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Birch Bay Village Lakes 2009 Final Report

Robin A. Matthews
Western Washington University, robin.matthews@wwu.edu

Joan Vandersypen
Western Washington University, joan.vandersypen@wwu.edu

Jessie Rosanbalm
Western Washington University

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Dr. Robin A. Matthews
Ms. Joan Vandersypen
Ms. Jessie Rosanbalm

Institute for Watershed Studies
Huxley College of the Environment
Western Washington University

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1 Project Description and Sampling Methods

The Institute for Watershed Studies was contracted by the Birch Bay Village Lakes Committee to continue water testing at two sites in Kwann Lake and two sites in Thunderbird Lake (Figure 1, page 4). The sampling effort was initiated in August 2007 and the results were summarized in the Birch Bay Village Lakes 2008 Final Report. The 2009 final report summarizes all results collected from August 2007 through August 2009.

Water samples were collected in August, October and December 2007, February, April and June 2008, and February, April, June, and August 2009. Temperature and dissolved oxygen concentrations were measured in the field at the surface (0.3 m) and at 1 meter depth intervals using a YSI field meter. Both lakes are very shallow, so the deepest collection depth at any site was 3 meters.

Surface water samples were collected at each lake site and transported to the Institute for Watershed Studies (IWS) laboratory to measure pH, conductivity, phosphorus (total phosphorus and orthophosphate), nitrogen (total nitrogen, nitrate/nitrite[1], ammonium), turbidity, and alkalinity. Separate surface water samples were collected to measure chlorophyll concentrations. All water samples collected in the field were stored on ice and in the dark until they reached the IWS laboratory and were analyzed as described in Table 1. Coliform samples were collected in 2009 and analyzed by Exact Scientific Services, Inc.

[1]Nitrate and nitrite were analyzed together because nitrite concentrations are usually very low in surface water and require low level analytical techniques to measure accurately.

Analyte	Method Reference[†]	Detection Limit/ Sensitivity
Alkalinity	SM2320, titration	±0.5 mg $CaCO_3$/L
Chlorophyll	SM10200 H, acetone extract, phaeophytin corrected	±0.1 μg/L
Conductivity	SM2510, lab meter	±0.1 units
Dissolved oxygen - field	SM4500-O G.,membrane electrode (field meter)	±0.1 mg/L
Dissolved oxygen - lab	SM4500-O C., Winkler with azide modification	±0.1 mg/L
Fecal coliforms[‡]	SM9222 D, membrane filter	1 cfu/100 mL
Nitrogen - ammonium	SM4500-NH3 H., flow injection, phenate	10 μg NH_3-N/L
Nitrogen - nitrate/nitrite	SM4500-NO3 I., flow injection, Cd reduction	10 μg NO_3-N/L
Nitrogen - total	SM4500-NO3 I., flow injection, persulfate digest	20 μg N/L
pH - lab	SM4500-H, electometric	±0.1 units
Phosphorus - ortho	SM4500-P G., flow injection	3 μg PO_4-P/L
Phosphorus - total	SM4500-P G., flow injection, persulfate digest	5 μg P/L
Temperature - field	SM2550 thermistor (field meter)	±0.1 C
Turbidity	SM2130, nephelometric	±0.2 NTU

[†] APHA, 2005. Standard Methods for the Examination of Water and Wastewater, 20th Ed., Amer. Public Health Assoc., Amer. Water Works Assoc., Water Env. Fed., Washington, DC.

[‡] Analyses done by Exact Scientific Services, Inc., 3929 Spur Ridge Ln, Bellingham, WA 98226

Table 1: Summary of analytical methods for the Birch Bay Village Lakes project.

2 Results

All of the 2007–2009 Birch Bay Village Lakes water quality data are included in Appendix A of this report. In addition, each parameter has been plotted (Figures 2–14, pages 5–17) and included in the report. Each figure includes descriptive captions that discuss the general patterns in the data. It is beyond the scope of this project to provide a detailed analysis of the data; however, if you have additional questions, please contact Dr. R. Matthews at the Institute for Watershed Studies.

To facilitate pattern descriptions, the figures are discussed in the following order:

- Figure 1: Sampling locations
- Figures 2–6: Physical structure of the lake (temperature, dissolved oxygen)
- Figures 4–6: Chemical structure of the lake (conductivity, pH, turbidity)
- Figures 7–11: Algal nutrients (nitrogen and phosphorus)
- Figures 12–13: Lake trophic state (chlorophyll and trophic index)
- Figure 14 (page 17): Bacterial indicators (fecal coliforms - 2009 only)

3 Quality Control

Ten percent of the water samples were collected in duplicate (field duplicates) to estimate variation between samples collected at the same location, depth, and time. Ten percent of all laboratory samples were measured in duplicate to estimate analytical variation for samples from the same bottle. Laboratory blanks, matrix spikes, and laboratory control/check samples were included with all analytical runs to estimate background noise and recovery of known concentrations of each analyte. All of the quality control data are included in Appendix B of this report.

GPS Coordinates for Sampling Sites:

K1	48.94211°N, 122.77848°W	T1	48.93774°N, 122.78495°W
K2	48.94195°N, 122.77327°W	T2	48.93766°N, 122.78697°W

Figure 1: Kwann Lake and Thunderbird Lake sampling sites.

