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Cyanobacteria Task Force Briefing – Jan 2019

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Eutrophication

the process by which a body of water becomes enriched in dissolved nutrients (such as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Stages of eutrophication

Ogliotrophic = good water quality – all of our lakes, except Mirror Lake and Sargents Pond
Mesotrophic = moderate water quality - Mirror Lake and Sargents Pond
Eutrophic = poor water quality - None

Key concerns relating to eutrophication

- Plants
- Algae
- Biofilms
- Cyanobacteria

These biological concerns are all driven by four factors that we have little control over:

- Light
- Iron and other mineral nutrients
- Warm water temperatures (especially cyanobacteria)
- Calm waters (especially cyanobacteria)

And two over which we have more control:

- Nitrogen (N)
- Phosphorous (P)

There are several different forms of P and N that can be converted into one another and that have some different consequences. Also, there is a complex interplay between N and P in the growth of cyanobacteria. However, given that the additional, controllable sources of all the different forms of the two to our lakes are the same (except as noted), this briefing will just refer to P and N and focus upon P.

Phosphorous is the factor over which we have the most control

Typical sources of phosphorous:

- Wildlife (ducks, etc.) small
- Groundwater sources, including septic system failures 5-7%
- Atmospheric deposition 15-20%
- Streams/Tributaries
- In-lake (legacy)
- Storm water runoff

Lakes have three important zones that influence water quality in different ways

- Surface water column
- Deeper waters that don't mix with surface waters when lakes become stratified in the summers and winters as the surface waters become warmer or colder than the deeper waters
- Lake bottom

Surface waters

Most of the focus is upon the surface waters, as that is the zone which we see and drink and in which we swim, fish, and boat. Thus, it is the zone that has been the focus of most water quality monitoring. This is also the zone that has been the focus of most watershed assessments, discussed later.

Generally, surface-water-column-total-P concentrations that are

- 8 ug/l or less are considered good,
- 10 ug/l or above are considered at risk for algal and cyanobacteria growth, and
- 20 ug/l or above are considered impaired

Typical mid-summer surface water total phosphorous concentrations for our lakes are

- Lake Wentworth 5-9 ug/l (2017)
- Crescent Lake ~7 ug/l (2017)
- Rust Pond P ~9 ug/l (2018)
- Mirror Lake P 8-16 ug/l (2017)
- Winnipesaukee, The Broads, 5-9 ug/l (2017)
- Wolfeboro Bay ~ 6 ug/l (2017)
- Winter Harbor (Carry Beach end) 4-5 ug/l (2018)

Deeper waters

- Algae, plants, and other organic material that sink into the stratified deeper waters, where there is no mixing with the surface waters, can die, and use up the oxygen in the water, setting off anaerobic chemical and biological processes.
- Fish and other forms of life can die under these conditions from lack of oxygen.
- Among the anaerobic processes are reactions that convert insoluble forms of phosphorous on the bottom to soluble forms that can enter surface waters during turnover in the autumn and spring (when the surface water and the deeper water temperatures are similar).

Mirror Lake has a relatively large-sized deeper water zone that in most years becomes anaerobic. In 2017, during turnover total phosphorous levels in its surface waters reached 112 ug/L. So, the lake has a significant in-lake (legacy) source of phosphorous.

Rust Pond has a deep anaerobic zone, but its legacy contribution of P seems to be more modest.

Lake Bottoms

The bottoms of freshwater lakes consist of sand, gravel, and rocks. They are habitats and sources of nutrients for a wide variety of animal, plant, and other forms of life. However, fewer chemical and biological measurements have been made of the bottoms of our lakes than of the waters above. The lake bottom along the shoreline of Winter Harbor, which is covered with storm water runoff sediment is very important.

Cyanobacteria

Cyanobacteria, once called blue-green algae, are a distinct and very ancient form of life. There are many types of cyanobacteria with many different strains of each type and they are found everywhere (e.g. in soils, deep underground, in polar ice, fresh waters, and the ocean). While much is known about them, much more is yet to be learned. The many types and strains differ widely in their characteristics. However, several fresh water cyanobacteria may out compete other microbial life forms (such as green algae) and proliferate, particularly in warmer, relatively calm water.

Most cyanobacteria cause rashes and other dermal effects. Many, but not all, cyanobacteria have the ability to produce and potentially release a variety of cyanotoxins (toxic chemicals), particularly in blooms containing large numbers.

The cyanotoxins, all of which are potentially very dangerous, tend to fall into four broad categories:

- Microcystins – liver toxins
- Anatoxins - neurotoxins
- Saxitoxins - neurotoxins
- BMAA – neurotoxins (the toxins postulated to be associated with ALS and/or Parkinson's)

Why certain cyanobacteria produce cyanotoxins and when they release the cyanotoxins to the water are not understood. Cyanobacteria are living organisms; cyanotoxins are not. So, cyanotoxins cannot be killed or removed by boiling or disinfection. Indeed, boiling cyanobacteria-containing water will cause any cyanotoxins still in the organism to be released, thereby increasing the toxicity of the water.

