Relationship Between Soil pH and Dissolved Oxygen (DO) Concentration in Salish Creek and Canyon Creek

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Abstract

Soil pH and dissolved oxygen (DO) concentration are two important abiotic factors for the survival of salmon. We were interested in determining whether a linear relationship existed between soil pH and DO concentration in the upper portions of Vancouver's Salish Creek and Canyon Creek. Soil pH and DO concentration were measured with pH meters and oxygen concentration meters. It was found that the aggregated pH measurements from both creeks have a mean of 6.0 and the DO measurements have a mean of 8.5 mg/L. A linear regression model was performed to determine if the two variables were significantly correlated in creek water. It was found that the *p*-value of the slope of the fitted line being equal to 0 was 0.57, which was not significant at the significance level of 0.05 used for this study. Therefore, we failed to reject the null hypothesis and concluded that there was no significant relationship between soil pH and DO concentration based on our study.

Introduction

Salmon are anadromous, which means they are born in freshwater, migrate to the ocean, and return to their original birthplace to spawn (Kitahara, 1983). During the last few decades, researchers have studied the importance of salmon on our ecosystem and have closely looked at the relationship between salmon and abiotic factors: pH of water (Peterson, Daye, & Metcalfe, 1980; Lacroix, Gordon, & Johnston, 1985), oxygen (Davis, Foster, Warren, & Doudoroff, 1963; Tran-Duy, van Dam, & Verreth, 2008), carbon dioxide (CO_2) (Fivelstad, Olsen, Kløften, Ski, & Stefansson, 1999), and more. However, research about the relationship between soil pH and dissolved oxygen (DO) concentration in freshwater and its impact on salmon population is insufficient.

Soil pH is determined by the interaction between the pH of water and soil. It represents the hydrogen concentration in the soil: higher pH values imply lower hydrogen concentrations and lower pH values imply higher hydrogen concentrations (Krug, 1991). The pH can rise or drop based on other abiotic factors, including CO_2 (Oh & Richter, 2004). When salmon are exposed to low or high pH, their reproduction rate, survival rate and swimming performance significantly decrease (Jensen & Snekvik, 1972). The DO is the amount of oxygen that is dissolved in water. It is an important requirement for the growth of aquatic species and their metabolic processes (Zang et al., 2011). In hypoxic or oxygen-depleted water, salmon are born premature or die off (Alderdice, Wickett, & Brett, 1958). The pH and DO are influenced by photosynthesis and respiration in freshwater, and CO_2 is often the main cause of changes in the soil pH and DO (Zang et al., 2011). Moreover, CO_2 can be removed during photosynthesis by algae which increase pH and DO concentration in water (Wurts & Durborow, 1992).

In this research article, our work aims to fill a research gap by investigating the relationship between the soil pH and DO concentration collected from the upper creek of Salish Creek and Canyon Creek, which are known to be populated with Pacific salmon species (*Oncorhynchus* genus). The null hypothesis is that there is no linear relationship between soil pH and DO concentration. The alternative hypothesis is that that there is a linear relationship between soil pH and DO concentration. If the alternative hypothesis is valid, then we predict that as soil pH increases, DO concentration increases in water. The prediction was formed based on the fact that a hydrogen ion reacts with oxygen and they combine to form water as shown in Eq. 1:

$$1/2O_2 + H_2 \rightarrow H_2O \qquad (1)$$

Hydrogen ion concentration decreases as the pH increases, and as a result the equilibrium is shifted to the left, increasing the oxygen concentration (Zang et al., 2011). If the null hypothesis is valid, this could be due to other abiotic factors that cause changes in the soil pH and DO such as temperature and light intensity (Matthews & Berg, 1997; Romaire & Boyd, 1979). This investigation is important because salmon lay eggs on the ground. The eggs are directly in contact with the soil, and DO is critical to their growth. Young salmon and adult spawning salmon are sensitive to the surrounding environment.

Materials and Methods

On October 28, 2018 and November 4, 2018 at approximately 1 PM, we measured the soil pH, water oxygen level, and temperature at both Salish Creek and Canyon Creek. A 10 metre transect line was set at both creeks. Measurement points along the 10 metre transect line were determined by using a 0 to 100 random number generator. The result was then divided by 10 to yield the transect line point. From each creek, six samples of each abiotic factor (soil pH and oxygen level) were taken from four different spots from the creek.

