A CORRELATIONAL STUDY BETWEEN ORGANIC MATTER CONTENT IN SOIL AND STREAM WATER pH OF SALMON-ASSOCIATED STREAMS IN PACIFIC SPIRIT REGIONAL PARK

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ABSTRACT

Due to the rapid decline of salmon populations, we turn our focus to the habitability of streams. Looking into three streams that are either salmon-residing, non-residing, or under restoration. We study the relationship between organic matter in soil and stream pH, two abiotic factors that influence the ecosystem and salmon survival. Using a pH meter on site and a 3% hydrogen peroxide test to measure organic matter content in dehydrated soil samples, we collected data from Musqueam (M), Canyon (C), and Spanish Banks (S) Creeks respectively. The results show that there are no significant differences between the mean pH (M: 6.21 $\pm$ 0.058, C: 6.16 $\pm$ 0.123, S: 6.27 $\pm$ 0.059) and mean organic matter content (M: 3.99% ± 1.119, C: 3.01% ± 0.095, S: 3.03% ± 0.199) across the streams, and no statistically significant correlational relationship (r = - 0.06246) can be extracted. We conclude that the two variables are consistent across the three streams and that there is no apparent relationship between soil organic matter and pH. This suggests that the stream habitability for salmon fall within similar range in terms of pH and organic matter across the three distinct streams.

INTRODUCTION

As one of the keystone species here in British Columbia, salmon supports not only water ecosystems by bringing in marine nutrients, but also supports local economies and communities (Helfield & Naiman, 2006). An important determiner of salmon survival in aquatic ecosystems is water pH (Lacroix, 1989; Chambers, Moran, Trasky, & Trenholm, 2012). Adverse effects including mortality have been observed when salmon is subjected to pH significantly lower or higher than its optimal pH of 7 to 8 (Chambers et al., 2012). These effects can include imbalance of vital ions in the blood such as sodium and chloride, difficulties with circulation, absorption and elimination of biological fluids (Lacroix 1989; Chambers et al., 2012). A pH higher than the optimal range has been associated with direct damage to body surfaces such as the gills and skin, impaired ability to reproduce and reduced capacity to eliminate metabolic wastes (Chambers et al., 2012). Low water pH can also influence metal concentrations in water systems, specifically aluminum. An increase in cationic aluminum species often leads to toxicity not just for salmon, but for multiple organisms in the ecosystem (Adams et al., 2017)

One factor that is known to influence pH is the amount of organic matter in soil due to processes of decomposition (McCauley et al., 2009). Organic matter has profound effects on soil pH as well as neighbouring streams due to leaching, run-offs and the consequent erosion (Lydersen, 1998; Utah State University, 2013). Although many studies have investigated the effects of organic matter on pH, the results have been inconsistent. Some have found a correlation between low pH and high organic matter (Bishop et al., 2001; Reich et al., 2005), while some suggest that organic matter acts as a buffer instead, to resist pH changes (McCauley et al., 2009). This inconsistency is due to the many confounding factors including previous use of land, climate, soil age, parent material, topography and hydrology (Reich et al., 2005). One experimental study, however, in which 14 tree species, eight broadleaves and six conifers were closely monitored over a period of three decades with most confounding variables controlled, found soils under conifers more acidic than soil beneath broad leaves (Reich et al., 2005). This difference was attributed to calcium levels, with less calcium (basic cation) in conifer decomposition, resulting in less neutralization of acidic cations (hydrogen, aluminum) on soil particle surfaces and hence lower pH than broad leaves (Reich et al., 2005; Lovblad, G., Tarrason, L. & Torseth, K., 2004).

In this study, our aim is to determine whether organic matter in soil is correlated with stream water pH in British Columbia, using data collected from three creeks in the heart of Pacific Spirit Regional Park: Musqueam, Canyon and Spanish Banks. We hypothesize that there will be a correlation between soil organic matter and stream pH. We predict that due to the great amount of organic material from conifers in the park Douglas-fir, Western Red Cedar, Western Hemlock, Sitka Spruce (Douglas, G., Meidinger, D., & Pojar, J., n.d.) with lower calcium levels, there will be a higher probability of acidic soil and therefore, lower stream pH (Reich et al., 2005). We also hypothesize that the mean organic matter content and mean pH will be different between the three streams. This is due to the differences in salmon-associated conditions across the three streams (salmon-residing, non-residing, and under restoration). We speculate that the Musqueam and Spanish Banks creeks (salmon-residing and/or under restoration) (Hume, 2018; Scarth, 2006) will have a water pH that is within the suitable limits for salmon, but Canyon creek will have a water pH out of range for salmon survival as it does not have a salmon population.

