EPA Region 9 HAB Workshop and Meeting
Southern California Coastal Water Research Project, Costa Mesa, CA
April 27, 2017

Waterbody Management Approaches for HABs

Mario R. Sengco
U.S. Environmental Protection Agency
Office of Water/Office of Science and Technology
Washington, D.C.

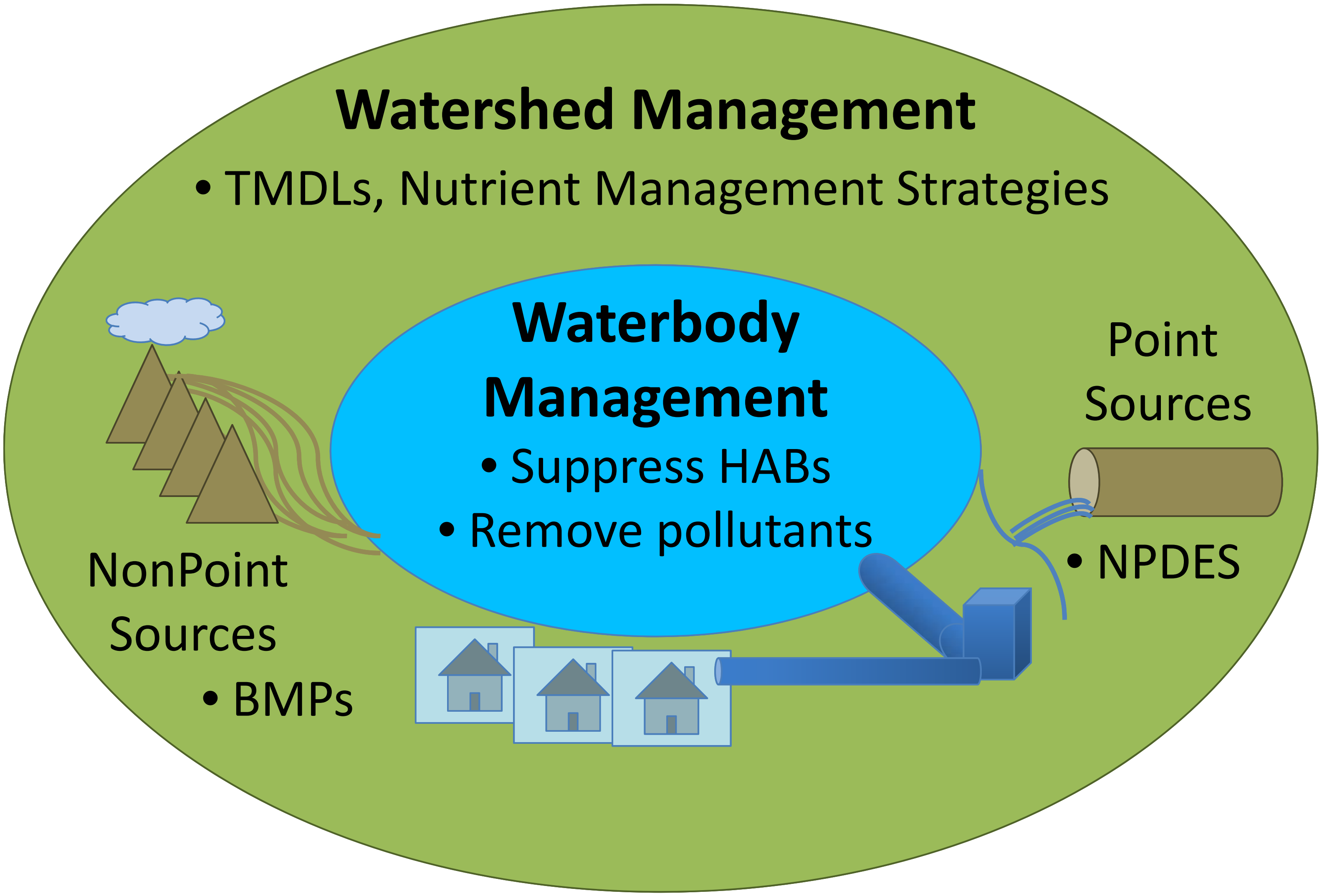
Email: sengco.mario@epa.gov

Disclaimer

The purpose of this presentation is to provide information for awareness and to describe various approaches for managing harmful algal blooms (HABs) in a waterbody as they are reported in the literature and other publications (e.g., state reviews).

The EPA has not conducted its own independent, systematic, scientific review or technical analysis of these approaches. Therefore, the EPA does not endorse or recommend any particular approach.

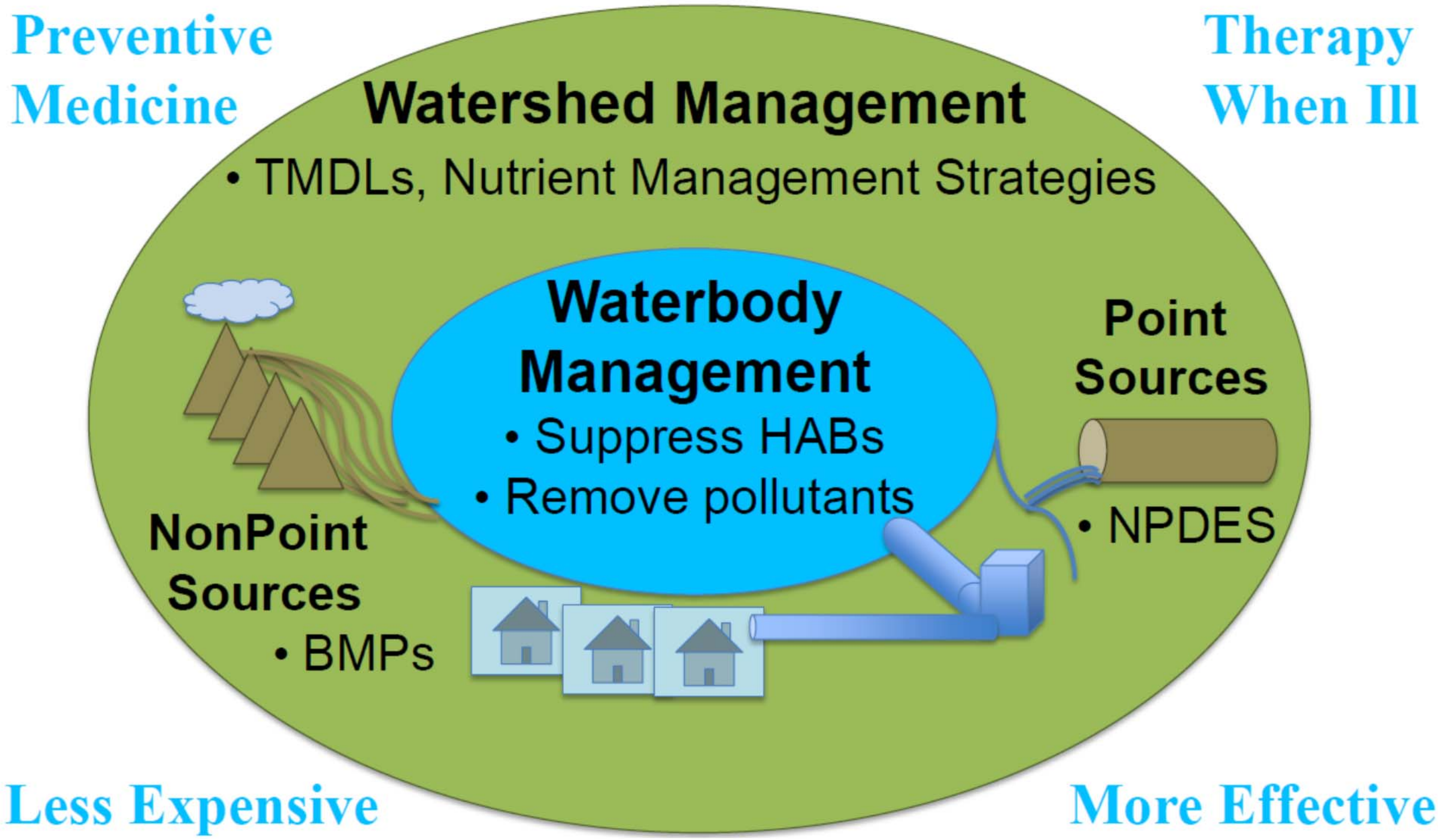
What is Waterbody Management?



