A Look into the Interwoven Relationship Between Salmon Population and Soil Health in Respect to Organic Carbon

Jiyoon Chang, Leah Kim, Julian Kunik, Alexis Llewellyn, and Mark Penner

Abstract

Total Organic Carbon (TOC) found in soil is an indicator of the forest health and is indirectly related to the relative amount of spawning salmon. Our team studied two creeks; Spanish Bank Creek which sustains a consistent salmon run and Salish Creek, which has not had as much success. It was firstly hypothesized that Spanish Bank Creek would have higher levels of TOC than Salish Creek, because it has a higher yield of spawning salmon, and therefore a healthier creek. We took multiple soil samples from the mouth, middle and headwaters of each creek and applied a H_2O_2 catalyst to determine the percent decrease of organic matter, which is a presentation of TOC. In addition to our primary hypothesis, a secondary hypothesis was made pertaining to the levels of TOC at locations within each creek. It was predicted that the headwaters would have the highest levels of TOC, as this is where the salmon are dying. This study found that there was a significant difference ($p = 0.0075$) between the two creeks, where Spanish Bank had a greater average TOC (by 0.3 g), however there was no significant difference ($p = 0.6015$) in TOC levels among the locations within each creek.

Introduction

For years, it has been known that spawning salmon act as a keystone species in their respective ecosystems (Garibladi & Turner, 2004). When the salmon population die after spawning, their carcasses provide nutrients such as nitrogen (N), carbon (C), Phosphorus (P) to freshwater systems (Juday et al. 1932). It has been found that streams with higher salmon population density have a greater level of nitrogen and organic carbon isotopes (Bilby et al. 1996). These nutrients are thought to have significant impact on the productivity of the freshwater ecosystem (See Figure 1).

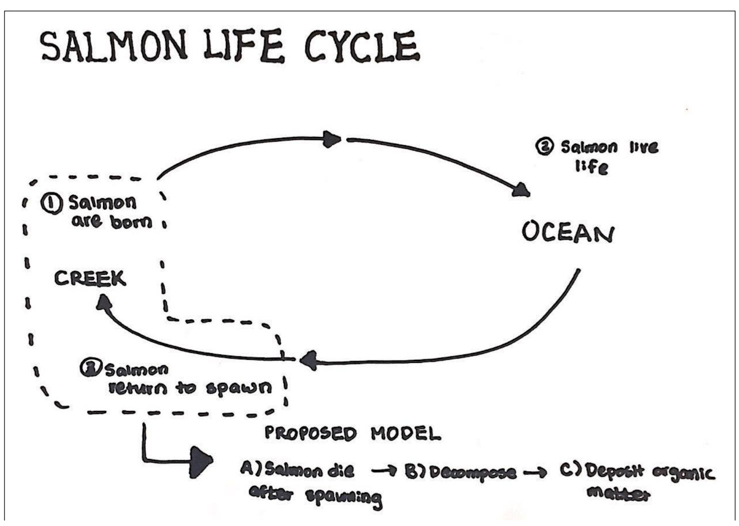

Figure 1. A model of the salmon life cycle. Salmon are born in the creek (1), then live their lives in the ocean (2), and finally return to spawn in the original creek (3). Our proposed model expands on the creek events, where salmon die after spawning (A), decompose (B), and their carcasses deposit nutrients, which increase levels of organic matter (C).

The health of an ecosystem is directly related to the chemical makeup of the soil. Total organic carbon (TOC) is one of the crucial components of soil as it has many benefits, which includes its ability to regulate respective nutrient and moisture levels. Thus, the determination of TOC is of great importance to characterize the health of a site (Schumacher, 2002). Hydrogen peroxide (H_2O_2) can be used to measure TOC levels in soil. H_2O_2 acts as a catalyst to break down large carbon chains into glucose (Maksimovic & Vucinic, 1998). This glucose then reacts with oxygen and is further broken down into carbon dioxide (CO_2) and water (H_2O) (Greenwood & Goodman 1965).

In this experiment, the TOC from the organic matter in the soil, bond with the oxygen (O_2) that is in H_2O_2 to form carbon dioxide bubbles and water. A large part of the soil organic matter will be decomposed by H_2O_2 and it is possible to determine TOC by treating a sample of soil with H_2O_2 and noting the weight differences. In other words, the larger the percent decrease in weight of the samples after the treatment, the greater amount of TOC in the soil. Moreover, the treatment with H_2O_2 will not affect the combined water content or the weight of the inorganic material (Petigara et al. 2002).

Our first hypothesis is related to the relative healthiness between both Spanish Bank and Salish Creek. These two creeks, both located in Pacific Spirit Park, were chosen as they were the best representation of the lower mainland ecosystems, and in closest proximity to our facilities. The null hypothesis (H_O^1) for this states that there is no difference in TOC between Spanish Bank and Salish Creek. The alternative hypothesis (H_A^1) is that we will observe a difference in organic carbon levels between the two creeks. According to British Columbia Streamkeepers (2000), Spanish Bank has had a more consistent salmon run, with a higher yield of returning salmon. We thus predict that Spanish Bank is a healthier creek, and is expected to have an overall higher % decrease in carbon, which is a direct relation to the amount of TOC.

