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Birch Bay Village Lakes 2013 Final Report

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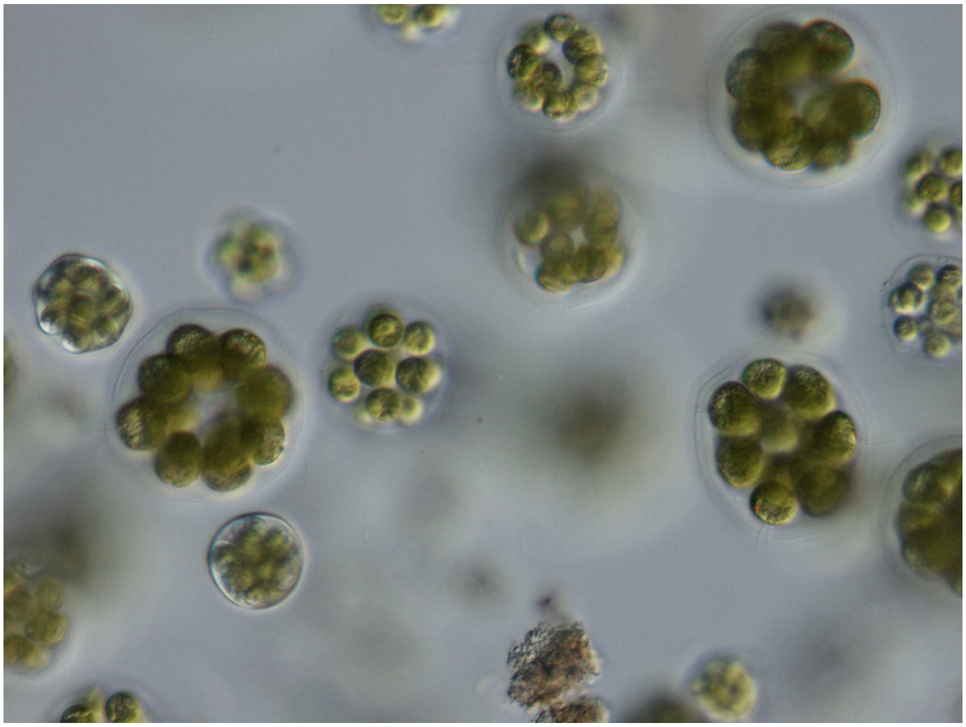

Birch Bay Village Lakes
2013 Final Report

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We thank Marilyn Desmul, Sean Cooper, and Thomas Craig for assistance with the project.

Contents

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 Kwan Lake and two sites in Thunderbird Lake (Figure 1, page 4). The sampling effort began in August 2007, and samples have been collected approximately 2–4 times each year through August 2013. This report provides an update to earlier data reports submitted to the Birch Bay Village Lakes Committee.

Water samples were collected on the following dates:

2007	2008	2009	2010	2011	2012	2013
Aug 21	Feb 28	Feb 19	Jul 14	Mar 10	Apr 30	Apr 22
Oct 25	Apr 17	Apr 24	Aug 11	Apr 14	Jul 31	Jul 17
Dec 11	Jun 12	Jun 16	Sep 16	Jun 28		
		Aug 21	Nov 17	Sep 22		

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 soluble phosphate), 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. Beginning in 2009, surface coliform samples were collected 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	#2320, titration	$\pm$0.5 mg $CaCO_3$/L
Chlorophyll	#10200 H, acetone extract, phaeophytin corrected	$\pm$0.1 μg/L
Conductivity	#2510, lab meter	$\pm$0.1 μS/cm
Dissolved oxygen - field	#4500-O G, membrane electrode (field meter)	$\pm$0.1 mg/L
Dissolved oxygen - lab	#4500-O C, Winkler with azide modification	$\pm$0.1 mg/L
Fecal coliforms[‡]	#9222 D, membrane filter	1 cfu/100 mL
Nitrogen - ammonium	#4500-NH3 H, flow injection, phenate	10 μg NH_3-N/L
Nitrogen - nitrate/nitrite	#4500-NO3 I, flow injection, Cd reduction	10 μg NO_3-N/L
Nitrogen - total	#4500-N C, flow injection, persulfate digest	20 μg N/L
pH - lab	#4500-H, electometric	$\pm$0.1 units
Phosphorus - soluble	#4500-P G, flow injection	3 μg PO_4-P/L
Phosphorus - total	#4500-P H, flow injection, persulfate digest	5 μg P/L
Temperature - field	#2550 thermistor (field meter)	$\pm$0.1 C
Turbidity	#2130, nephelometric	$\pm$0.2 NTU

[†]APHA, 2012. Standard Methods for the Examination of Water and Wastewater, 22nd 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

Each water quality parameter has been plotted with descriptive captions that discuss the general patterns in the data (Figures 2–16, pages 5–19). 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 the discussion, the figures are discussed in the following order:

- Figure 1: Sampling locations
- Figures 2–8: Physical structure of the lake (temperature, dissolved oxygen)
- Figures 6–8: Chemical structure of the lake (conductivity, pH, turbidity)
- Figures 9–13: Algal nutrients (nitrogen and phosphorus)
- Figures 14–15: Lake trophic state (chlorophyll and trophic index)
- Figure 16: Bacterial indicators (fecal coliforms)

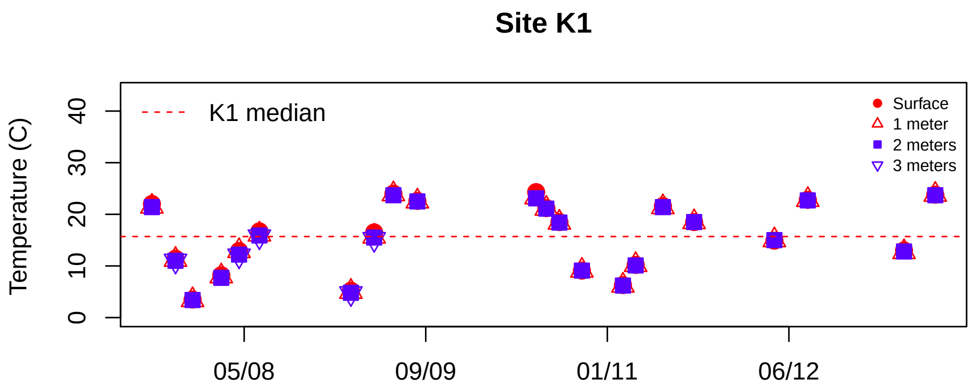
Ten percent of the water samples were collected in duplicate (field duplicates) to estimate variation between samples collected at the same location, depth, and time. Ten percent of all laboratory samples were measured in duplicate to estimate analytical variation for samples from the same bottle. Laboratory 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 water quality and quality control data are included in printed copies of this report (Appendix A). Online report copies do not include the printed data, but electronic copies of the data are available from the Institute for Watershed Studies.

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: Kwan Lake and Thunderbird Lake sampling sites.