Source: Hudnell, K. H., "A Systems Approach to Freshwater Management: Waterbody Treatments", U.S. EPA Webinar, May 14, 2014.

Systems Approach

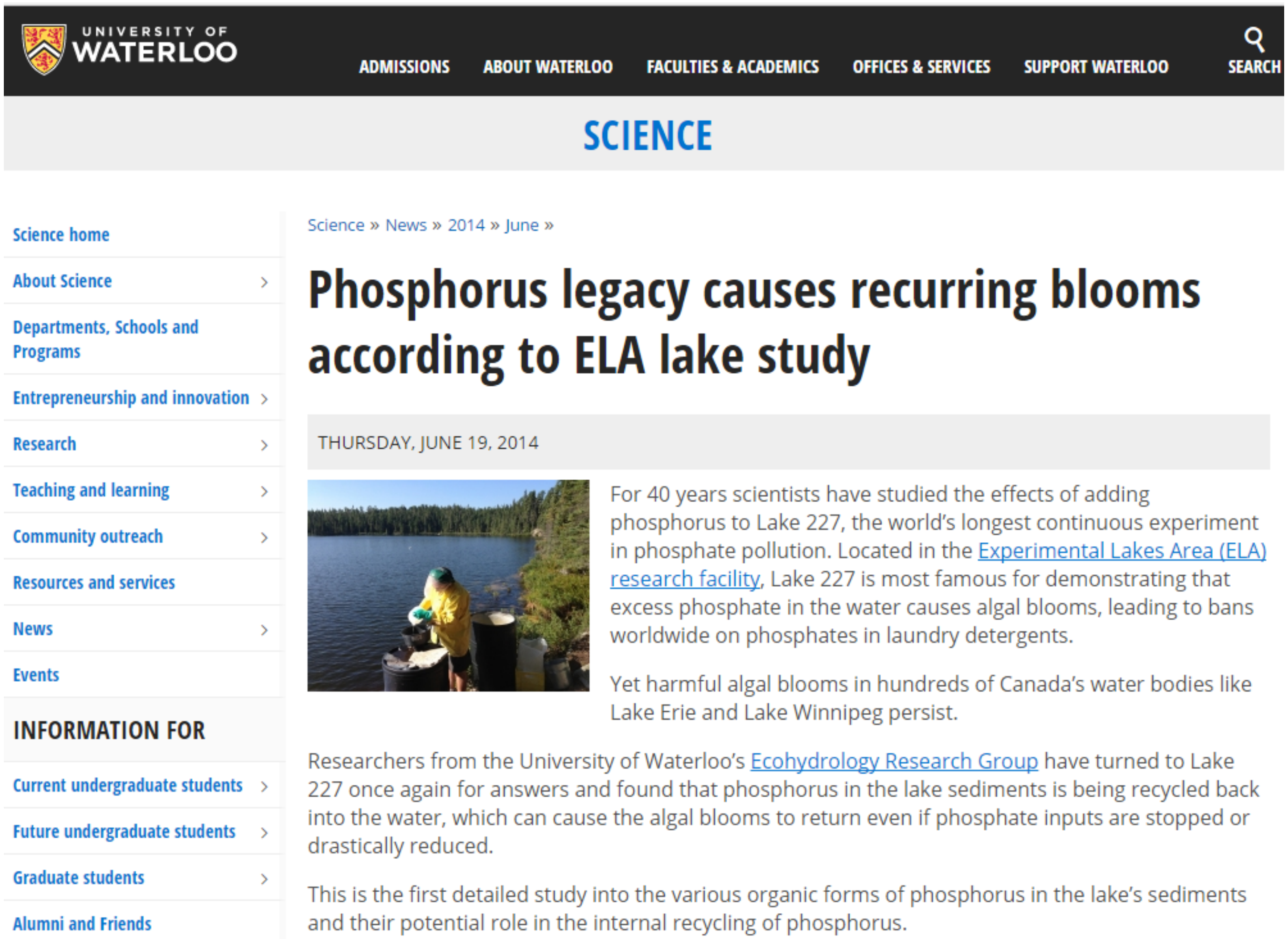
Systems Approach = Waterbody + Watershed management



Source: Hudnell, K. H., "A Systems Approach to Freshwater Management: Waterbody Treatments", U.S. EPA Webinar, May 14, 2014.

Legacy pollution

Legacy pollution (e.g., phosphorus) is a challenge for many waterbodies. Even if new inputs can be prevented or limited, there can be sufficient amounts of nutrients in the system (e.g., in the sediments) to support harmful algal blooms into the future.



UNIVERSITY OF WATERLOO

ADMISSIONS | ABOUT WATERLOO | FACULTIES & ACADEMICS | OFFICES & SERVICES | SUPPORT WATERLOO | SEARCH

SCIENCE

- Science home
- About Science
- Departments, Schools and Programs
- Entrepreneurship and innovation
- Research
- Teaching and learning
- Community outreach
- Resources and services
- News
- Events

INFORMATION FOR

- Current undergraduate students
- Future undergraduate students
- Graduate students
- Alumni and Friends

Science » News » 2014 » June »

Phosphorus legacy causes recurring blooms according to ELA lake study

THURSDAY, JUNE 19, 2014

For 40 years scientists have studied the effects of adding phosphorus to Lake 227, the world's longest continuous experiment in phosphate pollution. Located in the Experimental Lakes Area (ELA) research facility, Lake 227 is most famous for demonstrating that excess phosphate in the water causes algal blooms, leading to bans worldwide on phosphates in laundry detergents.

Yet harmful algal blooms in hundreds of Canada's water bodies like Lake Erie and Lake Winnipeg persist.

Researchers from the University of Waterloo's Ecohydrology Research Group have turned to Lake 227 once again for answers and found that phosphorus in the lake sediments is being recycled back into the water, which can cause the algal blooms to return even if phosphate inputs are stopped or drastically reduced.

This is the first detailed study into the various organic forms of phosphorus in the lake's sediments and their potential role in the internal recycling of phosphorus.

https://uwaterloo.ca/science/news/phosphorus-legacy-causes-recurring-blooms-according-ela-lake

The EPA Blog

HOME

Posted on September 22, 2016 ← Previous Next →

Partnering with States to Cut Nutrient Pollution

Joel Beauvais

By Joel Beauvais

Nutrient pollution remains one of America's most widespread and costly environmental and public health challenges, threatening the prosperity and quality of life of communities across the nation. Over the last 50 years, the amount of excess nitrogen and phosphorus in our waterways has steadily increased, impacting water quality, feeding harmful algal blooms, and affecting drinking water sources. From the Lake Erie algae blooms to the Gulf of Mexico dead zone, nutrient pollution is impacting every corner of our country and economy.

Blog: Partnering with States to Cut Nutrient Pollution, Joel Beauvais, Sept 22, 2016

"This memorandum highlights the continued need for action to address this challenge, calls upon states and stakeholders to intensify their efforts in collaboration with EPA, and announces support for state planning or implementation of watershed-based, multi-stakeholder projects to reduce impacts to public health from nitrates in sources of drinking water and from nitrogen and phosphorus pollution contributing to harmful algal blooms."

