Chesapeake Community Research Symposium 2026

Session 24: Phytoplankton Dynamics in Chesapeake Bay: Analysis, Methods and Models

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From lab to space: Co-developing a regional prototype for a National HAB Observation Network (NHABON) in Chesapeake Bay

High frequency monitoring through satellite remote sensing has been beneficial in protecting public and environmental health in several key US waterways. In most instances, the success of these tools relies on strong optical signatures of high biomass Harmful Algal Bloom (HAB) species. Available algorithms from multi-spectral ocean color sensors use fluorescence or bulk Chl-a to estimate phytoplankton abundance, but provide no information on whether a bloom is likely to be harmful. Some nearly monospecific blooms, like Karenia brevis along the Gulf Coast and cyanobacteria in freshwater lakes worldwide, dominate their environment at certain times of the year, making them readily identifiable with optical satellites. In contrast, blooms in the Chesapeake Bay form year-round and are often characterized by dense, multi-species assemblages, making identification with remote sensing difficult. In both cases, regional forecasts still rely on state and volunteer monitoring programs to quantify phytoplankton abundance and verify species identification. Neither remote sensing nor in situ monitoring alone can give a comprehensive picture of bloom geographic distribution and phytoplankton composition, both of which are critical to assess HAB risks and potential management decisions.

In the Chesapeake Bay, no comprehensive data portal to support real-time monitoring and forecasting of HABs currently exists. In situ data on phytoplankton species and abundance are often collected by state management programs or academic institutions, and not readily available Bay-wide to support real-time monitoring and forecasting. Combining in situ datasets, satellite imagery, and volunteer monitoring observations from NOAA's Phytoplankton Monitoring Network and the MERHAB-funded Planktoscope Network in a single data portal maintained on MARACOOS OceansMap can successfully harness the benefits of each. More accurate real-time monitoring and improvements to ecological models can enhance early warnings of HAB events, minimizing potential impacts. Advances towards the co-development of a regionally focused prototype for a National HAB Observation Network (NHABON) will be presented.

Isabella Chandler (Old Dominion University), Victoria Hill

Using Planet Labs Satellite Imagery to Track Winter Harmful Algal Bloom Events

Harmful algal blooms (HABs) are well-studied events in the Chesapeake Bay. HABs are sampled monthly during summer with reduced sampling during the winter. Winter monitoring is reduced because HABs are assumed to be absent during colder months. Dense winter blooms deplete oxygen, leading to hypoxic conditions that disrupt aquatic ecosystems and affect juvenile fish's survival. Sampling has shown that blooms of Heterocapsa (a dinoflagellate) can occur in the Lafayette, Elizabeth, and Nansemond rivers from January to April. Planet Lab satellite imagery enables high-resolution mapping of bloom timing, intensity, and spatial distribution. Planet's cube satellites allow for daily high-resolution (3m) imaging, with 8-bands located between coastal blue and near infrared. Satellite imagery captures the full spatial extent of heterogeneous blooms, which in-situ sampling misses. Mapping of a Heterocapsa bloom in the Elizabeth and Nansemond Rivers in 2024 captured winter blooms starting March 11th and persisting for ten days. The bloom grew from 0.3 km^2 to over 4 km^2 in one day then declined over a week. Area-specific chlorophyll peaked at 83 kg/km^2 on the fourth day of the bloom. The bloom in the Elizabeth Rivers maximum spatial extent preceded peak intensity by two days, suggesting that horizontal expansion of the bloom occurred prior to peak phytoplankton growth and biomass accumulation. This project addresses a critical gap in our understanding of winter HABs by generating satellite-based maps to assess spatial distribution, timing, and collecting in-situ sampling. Combining satellite data and in-situ measurements will allow existing HAB detection algorithms to be tested, validated, and refined to enhance their accuracy for winter conditions. This work will contribute to a more complete understanding of bloom dynamics and their ecological impacts on the Lafayette, Elizabeth, and Nansemond Rivers.

Khari Crommarty (Old Dominion University)

Mapping the Risk of High Chlorophyll & HAB events in the Chesapeake Bay

Eutrophication in the Chesapeake Bay, exacerbated by human activities such as agriculture and wastewater treatment, poses significant challenges to water quality, primarily through the proliferation of harmful algal blooms (HABs). HABs, predominantly caused by dinoflagellates, occur seasonally in Chesapeake Bay tributaries, driven by nutrient-rich runoff. In-situ monitoring efforts, though in place, suffer from limited temporal and spatial coverage which results in the failure to capture short-term bloom events. Additionally, cryptic species and rapid bloom intensification further complicate monitoring efforts. Due to these limitations of in-situ monitoring, the use of satellites has become integral in detecting blooms. Satellites allow for almost real time, large-scale, and long-term monitoring of identified bloom hotspots. This project analyzed data collected from 2021-2023 within the Rappahannock River. This area was selected due to it experiencing annual blooms and it being frequently sampled for water quality data via ship cruises and continuous monitoring stations. PlanetScope satellite imagery was chosen due to its daily repeat frequency, high spatial resolution (3 meters) and 8 band spectral characteristics.

