Comments on Cayuga Lake TMDL

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by

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We offer these comments based on our work on nutrient pollution and water quality in aquatic ecosystems over more than 35 years, including work on Cayuga Lake and other lakes and rivers in New York. We have published over 100 papers on water quality and the source of nutrient pollution. Many of these are very highly cited in other peer-reviewed papers, and we have won awards from major professional societies (ASLO, the Association for the Sciences of Limnology & Oceanography, and CERF, the Coastal & Estuarine Research Federation) for two of our nutrient papers judged to be "transformational." One of us (RWH) chaired a 2-year study by the National Academy of Sciences on coastal nutrient pollution, chaired an 8-year study by the International Council of Science on nitrogen pollution, and served as the representative of the State of New York on the Science & Technical Advisory Committee of the Chesapeake Bay Program from 2005 to 2013.

We see significant omissions in the draft TMDL. One is the relatively small attention given to blooms of toxic cyanobacteria (called "HABs" for Harmful Algal Blooms, although the blooms in Cayuga are not algae). The overall focus is strongly on the original phosphorus impairment, which dates from 19 years ago in 2002. Toxic cyanobacteria blooms are a more recent phenomenon, with the first toxic cyanobacteria bloom confirmed in the lake only in 2014 and high levels of toxins from the cyanobacteria first confirmed only in 2017 (DEC 2018). We believe these toxic blooms likely pose a larger water quality threat to Cayuga Lake than did the original phosphorus impairment: toxic cyanobacteria blooms have led to several hundred beach closures in Cayuga and other Finger Lakes since 2017. The draft TMDL does not mention HABs until page 51, and then has only a brief discussion of HABs on pages 51-52 and 67-69 in the context of how the TMDL interfaces with the Cayuga Lake HAB Action Plan. The underlying assumption is that the HABs problem is closely related to the phosphorus impairment. This is not established in the TMDL, and it may not be the case. We note that with the exception of Honeoye Lake, HAB cyanobacteria blooms were not observed in the Finger Lakes until 2014: since 2017, they have become a significant water quality issue in many of the Finger Lakes, including Cayuga but also Skaneateles, an oligotrophic lake with low phosphorus levels (DEC 2018). The blooms are similar across the lakes, and the fact that they occur in Skaneateles as well as in Cayuga suggests to us that phosphorus is probably not the prime cause of the blooms in Cayuga and most of the other Finger Lakes. And importantly, phosphorus is probably not the factor controlling the toxicity of the blooms. We urge that the DEC revised the TMDL to fully consider the toxic cyanobacteria blooms since 2017 in Cayuga Lake.

Related to the toxic cyanobacteria HABs, we urge the TMDL to be revised to consider nitrogen inputs to the lake in addition to phosphorus. We completely agree with the draft TMDL characterization that Cayuga is a phosphorus-limited lake: phytoplankton growth rates are controlled by phosphorus availability (see Roberts & Howarth 2006 and Howarth et al. 2021). However, over recent years the scientific community has increasingly suggested that inputs of both phosphorus and nitrogen to lakes be managed for best water quality, rather than simply phosphorus (Conley et al. 2009; Xu et al. 2010; Paerl and Otten 2013). In the specific case of HABs in Cayuga and other Finger Lakes, recent limnological literature suggests that nitrogen may play a major role (as summarized by Howarth & Marino, Nitrogen Cycling at the Ecosystem Scale, Encyclopedia of Inland Waters, 2nd edition, in revision). High nitrogen may allow the cyanobacteria to produce more toxins such as microcystin, which are nitrogen rich (Dolman et al. 2012; Monchamp et al. 2014; Baker et al. 2018). The cyanobacteria produce these toxins to protect themselves from being eaten, and high toxin levels can reduce grazing by zooplankton, allowing blooms to form even if the cyanobacterial population growth is slow due to phosphorus-limitation; blooms are a function of both the growth rate and the death rate of the organisms (Howarth et al. 1999). While the zooplankton can evolve to better handle the toxins (Schaffner 2019), cyanobacteria may be able to evolve even faster, producing more toxins. This "evolutionary arms race" might be the reason that we are seeing a trend towards greater toxicity of the blooms in at least one of the Finger Lakes (Owasco) over the past few years (Halfman et al. 2018). This has been best studied in Owasco Lake but seems likely to be occurring in the other high-nitrogen lakes, including Cayuga. We note that the DEC has acknowledged that nitrogen may play a role in promoting the toxic cyanobacteria HABs in Cayuga Lake (DEC 2018), and also that the Finger Lakes that have the highest concentrations of cyanobacterial toxins are those lakes that have the highest concentrations of nitrate (DEC 2018). This connection of nitrogen to the blooms in Cayuga Lake is a hypothesis that is suggestive but not yet proven. Nonetheless, we suggest that the precautionary principle should lead to the TMDL for Cayuga Lake to establish nitrogen load limits in addition to phosphorus limits.

