

NATURAL RESOURCES BOARD AGENDA ITEM

SUBJECT: Information item on blue-green algae in Wisconsin waters - ecology and ecological effects, locations of blooms, human health effects, and Department monitoring and responses

FOR: SEPTEMBER 2011 BOARD MEETING

TO BE PRESENTED BY / TITLE: Dr. Jennifer Hauxwell, Chief; Gina LaLiberte, Research Scientist; WDNR SS
Dr. Mark Werner, Toxicologist, WI Div Public Health; Tim Asplund, WDNR WT

SUMMARY:

The Natural Resources Board requested that Science Services lead an information briefing on blue-green algae in Wisconsin. Blue-green algae blooms pose aesthetic, environmental, and public health challenges for Wisconsin waters. We will discuss the ecology of blue-greens, factors associated with bloom formation, waterbodies in the state which have been impacted by repeated bloom events, and the Department's monitoring program and response. Blue-green algae are capable of making a range of toxins which can have minor to serious effects on wildlife, livestock, pets, and humans. Dr. Mark Werner of the Department of Health Services will discuss what is known about the human health effects of these toxins.

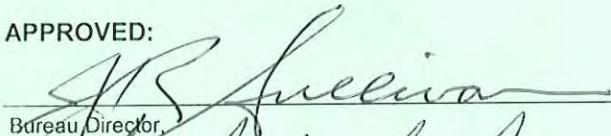
In addition to the presentation at the Board meeting, we provide background materials on blue-green algae related to ecology, distribution and public health, as well as DNR's efforts to understand the issues, educate the public, and manage the challenges associated with blue-green algae.

RECOMMENDATION:

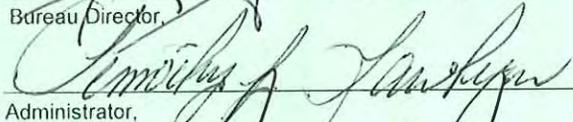
LIST OF ATTACHED MATERIALS:

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|----|-------------------------------------|---|-----|-------------------------------------|----------|
| No | <input checked="" type="checkbox"/> | Fiscal Estimate Required | Yes | <input type="checkbox"/> | Attached |
| No | <input checked="" type="checkbox"/> | Environmental Assessment or Impact Statement Required | Yes | <input type="checkbox"/> | Attached |
| No | <input type="checkbox"/> | Background Memo | Yes | <input checked="" type="checkbox"/> | Attached |

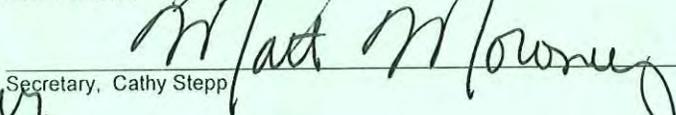
APPROVED:


Bureau Director

7/18/2011
Date


Administrator

7/20/2011
Date


Secretary, Cathy Stepp

7/28/11
Date

for
cc: NRB Liaison
DNR Rules Coordinator

DATE: July 18, 2011
TO: Natural Resources Board
FROM: Cathy Stepp
SUBJECT: Information item on blue-green algae

The Natural Resources Board requested that Science Services lead an information briefing on blue-green algae in Wisconsin. Blue-green algae blooms pose aesthetic, environmental, and public health challenges for Wisconsin waters. Staff will discuss the ecology of blue-greens, factors associated with bloom formation, waterbodies in the state which have been impacted by repeated bloom events, and the Department's monitoring program and response. Blue-green algae are capable of making a range of toxins which can have minor to serious effects on wildlife, livestock, pets, and humans. Dr. Mark Werner of the Department of Health Services will discuss what is known about the human health effects of these toxins.

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Background Information for Blue-Green Algae Informational Item Wisconsin Natural Resources Board Meeting September 28, 2011

Contents of Blue-Green Algae Supporting Information Packet

Each item includes file name and web address, if available.

A. Ecology and Distribution of Blue-Green Algae

1. DNR Talking Points on Blue-Green Algae
01_DNR_Talking_Points_2011.pdf
2. Occurrence of Toxic Blue-Green Algae in Wisconsin Waters map
02_DNR_Toxic_BGA_in_WI.pdf
3. Cyanobacteria: Biology, Water Blooms, Cyanotoxins, and Prohibited Species in Wisconsin
DNR
03_DNR_Review_Cyanobacteria_Biology_WaterBlooms_Cyanotoxins.doc
4. DNR Blue-Green Algae Frequently Asked Questions, from public DNR web page
04_DNR_Blue-Green_Algae_FAQs.pdf
<http://dnr.wi.gov/lakes/bluegreenalgae/WisconsinLakesBGA.pdf>

5. Wisconsin Natural Resources Magazine August 2010 article: "Less P is Key"
05_WNRM_Less_P_is_Key.doc
<http://dnr.wi.gov/wnrmag/2010/08/phos.htm>

6. Lakeline Spring 2001 article "Blue-green Algae in Eutrophic Fresh Waters"
06_Lakeline_2001_BGA_in_eutrophic_freshwaters.pdf

B. Public Health Aspects of Blue-Green Algae

7. Centers for Disease Control harmful algal blooms fact sheet
07_CDC_HAB_factsheet.pdf
<http://www.dhs.wisconsin.gov/eh/bluegreenalgae/pdfs/CDCHabfactsheet.pdf>

8. Department of Health Services Blue-Green Algae Fact Sheet
08_DHS_FactSheet-Public.pdf

9. Department of Health Services Blue-Green Algae Harmful Algal Bloom Brochure
09_DHS_HAB_Brochure.pdf
http://www.dhs.wisconsin.gov/eh/bluegreenalgae/pdfs/hab04_2010.pdf

10. Department of Health Services Pet Safety Brochure
10_DHS_Pet_Safety_2010.pdf
<http://www.dhs.wisconsin.gov/eh/bluegreenalgae/pdfs/petsafety021010.pdf>

11. Department of Natural Resources Algal Toxins Occupational Exposure Fact Sheet
11_DNR_Occupational_Exposure-AlgalToxins.pdf
<http://dnr.wi.gov/lakes/bluegreenalgae/OccupationalExposure-AlgalToxins.pdf>

C. Department of Natural Resources Program involvement with blue-green algae

12. 2010 Water Division Report: Managing Lakes, Rivers, and Streams section.
See pages 6 and 8.
12_DNR_2010_WaterDivision_Report_Lakes_Section_1_05_11.pdf
http://dnr.wi.gov/environmentprotect/waterDocuments/Lakes_Section_1_05_11.pdf

13. 2010 Water Division Report: Managing Emerging Issues section.
See pages 3 and 4.
13_DNR_2010_WaterDivision_Report_EMI_Section_1_05_11.pdf
http://dnr.wi.gov/environmentprotect/waterDocuments/EMI_Section_1_05_11.pdf

14. Wisconsin Natural Resources Magazine June 2011 article: "A Watershed Year" on the state of Wisconsin's lakes
14_WNRM_A_Watershed_Year.doc
<http://dnr.wi.gov/wnrmag/2011/06/lakes.htm>

Gina LaLiberte
608-221-5377
WI DNR

Talking Points on Blue-Green Algae June 2011

Background Information

- Blue-green algae are really photosynthetic bacteria (a.k.a. cyanobacteria)
- They make up a portion of the phytoplankton in many water bodies, but unlike most other phytoplankton, blue-green algae are largely inedible
- Most commonly detected genera include *Microcystis*, *Anabaena*, *Aphanizomenon*, *Planktothrix*, *Lyngbya*, and *Cylindrospermopsis*
- Can increase in number to "bloom densities" in surface waters with high concentrations of nutrients, particularly phosphorus
- Most species are buoyant and when their densities become high, they can accumulate on the surface and form scum layers, mats, or blobs
- These blooms are most often green or blue-green in color, but may also be blue, reddish brown, or brown
- Blooms tend to grow when there is a lot of sunlight, the temperature is warm, the water is shallow and there is little wind
- Sometimes when the wind kicks up, blue-green algae will pile up on the windward side of the lake
- Another important factor is the presence of zebra mussels
- Zebra mussels filter the water, allowing deeper penetration of sunlight (which increases potential for photosynthesis)
- Also, zebra mussels eat all types of phytoplankton except blue-green algae (they spit blue-green algae out), allowing blue-green algae to outcompete other phytoplankton species
- While blooms occur most frequently in summer, blooms have been observed in Wisconsin in fall and winter also (even occurring under the ice)

Issues Associated with Blue-Green Algae

- Discolored water
- Taste and odor problems
- Reduced light penetration
- Dissolved oxygen depletions during die-off
- Toxin production (most blue-green algae species commonly found in Wisconsin are capable of producing toxins)

Blue-Green Algal Toxins

- Some species of blue-green algae can produce one or more toxins
- Those that can produce toxins do not produce toxins at all times
- It is difficult to predict whether toxins are being produced by a particular bloom of blue-green algae
- Factors involved in toxin production may include environmental conditions and genetic strain
- Toxins can affect
 - fish and aquatic life
 - waterfowl
 - livestock (reports of cattle deaths widespread)
 - pets (reports of dog deaths widespread)
 - humans (70 deaths in Brazil following dialysis with microcystin-contaminated water, 1996; 1 in WI, 2002)

Types of Blue-Green Algal Toxins

- Dermatoxins and Gastrointestinal Toxins
 - affect skin and mucous membranes
 - can cause rashes, respiratory illness, headaches, gastrointestinal upset
 - lyngbyatoxin, lipopolysaccharide endotoxins
- Hepatotoxins
 - affect the liver (cell membrane integrity)
 - can cause hemorrhage, tissue damage, tumors, liver cancer, death
 - microcystins, nodularins
- Cytotoxins
 - affect the liver and other organs (protein synthesis)
 - can cause chromosome loss, DNA strand breakage, damage to organs
 - cylindrospermopsin
- Neurotoxins
 - affect the central nervous system (acetylcholinesterase, sodium channels)
 - can cause seizures, paralysis, respiratory failure, death
 - anatoxin-a, saxitoxin

BMAA (β -N-methylamino-L-alanine)

- “Novel” neurotoxin (actually identified in 1966) associated with blue-green algae
- Chamorro people (Guam) found to be dying of neurodegenerative diseases at a higher than expected rate

- Researchers found BMAA in cycad seeds used to make flour (blue-green algae inside seeds)
- But not high enough concentrations to account for illness
- Also ate bats that ate the seeds
- Cox et al. (2005) found 10,000X concentration in bats
- BMAA may be linked to Alzheimer's, Parkinson's, and ALS
- BMAA found in brains of some Alzheimer's patients in Canada
- Cox tested blue-green algae from all over the world
- BMAA in 29/30 samples
- BMAA may be capable of moving up the freshwater food chain

DNR's Blue-Green Algae Monitoring Project

- WI DNR conducted a multi-year study to investigate the frequency, severity, and duration of blue-green algae blooms, including information on which species of blue-green algae are present over the course of the summer
- We also looked for the presence and concentrations of specific toxins: anatoxin-a (a neurotoxin), microcystin-LR (a hepatotoxin), and cylindrospermopsin (a cytotoxin)
- Samples were (for the most part) collected from 5 lakes in each of 5 regions, 5 times over the course of each summer (2004 and 2005)
- Samples were also collected from 8 ponds in the South Central region of the State
- It is important to note that we chose to sample sites where blue-green algae blooms had occurred in the past or where they could potentially occur, based on nutrient concentrations
- Therefore, this was not a random sample of lakes and ponds meant to represent all lakes and ponds in Wisconsin
- Also, unlike the beach monitoring study for *bacteria*, this study was NOT designed to provide real-time information on the presence of blue-green algae or blue-green algal toxins, and only a limited number of surface waters could be monitored in each region of the state
- However, when DNR received information from the SLOH on the presence of high counts of blue-green algae or on the presence of blue-green algal toxins, this information was shared with the local public health agency
- Only DHFS or the local public health agency has the authority to close a beach

Results of the Blue-Green Algae Monitoring Project

- The total number of samples collected in the statewide monitoring study was 187

in 2004, and 194 in 2005

- Blue-green algae were present in 74% of all samples collected in both 2004 and 2005 (again, samples were collected from sites where we believed the potential for blooms was high)
- Blooms occurred in all regions of the state, with the biggest “hot spots” in WCR and SCR
- Alerts were sent out to local public health agencies when concentrations of blue-green algae likely exceeded the World Health Organization (WHO) guideline of 100,000 cells/mL. This concentration represents a “moderate risk to human health”.
- 33 alerts were sent out in 2004; 42 alerts were sent out in 2005
- A subset of the total number of samples collected was analyzed for toxins at the end of each summer (45 samples in 2004, and 34 samples in 2005)
- Microcystin-LR was the toxin detected most frequently and in the highest concentrations
- Microcystin-LR was detected in NOR, SCR, and WCR, and concentrations ranged from 1.2 to 7,600 µg/L (or parts-per-billion)
- The WHO has established a guideline value of 1.0 µg/L for microcystin-LR in drinking water
- The toxin anatoxin-a was detected in samples collected in NOR and SCR, and its presence was associated with a dog death in 2004
- Concentrations of anatoxin-a ranged from 0.7 to 110 µg/L
- The WHO has not established a guideline value for anatoxin-a, but several peer-reviewed papers have recommended a value of 3 µg/L
- The toxin cylindrospermopsin was never detected

Response by Local Public Health Departments

- Some closed/reopened beaches
- Some posted advisory signs only while the bloom was visible
- Some posted advisory signs from the time they received the alert until the end of the summer
- One obtained funds to do additional sampling

Measures People Can Take to Protect Themselves

- Do not swim in water that looks like "pea soup", green or blue paint, or that has a scum layer or puffy blobs floating on the surface
- Do not boat, water ski, etc. over such water (people can be exposed through inhalation)

- Do not let children play with scum layers, even from shore
- Do not let pets or livestock swim in, or drink, waters experiencing blue-green algae blooms
- Do not treat surface waters that are experiencing blue-green algal blooms with any herbicide or algacide-- toxins are released into the water when blue-green algae cells die
- Always take a shower after coming into contact with any surface water (whether or not a blue-green algae bloom appears to be present; surface waters may contain other species of potentially harmful bacteria and viruses)

Measures People Can Take to Help Reduce Future Blue-Green Algae Blooms

- Maintain native vegetation along shorelines as buffer areas
- Minimize activities that result in erosion
- Reduce the amount of fertilizer used on lawns
- Use only phosphorus-free fertilizer when possible
- Fix leaking septic systems
- Use only phosphorus-free detergents in dishwashing machines

Please see DNR web site for more information

-<http://dnr.wi.gov/org/caer/ce/news/on/2005/on050614.htm#art1>

-<http://dnr.wi.gov/org/water/wm/wqs/bgafaq.pdf>

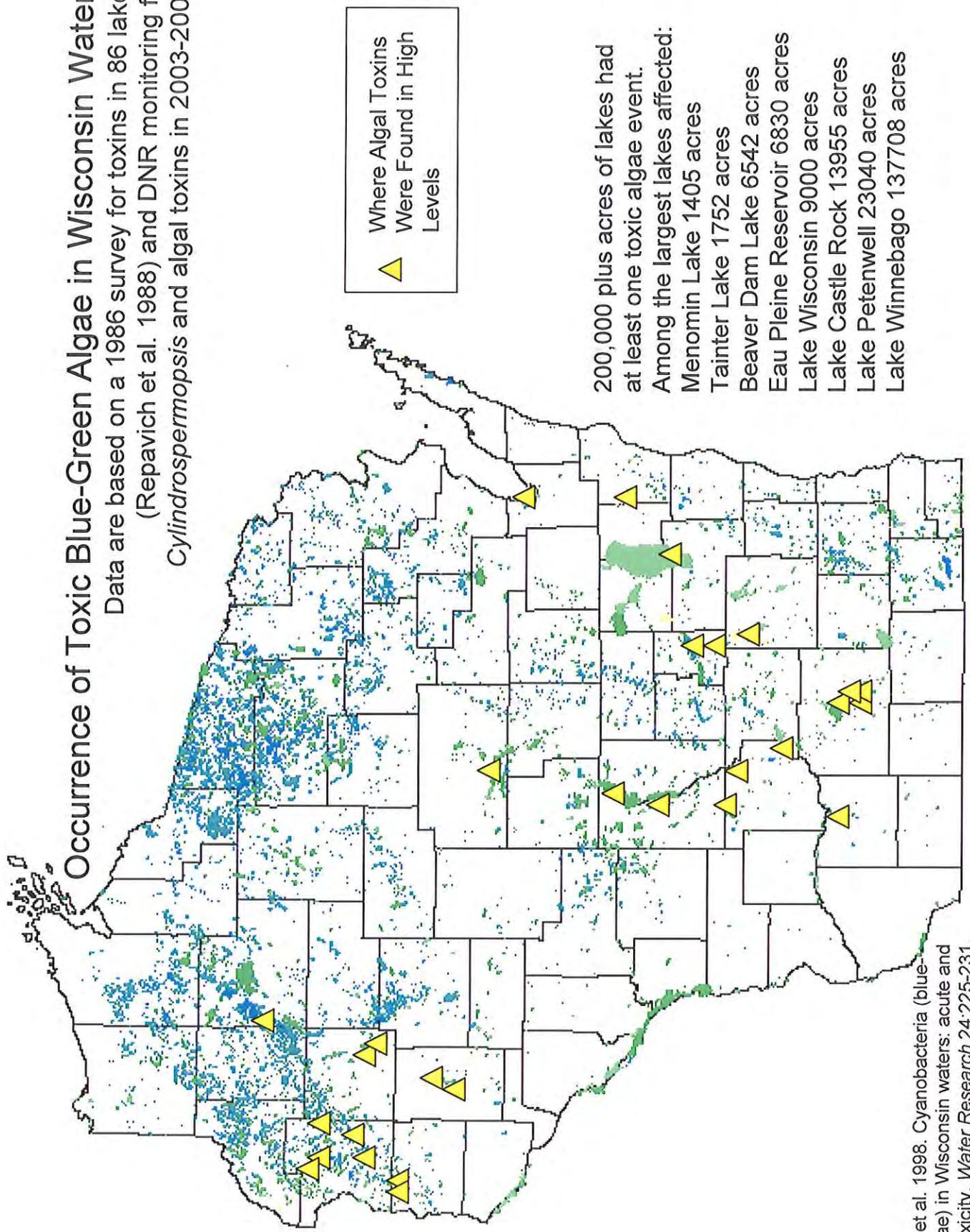
-<http://dnr.wi.gov/org/water/wm/wqs/bgabrochure.pdf>

Contact Gina LaLiberte (DNR) for general information on BGA at Gina.LaLiberte@wisconsin.gov, 608-221-5377, or Tim Asplund (DNR) at Tim.Asplund@wisconsin.gov, 608-267-7602.

Contact Dr. Mark Werner (DHS) for information on human health effects at Mark.Werner@dhs.wisconsin.gov, 608-266-7480.

Occurrence of Toxic Blue-Green Algae in Wisconsin Waters

Data are based on a 1986 survey for toxins in 86 lakes (Repavich et al. 1988) and DNR monitoring for *Cylindrospermopsis* and algal toxins in 2003-2006.



Repavich et al. 1988. Cyanobacteria (blue-green algae) in Wisconsin waters: acute and chronic toxicity. *Water Research* 24:225-231.