Some of the cyanotoxins can last weeks or months in lake water, long after the cyanobacteria that released them have gone. So, the risks of cyanobacteria blooms do not end when the blooms go away.

Algae and algal biofilms on the bottom of our lakes likely contain and live symbiotically with cyanobacteria and should not be ignored. Measurements have not been made of the concentrations and types of cyanobacteria that may be present in the benthic algae or in the biofilms of our lakes. Some algae-cyanobacteria biofilms on lake bottoms are known to become thick and float to the surface.

While we cannot avoid the presence of cyanobacteria, we should avoid conditions favoring blooms of them and we should be prepared to avoid the potential hazards of cyanotoxins that they may release.

<u>Gloeotrichia (Gloeo)</u>

- Gloeotrichia is the type of cyanobacteria that bloomed in late August in Winter Harbor
- Gloeotrichia (Gloeo) are not a common cyanobacteria but have been found in recent years in several New England lakes. So far, they haven't been grown in a laboratory setting, as a result, less is certain about Gloeo than other, more common, cyanobacteria.
- Unlike other cyanobacteria, Gloeo are believed to get their P and most other nutrients from the sediments at the lake bottom, instead of from the surface waters. They are reported to be the most efficient cyanobacteria in digesting organic forms of P found in the sediment.
- Gloeo rest over the winter in the sediment and come to life in the spring, living in conjunction with (benthic) algae growing on the lake bottom and slowly reproducing. They are reported to be associated with fresh (recent) sediments in water 15 feet deep or less.
- When waters are warm and calm, Gloeo are among the cyanobacteria with the ability to float to the surface in colonies of cells as often as three times a day.
- Gloeo are also among the cyanobacteria able (like peas and clover) to convert nitrogen in the air to a form that it and the green algae can use to grow faster (doubling 3-4 times per day).
- Gloeotrichia colonies in blooms typically grow to about 5,000 cells and are visible to the eye.
- Gloeo blooms can build over a week or two and often end quickly over a few days, with the Gloeo cells separating from their colonies and falling down to the sediment as akinetes (seeds).
- Gloeo blooms have been reported to produce and release microcystins, often as the blooms end.
- Microcystins are relatively stable compounds, which can remain in the water for weeks.
- NHDES Beach advisories are issued when Gloeo concentrations are at or above 15,000 cells/ml
- Guidance on microcystin limits:
    - drinking water 0.3 ug/l,
    - recreation 4-10 ug/l .

Winter Harbor

The bottom of Winter Harbor is important because of the presence and significant growth of biofilms and algae on top of the sediment and rocks in recent decades. It is also important because of a bloom of Gloeo, which lives most of its life on the lake bottom, in 2018 that resulted in a near monthlong NHDES Advisory to avoid contact with the lake water, including over Labor Day weekend.

That bloom was observed at the end of August 2018 and continued to build to much higher concentrations over a week to 10 days, after which it disappeared quickly over a 1 to 2-day period. The total cyanotoxins released into Winter Harbor during and after the Gloeo bloom were, months later, determined to be below 0.1 ug/l. (However, in addition to microcystins, these Gloeo may have also released anatoxins and BMAA, with BMAA in the highest concentration.)

Surveying cyanobacteria in the water by Whitegate Road in the spring and fall (after the Gloeo bloom) finds Anabaena and other cyanobacteria in modest concentrations. Gloeo are not seen in the water column until they start blooming and rising to the surface. None of the other types of cyanobacteria have been observed to have bloomed, as yet.

When the 2018 Gloeo bloom occurred the surface water total phosphorous levels in Winter Harbor were low (~4 ug/l). No other water column parameters were high. (Nitrogen levels have never been measured in Winter Harbor and seldom have been elsewhere in the town's lakes.)

Winter Harbor has a deep (~80ft) hole in the center of the bay about 30-50 yards in diameter, which was shown in September 2018 to be anaerobic in its bottom 20 feet. The rest of the harbor is 40 feet deep or less and is presumed to have no other anaerobic areas. One measurement has been made of the total P levels in the surface waters at the Wolfeboro/Whitegate Rd. end of Winter Harbor during turnover (Oct 2018) showed a four-fold increase above typical levels during the summer (17 ug/L vs. 4 ug/L). Subsequent samples are being collected this winter to determine how quickly the phosphorous levels go back down to those observed during the summer months. If they do go down quickly, it will be an indication that the deeper water in the harbor is currently a modest contributor of legacy phosphorous to the level in the surface waters.

