Introduction to Cyanobacteria: Identification, Ecology, Health Effects, and Tracking

2019 Wisconsin Lakes Partnership Convention Workshop

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All photos by Gina LaLiberte unless otherwise attributed.
Workshop Agenda

- Introductions
- Resources
- Caveats
- Cyanobacteria & algae background
- Hands-on
- Health impacts & recreational guidelines
Taxonomic Resources
How To Know
THE FRESH-WATER ALGAE

An illustrated key for identifying the more common Fresh-water Algae to genus, with hundreds of species named and pictured and with numerous aids for their study.

by
G. W. PRESCOTT, Ph.D.
Professor of Botany
Michigan State University

Woods Hole Oceanographic Institution
Clark Reading Room

MARINE
BIOLOGICAL
LABORATORY
LIBRARY
WOODS HOLE, MASS.
W.H.O.I.

WM. C. BROWN COMPANY
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DUBUQUE, IOWA
Freshwater Algae
Identification, Enumeration and Use as Bioindicators

Second Edition

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Freshwater Algae
of North America
Ecology and Classification

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WILEY Blackwell

ELSEVIER
Field and Laboratory Guide to Freshwater Cyanobacteria Harmful Algal Blooms for Native American and Alaska Native Communities
Online Resources
### Species Search

**Search results**

For more detail, click on the name or the currently accepted name.

<table>
<thead>
<tr>
<th>Name</th>
<th>Current accepted name (if different)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anabaena flosaquae f. lemmermannii</em> (P.G.Richter)</td>
<td>Dolichospermum lemmermannii (Richter) P.Wacklin, L.Hoffmann &amp; J.Komárek</td>
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<td>Canabaeus</td>
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<td><em>Anabaena lemmermannii f. laxa</em> (Skuja)</td>
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</tbody>
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4 Found - Displaying 1 through 4
WI Cyanobacteria Resources

dnr.wi.gov and dhs.wisconsin.gov
Search for “algae”
Microscopes
Caveats

- Introduction to cyanobacteria
- Tools to ID cyanobacteria vs. other algae
- Resources for accurate communication
What are algae?

- Have chlorophyll, like plants
- Lack specialized tissues, unlike plants
- They grow everywhere, even in deserts
- From tiny unicells to giant kelp
Species vs. Strains

- Cyanobacteria (blue-green algae) are true bacteria
- Bacteria only divide – no sexual reproduction
- Different genetic makeups can evolve – these are strains.
Key features for identification

- Color. All algae have chlorophyll-a. Many have additional pigments.
- Texture: stringy and hair-like? Tiny particles in water? Does it drape over your fingers or run right through them?
- Shape of colonies
- In most cases, light microscopy is necessary.
Look for tiny green specks in water or green “dust” on surface
Don’t mistake duckweeds or watermeal for blue-green algae

Duckweeds (Lemna, Spirodela) have roots

Lemna, Spirodela, Wolffia

Watermeal (Wolffia) Tiny, firm, grainy

Virginia Tech Weed ID Guide
Don’t mistake yellow pollen for blue-green algae

Look for similar yellow “dust” on land
Euglena
Don’t mistake filamentous green algae for blue-green algae

**Spirogyra & relatives**
slippery texture, hairlike, unbranched

**Cladophora & relatives**
wet cotton texture, usually branching

S. Pfeiffer
Jar test vs. stick test

Fine green particles collected from just below the surface

Floats = likely Cyanobacteria

Sinks = likely not Cyanobacteria

Long green hair-like filaments = not Cyanobacteria (with 1 exception)

Jar images from Kansas Department of Health and Environment
“Blue-green” is misleading

Growing blooms are most often green in color.
growing

decomposing pigments are released

Spirogyra

M. Meade

J. Williamson

B. Butterfield
Orders of Cyanobacteria
Chroococcales

Single cells or colonies of (mostly) spherical or ovoid cells
Uniseriate, unbranched trichomes (filaments)
Nostocales

Heterocysts for $\text{N}_2$ fixation, false branching, uniseriate
Stigonematales

Heterocysts for N\textsubscript{2} fixation, true branching, multiseriate

Aeotkthonos hydrllicola
Eagle-killer Hydrllla dweller.
Wilde et al. 2014 Phytotaxa 181:243-260
PLANKTONIC BLOOMS: *Microcystis* and other buoyant species appear black when viewed with a microscope, due to light refraction by the gas vesicles in the cells.
Microcystis

