**Comparing Oxygen and Visibility Levels in the Upper and Lower Streams of Salish Creek**

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**Abstract**

Dissolved oxygen and visibility levels are important abiotic factors in the freshwater streams that salmon reproduce and undergo early development in. We compared these two factors between the upper and lower streams of Salish Creek by measuring oxygen levels using an oxygen probe and water visibility using a colorimeter. We found that the lower stream had significantly greater oxygen levels with 10.4 ± 0.8 mg/L than the upper stream with 9.5 ± 0.4 mg/L ($p < 0.0001$). This may be because oxygen has a higher solubility at lower altitudes, recent rehabilitation efforts undergone at the lower stream to make it more suitable for salmon, and the close proximity of the upper stream to urbanization. The colorimeter measured high visibility levels with 100% transmittance at all samples at both sites. As a result, we did not find a difference in visibility between the two sites. Samples were taken during moderate rainfall and from the surface of the stream, potentially affecting visibility. Oxygen levels were above the minimum required levels for salmon and visibility was high at both sites, indicating these two factors are appropriate for salmon but the lower stream's significantly higher oxygen levels indicate it may be a better site for salmon. Further studies should use a more sensitive device, like an optical attenuator, to measure visibility instead.

**Introduction**

Water visibility and oxygen levels are important factors in the health of freshwater streams where salmon reproduce and undergo early development. Suspended sediment in water can decrease visibility and block light penetration which is needed for oxygen production through photosynthesis (Lloyd, 1985). Oxygen is required for cellular respiration in organisms to produce energy (Fellmann et al., 2015). Urbanization, like foot traffic, can negatively affect both factors by promoting erosion.

Salmon have anadromous life cycles in which they reproduce and undergo early development in freshwater, migrate to the ocean for maturation, then return to their native streams for reproduction (Fisheries and Oceans Canada, n.d.). During their early life stages, they are sensitive to oxygen and visibility levels and require a minimum of 5 mg/L of dissolved oxygen for optimal growth and function (Canadian Council of Ministers of the Environment, 1999). Hypoxia negatively affects development, feeding, and swimming performance (Canadian

Council of Ministers of the Environment, 1999 and Fellmann et al., 1985). Poor visibility caused by suspended sediment in water can suffocate eggs and inhibit vision for feeding (Lloyd, 1985).

In this study, we compared the oxygen and visibility levels of the upper and lower streams of Salish Creek. The upper stream is located near a hiking trail and an elementary school. It is relatively flat and is surrounded by an abundance of surrounding vegetation. The lower stream is located at a lower altitude, sloping downwards and opening up to the ocean. Compared to the upper stream, it is located further away from urbanization and has less surrounding vegetation. There was moderate rainfall on the day of data collection resulting in higher water velocity than usual at both sites.

**Figure 1.** The upper (left) and lower (right) streams of Salish Creek.

Our hypotheses for oxygen are:

$H_{O(Oxygen)}$: There is no difference in oxygen levels between the upper and lower streams.

$H_{A(Oxygen)}$: There is a difference in oxygen levels between the two sites.

Our hypotheses for visibility are:

$H_{O(Visibility)}$: There is no difference in visibility levels between the two sites.

$H_{A(Visibility)}$: There is a difference in visibility levels between the two sites.

We predict that oxygen and visibility levels will be higher in the lower stream than the upper stream. The reasoning is that the upper stream is located near a walking trail and elementary school, which can result in increased erosion from foot traffic. Erosion increases the amount of suspended sediment in the water, decreasing visibility and therefore decreasing the amount of light available for oxygen production through photosynthesis (Lloyd, 1985). In contrast, the lower stream is further away from urbanization. The objective of our study is to compare visibility and oxygen levels between the two sites and to determine if they are appropriate for salmon inhabitation.

