Session 20: Harmful Algal Blooms impeding restoration in the Chesapeake Bay watershed: From the Shenandoah River to tidal Freshwater to Estuarine Waters

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Photosynthetic pigment concentrations and taxonomic composition of benthic algal mats from Shenandoah River, Virginia

The Shenandoah River recently experienced benthic cyanobacterial Harmful Algal Blooms (HABs) in addition to historical proliferations of filamentous green algae. This resulted in the closure a of a 53 mile stretch of the North Fork of the river for much the summer in 2021. In 2022, the General Assembly appropriated funds to study HABs in the Shenandoah River basin. These studies are being funded through the Virginia Department of Environmental Quality in collaboration with the Virginia Department of Health. These studies will focus on the environmental factors that cause these HABs and management approaches that could prevent and mitigate their effects. During summer 2023, an in-depth study of benthic algal proliferations in river was initiated with the goal of characterizing the benthic algal and cyanobacterial composition. Quantitative benthic algal samples were collected monthly by personnel from the Interstate Commission on the Potomac River Basin from July through October from up to 10 sites across the North and South Fork of the river yielding a total of 27 samples. Chlorophyll a concentrations varied from 43-1422 mg/m2. We identified 16 filamentous cyanobacteria genera belonging to Oscillatoriales and 22 genera of green and charophyte macroalgae including Cladophora, Spirogyra, Hydrodictyon, Rhizoclonium, Oedogonium, and Ulothrix. Cyanobacteria were distributed in all sampling stations during all sampling events. The most common and abundant mat-forming cyanobacterial species, capable of producing a variety of cyanotoxins, were Microseira wollei, and species of Oscillatoria, Microcoleus, Phormidium, Geitlerinema and Anagnostidinema.

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Effect of different batch culture conditions on toxin production and growth of the riverine cyanobacterium Microcoleus anatoxicus

Microcoleus is a mat-forming benthic cyanobacterium recently recognized as an environmental problem in streams nationwide due to production of anatoxin-a (ATX), a neurotoxin implicated in dog deaths globally. However, environmental conditions stimulating its growth and toxin-production are little known. We cultured four unialgal, non-axenic strains determined by metagenomic analysis to be 99% ANI similar to Microcoleus anatoxicus Stancheva & Conklin isolated from the Russian River in 2015. This species initially produced ATX and higher concentrations of dihydroanatoxin-a (dhATX), but over time ATX production has become undetectable. We compared the growth and toxin-production of M. anatoxicus strain PTRS1 from the Russian River and strain RC9 from Rock Creek, both producing detectable dhATX during the experiment, to M. anatoxicus strains (SR16 and SR17), isolated from the Klamath River watershed which produced higher levels of ATX than dhATX. Strains were grown in batch monocultures for 46 days in liquid BG11 medium and reached stationary phase developing surface mats by day 30, with exception for RC9. The toxin production reached its maximum at day 13 for SR17 and at days 19 and 26 for the rest of the strains. Experiments with increased salinity concentrations showed maximum growth of M. anatoxicus in oligohaline waters with salinity of 4.6 ppt. Moderate salinity stress (up to 7.8 ppt) did not affect the growth and dhATX production significantly. In contrast, higher salinity above 9.3 ppt had a detrimental effect on cell growth and significantly suppressed dhATX production. M. anatoxicus grown for 40 days in nitrogen-deplete BG11 medium formed mats with significantly elevated dhATX, and slightly ncreased ATX concentrations. Morphological observations of storage granules, thylakoids and extracellular polysaccharide sheath were used to help understand trade-offs and energetic expense of toxin-production.

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Internal nutrient loading, the new climate, and cyanobacteria in four Linganore lakes, western Maryland

Four lakes outside of Frederick, MD comprise the aquatic systems of the Linganore community. Intense development typifies the area with approximately 6000 homes within the watersheds of the lakes, with croplands the dominant land use further upstream. The lakes are dominated by planktonic cyanobacteria, including toxic Microcystis and Planktothrix, and non-toxic Aphanizomenon with low standing stocks of phosphorus. A focus of recent work is estimating external and internal nutrient supplies, with the latter dominating availability of limiting phosphorus for these populations. Hypoxia/anoxia and high pH are two important drivers for phosphorus supplies, ensuring continuous production of the prokaryotes from late spring into fall, with occasional winter blooms as well. A concern is that these populations will expand even more as higher predicted temperatures select these taxa over sub-dominant eucaryotes. Fate of exported populations and toxins downstream remain unknown but may threaten drinking waters, public and wildlife health, and oxygen demand in the Potomac River and estuary, similar to multiple freshwater systems throughout the basin.

