Unknown Geochemical Phenomena in the Finger Lakes of New York: Foam Formation in Canandaigua Lake

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Introduction

- Canandaigua Lake is the 4th largest of New York State's 11 Finger Lakes, containing 1.6 million m³ of freshwater with a surface area of 42.3 km² (DEC, LMAS, NYSFOLA, 2018)

1. Conesus Lake
2. Hemlock Lake
3. Canadice Lake
4. Honeoye Lake
5. **Canandaigua Lake**
6. Keuka Lake
7. Seneca Lake
8. Cayuga Lake
9. Owasco Lake
10. Skaneateles Lake
11. Otisco Lake

Figure 1 – The 11 Finger Lakes of New York. Individual lake labels are shown to the right

- Despite its classification as a meso-oligotrophic lake with AA water quality (DEC 2018), the lake has experienced large volumes of surface foam production since the early 2000s. In summer, mid-lake foam streaks are frequently observed, and wind-driven stable foam accumulates along shorelines, which may contain water insoluble toxins

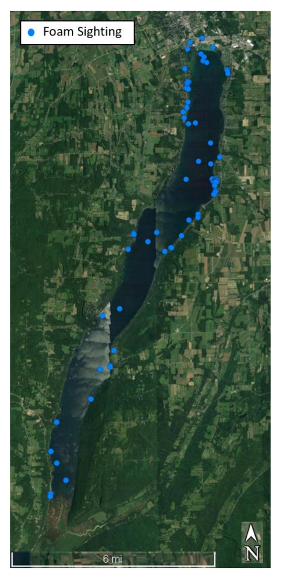


Figure 2 – Reported foam sightings, 2019-2020

Figure 3 – Shoreline accumulations of stable surface foam in Canandaigua Lake, NY. Photo credit goes to Sally Napolitano (L, 03/26/20), Lynn Klotz (C, 06/29/19), and Scott Kreher (R, 10/13/19).

- The purpose of this study is to identify the source of the foam on Canandaigua Lake by comparing its organic matter (OM) composition to potential terrestrial and aquatic OM contributors. Ultimately, we hope to understand why, despite having a similar watershed and chemistry to the other 10 Finger Lakes, Canandaigua Lake uniquely has a significant foam problem.

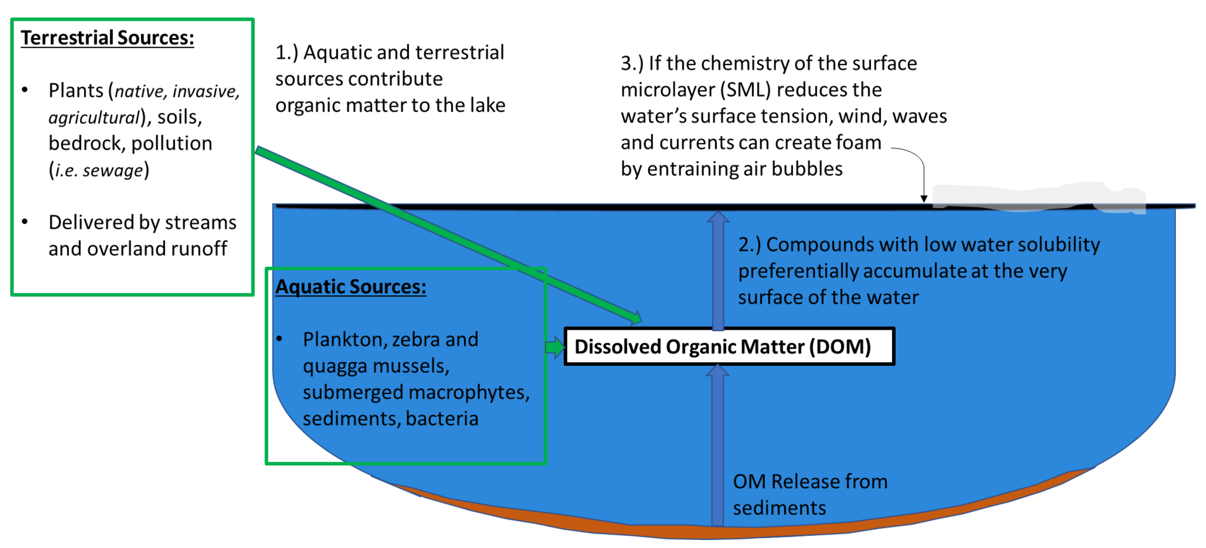
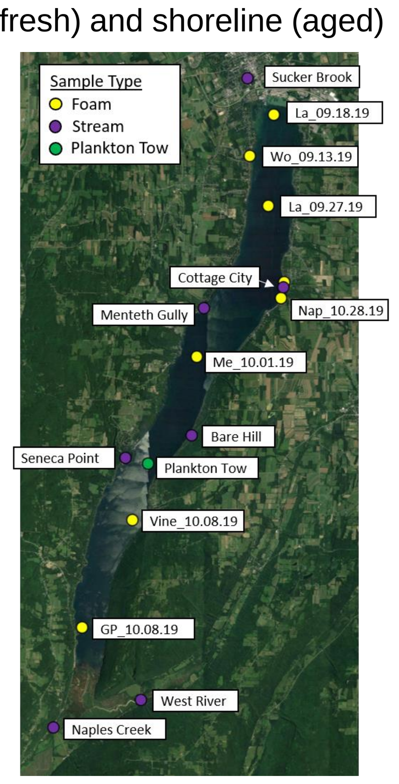