Cyanobacteria: Biology, Water Blooms, Cyanotoxins, and Prohibited Species in Wisconsin
Prepared by Gina LaLiberte
Fish and Habitat Research Section, Integrated Science Services
Wisconsin Department of Natural Resources
July 2011

A. Biology, Distribution, and Physiology of Cyanobacteria

Cyanobacteria were among the first photosynthetic organisms on earth and have been present for 2.5 – 3.4 billion years (1). Cyanobacteria are true bacteria which are aerobic and which use chlorophyll *a* for photosynthesis. They grow as single cells or are grouped in colonies or filaments of cells. They cannot be seen by the naked eye unless they are in large colonies, masses of filaments, or water blooms. Many cyanobacteria have a blue-green color from phycocyanin pigments, giving this group the informal name “blue-green algae.”

Cyanobacteria are found in almost every kind of aquatic and terrestrial habitat on earth including extreme environments such as hot springs, desert soil crusts, and frozen Antarctica lakes (2, 3). They likely occur in all freshwater ponds and lakes (4). Freshwater species can be particularly abundant in eutrophic systems and in hot, calm weather in late summer (3, 4).

There are hundreds of species of cyanobacteria in Wisconsin (4, 5). Planktonic species of *Microcystis*, *Anabaena*, and *Aphanizomenon* can dominate algal biomass in lakes, causing water blooms (5). An invasive tropical species, *Cylindrospermopsis raciborskii*, has been found in several southern and central Wisconsin lakes (6).

B. Physiological Advantages

Cyanobacteria have several physiological advantages which help them to compete for resources against other algae and to defend themselves against consumption by herbivores. They are able to both create and store nutrients that are scarce in their environment. Gas vesicles allow them to regulate their buoyancy and position in the water column. Preferences for higher temperatures allow them to grow and photosynthesize in warm water when other algal groups are inhibited. Toxins serve as a defense against consumption. These physiological advantages, coupled with human-induced environmental changes in the environment, have important implications for public health.

1. Nutrient Production and Storage

Like other kinds of algae and plants, cyanobacteria need the nutrients nitrogen and phosphorus. They require the nutrients in a certain ratio for peak growth and have adaptations for dealing with suboptimal amounts of these nutrients in the environment. Some species have special cells called heterocysts which they use to convert atmospheric nitrogen (N₂) to a form of nitrogen (ammonium, NH₄) that is easily taken up and used by their cells (7). *Anabaena*, *Aphanizomenon*, and *Cylindrospermopsis* have heterocysts and possess this nitrogen-fixing capability. Other taxa, such as some *Lyngbya* species, are able to fix nitrogen without the use of heterocysts (8). Some cyanobacteria species have the ability to take up phosphorus when it is abundant and store it for later use in a process called luxury consumption (9). These abilities to make and sequester nutrients allow cyanobacteria to outcompete other algal groups and dominate freshwater algal assemblages even when nutrients are scarce, and are discussed below in the water bloom section.

2. Buoyancy

The cells of many planktonic cyanobacteria, including species of *Anabaena*, *Aphanizomenon*, *Microcystis*, and *Oscillatoria*, contain gas vesicles that regulate buoyancy in the water column (10). Cell responses to light and nutrients affect buoyancy. In calm, non-turbulent conditions, cyanobacteria growing at low light levels make more vesicles to increase their buoyancy and float toward the water's surface, where they have the benefit of higher light intensities for photosynthesis (10). If surface light levels are so high that photosynthesis is inhibited, cells reduce the number of their vesicles and sink to depths with lower

light intensities. Buoyancy regulation also allows cyanobacteria to move down to anoxic waters at a lake's bottom and pick up phosphorus released from the sediments, then move back into the upper waters where phosphorus may be scarce (11).

3. Temperature optima

As a group, cyanobacteria have optimal growth and photosynthesis at temperatures higher than that of other algal groups, such as diatoms and green algae (12). A study in Lake Mendota (13) found that optimal temperatures for cyanobacteria ranged from 20° to 30°C (68° – 86°F) during the period of their dominance in the phytoplankton. Water temperatures ranged from 24° to 12°C (75° – 54°F) from August to November, so growth and photosynthesis had not reached their possible peak levels and were not limited by temperature until late in the growing season.

4. Chemical Defenses

Many plants have developed chemical defenses to deter their consumption by animals (1). Algae also possess these defenses, and cyanobacteria are able to produce several kinds of toxic compounds that prevent their grazing by zooplankton and other animals in aquatic systems (2). Later sections of this paper discuss these toxins in detail.

C. Water Blooms

When excess nutrients enter aquatic systems, cyanobacterial populations can increase rapidly to nuisance levels known as water blooms. Blooms can form at any time nutrients are high in lakes, but they are most prevalent in late summer when water temperatures are at their maximum (14). The relative abundance and bloom frequency of cyanobacteria in lakes is controlled by both phosphorus and nitrogen, but phosphorus appears to be the primary control on blooms (15).

Researchers (15) analyzed data from 99 lakes around the world and found that the risk of cyanobacterial dominance in water blooms was less than 10% when total phosphorus concentration (TP) was below 30 µg/L. The risk of cyanobacterial dominance rises to about 40% between 30 and 70 µg/L TP and levels off at 80% above 100 µg/L TP. Just above the level of 10% risk and 30 µg/L TP, algal biomass in the water column can reduce water transparencies to less than 1 m (16 cited in 15). Thus, even though the cyanobacterial dominance risk is low at these levels, the likelihood of a visible bloom on the waterbody is high. Reduction of total phosphorus concentrations in lakes is the best strategy for reducing the frequency of cyanobacteria blooms (15).

If phosphorus is plentiful but nitrogen is limited, cyanobacterial abundance tends to be higher because nitrogen-fixing cyanobacteria can fix useable ammonium from atmospheric nitrogen, compensating for deficient levels in the water and allowing them to outcompete other algae. When nitrogen is abundant and phosphorus is limited, cyanobacteria can use phosphorus stored earlier in luxury consumption to undergo 3 to 4 cell divisions and increase their biomass 10-fold or more (17).

When blooms form they float to the surface en masse, forming floating scums. The scums can be light green, powdery films on the water surface, or they can be thicker layers resembling paint. Winds blow scums around lakes and concentrate them in thicker mats (7). Turbulence breaks up blooms, but when the water surface calms, the cyanobacteria become buoyant, float back to the surface, and re-form the scum. *Cylindrospermopsis* is an exception. Instead of forming surface scums, *Cylindrospermopsis* blooms tend to occur a few meters down in the water column, so blooms cannot be detected by simply looking at the lake, unless they turn the water dark green (18, 19).

Invasive dreissenid mussels (zebra mussels and quagga mussels) can promote blooms of *Microcystis* in lakes with low to moderate levels of phosphorus (TP < 25 µg/L) (20, 21) and they can make blooms more toxic (22). Mussels feed on algae which they filter out of the water column, and they are able to selectively reject *Microcystis* if they ingest it (23). Instead of remaining on the lake bottom, rejected *Microcystis* is able to regulate its buoyancy and float back to the top of the water column. Although mussels consume some *Microcystis*, they still promote *Microcystis* blooms in low-nutrient lakes, possibly through altering nutrient availability to the algal community in a mechanism that is still not understood (20, 21). Preventing dreissenid mussel invasions into low-nutrient inland lakes is one strategy that may help to prevent *Microcystis* blooms.

One of the earliest scientific records of blue-green algal blooms in Wisconsin is in William Trelease's "Working of the Madison Lakes," published in 1889 (24). He describes blooms in Lakes Mendota and Monona:

Every season a greenish-yellow scum occurs in greater or less quantity on Third and Fourth Lakes (Mendota and Monona), during the hot weather of summer, after the water has been calm for a number of days in succession.

Since 1889, a handful of other studies have documented cyanobacterial blooms and toxins in Wisconsin lakes. Between 1967 and 1969 Karl (25, cited in 26) sampled 20 lakes around the state and found that 20%-40% of the samples contained toxins. Karl's study was initiated in response to animal deaths at Lake Delton (26). More recently, in a statewide survey of 86 lakes and ponds, cyanobacteria capable of producing toxins were found in all the sites, and 25% of the samples contained toxins, mostly from lakes in northwest and central Wisconsin (26, 27). Since these studies were conducted, the Wisconsin Department of Natural Resources (WDNR) has monitored lakes for the invasive cyanobacterium *Cylindrospermopsis raciborskii* (6) and conducted limited monitoring for toxins in lakes throughout the state.

Climate change is expected to create conditions conducive to increased cyanobacterial bloom events in the future. More severe precipitation events are predicted, which will bring more nutrients into aquatic systems (28). Longer growing periods and warmer temperatures are predicted, which will promote blooms through increased stratification of lakes and higher water temperatures, which cyanobacteria prefer (29).

Cyanobacterial blooms negatively impact water quality and can have serious health effects for humans and wildlife. Blooms are unsightly, and smell bad when they decompose. The increased biomass of algae causes dissolved oxygen levels in the water to drop when cyanobacteria are respiring at night. Dissolved oxygen levels also decrease when the bloom dies and the cells decompose, which can lead to drops in dissolved oxygen low enough to cause fish deaths from anoxia (30). Blooms may also alter aquatic food web structure by serving as a poor food source or even killing zooplankton if blooms are toxic (31). There are few natural controls on blooms, because many of the bloom-forming species have toxic chemical defenses that make them unpalatable to grazers (2).

D. Cyanotoxins

Although toxic chemical defenses are advantageous to cyanobacteria, cyanotoxins can have lethal effects on humans and wildlife with large enough exposure. Cyanobacterial populations in lakes are a mix of species and each species can contain a variety of strains. Strains are genetically identical cells. Many common cyanobacteria are capable of producing toxins, but it depends on their genetic identity, as there are great variations in toxin production among strains of the same species (32). Environmental variables such as temperature, light, nutrient concentrations, and pH may also play a role in inducing toxin production (32). Additionally, herbivory by grazers may induce toxin production (33).

Most of the toxic strains of cyanobacteria belong to the bloom-forming genera *Aphanizomenon*, *Anabaena*, *Microcystis*, and *Cylindrospermopsis* (34). Even though not all strains of these cyanobacteria are toxic, aquatic resource managers have come to rely on genus-level identification for assessing the potential for toxic blooms, because it takes substantial effort for genetic typing of strains (35). The recent development of quick testing kits has made determining toxin presence simpler and faster.

It is difficult to quantify how widespread toxin-producing cyanobacterial strains are in the environment, because toxin production can be highly variable by season or even by location within a single lake (30). Generally, cyanotoxin production is common, but it depends on conditions in the environment and the assemblage of strains within a bloom. A Canadian study demonstrated that 70% of bloom biomass samples from 19 Alberta lakes had detectable levels of microcystin (32). A survey of 86 lakes in Wisconsin found that 20 to 40% of lakes contained toxic cyanobacteria (26). Toxin levels are not necessarily related to cyanobacterial biomass (32). Depending on the species and strain, several toxins can be produced simultaneously (30). The ecological role of cyanotoxins and the triggers for toxin production are still unclear and under investigation, so it is difficult to predict the occurrence and intensity of cyanotoxins in aquatic systems (30).

Cyanotoxins are contained in the cyanobacteria cells and are not released into the environment until the cells die and break apart (30). Humans and animals are affected by cyanotoxins if they come in contact with water containing live blooms or cyanotoxins released from ruptured dead cells. Exposure occurs when cyanotoxins are consumed, inhaled, or come in contact with the skin (36).

There are 3 classes of cyanotoxins. Endotoxins are skin and gastrointestinal irritants, hepatotoxins affect the liver, and neurotoxins affect the nervous system. They are described in more detail below.

1. Endotoxins: Lipopolysaccharides (LPS)

Lipopolysaccharides (LPS) are found in the outer membrane of the cell wall of all Gram negative bacteria (30). They cause fevers, irritant and allergic reactions, and gastroenteritis (30, 36). A gastroenteritis outbreak in Pennsylvania in the 1970's was blamed on LPS (37). Since they are in all cell walls of gram-negative bacteria, all cyanobacterial blooms, regardless of species and strain, have the potential to cause problems because of LPS. Little is known about chronic effects of LPS (37).

2. Hepatotoxins: Microcystins, Nodularins, and Cylindrospermopsins

Microcystins and nodularins are cyclic peptide hepatotoxins (30). About 65 variants of microcystin and 6 variants of nodularin have been identified (38). Microcystins are made by bloom-forming strains of the common genera *Microcystis*, *Anabaena*, *Oscillatoria* and *Nostoc*, and by *Anabaenopsis*, *Hapalosiphon*, *Aphanocapsa*, and *Synechococcus* (30, 34). Nodularins are produced by *Nodularia spumigenia*, a filamentous cyanobacterium uncommon in Wisconsin (5). Most cyanotoxin poisonings worldwide are associated with microcystins (34). Poisoning by microcystins disrupts liver structure and function and results in death by respiratory arrest (36). Microcystins are tumor promoters in lab animals after chronic exposure to low doses (37), and are thought to be responsible for high liver cancer rates in regions of China where pond and ditch water containing cyanobacteria is used for drinking water (36, 37). Microcystins can accumulate in aquatic organisms, including mussels and fish (30, 34). Aquatic organisms face risks from living immersed in toxins from decayed blooms, with impacts on fish ranging from gill and organ damage to death (30). Microcystins are very stable molecules and can persist for months or years in the environment (30). They degrade very slowly inside cells, so if cells dry intact, for example from a scum washing ashore and drying, the microcystins remain in the cell. Microcystins can still harm any animal that eats the dried cells. Microcystins can be released to the environment if the dried cells are washed back into the water and break open (30). In water, sunlight breaks down microcystin molecules slowly, from 2 to 6 weeks for 90% breakdown (30).

Cylindrospermopsin is a hepatotoxic alkaloid produced by *Cylindrospermopsis raciborskii*, *Aphanizomenon ovalispirum*, *Raphidiopsis*, and *Umezakia natans* (34). The toxin was first isolated and identified in Australia in 1992. It blocks protein synthesis and damages the liver, kidneys, spleen, intestine, heart, and thymus (36, 38). Human health problems are often difficult to attribute to cylindrospermopsin poisoning because symptoms may not appear until several days after exposure (36). Cylindrospermopsin breaks down in 2-3 days in sunlight, if other algal pigments are present (30). Effects of long-term exposure to cylindrospermopsin are unknown (37).

3. Neurotoxins: Anatoxins and Saxitoxins

There are three kinds of anatoxins: anatoxin-a, homoanatoxin-a, and anatoxin-a(S) (38). They are produced by *Anabaena*, *Aphanizomenon*, *Oscillatoria*, and *Nostoc* (34, 36). Anatoxins block neural transmitters and cause paralysis and death by asphyxiation (37). Anatoxins are the second most common cyanotoxins found in US waters after microcystins (34). They degrade rapidly in sunlight (30).

Saxitoxins are produced by cyanobacteria and other algae and are the alkaloids that cause paralytic shellfish poisoning (PSP) (38). About 20 variants of saxitoxins have been identified (38). Saxitoxins block transmission of nerve impulses, resulting in respiratory arrest (36). A handful of animal deaths in the US have been linked to saxitoxins. Saxitoxins have been reported from only a few US locations (34) but are likely to be more widespread. Saxitoxins are produced by the common bloom-former *Aphanizomenon flos-aquae* and *Anabaena*, *Lyngbya*, *Cylindrospermopsis*, *Cylindrospermum*, and *Oscillatoria* (34, 37). Breakdown rates for saxitoxins are unknown (30).

4. Neurotoxins: beta-N-methylamino-L-alanine (BMAA)

Beta-N-methylamino-L-alanine (BMAA) is a non-protein amino acid which is considered a neurotoxin because of its hypothesized role in neurodegenerative diseases such as amyotrophic lateral

sclerosis, Parkinson's disease, and Alzheimer's disease (39). The role of BMAA in neurodegenerative diseases was elucidated via research into a neurodegenerative disease complex in the Chamorro people of Guam. The traditional diet of the Chamorro included cycad seeds, which contained BMAA from the plants' symbiotic *Nostoc* colonies, and flying foxes, which had biomagnified BMAA from their own diet of cycad seeds (40)

BMAA has since been found in numerous cyanobacterial taxa throughout the world. Researchers (41) tested 21 genera (41 samples in all) representing the 5 morphological sections of cyanobacterial algae. They found measurable BMAA in all sections of algae, 20 of the 21 of the genera tested, and 97% of the 30 free-living (non-symbiotic) strains they tested. In addition to the Guam cycad-flying fox food web, BMAA has been demonstrated to biomagnify in marine food webs of southern Florida (42). A recent study demonstrated that BMAA can be taken up by the common freshwater plant coontail (*Ceratophyllum demersum*) in experimental conditions (43). Additionally, BMAA is being investigated as a cause in the emerging wildlife disease Avian Vacuolar Myelinopathy (AVM), which affects birds near aquatic habitats in the southeastern United States (44). A cyanobacterial alga associated with *Hydrilla verticillata* has been found to produce BMAA (44). Water birds such as coots are exposed through their consumption of *Hydrilla* plants, and then bald eagles are exposed through their consumption of coots (45). Both *Hydrilla* and the alga ("Stigonematales spp.") have been classified as Prohibited Species under NR40.

Much is still unknown about the mechanisms of BMAA in neurodegenerative diseases, how and in what species it is most likely to biomagnify, and whether it can exist in a free state in water, which would have great implications for drinking water sources and treatment (46).

E. Cyanotoxin Exposure Pathways: Endotoxins, Hepatotoxins, and non-BMAA Neurotoxins

Exposure to cyanotoxins occurs via skin contact or ingestion, either of algal material or of water containing toxins released when the algae die and disintegrate. Wildlife and pets are exposed to the toxins by wading and swimming in blooms and licking their coats, or by drinking water containing cyanobacteria. Cyanotoxins can sicken and kill animals ranging from dogs, sheep, and cattle to fish, ducks, and rhinoceros (36). Animals are often exposed to very high doses of cyanotoxins because they do not hesitate to drink scummy water.

Evidence linking human health problems and cyanotoxins is open to criticism because often cyanotoxin poisonings are not diagnosed until after other factors are eliminated, and the affecting cyanotoxin cannot be identified or the toxin dosage quantified (36, 38). Much of the evidence for cyanotoxin effects on humans has been derived from epidemiological studies of human and animal poisonings and animal toxicity tests in the laboratory (37). Nevertheless, these indirect methods do establish links between cyanotoxins and adverse human health effects.

Recreational use of bloom-containing waters can expose a person to enough cyanotoxins for illness to develop (36). Swimming in blooms causes skin irritations from LPS and accidental ingestion of water through the nose and mouth can lead to gastroenteritis or flu-like symptoms. Inhaling water sprays while sailing or water skiing can also cause these problems (47). Gastroenteritis and pneumonia have been documented in people exposed to toxins from *Anabaena* and *Microcystis* while swimming and canoeing (36). Use of contaminated lake or river waters on land can also expose humans to cyanotoxins. Agricultural workers can be exposed by inhaling cyanotoxins from irrigation water sprays. Terrestrial plants have been shown to take up microcystins, although long-term or more detailed information is still unknown. Finally, if water containing cyanobacteria is sprayed on food crops, toxin-containing cells may dry and later be consumed with the food crop (48).

