Water Quality Summary: Temperature

2019 Barr Lake & Milton Reservoir

Twenty times a year since 2003, **Barr Lake** and **Milton Reservoir** have been sampled for water quality. These 340 trips to both reservoirs have produced an abundance of data and information. This is Part 4 of 8 of a water quality summary series for 2019 calendar year for both reservoirs. The first three summaries focused on pH, chlorophyll-a, and dissolved oxygen; this one discusses water temperature.

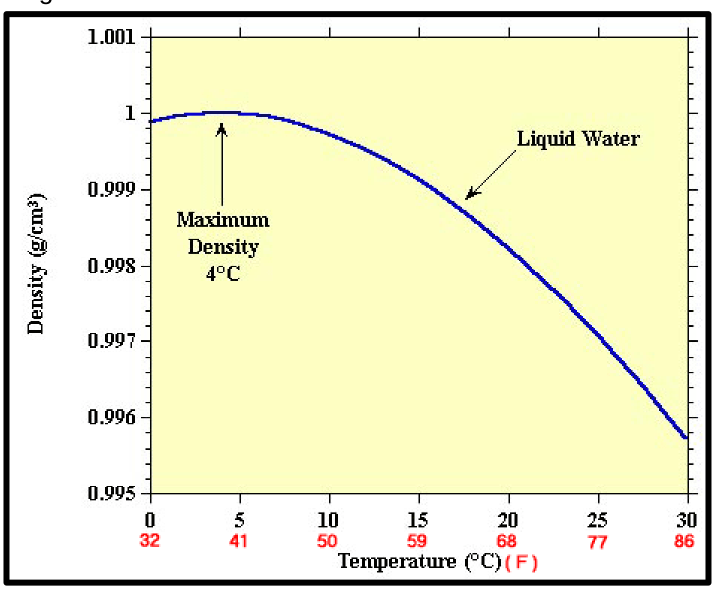
The Big Picture – Eutrophication is the addition of nutrients to water bodies resulting in nuisance algae growth and sedimentation. This natural process usually occurs over a long geological period of time. Many lakes, reservoirs, and even estuaries and bays throughout the world experience "*cultural eutrophication*". This term means that water bodies tend to become more productive and shallower over relatively short periods of time due to increased inputs of nutrients and sediments from human activities. Accelerated aging of lakes causes a quick biological response – severe algae growth. This response then leads to other chemical and physical changes within the water – pH, oxygen, water clarity and color, fish, plants, and aesthetics can all change.

Temperature – A unique property of water is the temperature/density relationship (Figure 1). Water changes density as it changes temperature. Water is heaviest at 4 ^{0}C. Any warmer or colder and the water is less dense. This is why ice (0 ^{0}C) floats during the winter and warm water (25 ^{0}C) floats during the summer. The bottom water temperature in many deep lakes is around 4 ^{0}C year round. This density gradient associated with temperature defines a lake's ecology and mixing cycles.

A lake's annual temperature cycle is determined by its local climate and angle to the sun (i.e., latitude). **Barr Lake** and **Milton Reservoir** are considered *dimictic* when deeper than 7.0 – 8.0 meters by mixing twice a year; once in the spring and again in the fall with thermal stratification occurring during the winter and summer months. If the reservoirs are less than 7.0 – 8.0 meters, they become *polymictic*; mixing multiple times when wind and wave action is strong enough to mix the entire water column.

Thermal stratification is important to understand. It is the layering of water caused by temperature differences. During the summer, the uppermost, warmest layer (epilimion) is the lightest and well mixed. The middle water is where the temperature transitions to the cooler bottom water. Each change in temperature forms a layer of non-mixing water (metalimnion). It only takes half of a degree Celsius to form stratification. The bottom layer (hypolimnion) is the coldest and is isolated from any other water.

Figure 1.



