Chesapeake Community Research Symposium 2026

Session 21: General: Estuarine and Watershed Processes and Coupled Human-Natural Systems in Chesapeake Bay

Session Leads: Raleigh Hood, DG Webster, Patrick Bitterman, Victoria Coles, Peter Claggett, Sevgi Erdogan, Theodore Lim

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Balancing Interests: improved understanding of shellfish aquaculture production and submerged aquatic vegetation through studies and synthesis

The continued expansion of oyster aquaculture is widely recognized as a key strategy for supporting coastal economies, enhancing local seafood production, and reducing pressure on wild fisheries. At the same time, aquaculture development in shallow estuarine systems often overlaps spatially with submerged aquatic vegetation (SAV), a foundational habitat that supports biodiversity, stabilizes sediments, and regulates nutrient and carbon cycling. Balancing the desire to expand aquaculture while protecting SAV remains a central management challenge in many coastal regions, including Maryland's Chesapeake Bay.

To inform this balance, we conducted a multi-year study examining ecological interactions between surface oyster culture and SAV within and adjacent to an active aquaculture lease in the Choptank River. From 2023 to 2025, we combined repeated field surveys of SAV abundance and species composition with high-frequency environmental monitoring across aquaculture, reference, and natural SAV areas. Light availability was quantified using underwater sensors deployed beneath oyster gear, in non-gear areas, and within SAV beds to assess shading and light attenuation. Sediment cores were analyzed for grain size, organic matter content, and the short-lived radionuclide ^{7}Be to evaluate sediment deposition and disturbance dynamics. Select sites were also used for biogeochemical incubations to characterize benthic processes at lower temporal resolution.

During this case study, we found little evidence of oyster production harming SAV growth. This and other recent studies suggest aquaculture impacts to SAV are likley to be site-specific and variable. Rather than treating aquaculture impacts as binary, this study helps identify the conditions under which surface oyster culture coexists with SAV, as well as the limits beyond which measurable impacts may emerge. By resolving these thresholds, our results contribute to a more nuanced framework for managing aquaculture expansion while safeguarding essential SAV habitat, supporting evidence-based permitting and sustainable coastal development.

Gulnihal Ozbay (Delaware State University)

Assessing Interactions Between Shellfish and Seagrass Beds and Macroalgae to Promote Sustainable Aquaculture in the Delaware Inland Bays

Seagrass is an important keystone species in the Delaware Inland Bays. Seagrass helps to maintain populations of fish and invertebrate species by providing permanent habitat, feeding areas for various life stages, nursery areas for successful development of juveniles, and protection from predators. Seagrass also plays a fundamental role in mitigating climate change through its potential for carbon sequestration and mitigation of ocean acidification. Due to its high importance in coastal environments, understanding the interactions between shellfish and seagrass productivity can be a determinant of aquatic environment health and can promote sustainable aquaculture. An in-depth literature review was conducted to identify the interactions between shellfish and seagrass beds and macroalgae to determine the impact these two factors have on aquaculture practices. As a complementary method, underwater cameras were deployed during the months of June to October for real-time monitoring of oyster reefs and aquaculture sites to get a visualization of vegetation and species diversity at oyster locations. Through these combined efforts, it was identified that seagrass has a beneficial impact on oyster productivity and can help promote sustainable aquaculture. Based on the assessment, seagrass does seem to be more present at small oyster reefs and shellfish aquaculture farms.

Elka T. Porter (St. Mary's College of Maryland), Lawrence P. Sanford, Jeffrey C. Cornwell

Denitrification in the STURM Resuspension Mesocosms, Part 1: Particle Dynamics

Though denitrification primarily occurs in the upper layers of bottom sediments, recent studies have indicated denitrification can also occur in suspended sediments under appropriate conditions. We report here on a mesocosm experiment examining both particle dynamics and denitrification in the water column. A 29-day experiment with tidal resuspension cycling (days 1-22) and no resuspension cycling (days 23-29) was carried out using six STURM (Shear TUrbulence Resuspension Mesocosm) tanks, three receiving regular additions of oyster biodeposits and three receiving no biodeposits. A Laser In Situ Scattering and Transmissometry (LISST 200X) instrument measured particle sizes and volume concentrations during resuspension, non-resuspension, and settling phases. Measurements of turbidity, temperature, and dissolved oxygen were also collected, along with suspended sediment samples for mass concentration and composition, and measurements of whole system denitrification. This paper focuses on the observed particle dynamics and characteristics, deferring denitrification dynamics for a later report. Our preliminary results show that smaller particles were both denser and more organic than larger, more inorganic resuspended flocs. The larger particles appeared to dominate resuspension and deposition cycling, while smaller, highly organic particles remained in suspension longer. Nevertheless, flocculation processes were ubiquitous and

resulted in fractal particle behavior involving all particle types. Particulate organic carbon content was an important factor in suspended particle dynamics, which may explain observed influences of biodeposit additions.