Memo: Renewed Call to Action to Reduce Nutrient Pollution, Joel Beauvais, Sept 22, 2016

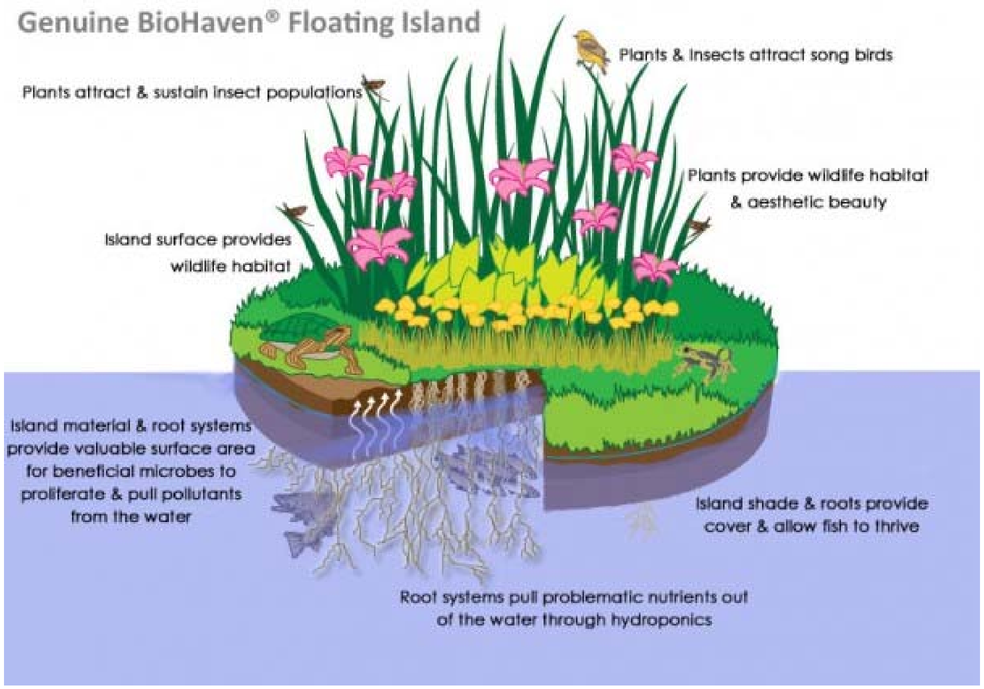
Waterbody Management Approaches

A. Bloom prevention – before a bloom occurs

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Biological Controls (Bio-manipulation)			
Floating Treatment Wetlands (FTW)	Consists of emergent wetland plants growing on floating mats on the water's surface. The plant's roots provide enough surface area to filter and trap nutrients. FTWs also encourage biofilm processes that reduce cyanobacteria levels. Periodic harvesting of mature plants is conducted to prevent stored nutrients from re-entering the aquatic ecosystem, mitigating risk of HABs by keeping nutrient levels in balance.	Assimilates nutrients and encourages particle adsorption. Covered surface area minimizes light penetration and limits opportunity for algae growth. Able to tolerate fluctuations in water depth. Utilizes natural processes with minimal technical attention required.	Often dependent upon the amount of input (i.e., the number of plants and mats). Excessive coverage can lead to de-oxygenation of the water. Plants only have access to nutrients in the water column and not ones in sediment.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Floating Islands



http://www.prlog.org/11132852-biohaven-floating-island.jpg

http://www.lowtechmagazine.com/images/2008/11/12/floating_island_rhizome_collective.jpg

http://www.wef.org/assets/0/86/108/668/773/6442452995/6442453001/1cf66293-bbae-4476-8f88-5d76eaef71fc.jpg

http://lake-savers.com/wp-content/uploads/2013/03/feature-floating-island.jpg

A. Bloom prevention – before a bloom occurs

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Biological Controls (Bio-manipulation)			
Riparian Vegetation	Vegetated zones (trees, shrubs, and other plants) adjacent to surface waters serve as a buffer between the water and point/non-point sources of pollution.	Intercept nutrients and other pollutants from entering surface waters. Provides shade from sunlight, which helps to reduce higher temperatures that can cause HABs. Long-term sustainability. Little maintenance and upkeep once installed.	Feasibility and effectiveness largely depend on geographic characteristics of water body and surrounding land mass.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

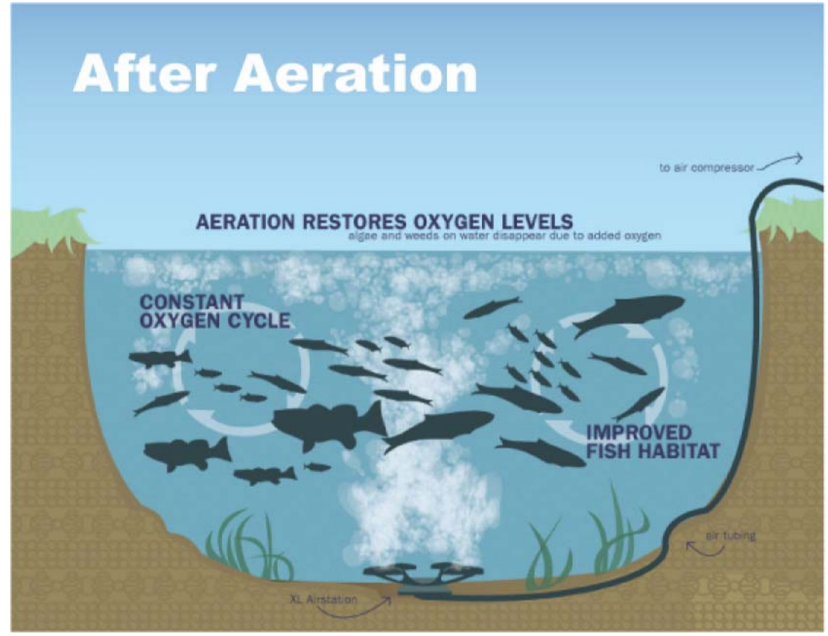
A. Bloom prevention – before a bloom occurs

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Physical Controls			
Aeration	Aerators pump air throughout the water column to disrupt stratification. Many operate by pumping air through a diffuser near the bottom of the water body, resulting in the formation of plumes that rise to the surface and create vertical circulation cells as they propagate outwards from the aerator.	Limits the accessibility of nutrients to the surface. Disrupts the behavior of cyanobacteria to migrate vertically. Reduces competitive advantage of cyanobacteria by maintaining healthy levels of dissolved oxygen.	Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth. De-stratification of the water column may harm aquatic habitats that rely on colder bottom temperatures.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Aeration and Oxygenation

http://www.vertexwaterfeatures.com/sites/default/files/imagecache/billboard_frontpage_aeration/billboard-frontpage/billboard_A1.jpg



