HABs in the Delta

Information Sheet

Delta Science Program
DELTA STEWARDSHIP COUNCIL

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- Harmful algal blooms (HABs) are the overgrowth of microalgae caused by a combination of environmental conditions.
- HABs can adversely affect human health, wildlife, and the environment by producing toxins and degrading water quality.
- Understanding HAB development in the Sacramento-San Joaquin Delta is a challenging process, as drivers are not currently monitored to understand the likelihood of blooms or reoccurring blooms.
- The Delta Stewardship Council's Delta Science Program is hosting a workshop to inform the development of a Delta-region-specific HABs Monitoring Strategy for monitoring, modeling, and addressing current knowledge gaps.

Defining HABs

HABs are large masses of microalgae, a diverse group of photosynthetic aquatic organisms that can cause serious harm to animals, humans, and the environment. Some blooms are visually detectable as they cause discoloration on the water surface and appear to have a scum texture. They can also be less visible as they float within the water column or settle on the bottom of a water body.

In the Sacramento-San Joaquin Delta (Delta), the most common HABs are cyanobacterial HABs (cyanoHABs). Cyanobacteria (also called blue-green algae) form cyanoHABs in many freshwater ecosystems across the globe. Such HABs are a leading management and research concern due to their ability to take advantage of certain environmental factors and quickly multiply throughout the water body where they can produce harmful toxins (cyanotoxins) and degrade water quality.

The Delta watershed spans nearly 500 miles and supplies a portion of the water used by two-thirds of Californians. Thus, cyanoHABs in the Delta are a water quality and public health issues of statewide relevance. Ensuring good water quality by preventing and managing negative consequences from HABs is important for drinking water supplies, recreation, and other uses of Delta water.

Most Common HABs in the Delta

In the San Francisco Estuary (SFE) there are diverse marine, brackish, and freshwater HABs. For example, the recent bloom in the San Francisco Bay in August 2022 was a bloom of the species *Heterosigma*, but in the Delta the blooms are generally cyanobacterial and dominated by *Microcystis aeruginosa.* Although *Microcystis* is the most common HAB in the Delta and has garnered much attention, other cyanobacterial taxa also occur, including *Anabaenopsis, Aphanizomenon, Dolichospermum, Lyngbya, Phormidium, Planktolyngbya, Planktothrix, Oscillatoria.* Of these taxa, *Dolichospermum* and *Aphanizomenon* have been documented in high abundances (Kudela et al., in press).

The information included in **the preworkshop materials largely pertains to cyanobacteria HABs, which are of the greatest concern for the Delta**. For the greater SFE, the HABs of concern also include *Pseudonitzschia, Alexandrium, Dinophysis, Akashiwo, Karenia, Karlodinium, Heterocapsa,* and *Heterosigma.* We could not include information for all these HABs in this document, yet some information included here may lend itself to a monitoring strategy for the greater SFE.

Photo by Janis Cooke, CVRWQCB (Stockton Waterfront)

Timing and geography of HABs in the Delta

HABs in the Delta have been documented every year, with the warmer months of the year having the highest prevalence of cyanoHABs occurrence. Without adequate baseline monitoring, it is challenging to know where and when HABs will occur in advance of bloom development; however, blooms occur throughout the SFE. The California State Water Resources Control Board funded the San Francisco Estuary Institute (SFEI) to build a web interface (fhab.sfei.org/) that uses satellite imagery provided by the National Oceanic and Atmospheric Administration (NOAA) to assist with cyanoHAB monitoring in the Delta. The satellite map depicts estimated amounts of cyanobacteria in large water bodies. Subsequent field testing is required to confirm the presence of cyanoHABs in the body of water and generate the appropriate management actions (Satellite CyanoHAB Map, CWQCB), Unfortunately, the NOAA imagery cannot be used across the entire Delta because the resolution of the satellite product is incommensurate with the scale of narrower channels of the Delta where HABs occur. Improvement of satellite products and satellite-based analyses of HABs events is an area of research opportunity for advancing the monitoring of Delta HABs.

