Comparing the Dissolved Oxygen, Nutrient Levels, Macroinvertebrates, and Chlorophyll A Levels of Burt Lake and Douglas Lake

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Abstract

Lakes attract humans, inevitably causing development along lake shores. It is important to know how development is affecting the ecosystems of these lakes. To test the effects of human development, we compared the nutrient levels, chlorophyll A and amount of macroinvertebrates in two northern Michigan lakes, Douglas Lake and Burt Lake. Burt Lake has almost twice as many residences per mile of shoreline than Douglas Lake. We sampled dissolved oxygen, nutrient levels (phosphorus and nitrogen), macroinvertebrates, and chlorophyll A from two sites in undeveloped areas of each lake, two in developed areas of each lake, and two in the middle of each lake with three samples at differing depths. We also measured dissolved oxygen in each area and sites had a constant temperature. We hypothesized that Burt Lake would have higher levels of nitrogen, phosphorous, and chlorophyll A because of nutrient runoff and that Douglas Lake would have a higher proportion of Ephemeroptera, Plecoptera, and Trichoptera insect orders and higher Dissolved Oxygen levels. We found that there was a significantly higher amount of total phosphorous in Burt Lake, while the dissolved oxygen was only higher in Douglas Lake in the undeveloped areas. There was no significant difference in the amount of soluble reactive phosphorous or nitrogen between the two lakes. Though no significant difference was found in EPT proportions, Douglas Lake had slightly higher proportions than Burt Lake in both developed and undeveloped areas. Nutrient runoff in each lake could be higher later in the summer because of increased use of lawn fertilizers and general human activity on the lakes. Many of the findings showed the overall water quality to be slightly better in Douglas Lake than in Burt Lake.

Introduction

Anthropogenic development and changes near freshwater lakes undoubtedly affects freshwater ecosystems (Capuzzo 2008). As residences and businesses along shorelines become more common, it is important to understand what these effects are in order to avoid causing harm to these delicate ecosystems. A study of two freshwater lakes in New Zealand showed that nutrient runoff caused by humans affected algae levels by increasing their productivity in terms of how quickly the algae levels increased in biomass (Downs et al. 2007). These lakes had similar nutrient inputs, though development on one lake began in the 1960s, while development on the other did not begin until 1990 (2007). The addition of excess nutrients into an aquatic system is called eutrophication, which can result in excessive plant growth and algal blooms (USGS Eutrophication 2008). Eutrophication causes algae to die and decompose, leading to decreased levels in dissolved oxygen (DO) and causing other organisms such as macroinvertebrates to die off (2008). Carpenter et al. (1998) showed that there was a positive relationship between increased water nutrients and other adverse effects. Increased water nutrient levels caused decreased aquatic oxygen levels, less biodiversity, and fish kills (Carpenter et al. 1998). In addition to harming aquatic ecosystems, nutrient enrichment was found to impair the water for drinking purposes (Carpenter et al. 1998). Nitrogen and phosphorus are two major nutrients that researchers study regarding water quality (Oregon State). Nitrogen is a fundamental component of proteins, amino acids, and living cells (Oregon State). There are three major nitrogen type forms that are utilized by algae: ammonia, nitrate, and nitrogen gas. Phosphorus is typically scarce in the aquatic environment and the only source of bioavailable phosphorus is known as soluble reactive phosphorus, or SRP (Oregon State).

Many previous studies used macroinvertebrates to assess water quality (Lenat 1988; Rose et al. 2008; Lovett et al. 2009). Macroinvertebrates are ideal organisms to study because they are a vital part of the food chain of aquatic systems and can be used to estimate relative ecosystem health (Bode and Novak 1995). Measuring the percentage of morphotypes within the Ephemeroptera, Plecoptera and Trichoptera (EPT) insect orders out of the total macroinvertebrate morphotypes is one procedure that is used to assess water quality by the Environmental Protection Agency (EPA BMP 2006). Lenat (1984) conducted a study which showed that the water systems with higher levels of nutrients contained the smallest percentage of EPT. A higher EPT percentage generally indicates a higher water quality (EPA BMP 2006).

Institutions such as the U.S. Environmental Protection Agency (EPA DO & Biochem 2006) use measurements of chlorophyll A as a standard mechanism for analyzing water quality. Chlorophyll A is a major component in algae, which grows well in warm waters (Fang and Stefan 1999). Chlorophyll A is a good indicator of algal biomass; therefore, by measuring chlorophyll A, researchers are able to evaluate potential eutrophication of a system (Smith et al. 1999). Consistently high levels of chlorophyll A in a system are an indicator of potential eutrophication, which is harmful to aquatic organisms (1999).

