Phytoplankton Diversity and Abundance in UBC Freshwater Sources

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Abstract

In this study, we conducted a question-based project to investigate the relative abundance of phytoplankton in the Botanical Garden, Nitobe Memorial Garden, main fountain, fountain near bookstore, and two fountains near the Beaty Biodiversity Museum at the University of British Columbia. We also wanted to see if there was a correlation between oxygen concentration and the phytoplankton abundance, given there was reasonable differences between the sites. We collected samples of water from each location and observed the samples under a compound microscope to determine the different species present and abundance of each. Using Shannon's Diversity Index, we found that Nitobe Garden had a diversity of 1.2754 and the highest abundance of 300 individuals, Botanical Garden had a diversity of 1.0397 and 4 number of individuals, the Bookstore fountain had a diversity of 0.6098 and 44 number of individuals, and no species were observed in the main fountain and the two Beaty fountains. As well, we measured the oxygen concentration at each location and observed relatively similar values across the locations. A Pearson's correlation test between the oxygen concentrations and phytoplankton abundance at each location revealed no significant correlation ($R = 0.54892$, $p = 0.63008$). Finally, Nitobe Garden was observed with the highest diversity and highest abundance of individuals, therefore, we would predict that it would be the most favourable freshwater source for salmon among the locations we sampled.

Introduction

Phytoplankton are microscopic, plant-like organisms that inhabit oceanic and freshwater ecosystems. They live near the water surface, where they carry out photosynthesis and synthesize nutrients from sunlight and carbon dioxide. Phytoplankton are essential to the salmon ecosystem because they are primary producers and constitute the foundation of the salmon food web. In fact, photosynthesis by phytoplankton accounts for up to half of global primary production (Longhurst et al., 1995). They also provide the primary food source for the zooplankton, which in turn provide sustenance for salmon and the small feeder fish salmon prey on (Peltomaa et al., 2017). Furthermore, many studies have shown a strong

correlation between salmon larval fish survival and the timing of phytoplankton spring blooms (Platt et al., 2003). The timing of these spring blooms directly depends on water temperature, solar radiation and nutrient availability (Townsend et al., 1994). As well, phytoplanktonic photosynthesis causes a direct increase in the dissolved oxygen concentration of water, prompting us to predict that freshwater locations with a higher phytoplankton count would, in turn, have a higher dissolved oxygen concentration (Yoshikawa et al., 2007). In terms of oxygen concentration and phytoplankton abundance at the sites where phytoplankton were found, our null hypothesis (H_0) was that there would be no positive correlation between phytoplankton abundance and oxygen concentration, and our alternative hypothesis (H_A) was that there would be a positive correlation between phytoplankton abundance and oxygen concentration.

Given the importance of phytoplankton to salmon as well as aquatic ecosystems, we set out to examine its prevalence on campus at the University of British Columbia. We will accomplish our investigation by conducting a question-based research project. Specifically, our goal is to determine the relative abundances of phytoplankton in unmoving freshwater at six locations around UBC. These locations include the UBC fountain, the water display near the UBC Bookstore, two fountains near Beaty Biodiversity Museum, Nitobe Memorial Garden, and the UBC Botanical Garden. Phytoplankton growth and proliferation is usually strongly tied to the amount of solar radiation, as well as temperature. Thus, being in the latter half of fall going into winter, we should expect there to be less variety and density than what we might find in warmer seasons. We will then investigate whether or not there is a correlation between the oxygen concentration at these locations and the abundance of the phytoplankton we find if the oxygen concentrations differ reasonably between the locations. If we do see a fair difference between the oxygen concentration at each site, then we would expect a positive correlation between the two variables, since oxygen is a product of phytoplankton photosynthesis.