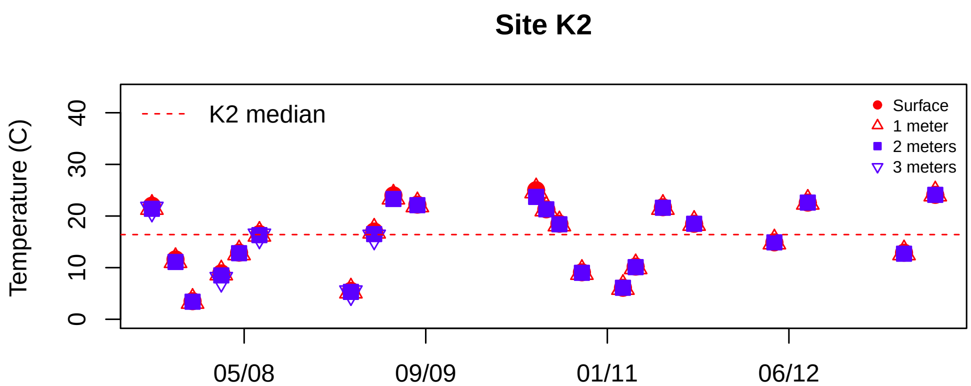
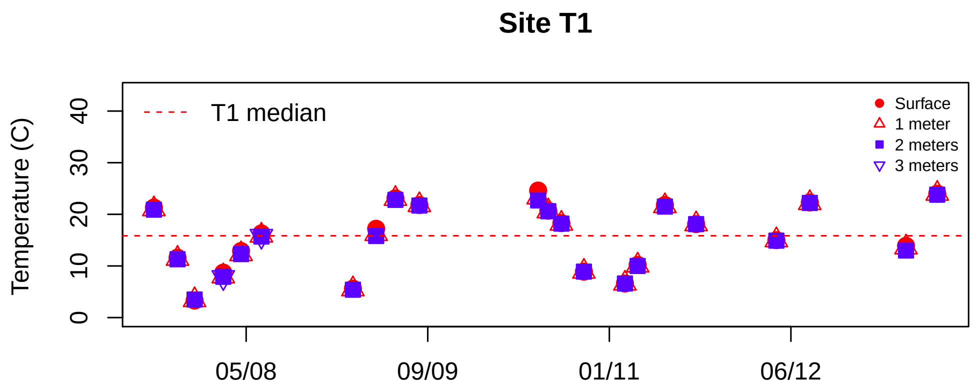


Figure 2: Temperature measurements were collected at the surface and at 1 meter intervals in Kwan Lake. All sites were shallow ($\leq$3 m), so the water column was thoroughly mixed on each sampling date, resulting in similar temperatures at all depths. Seasonal warming and cooling was evident; temperatures were warm during the summer and cold during the winter. The median water temperature was slightly cooler at K1 (15.7°C) compared to K2 (16.4°C).



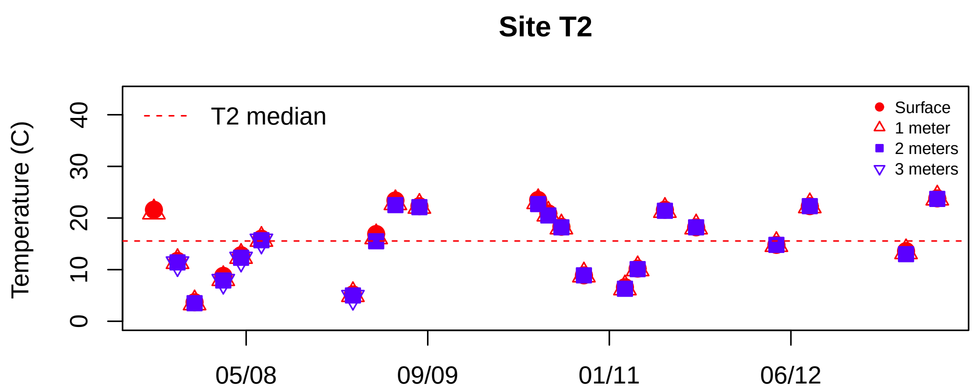


Figure 3: Temperature measurements were collected at the surface and at 1 meter intervals in Thunderbird Lake. All sites were shallow (≤3 m), so the water column was thoroughly mixed on each sampling date, resulting in similar temperatures at all depths. Seasonal warming and cooling was evident; temperatures were warm during the summer and cold during the winter. Both sites had similar median temperatures (T1 = 15.8°C; T2 = 15.6°C).

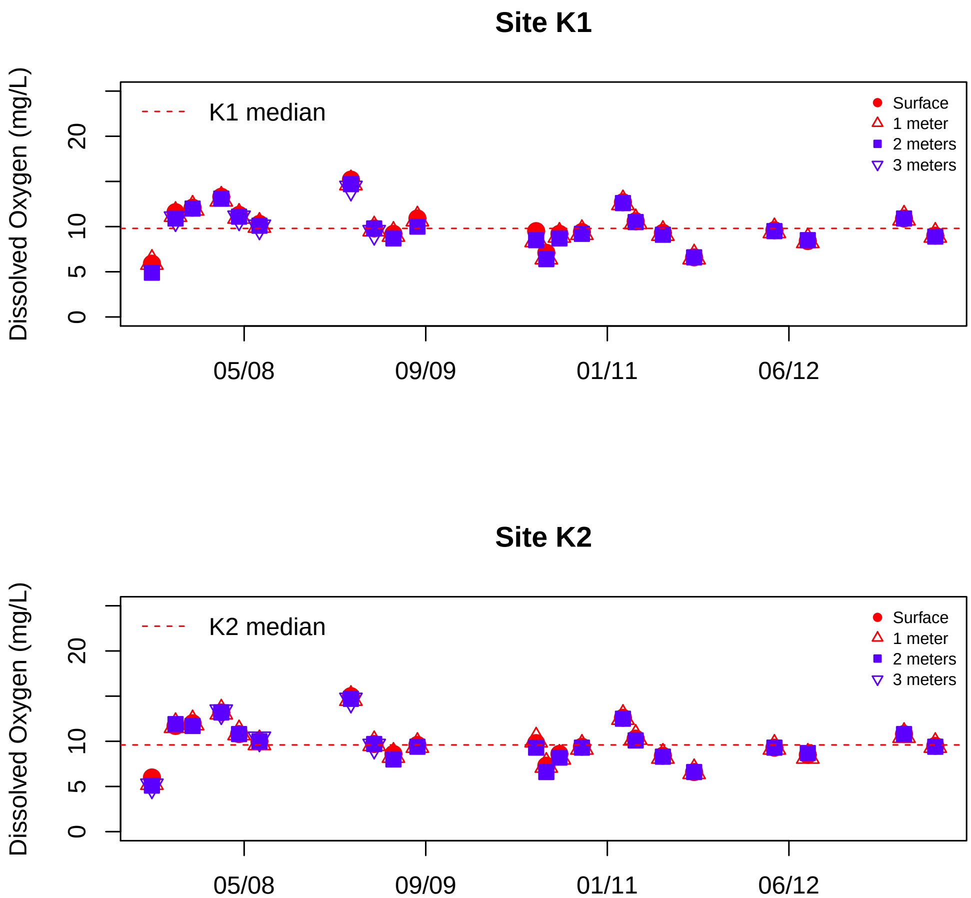


Figure 4: Dissolved oxygen measurements were collected at the surface and at 1 meter intervals in Kwan Lake. All sites were shallow ($\leq$3 m), and the lakes contain aerators that introduce oxygen into the water column, so oxygen concentrations were more or less similar at all depths. Higher oxygen 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 median dissolved oxygen levels were similar at both sites (K1 = 9.8 mg/L; K2 = 9.6 mg/L). Kwan Lake had slightly higher oxygen medians than Thunderbird Lake (Figure 5).