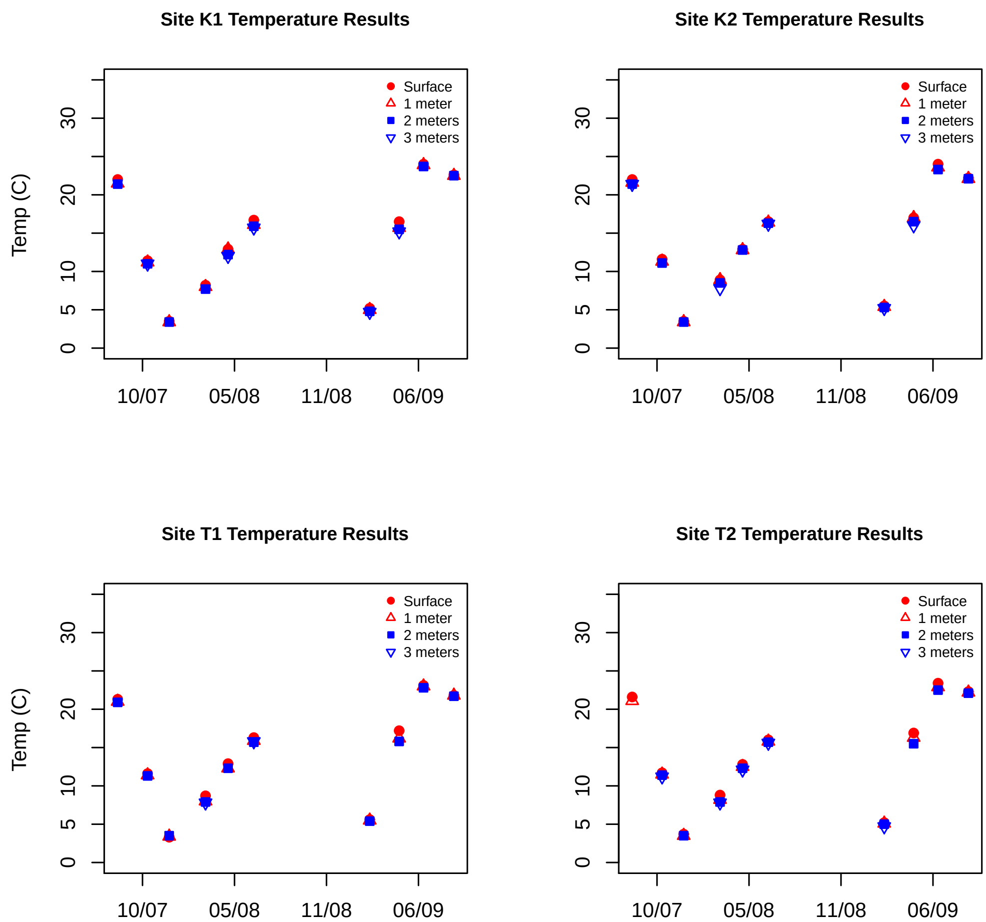

Figure 2: Temperature measurements were collected at the surface and at 1 meter intervals at each site. All sites were shallow ($\leq$3 m), so the water column was thoroughly mixed on each sampling date, resulting in similar temperatures at all depths. Seasonal warming and cooling was evident; temperatures were warm during the summer and cold during the winter. There were no obvious temperature differences between lakes or between the sites within each lake.

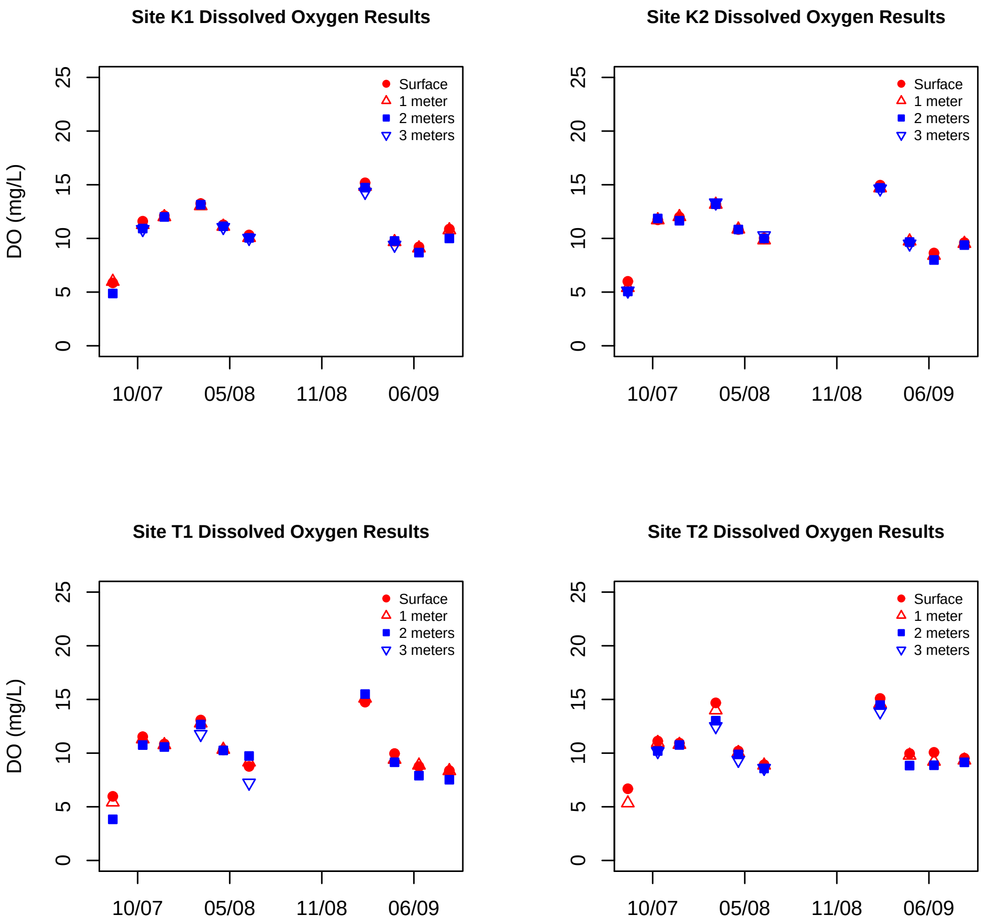

Figure 3: Dissolved oxygen measurements were collected at the surface and at 1 meter intervals at each site. All sites were shallow (≤3 m), and the lakes contain aerators that introduce oxygen into the water column, so oxygen concentrations were more or less similar at all depths. Higher oxygen concentrations were measured during the winter (cold water holds more oxygen than warm water) compared to the summer, when warm water temperatures and high rates of organic matter decomposition work together to produce lower oxygen levels in the water column. The summer oxygen concentrations were often slightly higher near the surface, probably due to decomposition near the bottom of each lake.