Method & Materials

We collected three samples of freshwater from six locations across UBC campus: the UBC main fountain, the UBC fountain near the bookstore, Nitobe Memorial Garden, Botanical Garden, and two samples from water displays outside the Beaty Biodiversity Museum (Figure 1). At each location, the temperature and oxygen concentration of the water was measured, using a thermometer and oxygen probe respectively (Figure 1). Each water sample was approximately 15 mL in volume, collected in a Falcon Tube (Figure 1). The samples were taken from the surface of each location, equidistant from the edge of the water. A qualitative observation of the surroundings was taken from each location, as well. A 1:100 ratio of Lugol's iodine solution was added to each Eppendorf tube to preserve any species of phytoplankton that had been collected, and the tubes were then placed on a rack and stored in a refrigerator (Figure 1).

The following week, the three samples from each location were combined and centrifuged for 10 minutes, and each combined sample was then concentrated down to 50μL (Figure 2). Wet slides were prepared using 25μL of each sample, making sure to invert each Eppendorf tube a few times before collecting the sample with a micropipette (Figure 2). The wet slides were then observed under a Axiostar compound microscope. Kohler illumination was performed on the microscope prior to observing any samples. Shannon's Diversity Index was calculated for the locations that had species observed in the samples in order to determine the diversity and abundance of the phytoplankton. As well, a linear regression and Pearson's Correlation Coefficient was calculated for phytoplankton abundance and oxygen concentration at the three locations in which phytoplankton were observed. We set significance level to 0.05 ($\alpha = 0.05$) and assumed that our samples were random and our data were normally distributed.

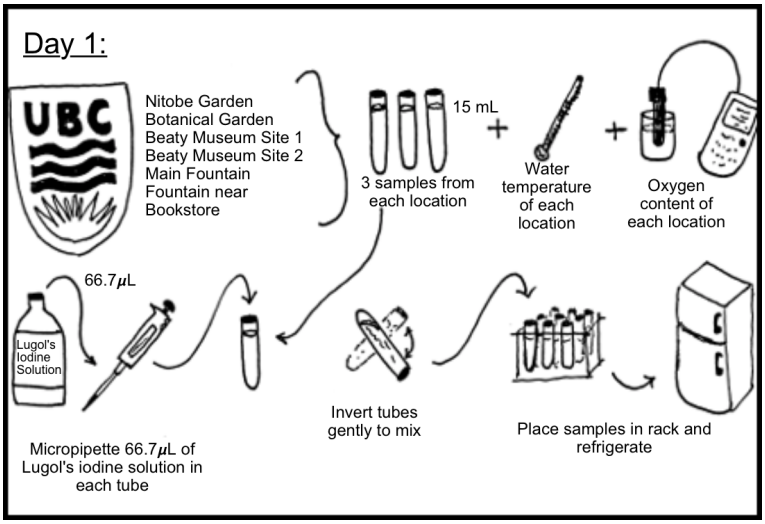

Figure 1: Day 1 flowchart of samples being collected and prepared for use. Temperature and oxygen content of water was measured at location, as well.

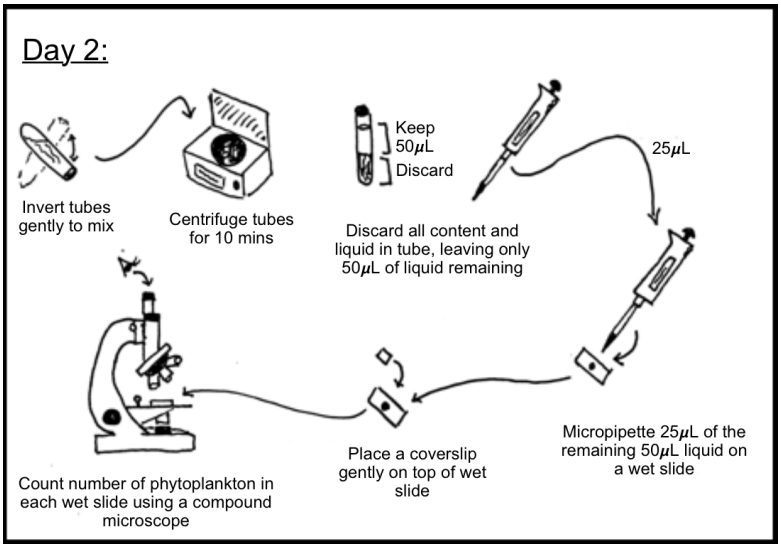

Figure 2: Day 2 flowchart of samples being centrifuged, micropipetted, placed on a wet slide and observed under a compound microscope.