Amy Hamilton (MD Dept of Natural Resources), Catherine Wazniak

Hidden Neurotoxins in Cyanobacterial Harmful Algal Mats in Maryland

Presence of cyanobacterial Harmful Algal Mats (cyanoHAMs) have been increasing in many regions around the U.S. and internationally. Detection of microcystin in benthic mats was first noted in Maryland in 2017 and 2019 associated with Oscillatoria mats. Freshwater saxitoxins have recently been detected in cyanoHAMs dominated by Microseira (formerly Lyngbya) wollei. Saxitoxins were detected by ELISA method in Maryland lakes (<1-192 μg/g saxitoxin equivalents), streams (EPA Region 3 project; toxin data not completed yet), Chesapeake Bay tributaries (Potomac 48 μg/g, Mattawoman Creek, 3.48 μg/g and North East River 0.21 μg/g) and in the Susquehanna Flats region of the upper Chesapeake Bay (0.03-81.22 μg/g saxitoxin). Limited samples were analyzed for saxitoxin using both ELISA and LCMS/MS. ELISA method significantly underestimated freshwater saxitoxin concentration due to cross reactivity. Detected levels are similar to those observed in other areas (CA, SC, Great Lakes, NZ, and Canada). Anatoxin has also been documented in cyanoHAMs dominated by Microcoleus/ Phormidium. Anatoxin, homo-Anatoxin, and dihydro-Anatoxin have all been detected in Maryland. Anatoxin was detected in the non-tidal Potomac River (0.12- >1000 ppb, ELISA) and 6 State-owned lakes (0.048-103.44 ppb, LCMS/MS). Cylindrospermopsin has not been detected in over 250 samples tested from 2021-2024. Impacts to biota and downstream transport of toxins are concerning to managers as extensive detached toxigenic benthic mats have been observed downstream. Currently, toxins associated with mats have not been detected at significant concentrations in associated water samples. Maryland does not currently post waterbody advisories based on cyanoHAMs cyanotoxins, but has issued several pet health advisories due to anatoxin detection in mat samples.

Qubin Qin (East Carolina University), Xun Cai, Jian Shen, and Lewis Linker

Quantifying Inter-Tributary Freshwater Connectivity and Its Implications for Flushing Time in Chesapeake Bay

Riverine freshwater regulates estuarine circulation, stratification, and material transport, yet large estuaries operate as connected networks in which tributary waters redistribute across the system. Using a calibrated three-dimensional hydrodynamic model of Chesapeake Bay with source-resolving passive tracers, we quantify inter-tributary freshwater connectivity and evaluate how connectivity alters the physical interpretation of salinity-based flushing time. Connectivity is described with two complementary metrics: (1) a Percentage Metric that maps the system-wide footprint of freshwater from a supplying tributary, and (2) a Contribution Metric that quantifies the influence of that source on water composition in receiving tributaries. Most freshwater is retained within its source tributary and the main stem, while inter-tributary exchange is generally low but non-negligible (<0.01%–6.39%). Despite small exchanged fractions, externally sourced freshwater can contribute substantially to water composition in some receiving tributaries (up to ~50%). The Contribution Metric scales strongly with river discharge, whereas the Percentage Metric depends more on tributary volume and location. Intrusion lengths of freshwater constituents track salinity intrusion, consistent with shared pathways set by estuarine circulation and mixing.

Building on these diagnostics, we show that under strong inter-tributary connectivity, the freshwater volume inferred from salinity can integrate multiple source waters with distinct pathways, while the inflow term in classical formulations represents only local discharge. This source–flux inconsistency can bias interpretation of flushing time and, by extension, perceived vulnerability to watershed inputs and water-quality impairment. By separating locally sourced from externally sourced freshwater and enforcing source–flux consistency, we derive connectivity-adjusted flushing times that reconcile salinity-based estimates with tracer-derived renewal scales. The resulting metrics provide a practical, transferable basis for identifying tributaries whose water composition and renewal are strongly influenced by cross-system redistribution, improving interpretation of monitoring data and supporting scenario analyses of high-flow events and management actions.