In Northern Michigan, Douglas and Burt Lakes are ideal places to quantitatively measure and analyze the effect that human development has on different aspects of water quality. Douglas Lake is predominately untouched by anthropogenic influences and has roughly 22 residences per mile of shore. Burt Lake (less than two miles away at the closest points) is more developed, with an average of 40 residences per mile of coast (Monaghan 2008). Although Burt Lake has an average depth of 12 meters in comparison to Douglas Lake's average depth of five and a half meters, Douglas Lake is deeper in the middle (Gold 1972). Also, Douglas Lake has seven depressions that can reach 27 meters deep (Gold 1972). In 2008, an experiment was conducted to evaluate how lake shore development affects fish communities in the two lakes, but no studies from the University of Michigan Biological Station (UMBS) currently exist comparing the water quality of the two lakes using nutrient levels, EPT percentage, and chlorophyll A levels (Dengate et al. 2008). Further experimentation needs to be conducted in order to know what other effects human development has on freshwater lakes, as increased lake shore development is causing undeveloped lakes to become scarcer, which could be detrimental to water quality around lakes with high anthropogenic influences.

Our objective for this experiment was to compare the water quality between Burt Lake and Douglas Lake using measurements of DO, nutrient levels, EPT proportion, and chlorophyll A levels. We developed two hypotheses. We hypothesized that if Burt Lake is of a lesser water quality than Douglas Lake, Burt Lake will have higher amounts of nutrients such as phosphorus and nitrogen and will also have increased amounts of chlorophyll A. Next, we hypothesized that if Burt Lake has a lower water quality compared to Douglas Lake, Burt Lake will have lower DO levels and a smaller EPT percentage. We predicted that nutrient levels at different depths would be approximately equivalent in both lakes. By testing levels of SRP, total phosphorus, and total nitrogen, we were able to see whether or not anthropogenic development has a significant impact on the amount of nutrients present in the water. If nutrient levels are significantly higher in Burt Lake, we predicted that it may cause more algal blooms and therefore more chlorophyll A and lower DO. The decreased amount of DO would then lead to a lower proportion of EPT.

Materials and Methods

Burt and Douglas Lake are both located in Cheboygan County, MI. They are located in a temperate forest region and the average temperature for Burt Lake and Douglas Lake in June is 19°C and 18°C, respectively (Climate). We sampled at two undeveloped, two developed, and two deep areas of each lake. All undeveloped and developed areas were approximately one and a half to three meters deep. All of the tests that were run for our experiment lack natural controls due to the comparative nature of our study. For all portions of the study, we tried to sample areas with similar temperatures.

Dissolved Oxygen

When sampling, finding areas of the lake with similar temperatures was extremely crucial because greater amounts of DO exist in cold water than warm water. We measured DO levels at each sampling site (YSI 55; EPA DO & Biochem 2006).

Chemical Analyses

Twice a year, once in the fall and once in the spring, most freshwater lakes in temperate zones go through a process called overturning, evenly distributing the oxygen, nutrient, and toxicant levels throughout the lake (Molles 2008). Both Burt Lake and Douglas Lake go through lake turnover. During this time, nutrient levels should be relatively even at different depths within Burt Lake and Douglas Lake (Gold 1972). However, after a short period of overturning, stratification occurs (Molles 2008). Different depths of the lake were measured to accurately represent nutrient levels throughout each lake. We used all the original study sites.

Before any samples were taken, acid-washed sampling vials were rinsed in the lake. At the shoreline sites, a 250mL acid-washed vial was submerged in water. The cap was then tightened while still submerged (Grant, pers. comm.). All samples were immediately placed into a cooler; this procedure was done three times at each site.

At the deeper areas of the lake, it was not feasible to just submerge the sampling vials in water. Therefore, a Van Dorn Sampler was used in order to collect samples at different depths (Harter and Rollins 2008). A depth meter was used to determine sampling points for deep areas in Douglas Lake (Eagle Ultra II). However, a depth meter was not used at Burt Lake; rather, we made markings on the Van Dorn cord and measured how deep each sample was taken using a meter stick back in the classroom. At each site in the deeper areas, one sample was taken from the surface, middle, and bottom of the lake. In Douglas Lake, measurements were taken at surface level, 11 m, and 21m deep.

Since Burt Lake is shallower than Douglas Lake, measurements were taken at the surface, two and a half meters, and five meters. Water from the Van Dorn Sampler was then transferred into the 250mL acid-washed sampler containers. These samples were placed into a cooler as quickly as possible. The samples were taken to the UMBS Wet lab for nutrient level analysis.

In order to determine whether or not Burt Lake truly has different nutrient concentrations, the amounts of soluble reactive phosphorous levels (SRP), total phosphorous, and total nitrogen levels were compared to those of Douglas Lake. We measured SRP to see how much phosphorus could be used by aquatic plant life (Grant, pers. comm.). In addition to SRP we tested for total phosphorus which may potentially indicate greater nutrient inputs into Burt Lake. Although ammonium or nitrate levels may vary at a given location the overall nitrogen level should stay fairly consistent (Grant, pers. comm.); therefore we took the measurements of total nitrogen rather than its different forms. The UMBS Wet lab used standard techniques to assess chemical levels (American Public Health Association 1998).