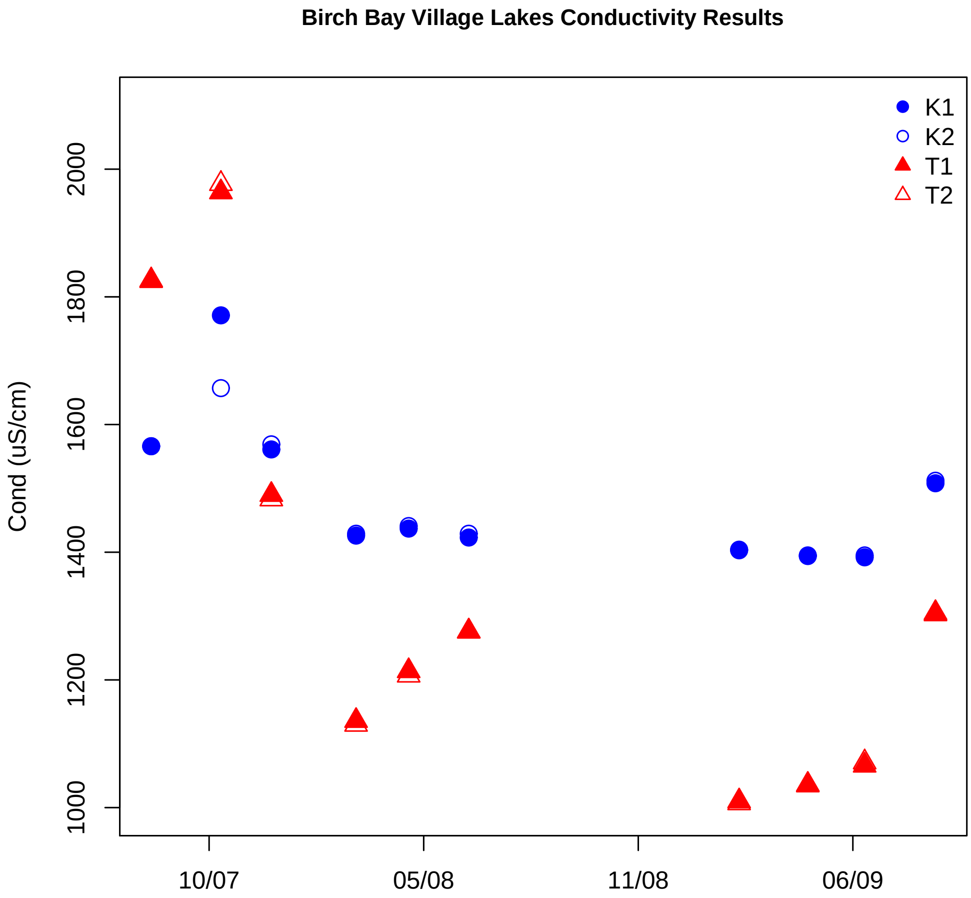

Figure 4: Conductivities were measured in the laboratory using surface water samples collected at 0.3 m. The Kwann Lake conductivity levels were relatively high for freshwater samples ($\geq$1400 μS/cm). Thunderbird Lake conductivities were typically lower, but were still $\geq$ 1000 μS/cm. The August and October 2007 Thunderbird Lake conductivities were unusually high, suggesting saltwater influence. The conductivities in both lakes were lower during the winter and spring, probably due to the inflow of surface runoff.

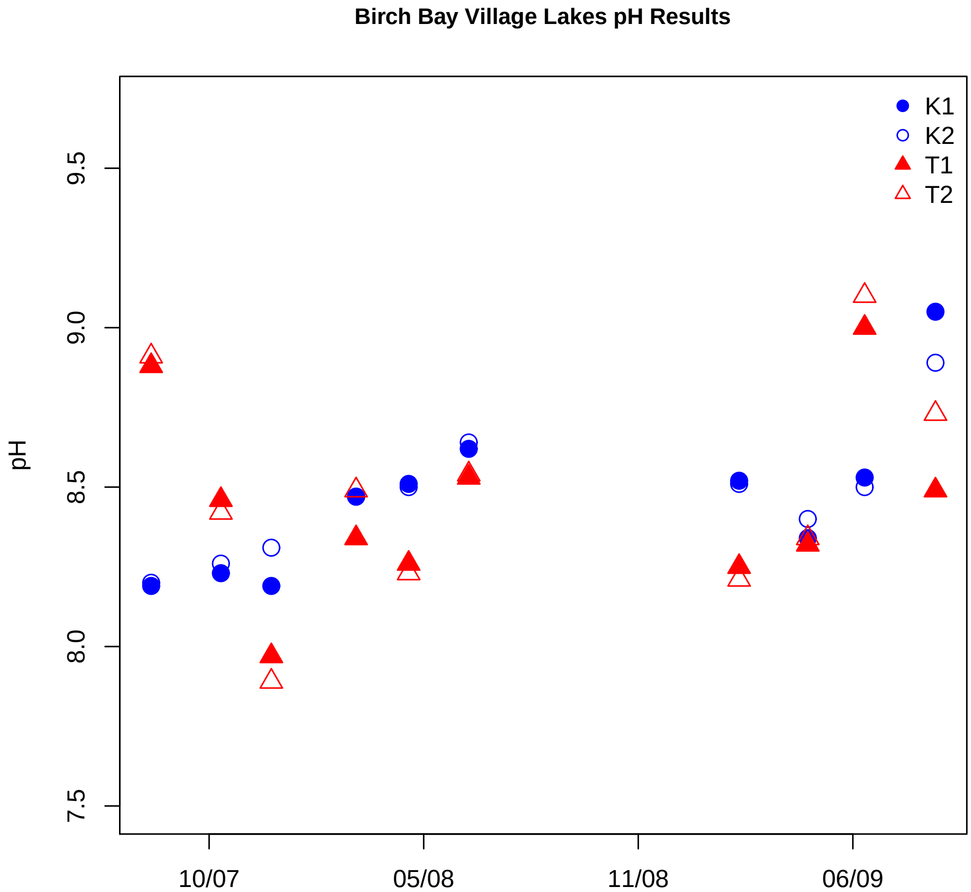

Figure 5: The pH levels were measured in the laboratory using surface water samples collected at 0.3 m. All pH levels were slightly alkaline (>7). Most pH values were >8.0, which is typical for lakes with high conductivities and high algal concentrations (Figure 12, page 15).