The most common bloom-forming cyanobacteria genus in Wisconsin lakes
Aphanizomenon
Tiny grass clippings

C. Carlson
Dolichospermum lemmermannii viewed with dissecting microscope
Dolichospermum lemmermannii
(previously Anabaena)

J. Lamers, Pickerel Chain Lake Association
Dolichospermum lemmermannii bloom
Lake Superior July 2012

Gina LaLiberte, Wisconsin DNR

NOAA MODIS July 1, 2012
Dolichospermum lemmermannii
Sea caves, Apostle Islands National Lakeshore

B. Moraska Lafrancois, NPS
Gloeotrichia echinulata

Not usually associated with toxic bloom events, although some populations have been shown to produce microcystin at low levels. Blooms may be increasing, even in low-nutrient lakes. Resting cells overwinter in lake sediments.
Dense Gloeotrichia colonies
J. Williamson, Polk County Land & Water Resources Department
Woronichinia
(formerly Coelosphaerium)
Cylindrospermopsis raciborskii

Blooms may occur at depth

NR40 Prohibited species; subtropical but expanding its range in temperate regions
Floating Benthic Algal Mats: Oscillatoria, Lyngbya, Plectonema, Planktothrix
Oscillatoria princeps mats

E. Evensen
Cyanobacterial mat material received for identification

G. LaLiberte
Filaments are more evident in water. These filaments are very long for cyanobacteria – up to 10 mm.
Microseira wollei
(formerly Lyngbya, Plectonema)

Up to several cm long - huge for a cyanobacterium. “Breaks” are gaps between trichomes inside sheath.

R. Clements
Microseira wollei
forming balls in Lake Erie
Possible look-alike: purple sulfur bacteria. If material is very finely granular, use a microscope to confirm identity.
*Tolypothrix*

Can form balls on lake bottoms that later float to surface

Microscope needed for identification

False branching; heterocyte at branch

Olive-green to brown color
Aphanothece & Aphanocapsa
Colonies consist of small spherical or ovoid cells
Difficult to identify to species – microscope necessary
Aphanothece stagnina:
Globular or irregular colonies up to a few cm diameter
May form large masses on lake beds, or float
May contain calcite crystals
**Nostoc**
Aquatic species: pinhead to egg-size, on lake bottom or floating
*N. pruniforme*: “lake plums,” “mare's eggs”

Colonies consist of unbranched filaments in a firm gelatinous matrix
Filaments have heterocysts – *Nostoc* uses them to fix atmospheric nitrogen
Nostoc zetterstedtii: “lake blackberries”
Rare! Red-list species in Europe
Prefers Lobelia & Isoetes lakes (oligotrophic, clear water)
Replaced by N. pruniforme as lake water becomes more eutrophic

Please let me know if you find N. zetterstedtii or N. pruniforme! Gina.LaLiberte@wiscosin.gov
Nostoc commune

Terrestrial!

Star jelly, witches’ butter
*French: Crachat de lune*
(moon spit)

Outer mucilage layer
often dark yellow

Black and crispy when dehydrated
Rehydrates & is more noticeable after rain

That's not goose poop!
COULD BE MISTAKEN FOR NOSTOC: *Ophrydium versatile*

Colonial protozoan

Internal symbiotic algae (*Zoochlorella*) give colonies their green color

Soft, gelatinous texture

Colony may be attached to plants, on the lake bottom, or broken free and floating
Unbranched filamentous green algae: *Spirogyra* and relatives *Mougeotia*, *Zygnema*
"water silk," "frog spit"
Secretes pectin, giving it a slippery texture
Unbranched filamentous green algae: *Oedogonium*

Often covered with epiphytic algae and mixed in with other filamentous greens

Microscope needed for identification

Rings of apical caps from cell division are a key diagnostic feature.
Branched filamentous green algae: *Cladophora*

Microscope needed for identification, but cottony, highly branched greens on hard substrates at lake margins are usually *Cladophora*.

On rock in splash zone

Can be highly branched or have minimal branching.

Older portions are often covered with algal epiphytes. Diatoms make it appear to be a golden-brown color.
Branched filamentous green algae: *Cladophora* & *Rhizoclonium*

Microscope needed for identification.

Phenotypically plastic so they are difficult to identify to species.

*Cladophora* species with minimal branching are confused with related *Rhizoclonium*.

Often entangled with macrophytes or forming nuisance growths.