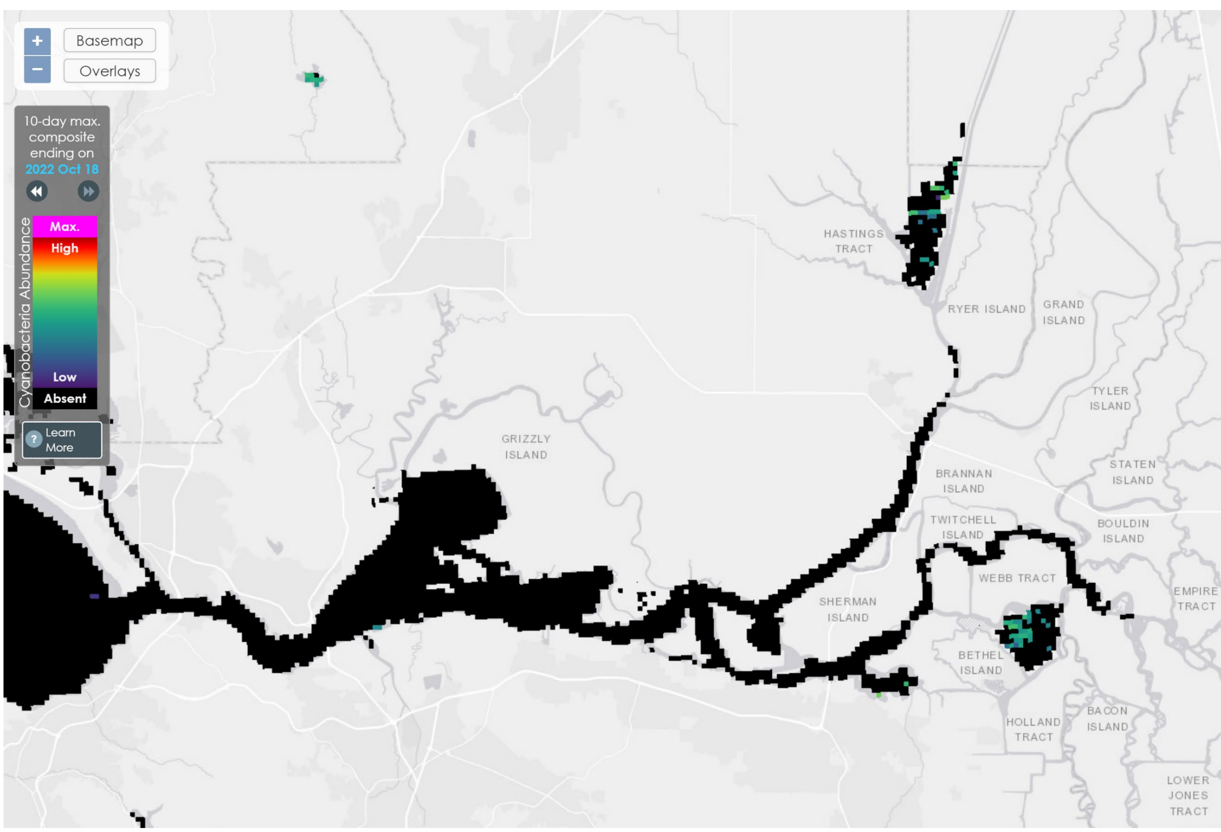


Figure 1. Screenshot of SFEI FHAB Monitoring tool captured on October 19, 2022

Drivers of HABs

Controls and drivers of HABs are understood to a moderate extent, and major environmental conditions creating cyanoHABs in the Delta can be seen in the two conceptual models developed for this workshop. The following drivers and controls are further expanded in Kudela et al., in press.

Water Temperature

The growth of all microalgae is temperature dependent. Temperature often serves as a driver of the abundance of HAB-forming organisms, but the effect is mixed and often species-specific. The optimal growth rate for many HAB-forming cyanobacteria occurs at higher temperatures (20-25 degrees Celsius) than other algae. However, marine HAB organisms may perform poorly or cease growth in warm conditions.

