# Monitoring and Mitigating a Global Proliferation of Toxic Cyanobacterial Blooms

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A global proliferation of harmful (toxic, hypoxia-generating, food web disrupting) cyanobacterial blooms (CyanoHABs) is taking place in response to human nutrient over-enrichment and climatic changes, specifically warming and more extreme hydrologic events, including intensifying storms, floods and droughts. This threatens access to safe drinking, bathing, fishing and recreational waters needed to support a burgeoning global human population. Furthermore, proliferating CyanoHABs adversely impact biodiversity and sustainability of impacted aquatic ecosystems. In this presentation, strategies for monitoring and characterizing the linkages between human and climatic drivers and CyanoHABs and their toxic properties will be preseneted with the aim of utilizing this information for developing and applying appropriate and effective bloom mitigation strategies aimed at reverse this troubling trend.

**Keywords:** Harmful cyanobacteria, nitrogen, phosphorus, water quality monitoring and management, mitigation, climate change.

Cyanobacteria are ancient photosynthetic microorganisms that have had major impacts on shaping Earth's biosphere[1]. Their long evolutionary history (~ 3.5 by) has enabled them to adapt to geochemical and climatic changes and more recently, anthropogenic modifications of aquatic environments, including nutrient over-enrichment (eutrophication), hydrologic modifications (water withdrawal, reservoir construction), and salinization[2] (Fig. 1). Bloom-forming harmful cyanobacterial taxa (CyanoHABs) can be harmful from environmental, organismal and human health perspectives by outcompeting beneficial phytoplankton, creating low oxygen conditions (hypoxia, anoxia) upon bloom senescence and by producing a variety of toxic secondary metabolites (cyanotoxins) that have been shown to affect liver, neurological and immunological functions in vertebrate consumers and inhabitants of affected waters, including humans[3]. In addition, some CyanoHABs can cause skin disorders upon contact[3]. Proliferating CyanoHABs are considered a serious threat to biological integrity, sustainability and utility (for drinking and irrigation water) of impacted aquatic ecosystems worldwide[4,5].

Cyanobacterial genera exhibit optimal growth rates and bloom potentials at relatively high water temperatures; hence global warming plays a key role in their expansion and persistence[6,7]. CyanoHABs are regulated by the combined, and often synergistic, effects of nutrient (nitrogen; N and phosphorus; P) supplies, light, temperature, vertical stratification, water residence/flushing times, and biotic interactions. Control strategies should generally be focused on reducing *both* N and P inputs, in conjunction with manipulating physical and biotic dynamic factors. Strategies based on physical, chemical (nutrient) and biological treatments and manipulations can be effective in reducing CyanoHABs[7,8] (Fig. 2). However, these strategies are largely confined to relatively small systems, and are prone to numerous ecological and environmental drawbacks, including enhancing release of cyanotoxins, disruption of benthic communities and fisheries habitat. All strategies should consider and be adaptive to climatic variability and change in order to be effective for long-term control of CyanoHABs[7,8]. For example, rising temperatures cause shifts in growth rates and critical nutrient thresholds at which cyanobacterial blooms can develop; thus, nutrient reductions for bloom control may need to be more aggressively pursued in response to climatic changes taking place worldwide.

