2015 Water Quality Summary Series – Nitrogen

Twenty times a year since 2003, **Barr Lake** and **Milton Reservoir** have been sampled for many water quality parameters. These 240 sampling trips have produced an abundance of data and information. This is Part 6 of a continuing series summarizing the 2015 water quality data. The first five summaries focused on pH, chl-a, dissolved oxygen, water temperature, and phosphorus. This summary covers nitrogen (N).

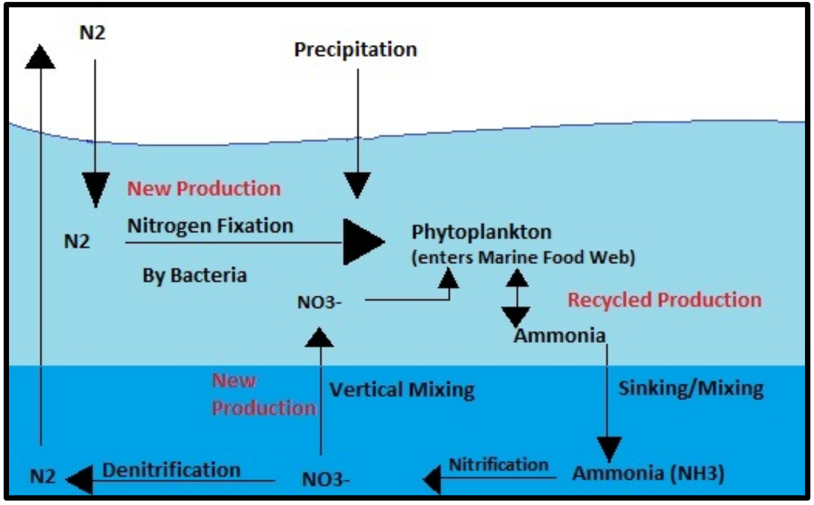
The Big Picture – Many lakes, reservoirs, and even estuaries and bays throughout the world experience "*cultural eutrophication*". This term means that water bodies tend to become more productive and shallower over relatively short periods of time due to increased inputs of nutrients and sediments from human impacts in the watershed. Eutrophication is a natural process, but it generally occurs over a much longer geological period. This 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 column– pH, oxygen, water clarity, water color, and aesthetics.

Nitrogen – N is an element that is required by all living organisms and comes in many forms. N is the most abundant element in the atmosphere, 78%. Typically, saltwater is nitrogen limited while freshwater is phosphorus limited. Under the right conditions, N can also be the limiting nutrient for lakes.

In water, N can occur in three forms, dissolved N gas, inorganic N, and organic N (Figure 1). Only a few blue-green algae can use dissolved N gas while other plants use inorganic N. Nitrogen fixation by blue-green algae is one reason why they grow so well; they are capable of fixing (assimilating) the dissolved N gas that other algae cannot use when there are no other forms of N in the water.

Organic N is the nitrogen that is in living, dead, or decomposing plants and animals. Examples of organic N are proteins, amino acids, and some humic compounds.

Figure 1



The two main forms of inorganic N are ammonia (NH_3) and nitrate (NO_3^-). NH_3 is preferred by plants because it takes the least amount of energy to assimilate. NH_3 is released from decomposing organic N and ammonification of NO_3^- by bacteria when dissolved oxygen is not present. NH_3 is the most reactive form of N and can adhere to sediment particles. NH_3 in water is present primarily as ammonium (NH_4^+). Ammonia is toxic to aquatic organisms but NH_4^+ is not. Water temperature and pH determines the ratio of NH_3 and NH_4^+in the water.

Nitrification is the biological conversion of organic and inorganic N from a reduced state to a more oxidized state. NO_3^- is the next inorganic compound that plants use and is the most common inorganic form in lakes. NO_3^- can convert back to NH_3 by ammonification or convert back to dissolved N gas that can then leave the water and go back into the atmosphere. NO_3^- does not bind to soil and can leach into groundwater. Nitrite (NO_2^-) is the slightly reduced form of NO_3^- but is not as common.

Total nitrogen (TN) is the summation of all N in the water (organic, inorganic, particulate, and dissolved). Total Kjeldahl Nitrogen (TKN) is the measurement of organic N, NH_3, and NH_4^+. To calculate TN, nitrate/nitrite needs to be added to TKN. Total inorganic N (TIN) is the summation of NH_4^+, NH_3, NO_3^-, and NO_2^-; this is what is readily available for plants.