Ephemeroptera, Plecoptera, and Trichoptera (EPT)

For this section of the experiment, the original sampling sites were used; however, we did not sample at the deeper sites. EPT are most commonly sampled from shallow streams or rivers, so sampling for EPT was only done in shallow areas of the lake near shorelines (Lenat 1988; Rose et al. 2008; Lovett et al. 2009). Before beginning, some rocks at the bottom were overturned in case some macroinvertebrates were residing there. In order to collect macroinvertebrates from the water, the sweep netting technique was utilized (Humphries et al. 1998). We collected the samples from each site, placed them in non-acid-washed vials and calculated all of our EPT morphotypes in the classroom. In order to determine the population proportion, the total EPT morphotypes were counted and divided by the total amount of macroinvertebrates in the sample (EPA BMP 2006; Triplehorn and Johnson 2005).

Chlorophyll A test

In order to test for amounts of Chlorophyll A in the algae, the original sampling sites were used except for the deep areas (Carlson and Simpson 1996). At each site, two samples of chlorophyll A were taken at one and a half to three meter depths; because areas near the shoreline generally have a warmer water temperature, it provides a more conducive environment for algal growth (Fang and Stefan 1999). After every filtration, the sample was wrapped in aluminum foil and placed into the cooler. The samples were then taken to the UMBS Wet lab for analysis of chlorophyll A levels. All samples that were taken from the undeveloped areas in Burt Lake were lost so we were not able to obtain that set of data.

Data Analysis

Before combining the data for each lake, one-way ANOVA tests were performed to determine whether there were significant differences between the different areas of the lakes. Where significant differences were found, the data was not combined for the lakes as a whole. Where significant differences were not found, the data for all the sites was combined to compare the two lakes as a whole.

We compared the DO levels between corresponding locations at the two lakes using a paired t-test (n=4). Next, we ran independent samples t-tests to analyze both the nutrient (n=12) and chlorophyll A levels (n=8) between the lakes. This test compared the mean amount of nutrients and chlorophyll A at each of the corresponding sites between the two lakes. An ANOVA was used in order to determine whether depth caused a significant difference in nutrient levels. The question regarding the EPT method was tested using a t-test and compared the percent EPT at each of the corresponding sites between the two lakes (n=8).

Results

Dissolved Oxygen

Though we predicted DO to be the same in all areas of each lake, we found the amount of DO to vary greatly between the different sampling areas in each lake. Between the undeveloped sites in each lake, Douglas Lake had a significantly higher amount of DO than Burt Lake (p=0.035; Fig1). Between the developed sites in each lake, the p-value approached significance, with Burt Lake having a slightly higher amount of DO than Douglas Lake (p=0.052; Fig1). Between the deep sites, no significant difference was found in the DO content (p=0.296; Fig1).

Chemical Analyses

We predicted that there would be significantly higher levels of all nutrients in Burt Lake. However, not all of our results supported our predictions. There was a significantly higher amount of total phosphorous in Burt Lake than in Douglas Lake (p=0.047; Fig2). Total nitrogen was slightly higher in Douglas Lake than in Burt Lake, but not significantly higher (p=0.508; Fig3). There was not a significant difference in the amount of SRP in each lake, though Douglas Lake contained slightly less SRP than Burt Lake (p=0.443; Fig4).

We noticed a lot of sediment material in the two deepest samples we took for Douglas Lake; therefore, we eliminated this from the data set since it skewed results. Even after eliminating this, we still found that depth made a significant difference in total phosphorus levels (p=0.006). Phosphorous levels were higher at greater depths. Burt Lake did not have a significant difference between depths for total phosphorous (p=0.960). There was also not a significant difference in the amount of total nitrogen found at different depths in Douglas Lake (p=0.316) or Burt Lake (p=0.084).

Macroinvertebrates

The proportion of EPT found in each lake was not significantly different at either the developed or undeveloped sites (p=0.356; Fig5). However, the proportion of EPT found in each sample of macroinvertebrates was slightly higher in Douglas Lake than in Burt Lake.

Chlorophyll A

Although Burt Lake had slightly higher levels of chlorophyll A there was not a significant difference between the levels found in each lake (p=0.822; Fig6).

Discussion

The level of phosphorous found in each lake supported our predictions, but were the only significant findings. The nitrogen levels and SRP levels were not significantly different between the lakes. The significant difference in total phosphorus levels may imply that anthropogenic influences such as the application of fertilizers to lawns or other agricultural practices may have an impact on the water quality of Burt Lake (Carpenter et al. 1998). Another reason why we could have seen such a significant difference between the phosphorus levels is because of heavy rainfall (USGS Earth’s Water: Runoff 2009). We took the samples in Douglas Lake and Burt Lake on two different days. The day we took the Burt Lake samples was preceded by two days of heavy rain; however the week before we took the Douglas Lake samples, there was no rainfall and most days were sunny. Heavy rainfall for two days could cause more runoff from the areas around Burt lake (USGS Earth’s Water: Runoff 2009). There could also be higher levels of phosphorus in Burt Lake due to septic tanks being placed near poor soil or too close to the lake, causing for grey water to be released into the lake (Grant pers. comm.). Grey water is waste water that comes from showers, sinks, or laundry (Ludwig 2009). Substances in grey water may contain high amounts of phosphorus, (Grant pers. comm.) which could account for the higher amounts of phosphorus in Burt Lake than Douglas Lake. A study done by Chris Mainstone and William