Most cases of acute cyanotoxin poisoning in humans have been caused by contaminated drinking water. Children and people in poor health are more at risk for severe poisoning symptoms from water supplies (36). Algae blooms in reservoirs can cause taste and odor problems in drinking water, and if water managers respond to cyanobacterial blooms by killing them with copper sulfate, the cells rupture and the cyanotoxins are released into the water (17). Standard drinking water purification processes do not remove cyanotoxins unless they include processes such as charcoal adsorption or ozonation (36). Lack of adequate treatment of a reservoir algae bloom caused a massive gastroenteritis outbreak in Pennsylvania in the 1970's; several filamentous cyanobacteria genera was believed to be the cause (17). A *Cylindrospermopsis raciborskii* bloom in an Australian island reservoir was treated with copper sulfate in 1979. Toxins released from the dead cells entered the island's water supply and caused severe hepatoenteritis in 140 children and

10 adults (17). The deadliest occurrence of cyanotoxin poisoning occurred in 1988, when water from the newly flooded Itaparica Dam reservoir in Brazil caused a severe gastroenteritis epidemic. The reservoir was highly eutrophic and developed a huge bloom of *Anabaena* and *Microcystis*. Approximately 2000 people were sickened by cyanotoxins in their drinking water and 88 people, most of whom were children, died in a 6-week period (17). In 1996 in Caruaru, Brazil, 116 dialysis patients developed symptoms ranging from visual disturbances to excessive liver enlargement after exposure to microcystins in the water of a clinic's dialysis system. Of the 116 affected patients, 100 later developed acute liver failure. Fifty-one patients died within two months of exposure, and a total of 76 patients died after 20 months had elapsed. The clinic's water was trucked from a reservoir where cyanobacteria were dominant and the clinic's filtration system failed to remove the microcystins from the source water (49). The majority of acute cyanotoxin poisonings worldwide have been associated with microcystins (34). Microcystins are also believed to have chronic effects on humans and are correlated with high rates of liver cancer in some areas of China (36).

F. Cyanotoxin Poisoning Incidents in Wisconsin

Until 2002, the only worldwide records of human deaths from cyanotoxins were from the Caruaru dialysis clinic and Itaparica Dam incidents in Brazil. In July 2002 the first case of death from cyanotoxins in the United States occurred in Dane County, Wisconsin when a teenager died from the effects of anatoxin-a poisoning. He swam in a golf course pond covered with a cyanobacteria bloom and accidentally swallowed some water. He went into shock and died of heart failure 2 days after exposure. Another boy who swam with him suffered from diarrhea and abdominal pain (50). The Dane County Coroner initially thought that pesticides or herbicides in the pond might have been responsible for the boy's symptoms (51). Diagnosis took nearly a year. Blood, tissue, and stool samples from the two boys revealed the presence of anatoxin-a and *Anabaena flos-aquae* (49; 52). Wayne Carmichael, a world expert in algal toxicology, considered this case unusual because anatoxin-a is usually fatal in animals within two hours, but all the evidence of the case otherwise indicated anatoxin poisoning (50).

Cyanotoxin poisonings have also affected animals in Wisconsin. There are two accounts published in 1987 of dairy cattle dying after drinking pond water contaminated with toxic blooms of *Microcystis*. These incidents occurred near Monroe and Eau Claire (32). In 2004, two dogs had seizures and one died after swimming in and drinking from a Dane County lake and pond (53). *Anabaena* was blooming on the pond and lake, so anatoxin-a was thought to be the toxin responsible for the dogs' deaths. The Lake Kegonsa State Park beach where the dogs played was closed for several days as a precaution and one week later the swimming portion of the Badger State Games triathlon, which was to take place at Lake Kegonsa State Park, was cancelled because the athletes' safety could not be guaranteed (53, 54).

G. Cyanobacterial species Prohibited under Chapter NR 40, Wisconsin's Invasive Species Identification, Classification and Control Rule

1. *Cylindrospermopsis raciborskii*

Cylindrospermopsis raciborskii, known as "Cylindro" in popular literature, is a tropical freshwater cyanobacterium. It was originally described from Java in 1913 as *Anabaenopsis raciborskii* (55). Physiological attributes were used to separate it from other species of *Anabaenopsis* in 1972 and it was renamed *Cylindrospermopsis raciborskii* (56). However, its old name is still used occasionally.

It is of particular concern because it makes three different cyanotoxins and it may produce the toxins more consistently than other cyanobacteria (57). It produces the hepatotoxin cylindrospermopsin and the neurotoxin saxitoxin in addition to the endotoxin LPS (38). The EPA cites recent findings that cylindrospermopsin may also be carcinogenic and genotoxic (58).

This alga is considered invasive because it is increasingly being found in temperate areas of the world far outside its original tropical habitat. The first records of it in the United States were in an Emporia, Kansas lake in 1955 and some Hennepin County and Carver County, Minnesota lakes in 1970 (59, 60). It was discovered at bloom densities in Florida lakes in 1995 and subsequent examination of archived Florida material placed its arrival at some time between 1967 and 1995 (56). It was first found in Wisconsin in Lakes Wingra, Monona, and Mendota in Dane County in 2002 (6). In late summer of 2003 the WDNR and University of Wisconsin started a short-term program to monitor 34 lakes in southern Wisconsin to

determine the distribution of *C. raciborskii* in the state's lakes. It is believed to be transferred between water bodies on birds, boats, or recreational gear (57). In August 2003 the WDNR monitoring program detected blooms of *C. raciborskii* in Waukesha County's Pewaukee Lake, which resulted in a beach closing to prevent possible exposure of the public to cylindrospermopsins and other toxins produced by *C. raciborskii* (61).

The growth of a *C. raciborskii* bloom in Lake Balaton, Hungary was promoted by warm water temperatures and windless weather following large inputs of nutrients into the lake from storm runoff, conditions that are common in Wisconsin summers (19). *C. raciborskii* is physiologically tolerant of a wide range of climates, and global warming may enable its spread in years to come (62). That, coupled with its decades-long presence in the region (61), makes its occurrence and spread in Wisconsin lakes likely.

2. Novel cyanobacterial epiphyte of order Stigonematales

This species does not yet have an official scientific name. It came to the attention of scientists in association with waterfowl and bald eagle deaths in reservoirs in the southeastern United States. The deaths were caused by a new neurological disease called Avian Vacuolar Myelinopathy (AVM) (63). Experimental work linked AVM to the aquatic plant *Hydrilla verticillata* and a new cyanobacterial species (45, 64, 65).

This new cyanobacterial species is capable of fixing atmospheric nitrogen and lives in association with the invasive aquatic plant *Hydrilla verticillata* (64), which is also a prohibited species under NR 40. Since its initial discovery, this alga has been found in association with *Hydrilla* in states from Texas and Arkansas to North Carolina (66) and is present in association with *Hydrilla* at all sites where AVM has been diagnosed (64). Laboratory tests detected BMAA in the alga and alga-*Hydrilla* association, and it is hypothesized that the BMAA is the agent responsible for the suite of symptoms of AVM (45).

H. Summary

Cyanobacteria are widespread in Wisconsin and are important primary producers in aquatic systems. They are adapted for bloom formation in conditions associated with environmental degradation, such as eutrophication, and the predicted warmer temperatures of climate change. Additionally, invasive species such as dreissenid mussels can act to promote bloom formation. With the continuation and exacerbation of environmental conditions favoring blooms, coupled with their possible toxicity, cyanobacterial blooms will continue to be a challenge to the quality of Wisconsin's water resources and public health.

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Wisconsin Lakes

Water Quality

- Hunting Dogs

Outdoor Recreation

- Activities A-Z
- State Parks and Forests
- Safety

Blue Green Algae Resources

- A Poster about Blue Green Toxins
- A Sign for Blue Green Toxins

Contacts

- Report a Case, Exit DNR

Blue-Green Algae In Wisconsin Waters

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- Fish Consumption Concerns
- Measures People Can Take to Protect Themselves
- Measures People Can Take to Help Reduce Future Blue-Green Algae Blooms
- This information in PDF [PDF]

Contact and General Information

If you think you are experiencing symptoms related to exposure to blue-green algae (e.g., stomach cramps, diarrhea, vomiting, headache, fever, muscle weakness, difficulty breathing), contact your doctor or the Poison Information Hotline (800-222-1222) right away.

If your pet displays symptoms such as seizures, vomiting, or diarrhea after contact with surface water, contact your veterinarian right away.

Report a Case with potential health effects caused by blue-green algae, visit the Department of Health Services, or contact the Bureau of Environmental and Occupational Health at 608-266-1120.

For more information about contacting your local health department, check the Department of Health Services Web site.

If you are (or your local community is) interested in collecting samples for analysis, please contact the **Wisconsin State Laboratory of Hygiene** at (800)442-4618. The Wisconsin Department of Natural Resources is not currently conducting any routine monitoring for blue-green algae or blue-green algal

toxins.

What are blue-green algae?

Blue-green algae, also known as Cyanobacteria, are a group of photosynthetic bacteria that many people refer to as "pond scum." Blue-green algae are most often blue-green in color, but can also be blue, green, reddish-purple, or brown. Blue-green algae generally grow in lakes, ponds, and slow-moving streams when the water is warm and enriched with nutrients like phosphorus or nitrogen.

When environmental conditions are just right, blue-green algae can grow very quickly in number. Most species are buoyant and will float to the surface, where they form scum layers or floating mats. When this happens, we call this a "blue-green algae bloom." In Wisconsin, blue-green algae blooms generally occur between mid-June and late September, although in rare instances, blooms have been observed in winter, even under the ice.

Many different species of blue-green algae occur in Wisconsin waters, but the most commonly detected include *Anabaena* sp., *Aphanizomenon* sp., *Microcystis* sp., and *Planktothrix* sp. It is not always the same species that blooms in a given waterbody, and the dominant species present can change over the course of the season.

How do blue-green algae differ from true algae?

Blue-green algae, like true algae, make up a portion of the phytoplankton in many water bodies. However, blue-green algae are generally not eaten by other aquatic organisms, and thus are not an important part of the food chain. True algae (e.g., green algae) are very important to the food chain. They are known as "primary producers", a name given to living organisms that can convert sunlight and inorganic chemicals into usable energy for other living organisms. Most algae are microscopic and serve as the main supply of "high energy" food for larger organisms like zooplankton, which in turn are eaten by small fish. Small fish are then eaten by larger fish, and both small and large fish are eaten by mammals, raptors, and people.

What are the concerns associated with blue-green algae?

Concerns associated with blue-green algae include discolored

water, reduced light penetration, taste and odor problems, dissolved oxygen depletions during die-off, and toxin production. Discolored water is an aesthetic issue, but when blue-green algae reach bloom densities, they can actually reduce light penetration, which can adversely affect other aquatic organisms both directly (e.g., other phytoplankton and aquatic plants) and indirectly (e.g., zooplankton and fish that depend on phytoplankton and plants). Blue-green algae blooms can be quite smelly, and though it is recommended that people never drink raw water, blue-green algae have been known to affect the taste of drinking water that comes from surface waters experiencing a bloom. Here in Wisconsin, most of the state relies on groundwater, rather than surface water, for drinking water. When a blue-green algae bloom dies off, the blue-green algae cells sink and are broken down by microbes. This breakdown process requires oxygen and can create a biological oxygen demand. Increases in biological oxygen demand result in decreases in oxygen concentration in the water, and this can adversely affect fish and other aquatic life, and can even result in fish kills.

Blue-green algal toxins are naturally produced chemical compounds that sometimes are produced inside the cells of certain species of blue-green algae. These chemicals are not produced all of the time and there is no easy way to tell when blue-green algae are producing them and when they are not. When the cells are broken open, the toxins may be released. Sometimes this occurs when the cells die off naturally and they break open as they sink and decay in a lake or pond. Cells may also be broken open when the water is treated with chemicals meant to kill algae, and when cells are swallowed and mixed with digestive acids in the stomachs of people or animals. The only way to be sure if the toxins are present is to have water samples analyzed in a laboratory using sophisticated equipment.

Are blue-green algae blooms a new problem?

No. Fossil evidence suggests that blue-green algae have been around for millions of years. Scientists have recorded blue-green algae blooms dating back to the 12th century and they have documented the toxic effects to livestock for more than 100 years. However, it is possible that the frequency and duration of blooms are increasing in some Wisconsin waters as a result of increased nutrient concentrations. Nutrients, particularly phosphorus and nitrogen, can be carried into water bodies as a result of many human activities, including agriculture, discharge of untreated

sewage, and use of phosphorus-based fertilizers and detergents.

What is *Cylindro* and how is it different?

Cylindrospermopsis raciborskii, also referred to as "Cylindro," is a blue-green algal species that is not native to Wisconsin. Recent reviews of archived samples by DNR scientists have shown that Cylindro has been present in some southern Wisconsin lakes dating back to the early 1980s. It is likely that migratory waterfowl brought this algae to Wisconsin and other Midwestern states. In lakes where Cylindro has been detected, blooms typically occur any time between late July and late September. Cylindro is different from many other blue-green algae in that it does not typically float to the surface to form scums. Thus, it can be difficult to see a bloom of this species. Cylindro is capable of producing more than one toxin, including cylindrospermopsin, which can affect the liver. However, to date, cylindrospermopsin has not been detected in any Wisconsin waters.

Why do blooms sometimes appear overnight?

Even if you can't see blue-green algae floating on the surface of the water, that doesn't mean they aren't there. Blue-green algae can be suspended at various depths in the water, and their location depends on a number of factors. The most important of these are light and nutrients (phosphorus and nitrogen). Many species of blue-green algae have evolved to be able to control their buoyancy as the availability of light and nutrients change with the time of day and local weather conditions. At night, when there is no light, cells are unable to adjust their buoyancy and often float to the surface, forming a surface scum. So this scum can literally appear overnight and may linger until wind and waves scatter the cells throughout the water body.

Should I get treat a blue-green algae bloom with a chemical to get rid of it?

No. Treatment of a surface water that is experiencing a blue-green algae bloom with an herbicide or algaecide may kill the blue-green algae, but any toxin(s) contained in the cells will be released at once, resulting in a slug of toxin(s) in the water. So while the bloom may no longer be visible, toxin(s) may be present for some period of time following treatment. It is best to stay out of a water experiencing a bloom and wait for the bloom to dissipate on its own.

What can be done to reduce the frequency and intensity of blue-green algae blooms?

There are no quick or easy remedies for the control of blue-green algae once they appear in a lake or pond. Reducing the amount of nutrients that wash into our lakes and ponds will eventually reduce the frequency and intensity of blue-green algae blooms, but it may take a long time and a lot of community involvement to effectively change the nutrient concentrations in a water body. This is because there may still be large amounts of nutrients in the sediment at the bottom that may continue to serve as food for the blue-green algae.

Regulatory agencies like the Wisconsin Departments of Natural Resources and Agriculture, Trade, and Consumer Protection are working with communities around the state to reduce stormwater runoff, and to encourage agricultural practices that reduce soil erosion while maintaining high crop yields. Locally, landowners and interested citizens can help minimize the problems associated with algal blooms by working together with partners in their watershed to reduce the amount of nutrients that reach nearby lakes, streams, and ponds. You can help reduce nutrient concentrations by promoting the following practices in your community:

- Use lawn fertilizers only where truly needed
- Prevent yard debris (e.g., leaves, grass clippings, etc.) from washing into storm drains
- Support local ordinances that require silt curtains for residential and commercial construction sites
- Plant and maintain vegetative buffer strips along shorelines of lakes, ponds and streams. Note: Native plants are much more effective at filtering runoff than the typical grass species found on residential lawns.

Has the Wisconsin Department of Natural Resources conducted any monitoring for blue-green algae?

The WI DNR conducted a two-year study to investigate the frequency, severity, and duration of blue-green algae blooms, including information on which species of blue-green algae are present over the course of the summer. We also looked for the presence and concentrations of specific toxins: anatoxin-a (a neurotoxin), microcystin-LR (a hepatotoxin), and cylindrospermopsin (a cytotoxin). Samples were (for the most part) collected from five lakes in each of five regions, five times

over the course of each summer (2004 and 2005). Samples were also collected from eight ponds in the south central region of the State. It is important to note that we chose to sample sites where blue-green algae blooms had occurred in the past or where they could potentially occur, based on nutrient concentrations. Therefore, this was not a random sample of lakes and ponds meant to represent all lakes and ponds in Wisconsin.

Also, unlike the beach monitoring study for bacteria, this study was not designed to provide real-time information on the presence of blue-green algae or blue-green algal toxins, and only a limited number of surface waters could be monitored in each region of the state. However, when DNR received information from the State Laboratory of Hygiene on the presence of high counts of blue-green algae or on the presence of blue-green algal toxins, this information was shared with the local public health agency. Only the Department of Health and Family Services or the local public health agency has the authority to close a beach.

The total number of samples collected in the statewide monitoring study was 187 in 2004, and 194 in 2005. Blue-green algae were present in 74% of all samples collected in both 2004 and 2005 (again, samples were collected from sites where we believed the potential for blooms was high). Blooms occurred in all regions of the state, with the biggest "hot spots" in the west central and south central regions. Species of blue-green algae most commonly detected included *Anabaena* sp., *Aphanizomenon* sp., *Microcystis* sp., and *Planktothrix* sp. Alerts were sent out to local public health agencies when concentrations of blue-green algae likely exceeded the World Health Organization (WHO) guideline of 100,000 cells/mL. This concentration represents a "moderate risk to human health." The total number of alerts sent out was 33 in 2004 and 42 in 2005.

A subset of the total number of samples collected was analyzed for toxins at the end of each summer (45 samples in 2004, and 34 samples in 2005). Microcystin-LR (a hepatotoxin) was the toxin detected most frequently and in the highest concentrations. This toxin was detected in the northern, south central, and west central regions of the state. The toxin anatoxin-a (a neurotoxin) was detected in samples collected in the northern and south central regions, and its presence was associated with a dog death in 2004. The toxin cylindrospermopsin was never detected.

Potential Effects on Humans and

Animals

Can blue-green algae make me sick?

Yes, it is possible for blue-green algae to cause illness. Blue-green algae are capable of producing several different toxins. People may be exposed to these toxins through contact with the skin (e.g., when swimming), through inhalation (e.g., when motor boating or water skiing), or by swallowing contaminated water. Types of toxins and potential health effects include the following:

Dermatotoxins and Gastrointestinal Toxins—These toxins affect the skin and mucous membranes, and can cause allergy-type reactions such as rashes, eye/nose/throat irritation, and asthma, as well as headaches, fever, and gastroenteritis (nausea, stomach cramps, vomiting, diarrhea). Examples include lyngbyatoxin and lipopolysaccharide endotoxins.

Hepatotoxins—These toxins affect the liver and other internal organs, and can cause gastroenteritis, tissue damage, muscle weakness, paralysis, and respiratory failure (with acute exposure), tumors, and possibly liver cancer (with long-term, chronic exposure). Examples include microcystins and nodularins.

Cytotoxins—These toxins also affect the liver and other organs (though through a different mode of action than hepatotoxins) and can cause malaise, headache, anorexia, vomiting, chromosome loss, DNA strand breakage, and damage to organs. An example is cylindrospermopsin.

Neurotoxins—These toxins affect the central nervous system and can cause seizures, paralysis, respiratory failure or cardiac arrest. Examples include anatoxin-a and saxitoxin. (Saxitoxin is the same toxin associated with red tide and paralytic shellfish poisoning in marine systems).

Are children more vulnerable than adults?

Yes. Children may be at greater risk than adults for two primary reasons:

1. Children love to play in the water, but typically do not understand the health risks as well as adults. As a result, they may drink the water because they are thirsty or swallow it accidentally while swimming.
2. Children weigh less, and so a smaller quantity of toxin

may trigger an adverse effect.

Can blue-green algae make my pet sick?