MATERIALS AND METHODS

Data collection for our study took place at three different creeks in the Vancouver area on November 1, 2018; Canyon Creek, Musqueam Creek and Spanish Banks Creek. These creeks were selected based on the habitability for salmon. Six replicates were collected from each creek for each factor for a total of 18 soil samples and 18 water samples. Data was collected at relatively similar locations across the creeks, along the upper range of the creek with relatively still waters. It is important to select testing sites as similar as possible across the three streams and collect samples from consistent depths to minimize variability and influence of other confounding variables.

Water samples were collected at randomly selected sites approximately 5 cm deep and in close proximity to the riverbank where water had relatively slow stream flow. A pH meter connected to a TI-83 graphing calculator with EasyData software installed was used to measure the pH of each water sample on site. To measure the pH, the pH probe was immersed into roughly 80 ml of water per sample and measurements were recorded once the pH measurement had stabilized. The probe was rinsed with distilled water between measurements. (Adapted from: Vernier.com, 2016).

Soil samples were collected in the riverbank of the same randomly selected sites up to 5 cm deep with a spoon in close proximity to the water where soil was present. Back in the lab, soil samples were dried in a drying oven for a week at 55 degrees celsius in plastic containers. The amount of dry soil measured out for each sample was 1.05g $\pm$ 0.01g using weighboats and a balance (Figure 1).

FIGURE 1. 18 soil samples each measured out to 1.05g $\pm$ 0.01g into corresponding weighboat and organized in rows by creek, top-to-bottom: Musqueam, Spanish Banks, Canyon.

All 18 samples were then each treated with 10 mL 3% hydrogen peroxide per gram of soil (1.05 g x 10 mL/g = 10.5 mL) using a serological pipet and immediately weighed and recorded as Initial H202 (g). After sitting for an hour, soil samples were weighed again and recorded as Post H202 (g) to calculate percentage weight loss in organic matter using Equation 1. The hydrogen peroxide method (modified from: Robinson, 1927) was selected by availability of resources and usefulness.

Equation 1. % Weight Loss = 100 - (Post H202/Initial H202 *100)

Assuming variables are normally distributed, have equal variances, and are random samples, means of water pH of Canyon, Musqueam, and Spanish Creeks were compared through a one-way ANOVA, to obtain p-values. Another one-way ANOVA was done to compare the percentage of organic matter in soil for Canyon, Musqueam, and Spanish Creeks and to get a p-value. A Pearson's product-moment correlation was performed to determine the presence of a correlational relationship between water pH and organic matter in soil. Assumptions were made that data was randomly sampled and water pH and soil organic matter have equal variance, normally distributed, and independent.

RESULTS

Site Descriptions of Canyon, Musqueam, and Spanish Creeks

All three selected creek sites were in the upper range of the creek and had relatively still waters (Figure 2). Canyon Creek had lots of surrounding soil, with decomposing logs and leaves and thin surrounding branches. In contrast, Musqueam Creek had many sword ferns and large, warm-coloured (yellow, brown, red) fallen leaves, with minimal surrounding soil, and a fishy scent. Lastly, Spanish Banks was very mossy with slightly greater streamflow, and soil composition with greater variety of biomass.

FIGURE 2. The three selected creek sites from left to right: Canyon, Musqueam, and Spanish Banks Creek.

Water pH across Canyon, Musqueam, and Spanish Creeks

Six samples from each stream produced mean water pH to be 6.16 ± 0.123 at Canyon Creek, 6.21 ± 0.0580 at Musqueam Creek, and 6.27 ± 0.0590 at Spanish Creek (Figure 3). Standard deviation was 0.302 at Canyon Creek, 0.142 at Musqueam Creek, and 0.145 at Spanish Creek. The pH values between the creeks seemed relatively similar.