Results

The day of sample collections, it was very cloudy and raining a bit. The pond that we collected samples from the Botanical Garden was shaded with lots of trees surrounding the pond and there were vegetation that covered some of the surface water. The Beaty Biodiversity Museum Site 1 had a tree log in the water and there were these green vegetation covering most of the surface water. The water at the both of the fountains were observed to be clear, with vegetation present in the UBC Bookstore fountain, and non in the main fountain.

Table 1 and Figure 3 shows the diversity and abundance of phytoplankton at the Botanical Garden, Nitobe Garden and the UBC Bookstore fountain pertaining to each species observed in a sample size of 25µL observed under the microscope. Nitobe garden was observed with the most number of individuals (300) and the highest diversity index of 1.2754 (Table 1). While Botanical garden had only 4 counts of individuals in total and UBC Bookstore fountain had 44 in total, Botanical was observed with a higher diversity index of 1.0397 than the Bookstore fountain with 0.6098 (Table 1). Table 2 shows the abiotic factors (oxygen concentration and water temperature) measured at each location. Although this was not the main focus of the study, we calculated the Pearson Correlation Coefficient between oxygen concentration and phytoplankton abundance only for the three sites that had phytoplankton count, which is shown in Figure 4. An R value of 0.54892 was found, indicating a positive correlation between oxygen concentration and phytoplankton abundance. However, $p = 0.63008$ which is much greater than α of 0.05, so this correlation is not statistically significant. As a result, we are unable to reject the null hypothesis that a correlation would exist between the phytoplankton abundance and oxygen concentration at the sites where phytoplankton were found. Additionally, the temperature across all the locations ranged from 8 - 13°C.

	Botanical Garden	Nitobe Garden	UBC Bookstore Fountain
Species	**Abundance (individuals)**	**Abundance (individuals)**	**Abundance (individuals)**
Stephanodiscus	**2**	**0**	**0**
Mystery Algae	**1**	**0**	**0**
Asterionella	**0**	**136**	**3**
Pediastrum	**0**	**82**	**2**
Cosmarium	**0**	**0**	**2**
Nostocaceae **(Cyanobacteria)**	**0**	**0**	**37**
Dinobryaceae	**0**	**63**	**0**
Scenedesmus	**0**	**13**	**0**
Bracteacoccus	**0**	**2**	**0**
Ankistrodesmus	**0**	**3**	**0**
Phacus	**0**	**1**	**0**
Ploima	**1**	**0**	**0**
Total	**4**	**300**	**44**
Diversity Index	**1.039720771**	**1.275395797**	**0.609817171**

Table 1: Species abundance (count of the individuals) of Botanical Garden, Nitobe Garden and UBC Bookstore fountain observed in sample size of 25µL. Nitobe had the most number of individuals (300) and the highest species diversity index of 1.2754, while Botanical had 4 individuals with 1.0397 diversity index and the Bookstore fountain had 44 individuals with a diversity index of 0.6098.

	Botanical Garden	Nitobe Garden	UBC Main Fountain	UBC Bookstore Fountain	Beaty Site 1	Beaty Site 2
Oxygen Concentration (mg/L)	**4.1**	**7.8**	**8.1**	**8.1**	**7**	**7.2**
Temperature (°C)	**8**	**10**	**9**	**10**	**13**	**8**

Table 2: The oxygen content (mg/L) of the water measured at each location along with the water temperature (°C). The oxygen concentrations were around 7 and 8 mg/L for most of the locations, with the exception of Botanical Garden having 4.1 mg/L. The temperature ranged from 8 - 13 °C.