The second hypothesis is related to the amount TOC at varying locations of each creek (mouth, middle, and headwaters). The null hypothesis (H_O^2) for this states that there is no difference in TOC levels between locations along both Spanish Bank and Salish Creek. The alternative hypothesis (H_A^2) is that there will be an observable difference in TOC levels depending on the location along the creeks. These salmons return to the furthest point of the creek, the headwater, as they travel back from the ocean to their origin of birth (Groot, 1991). Thus, we predict that the headwater location of both Spanish Bank and Salish Creek will have the highest amount of TOC as this is where salmon are spawning, dying, and decomposing.

Methods

We carried out an experiment to determine the TOC levels in the soil of two creeks; Spanish Bank and Salish Creek. Upon arrival, we identified three locations at each creek: mouth, middle, and headwater. We found it the easiest to first locate the mouth of the creek, which was where the creek met the ocean. At this point, both Salish Creek (also known as Acadia Creek) and Spanish Bank Creek meet Acadia Beach and Spanish Bank Beach, respectively. We then determined the relative locations for the headwater and the middle waters. Due to the difficulty of determining where the start and middle of the creeks were, the most accurate method that we used was to follow the creek to the furthest point of adequate water flow and bank width, and classified this as the headwater. From this point, we followed the creek in the opposite direction, back towards the mouth, and stopped at a central distance between the mouth and the headwater, which we determined as the middle for each creek.

Once these three locations at each creek were marked (with yellow tape), we proceeded to measure distance from the creek bank outwards, at each location. We laid out a transect line from the edge (bank) of the creek waters, and measured outwards, away from the creek. We marked at 5 metre increments; 0, 5, and 10 metres from the bank. At each point of collection (0m, 5m, 10m) we collected 5 samples, repeating this at the mouth, the middle, and the headwater. We collected a mass amount of soil at each point (approximately 75 grams) into labelled ziploc bags, and then transferred these large samples to an indoor location, to avoid contamination from the outdoor environments (See Figure 2A).

We then took our samples to a dry flat area, to protect our experiment from external disturbances and contamination. Using a spoon, 10.00 grams of soil (with an uncertainty of ± 0.5g) were weighed in a plastic weigh boat with a scale to the nearest hundredth of a gram. Prior to this step, we weighed the empty weigh boats, and then weighed by difference. In each soil sample, 10 ml of 3% hydrogen peroxide (H_2O_2) was added using a 10 ml graduated pipette (See Figure 2B). At this stage, bubbles should be seen, which is an indication that the decomposition reaction is occurring. Although 10 ml of water should have been added to the sample as well, the soil in this case was moist enough that this step was omitted with every sample being tested. We weighed each sample, following the initial addition of H_2O_2, and after 1 hour, we measured weight loss in each sample (See Figure 2C). We repeated this procedure twice at each creek. Thus, data was collected in Spanish Bank on October 27th, November 7th, while data was collected in Salish Creek on October 31st, November 10th. In total, we have collected 45 replicates per creek for each day. In the end, we finished off our experiment with 90 samples in total for each creek.

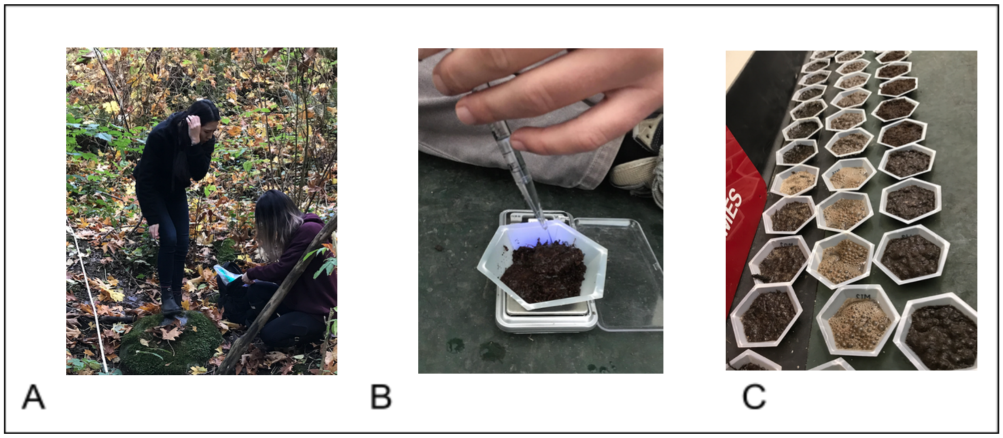

Figure 2. Process of collection and experimental procedure. Samples were collected at creek locations into ziploc bags (A). These samples (~10 g each) were then weighed, and H_2O_2 was added to each (B). Upon addition of H_2O_2 , a reaction occurred, where bubbles and foam were visible (C).