Chlorophyll concentrations were extracted from satellite imagery with an algorithm then compared to in-situ observations to evaluate their agreement in detection. Current findings of this work suggest that HABs were most intense in Spring 2021 among the study years, with blooms gradually decreasing in frequency each year thereafter. Additionally, blooms did not consistently display their highest chlorophyll concentrations in the same section of the Rappahannock river across the seasons or years. However, it can be observed that more intense blooms are occurring later in the year as time progresses which could be due to warming trends delaying or extending the growing season for phytoplankton.

Xin Yu (RPI, under contract to NOAA), Michelle C. Tomlinson

A short-term harmful algal bloom (HAB) forecasting system for the lower Chesapeake Bay

Recent advances in satellite remote sensing technology for detecting harmful algal blooms (HABs) make it possible to combine numerical modeling approaches and satellite imagery to track and predict HABs in estuarine and coastal waters. We employed an offline particle-tracking model coupled with a high-resolution hydrodynamic model to simulate HAB mixotrophic growth, respiration, and vertical diurnal migration, and predict the spatial distribution and temporal evolution of Margalefidinium polykrikoides blooms, which occur almost annually in the lower Chesapeake Bay, USA. Particle release location was identified using a fluorescence-based, red band difference (RBD) satellite algorithm while particle density was inferred from chlorophyll-a concentrations which were both obtained from Ocean Land Colour Imager (OLCI) satellite imagery. This model framework has been tested and validated for M. polykrikoides blooms in the York River, James River, and lower main-stem of the Bay from 2018 to 2023. The short-term (1-5 day) HAB satellite model forecast system was first deployed in real-time development mode for the past two summers (2024, 2025) to a select group of key stakeholders to track the location of dense M. polykrikoides blooms over the bloom season (~Aug.-Sep.). Following stakeholder feedback, the forecast system will be used to issue public-facing, real-time short-term HAB forecasts. We will discuss the advantages, limitations, and future direction of this developed HAB forecasting system.

Dante M. L. Horemans (Virginia Institute of Marine Science), Pierre St-Laurent, Marjorie A. M. Friedrichs, and Margaret R. Mulholland

Environmental controls on interannual Margalefidinium polykrikoides blooms in the Lafayette River

Margalefidinium polykrikoides is a mixotrophic dinoflagellate that exhibits strong interannual variability in the lower Chesapeake Bay, with intense blooms occurring in some years and complete absence in others. The mechanisms driving this variability, as well as bloom initiation and decay, remain poorly understood. Resuspension of resting cysts and temperature have been hypothesized as potential triggers for bloom initiation; however, although temperatures in

late September are often suitable for growth, blooms are not always observed at that time, suggesting the influence of additional, yet unidentified mechanisms. In this presentation, we systematically identify potential drivers of the interannual variability of M. polykrikoides by combining in situ cell count observations, results of novel laboratory experiments quantifying growth sensitivity to salinity and temperature, and numerical modeling. Specifically, we pair over 1,000 in situ cell count observations from the Lafayette River (2015-2023) with environmental conditions, including temperature, salinity, and precipitation, derived from continuous output of a 3D coupled hydrodynamic-biogeochemical model. This integrated approach yields a continuous dataset of M. polykrikoides abundance and associated environmental conditions, which we use to develop a predictive machine-learning model that both forecasts bloom occurrence and identifies key environmental drivers. We also apply the model to create spatial maps of the Chesapeake Bay in which we identify regions without direct observations that are likely bloom hotspots. Our results provide new insights into the environmental controls on the initiation, decay, and interannual variability of M. polykrikoides blooms. These findings can optimize monitoring campaigns, guide experimental design and focus, support management efforts aimed at mitigating harmful algal bloom impacts, and improve the representation of M. polykrikoides dynamics in numerical models.

Allen R. Place (Institute of Marine and Environmental Technology, University of Maryland Center for Environmental Sciences)

Karlodinium veneficum - The little dinoflagellate with a big bite is missing?

In the summer of 1997, Maryland was held captive by a single-cell microbe called Pfiesteria piscicida, which was reportedly implicated in killing more than 30,000 fish and sickening more than three dozen people in Maryland’s Pocomoke River. However, Karlodinium veneficum, which was present in the Potomac in 1997 prior to the fish kill, has been shown to produce water-soluble toxins to capture prey, which also kill fish by disrupting gills. The toxins have not only been isolated from laboratory cultures but also from water samples collected at the sites of fish kills, and their structures have been determined. Recent model simulations (Li et al. 2022) showed that K. veneficum blooms occurred during June-August and were confined to the upper and middle Bay, consistent with long-term field observations. Autotrophic growth dominated in spring, but heterotrophic growth dominated during the summer. Blooms of K. veneficum can be terminated by infection by a species-specific parasite, Amoebophrya sp. ex Karlodinium veneficum. While blooms of K. veneficum were frequent in the Baltimore Harbor, they have largely been absent for the last 5 years. We will examine possible environmental changes that have occurred, responsible for this species’ absence in the harbor.

