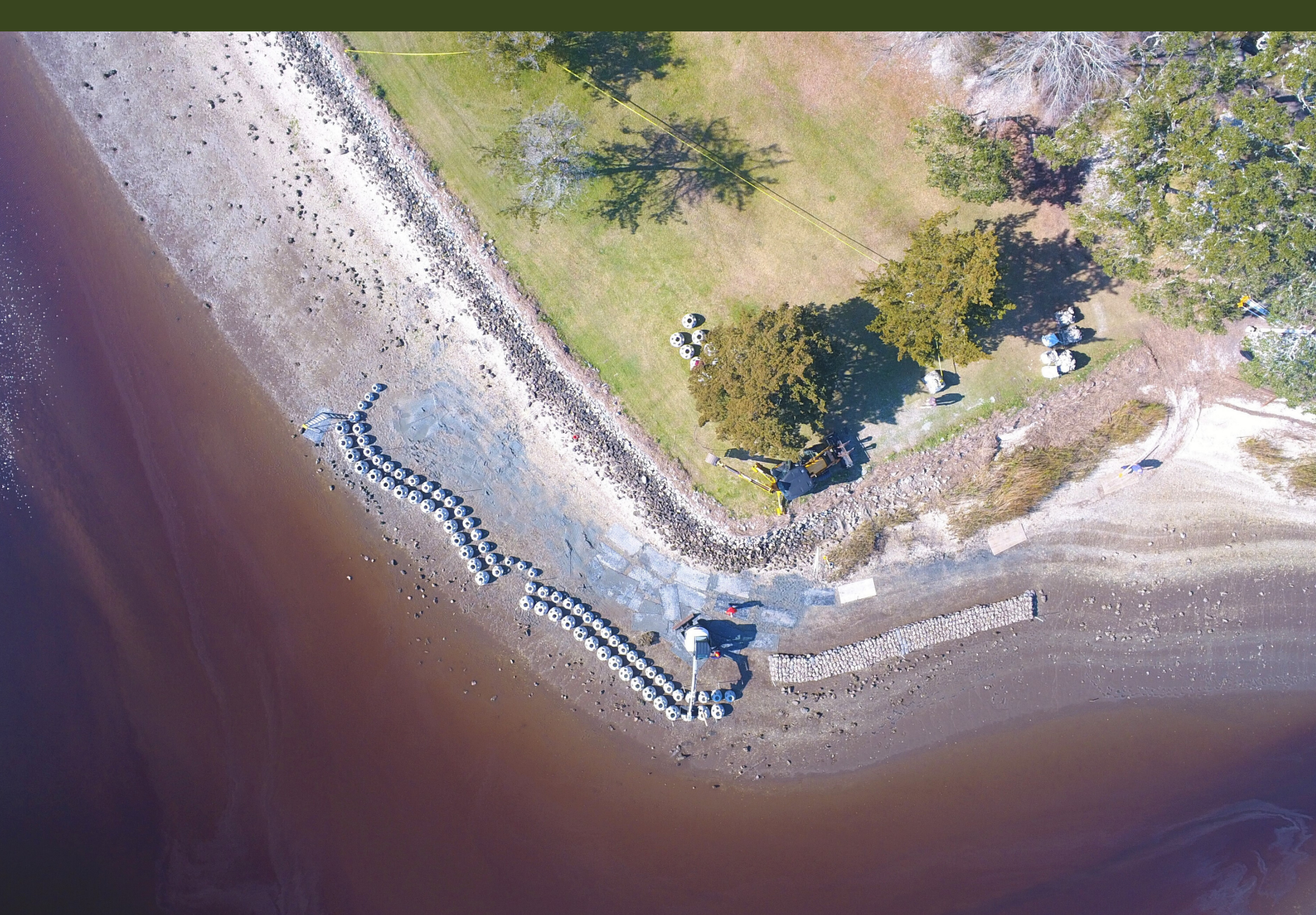


2019 LIVING SHORELINES TECH TRANSFER WORKSHOP

October 8-9 | Beaufort, North Carolina



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EXECUTIVE SUMMARY

Over two hundred proponents of nature-based coastal management came together to exchange ideas and learn from each other in scenic Beaufort, North Carolina for the 2019 Living Shorelines Technology Transfer Workshop. The crowd included property owners, researchers, contractors, regulators, coastal resource managers, and friends of many estuaries and bays around the region and across the country.

After opening remarks, the group split up and ventured out to one of three field sites for an opportunity to see living shorelines up close and to hear from local researchers about their progress. The field trips also offered plenty of opportunity for networking and casual conversation among attendees.

The first afternoon plenary covered a broad range of perspectives on living shorelines and why people opt to use them. The speakers represented multiple perspectives, from transportation planning and contractors, to private property owners, and could address a variety of pros and cons in selecting and building a living shoreline. The second afternoon plenary covered regulatory concerns. Nationwide permits and other local alternatives, such as requiring considering of living shorelines instead of armoring, have facilitated uptake of living shorelines in some areas. However, the permitting environment varies widely among the states.

The morning plenary on the second day included researchers discussing their observations and models of efficacy and durability of living shorelines. In many cases, living shorelines are better able to withstand the impacts of recent hurricanes in the region, however they do not provide the flood protection that seawalls can. The Army Corps of Engineers is developing guidelines for the design and construction of living shorelines, which should set a standard in the US and worldwide.

The late morning had five concurrent sessions covering a range of topics. The first discussed options for oyster reefs that avoid use of plastics. This was a popular and session that included presentations from numerous design firms and users discussing their experiences with developing alternatives. The second session discussed methods for training contractors in designing and building living shorelines. Participants discussed challenges such as designing a widely applicable curriculum and how to market living shorelines. The third session was a review of monitoring methods, focusing on how to best utilize the latest technology. Balancing the costs and training demands with the need for more and higher quality data was a concern for many attendees. The fourth focused on water quality and shellfish. This session had a wide range of concerns because the issues are so often highly localized, but managing the harvest of oysters off living shorelines and regulations around closed waters were common among many participants. The fifth session was about the costs of living shorelines. The speakers addressed some of the comparative costs, and include issues such as storm impacts and maintenance needs, although they indicated that there is not enough long-term data on maintenance and monitoring costs.

The final plenary focused on the future of living shorelines and how to make the case for using them in coastal management. The speakers emphasized the need to be more inclusive and work with local communities to earn their support for nature-based methods. They also underscored how sea level rise will be increasingly important, and that living shorelines need to be sited and designed properly in order to self-maintain.

The workshop offered participants a chance to discuss the challenges they face in implementing living shorelines, and to learn about how others have found success. The issues that came up most frequently include resistance in the permitting system, lack of awareness among property owners and contractors, lack of a good alternative to plastic for oyster bags, and the need for site-specific design. The workshop brought together people actively working towards solutions in one place to exchange ideas and find inspiration to take back home.