Judith O'Neil, Keller, S., Gurbisz, C., Landry, B., Hamilton, A., Wazniak, C., Owens, M. and Cornwell, J.

Growth of the cyanobacterium Microseira (Lyngbya) wollei in Submerged Aquatic Vegetation beds on Susquehanna Flats

The filamentous cyanobacterium Microseira (Lyngbya) wollei has been occurring in large densities as biphasic mats, first growing on the benthos, at the base of submerged aquatic vegetation (SAV), and then subsequently overtopping plants. This leads to the proliferation of floating mats that can shade the SAV on the Susquehanna Flats, in the northern portion of the Chesapeake Bay. Recently it has been determined that these mats contain the paralytic shellfish toxin (PST) saxitoxin. The fact that these large mats can transport potentially toxic biomass to other portions of the bay is of concern for management. After disappearing in the 1970s due to Hurricane Agnes, the SAV beds on the Susquehanna Flats are now the largest and most diverse in the Chesapeake Bay. This SAV bed acts as an important seasonal nutrient sink, which is important given the large particulate nutrient load delivered to the Chesapeake Bay from its largest tributary. Since approximately 2004, Microseira (Lyngbya) wollei has been observed every summer proliferating over the SAV. This is potentially problematic, as overgrowth of cyanobacteria can lead to reduced light availability and inhibited gas exchange, which ultimately decreases photosynthetic rates of the aquatic grasses and increases sediment anoxia and nutrient fluxes. Consequently, the severity of cyanobacteria coverage can be strongly related to changes in sediment biogeochemistry, SAV losses and seabed stability. The growth of this nitrogen fixing cyanobacteria seems to be enhanced by phosphorus obtained from the sediment. This proliferation may threaten SAV recovery and resilience. Therefore, we are investigating how these cyanobacteria are functioning in this system and what controls the dynamic interplay between cyanobacteria and SAV dynamics in terms of biogeochemical processes.

R. Christian Jones, Hannah Toney

Microseira wollei Studies in the Tidal Occoquan River in 2023: Growth, Toxin Production, and Epiphytes

The filamentous, toxin-producing cyanobacterium Microseira wollei (Farlow ex Gomont) G.B. McGregor & Sendall has been observed over the last several years in numerous locations in the tidal freshwater reaches of the Chesapeake Bay including the tidal freshwater Potomac. For the last several years it has appeared in substantial numbers in the tidal Occoquan River. My students and I have conducted various sampling programs trying to understand its dynamics. In 2023 we devised a very structured sampling plan to follow the development of the bottom mats starting in early May and continuing through early August. We established two transects, one parallel to shore and one perpendicular to shore in an area that had experienced abundant M. wollei growths in the past. At each site three ponar samples were collected from which 5 cores were extracted with a 3/8 inch diameter cork borer. These were returned to the lab and rinsed through a 0.5 mm sieve. Extraneous material like detritus, plant fragments, and small snails were removed from the sieved material which at that point was mainly M. wollei filaments. These were then filtered through GF/F filters for chlorophyll a determination. Chlorophyll levels increased some in the spring and were greatest at intermediate depths, but the expected robust growth of M. wollei did not occur in this area as we followed it into July and August. We were able to examine some of the filaments in floating and suspended mats and found significant concentrations of saxitoxin in May as well as a rich epiphyte community growing on its sheaths. We did find a few scattered areas where there were mats apparently had been growing more profusely so those could have provided a source for the floating and suspended mats. We will use these results to inform future studies.

