Symposium on Alternative Substrate for Oysters

Program Booklet

Virtual Symposium

Feb 26-28, 2024

Background

This **Symposium on Alternative Substrate for Oysters (SASSO)** 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 3: to evaluate alternative substrates used for oyster restoration, or repletion, in other regions. The focus of this year's symposium is on large areas and/or subtidal efforts with alternative substrates (i.e., anything other than fresh oyster shell). Next year, we will host a symposium on the use of alternative substrates in the near shore and the inclusion of oysters on existing grey infrastructure.

Symposium Sponsors

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

For questions regarding this symposium please contact Elizabeth North at **enorth@umces.edu** or Matthew Gray at **mgray@umces.edu.** For more information, please see the symposium webpage: **https://www.umces.edu/alternative-substrate-for-oysters**

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Scan here to access the symposium website

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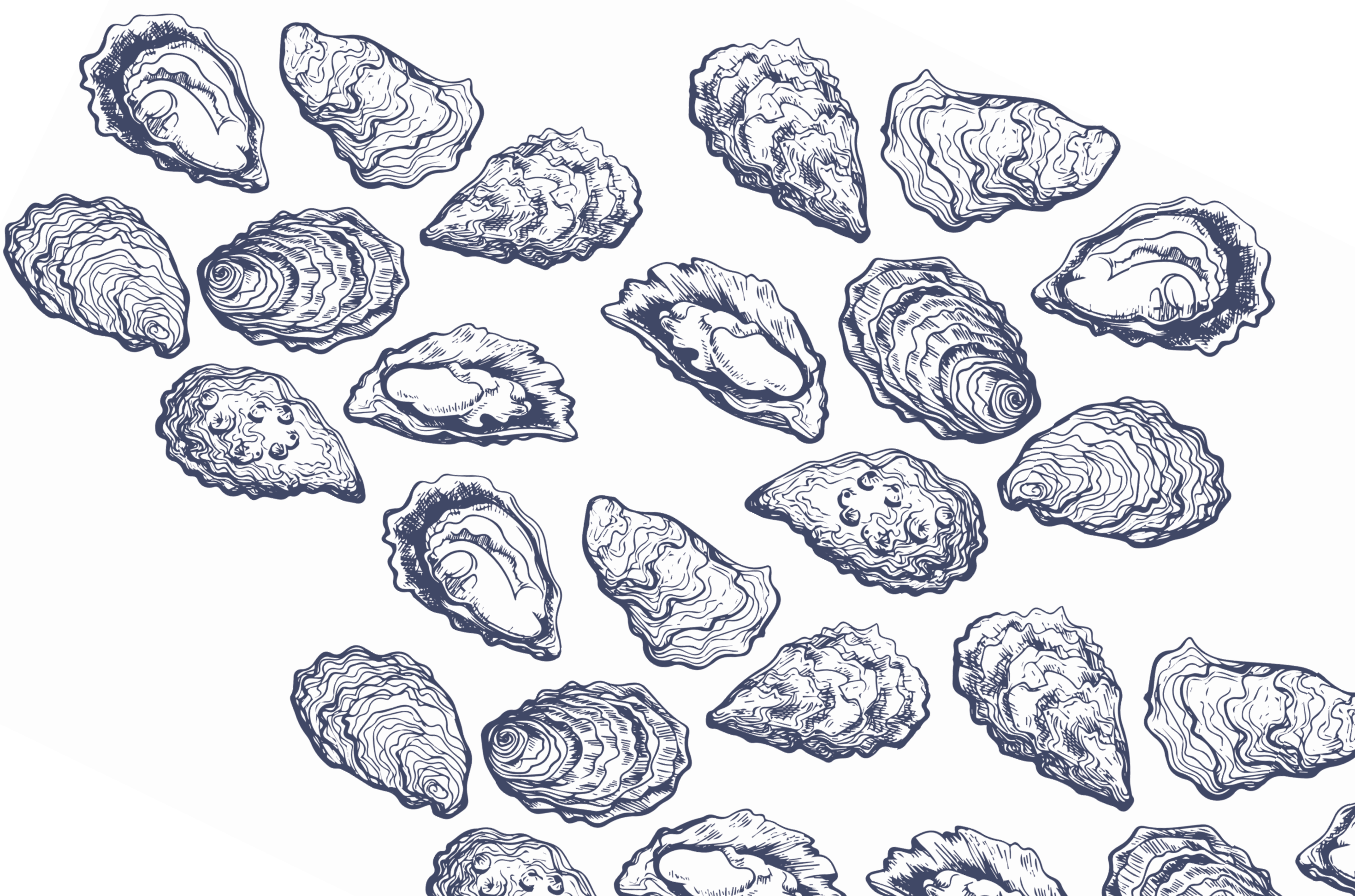


Schedule of Events and Logistics

Monday, Feb 26: Alternative Substrate for Use in Fisheries

10:00	Introduction
10:05	Sarah Elfreth, Maryland State Senator
10:15	Chris Judy, Maryland Department of Natural Resources
10:30	Andrew Button, Virginia Marine Resource Commission
10:45	Doug Munroe, North Carolina's Division of Marine Fisheries
11:00	William Rodney, Texas Parks and Wildlife
11:15	Sandra Brooke, Florida State University Coastal and Marine Lab
11:30	Kathy Sweezey, The Nature Conservancy
11:45	Matt Pluta, ShoreRivers
12:00	Speaker Q&A
12:30	Chat n' Chew Breakouts
01:00	Plenary Discussion
02:00	Adjourn

