Strengthening Habitats with Oysters on Retrofitted & Engineered Structures

Report on the
Virtual Symposium
Feb 26-27, 2025

Background

This symposium on **Strengthening Habitats with Oysters on Retrofitted & Engineered Structures (SHORES)** is part of an effort to fill key knowledge gaps in support of Maryland's oyster resource and oyster industries. Chesapeake Bay is home to thriving commercial fishing and aquaculture industries and one of the largest oyster restoration efforts in North America. The lack of fresh shell substrate has become a major impediment to all of these activities and alternatives are being considered for large-scale use in restoration and industry efforts. To address this challenge, the Maryland General Assembly mandated a program (SB830 2023) that will evaluate:

1. Types of substrate, including fresh shell, fossilized shell, combinations of shell and alternative substrates that are most appropriate for use in oyster harvest areas.
2. Benefits, including habitat-related benefits, of using stones of various sizes in oyster restoration areas.
3. Alternative substrates used for oyster restoration or repletion in other regions, including the success of efforts to use alternative substrates.
4. Potential for retrofitting existing structures, such as riprap revetments that are unrelated to oyster restoration, but use materials similar to artificial reefs including oyster plantings.
5. Effect of spat size upon deployment on oyster abundance.

This symposium directly addresses topic #4: Potential for retrofitting existing structures, such as riprap revetments, that are unrelated to oyster restoration but that use materials similar to artificial reefs, to include oyster plantings.

In 2024, the Symposium for Alternative Substrates for Oysters (SASSO) addressed topic #3: Alternative substrates used for oyster restoration or repletion in other regions, including the success of efforts to use alternative substrates. If you are interested in learning more about SASSO, see the symposium webpage: **https://www.umces.edu/alternative-substrate-for-oysters**

Symposium Sponsors

This symposium was sponsored by University of Maryland Center for Environmental Science (UMCES). Lead organizers were Dr. Matthew Gray, Dr. Elizabeth North, and Dr. William Nardin of UMCES Horn Point Laboratory. The symposium team also included Monica Fabra, Kurt Florez, Conor Keitzer, Roshni Nair, and David Nemazie. Graphic design and logistical support are from UMCES Integration and Application Network (IAN). Funding support was provided by the State of Maryland.

For questions regarding this symposium please contact Matthew Gray at **mgray@umces.edu** or see the symposium webpage: **https://www.umces.edu/shores-symposium**

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Executive Summary

The **Symposium on Strengthening Habitats with Oysters on Retrofitted and Engineered Structures (SHORES)** brought together more than 150 participants to explore how the Chesapeake Bay's extensive armored shoreline and growing use of living shorelines can be adapted to support Eastern Oyster (*Crassostrea virginica*) populations. Over 1,600 km of Chesapeake Bay shoreline are armored with bulkhead, riprap, or seawalls, structures that often degrade adjacent submerged aquatic vegetation (SAV) and limit ecological value.

These same hardened shorelines represent a vast amount of potential hard-bottom habitat for oysters if strategies can be developed to overcome limitations of material properties, intertidal positioning, and larval supply. Living shorelines are gaining traction across Maryland as a preferred stabilization method, but questions remain about how to incorporate oysters into their design and siting. The SHORES symposium directly addressed these challenges, advancing Topic 4 of Maryland Senate Bill 830 (2023), which called for evaluation of retrofits and engineered coastal infrastructure for oyster habitat creation.

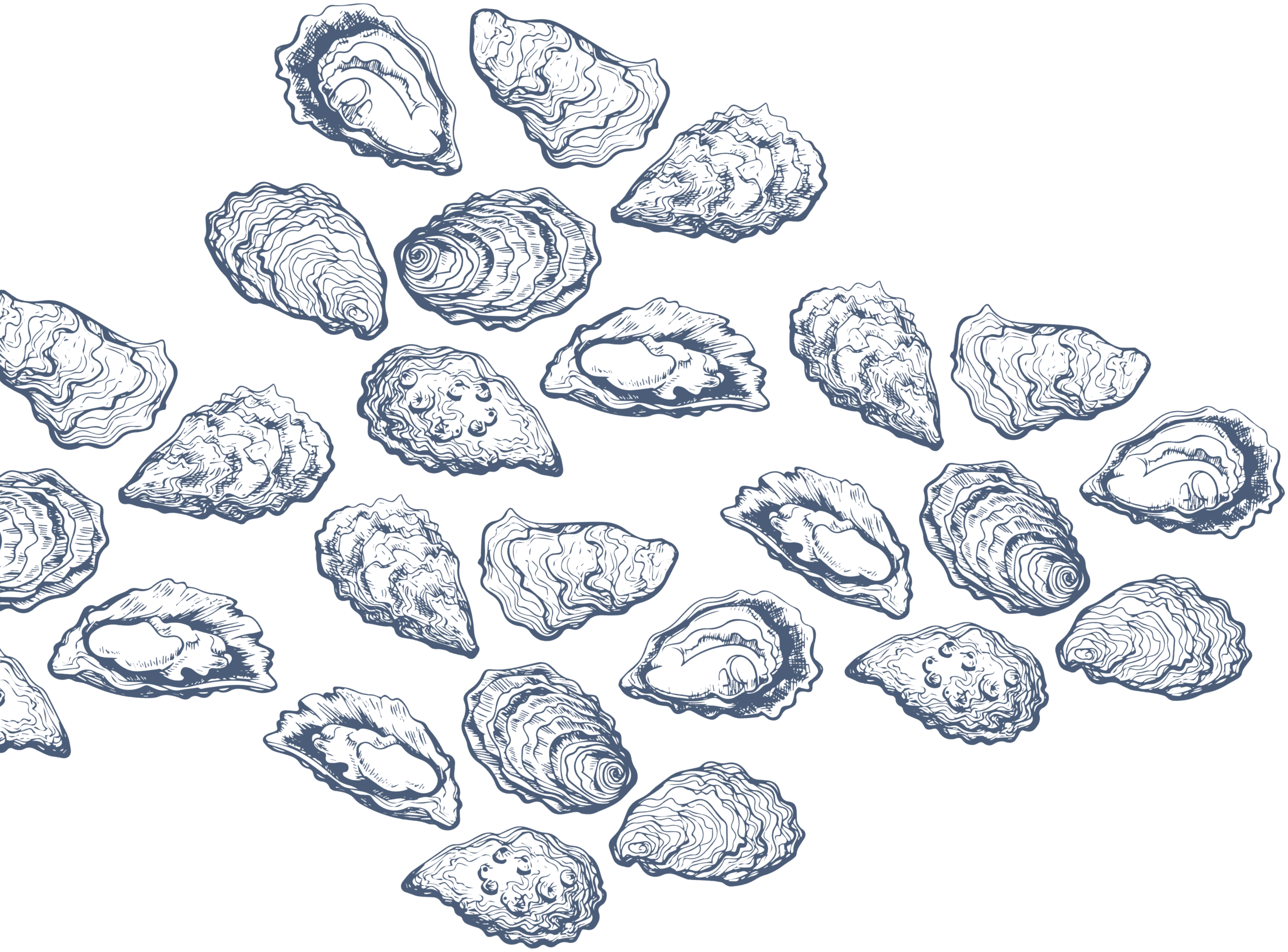
Over two days, fourteen invited speakers presented case studies spanning the Atlantic seaboard, Gulf of Mexico, and North Sea. Participants shared experimental approaches using alternative materials, structural modifications, and hybrid systems that integrate oysters into seawalls, docks, bulkheads, breakwaters, offshore wind turbines, and living shorelines. Across talks, several consistent themes emerged: the ecological value of microhabitats such as crevices for oyster survival; the potential for oysters to enhance the longevity and adaptive capacity of grey infrastructure; the promise of lightweight, modular structures for scalable deployment; and the importance of pairing physical engineering with biological monitoring.

Numerous key findings were highlighted in the symposium. The success of oyster recruitment on engineered seawall tiles with protective crevices was notable, as were trials of oyster-seeded tetrapods and sediment cubes at offshore wind turbines. Community-supported oyster gardening with biodegradable and natural materials showed promise, while hybrid breakwaters in Maryland's Choptank River improved wave attenuation by 20% when oysters were present. New commercial products are available, that combine engineering reliability with habitat uplift. Equally important were lessons from failures, such as the poor durability of some biodegradable plastics or the limited survival of oysters on pilings treated with toxic compounds. These case studies underscored the need to carefully match design and materials to local ecological and physical conditions.

Symposium discussions and participant polling emphasized both opportunities and barriers. Habitat creation (54% of participants), oyster recruitment (40%), and durability (26%) were consistently ranked as the most valued benefits of oyster-infrastructure integration. However, permitting complexity was identified as the single greatest barrier, with 42–60% of participants citing regulatory hurdles as a limiting factor. Other gaps included the need for standardized metrics to evaluate hybrid systems, long-term durability data for new materials, and better understanding of how oysters on hardened structures influence adjacent SAV and biodiversity.

Overall, SHORES demonstrated that integrating oysters into retrofitted and engineered coastal infrastructure can transform necessary shoreline protection into multi-functional systems that provide ecological, social, and climate resilience benefits. Lessons shared at the symposium provide immediate guidance for Maryland's restoration and permitting community, while also contributing to global innovation on how to "green the grey" with oysters.

Day 1: Retrofitting Existing Infrastructure

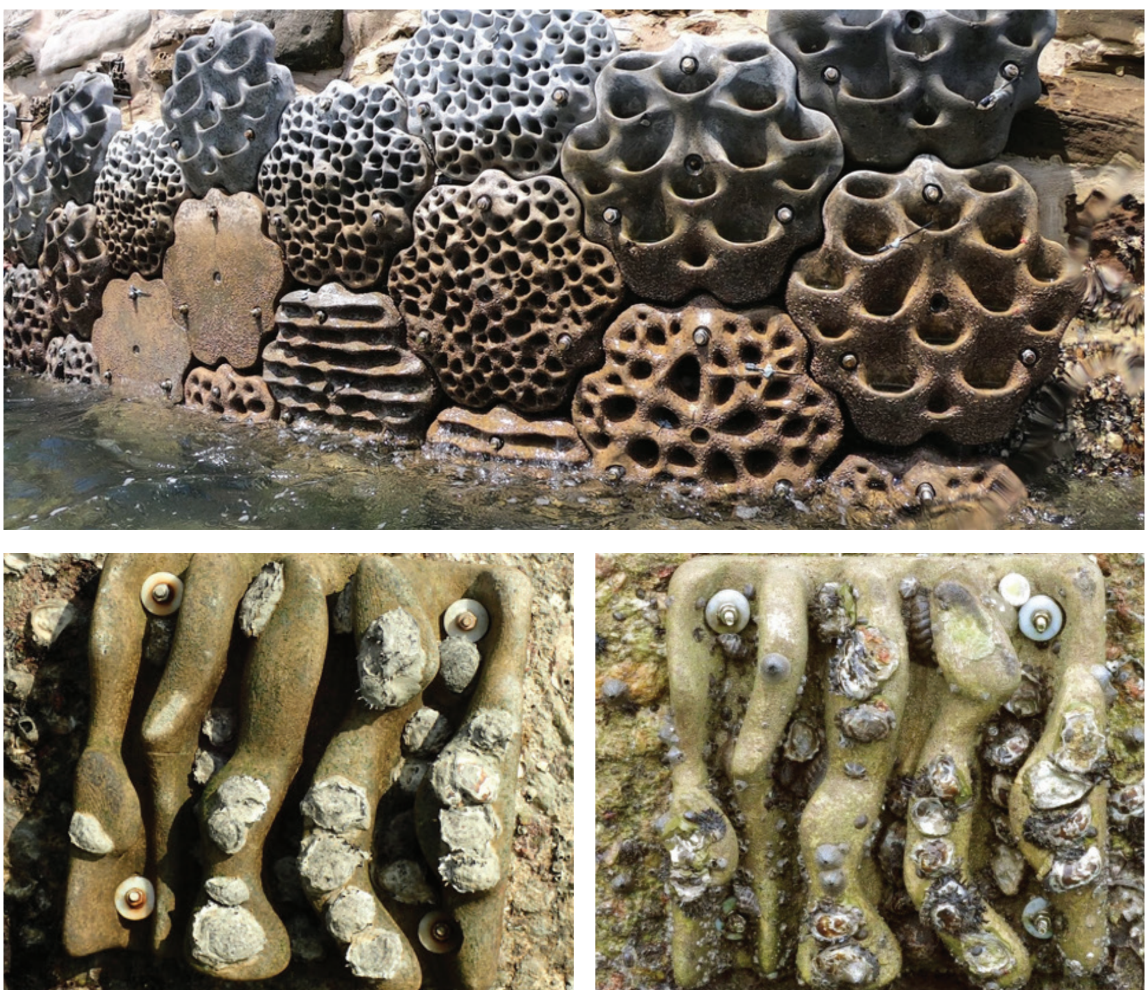


Day 1 Talk Highlights

Rochelle Seitz

Virginia Institute of Marine Science

Rochelle Seitz presented research on retrofitted seawall structures designed to support oyster settlement and survival. Her team used concrete tiles manufactured by Reef Design Lab with ridges and crevices of varying dimensions to create microhabitats. Juvenile oysters, approximately 23–25 mm shell length, were seeded onto the structures using non-toxic epoxy. The design was particularly effective because crevices protected from desiccation and predation, two major stressors for intertidal oysters. Seitz stated that she would recommend crevice-based structures for retrofitting seawalls, because they enhance oyster survival and habitat value. While her group did not measure the effects of oysters or added structures on seawall performance directly, she referenced other studies showing that "green" modifications can improve seawall longevity. Oyster survival data from her experiments are not yet published, though a manuscript is in preparation. An important social dimension of the work was highlighted: homeowners at the test sites were enthusiastic partners and expressed consistent interest in the project. This response suggests strong public acceptance of oyster-based shoreline interventions. Overall, Seitz's findings underscore how modest design modifications to grey infrastructure can substantially increase ecological value while maintaining shoreline protection.

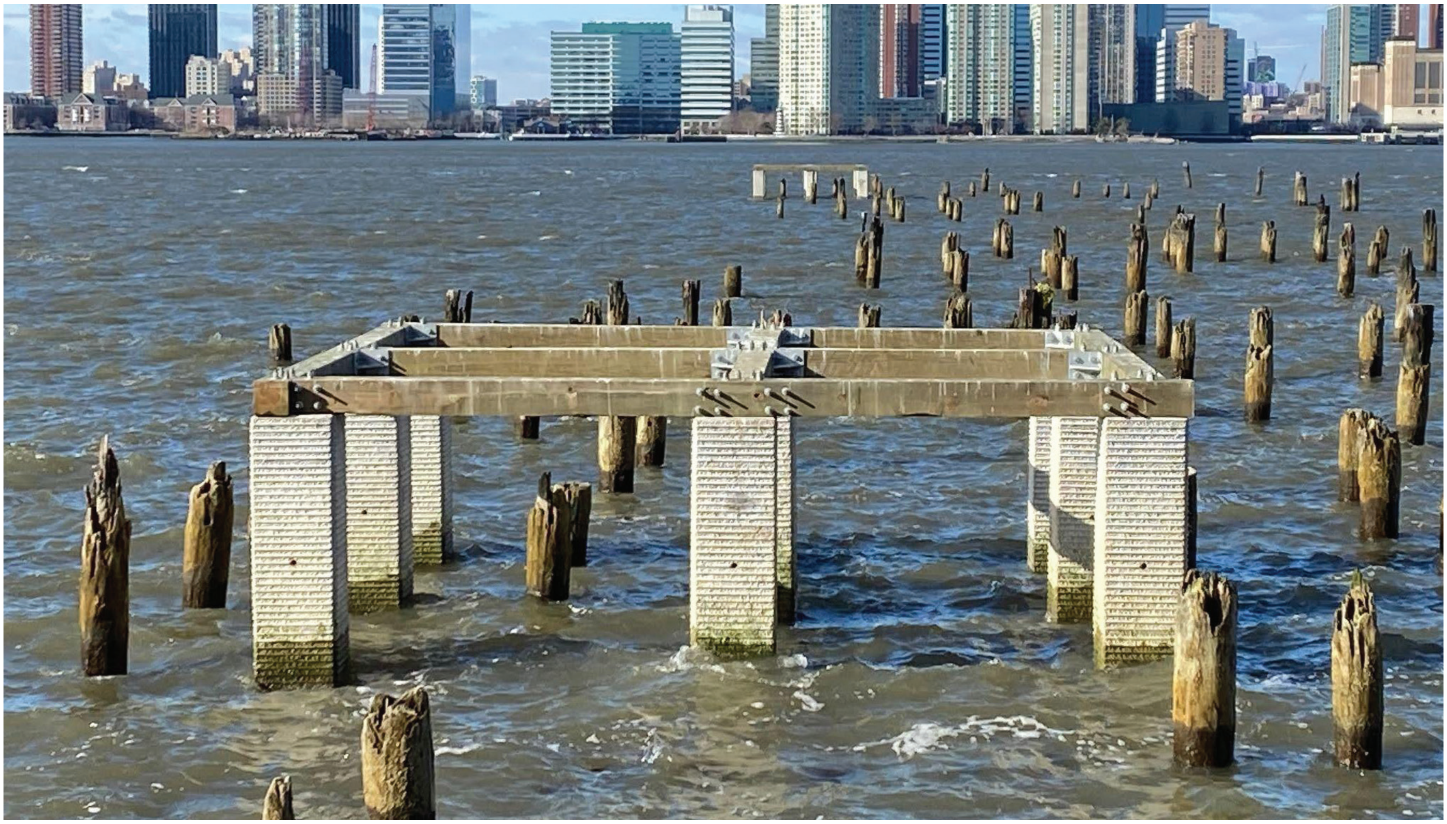


Seawalls with built in groves that produce a micro-habitat for settlement of bivalves and increase diversity of sessile and mobile invertebrates. Photos courtesy of Rochelle Sietz.

