**Chesapeake Community Research Symposium 2024**

Session 8: Water-quality patterns and trends in the Chesapeake Bay and its watershed: I. Innovative monitoring techniques and modeling tools

**Patrick Neale, Shelby Brown, Tara Sill, Alison Cawood, Maria Tzortziou, Jieun Park, Min-Sun Lee**

Chesapeake Water Watch: Validation of Volunteer Observations of Water Quality in Tidal Tributaries

Chesapeake Bay tidal tributaries are important transitional water bodies mediating how watershed and shoreline management efforts translate into improved water quality, and are a focus of efforts to reach Bay Program water quality standards. The Chesapeake Water Watch program enhances the monitoring of tributaries by 1) developing and testing methods for volunteers to easily measure in vivo chlorophyll, turbidity and colored dissolved organic matter (CDOM), and 2) improving remote sensing (RS) algorithms for monitoring tributaries with high resolution imagery from Landsat 8/9 and Sentinel 2. Volunteers measure surface turbidity using a smartphone app, Hydrocolor, calibrated with a photographer's gray card. In 2023, volunteer measurements in Maryland tributaries had a median percent error of 27% and RMSE of 2.9 NTU relative to benchtop measurements (n=201), except for when both Hydrocolor and RS backscatter-based algorithms underestimated benchtop (side-scatter) turbidity (n=25). Most volunteers find the app easy to use and produce consistent results (SD < 1 NTU for triplicates). In vivo chlorophyll and CDOM fluorescence are assessed with a hand-held fluorometer (Aquafluor)at sample processing "hubs" where volunteers drop-off samples for same day processing. In validation samples, in vivo fluorescence was a linear predictor of extracted chlorophyll (r2=0.83, RMSE=8 µg L-1, n=140) and CDOM fluorescence was a linear predictor of absorbance (r2=0.74, RMSE=0.11 m-1@ 440 nm, n=33). These methods are being used for both repeat sampling at fixed sites of interest and ad-hoc "blitzes" to synoptically sample tributaries all around the Bay in coordination with satellite overpasses. We make all of the data accessible on a public database (serc.fieldscope.org), and hope that is is a useful resource to monitor long-term trends in the tidal tributaries as well as detect and diagnose causes of events of concern such as algal blooms and storm-induced reductions in water clarity.

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**Peter Tango, Bruce Vogt**

Enhanced monitoring supporting improved aquatic habitat assessment for Chesapeake Bay

Since its formation in 1983, the Chesapeake Bay Program partnership has focused investments towards improving water quality of the Chesapeake Bay to achieve target levels of habitat health. Eutrophication resulting from excess nutrients entering the bay has been recognized as a major issue affecting habitat suitability for the bay's living resources. Bay-specific habitat protection criteria were developed based on survival, growth and reproduction needs of diverse living resources, published by USEPA in 2003, and adopted for water quality standards attainment assessment by tidal water states and Washington, DC. Monitoring capacity of the long-term water quality monitoring program sampling biweekly to monthly for over 150 tidal water stations was deemed ‘marginal’ for assessing the full temporal spectrum of dissolved oxygen criteria from instantaneous minima to 30 day means. Multi-season, multi-year high temporal density water quality data collections occur in nearshore habitats. However, offshore water quality dynamics are poorly represented at high temporal density. Research evaluating monitoring strategies and designs has suggested as few as 2 water column sensor units collecting continuous high temporal density (e.g., hourly, sub-hourly) data in the mainstem Chesapeake Bay would be an effective and efficient approach to improve tracking of annual deep-water hypoxia that limits the seasonal suitability of cool water habitat for many living resources in the estuary. A pilot study of water column habitat data collection with new robust, portable, and affordable sensor arrays was conducted in 2020 in the most challenging bay regions for data collection and proved suitable for extended data collection. In this presentation we review the new technology being deployed in open water habitats of the bay, considerations of site selection, initial data collection examples, operations and maintenance insights from initial test deployment periods, and anticipated applications of the new data streams to support improved habitat assessment in Chesapeake Bay.

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**Sergio A. Sabat-Bonilla, Marlaina Marvin, Kelly Maloney, Greg Noe, and Sally Entrekin**

Rethinking Stream Recovery Assessment in the Bay: A Functional and Structural Perspective

In the Chesapeake Bay Watershed, landuse significantly influences freshwater ecosystem health, impacting water quality and biological diversity. Despite the implementation of conservation practices (e.g., riparian buffer zones), historical landuse legacies still persist, inhibiting a biological recovery across many streams. This calls for an analytical approach that considers both the spatial and temporal effects of landuse on aquatic communities. Benthic macroinvertebrates (BMIs), crucial in many ecosystem services, are indicators of the impacts by agricultural practices within the Chesapeake Bay. Traditional bioassessment methods, focusing on structural metrics such as the abundance of sensitive taxa (Ephemeroptera, Plecoptera, Trichoptera), often yield mixed results, complicating conservation strategies. Our study aims to inform better measures of recovery by comparing both structural (density) and functional (biomass) responses of BMIs across streams in the Chesapeake Bay Watershed, affected by varying agricultural and conservation practices. We hypothesize that biomass will provide a more ecologically relevant perspective of BMI responses to conservation practices compared to traditional density metrics. By examining these responses within two distinct regions of the watershed (Ridge and Valley, Coastal Plain), our study seeks to offer insights into resource availability and ecosystem succession of recovering streams. Allowing for a clearer understanding of ecological integrity and a tangible impact of conservation practices, thereby informing more effective environmental management and policy decisions. Our goal is to contribute to the sustainable management and resilience of the Chesapeake Bay's freshwater ecosystems, ensuring their vitality for future generations.

