Bad Medicine Lake: Water Quality and Biotic Assessment (2017-2019): Brief summary of findings

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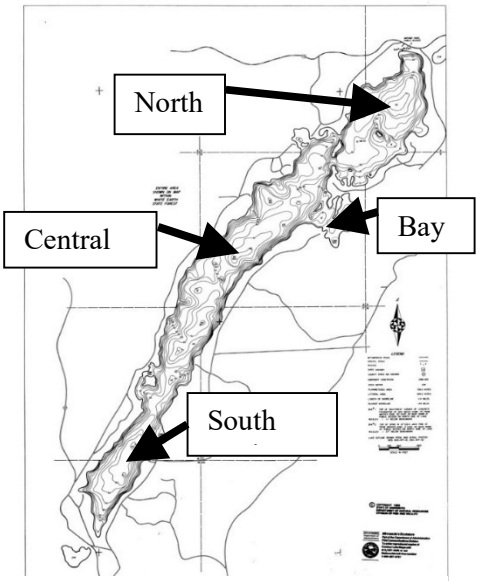
Bemidji State University students Mark Love and Brady Evans sampling with Dr. Koch for water quality on Bad Medicine Lake, May 2019.

Introduction

We are conducting a comprehensive assessment of water quality and biology of Bad Medicine Lake, Becker County, MN. Results from this study will provide a baseline with which to compare future data, and can be compared with the (limited) data previously collected as a means to assess recent changes in lake quality.

Bad Medicine Lake is of particular interest because of its susceptibility to water quality changes. As a spring fed lake, water levels fluctuate with regional water tables and the lake traps nutrients and other chemicals that enter. As a deep, cold water lake, a 2-tiered food web culminating in cold water bottom fishery (rainbow trout, cisco) and warmer water surface fish (walleye, bass, perch) makes this particular lake quite distinct from other lakes in the surrounding region.

Bad Medicine Lake remains an oligotrophic lake (i.e. low algal production and high water transparency) despite undergoing significant changes in its ecology in recent decades… the full extent of which are not yet known. Dramatic increase in native crayfish reduced aquatic plant populations in early 1970s, decreasing fish habitat, and increased nutrients resulting in more algal growth. Annual stocking of rainbow trout (1977 to present) and more recent stockings of walleye by MnDNR create important game fisheries and likely impact lake ecology further. Significant rising of lake levels in 1990s and subsequent slow declines have altered nutrient loading (especially of phosphorus) and changed patterns of water clarity and plankton communities in ways not yet determined.



Contour map of Bad Medicine Lake, Becker County, MN. The 4 main sample locations are noted.

Project overview

Water quality assessment occurred during ice-free season in 2017, 2018 and 2019 at time intervals of 1-4 weeks. Sampling occurred at deepest points in the 3 main basins (South Basin, Central Basin, and North Basin) and the eastern bay. Though wind driven water exchange occurs to some extent throughout the lake, the North Basin is somewhat isolated due to an island with shallow, narrow passages on either side separating it from the Central Basin. Physical (water temperature, transparency), chemical (nitrogen and phosphorus content) and biological (algae and zooplankton) were assessed biweekly during the ice-free periods (May-November). Completion of sample processing and data analyses will occur Fall/Winter 2020.

Summary of Findings

Our findings indicate that Bad Medicine Lake is a healthy, clear water, oligotrophic lake. No aquatic invasive species were found. Low nutrient availability and subsequent low algae and plant production are key to preserving this ecosystem.

Nutrient concentrations ranged from <1–3 *u*g phosphate L^{-1} and 90–270 *u*g nitrate L^{-1}. Seasonal and spatial variations in nutrients appear to drive community changes in plankton. Internal cycling of nutrients with the lake dominate nutrient dynamics, with limited release of phosphorus from surrounding soils. Efforts should be made

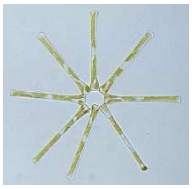
to maintain low nutrient inputs into these waters, especially phosphorus. Maintaining minimal shoreline and soil disturbances are key, as well discouraging nutrient application in the watershed.