Air and water temperature were measured at each creek on both days. Qualitative observations, such as the water flow, the weather, vegetation and the appearance of downed logs at each site was recorded for further discussion.

Soil pH was measured by using a Vernier pH sensor (PH-BTA) and a green capsule. Soil samples were collected from the riverbed of each site and filled to the bottom line of the test chamber of the pH meter by using a metal spoon. Distilled water and powder from the green capsule was then added to the upper line of the pH meter. The pH of the soil sample was recorded. A diagram of the pH collection procedure is shown in Figure 1 below.

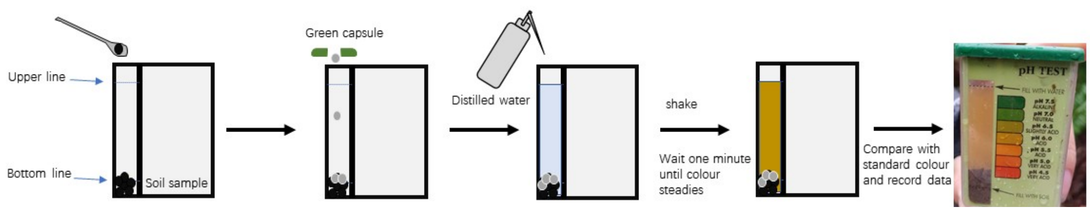

Figure 1. Procedure of measuring pH of soil collected from creek bed

The oxygen concentration of the water was measured by using a Texas Instruments TI-84 calculator attached to an oxygen probe. We first collected water samples from the creek using 100 mL plastic cups with lids. Then, we placed the pH probe into the sample collected and stirred gently until the reading stabilized. The data was then recorded. A diagram of the oxygen concentration measurement procedure is shown below as Figure 2.

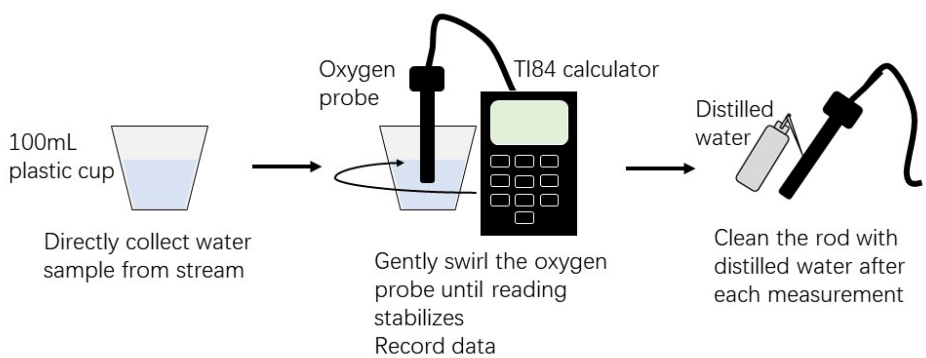

Figure 2. Procedure of measuring dissolved oxygen level from water sample collected from the creeks

RStudio was used for data analysis to find if there was a linear relationship between soil pH and water oxygen concentration level in the data collected.

Results

Soil pH and creek water oxygen concentration measurements were taken from Vancouver's Salish Creek and Canyon Creek on two days. RStudio was used to analyze the data collected, and the mean, median, standard deviation of soil pH (Figure 3) and oxygen concentration (Figure 4) for Canyon Creek, Salish Creek, and both Canyon and Salish Creek were determined. Air and water temperatures at Salish Creek and Canyon Creek sites were also recorded on October 28 and November 4, 2018 (Figure 5).

On October 28, when performing the first three replicates of the 2.5 m transect line site of Salish Creek, there was rainfall. This site was characterized by relatively fast water flow, downed logs and branches, ripples, leaves, soil, and stones. The 7 m transect line site of Salish Creek was characterized by shade and bushes overhanging the area and ferns. There were no branches, and less flow was observed compared to the 2.5 m transect line. The 9.7 m transect line site had a water level that was much deeper than the previous two transect line sites, with many long logs and ferns. The Canyon Creek site was characterized by large rocks, clear stream water, plentiful vegetation, many branches and leaves, and mushrooms growing on the fallen logs and branches. The branches hung over the streams, and they were much leafier than Salish Creek. This site was less accessible to humans, as it was surrounded by somewhat steep terrain and more dense vegetation; it was also deeper into the forest.

