Harmful Algae

Harmful algal blooms and climate change: Learning from the past and present to forecast the future

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Abstract

Climate change pressures will influence marine planktonic systems globally, and it is conceivable that harmful algal blooms may increase in frequency and severity. These pressures will be manifest as alterations in temperature, stratification, light, ocean acidification, precipitation-induced nutrient inputs, and grazing, but absence of fundamental knowledge of the mechanisms driving harmful algal blooms frustrates most hope of forecasting their future prevalence. Summarized here is the consensus of a recent workshop held to address what currently is known and not known about the environmental conditions that favor initiation and maintenance of harmful algal blooms. There is expectation that harmful algal bloom (HAB) geographical domains should expand in some cases, as will seasonal windows of opportunity for harmful algal blooms at higher latitudes. Nonetheless there is only basic information to speculate upon which regions or habitats HAB species may be the most resilient or susceptible. Moreover, current research strategies are not well suited to inform these fundamental linkages. There is a critical absence of tenable hypotheses for how climate pressures mechanistically affect HAB species, and the lack of uniform experimental protocols limits the quantitative cross-investigation comparisons essential to advancement. A HAB "best practices" manual would help foster more uniform research strategies and protocols, and selection of a small target list of model HAB species or isolates for study would greatly promote the accumulation of knowledge. Despite the need to focus on keystone species, more studies need to address strain variability within species, their

responses under multifactorial conditions, and the retrospective analyses of long-term plankton and cyst core data; research topics that are departures from the norm. Examples of some fundamental unknowns include how larger and more frequent extreme weather events may break down natural biogeographic barriers, how stratification may enhance or diminish HAB events, how trace nutrients (metals, vitamins) influence cell toxicity, and how grazing pressures may leverage, or mitigate HAB development. There is an absence of high quality time-series data in most regions currently experiencing HAB outbreaks, and little if any data from regions expected to develop HAB events in the future. A subset of observer sites is recommended to help develop stronger linkages among global, national, and regional climate change and HAB observation programs, providing fundamental datasets for investigating global changes in the prevalence of harmful algal blooms. Forecasting changes in HAB patterns over the next few decades will depend critically upon considering harmful algal blooms within the competitive context of plankton communities, and linking these insights to ecosystem, oceanographic and climate models. From a broader perspective, the nexus of HAB science and the social sciences of harmful algal blooms is inadequate and prevents quantitative assessment of impacts of future HAB changes on human well-being. These and other fundamental changes in HAB research will be necessary if HAB science is to obtain compelling evidence that climate change has caused alterations in HAB distributions, prevalence or character, and to develop the theoretical, experimental, and empirical evidence explaining the mechanisms underpinning these ecological shifts.