We used pure organic compost collected at the UBC garden as the positive control, as it is known to contain high levels of TOC, and thus would show a large percentage decrease in weight (Zmora-Nahum et al., 2005). In contrast, we collected raw sand from the sandbox at a school playground to be used as the negative control, as it should show little to no decrease in weight.

Upon calculating the change in weight (g), the percent decrease in soil mass was calculated by dividing the change in weight over the initial weight For each hypothesis, the variance between these values were calculated using a one-way ANOVA test. We chose to do one-way ANOVA tests for each hypothesis. Our first ANOVA was compare the means of TOC levels between the two creeks. The second ANOVA was to compare the means between the locations (mouth, middle, head). Both tests were used to determine whether they are statistically significantly different from each other. The healthiness of the two creeks were tested in the first hypothesis using all the data collected in each creek. The one-way ANOVA test was used again for th second hypothesis utilizing the data categorized in terms of creek location (mouth, middle, head), regardless of the specific creek. Ultimately, the F-Value and the P-Value, under a value of 5% significance, was determined for each hypothesis (Calculations; See Results).

Results

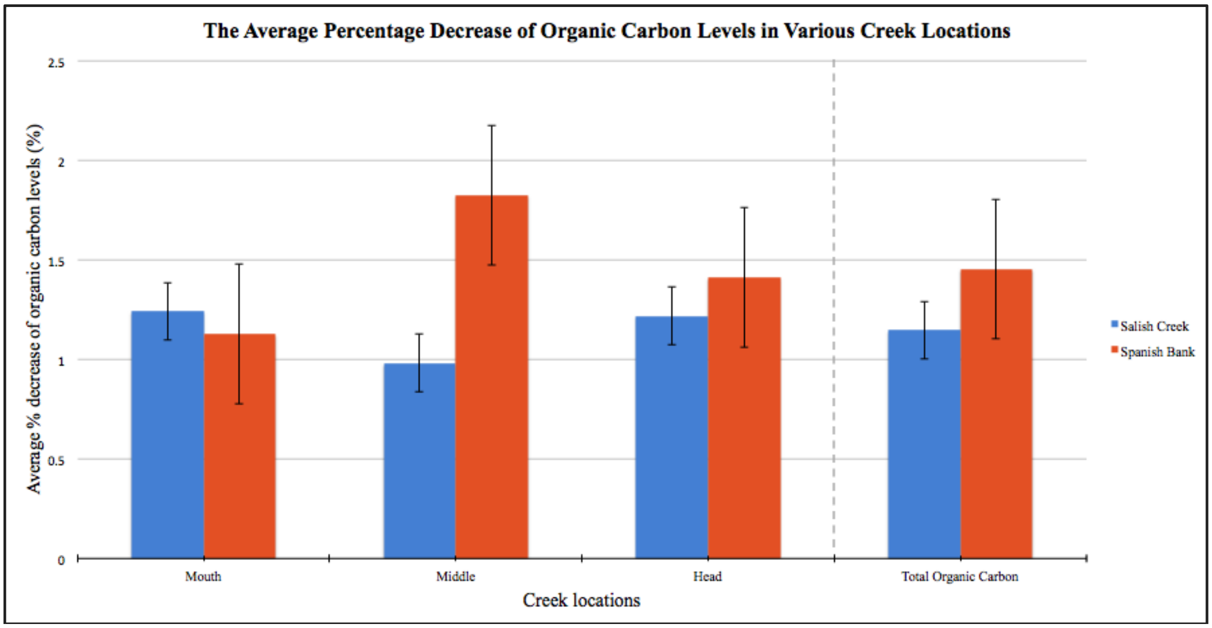

Figure 3. Side-by-side bar graph of the average percentage decrease of organic carbon levels at the mouth, middle and headwater locations at two creeks: Salish Creek (blue) and Spanish Bank (red). The coupled bars on the far right represent the comparison of overall TOC level decrease, regardless of relative location. Error bars represent the standard deviation present between results from each creek. Note that the error bars have the same range of variation within creeks.

The significance in difference of TOC between Salish Creek and Spanish Bank (Hypothesis 1); and the difference in TOC between locations along both Salish Creek and Spanish Bank (Hypothesis 2) were determined. We constructed a side-by-side bar graph (Figure 3) to summarize both hypothesis. The error bars represent the standard deviation of the averages of each creek. It is evident that Spanish Bank has a much larger range of error, when compared to the smaller error bars of Salish Creek. By comparing the average percentage decrease in TOC levels at various locations, (mouth, middle, and head) (*blue= Salish* and *red= Spanish*), we were able to see trends in the data. Firstly, Spanish Bank shows a greater % decrease at the middle, headwaters and TOC levels overall. In terms of these locations, although there is little variance between the two creeks at the mouth and head, a significantly greater decrease in TOC level at the middle waters of Spanish Bank is observed.