Kehinde Bosikun (University of Maryland, Baltimore County (UMBC)), Joel Moore and Claire Welty

Quantifying urban versus natural contributions to stream chemistry in a Chesapeake Bay tributary using reactive transport modeling

Chemical weathering of minerals in the critical zone regulates biogeochemical processes, delivers solutes to streams, and helps control long-term soil and water quality in the Chesapeake Bay watershed. In urbanized tributaries, this process is increasingly perturbed by road salt, infrastructure weathering, and altered hydrology, with implications for management of salinization, alkalinization, and corrosion in the Bay system. We use the reactive transport code PFLOTRAN to investigate how coupled mineral and infrastructure weathering (pipes), together with urban solute inputs, impact subsurface and stream chemistry in the Dead Run watershed, a suburban Baltimore catchment that drains to Baltimore Harbor and ultimately to the Chesapeake Bay. Our modeling approach first simulates long-term profile evolution in one-dimension for 500,000 years to characterize baseline mineral thermodynamics and reaction kinetics that control natural solute release. To evaluate urbanization impacts within a management-relevant horizon, we apply these results to contemporary urban conditions by running 100-year simulations that incorporate elevated chemical inputs from road salt application and infrastructure weathering, as well as altered hydrology from impervious surfaces. To assess urbanization effects within a management-relevant timeframe, we then take the final mineral assemblage from the long-term simulation as an initial condition and run 100-year scenarios representing elevated concentrations of urban-associated solutes from road salt application and contributions from infrastructure weathering, alongside hydrologic changes associated with impervious surface effects on infiltration. Model outputs approximate aqueous chemistry at the base of weathering profiles and are used to partition the relative contributions of natural mineral weathering versus urban inputs to stream-water solute loads. This work addresses critical needs for the Chesapeake Bay Program by providing mechanistic understanding of urban nutrient and contaminant sources that can inform management strategies.

Harry Wang (Virginia Institute of Marine Science), Breanna Maldonado, Derek Loftis, Zhengui Wang, Joseph Zhang, and David Forrest

Three-dimensional, non-tidal three-layered circulation in Baltimore Harbor – Insights into harbor-bay exchange

Baltimore Harbor, a sub-estuary of the Chesapeake Bay located along its western shore approximately 100 km south of the Susquehanna River, exhibits strong water-column stratification at its mouth during the spring freshet. During this high-discharge period, the buoyant surface plume originating from the Susquehanna River intrudes into the harbor along the surface, while saline bottom water simultaneously penetrates landward through the deep ship channel. This process produces a funnel-shaped longitudinal salinity structure within the harbor.

Based on these salinity characteristics, an ideal, two-dimensional (x–z) steady-state analytical solution was derived, revealing a symmetric three-layer circulation pattern consisting of surface and bottom inflows balanced by a compensating mid-depth outflow.

A realistic, three-dimensional baroclinic model using SCHISM confirms the presence of a robust, non-tidal three-layer circulation along the deep ship channel of the harbor. On the other hand, along the shallow flanks of the harbor, degenerated inversed two-layer patterns were identified in both the northern and southern portions, characterized by surface inflow and bottom outflow.

Because most effluents are discharged nearshore along the northern and southern banks, this inverse two-layered circulation has important implications for pollution management. Specifically, nearshore surface releases are susceptible to entrainment into the upstream surface inflow, potentially enhancing pollutant retention within the harbor. In contrast, bottom releases may promote seaward transport through the nearshore bottom outflow pathway."