Figure 4 – Current model of foam formation in aquatic systems. Terrestrial and Aquatic sources such as vascular plants, phytoplankton, and aged OM in sediments contribute to the DOM pool in the lake. Compounds with low water solubility preferentially accumulate in the SML, and can reduce the water's surface tension enough to promote foam formation when the water's surface is agitated

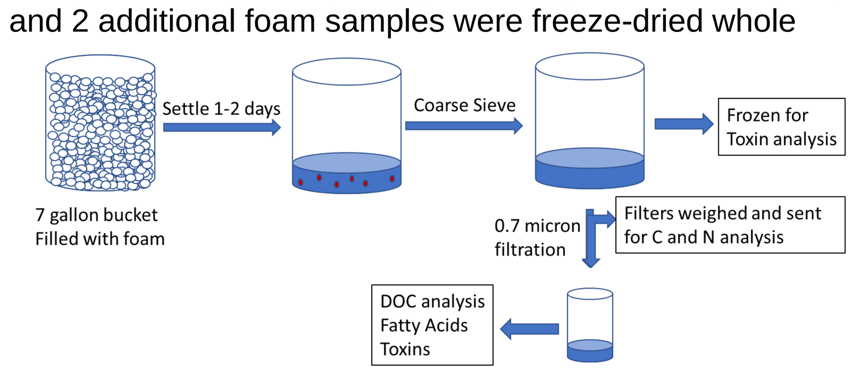
Methods

1.) Lakeshore residents report foam sightings with an online dashboard. 8 foam samples were taken along the length of the lake, including both mid-lake (fresh) and shoreline (aged) foam



2.) Foam was sampled with custom-made stainless steel equipment into 7gal HDPE buckets, and nearby lake water was sampled into 1L HDPE bottles. End-members include plankton (plankton tow), invasive dreissenid mussels, 7 streams, and free-floating and submerged aquatic macrophytes.

3.) Foam was allowed to collapse before analysis. 6 foam samples were filtered (0.7uM) and analyzed as water samples, and 2 additional foam samples were freeze-dried whole



Results

Comparing foam to lake water and streams: bulk and isotopic C and N analysis

- Foam was enriched in Dissolved Organic Carbon (DOC, 8.4-102 mg/L) relative to both lake water (2.7-4.1) and streams (1.5-8.6)
- Higher C/N ratios in the foam (49.6-339) are driven by the elevated DOC concentrations, as Total Dissolved Nitrogen (TDN) in the foam is similar to lake water (0.1-0.8 mg/L).
- δ^{13}-DOC values of foam (-29.3 to -33.4‰) were slightly depleted compared to lake water (-26.9 to -29.8) and stream water (-27.4 to -29.4), and similar to plankton and invasive mussels
- These data suggest the enrichment of a specific type of organic matter low in N in foam, and possibly N loss during foam formation and transport