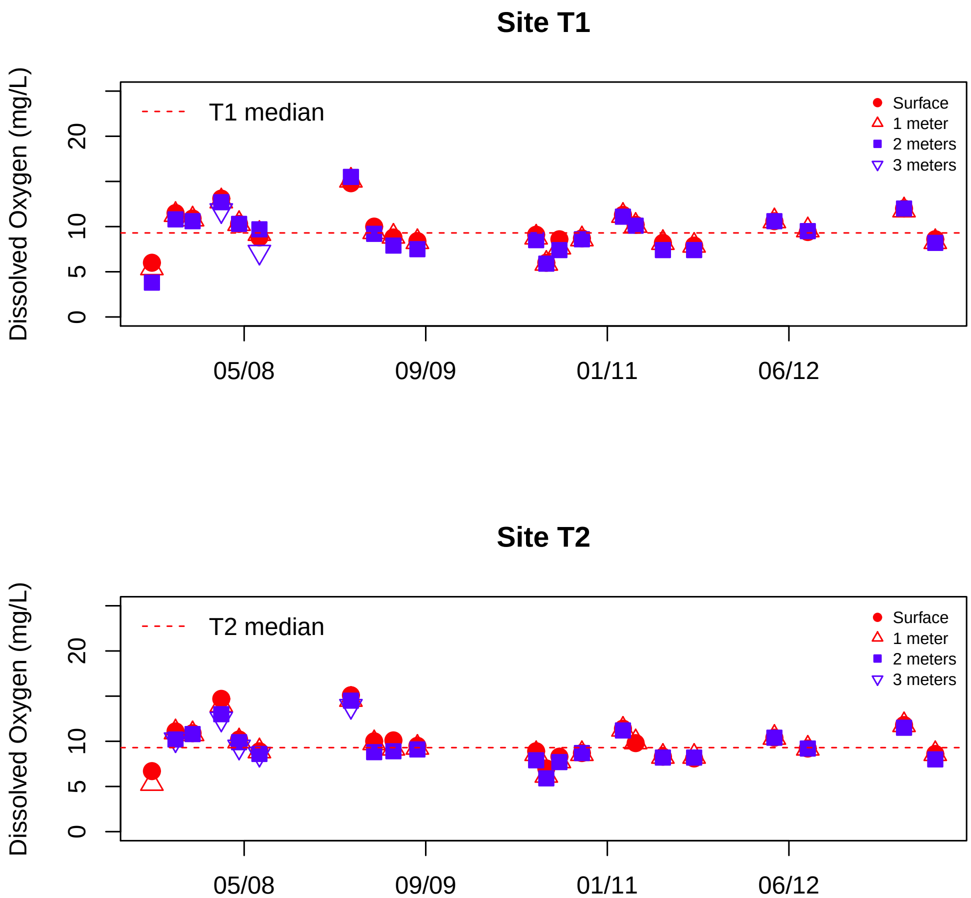


Figure 5: Dissolved oxygen measurements were collected at the surface and at 1 meter intervals in Thunderbird Lake. All sites were shallow (≤3 m), and the lakes contain aerators that introduce oxygen into the water column, so oxygen concentrations were more or less similar at all depths. Higher oxygen 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 median dissolved oxygen levels were the same at both sites (T1 and T2 = 9.3 mg/L). Thunderbird Lake had slightly lower oxygen medians than Kwan Lake (Figure 4).

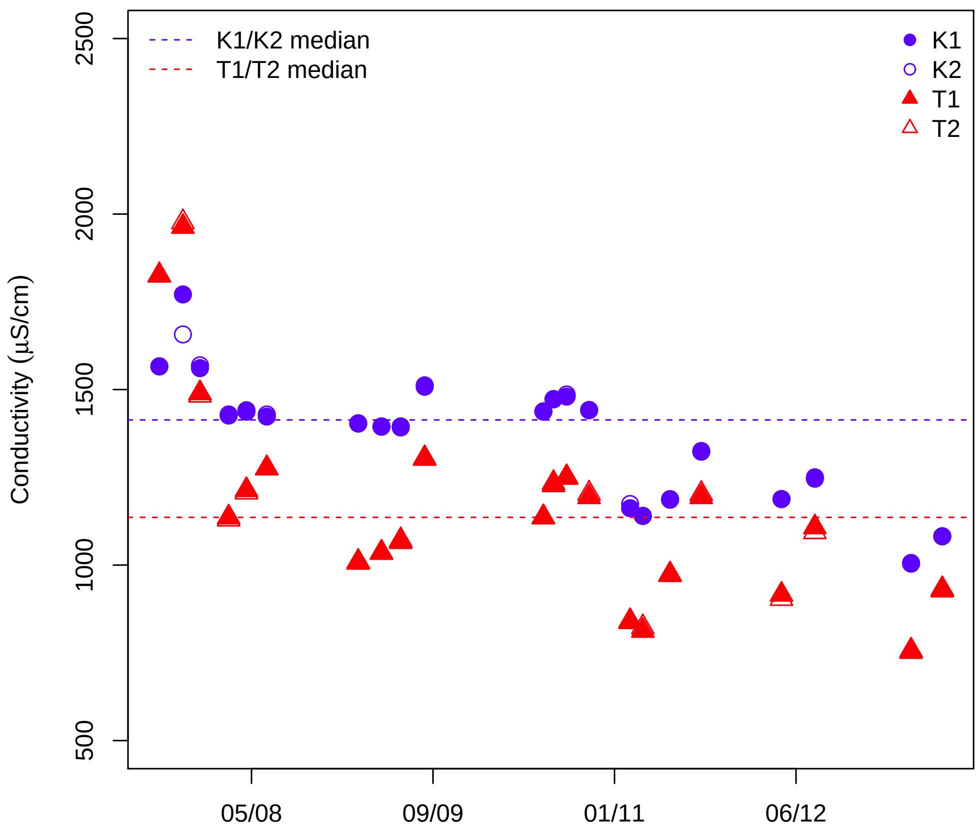


Figure 6: Conductivities were measured in the laboratory using surface water samples collected at 0.3 m. The Kwan Lake conductivity levels were relatively high for freshwater samples (median = 1414 μS/cm). Thunderbird Lake conductivities were slightly lower, but were still high for freshwater (median = 1136 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.