Animals are not necessarily more sensitive to blue-green algal toxins than humans. However, many animals, such as dogs and cattle, enjoy being in the water, even if there is an unsightly green scum layer floating on top. When such a bloom is present, animals may consume large quantities of blue-green algae if they drink the water, and if those blue-green algae happen to be producing toxin(s), the animals can become very ill, and even die. Symptoms of blue-green algal toxin poisoning may range from lethargy and loss of appetite to seizures, vomiting, and convulsions. Dogs are particularly susceptible to blue-green algal poisoning because scums can attach to their coats and be swallowed during self-cleaning.

Should I let my pets or livestock drink or swim in water containing algal blooms?

No. Animals can become extremely ill, and even die, after swallowing water containing blue-green algae. As public awareness has increased, so has the number of reports from veterinarians that blue-green algal toxins may have played a role in the deaths of dogs where other causes were not obvious. It is possible that the number of dogs that die from exposure to blue-green algae is an underreported statistic.

Drinking Water Concerns

Can I be exposed to blue-green algae or blue-green algal toxins through my drinking water?

Exposure to blue-green algae or blue-green algal toxins is unlikely if your water is provided by a municipal drinking water agency. For most Wisconsin residents and tourists, drinking water is provided by underground water sources that do not contain blue-green algae or blue-green algal toxins. While Lake Michigan and Lake Superior serve as water supplies for many communities on or near those lakes, there is no reason to worry since the water is pumped from far offshore, in deep water areas that are not affected by blue-green algal blooms.

Rainbow Lake in Waupaca County and Lake Winnebago are the only two Wisconsin inland lakes that serve as water supplies for

area communities (Appleton, Neenah, Menasha, and Oshkosh). While blue-green algae blooms may occur on these lakes in summer, studies have shown that blue-green algal toxins are removed by the local utilities' routine water treatment processes.

Keep in mind that water that is not treated may pose risks far beyond those associated with blue-green algae. All natural surface waters contain bacteria, algae, viruses, and other pathogens that if consumed may pose health risks to humans, pets, and other domestic animals. No one should ingest raw lake or pond water at any time.

How do water treatment plants deal with blue-green algae?

While most municipal drinking water treatment plants with surface water supplies do not regularly monitor for algal toxins, they do use treatment techniques that would remove the toxins if they were present. Conventional water treatment facilities can remove the cells of algae and other growing organisms by adding chemicals that bind them together. As the cells clump together, they become heavier and fall to the bottom of settling basins. Additional removal is obtained by filtration and through the use of activated charcoal. Studies conducted by scientists from the University of Wisconsin and the State Laboratory of Hygiene in the late 1990s did not detect any significant concentrations of algal toxins in the finished drinking water of several communities using Lake Winnebago as their water supply.

Can I treat my water at home to remove blue-green algae and their toxins?

There are a number of home water treatment options available to provide filtered water. Some of these systems include an activated charcoal step that will help remove certain chemicals like algal toxins if maintained and operated properly. However, variability in the design of the products on the market and in the operation and maintenance by homeowners prevent state health officials from declaring these products fail-safe.

Can I cook using water with blue-green algae in it?

No. Boiling water does not remove blue-green algal toxins. Because it is impossible to detect the presence of toxins in water by taste, odor or appearance, you are better off assuming they

may be present.

What about using water with blue-green algae for washing?

If blue-green algae are visible, try to find a better source of water for washing food (i.e., fruits, vegetables, etc.), dishes, and clothes. Also avoid bathing or showering in water containing blue-green algae, as skin contact with the blue-green algae may lead to skin irritation or other adverse health effects.

Recreational Water Concerns

Can water containing blue-green algae blooms be used for recreational activities?

Because local health officials cannot easily determine when blue-green algal toxins are being produced, anyone considering recreation on or in the water should use common sense. Simply put, if a scum-layer or floating mat is present, do not recreate in or on that water. The chance for health effects is greater if you or your children participate in water-related activities such as swimming, wading, water or jet-skiing, or wind surfing. Try to find areas where a blue-green algae bloom is not present.

Is it safe to let your children or pets swim in ponds (e.g., farm ponds, stormwater detention ponds, golf course ponds)?

By design, many farm ponds, golf course ponds, and stormwater detention ponds are constructed to trap nutrients, eroded soil, and other debris. By doing so, they prevent such materials from reaching nearby lakes, ponds, and streams. But because more nutrients may be available and because these types of ponds are generally more shallow and warm, it is possible for them to experience more frequent blue-green algae blooms (which may produce toxins). Again, a common sense approach is recommended for such ponds: if a scum layer or floating mat is present, do not let your children or pets swim.

Is there a risk to SCUBA divers who swim in blue-green algae blooms?

It may not always be possible to avoid swimming in blue-green algae blooms. Rescue SCUBA divers may be required to swim in

areas where a bloom is present. In those cases, divers should try to minimize the ingestion of water during the course of the dive. Divers should also shower or rinse off thoroughly after exiting the water, and clean all gear after use. Divers who show any signs of illness after exposure should seek medical attention.

Do blue-green algae pose a risk to competitive swimmers such as triathletes?

When organizers establish the schedule and pick a course for a triathlon, they have no way of knowing whether or not a blue-green algae bloom will be present in the swim area. To the degree possible, race organizers are encouraged to establish a course that minimizes the exposure of participants to blue-green algae blooms. Race organizers may also want to consider having a rinse station established near the swimming finish area. All participants are encouraged to minimize the ingestion of water during the course of the event. As is the case in any organized race, participants should seek medical attention if they show any signs of illness during or after the event.

Fish Consumption Concerns

Can I eat fish from water containing blue-green algae?

Some blue-green algal toxins have been shown to accumulate in the tissues of fish and shellfish, particularly in the viscera (liver, kidney, etc.). Whether or not the accumulation levels are sufficient to pose a risk to humans is uncertain, although it would depend in part on the levels of consumption and on the severity of the blue-green algae blooms where the fish or shellfish were caught or collected.

The Wisconsin Department of Natural Resources has not received any reports of people becoming ill after eating fish caught in areas where a blue-green algae bloom was present. The World Health Organization advises that people who choose to eat fish taken from water where a blue-green algae bloom is present eat such fish in moderation and avoid eating the guts of the fish, where accumulation of toxins may be greatest.

Important Note About Hygiene

All natural surface waters contain bacteria, algae, viruses, and other pathogens that if consumed may pose health risks to

humans, pets, and other domestic animals (e.g., cattle, swine). No one should ever ingest raw water.

Measures You Can Take to Protect Yourself

- Do not swim in water that looks like "pea soup", green or blue paint, or that has a scum layer or puffy blobs floating on the surface
- Do not boat, water ski, etc. over such water (people can be exposed through inhalation)
- Do not let children play with scum layers, even from shore
- Do not let pets or livestock swim in, or drink, waters experiencing blue-green algae blooms
- Do not treat surface waters that are experiencing blue-green algae blooms with any herbicide or algacide--toxins are released into the water when blue-green algae cells die
- Always take a shower after coming into contact with any surface water (whether or not a blue-green algae bloom appears to be present; surface waters may contain other species of potentially harmful bacteria and viruses)

Measures You Can Take to Help Reduce Future Blue-Green Algae Blooms

- Maintain native vegetation along shorelines as buffer areas
- Minimize activities that result in erosion
- Reduce the amount of fertilizer used on lawns
- Use only phosphorus-free fertilizer when possible
- Fix leaking septic systems
- Use only phosphorus-free detergents in dishwashing machines

Links to Additional Information

[Minnesota \[exit DNR\]](#)

[Indiana \[exit DNR\]](#)

King County, Washington [exit DNR]

Contact Information

If you think you are experiencing symptoms related to exposure to blue-green algae (e.g., stomach cramps, diarrhea, vomiting, headache, fever, muscle weakness, difficulty breathing), contact your doctor or the Poison Information Hotline (800-222-1222) right away.

If your pet displays symptoms such as seizures, vomiting, or diarrhea after contact with surface water, contact your veterinarian right away.

For more information about contacting your local health department, check the Department of Health Services Web site.

For more information on potential health effects of blue-green algae, contact Dr. Mark Werner, Department of Health and Family Services, (608) 266-7480.

For more information on the ecology of blue-green algae or environmental factors that influence their growth, contact Jim Vennie, Department of Natural Resources, (608) 266-2212



dnr.wi.gov

The Official Internet Site for the Wisconsin Department of Natural Resources

101 S. Webster Street, PO Box 7921, Madison, Wisconsin 53707-7921 608.266.2621

<http://dnr.wi.gov/wnrmag/2010/08/phos.htm>

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Excess phosphorus flowing into lakes provides nutrients that can spur weed and algae growth in Wisconsin waters.

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Less P is key

Controlling phosphorus remains a key to improving health and water quality.

Lisa Gaumnitz

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Peggy and Mike McAloon's retirement home overlooking Tainter Lake in Dunn County is everything they dreamed about – for eight months of the year.

Towering pines ring the home, eagles soar overhead, and deer and wild turkey frequently linger in front of their picture windows.

"It's got to be one of the most perfect spots in the world," says Peggy McAloon, enjoying a sunny May day from a lawn chair on her deck. "But by June 15, the lake will be green with algae, and by August, it [looks like] a toxic waste dump. The stench is unbearable, and if you have existing health problems, it can be very dangerous."

She struggled to breathe after spending days working as a volunteer boat inspector at a boat launch on the lake."

Suddenly, I'm up in the middle of the night and I can't breathe. My throat would literally close up," McAloon recalled recently. "It was very scary."

She got an inhaler and stopped inspecting boats, but her breathing difficulties continued, and McAloon suspects the algae may be behind a flare-up in her lupus.

"Now I pretty much stay inside with the air conditioning on and run to the car," she says. "I've lost everything here, from a health and economic standpoint. I can't sell the house. And yet for eight months of the year, it's the most beautiful place in the world."

McAloon's health concerns and conundrum are shared by many Wisconsinites. Last year, 35 people reported human health concerns and the death of at least two dogs related to blue-green algae. Human health effects ranged from skin rashes and gastrointestinal problems after swimming, waterskiing or coming into contact with the water, to acute respiratory distress, fever, sore throats, and gastrointestinal problems from the ammonia and hydrogen sulfide gas coming off the decomposing algae.

"It's a source of concern because these are toxins we know can have health effects and because it's a concern we get often from local health departments and natural resource agencies," says Mark Werner, PhD, supervisor of the Environmental and Occupational Epidemiology Unit. The state health department is entering its second year of tracking such complaints as part of a five-year national study funded by the Centers for Disease Control in Wisconsin and nine other states.

A 2004-05 DNR study found high concentrations of blue-green algae in all regions of the state. The highest toxicities were documented in 31 waters including eight of the state's biggest, most popular lakes.

"We don't have to have this occurring in our state," says Buzz Sorge, a veteran DNR lakes specialist who works in western Wisconsin.

"Our science is telling us that we can alleviate these water quality symptoms with good watershed management from agricultural, urban runoff and point sources. We just need the political will and the social will to get it done. We aren't asking for a pristine condition – we're asking for fishable, swimmable water," Sorge says. "We don't want our children swimming in toxic blue-green algae and we don't want people getting sick just by being near a lake."

Too much of a good thing – in the wrong place

Phosphorus is an essential nutrient. It occurs naturally, mainly as phosphate, and has been mined for use in fertilizer, detergent and animal feed. It's in our food, in our waste, and in that of other animals. Too much phosphorus fuels excessive plant and algal growth. That can result in harmful algal blooms, changes in food webs, decreased water clarity and poorer water quality that can harm aquatic life and discourage swimming and other recreation.

"The amount of nutrients entering our waters has dramatically escalated over the past 50 years and nutrients now pose significant water quality and public health concerns across the United States," according to *An Urgent Call to Action*, an August 2009 report of the State-EPA Nutrient Innovations Task Group.

Even more disturbing, the report says as our population increases, the rate and impact of nitrogen and phosphorus pollution will accelerate, "potentially diminishing even further our progress to date."



Phosphorus levels are monitored from culverts, streams, lakes and rivers.
© DNR File Photo

In Wisconsin, most phosphorus entering our lakes and streams comes from "nonpoint" or "runoff" pollution. Within that category, farms contribute the most, when heavy rains and melting snow wash over farm fields and feedlots carrying fertilizer, manure and soil into lakes and streams.

Phosphorus also comes from stormwater runoff from urban areas; from the "point sources" – piped wastes such as municipal and industrial wastewater treatment plants that release liquid effluent to lakes and rivers or spread sludge on fields; and from natural sources, including past phosphorus loads that build up in lake bottom sediments.

How much these sources contribute to phosphorus problems in a lake or river can vary widely dependent on land use in a watershed and the number of point sources discharging into that lake or river.

For instance, about 80 percent of the phosphorus load to Tainter Lake in Dunn County comes from agricultural runoff. Such runoff is responsible for closer to half of the phosphorus load to the Petenwell and Castle Rock flowages, impoundments of the Wisconsin River where harmful algal blooms have been a problem and where there are many point sources. The Fox River at Waukesha receives the lion's share of its phosphorus load from point source discharges into the river and from urban stormwater from growing communities including Waukesha, Brookfield and Sussex.

"To achieve clean water, we need to look at how we deal with all of the sources," says Jim Baumann, a longtime DNR water quality engineer. "We need additional phosphorus controls on both point sources and nonpoint sources."

A watershed summer for Wisconsin lakes and rivers

In recent years, Wisconsin has enacted a ban on phosphorus-based lawn fertilizer, a new phosphate ban for dishwasher detergents, rules curbing urban stormwater, and rules to further reduce phosphorus runoff from large-scale farms and feedlots known as CAFOs, particularly during rain and melting snow.

This summer, other key components are being put in place. In June, the state Natural Resources Board approved proposals to better control phosphorus from farms and from wastewater treatment plants, Baumann says. Those rule proposals have been sent to the Legislature for its review.

They call for farmers to curb phosphorus potentially coming off their fields to an eight-year average that factors in land slope, phosphorus levels in their soil and average precipitation levels. After additional rulemaking, farmers in watersheds where an impaired lake or river has a cleanup plan may be required to meet more stringent standards.

Provisions affecting wastewater dischargers would limit phosphorus levels in lakes, rivers, reservoirs and the Great Lakes so the water can still support fish and other aquatic life. Limits have reduced phosphorus loads significantly, but some waters still have levels that are too high.

The idea is to determine how much phosphorus a waterbody can assimilate, then calculate what each source contributes and determine how much each must reduce to keep phosphorus levels under that limit.

Many wastewater dischargers won't have to reduce their phosphorus levels much, particularly in northern Wisconsin, where there is less industry, less farming and extensive forests to help keep the soil on the land. Other areas will have to reduce the phosphorus load they send downstream.

Some progress on the farm, but not enough

Eighty years of concerted effort by farmers, state, federal and local conservation officials, extension agents and natural resource staff have significantly cut soil loss from the Dust Bowl

days but we have not achieved water quality goals set by society, says Pat Murphy, state resource conservationist for the Wisconsin branch of the USDA Natural Resources Conservation Service.

Gordon Stevenson, who leads DNR's runoff management program, and other DNR water quality officials interviewed echoed that sobering assessment. They point to a bumper crop of factors, including:

- Farm conservation programs are voluntary. Government programs give farmers technical and financial help to install conservation practices that must be maintained for a period of time, typically 5, 10 or 15 years but are not required to be permanent. Even Wisconsin runoff rules cannot be enforced unless funds are available to pay the farmer 70 percent of the cost of the new conservation practices.
- Until now, the standard measure of tolerable soil loss, "T," was based on maintaining soil and crop productivity, not necessarily on keeping water clean. Now concerns are growing that "T" may need to be further reduced to protect soil and water quality.
- Too much phosphorus on the land, particularly from manure spread during spring thaw when weather and field conditions cause runoff. Only one-fifth of Wisconsin's nine million acres of cropland follow nutrient management plans that consider soil phosphorus levels and other factors in guiding where, when and how much manure and fertilizers farmers apply.
- Farm conservation practices have not been adopted widely enough to fully protect or restore water quality.
- Federal farm subsidy programs provide a safety net primarily for row crops like corn and soybeans, which have a higher risk of erosion and require more fertilizer and pesticides to produce. Hay and other forage crops that keep soil in place have traditionally not qualified for federal subsidies. A trend toward specialization in crop production and the retirement of many dairy farmers has decreased hay acreage by 50 percent over the last 40 years.
- More farmers rent cropland from absentee landowners now, often resulting in neither renters nor landowners willing to pay for conservation practices.
- A spike in commodity prices in 2007-08 coupled with more rigid requirements for maintaining land in the federal Conservation Reserve Program (CRP) may have spurred some landowners to drop out of CRP, which pays them to keep highly sensitive land out of production.
- Inadequate funding for the technical help to plan and install conservation practices has spread current staff ever thinner as farms and conservation programs increase in size and complexity.
- Global market pressures, highly volatile crop prices and the need to cut production costs to the absolute minimum press farmers to focus on the bottom line and less on conservation.

The net result, Murphy says, is that Wisconsin's soil loss is on the rise again. "Typical tolerable soil loss (T) in Wisconsin is 3 to 5 tons per acre per year. Erosion rates had dropped to 3.7 tons per acre per year during the heyday of CRP. Now we're back to losing an average of 4.4 tons per acre per year."

That average rate of soil erosion could increase as global climate change brings more frequent heavy rains, according to a draft report from a committee of UW, state and other experts on soil conservation. The current toolbox of conservation practices can meet this challenge if practices are more widely adopted by farmers. If not, soil erosion in Wisconsin may more than double by 2050 compared with 1990 rates, the report says.

University of Wisconsin research suggests that inappropriate farming practices on a small number of vulnerable fields are responsible for most of the problems. Mapping, modeling and monitoring tools have all advanced to make it easier to identify such fields, Stevenson says.

If the new rules adopted by the Natural Resources Board clear the Legislature, the DNR and partners can focus advice and cost-sharing funds to those vulnerable farms whose participation is vital to improving water quality, Stevenson says. Farmers will have to come into compliance and stay in compliance with the new phosphorus limits. If the farmers are not willing to accept cost-sharing and use these practices, the phosphorus rules could be enforced.

"If all goes well, there will be parity now between point sources and nonpoint sources, and conservation practices will be there for the long-term," Stevenson says.

Murphy says that the next generation of conservation programs must target vulnerable fields and offer subsidies for adopting conservation practices, not just to protect market prices for row crops. The Conservation Stewardship Program now offered to agricultural producers statewide has begun this shift.

Effective enforcement of existing environmental laws would provide an immediate improvement too. Murphy says the key will be if people demand action as phosphorus discharges to lakes and rivers continue to impair water quality and reduce the public's ability to enjoy public places.

"Society and the citizenry are going to have to make it clear they expect a certain level of water quality," Murphy said. "They are also going to have to be willing to pay for it."

A new approach to tackle a long-standing problem

There are signs of progress in individual watersheds, and Tainter Lake may just lead the way.

The watershed is poised to become one of the first in Wisconsin where all the point and nonpoint sources of phosphorus will be accounted for and a portion of what the waterways can accommodate will be apportioned among the pollution sources says Ken Schreiber, the DNR water quality planner helping lead that process. The 15 point sources that discharge into the watershed have already cut their total phosphorus levels by 70 percent since 1990.

The city of Menomonie in recent years has been implementing an aggressive plan to cut stormwater runoff to reduce sediment entering the lake by 40 percent by 2013.