DAY 1

Welcome

Jeff Benoit, President of *Restore America's Estuaries*, opened the workshop by acknowledging the Nuesiok peoples and their current decedents, the Coharie Indian Tribe. He then welcomed everyone to Beaufort and underscoring the importance of the topic of living shorelines. He explained how a recent report on climate change included models showing trends of temperature, sea level and other indicators all moving in the wrong direction. This alarming report drives home the importance of healthy, resilient estuaries. Estuaries are the first line of defense for the coast from rising seas as well as other stressors. It is critically important to enhance the resilience of estuaries.

Next, Todd Miller of the *North Carolina Coastal Federation* addressed the gathering. He spoke about how the string of major storms in recent history has impacted the region and described two recent bills that passed unanimously, facilitating living shorelines oyster restoration. North Carolina has over 12,000 miles of estuarine shoreline, and living shorelines are an essential element to their health.

The next speaker was Everette Newton, Mayor of Beaufort. He spoke dynamically about Beaufort and his lifelong connection to the community and the research facilities there. One big challenge in the region is the economic divide, which was further exposed by Hurricane Florence. He also spoke about the Newport River Estuary, which is already stressed and will become more stressed as new residents and visitors come to Carteret County. Currently, every single feeder to the estuary is closed for shellfish harvest. They need help to mitigate stressors throughout the watershed.

The final speaker of the morning was Sharon Harker, Mayor Pro Tem of the town of Beaufort. She highlighted how Beaufort was elected America's coolest small town in 2016, drawing national attention to the community. It was originally known as a fish town and remains proud and protective of its natural resources. She praised living shorelines as simple, efficient, and resilient.



Field Sessions

Hammocks Beach State Park's Jones Island | Swansboro

Jones Island has a variety of living shoreline techniques, including salt marsh grass plantings, oyster shell bag sills and marsh toe revetments, and loose oyster shell patch reefs. Participants heard about research on the stabilization of the shoreline over time and the development of marsh and oyster habitat post-installation. A granite sill with landward salt marsh grass plantings can was also visible at the Park's Visitor Center.

Pivers Island, Sandbar Oyster Co. Shellfish Lease | Rachel Carson National Estuarine Research Reserve and Beaufort/Morehead City

Participants rotated between Pivers Island (home of the Duke University Marine Laboratory and the National Oceanic and Atmospheric Administration Beaufort Lab), the Rachel Carson Reserve (part of the N.C. Coastal Reserve and National Estuarine Research Reserve), and Sandbar Oyster Company's shellfish lease located at the mouth of the Newport River. Living shoreline example across a range of wave energy environments at these sites include salt marsh grass plantings, granite sills, loose oyster shell placement, oyster shell bag marsh toe revetments, and marsh toe revetment and sandflat oyster reef creation with OysterCatcher™. Participants heard about research on the long-term performance of living shorelines, as well as factors to consider when installing living shorelines in high-energy environments.

Trinity Center and N.C. Aquarium at Pine Knoll Shores | Bogue Banks

Participants viewed a variety of living shoreline techniques at Trinity Center and the N.C. Aquarium at Pine Knoll Shores including granite and oyster shell bag sills and OysterCatcher™ marsh toe revetments. Researchers discussed their findings on fish utilization of living shorelines, as well as the performance of living shorelines during Hurricanes Irene, Arthur, Matthew, and Florence as compared to bulkheads.



Workshop attendees boarding boats for the workshop field sessions.

Plenary Session I

Engagement and Changing Attitudes: What makes people and sectors adopt living shorelines?

Moderator: Bob Stokes | Galveston Bay Foundation

Nature-Based Solutions for Coastal Highway Resilience

Tina Hodges | Federal Highway Administration

There are 60,000 miles of coastal roads in the US, providing an opportunity for coastal resource managers and transportation agencies to work together on nature-based solutions, which can both protect roads from flooding and offer habitat and other environmental benefits. The Federal Highway Administration wants to encourage more and better use of nature-based solutions, which includes natural features, nature-based features, and hybrid approaches. These types of improvements mimic nature by using natural materials and processes.

The FHWA sponsored pilot projects, held workshops and produced an Implementation Guide to provide information to transportation agencies so they can implement nature-based solutions to protect their highways. The guide includes technical factsheets, analysis of benefits and estimates of typical costs. It then provides step by step guidance on how to implement nature-based solutions in the transportation context, starting with planning and continuing through funding, site assessment, design, permitting, construction, maintenance, and adaptive management. Nature-based solutions provide transportation agencies with an opportunity to meet multiple goals: to protect roads and surrounding communities from wave impacts, erosion, and flooding, create habitat; and potentially offer compensatory mitigation credit.

The FHWA implementation guide provides examples of several nature-based solutions designed to protect roads from coastal flooding and erosion, including:

- Project Greenshores – Breakwaters and marsh

behind; led by FL Dep of Environmental Protection;

- Yorktown, VA – Pocket beaches solution; VA DOT; flood protection for the street;
- Corpus Christi, TX – Living shorelines (shellfish/saltmarsh) with reconstruction of Laguna Shores Rd.

What Makes People and Sectors Adopt Living Shorelines?

Matthew Lauffer | North Carolina Department of Transportation

NC DOT is looking at living shorelines for its 590 miles of roadway that are within 100 feet of the coast. Extreme events are increasing in frequency, some recent examples are Hurricane Matthew and Hurricane Florence. After Florence, I40 was down for a week and the city of Wilmington was closed off from the world for four days. Sea level rise is causing overwash and inundation. Nuisance/sunny day flooding is affecting more areas. We need to do more risk assessment, and to look at nature-based solutions to these problems.

There are incentives in place to encourage use of nature-based methods, including Executive Order 80 from the governor of NC. The state NPDES storm-water permit program has a really strong retrofit program and encourages resilience planning. The underlying philosophy is laid out in the *One Water* initiative, which seeks to interconnect water supply, waste water and stormwater systems.

The DOT has numerous tools to encourage more nature-based management. They are talking with NCCF about highway projects, particularly prioritization and site selection. They can provide training through peer exchanges, workshops, and other collaborations. Their guidelines currently don't address nature-based solutions and they need to, so there's room for improvement. They have streamlined approaches with permitting agencies such as CAMA, DEQ, etc.

Mr. Lauffer mentioned that through the attrition of staff and design work to consultants, the DOT have reduced partnerships with resource agencies and

project partners. They need to build relationships internally and with communities, university system, organizations like the federation.

Oyster Shell Bag Sill Living Shoreline in the Newport River

Dr. Thomas Steepy | Former Mayor, Town of Beaufort/Living shorelines property owner

NCCF was doing a project at Open Ground Farms in 2017 where Dr. Steepy met Lexia Weaver, and they got to talking. Dr. Steepy was considering a living shoreline for his property on the Newport River. Putting in a living shoreline meant going from a minor to major permit, 13 federal and state agencies had to sign off on the permit. They finally started building in late 2017, and it has been a great success.

Since then, oysters have grown on the sill so that now, two years after construction, the bags are cemented together with mature oysters. He mentions that it is also a great home for baitfish. He enjoyed the project so much that he has ordered 2500 more plugs for April. "I'm really pleased with what we've done," Tom says.

Working Towards a Better Coast

Josh Merritt and Grainger Coughtrey | Carolina Silvics Inc.