**Methods**

A field study was conducted at the upper and lower stream of the Salish Creek in Pacific Spirit Park to independently compare the dissolved oxygen and visibility levels in the water between the two sites. Samples of water were collected at the surface of the water to ensure standardization and obtained through randomization in 250 mL sample cups on Saturday, November 3rd, 2018 in the afternoon. For the randomization of our data collection, we used a number generator from 1 to 10 to determine the number of steps to take, and we moved in left direction when the number generated was odd and right when the number was even. Due to time constraints to return our equipment, there was moderate rainfall during the afternoon we collected our data which appeared to have increased the velocity of the water flow and volume of water in the stream when we had anticipated data collection with still water. A total of 20 samples were obtained at each site to ensure our data were representative of each site of the stream. For each sample, measurements for visibility and dissolved oxygen levels were taken using a colorimeter and dissolved oxygen meter probe respectively.

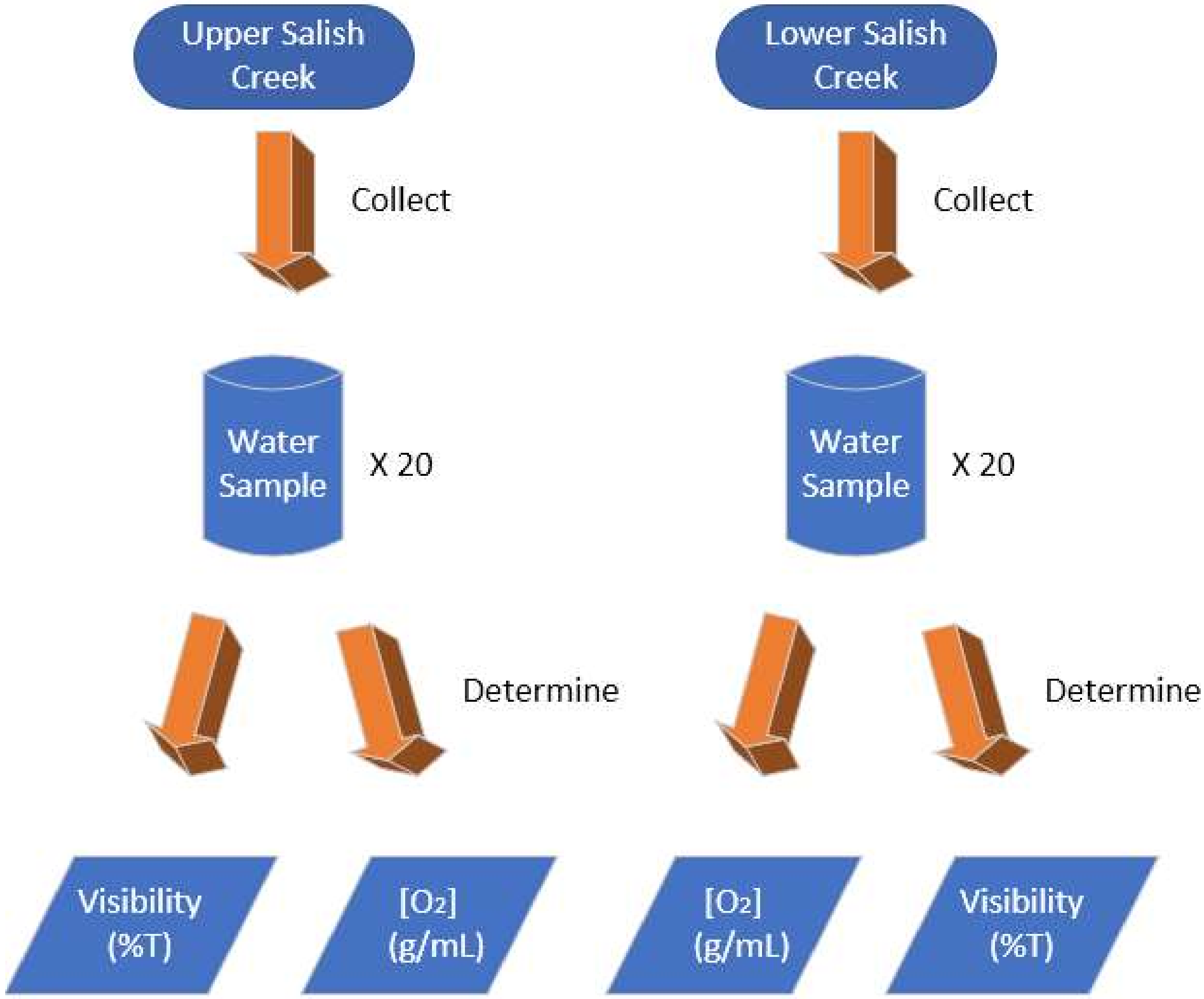


**Figure 2.** Flowchart of the data collection process on the field at the upper and lower site of the Salish Creek at Pacific Spirit Park.

For the visibility measurements, small portions of the samples in the sample cups were placed in cuvettes. The cuvette containing the sample was then placed in the colorimeter where red visible light at 635 nm travelled through the clear side of the cuvette ("Colorimeter User Manual", n.d.). Red visible wavelength at 635 nm was chosen as it is more readily absorbed by water than other visible wavelengths (Seraphin et al., n.d.). Absorbance values of the collected water samples were obtained from the colorimeter, and Equation 1 (Conversion Formulas, n.d.) was applied to determine the percent transmittance of light through the water samples.

$$\% Transmittance = antilog^{2-absorbanc} \qquad Equation\ 1$$

The percent transmittance of light through the water samples was interpreted as our variable, visibility, as it is the light that does not get absorbed, reflected, and scattered by sediment and soil particles in the water. We tested a sample with distilled water and a sample with dirt added into the water to ensure the colorimeter was functioning correctly.

For the dissolved oxygen level measurements, an oxygen meter probe was submerged in each of the sample cups containing the water samples (“Dissolved Oxygen Probe User Manual”, n.d.). We rinsed the probe with distilled water between each measurement to prevent contamination from previous samples.

The mean values for each variable from the two sites were compared independently and assumed to be normally distributed for statistical analysis using an unpaired two-tailed t-test. The mean value of dissolved oxygen at the upper Salish creek was compared to the mean value of dissolved oxygen at the lower Salish Creek using an unpaired two-tailed t-test for two independent means at a significance level of 0.05. Similarly, the mean value of visibility at the upper Salish creek was compared to the mean value of visibility at the lower Salish creek using the same statistical test and significance level. The unpaired two-tailed t-test was used as it allowed us to determine whether two means are significantly different from each other. A bar graph of the means of oxygen concentration and visibility levels at both sites was used to graphically represent our data.