The Tainter/Menomine Lake Improvement Association has focused on developing a coalition of all stakeholders within the Red Cedar Watershed and increasing political awareness, says Robyn

Morin, association president. They invited Sen. Russ Feingold to the lake in late summer to see and smell the algae, and they've been constantly in contact with local politicians. Locals are organizing an economic study of how lake degradation is depressing real estate values around the lake and in the area, consequently reducing property taxes and local government revenue.



No-till soybeans planted between rows of corn stubble hold more soil in place and minimize the flow of runoff and nutrients during rainfall.

© Lance Klessig

Perhaps the biggest signs of new success, however, are the tender shoots of corn poking through grass sod on a warm late May day on a farm in the Town of Grant.

Farmers who participated in a pilot project are using no-till and conservation tillage to minimize soil erosion. In "no-till" farmers plant seeds without first turning over the soil with a plow; each new crop is planted into the residue left from the previous crop. Some farmers even invested in updating their current planters, says Lance Klessig, a Dunn County conservation planner and a catalyst in the project.

He and Melanie Baumgart of the River Country Resource Conservation and Development Council met one-on-one with farmers in the township in 2007-08 to find out why they did not adopt conservation practices or enroll in government conservation programs. They learned which practices the farmers would be most likely to adopt if barriers could be overcome. Project partners rented a no-till soybean drill for the farmers to use in 2009, paid an operator to custom plant no-till corn that year and paid all costs to sample soil for phosphorus levels. Field days at no-till farms gave other interested farmers and neighbors the chance to see and ask questions about these cropping methods.

Close monitoring of fields and yields turned up good news: "In general, no-till yields were comparable or slightly less, but the profit per acre is more favorable because planting and field maintenance take fewer passes and use less fuel," Klessig says.

He sells the no-till practices to farmers as a way to improve their profitability and enjoy a higher quality of life because they can spend more time with their family and less time on the tractor during planting season.

Perhaps the most important lessons he's learned are to change how to do business. Rather than waiting to work with the farmers who walk through their doors, conservation agents go knocking door to door and leave fliers when no one is home.

We make it easier and convenient to participate, Klessig explained. Cooperative agreements are only one page. We hold meetings at town halls, not at government offices, and we always provide food. If invited, we'll join in at dinner time and ride shotgun on the tractor or combine. The most important thing "was real honesty and getting to know farmers on a personal level," he says. "I'm here to help you. I want to learn more and I want you to teach me."

Peggy McAloon takes heart from such approaches. She knows the problems on Tainter Lake won't be solved overnight or likely for several years at best.

"It's everybody's problem. I just pray this state embraces the problem and sits down and discusses things and doesn't point fingers," says McAloon, who herself has been actively involved in researching the issues and participating through the lake association.

"It's not city, versus country. Everybody can do a little bit, and some can do a little bit more. We've got so little fresh water in the world; we have to protect what we've got."

Lisa Gaumnitz is public affairs manager for DNR's water programs.

Blue-green Algae in Eutrophic Fresh Waters

Val H. Smith

Why Do They Dominate and What Can I Do About It?

Freshwater phytoplankton communities naturally may include one or more species of blue-green algae, or cyanobacteria. These cyanobacteria tend to be rare, or present only in very limited abundance, in waterbodies having low levels of fertility. However, cyanobacteria frequently dominate



the phytoplankton communities of surface waters receiving high nutrient inputs from their watershed. Extreme growths of cyanobacteria can create highly undesirable water quality conditions, and for the general public these blooms are probably the most commonly recognized symptom of eutrophic lakes, reservoirs, and rivers worldwide.

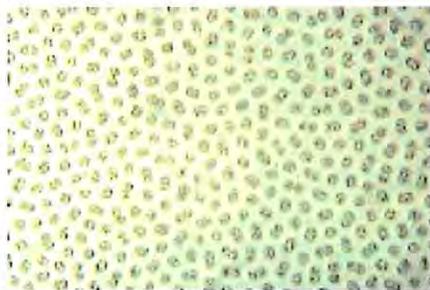
The phytoplankton communities of eutrophic waters may contain representatives from three especially notorious cyanobacterial genera: *Anabaena*, *Aphanizomenon*, and *Microcystis* (see Figures 1a-c). Water quality professionals, who often refer to them as “Anny,” “Fanny,” and “Mike,” have studied species from these bloom-forming genera with great interest since the early 1900s. Another major cyanobacterial genus, *Oscillatoria* (Figure 1d) is also particularly noteworthy because its occurrence in European lakes was considered clear evidence of deteriorating lake water quality. The appearance of *Oscillatoria* in Lake Washington (Seattle) was an alarm to W.T. Edmondson that



(a)



(b)



(c)



(d)

stimulated efforts in the metropolitan Seattle area to fund the diversion of incoming wastewater in 1963-1968. These efforts eventually led to the restoration of highly acceptable water quality in the lake.

Unique Features of Cyanobacteria

As a group, cyanobacteria exhibit a number of unique features. Unlike other phytoplankton, many species of cyanobacteria are buoyant because their cells contain tiny gas-filled vesicles that allow them to float in the water column. As a result, buoyant cyanobacterial cells can accumulate in unusually high numbers at the water's surface, creating highly unsightly scums. In exceptionally eutrophic lakes, these scums can be up to several feet thick! When cyanobacterial blooms die in lakes, the death and decay of the blue-green cells can create severe odor problems, and also may cause significant depletion of dissolved oxygen from the water column. Summer fish kills can sometimes result from cyanobacterial blooms as well.

Many cyanobacteria are also capable of producing and releasing substances that can impart strong tastes and odors to drinking water, and their growth can create very costly taste and odor problems in bodies of water that are used for municipal water supplies. Moreover, several cyanobacterial species can produce organic compounds

Figure 1 (all at left): (a) *Anabaena flos-aquae*. Note lighter green heterocysts (see arrow). Photo by J. Kann; (b) *Aphanizomenon flos-aquae*. Note the large flake-like colonies, which are too large to ingest by the *Daphnia pulex* shown in this picture. Photo by E. Swain; (c) (interior of a colony). Photo by F. deNoyelles. (d) *Oscillatoria* sp. Photo by F. deNoyelles.

that can cause death in domestic animals and livestock, and health problems in humans. Some of these toxins are even more potent than cobra snake venom (Table 1)! Cyanobacteria also tend to be much less edible by zooplankton than other phytoplankton, and their dominance in a waterbody potentially can reduce the efficiency of fish production.

Why do blue-greens become dominant in some waterbodies and not in others? The answer to this question is somewhat complex, because many potential factors contribute to cyanobacterial blooms. These conditions can be grouped into three general categories: physical factors, chemical factors, and biological factors.

Physical Factors: The Contribution of Stable Water Column Conditions

Cyanobacteria appear to be well-adapted to eutrophic waters characterized by periods of thermal stratification and stagnation when climatic and nutritive factors favor their growth. Surface accumulations of cyanobacteria in particular often tend to occur after a period of hot, still weather, when the intensity of sunlight has been high, and the water's surface has been calm. If large numbers of cyanobacteria already exist in the water column, a period of calm weather allows these cells to rise to the surface and to concentrate there as a scum or surface bloom, which may persist for days or weeks. Favorable physical factors cannot be the sole cause of nuisance cyanobacterial blooms, however. Calm weather conditions can only allow the surface accumulation of buoyant

cyanobacterial cells that are already present in the water column, and these cells can only have arisen as a result of active growth and reproduction. Such growth can only be supported by ample nutrient supplies.

Chemical Factors: The Key Role of Nutrient Availability

In order to generate the large cell numbers that lead to nuisance blue-green blooms, a waterbody must contain the nutrients necessary for abundant growth. As is true of each plant species in a farmer's pasture, each particular phytoplankton species has somewhat unique requirements for nutrient resources. Each species requires carbon dioxide (CO₂) and sufficient supplies of inorganic nutrients for their growth, just as the many different plant species that grow in a farmer's pasture do. However, carbon dioxide itself is rarely growth-limiting for extended periods because it can be rapidly re-supplied from the atmosphere soon after it is used by algal growth.

What nutrients *do* limit algal growth in lakes? For almost 150 years agricultural chemists have known that two principal nutrients, nitrogen and phosphorus, potentially limit the growth of plants in a farmer's field. Moreover, the final yield of a farmer's crop is often proportional to the amount of nitrogen and phosphorus fertilizer that is added. Nitrogen and phosphorus (N and P) have also been found to be the two primary limiting nutrients in surface waters worldwide. As was observed over half a century ago by C.N. Sawyer in his classic studies of the Madison (Wisconsin) chain of lakes, both the

summertime yield of algae and the likelihood of nuisance algal blooms in lakes are typically proportional to their phosphorus content. Sawyer's work has been confirmed by hundreds of researchers during the past 50 years, and this knowledge has led to development of the phosphorus-based eutrophication management frameworks that now used globally.

Farmers and agronomists are also very aware that the nutrient requirements for optimal growth differ significantly for different plant species. For example, legumes such as peas and clover have very high demands for soil phosphorus; peas and clover also can fix atmospheric nitrogen and use it for growth, while wheat or corn cannot. Similar differences in N and P requirements occur among phytoplankton. Like peas, cyanobacteria appear to have very high growth requirements for phosphorus, and their growth is strongly stimulated if their phosphorus supply is increased. The summer abundance and dominance of cyanobacteria have been found to depend very strongly on the concentration of total phosphorus in the water column, although this response to phosphorus appears to be altered somewhat in deep lakes.

All phytoplankton require nitrogen for their growth, but mounting scientific evidence suggests that under conditions of nitrogen limitation, cyanobacteria may be better competitors than are other phytoplankton. Like terrestrial legumes, several species of cyanobacteria have a specialized structure called a "heterocyst" that can be used to fix molecular nitrogen gas (N₂) dissolved in the water. In contrast, other phytoplankton species are only able to use dissolved inorganic nitrogen in the form of nitrate or ammonia, just as non-legume terrestrial plants do.

Nitrogen:phosphorus (N:P) ratios less than about 10:1 by weight in a waterbody's nutrient supply create conditions of nitrogen limitation, and these low N:P loading ratios have been found to strongly favor dominance by heterocystous cyanobacteria. Extensive evidence worldwide supports this N:P ratio hypothesis, even when it is extended to *all* species of cyanobacteria. Other recent studies, including one ⇒

Table 1. Comparison of the toxicities of three cyanobacterial toxins. The LD₅₀ represents the approximate dose of toxin needed to kill 50% of lab animals receiving injections of each toxin. These data were derived from Figure 2 in Skulberg et al. (1984).

Toxin	Source	LD ₅₀ micrograms per kilogram
Muscarine	<i>Amanita</i> mushroom	1,100
Anatoxin	<i>Anabaena</i>	250
Microcystin	<i>Microcystis</i>	60
Neurotoxin	cobra snake venom	20
Aphantoxin	<i>Aphanizomenon</i>	10

→ Blue-green Algae

by B.G. Kotak and colleagues in Alberta, Canada, have also concluded that low N:P ratios can contribute to the development of toxic blooms of *Microcystis*. Although a large body of evidence supports the N:P ratio hypothesis, other factors also are clearly important and may be overriding in some systems, however. These factors include differences in food web structure.

Biological Factors: The Role of Grazing Zooplanktons and Their Predators

Phytoplankton do not live alone in our surface waters, but instead are members of complex food webs that include a diverse community of microscopic consumers (zooplankton), and that can also include fishes. Evidence has accumulated during the past several decades that the food web structure of lakes can have important effects both on the total abundance of phytoplankton in lakes, and dominance by cyanobacteria.

For example, Jacob Kann has recently concluded that hypereutrophic Upper Klamath Lake (Oregon) is a shallow, well-mixed lake that lacks large fish populations because massive algal growth causes extremely stressful variations in pH and oxygen levels in the water. In the absence of significant fish predation, the zooplankton community of Upper Klamath Lake is dominated by large *Daphnia pulicaria*. Dominance of the zooplankton by this large grazer creates very high death rates for edible species of phytoplankton, but the presence of *Daphnia* also unfortunately appears to cultivate nuisance blooms by the inedible cyanobacterium *Aphanizomenon flos-aquae*. As can be seen in Figure 1b, the flake-like colonies of this colonial cyanobacterium can become too large for the *Daphnia* to eat, and under such conditions *Aphanizomenon* tends to be the only phytoplankton species that can persist when large *Daphnia* are present in high abundances in hypereutrophic lakes.

In less nutrient-rich lakes, the opposite effect appears to occur, however. Dick Osgood showed that in mesotrophic Square Lake (Minnesota), large *Daphnia pulicaria* effectively controlled the entire phytoplankton population, and *Aphanizomenon* was not present. Similarly, J. Elser and his colleagues added piscivorous fish to an experimentally fertilized lake in Ontario (Canada); after the piscivore additions, minnows were decimated and the zooplankton became dominated by large *Daphnia pulex*. At the same time that *Daphnia* became dominant in Lake 227, the total abundance of all phytoplankton was drastically reduced, and dominance by cyanobacteria was eliminated for the first time in 15 years!

A Proposed Pathway to Noxious Cyanobacterial Blooms

Elser (1999) has recently presented a synthesis of our knowledge that captures the major features of each of the critical factors discussed above. He has proposed a conceptual diagram (Figure 2) that asks three key questions:

1. Is the nutrient loading to the waterbody high?
2. Is the N:P ratio of the nutrient loading low?
3. Are hydrodynamic and light conditions favorable?
4. Does food-web structure inhibit *Daphnia* dominance?

If the answer to each of these four questions is *yes*, then Elser concludes that conditions overall are sufficiently favorable that noxious cyanobacterial blooms are very likely to occur. The answer to item number four may be conditional upon the trophic state of the lake, however, because

Daphnia dominance can lead to blooms of *Aphanizomenon* in exceptionally nutrient-rich lakes.

How Can I Prevent or Minimize the Occurrence of Nuisance Blue-green Blooms in My Waterbody?

The very strong phosphorus dependence of blue-green growth makes it clear that the primary strategy for cyanobacterial bloom control should be to restrict the supply of phosphorus that enters a waterbody from both point and non-point sources. A study of long-term data from eutrophic Lake Mendota (Wisconsin) by Dick Lathrop and

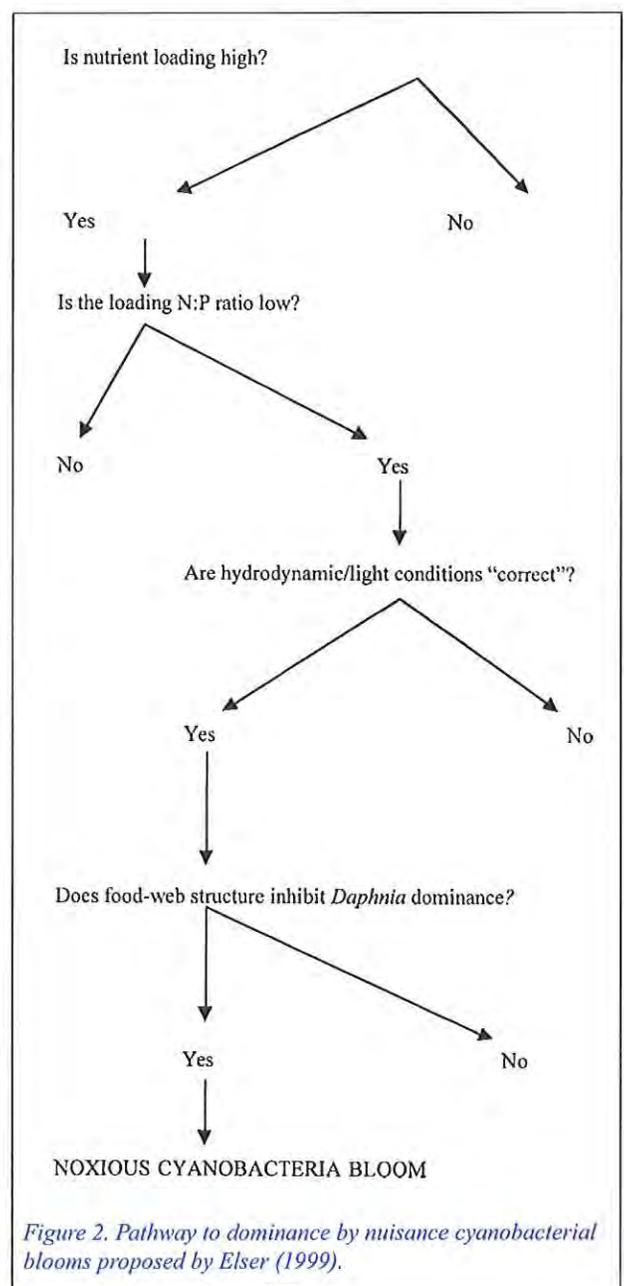


Figure 2. Pathway to dominance by nuisance cyanobacterial blooms proposed by Elser (1999).

colleagues demonstrates an excellent example of a quantitative method for calculating the phosphorus loading reductions that are needed to control blue-green algal blooms in waterbodies for which nutrient loading can be successfully managed and controlled. In cases where the external loading cannot be controlled, and where money and other resources permit, restoration measures involving physical, chemical, or biological manipulations of the waterbody itself may instead be required.

In contrast to phosphorus input restriction, it is extremely ill-advised to pursue nutrient management strategies that remove nitrogen alone, or to implement nutrient loading control measures that produce N:P loading ratios below ca. 10:1 (by weight) to the receiving waterbody. The ability of heterocystous cyanobacteria to obtain their nitrogen requirements from the atmosphere makes it extremely imprudent to restrict the incoming supplies of inorganic nitrogen unless strong restrictions on phosphorus inputs are made as well. Heterocystous cyanobacteria will tend to be favored by conditions of nitrogen limitation, and these undesirable species will tend to increase in abundance up to the limit imposed upon them by the supply of available phosphorus. For these reasons, Smith et al. (1995) argued against targeted nitrogen loading controls in Lake Okeechobee (Florida). Similarly, a report by LimnoTech (1991) to the Metropolitan Washington (D.C.) Council of Governments recommended that they *not* pursue a strategy of wastewater denitrification if nuisance blooms of cyanobacteria were to be avoided in the freshwater Potomac estuary.

It has also been suggested that the *addition* of nitrate-rich water can reduce or eliminate blooms of cyanobacteria because this might reduce the competitive advantage cyanobacteria have in nitrogen utilization. Dick Lathrop of the Wisconsin DNR explored this method by treating a shallow hypereutrophic Wisconsin lake in 1981 and 1982 with ammonium nitrate fertilizer in order to determine whether these inorganic N additions could

prevent the development of summer *Microcystis aeruginosa* blooms. Whole-lake N fertilization proved to be expensive, and did not fully prevent summer *Microcystis* blooms. However, the summer bloom was virtually non-existent during the entire 1982 nitrogen fertilization period. Evidence supporting the use of nitrate fertilizer to prevent blue-green blooms is thus unfortunately still limited, and further tests of this method would be valuable.

For Further Reading

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BLUE GREEN ALGAE

Blue-green algae, or cyanobacteria, exist in lakes and ponds throughout Wisconsin. They can grow very rapidly or 'bloom' when in water that is warm and rich in nitrogen and phosphorus. Blooms can occur at any time during the spring, summer and early fall months, but are most common in late summer.

Many blooms can look like foam, scum, or mats that float on the surface of lakes and ponds, but some blooms are present as a thick 'pea-soupy' appearance without a visible scum layer. If present, the scum layer can be blue, bright green, brown, or red and may look like paint floating on the water. As algae die, the water may have a foul smell. Algal blooms can also produce toxins that can make people, pets, and other animals sick.