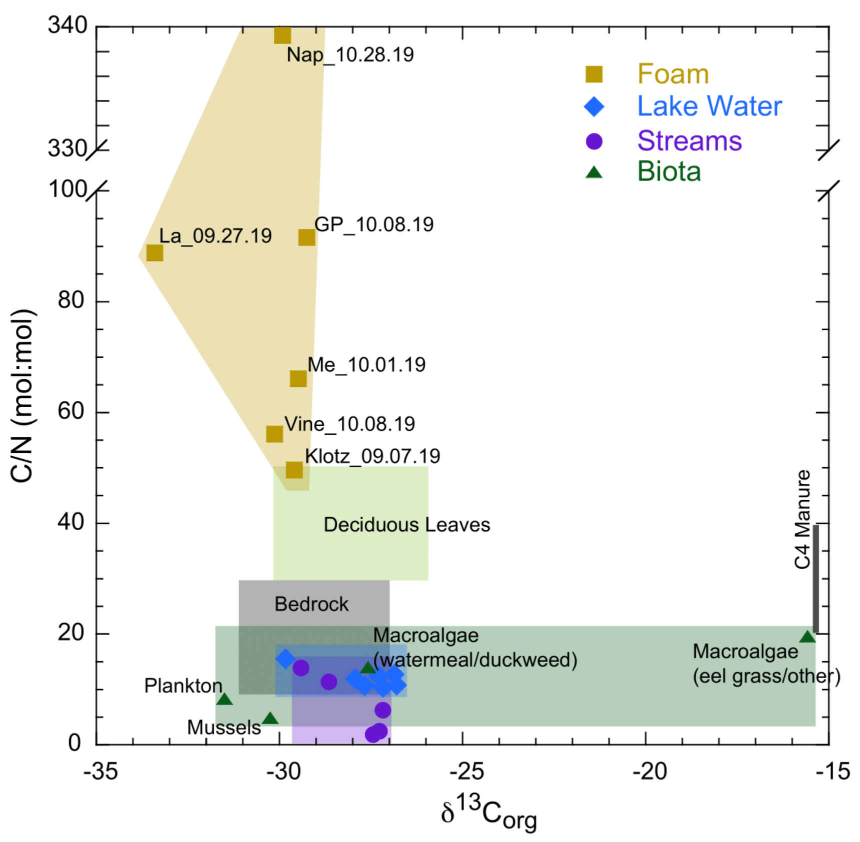
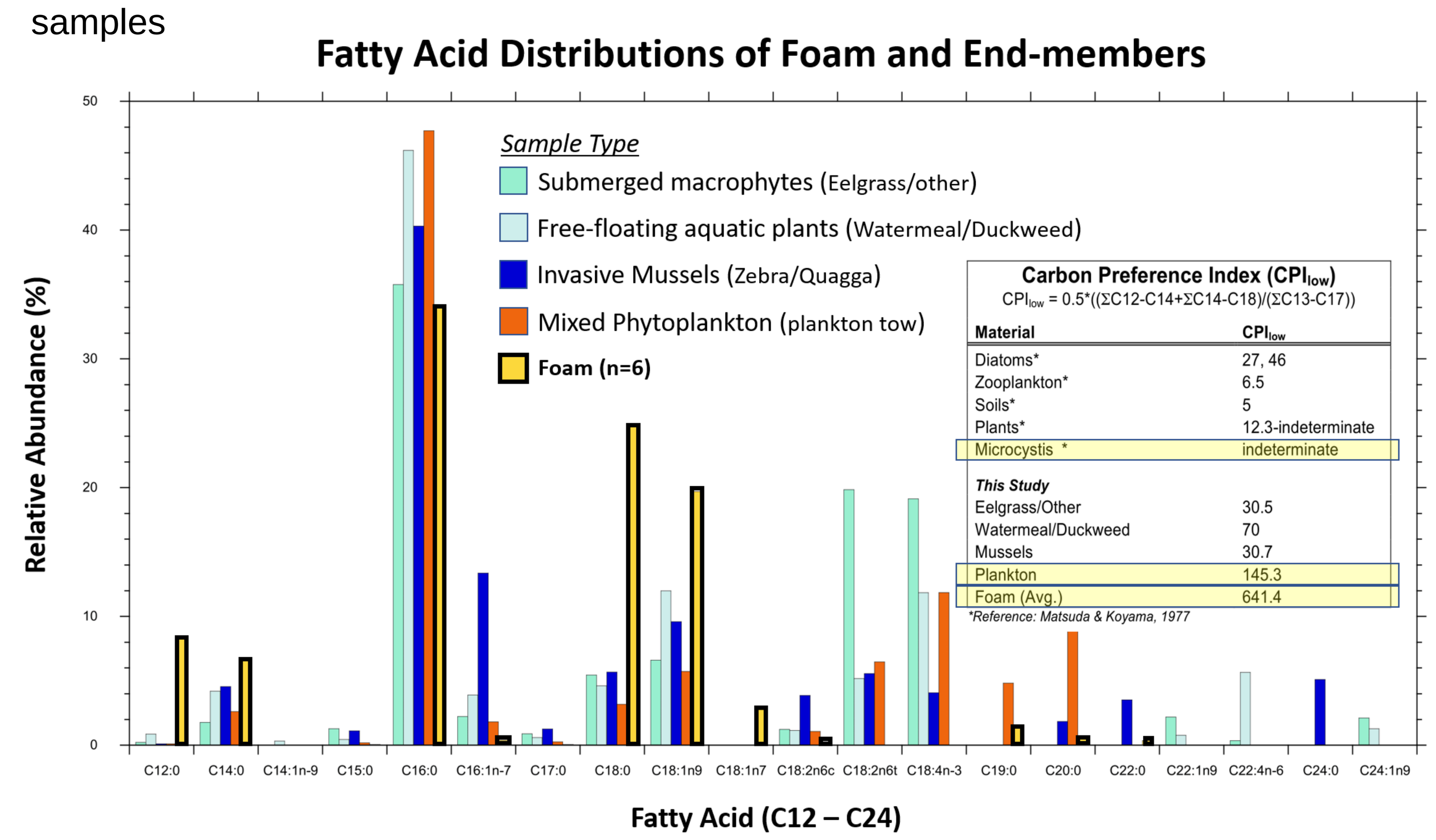


