Torch Lake's Golden Brown Algae (GBA)

Mini Symposium

April 27, 2017

Summary Notes

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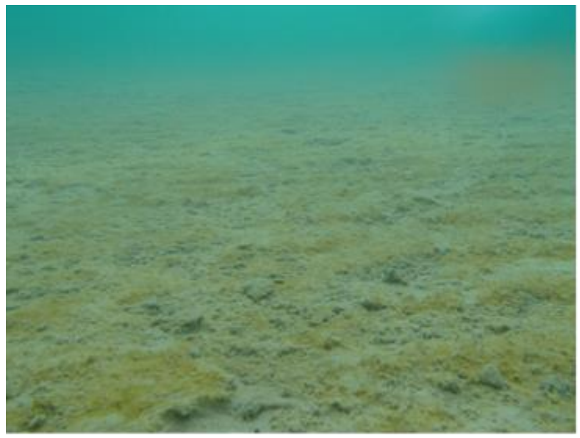


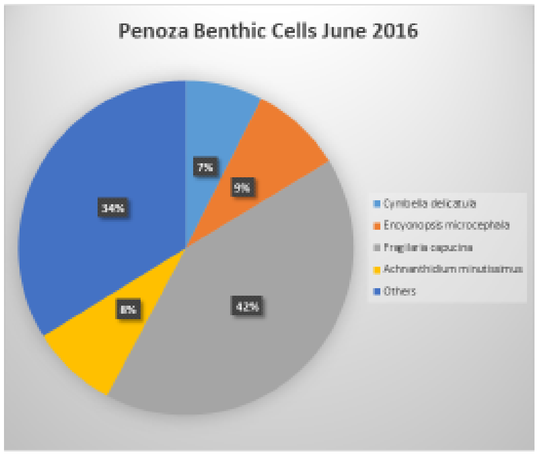
Dr. Becky Norris, Three Lake Association, TLA, Water Quality Chair presented the Torch Lake GBA story with findings from research studies performed in 2015 and 2016 with the assistance and guidance of Drs. Pat Kociocek, Rex Lowe and Jan Stevenson.

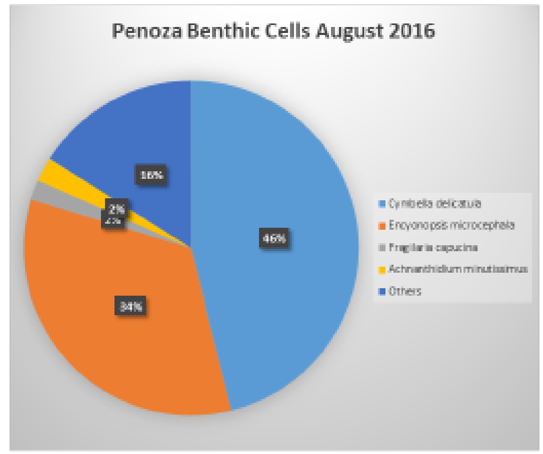
The results suggest:

1. GBA distribution is widespread in lakes in the NW lower MI around the 45th parallel.
2. GBA is a benthic (lake floor) phenomenon, not on the lake water surface or in the water column.
3. The rate-limiting nutrient promoting GBA growth is phosphorus based on findings from nutrient diffusing experiment performed by Drs. Kociocek and Lowe and students at the University of Michigan Biological Station (UMBS).
   a. Cooperative Lake Monitoring Program (CLMP) data (available on their website) indicates Torch Lake deep basin water has been in the range of an oligotrophic lakes for approximately 20 years of monitoring.
   b. Near-shore lake water phosphorus levels in 2015 and 2016 were higher than in deep water (where CLMP monitoring takes place) and higher than 2006 nearshore water samples collected during the Great Lakes Environmental Center (GLEC) and TLA Phosphorus Loading Model for Torch Lake (funded by the Michigan Department of Environmental Quality).
   c. Shallow groundwater entering the lake floor has higher phosphorus concentrations than nearshore lake water; the phosphorus levels in groundwater may have increased since the GLEC-TLA study of 2006 but can not be proven statistically due to a number of factors including low sample sizes plus differences in collection and analysis of samples between study designs.

