LET'S TALK ABOUT ALGAE, BLOOMs & HARMFUL ALGAL BLOOMS (HABs)

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What are Algae?

Algae are microscopic photosynthetic organisms with predominantly aquatic life.

They are an important primary producer and the base of the food web in aquatic systems.

They produce 50% of the Earth’s oxygen and provide energy to the entire aquatic ecosystem of the planet by turning carbon dioxide into organic matter using sunlight.

We NEED algae!
Bacillariophyta – Diatoms, showing live diatoms, Fred-Haffner Kettlehole collection 7/11/2022, All 1000x magnification

Genus Pinnularia

Species *Melosira varians* C. Agardh

Several *Gomphonema* and *Nitzschia* species epiphytic on *Cladophora*

Species *Navicula oblonga* (Kütz.) Kütz.
Species *Diatoma vulgaris* Bory, zig zag chains attached to Cladophora in Minnewashta Lake, IA

Genus *Mallomonas*, group *Synurophyta*, caught in young Cladophora (Chlorophyta) periphyton growth on the edge of Minnewashta Lake, IA

Cladophora (Chlorophyta) periphyton growth edge of Minnewashta Lake, 6/21/2022

Front shows young growth with no epiphyte, back shows golden brown with diatoms covering older Cladophora growth
Mini-wakan point Spirit Lake, IA, 6/28/2022, visible growth of Chlorophyta algae

*Stigeoclonium lubricum* (Dillwyn) Kütz.
(Chlorophyta, highly branching filament) 100x mag

Tetraspora sp. (Chlorophyta, Coccoid colony of cells arranged in sets of 4, in visible mucilage cloud)
Center Lake, IA west location, sampling 6/21/2022, taxa under the microscope show dominance of Cyanobacteria (all different shape colonies in black) but still co-dominance of high nutrient taxon like *Spirogyra sp.* (Chlorophyta, non branching filament).
Center Lake, IA west location, sampling 6/21/2022

Center Lake, IA west location, sampling 7/7/2022, extremely dangerous, there should be no fishing or swimming
Center Lake, IA west location, sampling 6/21/2022, taxa under the microscope show dominance of Cyanobacteria but also Ceratium hirudinella (Dinoflagellata)
Center Lake, IA west location, sampling 7/7/2022, taxa under the microscope show dominance of Cyanobacteria (all colonies in black), no representative of other algal groups were documented.
Microcystis aeruginosa (Kütz.) Kütz., FIELD IMAGE surface scum, Lake Sinclair GA, 2012

Microcystis aeruginosa (Kütz.) Kütz., at different magnifications
What are Algal Blooms?

Algal blooms are rapid increase in the population of algae in aquatic systems.

- They can occur in freshwater (lakes, ponds, rivers, or reservoirs) and marine environments.
- There can be millions of cells per milliliter of water.
- Algal blooms can be recognized by discoloration of the water and odor.
- Algal blooms can be variable in color and appearance.
- Some can be identified only with research grade microscope.
Visual evidence of cyanobacteria massive growth and potential toxin
What are HABs?
Harmful Algal Blooms (HABs)

Any visible on the surface algal growth is harmful for the ecosystem.

Like all living organism, algae respond to the environments. As primary producers they will grow when nutrients from agriculture runoff reach aquatic systems.....especially in summer....
dried up algal cells show blue (cyanobacterial phycocyanin) ... a good indicator to avoid water contacts and exposure

Visible colonies of *Aphanizomenon flos-aquae* Ralfs ex Bornet & Flahault 1886 ... a good indicator to avoid water contacts and exposure
Cyanobacteria Bloom, July 2022 Silver Lake, IA – note the blue-green surface of continuous algal layer and grass-clipping appearance of the colonies at closer look of (image 4, naked eye); images from 1 to 6 increase close-up look to colony structure of the filamentous *Aphanizomenon flos-aquae*, colonies appear black as each cell is full with air-vesicles called aerotopes.
When algal population grow rapidly, they may do the following to survive:

- Float to the surface using air bubbles (they all need sunlight to create energy) and create a continuous or streaking in appearance scum layers.
- All cells within these layers will photosynthesize when light is available (rarely more than 15 hours a day).
- Massive cell growth will shade out any other helpful algae and parts of individuals from own population.
- Algae take up oxygen 24 hours a day for cellular respiration, potentially creating anoxic (conditions causing fish kills).
- As the cells proliferate there is little space left between them for Carbon and other molecules.
- Synthesize toxins, which are byproducts needed for their survival; toxins help them concentrate carbon for the synthesis of organic material.
Cyanobacteria HABs are the most common

Cyanobacteria are one of the 11 groups of algae that can bloom. They can be present in most bodies of water and serve as an important part of aquatic ecosystems. Presence of Phosphorous will give advantage of cyanobacteria, as they can obtain gaseous N from the atmosphere without limitations at any time.