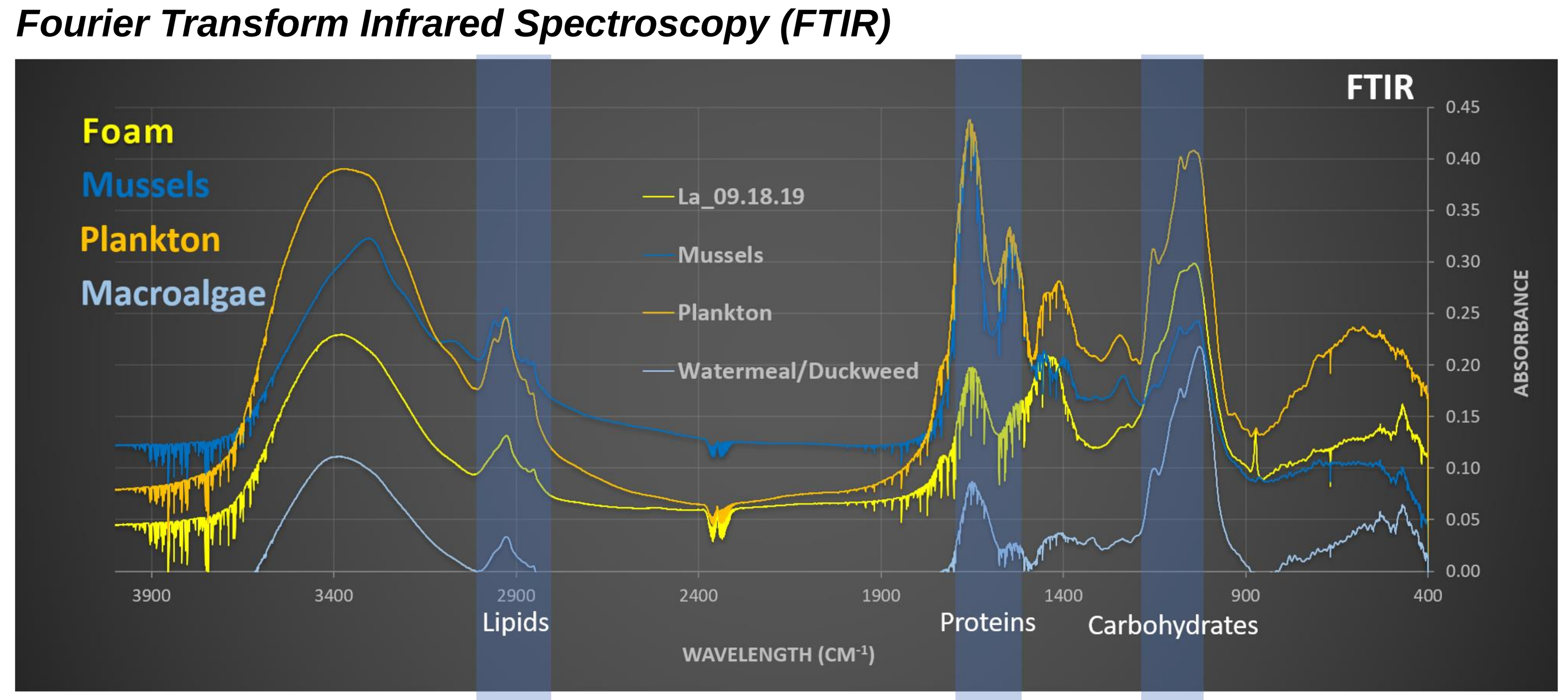
Figure 5 – C/N vs. d13C ratios of foam (dissolved phase) and potential OM contributors. Foam labels include the date sampled. End-member ranges with no datapoints were taken from the literature