Carolina Silvics is a local environmental consulting firm with expertise in storm water mitigation and wetlands. They were able to incorporate living shorelines into their business model, including marsh toe revetments, offshore sills, and native vegetation planting.

They have a long-time partnership with NCCF, having worked for 14 years on wetland restoration projects, and living shorelines took off in 2017. The demand for living shorelines has exceeded NCCF's capacity to build them with volunteers, so having a private consultant to pick up the additional projects has worked well. They currently have 12 shorelines built totaling over 2000 linear feet, of which four were completed solely by Carolina Silvics. They offer two main types of living shorelines:

- Offshore sills – Bags placed offshore, sediment fills in, marsh grows behind

- Marsh toe revetments – Bags placed against the shoreline to prevent erosion

To undertake a project, they first meet with the landowner at the property to discuss objectives and options, and to determine what type of permit will be necessary. They get approval from neighbors and submit the application for a permit. There are numerous challenges associated with installation of a living shoreline. Obtaining the needed materials and preparing bags in large quantity is a time-consuming and labor-intensive process. Because the materials are heavy and the sites are often remote, transport is an issue. At the site itself, they work hard to minimize the footprint of the construction process and avoid damaging the structural integrity of the shoreline. The maintenance requirements can vary by site, but early on there can be shifting and settling so monitoring is required.

They provided some rough pricing estimates for comparison:

- Bulkhead – Typically \$135/ft (can be more)
 - Expensive to repair
 - Take a lot of damage during storm events
 - Accelerate erosion on adjacent beaches/shorelines
- Living shoreline – \$75/ft
 - Incredible durability after and during large storms
 - Offshore sills typically more expensive than marsh toe revetments
- Rip Rap Revetments – \$90/ft
- Breakwaters – \$90/ft
 - Requires major CAMA permit
 - Engineers usually design the structure
 - Generally more expensive due to volume of stone needed

The question session included lots of interest about materials and use of plastics, as well as about public opinion. Tom Steepy said he had received only positive feedback from his neighbors. Carolina Silvics said they source their oysters from seafood restaurants, and numerous commenters said they are looking for non-plastic options for bags, but so far nothing lasts long enough.

Plenary Session II

Permitting and Regulatory Environment: What are the obstacles and challenges?

Moderator: *Todd Miller | North Carolina Coastal Federation*

Atlantic and Gulf Living Shorelines Project

Jessie Ritter | National Wildlife Federation

The National Wildlife Federation is conducting an inventory of living shorelines policies to understand the landscape of current federal and state-level policies. They researched resources for applicants and how permits can be accessible to them. The findings of this project are that general permits are critical, helping to streamline the permitting process, and that they can be national, regional or statewide. Currently, 14 out of 18 states have some kind of general permit. Just over 80 nationwide permit 54s were issued, and only six out of the 18 states have approved them. Maryland and Virginia have directly stated, suggested or indirect regulations that make it more difficult to get a bulkhead, and instead use living shoreline as the preferred alternative. By contrast, many states have state-specific regulations that make it more complicated to apply for a living shoreline. Ms. Ritter anticipates that the report will be finished soon, and it will be available through the Restore America's Estuaries website and other places soon.

General Permits for Construction of Marsh Sills

Daniel Govoni | North Carolina Department of Environment and Natural Resources

The Department of Coastal Management has had a living shoreline strategy for the past seven years. Currently, major permits for projects that will take place along the coast take about 75 days to be issued. By comparison, general permits are simpler, provide just an outline of the project, and are streamlined and done within a few days. The nationwide permit did not help North Carolina, so they needed something local and more specific.

The DCM averages around 150 new permits each year. They have already seen an increase since the passing of the general permit in 2019.

Living Shorelines Laws and Regulations in Maryland

Bhaskar Subramanian | Maryland Department of Natural Resources

The Maryland Army Corps of Engineers divides projects into categories for the purpose of permitting. Once that law was passed, the shoreline erosion control program was formed to provide technical and financial assistance to waterfront property owners. The State of Maryland has several strategies to encourage the use of living shorelines, including outreach and education: Demonstrations of projects with panels with community members, and workshops for homeowners. The goal is for water-front property owners to have a buy-in. There is also a coastal resiliency grant program that will start putting projects on the ground this winter. The challenges that remain are the timescale and designing projects for the future.

Shoreline Management in the Chesapeake Bay

Sadie Drescher | Chesapeake Bay Trust

The Chesapeake Bay Trust, which is primarily funded through a special license plate, has a 5-year contract with EPA to lead a shoreline management panel. As part of their mandate, the panel worked on shoreline management methods that prevent sediments and nutrients from entering the Bay. They found that living shorelines reduce tidal erosion. Different protocols have varying levels of efficacy, but the credits offered are conservative based on literature. Some of the waivers that Maryland allows are enabling more bulkheads to be put in, despite efforts to promote living shorelines. The panel recommends a living shoreline committee to train people on the benefits of living shorelines and to improve public perceptions.

DAY 2

Plenary Session III

Efficacy in storm and higher-energy environments

Moderator: *Capt. Al Modjeski | American Littoral Society*

Introduction

Understanding the performance of living shorelines in high-energy and storm environments is important to their long-term utility. Capt. Modjeski played a video montage of Cooks Beach “Shell-a-Bration” living shoreline construction event using volunteers. The video shows the development of three living shorelines, which help retain habitat for horseshoe crabs and red knots.

Dr. Rachel Gittman | Eastern Carolina University

Dr. Gittman explained that resilience is the capacity of an ecosystem or community to absorb disturbance without shifting to an alternative state. It encompasses both resistance to a state shift and recovery to original state. North Carolina, particularly Carteret County, has experienced numerous hurricane landfalls, including major events: Florence, Irene, Arthur, Matthew, Dorian, and Michael. These storms have variability in the length of stay, magnitude, direction, rain, etc., meaning that shoreline management techniques must be able to persevere in various conditions. Studies on the impacts of Hurricane Irene and Matthew assessed the performance of bulkheads, natural, and sill shorelines post-hurricane events in North Carolina. These studies found significantly more damage to bulkheads. Post-storm damage often results in costly repair or lack of repair from previous storms resulting in compounding damage. They also found that the elevation of marshes with sills was higher and they did see overall vegetation reduction and recovery one year later, but slower recovery rates at natural sites. Natural sites and bulkheads experienced much more waterward and landward

elevation loss compared to living shorelines. Living shorelines recovered more quickly than natural sites and bulkheads also showed a recovery in elevation because of property owner intervention. Bulkheads may be resistant, but they lack the capacity to recover like living shorelines. A waterfront residence survey of North Carolina found that damage and maintenance costs were higher for bulkhead owners compared to natural and riprap sites (there were not enough living shoreline respondents). There is also an ongoing survey related to Hurricane Florence and associated recovery, damage, and experiences of North Carolina residents. In another example, ongoing research at Carrot Island Rachel Carson Reserve NC with different living shorelines show that there has been an overall downward decline across the island due to multiple major storm events.