Large, coarse filaments (>40 μm diameter) are most likely *Cladophora*.
Branched filamentous green algae: *Pithophora*
Microscope needed for identification
Branching and coarse, rough texture.
Also known as “horsehair algae.”
Branches are at right angles and cells are long. Resting cells appear as dark ovals. Notorious for forming nuisance growths entangled in plants or floating.
Let’s look at algae!
Hazards of blue-green algae blooms

- They may form nuisance blooms.
- Blooms impact aquatic life.
- Some strains can make liver, cell, or nerve toxins if conditions are right.
- Toxins may irritate the skin in sensitive individuals; swallowing or inhaling them in water can cause illness.
- Not all blue-green algae make toxins, and toxins are not made all the time.
What causes harmful blooms?

- Excess nutrients are fertilizer for growth
- Primarily P, but N can be important too
- Warm water and calm weather
The details are more complicated...

- Species and strains
- Cell biochemistry
- Micronutrients (iron)
- Dissolved carbon
- Zebra & quagga mussels
- Nutrients & cells from lake sediments
- Herbicides?

“Favorable environmental conditions”
- Mark Vander Borgh, NCDENR
Are blooms more frequent?

- Yes – worldwide evidence
- Heavy rains & snowmelt: extra nutrients
- Drought – lower, warmer water
- Earlier warming & extended warming may lead to blooms

Figures from Wisconsin Initiative on Climate Change Impacts 2011: Wisconsin’s Changing Climate: Impacts and Adaptations
How do I get rid of it?

- Chemical treatment usually not permitted – killed cells can release toxins in 1 big dose.
- Other “solutions” are often ineffective or treat the symptom, not the cause.
- Reduce nutrient input, but internal loading can continue to fuel blooms.
Are blooms more toxic?

- New technology means we continue to learn more
- Ongoing research to identify toxins and their production pathways
Toxins

- We have a good idea of what common planktonic species contain strains that can make toxins.
- We know much less about uncommon or infrequently occurring species.
- About 2700 described species worldwide.
- Research carefully – unless you know the full story, inadequate information may cause you undue concern.
Toxin information online

- Assess your information sources.
- Papers – “toxic bloom-formers” without testing for toxins, or non-toxic taxa lumped in with toxic.
- E.g. *Nostoc zetterstedtii*. 
How to tell if it’s safe?

- What does the water look like?
- Can you see your feet?
- How does it smell?
- For pets, does the water look like something YOU would want in your mouth?
- Has there been a recent heavy rain? (higher bacteria levels)
Who is at risk

- Children, especially small children.
- People with compromised immune systems.
- People with allergies may have greater sensitivity.
Can I do my own testing?

- Yes – Wisconsin State Laboratory of Hygiene
- Keep in mind bloom may change significantly between time of collection and when results are available – concentration, toxin production
- Posting advisories should be left to public health officials
Who issues advisories?

Chapter 254.46 Beaches. The department or a local health department shall close or restrict swimming, diving and recreational bathing if a human health hazard exists in any area used for those purposes on a body of water and on associated land and shall require the posting of the area.

DNR has the responsibility for advisories at State Park and State Forest properties.
US EPA Draft Recreational Guidelines

Draft Recreational Advisory Levels for Cyanotoxins

<table>
<thead>
<tr>
<th>Microcystins (MC)</th>
<th>Cylindrospermopsin (CYN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 µg/L</td>
<td>15 µg/L</td>
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</tbody>
</table>

Swimming Advisory: not to be exceeded on any day (also dually proposed as Ambient Water Quality Criteria)

- Based on toxins’ **chronic** effects on target organs (liver, kidney), not on **acute** effects (e.g., allergic reactions, vomiting, diarrhea).
- Take children’s smaller size into account.
- Not enough data to determine cell densities or pigment levels (chlorophyll or phycocyanin) correlated with these toxin concentrations.

# WHO Recreational Guidelines

<table>
<thead>
<tr>
<th>Probability of Adverse Health Effects</th>
<th>Cell Density (cells/ml)</th>
<th>Microcystin-LR (µg/L)</th>
<th>Chlorophyll (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 20,000</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Moderate</td>
<td>20,000-100,000</td>
<td>10 – 20</td>
<td>10 – 50</td>
</tr>
<tr>
<td>High</td>
<td>100,000-10,000,000</td>
<td>20 – 2,000</td>
<td>50 – 5,000</td>
</tr>
<tr>
<td>Very High</td>
<td>&gt; 10,000,000</td>
<td>&gt; 2,000</td>
<td>&gt; 5,000</td>
</tr>
</tbody>
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**Images:**
- 31,000 cells/ml, MC 10.9 µg/L: S. Graham
- 3,000,000 cells/ml, MC 30.5 µg/L: K. Schreiber
- 51,000,000 cells/ml, MC 58.7 µg/L: C. Fitzgibbon
Signage – Mixed Interpretation by Public?