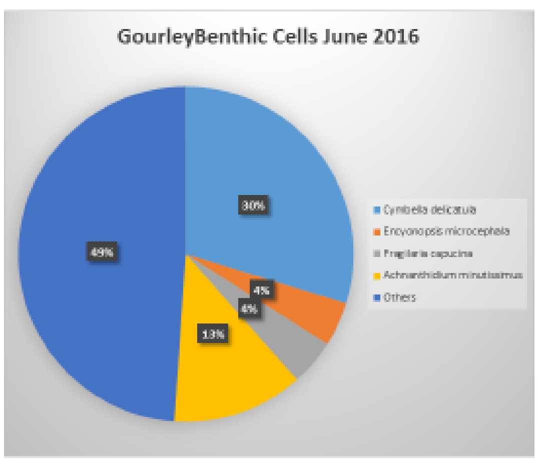
4. GBA assemblages (community of algae in a sample) includes over 100 diatom species. At least eight of these diatom species have not previously been reported in the scientific literature. Dr. Kociolek is preparing a manuscript for publication on the newly discovered diatoms.
    a. In 2016, algae samples were collected from Torch Lake, Clam Lake and Lake Bellaire. The dominant diatom species for most sites (7 total sites) were: *Cymbella delicutula, Encyonopsis microcephala, Fragilaria capucina, Achnanthidium minutissimus*.
    b. The Clam Lake algae samples were the most different among those examined, consisting of only a tiny fraction of *Cymbella delicutula* and composed of a variety of other species. This is not unexpected as Clam Lake is a eutrophic lake unlike the other two lakes.
    c. The proportion of dominant species in the Torch Lake and Lake Bellaire algae samples varied in the June and August. In all but the Hayowentha and Penoza June algae samples (where *Fragilaria capucina* was the predominant species), the predominant species was *Cymbella delicutula* .
    d. Between June and August 2016, Torch Lake and Lake Bellaire algal assemblages either changed predominant diatom species, *Fragilaria capucina* to *Cymbella delicutula*. (at the Hayowentha and Penoza sites) or increased the abundance of the predominant diatom species *Cymbella delicutula*.
    e. Most abundant 4 diatom species identified in benthic sediment samples for each Torch Lake sites are presented in pie graphs developed by Dr. Becky Norris.

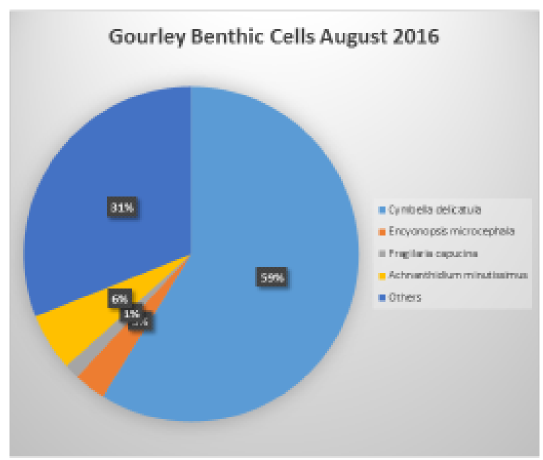
Benthic Diatom Distribution by Month Penoza Site