Mary LePere, Dr. Victoria Hill

Using Planet Satellite Imagery to Map and Quantify Harmful Algal Blooms in Chesapeake Bay Tributaries

This project utilizes 8-channel Planet satellite imagery to map and quantify harmful algal blooms (HABs) within Chesapeake Bay tributaries. Planet satellite imagery can capture the spatial extent of blooms at daily and sub daily temporal resolution, and the 3 m resolution resolves the high spatial heterogeneity often observed in HAB distribution. All cloud free images of the Lafayette River in Norfolk, VA from 2021 through 2023 were used to generate seasonal maps of HAB extent and concentration. HAB presence was identified based on the Normalized Differential Chlorophyll Index (NDCI) calculated using the red and rededge spectral bands, and then transformed to chlorophyll concentration using an algorithm created for shallow, turbid coastal environments. Bloom threshold was set to chlorophyll greater than 50 mg m-3.
Blooms were found to occur in the Lafayette River between the months of May and September, with mean bloom coverage of 0.16 km2, and mean maximum chlorophyll of 672 mg m-2. Bloom area and concentration were greatest between the months of July and August. While blooms were present every spring/summer between 2021 and 2023, bloom extent has appeared to be highest in 2021 and has decreased each year since then. Bloom extent has declined while intensity has increased, blooms appear to be increasing in concentration per area.
Planet's high-resolution, high-frequency imagery captures the entire scope of coastal HABs and highlights areas where blooms may not be seen by traditional methods of data collection. This project offers a promising framework for ongoing efforts to monitor and mitigate the impacts of HABs in coastal ecosystems.

Richard Hale, Adriana Amrhein, Amber Tymul, Margie Mulholland

Linking sediment resuspension to harmful algal blooms in the lower Chesapeake Bay

Harfmul algal blooms (HAB) are an increasingly common occurrence in estuaries including the Chesapeake Bay, despite extensive restoration and remediation efforts. Understanding the conditions that result in HAB formation is a critical first step in mitigating against their deleterious impacts. Eutrophication has long been discussed as an important driver of bloom activity, with urban infrastructure and agricultural runoff identified as important point sources for nutrients. In this study, we examine sediment resuspension in a shallow microtidal estuary connected to the lower Chesapeake Bay, and address the role that this process might play in initiating and accelerating HAB activity.

Our field site, the Lafayette River in Norfolk, VA, has been identified as a particularly important location for HAB initiation. In our multi-year field program, acoustic Doppler current profilers, high-frequency pressure sensors, and optical backscatter sensors have been deployed in multiple locations to monitor tidal currents, wave characteristics, and suspended sediment conditions. These observations complement a monitoring program measuring temperature, salinity, chlorophyll-a, nutrient concentrations, and dinoflagellate species abundance. Collectively, we have identified that physical resuspension of benthic material frequently results in increased nutrient concentrations, with increased algal productivity following in 3 to 5 days. Interestingly, we observe a similar number of instances where blooms either accelerate or are diminished, seemingly as a response to sediment resuspension. In these cases, we surmise that water-column mixing and enhanced resuspension work to decrease light availability, leading to the termination of bloom activity. Subsequent research will focus on the cumulative effect of multiple resuspension events, and whether many small events are more (or less) likely to initiate HAB activity than a single major resuspension event.

Adriana Amrhein, Rip Hale, Margaret Mulholland, Joseph Tamborski

How wind-induced sediment resuspension influences harmful algal blooms within a shallow tidal tributary of the Chesapeake Bay

Despite extensive restoration efforts, harmful algal blooms (HABs) are becoming more frequent and severe in the Chesapeake Bay and its connected tributaries. One possible explanation for the unrealized restoration efforts is the introduction of nutrients to the water column through wind-induced sediment resuspension. In this study, we examined the role of sediment resuspension in supplying nutrients to the Lafayette River in Norfolk, VA, which has been identified as a hot spot for the initiation of Margalefidinium polykrikoides blooms that can extend into the southern Chesapeake and the Atlantic Ocean. Quantifying these loads have been elusive because sampling excursions must be timed with resuspension events.
In summer 2023, we deployed acoustic and optical sensors to monitor resuspension events in the estuary. Water samples were also collected at multiple locations throughout the Lafayette to characterize the impact of wind events on water quality. We also collected surface grab samples and sediment cores to assess the nutrient content of the sediment and estimate diffusive and advective benthic flux to the water column.
Using the ratio of 224-Ra to 228-Th in core sediments, we observed disequilibrium (i.e., interaction with overlying water column) in the top 4-10 cm, depending on location. Corresponding NH4 fluxes ranged from 5 ± 1 μmol/m2/d to 107 ± 27 μmol/m2/d over these depth horizons. Sand content appears particularly important for controlling disequilibrium, depth of flushing and nutrient flux, as our mud-dominated site showed the lowest fluxes. A wind event in July resulted in increased wave heights and resuspended sediments, which lead to increased NH4 concentrations in the water column. While this did not initiate a HAB in 2023, future research will examine the implications of this additional nutrient source.