**CAUTION**

WATER QUALITY ADVISORY

This water may contain blue-green algae capable of producing toxins that can be dangerous to humans and pets.

FOR YOUR SAFETY

- If water is cloudy, looks like green paint or pea soup, or has a floating scum layer or floating clumps
- Do not swim or swallow water
- Do not allow pets to swim or drink
- Do not allow children to play in scum layer from shoreline
- Rinse off after swimming

For more information please contact the LOCAL HEALTH DEPARTMENT.

**HEALTH ALERT**

Toxic blue-green algae may be present in this area.

Avoid swallowing lake water and do not touch algal scums. Keep pets away from the water.

Do not swim in areas where you cannot see your feet in knee-deep water.

Be alert! Avoid water that:

- Looks like pea soup or spilled paint
- Is discolored or has colored streaks
- Has surface scums, mats, or films
- Has green dots or globs floating below the surface

For more information, call your local health department or visit http://dnr.wi.gov or http://www.dhs.wisconsin.gov

Sandusky Bay, Lake Erie

B. Culler, ODNR
Communication Caveats

• DON’T terrify your audience.

• Know who has the responsibility for issuing advisories. ALWAYS work with local public health officials (county or municipal) if there is a need to communicate risk to the public for a given water body.

• Be absolutely certain that a “bloom” is actually cyanobacteria!

• Recognize that conditions can change rapidly, so results may not reflect current conditions.

• Learn to identify impaired conditions, but recognize that toxins may persist after blooms abate, or may be produced by less noticeable benthic cyanobacteria.
Are they toxic? Can I even go in the water?

Can’t we test more?

Blooms change rapidly
Results delayed
Expensive!
Where to test on a large lake?
Satellite Monitoring

LANDSAT –
16 day interval + processing

UW SSEC and WisconsinView
Lake Erie Harmful Algal Bloom Forecast

Lake Erie Harmful Algal Bloom Bulletin
25 September, 2017, Bulletin 22

The Microcystis cyanobacteria bloom continues in the western basin along and offshore the Michigan and Ohio coasts from Maumee Bay east into the central basin, and northeast to the Ontario coast. Observed winds since Thursday (9/21-9/25) caused an increase in surface concentrations. Scums were visible within Maumee Bay extending northeast to the Ontario coast. Measured toxin concentrations are below recreational thresholds throughout most of the bloom extent, but concentrations can exceed the threshold within Maumee Bay and in the western basin extending toward the Ontario coast where the bloom is most dense (appearing green from a boat).

Forecast winds (2-5m) today through Wednesday (9/25-9/27) may increase the potential for scum formation. Forecast winds today through Thursday (9/25-9/28) may limit the transport of remaining Microcystis concentrations.

Please check Ohio EPAs site on harmful algal blooms for safety information: http://epa.ohio.gov/habalgae.aspx. Keep your pets and yourself out of the water in areas where scum is forming. NOAA/GLERL provides additional HAB data: https://www.glerl.noaa.gov/res/habs_and_hpoxia. The persistent cyanobacteria bloom in Sandusky Bay continues.

For more information, visit the NOAA HAB Forecast page: https://tidesandcurrents.noaa.gov/hab/lakeerie_bulletins/HAB20170925_2017022_LE.pdf
Lake Erie Harmful Algal Bloom Forecast

Figure 1. Cyanobacterial Index from NASA MODIS-Terra data collected 24 September, 2017 at 11:55 EST. Grey indicates clouds or missing data. The estimated threshold for cyanobacteria detection is 20,000 cells/mL.

https://tidesandcurrents.noaa.gov/hab/lakeerie_bulletins/HAB20170925_2017022_LE.pdf
Cyanobacteria Assessment Network

EPA, NASA, NOAA, & USGS

Data from NASA/USGS LANDSAT & European Space Agency Sentinel satellite missions

Most inland lakes are too small for satellite monitoring. **Toxins cannot be detected via remote sensing.**

Android app in beta testing.

D. Gurlin

https://www.epa.gov/water-research/cyanobacteria-assessment-network-cyan
Composite cyanobacteria cell count maximums (over 1 week) are updated weekly.

