Highland Lake Science Roundtable 2019 Summary

What we know:

Lake Limnology

- The shape and orientation of the lake relative to prevailing winds coupled with the deep north basin and the shallower south basin and numerous wetlands contribute to the specific characteristics of the limnology of Highland Lake.
- There was a longer period of anoxia in 2019 because the lake stratified later when the lake water was warmer so that there was less overall oxygen captured in the hypolimnion to start with. A physical weather-related effect, not a biological effect.
- Over the past 14 years, Highland Lake is experiencing ice out trending slightly later in the spring. [USM and DEP haven't seen this data.]

Secchi Disk

- Secchi Disk readings are essentially the same all over the lake at the same time as demonstrated in 2018 by the Secchi Blitz.
- There has been a steady decline in Secchi Disk readings since 1980: better description might be a decline between 1970 – 1980s. Since then the average of monthly means have declined some. Minimum secchi disk reading now show up more often in July and August, rather than in early spring diatom blooms. An indication of gradual eutrophication of the lake from mesotrophic to eutrophic.
- Dry hot spring in 2018 and wet cool spring in 2019, but essentially the same results – did not change much the timing or the magnitude or duration of the truncated bloom. These characteristics were very similar regardless of differences in total phosphorus, and weather. The alewife were later than usual in spawning and so was the start of the bloom.

Picocyanobacteria Bloom

- The picocyanobacteria bloom has been identified as belonging to the genus *Cyanobium*, a generally nontoxic, very small (1-2 microns in size), single-celled strain of cyanobacteria.
- 4 straight years of a sustained bloom, (2014 – 2017)
- The timing and rise of the bloom in 2018/2019 was similar to the previous years, but in these two years, the bloom never reached the intensity of the previous blooms (< 2 m secchi), and crashed before the bloom really got established in the way it had in previous years, July 24 was the peak of the bloom in 2018; in 2019 the peak of the bloom was around 30th of July.
- There is no apparent correlation of wind to bloom
- Not a strong correlation between rainfall and the bloom.
- Phosphorus does not peak before the bloom or during the rise of the bloom. Rather it seems to peak as the bloom crashes.
- The results from the 2018 eDNA are not yet available but should be in late January 2020.
- Pico bloom is defined by a shift in biomass to something that scatters light effectively

Alewives

- Generally, 38 to 64 thousand adult alewives entering the lake in the 2014 through 2019 period except for the 8,686 in 2015.
- These numbers correspond to 60 to 100 adult fish per acres (14/acre in 2015). This is low compared to many lakes with an alewife run.