Fatty Acid distributions

- Foam fatty acids were mostly even, short-chained (C12 to C18), and enriched in foam relative to biological tissues. Total Lipid Extracts (TLE) in foam were undetectable.
- High Carbon Preference Index (CPI) values in the foam and plankton tow suggests *Microcystis aeruginosa,* a toxic cyanobacteria that has recently caused beach closures across the region, may be contributing significant amounts of fatty acids to these samples



Fourier Transform Infrared Spectroscopy (FTIR)



- FTIR analysis was performed on freeze-dried foam and biological tissues to identify the major molecular classes in the foam relative to potential contributors
- Both foam and macroalgae showed the largest carbohydrate relative to protein peaks, while plankton had similar peak sizes in both regions. Mussels had the largest protein relative to carbohydrate peaks.

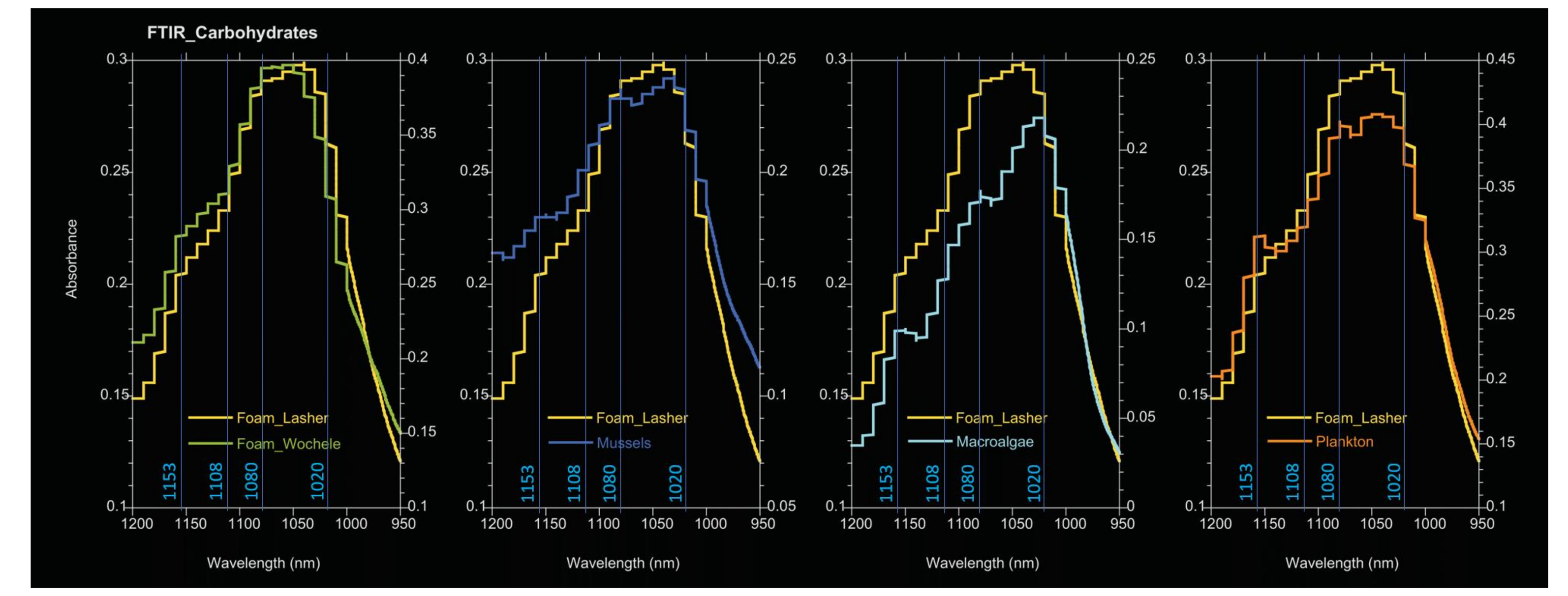


Figure 8 – FTIR spectra of Foam vs. Biota, 950-1200nm. Polysaccharide wavelengths shown as blue lines are from Fanesi et al. (2019). 'Foam_Lasher' is a fresh mid-lake foam sample, and 'Foam_Wochele' is an aged shoreline foam sample

