Harmful Algal Blooms in Ponds:
Causes, Concerns, and Management

Eugene Braig,
Program Director,
Aquatic Ecosystems

The Ohio State University
College of Food, Agricultural,
and Environmental Sciences

OSU Extension, School
of Environment and
Natural Resources
Harmful Algal Blooms in Ponds

• What is this stuff!? 
• What causes it? 
• Concerns 
• Management strategies
What is this stuff!?

- Cyanobacteria are ordinarily responsible for **harmful algal blooms** (HABs).
- Not true algae: **Cyanobacteria** are often called “blue-green” algae.
- They are now recognized as bacteria that contain **chlorophyll** and are capable of **photosynthesis**.
- Cells of most species grow together in **colonies**.
- Most are capable of fixing their own nitrogen from the atmosphere using specialized cells called **heterocysts**.
  - Without the need for N compounds as nutrients, P enrichment can favor cyanobacteria blooms.
- A **bloom** is simply an abundant or excessive growth of algae or cyanobacteria.
What is this stuff!?
The major HAB players

**Microcystis**

- Colonies of small, spherical, bright green globs that vary buoyancy to seek optimal light conditions.
- Can turn the water column green or form large green slicks on the surface.
- Patches of turquoise and white foaminess often appear.
- **Cannot** fix nitrogen.
- By far the most common to Ohio ponds and western Lake Erie waters (the “Mike” of “Annie, Fannie, and Mike”).
The major HAB players

**Planktothrix** (some species used to be known as *Oscillatoria*)

- Colonies of planktonic filaments that distribute through the water.
- Often appears as classic dark-colored “blue-green” water but some species have a reddish-brown hue.
- Can be associated with an oily-looking surface film.
- **Cannot** fix nitrogen.
- Recently very common to Ohio’s reservoirs and inland waters.

Photo credit: Linda Merchant-Masonbrink, Ohio EPA
The major HAB players

Aphanizomenon

- Colonies of planktonic filaments that often bundle together and look like tiny grass clippings.
- Fixes atmospheric nitrogen in heterocytes.
- Sometimes sold as a dietary supplement. However, the supplement is not regulated and may contain cyanobacterial toxins. Consumers beware!
- The third of the three historically dominant species in Lake Erie (the -phani- of “Annie, Fannie, and Mike”).

Photo credit: US Fish & Wildlife Service, Klamath Falls, OR
The major HAB players

*Oscillatoria* (and related benthic species)

- Colonies of rather globy-looking filaments growing on pond substrates.
- Often form mats along the bottom that float to the surface later in the growing season.
- Lacks specialized cells but still fixes nitrogen from the atmosphere.
- Very common to shallow waters of ponds and relatively tolerant of low-light conditions.

Photo credit: Frank Gibbs
The major HAB players

**Lyngbya** (the outdated name *Plectonema* is still sometimes used)

- Colonies of clustered filaments, usually visible to the naked eye.
- Often form dense mats along the bottom that float to the surface later in the growing season.
- Lacks specialized cells but still fixes nitrogen from the atmosphere.
- One of Ohio’s recently problematic species (specifically *Lyngbya wollei*), especially on Maumee Bay near Toledo.
The major HAB players

*Cylindrospermopsis*

- Colonies of planktonic filaments that distribute through the water column.
- Fixes nitrogen and can be distinguished from *Planktothrix* by teardrop-shaped heterocytes.
- A recent invader to Ohio’s Lake Erie waters and Buckeye Lake.

Photo credit: David Patterson and Bob Andersen, Provasoli-Guillard Center
The major HAB players

Anabaena

• Colonies of hair-like filaments.
• Can be planktonic or form mats along the bottom or near shore.
• Fixes atmospheric nitrogen in heterocytes.
• The second of three historically dominant species in Lake Erie (“Annie”).
The major HAB players

**Nostoc**
- Colonies of filaments that usually clump into a green, gelatinous, “marble-like” ball.
- Fixes atmospheric nitrogen in heterocysts.
- Sometimes sold as a dietary supplement. However, the supplement is not regulated and may contain cyanobacterial toxins. **Consumers beware!**
What it is not

Planktonic diatoms (photo credit: Kannan and Lenca 2012)

Duckweeds or watermeal (photo credit: Mick Micacchion, Ohio EPA)

Filamentous green algae: *Cladophora* (photo credit: Sairah Malkin, University of Waterloo)
Pop quiz!

