Investigating Fluctuations in Organic Matter Content Between Transects at Pacific Salmon Rearing Stream

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ABSTRACT

Pacific Salmon are some of the most influential keystone species in the coastal Pacific Northwest, crossing the barrier between ocean and land to deliver large amounts of marine-derived nutrients to terrestrial ecosystems after spawning and decomposing (Janetsk et al., 2009). This process enriches soil organic matter content by elevating levels of carbon, phosphorus, and nitrogen in the soils within proximity to salmon-bearing streams (Bilby et al., 2003). Evidence from previous studies suggests that the level of organic matter is higher near stream banks due to salmon decomposition, and decreases with distance away from this riparian region. However, there is a lack of literature investigating this phenomenon in urban streams. The fluctuation of salmon-derived organic matter was examined perpendicular to an urban salmon rearing stream in Cougar Creek, Delta, British Columbia. Samples were collected at increments of 5 metres, starting at the side of the stream and moving farther away into the forest. Using hydrogen peroxide as a reagent, the mass of organic content was measured at each transect. It was hypothesized that there would be a trend of decreasing organic soil content observed at samples farther away from the stream. While statistical analyses revealed that there was a significant difference between the means of organic matter at each transect ($p = 0.0003$), the experimental results did not demonstrate a decreasing trend in organic matter distribution at increasing distances perpendicular to the stream.

INTRODUCTION

Riparian forests are one of the most vital ecosystems present in the Pacific Northwest, representing the link between terrestrial and aquatic ecological communities (Macdonald et al., 2003). These influential regions are home to some of the most important ecosystem engineers known to humankind, the Pacific Salmon. Salmon-derived nutrient input in riparian ecosystems has a significant impact on ecosystem prosperity which in turn allows for the return of large amounts of high-quality organic matter to freshwater and riparian terrestrial systems (Reimchen, 2018). In addition to ecological significance, they are crucial for the support of coastal human economies (Helfield & Naiman, 2006). Studies demonstrate that coastal riparian ecosystems have enriched soils due to millennia of salmon spawning and decomposing alongside streambanks, subsequently releasing large amounts of organic biomass and nutrients such as carbon, nitrogen, and phosphorus into the soils which greatly increases soil organic matter content (Reimchen, 2018; Bilby et al., 2003).

Over the last several decades, studies have demonstrated that there has been a decreasing trend of salmon returning from the ocean to spawn in local streams off of the coast of British Columbia, Canada (Noakes et al., 2000). This salmon crisis has severe and wide-ranging economic, cultural, and ecological repercussions. The urbanization of once untouched salmon habitat is largely responsible since industrial and agricultural projects alter regional streams and increase pollution and run-off which makes them inaccessible or unsuitable for salmon (Gende et al., 2002). The Cougar Creek Watershed is a section of riparian forest intersecting Burns Bog in Delta B.C. The stream that flows through connects to the Fraser River and travels up through Burns Bog and into urban neighborhoods. Cougar Creek has historically been a successful salmon rearing stream and actively provides a habitat for spawning and rearing of a significant number of different salmonid species (Sierra, 2012). As an urban creek, this stream is highly sensitive to stressors and is greatly affected by urban activities which cause pollution and runoff (Sierra, 2012). With the increases in urbanization, the prosperity of Cougar Creek Stream is being greatly threatened and the resulting physical changes that are occurring require further investigation (Sierra, 2012).

Many studies have focused on investigating trends in salmon organic content near streams. A comprehensive study conducted by Reimchen et al. (2018) investigated the grand nutrient flow of salmon biomass through riparian ecosystems and found that 80% of salmon carcasses in spawning streams remain within 10 m of the stream with numbers declining at greater distances into the forest. Another study by Bilby et al. (2003) found that when sampling salmon-bearing streams, salmon-derived nitrogen in plant matter decreased with increasing distance from the stream. However, there is a lack of experimental evidence highlighting whether or not these trends correspond to an increase in overall organic content in the actual soils perpendicular to a stream. Additionally, all previous studies have focussed solely on sampling at streams isolated from human contact. There is an evident research gap in the literature examining how this trend upholds in urban salmon streams.