Tuesday, Feb 27: Alternative Substrate in Large-Scale Restoration

10:00	Introduction
10:05	Dr. Bill Dennison, UMCES Interim President
10:15	Stephanie Reynolds Westby, NOAA Restoration Center
10:30	Bennett Paradis, North Carolina Division of Marine Fisheries
10:45	Romuald Lipcius, Virginia Institute of Marine Science
11:00	Jay Lazar, NOAA Chesapeake Bay Office
11:15	Jennifer Zhu, Billion Oyster Project
11:30	David Schulte, US Army Corps of Engineers
11:45	Russell Burke, Christopher Newport University
12:00	Speaker Q&A
12:30	Chat n' Chew Breakouts
01:00	Plenary Discussion
02:00	Adjourn

Wednesday, Feb 28: Alternative Substrate- Aquaculture & New Technologies

10:00	Introduction
10:05	Josh Kurtz, Maryland Secretary of Natural Resources
10:15	H. Ward Slacum, Oyster Recovery Partnership
10:30	Steve Fleetwood, Bivalve Packing Company
10:45	Niels Lindquist, Sandbar Oyster Company Inc.
11:00	Christine Thompson, Stockton University
11:15	Mark Clark, University of Florida
11:30	Christopher J. Karwacki, C.J. Karwacki Consulting, LLC.
11:45	Hunter Mathews, University of North Florida
12:00	Speaker Q&A
12:30	Chat n' Chew Breakouts
01:00	Plenary Discussion
02:00	Adjourn

Symposium Logistics

To join the symposium: Follow this Zoom link
http://tinyurl.com/5h44vwjf
Passcode: 104153

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

To join a Chat n' Chew: Follow the link provided in the Zoom chat at lunchtime.

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.

Welcome Speakers

Senator Sarah Elfreth
Maryland State Senate

Sarah Elfreth is the youngest woman elected to the State Senate in Maryland history. Over the course of her first five years in office, she passed 84 bills into law on issues that actually impact Maryland families – protecting the Chesapeake Bay, strengthening the economy, expanding prenatal care, and helping veterans with PTSD. At the beginning of her second term, Sarah was appointed to an important leadership position in the Senate's budget committee, overseeing tens of billions of dollars of taxpayer investments in transportation, environmental, and public safety programs. As a member of the tri-state Chesapeake Bay Commission, she helps coordinate State and federal efforts to clean up the Bay. Sarah represents parts of the Broadneck Peninsula, the City of Annapolis, and southern Anne Arundel County.

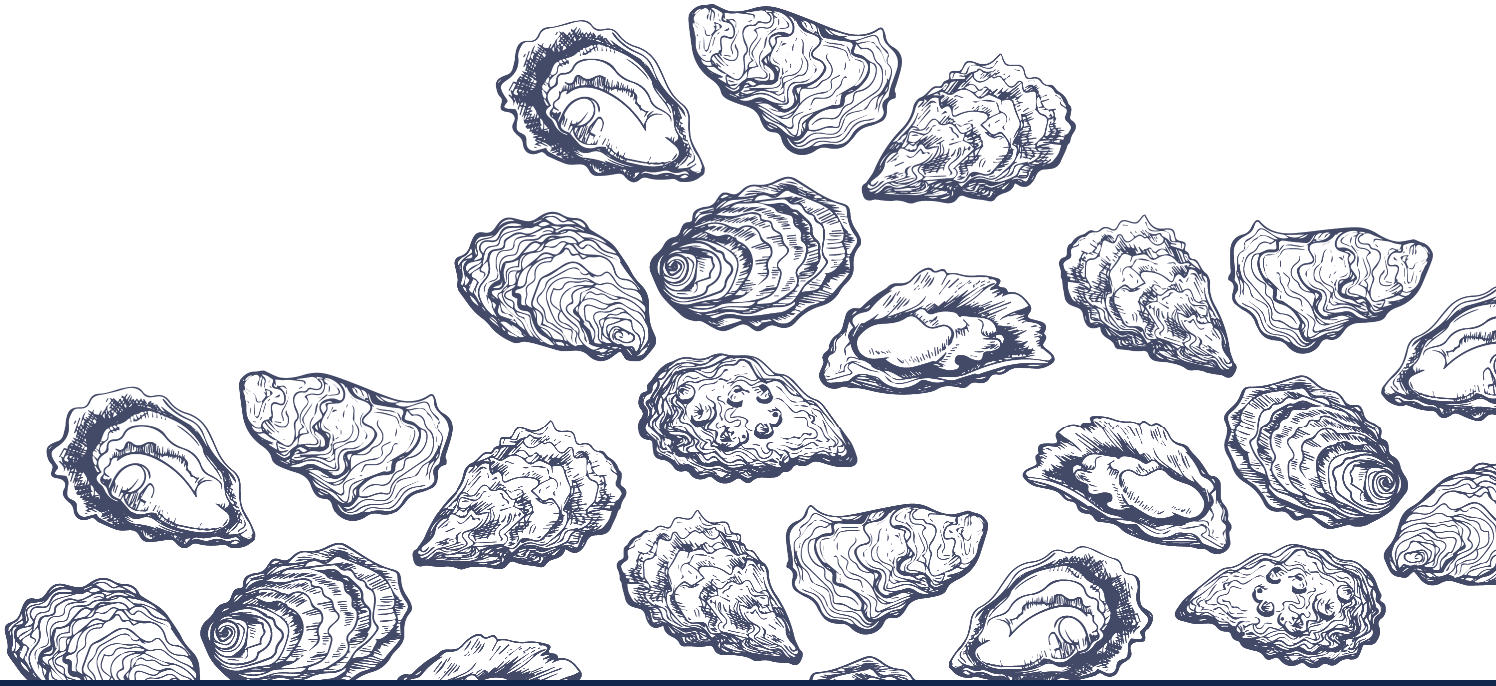
Bill Dennison
University of Maryland Center for Environmental Sciences (UMCES)