**Results**

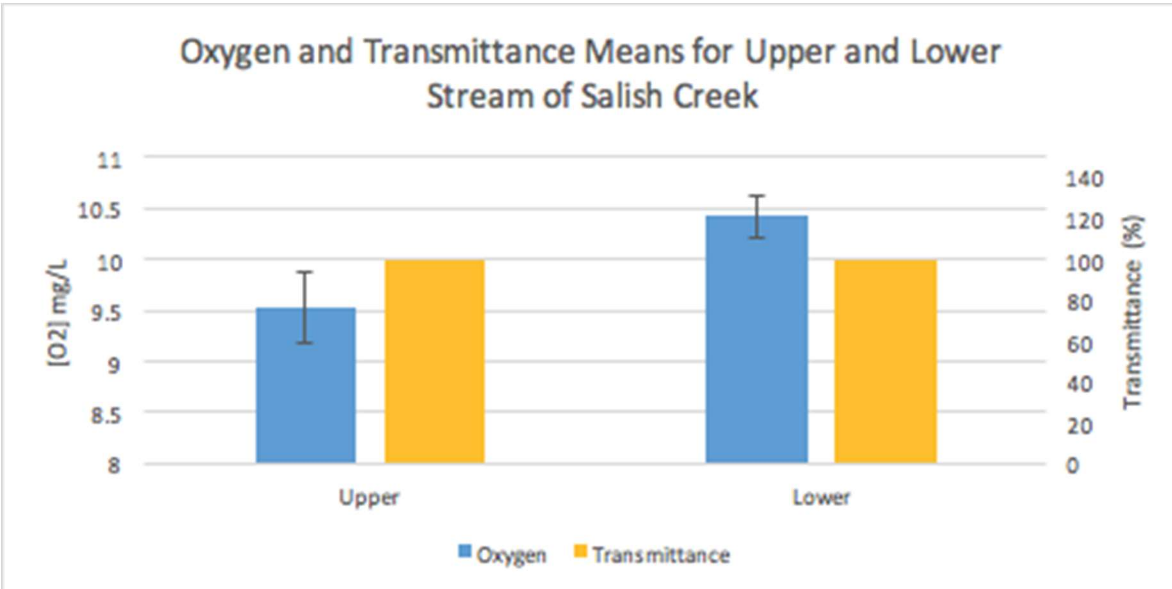


**Figure 3.** Graphical representation of the mean transmittance and oxygen measurements found at the upper and lower stream of Salish Creek with 95% confidence interval bars. Oxygen t-value was found to be 4.4613. Oxygen P-value was found to be <0.0001 indicating differences between upper and lower stream are significant (at a 0.05 significance level). P-value and t-value for transmittance could not be determined due to all data points being identical. 20 samples were taken for both oxygen and transmittance at the upper and lower stream.

In this experiment, 20 samples were taken for both oxygen and transmittance at the upper and lower stream of Salish Creek. Oxygen was found to have a mean of 9.525 mg/L, a standard deviation of 0.784 and a 95% confidence interval of 9.18 mg/L to 9.87 mg/L at the upper stream of Salish Creek. Thus, it can be said with 95% certainty that the true mean oxygen concentration at the upper stream is in between 9.18 mg/L and 9.87 mg/L. Oxygen also had a mean of 10.415 mg/L, a standard deviation of 0.426 and a 95% confidence interval of 10.2 mg/L to 10.6 mg/L at the lower stream of Salish Creek. Thus, it can be said with 95% certainty that the true mean oxygen concentration at the lower stream is in between 10.2 mg/L and 10.6 mg/L. Statistics for transmittance could not be determined due to all data collected being identical.

When comparing oxygen concentrations between the upper and lower stream of Salish Creek, a t-value of 4.4613 and a p-value of less than 0.0001 were found. These values indicate that at a 0.05 significance level, there is a significant difference between the upper and lower stream concentrations of oxygen. Thus, the null hypothesis that there is no significant difference in oxygen concentrations between the upper and lower stream of Salish Creek was rejected. Due to all data collected for transmittance being identical, it suggests there is no difference in transmittance levels between the upper and lower stream of Salish Creek. Furthermore, the t-value and p-value for transmittance could not be determined due to all data collected being identical. Thus, the null hypothesis that there is no significant difference in transmittance levels between the upper and lower stream of Salish Creek was not rejected.

**Discussion**

We reject $H_{O(Oxygen)}$ and support $H_{A(Oxygen)}$ and our prediction that oxygen levels are significantly higher in the lower stream than the upper stream. We are unable to reject $H_{O(Visibility)}$ because we did not find a significant difference in visibility levels. As a result, our prediction that visibility would be higher at the lower stream was not supported.

