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Factors Affecting Growth of Cyanobacteria with Special Emphasis on the Sacramento-San Joaquin Delta

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EXECUTIVE SUMMARY

A world-wide increase in the incidence of toxin-producing, harmful cyanobacterial blooms (cyanoHABs) over the last two decades has prompted a great deal of research into the triggers of their excessive growth. Massive surface blooms are known to decrease light penetration through the water, cause depletion of dissolved oxygen following bacterial mineralization of blooms, and cause mortality of aquatic life following ingestion of prey with high concentrations of toxins. Additionally, humans coming in contact with the water may develop digestive and skin diseases, and it may affect the drinking water supply.

The Central Valley Regional Water Quality Control Board (Water Board) is developing a science plan to scope the science needed to support decisions on policies governing nutrient management in the Delta. Blooms of cyanoHABs are one of three areas, identified by the Water Board, that represent pathways of potential impairment that could be linked to nutrients. The Water Board commissioned a literature review of the factors that may be contributing to the presence of cyanoHABs in the Delta. The literature review had three major objectives:

1) Provide a basic review of biological and ecological factors that influence the prevalence of cyanobacteria and the production of cyanotoxins;
2) Summarize observations of cyanobacterial blooms and associated toxins in the Delta;
3) Synthesize literature to provide an understanding of what ecological factors, including nutrients, may be at play in promoting cyanobacterial blooms in the Delta.

This review had four major findings:

#1. Five principal drivers emerged as important determinant of cyanobacterial blooms in a review of the global literature on factors influencing cyanobacteria blooms and toxin production. These include: 1) Water temperature, 2) Water column irradiance and water clarity, 3) Stratified water column coupled with long residence times, 4) Availability of N and P in non-limiting amounts; scientific consensus is lacking on the importance of N: P ratios as a driver for cyanoHABs, and 5) Salinity regime.

#2. Existing information is insufficient to fully characterize the threat of CyanoHABs to Delta ecosystem services because cyanoHABs are not routinely monitored. Based on existing data, the current risk to Delta aquatic health is of concern and merits a more thorough investigation. This observation is based total microcystin levels found in Delta fish tissues that are within the range of sublethal effects to fish as recently reviewed by the California Office of Environmental Health Hazards (OEHHA 2009), and dissolved toxin concentrations that occasionally exceed both the OEHHA action level and the World Health Organization (WHO) guideline of 1000 ng L-1 in certain “hotspots” of the Delta.

#3. Comprehensive understanding of the role of nutrients vis-à-vis other environmental factors in influencing cyanoHAB presence in the Delta is severely hampered by the lack of a routine monitoring program. Drawing on available information on the five factors influencing cyanoHABs, we can conclude the following:

- Temperature and irradiance appear to exert key roles in the regulation of the onset of blooms. Cyanobacteria require temperatures above 20°C for growth rates to be competitive with eukaryotic phytoplankton taxa, and above 25°C for growth rates to be competitive with diatoms. In addition, they require relatively high irradiances to grow at maximal growth rates.

- It appears that N and P are available in non-limiting amounts in the Delta; moreover, concentrations, or ratios, do not change sufficiently from year–to–year in order to explain year–to–year variation Microcystis biomass or occurrence. Therefore the initiation of Microcystis or other cyanoHAB blooms are probably not associated with changes in nutrient concentrations or their ratios in the Delta. However, as with all phytoplankton blooms, once initiated, cyanoHABs cannot persist without an ample supply of nutrients.

- Salinity is controlling the oceanward extent of cyanobacteria blooms in the Delta, but salinity gradients do not explain the spatial distribution of cyanoHABs in the Delta. Notably, salinity regime is not a barrier to toxin transport, as cyanotoxins have been detected in SF Bay.

- Turbidity, low temperatures, and higher flows during most of the year are likely restricting cyanobacteria blooms to the July-August time period.

#4. Climate change and anthropogenic activity associated with land use changes have the potential to alter cyanoHAB prevalence in the future. Climate change will likely result in warmer temperatures and increased drought, the latter of which could result in reduced flows, increased residence time and water column stability leading to higher light availability in the Delta. Both temperature and reduced flows would presumably result in a greater prevalence of cyanoHABs. It’s noteworthy that phytoplankton biomass and primary productivity are depressed relative to available nutrients in the Delta, so it’s unclear what the effect of modifying nutrient loads will have on frequency and intensity of cyanoHAB occurrence in the future. Given these findings, two major science recommendations are proposed:

R1: Implement Routine Monitoring of CyanoHABs. DWR is currently conducting a monitoring program which routinely samples many of the variables of interest known to influence cyanoHABs. Comprehensive cyanoHAB monitoring should be added as a component to this program. To begin, a work plan should be developed which specifically scopes the needed changes in the program to comprehensively monitor cyanoHABs. This report details specific components that should be considered in this workplan. The workplan should also consider monitoring needed to develop and calibrate an ecosystem model to further investigate controls on primary productivity and phytoplankton assemblage (see R2 below). The workplan should be peer-reviewed by subject matter experts. After an initial period of 3-5 years, the monitoring data should be used to comprehensively report on the status and trends of cyanoHABs and the factors that favor bloom occurrence in the Delta.

R2: Develop an Ecosystem Model of Phytoplankton Primary Productivity and HABs Occurrence to further Inform Future Risk and Hypotheses on Factors Controlling CyanoHABs. Because nutrients are not currently limiting cyanobacterial blooms, it is critical that an improved understanding is gained of the factors that are controlling phytoplankton primary productivity in the Delta, since increased phytoplankton growth could lead to increased risk of cyanoHAB blooms. To inform management action moving into the future, an ecosystem model of phytoplankton primary productivity and HABs occurrence should be developed. This model should have the capability to provide information on primary productivity and biomass as well as planktonic food quality and transfer of carbon to higher trophic levels. To step into model development, three actions should be taken: 1) examine existing models already available to determine suitability for this task, 2) utilize existing data to explore, to the extent possible, the relationships between chlorophyll a, phytoplankton composition, climate variables et al. factors. This analyses should inform hypotheses that can be tested through model development as well as potential future scenarios, and 3) a work plan should be developed that lays out the modeling strategy, model data requirements, and implementation strategy.

Full text: 869_FactorsAffectGrowthOfCyanobacteria-1.pdf