Dr. Johanna Rosman | University of North Carolina

Dr. Rosman presented her research on modelling wave transformation across vegetated shorelines to aid living shoreline evaluation and design, a study conducted along with Jana Haddad and Dr. Christine Voss. When waves touch the bottom, they begin to shoal, and drag from vegetation results in dissipation of wave energy. The inclusion of a sill will result in waves breaking and dissipating bottom friction sooner. But if water levels are too high the wave won't break, instead the vegetation will dissipate energy. They studied sites in the Newport Estuary and Bogue Sound, NC. They monitored pressure across a marsh and found that wave energy dissipates, but the wave attenuating factor is dependent on water depth. From this field study, they were able to develop a process-based wave model equation, where change in wave energy flux with distances equals the dissipation due to breaking, vegetation, and bottom friction. Their model is able to reproduce their field results very successfully. From their model, they were able to determine that the higher the vegetation density, the higher the dissipation rate. Likewise, the higher the mean plant height, the higher the dissipation rate. The aim is to turn this model into a tool for living shorelines to help evaluate designs and determine suitability of the height of sills and vegetation parameters.

Dr. Candice Piercy | USACE

Dr. Piercy presented on wetland and flood risk and their associated processes and considerations; which speaks to how the USACE is beginning to think about wetland and flood risk and the relevance of these factors to living shorelines. Substantial effort is being made by *Engineering With Nature* (EWN) to align natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes. They hope to provide international guidelines on the use of natural and nature-based features for sustainable coastal and fluvial systems and capture the full range of benefits that things like dunes, marshes, and reefs can provide. Although the guideline does not directly refer to living shorelines, as this is primarily a US-based vernacular, there is discussion with regards to reef systems in front of wetlands. A key consideration should be that wetlands exist on coastlines where slopes are 0.0325 m/m and tend to be in lower wave energy environment and do not have rigid boundaries. Additionally, wave energy exerted on marsh edges varies with

water levels. Most damage occurs on the marsh edges due to strong wind events and degraded below ground biomass makes the marsh more susceptible to erosion. It is important to note that sites are unique with varying conditions and not every solution will work everywhere. Field studies on vegetation and wave attenuation are happening globally; much of research tends to focus on low energy events but overall shows a 72% decrease on average of wave energy associated with vegetation. Greater stem density, greater stiffness of vegetation, greater height of vegetation, and greater marsh width all are factors that increase attenuation, but higher water depth lowers the attenuating factor of all of these.

In combination with an engineered structure, it may be possible to reduce the distance needed to dissipate energy even in a higher water level conditions. It is important to define the wave attenuation objectives of a project and recognize that narrow marsh system project may have limited but still important effects.



Participants networking at the Poster Session of the 2019 Living Shorelines Tech Transfer Workshop.

Breakout Sessions

Topic 1: Role of plastics and alternatives

Lead: Dr. Lexia Weaver | North Carolina Coastal Federation

Traditional plastic mesh bags are commonly used in oyster reef building, however there is a need to transition away from plastic and reduce marine debris. The Federation's goal is to find a degradable mesh that lasts at least 3-5 years so it will allow time for oysters to become established. This session allowed each presenter a chance to present their alternative, and then time for questions and discussion.

Eric Plage from Tampa Bay Watch (TBW) talked about their projects with plastic mesh bags. They filled the bags with fossilized shell, which costs \$60-65 a ton. It is extremely inexpensive, but is also a finite resource. They placed 10 tons of shell a day by shoveling shell into mesh bags and using boats to take them to the shoreline site. The mesh bags are extremely durable and hold the shell in place until oysters recruit to it. They only had one project where bags failed, which was using oyster domes in high energy areas. One challenge they have faced is the need for lots of volunteers, since the projects are labor-intensive, and they need a lot of "match" for the grants.

Joss Merritt of Carolina Silvics described their method for building living shorelines, which is similar to what TBW uses. He highlighted a successful project in Marshallburg, which withstood Dorian with minimal damage. For challenges, he mentioned logistics, permitting and marketing. They need hired labor to fill and move the bags. They use 15-20 lb bags, trying to balance between it being heavy enough to stay in place, but small enough that they can move and manipulate them for installation. He acknowledged that the permitting system has gotten better and faster recently. He has trouble with marketing because potential customers don't want to use plastic in their waterways.

In response to questions, he said that they build within the tidal range and interlock the bags to improve stability. They also had problems with one lot of bags breaking down prematurely and shells getting out. Most areas have excellent recruitment and the oysters will settle on anything they can find. Using alternate materials like rock can be expensive, have labor limitations, and have less surface area for habitat. Recruitment typically starts within 4-6 months and is fully covered by 24 months, but the structure needs the stability of the bags for 3-5 years before it has structural integrity. There is some concern about birds, turtles and marine mammals becoming entangled in living shorelines, but the presenters had never encountered the problem.

Jeff Opel represented Filtrexx and spoke about their products. Polylactic acid is starch-based, and they've had it on their site since the beginning. It was originally developed to be a compost-based product to replace plastic plates/silverware. They are going to start offering it as an alternative because it's a "non-petroleum-based plastic". They expressed their desire to understand the needs of the community- both physical parameters and how to address the marketing issues. In response to questions, he said that Filtrexx have tried hemp but have been unable to get it in industrial supply, and it lacks the needed durability and strength.

Andrew Isenhour from *Tensar*, is looking for an engineered approach to avoiding microplastics, and is focusing on how the plastics break down over time. Their products are common in marine mattresses, bedding and filtration, shoreline/slope protection, sediment capping, scour protection, and gabions. They are designed to lose very little strength over time, and to promote oyster growth. In response to questions, he explained that they have never explored carbon credits. One commenter said that their products had worked very well, and wanted to give the company credit for acknowledging the issues around plastics.

Neils Lindquist from the *Sandbar Oyster Company* introduced his firm as the "new kid on the block" local to Beaufort, NC, a collaboration between commercial fisherman and research scientists. They

are using plant fiber cloths fused with cement to create a structures and hardened products that degrade over time. They began working with the material on a shellfish lease in the Newport River and using the lease as a research site. They created a framework above the bottom, which enhances oyster growth on top and below the material. The oysters will grow in, lock the reef together, and create a robust reef that experience very little damage from storms. They can trap sediment under and behind the structures, which can mitigate eroded areas. These structures can be deployed quickly, and may be seeded with oyster spat. In response to questions, he said that they have not yet tested these structures in cold, icy environments. Currently, their coating operation is manually done.

Eric Plage spoke again, this time addressing Oyster Domes and Reef Balls. These options are community based and made with volunteers. They were able to make 25-30 balls in about 2 hours. They placed oyster domes that were 18 in tall and 24 in wide to act as a wave barrier and create a lower energy environment for the bags closer to shore. They roughened the surface so oysters could stick, and interlocked them to prevent wave energy from passing through, but left gaps to avoid trapping marine mammals. In response to questions, he explained that they are required to have a 5 ft buffer zone with seagrass, so some sites are very close to the salt marsh shoreline. They do up to four rows of structures, depending on the site. They have not noticed much sediment accumulation.