A one-way ANOVA test was used to further investigate our two hypotheses. Table 1 shows the summary of our F-test related to differences in organic carbon levels between the two creeks. Values in Table 1 were calculated using various equations.

Analysis Results

	Spanish Bank	**Salish Creek**	**Total**
N	86	89	175
Mean	1.4805	1.1596	1.3173
Std. Dev.	0.8255	0.7421	0.7983

F – value	*7.3226*
P – value	*0.007491*

Table 1. Summary of F-test analysis (One-Way ANOVA) for Hypothesis 1 (difference in TOC between two creeks).

Table 2 similarly shows the summary for the F-test related to difference in organic carbon levels between varying locations along each creek. See Calculation #2 for an example of how to calculate the values.

	Mouth	**Middle**	**Headwater**	**Total**
N	56	59	59	**174**
Mean	1.2455	1.3964	1.3164	**1.3207**
Std. Dev.	0.8656	0.8431	0.6879	**0.7994**

F – value	*0.50988*
P – value	*0.601481*

Table 2. Summary of F-test analysis (One-Way ANOVA) for Hypothesis 2 (difference in organic carbon level between mouth, middle, headwater).

Discussion

Salmon carcasses are an important source of organic matter in coastal streams (See Figure 1). Mass migrations of salmon can import about 55% of nutrients to the streams through their spawning behaviour (Moore et al., 2007). The nutrients support increased productivity within the ecosystem which then lead to an increased amount of TOC chiefly through leaf litter that is deposited from the trees (that utilize those very nutrients). TOC is one of the crucial components of soil as it has the ability to: absorb both naturally-occurring and anthropogenicallyintroduced organic compounds, absorb and release plant nutrients, and hold water in the soil environment. Ecosystems that have healthy levels of TOC (as well as other nutrients) also have the ability to support healthier streams; thus they are able to support more salmon (Helfield & Naiman, 2001). This fertilization of the soil and the population of salmon are interwoven in a positive feedback mechanism where the healthy ecosystems provide suitable habitats for salmon to spawn and reproduce, and increased salmon spawning increases the health of the stream and the surrounding forest.

This phenomenon was observed in our experiment as Spanish Bank Creek is known to have a larger salmon run than Salish Creek, and it also displayed greater levels of TOC (indicating a healthier ecosystem). In relation to our hypothesis 1, and according to ANOVA, the result is significant at $p < 0.05$ ($p=0.0075$). Therefore, we reject H_o and support H_A . Thus, there is a difference between organic carbon levels between Spanish Bank and Salish Creek.

Spanish Bank Creek has been previously restored so that salmon now return annually, however, Salish Creek is currently in the process of being restored so that more salmon can return to spawn in the creek. Our results that we have found are significant in that they show there is a correlation between salmon populations and forest productivity, and perhaps in the future more creeks can be restored so that the salmon can return. Wild salmon populations in British Columbia have been decreasing for years (Moore et al., 2007), which has had a devastating effect on the local economy, environment and Indigenous culture which has had a long tradition associated with the salmon run.

In relation to our hypothesis 2, and according to ANOVA, the result is not significant at $p < 0.05$ ($p=0.6015$). We failed to reject H_o , thus there is no difference between organic carbon levels between the mouth, middle, and headwaters of the creeks. Our secondary hypothesis focused on the varying levels of TOC along different locations of the creek (the mouth, middle and head). We found no significant difference between the three sites across the two creeks, and we also did not observe a trend. We predicted that areas where salmon spawned (and subsequently died) would be the areas that had the highest TOC. However, due to the lack of research and time, the true locations of the where the salmon spawned remained uncertain. In subsequent studies, a focus on where the salmon carcasses settle within these urban creeks would be useful in identifying key locations to harvest the soil samples.

Due to the nature of this experiment's limited resources and time, a few errors have been illuminated. Amongst our data, a couple of the data points collected from Spanish Bank Creek showed an increase in weight. This may have been due to human error in recording the data or in the use of the scales, nevertheless those data points were extrapolated. Beyond other human error that could have taken place (pipetting, zeroing of scales, data input…), other variables could have affected the data. Weather conditions were variable, therefore the soil samples also varied- mainly in their moisture levels. We did not need to add water to our soil samples before addition of hydrogen peroxide because the soil was already sufficiently moist, however in a future experiment it would have been more consistent to fully dehydrate the soil and then add a predetermined amount of water. On that note, when H_2O_2 was added to the soil, no uniform homogenization of the mixture was conducted which could have led to pockets of soil not being exposed to the catalyst.

Although the study that was conducted could have had logistical issues; in our opinion, this experimental setup could have been enlarged to include more creeks, a greater amount of data points along the creeks, and incorporate real data on the observed levels of salmon in each stream. In addition to this, the study of nitrogen levels within the soil could have been analyzed using nitrogen isotope analysis, in order to measure the more direct effects the salmon carcasses have on the ecosystem.