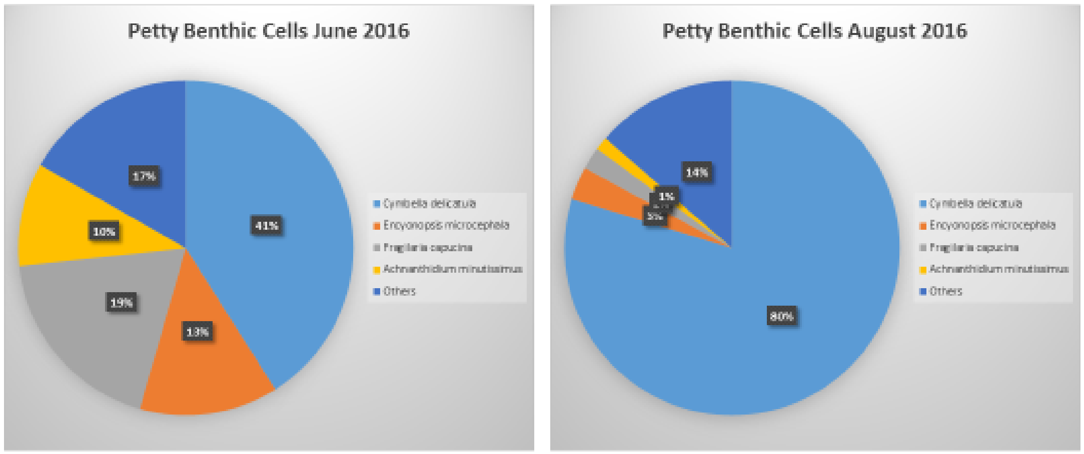


Benthic Diatom distribution by Month Gourley Site

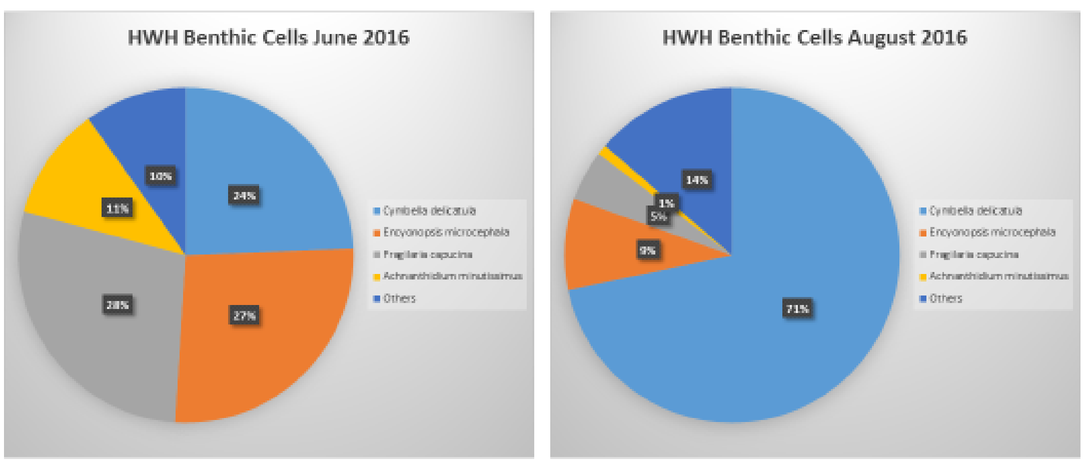




Benthic Diatom Distribution by Month
Petty Site



Benthic Diatom Distribution by Month
Hayo-Went-Ha Site



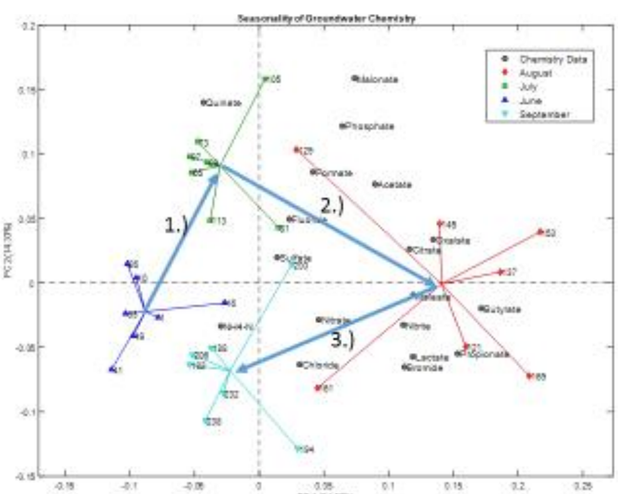
5. Factors other than the major nutrients (nitrogen and phosphorus) that could be responsible for GBA proliferation have not been studied to date in the TLA studies include:
    a. Temperature information analyzed by Dr. Stevenson's graduate student using Landstat data did not indicate significant temperature differences over a span of 10 years. Anecdotal reports suggest a recent warming of nearshore lake waters in the region.

b. Shallow groundwater samples analyzed for human-associated substances were never analyzed from the 2015 study and are not yet reported for the 2016 study.
c. A pilot study to distinguish differences in groundwater temperature between sites with and without bands of GBA was inconclusive, demonstrating temperatures lower than expected for groundwater and increasing as the ambient temperature and sunlight increased.
d. Infra-red photography using a drone during the early spring was not able to detect surface differences in temperatures that could distinguish 50°F groundwater from benthic seeps from surrounding 40°F lake water.
e. Atmospheric sources of nutrients have not been explored.
f. Pulse loading of groundwater into the lake following the regional exceptionally high precipitation in 2013 and concomitant rise in Lake Michigan lake water level (after years of declining water levels exposed lake weeds on beaches) and water table around Torch Lake.
g. Zebra mussel shunting of nutrients increased available benthic surface phosphate.

Tim Veverica Analytical Chemist at UMBS and supervisor of chemical analysis of the 2016 water samples presented findings.

1) There are seasonal variations in all reservoirs analyzed—nearshore water, groundwater, pore water and nearby house well water. . The groundwater concentration of phosphate (PO_4 also known as Soluble Reactive Phosphorus, SRP, which is consumed rapidly) increased as the summer progressed. In September the concentration of phosphate plummeted. These extremely low levels of phosphate after a maximum level the month before are guarded.

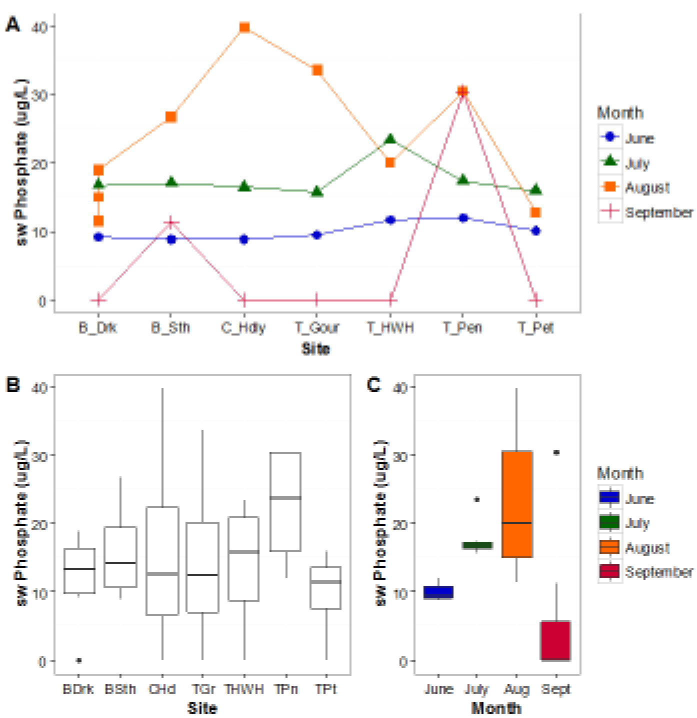
1.) PO_4 shows an increase from June-July **2.)** PO_4 decreasing, while NO_3 and NO_2 increasing July-August **3.)** PO_4 decreasing further August-September, NO_3 and NO_2 decreasing while NH_4 increases.