Salinity

Salinity gradients exert strong control over where HAB-forming organisms can be found in the SFE. Typically, marine HABs are dominated by diatoms, and dinoflagellates and can only successfully colonize areas with marine or brackish salinity (~10-33 PSU). Cyanobacterial HABs are more frequently found as blooms in the low-salinity (<10) upper SFE, or Delta. Despite these generalities, salinity boundaries are variable, and HAB-forming organisms can be found in salinities outside their usual range (Kudela et al, 2020, Preece et al., 2017).

Light

Light intensity is a major driver for HAB-forming organisms, many of which require the right amount of light—not too little and not too much. Many algae have developed evolutionary methods to achieve ideal light availability. Cyanobacteria often have air-filled vacuoles to provide buoyancy to remain suspended in the water column where light is more abundant. Some marine HABs have flagella enabling them to swim and relocate throughout the water column.

Nutrients

Nutrient concentration and type can drive the development of algal blooms. However, high nutrient conditions do not always lead to the development of blooms, as primary production is often low in the SFE despite being a high-nutrient system. However, when any phytoplankton blooms occur, nutrients are drawn down, and periods of nutrient limitation can occur.

Stratification

Stratification occurs when the vertical mixing of the water column is reduced and distinct layers form within the water. When mixing decreases and stratification develops, algal cells can sink into deeper and darker waters, where they grow slower or are removed from the surface layers. However, because many cyanobacteria are buoyant, they are not negatively impacted by stratification and weak mixing like many other algal species. In contrast, weak mixing enables cyanobacteria to accumulate at the surface and form surface scums. Where mixing is high and waters are flushed, bloom-forming algae surface scums and aggregations are broken up. Additionally, for flagellated organisms such as *Heterosigma*, stratification allows organisms to access light and nutrients more easily without being transported away.

Residence Time

Long water residence time (i.e., the length of time water remains in one area) allows slow-growing algae such as *Microcystis* sufficient time to form a bloom. Hence, cyanobacteria often aggregate in areas with reduced flow and high residence time.

Conceptual Model

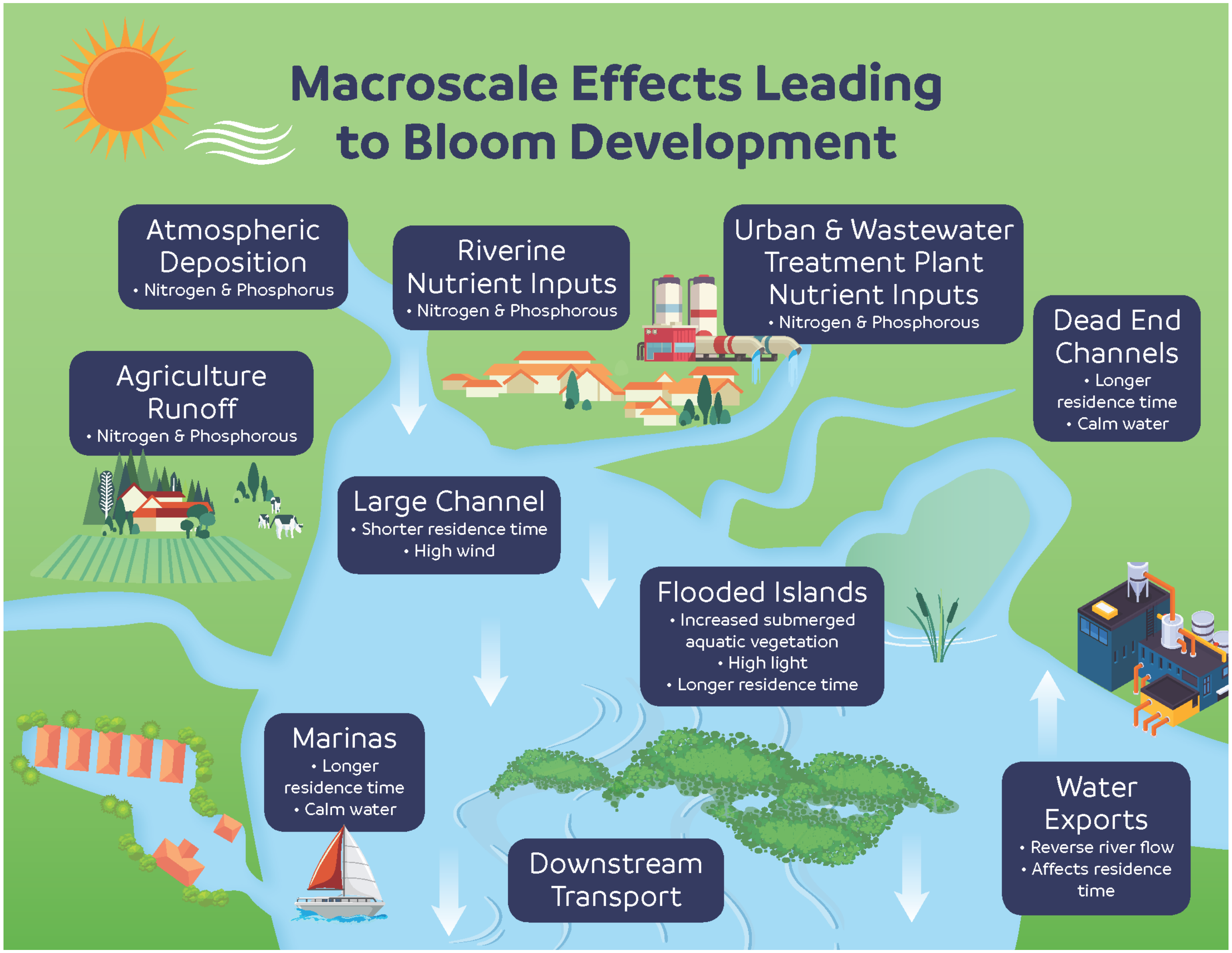
Creation of models informed by Jenna Rinde[1], Keith Bouma-Gregson[2], Janis Cooke[3], and Tricia Lee[4]