Bahia Del Mar Lake, St Petersburg, FL

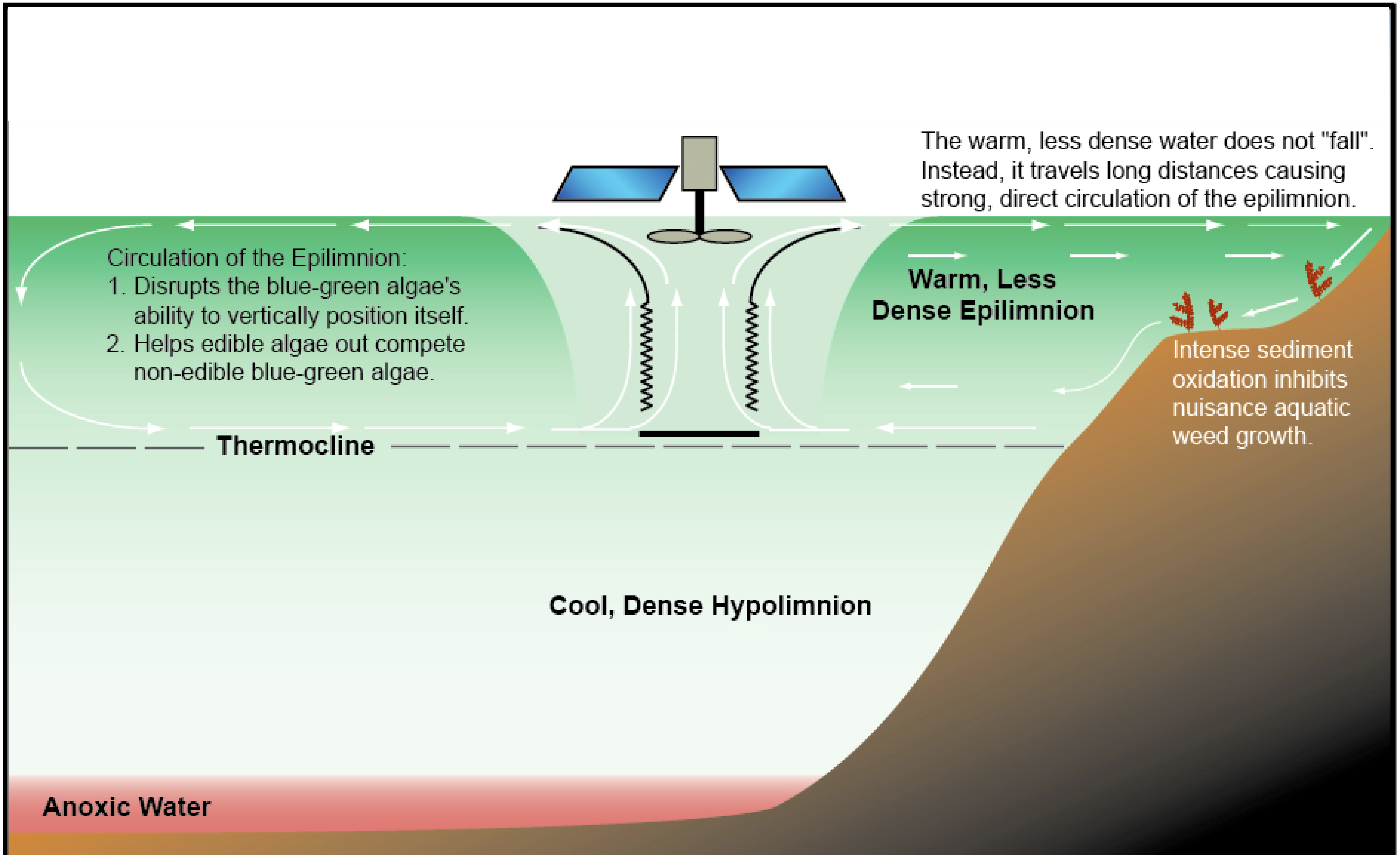
http://www.vertexwaterfeatures.com/sites/default/files/bdm_both.jpg

A. Bloom prevention – before a bloom occurs

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Physical Controls			
Mechanical Circulation	Mechanical circulators operate by pumping water from the surface layer downwards or draw water up from the bottom to the surface layer. Similar to aerators, mechanical mixers interfere with stratification of the water column, intercepting conditions ideal for HABs to occur.	Limits the accessibility of nutrients to the surface. Disrupts the behavior of cyanobacteria to migrate vertically. Reduces competitive advantage of cyanobacteria by maintaining healthy levels of dissolved oxygen.	Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth. Certain algae prefer an unstable environment and are benefitted by circulation.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Mechanical Mixing (Circulation)



http://www.vitalbodies.com/blog/wp-content/uploads/2009/04/solarbee_bga2.jpg

Jordan Lake (North Carolina)

WRAL.com By Tyler Dukes, Posted, May 5, 2016
http://www.wral.com/environmental-regulators-to-end-solarbees-pilot-project/15684958/


Spotlight | Noticias | Instant Savings | Classifieds | Jobs | Real Estate

WRAL.com News Weather Sports Business Opinion Consumer Health & Life

Local State @NCCapitol Education Traffic Investigations Nation World Politics

@NCCapitol

Environmental regulators to remove Jordan Lake SolarBees

Tags: Environment

Posted May 5, 2016

239 Share 0 10 Reactions

MORE ON THIS

Budget spends more on SolarBees

By Tyler Dukes

RALEIGH, N.C. — After two years and a more than $1

Copco Reservoir, Klamath River (California

A. Bloom prevention – before a bloom occurs

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Physical Controls			
Hypolimnetic Oxygenation	To increase oxygen concentrations in the hypolimnion layer. Mechanisms include submerged oxygen chambers, side stream oxygenation and direct oxygen injection.	High oxygen delivery rates reduce potential for sediment to release nutrients. Minimizes impact to hypolimnion by maintaining water column structure and temperature (thermocline, pycnocline, etc.).	Techniques are relatively expensive. Requires a significant understanding of system in order to operate.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

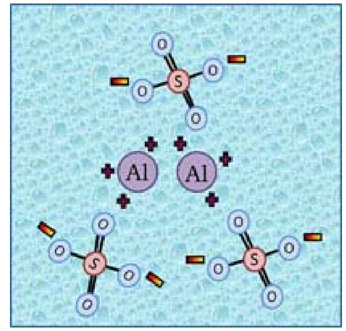
A. Bloom prevention – before a bloom occurs

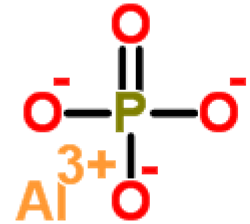
Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Chemical Controls			
Alum, ferric salts, clay (Coagulation and Flocculation)	Alum, ferric salts, or clay can be applied to the water body as coagulants that cause cyanobacteria to settle down away from the top layer of the water body. When applied to water, alum forms an aluminum hydroxide precipitate called a floc. As the floc settles, it removes phosphorus and particulates (including algae) from the water column. The floc settles on the sediment where it forms a layer that acts as barrier to phosphorus. Phosphorus, released from the sediments, combines with the alum and is not released into the water to fuel algae blooms.	Injection of aluminum compounds can be effective at reducing phosphorus levels in the water body.	Effectiveness varies with amount of alum added and depth of water body. The addition of aluminum can impact pH levels of the water body. Best suitable for well-buffered hard water. Buffering soft water lakes with either sodium aluminate or carbonate type salts to prevent undesirable pH shifts that can be toxic to biota may be needed.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Chemical flocculants (bind, aggregate and sink)

Chemical flocculants (dissolved and particulates)
- aluminum sulfate (alum)
- polyaluminum chloride (PAC)
- polymeric flocculants

