Acidification of the Fraser River due to Urbanization in Vancouver British Columbia and Potential Impact on Salmon Migration.

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Abstract

Salmon in BC migrate from the ocean and move up the Fraser river to spawn. Salmon, as well as other aquatic species, thrive in water with pH ranging from 6 – 8. In this experiment, water and soil acidity were examined at different locations along the Fraser River in Richmond, Surrey, and Langley with the objective of observing any effect of the local level of urbanization. It was hypothesized that urban areas would measure lower pH than the rural areas. pH measurements were collected on two different locations, urban and rural within each city and a T-test was performed for each of the three pairs of data to confirm statistical significance indicated by Two-way ANOVA. The results showed a statistically significant decrease in acidity for urban Surrey at a confidence level of 0.05, but not for Langley and Richmond. Differences between cities was observed, but these differences were not statistically significant with the exception of urban Langley and urban Surrey. We conclude that local differences in urbanization do not cause a measureable increase in acidity in the Fraser River.

Introduction

The development of cities has profound effects on the surrounding environment and the creatures inhabiting it. As cities are often built on major waterways, these important rivers are no exception. The Fraser River, which begins in the Rocky Mountains, enters the Pacific Ocean just after passing through the metropolitan city of Metro Vancouver. With a population of 2,463,431 (1), Metro Vancouver has a large urban footprint. According to a study by Moore et al. (2013) report an output of 23,000,000 tonnes of CO_2 from Metro Vancouver in 2006 (1). Vancouver also lies in the heart of an ecologically diverse landscape, particularly for the many types of salmon which utilize waterways such as the Fraser, as they migrate from the Pacific Ocean to spawn an important factor for migrating salmon is the quality of the water, including acidity (2-3). As Metro Vancouver continues to increase in population, the potential for continued increase in acidity is an important factor to consider when evaluating the health of this local keystone species.

Within Metro Vancouver, there are three important municipalities contacting the Fraser River that we are interested in. They are Richmond, Surrey, and Langley. Each contains both *urban* and *rural* areas by our definitions stated below, and are directly adjacent to each other along the Fraser. Urban areas have more air pollution and waste output, and may experience larger amount of precipitation[4] than countryside due to a concentration of heat. We will be testing if within-city urbanization affects the pH of Fraser River, as well as whether there is a between-city difference. We define two levels of urbanization: *urban* and *rural.* Urban sites have within a one km radius, at least one busy street or highway, and at least one compact real-estate development. CO_2 output from buildings and vehicles are reported to be the highest and second highest in Metro Vancouver respectively [(1)].

Our group will be exploring the Fraser River bank in different locations to measure soil and water pH. We hypothesize that the pH of the Fraser River is affected by urbanization based on the following:

> H_0: (Null hypothesis) Urbanization within one km has no effect on the acidity of the Fraser River.
>
> H_1: (Alternative Hypothesis) Urbanization within one km has an effect on the acidity of the Fraser River.

We predict that within cities, urban areas will have lower pH than rural areas and that in both urban and rural areas, the river pH in cities further west will be lower because any acidification effects will carry over as the river travels towards the ocean.

Methods

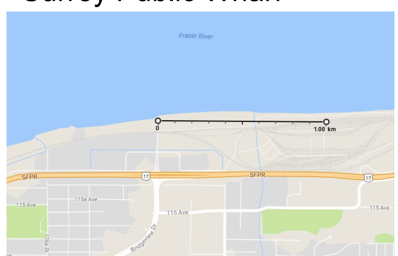
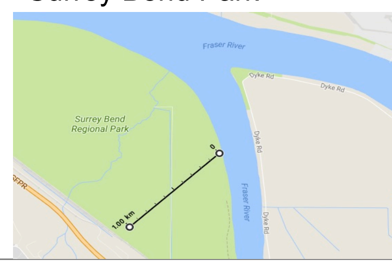
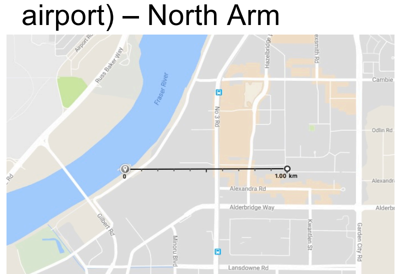
Within Richmond, Surrey, and Langley, two distinct locations were selected: one *urban* and one *rural*. The chosen sites in each city are contained in Table 1.

The acidity of the Fraser River directly affects salmon in its pathway. In order to get a broader idea of river acidification, both the river and the adjacent soil pH were measured.

Differences in variables such as weather and temperature may have an impact on pH. Procedures were repeated on three different days to in order to have a larger and more representative sample.

<table>
<tr><th>City</th><th>Urban</th><th>Rural</th></tr>
<tr><td>Langley
Pop. density = 380.8 [5]</td><td>Brae Island Regional Park

</td><td>Derby Reach Park

</td></tr>
<tr><td>Surrey
Pop. density = 1638.8 [5]</td><td>Surrey Public Wharf

</td><td>Surrey Bend Park

</td></tr>
<tr><td>Richmond
Pop. density = 1534.1 [5]</td><td>North West Dyke (near YVR airport) – North Arm

</td><td>South East Dyke – South Arm

</td></tr>
</table>

Table 1. Sites for pH measurements in Metro Vancouver, with 1 km radius shown.

