Chesapeake Community Research Symposium 2024
Session 4: Coupled human-natural systems in Chesapeake Bay

D.G. Webster

Media Representations of Risks and and Co-benefits of Water Quality Governance in the Chesapeake Watershed

In order to model the Chesapeake Bay watershed as a coupled human and natural system, it is necessary to improve our understanding of the feedback between changes in water quality and changes in human behavior. An important step toward this advance is assessing how people perceive the risks associated with poor water quality and the potential co-benefits that they may enjoy with improved water quality. While some people may have direct experience with these risks and co-benefits, the majority of the population in the watershed will get their information from news sources or social networks. This paper uses quantitative content analysis to examine changes in news coverage of risks and co-benefits in the watershed from 2005-2019. We find that coverage increased substantially over these years but that this growth was episodic, largely spurred by periodic extreme events like harmful algal blooms or fish die-offs. We also examine geographic and political variation in coverage, documenting a wide information disconnect that may be part of a larger reinforcing feedback which amplifies the transboundary problem that limits the effectiveness of water quality governance in the region.

Kwang il (Jason) Yoo, Patrick Bitterman

Generating Artificial WIPs Using Machine Learning Methods to Explore Management Responses to Land Use Scenarios

Agricultural activities, urban and suburban land use, stormwater runoff, and wastewater treatment plants contribute significant amounts of nitrogen, phosphorus, and sediment to the Chesapeake Bay This leads to algae bloom growth that creates low oxygen zones that harm aquatic life. To address nitrogen, phosphorus, and sediment pollution in the Chesapeake Bay, jurisdictions across the Chesapeake Bay Watershed periodically develop watershed implementation plans (WIPs), which contain suites of best management practices (BMPs). These plans are necessarily responsive to land use land cover (LULC) and nutrient load sources and provide a blueprint for how practices will be implemented across the watershed. To understand how these plans might respond to future land use scenarios and, therefore, changes in landscape characteristics, we developed a multi-scale, machine-learning-based model that generates artificial WIPs. The model integrates local geographical context and past state-level decisions to generate representative plans under new scenarios, providing insights into the potential futures of the Bay and Watershed. These results aid decision-makers in understanding how plans and priorities might change under future policies, transportation scenarios, and

growth projections. Accordingly, this research offers valuable insights into the spatial patterns of management practices that collectively protect the health of the Chesapeake Bay ecosystem.

Patrick Bitterman, Kwang il (Jason) Yoo

Spatial Insights into Water Governance Challenges in the Chesapeake Bay Watershed: Mismatch, Inequality, and Path Dependency

The complex regional water governance system in the Chesapeake Bay Watershed is responsible for meeting water quality goals by identifying, prioritizing, funding, implementing, and maintaining projects aimed at improving water quality or quantity in the region. The outcomes of these decisions manifest spatially – investments in water quality projects have localized environmental benefits while also affecting local economic investment, infrastructure development, and capacity building in local firms and organizations. However, the spatiotemporal patterns of these decisions may create path dependency and further unequal investment. Early funding decisions create localized specializations and capacity, which attract additional investment in future rounds of project allocation. Therefore, a rational strategy of prioritizing locations of past success can lead to spatial mismatch and worsen economic and environmental inequalities among sub-watersheds. This study focuses on the implementation of water quality improvement projects across the Chesapeake Bay Watershed. First, we quantify the degree of spatial clustering in investment and implementation and measure spatial mismatch between environmental concern (e.g., nutrient load) and investment. Second, we develop multidimensional trade-off functions between investment and planned changes in environmental quality. We find that investment is uneven with respect to geographic space, best management practices, and water quality issues. Further, we show that early decisions may have created a situation where the system is "locked-in" to a state that promotes unequal outcomes across the watershed.