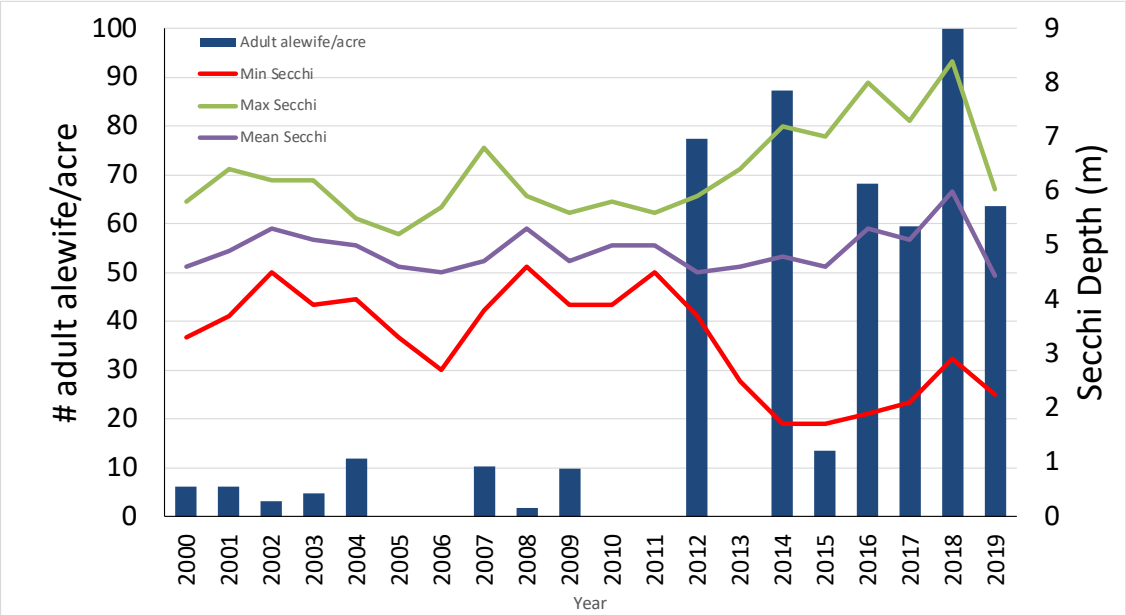

Figure 1. Adult alewife entering Highland Lake. Years with no bars = no data. Secchi values are from lakesofmaine.org.

- YOY alewives are leaving the lake later in the year than alewife living in lakes that have good egress, and Highland Lake YOY are in general the same size or smaller than in other lakes.
- Alewife egress is marginal at best, unless heavier rains allow the alewives to go over the crest of the dam. In the spring, adult alewives can be caught in the lake if water levels drop; in fall YOY alewives may not leave until fall rains. [USM & DEP have not seen the water level data]
- The night seining of alewives takes place in the deeper water, and the catch is almost exclusively alewives, only a few specimens of other species have been caught over the past two years – although this is not surprising.

Phosphorus

- Average nutrient levels in the lake compared to most in Maine. Lakes in Maine that have classic colonial cyanobacteria blooms usually have much higher TP levels (15 – 20 µg/l).
- In both years, TP values differed by depth.

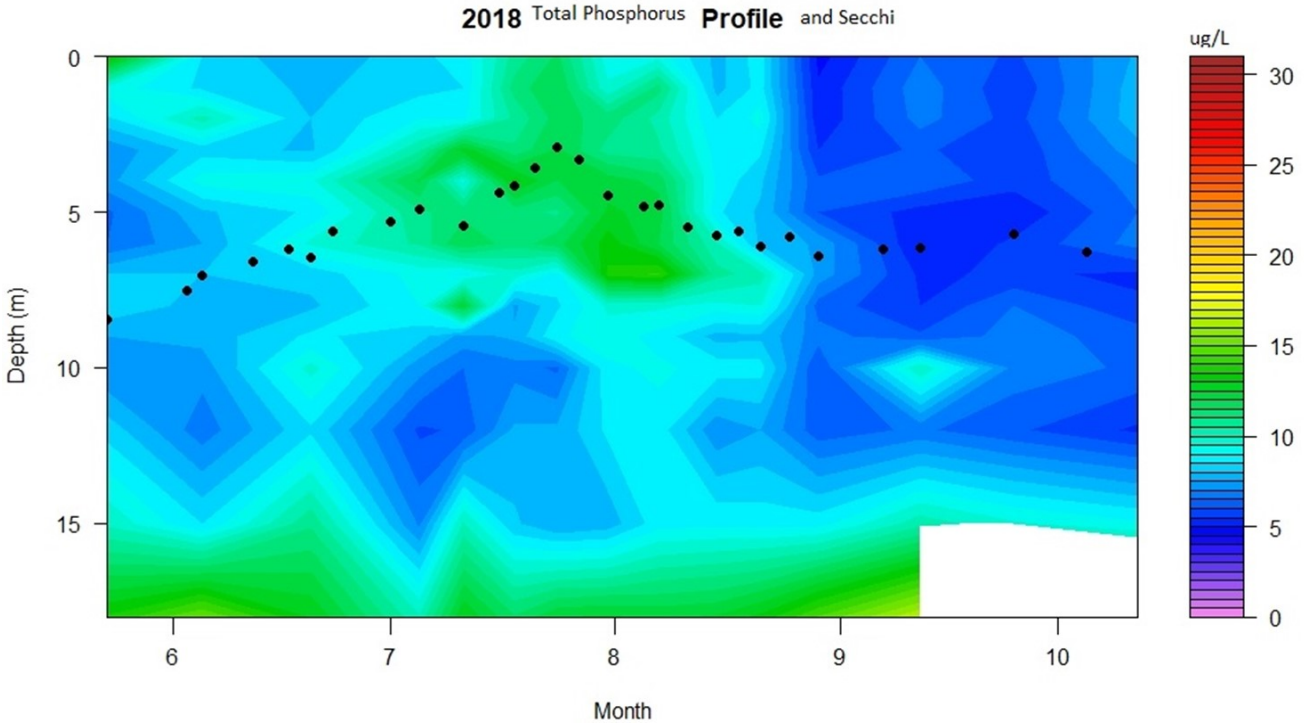

Figure 2. Total phosphorus by depth in 2018. Secchi depth (black dots) indicates the peak in the bloom.

