Higgins Lake Property Owners Association
Algae and Water Chemistry Sampling Project, 2016

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The purpose of this preliminary study was to document the benthic algal community and associated levels of phosphorus (ortho-phosphate) and nitrogen (nitrate-nitrogen and ammonia-N) in the littoral zone of Higgins Lake. The locations where algae and nutrient samples were collected were based on sites where total phosphorus levels were reported to range from low (130-167 ug/L) to high (212-240ug/L) in an attempt to correlate algal community structure with areas of the lake having different nutrient levels. Some sites were selected at locations where snail density studies were collected by SICON in 2015. This study will provide baseline information showing the relationship between benthic algal species and nutrient levels in the littoral zone and may show correlations between algal community structure, nutrient levels and snail densities upon which further studies can be conducted. A total of 11 sampling locations (Figure 1, table 1) were established in one meter or less of water during a reconnaissance of the lake conducted on June 3, 2016. While on the reconnaissance we examined sandy sites and sites dominated by cobble substrate. We observed that at a majority of the sandy substrates the sediment several cm below the surface was reduced, black and probably anoxic which would be very unusual for an oligotrophic lake. Information from field notes is presented in the following table. One additional sample was collected at Sam-O-Set Townline to better reflect the area where snails are being studied.

Figure 1. Sampling Locations.

#	Location	Substrate Description
B	West tip of Treasure Island	Clean sand and gravel with calcium carbonate and blue green algae on the bottom of the larger cobble.
1	Dragonfly House	Anoxic, FLAB*, area of organic accumulation, sand and gravel.
2	Hoffman's	Clean sediment, sand and gravel.
3	Sam-O-Set at Townline	Anoxic, sand and gravel.
4	West Boat Launch	Some AVP and anoxic sand bottom.
5	North Park Launch	Sandy.
6	No Mans Land (N. Shore)	Sand with gravel and small cobble, organic sediment.
7	Gerrish Township Park North	Highest snail density reported, organic sediment deeper, abundant plant growth (*Chara sp*., *Najas sp*. and thin leafed *Potamogetans*).
8	Kelly Beach	Sandy, windswept, anoxic conditions.
9	Columbine Lane	Sandy, organic sediment deeper.
10	South State Park East end	Clean sandy bottom.

Table 1. Nature of sampling sites. *FLAB = floating algal benthos

Methods & Materials

Samples were collected on July 13, choosing the predominate substrate available at each site (cobble or sand). Samples were put on ice and transported back to the University of Michigan Biological Station for processing. The surface area from which samples were collected was measured and recorded and the volume of the sample also recorded. The surface area of cobble samples was calculated by covering he surface of the coble that had been sampled for algae with a layer of aluminum foil. The foil was weighed on a balance. The weight of the foil was divided by the weight of a 25-cm2 piece of foil and the appropriate multiplications were made. Sand substrates were collected by covering the sand with a can with a diameter of 53mm and pushing the can to a depth of 1 cm. The can was retrieved while retaining the sample with a spatula placed under the can. The surface area sampled was the area of the can opening (πr^2 = 19.94cm^2). A subsample of each of the samples was preserved in 3% gluteraldehyde for analysis of "soft non-diatom algae" while the remainder was used for preparing permanent diatom slides.

Water samples for chemical analysis were collected in an acid-washed bottles at all stations except Sam-O-Set which was a station added while on the survey. However, station 3 is close enough to Sam-O-Set to justify using chemical data from station 3 to characterize Sam-O-Set. Water was filtered and analyzed for phosphate-phosphorus, nitrate-nitrogen and ammonium-nitrogen at the analytical chemistry laboratory at the University of Michigan Biological Station. Samples were analyzed for anions on a Dionex integration HPLC. Detection limit for phosphate was 1 µg/L. NH4 was analyzed on a Bran + Leubbe Autoanalyzer using the automated phenate method.

Algal samples were analyzed in a Palmer-Maloney counting chamber using a research grade Olympus compound microscope operating at 400X magnification. This allowed quantitative analysis of all algae and taxonomic identification of non-diatom algae. Diatoms were later added to the data set by examining cleaned permanent mounts. Algal densities were calculated using the following formula: cells/mm2 = (cells counted) X (sample volume/volume counted)/surface area sampled.

Results & Discussion

Chemical data are presented in table 2 below.

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NH4 was analyzed on a Bran + Leubbe Autoanalyzer using the automated phenate method.