N is a key nutrient that determines how much algae can grow in a lake. Concentrations are typically expressed in units of milligrams per liter (mg/L) or parts per million (ppm). The forms that are analyzed are: NH_3, NO_3, NO_2^-, and TKN. Because of blue baby syndrome where too much NO_3 gets into the bloodstream, it is important that NO_3 concentrations are below 10 mg/L in drinking water. TN concentrations over 10 mg/L are considered high in general terms.

Excessive nutrients are the main cause of *cultural eutrophication*. Too many nutrients leads to aesthetic issues, odor problems, cyanotoxins, large dissolved oxygen fluctuations, and lower water clarity. A TN standard has been established for **Barr Lake** and **Milton Reservoir** at 0.91 mg/L. A ratio of TN:TP greater than 20 would result in a phosphorus limiting system and help control blue-green algae that use dissolved N gas.

2015 Nitrogen Data – Nitrogen data are collected from the one meter depth and one meter from the bottom lake sediment during each visit. For 2015, there were 40 nitrogen samples analyzed for each reservoir. Only top water data is shown in Table 1.

Table 1. Barr Lake and Milton Reservoir 2015 epilimnion nitrogen data (mg/L). Bold values exceed the water quality standard.

	Barr Lake (mg/L)					Milton Reservoir (mg/L)				
Month	**NH_3**	**NO_{3+2}**	**TKN**	**TN**	**TN:TP**	**NH_3**	**NO_{3+2}**	**TKN**	**TN**	**TN:TP**
Jan	0.38	3.27	1.4	4.67	10.9	0.25	0.20	1.0	1.2	8.6
Feb	<0.05	2.76	1.6	4.36	11.5	0.09	0.12	0.8	0.92	15.3
Mar	<0.05	2.39	1.9	4.29	12.3	<0.05	<0.02	1.6	1.60	8.0
Mar	0.13	2.00	1.8	3.80	13.6	0.05	0.03	1.0	1.03	10.3
Apr	0.08	2.6	2.1	4.70	16.2	0.77	0.88	1.5	2.38	11.9
Apr	0.48	1.44	1.5	2.94	10.4	0.54	0.21	1.5	1.71	10.7
May	0.53	1.29	1.6	2.89	10.3	0.50	0.25	1.4	1.65	10.3
May	0.28	1.04	1.3	2.34	10.2	0.41	0.22	1.2	1.42	9.5
Jun	0.22	0.91	1.3	2.21	13.0	0.21	0.20	1.0	1.20	10.0
Jun	0.08	0.58	1.7	2.28	8.8	<0.05	0.09	1.0	1.09	5.7
Jul	<0.05	0.05	3.3	**3.35**	8.4	0.16	0.08	1.6	**1.68**	4.5
Jul	<0.05	<0.02	1.8	**1.80**	7.5	0.08	<0.02	1.8	**1.80**	4.1
Aug	0.08	0.04	0.9	**0.94**	5.5	<0.05	0.03	1.3	**1.33**	2.8
Aug	<0.05	<0.02	1.2	**1.20**	6.0	<0.05	<0.02	1.3	**1.30**	4.8
Sep	0.16	0.19	1.1	**1.29**	8.6	0.12	0.72	1.8	**2.52**	11.5
Sep	0.07	<0.02	1.2	**1.20**	9.2	<0.05	0.03	1.5	**1.53**	10.9
Oct	<0.05	<0.02	1.3	1.30	9.2	<0.05	0.56	3.4	3.96	7.3
Oct	0.39	0.05	1.7	1.75	7.6	<0.05	0.20	2.4	2.60	9.0
Nov	0.37	0.31	1.8	2.11	11.1	<0.05	1.67	2.8	4.47	21.3
Dec	<0.05	0.19	1.8	1.99	10.5	<0.05	2.51	1.2	3.71	13.3

The average TN for **Barr Lake** in 2015 was 2.57 mg/L and 1.96 mg/L for **Milton Reservoir**. TN always decreases through the growing season for both reservoirs until they begin to refill in the winter. TKN increased in Milton during the drawdown.