With the aforementioned circumstances in mind, this study was conducted to investigate how organic matter differed with proximity to, and distance from, the Cougar Creek Stream in Delta, B.C. The underlying motivation was to observe whether decreased salmon spawning in combination with recent urbanization effects has potentially affected organic soil content in this region in comparison to trends highlighted in the literature. Soil samples were collected at various transects of increasing distance from the stream and the soil was tested for organic matter composition to see whether this differed between transects. It was hypothesized that since organic matter content in healthy riparian ecosystems is related to kelt salmon decomposition, there should be a trend of decreasing organic soil content at samples farther away from the stream. The findings from this study will provide valuable information regarding the current state of this stream and will help instigate action needed to protect the creek and its salmon habitat.

PROCEDURE/METHODS

The soil samples were collected at five different transects located on a salmon spawning stream in Delta's Cougar Creek. Cumulatively, 15 sets of samples were extracted over the span of one hour. The area that was selected as the extraction site was approximately 150 meters from the entrance of the park, which allocated sufficient clearance to lay down a transect line that extended outwards perpendicular to the stream. Each transect was separated into five meter increments between 0 meters (right beside the stream) and 20 meters (Figure 1). Three soil replicates were extracted with a stainless steel spoon per transect where each sample consisted of approximately half a cup of soil.

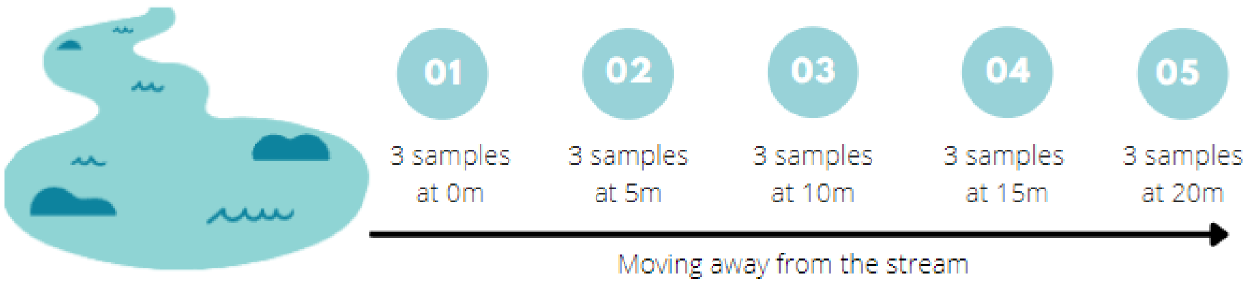

Figure 1. Overview of soil sample collection method. Blue circles display the transect number; transects are located every 5 m moving away from the stream; 3 samples were taken at each transect; each sample was taken around 10cm below the surface.

In order to avoid unnecessary debris in the samples (i.e. small leaves, wood chunks, rocks etc.), preliminary digging was required to expose an adequate abundance of soil for extraction. The samples were taken around 10 cm below the soil's initial surface. Following the soil collection, the samples were covered securely with lids and placed indoors at room temperature for approximately 24 hours. Subsequently, the samples were transferred into large weigh boats in the laboratory that were labelled corresponding to each sample specification (Figure 2). An empty weigh boat was placed inside the drying oven at an initial temperature of approximately 80 degrees to determine the threshold of heat that the plastic vessels could withstand. An initial examination of the weight boat revealed that the vessel became slightly deformed. Consequently, the oven temperature was lowered to approximately 60 degrees celsius in which all 15 samples were left to dry. Approximately 4 hours later, all of the samples were removed from the oven for another inspection, and all distorted weigh boats were replaced with new ones. Further, samples that appeared to have dried up in clumps were crushed up to produce an equal dispersion of the soil. Once completing the inspection, all of the samples were placed back into the oven to dry overnight.