Day 1 Talk Highlights

Anthony Dvarskas
Ørsted

Anthony Dvarskas discussed efforts to integrate oysters into offshore wind lease areas. As part of Ørsted's 2030 biodiversity ambition, the company seeks to deliver a net positive biodiversity impact across all projects commissioned after 2030. One strategy being piloted is to use offshore wind infrastructure to restore the European flat oyster, which was once widespread in the North Sea but is now nearly nonexistent near the Netherlands. At the Borssele 1 & 2 wind farms off the Dutch coast, his team deployed lightweight, easily handled oyster structures in 2024. Two types were used: tetrapod concrete units and sediment-based cubes with binders, both seeded with flat oysters and designed for manual deployment from small crew transport vessels. The structures were placed on existing scour protection layers around turbines, which already provide some hard substrate but lack sufficient complexity for oyster recovery. In total, 70 tetrapods and 10 sediment cubes were deployed, with careful site selection to maximize larval spread and avoid cables. Deployment was straightforward, though sediment cubes crumbled during handling, highlighting durability challenges. Monitoring is being conducted with remotely operated vehicles (ROVs), with follow-up scheduled at 1, 3, and 5 years post-deployment. This work examines how engineered offshore energy infrastructure can be retrofitted with oyster habitat, effectively creating multi-use platforms for energy and biodiversity. If successful, the approach could be expanded across Ørsted's global lease areas. While results on oyster survival are not yet available, the project demonstrates a promising, scalable, low-cost, and lightweight deployment method for integrating oysters into large-scale grey infrastructure.



Pier piles retrofitted with textured pile to encourage habitat for oysters in the Hudson River. Photo courtesy of Hudson River Park Trust.

Siddhartha Hayes
Hudson River Park Trust

Siddhartha Hayes described efforts to enhance habitat along heavily urbanized waterfronts. The Park encompasses four miles of Manhattan's shoreline, much of which is dominated by hard bulkheads, piers, and mudflats. Historically, Eastern Oysters were abundant in this estuary, but today the system is larval-limited and lacks suitable substrate. Hayes and collaborators first tested whether oysters could survive in suspended pile wraps, and found that they grew and even reproduced despite harsh winter conditions. Dive surveys also revealed oysters and other organisms already using pier piles and shaded habitats, suggesting vertical structures hold promise. Building on this, the Park launched large-scale enhancement projects. In Tribeca, nearly 200 structures were deployed, including reef balls, gabions filled with shell, pile wraps, and textured concrete piles. Monitoring has shown that oysters survived, grew, reproduced, and recruited new spat on these structures, while also supporting diverse fish and invertebrate communities. A second project at Gansevoort created a more compact artificial reef of about 300 structures adjacent to a salt marsh restoration site, requiring novel monitoring methods like sonar and underwater video because the units could not be lifted easily. Early results showed healthy oysters, strong plant growth, and expanding biodiversity. Hayes emphasized that these projects were designed not just to restore oysters, but to enhance the broader ecosystem and reconnect urban residents with their estuary. The work demonstrated that even in a stressed, turbid system like the Hudson, oysters can be successfully integrated into existing infrastructure and paired with marsh restoration.

Adrian Sakr
University of Florida

Adrian, a PhD student at the University of Florida, presented research on improving oyster gardening techniques for restoration and community engagement. Oyster gardens are small modular structures hung from docks or seawalls to provide habitat, improve water quality, and engage the public in restoration. While widely used, current oyster gardens often rely on unsustainable materials like PVC or plastic mesh, and there is little standardization on which designs perform best. Sakr's project tested several alternative garden structures, including biodegradable potato-starch mesh, jute fiber cylinders coated in cement, reef discs, and drilled oyster shells strung on wire. The gardens were deployed in residential canals on Sanibel Island, Florida, in collaboration with local homeowners. Within months, oyster recruitment began, but in September 2022, Hurricane Ian struck, killing most oysters due to poor post-storm water quality. After 15 months, the biodegradable plastics had disintegrated without supporting oysters, while the jute-cement cylinders, reef discs, and shell-on-wire structures remained intact and supported dense oyster and mussel communities. These surviving gardens also demonstrated strong biofiltration capacity, reducing chlorophyll a and turbidity in controlled tests. Sakr emphasized that water quality was a critical factor, because gardens in poor-quality sites performed poorly regardless of structure type. Cost and durability analyses showed tradeoffs: natural-material gardens were inexpensive and effective, while prefabricated units like reef discs were more costly but easier to handle. The study demonstrated that simple, low-cost structures can be both ecologically effective and community-friendly, especially when paired with strong homeowner engagement. The work highlights how oyster gardening can retrofit private docks and seawalls into functional habitat, while also creating grassroots support for oyster restoration.

Day 1 Talk Highlights

Niels Lindquist
SANDBAR Oyster Company Inc.

Niels discussed the development of Oyster Catcher™, a cement-infused jute cloth designed to enhance oyster settlement on hardened structures. His work was motivated by the observation that oysters thrive on concrete pilings but are largely absent from chemically treated wood pilings that dominate docks along the coast. Oyster Catcher™ can be manufactured into cuffs or wraps that are strapped around pilings, creating textured, cemented surfaces suitable for oyster colonization. Early trials in North Carolina's Bogue Sound showed high oyster settlement during the first summer, suggesting the material was effective at attracting spat. However, after one year, oyster growth slowed and degradation of the material began, raising questions about long-term durability. Lindquist pointed to possible factors such as the toxicity of treated wood pilings, predation from fish and crabs, and stormwater runoff affecting water quality. He suggested several improvements, including making the cuffs more cement-rich, timing deployment just before spawning season, strapping them tightly to pilings to reduce predator access, or adding liners to buffer wood toxicity. Despite these challenges, the material has proven to be versatile, easy to manufacture, and effective in creating settlement surfaces in otherwise inhospitable zones. Oyster Catcher™ represents a promising retrofit technology that could transform underutilized pilings and docks into productive oyster habitat. The project highlights both the ecological potential and the engineering challenges of adapting living substrates to grey infrastructure in high-energy, human-dominated shorelines.

Oyster Catcher™ piling cuff installed in Bogue Sound, Morehead City, NC in February 2024, and photographed a year later. Photo courtesy of Niels Lindquist.

Jason Spires

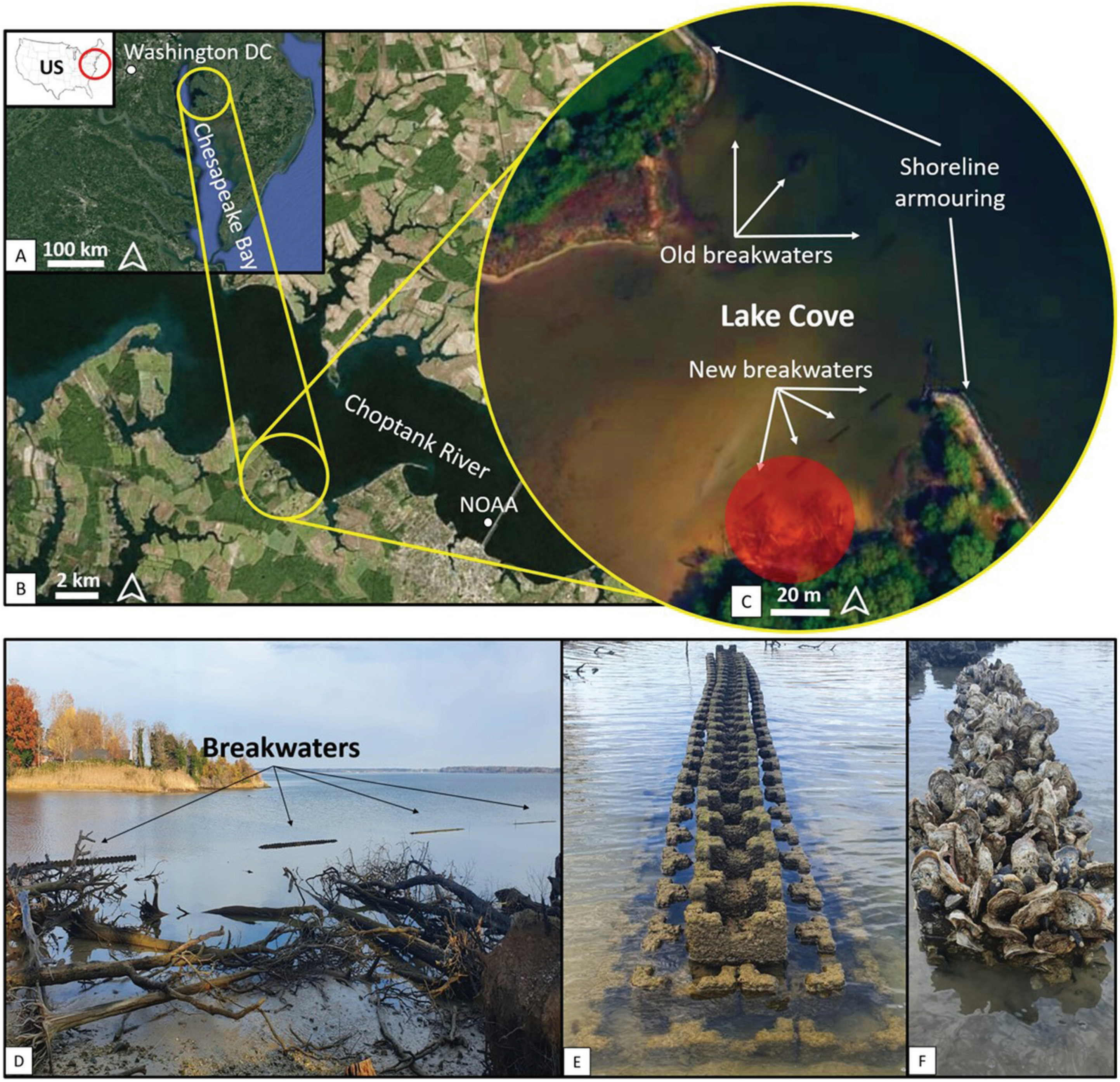
National Oceanic and Atmospheric Administration

Jason Spires described experiments exploring new ways to colonize hardened shorelines with oysters. His work focused on regions of Chesapeake Bay with poor larval supply, where natural recruitment onto seawalls and riprap is unlikely. One strategy tested was using natural-derived materials such as coconut fiber mats and basalt fibers, which could be pre-seeded with oyster larvae in hatcheries and then wrapped around pilings or stones. In settlement trials, oysters attached readily to coated basalt but performed poorly on coconut fiber, which degraded quickly. Larger mats of coated basalt retained oysters for over a year in high-energy conditions, showing promise as a veneer for pilings. Spires also tested whether bubble curtain diffusers—commonly used for oil rigs, canals, and algal control—could retain oyster larvae around hardened structures to encourage settlement. Initial trials showed larvae escaped the curtains, but he plans to refine pore size and flow rates to improve retention. This concept could allow direct *in situ* colonization of bulkheads and piers without needing to transplant seeded material. His experiments underscore the importance of finding materials that both support initial settlement and withstand predation, wave action, and fouling. The work demonstrates creative methods to retrofit existing grey infrastructure with oysters, even in larval-limited systems. By testing biodegradable substrates and scalable diffuser technologies, the project provides potential tools to expand oyster-based habitat enhancement in challenging urban and estuarine settings.

Iacopo Vona

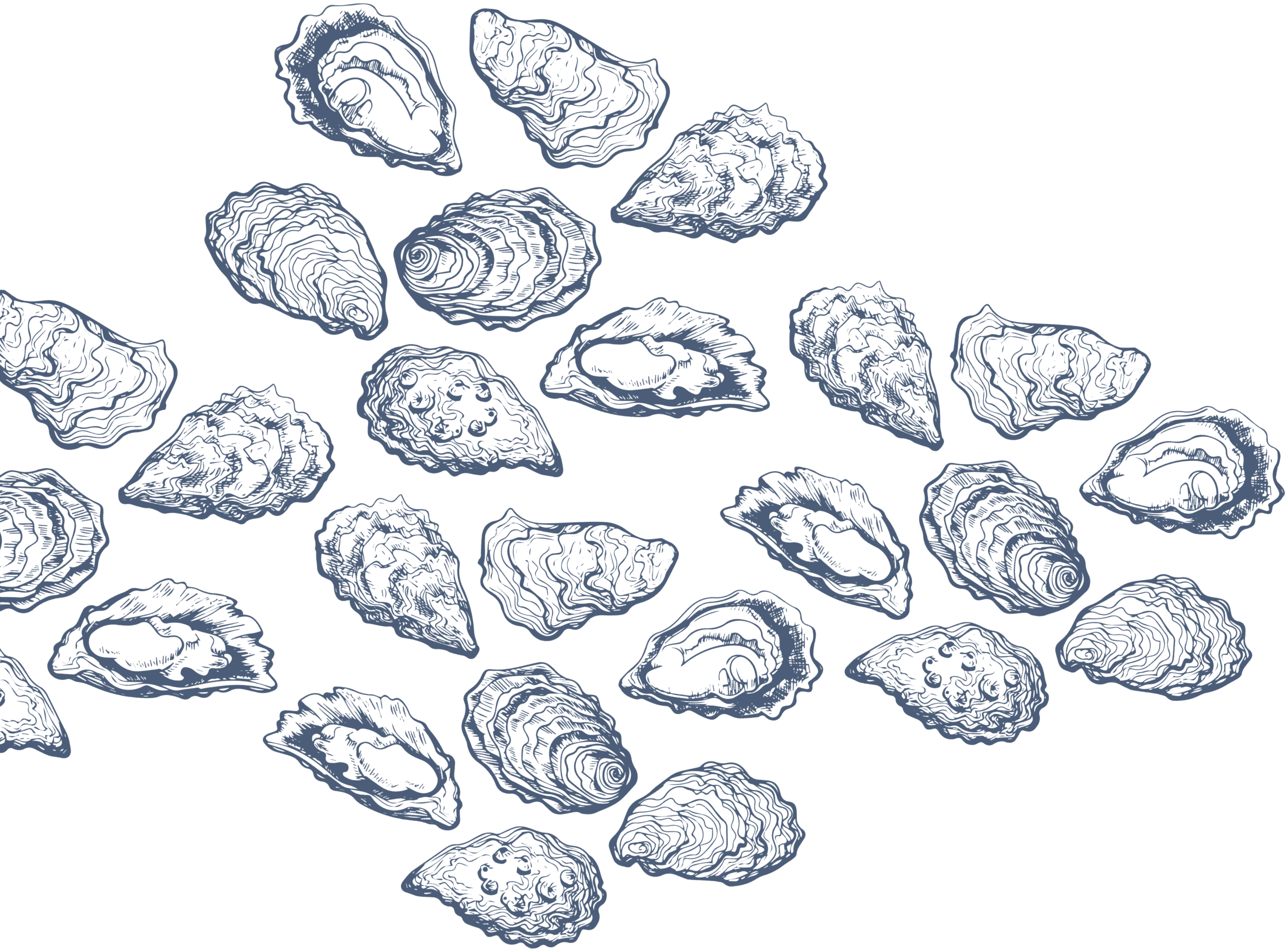
UMCES, presently at University of Central Florida

Iacopo Vona presented his PhD research on combining submerged breakwaters with oysters as a nature-based solution for shoreline protection. Traditional grey structures, such as breakwaters and seawalls, lose effectiveness over time with sea level rise and provide no ecological services. By contrast, oysters form three-dimensional reefs that can attenuate waves, self-repair, and grow vertically with rising seas, while also delivering ecosystem benefits. Vona's work tested this integration in the Choptank River, Maryland, where four breakwaters were built in 2019 using oyster castles. Monitoring revealed that adding oysters improved wave attenuation by about 20% compared to grey breakwaters alone. Field data on bed-level changes and sediment deposition were used to calibrate a numerical model simulating future sea level rise scenarios. Modeling showed that while grey breakwaters alone lose functionality under higher sea levels, oysters sustain sediment retention and wave attenuation into the future. Importantly, the research emphasized the engineering–ecology tradeoff: taller structures attenuate more waves but reduce oyster survival, while lower structures favor oysters but attenuate less. The team also experimented with retrofitting old, degraded breakwaters by adding oyster castles, effectively "reviving" them through oyster colonization. In discussion, Vona noted that oyster castles naturally recruit oysters but can also be hatchery-seeded, and he flagged cold winters as a survival risk for intertidal oysters. Overall, his results demonstrate that integrating oysters into coastal defense structures provides adaptive protection that strengthens with time.