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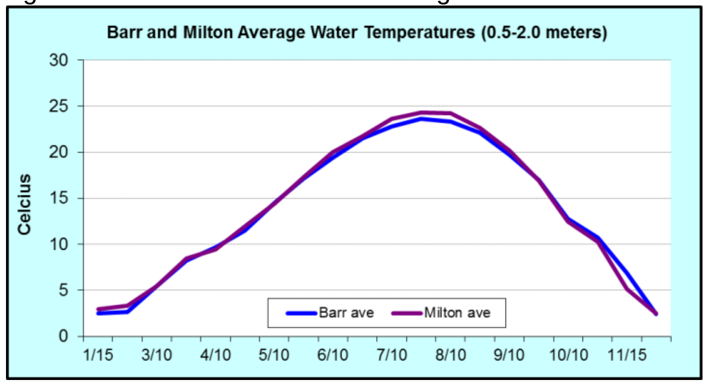
It takes a large amount of energy to change the temperature of water. This is why the unit of energy (calorie) uses water in its definition. A dietary calorie is the amount of energy it takes to heat 1 kilogram of water by 1 ^{0}C.

Figure 2. 2003 – 2019 Annual Average



Because of this thermal resistance, lakes tend to have very predictable and gradual temperature cycles. This is good for aquatic organisms and explains why they have evolved to have specific temperature ranges for various life stages (e.g., spawning). The annual temperature cycle for both **Barr Lake** and **Milton Reservoir** changes little from year to year (Figure 2). The warmest water occurs during the last week of July and the coldest in December and January.

The temperature standard for warm-water, lakes (deeper than 5 meters) only applies to the top water (0.5 – 2.0 meters). The temperature standard for **Barr Lake** and **Milton Reservoir** is 26.2 ^{0}C (chronic) and 29.3 ^{0}C (acute) between April and December and 13.1 ^{0}C (chronic) and 24.1 ^{0}C (acute) between January and March.

Table 1. Barr and Milton Temperature Data for 2019 in degrees Celsius (^{0} F).

Month	Temperature (Barr)	Temperature (Milton)
Jan	3.2 (37.7 F)	2.9 (37.2 F)
Feb	2.4 (36.3 F)	2.5 (36.5 F)
Mar	3.9 (39.0 F)	4.0 (39.2 F)
Mar	6.5 (43.7 F)	7.6 (45.7 F)
Apr	11.2 (52.1 F)	12.3 (54.1 F)
Apr	13.0 (55.4 F)	14.1 (57.4 F)
May	13.2 (55.7 F)	14.5 (58.1 F)
May	14.0 (57.2 F)	14.8 (58.6 F)
Jun	19.6 (67.2 F)	19.5 (67.1 F)
Jun	20.3 (68.5 F)	20.2 (68.4 F)
Jul	23.3 (73.9 F)	22.9 (73.2 F)
Jul	24.7 (76.5 F)	24.9 (76.8 F)
Aug	24.2 (75.6 F)	24.3 (75.7 F)
Aug	22.4 (72.3 F)	23.9 (75.0 F)
Sep	21.7 (71.1 F)	22.0 (71.6 F)
Sep	18.5 (65.3 F)	17.9 (64.2 F)
Oct	14.9 (58.8 F)	14.1 (57.4 F)
Oct	9.9 (49.8 F)	8.7 (47.7 F)
Nov	5.5 (41.9 F)	6.2 (43.2 F)
Dec	1.8 (35.2 F)	3.7 (38.7 F)

The acute standard is a daily maximum average, and the chronic standard is the maximum average during the growing season (July 1 – September 30). A lake can exceed these temperatures as long as there is deeper water that meets both DO and temperature standards.

2019 Temperature Data – Temperature data are collected throughout the entire water column in half meter increments during each visit. Temperature data from 0.5 meter to 2.0 meters are averaged for each visit. For 2019, there were 20 temperature averages recorded for each reservoir (Table 1). For **Barr Lake** and **Milton Reservoir**, the temperature standard was achieved.

The growing season average for **Barr Lake** was 22.48 ^{0}C and 22.64 ^{0}C for **Milton Reservoir**.