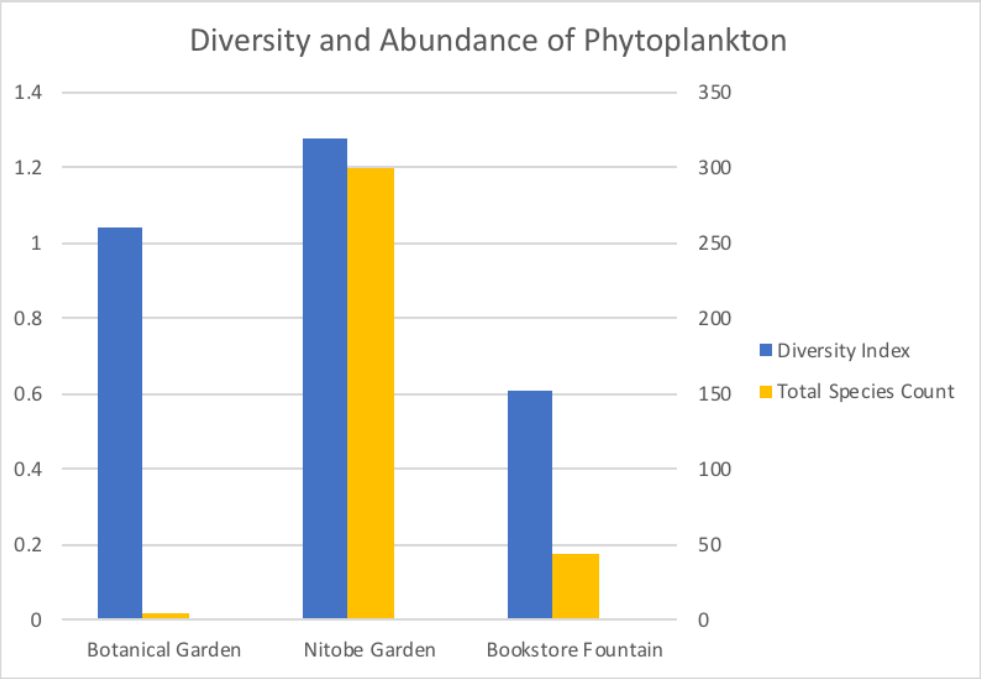

Figure 3: Graph of phytoplankton abundance and diversity in freshwater sources at UBC. Nitobe Garden has the highest count and diversity index, Botanical Garden had the lowest count but a diversity index higher than Bookstore fountain, and Bookstore fountain had the lowest diversity but a higher count than Botanical. No phytoplank were observed in the main fountain and two fountains at Beaty Museum.