(A) Study area frame on the eastern shore of the US, within the Choptank River in Chesapeake Bay.
(B) Zoom on the Choptank River.
(C) Zoom on the Lake Cove. The red circle indicates the area impacted by fallen trees.
(D) Breakwaters view from the shoreline side, with details of fallen trees into the water.
(E) Detail of one breakwater within the Lake Cove.
(F) Detail of 2 year old oyster castles colonized by oysters.
Photos courtesy of Iacopo Vona.

Day 2: Building Engineered Living Shorelines



Day 2 Talk Highlights

Kate Orff
SCAPE

Kate Orff opened Day 2 with reflections on the Living Breakwaters project in Staten Island, New York. She described its origins in early design concepts like "Oyster-tecture," which envisioned oyster reefs as ecological and cultural infrastructure. After Superstorm Sandy, these ideas gained urgency, leading to a decade-long effort combining science, design, and community engagement to build engineered breakwaters seeded with oysters. The project consists of eight rubble mound structures enhanced with ecological concrete, reef ridges, reef streets, and tide pools to foster oyster colonization and fish habitat. Orff emphasized that the breakwaters serve multiple purposes: reducing coastal risk, restoring habitat, and strengthening community resilience. She highlighted the long permitting, modeling, and engineering process, which included wave tank testing and iterative design to ensure both structural stability and ecological value. The project also integrated extensive educational and outreach components through the Billion Oyster Project, embedding oyster restoration into school curricula and citizen science. Orff stressed that oysters were both a functional engineering partner and a cultural connector, helping engage residents in coastal resilience. She concluded that the Living Breakwaters represent a new model for large-scale, nature-based infrastructure, balancing grey engineering with oyster-driven ecosystem services.

Carolyn Khoury
Billion Oyster Project

Carolyn Khoury described the Living Breakwaters project on Staten Island as a model of climate-adaptive, nature-based infrastructure. The $111 million effort constructs 2,400 linear feet of nearshore breakwaters made of stone and ecologically enhanced concrete to reduce wave energy, slow erosion, and create habitat for oysters and finfish. Developed after Superstorm Sandy through the HUD "Rebuild by Design" competition, the breakwaters aim to both reduce physical risk and reverse shoreline loss. Billion Oyster Project (BOP) is leading the biological component, adding seeded substrate beginning in 2025 to accelerate oyster colonization. The design includes "reef ridges" and "reef streets" that create diverse habitat niches and are intended to support self-sustaining oyster populations. Beyond ecological goals, Khoury emphasized the project's social dimension: partnering with local schools to create curriculum and hands-on education linked to oyster restoration. The breakwaters are expected to enhance community resilience by blending physical protection with environmental stewardship. This layered approach—physical, ecological, and social—demonstrates how engineered shoreline systems can be strengthened by oysters. Khoury positioned the project as both a large-scale experiment and a transferable model for other coastal communities seeking to integrate oysters into shoreline protection.

Tyler Oretego
Natrx

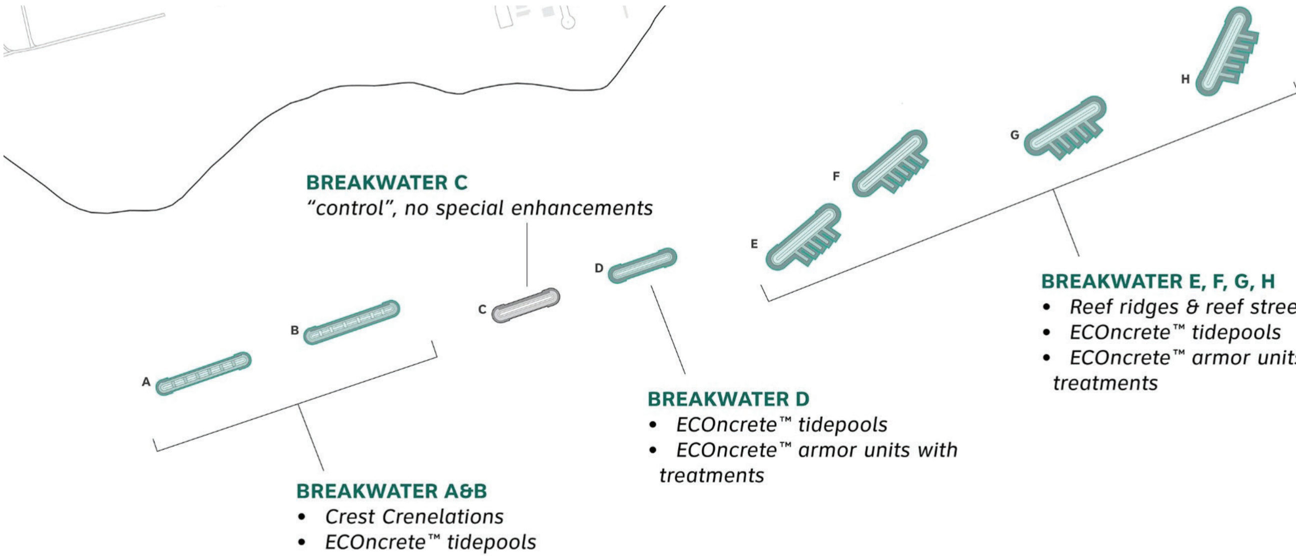
Tyler Ortego presented Natrx's approach to integrating engineered structures with oyster habitat to create resilient shorelines. His company has developed a proprietary Dry Forming™ manufacturing process that produces cement-based units with customizable voids and naturalistic surfaces. These structures are designed to optimize oyster recruitment, enhance biodiversity, and deliver wave attenuation while still functioning as protective shoreline infrastructure. Ortego emphasized that digital design tools allow tailoring the units to site-specific conditions, ensuring both ecological performance and structural stability. He showcased a case study from Hog Island, Virginia, where Natrx ExoForms™ were deployed in both high-energy and low-energy environments. In exposed sites, large stacked ExoForms provided marsh protection, while in calmer areas, lower crested oyster reefs were installed to maximize oyster colonization. The project created habitat capacity for millions of oysters, with the potential to filter vast amounts of water and prevent tens of thousands of tons of sediment from entering the Chesapeake Bay. Importantly, monitoring showed resilience to storm events, suggesting the units balance engineering needs with natural processes like overwash and sediment deposition. Ortego concluded that combining advanced manufacturing with ecological design offers scalable, adaptive solutions for shoreline protection that integrate seamlessly with existing grey and hybrid systems.

Amanda Poskaitis & Camille Calure
Underwood & Associates

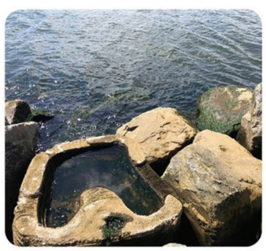
Amanda Poskaitis and Camille Calure discussed work on dynamic living shorelines that use vegetated headland–bay systems to restore natural coastal processes while incorporating oysters. Their designs rely on native stone, sand, and woody materials to create variable habitats that accrete sediment and promote marsh growth. At the Assateague State Park boat ramp project, these techniques were tested in partnership with the Maryland Coastal Bays Program. Natural oyster recruitment was found on the boat ramp infrastructure after construction. Surveys since 2021 showed oysters were settling but typically survived only one to two years, likely due to disease, predation, and water quality stressors. Despite these challenges, the ironstone headlands used in the shoreline design proved to be suitable substrates for oyster attachment. Poskaitis noted that the project demonstrates how oysters can be a co-benefit of properly designed living shorelines, even in regions without self-sustaining populations. She also described experiments suspending oysters in cages and testing different placements around headlands, which provided insights into survival limits and site-specific suitability. The team is extending these methods to other Chesapeake and Coastal Bays projects, with interest in pairing oyster restoration with marsh stabilization. Poskaitis concluded that integrating oysters into dynamic shoreline designs requires careful site assessment but can substantially increase the ecological value of protection projects.

Oysters growing on grey infrastructure. Photo courtesy of the Maryland Coastal Bays Program and Amanda Poskaitis.

Day 2 Talk Highlights



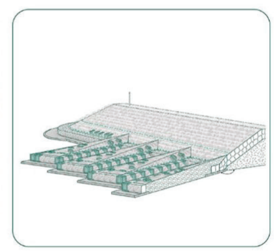
Crest Crenelations



ECOncrete™ tidepools

ECOncrete™ armor unit with mesh treatment

ECOncrete™ armor unit with mesh and rock treatment



Reef ridges & reef streets

Diagram of the Living Breakwaters project in Staten Island, New York, demarking the various types of units used to retrofit the breakwaters. Diagram and photos courtesy of Kate Orff.

Oysters self-sustaining growth documented around .the Living Breakwaters project in Staten Island, New York. Photo courtesy of Carolyn Khoury.

Mary-Margaret McKinney
Native Shorelines, A Davey company

McKinney described Native Shorelines' QuickReef® technology, an oyster-centric living shoreline system designed as an alternative to traditional rubble mound structures. QuickReef® units are made from native coastal materials such as limestone, marl, sand, and recycled oyster shell bound with cement, and are engineered to provide immediate wave attenuation and habitat for oysters. More than five miles of QuickReef® have already been deployed in North Carolina and Virginia, where qualitative observations showed strong oyster recruitment and reduced shoreline retreat. To validate these outcomes, the company partnered with Southern Shores Engineering and the University of South Alabama to conduct quantitative wave flume studies. Testing measured wave attenuation, structural stability, and current velocities, and results indicated that QuickReef® attenuated waves at levels comparable to rubble mound sills while remaining highly stable. Importantly, the structures are designed to improve further over time as oysters colonize, cementing the units together and enhancing roughness. McKinney emphasized that scaling these systems requires engineering data that regulators and contractors trust, which is why quantitative validation is critical. She also highlighted the versatility of QuickReef®, which can be manufactured in units small enough for hand placement or in panels weighing several thousand pounds for large-scale projects. Ultimately, QuickReef® aims to combine the engineering reliability of traditional armoring with the ecological uplift of oyster reefs, offering a cost-effective and habitat-positive shoreline solution.

Adrian Sakr
University of Florida

Adrian Sakr discussed the environmental tradeoffs of materials commonly used in living shorelines and coastal restoration. He emphasized that while concrete, metal, and plastic are widely used because of cost and predictability, their full life-cycle impacts—production, transportation, installation, and degradation—carry significant environmental costs. His review of the literature showed that despite heavy reliance on these conventional materials, reduced-impact alternatives like biodegradable plastics, natural fibers, and recycled aggregates are rarely used at scale. Sakr presented a comparative framework that indexed both dollar cost and carbon footprint, revealing that natural and biodegradable options can often outperform conventional materials when full environmental costs are considered. He highlighted case studies showing how local sourcing, recycled shell, or plant-based binders can reduce impacts and support sustainable shoreline construction. Importantly, he argued that not all projects require long-lasting, durable materials—shorter-lived substrates may be appropriate where oysters or vegetation quickly establish and provide structural resilience. Sakr urged the development of standardized specifications for materials to help practitioners, regulators, and contractors evaluate performance and select low-impact alternatives with confidence. He also noted that policy shifts, such as Florida's encouragement of plastic-free restoration, are already pushing the field in this direction. His conclusion was that material choice is a central but often overlooked factor in scaling sustainable oyster-based shoreline projects, and a life-cycle lens can improve both ecological and economic outcomes.

Panel Discussion and Participant Input

Knowledge Gaps:

Panelists identified key knowledge gaps around how oysters interact with engineered shorelines, particularly regarding long-term resilience, recruitment in larval-limited systems, and ecological uplift beyond the footprint of structures. There is still uncertainty about the relative performance of different substrates (e.g., rock types, concrete formulations, biodegradable materials) and their durability in diverse environments. Participants also noted the need for standardized specifications and datasets to compare materials and methods across projects. Understanding how oyster reefs recover after storms and self-repair over time was highlighted as areas needing more systematic study.

Permitting & Policy:

A recurring theme was the difficulty of navigating permitting for living shorelines that integrate oysters, with barriers ranging from "fill" classifications to limited regulator familiarity with novel substrates. Practitioners stressed the importance of early and consistent engagement with permitting agencies and building trust through pilot projects. Policy frameworks were seen as lagging behind restoration innovations, especially regarding material approval and hybrid approaches. In urban settings like New York, additional hurdles exist where aquaculture regulations intersect with restoration goals, creating tension around risk to harvestable waters.

Metrics:

Participants recommended expanding success metrics beyond simple oyster presence or absence to include wave attenuation, sediment retention, and broader ecological uplift. Tracking genetic diversity and larval contributions of restored populations could clarify long-term sustainability. Several panelists emphasized measuring resilience—how well oyster structures recover from disturbance—as a critical indicator. There was consensus that monitoring programs should integrate engineering and ecological measures to fully capture project outcomes.

Overcoming Barriers:

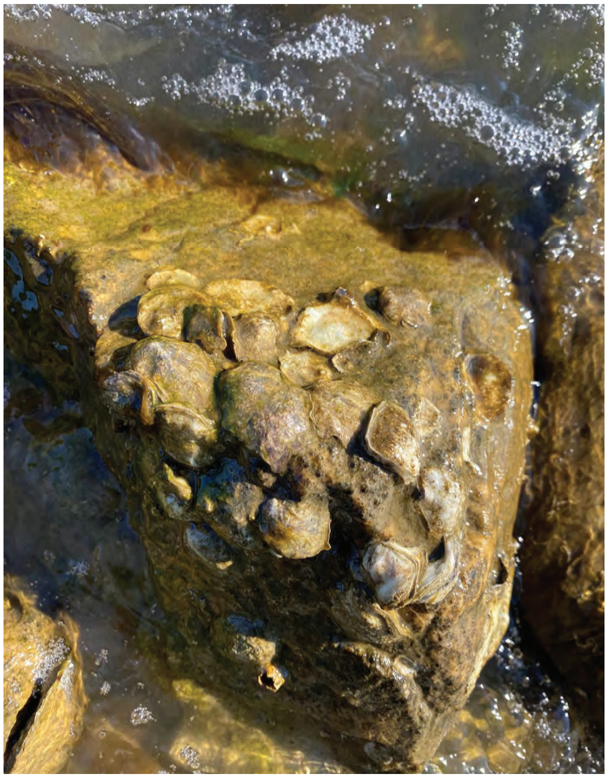
Contractor involvement, cost, and logistics were cited as major barriers to scaling oyster-based living shorelines. Speakers noted that designs must not only be ecologically sound but also deployable by marine contractors under real-world conditions. Education and public outreach remain important, since many landowners still default to bulkheads or riprap out of habit. Participants stressed the value of hybrid solutions, partnerships across disciplines, and demonstration projects to build confidence and reduce risk perceptions.