How can they be harmful?

Being on this planet for more than 3 billion years in low abundance of cells within a population, cyanobacteria are not harmful. Unfortunately, they can form extremely dense colonies called "blooms" within both freshwater and marine waters. Only blooms where Carbon becomes limited, Cyanobacteria can become potentially toxic.

Algal cell density visualization, all collected just below surface of a calm lake showing water discoloration, the middle vial has more than 10,000 cells per ml
How climate change will impact HABs

So far, global warming has been the most studied aspect of climate change on algae. Scientists have found that as the planet warms, atmospheric Carbon Dioxide (CO$_2$) is increasing. Higher amounts of CO$_2$ in the atmosphere have led to more and bigger harmful algal blooms.
BUT WHAT DOES THIS HAVE TO DO WITH YOU?

WHY SHOULD YOU CARE?
This has a lot to do with you...

HABs can:

• Permanent change of food sources
• Lower water quality
• Cause degradation of habitats
• Destruction of recreational areas
• Oxygen depletion -> cause fish/other aquatic wildlife kills
• Economic threat -> loss of revenue for tourist destinations
• Contact with toxins -> can cause serious health problems (long or short term, dependent on bioaccumulation)
Health Problems

Here is where you should begin to listen. These are just some of the toxins that could be present within the HAB in our water.

- **Microcystins**
  - Protein inhibitors
  - Severe liver damage
  - Pulmonary, neurological, and reproductive system effects
  - Deaths of diverse living organisms
  - Known human fatalities

- **Saxitoxins**
  - Some of the most potent natural toxins known
  - Block the channels within neurons
  - Can accumulate in shellfish, and then be eaten by humans
  - Rapid paralysis

- **Anatoxins**
  - Rapid neurotoxicity in mammals and birds
  - Potent neurotoxin
  - Causes excessive salivation

- **BMAA**
  - Neurotoxicity
  - Associated with human neurodegenerative diseases
  - Amyotrophic lateral sclerosis
  - Alzheimer's

- **Cylindrospermopsin**
  - Inhibits protein synthesis in animals and plants
  - Affects tissues in animals and other living organisms
  - Caused a hepatitis like illness within 10 adults and 100 children in Australia (Huisman et al. 2018)

- **Lipopolysaccharides**
  - Human skin irritations and rashes
  - Intense blisters
  - Upset stomachs
Okay so,

WHAT DO WE DO?
We need to first realize how different algae, and their blooms, can be.

"the genetic diversity and physiological flexibility of cyanobacteria CCMs enable rapid adaptation of bloom-forming cyanobacteria to rising CO₂ concentrations" (Huisman et al., 2018)

Some respond well to certain mitigation efforts, while others do not.
Some algae love high dissolved CO₂ levels while some love low.
Some algae are killed by parasites and fungi, while others get stronger and grow more as they develop stronger responses to it.
Dealing with HABs can be extremely challenging as microbial population are diverse and they ecology is largely unknown.
Watersheds and Airsheds

One way of looking at how we deal with HAB blooms today

Agricultural Best Management Practices

The increased use of fertilizer, the discharge of animal waste, the soil disturbance and erosion caused by farming, the atmospheric fossil fuel release from farm tools, agricultural emissions, and more are leading to immense problems. "Therefore, control of anthropogenic nutrients must be the primary focus when addressing CyanoHABS" (Paerl et al., 2015).

Organizations, like the National Pollution Discharge System, attempt to target point sources in order to stop nutrient release before it can begin.

From looking at the number of fertilizers and plows/other tools being used, to physically building land barriers between agricultural land and water sources, targeting point sources is an important mitigation strategy, particularly for large water sources.

Nitrogen Testing

Using nitrogen testing tools all farmers to choose the ideal time to place their Nitrogen. They can also determine how much Nitrogen they need to use based on how much is already in the soil.

Ultimately, Nitrogen testing can help farmers maximize their use of Nitrogen so that they can minimize the overall duration and amount they typically apply.

