rock structures indicates greater possibility of project success
Plant Diversity	Existing plants provide a great biological benchmark in addition to a clue to the expected outcome

Table 1. Recommendations on site characteristics based on the US Fish and Wildlife Service (USFWS) observation of pilot project successes and failures. These are intended as lessons learned to assist with site selection - results may vary based on project attributes. Additional data is required.

Appendix E: Participant Responses to Mentimeter Polls and Jamboard Prompts

Figure 7. Mentimeter results from a full-group exercise. Participants were asked to 1) identify new and suitable locations for future Green Riprap demonstration projects within the Chesapeake Bay region and 2) record any additional barriers to Green Riprap implementation not discussed in workshop presentations. Answers live populated as participants responded to the posed question.

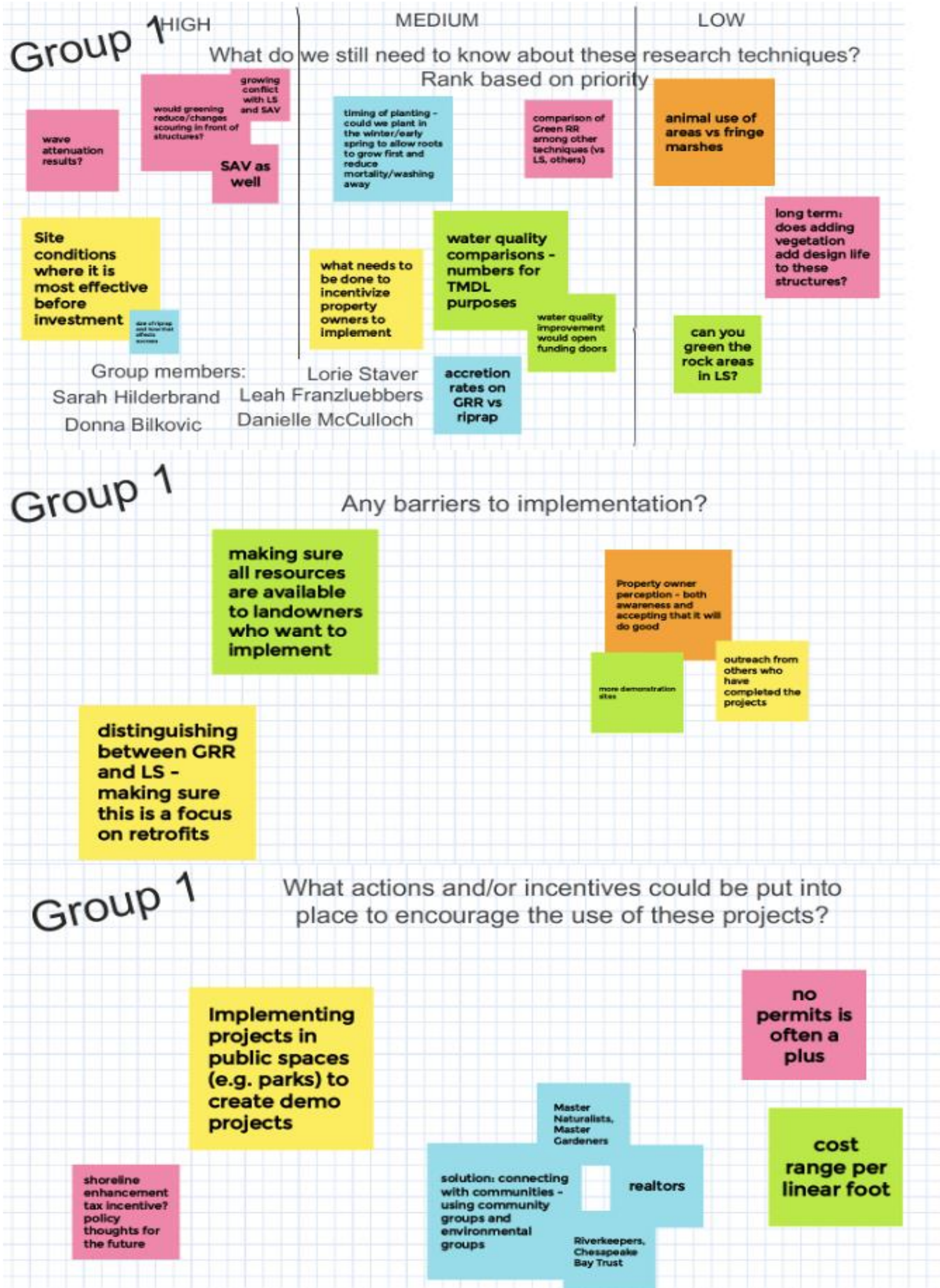

Figure 8. Jamboard Slides from Breakout Group 1 during the afternoon breakout session.