A one-way ANOVA was done to compare the mean water pHs between Canyon, Musqueam, and Spanish Banks Creek to determine whether they are statistically different. The $F_{0.05(2),5} = 0.386$, which gives us a p-value of 0.686. Because the p-value is greater than 0.05, we cannot reject the null hypothesis. This suggests that mean water pH between Canyon, Musqueam, and Spanish Banks Creeks are not statistically different, but rather quite consistent across streams.

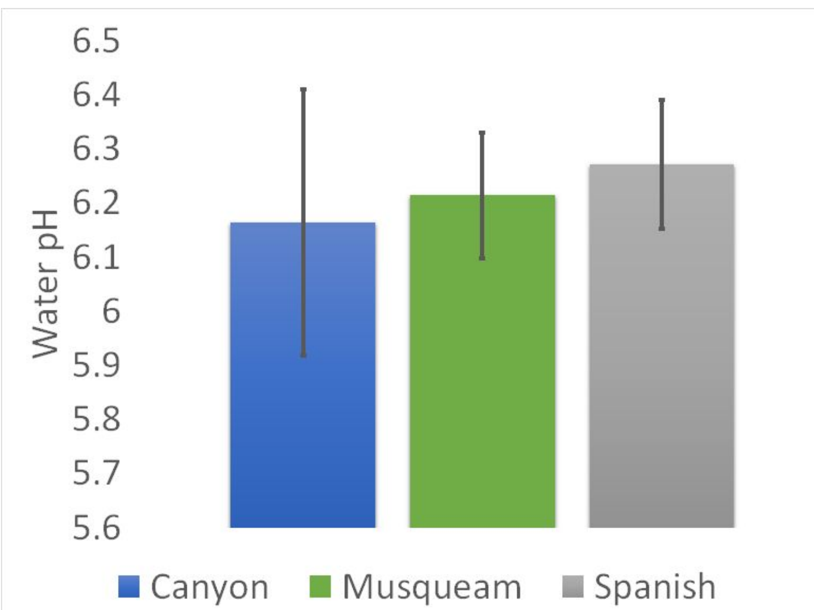

FIGURE 3. Mean water pH was measured to be 6.16 ± 0.123 at Canyon Creek, 6.21 ± 0.0580 at Musqueam Creek, and 6.27 ± 0.0590 at Spanish Creek (n = 6 per creek; p-value = 0.686). Error bars represent 95% confidence interval.

Organic Matter in Soil across Canyon, Musqueam, and Spanish Creeks

After one week in a drying oven, there was an observable difference in appearance and composition of soil samples collected at the different streams. Soil collected at Canyon Creek was very sandy, light in colour, and fine-grained. Soil collected from Spanish Banks was more coarsely grained scattered with strands of moss, whereas soil samples collected from Musqueam Creek was the darkest in colour, largest in particle size, and the only sample that contained rocks.

Organic matter was quantified as a value of percentage weight loss via a hydrogen peroxide test. For example, using Equation 1 and the data from soil sample 1 of Musqueam Creek we get the following calculation: % Weight Loss = 100 - (12.900/13.357*100) = 3.421%. Repeating this calculation across all samples, the mean percentage of organic matter in soil (grams of CO_2) was then calculated to be 3.01% ± 0.095 in Canyon Creek, 3.99% ± 1.119 in Musqueam Creek, and 3.03% ± 0.199 in Spanish Creek (Figure 4). Standard deviation was calculated to be 0.116 at Canyon Creek, 1.371 at Musqueam Creek, and 0.244 at Spanish Creek.

A one-way ANOVA was done to compare the mean percentage of organic matter between Canyon, Musqueam, and Spanish Creek to determine whether they were statistically different. F_5f 2.933 and a p-value of 0.841 was obtained. Since the p-value is greater than the significant value of 0.05, we cannot reject the null hypothesis. This suggests that the mean percentage of organic matter in soil between Canyon, Musqueam, and Spanish Creeks are not statistically different.