People and animals can be exposed to algal toxins when they **SWIM** in affected lakes, **DRINK** contaminated water, or **BREATHE** aerosolized water while jet-skiing or boating.



Skin contact with algal material can cause painful **rashes or blistering** (Left).

Inhaling water droplets from irrigation or water-related recreational activities can cause **irritation of the eyes and nose, a sore throat, and breathing problems.**

Swallowing water that contains algal toxins can cause severe **diarrhea and vomiting**, as well as **numbness of the lips, tingling fingers and toes, or dizziness.***

In **dogs**, ingestion of algae can cause **drooling, weakness, staggering, difficulty breathing, convulsions, and even death.***

Poisonings are more severe the smaller the person or animal and the larger the amount of toxin ingested.

DON'T swim, water ski, or boat in areas where the water is discolored or where you see foam, scum, or mats of algae on the water.

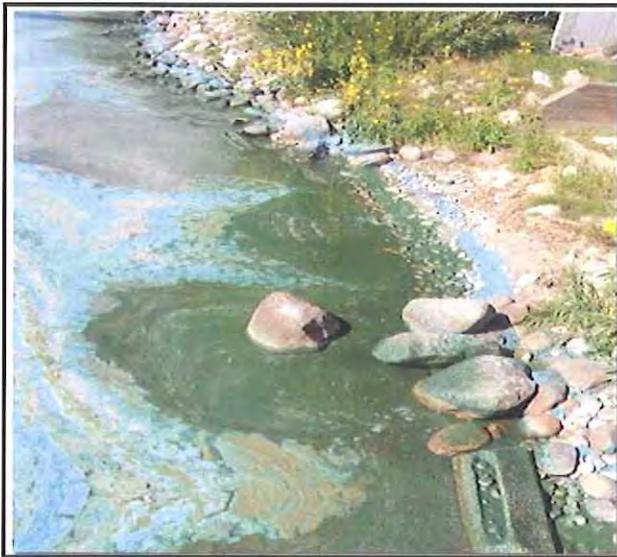
DON'T let pets or livestock swim in or drink from areas where the water is discolored or where you see foam, scum, or mats of algae on the water.

DON'T let dogs lick the algae off their fur.

DO rinse yourself and your pet off immediately if there is contact with algae-affected waters.

DO look for beach postings and water quality notices before swimming.

DO get medical treatment right away if you think you, your pet, or your livestock might have been poisoned by algal toxins.



Keep our lakes clean!

Minimize the use of lawn fertilizers.

Don't use phosphate-containing fertilizers.

Maintain septic systems.

Plant natural vegetation around ponds and lakes to filter incoming water.

For more information or to report a human or animal illness suspected of being algae-related, visit www.dhs.wisconsin.gov/eh/bluegreenalgae or call us at 608 266-1120.

How Can I Tell if the Water is Safe?

You may see these blooms on lakes throughout Wisconsin. They can be a variety of colors such as fluorescent blue, green, white, red or brown. More than one color may be present. They may look like thick paint floating on the water and frequently give off a foul odor.



The Dos and Don'ts of Harmful Algal Blooms

DON'T swim, water ski, or boat in areas where the water is discolored or where you see foam, scum, or mats of algae on the water.

DON'T let pets or livestock swim in or drink from areas where the water is discolored or where you see foam, scum, or mats of algae on the water.

DON'T let pets lick the algae off their fur.

DO rinse yourself and your pet off immediately if there is contact with algae-affected waters.

DO look for beach postings and water quality notices before swimming.

DO get medical treatment right away if you think you, your pet, or your livestock might have been poisoned by algal toxins.

Harmful Algal Blooms in Wisconsin's Lakes



Harmful algal blooms (or HABs) are the result of a rapid increase or accumulation of algae in a surface water body. Cyanobacteria (or blue-green algae) can flourish and cause blooms in Wisconsin lakes in the presence of nutrients, sunlight and other factors. Some types of blue-green algae can produce toxins which can harm the liver or nervous system in humans and animals, and the blooms can cause GI symptoms, rashes or respiratory problems.

For more information or to report an illness: (608) 266-1120
<http://dhs.wi.gov/eh/bluegreenalgae>



HAB-Related Dermal Rash



Large Decaying Algal Mat



Characteristic "pea soup" water

Harmful Algal Bloom Surveillance Program

The Wisconsin Division of Public Health (DPH) is asking the public to notify them of any human or animal illnesses resulting from a blue-green algae exposure. Animal illnesses can include pets, livestock or wildlife.

The HAB program will collect information about symptoms and any treatment received or provided. They will also collect exposure information, and may seek to quickly collect environmental samples.

With this information DPH will be able to better understand and measure the public health problem posed by HABs, raise awareness of these problems, and inform efforts to prevent exposures from occurring.

Potential Symptoms

Blue-green algae related illness becomes a concern for Wisconsin as the weather warms and people and pets spend more time outside on and near lakes. Illnesses can be caused by different types of toxins and symptoms can vary depending on the exposure. Exposures are generally grouped into: **inhaling** aerosolized water droplets that contain algal toxins, **ingesting** water with toxins or cell bodies and **skin contact** with scum or water containing toxins or cells.

Common human symptoms

include: Sore throat, congestion, cough, wheezing, eye irritation, rash, blistering, abdominal pain, headache, vomiting, and diarrhea.

Common animal symptoms

include: Lethargy, vomiting, diarrhea, convulsions, difficult breathing, and general weakness.

If you need urgent information related to a suspected algal exposure, you can call the

**Wisconsin Poison Center at:
1-800-222-1222**



About Harmful Algal Blooms

BACKGROUND

Algae are vitally important to marine and fresh-water ecosystems, and most species of algae are not harmful. However, a **harmful algal bloom** (HAB) can occur when certain types of microscopic algae grow quickly in water, forming visible patches that may harm the health of the environment, plants, or animals. HABs can deplete the oxygen and block the sunlight that other organisms need to live, and some HAB-causing algae release toxins that are dangerous to animals and humans. HABs can occur in marine, estuarine, and fresh waters, and HABs appear to be increasing along the coastlines and in the surface waters of the United States, according to the National Oceanic and Atmospheric Administration (NOAA).

Responding to this suspected increase, the U.S. Congress in 1998 passed a law that required NOAA to lead an Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia, and funded research into the origins, types, and possible human health effects of HABs.

ASSESSING THE IMPACT ON PUBLIC HEALTH

Although scientists do not yet understand fully how HABs affect human health, authorities in the United States and abroad are monitoring HABs and developing guidelines for HAB-related public health action. The U.S. Environmental Protection Agency (EPA) has added certain algae associated with HABs to its Drinking Water Contaminant Candidate List. This list identifies organisms and toxins that EPA believes are priorities for investigation.

CDC works with public health agencies, universities, and federal partners to investigate how the following algae, which can cause HABs, may affect public health:

- **Cyanobacteria**, also known as blue-green algae, can produce toxins that may taint drinking water and recreational water. Humans who drink or swim in water that contains high concentrations of cyanobacteria or cyanobacterial toxins may experience gastroenteritis, skin irritation, allergic responses, or liver damage.
- **Harmful marine algae**, such as those associated with **red tides**, occur in the ocean and can produce toxins that may harm or kill fish and marine animals. Humans who eat shellfish containing toxins produced by these algae may experience neurologic symptoms (such as tingling fingers or toes) and gastrointestinal symptoms. Breathing air that contains toxins from algae associated with red tide may cause susceptible individuals to have asthma attacks.
- ***Pfiesteria piscicida***, a single-celled organism that lives in estuaries, has been found near large quantities of dead fish. Scientists do not yet know whether *P. piscicida* affects human health. However, reports about symptoms such as headache, confusion, skin rash, and eye irritation in humans exposed to water containing high concentrations of *P. piscicida* have prompted public concern.

For more information about HABs, go to the [Links](#) page.

Keeping Your Pet Safe from Harmful Algal Blooms



What you need to know about preventing algae-related illness:

- HABs or Harmful Algal Blooms appear on lakes and ponds during the summer and fall and result from an excess amount of blue-green algae
- HABs can make recreational waters look pea soupy. They can also form a blue, green, red, white or brown scum layer on the water's surface.
- Some blue-green algae species can produce toxins that make animals and humans sick.
- These toxins can cause illness through inhalation, ingestion or direct skin contact.
- For pets, **ingestion** of toxins is the typical route of exposure.

Pets are especially susceptible to HABs because they don't naturally avoid green, smelly water likes humans do. Many dogs have gotten sick and **some have died** in Wisconsin by drinking water from lakes or ponds experiencing an algal bloom.

Pets also require ingestion of a smaller amount of toxins to harm them due to their smaller size.

What You Can Do To Protect Your Pet

Be aware of HABs in areas where your pet swims or plays and watch for scum material on the shore. After a possible HAB exposure monitor your pet closely for the next 24 hours and contact your veterinarian immediately if your animal shows any of the following symptoms:

Lethargy, Vomiting, Diarrhea, Convulsions, Difficulty Breathing, General Weakness

DO NOT let pets swim in or drink from areas where the water is discolored or where you see foam, scum, or mats of algae on the water.

DO NOT let pets lick the algae or scum off their fur.

DO rinse yourself and your pet off immediately if there is any contact with algae-affected waters.

DO watch for beach postings and water quality notices before swimming or allowing your pet to play in the water.

DO seek medical treatment right away if you think you or your pet may have been poisoned by algal toxins.

Please report any algae-related illnesses to the Harmful Algal Blooms Surveillance Program

The Wisconsin Division of Public Health and the CDC are asking the public to quickly notify them of any human or animal illness related to blue-green algae.

**For more information or to report an illness, please call or visit:
(608) 266-1120**

<http://dhs.wi.gov/eh/bluegreenalgae/>

Occupational exposure to algal toxins:

WI DNR
April 2008



Audience –

DNR staff & DNR volunteers.
Others with occupational exposure- Water rescue, military, construction, water sports competitions, waterfront maintenance, etc

As a person who works around water, you should be aware of problems associated with algal toxins. They have been implicated in deaths of pets, livestock and, in one case, a man in Wisconsin. Since few people drink algae laden water, the primary danger comes from skin reactions or respiratory problems associated the toxin. While most people avoid entering or handling heavily algae-laden water as part of recreational pursuits, some have jobs or other circumstances that necessitate contact. Although green lake conditions are common, reports of human health problems related to exposure to algal toxins are rare. Some of this is no doubt due to avoidance. Plus, the symptoms can resolve within a few hours or days without medical attention. Also, studies suggest that allergic reactions occur in only 20-25% of the exposed population. Please make yourself familiar with the symptoms and treatment of toxin exposure and, more importantly, how to avoid the problem.

For more information on algal toxins see:
<http://dnr.wi.gov/lakes/bluegreenalgae/>
<http://www.cdc.gov/hab/cyanobacteria/facts.htm>



Dermal contact - Symptoms:

Skin irritation, visible rash, hives and blisters, especially under clothing or wetsuits

Dermal contact - Exposure avoidance:

Wear boots & gloves

Immediately rinse exposed skin with clear water. Extended contact under wet clothing or wetsuits can trigger and accelerate reaction.

Fill wetsuits with clear water before entering algae laden water and clean suit after use.



Inhalation reaction - Symptoms

Runny eyes and nose, sore throat, asthma-like symptoms or allergic reactions.

Inhalation reaction – Exposure avoidance:

Minimize aerosols of algae-laden water caused by agitation.

Be aware of wind direction. Do preparation work outside of affected areas. Get in and out fast.

Be aware of the possibility of aerosols associated with irrigating with algae-laden surface water.

Treatment:

Remove from exposure and provide supportive treatment. For severe reactions contact your doctor or the Poison Information Hotline (800-222-1222).

Managing Lakes, Rivers and Streams

It is our job to keep track of the quality of our vast water resources. We cannot do this job alone. As stewards of our water resources, we work in partnership with universities and other schools, citizens, lake and river organizations, Native American tribes, nonprofit groups, local governing bodies and other agencies to monitor, plan, educate the public and restore our waters. The tools we use are varied and applied across watersheds. The Bureau of Watershed Management coordinates a variety of programs and grant funding sources to help manage and protect the 15,081 inland lakes and 12,600 streams and rivers that belong to us all. One of our major goals is that through these measures, all of our state's waters will once again be able to fully support the fish and other aquatic life communities and recreational uses that they should be capable of supporting and be protected for the enjoyment of future generations.



Left to right: Art Bernhardt, Fisheries Technician; Ken Schreiber, TMDL Monitoring Coordinator; Chris Willger, Wastewater Specialist; Tim Hanson, Water Supply Specialist; and Lacy Hillman, Environmental Program Associate, pose with a brown trout caught during a fish survey in Plum Creek, Pepin County. WDNR photo.

Success Story: Partnership Provides Vital Data on Water Quality

Water quality monitoring gives us data on the state of our waters and helps us determine water quality problems. WDNR Watershed Management staff and Fisheries Management staff join forces to collect and assess a variety of data on the status of our waters. Monitoring is truly a partnership with the public in Wisconsin because our Citizen-Based Monitoring Network also provides a tremendous amount of water monitoring information.

Data are essential in watershed management.

The Water Division Monitoring Program gathers data to assess the aquatic environmental health of our lakes, rivers and streams. This information is evaluated to identify fisheries and aquatic life status and environmental problems. Once the problems are identified and understood, the WDNR, local communities and groups, businesses, nonprofit organizations, lake associations and citizens can all take actions to both correct and prevent problems. The final step in the process is then to collect data on the success of the management actions. Good data help us determine what to do and what works best. Some of the ways data are collected are described below. Learn more about the Water Division Monitoring Program at: <http://dnr.wi.gov/org/water/monitoring/>.

Wadeable Stream Assessments: Scientists at WDNR are finalizing a report on data collected as part of a statewide assessment of wadeable streams. A total of **200 randomly selected stream sites**, equally distributed among five types of stream sizes, were sampled in each of the four major ecoregions – areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources (see map on page 3). Physical, chemical and biological data collected in 2003 and in 2007-2009 from the 200 stream sites were used to develop reference conditions to determine whether or not a stream is in good, fair, or poor condition. Standardized sampling protocols were used at all of the sites. Physical measures of in-stream and riparian habitat conditions, electronically-measured water quality parameters, laboratory- analyzed water chemistry samples, macroinvertebrate data, and fish assemblage data were collected at all sampling sites.

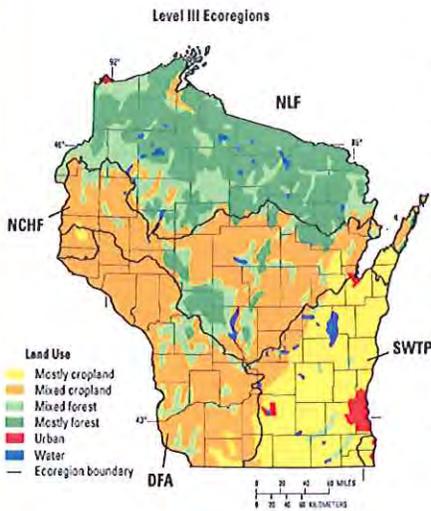
Water quality is influenced by natural watershed characteristics and by land and water use. Data collected in the field with electronic meters and from laboratory-analyzed stream samples provide information on water quality conditions and pollutant concentrations that influence stream integrity. These data can also help identify pollutant sources and measure the relative importance of various human activities that impact streams. Aquatic insects, crustaceans and fish numbers and species provide key information on stream quality and specific factors degrading streams. This type of information assists in determining:

- Stream health with statistically defensible data;
- The estimated number of streams in good or poor condition;
- What factors are causing stream degradation; and
- The geographical differences that affect stream health.



Left to right: Water Resources Technicians Ron Dolen, Don Barrette, and Frank Younger conduct a fish assemblage survey on French Spring Creek. WDNR Photo.

Water Quality Data Partnerships (continued)



Information from the wadeable stream data collection sites was used to help characterize other streams within the State's **42,000 miles of perennial streams**. This type of sampling design is called a "probabilistic" study. Initial results of the wadeable streams assessment indicate reduced stream quality is correlated with areas of higher proportions of cropland or urban development. Stream habitat was found to be in the best condition in the Northern Lakes and Forest (NLF) Ecoregion, followed by the North Central Hardwoods Forest (NCHF) Ecoregion, the Driftless Area (DFA) Ecoregion, and lastly the Southeast Wisconsin Till Plains (SWTP) Ecoregion. Similar trends among ecoregions were found for most of the water quality measures as well as biological indicators.

Ecoregion Map.



Valley Stewardship Network Citizen Stream Monitoring volunteers. WDNR Photo.

Fisheries Assessment Studies: Fisheries Management staff conduct annual assessments on about **150 lakes, 850 sites** on smallmouth bass and trout streams, and **50 non-wadeable river sites**. Fisheries assessments are used to determine the status of fish populations in important recreational fisheries, relative to established standards for similar waters. These fish assessments are the basis for management plans for key fisheries around the state.

Citizen-Based Water Monitoring Network: In recent years, trained monitoring volunteers in the Citizen-Based Water Monitoring Network have increased the number of waters with baseline data. Citizen Lake Monitoring volunteers collected data at 798 monitoring stations and entered the data into online WDNR databases. The Citizen Stream Monitoring Program continues to operate with three levels of involvement. Level 1 introduces citizens to monitoring and helps them understand linkages between land use and water quality. Level 2 engages citizens in more intensive monitoring, using WDNR staff methods to assess stream health. Level 3 allows citizens to address specific hypothesis-based questions.

Volunteers play a critical role in the success of our water monitoring program. WDNR staff support this initiative with training and on-going educational outreach. Replicated monitoring using consistent methods and equipment types over time builds a valuable repository of information. The data can be evaluated in the context of local land use changes, inherent flows and temperatures for streams, and with stream type reference condition values for biological, physical or chemistry data.

CITIZEN LAKE MONITORING FAST FACTS FOR THE 2009 SEASON:

- 934 volunteers monitored water quality at over 798 monitoring stations.
- 139 new Secchi disk volunteers joined the program.
- 77 new chemistry volunteers participated.
- Learn more about Citizen Lake Monitoring at: <http://dnr.wi.gov/org/water/monitoring/citizen.htm>.

CITIZEN STREAM MONITORING FAST FACTS FOR THE 2010 SEASON:

- Level 1 Volunteers made 858 visits at 221 sites.
- About 200 active Level 2 volunteers made 887 visits at 179 sites.
- Learn more about Citizen Stream Monitoring at: <http://dnr.wi.gov/org/water/swims/cbsm/index.htm>.

WISCONSIN WATERS FAST FACTS:**Rivers and Streams**

- Wisconsin has more than 12,600 rivers and streams.
- About 42,000 miles of these streams are perennial.
- There are approximately 2,931 trout streams in Wisconsin; put end to end, they would stretch more than 10,266 miles.
- 254 streams and rivers are designated as Outstanding Resource Waters (ORW).
- 1,544 streams and rivers are designated as Exceptional Resource Waters (ERW).