The observations on November 4 were characterized by sunny weather, with clearer water that flowed more quickly. At Canyon Creek, white foam was seen near the 9.8 m site. The flow was much faster than Salish Creek, and Canyon Creek was sloped, with a narrow bank width. The water looked cleaner in Canyon Creek relative to Salish Creek.

Sampled Site	Mean	Median	Standard Deviation
Canyon Creek (*n* = 24)	5.8	6.0	0.35
Salish Creek (*n* = 24)	6.2	6.5	0.54
Both Creeks (*n* = 48)	6.0	6.0	0.49

Figure 3. The mean, median, and standard deviation of soil pH for Canyon, Salish, and both creeks.

Sampled Site	Mean (mg/L)	Median (mg/L)	Standard Deviation (mg/L)
Canyon Creek (*n* = 24)	8.6	7.4	1.9
Salish Creek (*n* = 24)	8.4	7.1	2.0
Both Creeks (*n* = 48)	8.5	7.3	1.9

Figure 4. The mean, median, and standard deviation of oxygen concentration for Canyon, Salish, and both creeks.

Date of Measurement	Creek	Air temperature (˚C)	Water temperature (˚C)
10/28/2018	Canyon	9	9
11/4/2018	Canyon	9	9
10/28/2018	Salish	10	8
11/4/2018	Salish	11	10

Figure 5. Air and water temperatures at Salish Creek and Canyon Creek sites on October 28 and November 4, 2018.

Using this data, a linear regression model that used the oxygen concentration as the response variable and the soil pH as the predictor variable was created for a dataset containing all replicates sampled. A significance level of 0.05 was used in our analysis. The resulting best-fit line, shown in Figure 6, had a slope of 0.34, a *p*-value of 0.57, and a correlation coefficient of 0.09. In Figure 6, the red points denote measurements taken on October 28, 2018, the blue points denote measurements taken November 4, 2018, the circular points represent measurements taken at Salish Creek, and the triangular points represent measurements taken at Canyon Creek.