Danyang Zhai (Virginia Institute of Marine Science), Jian Shen

Primary production in Chesapeake Bay: Spatial and Temporal Patterns Using Open Water Method

Gross primary production (GPP) is widely used to characterize ecosystem productivity and water-quality response, yet traditional incubation and bottle-based measurements are limited in spatial coverage and temporal continuity. The Chesapeake Bay buoy network provides long-term, high-frequency dissolved oxygen and chlorophyll observations that enable whole-system metabolism estimates from in situ data. Here we apply the open-water diel oxygen method to 15 years of buoy records to derive long-term time series of GPP and net ecosystem production (NEP). The resulting records resolve spatial and seasonal variability in metabolic rates across stations. We evaluated multiple methods and applied the necessary corrections to estimate GPP, ensuring that both the magnitude and seasonal structure of the estimates are consistent with previously reported laboratory and model-based results. Multi-year NEP series are further analyzed against nutrient loading indicators and environmental forcing variables. The results provide sound information for understanding how metabolic processes respond to loading variability and physical conditions. This observation-based open-water framework provides a scalable approach for long-term productivity assessment and model evaluation in estuarine systems.

Margaret R. Mulholland (Old Dominion University), Eileen Hofmann, Peter Bernhardt, Megan Ladds, Jessica Kellner, Chyna Laws, Marjy Friederichs, Pierre St-Laurent, Dante Horemans, Savannah Mapes, Kimberly Reece, Willy Reay, Susanna 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. 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 have set up enhanced surveillance systems through deployment of low-cost, high throughput, phytoplankton imaging PlanktoScopes. Results are being used to advise state-of-the-art estuarine forecast models for M. polykrikoides in the mid-Atlantic region 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’s progress, its evolution and the pathway to building monitoring and observational networks to support the national HAB observing network (NHABON).

Kami Lentzsch (MD DNR/Chesapeake Conservation and Climate Corps), Amy Hamilton, Catherine Wazniak and Beth Larson

Evaluating FlowCam Precision for Reliable Phytoplankton Assessment in the Chesapeake Bay

The role of Maryland Department of Natural Resources’ Phytoplankton Laboratory is to characterize routine and investigatory water and algal samples, with one objective being to monitor for Harmful Algal Blooms (HABs). HABs have the capacity to be detrimental to human, animal, and ecosystem health. In 2024, the Maryland Department of Natural Resources purchased a FlowCam Cyano, a laboratory instrument that combines particle analysis with automated flow cytometry and microscopy. The instrument is able to operate in two modes: auto-image and trigger mode, which uses fluorescence to prompt capture of images. FlowCam users must create image libraries and classification filters for target phytoplankton genera. Precision assessments of these tools generated for three algal species: Akashiwo sanguinea, Levanderina fissa, and Thalassionema nitzschioides, were conducted at six stations sampled March-October 2025. The stations were located throughout the Bay (mainstem Chesapeake Bay, Eastern Bay, Patuxent, Potomac, and South Rivers). All four combinations of magnification and image capture mode were tested. Classification results using FlowCam were compared to traditional microscopy counts (total n=589). Results of this assessment showed that 10x auto-image mode yielded the best results overall with r^2 from 0.63 to 0.97. Trigger mode is expected to be more accurate for cyanobacteria assessments, with that analysis ongoing. An end goal is to make validated image libraries available to the Chesapeake Bay community.

Catherine Wazniak (MD Dept of Natural Resources), Jeremy Testa

Benthic Microalgae in the Chesapeake Bay

Benthic microalgae (BMA) are a significant component of coastal ecosystems. BMA are major contributors to primary production, biogeochemistry and food webs in estuaries but are often overlooked in system production estimates. In the Chesapeake Bay limited data on benthic chlorophyll exists. New benthic chlorophyll data was collected annually in conjunction with Maryland's long term benthic macroinvertebrate monitoring from 2021 to 2025. Five years of fixed station data at 26 stations and one year of randomly selected stations (n=88) across the MD portion of the Chesapeake Bay. Active benthic chlorophyll concentrations ranged from 5.3 to 694 mg/m² and had an average of 56.2 mg/m² and pheophytin concentrations ranged from 18.9 to 300.3 mg/m² with an average of 167.9 mg/m². Results showed significant spatial variability and annual change. These new data are placed in the context of historical measurements made across Chesapeake Bay, its tributaries, and the nearshore shelf. Relationships of benthic

microalgae to sediment type, salinity, and region are investigated for future incorporation into the Chesapeake Bay model.