Dante M. L. Horemans, Marjorie A. M. Friedrichs, Pierre St-Laurent, Raleigh R. Hood, Christopher W. Brown

Unraveling environmental factors controlling harmful algal blooms in the Chesapeake Bay using generalized linear models

Forecasts of harmful algal blooms (HABs) are needed to mitigate risks associated with HAB presence. A crucial step in constructing correlative models for HAB forecasting is identifying the main environmental factors leading to HABs. The complex and often unknown reasons for their presence makes this challenging, as the interplay and correlation between physical and biogeochemical factors driving HABs increases model parameter uncertainty. Additionally, although correlative HAB models are typically developed using in situ observations, they are commonly applied using environmental information simulated by hydrodynamic models, further increasing errors in model parameterization. To better understand the uncertainty introduced by applying correlative models constructed with in situ observations, we trained generalized linear models (GLMs) to predict seven (mostly harmful) algal taxa commonly observed in the Chesapeake Bay using different types of training information (i.e., in situ observations or hydrodynamic model output). We then identified the main environmental factors causing HABs, and studied their associations with HAB probability. To determine how correlations between nineteen environmental factors and a mismatch between environmental hydrodynamic model output and in situ observations affect our HAB predictions, we removed environmental variables that surpass a specific correlation threshold and train new GLMs using hydrodynamic model output. We found that using these different types of training information hindered the detection of key environmental predictors of HABs. However, strong positive or negative associations between environmental variables and bloom occurrence did not considerably change. Water temperature was always selected as an important predictor of HAB presence and blooms of some taxa (e.g., Prorocentrum minimum and Heterocapsa rotundata) were associated to similar environmental conditions, making it challenging to attribute some blooms to a specific taxon. Our results are of critical importance as identifying the key environmental predictors of HABs is essential not only to constructing HAB models, but also to optimizing monitoring campaigns.

Margie Mulholland, Eileen Hofmann, Peter Bernhardt, Leah Gibala-Smith, Marjy Friederichs, Pierre St-Laurent, Kim Reece, Willy Reay, Suanna Musick, Mary Ford, and Shelly Tomlinson

Enhanced surveillance to improve HAB monitoring and detection: toward an early warning system for HABs in the lower Chesapeake Bay

Destructive blooms of the ichthyotoxic harmful algal bloom (HAB) species Margalefidinium polykrikoides, have occurred nearly annually in late summer in the lower Chesapeake Bay and mid-Atlantic coastal waters for decades. Since 2007, M. polykrikoides blooms have been succeeded by blooms of Alexandrium monilatum. Blooms have been linked to eutrophication and warming temperatures and contribute to regional hypoxia/anoxia, and finfish and shellfish mortality. Through previous research, bloom initiation hotspots were identified, transport pathways from initiation sites established, and models for bloom development and transport implemented. Networks for bloom detection and monitoring that include fixed station sampling, underway “DataFlow” sampling from boats, and satellite surveillance are in place and we are setting up enhanced enhanced surveillance systems through deployment of low-cost, high throughput, phytoplankton imaging PlanktoScopes. Results will advise state-of-the-art estuarine forecast models, that will be leveraged to build an operational forecast system for M. polykrikoides and A. monilatum blooms in the mid-Atlantic region and that will be accessible to stakeholder groups in near real time through the Chesapeake Bay Environmental Forecasting System (CBEFS) and MARACOOS' OceansMap portal. This presentation will describe this project, its evolution and the pathway to building monitoring and observational networks to support the national HAB observing network (NHABON).