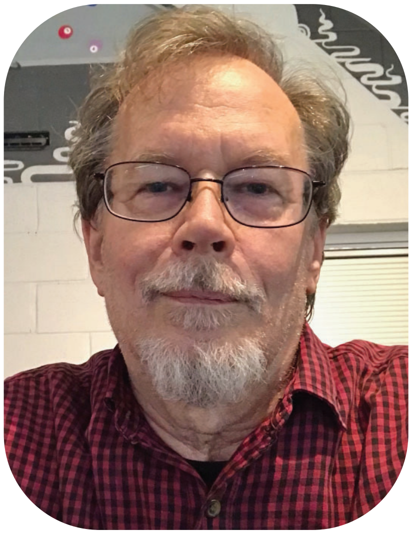
Bill Dennison is a Professor of Marine Science and Interim President for the University of Maryland Center for Environmental Science. Since 2003, he has served as Vice President for Science Application and led the Integration and Application Network (IAN), charged to inspire, manage and produce timely syntheses and assessments on key environmental issues with a special emphasis on Chesapeake Bay and its waters. He has published hundreds of papers and books on coastal ecosystem ecology and has presented at international, national, and regional meetings, and at various universities, research institutions, and government agencies.

Josh Kurtz
Maryland Department of Natural Resources

Under the Moore/Miller administration, Secretary Kurtz leads teams across the state, working to improve water quality and bay resilience, restore and conserve forested land, expand access to our state parks, monitor and slow the spread of invasive species, and ensure the state maintains sustainable fisheries.

Kurtz previously served as the Maryland executive director of the Chesapeake Bay Foundation, and has also served as policy and government relations director for The Nature Conservancy in Maryland where he created and led advocacy campaigns leveraging strong relationships with partners and industry leaders to build support for policies regarding conservation and climate change in both the Maryland General Assembly and the DC City Council.





Chris Judy
Director, Shellfish Division, Maryland Department of Natural Resources

Chris Judy is currently the Shellfish Division Director for MD DNR and has held this position for over 10 years. His experience includes oyster enhancement projects and management programs in both fishery and sanctuary areas. He helps coordinate many diverse groups that often have competing interests.

Andrew Button
Virginia Marine Resource Commission

Andrew Button is currently the Deputy Chief of the Shellfish Management Division and Head of the Conservation and Replenishment Department (CRD). He has been with VMRC since 2014. The CRD has been in the business of large-scale oyster restoration and replenishment since its inception in 1929. The Division maintains and monitors both harvest and sanctuary areas on more than 240,000 acres of public oyster ground in the waters of the Commonwealth, manages a leasing and aquaculture permitting program on more than 130,000 acres of private ground, develops harvest regulations on both public and private oyster grounds, and coordinates with or is directly involved in a multitude of oyster and shellfish focused activities with multiple governmental and non-governmental groups.

Doug Munroe
North Carolina Division of Marine Fisheries

Doug received his AS in Aquaculture from Carteret Community College and a BS in Biology from East Carolina University. He has worked at the NC Division of Marine Fisheries for two years, currently filling the Cultch Planting Biologist role in the Habitat and Enhancement section of DMF. Doug also enjoys wildlife photography and kayaking.

William Rodney
Texas Parks and Wildlife Department

Bill has a MS from the University of Maryland College Park in ecology as well as a BS in biology from University of Maryland College Park and a BS in journalism from West Virginia University. He has over 25 years of experience in marine science and natural resources management focused on ecological restoration and habitat assessment. In his 16 years at TPWD, Bill has been involved in several large-scale oyster restoration projects in Galveston Bay and Sabine Lake. He is currently the oyster habitat restoration specialist on the new Restoration and Artificial Reef Team (RART).

Stephanie Reynolds Westby
NOAA Restoration Center

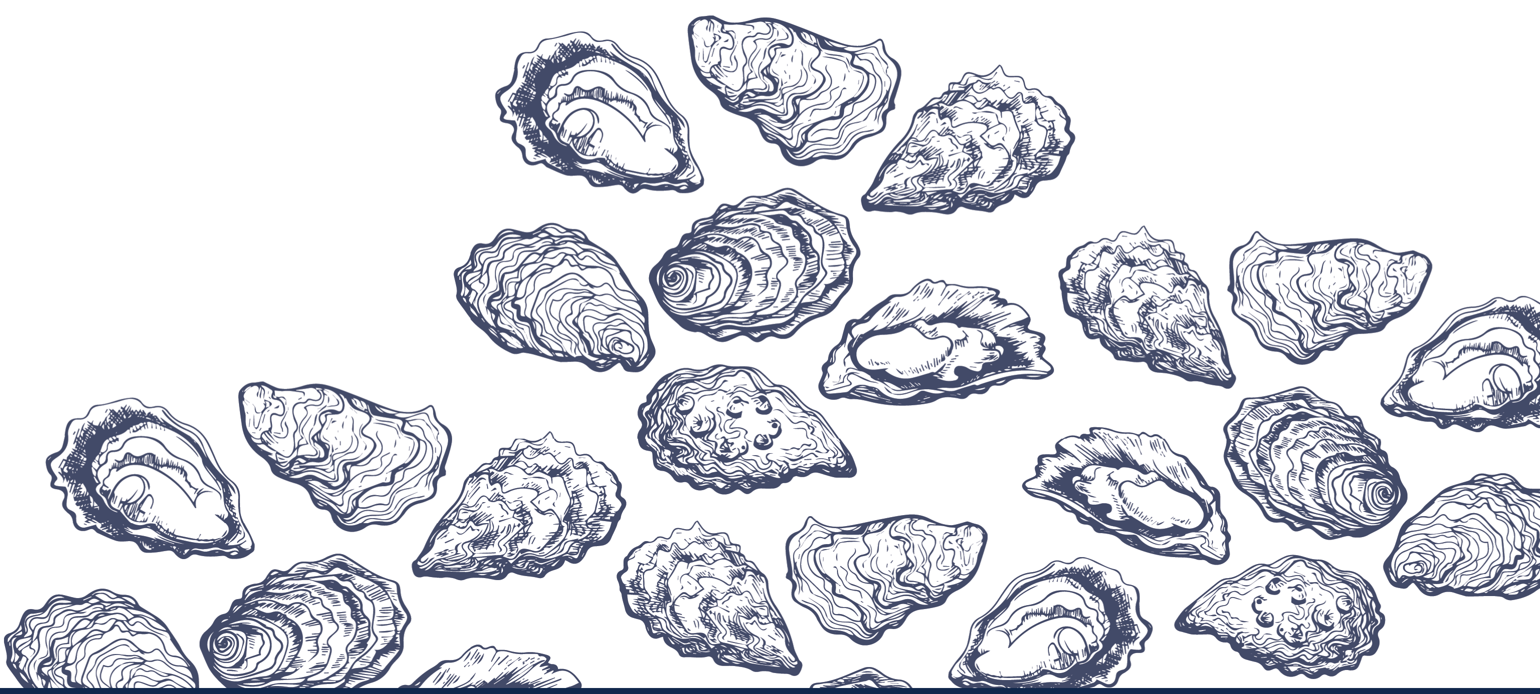
Stephanie Reynolds Westby directs NOAA's Chesapeake Bay oyster restoration program. She has also worked as a lobbyist and fisheries scientist for a regional nonprofit, and earlier as the captain of several educational vessels, both power and sail. She holds a master's degree in environmental science and policy from John Hopkins University, and a 100-ton master's license ('captain's license'). When not on the water, she paints and plays the ukulele (though not simultaneously).