Poll Results:

Polling during the symposium revealed strong support for oysters as a habitat-building tool.

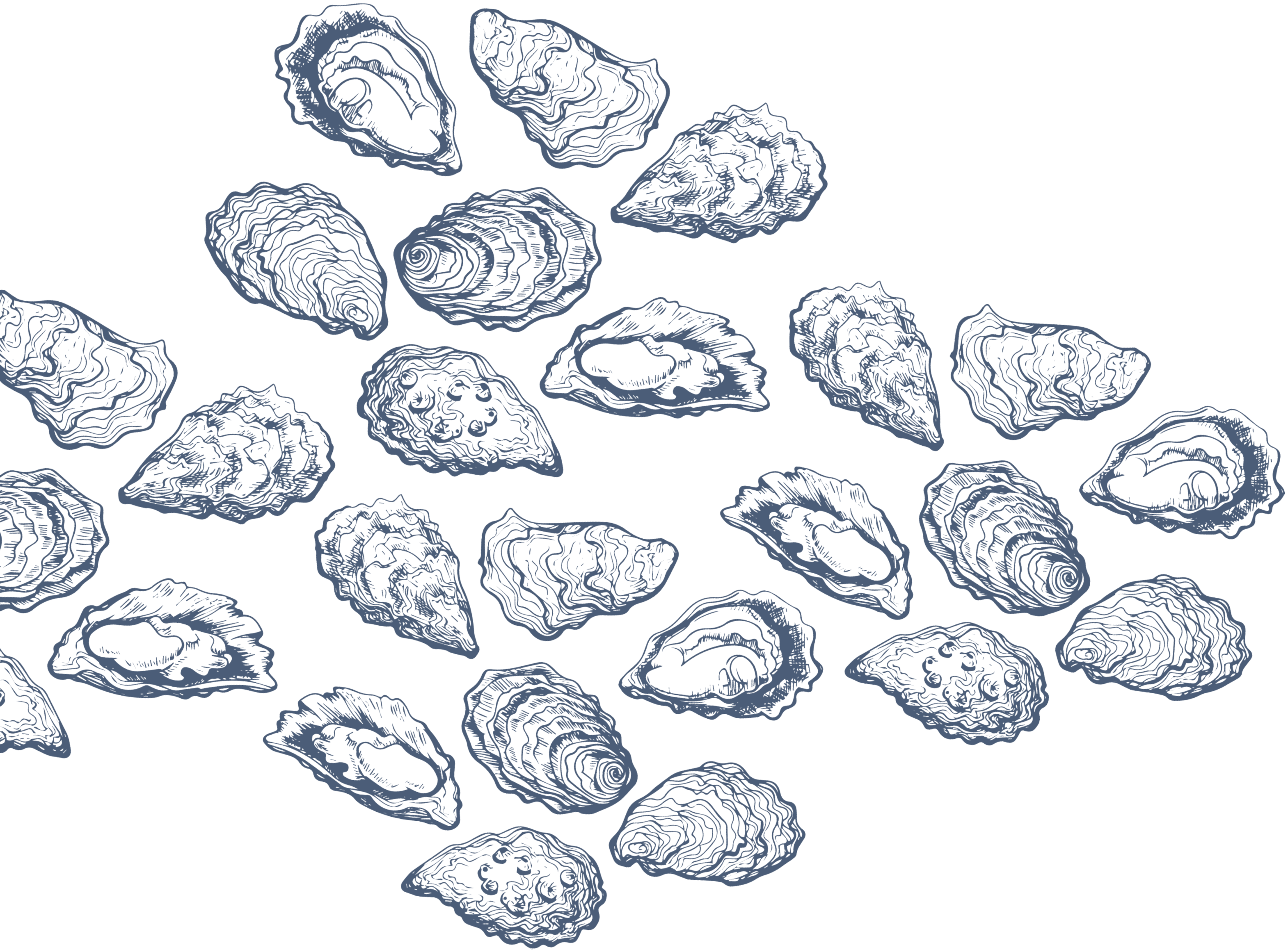
On Day 1, when asked about the benefits of retrofitting existing infrastructure, 83 respondents (63%) ranked habitat creation as most important, followed by 46 (35%) for oyster spat recruitment and 31 (24%) for biodiversity enhancement. Durability (28%), cost-effectiveness (23%), and public perception (15%) were also noted but less frequently prioritized. On Day 2, the most valued benefits of oyster-inclusive living shorelines were again habitat creation (54%), oyster spat recruitment (40%), and durability of structures (26%). Participation data indicated that most attendees had practical experience: 71% reported involvement in living shoreline projects, and of those, nearly 90% included oysters. Oyster castles, reef balls, and shell bags were the most frequently used substrates, though participants also reported experimenting with newer options like biodegradable mats and manufactured wire reefs.

Across both days, permitting and regulations were identified as the top barrier (42–60% of respondents), followed by biological suitability (39%) and logistical constraints (33%). Maryland-specific concerns highlighted in the poll included the availability of suitable substrate, managing shallow-water habitat alongside SAV, and ensuring oyster survival in fresher and colder waters.



Oyster growing on rocks and on oyster shell at the Assateague State Park boat ramp in Maryland. Photo courtesy of the Maryland Coastal Bays Program and Amanda Poskaitis.

Appendices



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10:30 **Iacopo Vona**, University of Central Florida, Department of Civil, Environmental, and Construction Engineering

10:45 **Anthony Dvarskas**, Ørsted

11:00 **Jason Spires**, NOAA Cooperative Oxford Laboratory

11:15 **Niels Lindquist**, SANDBAR Oyster Company Inc.

11:30 **Siddhartha Hayes**, Hudson River Park Trust

11:45 **Adrian Sakr**, University of Florida

12:00 Poster session & Chat n' Chew breakouts

01:00 Plenary discussion

02:00 Adjourn

Thursday, Feb 27: Building Engineered Living Shorelines

10:00 Introduction

10:15 **Kate Orff**, SCAPE

10:30 **Carolyn Khoury**, Billion Oyster Project

10:45 **Tyler Ortego**, Natrx

11:00 **Amanda Poskaitis**, Underwood & Associates

11:15 **Mary-Margaret McKinney**, Native Shorelines, a Davey company

11:30 **Adrian Sakr**, University of Florida

11:45 **Alberto Canestrelli**, University of Florida

12:00 Poster session & Chat n' Chew breakouts

01:00 Plenary discussion

02:00 Adjourn

Poster Session Presenters on both symposium days:

Savanna Barry, University of Florida

George Birch, Oyster Heaven (Day 1 only)

George Thatos, Coastal Technologies

Niels Lindquist, SANDBAR Oyster Company

Nicholas Muzia, Sea & Shoreline

Symposium Logistics

To join the symposium:
https://tinyurl.com/SHORES-Virtual-Symposium

To ask the speakers a question: Type your question in the Zoom chat. Only the speakers and moderators will be able to see your questions.

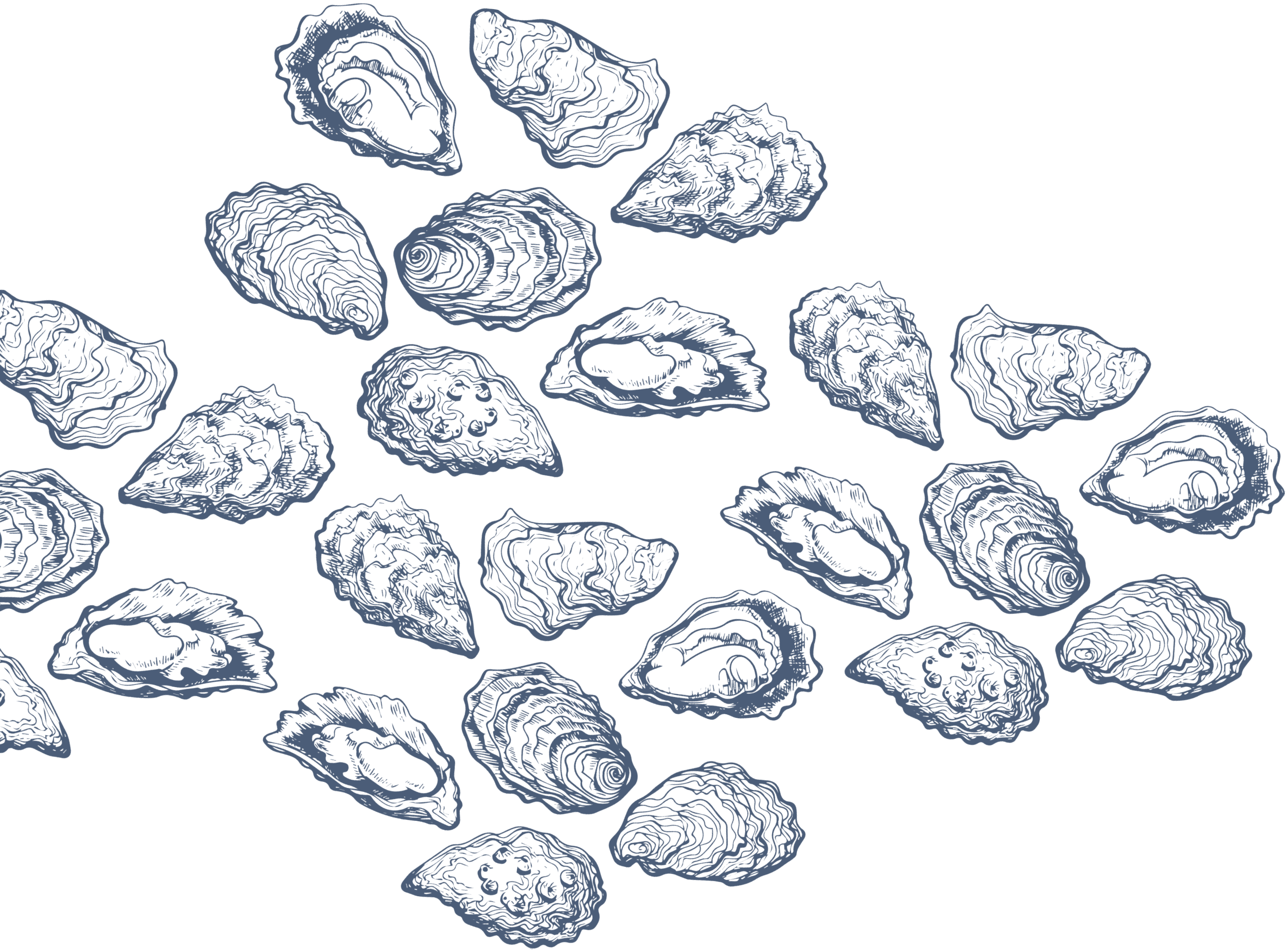
To join the Poster session & Chat n' Chew:
https://tinyurl.com/Posters-and-Chat-n-Chew

To ask a question or make a comment during plenary: Type your question or comment in the Zoom chat. The moderators will be able to see your questions and comments and will relay them to the panelists.

To receive a copy of the symposium report: All registrants will be sent the report this spring.

Day 1: Retrofitting Existing Infrastructure

Talk Abstracts



Anthony Dvarskas
Ørsted

Integrating oysters into offshore wind lease areas: droppable oyster structure deployment at Borssele 1&2

Authors: Anthony Dvarskas, Karin Bilo, Tommy Kristoffersen

In 2021, Ørsted announced its ambition to have a net-positive impact on biodiversity for all renewable energy projects commissioned by 2030 or later. As a part of meeting this ambition, Ørsted is investigating the potential for nature-inclusive design at its offshore lease areas, including the addition of structured habitat and hard surfaces to benefit critical keystone species like cod and oysters. European flat oysters are a particular concern in the North Sea, given the substantial decline in their numbers and the absence of these reef-builders from areas where they had historically been present.

To address this, Ørsted recently collaborated with Van Oord to install droppable oyster structures at the scour protection for Ørsted's Borssele 1&2 wind lease area in the North Sea. Adult oysters were attached to these structures and, if successful, will generate larvae to colonize the areas adjacent to the installation, providing benefits to biodiversity and local water quality. Video footage will be collected at multiple time points following installation to monitor the structures. These structures are innovative for their lightweight design and their potential to be integrated into scour protection during routine maintenance activities. Some of the droppable structures were also composed of reused materials. This presentation will describe the characteristics of the droppable oyster structures, the installation approach, and the planned monitoring activities to evaluate the success of the deployment.

Siddhartha Hayes
Hudson River Park Trust

Enhancing infrastructure and nearshore habitat in an urban estuary, Hudson River Park, NYC

Authors: Siddhartha Hayes, Carrie Roble, Michaela Mincone

Located on Manhattan's west side between Chambers and W59th Street, Hudson River Park's 400-acre Estuarine Sanctuary waters are predominantly characterized by a homogeneous, fine silt/mud bottom. In a concerted effort to enhance both these mud flats and existing relict marine infrastructure with greater habitat variety, the Park installed over 200 enhancement structures between Piers 26 and 34 from 2021 to 2023. These structures include pile wraps, biohuts, textured concrete pile encasements, reef balls, and gabions. The Park designed the on-bottom reef balls and gabions in clusters to function as a contiguous corridor for nekton seeking shelter in Park piers and piling fields. The pile wraps, biohuts and textured pile encasements were designed to test vertical and off-bottom habitat opportunities that utilize Park pilings. Collectively, these enhancements aim to simultaneously introduce Eastern oysters (*Crassostrea virginica*), to supplement low-but-present annual wild recruitment, and to provide increased and varied benthic and demersal habitat for fishes, crustaceans, other nekton, and non-oyster epibionts. The enhancement structures are being monitored over a five-year period to assess oyster health, estuarine community utilization, water quality, and structure performance. This enhancement project was supplemented in 2022 by another installation of ~300 reef balls and gabions further north along Gansevoort Peninsula, as well as a ~100m cordgrass (*Spartina spp.*) salt marsh that has an associated four-year monitoring program. The Park is currently planning an additional enhancement project for an area north of 14th street that will continue to explore adapting marine infrastructure for improved habitat value.

Niels Lindquist
SANDBAR Oyster Company Inc.

Use of Oyster Catcher™ substrates as oyster-enhancing amendments for hardened structures

Authors: SANDBAR Oyster Company Inc.

Hardened structures, such as rock revetments, seawalls, and bulkheads, have long been used for shoreline erosion control and to protect built infrastructure. While certain types of hard armoring, as well as dock and pier pilings, can support the growth of oyster reef communities, their general lack of complex structure and rough surface texturing can limit the extent of oyster community development.

In recent years, structural amendments have been designed to integrate with existing hard structures, aiming to create habitats that foster more robust oyster communities. SANDBAR Oyster Company is currently developing Oyster Catcher™—cement-infused cloth hardscapes—as "cuffs" for pier and dock pilings to enhance oyster community growth in estuarine waters. These cuffs consist of Oyster Catcher™ panels shaped to encircle about half the circumference of a piling and are strapped in place at the optimal intertidal zone for oyster growth (Ridge et al. 2015, Scientific Reports 5; doi:10.1038/srep14785). The cuffs have either a flat or corrugated design. Oyster Catcher™ products are engineered to degrade over time at variable rates, allowing the developing oyster communities to naturally detach and settle on the surrounding seabed. Replacing degraded cuffs can help accelerate oyster accumulation at the base of pilings.