The following two conceptual models demonstrate the environmental conditions, processes, and impacts involved in the development of harmful algal blooms (HABs).

[1] California Department of Fish and Wildlife
[2] U.S. Geological Survey
[3] Central Valley Regional Water Quality Control Board
[4] Delta Science Program

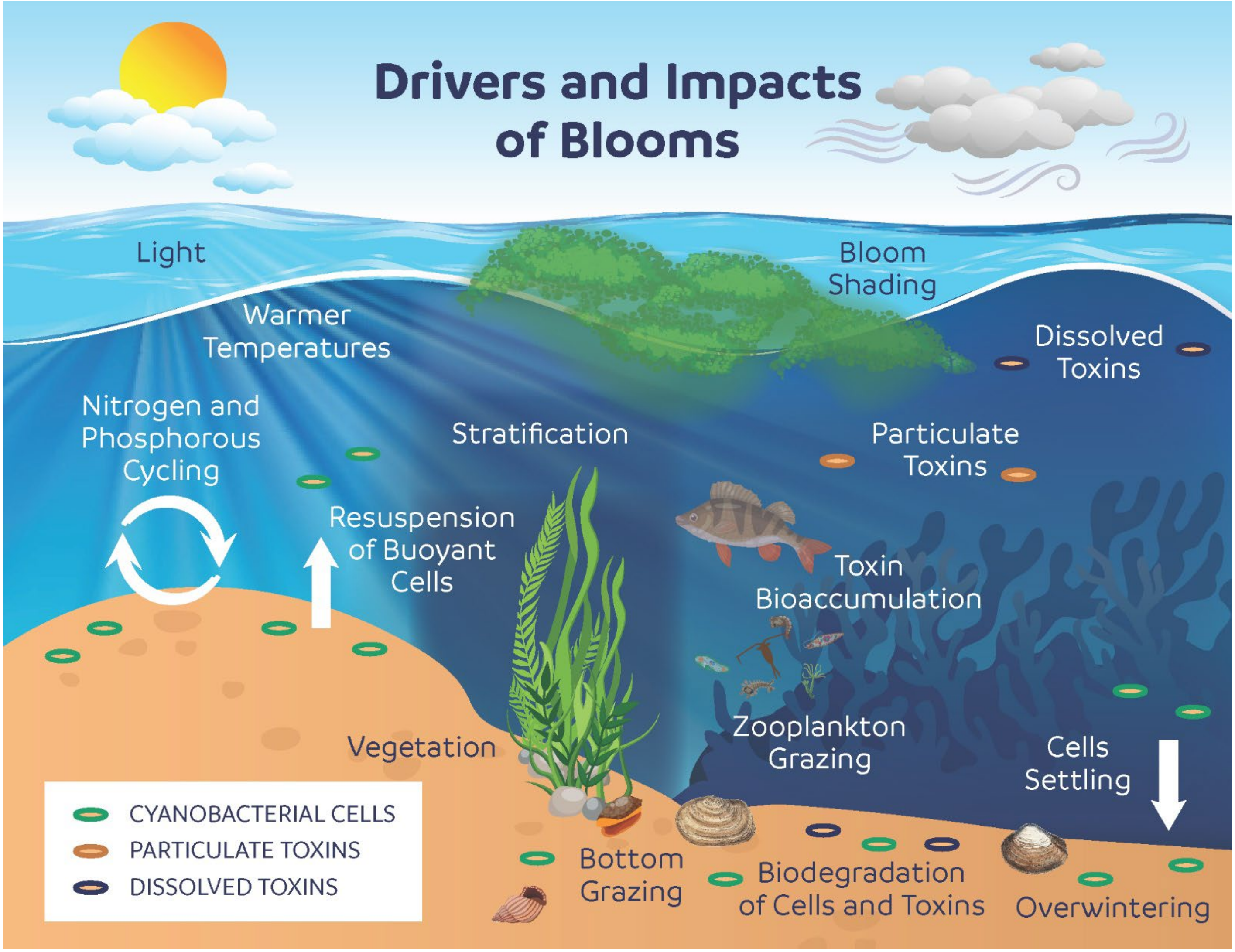
Model One: Macroscale Effects Leading to Bloom Development