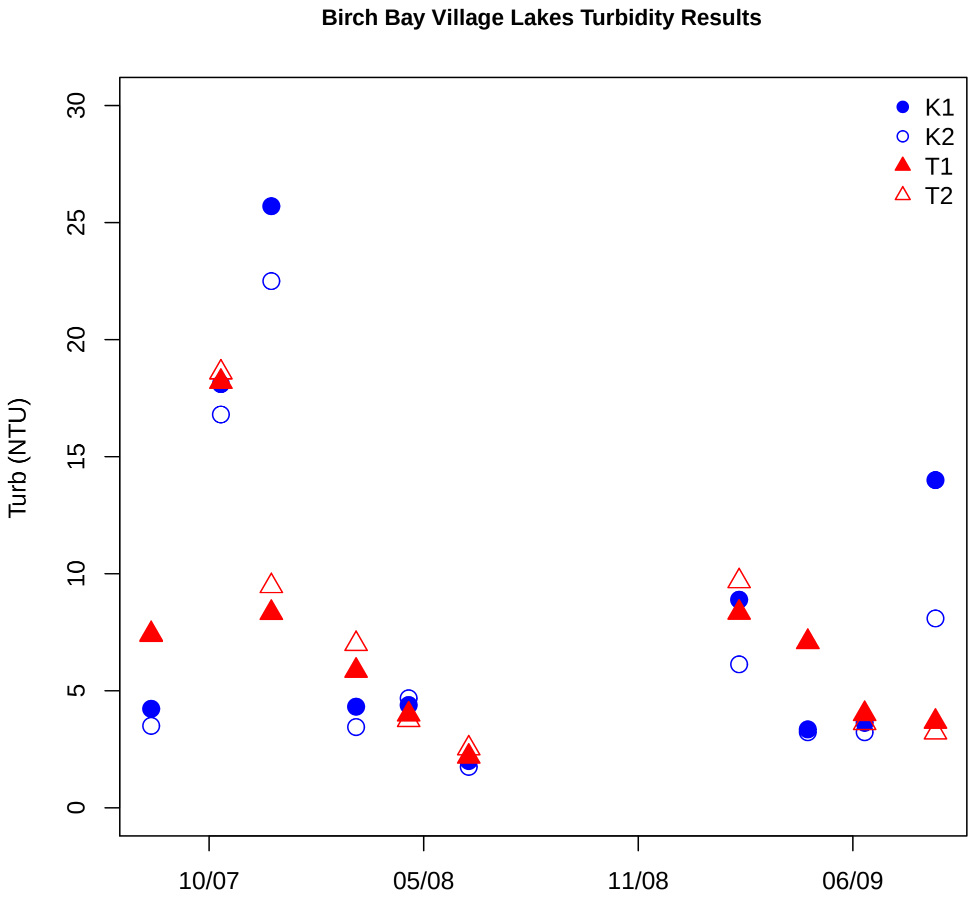

Figure 6: Turbidity values were measured in the laboratory using surface water samples collected at 0.3 m. Turbidity indicates the amount of suspended particles, including algae and other types of suspended sediments. The highest turbidities levels occurred in December 2007, probably due to storm events causing sediments to enter the lakes via surface runoff or from wind-related lake turbulence that resuspended lake bottom sediments. High turbidities were also measured in October 2007 (all sites) and August 2009 (K1). These high turbidities corresponded to high chlorophyll levels (see Figure 12 on page 15).

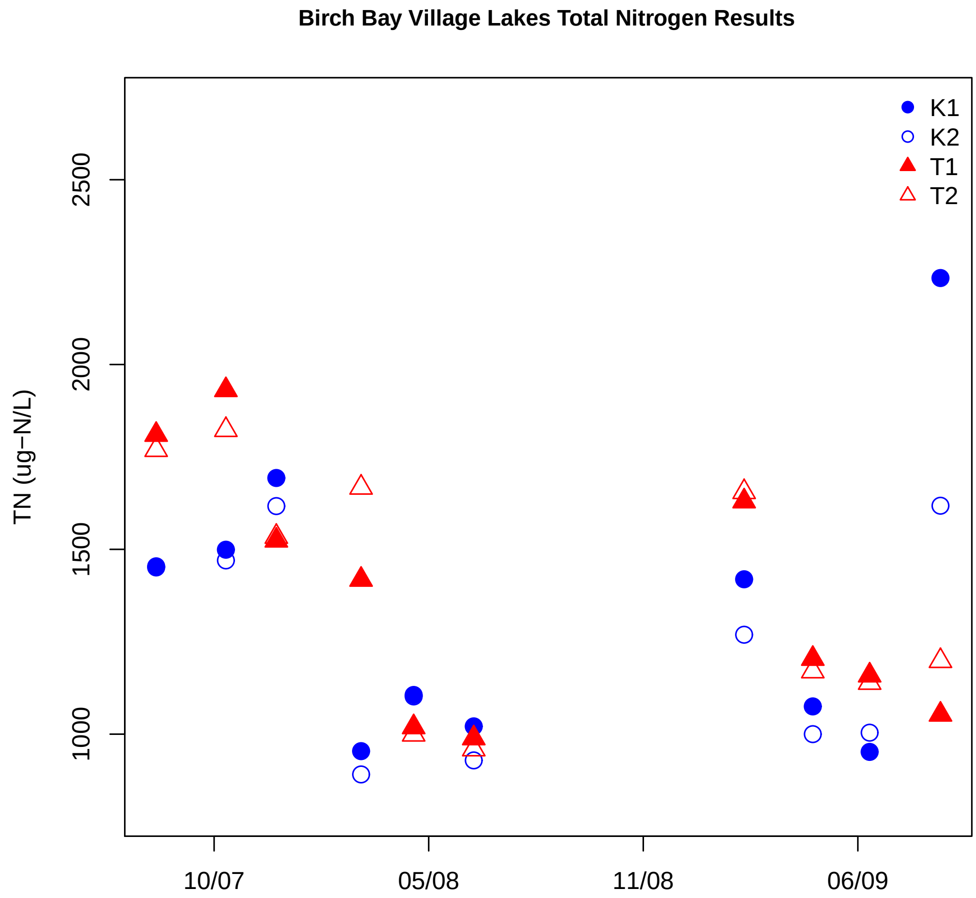

Figure 7: Total nitrogen concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Total nitrogen represents the combined concentrations of organic nitrogen (nitrogen associated with algae and other biota) and dissolved inorganic nitrogen (nitrate, nitrite, and ammonium). Usually, total nitrogen concentrations are similar to nitrate concentrations (Figure 8, page 11), but in the Birch Bay Village Lakes, total nitrogen concentrations were much higher than nitrate concentrations. This indicates that the lakes contain large amounts of organic nitrogen, which is consistent with the high chlorophyll concentrations and eutrophic trophic state (Figures 12–13, pages 15–16).