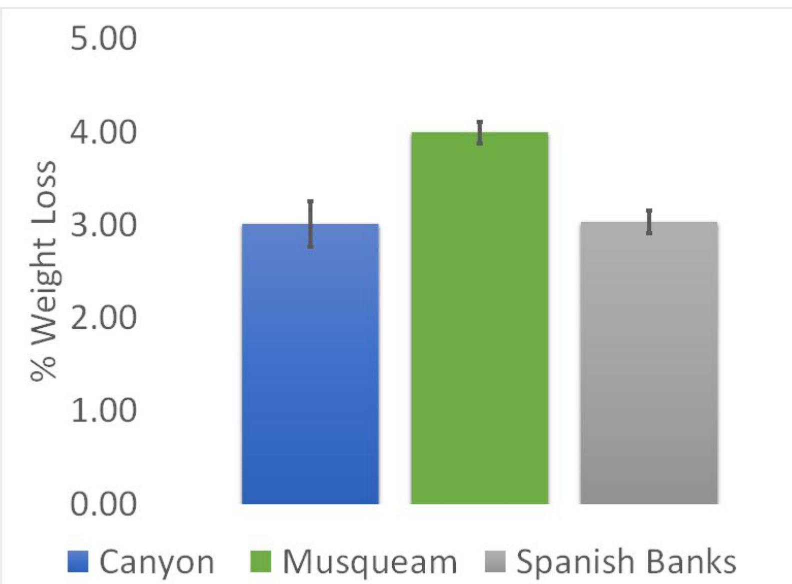

FIGURE 4. Mean percentage of organic matter (CO_2) in soil was 3.01% ± 0.095 at Canyon, 3.99% ± 1.119 at Musqueam, and 3.03% ± 0.199 at Spanish Creeks (n = 6 per creek, p-value = 0.084). Error bars represent 95% confidence interval.

No correlational relationship was observed between organic matter in soil and water pH

Organic matter in soil and water pH has no correlational relationship (Figure 5). As both our variables are independent, Pearson's product-moment correlation was run to procure r^2 = - 0.06246, a p-value of 0.9811. A Pearson's correlation coefficient of -0.006246 suggests that organic matter in soil and water pH are not correlated. Furthermore, because the p-value is greater than the significant value of 0.05, we cannot reject the null hypothesis.

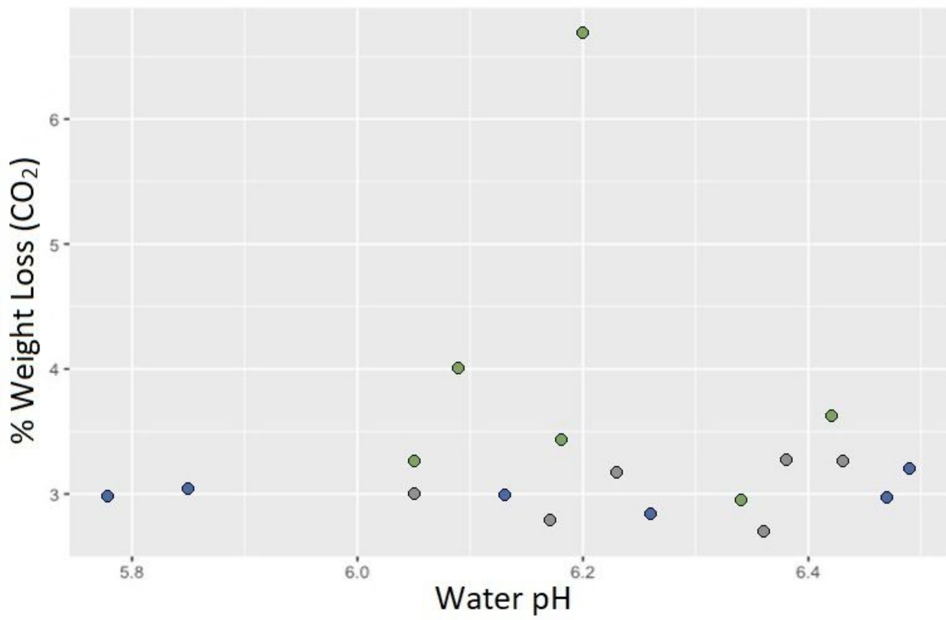

FIGURE 5. Relationship of percentage of organic matter in soil and water pH (r^2 = -0.06246, n = 18; 6 per creek) from Canyon, Musqueam, and Spanish Creeks. (p-value = 0.9811)