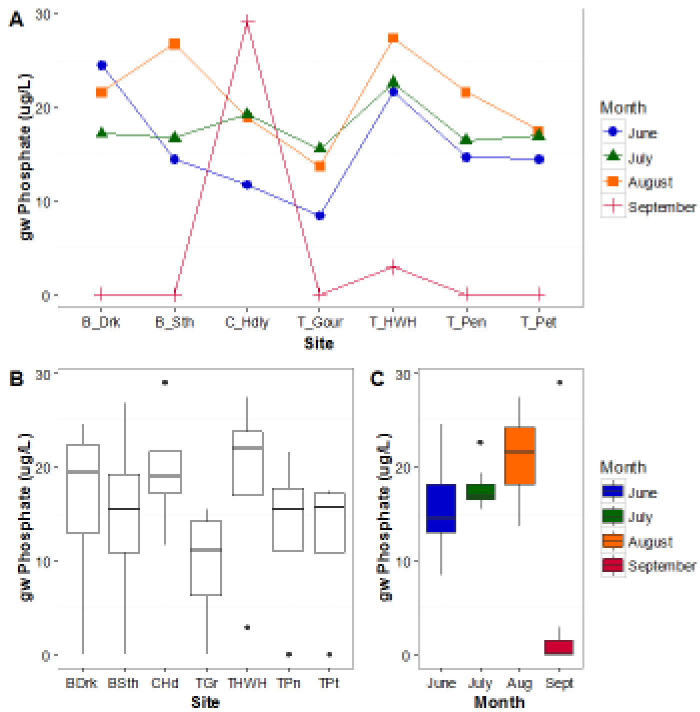


2) Similar seasonal trends between lake water, pore water, groundwater, and well water chemistry indicates that there is perhaps greater connectivity between these pools than one might expect.
3) Chloride concentrations in area lakes including Torch Lake are increasing. Chloride does not trigger algae growth. It is common in limestone found in the regions bedrock. Once baseline levels are established, chloride can be used as an indicator of human impact on lakes.
    a. Is chloride coming from water softeners dumping brine into septic systems
    b. Is chloride coming from Road deicing salt
4) One site on Torch Lake had alarmingly high levels of ammonium. TLA has shared this finding, which has been found in both 2015 and 2016 samplings with the landowner and the Supervisor of the NW Community Health Department.

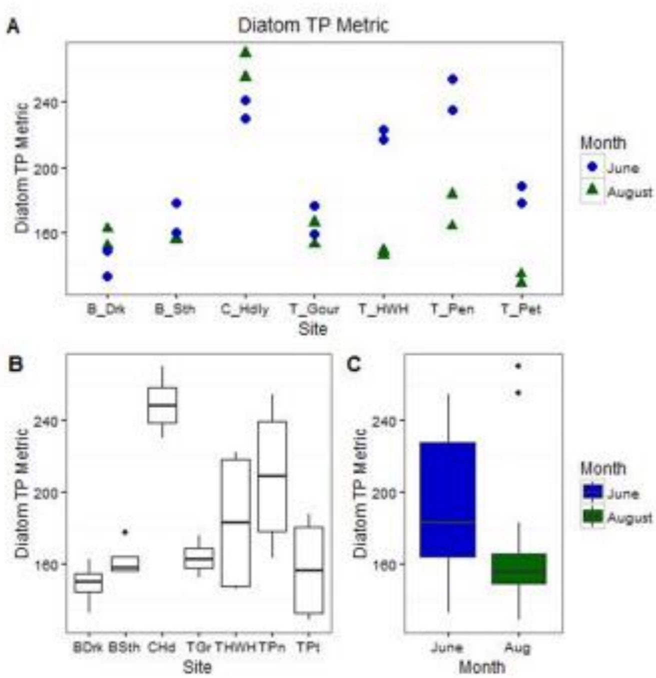
Dr. Jan Stevenson presented results and conclusions for 2016 algae samples his laboratory analyzed and the complementary water chemistry provided by UMBS.