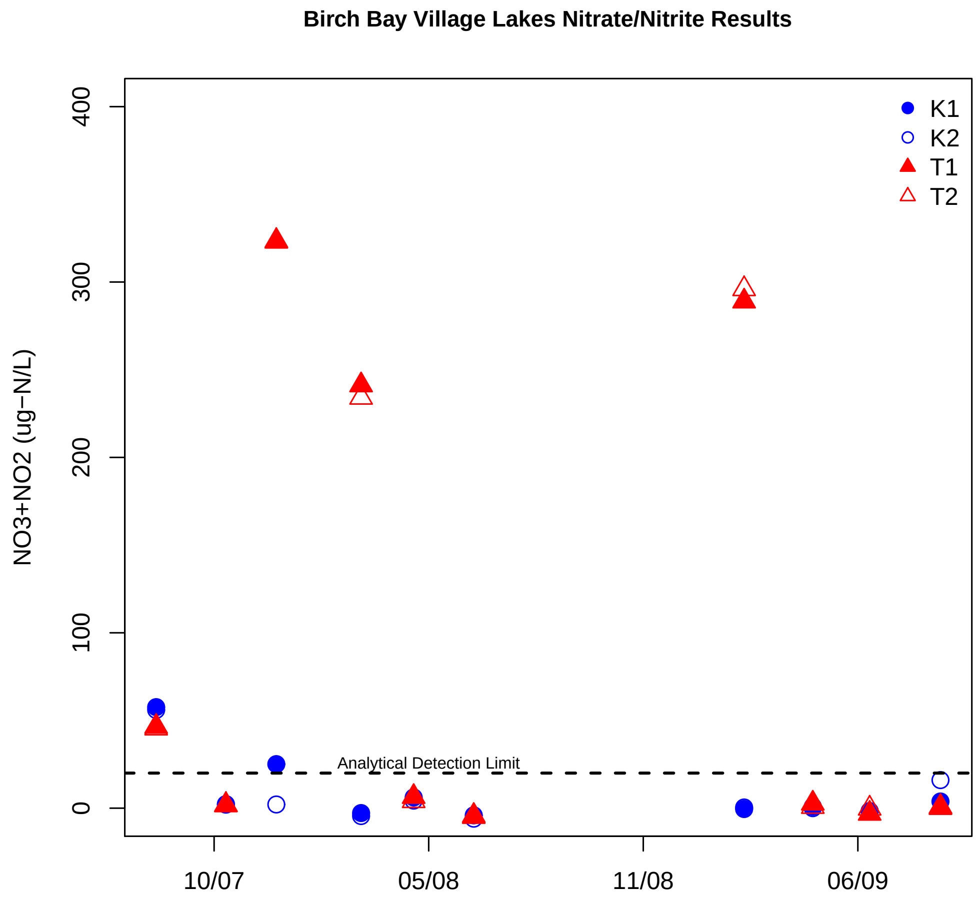

Figure 8: Nitrate concentrations were measured in the laboratory using surface water samples collected at 0.3 m. The results include both nitrate (NO_3) and nitrite (NO_2), which are normally measured in combination. Nitrate, along with nitrite and ammonium (Figure 9, page 12) are important nutrients for most algae, and when the concentrations of these nutrients are low, conditions favor the growth of cyanobacteria or bluegreen algae. (Cyanobacteria can use dissolved N_2, which is replenished from the atmosphere). Nitrate concentrations were usually very low, and often fell below the analytical detection limits (20 μg-N/L), indicating that conditions probably favored cyanobacteria growth most of the year. Thunderbird Lake had high nitrate concentrations during the winter, so Thunderbird Lake may support algae that are not cyanobacteria (e.g., diatoms) during the winter and early spring. This determination was beyond the scope of the monitoring project.