- In the carbohydrate region of the FTIR spectra, we observe noticeable inflection points at previously documented wavelengths for polysaccharides
- The polysaccharide spectra of biomass from the plankton tow, confirmed via microscopy to contain significant amounts of *Microcystis aeruginosa*, was most similar to those of the foam samples

Conclusions

- High C/N, low TLE, and FTIR data suggest polysaccharides are a dominant component of foam
- Lipid and FTIR data indicate the source may be *Microcystis,* which produce significant quantities of exopolysaccharides (EPSs)
- Interactions between invasive dreissenid mussels and *Microcystis* likely further exacerbate harmful algal blooms (HABs) and polysaccharide enrichment in the surface microlayer (SML)
- There may yet be low levels of unknown compounds that increase the stability of foam in Canandaigua Lake, explaining why other Finger Lakes do not experience the same intensity of foam production despite having seasonal HABs.

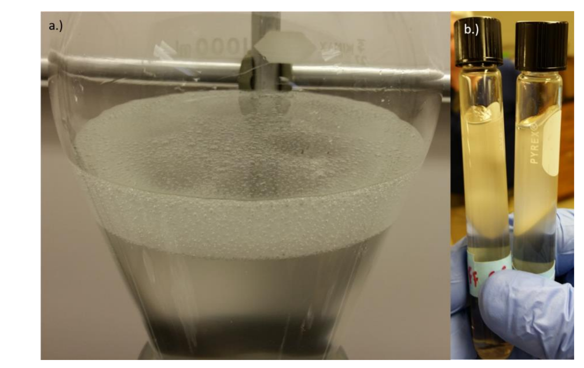


Figure 9 – Lipid extractions with hexane created a thick emulsion that may be the foaming agent

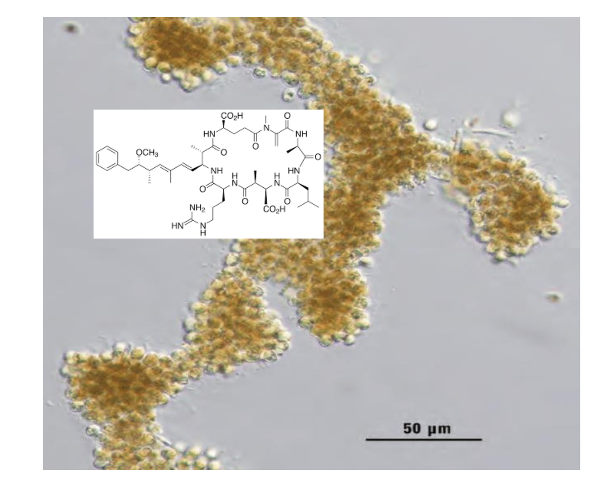


Figure 10 – Microcystis aeruginosa, USGS 2015. Inset molecule is microcystins-LR, a hepatotoxin.