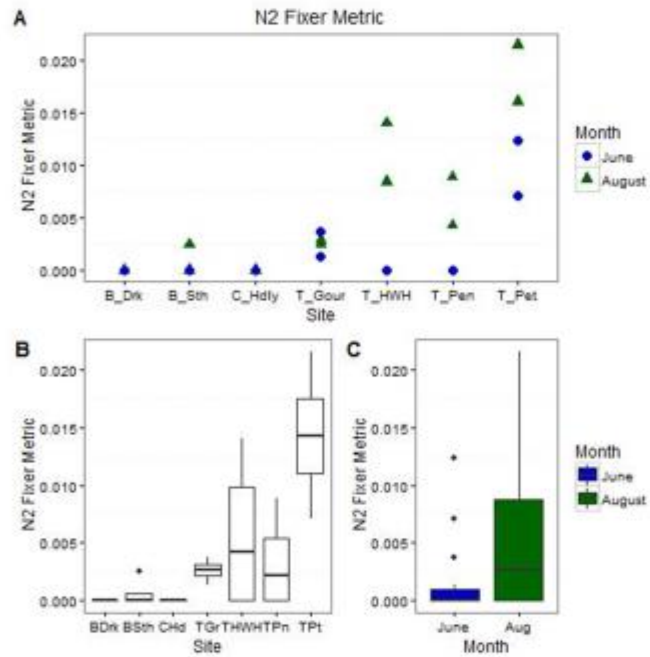
1. Algal samples were approximately 97% diatoms.
2. Diatom communities differ among the lakes. Clam Lake, a eutrophic lake, differs more from the other two oligotrophic Torch Lake and the mesotrophic Lake Bellaire. The latter two lakes benthic algae communities are more similar with overlapping species.
3. Below graphs demonstrate seasonal variation of surface water and ground water phosphate concentration (PO_4) at the 7 sites determined by UMBS water chemistry analysis.





4. The diatom communities differ from June to August.

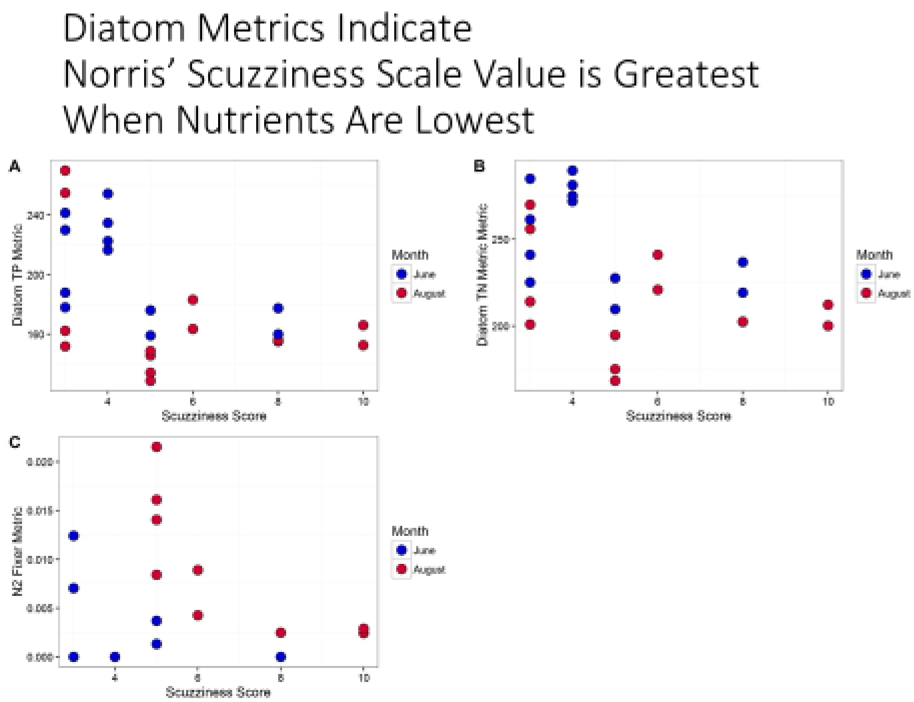




5. The composition of diatoms varies with season and water phosphate (PO_4) concentrations.
6. More PO_4 indicator species are present in the spring while more N fixing species are present in August when P has decreased and stalking of diatoms is observed.

Diatom Succession Process occurs as PO_4, (SRP) in 2016 groundwater samples appeared to decrease to a level that stresses the diatoms. The stressed diatoms grow stalks above the lake bed in search of more phosphorus-similar to trees in forest growing up or out for sunlight in order to compete with the nitrogen fixing diatoms that flourish in current low phosphorus conditions.

7. The diatom species composition varies with the Norris Scuzziness (Visual Appearance based on percent coverage and shades of coloration) scale.
8. The diatom species that are indicators of phosphorus availability decrease as the Norris Scuzziness scale increases. So with low nutrient levels, there is great coverage and darker coloration of diatom mats on the lake floor.