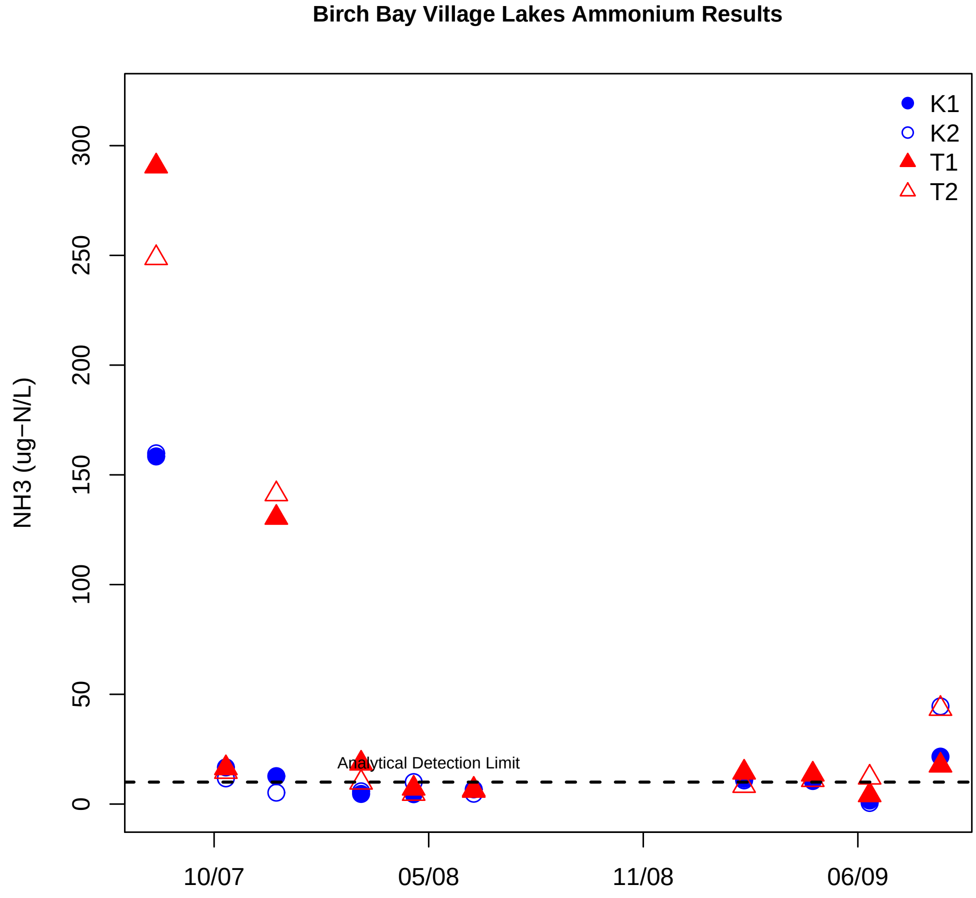

Figure 9: Ammonium concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Ammonium concentrations are usually very low in oxygenated water, and are typically associated with anaerobic lake sediments or other low oxygen environments. On most dates the ammonium concentrations were near the analytical detection limits (10 μg-N/L) at all sites. High concentrations of ammonium were present during August 2007 (all sites) and December 2007 (Thunderbird Lake sites). The August ammonium results probably reflect very high production of ammonium in the lake sediments combined with calm weather (minimal lake mixing), warm water temperatures, and relatively low oxygen levels (Figure 3, page 6). The December results from Thunderbird Lake do not fit with any obvious patterns in the other water quality data, and may represent a spill or runoff from a local source (e.g., septic overflow, fertilizer leaching, ammonium from marshy soils).

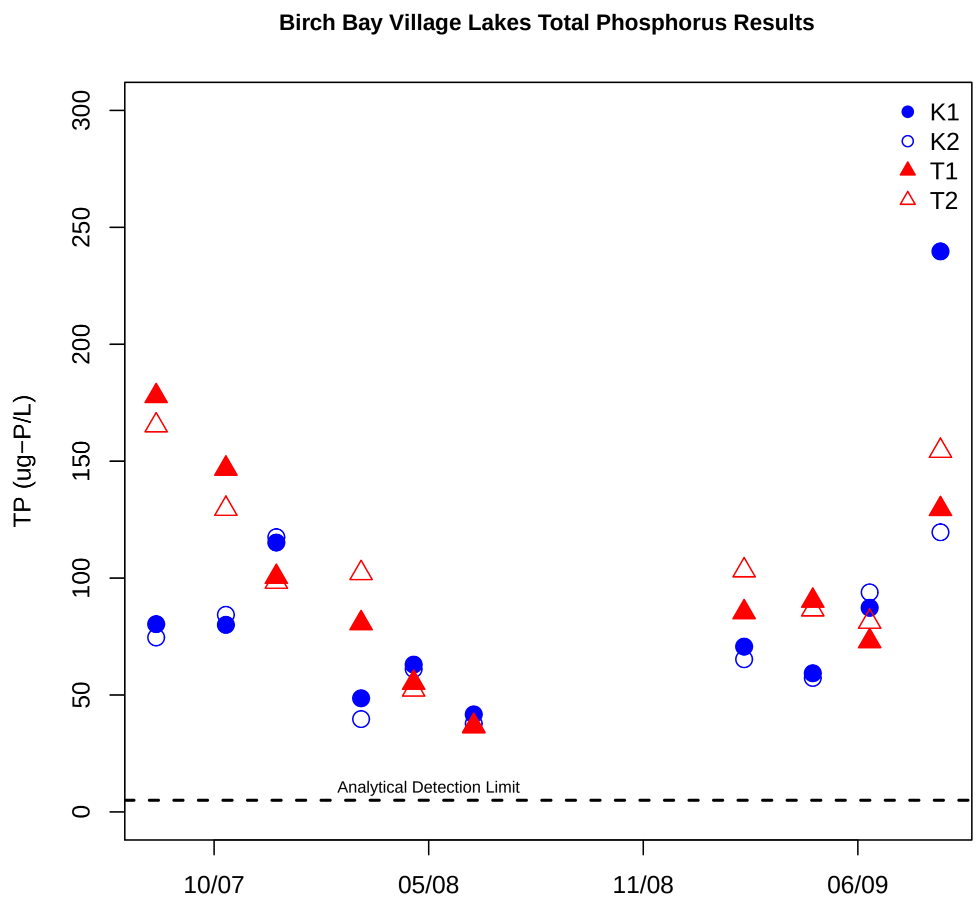

Figure 10: Total phosphorus concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Total phosphorus includes organic phosphorus (phosphorus associated with algae and other biota) and dissolved phosphate (primarily soluble or orthophosphate). Phosphorus is an important nutrient for algae, and is generally considered the nutrient that limits the amount of algae in a lake. The total phosphorus concentrations were very high on all sampling dates at nearly all sites ($\geq$35 μg-P/L), indicating that both lakes can support a large amount of algal biomass.