Rebecca Hale (Smithsonian Environmental Research Center), Megan Stallard, Katrina Lohan, Maureen Mitchell, Derek Shea, Alyssa Freedman

Combining incubations, sensors, and molecular approaches to understand E. coli sources across the Anacostia Watershed

Recreational access to these streams is increasing, providing much-needed ecological amenities to urban residents, but high concentrations of bacteria and other pathogens in urban streams frequently affect the safety of urban streams for recreational usage. E. coli is frequently used as an indicator of fecal contamination to assess the relative safety of waters for recreation because these measurements are relatively low-cost and easy to implement. However, the interpretation and use of E. coli concentrations is hampered by two challenges: 1) E. coli has multiple sources within urban environments, limiting its use as a tracer of human fecal contamination; and 2) measuring E. coli directly requires a 24-hour incubation, so data on risk is never real-time. In a new collaborative project between the Smithsonian Environmental Research Center and the Anacostia Riverkeeper, we are 1) combining traditional incubation methods (IDEXX) with molecular source tracking (MST) to characterize E. coli sources across the Anacostia River watershed at 20 existing tributary monitoring locations, and 2) at three sites that are expected to have different sources of E. coli, are using high-frequency water quality sensors with regular sampling for E. coli concentrations and MST to identify potential sensor proxies for E. coli.

Patrick Bitterman (Kent State University)

Leveraging CHANS Science for Chesapeake Bay Restoration: Findings from a 2026 State of the Science Workshop

This presentation reports the findings of the completed STAC “State of the Science” workshop, ""Challenges and Opportunities in Operationalizing Coupled Human and Natural Systems Research in the Chesapeake Bay Watershed"". Convened in early 2026, the workshop examined how coupled human and natural systems (CHANS) frameworks can be more effectively operationalized within Chesapeake Bay restoration and adaptive management activities, particularly in light of persistent implementation and response gaps.

The workshop brought together federal and state agency staff, academic researchers, and practitioners to assess the current state of applied CHANS science in the Chesapeake Bay Watershed and its relevance for decision-making. Through plenary syntheses and structured breakout sessions, participants identified and mapped critical socio-ecological feedbacks linking land use, economic incentives, institutional design, climate variability, and water quality outcomes. Special attention was given to limitations in existing modeling and monitoring systems, including the limited representation of behavioral dynamics, cross-scale interactions, and endogenous policy feedbacks.

The final report synthesizes three primary products: 1) system models formalizing key feedbacks across agricultural, urban, climatic, and governance domains; 2) a structured gap analysis documenting misalignments between system dynamics and current management, data, and modeling capacities; and 3) actionable recommendations designed to test CHANS-informed policy and institutional innovations. This presentation summarizes the report's principal findings and outlines their implications for advancing feedback-aware, adaptive restoration strategies in a non-stationary socio-environmental context."

Amalia Deloney (Principal, Point A Studio, Candidate for MA in Design for Social Innovation, University of Cyprus)

The Amphibious Council: Experiential Futures and More-Than-Human Governance in the Baltimore Harbor

Restoration in a ""dynamic future"" requires a bridge between the syntax of technological data and the language of embodied, cultural wisdom. While high-resolution monitoring provides essential data, that data often remains an abstraction to the communities most impacted by environmental change. This presentation shares findings from the Amphibious Council, an experiential design project and Political Theatre Charrette developed within an MA in Design for Social Innovation.

The Amphibious Council functions as a speculative city planning meeting where traditional stakeholders—planners, architects, and sustainability advocates—convene alongside immigrant workers and ""more-than-human"" partners, including the Eastern Oyster and the Baltimore Harbor substrate. In this framework, ecological elements are treated as full vocal partners, moving beyond mechanistic simulations toward a ""somatic"" understanding of the watershed.

Drawing on methodologies from Design Futures, Possibility Studies, and Imagination Infrastructures, this work interrogates how we can make data ""felt"" and ""inherited"" rather than just ""read."" By centering the lived experience of immigrant communities and the ancestral presence of the Bay's living resources, the Council addresses the symposium's call for ""effective communication"" and ""transdisciplinary team science.""

The findings demonstrate that when we integrate technical information with story and embodiment, we create a more inclusive planning process capable of navigating a changing human environment. This session will argue that for Chesapeake restoration to be successful in the third decade of the 21st century, our ""next generation tools"" must include the data of the body and the imagination. By treating more-than-human partners as essential collaborators, we move closer to a future worth inheriting—one where scientific rigor is inextricably linked to cultural and ecological legacy.

Patrick Bitterman (Kent State University), Jason Yoo

A Novel Integrated Framework for Simulating BMP Prioritization and Governance Dynamics in the Chesapeake Bay Watershed

Effective water governance systems increasingly rely on the prioritization and spatial targeting of best management practices (BMPs) to achieve regional water quality goals under dynamic environmental and institutional conditions. In the Chesapeake Bay Watershed (CBW), BMP prioritization and implementation are central to meeting nutrient reduction targets under the Total Maximum Daily Load (TMDL) framework.