Duckweeds and watermeal: a nuisance, but harmless.

Microcystis: potentially toxic!
Harmful Algal Blooms in Ponds

• What is this stuff!?
• What causes it?
• Concerns
• Management strategies
What causes it?

Available resources (from the perspective of green stuff that lives in freshwater):

• Water.
• Physical habitat (the water column itself or substrate/sediment).
• Sunlight (to fuel photosynthesis) and heat energy.
• Nutrients.
What causes it?

• Primary nutrients: C and N.
  – Carbon (C) tends to be abundant as carbonate (CO$_3^{2-}$: especially in the presence of limestone substrates) and carbon dioxide (CO$_2$: a byproduct of respiration).
  – Nitrogen largely present as dissolved nitrogen gas (N$_2$), nitrate (NO$_3^-$), ammonia/ammonium (NH$_4^+$), nitrite (NO$_2^-$), and organics. Unionized ammonia (NH$_3$) is both uncommon and toxic.

• Nitrogen cycle is bacteria driven; moves toward nitrification in the presence of O$_2$: ammonia $\rightarrow$ nitrite $\rightarrow$ nitrate.

• Carbon and nitrogen are abundant enough to not commonly be limiting to freshwater systems.
What causes it?

• Primary nutrients: P.
  – Solid/precipitate/particulate forms of phosphorus (P) are not readily available as nutrients.
  – Dissolved/soluble forms and especially phosphate (PO$_4$) tend to be retained by landscape, are ordinarily present in low concentrations in water, and thus are almost always limiting.
    • Productivity algae and cyanobacteria responds directly to dissolved reactive (DRP)/soluble reactive P (SRP) concentrations.
  – P is much more soluble in the absence of oxygen.
Internal sources of excessive P

(...where DO is dissolved oxygen)

What causes it?

- **Primary nutrients:** P.
  - **A useful metric:** the N:P ratio (A big player in presence of HABs).
    - In natural systems, 16:1 (the “Redfield ratio”) is a benchmark; too far below can indicate P enrichment and make problems.
  - **The role of nutrient richness and temperature:**
    - That threshold is higher in warm and/or nutrient enriched systems like many ponds: problems often evident below 20:1.
What causes it?

(Heidelberg University, National Center for Water Quality Research and Joe Conroy, The Ohio State University as cited in Ohio EPA Div. of Surface Water. 2010. Ohio Lake Erie Phosphorus Task Force Final Report. Ohio EPA, Columbus.)
What causes it?

(Heidelberg University, National Center for Water Quality Research and Joe Conroy, The Ohio State University as cited in Ohio EPA Div. of Surface Water. 2010. Ohio Lake Erie Phosphorus Task Force Final Report. Ohio EPA, Columbus.)
What causes it?

- The *Microcystis–Anabaena* bloom of 2009 was the largest in recent years in our sampling region (Tom Bridgeman, University of Toledo, 2012).
- ...until 2011!
Lake Erie HAB Bulletin, 11 October 2011
(National Oceanic & Atmospheric Admin. 
Lake Erie HAB Bulletin, 11 July 2012.)
Dissolved P loading in 2011 and ’12

(Heidelberg University, National Center for Water Quality Research)
Seasonal Succession of Phytoplankton Populations

Abundance

Diatoms

Green Algae

Blue-Green

Diatoms

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
What causes it?

A summary of contributing factors

• **First and foremost**: The presence of excessive nutrients. Excessive nutrient loads and low N:P ratios favor HABs.
• Low water levels / low rainfall (can concentrate nutrients).
• Excessive runoff of nutrients with surface waters (a problem on large watersheds, like Lake Erie or Grand Lake).
• Lack of competition for nutrients (i.e., no vascular plants).
• Calm water.
• Warm water temperatures.
• Selective grazing by zooplankton and mussels.
• Progression of seasons.
Harmful Algal Blooms in Ponds

• What is this stuff!?  
• What causes it?  
• Concerns  
• Management strategies
First, a contrast: “true” algae

Some major groups of planktonic freshwater algae:

• **Diatoms**
  – Glass (silica) cell wall.
  – High lipid content (i.e., nutritional for zooplankton).
  – Cool-water blooms typical (even in winter).