Natural and anthropogenic drivers for HAB development in the Delta include nutrient loading of nitrogen and phosphorus from various sources. Landscape features that protect waterbodies from wind and water flow influences on water residence time and stratification also affect bloom development as seen in the different waterbody types.



Model one: Conceptual model depicts the macroscale effects leading to HAB development in the Delta.

Model Two: Drivers and Impacts of Blooms



Model two: Conceptual model of the environmental drivers of HABs and the toxins produced by the blooms.

Major drivers of HABs are included in this conceptual model as well as the impacts resulting from HABs. The presence of these drivers does not necessarily indicate a HAB will develop. Instead, HAB development is reliant on the combination of environmental conditions collectively catalyzing a bloom and leading to harmful impacts such as the production and bioaccumulation of cyanotoxins.

Why We Are Concerned

Public Health Impacts

CyanoHABs can produce toxins (cyanotoxins) that affect various organs and body parts, including the skin, eyes, throat, liver, lungs, and nervous system. Delta communities can encounter cyanotoxins through direct contact from recreational activities, drinking water that is contaminated with cyanotoxins, or consuming fish living in water contaminated with a cyanoHAB. Ongoing studies are also investigating whether toxins can become aerosolized and inhaled (Plaas and Paerl, 2020). Similarly, cyanoHABs have harmful health impacts on pets or livestock exposed to cyanotoxins that can be fatal. (FAQs on Pets and Livestock, CWQMC). Communities also come into contact with cyanotoxins through their presence in sources supplying public water systems. Unfortunately, disinfecting water of cyanotoxin can also generate health concerns, as the disinfectant by-products (e.g., trihalomethanes and haloacetic acids) have their own unknown toxicities resulting from the treatment of cyanotoxins or decaying cyanobacteria (Zamyadi et al. 2012). Communities that obtain drinking water from private water systems (i.e., private intakes and wells) can also become exposed to cyanotoxins due to inadequate treatment in privately managed systems. This risk to tap water has been documented for two years in Lake County from a lake with reoccurring HABs.