Results of using these Nitrogen tests, specifically handheld Nitrogen testers, have been promising. For example, if the same level of nutrient reductions, found in areas already utilizing this testing, was applied to the 20 million ha of the Mississippi River watershed cropland, it would virtually eliminate the excess anthropogenic N load to the Gulf of Mexico..." (Paerl et al. 2015).
Within the waterbody

Another way of looking at how we deal with HAB blooms today

Physical Manipulation

Scientists have worked to find physical ways to mitigate and remove excess nutrients from lakes to eliminate HAB.

Sometimes, teams can physically skim the water and collect the blooms. This physically collected organic material can then be used as mulch or fertilizer once any toxins have been removed.

Organizations can also vertically mix water sources; this means that the HABs are not able to sit upon the top of the water where they would steal sunlight and nutrients from other organisms in their ecosystems. This also encourages the growth of other organisms that could be competition for blooms.

Unfortunately, these methods often are costly, and they work well in small, shallow water for rapid periods of time, but they cannot provide long term relief, or aide within larger and deeper water.

Chemical Additions

- adding chemicals into water ecosystems can lead to the death and destruction of other living things within these ecosystems.
- addition of Hydrogen Peroxide has been seen as a good option when it comes to HAB mitigation, but not very widespread. It fades fast as it mixes with water, which makes it necessary to continuously add the Hydrogen Peroxide, leading to high costs.
- adding "Phospholock," which can lock nutrients within water. Phospholock specifically locks onto Phosphorous, leading it to settle on the bottom of water sources.
- This will not be the best option for large and deep-water sources, due to costs and space to cover.
Biological Mitigations

-one mitigation strategy is to remove the benthic fish that are present within high bloom locations. These fish feed along the bottom of water sources, grazing upon nutrient rich organic materials and then releasing more of nutrient into the environment once more. Through removing this fish, they won’t be present to stir up and re-release anthropogenic nutrients.

-can also add clay or other materials into water sources to physically suppress blooms.
Unfortunately, there is no easy solution...

Warmer waters, droughts, and more uses of water (drinking, recreation, agriculture, etc.) continue.

We must remember that our actions, such as allowing run-off of nutrients into water sources, has been going on for YEARS.

Even when nutrient sources are removed from reaching aquatic habitats, there is commonly a delayed recovery of affected lakes.

Scientists have a lot of work to do!

Study:
.....extremely adaptive algae species.

.....how our changing climate alters precipitation patterns.

.....how changing wind patterns will alter the temperatures of water, and how that change will affect HABs.

.....consistently monitoring the impacts of their work and change their methods to do better whenever possible.
So, where do we go from here...

"While forecasting the effects of climate change is a challenge, especially on local and regional scales, the high probability that future climatic conditions will favor bloom formation poses an added challenge to developing effective mitigation strategies that consider both nutrient and climate drivers"

(Paerl et al. 2015)

- Climate change will not be reversed immediately!
- Increasing human population will lead to more effects of fossil fuels, need for more agricultural products, and pollution to our environment.
- Algae can remove nutrients and toxins to improve drinkable, recreational, and navigational waters; can serve as food source and provide antioxidants
So, we add, that understanding the biology, ecology, and systematics of these ancient organisms is important for our future and survival.
So, where do we go from here...

At Lakeside we Educate, Communicate, and Inform

Through making you aware of algae and algal blooms (harmful and/or toxic), and ‘knowing that every second breath you take is from algae’ we hope that you and more people may be determined to learn about algae and bring attention to the mitigation of conditions that will push them to grow uncontrollably and as part of their survival alter our ecosystems to a point where they will be unusable for us!
Independent research HAB project, summer 2022 team members:

**Cassandra (Cassie) Araujo**, Ecology and Systematics of Algae student, first year graduate student at Ball State University, IN and the Charlie Reimer Scholarship recipient at Lakeside Lab.

**Veronica Hamilton**, Ecology and Systematics of Algae student, second year graduate student at Ball State University, IN; is a recipient of the Phycological Society of America research grant, and a US AF Veteran Graduate student.

**Sydney Brown**, second year phycology graduate student at Georgia College & State University and the Becker Family Graduate Research Fellowship recipient given by the Friends of Lakeside Lab.

**Callaghan (Callie)Thomas**, is an undergraduate student from the University of Iowa and took Cyanobacteria and Green algae virtual class this summer.

For more questions or more information contact **Dr. Kalina Manoylov**, who has been coming to Lakeside lab since 2006 to teach the Ecology and Systematics of Algae class (4 weeks class), covering Cyanobacteria and Green Algae as 2 weeks.

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• https://idph.iowa.gov/Environmental-Health-Services
• web: https://www.epa.gov/cyanohabs/health-effects-cyanotoxins