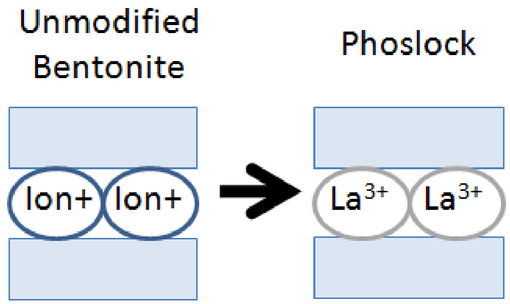


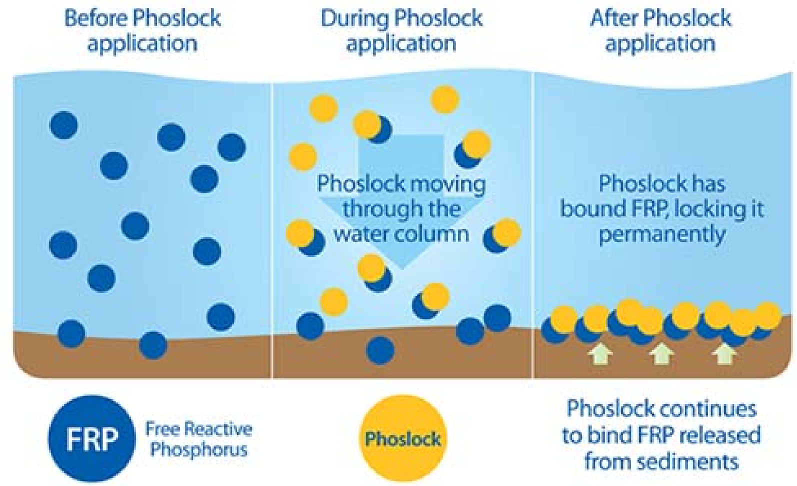


http://www.chemspider.com/ImagesHandler.ashx?id=58204&w=200&h=200
http://sinarindahcentral.files.wordpress.com/2011/11/aluminium-sulfat-solid1.jpg
http://www.teachengineering.org/collection/usf_/lessons/usf_flocculant
/usf_flocculants_lesson01_figure3web.jpg

Alum Treatment in Lake Stevens (WA)

http://aquatechnex.com/wp-content/uploads/2013/06/IMG_5531.jpg





http://www.cygnetenterprises.com/ftp/productimages/Pics/Phoslock%2055lb%20bag_300x375.jpg
http://www.sepro.com/phoslock/images/HowPhoslockWorks.png
http://www.phoslock.eu/en/phoslock/about-phoslock/
http://elements.geoscienceworld.org/content/5/2/99/F2.large.jpg

The Netherlands

http://www.sepro.com/phoslock/images/PhoslockSideBySide.jpg

Lake Lorene, WA

A. Bloom prevention – before a bloom occurs

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Chemical Controls			
Barley Straw	Barley straw, when exposed to sunlight and in the presence of oxygen, produces a chemical that inhibits algae growth. Barley straw bales are broken apart and placed in a buoyant net deployed around the perimeter of the water body to facilitate the necessary chemical reactions and natural processes that prevents algae growth.	A low cost method to preventing HABs.	Amount used depends on size of water. Does not kill existing algae, but inhibits the growth of new algae. May take anywhere from 2 to 8 weeks for the barley straw to begin producing active chemical. Potential to cause fish kills through the deoxygenation of the water body due to decay.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Barley Straw

England

http://aquatic-solutions.co.uk/wp-content/uploads/2012/04/Barley-Straw.jpg

http://www.mankysanke.co.uk/assets/images/autogen/a_Barley_straw_reservoir.jpg

Tommy's Pond, Metuchen, NJ

http://www.metuchenmatters.com/IMG_3585.JPG

B. Bloom control and remediation – when a bloom is present

Waterbody Management Method	Description	Benefits/Effectiveness	Limitations
Physical Controls			
Aeration	Aerators operate by pumping air through a diffuser near the bottom of the waterbody, resulting in the formation of plumes that rise to the surface and create vertical circulation cells as they propagate outwards from the aerator. This mixing of the water column disrupts the behavior of cyanobacteria to migrate vertically in addition to limiting the accessibility of nutrients.	Successfully implemented in small ponds and waterbodies. Proven effectiveness in several field studies. May also provide more favorable growth conditions for competing organisms.	Generally more efficient in deeper water columns. Also highly dependent upon the degree of stratification and the air flow rate.
Hydrologic manipulations	Low flow conditions in waterbodies can lead to stratification of the water column, which aids cyanobacterial growth. Particularly in regulated systems, the inflow/outflow of water in the system can be manipulated to disrupt stratification and control cyanobacterial growth.	Easy to implement in controlled systems (i.e., reservoirs, dams, treatment facilities).	Requires sufficient water volume and the ability to control flow. Oftentimes can be expensive. Unintended consequences for other aquatic organisms are likely.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

B. Bloom control and remediation – when a bloom is present

Waterbody Management Method	**Description**	**Benefits/Effectiveness**	**Limitations**
Physical Controls			
Mechanical mixing (circulation)	Mechanical mixers are usually surface-mounted and pump water from the surface layer downwards or draw water up from the bottom to the surface layer. This mixing of the water column disrupts the behavior of cyanobacteria to migrate vertically in addition to limiting the accessibility of nutrients.	Successfully implemented in 350+ waterbodies in the U.S. Also used in other countries.	Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth.
Reservoir drawdown/dessication	In reservoirs and other controlled waterbodies, can draw down the water level to the point where cyanobacteria accumulations are exposed above the waterline. Subsequent dessication and/or scraping to remove the layer of cyanobacteria attached to sediment or rock is required, in addition to the reinjection of water into the system.	Easy to implement in controlled systems (i.e., reservoirs, dams, treatment facilities).	Can have a significant impact on other aquatic organisms in the system. Often times is expensive and requires a significant input of resources.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Drawdown and Desiccation

ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF
Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

WD-BB-12 2010

Lake Drawdown for Aquatic Plant Control

Lake level drawdown and the subsequent exposure of sediments to prolonged freezing and/or drying is an inexpensive means of aquatic weed control. Drawdowns serve to stress plants and could physically remove them from their habitat. Low water levels will expose the plants to desiccation and could ultimately affect plant vascular structure, thereby rendering the plant incapable of nutrient transport and function. This can temporarily reduce plant density for an undetermined period of time.

While being an economical means of plant control, lake drawdown is also rather unpredictable, and may cause some species to actually increase in abundance, or not affect some target species at all. Further, draining the water from an aquatic system can be detrimental to non-target organisms.

Factors Necessary to Increase Potential for Drawdown Success

Several factors are necessary to increase the potential for drawdown success. The amount and degree of the drawdown are probably the foremost important factors to consider. Most importantly, the capability to draw down the lake to a level suitable to maximize the exposed littoral zone is necessary.

Note: Causes increased methylation of mercury – a big concern in many western lakes from gold mining history

https://www3.nd.edu/~aseriann/Lake_Drawdown.pdf

B. Bloom control and remediation – when a bloom is present

Waterbody Management Method	Description	Benefits/Effectiveness	Limitations
Physical Controls			
Surface skimming	Cyanobacterial blooms often form surface scums, especially in the later stages of a bloom. Oil-spill skimmers have been used to remove cyanobacteria from these surface scums. Often times this technique is coupled with the implementation of some coagulant or flocculant.	Useful method for blooms that are in later stages and have formed surface scums. Successful results seen in field studies in Australia.	This technique cannot be effectively employed until the later stages of a bloom, at which point many of the harmful aspects of a bloom have materialized. Requires proper equipment prior to implementation.
Ultrasound	An ultrasound device is used to control HABs by emitting ultrasonic waves of a particular frequency such that the cellular structure of cyanobacteria is destroyed by rupturing internal gas vesicles used for buoyancy control.	Successfully implemented in ponds and other small waterbodies. A single device can cover up to 8 acres. Non-chemical; inexpensive.	Also disrupts cellular functioning of green algae. Effectiveness are dependent upon waterbody geometry and cyanobacteria species. Further research of method is required.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Mechanical Removal