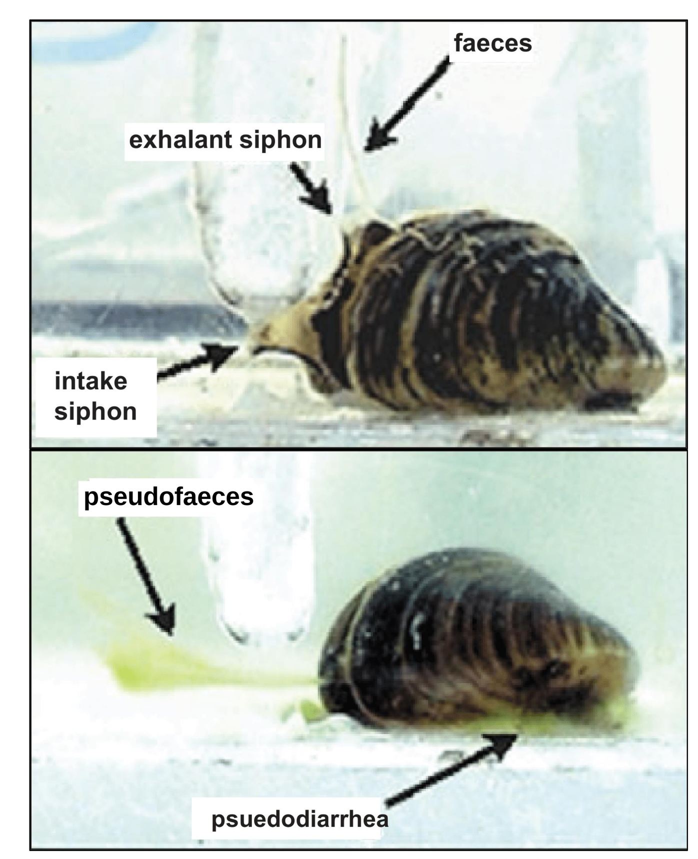


Figure 10 – Invasive Quagga mussels become 'sick' and increase carbohydrate excretion when feeding on toxic Microcystis cyanobacteria (Juhel et al., 2006)

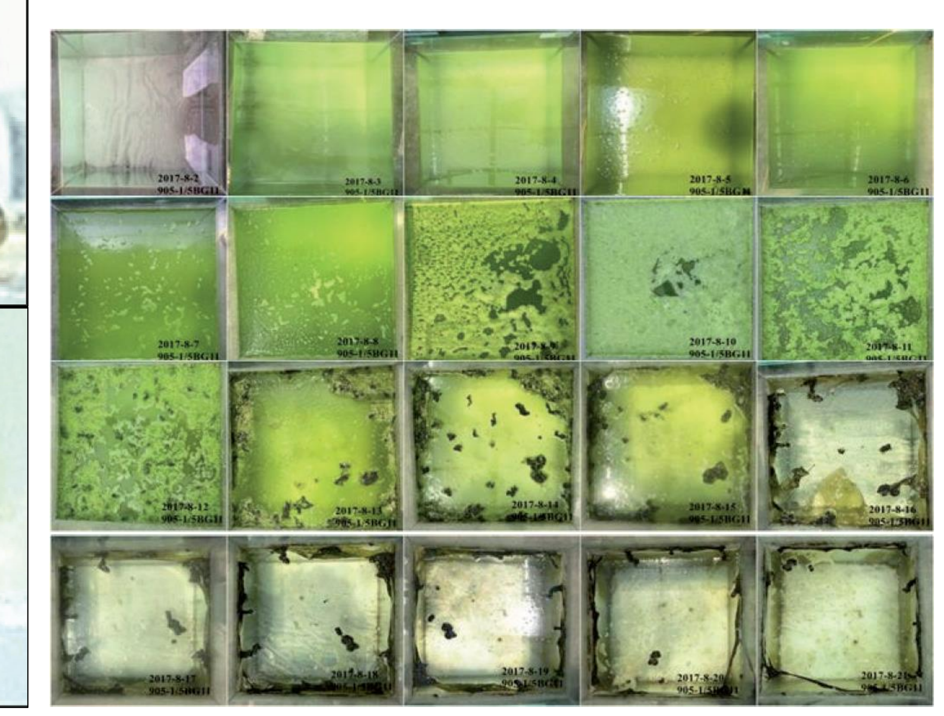


Figure 11 – Mesocosm incubation of Microcystis aeruginosa by Wang et al. (2020), as shown as time-series photographs from left to right and top to bottom, documenting EPS production and foam formation during the termination of the bloom

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