Lake ***water temperature*** changes slowly with the seasons. Bad Medicine Lake exhibits a pattern of stratification (temperature layering) typical of deep lakes in the region. Warming water during summer, creates an increasingly warmer (up to ~75ºF) layer of surface water (epilimnion) overlaying permanently colder (~40ºF) deeper water (hypolimnion). The layer of transition (thermocline) becomes very pronounced at 9-12 meters depth as summer progresses, decreasing 20ºF in a single meter in late July. Algae and particulate matter may accumulate here as they settle out from surface waters, creating a noticeable turbid layer. Fish and zooplankton must work harder to penetrate pronounced thermoclines.

Dissolved oxygen concentrations in Bad Medicine Lake ranged from 0 (near bottom) to ~15 mg/L (above thermocline). The epilimnion (surface layer) remained well oxygenated throughout, with highest DO readings from just above the thermoclines (super saturated on most dates), suggesting healthy levels of algal photosynthesis producing excess oxygen. Water below the thermocline had lower oxygen levels, especially as the thermocline became more pronounced in late summer. Anoxic (low oxygen) conditions were confined to near sediment waters in May, but rose to within 13m of the surface as summer progressed. Oxygen stress to biota is evident in deeper waters of Bad Medicine by late summer/fall, especially in the North Basin. Some fish and invertebrates respond by shifting to shallower positions. However, cold water fish like trout, cisco and burbout become constrained between low oxygen levels in deep water and too-warm temperatures in surface water. Climate change leading to longer ice-free seasons and warmer summers may worsen this scenario. Lake turnover, occurring in late November, resets higher oxygen levels in deeper waters as cooled, oxygenated surface waters descend.

Water transparency (secchi disc) in Bad Medicine Lake ranges from 3.2-8.0 m (10-26 ft), with highest clarity usually in June and lowest in early August. Photosynthesis is supported to depths of 10-25 m (33-82 ft), suggesting that much of the water column may support algae, though at limited densities due to low nutrient availability. Also, a significant part of the lake bottom has potential for periphyton (attached algae) and macrophyte growth, though these also remain nutrient limited under current conditions.

Algal biomass ranged from 0.1 to 25 ug chlorophyll L^{-1} and are typical for an oligotrophic (low nutrient), clear water lake. A low diversity of algae is present, with select diatoms dominating, especially in spring and fall, with episodic risings of a few green and bluegreen taxa at some areas of the lake. Temporary blooms of nitrogen-fixing bluegreen algae (mostly *Microcystis* and *Anabaena*) occur lake wide during late summer/autumn as phosphate is released from deeper water, but such cycles are quick, natural, and create no discernable negative impact. Such blooms, however, should be monitored, as an increase in frequency or severity may be an indication of larger changes occurring. Phytoplankton may respond rapidly to increases in nutrient availability. No apparent concerns were found through our sampling, however, the fragility of the system is apparent and care should be taken to maintain limited nutrient inputs.



Asterionella. A common diatom of Bad Medicine Lake that may collect on fishing lines

Zooplankton communities in Bad Medicine are productive and support a strong fisheries. *Daphnia*, in particular predominate and are a favored food resource for many fish, including rainbow trout, perch and walleye. Larger bodied zooplankton actively migrate in bad medicine in response to light (and visual predators). Daily vertical migration of zooplankton is common as zooplankton hide in deeper waters during brighter periods. Our findings also suggest significant horizontal movement as zooplankton seek refuge in rocky crevices. This is especially prevalent in large zooplankton which hide in deep waters during the day, moving to near surface waters to graze overnight.

Daphnia. A common zooplankton in Bad Medicine Lake

Recommendations. Low phosphorous loading is the key to preservation of the oligotrophic nature of Bad Medicine. Care should be taken to limit shoreline disturbance, maintain functioning septic systems and limit the use of anthropogenic fertilizers. Continued efforts to prevent the introduction of aquatic invasive species is also recommended.