9. The Diatom Succession Process during the growing season occurs as nutrient chemistry shifts
    a. Algal density does not increase
    b. Shift in diatom composition occurs as nutrients get lower
    c. Shift in diatom composition occurs when Norris Scuzziness Scale increases
    d. Stalked diatoms like *Cymbella delicatula,* a common in low nutrient taxa increase later in the growing season
10. Hypotheses posed by Dr. Stevenson for the cause of GBA becoming more observable/noticable during the growing season in the diatom succession process.
    a. Increase in public awareness makes it more observable/noticeable
    b. Shifts in non-nutrient chemistry changes algal species composition so GBA is more observable/noticeable
    c. Continual nutrient enrichment causes more GBA to grow
    d. Shift in nutrient chemistry causes GBA to be more observable/noticable.
11. Conclusions by Dr. Jan Stevenson:

Conclusions Related to Evaluated Hypotheses

1. Surface sediment algal species composition differs among dates, lakes, and sites.
    1. Most differences are among dates and lakes.
2. Surface sediment algal species composition is related scuzziness score and algal density.
    1. Yes, but inconsistencies are a concern because the samples come from just a few lakes.
3. Scuzziness score, NLA diatom TN & TP metrics, algal density, and are interrelated and related to date, lakes, and sites.
    1. Scuzziness is higher at a couple sites in Torch and Bellaire, than most other sites, and is low in Clam Lake.
    2. Diatom TN and TP metrics are negatively related well to Scuzziness and Algal Density.
    3. Diatom TN and TP metrics indicated nutrients decrease with date when Scuzziness increases.
    4. Torch Lake species have lower nutrient requirements than Bellaire and Clam Lake species.
    5. Torch Lake species have higher N demand than Bellaire and Clam Lake species.
    6. Diatom metrics and date are positively related to scuzziness score and algal density.
4. Surface sediment algal species composition, diatom metrics, algal density, and scuzziness score are related to water chemistry, and especially, nutrient concentrations.
    1. They are related to water chemistry by ordination, but not too nutrient concentrations.
5. Surface and deep sediment diatom species composition differ.
    1. Metrics for scuzziness, algal density, and nutrient concentrations are ~~higher~~ lower in surface sediment (past) than deep sediment samples (past).
    2. But the difference could be due to annually averaged conditions versus summer and scuzzy conditions.

Mug capturing the summer growing season of benthic diatoms on Torch Lake.

Idealized Scenario of Diatom Succession on Substrata

Dr.Anthony Kendall (MSU, Hydrogeology) provided background information on groundwater.

Groundwater principles:

1) Shallow groundwater inputs highly variable in time and location.

2) Large lakes gain and lose groundwater at the same time
3) Groundwater sheds different than Surface water sheds.
4) Groundwater inputs greatest nearshore and decrease exponentially lakeward but at drop-offs site can have groundwater seeping in
5) Groundwater smooth flow path with little mixing over short distances

Influences on TL groundwater

1) Lake level of Lake Michigan
2) Elk Rapids Dam first put in 1850s increased lake levels in Torch Lake.
3) Newer homes changes in setbacks and septic ordinances

Phosphorus inputs into lakes

1) Atmosphere
2) Manure
3) Chemical application farm/orchards
4) Septic systems
5) Urban
6) Point source

Dr. Kendall's questions to guide further GBA research

1. Physical processes
    - Are the GBA communities/assemblages largely recycling nutrients, or is delivery of new nutrients controlling their growth?
    - How does the Torch Lake hydrologic system respond to its landscape and climate inputs?
2. Variability in space
    - Where is groundwater flowing into the lake, and where is it flowing out?
    - How are nutrient sources distributed?
    - Are other (non hydrologic or nutrient) factors controlling GBA mat locations: i.e. substrate, predation, disturbance, etc.?
3. Variability in time
    - How does groundwater input change through time?
    - How do land use legacies affect the delivery of nutrients?
    - If we take actions today (i.e. improve septic system function), when would we expect to see improvements?

4. **Dr.Dave Long** (MSU Geology):
   Sediment cores tell us the history of a lake.
   Sediment accumulated comes from these sources
   1)Erosion—terrigenous or land based such as Al, Ca, P
   2)Diagenesis-chemical changes occur in top sediment with pressure or as sediment turns to solid
   3)Biological processes such as C (carbon)
   4)Torch Lake also has the physical process of $CaC0_3$, calcite formation that is driven by CO_2 in atmosphere shifting pH and increasing temperature in water to favor precipitation of calcite.