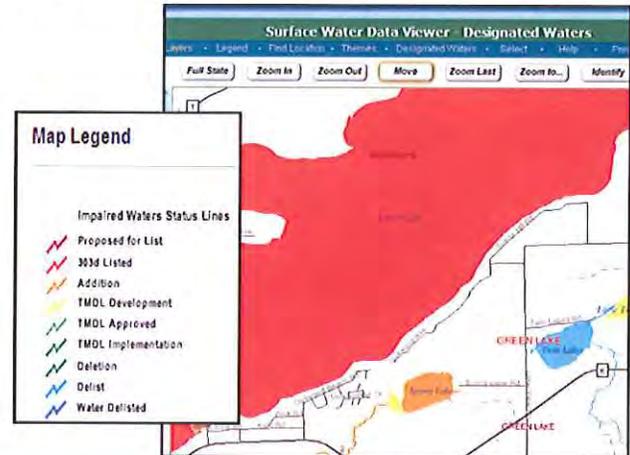
Lakes

- Wisconsin has 15,081 documented inland lakes.
- Inland lakes cover about 1 million acres of the state's 35 million acres.
- Green Lake in Green Lake County is the deepest inland lake: 236 feet.
- Lake Wazee in Jackson County is the deepest manmade lake: 350 feet.
- Lake Winnebago is the largest inland lake: 137,708-acres.
- Only about 40 percent of Wisconsin lakes have actually been named.
- The majority of the unnamed lakes are very small: less than 10 acres.
- About one quarter or 3,620 of the state's lakes are larger than 20 acres, and they constitute more than 93 percent of the surface area of Wisconsin's inland lakes.
- Vilas County has the most lakes: 1,318.
- Brown and Outagamie counties have the fewest named lakes: 4 each.
- Mud Lake is the most common lake name in Wisconsin: 116 lakes.
- 103 lakes and impoundments are designated as Outstanding Resources Waters (ORW) – fewer than 1%.

Databases Generate Water Quality Maps

The ongoing collection of good data is essential for decision-making and future planning. The sources of pollutants degrading water quality must be determined before management approaches can be identified and restoration projects are planned. Pollutant limits incorporated in rulemaking initiatives rely on the availability of good data. Water quality data are used in a wide variety of watershed management programs to assist in developing grant priorities, management plans, and the evaluation of program effectiveness.

The WDNR's SWIMS and WATERS databases were created to store water quality information on our abundant resources. WDNR Fisheries staff, field biologists, water resources staff and citizen volunteers use the SWIMS database to locate monitoring stations and input data collected in our state's lakes, rivers, streams and wetlands. Developed over a six-year period from 2002 to 2008, the databases provide data through the GIS-platform Surface Water Data Viewer (SWDV).

**SURFACE WATER DATA VIEWER DATABASE:**

The Surface Water Data Viewer Database mapping application provides the public access to information on water resources, monitoring data and water quality assessment data. View and analyze watershed-related data: lakes and streams, monitoring stations, impaired waters, Outstanding/Exceptional Resource Waters, and lake grant partners. Learn more at:

http://dnr.wi.gov/org/water/data_viewer.htm.

Water Data are Used in Classification System

Water quality data are used to determine the condition of each waterbody, ranging from excellent to poor. To do this, data obtained by measuring current conditions in the waterbody, such as the number and type of fish present, are compared against a set of criteria or quality guidelines that identify expected values for a range of conditions. The guidelines are derived based on the water quality standards, use designations and related water quality criteria established in Wisconsin's administrative code.

Water quality standards help define designated uses.

Water quality standards are the foundation of the water quality-based pollution control program mandated by the federal Clean Water Act. The standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. Learn more about water quality standards and the WDNR's Water Evaluation Section at: <http://dnr.wi.gov/org/water/wm/wqs/>.

One of the first steps in managing water quality is to assign use designations for each waterbody, such as Fish and Aquatic Life Use or Recreational Use. Use designation is a scientific process that involves evaluation of the resource and its natural characteristics. Each use designation category carries with it a set of goals for a waterbody's performance. For some designations, such as Fish and Aquatic Life Use, a detailed sub-categorization occurs to classify the water according to its specific potential.

Data are analyzed in condition assessments.

Thousands of water assessment sites were analyzed in 2008-2009 by WDNR biologists and technical staff to create condition decisions such as excellent, good, fair or poor. The condition assessments are made in reflection of the water quality standards and whether or not those standards

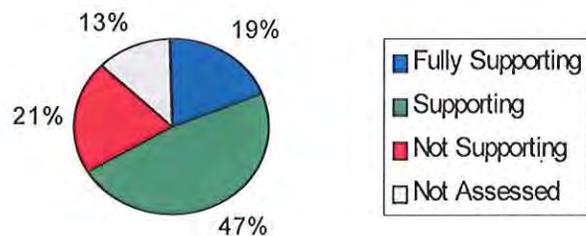
are being attained. Specifically, comparing existing water quality to water quality necessary to achieve standards can help to identify water quality problems in lakes, rivers, and streams that may have been caused by human activities such as improperly treated wastewater discharges, runoff or discharges from abandoned mining sites and farms, excessive sedimentation from runoff of soil, over-application of fertilizers and chemicals from agricultural areas, or erosion of stream banks caused by improper grazing practices.



Discharges of manure-laden runoff into the waterway below the grazing area impairs water quality. WDNR enforcement actions were necessary to correct this problem. WDNR Photo.

Wisconsin has assessed approximately **4,200 lakes (762,741 lake acres)**. Of those assessed, 21% of the lake acres are not supporting the Fish & Aquatic Life Designated Use. Advancements in study design, monitoring technologies such as satellite imagery and data analysis are reviewed regularly by staff and are used whenever resources allow. The condition assessments indicate whether waterbodies are meeting their designated uses. As shown in the graph below, 66% of the assessed lake acres either "Fully Support" or "Support" Fish and Aquatic Life Use.

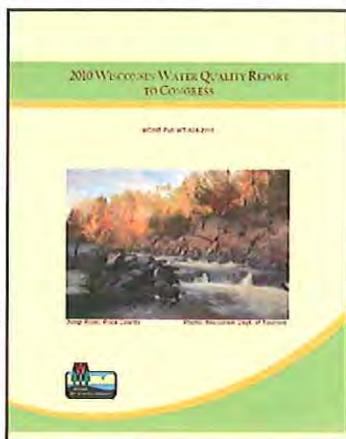
Percent of Lake Acres* in WDNR databases that support Fish & Aquatic Life Use (*does not include impoundments)



Water Data (continued)**Data are used to create condition assessments and the Impaired Waters List.**

Wisconsin is required to submit an “Impaired Waters List” every two years to meet requirements under Section 303(d) of the federal Clean Water Act. The 303(d) List of Impaired Waters contains waters that are not meeting water quality goals (see Water Quality Standards process above). It should be noted that not all waters categorized as “poor” from a condition assessment are included on the state’s Impaired Waters List.

Site-specific considerations of land-use, historical changes in the hydrology of water body and other factors may affect whether or not a waterbody should be listed as impaired. Often times, these factors require the collection of additional data to finalize a decision on whether or not the water body belongs on the Impaired Waters List. Learn more about water quality in the 2010 Wisconsin Water Quality Report to Congress and the Impaired Waters List at:



http://dnr.wi.gov/org/water/condition/2010_IR/.

Total Maximum Daily Loads are required for impaired waters.

A Total Maximum Daily Load, or TMDL, is an analysis of the various pollutant sources that contribute to an impairment for a given waterbody. The development of a TMDL is required by the federal Clean Water Act for waters on the state’s Impaired Waters List. The result of that analysis is a determination of how much pollutant reduction is needed to meet water quality standards so the waterbody can be removed from the Impaired Waters List. Learn more about impaired waters at:

<http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html>.

The WDNR initially focused on simple TMDLs addressing sedimentation of streams from areas with significant streambank erosion and soil runoff from farm fields. In the past few years, however, the focus has evolved toward the development of more complex TMDLs that begin to address the impacts associated with excessive phosphorus in our waterways from both point and nonpoint sources.



Algal bloom on Parsons Creek, which is on the Impaired Waters List. WDNR Photo.

As the WDNR identifies more and more situations where nutrients such as phosphorus and nitrogen are causing water quality problems, more effort will be put into using TMDLs to help drive efforts to control nutrients and improve water quality. Currently, several large basins in Wisconsin are undergoing TMDL development to determine necessary reductions in phosphorus loadings. Looking to the future, WDNR is exploring whether or not to address TMDLs for nutrients on a watershed basis.

Read about the Lake Pepin TMDL in the “Managing the Mississippi River” section and the Fox River/Green Bay TMDL in the “Stewardship of the Great Lakes” section of this report. Also read more about the challenges of TMDL development in the “Emerging Issues” section of this report.

Updated Watershed Plans are Available Online

During 2009-10, resource conditions in **24 of the state's watersheds** were monitored, assessed, and written up in watershed plans. These plans are formal amendments to the state's Areawide Water Quality Management Plan and are the primary avenue through which water quality biologists and managers update the state's water condition status for Clean Water Act reporting. These continually updated plans are available in electronic format through "online watershed pages". Publishing the documents as online "dynamic" webpages reflects the agency's need to reduce production costs and meet user demand for up-to-date, high quality information in a readily accessible format. View these plans from the WDNR's Explore Wisconsin's Waters! website at:

[http://dnr.wi.gov/org/water/condition/wtplans/.](http://dnr.wi.gov/org/water/condition/wtplans/)

Lake Partnerships Help Protect Lakes

Since its genesis in the early 1970s, the Wisconsin Lakes Partnership has been recognized as a national model of collaboration. Three groups form the core of this team: 1) The WDNR supplies technical expertise, financial support and regulatory authority; 2) The University of Wisconsin-Extension assists the formation of lake organizations, builds linkages among stakeholders and provides supporting educational materials and programs; and 3) The Wisconsin Association of Lakes and local citizens provide advocacy and take actions to protect and restore their lakes. Citizen volunteers from around the state – lake organizations, property owners, and local governments – provide the political will and hard work to accomplish watershed restoration and lake protection goals. Core objectives of the Lake Partnership are to: ensure that our lakes are protected and enjoyed for future generations; help develop a common lake ethic; develop common goals for lakes; and create a mutual understanding of lake ecology and lake health.

The Partnership sponsors an annual Wisconsin Lakes Convention to bring various partners together to achieve these objectives. In 2010, over **500 people** attended this three day event. Four issues of "**Lake Tides**" – a newsletter for people interested in Wisconsin Lakes – are distributed to over **26,000 subscribers** each quarter. WDNR staff participate in a variety of educational outreach activities with the public and nonprofit organizations. WDNR staff also administer grants to local communities and organizations to help implement the core Lake Partnership objectives for planning, protection and aquatic invasive species control.

Fiscal Years 2009-2010 Lake And Aquatic Invasive Species Grants:

- Small-scale Planning—\$1,487,617.
- Lake Protection—\$3,611,063.
- Aquatic Invasive Species Control— \$7,817,520.

Learn more about lake grants at:

[http://dnr.wi.gov/lakes/grants/.](http://dnr.wi.gov/lakes/grants/)

Wisconsin Watersheds Upper and Lower Willow Watershed

2010 Water Quality Management Plan Update
St. Croix River Basin, Wisconsin August 2010

The Upper and Lower Willow watersheds are located in southwestern Wisconsin in both and St. Croix counties (Map 1). These watersheds are part of the St. Croix River Basin (which is located in both north and Wisconsin and not Minnesota). The Willow watersheds are two of approximately Wisconsin watersheds in this basin. This watershed area is sprinkled with an assortment of inland lakes, major rivers and small streams.

Map 1. Willow River Watershed, St. Croix Basin

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The Upper Willow River watershed is approximately 184 square miles and originates in the southeastern portion of Polk County and extends south into the northeastern portion of Saint Croix County. This watershed contains 319 total stream miles, 517 lake acres and approximately 5,600 total wetland acres. Streams joining the Willow in the upper portion include the South Fork of the Willow, Dry Run Creek, Carr Creek, Horton Creek, Black Brook, Wolf Creek, Jack Green Creek, and other unnamed creeks. Pine Lake in St. Croix County is the only lake over 100 acres in this watershed.

The Lower Willow watershed is situated entirely within St. Croix County. In this watershed

Willow River Watershed Plan 2010

Success Story: Bass Lake Restoration Reflects Teamwork

When a water body has been restored it can be “delisted” from the 303(d) List of Impaired Waters. Restoration and delisting happens through the hard work and commitment by local governments, citizens, nonprofit groups, Native American tribes, farmers, other agencies and the WDNR in addressing the source of the water quality problems. Over the years, **129 water/pollutant listings have been declassified as impaired** due to restoration and water quality improvement efforts. Bass Lake was recently delisted and demonstrates a watershed approach to improving water quality.

The Marinette County Land and Water Conservation Department led efforts to restore Bass Lake. The lake was part of a state priority watershed project in the late 1980s to address runoff pollution from agricultural operations that led to excessive phosphorus in the lake. The phosphorus fueled heavy algal blooms in the summer and low dissolved oxygen levels in the winter that contributed to fish kills when ice covered the lake. More work needed to be done, so the county worked with two livestock operations that were identified as the major sources of excessive phosphorus entering the lake.



Algal bloom on Bass Lake before restoration. WDNR Photo.

County staff secured WDNR Targeted Runoff Management grants and worked with the farmers to install state-of-the-art runoff control practices that significantly reduced phosphorus entering the lake. (See the “Controlling Pollutants in Wastewater and Storm Water” section of the report for more information on Targeted Runoff Management Grants.) State Stewardship funds were utilized to place 2,000 feet of Bass Lake shoreline and 55 acres of cropland under permanent easement. The WDNR Lakes Protection Grants helped pay for treating the lake with alum in 1999 to prevent the phosphorus buried in lakebed sediments from being seasonally recycled and causing water quality problems. The U.S. Fish & Wildlife Service helped install sediment basins and restored wetland areas to help filter out pollutants. The combined impact of these efforts **reduced the average phosphorus concentrations by 99 percent, from 490 $\mu\text{g/L}$ to 10 $\mu\text{g/L}$** . Without the high concentration of phosphorus, heavy blue-green algae blooms no longer cover the lake, water clarity continues to improve, and no fish kills have been noted since the alum treatment. Project costs are estimated at \$696,100.



Bass Lake after restoration. WDNR Photo.

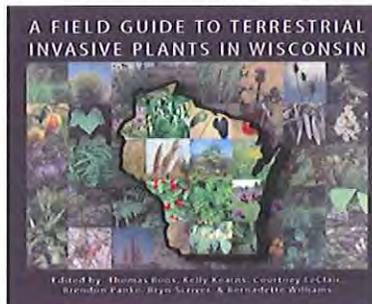
Learn more about phosphorus reductions in Bass Lake at: <http://dnr.wi.gov/org/water/wm/wqs/303d/EAP/basslake.html>.

Read about new EPA-required Phosphorus Standards in the “Controlling Pollutants in Wastewater and Storm Water” section of this report.

Local Prevention of Aquatic Invasive Species Grows

Aquatic Invasive Species (AIS) are finding it harder to get around thanks to new regulations. Effective September 1, 2009, the WDNR's Invasive Species Classification Rule – Chapter NR 40, Wis. Adm. Code, makes it illegal to transport, possess, sell or introduce the most dangerous potential invasive species that are not yet here in Wisconsin, and ones we want to be sure to keep out. The new invasive species rule classifies invasive plants and animals as “prohibited” or “restricted” and sets regulations for each category. Learn more about Wisconsin's Invasive Species Identification, Classification and Control Rule at: <http://dnr.wi.gov/invasives/classification/>.

The WDNR released a [Strategic Plan to Manage Invasives](#) in 2010 that includes outreach and education to gardeners, naturalists, landowners, outdoor enthusiasts, utility and highway workers and land managers who oversee parks, trails, and forests. A “[Field Guide to Terrestrial Invasive Plants of Wisconsin](#)” and photo gallery of plant invasive species is available at: <http://dnr.wi.gov/invasives/plants.asp?filterBy=Classification>.



In addition, the WDNR issued a new permit regulating ballast water discharge of ocean-going ships to ensure that new invaders do not reach the state via our Great Lakes coastline. Read more about Ballast Water Discharge General Permits in the “Stewardship of our Great Lakes” section of this report.

Grants to local partners increases outreach.

The fight against AIS in Wisconsin is truly a team effort. State agencies, universities, county governments, Native American tribes, lake associations, non-profit organizations and volunteers all play a vital role in preventing the spread of aquatic invaders. The number of local partners working

on controlling invasive species continued to grow in 2008-2010, bolstered by increased state prevention and control grant money available to communities through the “Clean Boats, Clean Waters” Program. The WDNR awarded slightly over **\$7.5 million** in 2008-2010 to counties, tribes, universities, lake groups and other eligible recipients for assistance in helping control the spread of AIS. More than 30 county and regional partners now have staff coordinating their efforts to prevent and contain the spread of invasive species.



Volunteers receive aquatic plant identification training from Susan Knight, University of Wisconsin Outreach Specialist, Center for Limnology. WDNR Photo.



Removal of aquatic invasive plants from boats and trailers at the boat ramp helps prevent the spread of these plants to other lakes. WDNR Photo.

Volunteers and “Water Guards” help educate boaters.

The corps of dedicated volunteers who spend their weekends and holidays educating boaters play a vital role in education, boat inspection, and monitoring waters for new invaders. Volunteers accounted for 70 percent of the hours spent on boat inspections statewide in 2009. In surveys of boaters, 90% say they were aware of invasive species laws and **93% claim to remove plants** from their boats and trailers and drain all water before leaving. Through the combined efforts of partners all across the state, Wisconsin

Aquatic Invasive Species (continued)

citizens are getting the message about AIS, and boaters and anglers are increasingly doing the right thing to make sure that they do not give these species a ride. Learn more about "Clean Boats, Clean Water at:

<http://dnr.wi.gov/lakes/CBCW/about.html>.

Wisconsin's "Water Guards" are a specialized group within the WDNR's Conservation Warden Service that focuses on education and enforcement to prevent the spread of AIS and fish infected with Viral Hemorrhagic Septicemia (VHS). See the "Creating Outstanding Fisheries" section of this report to learn more about this deadly fish virus that is threatening Wisconsin's fish. Read more about the future challenges in controlling AIS in the "Emerging Issues" section of this report.



John Preuss, Water Guard, performs a boat inspection. WDNR Photo.

Quick Response Eradicates Surprise Invader

In late summer 2009, a new invasive crayfish that can harm native fish, frog and indigenous crayfish populations was found in a private pond in Germantown, Wisconsin. The red swamp crayfish, which is native to the southern United States, is commonly used in the restaurant industry and by teachers in their classrooms. The pathway by which it reached Wisconsin is unknown.



Red swamp crayfish. WDNR Photo.

Fencing was installed to restrict movement of the crayfish to nearby waterways. WDNR Photo.



AQUATIC INVASIVE SPECIES FAST FACTS:

- 75% of our lakes with public access are free of Eurasian water-milfoil and zebra mussels.
- Just 4% of lakes predicted to be suitable for zebra mussels are currently infested.
- 538 waters have Eurasian water-milfoil and only 116 in northern Wisconsin.
- 0 new waters with VHS virus in 2009. Disease successfully contained in Lake Winnebago and Great Lakes.

Fast eradication was key in keeping this invader from migrating to nearby Lake Michigan and tributaries. A response team of experts and partners was quickly mobilized to contain and control this isolated population with the goal of eradicating it completely. WDNR and UW-Madison staff trapped over 1000 crayfish. Fencing was also installed to contain the crayfish and nearby waters were monitored to determine if any spread had occurred.

WDNR determined that trapping alone wouldn't work. WDNR fisheries staff worked with subdivision property owners to develop a control plan, including chemical treatment of the pond. The November 2009 chemical treatment appeared successful in eliminating the red swamp crayfish. Learn more and watch video about the eradication of aquatic invasive species at: <http://dnr.wi.gov/invasives/>.