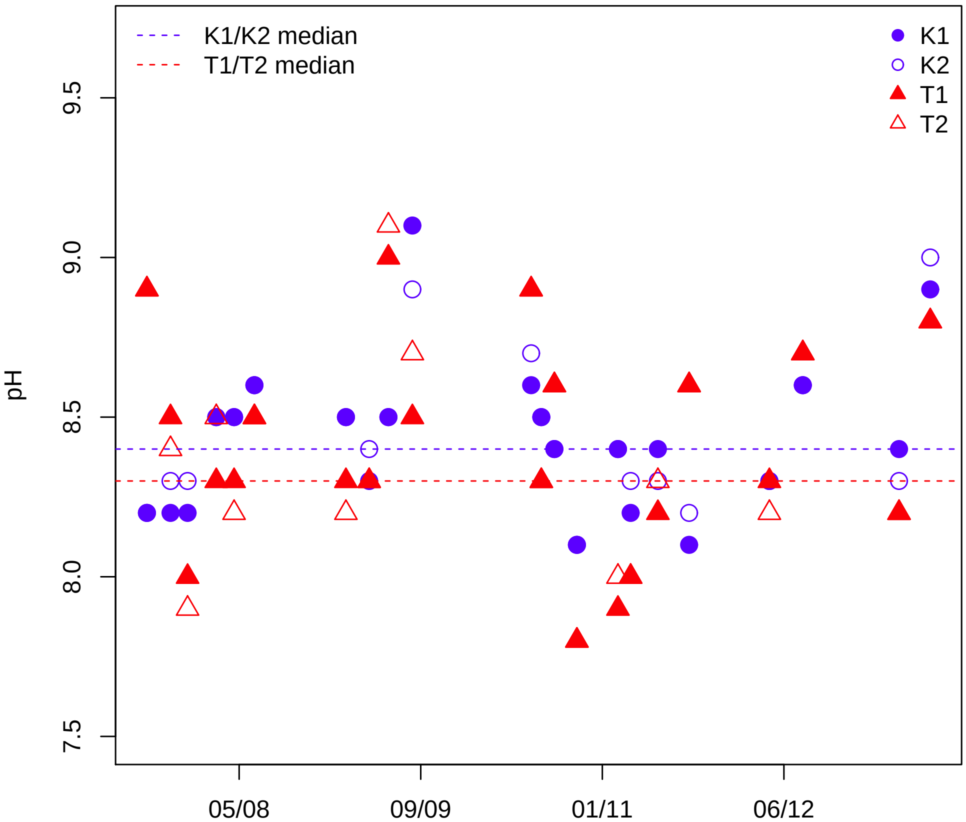


Figure 7: The pH levels were measured in the laboratory using surface water samples collected at 0.3 m. The median pH values at all sites were very similar (K1/K2 = 8.4; T1/T2 = 8.3). All pH levels were slightly alkaline (>7), and most were >8.0, which is typical for lakes with high conductivities and high algal concentrations (Figure 14, page 17)

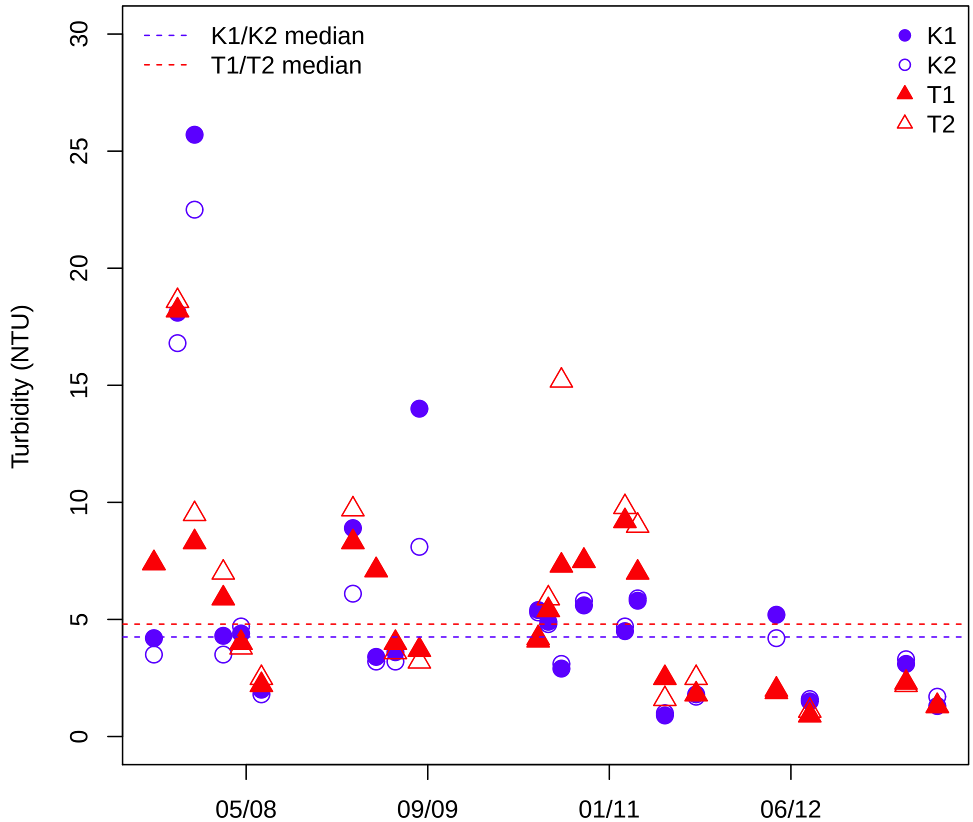


Figure 8: Turbidity values were measured in the laboratory using surface water samples collected at 0.3 m. Turbidity indicates the amount of suspended particles, including algae and other types of suspended sediments. The highest turbidity levels occurred in December 2007, probably due to storm events causing sediments to enter the lakes via surface runoff or from wind-related lake turbulence that resuspended lake bottom sediments. The median turbidity was slightly higher in Thunderbird Lake (4.8 NTU) compared to Kwan Lake (4.2 NTU).