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**Aaron Porter**

Monitoring water-quality response to urban-stream restoration in Fairfax County, Virginia

The Chesapeake Bay total maximum daily load (TMDL) was established in 2010 to reduce loads of nutrients and suspended sediments delivered from the Chesapeake Bay watershed to its estuary. Chesapeake Bay states and local governments are using management practices to reduce these loads; however, the positive effects of implemented management practices on water-quality remains uncertain. Long-term monitoring studies can help evaluate the effectiveness of water-quality management practices. This presentation will describe the objectives, design, and initial findings of a new monitoring study in Fairfax County, Virginia. Fairfax County has partnered with the USGS on a county-wide monitoring program since 2007 that has included a streamgage and water-quality monitoring station at the outlet of the Long Branch watershed since 2013. In 2021, monitoring was expanded to evaluate the effects of stream restoration practices in Long Branch. Fairfax County plans to restore much of the main channel and major tributaries and implement 75 outfall improvements. This work, referred to as the Long Branch Central Watershed Management Area Project, is designed to meet a local suspended sediment TMDL, and is anticipated to reduce the rate of sediment infill in Lake Accotink, which currently necessitates costly dredging on a reoccurring basis. The monitoring approach is designed to quantify the response of watershed-wide stream restoration on stream hydrology and sediment and nutrient transport, with a specific focus on the role of improved floodplain connectivity and streambank stabilization. Data collection elements consist of 1) continuous streamflow, water quality, and meteorological monitoring, 2) discrete water quality sample collection 3) longitudinal measures of streambank erosion, floodplain deposition, and in-channel sediment storage, and 4) measuring the frequency and duration of floodplain inundation. These elements support the computation of constituent loads, quantification of sources and sinks of suspended sediments, and an evaluation of changes in watershed hydrology and stream hydraulics.

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**Marina Metes, Zachary Clifton, Matthew Cashman**

Tracking the downstream fate of dam-removal sediment pulses in the Patapsco River using lidar and streamgage data

The erosion and release of impounded sediment after a dam removal has been shown to follow a two-phased response in rivers of the Northeastern United States. The first, shorter phase that occurs immediately after a dam removal is ‘process-driven’ by base level change and an increase in energy gradient, resulting in rapid erosion of impounded sediment, independent of flood events. The second, longer phase is ‘event-driven’, dependent on flood events to erode remaining impounded sediment located outside the newly formed channel. This two-phased process was observed in the Patapsco River following the Simkins Dam removal in 2011 and the Bloede Dam removal in 2018. Both dam removal sites are situated along a steep, narrow valley within the Piedmont physiographic province southwest of Baltimore. Downstream, there is a sharp reduction in longitudinal slope as the river flows into the Coastal Plain and transitions to a wide, unconfined valley that actively traps sediment. In the time period between the two dam removals, the Patapsco River flooded to historic levels during the Ellicott City floods of 2016 and 2018, along with additional unnamed high-flow events. Stage, discharge, suspended sediment, and field measurements from three USGS streamgages situated along the Patapsco River, one upstream of both sites, one in between, and one downstream of both sites, were used to monitor the short- and long-term geomorphic response of the river to these storm and dam-removal events. A topographic analysis was conducted using repeat lidar measurements to assess changes in floodplain sediment deposition further downstream of the dam removals. This presentation demonstrates how routine gage data, along with repeat lidar, can be used to gain a better understanding of the spatiotemporal movement of dam-removal sediment pulses, especially as the river shifts to the low gradient Coastal Plain system, representative of many rivers entering the Chesapeake Bay.

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**Claire Welty, Joel Moore, Daniel J. Bain, Mahdad Talebpour , John T. Kemper, Peter M. Groffman, Jonathan M. Duncan**

Use of synoptic baseflow sampling coupled with groundwater modeling to assess groundwater contamination of urban streams

Legacy groundwater contamination can be a source of elevated solutes to urban streams. Given the dearth of observation wells in urban areas, synoptic base flow sampling after dry periods can be used as a means of characterizing the spatial variability of stream contamination originating from groundwater sources. We have carried out such stream synoptic sampling after 5-10 days of no rain, where no point source inputs are present. We have analyzed for selected anions (chloride, sulfate, nitrate, fluoride) and have observed spatially variable but temporally stable patterns of stream solute concentrations over multiple years. Work has been carried out in Dead Run in suburban Baltimore, MD over a 6-km reach of stream with samples collected every 50 m. As a method to relate solute sources to land use, we have constructed a three-dimensional groundwater flow model of the watershed and conducted backward particle tracking from stream sampling locations to determine where flow paths are predicted to enter the subsurface from the landscape. We have carried out cross-covariance analysis between stream solute concentrations and urban landscape features at flow path entry points using calculated subsurface flow paths as separation distances. Results suggest associations of stream solute spatial patterns with mapped impervious area, urban fill, potable water pipe density, and sanitary sewer pipe density and imply that legacy groundwater contamination drives stream chemistry. This talk is a synopsis of work that has been published at https://doi.org/10.1029/2021WR031804.

