Chesapeake Community Research Symposium 2026

Session 15: Next Generation Tools and Team Science for Chesapeake Bay Living Resource Assessment and Management

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High-Frequency Imaging of Phytoplankton and Zooplankton Dynamics in the Chesapeake Bay

High-frequency monitoring of plankton communities is essential for understanding ecosystem responses to episodic environmental events in estuarine systems such as the Chesapeake Bay. Traditional ship-based or low-frequency sampling approaches often fail to resolve short-term, event-driven variability that can strongly influence plankton community structure and trophic dynamics. Here we present preliminary results from the deployment of PlanktonScope for zooplankton and PhytoScope for phytoplankton in the Chesapeake Bay. These imaging systems provide direct, taxon-resolved abundance estimates across a broad size spectrum while preserving information on organism morphology, size, and life-history stages. The resulting high-frequency datasets enable us to capture rapid plankton responses to episodic events such as storms, freshwater pulses, and abrupt temperature changes. In particular, we demonstrate how these observations reveal transient phytoplankton including dinoflagellate blooms, shifts in zooplankton community composition, and the emergence of planktonic life stages of gelatinous species that are difficult to quantify using conventional methods. The near-real-time nature of imaging-based observations offers a pathway toward early warning and adaptive management of harmful plankton events. Together, these results highlight the value of high-frequency plankton imaging as a core component of integrated observing systems for living resource assessment and ecosystem-based management in estuarine environments.

Alexandria Rhodes (Old Dominion University), Victoria Hill, PhD & Richard Zimmerman, PhD

Mapping Submerged Aquatic Vegetation Around the Tangier-Smith Archipelago Using Satellite Imagery

Submerged aquatic vegetation (SAV) around Tangier, Smith, and Bloodsworth Islands provides essential habitat for blue crabs and other species that support the local economy. SAV meadows also improve water quality, stabilize the sedimentary seafloor, and reduce erosion that is rapidly claiming much of the islands' landmass. This research seeks to better understand the temporal dynamics of this critical resource in terms of area and density across the submarine landscape. A support vector machine model was used to classify SAV abundance from 8-band

Planet satellite imagery. Near-daily coverage by this satellite constellation enabled quantification of seasonal variations in plant distribution and density and provided initial estimates of Blue Carbon storage from 2021 to 2025.

Results show a consistent seasonal pattern in SAV extent, reaching a maximum area of 20–30 km^2 in the summer and declining to less than 10 km^2 in the winter months. Leaf area index (LAI) and carbon density exhibited similar seasonal cycles, with peaks during late summer growth. However, monthly mean LAI was weakly correlated with total meadow area, indicating that changes in meadow extent and canopy density are not tightly linked. LAI also shows indications of a subtle increase over the study period. These results demonstrate that sustained satellite-based monitoring effectively captures seasonality and trends in SAV area, density, and Blue Carbon storage. This approach provides a timely indicator of ecosystem stress and recovery that traditional annual mapping may miss.

Matthew Ogburn (Smithsonian Environmental Research Center), Allison Blanchette

Leveraging Underwater Video, High-Resolution Sonar, eDNA, and Animal Telemetry for Fisheries and Fish Habitat Monitoring

The emphasis on thriving habitat, fisheries, and wildlife in the revised Chesapeake Bay Watershed Agreement demands new and integrative approaches to study and understand the Bay's living resources. Across a range of projects and partnerships, the Smithsonian Environmental Research Center has applied underwater video, high-resolution imaging sonar, environmental DNA (eDNA), and animal telemetry to advance next-generation tools and integrative approaches to ecological monitoring. In oyster reefs, video, sonar, and eDNA approaches have been combined with SCUBA diver surveys to understand interactions between reef protection, restoration, and harvest while documenting ecosystem services oysters provide, including food, cultural value, and fish habitat. For juvenile striped bass, acoustic telemetry and eDNA approaches have improved understanding of habitat use, diet, and parasites. For river herring, eDNA, sonar, and telemetry have been combined to document recolonization of historical spawning habitat after dam removal, conduct spawning run counts, and evaluate connectivity among river, Bay, and ocean environments. These examples illustrate the potential of new tools and integrative approaches to inform management and conservation decision-making.

Julie Reichert-Nguyen (NOAA Chesapeake Bay Office), Julia Fucci, Ron Vogel, Jamileh Soueidan, Marjorie Friedrichs, Aaron Bever, Charles Pellerin, Bruce Vogt

From Buoys, Satellites, and Models: Data Comparisons to Inform Marine Heatwave Forecasting for Fisheries Management Application

Climate-driven changes in environmental conditions pose increasing challenges for Chesapeake Bay fisheries. Temperature extremes influence fish survival, spawning cycles, and growth, creating management challenges. These issues prompted fisheries managers to request improved tracking and forecasting of marine heatwaves—prolonged periods of anomalously high water temperature relative to historical conditions.