5)Atmospheric Lead (Pb) and Mercury (Hg) and other toxins

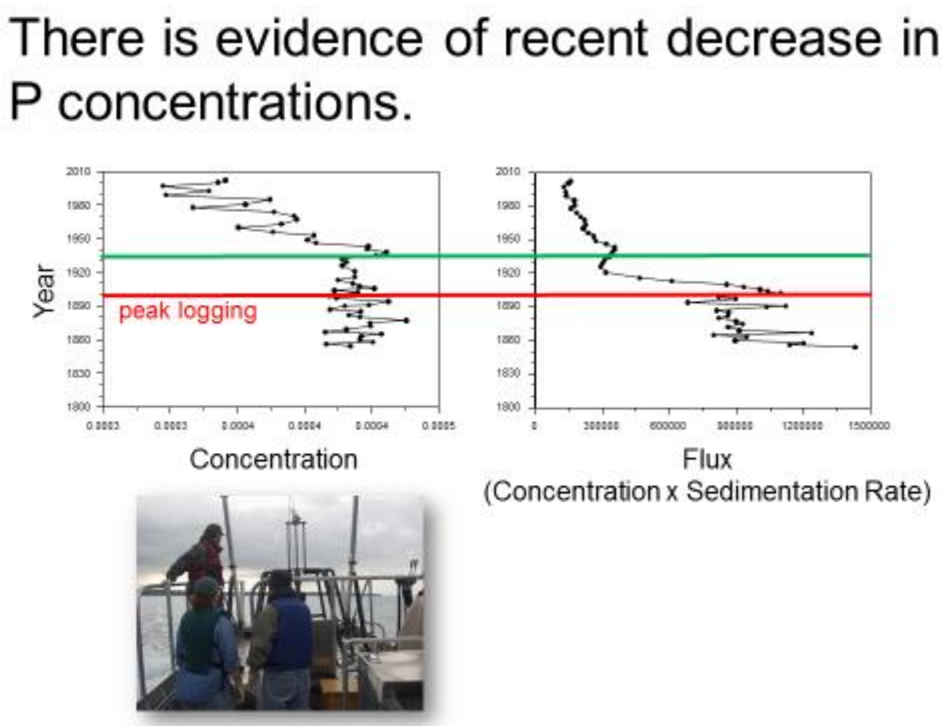
Note:Ca can be from terrestrial and in lake processes.

Torch Lake, like Lake Superior and Crystal Lake has a low watershed area to lake surface area ratio(WA:LA)—2.5 so it is an atmospheric driven lake with groundwater influence.

Torch Lake has extremely low Phosphorus (P) in surface sediments 350 mg/gk compared to Crystal Lake with 1000 mg/kg.

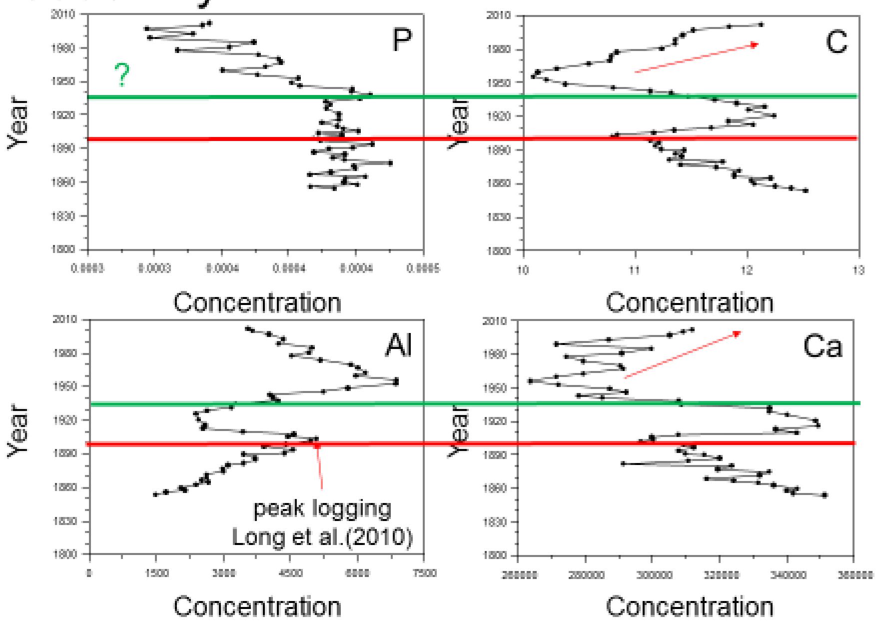
Analysis of a Torch Lake core indicates since 1930, Torch Lake's core shows recent decline in P. Both concentration and flux (concentration X Accumulation rate).

Due to the year of retrieving the Torch lake core sample (early 2000) information on the last 13 years is not available and thus cannot provide information on elemental changes that occurred when GBA became observable in Torch Lake in 2014.



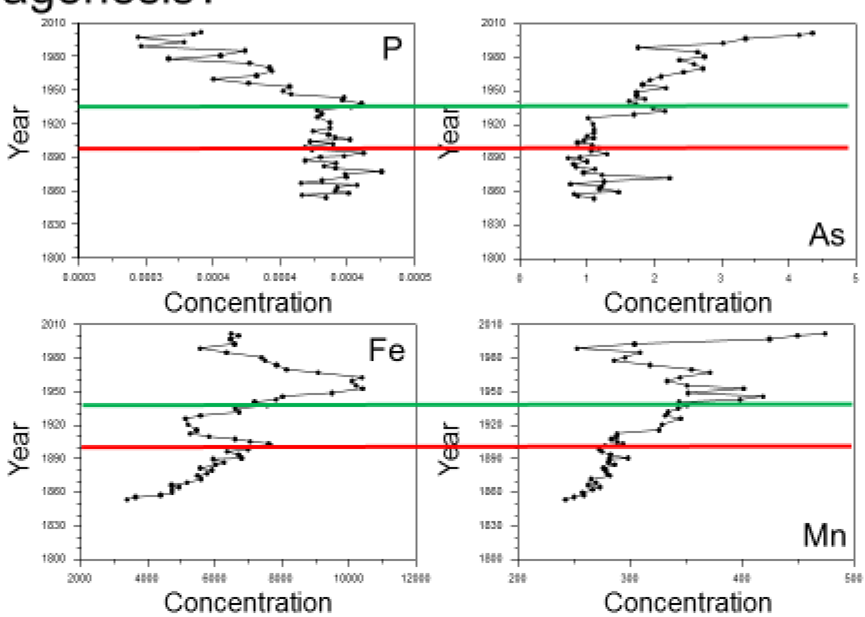
The boat Nibi is specially designed to collect core samples in inland lakes.