Parr (2002) showed that grey water from septic tanks was a significant source of phosphorus in river ecosystems. As a result, they found higher amounts of SRP in the river which contributed to algal growth (Mainstone and Parr 2002). Previous UMBS studies done on Burt Lake have shown high amounts of nitrogen during the summer, possibly due to lawn fertilizers (Gold 1972). We conducted our project in the spring, so it is possible that residents on Burt Lake have not yet started to use fertilizer for their lawns. This could be a reason why we did not find a significant difference in nitrogen levels (Gold 1972). Although we found total phosphorus levels to be significantly different at various depths in Douglas Lake, we did not find any significant difference for the other nutrients at different depths in either lake. The difference in phosphorus at various depths may be because the water is well mixed and lakes have not yet overturned; however, we are unclear as to why only phosphorus would be significantly different and not the other nutrients as well.

In the undeveloped areas, there were significantly higher levels of DO in Douglas Lake than Burt Lake. DO levels between the deep areas and developed areas were not significantly different between the two lakes. It was expected that we would get higher levels of DO in Douglas Lake, potentially because Douglas Lake is less developed overall than Burt Lake. As a result, we expected there to be more nutrients present in Burt Lake which could result in more algal blooms. These algal blooms could then consume oxygen, causing the levels of DO to be lower in Burt Lake (EPA DO& Biochem). The fact that DO levels do not differ significantly at the developed or deep areas may imply that the impact of development around those areas were generally the same and that human impact around the undeveloped areas are greater in Burt Lake than Douglas Lake.

We expected EPT percentages to be higher in Douglas Lake than Burt Lake. Although not statistically significant, the tests run on the proportion of EPT in each of the lakes showed that there was a higher proportion of EPT in the undeveloped sites of Douglas Lake than in the undeveloped sites at

Burt Lake. We expected this because Burt Lake is more developed (Monaghan 2008). We predicted Douglas Lake to have a higher proportion of EPT, which was true, though not significantly higher. A study in Southwestern Georgia assessed the percentage of EPT in comparison to the total number of macroinvertebrates to assess water quality and found that a lower proportion of EPT was indicative of lower water quality (Muenz et al. 2006). Although we found no significant difference between the EPT percentages of the two lakes, Burt Lake had slightly lower percentage, possibly indicating lower water quality.

One problem we encountered was finding macroinvertebrates in the lakes, which resulted in a small sample size. Our sites were not necessarily where streams and other bodies of water were flowing into the lake, where macroinvertebrates would be commonly found (Moroz et al. 2006). Ephemeroptera, specifically, feed on algae as their main source of food. At the time when we sampled the lakes, both Douglas and Burt Lake, in general had cooler temperatures, some even as low as 12.6°C. Therefore, it would be reasonable to infer that Douglas Lake and Burt Lake, at this current time do not have a large amount of algal growth, which would contribute to the small amount of Ephemeroptera found at each site (Brown 1961). If EPT were collected at times of warmer water temperature, then perhaps more EPT samples could be collected and there would be more data.

Although Burt Lake had slightly higher levels of chlorophyll A than Douglas Lake, the values were not close to approaching significance. As a result, we cannot determine whether or not Burt Lake has a greater algal biomass than Douglas Lake in terms of chlorophyll A. In the future, to improve this portion of the experiment, warmer areas of the lake should be tested only. Algae are more likely to grow in warmer environments; therefore, we would be more likely to find algal growth (Fang and Stefan 1999).

Although we did not find any data resulting in statistically significant differences in levels of chlorophyll A between the lakes, this is consistent with water quality measurements taken for the UMBS profile of both lakes. In the water quality measurements taken 37 years ago, the chlorophyll A levels for Burt Lake were 5.5µg/L and Douglas Lake was 5.6µg/L. These data show that the water quality in terms of chlorophyll A levels were approximately the same between the lakes (Gold 1972). However, much development has occurred on Burt Lake since that time, so we were interested to see if there has been an increase in algal biomass on Burt Lake. From our study, we can see that although our numerical data varies from the UMBS profile, our general trend is consistent with that of 37 years ago. This may be attributed the fact that Burt Lake and Douglas Lake watershed councils are assisting in maintaining the water quality of the two lakes.