We present results from evaluating marine heatwave forecasts using buoy and satellite data from representative locations in the Upper, Mid, and Lower Chesapeake Bay. Observed sea surface temperature records were created by merging continuous buoy observations from the NOAA Chesapeake Bay Interpretive Buoy System with gap-filled satellite temperature data from AVHRR and VIIRS sensors. Modeled estuarine surface temperature data were obtained from the Virginia Institute of Marine Science's Chesapeake Bay Environmental Forecast System. Comparisons between observed and modeled temperature datasets for identifying marine heatwaves are discussed, along with considerations for applying these approaches to support fisheries management.

Genny Nesslage (University of Maryland Center for Environmental Science), Vyacheslav Lyubchich, Glenn Davis, Eric Durell, Mary Fabrizio, Marjorie Friedrichs, James Gartland, Robert Latour, Romuald Lipcius, Julie Reichert-Nguyen, Pierre St-Laurent, Troy Tuckey, Beth Versak

Quantifying Linked Rare Events in Fish and Environmental Chesapeake Bay Time Series

Climate change is associated with increased occurrence of rare weather events that can produce extreme environmental conditions influencing fish and shellfish productivity. Traditional analyses rely on predefined thresholds for biologically meaningful anomalies, which may not remain relevant as environmental baselines shift. This study applied data-driven statistical and machine learning approaches to identify linked rare events in environmental and biological time series from the Chesapeake Bay.

Two long-term environmental time series and eight long-term fish and shellfish monitoring datasets were analyzed, including species such as Atlantic striped bass, Atlantic menhaden, blue crab, bay anchovy, summer flounder, black sea bass, red drum, cobia, and the invasive blue catfish. Rare events were detected using isolation random forest algorithms. Correspondence analysis with time series lags identified relationships between environmental extremes and biological responses. PCA quantile regression models were used to quantify the influence of extreme environmental conditions on rare catch-per-unit-effort events. Insights from this study support the development of climate indicators for improved ecosystem-based fisheries management in the Chesapeake Bay.

Robert Daniels (NOAA NCCOS), Ava Ellett

Chesapeake Bay Vibrio Seasonal Outlook

Vibrio bacteria are naturally occurring opportunistic pathogens found in brackish coastal waters such as the Chesapeake Bay. Nationally, the CDC estimates approximately 80,000 vibriosis infections per year from all Vibrio species. Vibrio parahaemolyticus is the most common cause of illness and is typically associated with seafood consumption, while Vibrio vulnificus infections are less common but more severe and can result from wound exposure or consumption of raw seafood such as oysters.

Developing accurate seasonal predictions for these illnesses is crucial for public health preparedness and seafood safety. Vibriosis cases linked to seafood consumption and water exposure in the Chesapeake Bay were compiled from the CDC's Cholera and Other Vibrio Illness Surveillance (COVIS) database from 2007–2024. A forecasting approach using multi-model ensemble predictions from the North American Multi-model Ensemble (NMME) was developed to identify the most reliable model combinations for predicting seasonal risk. The resulting seasonal outlook provides a projected range of expected illnesses and categorizes the upcoming season as above, below, or near average—similar to seasonal hurricane outlooks issued by the National Weather Service.

Allison Dreiss (Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science), Ryan E. Langendorf, Ryan Woodland, Vyacheslav Lyubchich, Jeremy Testa

Modeling Benthic Biomass Responses to Climate Change in the Chesapeake Bay

Global environmental change strongly affects coastal ecosystems, particularly estuaries where eutrophication and climate change act as major stressors. Hypoxia, a widespread consequence of these changes, has well-known biological and biogeochemical impacts—especially on benthic invertebrates and their food webs. However, models that capture hypoxia–benthos interactions under future environmental conditions remain limited.

To project past and future hypoxia in the Chesapeake Bay, we applied new benthic invertebrate habitat and biomass models to existing coupled physical–biogeochemical models validated through historical hindcasts. These models incorporated downscaled climate projections from the North American Regional Climate Change Assessment Program (NARCCAP), which uses regional climate models nested within global models from the CMIP3 dataset. Simulations spanned a historical baseline period (1989–1998) and a mid-21st-century projection (2049–2058) under the A2 emissions scenario.

For each climate downscaling projection, spatial and temporal patterns of bottom-water oxygen, chlorophyll, particulate organic carbon, temperature, and salinity were analyzed across the Chesapeake Bay and its tributaries to evaluate their influence on benthic invertebrate biomass. Results suggest mixed responses across benthic groups, with the largest biomass changes projected to occur in shallow areas of the Bay (0–5 m depth).