In initial tests, cuffs were installed on dock pilings adjacent to a major navigation channel, where they were exposed to boat wakes and large wind-generated waves. Oysters successfully recruited to the cuffs; however, community development was limited by the use of cuffs designed to degrade relatively quickly. Additionally, the complex habitat created by the cuffs served as a refuge for stone crabs (Menippe mercenaria), which preyed on oyster spat and accelerated cuff degradation. Future testing of Oyster Catcher™ cuffs for enhancing oyster communities on hardened structures will involve longer-lasting cuffs and designs that minimize spaces where crabs can shelter.

Adrian Sakr
University of Florida

Changing of the garden: evaluating the performance and ecosystem functionality of novel oyster garden structures

Authors: Adrian Sakr, Logan Mazor, Joseph P. Morton, Andrew Altieri

Oyster gardening, in which modular oyster reefs are suspended from docks, has become an increasingly common and accessible technique for coastal communities to enhance oyster populations for water filtration and biodiversity enhancement. However, little research has been done to evaluate materials and methods for oyster gardens regarding durability and ecosystem benefits, making it difficult to scale up efforts and maximize project success. We conducted a field experiment in a residential canal system of Sanibel Island, Florida where we deployed a variety of oyster garden structures to evaluate performance in oyster recruitment, durability, water filtration rate, and biodiversity. Additionally, the occurrence of Hurricane Ian during the deployment provided an opportunity to evaluate how these structures resisted severe storm events. We tested five structures: (1) a conventional design made of drilled oyster shell on steel wire; and four alternatives (2) GROW concrete discs; (3) jute fiber coated with calcium sulfoaluminate cement; (4) BESE biodegradable plastic matrix panels; and (5) BESE biodegradable plastic mesh bags filled with oyster cultch. All structures survived Hurricane Ian; however, both BESE structures ultimately disintegrated without recruiting oysters. Disc, jute, and shell wire structures demonstrated similar levels of durability, oyster recruitment and growth, and biofiltration rates. Thus, we conclude that material selection considerations may come down to the availability of materials and labor as well as the extent to which cost and biodegradability are prioritized. Our results provide important information for optimizing oyster garden performance while minimizing environmental impacts.

Rochelle Seitz

Virginia Institute of Marine Science

Retrofitting seawalls with artificial substrates promotes oyster recruitment and macrofaunal communities

Authors: Rochelle D. Seitz, Kathleen E. Knick, Alison Smith, Michael S. Seebo, Gabrielle G. Saluta

With the urbanization of coastal cities, natural shorelines have been extensively modified. Shoreline development has increased the presence of vertical seawalls, which can negatively impact benthic macrofaunal communities. Green engineering techniques can be used to enhance inhospitable seawall structures by creating micro-habitats on the structures and using materials that increase the settlement of bivalves. Oysters enhance benthic communities by creating complexity and heterogeneity, providing microhabitats for other macrofauna, which protects them from predation and physical stressors. At two field sites in the Chesapeake Bay, we retrofitted seawalls with artificial substrates with varying habitat complexity and oyster seeding density and investigated the effects on oyster densities and macrofaunal communities. The substrates included 3D printed tiles (0.25 × 0.25 m) with three levels of complexity (flat, 2.5 cm ridges, and 5 cm ridges) plus control tiles of the existing seawall, at three seeding densities (0, 36, and 56 oysters per tile). Tiles were monitored every three months for oyster survival, oyster growth, and primary cover. After a year, tiles were destructively sampled for oyster survival, oyster recruitment, and the macrofaunal assemblage. Both increased tile complexity and higher seeded oyster density increased seeded oyster survival and recruitment of oyster spat. The high-complexity, high-seeded tiles had 10x more recruits than flat, unseeded tiles and 70x more recruits than the controls of the existing seawall. Macrofaunal abundance and biomass also increased as habitat complexity of the tiles increased, providing habitat for larger organisms, such as mussels and mud crabs. Using retrofitted structures on seawalls increased habitat complexity, leading to higher seeded oyster survival, oyster recruitment, macrofaunal abundance, biomass, and species richness in coastal ecosystems.

Jason Spires

National Oceanic and Atmospheric Administration

Nature based oyster settlement substrate investigations

Authors: Jason Spires

Oysters occupy a unique space in coastal ecosystems and communities. These bivalves provide a range of ecosystem services and direct (wild and farmed fisheries) and indirect (habitat for other fauna, recreational fisheries) economic benefits. Additionally, oysters are increasingly considered as a tool for mitigating effects of climate change and promoting coastal resilience. Current oyster restoration practitioners frequently desire to place oysters along hardened shorelines but are hampered by inefficient or costly methods. In regions of high natural recruitment, oysters settle naturally on a variety of hardened surfaces, however, in regions of low natural recruitment this type of greening gray infrastructure is more challenging. Our work investigates novel population replenishment techniques by using biodegradable oyster setting materials (basalt, coconut fiber) and mechanical behavioral manipulation (bubble curtains) to create oyster communities on hardened structures. Our objectives are to develop a cost-effective material/technique that can be used to create oyster populations on hardened surfaces. Initial oyster settlement rates are similar among tested materials, however, retention is poor on the most pliable materials. Additionally, larval behavior was not controlled by bubble curtains and modifications to the experimental design are required.

Iacopo Vona

University of Central Florida

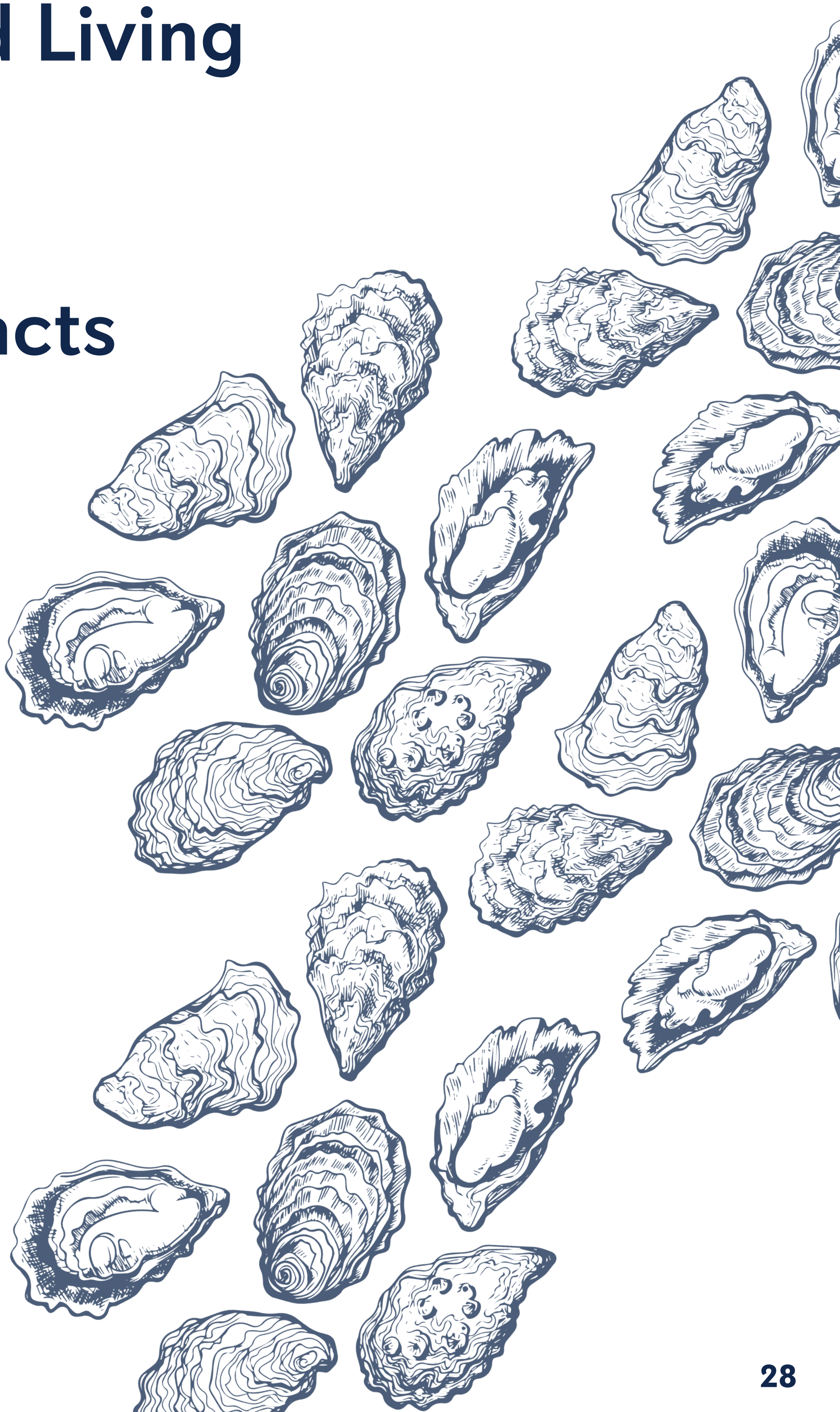
Integration on submerged breakwaters offers new adaptive shoreline protection in low-energy environments in the face of sea level rise

Authors: Iacopo Vona and William Nardin

Sea level rise (SLR) and increasing storm frequency threaten coastal environments. To naturally protect our coasts, living organisms such as oysters can be used. They provide a multitude of benefits for the surrounding environment, including coastal protection. Unlike any common gray structure used for coastal defense, such as breakwaters, oysters can grow with SLR and self-repair from damage following extreme events. In this study, we analyzed the coupling between breakwaters and oysters through a numerical model, Delft3D-SWAN, validated with field data. The research aimed to evaluate the performance of this hybrid solution under future scenarios of climate change and SLR. The study results showed that the coastline was more preserved and protected over time when oysters were included in the simulation, thanks to their capability to self-adapt over a changing climate. Incoming wave heights and sediment export from the shore were reduced compared with the use of gray breakwaters alone, resulting in a resilient and healthier coast. The coupling between oysters and breakwaters may represent a valuable and effective methodology to protect our coast over a changing climate and a rising sea, where optimal conditions for oyster survivability occur and are maintained over time.

Day 2: Building Engineered Living Shorelines

Talk Abstracts



Alberto Canestrelli
University of Florida

Integrating physical and numerical models to assess wave dissipation and sediment accumulation at restored oyster reefs

Authors: Alberto Canestrelli, William Nardin, Rafael O. Tinoco, Jacopo Composta, Salman Fahad Alkhidhr, Kamil Czaplinski, Luca Martinelli, Savanna Barry, Anthony Priestas, Duncan Bryant

Oyster reef ecosystems are increasingly recognized for their resilience and ability to provide sustainable, nature-based alternatives to traditional “gray” infrastructure. These reefs offer critical benefits, such as mitigating shoreline erosion, promoting sediment deposition, and supporting adjacent habitats like salt marshes. Despite their potential, there is a limited understanding of the physical processes driving sediment transport around oyster reefs under varying wave and tidal conditions, reef geometries, and locations. Bridging this gap is vital for optimizing sediment retention and supporting shoreline progradation.

This study aims to quantify the mechanisms through which oyster reefs stabilize sediments. Using a combination of physical and numerical modeling, researchers are investigating the influence of tidal and wave dynamics, longshore currents, reef geometries, and distances from the coast. Initial experiments employ 1:7 scaled 3D-printed oyster reefs in a wave flume at the Ven Te Chow Hydrosystems Lab, University of Illinois Urbana-Champaign. Concurrently, numerical simulations with OpenFOAM on the HiPerGator high-performance cluster analyze wave-reef interactions under varying conditions.

Findings from these efforts will guide large-scale experiments at the Large-scale Sediment Transport Facility (LSTF) in Vicksburg, MI, conducted at a 1:2 scale. These tests will include regular and irregular waves (i.e., wave spectra in both frequency and direction), wind-driven and tidal longshore currents, and tidal variations in water level. Four distinct reef geometries will be tested under these hydrodynamic conditions. The collected data will calibrate a numerical model, enabling predictions of reef-induced sediment aggradation beyond experimental conditions and identifying optimal reef designs.

The outcomes of this research include a robust dataset on sediment dynamics, calibrated models, and actionable guidelines for oyster reef restoration. These results will inform sustainable coastal management strategies, enhancing shoreline protection and promoting the use of oyster reefs as effective, nature-based solutions for long-term resilience in coastal environments.

Carolyn Khoury
Billion Oyster Project

Living breakwaters: engineering with nature and restoring oyster reef habitat

Authors: Pippa Brashear, Carolyn Khoury

Widely considered a model for climate-adaptive nature-based infrastructure, Living Breakwaters is a $111 million project with a layered approach to risk reduction—enhancing physical, ecological, and social resilience along the South Shore of Staten Island.

The project consists primarily of 2,400 linear feet of near-shore breakwaters—partially submerged structures built of stone and ecologically-enhanced concrete units—that break waves, reduce erosion of the beach along Staten Island's Tottenville shoreline, and provide a range of habitat spaces for oysters, fin fish and other marine species. The Living Breakwaters concept was developed by a large, multi-disciplinary team led by SCAPE as part of a winning proposal for Rebuild By Design, the design competition launched by the U.S. Department of Housing and Urban Development (HUD) after Superstorm Sandy.

The breakwaters are designed to reduce the impact of climate-intensified weather events on the low-lying coastal community of Tottenville, which experienced some of the most damaging waves in the region and tragic loss of life during Superstorm Sandy. Informed by extensive hydrodynamic modeling, the breakwaters are also designed to slow and, eventually, reverse decades of beach erosion along the Tottenville shoreline. The breakwaters are constructed with "reef ridges" and "reef streets" that provide diverse habitat space. Billion Oyster Project (BOP), a non-profit organization based in New York City whose mission is to restore functional, self-sustaining oyster reefs to New York Harbor, will introduce additional substrate seeded with juvenile oysters to the breakwaters beginning in 2025.

Beyond the physical breakwaters and habitat restoration, the project also aims to build social resilience in Tottenville through educational programs and the implementation of an open-access curriculum for local schools for local schools in partnership with BOP and local community committees and action groups.

Mary-Margaret McKinney
Native Shorelines, A Davey company

Quantitative evaluation of an alternative oyster-centric living shoreline system

Authors: Mary-Margaret McKinney, Worth Creech, Whitney Thompson, Chris Paul, John Darnall, and Bret Webb.

Coastal erosion and shoreline retreat, resulting from both from extreme weather events and sea level rise, pose great challenges to coastal management across U.S. coastal areas. To address this challenge, many State, Local, and Federal stakeholders have deployed living shorelines as a cost-effective method of reducing shoreline retreat rates and providing ecological benefits such as marine habitat, fish spawning areas, and shellfish and oyster habitat.

As such, the deployment of these structures has gained increasing popularity, and many new technologies and variations of living shorelines have been developed in recent years. However, coastal engineering metrics such as wave attenuation, structural stability, and changes to current velocities are rarely validated prior to deployment. Native Shorelines' QuickReef® technology is one of the new types of living shorelines and has been deployed along over 5 miles of shorelines in North Carolina and Virginia. Qualitative observations from deployment sites appeared to show significant oyster spat recruitment and a reduction in shoreline retreat rates. In early 2024, QuickReef® designs were evaluated via physical and numerical modeling to determine the effectiveness and stability of the structures.

A desktop study evaluating field conditions at representative sites was performed to inform critical design forcings for flume study purposes, which was then conducted at the University of South Alabama Center for Applied Coastal Engineering and Science. Wave attenuation, stability, and current velocities were measured during physical modeling. Results from the wave flume study were utilized to calibrate FLOW-3D models. This presentation will discuss findings from the physical and numerical modeling studies as well as demonstrate the overall effectiveness of living shoreline designs using quantitative methods.

Kate Orff
SCAPE

Living Breakwaters

Designed by SCAPE, COWI, Arcadis, SeArc Ecological Marine Consulting, WSP, MFS Engineers, Prudent Engineering. Engagement by Billion Oyster Project. Construction by Weeks Marine, Ramboll, Baird. Environmental Review & Permitting by AKRF.

