How Unusual Was the 2016 Phytoplankton Spring Bloom in the Delta?

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Phytoplankton spring blooms are a common occurrence and important food source in many aquatic systems, including rivers, estuaries, and the ocean. In the Sacramento-San Joaquin River Delta (Delta), the long-term decline in spring diatom bloom frequency and magnitude has contributed to the food scarcity that has been identified as a major ecosystem stressor in this estuarine system. Many management strategies, from wetland restoration to flow manipulations, are aimed at improving the availability of nutritious food sources for aquatic organisms in the Delta. A better understanding of the dynamics and drivers of nutritious phytoplankton blooms is needed to improve the likelihood of success of these management strategies. An extensive network of high-frequency water quality and flow monitoring stations now spans most of the Delta. In spring 2016, Chlorophyll *a* fluorescence data recorded at these stations, along with additional data from boat-based monitoring cruises, showed a substantial Delta-wide phytoplankton bloom that started in the rivers and the Yolo Bypass along the margins of the Delta in February and March. By May, the bloom had greatly intensified and spread throughout the central and western portions of the Delta. This talk is intended to provide an introduction to a special session about the 2016 Delta spring bloom. It gives an overview of the temporal and spatial dynamics of the Delta-wide spring 2016 bloom and potential drivers and compares them to blooms observed in other seasons and in previous years in the Delta and elsewhere. Results presented in this talk are intended to stimulate further discussions about phytoplankton research, monitoring, and management strategies in the Delta.

Keywords: phytoplankton, spring bloom, monitoring, management strategies
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Field and Satellite Observations of the Spring 2016 Phytoplankton Bloom in the Northern San Francisco Estuary

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The magnitude, location and timing of phytoplankton blooms in the northern San Francisco Estuary are all highly variable and not easily predictable. In the decade of the 70's, chlorophyll levels of 70-80 µg/L occurred regularly in the Low Salinity Zone (LSZ), but summer blooms diminished about the end of the 1980's coincident with the establishment of an invasive bivalve, *Potamocorbula amurensis* and increased ammonium discharge to the Sacramento River. The question of which element is the main driver of reduced phytoplankton productivity in the LSZ is controversial and unresolved; however, spring blooms are observed in the LSZ despite the presence of clams. The spring bloom of 2016 provides an opportunity to investigate the processes leading to blooms in this ecosystem. Our NASA funded project on modeling and remote sensing of the Bay/Delta ecosystem had cruises in March and May, 2016; the latter occurred at the height of the bloom and occupied stations in the bloom region. The data set acquired included nutrients, chlorophyll, measurements of N and C uptake, a full suite of optical measurements in support of satellite observations, standard CTD casts and underway recorded data. High resolution satellites images confirm the widespread bloom occurrence.

Keywords: bloom, phytoplankton, nutrients, remote sensing
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Nutrients, Phytoplankton and Zooplankton in the Lower Sacramento River and Deepwater Ship Channel, 2012-2016

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The lower Sacramento River and Deepwater Ship Channel (DWSC) occupy ~30% of the Sacramento-San Joaquin Delta's total volume and are important rearing areas for Delta Smelt (*Hypomesus transpacificus*), an endemic fish population listed as threatened under the federal Endangered Species Act. The two areas differ markedly in their hydrodynamic, water quality and ecological characteristics. This talk will present the results of monthly sampling cruises conducted during 2012-2016 with a primary focus on concentration and composition of nutrients, phytoplankton and zooplankton during spring. The findings of this study will be used to inform and provide a baseline for experiments focused on increasing the food supply of the North Delta.

Keywords: Delta food supply, lower trophic level production, phytoplankton, zooplankton, smelt
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Spring Phytoplankton Bloom in the Delta Determined with Dissolved Oxygen Data

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Phytoplankton spring bloom develops when the right environmental conditions induce a strong algal growth. Such algal growth response has been monitored by assessing the chlorophyll a sensors throughout the Delta. Diel changes in dissolved oxygen (DO) at three water quality monitoring stations (FPT: Freeport; SDC: above the Cross Channel; and SDI: Decker Island) along the Sacramento River were analyzed to assess the progression of algal growth. At FPT, the daily average DO % saturation stayed relatively constant ranging from 90% to 95% until mid-February; increased to 99% by late February; decreased to 90% in mid-March apparently by the storms; regained to 95% quickly and stayed until mid-April; then reached to almost 100% by late-April; maintained, and sometimes exceeded the saturation until the late-May indicating very high algal growth (bloom). SDC had a DO trend similar to FPT; with the late-February to early March algal growth followed by a brief period of low growth after March storms, and a period of high DO % from mid-April to late May. At SDI, the early season (until late February) DO % saturation values (85% - 90%) were slightly lower than upstream locations; briefly increased to 95% in early March, followed by a brief low DO period (76% - 90%) until late March; and reached and maintained high DO % saturation sometimes exceeding 110% in May. The continuous DO measurement data was used to calculate the gross primary production (GPP) and community respiration (CR) with the open-system method. Preliminary estimates for the SDC location (5/20/2016) indicated the overall low productivity (GPP = 0.79 mg/L/day; CR = 0.93 mg/L/day) and a heterotrophic system (NDM = -0.37 mg/L/day). The use of DO data would help to understand the dynamics of unusual phenomena such as spring algal bloom and to estimate algal production in the Delta.

Keywords: phytoplankton, Dissolved oxygen, spring bloom, food web, monitoring, long-term, high-frequency
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Views of the 2016 Spring Bloom from Multiple Spatial and Temporal Scales

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While one of the drivers of the widespread pelagic organism decline in the Sacramento-San Joaquin Delta and San Francisco Estuary is thought to be declines in aquatic primary production, particularly in diatoms, the spring of 2016 saw a large diatom bloom with chlorophyll concentrations exceeding 80 µg/L extending from the Cache Slough complex to Suisun Bay, and up the San Joaquin River past Prisoner's Point. The bloom appeared to originate within the Cache Slough complex well after storm flows receded from the system, and then propagated southward through the mainstem of the lower Sacramento River and into the confluence area. It persisted for a period of approximately 3 weeks. After this time it declined to near ambient chlorophyll concentrations within a matter of days despite ample nutrients and no obvious change in hydrodynamics. We will present data regarding the conditions that led to the bloom, the types and concentrations of phytoplankton comprising the bloom, and the extent to which this bloom may have benefited zooplankton. We will explore the biogeochemical dynamics, physical dynamics, and nutrient concentrations that preceded and existed during the bloom, seeking to understand the conditions that led to formation of this large bloom and what led to its decline. These results will help identify management actions that may promote pelagic productivity within the Delta and estuary.

Keywords: Phytoplankton, diatoms, spring bloom, primary production, aquatic ecosystems, zooplankton
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