Bennett Paradis
North Carolina Division of Marine Fisheries

Bennett has worked as North Carolina's Oyster Sanctuary Biologist for two years. He received his Bachelors in Biology at Boston University, and his Masters in Biology from Auburn University where he studied coral physiology. During COVID he worked as a Fisheries Observer in Alaska and briefly lived in Colorado before accepting his current position.

Romuald Lipcius
Virginia Institute of Marine Science

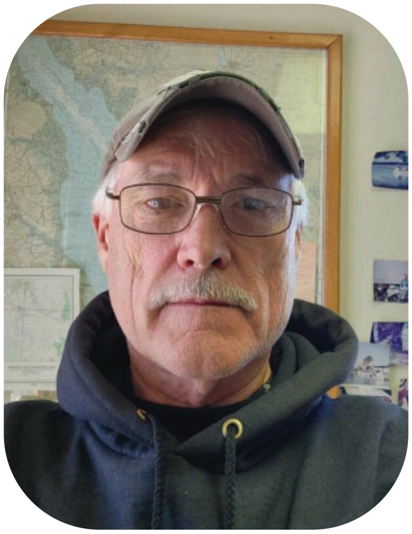
Rom Lipcius is a Professor of Maine Science at VIMS, William & Mary. Lipcius joined the VIMS/W&M faculty in 1986 after postdoctoral fellowships at the Smithsonian Institution and U.S. National Research Council and a Ph.D. degree from Florida State University. Scientific expertise includes Ecology, Conservation and Restoration of Crustaceans and Molluscs (blue crab, native oyster, spiny lobster, queen conch), Fisheries Management, Mathematical Biology, and Ecological Statistics, with emphasis on globally relevant solutions for major threats to marine ecosystems.



H. Ward Slacum

Oyster Recovery Partnership

Ward Slacum leads ORP's strategic growth initiatives to strengthen our region's blue economy and coastal communities through oyster restoration and sustainable fisheries initiatives. Ward has a proven record of producing results through stakeholder engagement, research, and innovation.



Steve Fleetwood

Bivalve Packing Company

Steve Fleetwood is the co-owner of Bivalve Packing Company. He is a grower, harvester, and shipper of Delaware Bay and Atlantic coast oysters and clams, both aquaculture and traditional fishery.

Sandra Brooke

Florida State University, Coastal and Marine Lab

Evaluation of materials for sub-tidal oyster reef restoration in Apalachicola Bay, Florida

In 2013 the Apalachicola Bay oyster fishery was declared a Federal Fishery Disaster, and several restoration projects were initiated to facilitate oyster population recovery. These projects maximized the restoration area by placing a thin layer of fossil shell or small (~5 cm) limestone rocks on the natural substrate. The construction goals of the projects were met, but oyster populations continued to decline. A few years after deployment, the fossil shell restoration material had deteriorated significantly and the only sub-tidal habitats that supported oysters were those restored with limestone. The Apalachicola Bay System Initiative (ABSI) is a five-year (2019-2024) multi-disciplinary project that includes research into restoration approaches for Apalachicola Bay oyster habitats, which are so degraded that the reefs have been reduced to compacted shell hash. Oysters recruiting to unstable substrate may be swept away, buried, or exposed to hypoxia, and without the structural complexity that provides refuge, oyster juveniles are exposed to predation. The ABSI conducted a series of experiments to evaluate different materials for stability and oyster population development. The first experiment tested shell, small limestone (~ 5cm), and larger limestone (~15 cm), which was intended to create habitat niches for predator refuge and reef community development. The reefs were constructed with ~0.5m relief and were surveyed twice annually using hand tongs. The larger limestone performed better than the other materials, so a second experiment compared limestone with cleaned, crushed construction concrete of similar size. Half of the reefs for each material had a layer of natural shell (~ 8 cm deep) to assess the cost-benefit of this approach. Preliminary results indicate similar performance among all treatments. Our presentation will discuss the positive and negative aspects of these approaches for large scale oyster restoration.