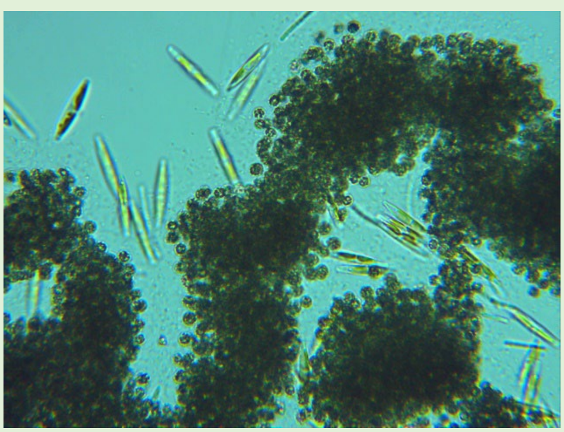
Socio-economic Impacts

When cyanoHABs bloom in a body of water, their toxins make the impacted water dangerous for many beneficial uses of Delta water, and costly treatment may be needed to make the water usable. Whether or not water treatment is pursued, HABs impact the local communities and economies by disrupting sport and subsistence fishing, recreational activities like kayaking, and contaminating the drinking water supply. The impacts on agriculture from irrigation with water that has been impacted by cyanoHAB toxins are not well characterized.

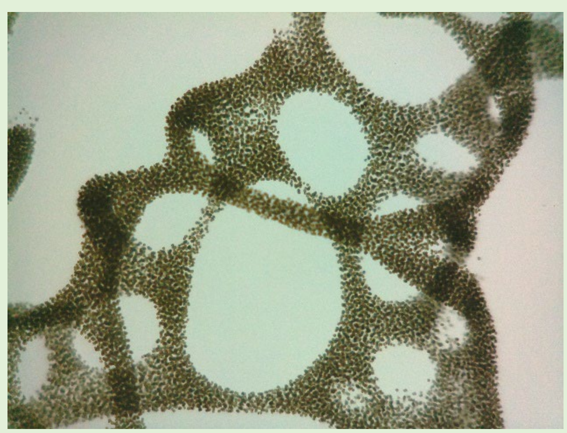
Ecosystem Impacts

There are multiple cyanoHAB impacts on ecosystems. As with humans, wildlife species can experience adverse reactions or mortality from exposure to cyanotoxins. Fish, mammals, and birds that live in, drink or get their food from affected water bodies can experience endocrine disruption, gill dysfunction, acute poisoning, or other effects. Wildlife mortality can also occur as a consequence of these effects or from the reduced water oxygen levels that cyanoHABs can cause through large bloom decay or nocturnal respiration (Paerl et. al., 2001).

Cyanobacteria produce a suite of cyanotoxins and other less-studied compounds that threaten humans, wildlife, and the ecosystem. Despite research indicating which cyanobacteria can produce toxins, it is impossible to tell if a cyanobacteria bloom is actively toxic without testing the bloom for specific toxins. Also, cyanobacteria toxin production rates can rapidly change, meaning that more frequent monitoring is needed than for persistent contaminants like mercury. Thus, monitoring and managing the impacts of cyanoHABs in the Delta is a complicated task that would greatly benefit from coordinated efforts.



Microcystis sample under a microscope clustered with diatoms. The sample was collected by Janis Cooke and Jerry Burns of the Central Valley Regional Water Quality Control Board from the Port of Stockton in California.



Microcystis sample under a microscope collected by Keith Bouma-Gregson of the U.S. Geological Survey.

Monitoring HABs in the Delta

HABs monitoring in the Delta has been conducted inconsistently over the last decade, primarily through special studies. Some programs have dedicated funding for monitoring water quality parameters due to regulatory requirements, while other parties have an interest in conducting monitoring but lack the funding. A list of the various parties that are currently conducting HABs monitoring for the Delta can be found in the Delta HABs Monitoring information sheet.

The Problem

HAB monitoring efforts and targeted studies are growing in number and scope in the Delta, along with concerns that blooms will increase in frequency and severity. With the growing scientific and public attention on the issue, **there is a need for increased coordination amongst the many groups that work on HABs in the Delta**. This workshop will lead to the development of a Delta-region specific HABs monitoring strategy that serves as a framework for monitoring, modeling, and addressing current knowledge gaps.