• **Green Algae**
  – Closely related to higher plants.
  – Rarely bloom.
  – Less lipid, but still nutritious.

(modified from Chaffin 2013)
Blue-green Algae/Cyanobacteria

Simplified Aquatic Food Web

Phytoplankton ("algae")

Zooplankton

Forge & Young Game Fish (planktivores)

Benthic Organisms (Detritivores)

Adult Game Fish (piscivores)

Nutrients

Sunlight (energy)
Concerns

HABs can:

- Pollute ponds and recreational areas with scums.
- Cause **taste and odor problems** in drinking water and fish tissue.
- Reduce oxygen levels through the diel cycle or population crashes.
- Cause processing problems for water processing…
Concerns

• ...and HABs have the capability to produce toxins.
  – These toxins can cause health problems for animals and humans, particularly if ingested.
  – The presence of a HAB-forming organism does not necessarily mean toxin is being produced.

*Microcystis* (photo credit: Dr. Thomas Bridgeman, University of Toledo)
Off-flavor compounds

- **Geosmin** imparts a “muddy” flavor and…
- 2-Methylisoborneol (MIB), a “musty” one to water and fish.

  - Predictors in ponds:
    - Presence of a cyanobacteria bloom.
    - Positive correlations to temperature
    - Negative correlations to seasonal wind velocity.
Off-flavor compounds: human detection thresholds

<table>
<thead>
<tr>
<th></th>
<th>Geosmin (ppb)</th>
<th>MIB (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water¹</td>
<td>0.015</td>
<td>0.035</td>
</tr>
<tr>
<td>Lean fish (Channel Catfish)²</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Oily fish (trout)³,⁴</td>
<td>1.2–1.5</td>
<td>0.5–0.8</td>
</tr>
</tbody>
</table>

Rules of thumb:
• Easily detected in water (yucky!).
• For recreational fishing ponds, more problematic with larger fish.
• Fattier tissues (like trouts) hold increased concentrations for longer times.
• In spite of lower concentration, much more easily detected in leaner fish (e.g., black basses, sunfishes, catfishes, and Yellow Perch).

¹ Howgate (2004)
² Grimm et al. (2004)
Cyanobacterial toxins

- **Neurotoxins**: affect the central nervous system, causing tingling, dizziness, headaches, etc. Cumulative effects of some over time can lead to dementia or degenerative disorders (e.g., saxitoxins and anatoxin-a).
- **Hepatotoxins**: affect the liver, causing gastrointestinal symptoms. These are the most publicized affects of HABs and sometimes attributed with livestock deaths (e.g., microcystins and cylindrospermopsin).
- **Dermatotoxins**: affect the skin, causing rashes and itching (“seaweed dermatitis”) or allergic reactions (e.g., Lyngbyatoxin-a).

Ohio’s common cyanobacteria are known to produce toxins in all these categories.
Common Ohio cyanobacterial taxa and toxins that may be produced

<table>
<thead>
<tr>
<th>Cyanobacteria genus</th>
<th>Dermatoxins</th>
<th>Hepatotoxins</th>
<th>Neurotoxins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cylindrospermopsin*</td>
<td>Microcystins*</td>
<td>Anatoxin-a*</td>
</tr>
<tr>
<td>Anabaena</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aphanizomenon</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Cylindrospermopsis</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lyngbya</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Microcystis</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Nostoc</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Planktothrix</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

* Toxins for which the Ohio EPA may test in public waters.
Toxicity of Algal Toxins Relative to Other Toxic Compounds found in Water

- Reference Dose = amount that can be ingested orally by a person, above which a toxic effect may occur, on a milligram per kilogram body weight per day basis.
Cyanobacterial toxins

**Microcystins**, liver toxins produced by *Microcystis* and several other cyanobacteria, is the only cyanobacterial toxin well enough studied to have guidelines issued by the World Health Organization (2003).

- Increased monitoring of drinking water at microcystin concentrations > 1 ppb (μg/L).
- Risk to adult health from recreational contact with microcystin moderate at concentrations of 4–20 ppb.
- Ohio Environmental Protection Agency can post contact advisories at 6 ppb to protect children.