Russell Burke

Christopher Newport University

Large-Scale Implementation of Shallow Subtidal Alternative Substrate Reefs as Part of a Comprehensive Oyster Reef Mitigation Strategy in the Elizabeth River, VA, Chesapeake Bay

The Eastern Oyster (*Crassostrea virginica*) fulfills numerous essential ecological roles in marine ecosystems, including prevention of shoreline erosion, water filtration, and provision of habitat for many marine organisms. In response to ecological functions and services that might be lost resulting from the Craney Island Eastward Expansion (CIEE) Project in Southeast Virginia, the US Army Corps of Engineers, in support of the Virginia Port Authority's (VPA) port expansion project, was tasked with supervising construction and placement of oyster reefs (2013-14) as part of a comprehensive mitigation strategy. Seven oyster reefs (16.5 acres), composed of shell, granite and prefabricated concrete structures, were placed at five sites: the Lafayette River, the Elizabeth River's Western and Southern Branches, and the Lower James River (Hoffler Creek). As part of the Project Compensation Plan, the Virginia Department of Environmental Quality (VDEQ) mandated that each of these reefs be monitored and assessed for a period of five consecutive years (2015-2020) – Christopher Newport University (CNU) has overseen this program in collaboration with the Virginia Institute of Marine Science; CNU has continued monitoring the project since its implementation of an adaptive management strategy that included a number of alternative substrate reefs composed of concrete with oyster shell embedded in all outward-facing reef surfaces. By 2019, oyster density (50 oysters m^2) and biomass targets (50 g AFDM m^2) were exceeded across alternative substrates at all sites. In addition, CNU surveyed ~5 acres of granite breakwaters and revetments along the perimeter of Craney Island in 2022 which ultimately resulted in formal inclusion of this reef acreage within the official oyster reef compensation package. Most recently (January 2024), the CIEE project team received confirmation from the VDEQ that the oyster mitigation requirements for the associated permit had been fulfilled – a true testament to innovative project design, effective adaptive management, and inter-agency collaboration.

Mark Clark

University of Florida

Jute Reinforced Calcium Sulfoaluminate (JR-CSA)

Jute Reinforced Calcium Sulfoaluminate (JR-CSA) was developed in 2017 at the University of Florida and first deployed along Florida's central west coast in 2018. Initially developed as a plastic-free alternative to mesh shell bags and used as a low intertidal sill and wave break element of living shorelines, configuration now includes application as a high surface area substrate for oyster recruitment and habitat restoration on declining natural reefs. The material is a combination of readily available Jute erosion control mat and Calcium Sulfoaluminate (CSA) as either premixed Cement-All® (CTS Rapid Set®) or a tailored mix of CSA, sand, and water reducing additive. The CSA coated jute is then placed on a form for curing. Although the material can be arranged in almost any shape, the two principal shapes utilized are triangular prisms 30 cm x 120 cm and referred to as a "reef prism", or a corrugated panel 5 cm x 120 cm x 120 cm and referred to as a "reef panel". CSA was chosen over ordinary portland cement due to its rapid set times (20-30min), early curing strength and reduced carbon footprint. These characteristics facilitate a more efficient use of forms during production and the potential for rapid deployment. Another design objective of JR-CSA was a material where volunteers or a stakeholder labor force could readily participate in the construction process and deployment did not require specialized equipment. Since inception, the material has been deployed at over 15 sites throughout Florida and South Carolina. When compared to other substrates, JR-CSA performs very well for oyster spat colonization and growth. Depending on the CSA mix and deployment site water quality, JR-CSA can last between 18 months and at least 5 years with the original deployment site still seeing little or no degradation of the material.

Chris Karawacki

C.J. Karwacki Consulting, LLC

Biomimetic Nacre-Like Material For Recruitment And Growth Of Oyster Spat

Watermen and scientists have observed for many years the strong dependence of shell mass on oyster recruitment rate and abundance across several destabilizing factors, such as disease, natural mortality, and fishing. Today there is an urgent need for suitable alternative nacre like materials that can offset the decreasing supply of natural oyster shell used for the recruitment and growth of oyster larvae in the Chesapeake Bay and surrounding estuaries. Here we discuss an approach to develop a material that mimics the natural oyster shell's chemical composition, structure and cueing properties for the setting and growth of oyster larvae with the aim to maximize the recruitment and growth of oyster larvae throughout their life cycle. Natural oyster shell is formed by a biological-driven process involving sequencing of water-borne calcium and magnesium ions, carbonic acid, amino acids, and chitin to form a layered assembly of fortified crystalline calcium carbonate. During the transitional assembly of calcium hydroxide to amorphous calcium carbonate, calcium ions bind at oxygen centers on amino acids such as aspartic and glutamic acids to form ionic/covalent bonds that significantly strengthen the bulk structure compared to calcium carbonate alone. Amino acids in combination with magnesium ions influence the formation of specific forms of crystalline calcium carbonate (node), such as aragonite while retarding formation of calcite. Finally, chitin is synthesized in-situ and systematically excreted to form an encapsulated organic sheath (linker) across layers of crystalline calcium carbonate. Chemical binding with oxygen centers on the chitin to calcium ions further increases the strength of the bulk shell while providing a protective barrier.

Jay Lazar

National Oceanographic and Atmospheric Administration

Applying a Novel Oyster Reef Habitat Quality Monitoring Methodology in Harris Creek, MD

2021 marked the end of formal monitoring for the Harris Creek large-scale oyster restoration project, the first of five in MD. Challenges with comparing results across treatment types arose from using two sampling gears, patent tong and diver. A novel video based approach to score habitat quality with one gear type was created by the Smithsonian and applied across all reefs in Harris Creek during summer 2022. The study used a video based rapid assessment protocol to assess the impact of different restoration treatments on oyster reef habitat quality in Harris Creek. Sites included seed-only, mixed shell and variations of stone substrates within the sanctuary and harvest areas outside the sanctuary. We conducted field sampling to collect underwater GoPro photos at each site. We then assigned each site a qualitative habitat score from 0-3 based on oyster shell coverage and reef height (oysters growing vertically), with 3 indicating the highest quality habitat.