Due to our small sample size and limited period of time given to carry out the experiments, we could only observe different trends and draw limited conclusions. In order to ensure accuracy in the future it would be better to have a larger sample size. Larger sample sizes would have allowed us to have more confidence in finding differences. One factor that should be kept the same when sampling for nutrient levels is sampling the lake at different depths. Although turnover of the lakes causes the nutrients to be evenly distributed for a period a time, shortly after turnover occurs, stratification of the lakes takes place and the nutrients will not be evenly distributed (Molles 2008). If it turns out that the lakes have undergone stratification, then sampling at various depths would be crucial to the experiment. Not only should samples be taken at different depths, but they should be taken at different times. Bi-weekly or monthly sampling of the lakes could ensure that at least some of the samples taken would be during the period of turnover. This data would also be useful in determining when a certain lake turns over. Another source of error could have been due to the time of year that we sampled. Macroinvertebrates may not have yet had an opportunity to breed this season, causing the amount found at each site to be low (Meyer 2005). Also, Burt Lake's larger volume could also be a source of error. Douglas Lake contains 89,306,400m^3 of water while Burt contains 632,173,568m^3 of water (Gold

1972). Although Burt Lake may have more runoff than Douglas Lake, it is possible that the effects of the nutrient runoff could be less than expected because the nutrients in Burt Lake could be highly diluted. This could result in less algae growth than expected which would consequently cause less chlorophyll A and more DO. Our study is important to understanding exactly what changes are occurring to lakes, as a recent study sought to understand anthropogenic changes to freshwater ecosystems and discover means for restoration (Sondergaard and Jeppesen 2007).

Overall, we were unable to determine whether or not Douglas Lake or Burt Lake is of a higher water quality; however, we were able to determine that nutrients are varied throughout the lakes. We did not take into account many of the different physical features between the lakes which could have caused some of the discrepancies that we found in our results. From our results we can see that the only significant differences in water quality between the lakes are because of the phosphorus levels. Although this currently does not seem to be having a large impact on the water quality of the two lakes in terms of chlorophyll A or macroinvertebrate levels, in the future, if phosphorus runoff continues to increase, it could potentially lead to eutrophication, providing more SRP for algae, which could cause decreased dissolved oxygen, more significant differences in EPT proportions, and higher chlorophyll A levels in Burt Lake (Mainstone and Parr 2002).

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Results

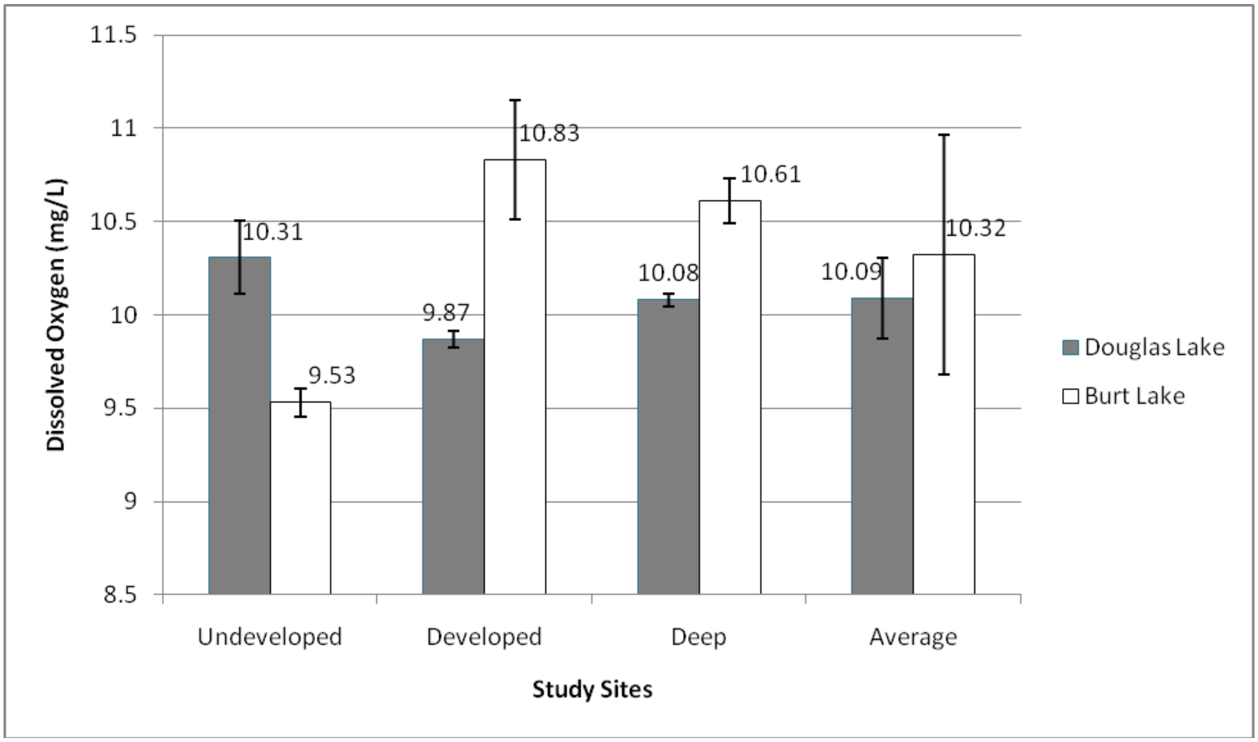

Figure 1. Dissolved oxygen content between Douglas Lake and Burt Lake. Independent samples t-test. Undeveloped p= 0.035, Developed p=0.052, Deep p=0.296.