Including nitrogen (in addition to phosphorus) in a revised TMDL is an important step to reduce the possibility that management actions do not inadvertently aggravate blooms of toxic cyanobacteria in Cayuga Lake. For example, some best management practices (BMPs) that are effective for phosphorus are ineffective for nitrogen (see review by Howarth et al. 2005). This is particularly true for no-till agriculture: while no till reduces phosphorus losses in surface runoff, in wet climates such as here in the Finger Lakes, no-till leads to greater downstream nitrogen pollution (Daryanto et al. 2017). Many of the BMPs that are promoted in the draft TMDL focus on stream and field buffers: these too are usually quite effective for phosphorus since most of the phosphorus leaving fields is bound to particles and the buffers trap these particles and associated phosphorus. But buffer strips are sometimes ineffective for nitrogen, which is more soluble than phosphorus and more likely to reach surface waters by flowing in groundwater, sometimes underneath the rooting zone of buffer strips (Howarth et al. 2005). Buffer strips are particularly ineffective for nitrogen when drain tiles (which are very common in the watersheds of Cayuga Lake) move nitrate-rich water from crop fields through the strips to road-side ditches.

When revising the TMDL, even if our recommendation to expand and include HABs and nitrogen in TMDL is not taken at this time, we strongly urge that the recommended BMPs for control of non-point source phosphorus inputs focus on those that are also effective for nitrogen. Examples would be to encourage perennial rather than annual crops, and to encourage winter cover crops when annuals are grown (Howarth et al. 2005).

We strongly believe that improvement in water quality in Cayuga Lake will require a sustained, sufficiently funded, and year-round monitoring program that includes both the tributaries through which nitrogen and phosphorus reach the lake and in-lake monitoring of nutrients, bloom organisms, and related factors. Current monitoring efforts such as those of the Community Science Institute (CSI) of nitrogen and phosphorus in tributaries provide very important information, and hopefully can be not only continued but expanded. However, this program and much of the other monitoring on Cayuga Lake is based on sampling by citizen volunteers and relies very heavily on limited funding by local municipal and citizen donations. The CSI monitoring is the most detailed and comprehensive information available on nutrient inputs to Cayuga Lakes, and our lab is using this information to analyze trends in nutrient loading and to ascertain how climate change may be changing nutrient loads (Swaney et al., manuscript in preparation). This CSI monitoring data is truly essential to understanding the causes of water quality impairments in Cayuga Lake, and we continue to be surprised by the lack of support from the State for these efforts. We believe New York State should better support these efforts as well as in-lake monitoring of HABs and nutrients, and ensure they truly are sustained.

Finally, there should be explicit monitoring to determine the effectiveness of BMPs on reducing fluxes off farm fields (including those used by permitted CAFOs) in the context of local climate (and increasing climate variability), soils, and agricultural activities. The Chesapeake Bay Program severely under-invested in monitoring of BMP effectiveness in the early decades of the Program, resulting in large sums spent on BMPs that were eventually determined not to be effective. We should not repeat this mistake in the Finger Lakes.

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