Of the 574 sites sampled over 8 days, 84% (484) were usable with an average of 20 samples collected an hour. Sites restored with stone treatments had the highest proportion of 3 scores (93%), followed by mixed shell (71%), seed only (62%), unrestored sanctuary sites (14%), and unrestored harvest sites (5%). These results suggest that there may be benefit to stone treatments for future oyster reef restoration efforts, as stone treatments may provide more surface area for larval recruitment and the interstices act as a sink to sediment, providing longevity to the available recruitment surface. Additionally, the rapid assessment protocol proved to be a viable alternative monitoring tool to understand sedimentation, observe and catalog reef evolution and potentially do so in a more efficient manner. Together, our study provides a clearer image of Harris Creek post-restoration and a method to compare the future condition of the restored tributary.

Niels Lindquist

Sandbar Oyster Company Inc

Use of Oyster Catcher™ Substrates for Facile Setting of Oyster Larvae and Relaying of Juvenile Oysters

The long-term success of oyster habitat restoration efforts is dependent upon reliable stocking via natural recruitment and/or seeding. With global climate change accelerating sea-level rise, salinity levels of many estuaries are increasing and thereby shifting areas conducive to sustainable subtidal reef development farther up estuaries (Tice-Lewis et al. 2022, Ecol Appl). While potentially opening vast areas previously devoid of reefs to reef development, these up-estuary shifts may incur recruitment limitation if estuarine waters replete with larvae aren't reliably transported to the sites. Additionally, these areas may be at high risk for prolonged freshets that could periodically cause mass oyster mortality and create the need to seed reefs located where levels of natural recruitment are low. For millennia, recruitment limitation has been overcome by seeding cultch and transporting spat-coated materials from areas of high oyster recruitment to areas of low recruitment. Oyster shell and stone materials have long been used for seeding and relay, but various features of these materials may limit their utility, including weight, relatively low surface area/volume ratios, bulk and handling logistics. Sandbar Oyster Company (hereafter SANDBAR) is pioneering the use of cement-infused plant cloth substrates having features and benefits ideal for facile seeding and relay of vast numbers of juvenile oysters. These proprietary, patent-pending substrates are trade named Oyster Catcher™. The "Tuft" form of Oyster Catcher™, which is shaped like a three-dimensional pretzel, is light-weight, has a very high surface area/volume ratio, is easily handled and degradable. The latter feature allows spat-covered Tufts to break apart and detached oysters to disperse thereby lowering mortality associated with tightly clustered oysters. This presentation introduces SANDBAR's use of Tufts seeded with wild spat to source juvenile oysters into oyster restoration projects (e.g. New River Estuary Oyster Highway) and aquaculture. Tufts have also been successfully seeded in a hatchery setting.

Rom Lipcius

Virginia Institute of Marine Science

Ecosystem-based planning, implementation and success of subtidal, granite oyster reefs in the Piankatank River, VA, Chesapeake Bay

Although oyster restoration practitioners have adopted alternative reef substrates for projects in subtidal waters, a comprehensive strategy for this approach has not been fully developed. As part of the Chesapeake Bay Native Oyster Recovery Project, the USACE constructed a large subtidal granite reef in the Piankatank River (PR) of lower Chesapeake Bay. We describe a restoration strategy implemented in the PR, which included (i) hydrodynamic modeling of metapopulation connectivity, (ii) field validation of connectivity, (iii) habitat suitability modeling, (iv) high-resolution benthic habitat mapping, (v) historical data on oyster distribution, (vi) reef geometry proven to be successful, and (vii) surveys of oyster and mussel abundance on the reefs to examine restoration reef performance. Based on the hydrodynamic model, mid- to down-river reaches could support a source metapopulation that self-sustains and exports larvae to sink habitats farther downriver and outside the mouth. Upriver segments would not receive larvae despite availability of suitable habitat, which was validated by field surveys. Two years after construction, the reef network harbored a dense population of age-0 juveniles and age-1 adults. Adult oyster density averaged 219.3 per square meter and biomass 75.3 g dry weight per square meter. Mean live mussel density was also high at 194.5 per square meter. Mean live oyster volume was 3.2 L per square meter and consistent with a positive shell budget, even though it was an underestimate because it did not include the volume of underlying reef base of oxic dead shell normally aggregated with live oyster shell volume. ROV video corroborated high species diversity from lab samples, which included shrimp, fish, crabs, clams, snails, mussels and sponges. Several predatory fish species were on the reef, while crustaceans, including blue crabs, mud crabs and shrimp, were walking and feeding on the reef surface, indicating a successfully restored oyster reef community.

Hunter Mathews

University of North Florida

Early performance of the Pervious Oyster Shell Habitat (POSH) in restoring intertidal habitat for oysters and associated nekton along energetic shorelines in northeast Florida

The "Pervious Oyster Shell Habitat" (POSH) is a novel artificial reef structure designed to minimize pollution and provide quality oyster habitat in high-energy systems. The POSH is composed of oyster shell bound by a thin layer of Portland cement, into a dome. POSH modules were compared in-situ to the industry standard "Oyster Ball" model Reef Ball™ for oyster recruitment and utilization by fish and crustaceans. The study took place from June 2021 to June 2023, along two energetic shorelines in northeast Florida: Kingsley Plantation along the Fort George River (Duval County) and Wrights Landing along the Tolomato River (St. Johns County). Oyster demographics and densities were assessed on the structures throughout the first year of deployment. Nekton densities and communities were assessed throughout the second year, using $2m^2$ bottomless lift nets. Artificial reefs were compared to an adjacent oyster reef at Kingsley Plantation. Oyster recruitment was significantly greater on the POSH compared to the Oyster Balls at both Kingsley Plantation ($p < 0.000$) and Wrights Landing ($p < 0.01$). Fish densities did not differ among treatments at either site ($p > 0.05$). At Kingsley Plantation, crustacean densities were significantly greater on the natural oyster reef than both artificial reef structures ($p < 0.01$), excluding with the Oyster Ball in winter ($p = 0.263$). Densities were significantly greater on the POSH than the Oyster Ball during summer ($p < 0.001$), fall ($p < 0.001$), and spring ($p < 0.0001$), and greater on the Oyster Ball in winter ($p < 0.05$). At Wrights Landing, crustacean densities were greater on the POSH in summer ($p < 0.0001$) and spring ($p < 0.05$). Fish and crustacean diversity metrics were similar among treatments at both sites. Early findings for the POSH indicate that it can be a viable method for rapidly restoring oyster reef communities in high-energy systems.