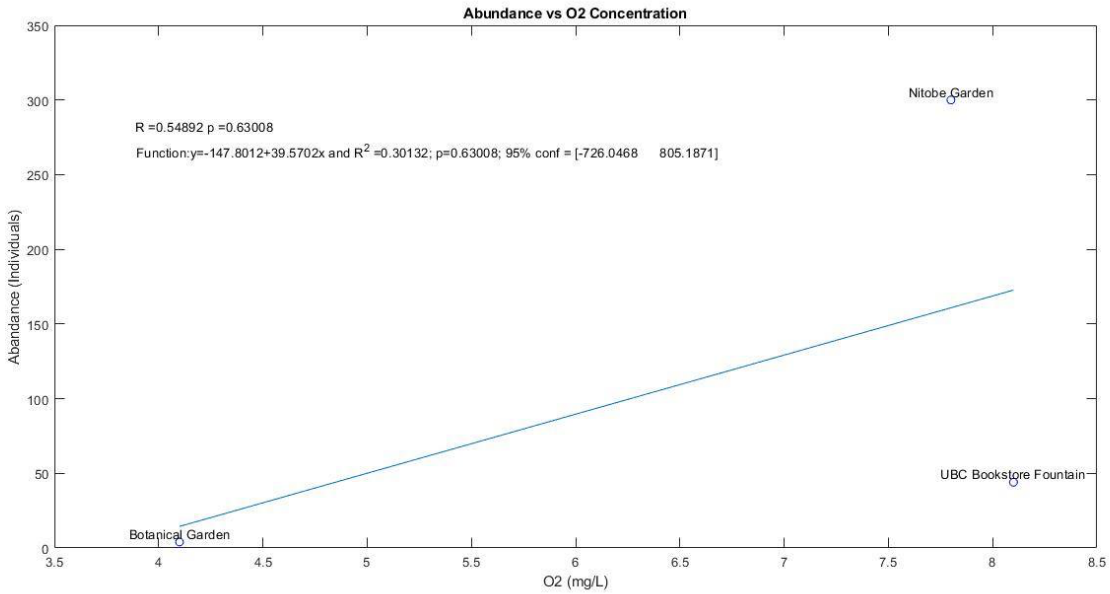

Figure 4: Linear Regression with Pearson Correlation Coefficient for phytoplankton abundance and oxygen concentration. R was found to be 0.54892 and p was 0.63008.

<u>Sample Calculations for Shannon's Diversity Index:</u>

$$H = \sum_{i=1}^{s} - (P_i * \ln P_i)$$

Equation of Shannon's diversity index, where H is the diversity index and P_i is the proportion of each species.

First, we had to find out the proportion of each species at each location. Then the natural log of each proportion, and then multiply the proportion by the natural log. Finally, to get the diversity index all the (proportions*ln(proportions)) of the species at the location were added together and multiplied by 1.

For *Stephanodiscus* observed in Botanical Garden we'd do the following:

Proportion = Abundance/Total → 2/4 = 0.5

Natural log = ln(proportion) → ln(0.5) = -0.6931472

Proportion * ln(proportion) → 0.5 * -0.6931472 =-0.3465736

We would repeat the same calculations for the rest of the species (mystery algae and Ploima) observed in Botanical. Mystery algae and Ploima both had -0.3465736 as the product of their proportion and natural log of their proportions. Then all the products in a location were added together and multiplied by -1.
Diversity index = -1 * (-0.3465736 + -0.3465736 + -0.3465736) = 1.039720771

Discussion

Our results show that the diversity in the Nitobe Memorial Garden is the highest, followed by the Botanical Garden and the UBC Bookstore fountain (Figure 3). Moreover, more than 70% of the abundance of individuals belong to two species (*Asterionella* with 45% and *Pediastrum* with 27%) in Nitobe and more than 84% of the abundance of individuals belonging to a single species (*Nostocaceae*) in the Bookstore fountain, while Botanical had the abundance of individuals more equitably distributed among the species even though it had the least number of individuals present (Table 1). Since the Nitobe Garden was observed with the highest diversity and abundance of phytoplankton, we would expect this location to be the most ideal for salmon, purely based on the phytoplankton abundance and diversity.

There are several possible explanations for the high diversity and abundance levels of phytoplankton observed at Nitobe Garden compared to the other sites that were studied. Phytoplankton diversity and abundance are controlled by a variety of environmental factors. Some of these factors include water temperature, light intensity, salinity, amount of water column mixing, and nitrate concentration (Reynolds, 1984). For the most part, we may discount salinity and water column mixing as causes of variability because all data points were gathered from still, freshwater sources.

Although we did not directly measure light intensity, we made qualitative observations that samples gathered at Botanical Garden were heavily shaded, while samples at Nitobe Garden were directly exposed to sunlight. Phytoplankton are autotrophic, meaning they produce their own nutrients for survival and growth. They use energy from light sources to produce organic compounds through photosynthesis. As light intensity and availability is crucial in controlling phytoplankton growth, it may be a significant contributing factor to the differences in levels

of abundance in our results (Reynolds, 1984). We did not expect to observe any phytoplankton in the Main Fountain as there was no vegetation present, and no nutrient availability. In terms of why no phytoplankton were observed at either Beaty Biodiversity site, both locations were significantly shaded from the sun compared to the other sites. Both locations had large concrete walls blocking the sun from shining on the water, which could explain the lack of phytoplankton at these locations.