Approximately 15 grams of each thoroughly dried sample was weighed out utilizing a calibrated standard jewelry scale. 25 milliliters of 3% hydrogen peroxide (H_2O_2) was added to each sample and mixed by shaking the weigh boat lightly, while setting aside another 25 milliliters of H_2O_2 as our control. After letting the samples sit for 24 hours, the weight was recorded once again and the organic soil content was determined by taking the difference from the two recorded weights.

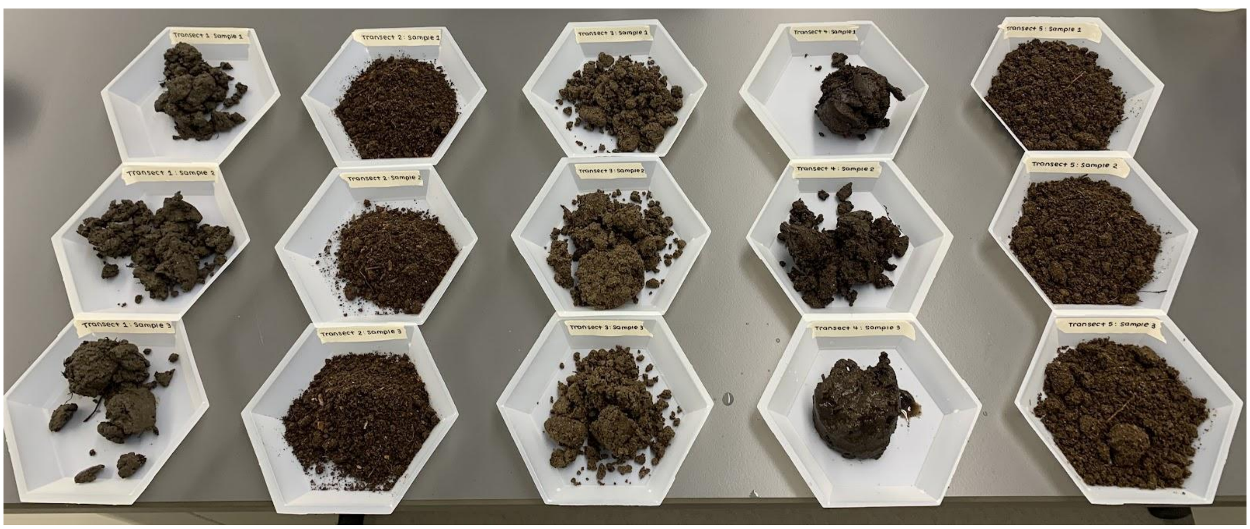

Figure 2. Soil samples (n=3) at transects 1 to 5 prior to drying.

Statistical Analysis

The data collected was statistically analyzed using *GraphPad*. The raw data showing the amount of weight lost for each transect was entered in 5 separate columns to obtain the mean and

95% CI for each transect which was graphed in Figure 3. The raw data was also used for the one-way ANOVA to see if the results were significant ($p<0.05$). To determine which specific groups are significantly different, a Tukey Kramer test was conducted.