Doug Munroe

North Carolina Division of Marine Fisheries

North Carolina's Use of Alternative Substrate for Cultch Planting in Support of Oyster Rehabilitation Strategy

North Carolina has been utilizing various materials to construct low-relief (< 1') oyster cultch reefs since 1915. These efforts are designed to support the state's oyster restoration program. Cultch sites provide a suitable substrate for larval oysters to settle and develop on in North Carolina's estuarine waters. Due to limited availability of oyster shell, the Cultch Planting Program has adapted the use of alternative material types. Shell only accounts for 10-20% of total materials deployed on cultch sites constructed since 2018, while materials such as limestone marl and crushed concrete, which are more readily available, have taken the place of oyster shell in the construction of cultch reefs. North Carolina constructs 40-50 acres of cultch reefs annually, which are opened to commercial harvest, once the oysters on the reefs have grown to harvestable size. Cultch sites support valuable biological and ecological functions, are designed to help reduce overall fishing pressure on natural oyster reefs and create additional opportunities for commercial fishermen to harvest oysters.

Bennett Paradis

North Carolina Division of Marine Fisheries

North Carolina's Oyster Sanctuary Program: Restoring Pamlico Sound's Subtidal Oysters with Artificial Reefs

Beginning in 1996, North Carolina's Division of Marine Fisheries has been investing in the construction and monitoring of no-take oyster sanctuaries with the intention of subsidizing larval availability in Pamlico Sound. In total, 17 large scale artificial reefs covering 566 acres of protected habitat have been built by deploying 223,640 tons of various materials. While most of these sanctuaries were built with marl limestone rip-rap, other materials have also been used including reef balls, granite, basalt, crushed concrete, recycled concrete pipe, and a variety of recycled shells. Annual monitoring of the sanctuaries provides high resolution data into the performance of each site in terms of oyster density and population structure. The long-term dataset has given managers and biologists valuable insight for comparing materials, salinity regimes, and reef design across time, guiding future large scale oyster restoration projects.

Matt Pluta

ShoreRivers

Natural recruitment to alternative substrates in the Tred Avon River: a pilot study

Oyster shell represents a critical resource for restoration, aquaculture, and fisheries in the Chesapeake Bay. The exploration of alternative substrates, as substitutes for natural oyster shells, to capture spat and facilitate recruitment is gaining significant attention. While numerous potential alternative substrates exist, only a limited number have undergone testing in field conditions during natural spat fall events. In our study, we deployed replicate platforms, each hosting 12 different substrates, including oyster shell, clam shell, and various building materials such as brick, granite slabs, ceramic tile, etc., that have been suggested for potential large-scale use. These platforms were strategically placed in three distinct sites within Tred Avon River during the summer of 2021, coinciding with a notably favorable year for oyster recruitment in the Maryland portion of the Bay. At the end of the study, eight of nine platforms were retrieved, gently cleaned, and photographs of each substrate were meticulously taken. Utilizing image analysis, we recorded oyster recruits across the different substrates. Oyster spat exhibited a higher affinity for oyster shells, with clam shells following closely. Conversely, the remaining tested materials did perform nearly as well in attracting oyster spat. The study demonstrated a preference for shell but we also noted many oysters recruited to the underside of the plastic platform supporting the tested materials on the surface. These and other study details will be discussed.

William Rodney

Texas Parks and Wildlife Department

A Summary of TPWD Oyster Restoration Activities Utilizing Alternative Cultch Materials

Since 2007, Texas Parks and Wildlife Department's (TPWD) Coastal Fisheries Division has been actively working to restore oyster reefs for the purpose of enhancing the oyster fishery as well as the ecosystem services that these critical habitats provide. These efforts began in 2007 when TPWD received an appropriation from Congress in response to impacts from hurricanes Katrina and Rita. As of 2023, $16 million has been spent and more than 600 acres of oyster habitat has been restored through cultch planting. About 95% of TPWD's restoration efforts were completed in commercially harvestable waters and thus directly benefitted the commercial oyster industry. The remaining 5% was placed in waters that are closed to commercial harvest, and thus provided enhanced ecosystem services. Over the years, a variety of substrate types and design approaches have been successfully employed. Substrates have included river rock, recycled crushed concrete, and crushed limestone of various sizes. Designs have featured flat layers with low vertical relief and mounds with moderate vertical relief. Decisions on cultch types and design approaches were informed by restoration goals. Several projects utilizing different cultch types and designs are discussed.

David Schulte

US Army Corps of Engineers

Lynnhaven River, VA results of large-scale reef ball-based oyster restoration

In 2021, a large network of reef balls (28,500), each 0.4572 m (1.5 ft) wide and 0.3048 m (1.0 ft) tall covering 8.0 acres of subtidal, sand/clay/silt mix bottom in the polyhaline waters of the Lynnhaven River, VA, the most southeastern tributary river of Chesapeake Bay. The site selected was determined by both historical documentation as well as modern-day hydrodynamic modeling to be a good site for reef construction. Monitoring results have demonstrated the reef ball system, despite its young age, already is well in exceedance of Chesapeake Bay Program goals for oyster density and biomass, and exceeds the more ambitious goals of the Lynnhaven River Ecosystem Restoration Plan written by the USACE. At present, the three-dimensional reefs have a mean of 1137.6 ± 94.99 SE g/m^2 DM oyster tissue, 4,275.1 live oysters/m^2/river bottom area, consisting of 2,884.3 ± 240.23 SE spat and 1390.8 ± 104.85 SE adults. Live shell volume was also exceptionally high at 40.1 ± 2.80 SE l/m^2/river bottom area. The largest oysters observed on the reef balls were over 150 mm in shell height. These results suggest that oyster restoration using alternative materials in subtidal, polyhaline waters of Chesapeake Bay can produce exceptionally good results, and suggests that such alternative material based efforts can greatly assist in oyster restoration efforts in Chesapeake Bay.