Caveats:
Lag in data availability from ESA.
Thin clouds & ice may register as blooms.
Data better for lakes > 900m (0.56 mile).
**Data are most reliable for open water in the middle of a lake.** Pixels containing land & water are not accurate so this is not suitable for assessing blooms near shore.

Consider this a research level tool.
7-day composite value from August 27, 2017 through September 2, 2017
How can I help track blooms in Wisconsin?

“Jar Test”
Does it form a floating layer?

“Stick Test”
Is it filamentous green algae?

Please let the DNR know about significant bloom events!
DNRHABS@wisconsin.gov

Bloom location, size, duration, photos

- DNR cannot test for each bloom, but knowledge of blooms helps us to track where HABs are a public health burden.
- Most bloom-tracking apps/websites DO NOT report to DNR.
- The exception is bloomWatch: https://cyanos.org/bloomwatch/ BUT follow-up information by states to bloom reporters is not supported.
HAB Incident Reports Map

Where are freshwater and estuarine HABs occurring in California?

This map only shows locations where harmful algal blooms (HABs) have been voluntarily reported. California currently does not have adequate funding for a statewide routine monitoring program so monitoring data is limited. A waterbody with no data is not an indication that a bloom is not present. Data represent reported locations with pop-up windows providing additional data for each HAB incident such as host and lab results. Several routine monitoring programs exist for some locations (HABWatch, East Bay Regional Parks, Delta Limit, and reservoirs along State Water Projects), which may share monitoring data to present in this map.

Note: The exact location, extent, and toxicity of the reported bloom may not be accurate and may not be affecting the entire waterbody. Please use data presented in this map for general purposes only, as it may contain errors. The data are subject to change as new information is received. Please check back for daily updates.

To download the full data set, click the download button located on the bottom right of the map below. A recent copy of the HAB Incident Report data set is also available as a "zip" file on the California Open Data Portal.

https://mywaterquality.ca.gov/habs/where/freshwater_events.html
How can I get updates?

Updates to the DNR blue-green algae website, HAB tracking, and webinars will be posted to GovDelivery.

Subscribe to email or text updates – check the box for “Blue Green Algae” under the Lakes heading, and submit.
Are they toxic? Can I even go in the water?

Knowing instantaneously if toxins are not present, or if the cyanobacterial population does not have toxin genes, is the only way to be certain that it is safe. We're not there... yet.

The tricorder reading indicates a high level of cyanobacterial toxins.
For now, common sense applies.

Can you see your feet in knee-deep water?

Avoid water that resembles a green milkshake, pea soup, or paint.

Smell earthy or musty odors? Toxins might be present.


Cyanotoxins can still be present without odors

Choose the clearest water possible for swimming.

Try to avoid swallowing water, no matter how clean it looks, especially after a rainstorm!
Sometimes the risk is obvious.
If there’s no public health testing, how can you stay safe?

Learn what to look for.
Use common sense.
Avoid submerging your head if water contains lots of particles or debris.
This will help to protect you from other bacteria, viruses, and parasites.
Keep water out of your mouth!
You can see the blooms that are of highest concern

Planktonic (free-floating) blooms are visible either as surface scums or mixed into water in high concentration ("pea soup" appearance)
What about other situations?

- Blooms patchy or in small areas
- Chunks of material floating or growing on lake bottom
- Fine dusting of cyanobacteria on surface

Judgment call – account for health vulnerabilities, ability to keep water out of the mouth. Consider choosing another area for recreation if better conditions are available.
How to be safe?

- Avoid swimming in and boating through blue-green algal scums and "pea soup" water.
- **Can you see your feet in knee-deep water?** If not, avoid ingesting any water.
- Choose the **clearest** water possible for small children and pets.
- Always shower after swimming in a lake, river, or pond.
- Try to avoid swallowing water, no matter how clean it looks (especially after a rainstorm!)

When in doubt, keep out!
Keep your pets safe!

- Animals don’t instinctively know if water is safe.
- Provide clean drinking water.
- Keep pets out of scummy water, and wash them off immediately after they swim.
- Don’t allow dogs to eat dried scum on shore or floating mats.
Report illnesses in humans & animals online, or call 608-266-1120

Search for “algae”

Please let the DNR know about significant bloom events!

DNRHABS@wisconsin.gov
Bloom location with lake, town, & county name, size, duration, photos

DHSDPHHABS@dhs.wisconsin.gov  Gina.LaLiberte@wisconsin.gov