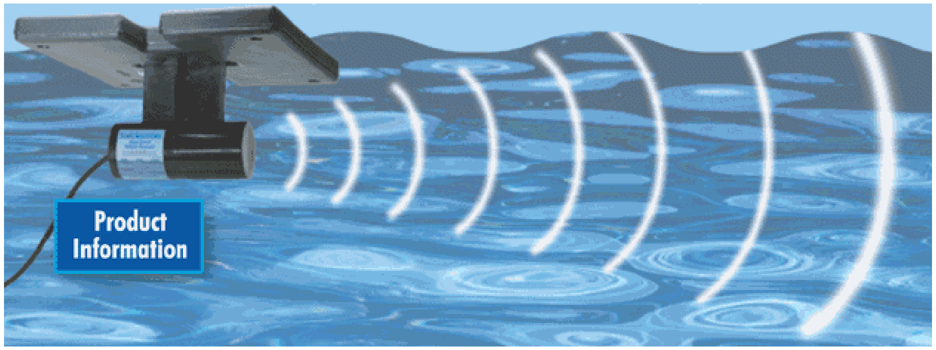
Skimming

Swan River, Perth, WA

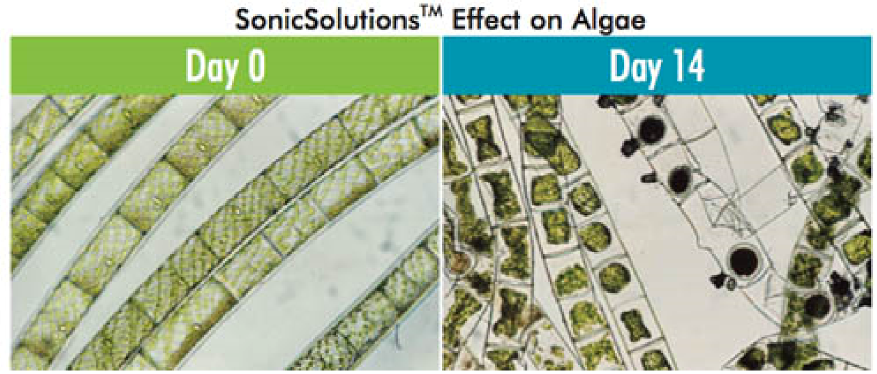
Note: Disposal of surface scums or skimmed material may need to meet regulations when toxins are present (could be considered hazardous waste)

Lake Sediment Removal

Ultrasonics



http://www.sonicsolutionsllc.com/images/SonicAnimat630pxforDisc%20-%20Optimized.gif



http://cdn2.hubspot.net/hub/227988/file-201537022-jpg/images/effectsOfAlgae.jpg?t=1371692499000

http://www.marylandbiochemical.com/images/WildingAcres.jpg

http://www.smokytroutfarm.com/Sonic%20Solutions%20Ultrasound%20Algae%20Control.jpg

Note: Cell lysis may result in release of toxins

B. Bloom control and remediation – when a bloom is present

Waterbody Management Method	Description	Benefits/Effectiveness	Limitations
Chemical Controls			
Algaecides	Algaecides are chemical compounds applied to a waterbody to kill cyanobacteria. Several examples are: • Copper-based algaecides (copper sulphate, copper II alkanolamine, copper citrate, etc.) • Potassium permanganate • Chlorine • Lime	Wide range of compounds with a history of implementation. Relatively rapid and well-established method. Properties and effects of compounds are typically well-understood.	Risk of cell lyses and the release of toxins. Thus, is often used at the early stages of a bloom. Certain algaecides are also toxic to other organisms such as zooplankton, other invertebrates, and fish.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

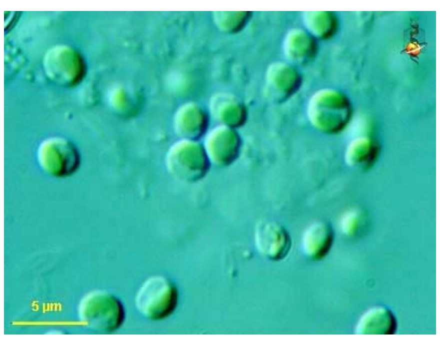
Algaecides (Kill or inhibit cells)

Inorganic chemicals

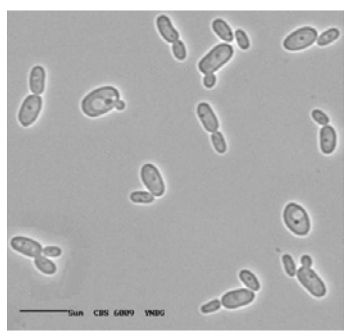
- $KMnO_4$, $FeCl_3$, chlorine, alum, flocculants
- NaOCl (bleach from electrified seawater)
- Hydrogen peroxide

Organic chemicals

- Aponin (from alga *Nannochloris* sp.)
- Sophorolipids (from fungus *Candida bombicola*)
- Phlorotanins (from brown alga *Ecklonia kurome*)
- Barley straw bales and extract



Nannochloris sp.