Theresa Davenport (University of Maryland Center for Environmental Science), Kenny Rose, Limin Sun, William Nardin, Lorie Staver, Matt Gray, Cindy Palinkas, Ming Li, Vincent Pham, Vyacheslav Lyubchich, Anna Johnson, Megan Barnier, Evan Mazur

Coupling Hydrodynamic, Water Quality, and Habitat Suitability Models to Assess the Habitat Co-Benefits from Living Shorelines

Living shorelines are increasingly used in the Chesapeake Bay to mitigate coastal erosion and reduce flood risk while providing habitat benefits for species that depend on near-shore environments. Hybrid structures that combine traditional gray infrastructure with nature-based solutions are also being explored.

A key challenge in designing these hybrid living shorelines is ensuring that erosion control and flood mitigation objectives are met while simultaneously enhancing ecological habitat. To address this challenge, we present a modeling framework that couples hydrodynamic, water quality, and habitat suitability models to evaluate habitat trade-offs and benefits under different shoreline design scenarios.

Using an ongoing Chesapeake Bay project as a case study, we demonstrate how this modeling framework can predict habitat suitability for key species under alternative living shoreline designs. The approach allows practitioners to explore trade-offs among habitat outcomes while still meeting primary engineering objectives. Coupled models provide a powerful tool for designing living shoreline projects that maximize ecosystem benefits while maintaining effective coastal protection.

Emi McGeady (University of Maryland Center for Environmental Science Horn Point Laboratory)

Evaluating Localized Food Web Response to Oyster Restoration Using a 3D Multispecies Individual-Based Model

The eastern oyster, *Crassostrea virginica*, provides multiple ecosystem services, including water filtration, pelagic–benthic coupling, and the creation of habitat for ecologically and commercially important fish species. Through suspension feeding, oyster reefs reduce phytoplankton abundance, improving water quality and clarity. These benefits have motivated large-scale oyster restoration efforts throughout the Chesapeake Bay.

As restoration expands to additional tributaries, understanding how localized oyster filtration influences surrounding food webs becomes increasingly important. Existing mechanistic models often simplify predator–prey interactions using aggregate representations that do not account for individual-level behaviors such as movement, size-dependent predation risk, or foraging decisions.

To address this limitation, we developed an agent-based multispecies model that incorporates dynamic energy budget models to simulate individuals of key predator and prey species. This framework captures fine-scale predator–prey interactions and allows emergent food web responses to oyster filtration to be examined. Preliminary simulations and model development are presented. This modeling framework will help evaluate restoration scenarios and identify potential trade-offs between water quality benefits from oyster filtration and changes in local food web structure.

Vaskar Nepal (Western Illinois University), Mary C Fabrizio; Troy D. Tuckey, Colin Hawes, Marjorie A.M. Friedrichs, Pierre St-Laurent, Aaron J. Bever

Mechanistic Habitat Modeling for Chesapeake Bay Fish and Shellfish: From Individual Physiology to Management Tool

Habitat suitability models are widely used for ecosystem management, but traditional correlative models that link species presence to environmental variables often fail under novel conditions such as climate change or species invasions. Physiology-based models offer a more mechanistic alternative.

We present a bioenergetics-based habitat suitability framework that evaluates habitat quality on a probabilistic scale rather than binary presence–absence predictions. This approach allows resource managers to adjust threshold values to align with specific management objectives.

The framework offers several advantages. It incorporates interactions among environmental variables such as temperature, salinity, and dissolved oxygen, and accounts for the distinct physiological mechanisms through which each variable affects organisms. For example, hypoxia reduces ingestion and assimilation efficiency, while salinity increases metabolic maintenance costs through osmoregulation.

We also discuss practical considerations for applying physiology-based models, including data requirements and strategies for scaling individual-level bioenergetics to population-level dynamics. Using Chesapeake Bay fish and shellfish species as case studies, this framework demonstrates how mechanistic modeling can improve management predictions under changing environmental conditions.

Colin A. Hawes (Virginia Institute of Marine Science), Marjorie A.M. Friedrichs, Pierre St-Laurent, Vaskar Nepal, Mary C. Fabrizio, Troy D. Tuckey, Aaron J. Bever

Modeling Juvenile Atlantic Croaker Habitat Suitability: Impacts of Future Climate and Nutrient Management

Atlantic croaker is an important species for recreational and commercial fisheries along the U.S. East Coast, and the Chesapeake Bay provides critical nursery habitat for juvenile fish. Climate change and planned nutrient load reductions may alter the quality and extent of this habitat.