For oxygen, we predicted that the lower stream would have higher levels of oxygen for two reasons. Firstly, more oxygen dissolves in water when the pressure is higher (Murphy, 2007). The lower stream is at a lower altitude which means there is higher atmospheric pressure. The second reason is because the upper stream is in closer proximity to foot traffic and urban sites such as the elementary school. In general, pollution that comes from human activity and urbanization will result in a lower amount of oxygen (Murphy, 2007). Our results supported our prediction, because the lower stream had an average oxygen level of 10.42 mg/L, while the upper stream had an average oxygen level of 9.53 mg/L, which were concluded to be significantly different. Furthermore, although they differed, both lower and upper stream have enough oxygen for salmon survival. The minimum oxygen requirement for salmon survival is 5 mg/L (Canadian Council of Ministers of the Environment, 1990). Since the values were higher than this in both locations, salmon living in this location likely will not be inhibited by oxygen availability.

For visibility, our prediction was that the lower stream would also have higher visibility than the upper stream since the upper stream was closer to the school and urbanization, which could lead to increased foot traffic. As stated in the introduction, this could lead to increased erosion, which would decrease visibility (Lloyd, 1985). This prediction was proved incorrect since transmittance values were 100% for all upper and lower streams measurements. This is likely due to collecting the water samples from the surface of the water. Visibility is mainly determined by turbidity, which is the presence of suspended particles, and these particles will sink. Since we took the samples from the very surface of the river, it's possible that a lot of the particles were deeper down. These high visibility values support salmon life. The main source of food for salmon are zooplankton, and zooplankton eat phytoplankton (Salmon, n.d.). Phytoplankton grow through photosynthesis at the surface of the water, which requires sunlight that becomes available with high visibility. As long as phytoplankton are able to grow, zooplankton can thrive, and salmon will have a sustainable food source. This visibility data obtained was unexpected, and does not match with what literature suggests. Two major factors that affect turbidity, and visibility as a result, are rainfall and water velocity. The experiment was conducted on a rainy day, where the water was flowing with high velocity. Higher velocity keeps particles suspended in the water, and rain is also likely to pick up particles from the ground on its way to the river (Fondriest Environmental, Inc, 2014). Both of these would cause higher turbidity, which should have resulted in lower visibility and transmittance. We originally thought that there might be a machine malfunction, but by adding a little dirt into the water, we were able to confirm that the machine readings do change with suspended particles. This suggests that the equipment wasn't the issue.

**Figure 4**. A close up of the water in the upper (left) and lower (right) streams of Salish Creek shows that visibility appears high at both. The water is relatively clear and rocks can be seen through it.

We had anticipated collecting data on a clear day to minimize the influence of other factors such as heavy rainfall which may result in erosion. However, due to time constraints to return our equipment and a rainy week, the data was collected on a day with moderate rainfall. There was likely contamination of the samples due to rain as we had collected the samples at the surface of the water as a means for standardization of sample collection.

In future studies, other methods of measuring visibility with greater sensitivity should be used to verify our results. Similar variables to visibility such as turbidity and presence of suspended sediment could be studied to optimize understanding of how cloudiness in the water affect the salmon ecosystem. For example, measuring the amount of cloudiness in the water using an attenuation-based method with turbidity-measuring devices calibrated with precise optical attenuators would minimize the inconsistencies of turbidity and presence of suspended sediment data which is an often subjective relationship (Kitchener, Wainwright, & Parsons, 2017).

## Conclusion

We found that the lower stream had significantly higher levels of oxygen than the upper stream with 10.4 ± 0.8 mg/L compared to 9.5 ± 0.4 mg/L ($p < 0.0001$). This supports $H_{A(Oxygen)}$

that there is a significant difference between the two sites and our prediction that oxygen would be higher at the lower stream. We found that the visibility levels for all samples at both sites were measured as 100% transmittance. This supports our second null hypothesis that there is no difference in visibility between the two sites and does not support our prediction that there would be higher visibility in the lower stream. The oxygen levels were higher than the recommended minimum levels for salmon of 5 mg/L and visibility levels were high at both sites, indicating that the oxygen and visibility levels are suitable for salmon at both the upper and lower streams of Salish Creek.

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