Carter Smith from Duke spoke about Oyster Castles, which are essentially concrete legos typically 12x12 in and 8 or 9 in tall. These have numerous advantages: They can be built using minimal labor, can be shaped according to site, and contain no plastic. Bo Luck of the Nature Conservancy also used Oyster Castles for large scale restoration projects. He had better luck with oyster recruitment by raising the reef slightly. The University of VA did some research showing that reefs attenuate wave energy, with the greatest impact at low tide. They do not impact storm surge. A project at the Chincoteague National Wildlife Refuge was heavily damaged after a hurricane, so they built castle reefs along road to

"beef up" the marsh edge. Commenters added that the castles hold up well in icy conditions, that they will support packing sand even when stacked 3-4 blocks high, and that plants can be added to the reef for additional benefits.

Randy Boyd from Atlantic Reef Makers spoke about their products. Their larger product is 1300 lbs and designed for very high energy environments. It requires a CAMA major permit to install. The smaller product is 70 lbs and meant for residential use, and was designed specifically for the Coastal Federation. They are octagonal to allow for modular use, and dissipate wave energy.

Topic 2: Training Successes and Lessons Learned

Leads: *Whitney Jenkins | North Carolina national Estuarine Research Reserve & Chris Hilke | National Wildlife Federation*

Speakers presented their local training programs, including challenges and lessons learned. The session opened with a snapshot of living shorelines nationally. Recent federal legislation S3087 has created a new grant program for living shorelines.

In the spring of 2018, the Atlantic and Gulf Living Shoreline Project assessed living shoreline trainings for marine contractors. Outreach has occurred in every coastal state. One key lesson is that having attendance from multiple audiences recognize the breadth of information that we can deliver about living shorelines; whereas a more discreet geography increases the number of property owner attendance.

In response to questions, it was clarified that a few trainings provide energy and design guidelines, but they are site-specific. There are also training programs through the Army Corps of Engineers. The *Living Shorelines Academy* is designed to have different lesson plans and programs on the site to help with training.

The NC Coastal Reserve *Living Shoreline Strategy* targets decision-makers such as contractors,

engineers, realtors, and property owners. They offer professional credits to land-use planners, landscapers, and engineers. The workshop covers: The economic reasons for living shorelines, the permitting process, and design best practices. Their challenges so far include reaching marine contractors, getting more information on costs, and appropriate design guidance.

The Federation has done outreach through grants and living shoreline open houses for landowners and contractors. Dr. Weaver takes contractors on 1-on-1 site visits to help them to better understand the process.

Florida Living Shoreline Training included a master naturalist program for marine contractors. The first training is coming up in 2 weeks, with the goals that contractors be familiar enough to communicate the benefits to landowners, and the course manual that includes references and contacts. The FL Marine Contractors' Association conducted a needs assessment and found a lack of awareness, and that homeowners had unrealistic expectations for how it would perform. There is potential for certification and developing a mentorship program in the future. One major challenge with the course is the difficulty in having hands-on activities.

When asked to identify the primary challenges facing living shoreline trainings, the group had plenty of responses:

- Marine contractors can be set in their ways and not interested in learning something new;
- Convincing the landowner that a living shoreline is a better option, especially without a warranty; Who needs the information first? Which audience do we prioritize?
- Geographical variability and the need for site specific instructions;
- When is the ideal time to install a LS? Is it seasonal?
- Anticipating homeowner questions so the first visit meets their expectations;
- Can't make recommendations for certain contractors;

- Field experience during the training and funding for materials and instructors;
- Awareness of funding sources;
- Trainings for multiple audiences Staff timing if agencies host workshops;
- Who is responsible for LS training? Who takes the lead in each state/region?
- Identifying challenges people face to turning trainings into action;
- What do we define as "working" and "not working"? Reframing the issue on habitat and resilience vs just erosion control.

Then the group brainstormed potential solutions to some of the biggest challenges.

For the issue of geographic variability (tides, salinity, etc.), potential solutions are:

- Smaller more localized trainings that allow for greater specificity;
- Decision trees and matrix;
- More educational failures & successes case studies;
- Expanding site suitability tools/analysis;
- Having a follow-up session after training to share lessons learned;
- Different materials for homeowners to understand how each site is different and being able to communicate that to them.

For the issue of design standards, comments included:

- Design standards are a bad idea because each site is different – guidelines would be helpful;
- Current design standards in MD are out of date in terms of a "living shoreline" - it can be done but it is a really difficult process;
- Maybe it should be based on goal (erosion control, property protection etc.) for each property owner;
- Incorporating design standards or guidance into state environmental regulations;
- Would be good to have examples of as many different shoreline projects as possible, success as well as failure case studies;
- Standardized high-level guidance to create a level playing field prior to site-specific characterization.

Topic 3: Developments in monitoring, emphasis on technology

Lead: *Dr. Devon Eulie | University of North Carolina Wilmington*

This session was geared towards technological applications in monitoring. The technology ranged from basic, and introductory to advanced, high-end technology being applied to management. There are a suite of technological options available, each of which has benefits and challenges. Some of the more advanced positional technology includes high accuracy GPS units, including Real-time Kinematic (RTK; upwards of \$30,000) and terrestrial LIDAR (upwards of \$60,000). These options are excellent when there is a need for highly accurate positional data or a fine-scale analysis of a site and can reduce the number of man hours in the field. Some systems like RTK-GPS, do not need a much post-processing, are easy to train team members to use and are relatively easy to troubleshoot, while terrestrial LIDAR requires relatively more training and precision during set up to ensure data is collected accurately.

Drones are a growing technology in monitoring, particularly as they become more cost effective and sensors become more available. In partnership with NOAA, Duke University's drone lab is beginning to develop guidelines for monitoring marshes. Drones are relatively approachable and have a range of utility, for example vegetation classification, 3D modeling, measuring the dimensions of objects or sites, and multi- and hyper-spectral analysis. Drones can range in cost from ~\$2,000 to over \$20,000; costs increase with the inclusion of various sensors. Drone regulation is constantly improving. To fly, a FAA certified drone pilot is required. Logistically, flying can be influenced by weather and site conditions, such as tree canopy coverage, limited visibility, limited landing space, etc. Additionally, consideration should be taken regarding image processing and program costs, many software programs that mosaic images are moving towards annually renewable licenses or one-time fee access that do not include program updates.

During this breakout session, participants were

asked to identify challenges and utilities associated with technology. Specifically, this session identified data gaps that emergent technology could address. The session found that new, emergent technology has the potential to enhance digital elevation models (DEM) through improved accuracy and resolution; however, resolving land and water interface continues to be an issue that often needs multiple technological solutions to address. Additionally, monitoring of ecological factors, such as species composition and abundance, can be a time intensive process that requires multiple field technicians. Terrestrial LIDAR can monitor vegetation density and multispectral sensors to identify vegetation, while trail cameras can aid in mammal monitoring. Another large data gap in monitoring living shorelines is hydrodynamics, particularly wave energy data.

This session identified some new or novel technology being used to monitor living shorelines, including sensors that can be mounted on shore or on drones that can capture multi- or hyper-spectral high-resolution data and to monitor wave energy. To resolve topobathymetry, a solution may be to combine side scan sonar or RTK-compatible echosounders that can work with RTK units that some may already own. Other water monitoring technology is the use of autonomous underwater vehicles (AUV) or aquatic remote operated vehicles (ROV) systems that also have a suite of sensors available. Data access and sharing was identified as a significant mechanism to influence monitoring of living shorelines, particularly if combined with data-sharing community standards. An example of this would be Data Version Control (DVC), a digital database that may be a solution to open source data needs.