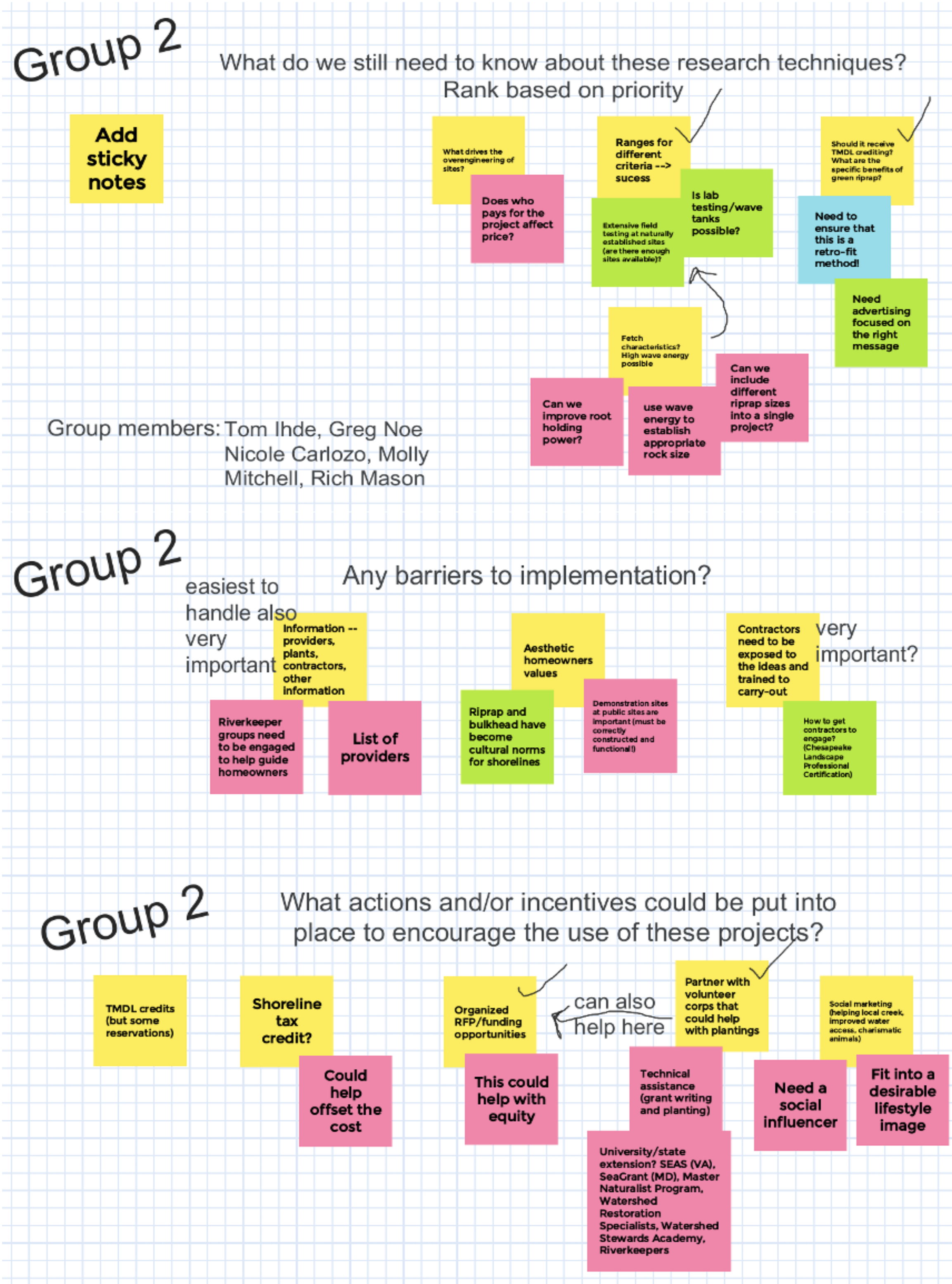

Figure 9. Jamboard Slides from Breakout Group 2 during the afternoon breakout session.