WPDES Permits (continued)**New U.S. EPA pesticide general permit will also increase workload.**

On June 2, 2010, U.S. EPA announced the public availability of a draft National Pollutant Discharge Elimination System (NPDES) permit for point source discharges from the application of pesticides to waters of the United States. This permit is also known as the Pesticides General Permit (PGP). The PGP was developed in response to a decision by the Sixth Circuit Court of Appeals (*National Cotton Council, et al. v. EPA*).



Aquatic application of pesticides for weed and algae control. WDNR Photo.

As a result of the Court's decision, discharges to waters of the U.S. from the application of pesticides will require NPDES permits when the court's mandate takes effect, on April 9, 2011. Because Wisconsin has NPDES state authority, the WDNR has responsibility for implementing the provisions of the federal CWA through its WPDES permits.

The WDNR is required to develop a pesticide general permit to meet these new federal permitting requirements to regulate discharges to waters of the U.S. from the application of biological pesticides and chemical pesticides that leave a residue. The following pesticide activities are covered under the PGP: mosquito and other flying insect pest control, aquatic weed and algae control, aquatic nuisance animal control, and forest canopy pest control. The WDNR estimates it will regulate an additional 3,000 permittees with the new pesticide general permit. This additional workload is likely to increase the backlog for WPDES permit issuance and decrease service to facilities.

Impaired Waters:***Development of TMDLs is Tied to Federal Funding.***

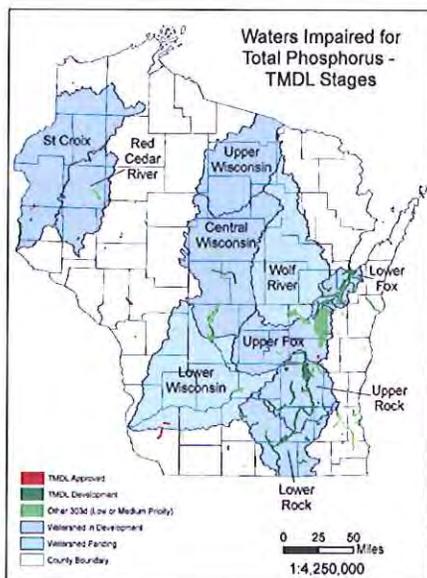
The WDNR is responsible for administering the federal CWA which has as its primary objective the restoration and maintenance of the chemical, physical, and biological integrity of the Nation's waters. As discussed in the "Managing Lakes, Rivers and Streams" section of this report, a key part of this responsibility is to identify which lakes, rivers, and streams are not meeting applicable water quality standards. That list of waters becomes the core of Wisconsin's Impaired Waters Program and is updated and submitted to U.S. EPA once every two years as required by Section 303(d) of the CWA.

Removing waters from the Impaired Waters list most often requires a Total Maximum Daily Load (TMDL) report - a study that evaluates all sources of a pollutant and then allocates the amount that each of those sources can emit, such that water quality goals for the receiving water are met. Sources of pollutants can be numerous and include: runoff from farms or urban streets, effluent discharges from wastewater treatment plants or other manufacturing facilities, atmospheric deposition, and contaminated sediments at the bottom of lakes and streams. Currently, Wisconsin has about 700 waters on the Impaired Waters list.

Nearly 50% of those waters are impaired due to the atmospheric deposition of mercury which drives restrictions on how many fish should be consumed to avoid human health problems. Excessive deposition of sediment (soil) and phosphorus are the two other primary causes of water quality problems in the state and heavily influence which waters are on the Impaired Waters list.

The WDNR relies solely on federal funding to develop TMDLs and move them towards implementation. While a Water Division goal exists to complete at least 15 TMDLs annually, resources and select state and federal policies are a limiting factor and reaching that goal is often challenging. Currently, the WDNR is actively developing several large scale basin-wide TMDLs, including studies for the Lower Fox River Basin and Lower Green Bay, the Upper Fox/Wolf

River Basin, the Rock River Basin, and the Central Wisconsin River Basin. A number of smaller scale TMDLs have already been completed or are currently under development. Read more about the Lower Fox River/Green Bay TMDL in the “Stewardship of the Great Lakes” section of this report.



Waters that are on the Impaired Waters list may have restrictions on the approval of new sources of pollutant discharges. In some cases, these restrictions may prohibit certain types of development and activities within the watershed until a TMDL can be finalized. Industries interested in locating within a watershed awaiting completion of a TMDL may experience delays in the approval process for issuance of a WPDES permit. While the WDNR currently lacks the resources to move more quickly on developing TMDLs across the entire state, it is exploring opportunities to do so in partnership with other water quality agencies, universities, and other interest groups. Absent an increase in the resources for TMDL development, these partnerships will be a key component to timely TMDL development.

In addition, the WDNR anticipates an increase in the number of requests for 3rd Party TMDLs in reflection of the limitations mentioned above. In the case of 3rd Party TMDLs, an external group that is not affiliated directly with the WDNR may develop a TMDL for consideration by WDNR. Ultimately, any TMDL developed by a group must be submitted by WDNR to U.S. EPA for federal approval. It will be critical for 3rd Party groups and the WDNR to have agreement on study design before initiating projects.

Aquatic Invasive Species: Additional Preventive Efforts are Needed.

The successful Aquatic Invasive Species (AIS) Partnership with local communities and volunteers is included in the “Managing Lakes, Rivers, and Streams” section of this report. There are several areas that will need to be addressed in the next two to five years to ensure this program’s continued success: monitoring, addressing different pathways and emerging threats, enforcement, developing control options, and partnerships.

Monitoring: The AIS partnership has asked a lot from its volunteers. Early detection monitoring has largely been accomplished by volunteers and regional staff. The breadth of this monitoring needs to be expanded to better position the WDNR to respond to early infestations of AIS and to document our Partnership’s successes.

Assessment of pathways: Various commercial service and trade industries may be an important source of invasives. AIS reach our state through various pathways including the pet, restaurant, nursery, and aquarium trade industries. We are beginning to realize that invasive plants and animals are being purchased and shipped right to our backyard ponds, restaurants, and aquariums and through accidental or intentional release these organisms are finding their way to our waterways. The AIS Partnership needs to complete an assessment of these pathways and put measures in place that will protect our waterways.



Hand removal of an aquatic invasive—Water Hyacinths. WDNR Photo.

<http://dnr.wi.gov/wnrmag/2011/06/lakes.htm>

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Wisconsin lakes are in better shape than many lakes nationally.
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June 2011

A watershed year

Discover the state of the lakes.

Lisa Gaumnitz

[Signature success stories](#)

It's a watershed year for Wisconsin lakes. New studies suggest they're in better shape here than nationally and are demonstrably cleaner than 40 years ago when the federal Clean Water Act triggered a generation of investments in wastewater treatment improvements. The baby boomers hired to carry out that landmark federal law and groundbreaking state laws have done their job well and are heading toward the exits – if they haven't already left.

As Wisconsin lake managers, educators and volunteers come together in 2011 to chart the course for the next 10 years, they recognize that protecting and restoring water quality alone isn't enough, that habitat is king, and that tackling new threats will require new approaches and leadership.

"We had a huge influx of staff in the 1970s as a result of the Clean Water Act and the funding available to states. Those people have done a good job in implementing it, and we're seeing that in cleaner water in the middle of the lake," says Carroll Schaal, who leads the lakes team for the Department of Natural Resources.

"Now that they're moving on, another generation needs to come forward and deal with these other challenges: habitat loss, water levels, toxic algae, invasive species and climate change. Those weren't on the radar 10 years ago, but they are now."

Sandy Gillum, a longtime lake volunteer, scientist and author who lives on Anvil Lake in Vilas County, is seeing those challenges up close.

Anvil Lake and others like it – groundwater fed and perched high on the topography – are suffering significantly lower levels during the prolonged northern drought, while lakes sitting lower in the topography are in better shape or in some cases may be getting too much water.



Sandy Gillum

© Photo submitted by Sandy Gillum

"Anvil Lake's profile is that of a classic glacial kettle lake that is shifting to a shallow water lake system," Gillum says. "Water clarity has been decreasing, algae, some toxic, have been a growing problem, and the assemblage of fish, aquatic plants and other aquatic creatures is shifting. It's not fun to watch." She hopes that some of the Anvil Lake watershed studies will open opportunities for improved management decisions for many lakes experiencing a shift to a shallow water regime.

Gillum, vice president of the board of directors of Wisconsin Lakes, a statewide nonprofit organization previously known as the Wisconsin Association of Lakes (representing over 80,000 citizens), says that state laws, administrative rules and policies need to be flexible in order to respond to emerging situations on a regional or local basis and that grant and other assistance programs should be available accordingly.

"Lake stressors vary across the state. In some cases, we have one-size-fits-all laws and action responses," she says. "We also need to learn to live with the lakes. We try to manipulate the environment to fit our needs when we should manipulate our habits to fit the environment."

Progress at the end of the pipe

The federal Clean Water Act of 1972 sought to assure that all lakes and rivers nationwide would be safe for swimming and fishing. It set national standards for "point source" pollution – the liquid wastes flowing out of discharge pipes from factories and sewage treatment plants and into lakes, rivers and streams. The law also launched a massive grant program to help communities rebuild aging sewage treatment plants and included a "citizen suit" provision that allowed environmental watchdogs and other groups to sue polluters and the agencies regulating them.

Wisconsin was the first state to gain federal authorization to issue its own permits limiting point source pollution and, a decade later, the first state to have its point source permits require a greater level of treatment. The state was also a leader, starting in the late 1970s, in tackling the diffuse sources of pollution to lakes and rivers, so-called runoff pollution or "nonpoint source pollution."

These investments have paid off in those lakes where point sources were a problem, according to the first ever baseline study of the nation's lakes. In summer 2007, EPA's National Lakes Assessment looked at 1,028 inland lakes across the country, including 32 in Wisconsin. Sampling crews from each state followed uniform procedures for collecting information on water quality, habitat, biological health, and presence of toxic algae on randomly selected lakes intended to provide insight on a regional basis.

Nationally, and in Wisconsin, most lakes sampled 35 years ago that were impacted by wastewater discharges have shown improvement or no increase in phosphorus.

Wisconsin also fared relatively well in other measures of lake health, with northern lakes in better shape than southern lakes, and with different stressors affecting them.

Northern Wisconsin lakes were part of the Upper Midwest eco-region, which also included northern Minnesota and Michigan, and which came out strong:

- 91 percent of lakes were in good biological condition, compared to 56 percent nationally.
- 64 percent of lakes had good shoreline condition, compared to 47 percent nationally.
- 91 percent of lakes had low to moderate levels of nutrients, compared to 80 percent nationally.
- 77 percent of lakes didn't have detectable levels of a toxin produced by excessive blue-green algae, compared to 70 percent nationally.

Overall, habitat loss was the biggest stressor for northern lakes.

Southeastern Wisconsin lakes, grouped in the Temperate Plains region that included Indiana, Illinois, Iowa, Missouri and parts of the Dakotas, didn't fare as well nationally but beat the

regional averages. These lakes had a variety of major stressors, from high nutrient loads to aquatic invasive species to habitat loss.

The national results are consistent with Wisconsin's monitoring results as reported in the DNR's 2010 Water Quality Report to Congress, notes Tim Asplund, DNR's statewide limnologist.

Seventy-five percent of the 3,200 lakes assessed exhibited excellent or good water quality, and the number of lakes judged as such has grown since 1980 in each of the classifications DNR has assigned lakes based on their size, depth, water sources, drainage area and position within the landscape.

"I'm encouraged by these findings that most of our lakes are in excellent or good condition overall," Asplund says. "We should be proud we have an important resource and we have maintained that. But keeping Wisconsin lakes in good condition is going to take vigilance and investing dollars where we know we can make a difference because the cost and effort to restore a lake once it's degraded can be so great."

Habitat is king

One of the most significant findings of the National Lakes Assessment, Asplund says, points to one of the biggest challenges to lake management in the 21st century – keeping habitat intact.

"The stressors affecting the largest proportion of lakes are in fact habitat alterations to the lake shorelines and shallow water areas," Asplund says.

"What we've increasingly realized, from multiple lines of evidence, and what the national study confirmed, is that both water quality and biological condition are driven by what happens on the shoreline and shallow water areas of the lake."

Nationally, lakes with poor lakeshore habitat were three times as likely to have poor biological health as lakes with good lakeshore habitat. Good biological health is characterized by the composition of the zooplankton and phytoplankton community, key to the production of oxygen and food to support a diverse and healthy population of fish, insects, algae, plants and other organisms.

Asplund says those national findings also suggest that Wisconsin's existing protections for shorelands and shallow water areas are benefitting lakes by preserving natural habitats and their filtering capabilities. Wisconsin was the first state to adopt statewide minimum development standards and many counties have gone beyond those state minimums to enact more protective standards.

And Wisconsin for decades has required environmental review for dredging, grading, aquatic plant management and other activities in the shallow water that can disturb or destroy habitats.

"The Lakes Assessment says that shoreline development in and of itself doesn't automatically make lakes worse — it's how you develop it that determines the impact on the lake," Asplund

says. "It also says that if people who live on the lake engage in proper stewardship and restoration activities, it does benefit the lake. Some of the damage can be undone."

New threats surface

As point source pollution has been controlled, runoff pollution from farms, cities, roads and construction sites has become the leading cause of poor lake water quality. Rules to address these so called "nonpoint sources" have been tightened in the last decade. But because of the sheer number of these diffuse sources, it will take a lot longer to control them and see the kind of improvement witnessed after point sources were controlled, Schaal says.

The spread of aquatic invasive species like zebra mussels, rusty crayfish, common carp and Eurasian water-milfoil, along with water level issues, have emerged as some of the most concerning challenges. Algae blooms, sometimes toxic, are a growing problem on lakes, especially large reservoirs, where nutrient levels are still too high.

The lower water levels Gillum observes on Anvil Lake, which is down 6.5 to 7 feet from its all-time high in 1943, and about 3.8 feet since 1995, is a problem in other parts of Wisconsin. Some central Wisconsin lakes are particularly susceptible because of a combination of factors including their reliance on groundwater, their location in the watershed, weather patterns, and increasing groundwater use by humans. Central Wisconsin now contains the highest density of high capacity wells in the state – those pumping 100,000 or more gallons a day – with about 2,100 wells in Adams, Marquette, Portage and Waushara counties.

Seepage lakes located close to a groundwater divide (a high point where water divides and flows in different directions) have less area to draw water from than lakes farther down the hill which intercept more groundwater sources. So when a lack of water lowers the water table, "high" lakes are more susceptible to fluctuations.



Mary Jane Bumby

© Photo submitted by Mary Jane Bumby

In other parts of Wisconsin, lake lovers are coping with effects associated with too much water.

Mary Jane Bumby, a retired high school biology teacher who lives along Green Lake, has been monitoring water quality and aquatic plants in the lake for 40 years, and for some years, had recorded improved water quality on the lake, Wisconsin's deepest natural lake at 236 feet. Then came the flood of 2008. The Ripon area received 13 inches of rain in a few days and water from the 114-square-mile watershed rushed toward the lake.

"Water is a mighty force," Bumby says. The rains washed sediment and nutrients from surrounding rich farm fields into the lake, shorelines collapsed, adding more sediment, and piers and boats floated away with the high water levels.

"It's very sad to look out and see how muddy the lake can be when we have high winds," Bumby says. During the drought of 1992, she measured water clarity down to 50 feet. Last summer, clarity was 20 feet. "The lake is changing because of runoff from its watershed of two counties and water retention in the deep lake of 17 to 19 years."

That story has been repeated elsewhere in the state. The improving water quality seen across all classifications of lakes since 1980 has dropped off somewhat in the last five years, possibly due to extreme weather conditions, including the drought in northern Wisconsin and a series of unusually wet years in southern Wisconsin, Asplund says. Such flooding and drought are expected to intensify as a result of climate change in Wisconsin.

New leadership and approaches needed

For the last 30 years, a partnership involving the Department of Natural Resources, UW-Extension and citizen and lake communities has helped Wisconsin keep its lakes healthy.

The partnership builds on the efforts of other DNR programs and local, state and federal agencies to control pollution sources and other stressors that can impact lakes. The state provides educational, financial and technical support to lake communities. Citizens provide local leadership, initiative and the political will.

The Wisconsin Lakes Partnership is considered a national, if not international, model for successful lake management.

But key architects are now sailing into retirement, including Bob Korth, lakes team leader for UW Extension's Lakes program at UW-Stevens Point, and Jeff Bode, the longtime leader of DNR's lakes and wetlands section.

New leaders are grabbing the tiller. Eric Olson has been hired to take on the Korth job; Karen von Huene is leading Wisconsin Lakes. Together with DNR's Carroll Schaal, they are steering an effort to develop a new strategic plan for the Wisconsin Lakes Partnership.

"Collaboration has been a critical component to addressing lake issues over the past decades," Olson says. "As we look to the future, the Wisconsin Lakes Partnership hopes to extend their

collaborative network to ensure that everyone who cares about lakes can take an active role in protecting and restoring them."

Gillum says the new strategic plan needs to embrace adaptive management and replace the one-size-fits-all approach. This is already happening. Wisconsin Lakes is developing regional leadership teams to be the ears and sounding boards for Wisconsin lakes. These will be non-agency representatives who have solid backgrounds in lake issues and will be helping identify some of the most important concerns in their areas, she says.

For its part, the DNR has been classifying its waters in 10 classes based on lake size and depth, water sources, how much land drains to the lake, and its position within the landscape. Sediment core studies help give an idea of what the water quality was before statehood for a particular lake class. From those measurements, data collected by the Department of Natural Resources, other agencies and by volunteers through the self-help lakes monitoring program can be used to determine if a lake is good, fair or poor in certain health indicators.

"There are different expectations for different lakes, so we expect shallow drainage lakes with large watersheds to be different than deep seepage lakes with small watersheds," Asplund says. The classifications are helping set realistic expectations for lakes and can help better steer funding to where it will make the most difference.

The DNR is hoping that Wisconsin's involvement in the Midwest Glacial Lakes Partnership, one of several emerging national fish habitat protection efforts, can help bring new information, recommendations and resources to the fight. When all is said and done, though, the success of the strategic plan rests on the shoulders of citizens like Gillum and Bumby.

Their energy and involvement seem limitless. Gillum, former education director and past president of the Vilas County Lakes Association, served on the Loon Watch Advisory Council of the Sigurd Olson Environmental Institute at Northland College in Ashland and designed and supervised a number of shoreline restorations in Vilas, Oneida, Forest and Florence counties, in addition to conducting and publishing research on the habitat values of natural shorelines and other topics. She now serves as Chairman of the Town of Washington Water Resources Committee and is involved in studies on Anvil Lake that she hopes can help lead to improved management decisions for lakes shifting to shallow water states.

Bumby also has a very hands-on approach.

She pilots her small motorboat to two sites in Big Green Lake, taking water clarity measurements by lowering a state-supplied Secchi disk into the water until she can no longer see its black and white markings, before recording the depth. She takes the water temperature, and completes her other sampling. This summer she'll be working with a group of volunteers to conduct a survey of submersed aquatic plants. The first such survey was done in 1921; she repeated that study in 1971 and has done it every decade since.

"I love to see what's going on in the lake," she says.

Lisa Gaumnitz is the public affairs manager for the DNR Water Division.