The session identified some of the biggest challenges associated with technology today – logistics, training, land-water interface, and costs. This session identified that even with technology logistics and associated influencing factors can be a major obstacle to successful use of technology, such as: Weather conditions, water quality, time constraints, gear transportation, battery life, and digital memory. Another issue is training technicians

both in the field and post-processing data. It was noted that a persistent issue is a misalignment of expertise and equipment, where an organization may have the expertise but lacks access to the technology or may have the technology but may no longer have the expertise to maximize the technology or resulting data. Additionally, the ability for technology to resolve the complexities of the land-water interface is an issue for all data types and methods. Finally, costs and funding are the biggest limitations to access to technology.

The session offers the following potential solutions to some of these challenges: improvements to currently available technology, development of community standards, partnerships, and monitoring integration. Technology is ever improving and the potential to integrate commonly available technology, such as cellphones, with sensors may aid in overcoming logistical and cost-limitations. The development of standards in monitoring of living shorelines is critical in understanding how they are functioning. The development of partnerships has been and continue to be a means to overcoming limitations in training or costs. Finally, the integration of monitoring in the permitting process of any shoreline management project could be an important mechanism to improving monitoring methods, increasing data, and result in enhanced technology.

Topic 4: Intersection of living shorelines, shellfish, and water quality

Lead: *Erin Fleckenstein | North Carolina Coastal Federation*

Erin explained the hierarchy of erosion control options: No action; Relocate threatened structures; Non-structural stabilization measures (slope grading, marsh creation); Combination approaches (sills, breakwaters with plantings, etc.); and Hardened structures. The functions and values of living shorelines are: Stabilization, water quality, productivity, and habitat enhancement. Oysters are important because they improve water quality, stabilize shorelines, provide habitat, and are integral

to coastal culture, heritage, and economy. They are also highly threatened. Christa Russell, of the Coalition to Restore Coastal Louisiana (CRCL), explained some of their activities. CRCL has run a shell recycling program since 2014. They do not seed reefs, just rely on natural recruitment. One challenge is a lack habitat suitability due to water quality – saltwater coming from the Gulf is too saline, and water in Lake Pontchartrain is too fresh. They also have problems with hypoxia – freshwater from Mississippi River leads to eutrophication.

The Coastal Protection and Restoration Authority is tasked with tackling land loss. The Mississippi River can no longer deposit sediment as it naturally did due to levees, so the land is subsiding. Diversion projects are therefore planned. These allow water and/or sediment out of levees into a marsh to maintain habitat and replenish the coast with new land. The planned outfall areas are right in the most important oyster habitat.

CRCL only has 2 reefs constructed at the moment. They currently monitor temperature, salinity, and dissolved oxygen. Reefs could provide areas for rooted plants to establish. Salinity in the teens or twenties is usually fine; oysters can handle periods of low salinity for short periods but start to die when it is prolonged.



Sadie Drescher, of the Chesapeake Bay Trust, gave a snapshot of the Chesapeake. The Trust went through an expert panel process to develop a credit program for load reductions from certain shoreline management practices. The reductions were calculated for prevented sediment loss, denitrification, sedimentation, Redfield Ratio, and default values. Sediment reduction credit is tied to tidal erosion rate and can be quite high. The panel recommended the report be updated every 2 years, but this has not been done. Oysters are not common in shoreline practices in Maryland. There are perceived (and real) obstacles to getting a living shoreline with oysters permitted.

Steve Murphy, of the North Carolina Department of Marine Fisheries, provided the North Carolina Snapshot. The DMF runs a shellfish lease program, oyster enhancement and sanctuary program, shellfish sanitation (public health), enforcement, management of wild shellfish and finfish resources, and comments on permits. The DMF supports living shorelines, as a much better alternative to bulkheads or hardened shorelines. However, living shorelines are public trust and the technology might get out ahead of the regulations. Right now, if a living shoreline is in open waters and an oyster grows on it, you can harvest it. We need to realize that without rules and proper enforcement, DMF can't stop someone from harvesting on your living shoreline.

Discussion followed about legal and health issues related to taking oysters from living shorelines or closed waters. The discussion included dealing with environmental fluctuations in salinity, dissolved oxygen and prolonged anoxic periods, rapid temperature changes. The top five challenges that the group identified were:

1. Public demand for living shorelines with oysters (or lack thereof);
2. Incorporating living shorelines into watershed management;
3. Funding of living shorelines;
4. Incentives to homeowners to build living shorelines;
5. Messaging and public awareness.

Some messaging best practices included: choose powerful messengers, such as celebrity chefs in LA, use understandable messages, put signs at demonstration sites and other destinations (zoos, aquariums), address the range of solutions – avoid binary definitions of natural vs. un-natural, continue to educate contractors, and carry the message to local governments/policy makers.

Suggestions for incorporating LS into watershed management include: Putting them into hazard mitigation plans and TMDLs and working with regional planning groups that include agencies and non-profits.

Topic 5: Cost of living shorelines vs other approaches

Leads: *Melanie Ray Culp | Coastal Program Coordinator, U.S. Fish & Wildlife Service & Tom Ries | President, Ecosphere Restoration Institute*

It is not easy to come up with broad costs for living shorelines. They are determined by physical factors (sediment, slope, consistency of bottom materials, currents, offset, access), and there are so many factors that you can really only give general costs, or specific costs for specific projects. Each site is different!

If a shoreline is experiencing erosion, you have to look at the issues that the area is experiencing. Maybe there is no further threat, in that case you would not need to do anything large, you could simply plant. You must determine what those initial impacts were so you can decide what approach you will need. Planting is likely cheaper than installing a large sill for example, and maybe you do not need one.

Any hard structure requires continued maintenance. Around 10% of the overall costs of installing the structure is required for maintenance. Living shorelines also require maintenance but more in the short-term to ensure bags do not move and vegetation does not die off due to poor planting. Over time, these structures become self-maintaining. Green structures costs range from \$15-500 dollars

for installation within Florida. Hard structure costs range from \$200-2700. Seawalls generally cannot be removed because infrastructure is too close behind them. They are not living shore-lines because they do not provide the resiliency. To enhance the existing seawall- for example, providing riprap structures outside of seawalls and you plant within these- they have great biological implications. However, they do result in blocking views which can cause issues for local homeowners. One solution to this problem is written in the permit that the homeowner may trim the mangroves.

Mr. Ries recommends using the public/volunteers for installation to build buy-in. You are restoring it for the environment, but also for the people who live in the area. Trees will provide more protection than simply a marsh. The project needs hearty plants that will take off right away, so its best to purchase larger plugs. It is best to source plants from local nurseries to minimize the variance of species as well as transport cost and keeping plant strains local, it will also cut down on the cost of the plants overall. You can leverage volunteer hours to match grants.