Conclusion

As predicted, the findings of this study conclude that Spanish Bank Creek is in fact healthier than Salish Creek. However, the difference in TOC is not significantly different at the different locations along each of these creeks. TOC levels are important as they are a measure of how salmon affect forest health, and how they contribute as a keystone species to their ecosystem.

Acknolwedgements

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Citations

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Appendix

Data Tables

i)

#	Weight Boat (g)	Weight Boat + Soil (g)	Soil (g)	Soil+ H2O2 initial (g)	Soil + H2O2 final (g)	Change in weight (g)	% decrease
MO1	1.49	11.95	10.46	21.22	21.24	(+)0.02	N/A
MO2	1.54	11.85	10.31	21.23	21.35	(+)0.12	N/A
MO3	1.71	11.96	10.25	21.38	21.3	0.08	0.374181478
MO4	1.73	11.39	9.66	21.23	21.2	0.03	0.141309468
MO5	1.69	11.92	10.23	21.26	21.19	0.07	0.32925682
MO6	1.7	12.06	10.36	21.89	21.87	0.02	0.091365921
MO7	1.69	11.37	9.68	21.02	20.98	0.04	0.190294957
MO8	1.65	11.26	9.61	21.06	20.93	0.13	0.617283951
MO9	1.69	11.34	9.65	21.03	20.9	0.13	0.618164527
MO10	1.74	11.88	10.14	21.53	21.44	0.09	0.418021366
MO11	1.67	11.94	10.27	21.86	21.81	0.05	0.228728271
MO12	1.68	11.2	9.52	20.59	20.56	0.03	0.145701797
MO13	1.75	12.06	10.31	21.91	21.87	0.04	0.182565039
MO14	1.68	11.4	9.72	21.33	21.32	0.01	0.046882325
MO15	1.71	11.53	9.82	21.49	21.42	0.07	0.325732899
averages	1.674666667	11.674	9.999333333	21.33533333	21.292	0.060769231	**0.285345294**
MID1	1.81	11.81	10	21.52	21.34	0.18	0.836431227
MID2	1.66	11.72	10.06	21.67	21.55	0.12	0.55376096
MID3	1.6	11.92	10.32	21.59	21.36	0.23	1.065308013
MID4	1.67	12.02	10.35	21.96	21.9	0.06	0.273224044
MID5	1.67	11.49	9.82	21.55	21.41	0.14	0.649651972
MID6	1.6	11.81	10.21	21.55	21.29	0.26	1.20649652
MID7	1.68	11.85	10.17	21.66	21.15	0.51	2.354570637
MID8	1.68	11.94	10.26	21.66	21.18	0.48	2.216066482
MID9	1.67	11.45	9.78	21.16	20.65	0.51	2.41020794
MID10	1.68	*11.82*	*10.14*	21.64	21.02	0.62	2.865064695
MID11	1.61	11.83	10.22	21.81	21.26	0.55	2.521779
MID12	1.69	12.19	10.5	21.87	21.33	0.54	2.469135802
MID13	1.66	12.02	10.36	21.95	21.31	0.64	2.91571754
MID14	1.6	11.42	9.82	21.46	20.94	0.52	2.423112768
MID15	1.68	11.9	10.22	21.71	21.14	0.57	2.625518194
averages	1.664	11.81266667	10.14866667	21.65066667	21.25533333	0.395333333	**1.825736386**
H1	1.67	11.9	10.23	19.76	19.95	(+)0.19	
H2	1.67	11.57	9.9	20.63	21.37	0.74	3.58700921
H3	1.66	11.53	9.87	21.48	21.2	0.28	1.303538175
H4	1.68	11.53	9.85	21.38	21.19	0.19	0.88868101
H5	1.74	12.28	10.54	22.23	22.04	0.19	0.854700855
H6	1.64	11.83	10.19	21.72	21.6	0.12	0.552486188
H7	1.68	11.27	9.59	21.21	21.06	0.15	0.707213579
H8	1.69	11.67	9.98	21.61	21.45	0.16	0.740397964
H9	1.65	11.29	9.64	21.09	20.89	0.2	0.948316738
H10	1.64	11.33	9.69	21.09	20.94	0.15	0.711237553
H11	1.53	11.33	9.8	21.09	20.92	0.17	0.806069227
H12	1.53	11.93	10.4	21.71	21.37	0.34	1.566098572
H13	1.5	11.66	10.16	21.64	21.36	0.28	1.293900185
H14	1.58	11.49	9.91	21.36	21.23	0.13	0.608614232
H15	1.56	11.69	10.13	21.92	21.15	0.77	3.512773723
averages	1.628	11.62	9.992	21.328	21.18133333	0.276428571	**1.291502658**

ii)