Michele Romolini, Alexa Siglar, Paul T. Leisnham, Amanda Rockler

Agricultural Water Management in a Changing Mid-Atlantic: Stakeholder Experiences and Attitudes Towards Alternative Water Sources, Weather Variability, and Related Factors

The mid-Atlantic has experienced significant but commonly overlooked impacts on water quality and quantity due to climate change, population increases, and land use modifications. Future climate change is predicted to cause even greater decreases in water availability for crop production and aquifer recharge. This talk presents findings from interviews with 17 mid-Atlantic stakeholders—including farmers, extension agents, state agency personnel and academics—to examine perceptions toward nontraditional water sources and water conservation practices. Semi-structured interviews completed in 2023 were designed to better understand stakeholders' perceptions and experiences with: 1) water use and management in agriculture, including both freshwater and reusable resources; 2) past, existing and future weather variability; and 3) related factors impacting water use and management. We found interviewee experiences with water use and management varied substantially, especially related to the geographic location of

the farm and type of the farming operations. Interviewee interest in nontraditional water sources also related to farm location and product type, but included other factors such as land ownership, lack of access, and water quality and quantity concerns. We will describe emergent themes and key findings, how they inform our overall research project, and implications for water management in the region. The broader project explores the use of nontraditional water sources and water conservation practices that help increase water availability and decrease water demand for irrigation with the goal of helping make the mid-Atlantic region water sustainable under current and future climate scenarios. Project goals will be achieved through the development and Extension-facilitated adoption of transdisciplinary Agent-Based Modeling (ABM) and Diagnostic Decision Support System (DDSS) tools. The DDSS will include critical stakeholder input through interviews and surveys, linked with an ABM tool to identify and implement BMPs for efficient use of freshwater and recycled water sources in the mid-Atlantic and beyond. The DDSS tool will include a hydrologic and water quality model that will help quantify water fluxes and pollutant fates under any selected BMP.

Sean Emmons, Taylor Woods, Kelly Maloney

Prioritizing Stream Health Alongside Social Equity in the Chesapeake Bay

In coupled human and natural systems, it is increasingly challenging to model the complex interactions between people and nature to better understand tradeoffs. For example, management and policy actions increasingly pursue social, economic, and conservation outcomes to boost equity, return on investment, and environmental impacts. However, decision-makers face complex tradeoffs between social and conservation outcomes because the most equitable outcome might result in weak conservation outcomes (and vice-versa). In the Chesapeake Bay watershed, there is growing interest in incorporating social outcomes alongside conservation outcomes (e.g., Stream Health Outcome - improve the health and function of 10% of non-tidal stream miles above a 2008 baseline), but no framework exists to identify areas where both stream health and social equity outcomes can be boosted. Here, we present a preliminary spatial planning framework that incorporates stream health (Chessie BIBI) and social (CDC's Environmental Justice Index) data to prioritize locations for stream health improvement that are also in areas with socially vulnerable populations with high environmental burdens. We discuss how to prioritize sites for restoration, conservation, or management outcomes, tradeoffs between social equity and stream health outcomes, and the spatial relationships between social and stream health data. Our approach highlights how some carefully designed management programs or policies could enhance both social equity and stream health outcomes. We underscore the importance of assessing both human and environmental outcomes to better understand both the challenges and opportunities of integrated models of coupled human and natural systems.

Allison Reilly, Jerin Tasnim, Birthe Kjellerup, Rachel Goldstein, Margaret Walls, Penny Liao, Emily Speierman, Oberholtzer, Celso Ferreira, Andrew Lazur, DeLima, Cameron Smith

Septic to Sewer? Justice-focused strategies for addressing coastal septic failures under sea-level rise and increased flooding