On the other hand, the soluble reactive P levels in the sediment in the shallow waters by Whitegate Road are manifold the levels in the water column above them. (The cyanobacteria content of the biofilms and algal blooms on the bottom of the lake have not been determined.) Meanwhile, the total P levels of the storm water runoff stream (40 Whitegate Road) feeding the sediment are as high as 7,850 ug/l. (Note: the Whitegate BMP is based on a stream concentration of 30-80 ug/l of P.) There are three of these storm water streams along Whitegate Road, all of which arise primarily from water managed by the town in the development up the hill from the shoreline properties. Presumably there are several other similar storm water runoff sources along the shoreline of the harbor.

Mitigation of Sources of Additional Nutrients

The addition of more nutrients to our lakes risks not only more Gloeotrichia blooms, but also of other types of cyanobacteria, algae and other organisms in the surface water that could significantly diminish water quality. Also, the addition of more nutrients in our lakes would add to the in-lake (legacy) sources and make it harder to improve water quality and prevent future cyanobacteria blooms. Fortunately, much of the nutrient additions from surface water runoff are controllable, particularly when they are associated with water being managed by the town along its roads.

There are completed watershed assessments covering Lake Wentworth, Crescent Lake, Rust Pond, and Mirror Lake that have identified major sources of nutrients to be addressed. A few of these are tributaries and point sources, but most involve storm water runoff. Such assessments and the sources that they identify are prerequisites for state and federal matching funds for mitigation of the sources.

There is an ongoing assessment of sources of nutrients to Lake Winnipesaukee in Tuftonboro and Winter Harbor. (There are methodical concerns with the ongoing assessment of Winter Harbor that should be addressed before it is finalized.) With no streams/tributaries and no significant point sources feeding Winter Harbor, the controllable sources of additional nutrients involve mostly storm water runoff.

There have been no watershed assessments for any of the other shorelines in Wolfeboro and it is rumored that there will be no further state funds available in the future to do more assessments.

While I have focused on the need to address water quality problems in Winter Harbor, it is not the only waterbody that deserves attention. Some of the issues and source mitigation options for the other waterbodies have been identified in watershed assessments and other issues, particularly for other shorelines in Wolfeboro on Lake Winnipesaukee have yet to be identified. Formal watershed assessments should not be necessary to fill the gaps, but they may be needed to qualify for state and federal mitigation funding.

It would be valuable to get information to enable us to assess the possibility of various in-lake mitigation options <u>to supplement</u>, not substitute for, the necessary nutrient source reduction measures.

<u>Detecting and identifying cyanobacteria blooms</u>

Detecting cyanobacteria blooms is relatively easy. They are visible to the naked eye. With a little training, volunteers and town employees (such as beach guards) should be able to meet the needs of Wolfeboro in detecting future cyanobacteria bloom.

Determining what type of cyanobacteria is blooming is not as easy, unless it is Gloeotrichia. If it is one or more the other cyanobacteria, a sample will need to be collected and be identified under a microscope by NHDES or and a qualified scientist elsewhere. Whomever does it should be able to get a determination of the type of cyanobacteria within a business day or two.

<u>Detecting and quantifying cyanotoxins associated with a cyanobacteria bloom</u>

Determining the presence and concentration of any cyanotoxins associated with a bloom is not as easy as detecting and identifying the type of bloom. There are few labs capable of conducting such analyses. NHDES and UNH are two of them. However, they are stretched thin and have multiple priorities, so in 2018 were unable to give us a determination of the cyanotoxin concentrations of the late August Gloeo bloom in Winter Harbor until early December, in the case of NHDES, and not as yet, in the case of UNH.

If our lakes experience a future cyanobacteria bloom, it would be good to identify a lab that could get us cyanotoxin level results within a few days. Rapid results are needed to advise those seeking to swim in and to fish in or to drink from the affected waters to let them know when it is safe to do so.

Note: a Gloeo bloom was reported near in the Broads by the mouth of Winter Harbor in 2009. Gloeo also have been previously observed elsewhere in recent years in Lake Winnipesaukee in Wolfeboro and in Lake Wentworth in concentrations below bloom-levels.

There have several blooms in Mirror Lake, primarily of Oscillatoria and Microcystis, not Gloeo. While fewer blooms have been observed in the surface water of the lake in recent years, some reoccurring Oscillatoria blooms have been seen in late summer sitting on the top of the deeper anaerobic water.

There have been several other cyanobacteria blooms reported elsewhere in Lake Winnipesaukee in recent years, and the waterbodies in New Durham feeding into Lake Winnipesaukee at the bottom of Alton Bay regularly have blooms of Oscillatoria, Microcystis, and Anabaena.