#	Weight Boat (g)	Weight Boat + Soil (g)	Soil (g)	Soil+ H2O2 initial (g)	Soil + H2O2 final (g)	Change in weight (g)	% decrease
MO1	1.84	12.06	10.22	21.93	21.44	0.49	2.234382125
MO2	1.81	11.8	9.99	21.77	21.29	0.48	2.204869086
MO3	1.84	12.02	10.18	21.91	21.46	0.45	2.053856686
MO4	1.8	11.69	9.89	21.64	21.23	0.41	1.894639556
MO5	1.87	11.99	10.12	21.94	21.53	0.41	1.868732908
MO6	1.85	11.66	9.81	21.56	21.09	0.47	2.179962894
MO7	1.83	11.92	10.09	21.84	21.39	0.45	2.06043956
MO8	1.76	11.92	10.16	21.58	21.18	0.4	1.853568119
MO9	1.8	12.16	10.36	21.93	21.4	0.53	2.416780666
MO10	1.77	11.56	9.79	21.34	20.9	0.44	2.06185567
MO11	1.77	12.24	10.47	21.96	21.56	0.4	1.821493625
MO12	1.8	11.54	9.74	21.21	20.9	0.31	1.461574729
MO13	1.81	11.76	9.95	21.53	21.13	0.4	1.857872736
MO14	1.76	11.83	10.07	21.81	21.42	0.39	1.788170564
MO15	1.81	12.09	10.28	21.95	21.55	0.4	1.822323462
averages	1.808	11.88266667	10.0746667	21.72666667	21.298	0.428666667	**1.972034826**
MID1	1.7	12	10.3	21.95	21.72	0.23	1.047835991
MID2	1.54	11.6	10.06	21.47	21.21	0.26	1.210992082
MID3	1.67	12.11	10.44	21.94	21.68	0.26	1.185050137
MID4	1.5	11.9	10.4	21.7	21.47	0.23	1.059907834
MID5	1.57	11.45	9.88	21.5	21.29	0.21	0.976744186
MID6	1.63	11.55	9.92	19.8	19.33	0.47	2.373737374
MID7	1.7	11.62	9.92	21.46	20.97	0.49	2.283317801
MID8	1.64	11.55	9.91	19.68	19.23	0.45	2.286585366
MID9	1.65	11.95	10.3	20.24	19.75	0.49	2.420948617
MID10	1.74	11.96	10.22	20.04	19.58	0.46	2.295409182
MID11	1.69	11.54	9.85	21.36	20.91	0.45	2.106741573
MID12	1.6	11.99	10.39	20.24	19.87	0.37	1.828063241
MID13	1.73	11.74	10.01	20.65	21.21	N/A	N/A
MID14	1.7	11.61	9.91	21.46	20.98	0.48	2.236719478
MID15	1.71	11.54	9.83	21.46	20.98	0.48	2.236719478
averages	1.651333333	11.74066667	10.0893333	20.99666667	20.67866667	0.380714286	**1.82491231**
H1	1.8	12.02	10.22	21.9	21.65	0.25	1.141552511
H2	1.69	11.85	10.16	22.06	21.81	0.25	1.133272892
H3	1.71	11.51	9.8	21.37	21.1	0.27	1.263453439
H4	1.8	11.66	9.86	21.63	21.36	0.27	1.248266297
H5	1.69	11.71	10.02	21.73	21.43	0.3	1.380579844
H6	1.72	11.93	10.21	20.35	19.94	0.41	2.014742015
H7	1.83	11.61	9.78	21.48	21.12	0.36	1.675977654
H8	1.84	11.81	9.97	21.8	21.46	0.34	1.559633028
H9	1.81	11.72	9.91	21.58	21.2	0.38	1.760889713
H10	1.61	11.42	9.81	21.4	21.05	0.35	1.635514019
H11	1.78	12.15	10.37	22.05	21.7	0.35	1.587301587
H12	1.74	11.73	9.99	21.7	21.32	0.38	1.751152074
H13	1.56	11.6	10.04	21.61	21.25	0.36	1.665895419
H14	1.61	11.7	10.09	21.63	21.29	0.34	1.571890892
H15	1.54	11.54	10	21.53	21.18	0.35	1.625638644
averages	1.715333333	11.73066667	10.0153333	21.588	21.25733333	0.330666667	**1.534384002**

Table 3. Raw data table of soil samples collected at Spanish Bank. ***(i)****, Are the samples extracted on October 27th and* ***(ii)****, are the sample datas extracted on November 7th, 2017. Where MO=mouth, MID=middle, and H=headwaters. Soil #1-5 is sample collection at 0 metres, soil #5-10 is sample collection at 5 metres and soil # 11-15 is sample collection at 10 metres (ex. MO1 to MO5).*

iii)