Perhaps evidence of recent increase in productivity?



The decrease in P could be a sign of recent increase in lake productivity—algal growth. As carbon increasing since 1930 and Al a terrestrial runoff marker decreased in this time period.

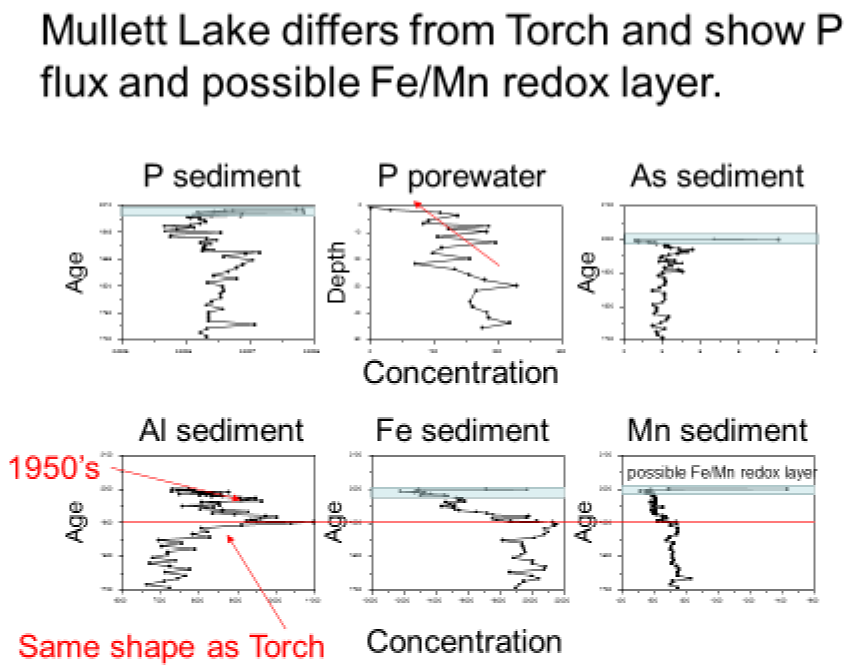
There is evidence of influence of early diagenesis?



Diagenesis markers changing too. Arsenic is influenced by Fe and Mn.

Mn and As are more mobile than Fe.

Mullett Lake has Watershed Area vs Lake Surface Area ratio of 19which is much higher than Torch Lake but was used as a comparable lake because the Torch Lake core unfortunately was compromised. Yet, the similarity of Surface sediment P levels in Mullett Lake are like Torch Lake.



Porewater in Torch Lake is likely decreasing with time as in Mullett Lake.

Rapporteurs

6 Dr.**Dave Hyndman** (MSU-Hydrogeology) input into future research

Find a spot and really study the heck out of it—temperature sensitive cables to get groundwater inflow delineated.

Increase sample spots on lake as done in Higgins Lake study

Drones over failed septic systems over lake water to look for green spots where septic outflow occurs

Make hypothesis Septic system density or flux is causing GBA and tie it to groundwater

7. **Dr. Joan Rose** (MSU-Public Health) input for future study

Find Groundwater shed

Small study with human marker B theta—perhaps cow one too. B theta travels in groundwater from septic systems.

Proposed Future Research Questions and Research Methods

1) What has changed in Torch Lake over the last few decades that could cause GBA to appear in 2014?

Sediment core in Torch Lake for both element analysis and diatom analysis. Emphasis in top 10-15 cm

2) What is the groundwater shed for Torch Lake?

Map groundwater shed for a better understanding of groundwater inputs, outputs and flow rates.

3) Does nearshore lake water, groundwater, pore water phosphorous follow the seasonal trend observed in 2016 with increasing levels until September when levels drop to non-detectable (<1ppb) ?

Monitor nearshore water, groundwater and porewater monthly during summer of 2017.

4) Are septic systems contributing to the phosphorus entering the groundwater and stimulating diatom growth?

Test groundwater for sewage and human markers monthly during summer of 2017 using E. coli tests, Sniffer dogs trained to identify human waste and B theta test which is highly sensitive to identifies human feces source in water samples.

5) Does the diatom assemblage change seasonally as it did in the 2016 in relationship to phosphorus?

Monitor phosphorus levels in sediment with peeper and porewater sampling and algae samples monthly during summer of 2017