RESULTS

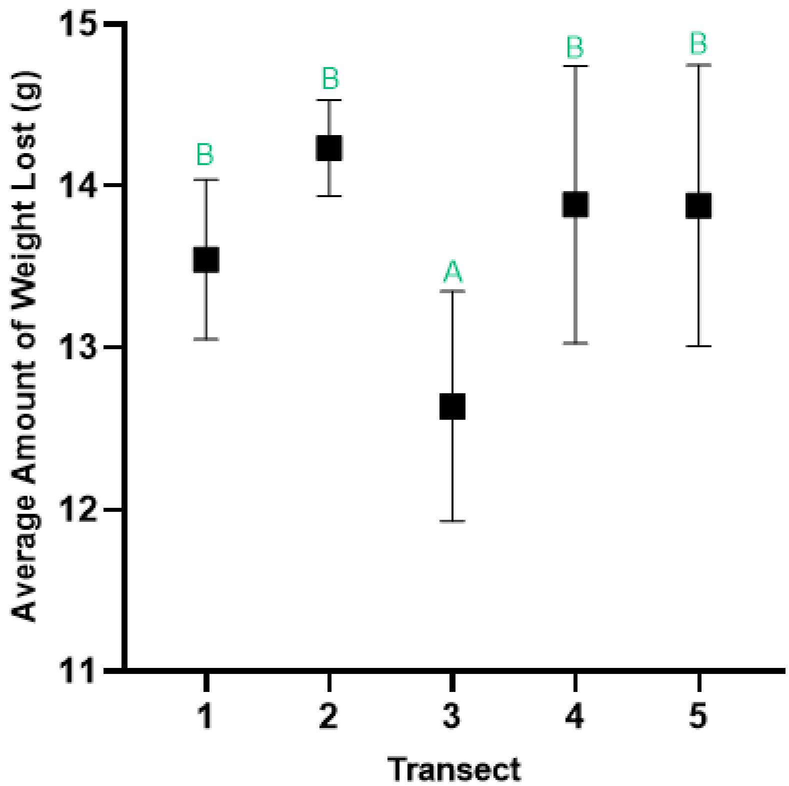

Figure 3. Mean weight lost at each of the 5 transects from soil samples at Cougar Creek (n=3). Square plots represent the mean; error bars show the 95% confidence intervals; letter differences represent significant differences between treatments ($p<0.05$).

The experimental results indicate that the 25 mL hydrogen peroxide control lost 4.8 grams and that transect 2 lost the most weight (14.23 +/- 0.14 g), when compared to transect 1 (13.54 +/- 0.22 g), transect 3 (12.64 +/- 0.32 g), transect 4 (13.88 +/- 0.39 g), and transect 5 (13.87 +/- 0.40 g). A Tukey Kramer test revealed that transect 3 is significantly different from transect 1 (p=0.0156), transect 2 (p=0.0002), transect 4 (p=0.0017), and transect 5 (p=0.0018) respectively. With the exception of the relationships between transect 3 and each of the other individual transects, there were no other transects that were significantly different from one another. The P-value (0.0003) calculated from the one-way ANOVA test demonstrates that there are statistically significant differences between the means of organic matter at each transect, however, we fail to reject our original null hypothesis as there is no evident decreasing trend in organic matter at increasing distances perpendicular to the stream.

DISCUSSION

The current study sought to investigate whether organic matter levels at increasing distances perpendicular to Cougar Creek Stream, a documented urban salmon spawning location, paralleled trends observed in literature, downstream of salmon spawning sites. As hydrogen peroxide dissolves organic matter, further analysis can be conducted on the amount of weight lost from the soil samples at each transect (Mikutta et al., 2005). We reject the null hypothesis that there is no significant difference in the mean organic matter between transects. However, there is no observable trend in organic matter content with increasing distance away from the stream. Overall, the experimental results did not indicate a decreasing trend of organic matter content at increasing distances perpendicular to the stream which contradicts the original hypothesis.

A study that was conducted in 2017 investigated the impact of land-based aquacultures on the quality and bacterial degradation of riverine dissolved organic matter. The research focused on measuring the differences in organic matter at transects located upstream and downstream, rather than at transects laid perpendicular to the stream site (Kamjunke et al., 2017).

However, the experimental results displayed a distinguishable difference in organic content that was discovered upstream and farther away from the stream site compared to the data downstream. Based upon the outcome of the aforementioned study in conjunction with the difference in organic matter found downstream of an active salmon spawning stream, it can be inferred that soil samples that are extracted at more distant transects contain greater abundances of organic matter. Following this principle, the current study incorporated perpendicular transects at increasing distances from the stream site. While the comparison of these two outcomes lack a level of accuracy due to the absence of recent research incorporating perpendicular transects away from the stream site, it is used as a current guideline for future research on this topic.