#	Weight Boat (g)	Weight Boat + Soil (g)	Soil (g)	Soil+ H2O2 initial (g)	Soil + H2O2 final (g)	Change in weight (g)	% decrease
MO1	1.68	11.74	10.06	21.56	21.01	0.55	2.551020408
MO2	1.68	11.73	10.05	21.65	21.19	0.46	2.124711316
MO3	1.69	11.86	10.17	21.86	21.42	0.44	2.012808783
MO4	1.71	11.62	9.91	21.46	21.02	0.44	2.050326188
MO5	1.73	11.49	9.76	21.35	20.91	0.44	2.06088993
MO6	1.73	11.67	9.94	21.63	21.21	0.42	1.941747573
MO7	1.72	12.15	10.43	22.14	21.67	0.47	2.122854562
MO8	1.71	11.6	9.89	21.72	21.24	0.48	2.209944751
MO9	1.73	11.45	9.72	21.28	20.85	0.43	2.020676692
MO10	1.69	11.52	9.83	21.55	21.11	0.44	2.041763341
MO11	1.67	12.06	10.39	22.1	21.67	0.43	1.945701357
MO12	1.73	11.41	9.68	21.35	20.93	0.42	1.967213115
MO13	1.7	11.48	9.78	21.53	21.09	0.44	2.043660009
MO14	1.63	11.34	9.71	21.19	20.78	0.41	1.934874941
MO15	1.7	11.63	9.93	21.65	21.21	0.44	2.032332564
averages	1.7	11.65	9.95	21.60133333	21.154	0.447333333	**2.070701702**
MID1	1.7	11.92	10.22	22	21.67	0.33	1.5
MID2	1.53	11.76	10.23	21.66	21.36	0.3	1.385041551
MID3	1.68	11.94	10.26	22	21.72	0.28	1.272727273
MID4	1.53	11.72	10.19	21.55	21.29	0.26	1.20649652
MID5	1.61	11.93	10.32	21.92	21.63	0.29	1.322992701
MID6	1.61	11.56	9.95	21.53	21.15	0.38	1.764979099
MID7	1.7	11.79	10.09	21.69	21.26	0.43	1.982480406
MID8	1.67	11.73	10.06	21.5	21.16	0.34	1.581395349
MID9	1.63	11.85	10.22	21.61	21.23	0.38	1.758445164
MID10	1.73	11.62	9.89	21.4	21.06	0.34	1.588785047
MID11	1.67	11.73	10.06	21.43	21.08	0.35	1.633224452
MID12	1.56	11.54	9.98	21.29	20.91	0.38	1.784875528
MID13	1.72	11.63	9.91	21.36	20.96	0.4	1.872659176
MID14	1.73	11.44	9.71	21.29	20.91	0.38	1.784875528
MID15	1.75	11.89	10.14	21.49	21.07	0.42	1.954397394
averages	1.654666667	11.73666667	10.082	21.58133333	21.23066667	0.350666667	**1.626225013**
H1	1.72	12.09	10.37	20.18	19.82	0.36	1.7839445
H2	1.67	12.1	10.43	21.6	21.5	0.1	0.462962963
H3	1.64	11.86	10.22	21.57	21.23	0.34	1.576263329
H4	1.65	11.36	9.71	21.21	20.82	0.39	1.838755304
H5	1.71	11.82	10.11	21.56	21.17	0.39	1.80890538
H6	1.65	11.76	10.11	21.65	21.23	0.42	1.939953811
H7	1.64	11.68	10.04	21.53	21.11	0.42	1.950766373
H8	1.67	12.11	10.44	22.02	21.6	0.42	1.907356948
H9	1.72	12.09	10.37	20.11	19.71	0.4	1.989060169
H10	1.54	11.75	10.21	20.14	19.76	0.38	1.886792453
H11	1.65	11.98	10.33	21.89	21.53	0.36	1.644586569
H12	1.71	11.78	10.07	21.73	21.39	0.34	1.564657156
H13	1.51	11.54	10.03	19.56	19.23	0.33	1.687116564
H14	1.59	11.51	9.92	21.24	20.87	0.37	1.741996234
H15	1.53	11.56	10.03	21.44	21.03	0.41	1.912313433
averages	1.64	11.79933333	10.1593333	21.162	20.8	0.362	**1.713028746**

iv)