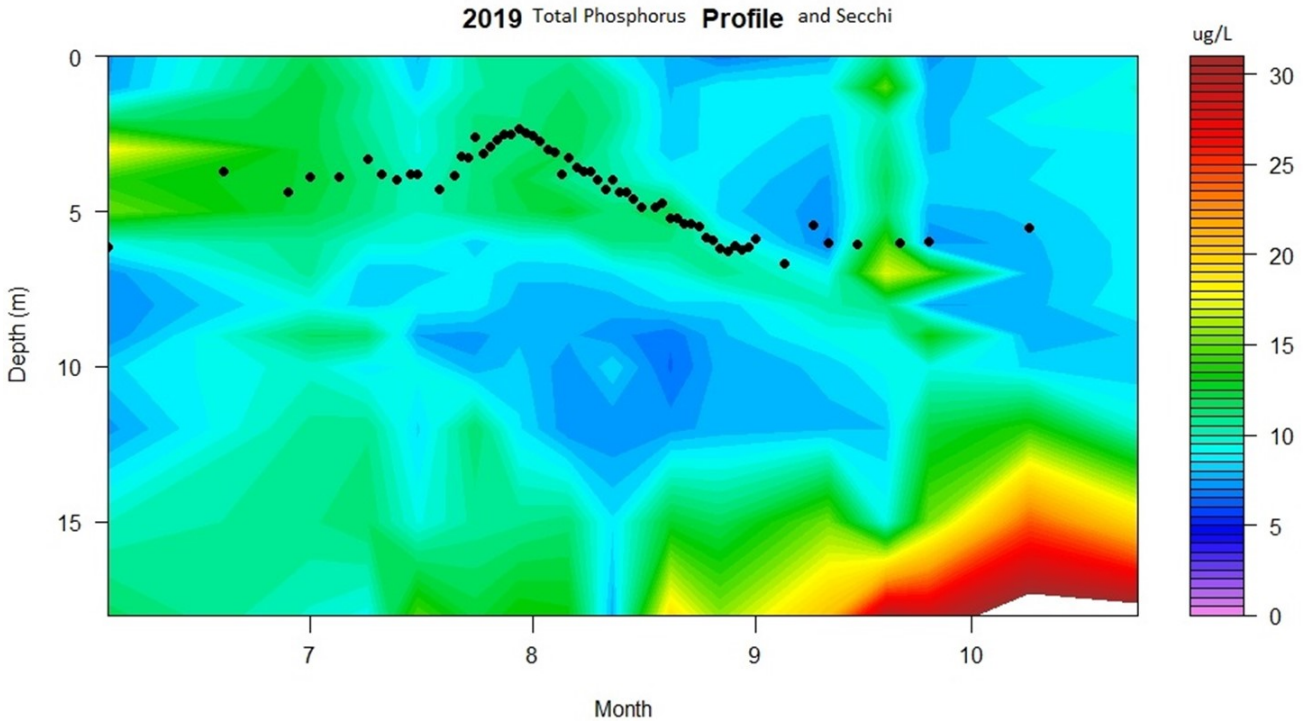

Figure 3. Total phosphorus by depth in 2019. the black dots represent secchi depth and indicate the peak of the bloom.

- In 2018 TP peaked after the peak of the short bloom. A similar pattern was observed in 2019 but muted by overall higher TP values in the lake (presumably from spring rains). In both years TP mass decreased in the fall.