One notable factor that may have played a role in determining smaller differences of organic matter within the extracted soil samples is due to the increase in urbanization. Since 1978, several areas in North America have been dealing with an increase in urban development which has been interfering with natural aquatic ecosystems, thus leading to less critical salmon spawning streams (May et al., 2006). These stream ecosystems serve as habitats for several native species of salmon that hold great cultural, ecological, and socio-economic value. As a result, the cumulative effects of different land-uses including agricultural, recreational, residential, and commercial practices, could have potentially promoted processes such as leaching where particular levels of soluble organic matter were removed from the soil. Similarly, flooding and runoff pollution are also processes that may have been influenced by these land-use practices, where an abundance of organic matter was washed away through storm drains and were left untreated.

A limitation of this study comes from the surrounding terrain of the collection site as physical barriers such as large trees restricted the extent that the transect line could extend perpendicular to the stream. Thus, a potential reason to explain the lack of decreasing trends in organic matter content at increasing distances from the stream can be attributed to the failure to select significant transect increments. In practice, several experimental procedures outlined in previous literature utilized much larger distances between transects such as a similar study conducted by Kamjunke et al. (2017), which considered transects 100-200m downstream from a salmon spawning site. The experimental procedure utilized 5 metre increments, however, it is unlikely that the quantity of organic matter would differ significantly between such minimal distances. Consequently, this rationale could account for the lack of significant differences observed between each transect.

In addition, further literature investigation revealed that hydrogen peroxide is not the most effective oxidative reagent available to remove organic matter from soils. A study conducted by Mikutta et al. (2005), compared the performance of three recognized reagents in the removal of organic matter and determined that both sodium hypochlorite and disodium peroxodisulfate are more effective at removing organic content than hydrogen peroxide. Moreover, the treatments outlined for the current experimental samples allowed for the hydrogen peroxide to react with the soil for a day-long period. However, according to Mikutta et al. (2005), previous experimental procedures have demonstrated that the removal of organic matter from soils with hydrogen peroxide requires several days. As such, it is probable that the selected treatment period failed to allocate a sufficient time to dissolve significant amounts of organic matter as observed in the results.

Furthermore, soil from Transect 2 lost the most weight in the experimental results as it possessed the highest quantity of organic content (Figure 3). Following the addition of the hydrogen peroxide, the soil sample from Transect 2 absorbed the reagent the fastest, while the other transect samples developed a layer of the reagent on the surface of the soil. From qualitative observations, the soil samples from this transect appeared both darker and richer (Image 1). A potential reason that could explain the higher quantity of organic matter observed from Transect 2 is a result of it being sampled within close proximity to a large tree. Organic matter is one of the key components in soil development (Van Cleve & Powers,1995, as cited in Strand et al., 2016) which promotes and supports vegetation growth. Decreases in organic matter content are associated with decreasing soil quality (Dexter, 2004), therefore, it is highly conceivable that the mean organic content of transect 2 would be significantly higher in comparison with other transects as observed in the experimental results.

Future studies following this methodology should consider implementing the following modifications to improve the experimental results. Firstly, the experimental procedure should be amended to consider utilizing transects with larger distances between one another; to allow for a greater observable difference between the organic matter content at each site. Additionally, future replicates of this study should allow a greater period of time for the selected oxidative reagent to efficiently remove the organic matter from the soil samples. Further, prior to determining the transect location, the surrounding terrain should be taken into consideration to eliminate extraneous variables such as the amount of vegetation surrounding each transect as vegetation can affect organic matter levels.

CONCLUSION

Overall, we reject the null hypothesis that there is no significant difference in the mean organic matter between transects. However, the experimental findings do not demonstrate any indication of decreasing trends between the amount of organic matter in the soil with increasing distance perpendicular from Cougar Creek, a salmon-bearing stream. A variety of possible explanations have been proposed, with the predominant cause likely being a conjunction of urbanization effects on Cougar Creek Stream along with methodological errors which in turn yielded the discrepancy in measurements. As such, further investigation is required to address the research gap analyzing the relationship between salmon decomposition and organic matter content of soils perpendicular to rather than parallel to the streams.

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