#	Weight Boat (g)	Weight Boat + Soil (g)	Soil (g)	Soil+ H2O2 initial (g)	Soil + H2O2 final (g)	Change in weight (g)	% decrease
MO1	1.68	11.68	10	19.97	21.66	(+) 0.69	
MO2	1.68	11.68	10	21.65	21.66	(+) 0.01	
MO3	1.69	11.69	10	21.48	21.44	0.04	0.186219739
MO4	1.71	11.71	10	21.74	21.62	0.12	0.551977921
MO5	1.73	11.73	10	21.63	21.58	0.05	0.231160425
MO6	1.73	11.73	10	21.64	21.53	0.11	0.50831793
MO7	1.72	11.72	10	21.34	21.21	0.13	0.60918463
MO8	1.71	11.79	10.08	21.84	21.83	0.01	0.045787546
MO9	1.73	11.63	9.9	21.47	21.39	0.08	0.372612948
MO10	1.69	11.69	10	21.7	21.61	0.09	0.414746544
MO11	1.67	11.53	9.86	21.05	21.01	0.04	0.190023753
MO12	1.73	11.74	10.01	21.41	21.21	0.2	0.934142924
MO13	1.7	11.55	9.85	21.26	21.18	0.08	0.376293509
MO14	1.63	11.4	9.77	21.52	21.4	0.12	0.557620818
MO15	1.7	11.74	10.04	21.4	21.31	0.09	0.420560748
averages	1.7	11.66733333	9.96733333	21.40666667	21.44266667	0.089230769	**0.415280726**
MID1	1.7	11.63	9.93	21.56	21.54	0.02	0.092764378
MID2	1.53	11.32	9.79	21.31	21.21	0.1	0.469263257
MID3	1.68	11.99	10.31	21.82	21.79	0.03	0.137488543
MID4	1.53	11.57	10.04	21.55	21.49	0.06	0.278422274
MID5	1.61	11.99	10.38	22.05	21.96	0.09	0.408163265
MID6	1.61	11.51	9.9	21.74	21.73	0.01	0.04599816
MID7	1.7	11.67	9.97	21.71	21.71	0	0
MID8	1.67	11.4	9.73	21.41	21.34	0.07	0.326950023
MID9	1.63	12.05	10.42	21.82	21.71	0.11	0.504124656
MID10	1.73	11.38	9.65	21.31	21.25	0.06	0.281557954
MID11	1.67	11.84	10.17	21.56	21.38	0.18	0.834879406
MID12	1.56	11.16	9.6	21.22	21.16	0.06	0.282752121
MID13	1.72	11.53	9.81	21.46	21.39	0.07	0.326188257
MID14	1.73	11.83	10.1	21.78	21.69	0.09	0.413223141
MID15	1.75	11.58	9.83	21.37	21.23	0.14	0.655124006
averages	1.654666667	11.63	9.97533333	21.578	21.50533333	0.072666667	**0.337126629**
H1	1.72	11.63	9.91	21.64	21.63	0.01	0.046210721
H2	1.67	11.42	9.75	21.5	21.33	0.17	0.790697674
H3	1.64	12.12	10.48	22.07	22.07	0	0
H4	1.65	12.09	10.44	22.1	21.99	0.11	0.497737557
H5	1.71	11.88	10.17	21.84	21.79	0.05	0.228937729
H6	1.65	11.78	10.13	21.3	21.27	0.03	0.14084507
H7	1.64	11.41	9.77	21.61	21.37	0.24	1.110596946
H8	1.67	11.85	10.18	21.85	21.61	0.24	1.098398169
H9	1.72	11.28	9.56	21.36	21.14	0.22	1.029962547
H10	1.54	11.44	9.9	21.62	21.4	0.22	1.017576318
H11	1.65	11.76	10.11	21.75	21.56	0.19	0.873563218
H12	1.71	12.05	10.34	21.97	21.83	0.14	0.63723259
H13	1.51	11.36	9.85	21.27	21.15	0.12	0.564174894
H14	1.59	11.18	9.59	20.99	20.76	0.23	1.095759886
H15	1.53	11.88	10.35	21.8	21.42	0.38	1.743119266
averages	1.64	11.67533333	10.0353333	21.64466667	21.488	0.156666667	**0.724987506**

*Table 4. Raw data table of soil samples collected at Salish Creek. **(iii)** Are the samples extracted on October 31st and **(iv)**, are the sample datas extracted on November 10th, 2017. Where MO=mouth, MID=middle, and H=headwaters. Soil #1-5 is sample collection at 0 metres, soil #5-10 is sample collection at 5 metres and soil # 11-15 is sample collection at 10 metres (ex. MO1 to MO5).*

v)

SOIL --> (-) CONTROL SANDBOX							
	Weight Boat (g)	**Weight Boat + Soil (g)**	**Soil (g)**	**Soil+ H2O2 initial (g)**	**Soil + H2O2 final (g)**	**Change in weight (g)**	**% decrease**
Trial #1	1.7	11.98	10.28	21.63	21.6	0.03	0.138696255
Trial #2	1.67	11.65	9.98	21.26	21.25	0.01	0.047036689
Trial #3	1.71	11.72	10.01	21.64	21.62	0.02	0.092421442
Average							**0.092718129**

vi)

SOIL --> (+) CONTROL COMPOST							
	Weight Boat (g)	**Weight Boat + Soil (g)**	**Soil (g)**	**Soil+ H2O2 initial (g)**	**Soil + H2O2 final (g)**	**Change in weight (g)**	**% decrease**
Trial #1	1.67	11.72	10.05	21.36	20.8	0.56	2.621722846
Trial #2	1.69	11.55	9.86	21.42	20.83	0.59	2.754435107
Trial #3	1.73	11.74	10.01	21.72	21.07	0.65	2.992633517
Average							**2.789597157**

Table 5. Raw data table of soil samples collected for controls. ***(v)****, Are the extracted data of sand from the sandbox; used as the negative control.* ***(vi)****, Are the extracted data of soil from the UBC garden; used as the positive control.*