Many rural communities are on the front lines of climate change which can have multiple direct and indirect human health impacts. One concern is septic tank failures and how increased flooding and sea-level rise will cause septic systems to fail. This can and has led to more gastrointestinal illness and parasitic infections. This is acutely problematic in areas with higher proportions of people of color. People of color are more likely to reside on flood-prone land and historically have been less likely to be connected to municipal sewer systems. Sewer systems, while expensive in rural areas, can improve health outcomes and often increase home values. In this work, we are conducting an interdisciplinary multi-scale empirical examination of these problems, with a geographic focus on the Eastern Shore of Maryland. We are deliberately investigating the risk of septic system failures now and in the future, while addressing the antecedent conditions (including historical settlement patterns and exclusion from municipal sewers), that potentially exacerbate this exposure. We have and will continue to collect primary data on septic health and leverage a myriad of secondary data to develop a composite risk. This data is being augmented with community input and experience, which aids in understanding the potential of specific policy and technology solutions, while ensuring the benefits accrue in a way that addresses past discriminatory practices.

Alicia Lawson, Patrick Bitterman

Rising Tides, Sinking Heritage: A GIS-Based Analysis of Sea-Level Rise Impacts on Chesapeake Archaeological Sites

The Chesapeake Bay Watershed (CBW) was first settled by Europeans in 1607 with the establishment of Jamestown although the region has been inhabited by Native Americans since the late Pleistocene. Today, Chesapeake Bay's coastline region is occupied by ten million people. This long period of intense occupation has resulted in a conservatively estimated 50,000 archaeological and cultural heritage sites located within the watershed. The sites within the CBW span from some of the earliest evidence of human occupation in the region during the last glacial period to towns, such as Jamestown, Williamsburg, and Washington, D.C., that were central to European colonization of North America and the founding of the United States. However, climate change has increased the threat of sea-level rise and storm-surge to coastal regions. These concerns are compounded by evidence that much of the land of the CBW is sinking. The archaeological and cultural resources in the CBW are non-renewable and require conservation because of the depth of knowledge preserved within them. The effects posed to these archaeological resources include partial or total flooding of archaeological sites and/or the erosion of archaeological materials and sites, resulting in either partial or complete loss of these resources. This presentation details a geospatial analysis that determined the number and

locations of archaeological sites that would be threatened by fluctuations in sea levels. Our results identify areas with the greatest risk near the bay and its tributaries, indicating areas where conservation efforts should be prioritized to preserve these irreplaceable cultural resources. Policies aimed at mitigating the impacts of sea level rise should include these areas of greatest risk and direct the focus of the archaeological community on conservation efforts, including surveying, documenting, and excavating sites before they are lost to rising waters.

Michelle Katoski, Peter Claggett, Sarah McDonald

Implications of using high resolution data for forecasting land use change

High spatial and categorical resolution land use/land cover (LULC) data are helpful for informing land change forecast models. The Chesapeake Bay Program funded the development of 1-meter resolution, 62-class LULC data for all counties intersecting and adjacent to the Chesapeake Bay watershed, a 256,000 km2 region for the years 2013-14, 2017-18, and 2021/22. These data provide information on the spatial patterns and trends of land use change and development densities and increase the transparency, accuracy, and plausibility of future urban growth forecasts. The U.S. Geological Survey has developed the Chesapeake Bay Land Change Model (CBLCM) to forecast future land use scenarios informed by historic patterns and trends in land use. This presentation will showcase how these new LULC data inform future land use scenarios produced with the CBLCM for the state of Delaware and how results can be used to inform environmental restoration and conservation strategies.

Vishwa Shah, Lalit Pal, Mahabub Arefin Chowdhury, Siddharth Saksena, Stanley Grant

Evaluating the Effectiveness of Integrated Hydrologic and Water Quality Models for predicting WQQ in Occoquan Watershed