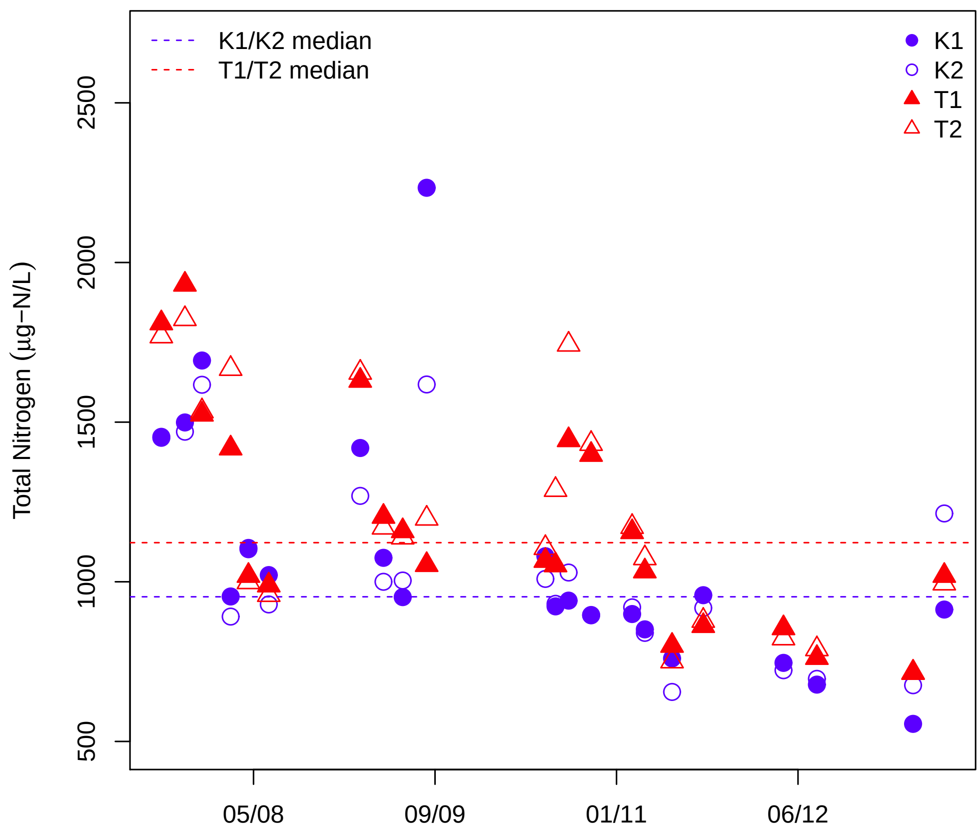


Figure 9: Total nitrogen concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Total nitrogen represents the combined concentrations of organic nitrogen (nitrogen associated with algae and other biota) and dissolved inorganic nitrogen (nitrate, nitrite, and ammonium). Usually, total nitrogen concentrations are similar to nitrate concentrations (Figure 10, page 13), 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 14–15, pages 17–18). The median total nitrogen concentration was higher in Thunderbird Lake (1122 μg-N/L) than in Kwan Lake (953 μg-N/L).

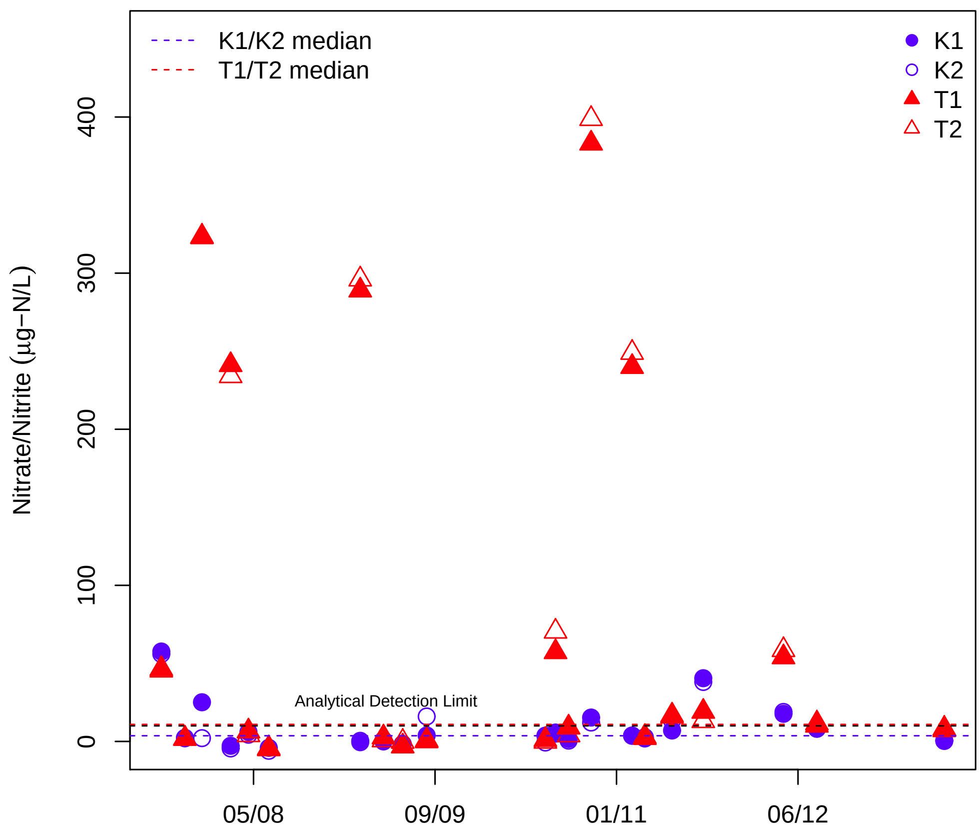


Figure 10: Nitrate concentrations were measured in the laboratory using surface water samples collected at 0.3 m. The results include both nitrate (NO_3) and nitrite (NO_2), which are normally measured in combination. Nitrate, along with nitrite and ammonium (Figure 11, page 14) are important nutrients 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. The median concentrations at both sites were below the analytical detection limits (10 μg-N/L), indicating that conditions favored cyanobacteria growth most of the year. Thunderbird Lake occasionally had high nitrate concentrations, usually during the winter, which might support algae blooms that are not dominated by cyanobacteria.