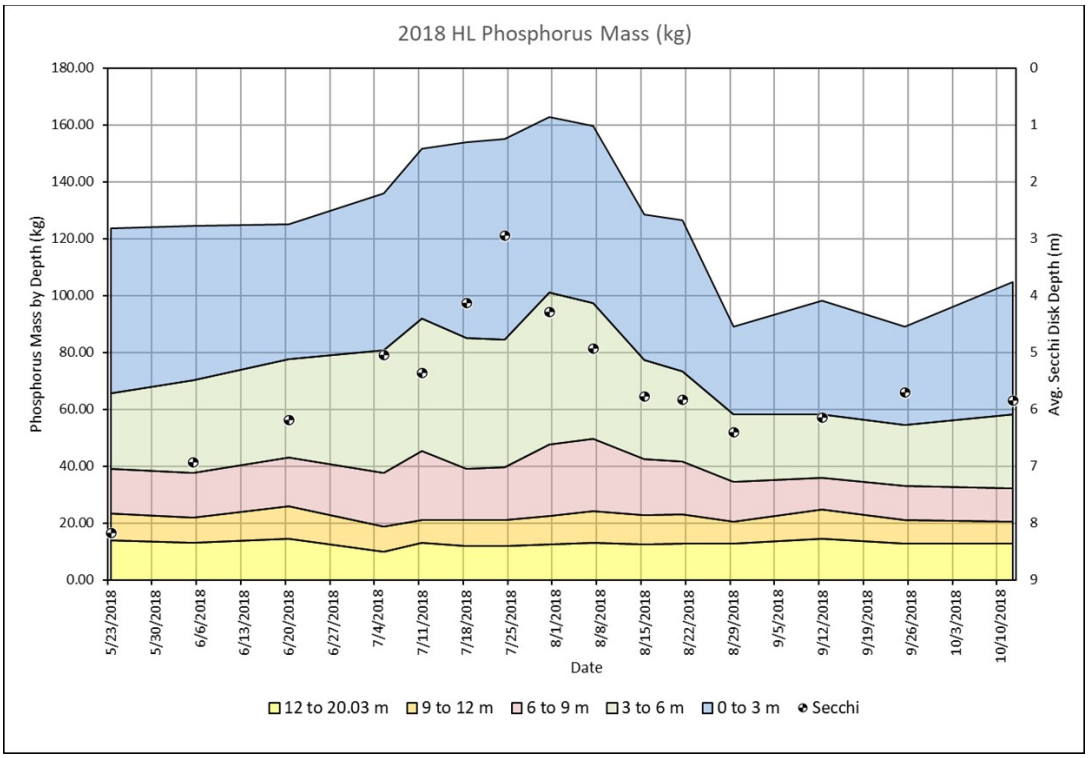

Figure 4. Total phosphorus mass by depth strata for 2018. Secchi depth is superimposed. The peak of the limited bloom occurred on July 24th.