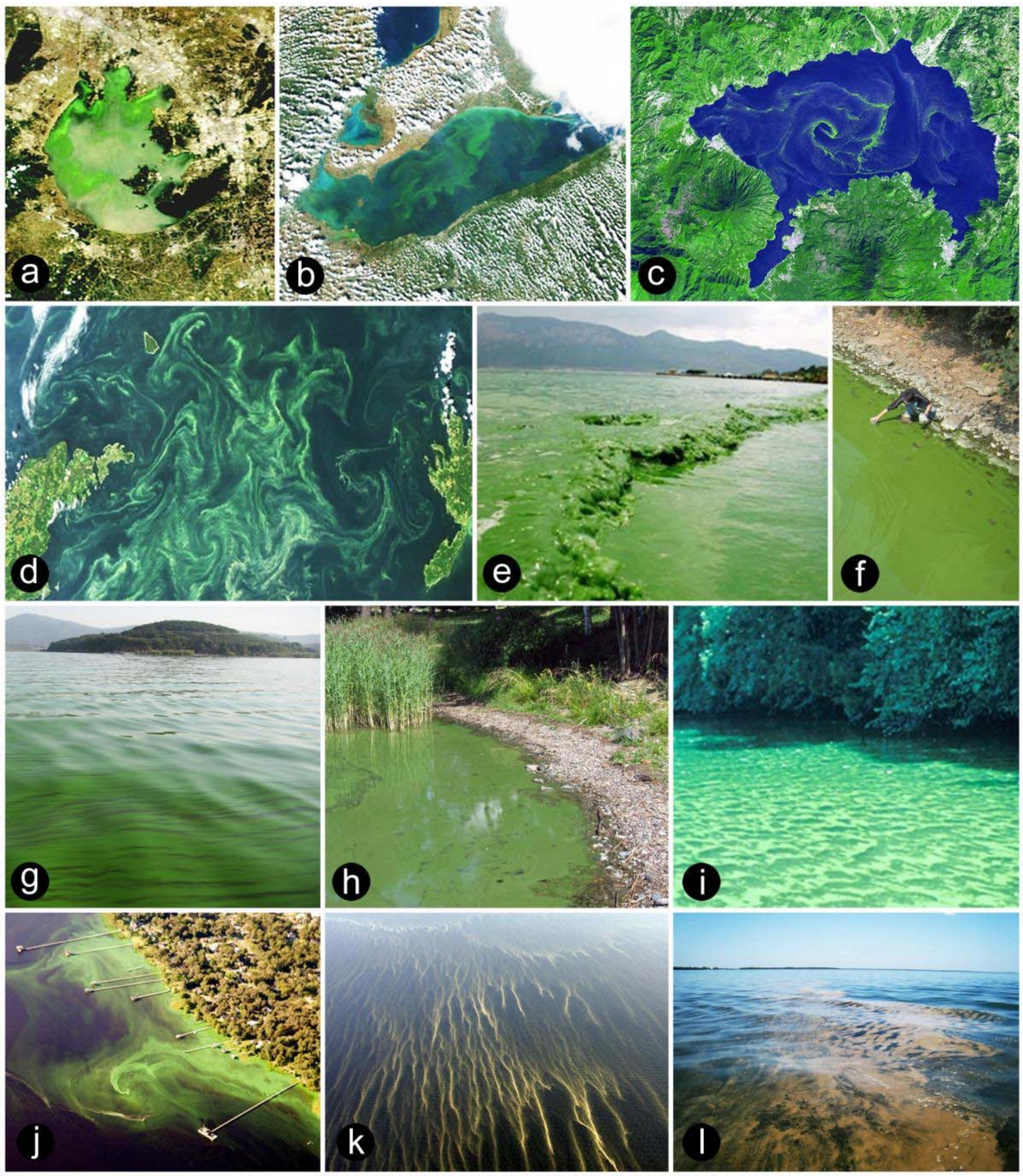

**Figure 1:** Harmful cyanobacterial blooms in a variety of aquatic environments. Where known, specific genera are indicated. Figures 1a-1d are remote sensing views of surafe blooms in; a) Lake Taihu, China (*Microcystis* spp.) (courtesy NASA-MODIS), b) Lake Erie, USA-Canada (*Microcystis*)(Courtesy NASA-MODIS, c) Lake Atitlan, Guatamala (*Lyngbya*) (Courtesy NASA-MODIS), d) Baltic Sea-Gulf of Finland (*Nodularia*, *Anabaena*, *Microcystis*)(Courtesy NASA-MODIS). 1e, Lake Dianchi, China (*Aphanizomenon* sp.) (Courtesy Chinese Academy of Sciences). 1f and 1g, Lake Tahiu, China (*Microcystis* spp.) (Photos by H. Paerl).1h, Taivallahti Bay, Baltic Sea, Finland (Finnish Environment Institute-SYKE). 1i, Neuse River Estuary, North Carolina, USA (*Microcystis* sp.) (Photo H. Paerl). 1j, St. John's River, FL (Photo, J. Burns).1k, Baltic Sea, Gulf of Finland (*Nodularia*) (Finnish Border Guard). 1l, Sanibel Inlet, coastal Gulf of Mexico, Florida USA (*Trichodesmium* sp.) (Photo, H. Paerl).

**Figure 2**: Various CyanoHAB mitigation strategies implemented in watersheds and waterbodies. (Clockwise from top left) Floating booms at Hartbeespoort Dam, located in the North West Province of South Africa, are used to concentrate cyanobacteria so they can be pumped out and composted (photo credit: Dept. of Water and Sanitation, Republic of South Africa); a constructed wetland at Open Grounds Farm, near Beaufort, NC, designed to reduce the amount of nutrients and sediments entering the headwaters of the South River, a tributary of the Neuse River (credit: Google Earth); a pumping barge is used to remove harmful cyanobacteria from Dianchi Lake, China (photo credit: J.Carl Ganter/ Circle of Blue); aluminum sulfate and sodium aluminate are pumped into Ticklenaked Pond in Ryegate, VT, to combat phosphorus loading and harmful cyanobacterial blooms (photo credit: Vermont Dept. of Env. Conservation, Watershed Management Div.); a dredging operation in Lake Roaming Rock, Ohio, to remove

nutrient-rich sediments (photo credit: RomeRock Association); a riparian buffer along Bear Creek in Story County, Iowa, designed to filter runoff of nutrients and sediments from adjacent farmland (photo credit: USDA); a LG Sonic, MPC-Buoy uses ultrasound waves to control algae (photo credit: LG Sonic); a SolarBee solar water circulator, used to improve water quality and alleviate harmful algae blooms in Santuit Pond in Mashpee, Massachusetts (photo credit: Friends of Santuit Pond); Phoslock is applied to Laguna Niguel Lake, CA, to bind and remove phosphorus from the water column (photo credit: Aquatechnex).

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