DISCUSSION

The relationship between soil organic matter and water pH has never been clearly established, largely because of the several confounding factors such as the climate, soil age, parent material, topography and hydrology (Reich et al., 2005). Previously, an increase in water pH has been shown to be correlated to an increase in organic matter in soil (You et al., 1999). Conversely, an increase in water pH has also been linked to lower organic matter in soil (Reich et al., 2005). Considering past studies, we hypothesized that pH and soil organic matter would be correlated due to the presence of organic matter from the coniferous trees present in Pacific Spirit Regional Park, Vancouver. However, our results present the absence of a correlational relationship between soil organic matter and water pH (Figure 4). Furthermore, a calculated p-value of 0.9811 presents our data as insignificant, thus, we fail to reject the null hypothesis.

The study done by Reich et al. mentions that the presence of conifers creates acidic soils because the plant litter, parts of the plant that have fallen to the ground, contain lower levels of basic cations (2005). Therefore, it would be expected that the areas with a higher concentration of conifers would have acidic cations within the soil, which can leach into the stream waters to create an acidic environment. Although there are several coniferous trees within the regional park, their proximity to the creek itself may have limited this effect. The water was collected from regions upstream of the creek and the surrounding areas were mossy and muddy rather than populated with conifers. There is a possibility that the conifers decomposed, but the litter was not in close proximity to the waters for the acidic organic matter in the soil to leach directly into the stream water.

With respect to the organic matter in soil and the pH of the stream water at the different creeks, we failed to reject the null hypothesis. Thus, we found that there was no statistical difference between the organic matter in soil and water pH of the creeks that were and were not suitable for salmon habitability. Previous studies and research have suggested that the optimal water pH range for salmon growth and development is 7 to 8 pH units and any pH below or above this could have drastic effects on the salmon population (Chambers et al., 2012). Possible effects of an unsuitable pH waters include: difficulties with metabolism, an impaired circulatory system and issues with body surfaces (Lacroix, 1989; Chambers et al., 2012). We originally predicted that the creeks that are known for salmon spawning (Musqueam and Spanish Banks Creeks) would have a pH within this range and the creek (Canyon Creek) not known for salmon spawning would be drastically below or above this range. Our results suggest otherwise, since the pH of the streams was approximately 6.

However, there are possible limitations in the results. Canyon Creek, which is only a few kilometers away from Spanish Banks Creek may be influenced by factors such as the plant-life and weather patterns that cause the properties of both creeks to be similar. Hence, it would have been preferable to test the water pH and organic matter content in creeks that were further away from one another or located in different regions of the Lower Mainland of British Columbia while ensuring that confounding factors were controlled best as possible. In addition to this, we sampled from steady water sites upstream of the creeks, however due to limited accessibility it was difficult to maintain reciprocity of specific locations at each creek, which may have influenced the pH and organic matter samples because there was limited accessibility to the upper bed of each the creek.

Another limitation of our findings, is the weather pattern may have disrupted the pH of water and the organic matter content in the soil. Acidic rainfall could have lowered the pH of the streams (Likens, 1989). The week of our study the weather was primarily dry, sunny, but the day our team completed the sampling there was heavy to moderate rainfall that occurred. Thus, it is recommended to measure the pH of the water and the organic content of the soil over a larger time period of several days to see if the weather had any drastic effects on the findings.

Moreover, the pH of water across Canyon, Musqueam, and Spanish Creek was fairly similar, hence this produced a lack of variation in our data. In other words, as the stream pH of the three streams were within one pH level, we did not have sufficient data to represent how low pH and high pH streams may correlate with soil organic matter. Ergo, a correlational relationship between organic matter in soil and water pH was not shown. For future reference, streams included in a correlational study between soil organic matter and water pH should have more variation in pH to truly test their relationship.

CONCLUSION

Despite differences in the presence of salmon, there is no significant difference in both mean pH and soil organic matter content at Musqueam, Canyon, and Spanish Banks Creeks. There is no evident correlation and we do not reject the null hypothesis. The data does not support our predictions, but rather highlights the consistency of the two variables across the differently salmon-associated streams.

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