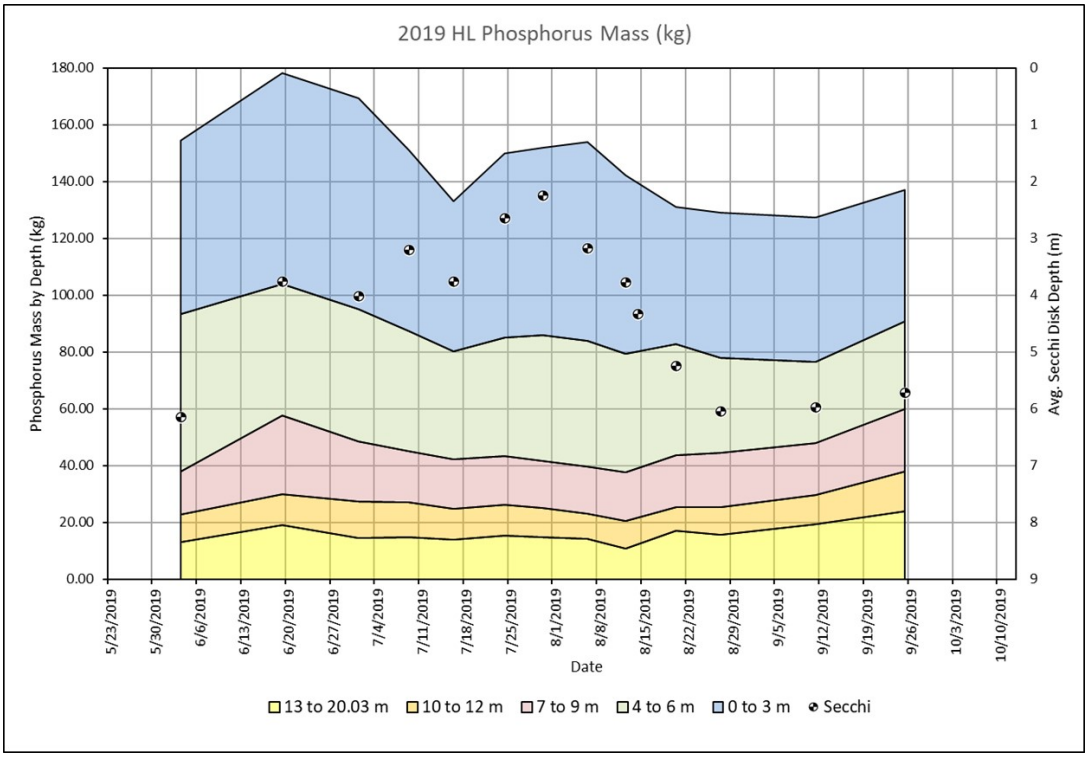

Figure 5. Total phosphorus by mass summed for each depth strata. High TP values in spring correspond to a rainy spring. The bloom peaked around July 30th; a small peak in TP occurred thereafter. Secchi values are indicated by the small secchi disk symbols.

- Phosphorus levels as measured in the lake changed significantly around the bloom, but only certain compartments studied. Compartments include different places that the phosphorus could be. If TP was absorbed by the juvenile alewives, it wouldn't have been measured, since the data only measure what's in the water samples, not fish or other larger organisms. Bottom sediment is also not included in the change in the water column levels of phosphorus. We made a preliminary estimate of the mass of TP contained in juvenile alewife in October: 8 – 10 kg (max) which is not enough to account for the missing TP.
- Large amounts of aluminum and iron coming into the lake via streams, and relatively little aluminum and iron leaving. Aluminum in the sediments, binds chemically with phosphorus and prevents phosphorus from recycling. Iron on also combines with phosphorus, but will release the phosphorus in anoxic environments.
- Sediment samples from the deep hole suggest that there is more than enough aluminum to preclude phosphorus recycling, and all the phosphorus in the sediment there is bound by the aluminum.
- The south basin shows characteristics of not promoting recycling of phosphorus, but interestingly, the site between the deep hole and the south basin sampling point may very well contribute to recycling.

Zooplankton/Phytoplankton

- Nanoplankton (mixotrophic, heterotrophic and autotrophic) all effect secchi disk readings**.**
- Large zooplankton are relatively rare in the lake from July on.
- Larger rotifers are more common in August and September as are some copepods.