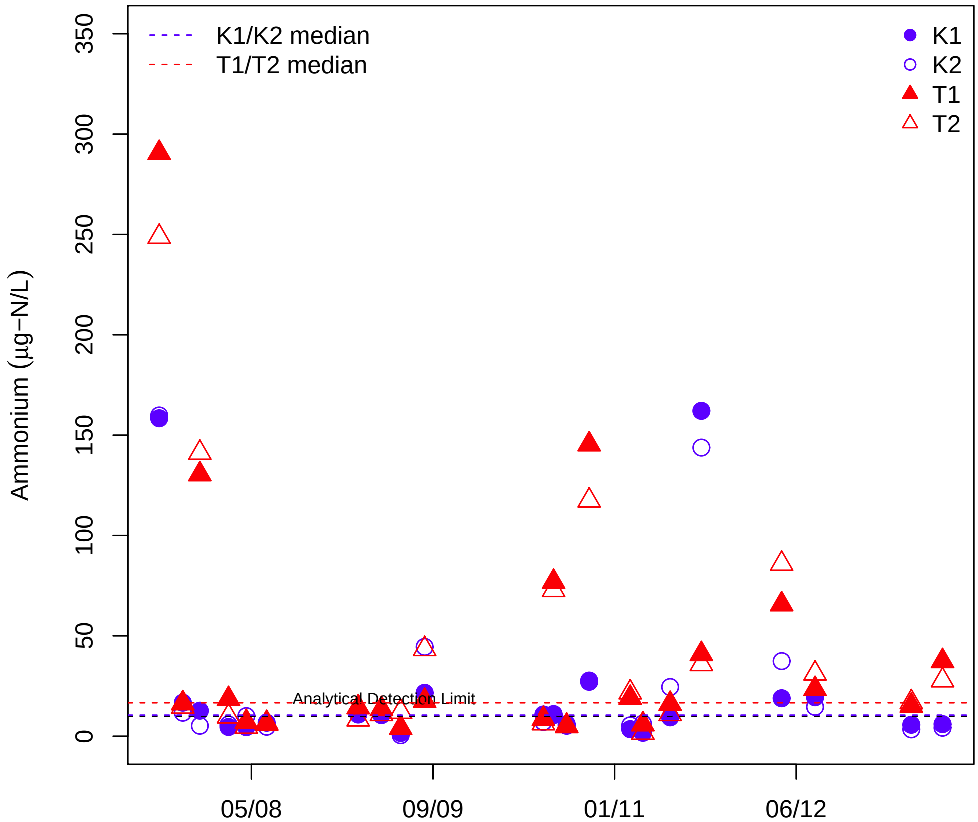


Figure 11: Ammonium concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Ammonium concentrations are usually very low in oxygenated water, and are typically associated with anaerobic lake sediments or other low oxygen environments. On most dates the ammonium concentrations were near the analytical detection limits (10 μg-N/L), and the median concentrations at both sites were near the detection limit (Kwan = 10.5 μg-N/L; Thunderbird = 16.6 μg-N/L). High concentrations of ammonium were occasionally detected in both lakes. There was no obvious pattern for the occasional ammonium peaks, but typical sources would include the lake sediments and runoff from a local source (e.g., septic overflow, fertilizer leaching, ammonium from marshy soils).

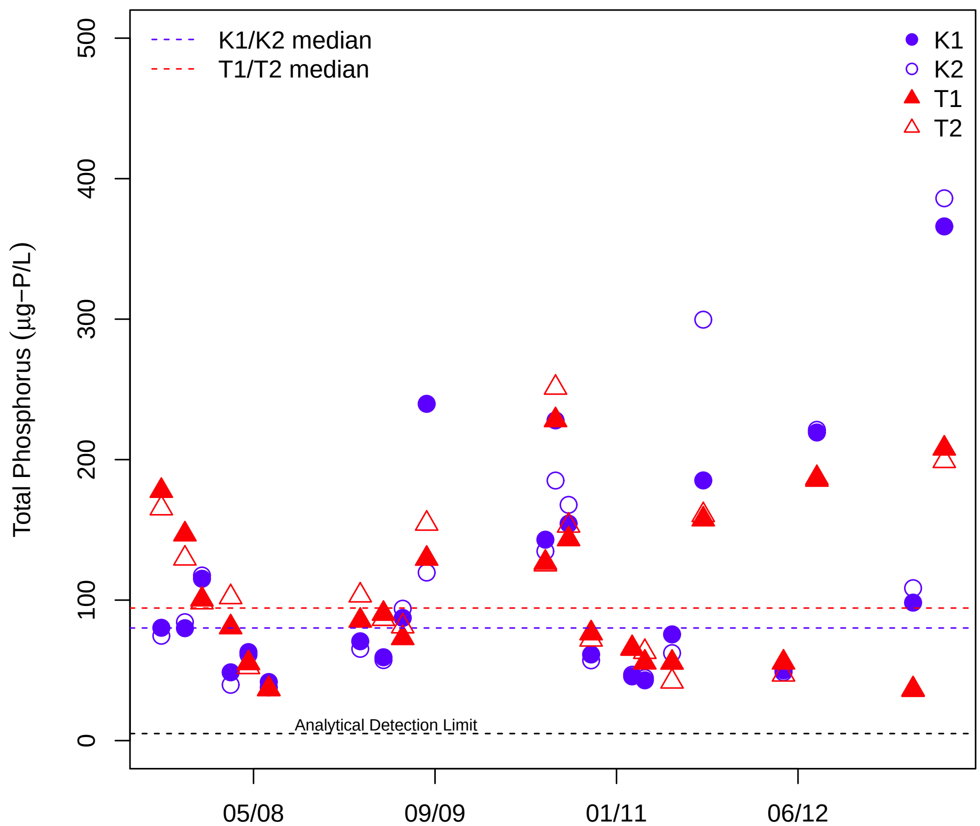


Figure 12: Total phosphorus concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Total phosphorus includes organic phosphorus (phosphorus associated with algae and other biota) and dissolved phosphate (primarily orthophosphate). Phosphorus is an important nutrient for algae, and is generally considered the nutrient that limits the amount of algae in a lake. Although the median total phosphorus concentration was slightly lower in Kwan Lake (80.2 μg-P/L) than Thunderbird Lake (94.4 μg-P/L), both lakes had relatively high concentrations on all sampling dates. This indicates that both lakes can support a large amount of algal biomass, which is consistent with the chlorophyll and trophic state results (Figures 14 and 15).

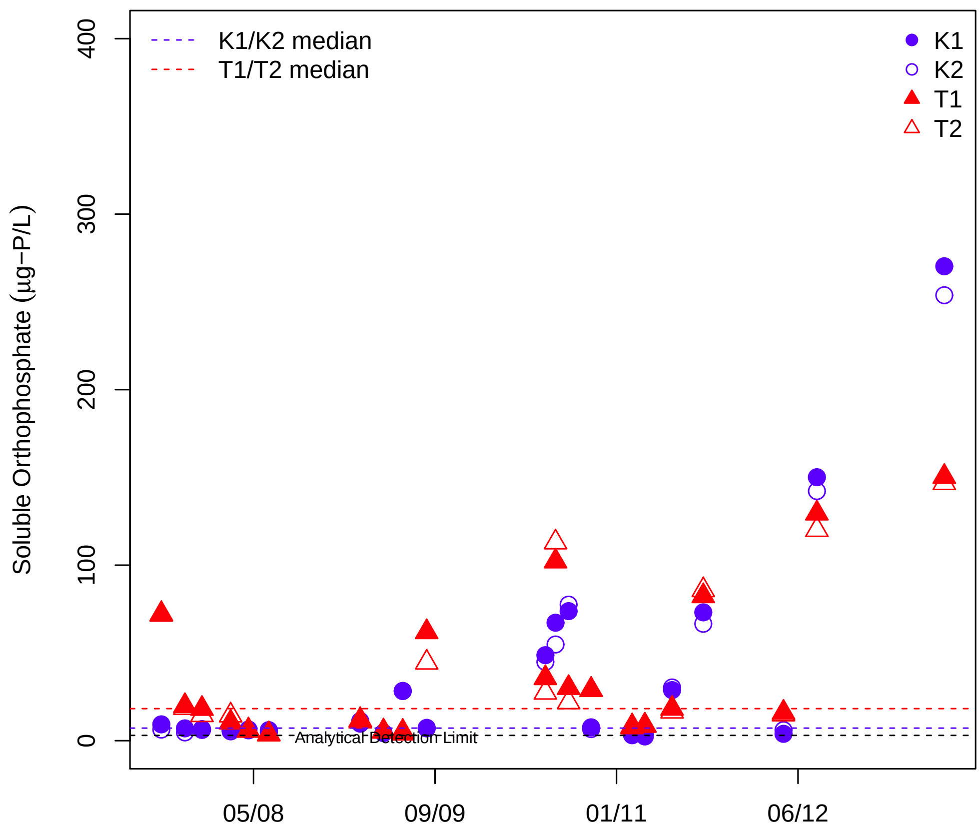


Figure 13: Soluble phosphate concentrations were measured in the laboratory using surface water samples collected at 0.3 m. Soluble phosphate is quickly taken up by algae and other biota, so low concentrations in the water column do not always indicate that a lake will have low concentrations of algae. The phosphate that has been taken up by algae will be measured by the total phosphorus analysis but not the soluble phosphate analysis. Although Kwan and Thunderbird Lakes had low median concentrations (7.2 and 18.2 μg-P/L, respectively), both had peaks exceeding 20 μg-P/L. When these peaks occur, large amounts of soluble phosphate are available to support algal growth.