Celsius to Fahrenheit = double it and add 32

F = (1.8 x C) + 32

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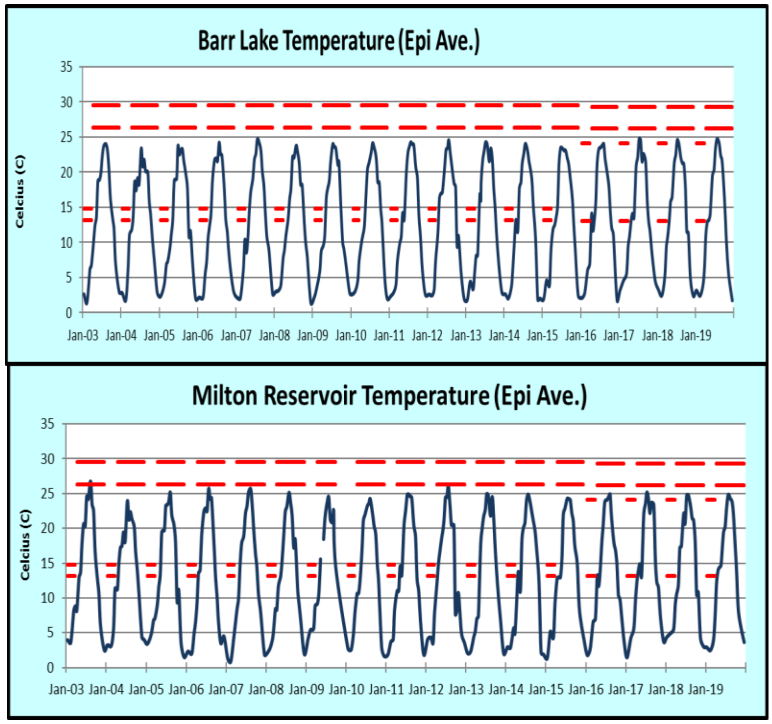
Figure 3 shows the long term temperature averages for the top water in both reservoirs. Both reservoirs are below the chronic and acute standards for both seasons (dashed lines).

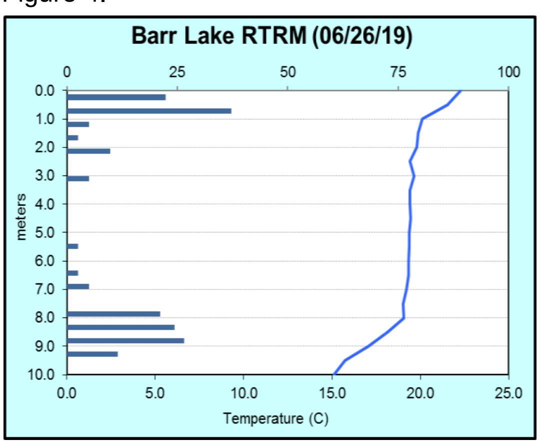
Relative Thermal Resistance to Mixing (RTRM) – It takes a small change in temperature to keep water from mixing due to density differences. RTRM is a way to measure this resistance throughout the water column. The greater the temperature difference, the greater the density difference; therefore, the more energy it takes to mix.

Figure 3.



RTRM is a ratio that looks at each half meter layer and compares the density changes to the density difference between water at 5 ^{0}C and 4 ^{0}C. Barr Lake's temperature profile from 06/26/19 is a good example (Figure 4). The top meter of water was the warmest while the bottom two meter of water was the coolest at 15.1 ^{0}C. For every half meter depth change, the RTRM was calculated. In late June, most of the water column was warm and capable of mixing down to 8.0 meters. The metalimnion was large and capble of warming deeper waters. The strongest thermal barrier was at 1.0 meter because of absorption of infra-red heat waves. The bottom two meters of water was also a strong barrier allowing for no oxygen in near the sediments.

Figure 4.



This is an uncommon profile for Barr because the reservoir typically is not that deep that late into the summer. Adding up the RTRM values yields a value of 171 (2018 total was 79). This accumulative RTRM can be used to compare lakes, to help size aeration systems and to determine when a lake is about to mix. The higher the number, the more energy it takes to mix. Periodic mixing events (i.e., low RTRM values) can bring up bottom water that includes nutrients from the sediments, but at the same time it can also push algae into the darker water to control their growth.