For short-term protection, he recommends using fiber logs or geoweb. The fiber log is inexpensive and better for lower energy environments. It does a great job holding the bank in while there are plants behind it. Once the plants take off you remove the stakes holding the material. They do not seem to last as long in salty water, and there are transportation costs. The geoweb is a plastic accordion that has 6in cells that you fill with material. This option is great for bank stabilization and better for high energy environments that have a slope. It allows plants to grow within the cells.

For long-term protection, he recommends oyster bags, rock sills, or just restoring vegetation. Oyster bags are great for protection just offshore and are relatively long lived. This method can be expensive if done privately, but using volunteers brings that cost down. When installing the bags, you have to leaving openings every 100' to allow wildlife to pass through. You could experience scour, however if you baffle your bags, then the openings should be protected. For shorelines that experiences a lot of

wave energy, rock sills may be a good option as they are stronger than the oyster sills.

If a site has minimal wave energy, you can simply plant and restore the area. Vegetative plantings can be done in unison with other BMP's such as planting behind a fiber log installation, or plantings within the geoweb.

The group then brainstormed about the challenges and lessons learned regarding options and alternatives for living shorelines:

Challenges:

- Transportation of materials;
- If you have to use funding before it expires, obtaining permits and design of structures is rushed;
- Communicating the importance of green structures to homeowners, training contractors or real estate agents to inspire people – some contractors see this as a threat;
- Uncertainty of costs – Prices vary regionally and nationally. Could there be a database so people could get an idea of what to expect?
- Access to materials – What if you need rock but there are no local quarries? Who can you ask for alternatives to materials?
- Getting the word out about the true cost of seawalls (repair, maintenance) and the real life of the materials used (how fast they degrade, what are the environmental impacts);
- Missing Link of Property Values – Is your house worth more with a seawall vs. a living shoreline? How do real estate agents value properties that have LS over bulkheads or seawalls?
- Failure of designs that may result in negative feelings towards LS or green structures;
 - Liability issues and insurance if the structure fails;
 - Perhaps performance bonds from a state standpoint?

Lessons Learned:

- Use demo projects to inspire people and as a way for them to interact with LS structures;
- Oyster recycling is a great way to cut down costs and reuse;

- There are places where you can get free cord grass plugs for homeowners, but only a small amount;
- Get companies to sponsor a project – they will pay for supplies, bring volunteers and they get a huge PR boost (companies such as Shell who need a repair to their reputation);
- Having partnerships between organizations (master gardeners, local arboretums, high school students, etc.) then you can really build a successful project that has a strong outreach component;
- Off-brand shell types (scallop, clam, etc.) can help to reduce costs if they are included within bags of oyster shells, especially for areas where you may not have access to oyster shells;
- Can there be a matrix for LS that has a list of all the considerations that you need to take into account?
 - Broward County, FL has a handbook for every step of LS install, from permitting to install;
 - Living Shoreline Academy has a lot of resources;
- Change perceptions of homeowners and buyers by educating real estate agents and companies;

Lunch: The Philosophy and Science That Drives Dynamic Living Shorelines in Maryland

Chris Becraft, from Underwood & Associates, said that all of their work is based on the philosophy of ensuring that coastal processes remain intact while achieving project goals. The process of a living shorelines project is to start with an assessment, then move to design and permitting, construction and finally adaptive management.

The goal of the assessment is to identify the problems and the overall goal of the project. In the Chesapeake, they want to focus on creating habitat then providing some sort of resilience. They aim to design projects to embrace coastal processes. The project construction includes: A site visit, sediment and erosion control, establishing efficient construction access, the construction itself, and inclusion of vegetation. He emphasized the need to

minimize disturbance, allow vegetation to acclimate, and plant in bunches rather than evenly spaced. The goal of adaptive management is to find a dynamic equilibrium. In this environment there is natural movement, and therefore a project must have the ability to move, material sizing is key to this balance. Monitoring storm events is also important. He described an example project on Assateague Island, which had shallow water, a long 18 mile fetch, and extensive erosion. The project design had to facilitate a lush SAV bed and robust marsh nearby. They used offshore breakwaters to stem the erosion and protect both of these habitats. He respectfully disagrees when people say living shorelines aren't applicable everywhere. It's not that the living shoreline can't be implemented, but rather an unwillingness to change the land use.

Plenary 4: Breakout Reports

In this session, one member from each Breakout Session reported on the discussion and takeaways from that session.

Plenary 5: The future of and living shorelines

Making the Case for Living Shorelines

Penny Hooper | Community Advocate and Leader, Carteret County, NC

It is important to think about who is not at the table to discuss the importance or need of living shorelines, and who do we need to look out for. The future of living shorelines is dependent upon how we communicate and get buy-in from local communities. There is not a huge rush from the public to build LS, but that is something we need to address. There are sociological factors involved in the implementation of LS. In rural NC the weather and seasons dictate a way of life for locals. The commercial fishermen notice the changes in the weather, because it impacts their livelihood. The most rural areas that are most at risk, do not have the money or man-power to implement green shoreline techniques, and often times they do not know anything about it.

Community support is critical to advance LS. Often you are missing those locals who are not educated, people of color, etc. but these people are the ones who have to be behind green shoreline techniques. You have to “advocate with compassion” in order to support the public, reach out to people through local organizations who they trust.

Ms. Hooper outlined several strategies for engagement with the public. Local government entities such as the coastal resources commission and Rachel Carson Reserve can get involved within their local communities to work towards the future. Local successes need to be celebrated and shared so people get the idea. Many organizations are adding positions that directly deal with sea level rise from both a social and scientific standpoint. How do we cultivate community resilience in Eastern Carteret County in the face of climate change and current economic conditions?

Questions like this can be answered through grants that provide funding. It is important to bring together communities that are already dealing with justice issues, racial issues, economic issues, to discuss something that may not at the top of their minds. Churches are trusted resources within rural communities, and can be a way to share tangible solutions and listen to what the community says they need.

As one example, Interfaith Power and Light works with local churches to encourage congregations across all religions to teach how to live a greener lifestyle, the importance of caring for your shores, etc. Other NGOs such as the Sierra Club can help build relationships within rural communities through fun and educational field trips and advocacy actions. Other examples include working with youth groups to go on field trips and taking children of color out to the beach to experience something they may not have before. Focus on those who are not at the table, those who are an integral part of the community that may not have a say otherwise.

Performance of Natural Marsh Shoreline vs Marsh Sill Living Shorelines

Dr. Jenny Davis | NOAA Beaufort Lab

Dr. Davis discussed a study which has been tracking natural marsh shorelines, which are common in Beaufort, compared to marsh with living shoreline sills. The study covers 15 years of data across three shorelines with paired natural and sill marshes: North Carolina Maritime Museum, Pivers Island, and Pine Knoll Shores Aquarium. The research uses surface elevation tables (SET's) which measure changes in sediment accumulation on a mm scale as well as elevation change data, as well as vegetation. Average elevation changes over time on shorelines with a sill show there is a significant difference between those and natural marshes. Natural marshes at lower SET's have had a net loss in surface elevation over time. Some sites are keeping up with sea level rise, but some area not. Loss and gains vary between sites even if both have a sill or are natural.