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**James Webber**

Evaluating Water-Quality Trends in Agricultural Watersheds Prioritized for Management-Practice Implementation

Nutrient and sediment load reductions rely on the voluntary use of management practices (MPs) in many Chesapeake Bay agricultural watersheds; however, it is difficult to identify the potential water-quality effects of MPs. Many human activities and natural processes affect water-quality responses and, therefore, need to be considered to confidently identify MP effects. This presentation will summarize how monitoring data and statistical techniques were used to develop insights about water-quality responses and MP effects in three agricultural Chesapeake Bay watersheds. The Smith Creek (Virginia), Upper Chester River (Maryland) and Conewago Creek (Pennsylvania) watersheds were prioritized for MP implementation since the early 2010s to showcase agricultural conservation efforts. In each watershed, patterns in MPs, climate, land use, and nutrient inputs were analyzed to better understand factors affecting nutrient and sediment loads. Relations between MPs and expected water-quality improvements were not consistently identifiable. The number of MPs increased in all watersheds since the early 2010s, but most monitored loads did not decrease. Nutrient and sediment loads increased or remained stable in Smith Creek and the Upper Chester River. Sediment loads and some nutrient loads decreased in Conewago Creek. In Smith Creek, a 36-year time-series model suggests that, after accounting for annual streamflow differences, changes in the amount of applied manure affected total nitrogen loads. In all watersheds, increases in nutrient applications may have overshadowed some expected MP effects. Although MPs might have stemmed further water-quality degradation, nutrient improvements may rely on reducing manure and fertilizer applications to amounts that meet local crop and pasture demand. These findings highlight the value of partnerships between researchers and resource managers to understand the complex factors affecting agricultural water-quality responses. Sustained investments in monitoring data, MPs, and statistical tools that evaluate cause and effect relations can help maximize information from this research and from other monitoring-based studies.

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**Rui Jin**

Unraveling the CDOM Conundrum - The Interplay of Optics, Nutrient Loading, Productivity, and Hypoxia Dynamics in Chesapeake Bay

Excessive nutrient loading is a well-established driver of hypoxia in aquatic ecosystems. However, recent limnological research has illuminated the role of Chromophoric Dissolved Organic Matter (CDOM) in exacerbating hypoxic conditions, particularly in freshwater lakes. In coastal ocean environments, the influence of CDOM on hypoxia remains an underexplored area of investigation. This study seeks to elucidate the intricate relationship between CDOM and hypoxia by employing a nitrogen-based model within the context of Chesapeake Bay, a large estuary with unique characteristics including salinity stratification and the localization of hypoxia/anoxia in a 30-meter-deep channel aligned with the estuary's primary stem. Our findings indicate that the impact of CDOM on nutrient dynamics and productivity varies significantly across different regions of Chesapeake Bay. In the upper Bay, the removal of CDOM reduces light limitation, thus promoting increased productivity, resulting in the generation of more detritus and burial, which, in turn, contributes to elevated levels of hypoxia. As we transition to the middle and lower Bay, the removal of CDOM can cause a decline in integrated primary productivity due to nutrient uptake in the upper Bay. This decrease in productivity is associated with reduced burial and denitrification, ultimately leading to a decrease in hypoxia levels. Streamflow modulates this impact. The time integral of the hypoxic volume during low-flow years is particularly sensitive to CDOM removal, while in high-flow years, it is relatively unchanged. This research underscores the necessity for a comprehensive understanding of the intricate interactions between CDOM and hypoxia in coastal ecosystems.

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**Anand Gnanadesikan**

What can the abundance of functional genes tell us about how to model Chesapeake Bay?

Although microorganisms play critical roles in these models, the evolution of microbial biomass apart from photosynthesizers is not typically simulated, in part because data to constrain such representation is lacking . Although metagenomic information could provide useful constraints for these models it is not clear how best to use it. Here we compare the abundance of a subset of metabolic genes identified in Chesapeake Bay during the summer of 2017 with rates predicted by a numerical model. We focus on genes associated with photosynthetic primary production , nitrification, denitrification, and sulfur cycling. Certain modeled rates are significantly correlated with associated genes or genes subset by key taxa . However, we also find interesting discrepancies such as an overabundance of photosynthesis and denitrification genes in the deep waters in the spring when the model expects rates of both processes to be small. Our work demonstrates that metagenomics could serve as a useful indicator for some, but not all rates. Future work to advance this field should focus on improving the detection and proper classification of genes encoding key enzymes for modeled processes and when adding taxonomically-resolved representations of key processes informed by metagenomics is warranted.