<table>
<thead>
<tr>
<th>Human-health risk</th>
<th>Cell concentration (per milliliter)</th>
<th>Chlorophyll a concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 20,000 cells</td>
<td>1-10 ppb</td>
</tr>
<tr>
<td>Moderate</td>
<td>20,000-100,000 cells</td>
<td>10-50 ppb</td>
</tr>
<tr>
<td>High</td>
<td>&gt; 100,000 cells</td>
<td>Visible scums</td>
</tr>
</tbody>
</table>
Cyanobacterial toxicity

• “In comparing the available indications of hazards from cyanotoxins with other water-related health hazards, it is conspicuous that cyanotoxins have caused numerous fatal poisonings of livestock and wildlife, but no human fatalities due to oral uptake have been documented.”

Cyanobacterial toxins in fish tissue

- Toxins highest in internal organs, but also can be found in fillets in small concentrations.
- Cyanotoxins actively eliminated by the liver: likely do not bioaccumulate from lower trophic levels into predatory fish (Ibelings and Chorus 2007).
- Microcystin is taken into muscle tissue of fish with exposure, but is eliminated within hours to days (e.g., Wilson et al. 2008).
- However, black crappie fillets collected by the Ohio EPA on Grand Lake St. Marys in June 2011 did contain microcystin (Schmidt et al. 2013).
- At a minimum, remove skin from fillets and wash thoroughly prior to cooking with water from a municipal water supply.

Bottom line...
A brief word for *Euglena*

- Blooms often have reddish hue.
- Historically thought to be harmless.
- Mysterious 2002 fish kill at a North Carolina culture facility.
- Fish toxin *euglenaphycin* first isolated in 2004 and described in publication in 2009 (NOAA).
- One to watch: not yet well researched.

(Photo credit: Clemson University Cooperative Extension 2015)
Harmful Algal Blooms in Ponds

- What is this stuff!?
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- Management strategies
Management strategies

• Management by cliché:
  – Approx. 1 proverbial g of prevention is of similar value to 1 proverbial kg of cure!

• i.e., Prevention or at least reducing the likelihood of bloom issues is much more valuable than treatment.
Management strategies: preventative

Manage nutrients and oxygen (and thereby the dissolution of P) proactively.

- Manage the pond’s watershed to minimize the input of nutrients:
  - Fertilize conservatively, avoiding P applications if possible.
  - Plant terrestrial vegetation in the watershed.
  - Manage to exclude Canada Geese whenever possible.

- Aerate with diffusers: ideally 2–3/ac spaced along the pond’s deep water.

- Tolerate up to approx. 25% coverage of submersed vegetation: ideally a combination of native pondweeds and naiads.
  - Limits cyanobacteria blooms via competition for available/soluble nutrients.
  - More stable supply of dissolved oxygen.
  - Dyes can help limit vegetation growth to shallow water, but confound colorimetric nutrient tests.
Management strategies: testing

Testing for toxins:

• Costly!

• Greater concern: ponds accessible by public or some clientele or used for domestic water supply.

• If you feel you must, Ohio EPA has compiled a fact sheet that lists Ohio consultants to do so:
Management strategies: treatment

Consider circumstances very carefully before treating an existing bloom!

- Most cyanobacteria respond to algaecides (especially copper chelates or sodium carbonate peroxyhydrate) similarly to true algae.
  - Tricky Oscillatoria blooms sometimes treated with a mixture of copper chelate, diquat, and a surfactant.

- Sudden kill of substantial summer bloom often results in oxygen crash, possibly even overwhelming the capacity of aeration.

- Alum treatment will remove phosphorus, but also kill the bloom, resulting in problematic low-oxygen issues.
  - Be careful with alum: can acidify ponds.
Additional sources of info

- Including current revision of Ohio’s HAB Response Strategy.
- Good visual catalog of blooms for comparison.
Additional sources of info

• HAB fact sheet: free from Ohio Sea Grant or OSU-SENR Extension agents:
  • Co-written by personnel from Ohio Sea Grant, OSU-SENR Extension, Ohio Dept. of Natural Resources-Division of Wildlife, and Ohio Environmental Protection Agency.
Additional sources of info

  – Pages 5–10 are especially relevant.
Questions?
Harmful Algal Blooms in Ponds

Eugene Braig,
Program Director,
Aquatic Ecosystems
614-292-3823
braig.1@osu.edu