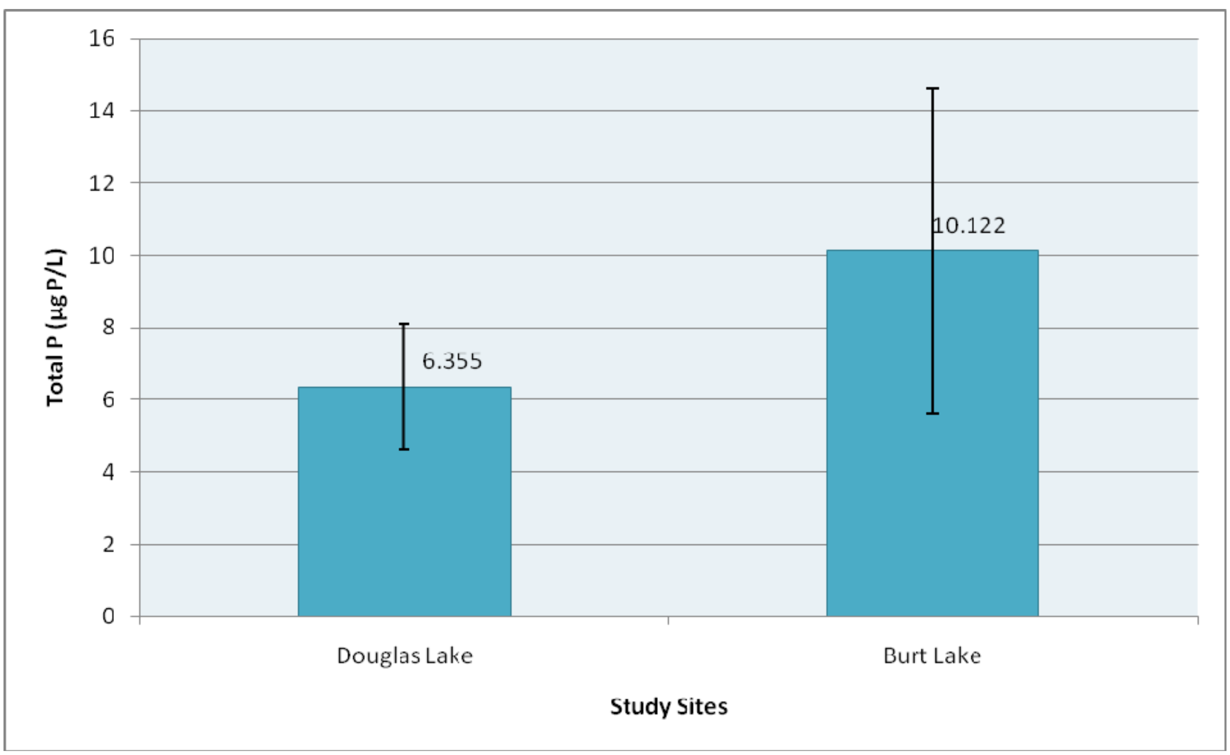

Figure 2. Average total phosphorous of Douglas Lake and Burt Lake. Independent samples t-test. P= 0.047.