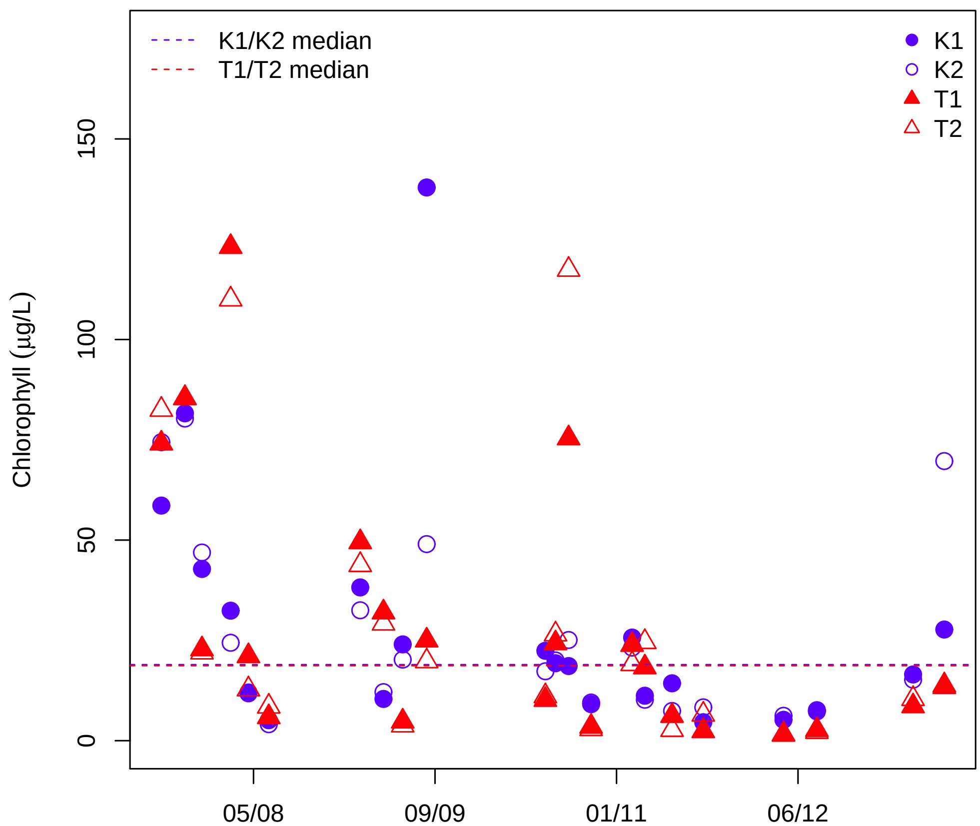


Figure 14: Chlorophyll concentrations were measured in the laboratory using surface water samples collected at 0.3 m. The highest chlorophyll concentrations were usually collected in late summer/early fall, when cyanobacteria biomass often peaks in local lakes. The 2007–2013 median chlorophyll concentrations were nearly the same for both lakes (Kwan = 19.0 μg/L; Thunderbird = 18.7 μg/L). Prior to 2010, both lakes had more frequent blooms and median chlorophyll concentrations were $>$20 μg/L. During the 2010–2013 sampling period the chlorophyll concentrations have been lower, with medians of 13.6 and 16.9 μg/L in Kwan and Thunderbird Lakes, respectively.

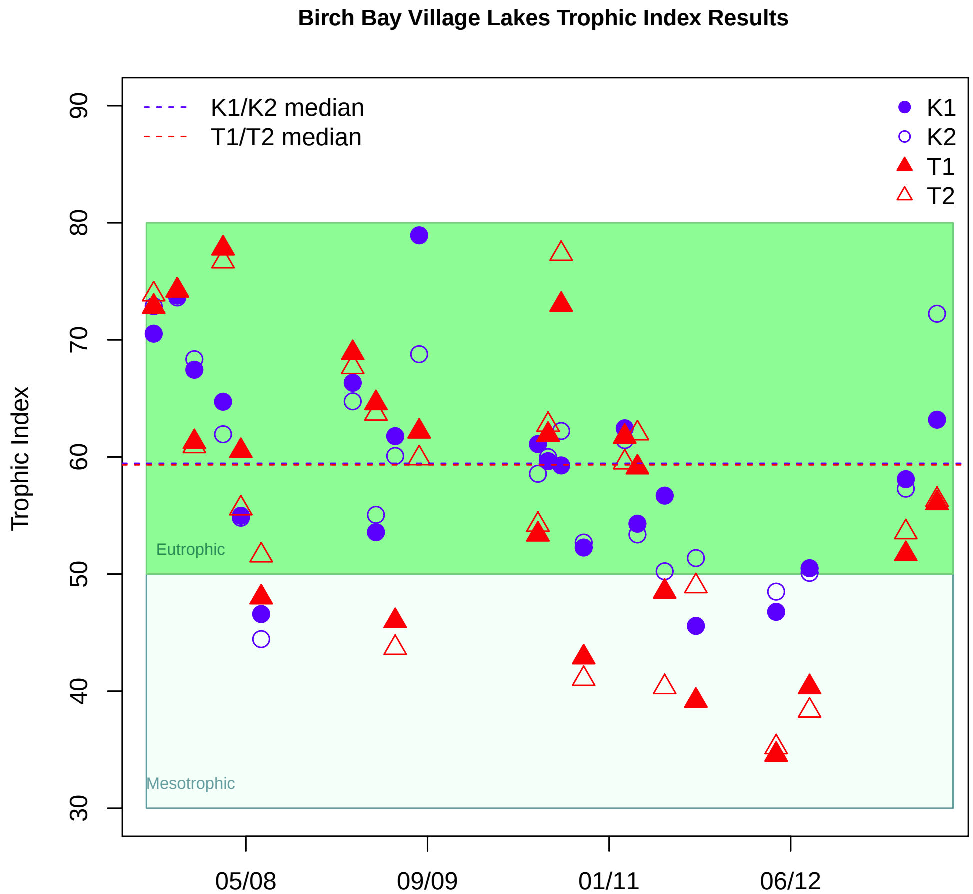


Figure 15: Carlson's Trophic State Index is used to classify lakes based on chlorophyll concentrations ($\mathrm{TSI}_{\mathrm{chl}} = 9.81(\ln \mathrm{Chl},\ \mu\mathrm{g/L}) + 30.6$). Lakes with low concentrations of chlorophyll are biologically unproductive (*oligotrophic*, $\mathrm{TSI}_{\mathrm{chl}}$ <30); lakes with high chlorophyll concentrations are biologically productive (*eutrophic*, $\mathrm{TSI}_{\mathrm{chl}}$ >50); lakes between these classifications are moderately productive (*mesotrophic*, $\mathrm{TSI}_{\mathrm{chl}}$ 30–50). Nearly all of the $\mathrm{TSI}_{\mathrm{chl}}$ values for Kwan and Thunderbird Lakes fell within the eutrophic range (Kwan median = 59.4; Thunderbird median = 59.3). Several recent samples had low $\mathrm{TSI}_{\mathrm{chl}}$ values, which may be an artifact of sampling when algae are beginning to die back in the fall and before the algae are established in the spring. Alternatively, it could indicate lower algae concentrations because the lake was treated with algicides (IWS does not maintain records of algicide application dates).