H. Ward Slacum Jr.

Oyster Recovery Partnership

Advancing alternatives to shell for oyster production

Natural oyster reefs depend on shell accretion for long-term growth and survival, and their restoration is dependent on the availability of oyster shell as substrate for successful recruitment. In most coastal environments, shell loss has been accelerated by fishing activities and increased sediment deposition. To account for this, management agencies encourage initiatives to expand oyster production through aquaculture, public fishery management activities, and oyster restoration. This three-pronged management approach has increased the demand for shell, and availability is insufficient to meet demand. There are several ongoing initiates underway in Maryland to identify alternatives and alleviate the demand for native shell resources.

Kathy Sweezey

The Nature Conservancy

A Discussion on the Challenges of using Alternative Substrate: A Project Manager's Perspective

Despite the many benefits they provide, oyster reefs are one of the most imperiled marine habitats on earth. Globally, over 85% of oyster reefs have disappeared. Oyster populations in Texas are at a historic low, emphasizing the need for oyster reef restoration and protection efforts.

Restoration practitioners face many challenges including the increasing cost of commonly used "traditional" substrate like shell or limestone, limited availability of traditional substrate near project locations, and increased emissions to transport and deploy substrate for the project. Alternative substrate provides an opportunity to address each of these challenges and potentially leads to additional benefits and a more effective way to reach project goals.

Beezley Reef is a 40-acre subtidal oyster reef restored by The Nature Conservancy in Galveston Bay, Texas. This reef has a unique design as a hybrid part harvestable, part sanctuary reef complex. During the second phase of this project which focused on expanding the sanctuary reef by two acres, project managers emphasized the desired preference for alternative substrate with the engineer and in bid documents. However, the low number of bids returned, the cost of the alternative substrate bid obtained, and the limitation of alternative substrate that could be used on a subtidal reef all led to the decision to restore the reef using traditional substrate, limestone. Project managers met with multiple alternative substrate providers during the design phase to discuss Beezley Reef, assess feasibility, and gauge interest. Unfortunately, the providers met with were either unable to support a subtidal oyster reef or did not bid on this project.

For discussion, project managers ask: How do other practitioners seek alternative substrate providers? What alternative substrates are available for subtidal oyster reef restoration? How can restoration practitioners and alternative substrate providers enhance collaboration to best reach the project goals within limited budgets?

Christine Thompson

Stockton University

Optimizing remote setting on different cultch types for oyster restoration in Barnegat Bay, NJ

Restoration efforts for the eastern oyster, *Crassostrea virginica*, are often limited by sources and availability of cultch for remote setting. In Southern New Jersey, a shell recycling program has been created to provide shell for restoration purposes, but the types and availability of shell can vary. Additionally, the growth of oysters on these shell types once planted may affect restoration success if set ratios are too high or low. This study evaluated the average settlement of eyed oyster larvae in circular setting tanks with mixtures of three shell types: eastern oyster (*C. virginica*), surf clam (*Spisula solidissima*) and knobbed whelk shell (*Busycon carica*). Spat settlement was assessed prior to deployment on the subtidal reef site and again four months post-planting. Initial settlement numbers (no. oysters per shell) significantly differed between each shell type and were highest for surf clam shell and lowest for whelk shell ($p<0.001$). During post-planting monitoring, oysters and surf clam shell had the largest oysters but also had the highest mortality. This study is important for optimizing aquaculture techniques for both large and small-scale remote setting that can be restricted by both the availability of shell types and permitting requirements prohibiting certain substrates in shallow-water bays.

Jennifer Zhu

Billion Oyster Project

Innovative Approaches in Oyster Restoration: Exploring Alternative Materials and Substrates in the New York Harbor

With a growing focus on microplastics and individual and collective carbon footprints, many restoration practitioners and innovative suppliers are actively exploring alternative materials for application in marine restoration projects. Billion Oyster Project is enthusiastic about ongoing research and collaboration with industry professionals to understand how these materials can enhance oyster restoration efforts throughout New York Harbor. This presentation highlights the alternative materials and substrates that have been applied to oyster restoration projects since 2016.

Materials such as coir, burlap, and biodegradable mesh offer an eco-friendly alternative to the conventional plastic mesh bags used in bagged shell reef oyster restoration. However, their biodegradability often occurs at a pace that exceeds the time required for an oyster reef to develop. Burlap bags have degraded before oysters could cement to each other and form reefs. Some biodegradable meshes may also still leach microplastic material faster than traditional nylon bags. Further research is needed to understand how long biodegradable bags take to break down in marine environments and provide insight into their applicability across restoration projects and community engagement and education programs.

Alternative substrates seeded with oysters, such as reef balls and ECOncrete® disks are widely applicable restoration techniques with longer lifespans to sufficiently support the establishment of oyster populations at restoration sites. Cement is a primary ingredient in these concrete structures, which extends the lifetime of the structure but is more carbon-heavy. This can be offset through the addition of aggregates, such as rocks or shells, to the mixture. Structures such as piling wraps to attract wild oysters to settle on bulkheads have shown short-term success in the harbor, but are challenging to install and maintain. In New York Harbor, these types of applications are better suited for habitat enhancement than habitat creation. Hard substrate such as reef balls provide more surface area on which oysters can grow, and are easier to monitor, making them more optimal for use in oyster restoration projects.