Integrated or coupled hydrologic and water quality models are traditionally used for producing both short-term and long-term water quantity and quality (WQQ) predictions. In the era of climate change adaptation, the pivotal role of these models in the realm of efficient water resource management cannot be overstressed. These predictions are even more critical for locations like the Occoquan Watershed in Northern Virginia, which drains into the Occoquan Reservoir, a drinking water source for over a million people. This study presents a holistic evaluation of the factors such as physical process description, model structure, resolution, among others, that affect the performance of WQQ prediction models under the context of land use and climate change. This also includes understanding how different models predict the changes in WQQ variables such as streamflow, nitrogen-phosphorus concentrations, and total suspended solids due to changing land use patterns and climate projections. The assessment of these models uses a rich observational dataset spanning over ten years of daily observations of WQQ variables obtained through the Occoquan Watershed Monitoring Lab. This comprehensive evaluation currently contains the following models: The conceptual model "Génie Rural à 4 paramètres Journalier" (GR4J), characterized by reduced parameter complexity with only four adjustable parameters; and the physically based semi-distributed

model known as the Soil and Water Assessment Tool (SWAT). To fine-tune the flow parameters governing the behavior of GR4J and SWAT, we employ the Particle Swarm Optimization (PSO) algorithm. The PSO is a stochastic population-based technique harnessed with the aid of the R-package hydroPSO for GR4J and is inherently integrated into SWAT simulation engines. Additional models are being considered and will be subsequently added to the analysis. The broader impact of this study is to gain a better understanding of the model limitations and uncertainties under land use and climate change which is expected to ultimately lead to the development of a multi-objective integrated modeling framework for predicting WQQ in complex urban watersheds.

Shantanu V. Bhide, Stanley B. Grant, Ahmed Monofy, Hannah Whitley, Megan Rippy, Shalini Misra, Sujay Kaushal, Todd Schenk, Peter Vikesland, Vishwa Shah, Idowu Kayode Okeshola, Sydney Turner

Addressing the sodium surge: An interactive model to inform management decisions in the Occoquan Reservoir

The Occoquan Reservoir in Northern Virginia is an important drinking water source for over 1 million people and is also the country's first planned indirect potable reuse project for surface water augmentation. Rising sodium ion concentrations in the reservoir are a critical management challenge for stakeholders (e.g., water and wastewater utilities, government agencies) that operate in the Occoquan watershed, as sodium is not removed during production of drinking water from the reservoir. Sodium in the reservoir originates from a myriad of natural and anthropogenic sources (e.g., geologic and urban weathering, chemicals used in water and wastewater treatment, road salts, industrial discharges, sodium-rich household products, etc.). Understanding the origin, fate, and dynamics of different sodium sources and their relative contributions to sodium ion concentration in the finished drinking water sourced from the reservoir is critical information necessary to effectively manage rising salinization in the watershed. To that end, we developed a data-driven, computationally inexpensive, interactive pollutant transport (hydrologic + transit time) model that predicts daily sodium ion concentration in the Occoquan Reservoir up to the year 2100 based on various user inputs. The model incorporates user-defined scenarios of future climate (e.g., greenhouse gas emissions), human behavior (e.g., population growth, road salt use) and socio-economic development (e.g., land use changes, stormwater infrastructure) in the Occoquan watershed. As a pilot test, the model was deployed interactively during the Executive Committee on the Occoquan System's biannual meeting, where ~40 stakeholders explored different future scenarios for climate change, population growth, deicer use, land use change, etc., and assessed the impacts of various interventions on reservoir sodium ion concentration in a collaborative setting. The interactive model can potentially be a valuable tool for improving stakeholder collaboration and enabling informed decision-making in the management of sodium pollution at this site.

Cameron Smith, Alan Leslie, Benjamin Beale, Kelly Nichols, Shannon Dill, Sarah Hirsh, Jeff Semler, Andrew Kness, Emily Healey, Jack Keane, Marina Costa, Julie Yang, Raul Cruz-Cano, Rachel Goldstein, Andrew Lazur

The Presence of Total Coliforms and E. coli In Maryland Farm Private Drinking Water Wells