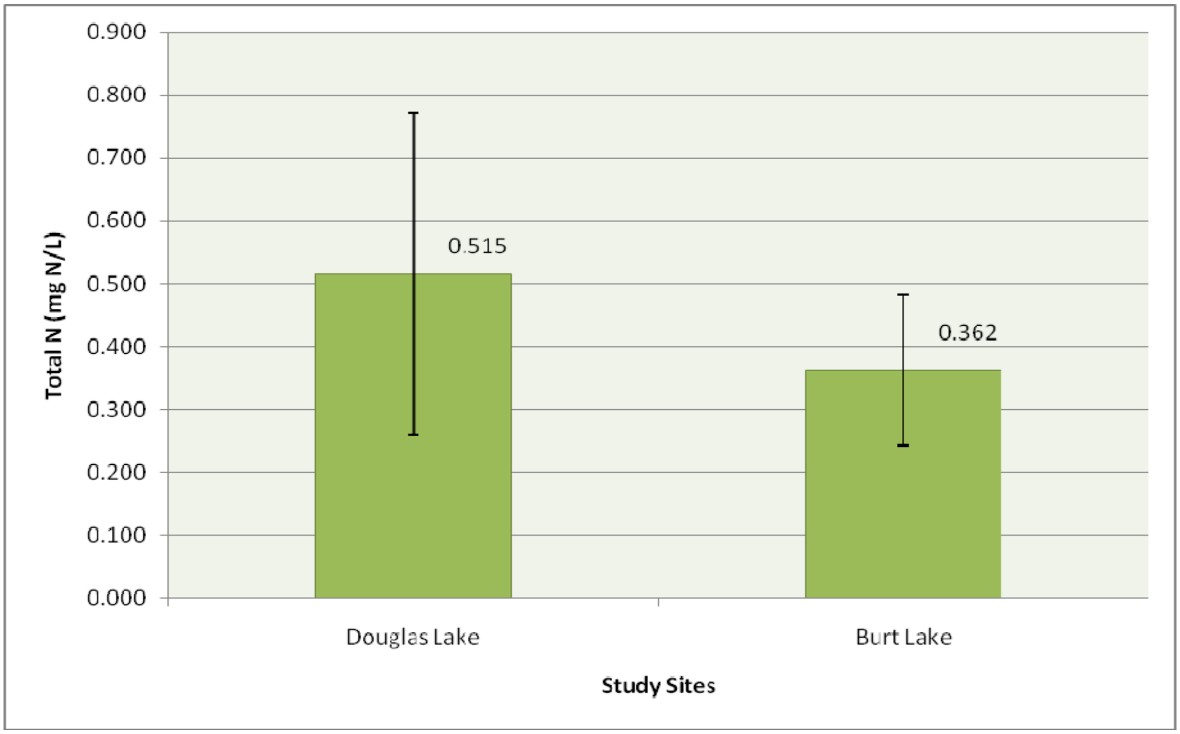

Figure 3. Average total nitrogen of Douglas Lake and Burt Lake. Independent samples t-test. P= 0.508.

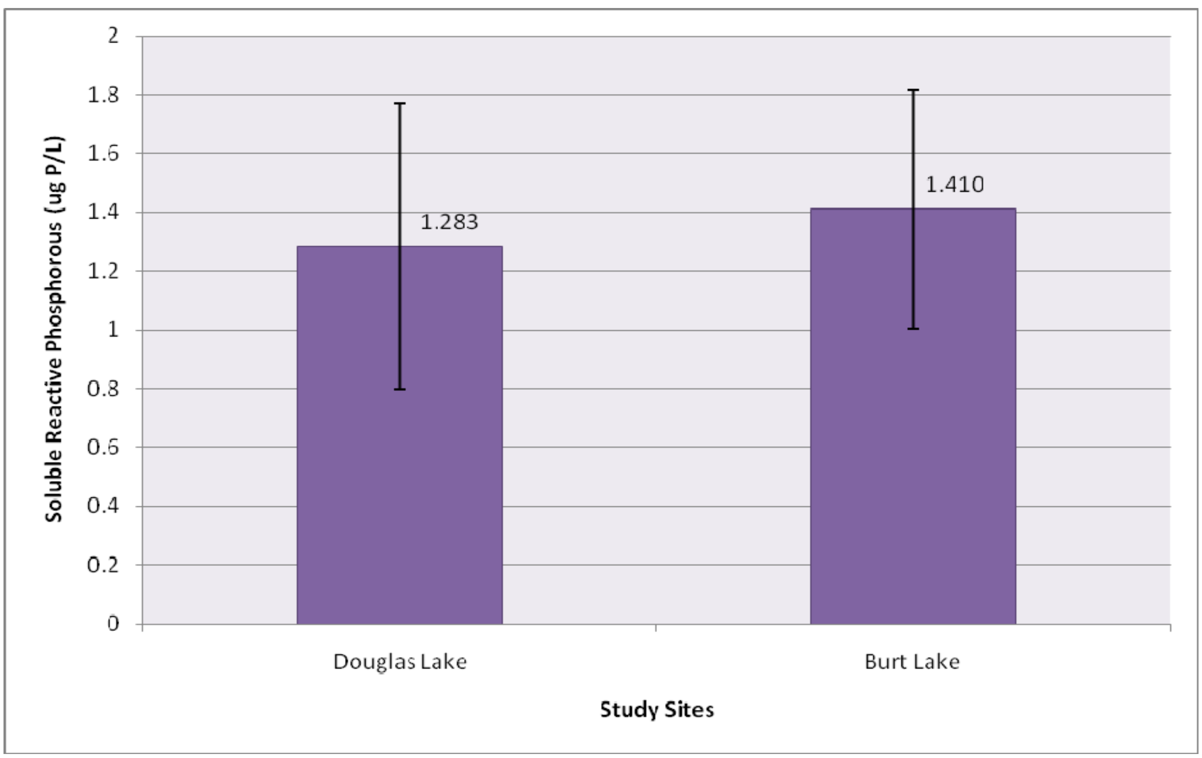

Figure 4. Average soluble reactive phosphorous of Douglas Lake and Burt Lake. Independent samples t-test. P= 0.443.