Kate's talk will focus on the trajectory of oyster restoration in the New York Harbor, and how Living Breakwaters evolved into a funded and implemented project in the post-Super storm Sandy recovery process. She will show how the Living Breakwaters project developed, including its engineering and approvals process, and will feature the work of SCAPE's many collaborators, including the Billion Oyster Project.

Tyler Oretego
Natrx

Integrating engineered structures and oyster habitat for resilient shorelines

Authors: Drew Keeley, Tyler Ortego

The integration of oyster and marine habitat with engineered structures offers a transformative approach to enhancing shoreline resilience and ecological health. Traditional materials and construction methods often lack adequate capability to balance coastal protection with optimal habitat formation. New technologies are emerging that provide new capabilities for coastal resilience and habitat restoration practitioners.

Natrx has pioneered the Dry Forming™ advanced manufacturing technique, which enables development of tailored, habitat-positive structures that address site-specific needs while promoting oyster colonization and ecosystem restoration. Natrx reef structures feature customizable void spaces and biomimetic surfaces to optimize conditions for oyster recruitment, habitat formation, and ecological uplift. These structures support shoreline stabilization and also deliver ecosystem services such as water filtration and biodiversity enhancement. By leveraging digital tools, advanced manufacturing, and material science innovations, Natrx can efficiently produce scalable, site-specific solutions that enhance the longevity of coastal infrastructure and integrate seamlessly with existing gray and hybrid systems.

Case Study: Hog Island, VA - A nature-based wetland protection and habitat restoration solution using Natrx ExoForms™ along Hog Island in Gloucester County, Virginia. The goals of this project was to protect the residential and commercial properties along Monday Creek and the York River, reduce erosion and sedimentation into the Chesapeake Bay, and a focus on enhancing maritime habitat for shorebirds, oysters, and other marine life. Designed customized interlocking ExoForms for highwave energy areas exposed to Mobjack Bay and low crested oyster reef ExoForms for low energy areas. Placed 972 linear feet of large stacked units and 122 linear feet of low crested oyster reefs. Added available surface area for 14 million oysters that will filter water and provide foundational habitat and prevent 40,000 tons of eroding sediment from entering the bay system and contributing to suspended sediment and nutrient loading.

Amanda Poskaitis & Camille Calure
Underwood & Associates

Oyster recruitment on dynamic living shorelines

Authors: Underwood & Associates, Maryland Coastal Bays Program

Underwood & Associates, a design/build stream and living shoreline contractor, developed the dynamic living shoreline, which can be adapted to various site conditions to create critical shallow water wildlife habitat and solve erosion issues for communities and property owners. Underwood uses all native stone material in our vegetated headland designs and we have been working to incorporate oysters into our living shorelines to achieve even greater habitat co-benefits on our project sites. An example of oysters thriving on one of our projects is at the Assateague State Park Living Shoreline – a partnership between Assateague State Park, Maryland Coastal Bays Program, and Underwood & Associates.

Oyster surveys have been conducted at the Assateague Living Shoreline site since 2021 by the Maryland Coastal Bays Program. The surveys started after noticing an abundance of oysters along the vegetated headlands. Years of surveying has shown that although this site experiences oyster recruitment, the oysters tend to not live past 1-2 years due to disease or other environmental factors. This is typical in the Maryland Coastal Bays watershed, which has not had a self-sustaining wild oyster population in over 50 years. In addition to the research conducted on oysters at the Assateague Living Shoreline, we are working on many other living shoreline projects throughout the Chesapeake and Coastal Bays that have potential for incorporation of oysters. We will be presenting on our work and exploring how to incorporate oysters into living shoreline designs effectively. We will share multiple projects, research, and lessons learned.

Adrian Sakr
University of Florida, Department of Environmental Engineering Sciences

Living in a material world: support for the use of natural and alternative materials in coastal restoration and living shorelines

Authors: Adrian Sakr, Andrew Altieri

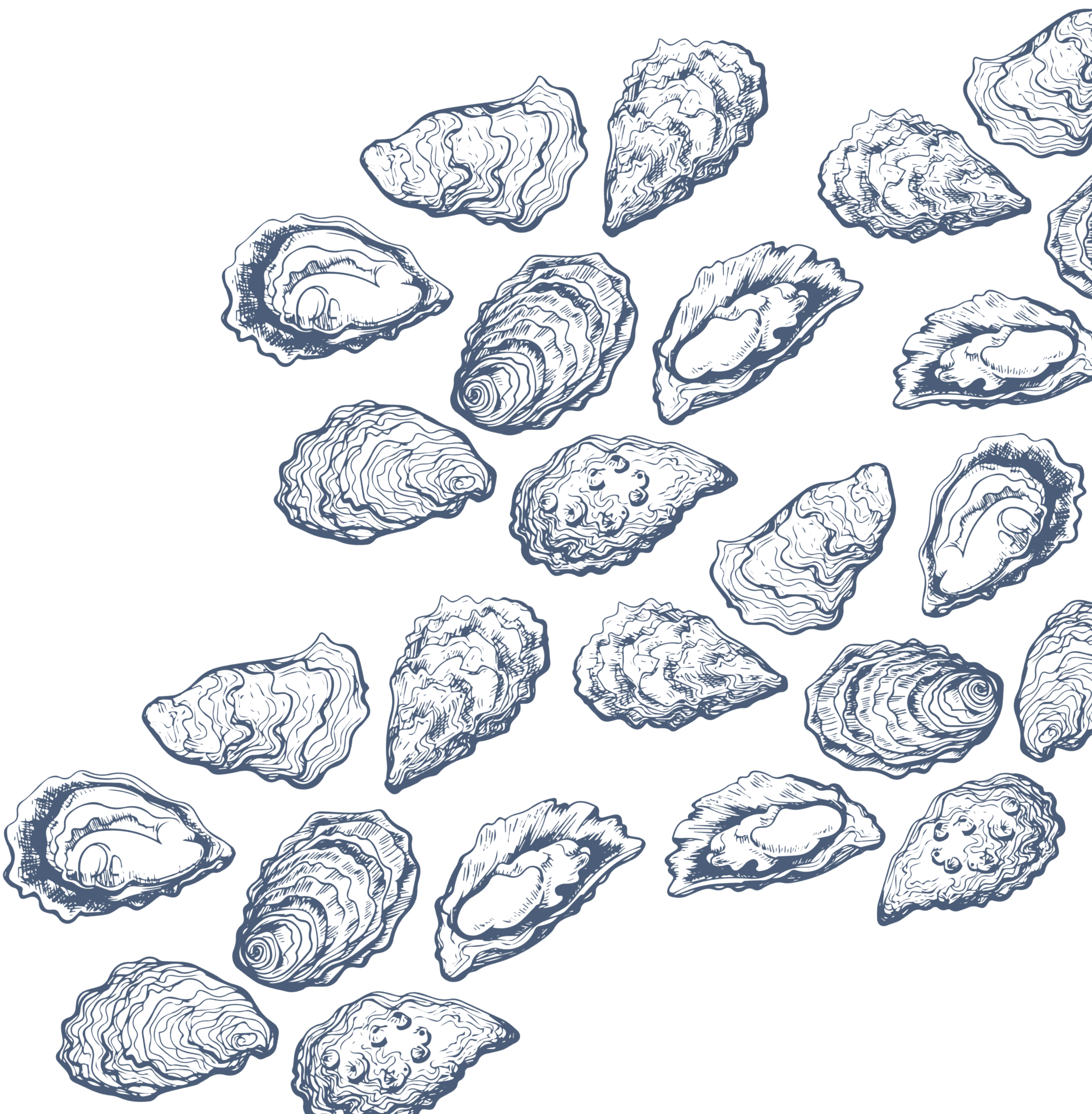
The size and expense of coastal restoration efforts are increasing exponentially to mitigate anthropogenic environmental impacts and achieve international conservation goals. As part of these efforts, a variety of conventional materials including plastic, metal, and concrete are used in

breakwater, settling substrate, vegetation stabilization, and sediment retention structures because of their availability, inexpensive purchase price, and predictable properties. However, questions regarding sustainability arise given the adverse environmental impacts of the life cycle processes for each material.

Life cycle impacts from production, transportation, installation, and degradation should be key considerations in material selection, with criteria that allow decision makers an opportunity to evaluate less impactful alternative materials. Natural and reduced-impact alternative materials include natural elements such as plant fibers and rock as well as reduced-impact materials such as bio-based and biodegradable plastics. These items may have comparable availability and functionality and exhibit reduced carbon, chemical, and particulate emission impacts. However, they are often not selected for full-scale restoration applications due to uncertainties regarding their financial cost and ability to replace conventional materials. Here, we compare conventional and reduced-impact alternative materials for use in coastal restoration applications. The function, engineering performance, and life cycle environmental impacts are reported for each material followed by a presentation of case studies that illustrate the value of appropriate material selection. We then compare the impacts of material sourcing and product lifespan to develop a material selection framework enhancing the selection process of reduced-impact alternatives.

This study reveals a need for more detailed and standardized life cycle information about the materials used in the coastal environment. The proposed framework allows more emphasis on material life-cycle implications in the design process, which could lead to enhanced use of alternative over conventional materials and improved project value and outcomes.

Poster Abstracts



Savanna Barry
University of Florida

Performance assessment of living shoreline retrofits on Florida's Gulf of Mexico coast

Authors: Savanna C. Barry, Elix M. Hernandez, and Mark W. Clark. University of Florida, Florida Sea Grant.

A community-driven effort in Cedar Key, Florida, USA, resulted in the construction of three living shoreline retrofits intended to bolster failing coastal infrastructure and restore habitat functions in Daughtry Bayou. A multi-year monitoring program tracked changes in elevation and vegetation communities across the entire shoreline profile from lower-intertidal to upland/transitional zones and measured wave attenuation during typical and extreme (hurricane) conditions. Overall, these living shoreline retrofits served to soften more than 30% of the bayou's shoreline, dramatically reducing the extent of armored shoreline in direct contact with tidal influence. The extent of vegetated habitat area has increased at all three sites, despite sediment export from higher elevation zones driven largely by repeated impacts from hurricanes and tropical storms. These living shorelines reduced wave energy by 33 to 79% in typical conditions and by up to 28% in hurricane conditions, consistently outperforming armored shorelines, even during an extreme event (Hurricane Idalia). The living shoreline retrofit projects assessed here have persisted through and shown signs of recovery after multiple tropical storms and hurricanes, while providing important energy reduction services. Thus, living shoreline retrofits continue to be a cost-effective shoreline management strategy in the short term for this area. However, our analyses suggest that persistence of these shorelines could be threatened by the combination of sea-level rise (by 2040), upland armoring, and an increasing risk of more intense tropical systems. Therefore, future interventions should more carefully consider these threats in conjunction with habitat enhancement goals.

George Birch
Oyster Heaven

The Mother Reef: A scalable clay based biodegradable substrate for oysters

Authors: George Birch, Ronald Lewrissa, Jochem van der Beek and Natacha Juste-Poinapen

The "Mother Reef," developed and patented by Oyster Heaven, is a step change in the scalability, predictability and permissibility for building oyster focused engineered living shorelines. The low fired clay structures are tunably biodegradable (depending on firing temperatures), they are an effective oyster settlement substrate and can be produced at generic brick manufacturers around the world. An average factory can be brought online in a matter of months and can produce enough substrate for 100 acres of reef per day for the same price as household bricks.

Constructed from locally sourced clay, Mother Reefs are designed to facilitate oyster settlement, growth, nutrient flowthrough, reproduction, and protection from predators. Their trapezoidal shape and sine wave patterned ribs maximize settlement surface area while minimizing contact area, reducing spat loss during transport.

The Mother Reef's innovative design and use of natural materials are key to its scalability and permissibility. As a biodegradable structure, it seamlessly integrates into the marine environment,

generating natural reef development without long-term ecological disruption. The scaffolding eventually melts away into the background sediment, chemically and physically indistinguishable from the sediment already there. This approach aligns with current policy trends that favor nature-based solutions for coastal protection, making it more likely to secure necessary permits for large-scale deployment.

The Mother Reef's adaptability to local conditions further enhances its scalability and permissibility. Its composition and structural arrangement can be tailored to optimize specific ecosystem services, such as biodiversity enhancement or coastal erosion mitigation, based on the needs of the local environment.

By providing a scalable, permissible, and biodegradable solution for oyster reef restoration, Oyster Heaven will play a pivotal role in building resilient and sustainable living shorelines. Its innovative design and alignment with policy objectives position it as a leading technology for large-scale coastal protection and marine habitat regeneration.

George Thatos
Coastal Technologies

Coastal Technologies Corp's Oyster Reef Building Technology

Authors: George Thatos, and Raphael de Perlinghi

Coastal Technologies Corp (CTC) introduces a revolutionary patented solution to address the global need for oyster reef restoration—a critical factor in coastal resilience, pollution remediation, and ecosystem recovery. Standard reef-building methods are slow, labor-intensive, and suffer from failure rates as high as 85%. CTC's innovative, nature-inspired technology overcomes these limitations, enabling near-instant reef creation while preserving coastal ecosystems.

Our Oyster Reef Building system uses stainless steel corkscrew armatures installed into sediments using simple tools. These armatures support stone plates, providing elevated, predator-resistant habitats for oysters. By raising reefs off the seafloor, our system avoids issues like siltation, hypoxia, and subsidence—common causes of failure in traditional methods. The vertical structure enhances resilience to climate change and allows for adjustments to rising sea levels. Easy installation, minimal disruption to coastal mudflats, and high surface area make this system efficient, scalable, and adaptable.

CTC's technology serves vulnerable coastal communities worldwide, particularly those threatened by storm surges, erosion, and sea-level rise. Oysters act as "ecosystem engineers," filtering water, preventing harmful algae blooms, and supporting diverse marine life. For communities like the Biloxi-Chitimacha-Choctaw Indians in Louisiana, our system offers food security, cultural preservation, and coastal protection.

Field-tested prototypes have demonstrated the technology's effectiveness, with further validation planned through partnerships with academic institutions, NGOs, and coastal restoration groups. CTC's team combines technical expertise with a passion for environmental and social justice, ensuring community involvement in every stage of implementation.

By dramatically increasing the capacity to build resilient oyster reefs at scale, CTC provides a practical, cost-effective tool to protect coastal populations, restore ecosystems, and mitigate climate impacts. With support from SHORES, we aim to advance this technology to market, navigate regulatory pathways, and foster partnerships that bring life-saving solutions to the communities that need them most.

Niels Lindquist
SANDBAR Oyster Company Inc.

A decade of development, refinement and scaling of Oyster Catcher™ hardscapes for oyster habitat creation, living shorelines and oyster culturing

Authors: Niels Lindquist and David Cessna

At the 18th International Conference on Shellfish Restoration in Charleston, SC in 2016, Niels Lindquist and the late David Cessna (co-inventors), made the first public presentation on an innovative, composite hardscape for oyster habitat creation/restoration and oyster culturing. Our degradable hardscape, trade named Oyster Catcher™, is a composite of plant-fiber cloths infused with cements (any and all mineral-based binders/hardeners claimed) made by soaking and manipulating the cloth in cement slurries to work the cement into the threads of the cloth.

Prior to cement hardening, we form the cement-infused cloth pieces into different modular shapes, some of which we use to build robust reef frameworks and others to trap sediments and thereby promote salt marsh development. The surface of Oyster Catcher™ is highly textured and exceptionally attractive to oyster larvae and protective of juvenile oysters. In addition to reef building, a 3-dimensional, pretzel-shaped Oyster Catcher™ derivative is proving to offer a facile path for capturing and manipulating wild and hatchery settled spat for culturing for food and oyster restoration products. In addition to Sandbar Oyster Company's direct development efforts with Oyster Catcher™, independent, third-party testing is showing Oyster Catcher™ to be an exceptionally valuable technology in the living shoreline/shoreline protection toolbox.

Oyster Catcher™ is now being used in multiple, large-scale living shoreline and oyster habitat creation projects in North Carolina, Virginia, Georgia and California. Our cement-infused hardscape technology is owned by UNC Chapel Hill and now patented in Australia, Canada and New Zealand and is under examination in the US and EU. Sandbar Oyster Company Inc. has an exclusive license from UNC to commercialize this technology. This presentation offers an overview of our work developing and testing Oyster Catcher™ and views of projects showing the range of applications of Oyster Catcher™ products.