	Fl (mg/L)	Cl (mg/L)	SO4 (mg/L)	Br (mg/L)	NO3-N (ug/L)	PO4-P (ug/L)	NH4-N (ug/L)
Rex B	0.009	13.0922	14.641	0.0259	3.77253	BDL	23.9
Rex 1	0.1041	14.395	16.0047	0.1325	42.22071	BDL	16.6
Rex 2	0.1052	12.8043	16.0362	0.1482	28.37304	BDL	94.9
Rex 3	0.0628	13.0003	10.6575	0.0711	22.38669	BDL	15.6
Rex 4	0.0817	12.8124	11.6172	0.1205	49.49469	BDL	27.9
Rex 5	0.0873	19.895	102.6797	0.2617	248.24151	BDL	10.4
Rex 6	0.0655	12.2562	10.0203	0.1297	30.45132	BDL	17
Rex 7	0.063	12.7716	18.9401	0.1362	90.36	BDL	24.1
Rex 8	0.092	12.8003	11.1879	0.1371	94.24548	BDL	5.9
Rex 9	0.0651	12.5454	10.496	0.1338	91.96389	BDL	20.2
Rex 10	n.a.	n.a.	n.a.	0.007	1.31022	BDL	25.1

Table 2. Water chemistry. Numbered collections correspond to locations on the sampling map (figure 1).

Bromide, chloride, fluoride and sulfate were not relevant to this study but are routinely measured while measuring other chemicals of interest. PO4-P was below limits of detection (1ppb) at all stations following filtration of the samples.

Algal cell densities and community structure are presented in table 3 in a separate document due to size.

The water chemistry is remarkable in that there is an abundant community of benthic algae while bioavailable phosphorus in the water column is at undetectable levels! This may indicate that planktonic algae which depend on water column nutrients are strongly P limited while benthic algae are receiving nutrients from ground water or are efficiently recycling nutrients within the benthic algal community. A cursory examination of the phytoplankton revealed very few cells and the water was extremely clear. Phytoplankton is clearly phosphorus limited. Available nitrogen (NO3-N and NH4-N) were highly variable across stations ranging from 1.3 at station 10 to 248.2 at station 5 for NO3-N and ranging from 5.9 at station 8 to 27.9 at station 4 for NH4-N.

These differences are difficult to explain and should be sampled further in the future to look at variability and the relationship with algal biomass. It is likely that there are no sinks for available nitrogen since the phytoplankton are P-limited. For example if algal growth is limited by phosphorus algae will not take up nitrogen.

Total cell density of benthic algae was variable across stations and ranged from 2,284-29,452 cells/mm2. Much of this variability was driven by high numbers of small cyanobacteria which were common on cobble substrates. For example at site 4 a 110 cell colony of the blue green alga *Microcystis* was largely responsible for the reported total blue green density reported in the algal spread sheet. This colony probably dropped out of the phytoplankton and elevated the benthic algal cell density.
But cell densities were less variable when only diatoms were considered (densities ranged from 620-9432 cells/mm2). This is important in that diatoms with their oil-rich food reserves are the optimal choice of consumers such as snails. This density is on par for sandy habitats that we have sampled elsewhere Dominant species *included Achnanthidium minutissimum Achnanthidium rosenstockii, Amphora pediculus, Delicata delicatula, Enyonopsis microcephalum, Fragilaria vaucheriae, Pseudostaurosira brevistrata* and *Staurosira construens* all of which are common on sandy substrates.
Cobbles were dominated less by diatoms and more by green and blue green algae which are less desirable source of benthic diet. Blue green algal densities ranged from 0-25038 cells/mm2. The high number was from a cobble at station 2 that had a dense cover of blue green algae. None of the blue green algae that we identified were in numbers posing a risk of toxicity.
Green algae were generally scarce and were most abundant at the control site B where cobbles were covered by the filamentous green alga *Mougeotia.*
It was a good idea to sample sand in addition to cobble at site 3 that demonstrated this site to have an abundant diatom community on sand but not on cobble.

Conclusions

Sandy sites are dominated by a healthy community of oil-rich diatoms providing a food source for snails and other invertebrates. Cobbles in the near shore have an abundance of blue green algae and may be less suitable habitats for snails. Site B, the intended control site, developed and extensive cover of *Mougeotia* over the cobbles between the initial reconnaissance on June 3 and the sampling date on July 11. In fact we observed the out breaks of filamentous green algae at many sites across the lake where ever boulders were seen. Finally, although not part of our research mission, the appearance of anoxic sediments at many sand-dominated stations was surprising given the oligotrophic appearance of the lake.

Finally, here are some thoughts on ideas for further study.

1. Given the lack of available phosphorus in the water column where is the PO4-P source the stimulates benthic algae? Is it from ground water or are the algal communities recycling P internally?
2. When did these changes in benthic algal density appear in Higgins Lake? Was it related to zebra mussel appearance? A core from the lake with diatom analysis may answer this question.
3. What currently limits benthic algal growth? The deployment of nutrient-diffusing substrates could help answer this question.

4. Is there a link between snail density and food quality and abundance? More closely paired sampling of snails and algae simultaneously would help clarify this. In addition some manipulative experiments with snail exclusion and inclusion corrals coupled with algal analysis and snail gut analysis might go a long way in understanding snail densities and might lead to novel pathways of reducing snail density.
5. The outbreak of green algae on boulder fields is extremely interesting. When does it appear? Why? Is it consumed?