The growing season (July – September) average for **Barr Lake** was 1.63 mg/L and 1.69 mg/L for **Milton Reservoir**. Typically, the growing season average is lower than the annual average because of the winter fill period and uptake, settling, and releasing of the N during the summer.

Figure 1

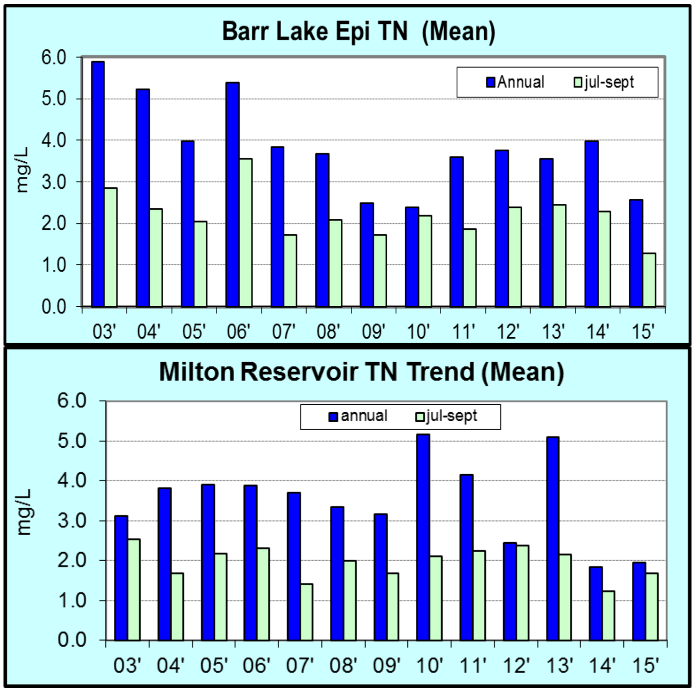
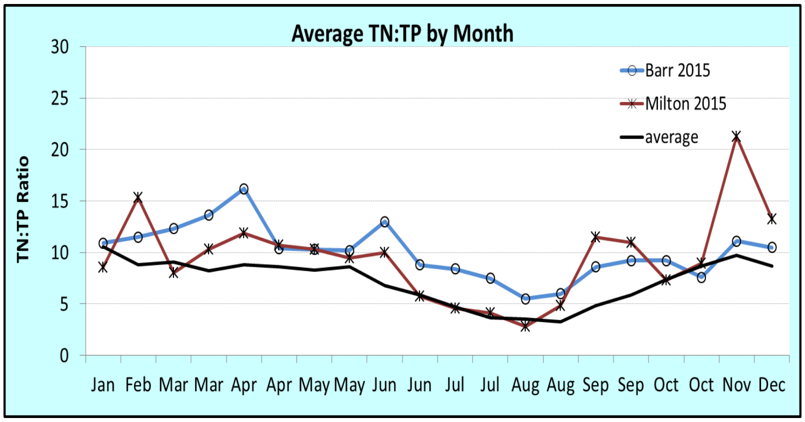


Figure 1 shows the annual and growing season averages since 2003. There was a downward trend in the annual average TN for Barr Lake until 2011. Then TN has increased until 2015. Milton Reservoir has slightly less TN on average than Barr Lake, and 2015 was low again and could have been even lower if the drawdown had not occurred.

TN:TP Ratio – In a complex reservoir system, there are multiple factors that are acting at once to determine how much algae grows. Both phosphorus and nitrogen are equally important. Other factors such as sunlight, water temperature, and even carbon also play an important role.

N is much harder to control since blue-green algae and bacteria can assimilate the dissolved N gas that comes from an endless source, the atmosphere. Phosphorus, on the other hand, is more controllable and less abundant. For these reasons, it is more desirable to have a phosphorus limited reservoir.

Figure 2



A TN:TP ratio great than 20 is a desirable ratio that would indicate a phosphorus limited system. Blue-green algae blooms can be reduced with a higher ratio. Figure 2 shows the TN:TP ratio for 2015 for both reservoirs. Even though there were reductions in TP and TN in 2015, the ratio still remained close to 10. The typical trend is to start at 10 in January, then slowly drop to a ratio below 5 in early August, and then increase back to 10 by winter. Both Barr and Milton did have slightly higher TN:TP ratios compared to the overall average, but it was well below the goal of 20. It is important to understand that the ratio of N and P is just as critical as the concentrations.