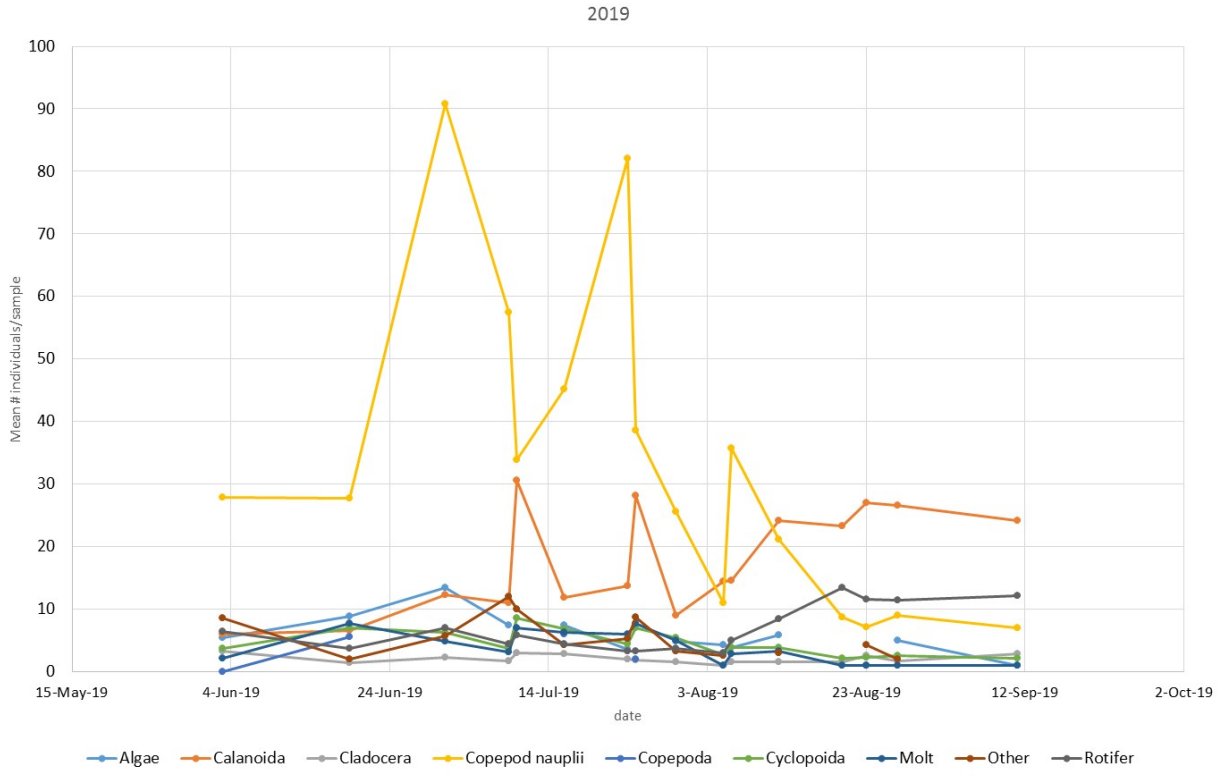

Figure 6. Zooplankton in Highland Lake, from daytime samples collected at the deep hole, 2019. There is considerable variability from week to week.

Hypotheses

Two unrelated hypotheses were shared as potential explanation for the bloom, and each needs more testing/analysis to confirm or dispute the validity:

Hypothesis #1: trophic interactions
This hypothesis is trying to explain why there is a *Cyanobium* bloom. Here's what we think is happening:

- Early June – Cyanobium population controlled by mixotrophic and heterotrophic nanoplankton grazing (including flagellates and ciliates).
- Late June/July – Larval alewives graze on nanoplankton, releasing Cyanobium from grazing pressure.
- Mid to late July – Cyanobium blooms
- Mid to Late July – YOY alewives grow, consuming larger prey and releasing nanoplankton from consumption. There is a lag while nanoplankton increase in numbers to a point where they can control the bloom.
- Late July to August (in 2018 and 2019) – nanoplankton graze Cyanobium and bloom crashes.
- In previous years when the bloom reached maximum levels and lasted well into August, the lag for the recovery in nanoplankton appeared to take several weeks longer than in 2018 and 2019.

Hypothesis #2: Wind Patterns
This hypothesis is trying to explain where the TP came from in July 2018 (see TP mass graph from 2018). The same may have been happening in 2019 but the peak after the bloom appears obscured by TP that were already relatively high as a result of spring rains.

Strong northerly winds move the water in a conveyor belt movement with surface water flowing south into the south basin, and the deeper water flows back to the north basin to replace the surface water. As this is happening, an opposite flow is set up in the metalimnion/hypolimnion. These flows can move phosphorus that is released from the iron in the anoxic sediment to other parts of the lake to be utilized by various phytoplankton and/or to settle out in different areas of the lake. This pattern could result in the recycling of phosphorus even though the amount of aluminum would suggest otherwise. This phosphorus would then be available to the *Cyanobium* to exacerbate the blooms, **but not cause them.**

Validation: More sediment sampling is necessary to see if the iron is recycling phosphorus annually and to more clearly identify the pattern of aluminum to iron ratios in various areas of the lake.

2020 Sampling Protocol

Hypothesis #1: We should try to do something similar this coming summer. At least repeat pigments, phosphorus (hope springs eternal!), what else, in case a bloom occurs in full. eDNA may be useful again, particularly if the lake has a full bloom ala 2014 thru 2017, but need zooplankton, etc., data to ground truth and calibrate.

Hypothesis #2: Steve Norton has ideas about what we should do to address this hypothesis.