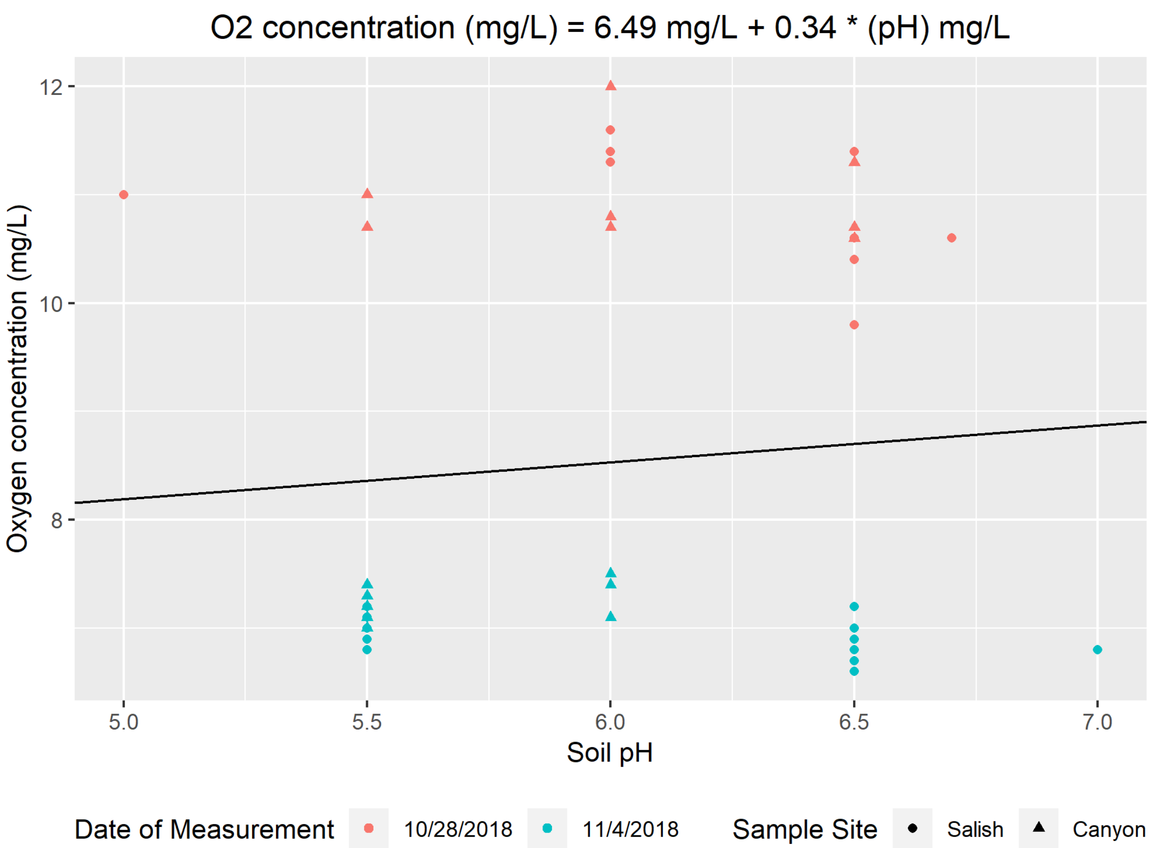

Figure 6. Oxygen concentration vs soil pH at Salish and Canyon Creek. Slope = 0.34, p = 0.57.

Discussion

The goal of the experiment was to determine whether a linear relationship existed between two abiotic factors: soil pH and dissolved oxygen (DO) concentration. Two creeks, Salish Creek and

Canyon Creek, were chosen as the experimental sites for data collection in hopes of obtaining a larger range of numbers compared to data collection from only one creek.

The alternative hypothesis was that there was a linear relationship between soil pH and DO concentration, while the null hypothesis was that there was no linear relationship between the two abiotic factors. If the linear relationship was significant, the *p*-value would be less than or equal to 0.05; if the linear relationship was insignificant, the *p*-value would be greater than 0.05. Based on the results obtained from Salish Creek and Canyon Creek, the data had a *p*-value of 0.57, demonstrating insignificance. Therefore, we concluded that there is no significant linear relationship between soil pH and DO and we failed to reject the null hypothesis. Additionally, the prediction was that as the soil pH increases, oxygen levels would increase as well. This trend was not observed in the aggregate results; thus, we failed to support our prediction.

There are many possible sources of errors to explain why the prediction could not be supported. The main reason could be that data was collected over two days with vastly different weather conditions. One day had high amounts of precipitation, while the other day was sunny with no precipitation. As a result, this may have factored in many confounding variables, such as acid precipitation, temperature, and water flow rate. These could have impacted the soil pH and dissolved oxygen concentration. Firstly, acid precipitation could have lowered the soil pH. Acidic rain, known to have a pH of 5-5.5 (Munton et al., 1999) could have led the soil to also be acidic. The heavy amounts of precipitation may have decreased the pH levels from their normal levels, as the normal pH range for aquatic environments is between 6.5-9.0 (Wurts & Durborow, 1992). In addition, temperature could have also affected the dissolved oxygen concentration. The sun on day 2 appeared to have increased the temperature at Salish Creek compared to day 1. Ficklin *et al.* (2013) had stated that the dissolved oxygen in a stream is inversely related to the stream temperature. Thus, the higher temperature could have led to a lower DO. Due to the mass vegetation at Canyon Creek, which may have blocked the sun rays from warming the creek water, this inverse relationship between DO and temperature was not observed. Yet dissolved oxygen concentration is not only influenced by temperature; water flow rate can also affect it. The precipitation on October 28, 2018 increased the water flow in both creeks. Higher rates of water have been known to be associated with higher dissolved oxygen concentrations in creeks (Hondzo, 1998). Therefore, the higher water flow rate from precipitation could have increased DO.

Additionally, there was difficulty in obtaining soil from the water due to high water flow rate, which could have led to variability in the soil pH data. Canyon Creek had stronger and faster water flow than Salish Creek, especially in the centre of the creek, making soil pH data collection difficult and not as precise. The strong water flow at Canyon Creek continuously washed away any soil that was being retrieved from the creek. Moreover, Canyon Creek had more stones and boulders within the creek, making it difficult to find soil samples for the soil pH measurement. Thus, soil had to be collected from the side where water flow was not as strong, and where there were fewer rocks. On the other hand, Salish Creek had smaller rocks and possessed more areas rich in soil compared to Canyon Creek. As a result, soil pH data collection was more precise, as soil was collected right where the transect line was laid.