Nicholas Muzia
Sea & Shoreline, LLC.

The Oyster Ark: A new role for oyster farming in ecosystem restoration

Authors: Nicolette Mariano, Nicholas Muzia P.E., Nicholas Bourdon

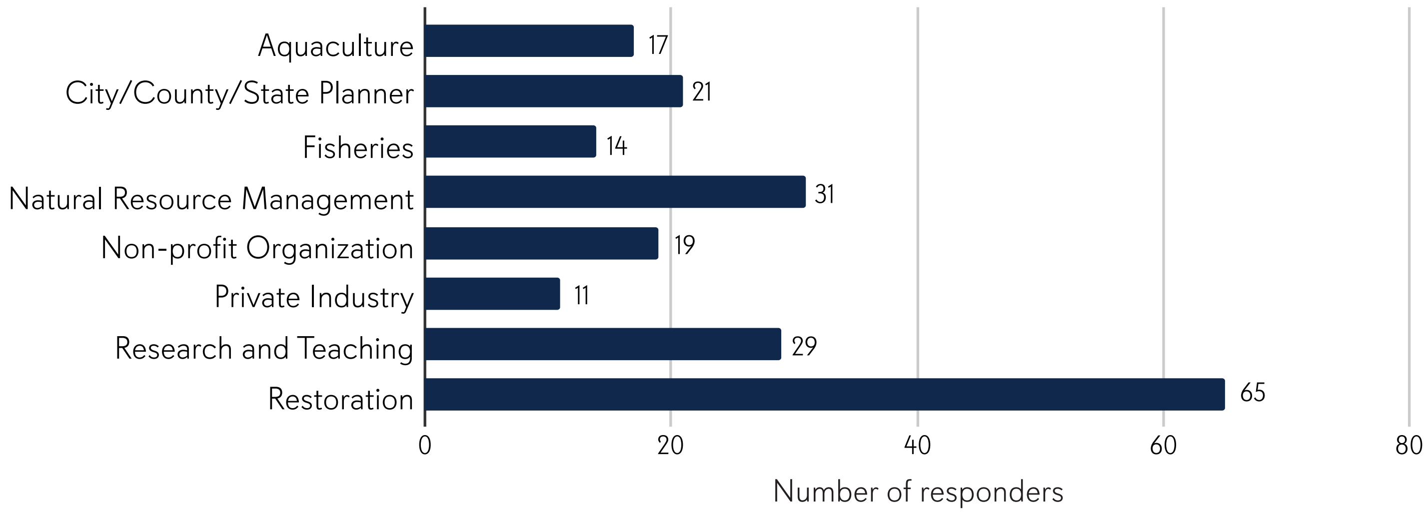
Oyster aquaculture offers a unique opportunity to enhance environmental restoration while supporting local economies. This presentation highlights a pilot project conducted in Florida's Indian River Lagoon by Treasure Coast Shellfish, which aimed to integrate oyster farming with ecosystem restoration efforts. The project evaluated a novel technique, the "Oyster Ark," designed to capture microorganisms from healthy sites and transplant them to less productive or restoration sites. By introducing live oysters and their associated microorganism communities, the Oyster Ark approach appears to accelerate the growth and success of restoration sites.

In addition to its restoration potential, the project documented the broader biological life supported by responsible oyster aquaculture, showcasing its role as an environmental asset. The initiative also explored the potential for oyster farmers to generate supplemental revenue through restoration activities, creating a symbiotic relationship between sustainable aquaculture and ecosystem health.

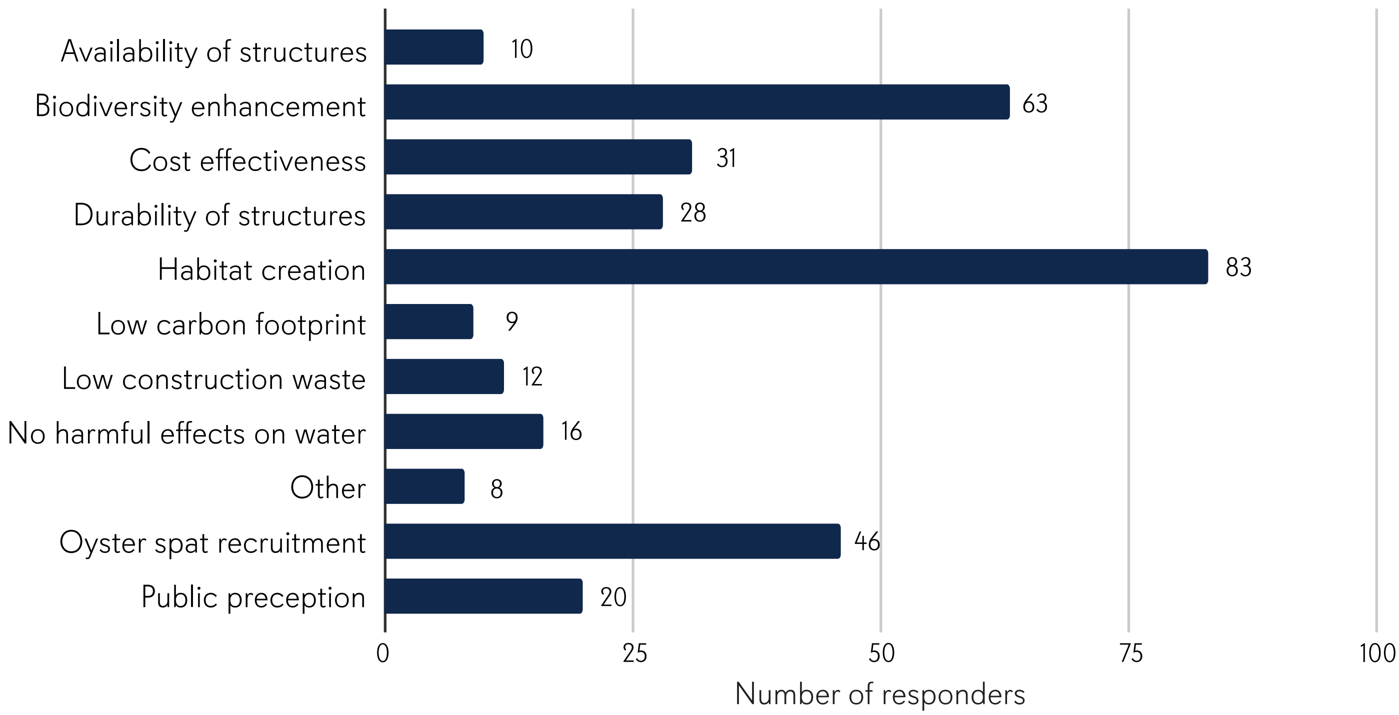
This presentation will discuss the outcomes of the pilot project, including its ecological and economic impacts, and seek feedback on how this approach could be refined and scaled to support both environmental restoration and the viability of local shellfish farms.

Appendix E: Poll Results Day 1

I work in the following sector(s):



What benefits of retrofitting existing infrastructure for oysters is most important to you? (Choose 3)

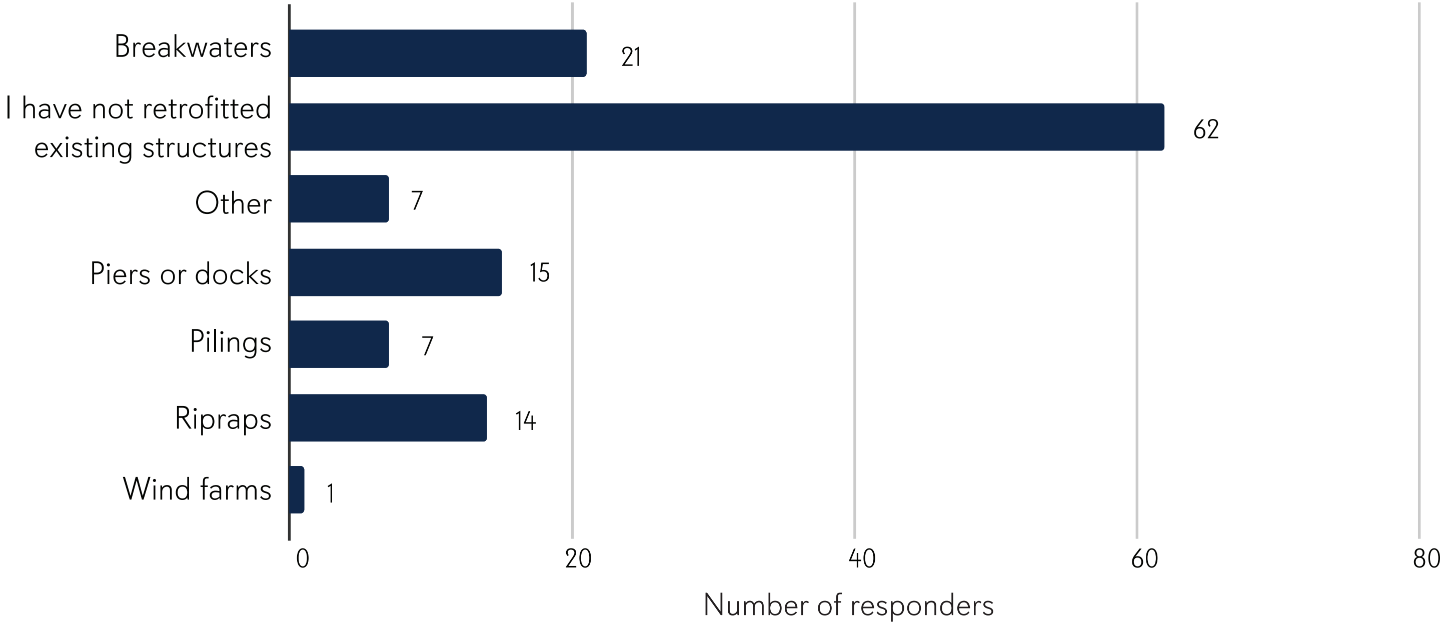


In the Other category, the following were listed:

- No negative impacts (structural, negative species composition changes, etc.)
- Boat wake attenuation
- Potential wave dissipation
- Positive benefits for waterways and water quality
- Water filtration
- Coastal resilience
- Wild harvest
- Erosion control

Appendix E: Poll Results Day 1

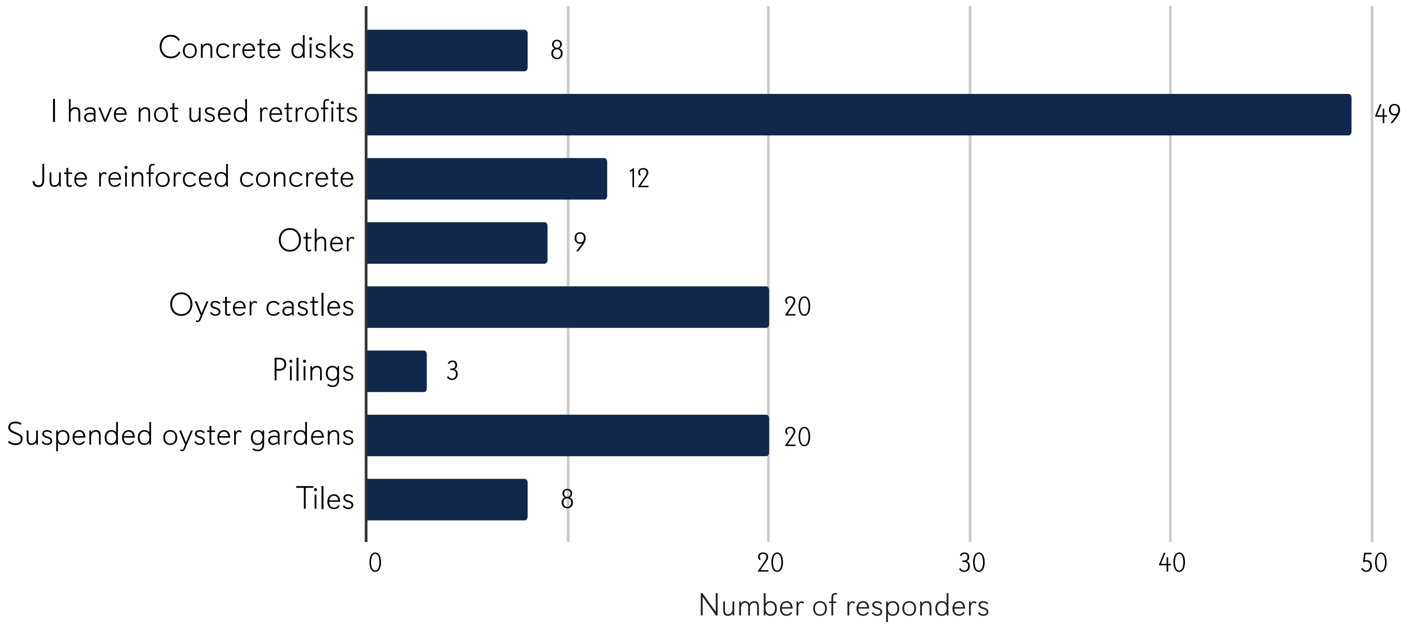
What types of structures have you retrofitted with oysters?



In the Other category, the following were listed:

- Bulkheads
- Levees
- Earthen berms
- Living shorelines
- Seawalls
- Marine Pontoons
- Estuaries around the world

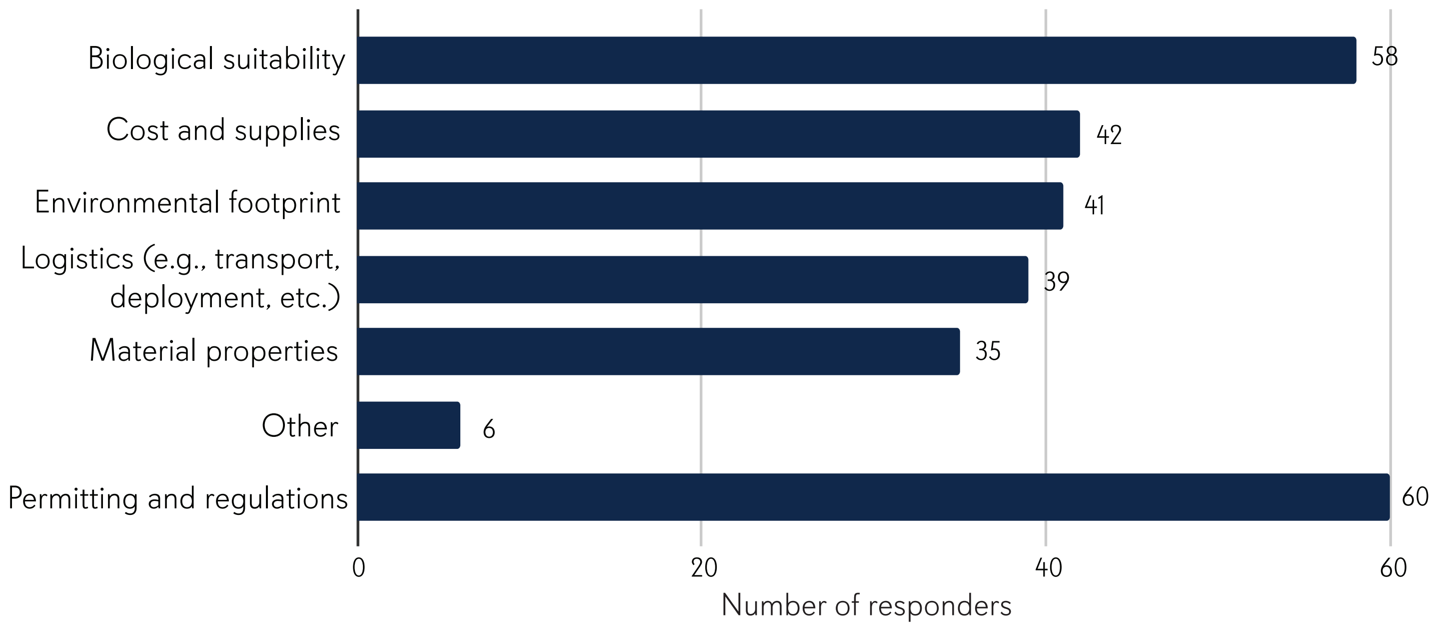
What types of retrofits for oysters have you used?