Delta HABs Monitoring Workshop Goal

HAB monitoring in the Delta is needed to fill knowledge gaps on HABs and to protect Delta communities from HAB toxins. The goal of this workshop is to inform the development of a Delta-region-specific HABs Monitoring Strategy that would serve as a framework for monitoring, modeling, and addressing current knowledge gaps. The Strategy will support collaborative efforts to understand the status, trends, and drivers of HABs for the creation of better management and mitigation plans and for creating a public health monitoring structure through which communities can be quickly notified when toxin levels are elevated.

Other Workshop Materials

The workshop planning committee has developed multiple information sheets that are recommended for attendees to review to prepare for the workshop. The materials are:

- Workshop Information Sheet
- Workshop Agenda
- Delta HABs Monitoring Information Sheet
- Draft Delta HAB Monitoring Strategy

Workshop Planning Team

The Delta Science Program is leading this effort with assistance from a team of individuals that serve as liaisons to their respective agencies or community constituencies and ensure that the workshop reflects the needs of the broader public. Their affiliations include the California Department of Fish and Wildlife, California Department of Water Resources, Interagency Ecological Program, California State Water Resources Control Board and Central Valley Regional Water Quality Control Board, Restore the Delta, U.S. Geological Survey, and the University of Minnesota.

References and Further Reading

Papers

Chorus, I., and Welker, M. eds. 2021. Toxic Cyanobacteria in Water. 2nd ed. Boca Raton, FL: CRC Press on behalf of the World Health Organization, Geneva, CH. doi: 10.1201/9781003081449.

Howard, M. D. A., Smith, J., Caron, D. A., Kudela, R. M., Loftin, K., Hayashi, K., Fadness, R., Fricke, S., Kann, J., Roethler, M., Tatters, A., Theroux, S. 2022. Integrative monitoring strategy for marine and freshwater harmful algal blooms and toxins across the freshwater-to-marine continuum. Integrated Environmental Assessment & Management, doi: 10.1002/ieam.4651.

Kudela, R.M., Hayashi, K., Caceres, C.G., 2020. Is San Francisco Bay resistant to Pseudo-nitzschia and domoic acid? Harmful Algae 92:101617. doi: 10.1016/j.hal.2019.05.010.

Kudela, R.M., Howard, M.D.A., Monismith, S., Paerl, H. In Press. Status, trends, and drivers of harmful algal blooms along the freshwater to marine gradient in the San Francisco Bay Delta system. San Francisco Estuary and Watershed Sciences.

Paerl, H., Fulton, R., Moisander, P., Dyble, J., 2001. Harmful Freshwater Algal Blooms, With an Emphasis on Cyanobacteria. The Scientific World Journal. 1:76-113. doi: 10.1100/tsw.2001.16.

Plaas, H.E. and Paerl, H.W., 2020. Toxic cyanobacteria: a growing threat to water and air 1751 quality. Environmental Science & Technology, 55(1):44-64. doi: 10.1021/acs.est.0c06653.

Preece, E.P., Hardy, F.J., Moore, B.C., Bryan, M., 2017. A review of microcystin detections in Estuarine and Marine waters: Environmental implications and human health risk. Harmful Algae 61:31–45. doi: 10.1016/j.hal.2016.11.006.

Zamyadi, A., L. Ho, G. Newcombe, H. Bustamante, and M. Prévost. 2012. Fate of toxic cyanobacterial cells and disinfection by-products formation after chlorination. Water Research 46 (5):1524-35. doi: 10.1016/j.watres.2011.06.029.

Webpages

Blue-Green Algal (Cyanobacteria) Blooms, California Department of Public Health

California CyanoHAB Network (CCHAB), California Water Quality Monitoring Council

California Harmful Algal Blooms Portal, California Water Quality Monitoring Council

Cyanobacteria Harmful Algal Blooms (HABs) and Cyanotoxins in Recreational Waters, California Office of Environmental Health Hazard Assessment

Frequently Asked Questions about Freshwater and Estuarine, California Water Quality Monitoring Council

Frequently Asked Questions on Pets, Livestock, and HABs, California Water Quality Monitoring Council

Satellite CyanoHAB Map, California Water Quality Monitoring Council

Strategies for Preventing and Managing Harmful Cyanobacterial Blooms (HCB-1), Interstate Technology & Regulatory Council

Visual Guide for Identifying a Harmful Algal Bloom, California State Water Resources Control Board Boards