To improve upon the experiment, rather than do a field experiment, one could bring these abiotic factors into a lab. One would use a range of pH levels and dissolved oxygen concentrations to determine whether a significant relationship exists between them, or if there is any relationship at all between the two abiotic factors. The advantage to doing the experiment in a lab is that one could limit the possibility the confounding variables listed above would occur. Plus, in a lab, the pH levels and oxygen concentrations would have a larger range compared to the ones used in the field experiment, as those are constrained to what is available in the natural environment. Zang et al. (2011) had a similar idea. They wanted to limit the number of confounding variables, so they did a field-enclosed experiment to investigate the relationship between pH and DO. They found a significant positive correlation between the two factors. In comparison, we did an open field experiment and found no significant correlation between the two factors. Additionally, to further this experiment, one could investigate how each abiotic factor—soil pH and DO—specifically impact the growth and development of salmon. Peterson et al. (1980) discovered that if the pH of water was low (4-5.5), Atlantic salmon eggs either did not hatch, or displayed delayed hatching. Waldrop et al. (2018) exposed Atlantic salmon to different levels of dissolved oxygen and found that higher DO lead to higher growth performance.

Conclusion

Based on the results, there was no significant linear relationship between soil pH and dissolved oxygen (DO) concentration at Salish and Canyon Creek, so we failed to reject the null hypothesis. It had been predicted that as soil pH increases, DO increases; the results failed to support this prediction. Determining the correlation between soil pH and DO is crucial to better understand the salmon ecosystem, and be able to help them thrive in a growing, industrialized community.

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Appendix

Canyon Creek Data:

Date of Measurement	Transect Line (m)	Replicate	pH	Oxygen concentration (mg/L)
10/28/2018	5.2	1	6.5	11.3
10/28/2018	5.2	2	5.5	10.7
10/28/2018	5.2	3	6.5	10.7
11/4/2018	5.2	4	5.5	7.3
11/4/2018	5.2	5	5.5	7.2
11/4/2018	5.2	6	5.5	7.4
10/28/2018	5.6	1	6.0	12.0
10/28/2018	5.6	2	6.0	10.7
10/28/2018	5.6	3	6.5	10.6
11/4/2018	5.6	4	5.5	7.3
11/4/2018	5.6	5	5.5	7.1
11/4/2018	5.6	6	5.5	7.3
10/28/2018	9.8	1	5.5	11.0
10/28/2018	9.8	2	6.0	10.7

10/28/2018	9.8	3	6.0	10.8
11/4/2018	9.8	4	5.5	7.2
11/4/2018	9.8	5	6.0	7.1
11/4/2018	9.8	6	5.5	7.1
11/4/2018	3.4	1	6.0	7.5
11/4/2018	3.4	2	6.0	7.5
11/4/2018	3.4	3	6.0	7.4
11/4/2018	3.4	4	6.0	7.1
11/4/2018	3.4	5	6.0	7.1
11/4/2018	3.4	6	5.5	7.0

Salish Creek Data:

Date of Measurement	Transect Line (m)	Replicate	pH	Oxygen concentration (mg/L)
10/28/2018	2.5	1	5.0	11.0
10/28/2018	2.5	2	6.5	9.8
10/28/2018	2.5	3	6.5	10.4
11/4/2018	2.5	4	6.5	6.6
11/4/2018	2.5	5	7.0	6.8
11/4/2018	2.5	6	7.0	6.8
11/4/2018	1.2	1	6.5	6.8
11/4/2018	1.2	2	6.5	6.7
11/4/2018	1.2	3	6.5	6.7
11/4/2018	1.2	4	6.5	6.8
11/4/2018	1.2	5	6.5	7.0
11/4/2018	1.2	6	6.5	6.9
10/28/2018	7.0	1	6.0	11.4
10/28/2018	7.0	2	6.0	11.6
10/28/2018	7.0	3	6.0	11.3
11/4/2018	7.0	4	5.5	7.0

11/4/2018	7.0	5	5.5	6.8
11/4/2018	7.0	6	5.5	6.9
10/28/2018	9.7	1	6.7	10.6
10/28/2018	9.7	2	6.5	11.4
10/28/2018	9.7	3	6.5	10.6
11/4/2018	9.7	4	5.5	7.1
11/4/2018	9.7	5	5.5	7.2
11/4/2018	9.7	6	6.5	7.2