In the Other category, the following were listed:

- Reef balls
- Wrap, net, overlaid coating
- Natrx ExoForms
- Bioconcrete made from waste shells and natural binders that were 3D printed/cast into artificial reefs
- Plastic mesh bags
- BESE biodegradable plastic
- Drilled shell on steel wire
- Oyster shell bags
- Econcrete

What aspects of retrofitting existing infrastructure for oysters require greater investigation?



In the Other category, the following were listed:

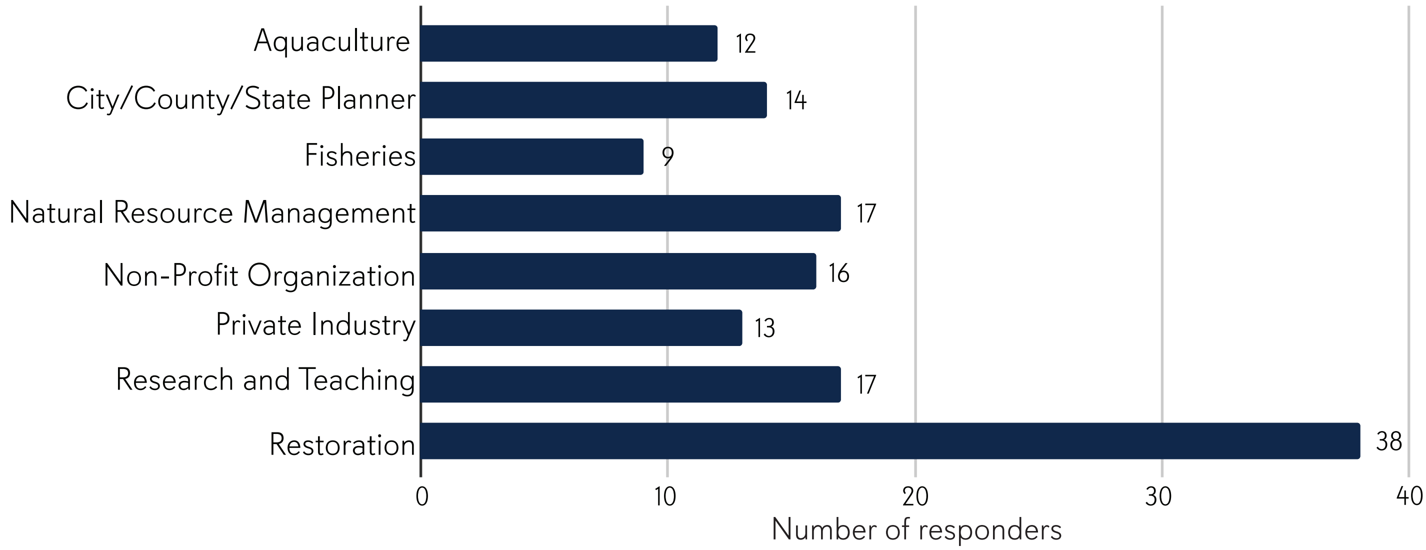
- Risk assessment of greener structures compared to traditional infrastructure
- Biogeochemical interfaces/gradients
- Scalability
- Biologically significant impact
- Resilience and adaptation to a changing marine environment

Are there other Maryland-specific issues that need addressing?

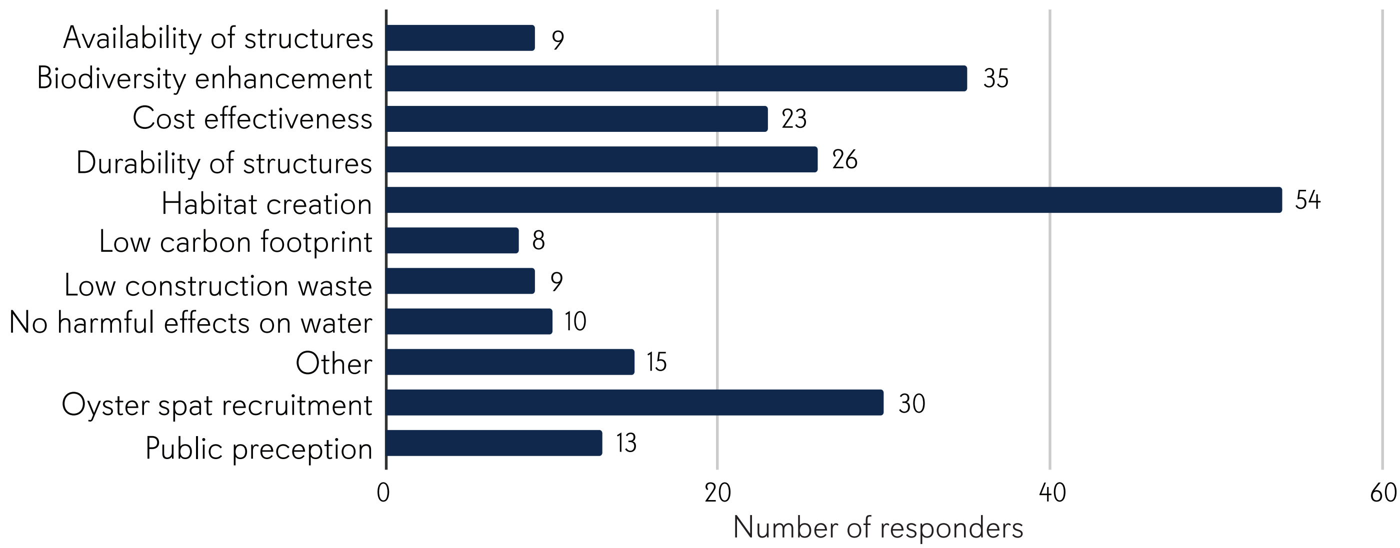
- Funding and other support for research (deployment procedures, costs, and integration with shoreline protection)
- MDE permitting
- Increasing oyster harvesting regulations RE methods of collecting and number of sanctuaries
- Making living shorelines and other nature based features more cost-effective and attractive to the general public
- Public engagement and support and being honest and communicative about pros/cons
- Shallow water habitat management in the context of changing baselines
- Increase shell collection efforts and using this abundant resource for restoration projects

Appendix F: Poll Results Day 2

I work in the following sector(s):



What benefits of creating living shorelines with oysters are most important to you? (Choose 3)

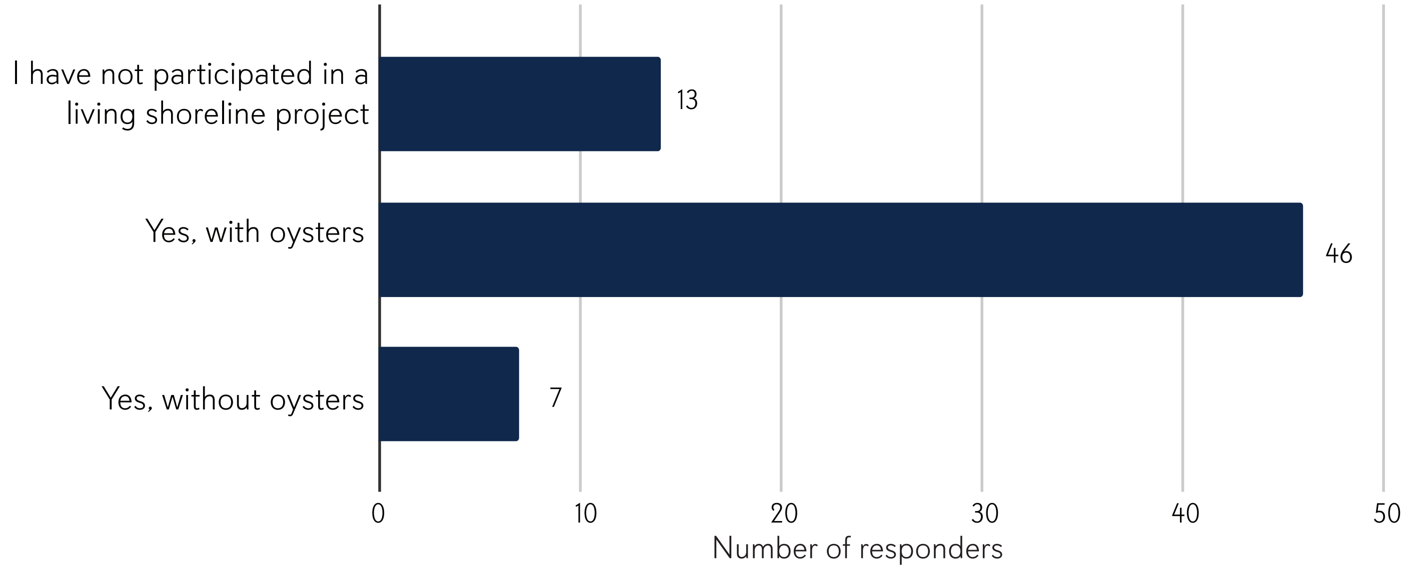


In the Other category, the following were listed:

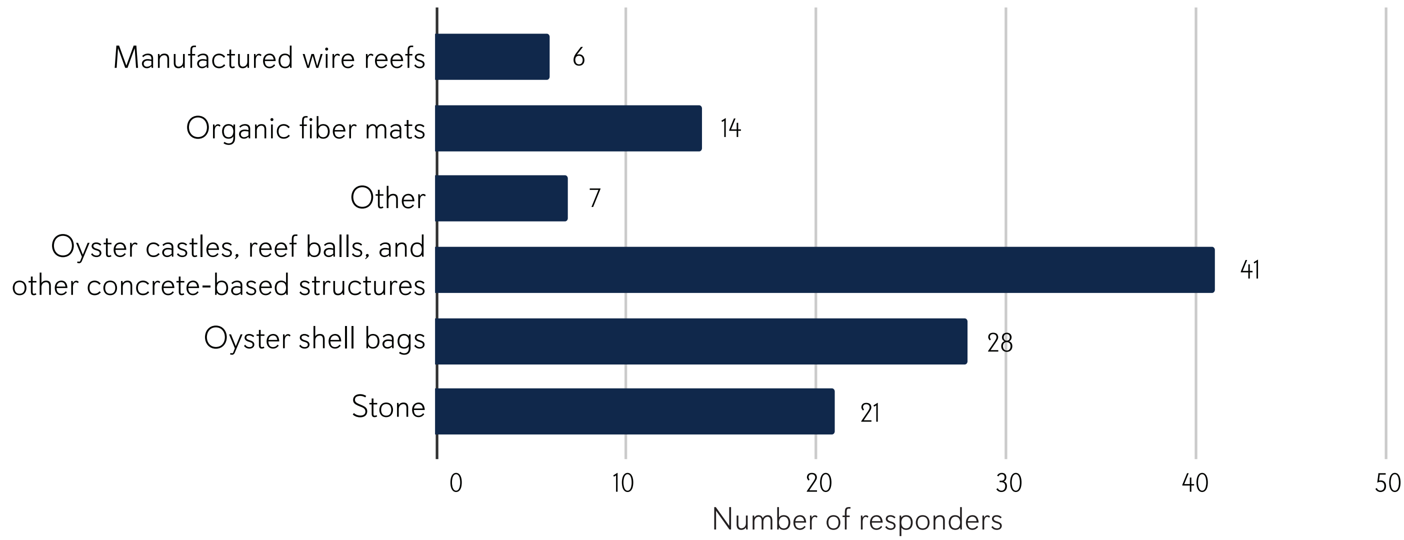
- Improved wave attenuation
- Habitat continuity
- Climate and coastal resilience
- Sediment capture
- Ensuring that structures allow for coastal access by other wildlife
- Shoreline stabilization and protection
- Facilitation of salt marsh communities
- Ecosystem services
- Increased living shorelines with oysters results in decreased riprap and bulkheads
- Adaptive solution

Appendix F: Poll Results Day 2

Have you ever participated in a living shoreline project, and if so, have you included oysters in the living shoreline?



If you have participated in a living shoreline project with oysters, what types of oyster focused substrates have you used?

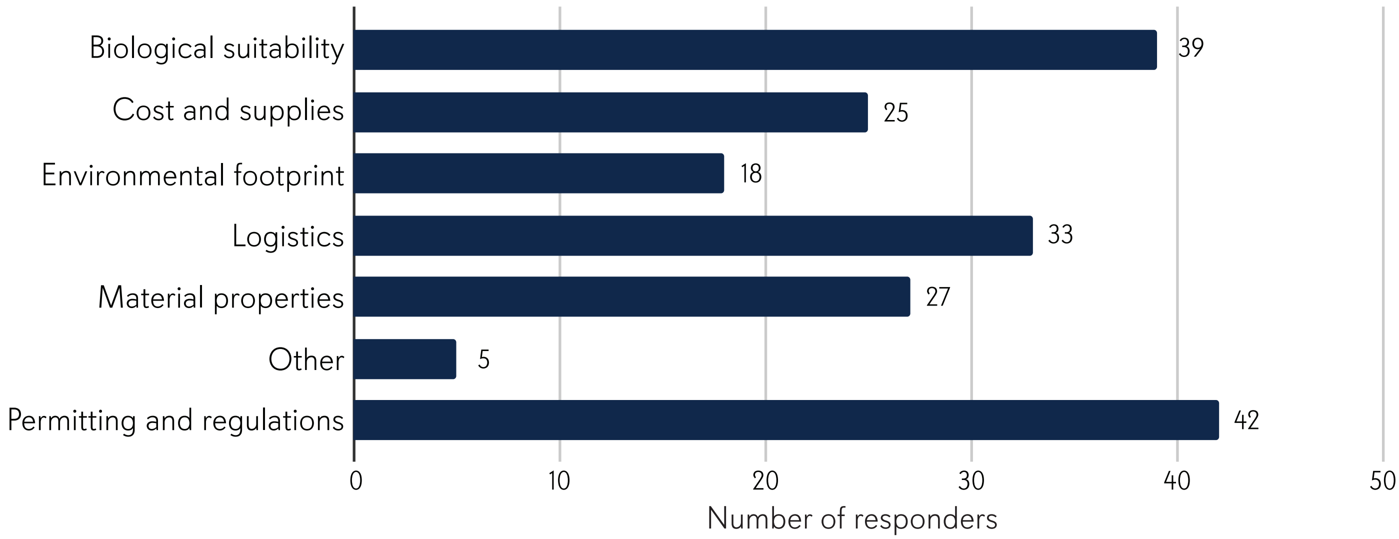


In the Other category, the following were listed:

- Oyster gardens
- Loose oyster shells
- Oyster catcher substrate from Sandbar Oyster Company
- QuickReef®
- Wave Attenuation Devices (WADs)
- Previous oyster shell habitats
- Bamboo (Non-native, cut, and coated with concrete)
- Oyster 'volcanoes' made of jute and cement

Appendix F: Poll Results Day 2

What aspects of retrofitting existing infrastructure for oysters require greater investigation?



In the Other category, the following were listed:

- Resilience of the shoreline over time
- Habitat suitability studies
- Potential effect of larval transport on retrofit reefs in close proximity to the bottom/ column leases
- The economic impacts on aquaculture
- The engineering analysis and design process
- Ecological trajectories and limitations
- True ecological uplift

Are there other Maryland-specific issues that need addressing?

- Hydrodynamics of oyster larvae
- Carbon sequestration
- Management of shallow water habitat acknowledging changing baseline for shallow water zones
- The mandated stone to vegetation ratio pushes project footprint channelward, impacting aquatic resources like SAV
- Riparian property owners should be expected to grade banks and align structures landward to minimize impacts to aquatic environments
- MDE and USACOE permitting
- Designed reef crest elevation to begin reefs
- Economic analysis to comprehensively and holistically analyze the cost/benefits including opportunity costs, without diminishing the benefits of oyster reef structures
- Addressing the native oyster species survival rates in cold/freezing temperatures and their struggle in low salinity waters
- Assessing the dangers and benefits of introducing species from other places that may overtake native species but can result in improvement of water quality