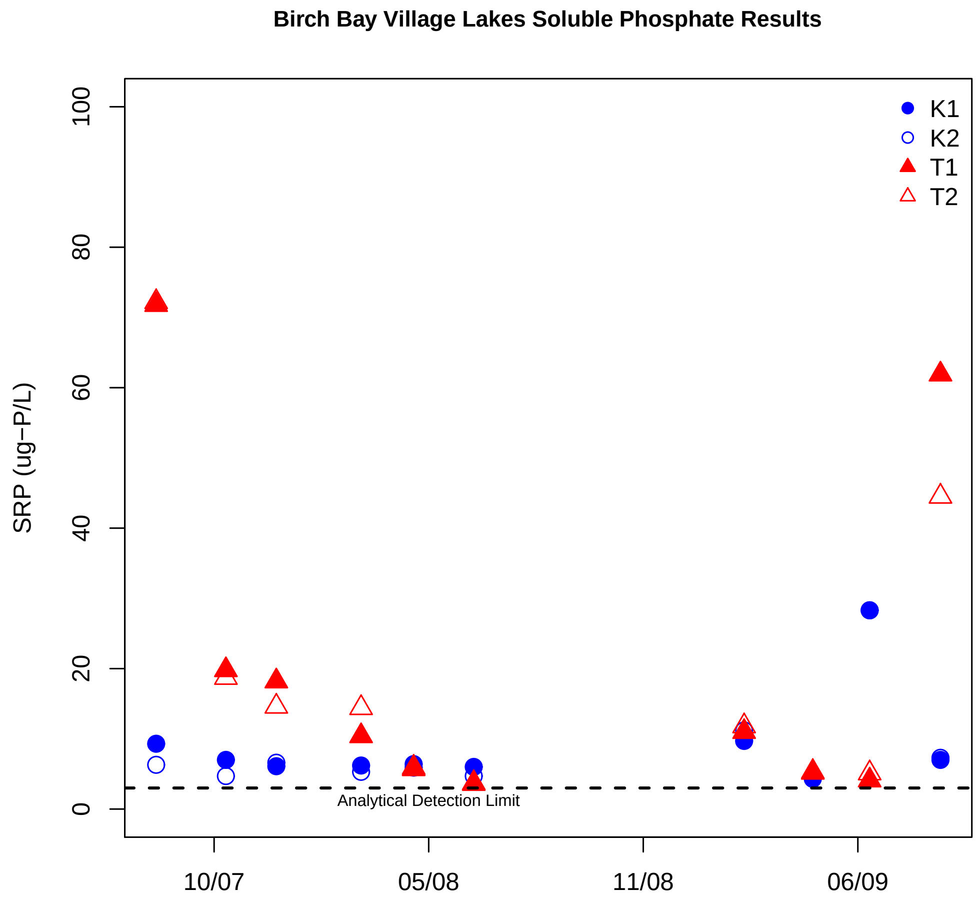

Figure 11: Soluble orthophosphate concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Soluble orthophosphate is quickly taken up by algae and other biota, so low concentrations in the water column do not always indicate that a lake will have low concentrations of algae. The phosphate that has been taken up by algae will be measured by the total phosphorus analysis but not the soluble phosphate analysis. Kwann and Thunderbird Lakes usually had moderately low soluble phosphate concentrations ($\leq$20 μg-P/L), but that amount of phosphorus is high enough to support algal growth. The soluble phosphate concentrations were often higher in Thunderbird Lake, and samples collected during August 2007 and 2009 exceeded 40 μg-P/L. By comparison, the two highest samples from Kwann Lake (June 2009) were $<$30 μg-P/L.

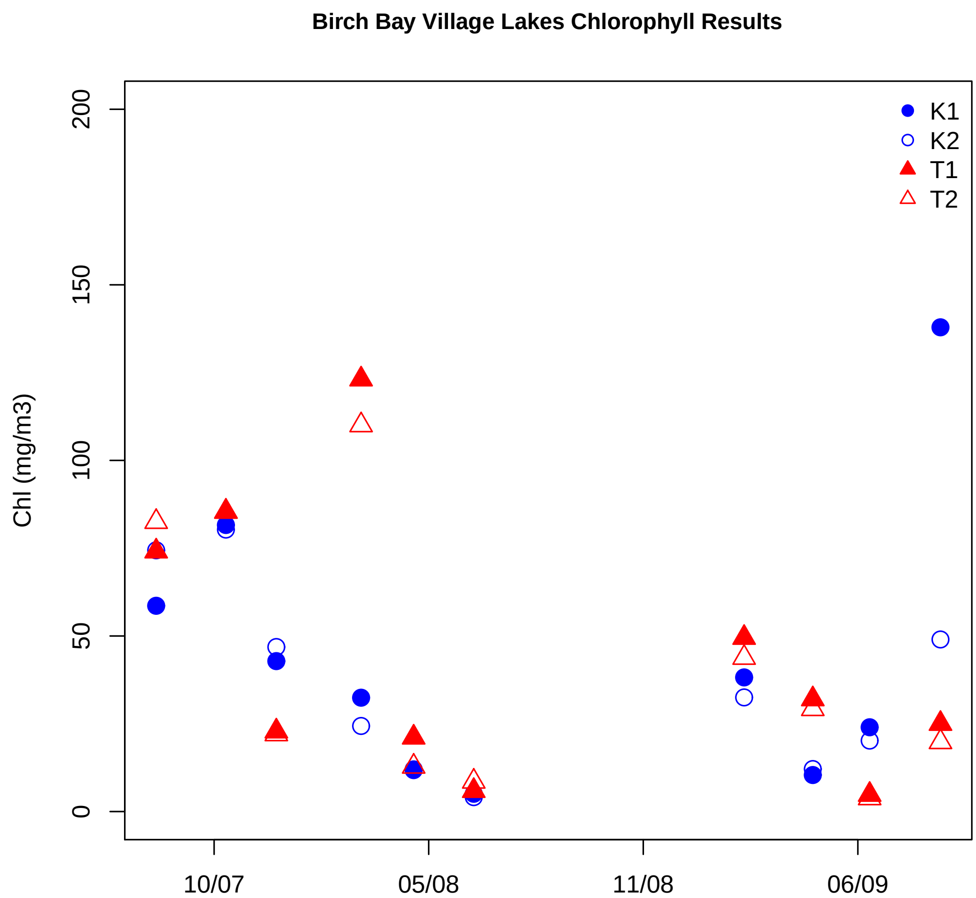

Figure 12: Chlorophyll concentrations were measured in the laboratory using surface water samples collected at 0.3 m. The highest chlorophyll concentrations were usually collected in August and October, when algal biomass often peaks (especially cyanobacteria biomass). Thunderbird Lake appeared to experience an algal bloom in February 2008. It is not unusual for lakes to experience winter or spring algal blooms, nor is it unusual for lakes in close proximity to have distinctly different algal blooms. Many species of diatoms and other chrysophytes are adapted to bloom quickly during winter and early spring. These types of algae require inorganic nitrogen (e.g., nitrate), which was abundant during February 2008 in Thunderbird Lake but not in Kwann Lake.