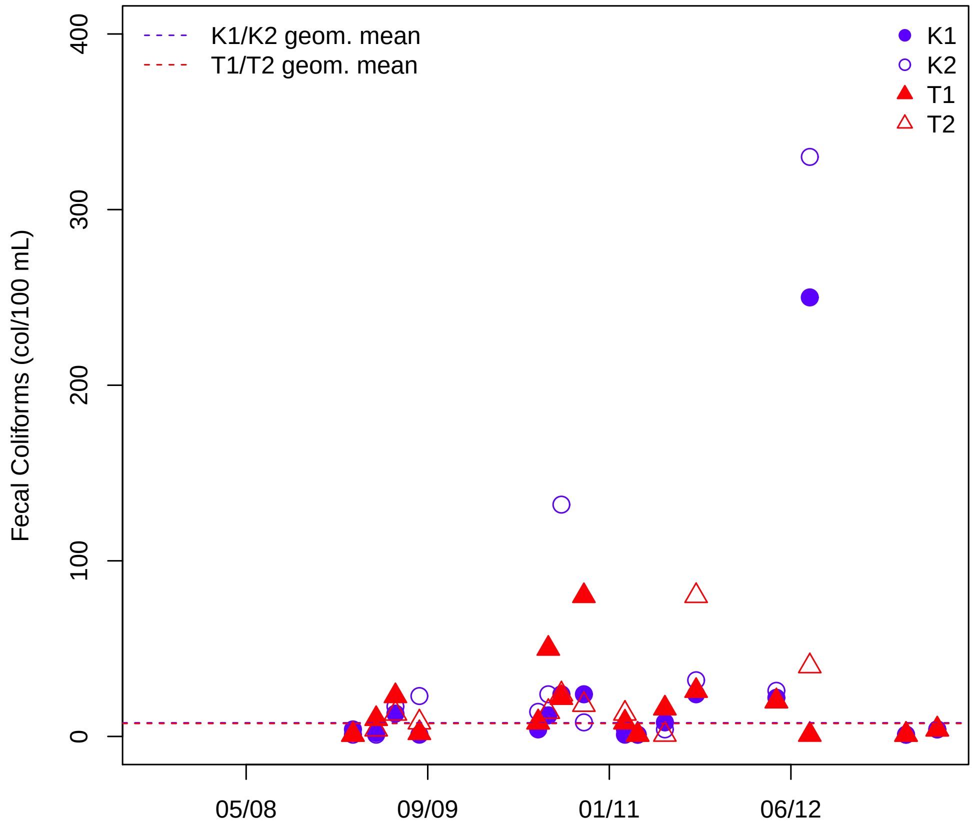


Figure 16: Fecal coliform counts were measured using surface water samples collected at 0.3 m. Fecal coliform bacteria are normally present in the intestinal tract of warm-blooded animals, and their presence in surface water is considered to be an indication that the water may be contaminated by fecal material from wildlife, domestic animals, or human sewage. Most of the coliform counts were low ($\leq$50 cfu/100 mL), and the geometric means* for both lakes were below 10 cfu/100 mL (Kwan geometric mean = 8 cfu/100 mL; Thunderbird geometric mean = 7 cfu/100 mL). It is important to note, however, that the samples were collected mid-basin, not in swimming areas.

*The geometric mean is the average of the $\log_{10}$ coliform values.

3 Comparison to Surface Water Quality Standards

The Washington State Department of Ecology has developed surface water quality criteria to ensure that a waterbody meets specific "designated use" standards.[2] In most cases, these standards are not directly applicable to the Kwan and Thunderbird Lakes, but the criteria are useful for determining whether there are water quality problems that might affect aquatic life or recreational use of the lakes. Table 2 lists the current surface water quality criteria compared to water quality in Kwan and Thunderbird Lakes.

	WAC–173–201A	K1	K2	T1	T2
Temperature (C)† (June - Sept maximum)	<16°C,	24.3 (n=34)	25.0 (n=35)	24.6 (n=34)	23.8 (n=33)
Dissolved oxygen (mg/L)† (1-day minimum)	>9.5 mg/L	4.9 (n=77)	5.1 (n=79)	3.8 (n=71)	5.3 (n=73)
pH† (range)	6.5–8.5	8.1–9.1 (n=22)	8.1–9.0 (n=22)	7.8–9.0 (n=22)	7.8–9.1 (n=22)
Fecal coliforms (cfu/100 mL)‡ (geometric mean)	<50 cfu/100 mL	6.6 (n=16)	9.2 (n=16)	7.4 (n=16)	7.3 (n=16)
Fecal coliforms (%)‡ (percent >100 cfu/100 mL)	<10%	6% (n=16)	13% (n=16)	0% (n=16)	0% (n=16)
Total phosphorus (μg-P/L)§ (June - Sept mean)	>20 μg-P/L	165 (n=11)	162 (n=11)	138 (n=11)	141 (n=11)

† Based on summer salmonid habitat requirements
‡ Based on extraordinary primary contact recreation (swimming)
§ Based on level that may initiate a lake study

Table 2: Comparison of water quality in Kwan and Thunderbird Lakes to WAC–173–201A–200 criteria.

[2] WAC–173–201A–200, Table 200 (1)(c), http://www.ecy.wa.gov/programs/wq/swqs/criteria.html, downloaded June 29, 2011.

The results from Kwan and Thunderbird Lakes indicate that the lake temperatures are probably too high, the dissolved oxygen levels too low, and the pH levels too high to sustain a healthy salmonid population, even if the salmonids are not reared in the lake. The data are from the mid-basin portions of the lake, so it is possible that there are some regions in the lakes that fit more closely to the habitat needs for salmonids, but this assessment was beyond the scope of our study.

Most of the fecal coliform counts were low enough to meet the basic criteria for recreational contact (e.g., swimming and boating). But, as stated earlier, we collected mid-basin samples and sampled only 3–4 times each year. If the lakes are used for swimming, we recommend following the WAC–173–201A sampling guidelines, which include averaging the counts by season, collecting at least five samples per season, and sampling from the swimming beaches.

The total phosphorus concentrations in both lakes was above the “action level” described in WAC–173–201A. This action level is used by the state to identify lakes that may be impacted by high phosphorus levels and should be considered for a more extensive water quality assessment. The phosphorus action level does not indicate a specific human health threat or threat to aquatic life, but it does identify lakes that are likely to have high chlorophyll concentrations and algal blooms.

A Water Quality and Quality Control Data