Candida bombicola

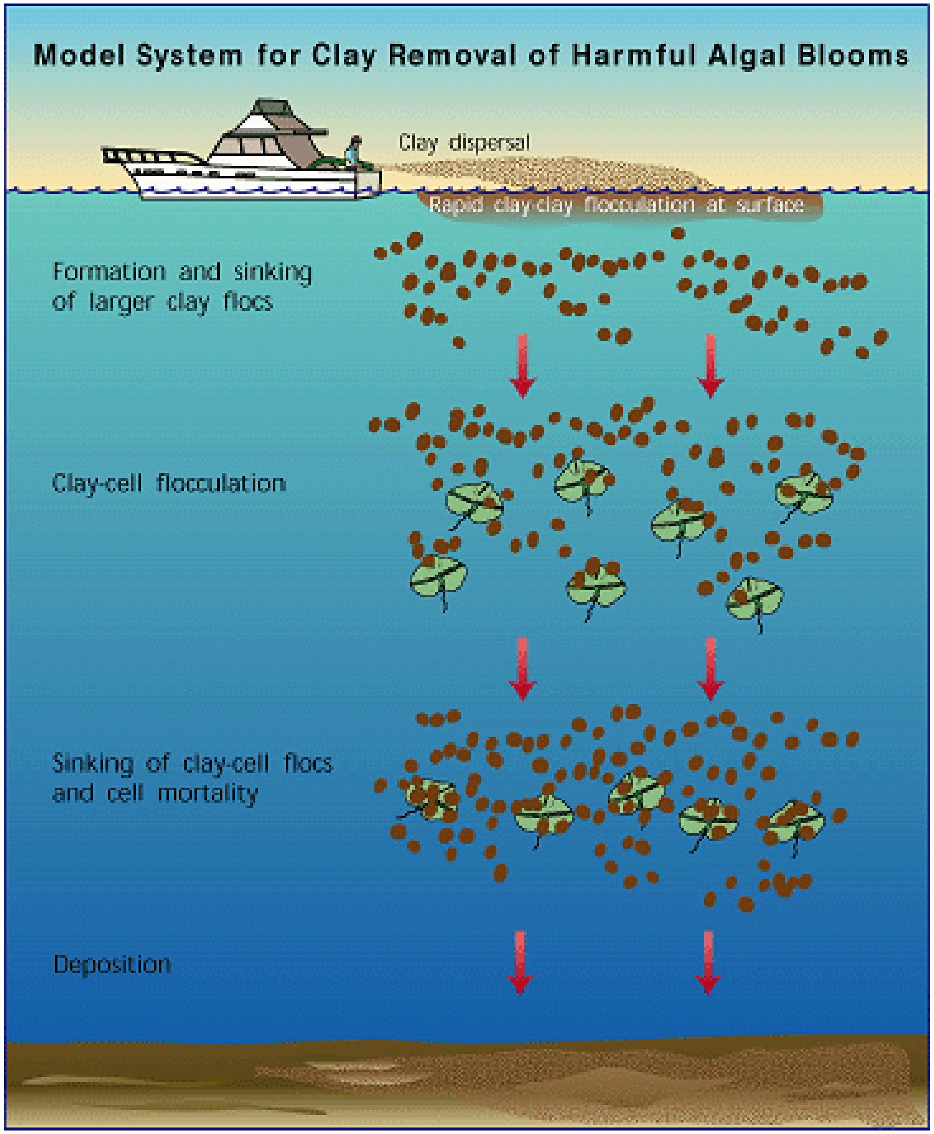
Ecklonia kurome

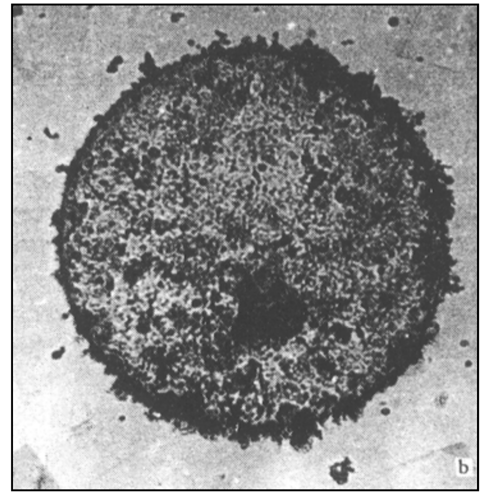
B. Bloom control and remediation – when a bloom is present

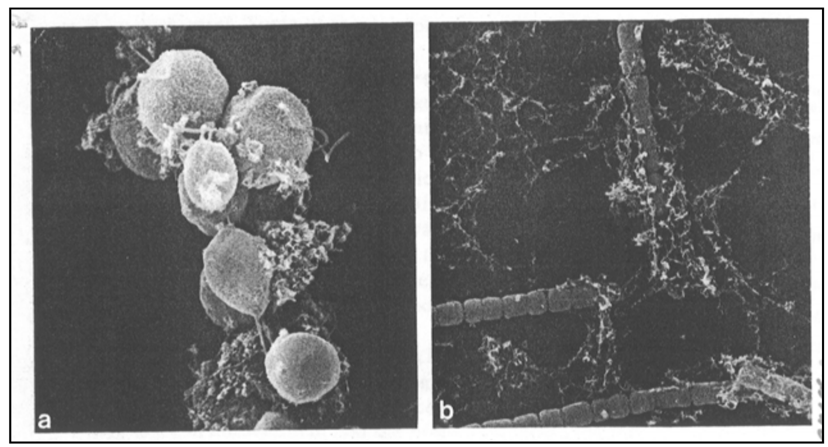
Waterbody Management Method	Description	Benefits/Effectiveness	Limitations
Chemical Controls			
Coagulation	Coagulants are used to facilitate the sedimentation of cyanobacteria cells to the anoxic bottom layer of the water column. Unable to access light, oxygen, and other critical resources, the cells do not continue to multiply and eventually die.	Several studies have shown that cells can be coagulated without damage; however, further research is required. Successfully implemented in several treatment facilities.	Subject to depth limitations. Coagulated cells become stressed over time and lyse, releasing toxins to the waterbody.
Flocculation	Flocculants are used to facilitate the sedimentation of nutrients to the anoxic bottom layer of the water column, thereby limiting nutrient levels in the waterbody and inhibiting cyanobacterial growth.	Successfully implemented in larger lakes and ponds (e.g., Florida DEP, Lake Hilaman).	Subject to depth limitations.

https://www.epa.gov/nutrient-policy-data/control-and-treatment

Clays (bind, aggregate and sink)







Clay treatment

South Korea

China

http://www.gangpan-environment.com/kindeditor/attached/image/20130514/20130514100056_3017.jpg

Sarasota Bay, FL

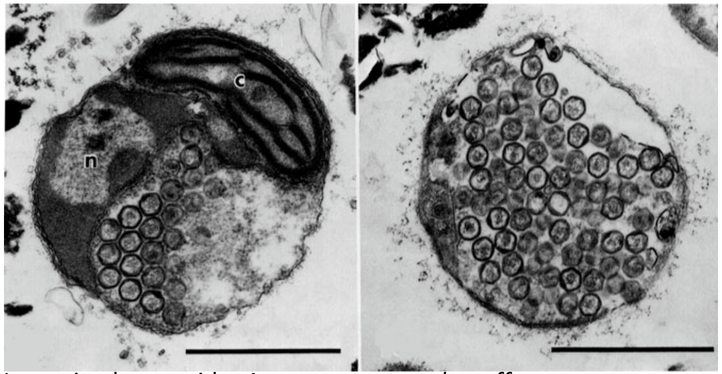
B. Bloom control and remediation – when a bloom is present

Waterbody Management Method	Description	Benefits/Effectiveness	Limitations
Biological Controls (Biomanipulation)			
Increasing grazing pressure	Various measures can be introduced to encourage the growth of zooplankton, benthic fauna, and other aquatic organisms that feed on cyanobacteria, thereby limiting the proliferation of cyanobacteria populations. Techniques include: • The removal of fish that feed on zooplankton and other benthic fauna or the introduction of predators to these fish, and • The development of niches to encourage the growth of beneficial organisms.	Biomanipulation has fewer direct detrimental effects on other aquatic organisms when compared to chemical and physical methods.	Unintended consequences may arise related to the deliberate modification of the biodiversity of the system. Requires constant monitoring. Increasing resource competition has only proven effective in shallow water bodies with moderate nutrient levels
Increasing resource competition	The introduction of other primary producers such as macrophytes can limit the available phosphorus and therefore limit cyanobacterial growth. An example of this technique is the introduction of floating wetlands (see above).		

https://www.epa.gov/nutrient-policy-data/control-and-treatment

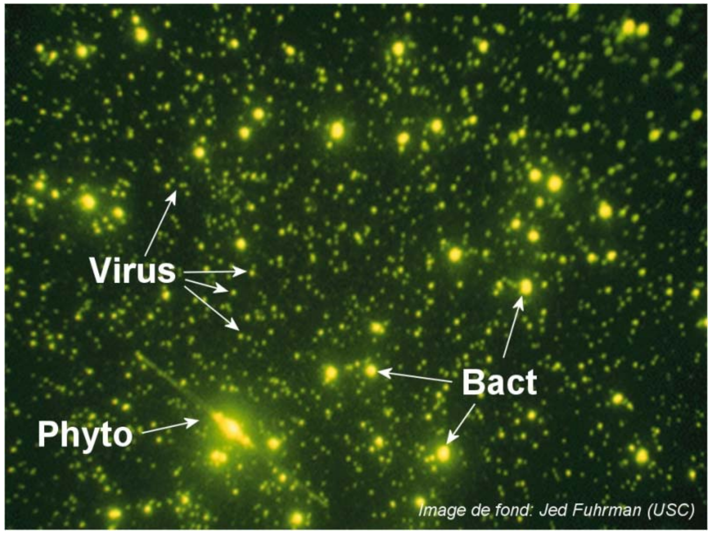
Biological Control and Biomanipulation

Viruses



In marine brown tide, *Aureococcus anophagefferens*

Bacteria



http://www.quebec-ocean.ulaval.ca/_images/Marine_microbe_A._Comeau_Jed_Furrman.jpg

Parasites

Parasitic dinoflagellate, *Amoebophrya* sp., in host dinoflagellate, *Dinophysis* sp.