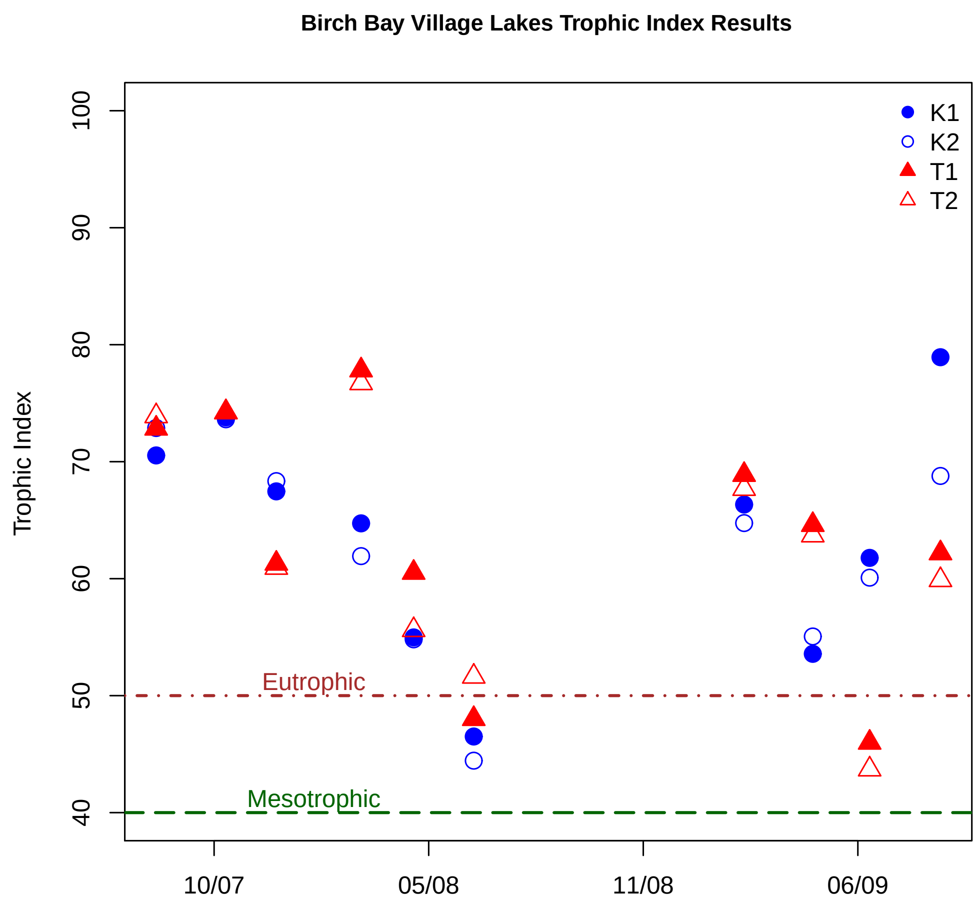

Figure 13: Carlson's Trophic State Index is a simple tool used to classify lakes based on the chlorophyll concentrations collected during the peak algal growth period (usually late summer and early fall). Lakes with low concentrations of chlorophyll are biologically unproductive or *oligotrophic* (TSI_{chl} <30); lakes that have high chlorophyll concentrations are biologically productive or *eutrophic* (TSI_{chl} >50); lakes that fall between these classifications are moderately productive or *mesotrophic* (TSI_{chl} 40–50) or *oligomesotrophic* (TSI_{chl} 30–40). Carlson's Index is calculated as: $TSI_{chl} = 9.81(\ln \mathrm{Chl}, \mu g/L) + 30.6$. Nearly all of the TSI values for Kwann and Thunderbird Lakes fell within the eutrophic range.

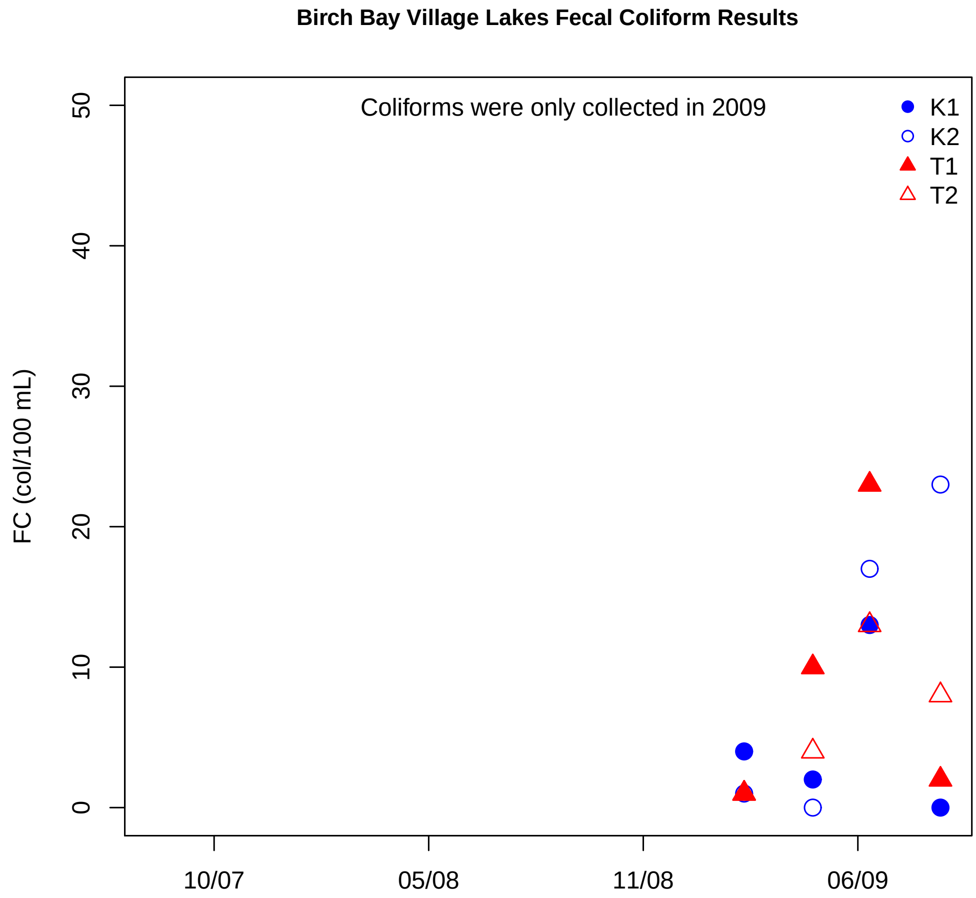

Figure 14: Fecal coliform counts were measured using surface water samples collected at 0.3 m. Fecal coliform bacteria are normally present in the intestinal tract of warm-blooded animals, and their presence in surface water is considered to be an indication that the water may be contaminated by fecal material from wildlife, domestic animals, or human sewage. All of the coliform counts were low ($\leq$25 cfu/100 mL); however, it is important to note that the samples were collected mid-basin, not in swimming areas.

A Water Quality Data

B Quality Control Data