The researchers also sampled before and after storm events. Since Florence and Dorian, they have noticed significant deposition compared to the range of elevations these marshes have gained overtime. The locations with LS are gaining significantly more than those with just natural shorelines. *Spartina alterniflora* cover has decreased at the shoreward edge of both sill types since 2008.

They also document biological activity at these sites. The study documented significantly more oysters within natural marshes than sills. When snails do show up, they are far more abundant within sites with a sill.

In conclusion, the trend in elevation is very different between sites – natural fringing marshes are losing net elevation on the front edge while marsh sill site is gaining elevation, however it is not occurring fast enough to continue lost term resilience. In order to protect these shorelines, marshes will need a continued increase in a sediment source so they can continue to move upwards.

Considerations for Designing Resilient Living Shorelines

Dr. Molly Mitchell | Virginia Institute of Marine Sciences

Living shorelines are not always self-maintaining or able to keep up with sea level rise, so what can we do to encourage LS to be more resilient through the way we design them? Marshes are more likely to be self-maintaining on the west coast opposed to the east coast. Natural marshes are resilient because they are dynamic, and LS mimic those natural marshes. Marshes migrate landward as SLR occurs. However, when we put barriers in the way, the marsh cannot move. The marshes will continue narrow with rising sea level, until they are eventually lost. Urban living shorelines are important, but they will only survive for so long without active support.

Marsh accretion is controlled by plant productivity. As roots grow and they build up the plant platform, other factors such as sediment availability and respiration will impact the sediment supply. Once marshes pass a certain threshold in elevation

above sea level, they have the capacity to increase rapidly and will grow in size. In urban areas, plant a very narrow low marsh, but a very wide high marsh which adds years to the life of a living shoreline. Do not plant trees too close to the shore, because the shading will actually inhibit vegetative growth as the grasses migrate. In the Chesapeake Bay, it will require by 2050 a 50% increase in the sediment supply in order to maintain the marsh surface in the face of SLR, but currently the state is working to reduce the amount of sedimentation within the bay from a water quality standpoint. Sills are built for today's standards, but are not always meant to be added to, meaning that in the future they will not be as effective in capturing sediment.

In summary, the most important thing to consider for the success of LS is siting. Focus on enhancing the living shorelines, allowing them to vegetate densely, supporting mussel and oyster growth on the surface. Maintain living shorelines and marshes as much as possible, which may include adding sediment. And one of the biggest things we run into with living shorelines is that they are dynamic, and that needs to be communicated to the public.



Participants gathered on Jones Island during the field session on Day 1.

POSTERS

Low-cost, low-impact alternative materials and methods for building resilient living shorelines

Savanna Barry, Ph.D. & Mark Clark, Ph.D., University of Florida, UF/IFAS Extension, Florida Sea Grant

Assateague Island State Park shoreline resiliency project

Chris Becraft, Underwood & Associates

Living shoreline implementation is better when we're all working together

Whitney Jenkins, NC Division of Coastal Management/NC National Estuarine Research Reserve

Applying living shoreline approaches to increase resilience and reduce risk in New England

Eric Roberts, The Nature Conservancy & Pete Slovinsky, Maine Geological Survey

Implementation of innovative hybrid living shorelines in the urbanized Elizabeth River: A case study for the nation

Josef Rieger, The Elizabeth River Project

Apalachicola Bay shoreline habitats and resilient coasts (SHaRC): A comprehensive GIS analysis to identify and prioritize restoration opportunities

Rick Harter, Ecology & Environment, Inc.

Adaptation planning using nature's boundaries: San Francisco Bay shoreline adaptation atlas

Katie McKnight, San Francisco Estuary Institute

Tiling the marsh: Utilization of sediment tiles to quantify erosion and accretion along shorelines

Mackenzie Taggart, University of North Carolina Wilmington

Intertidal reef construction methods and challenges in a higher energy environment

Quinn Whitesall, American Littoral Society

The Pointe-au-Chien living shoreline: Protecting cultural heritage on Louisiana's Coast

Christa Russell, Coalition to Restore Coastal Louisiana

Win some lose some: Monitoring results from an oyster reef breakwater at Gandy's Beach in Downe Township, NJ

Adrianna Zito-Livingston, The Nature Conservancy New Jersey

Bringing up bivalves: Establishing community-based oyster restoration in the Central Indian River Lagoon, FL

Katey Leban, Brevard Zoo

Incorporation of recycled oyster shell in living shorelines: Pros, cons, and lessons learned in Galveston Bay, Texas

Haille Leija, Galveston Bay Foundation

Operation oyster

Julianne Schumacher, American Littoral Society

Restoring oysters In New York Harbor: Proposed installations for the "Living Breakwaters Project," and emerging techniques for pilot projects

Danielle Bissett, Billion Oyster Project

Comparing the performance of alternative reef substrates in halting salt marsh erosion and supporting oyster reef development

Emory Wellman, Department of Biology, East Carolina University

Creation of a living shoreline in an urban harbor using reef ball modules and lab cultured oyster sets

Peter Solomon, The Sound School

Unoccupied aircraft system applications for salt marsh shorelines: A handbook

Kelly Dobroski, Duke University Marine Lab

Shoreline management BMP verification for Chesapeake Bay TMDL pollutant reduction credits

Aaron Wendt, Virginia Department of Conservation and Recreation, Shoreline Erosion Advisory Service (DCR SEAS)

THANK YOU

Special thanks to the Steering Committee for their help in planning the 2019 Workshop.

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Suzanne Simon | Restore America's Estuaries

Lexia Weaver | North Carolina Coastal Federation

Todd Woodard | Samish Indian Nation

About Restore America's Estuaries

Established in 1995, Restore America's Estuaries (RAE) is dedicated to the protection and restoration of bays and estuaries as essential resources for our nation. RAE is a national leader in understanding the economic importance of estuaries, advancing blue carbon science, creating an imperative for living shorelines, and promoting strategies to enhance coastal resilience. We work with strategic partners to advance this mission regionally and as an advocate in the nation's capital. RAE and its alliance members create a powerful and unified voice for coastal habitat restoration and the well-being of coastal communities.

About the North Carolina Coastal Federation

The North Carolina Coastal Federation is a member-supported 501(c)3 that focuses on protecting and restoring the North Carolina coast. Since 1982, the federation has been in the field restoring miles of coastline; training and educating students, adults and communities to take actions that result in cleaner coastal waters and advocating for an accessible, healthy, productive coast.

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Cover: Ariel view of living shorelines in North Carolina. *Photo courtesy of Mark Evans with Eye in the Sky Drone Photography.* | Page 4: Participants gathered for a Day 1 field session. *Photos courtesy of NCCF.* | Page 5: Workshop attendees boarding boats for the workshop field sessions. *Photo courtesy of RAE.* | Page 10: Participants networking at the Poster Session. *Photos courtesy of RAE.* | Page 15: Example of a living shoreline installed in North Carolina. *Photo courtesy of NCCF.* | Page 20: Participants gathered on Jones Island during the field session on Day 1. *Photo courtesy of RAE.*