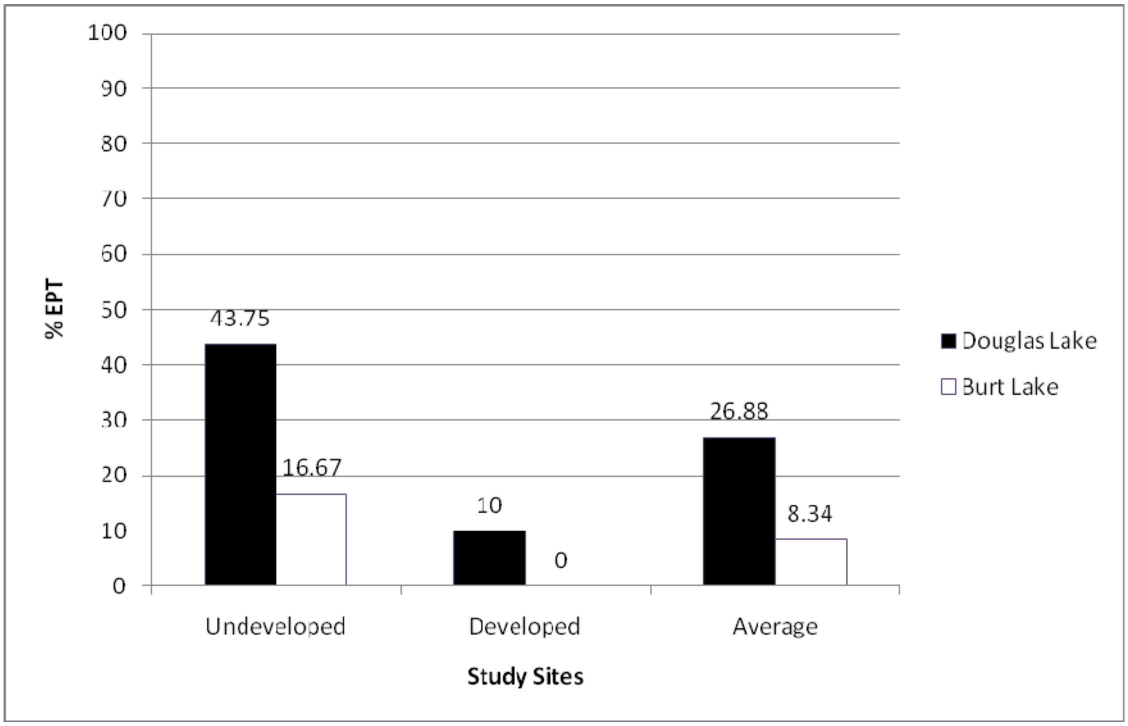

Figure 5.Percent Ephemeroptera, Plecoptera, Trichoptera at study sites in Douglas Lake and Burt Lake. Independent samples t-test. Undeveloped p=0.423, Developed p=0.508, Average p=0.356.

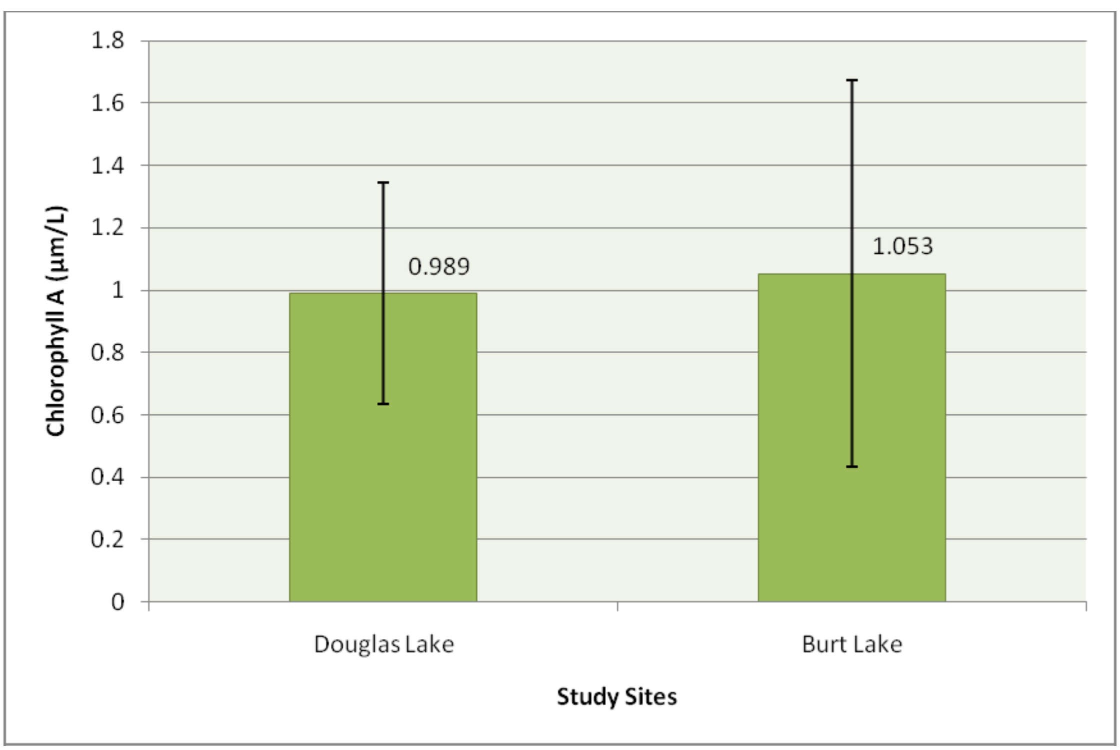

Figure 6. Average Chlorophyll A of Douglas Lake and Burt Lake. Independent samples t-test. P=0.822.