This presentation introduces a novel computational framework that integrates GeoAI with agent-based modeling to simulate the selection, prioritization, and spatial deployment of BMPs across the CBW. The GeoAI component leverages heterogeneous spatial datasets to characterize environmental risk and prior investment patterns, while the agent-based model represents decision-making by key actors, incorporating empirically informed prioritization mechanisms derived from qualitative interviews and documented governance processes. By coupling data-driven inference with process-based simulation, the framework captures feedbacks between environmental conditions, institutional investment strategies, and spatial outcomes. Our results demonstrate how investment clustering can generate path dependencies, reinforcing specialized BMP infrastructures and shaping subsequent funding flows. These dynamics may produce spatial mismatches between areas of greatest environmental need and those receiving sustained investment. The model further quantifies trade-offs among nutrient reduction efficiency, spatial equity, and governance flexibility under alternative allocation strategies.

In the context of emerging AI-enabled tools and increasingly uncertain futures, this integrated modeling approach illustrates how coupled human–natural systems frameworks can support adaptive, transparent, and reflexive water quality governance.

Raj Cibin (The Pennsylvania State University), Kalra Marali

Impacts of a warming climate and increased land use changes on crop productivity and water quality: a case study in the Susquehanna River Basin

In the coming decades, the Susquehanna River Basin (SRB) is projected to face rising temperatures and increasingly severe precipitation patterns, which could adversely impact crop yields and exacerbate existing water quality issues. Concurrently, urbanization in the region adds further stress to the region's agricultural systems. Utilizing precipitation and temperature data from the CMIP6 (both historical and projected from an ensemble of seven General

Circulation Models), alongside USGS urbanization forecasts for the Chesapeake Bay, we conducted simulations of crop yields and nutrient losses in the SRB for the period spanning 1991 to 2080. The study used the Soil and Water Assessment Tool to evaluate the impacts on crop productivity and water quality. The increasing heat stress has led to a consistent decline in crop yields across the basin, with average annual corn yield projected to decrease by 15% by the end of the century. Water quality also worsened over the course of the simulation period. Annual average sediment load at the SRB watershed outlet was 21% higher between 2051 and 2080 than between 1991 and 2020. The difference over the same period was 10% for total nitrogen load and 22% for total phosphorus load.

Farshad Hesamfar (Department of Civil and Environmental Engineering, University of Virginia), Teresa Culver

Assessing the social footprint of coastal groundwater variability under CMIP6 scenarios in Virginia's Eastern Shore

Groundwater on Virginia's Eastern Shore is the region's primary source of drinking water and the backbone of household sanitation, agriculture, and coastal livelihoods. Yet this shallow coastal aquifer is highly sensitive to climate-driven recharge changes and sea-level rise, which can raise the water table (waterlogging), mobilize salinity, and increase the risk of well contamination and septic system failure. In this study, we quantify how future groundwater variability translates into uneven impacts on residents across the Eastern Shore.
We couple bias-corrected Coupled Model Intercomparison Project Phase 6 (CMIP6) projections from four global climate models with two emissions pathways (SSP2-4.5 and SSP5-8.5) to generate future recharge inputs. These recharge scenarios, combined with a sea-level rise (SLR) boundary condition, are integrated into a variable-density groundwater flow and transport modeling framework to simulate changes in depth to water table, waterlogging, and salinity through mid-century and late-century periods. We summarize uncertainty using multi-model ensemble statistics and map hotspots where thresholds relevant to infrastructure performance are exceeded (e.g., groundwater too close to the land surface or insufficient separation for onsite wastewater systems). To evaluate social implications, we overlay hazard projections with the spatial distribution of domestic wells, septic systems, and public water/sewer service areas, and then summarize exposure for population subgroups (e.g., older adults, children, race/ethnicity groups, and low-wage workers) at consistent census geographies.
Results identify neighborhoods where groundwater hazards intensify under different climate projections and SLR, and where vulnerable groups are disproportionately exposed due to reliance on private wells and onsite sanitation. By linking hydroclimatic uncertainty to equity-relevant outcomes, this work provides actionable evidence to guide adaptation planning, targeted infrastructure investment, and public health protection in coastal communities.