Grazers

http://wilsonlab.com/images/daphnia.jpg

Competitors (including allelopathy)

http://cfb.unh.edu/phycokey/Choices/Prymnesiophyceae/PRYMNESIUM/Prymnesium_02_600x448_nies.go.jp.nies-1397.jpg

Waterbody Management

Pros

- Prevents/Limits the impacts of nutrient pollution and HABs over the *shorter term* in order to deal with real-time or impending threats to recreation, drinking water, and local economies.
- Allows time for criteria development and implementation, including policy challenges.
- Low costs relative to watershed management, particularly in the short term.

Cons

- Benefits may be temporary;
- Treatments may need to be repeated or maintained over time;
- Cost effectiveness can distract from addressing the problem itself (i.e., sources);
- Implemented in small scales. Some technologies untested for larger scales.

Watershed Management

Pros

- Addresses the sources of nutrients (both point and non-point), and aims to prevent or minimize excess nutrients from entering the system in the first place.
- Improvements over the *long term* and over a *larger geographic scale*, affecting multiple waterbodies.

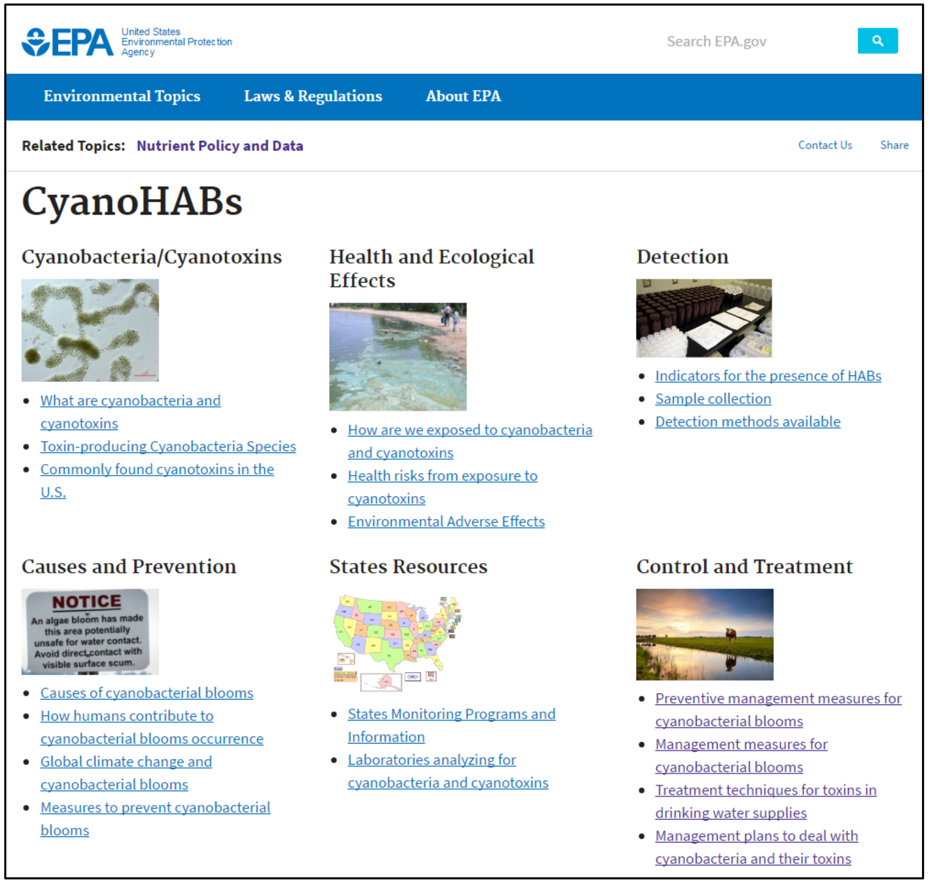
Cons

- Not designed to address imminent or existing HABs.
- Generally does not address the issue of legacy phosphorus in the sediment.
- Developing watershed management strategies and plans can present many technical and political challenges.
- May take time and resources to implement.
- Cost may be higher relative to waterbody management depending on size, number of inputs, and complexity of the watershed.

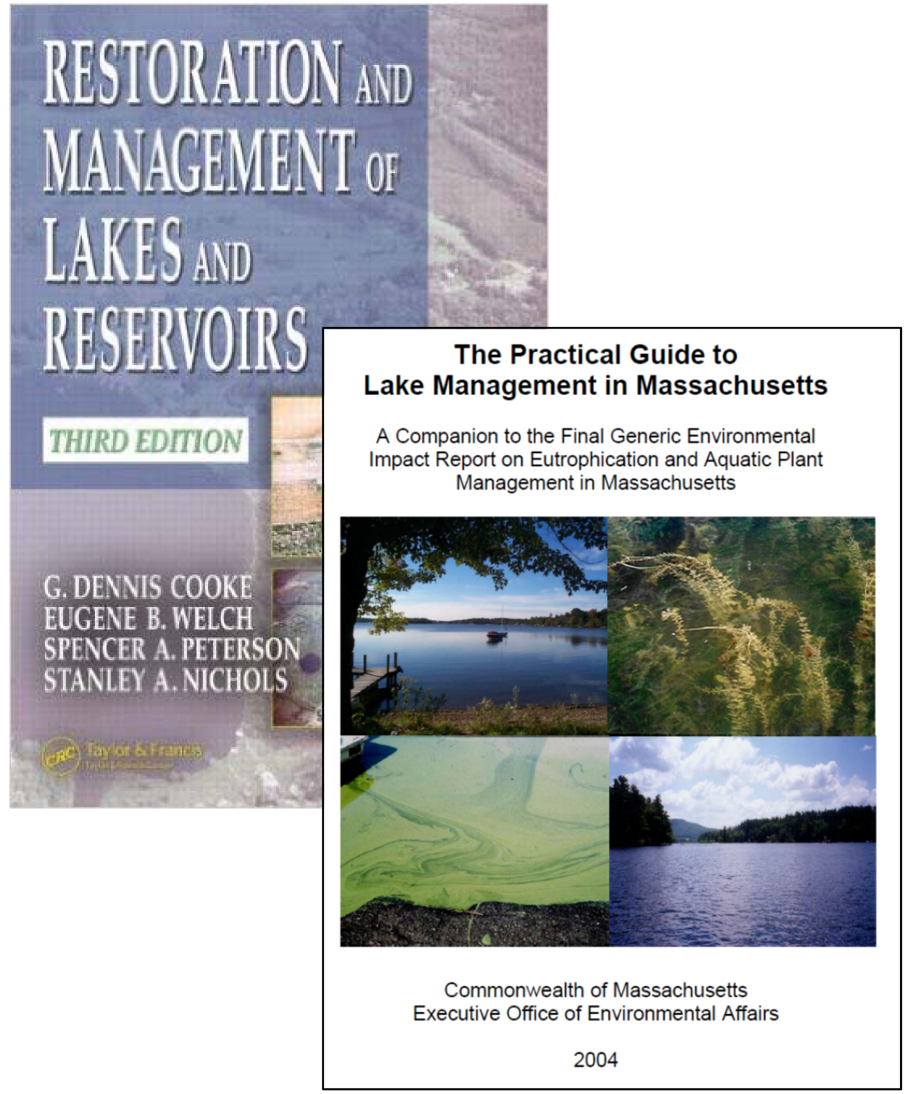
Resources

EPA CyanoHABs Website

https://www.epa.gov/nutrient-policy-data/cyanohabs



Publications, manuals, reports



http://archives.lib.state.ma.us/bitstream/handle/2452/36455/ocn244302727.pdf?sequence=1&isAllowed=y

Resources

See Chapter III.
Costs of Nutrient Pollution

Link to the report:
https://www.epa.gov/sites/production/files/2015-04/documents/nutrient-economics-report-2015.pdf

Link to the data spreadsheet:
https://www.epa.gov/sites/production/files/2016-03/nutrient-impacts-control-costs.xlsx