In 1974 the Safe Drinking Water Act was passed to improve drinking water quality and set a limit for acceptable contaminant levels as provided by the U.S. Environmental Protection Agency (EPA). However, the EPA does not regulate or monitor the drinking water quality of private wells. EPA estimates that over 23 million households in the U.S. obtain drinking water from private wells, including those on farms. The possible presence of contaminants in private wells poses a public health risk. Our team collected 86 water samples from farms with private wells located in seven regions across 20 Maryland counties to understand the risk of contamination for Maryland private well owners. We evaluated water samples for total coliform bacteria and Escherichia coli. We also determined the impact of well conditions, location, precipitation, and ambient temperature on the presence of bacteria in well water. Our preliminary results found that 41% and 9% of sampled wells were positive for total coliforms and E. coli respectively. A Fisher's Exact Test found that region, wellhead cover type, and well condition description were associated with the presence of these bacteria. These findings emphasize the importance of private well water testing. Future research should be conducted to evaluate the impact of failing septic systems on well water quality, especially as sea levels rise as a result of climate change.
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Joseph Delesantro, Thomas Butler

Estimating and projecting crop yields to inform watershed nutrient modeling

Yields of 23 major crops have increased by an average of 1.9 times since 1950 in the Chesapeake Bay watershed and have increased by up to 5 times for individual crops and counties. As crop yields increase, so does the demand for plant available nutrients. However, there is no watershed wide data source for nutrient application to cropland. To support the Chesapeake Bay Watershed Model, we estimated annual yields for 23+ crops accounting for greater than 95% of crop land N application from 1950 to present at the county level across the Chesapeake Bay watershed. We then applied trend analyses to estimate and project the yield which attracts nutrient application for each crop in each county and year. Multivariate linear models were fit to National Agriculture Statistics Service (NASS) Survey of Agriculture (annual) and Census of Agriculture (5-yr) yield data to generate gapless annual estimates of county level yields. The Chesapeake Bay Growth Regions, weather variables, climate stress metrics, and economic variables were significant predictors of crop yields explaining 72% of the variation in yields across crops, regions, and years. The addition of crop yield data as predictors from seven crop included in the Survey of Agriculture with near complete spatial and temporal data increased the model explanation to 88% of the variation in crop yields. Final model selection and trend analysis will prioritize spatially and temporally consistent results with input from regional experts.

Jonathan Craig, Patricia Delgado, Stephen MacAvoy, Barbara Balestra

Microplastic and Polycyclic Aromatic Hydrocarbons Concentrations in Patuxent River Watershed (Jug Bay Region), Maryland

Microplastics (particles less than 5mm in length) are an emerging pollutant of concern because of their potential to leach harmful chemicals into the environment and affect the health of different ecosystems. Polyaromatic Hydrocarbons (PAHs) are potentially toxic persistent organic pollutants that are produced via the burning of fossil fuels, and their presence in sediments can affect the health of the surrounding ecosystem life. Both pollutants in riverine systems, wetlands, and estuaries are not well studied together. The Jug Bay Wetlands Sanctuary located in Anne Arundel County Maryland is home to a variety of plant, aquatic life, and animal species. The Patuxent River flows through the sanctuary and eventually drains into the Chesapeake Bay. Microplastics and PAHs have not been studied in this area.
In this study, two sample locations, Station 1 (on the main stem of the Patuxent River) and Station 2 (on a tributary to the river), were used to collect two liters of water and water quality parameters for ten weeks total. Water samples were filtered and subsequently counted under a light microscope to detect microplastics. Sediment samples were collected at each sample station for weeks 1, 5, and 10. PAHs were extracted from the sediment samples using Soxhlet extraction and analyzed using GC/MS. The average microplastic concentration for Station 1 was 4.81 MP/L and for Station 2, 6.60MP/L. We didn’t find a statistically significant difference in the average microplastic concentrations between the two sample stations. However, some correlations between microplastic concentrations and water temperature, turbidity, and flow rate were detected. This research helped to provide a baseline for the presence of microplastics and PAHs in the Jug Bay wetlands sanctuary.