To project potential future changes, a bioenergetics-based habitat suitability model for juvenile Atlantic croaker was coupled with a three-dimensional hydrodynamic–biogeochemical model of the Chesapeake Bay embedded within the Regional Ocean Modeling System. The habitat suitability model incorporates fish weight along with environmental variables including water temperature, salinity, and dissolved oxygen.

Control simulations represented conditions from the 1990s, while future projections simulated the 2070s using warming estimates from three downscaled Earth System Models under two Shared Socioeconomic Pathways. Nutrient loading reductions were also incorporated based on anticipated watershed management goals.

Results suggest that by the 2070s, suitable juvenile croaker habitat in the Bay may persist for approximately 24 additional days each year compared to the 1990s, reflecting the species' preference for warmer conditions. Nutrient reductions improved summer oxygen levels and reduced unsuitable habitat by approximately 60%. When combined with climate change projections, suitable summer habitat remained greater than during the historical baseline period.

Aaron Bever (FlowWest), Colin Hawes, Marjorie A.M. Friedrichs, Pierre St-Laurent, Vaskar Nepal, Mary C. Fabrizio, Troy Tuckey

Realtime Forecasting and Seasonal Summaries of Habitat for Fishes in Chesapeake Bay

The amount of suitable habitat available to fish species varies annually due to environmental conditions and climate variability. Traditionally, understanding these changes requires environmental data collection, quality control, and analysis or model simulations conducted after observations are available, resulting in delayed insights for fisheries management.

To reduce this lag, physiologically based habitat models for four fish species were integrated into the Chesapeake Bay Environmental Forecast System (CBEFS). CBEFS is an automated three-dimensional hydrodynamic–biogeochemical modeling system that produces daily nowcasts and five-day forecasts of environmental conditions throughout the Chesapeake Bay.

Embedding habitat models directly into this forecasting workflow enables real-time tracking of suitable habitat conditions for individual fish species. In addition, a prototype automated reporting system was developed to summarize seasonal habitat availability relative to historical conditions.

This approach provides fisheries managers with near-real-time insights into habitat dynamics and allows comparisons between current conditions and historical baselines without waiting for lengthy post-processing analyses.

Matthew Gray (University of Maryland Center for Environmental Science – Horn Point Laboratory), Theresa Daven, William Nardin, Elizabeth North, Kenny Rose, and Jeremy Testa

Designing Oyster Restoration for Today's Bay: Leveraging Next-Generation Models to Maximize and Manage Ecosystem Services

Oysters provide numerous ecosystem services, including water filtration, habitat creation, shoreline stabilization, and support of fisheries. Although decades of investment have led to thriving oyster populations in some areas of the Chesapeake Bay, restoration strategies must evolve to address current and future environmental and socio-ecological conditions.

This presentation outlines a vision for next-generation oyster restoration that leverages advanced modeling tools to guide outcomes-driven ecosystem design. Advances in hydrodynamic modeling, larval connectivity analysis, ecosystem service valuation, reef growth modeling, and geomorphic forecasting now allow scientists to predict where oyster reefs will thrive and where restoration investments will produce the greatest ecological return.

Integrated modeling frameworks also serve as collaborative tools that help managers, scientists, engineers, and community stakeholders visualize trade-offs and align restoration objectives. By synthesizing recent modeling advances, this talk presents a strategic roadmap for scaling oyster restoration as climate-ready infrastructure that accelerates ecosystem service delivery while supporting transparent decision-making.

Kenneth Rose (University of Maryland Center for Environmental Science), Mark Monaco, Thomas Ihde, Eric Smith, Jay Stauffer, Kirk Havens, Lee McDonnell, Lewis Linker, Kaylyn Gootman, Bruce Vogt, Marjorie Friedrichs, Mary Fabrizio, Colin Hawes, Dante Horemans

CESR: Moving Forward with Assessing Living Resource Responses for Prioritizing Projects and Restoration Plan Formulation

The Comprehensive Evaluation of System Response (CESR) report recommended expanding efforts to assess how living resources respond to Chesapeake Bay restoration actions. Two key components of ecosystem restoration planning include prioritizing projects based on biological responses and selecting appropriate ecological indicators to evaluate restoration progress.

The CESR framework outlines statistical and ecological modeling approaches to examine in-situ responses of living resources to restoration actions. The framework integrates ecological principles with a structured analytical workflow to support development of an implementation plan that details the analyses needed to evaluate restoration outcomes.

In this presentation, we describe how this framework is being implemented in Phase 1 of a multi-phase effort to develop a habitat-based decision tool for the Chesapeake Bay Program. The tool will support prioritization of restoration projects by linking habitat improvements to population and food web responses. We also discuss how this approach aligns with restoration assessment strategies used in other large-scale coastal ecosystem programs across the United States.