The effects of water temperature on phytoplankton have been studied in many freshwater ecosystems and it was found that water temperature strongly regulates variation in phytoplankton (Richardson et al., 2000). Specifically, phytoplankton diversity and abundance were found to be positively correlated to increases in water temperature. Furthermore, in a study conducted at Kaftar Lake, a species of phytoplankton, *Cyanophyte* was observed to have the greatest density in the summer when the water temperature was above 23°C (Nowrouzi & Valavi, 2011). Admittedly, our temperature data is limited because we only took one measurement per site and thus fluctuations in temperature are not accounted for. Nevertheless, Nitobe Garden had the highest temperature (10°C) of the sites where plankton was present. Meanwhile, Botanical Garden had the lowest temperature (8°C) and plankton abundance compared to Nitobe and UBC bookstore fountain.

Nitrate and phosphate concentrations also play an essential role in supporting phytoplankton growth. Phytoplankton use nitrate, phosphate, and other minerals to produce their own food and grow (Reynolds, 1984). In the same study done at Kaftar Lake, there was a sharp increase in diversity and abundance of phytoplankton in autumn, despite decreases in water temperature. The researchers found a considerable increase in nitrate concentrations around the same time and attribute this as the main cause of diversity and abundance increases (Nowrouzi & Valavi, 2011). For a future study, these sites could be revisited with nitrate concentrations measured to determine if there are any correlations to be made with plankton.

Phytoplankton diversity and abundance are critically important to the salmon ecosystem because they directly impact levels of dissolved oxygen in the water. Dissolved oxygen concentrations have been found to increase with increasing total phytoplankton counts (Smith

& Piedrahita, 1988). Oxygen levels increase because the main process phytoplankton perform, photosynthesis, outputs oxygen as a byproduct. Oxygen is essential to salmon development across life stages and survival (Carter, 2005). Salmon are strong, active swimmers and thus thrive in highly oxygenated waters. Also, salmon use oxygen to oxygenate their blood and meet metabolic demands. It has been shown that salmon embryos become increasingly impaired as dissolved oxygen decreases (Carter, 2005). In regards to the linear regression performed between oxygen concentration and phytoplankton abundance at the three study sites, it is likely that the positive correlation ($R = 0.54892$) was not statistically significant ($p = 0.63008$) due to our very small sample size. Due to the lack of statistical significance, we fail to reject the null hypothesis that a correlation would exist between phytoplankton abundance and oxygen concentration. The positive correlation, however, was expected due to the evidence described previously in the literature.

In terms of their relation to salmon, studies have shown positive correlations between the timing of spring phytoplankton blooms and salmon productivity in British Columbia (Malick et al., 2015). When considering the global challenge of climate change, this fact has major implications for the health of salmon populations in the future, because changes in spring bloom timing as a result of anthropogenic climate change could severely impact salmon productivity (Malick et al., 2015). As well, synchronization of spring bloom timing and smolt migration could increase the chances of smolt survival (Chittenden et al., 2010). Of importance for this study in particular, a direct link has been found between increases in diatom populations and an increase in the number of “adult salmon spawners”, and *Asterionella* was a species of diatom found in high abundance at Nitobe Memorial Garden. This strengthens our assertion that Nitobe Garden would be the most favourable freshwater location for salmon spawning, of the locations we visited.

Conclusion

In this study, we collected samples from six freshwater sources on UBC campus in order to determine phytoplankton diversity and abundance at each of these locations. We only found phytoplankton in three of the six locations: Nitobe Garden, the Botanical Garden, and the UBC Bookstore fountain. Nitobe Garden had the highest diversity index and abundance (1.28

and 300, respectively), followed by Botanical Garden (diversity index = 1.04, abundance = 4) and the UBC Bookstore fountain (diversity = 0.61, abundance = 44). It is suspected that the differences in abundance and diversity between the three sites is due to the fact that Nitobe Garden had the most direct exposure to sunlight, as this is very important for photosynthesizing organisms such as phytoplankton. Upon analyzing oxygen concentration and phytoplankton abundance at these three locations, we found that there was not a statistically significant positive correlation between these two variables. Based on the phytoplankton diversity and abundance, we expect Nitobe Garden to be the most favorable freshwater for salmon.

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