River pH was measured using pH meters which had been calibrated. The pH probe was connected to a Texas Instrument TI84 graphing calculator with EasyData software installed. River water was collected directly and the probe was immersed until the reading was stabilized. This was repeated with two more samples of water from the same site to account for random variability.

Soil pH was measured a powder pH test. River-adjacent soil was dug using a metal spatula, then moved to a plastic container the indicated dotted line. Powder from one capsule was emptied into the container and Deionized water was added until the second indicated line. The container was sealed, shaken vigorously for 3-5 seconds for and left for one minute. The resulting color under sunlight was compared to a chart to measure pH. This was also repeated three times.

Data analysis

Two-way ANOVA was conducted using StatPlus software, with City (Langley, Surrey, or Richmond) and Site (*urban* or *rural*) as independent variables and water pH as the dependent variable. Results from ANOVA were used to guide further analysis. Data between *urban* and *rural* locations were analyzed using a paired T-test in Microsoft Excel. pH readings collected on each day were averaged for each site and the and averages from three days compared between sites. A second unpaired T-test was done between each city for each condition to confirm where difference indicated by ANOVA occurred.

Results

Urban vs. Rural

Results show the average water pH readings at each site (urban or rural) within each city (Langley, Surrey, Richmond) (Fig.1). Each site had a sample size of three, which were the averages of three technical replicates from three different days. Results from Two-way ANOVA indicated there was a significant difference between *urban* and *rural* at a confidence level of 0.05 ($p=0.0329$). In order to see which cities in which cities this difference occurred, a two-sample paired T-test was done for data from *urban* and *rural* sites within each city. Water pH Data from Surrey was statistically significant at a confidence level of 0.05 ($p=0.0189$), while data from the other two cities was not (p>0.05). Soil pH measurements did not vary between *urban* and *rural* (data not shown).

City Comparison

Two-Way ANOVA indicated a significant difference between cities (p=0.00209). Unpaired T-tests between each city for each condition indicate that this difference occurred only between *urban* Langley and *urban* Surrey. Soil pH was different between cities (Fig. 2) but this was not analyzed for statistical significance due to lack of variation in measurements between sites and between days.

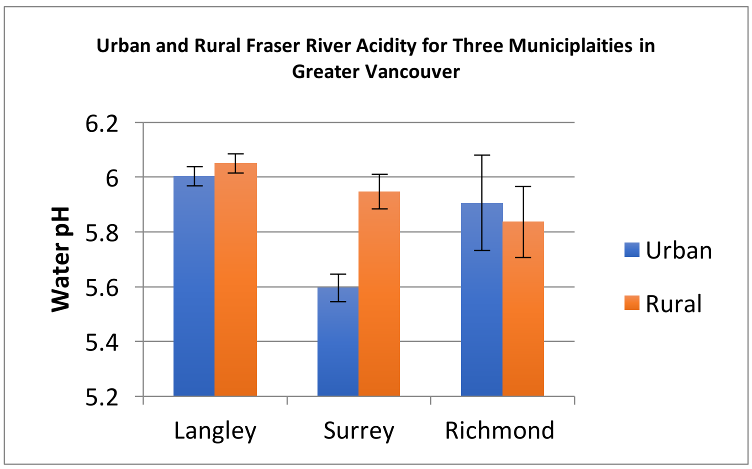


Fig 1. Fraser River water pH readings averaged from three different days (n=3) with error bars showing standard deviation. Data collection at each location occurred on the same days. Data from Langley (p=0.35) and Richmond (p=0.702) was not statistically significant, but data from Surrey was (p=0.0189).

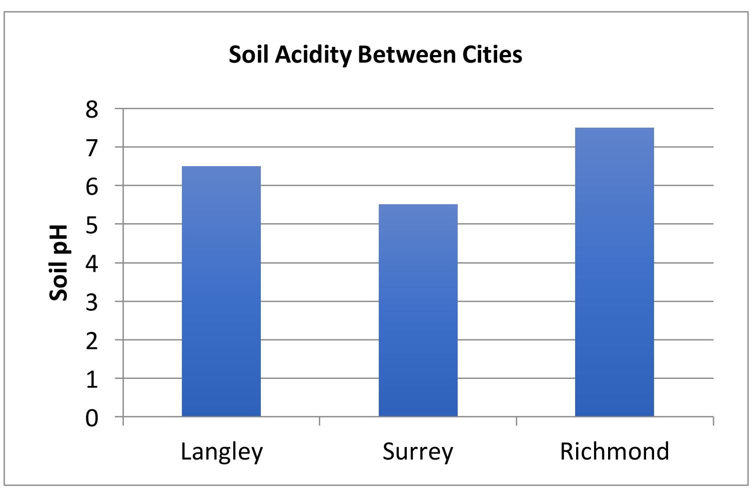


Fig 2. Soil pH measured at each city. pH measurements did not vary between urban and rural, or between measurements.

Discussion

Design Limitations

Before we discuss the results of our study, it is important to consider potentially influencing factors that we were not able to account for. Most importantly, due to time and resource constraints, we were no able to look in depth at various sources of acidity around the Fraser River. For instance, the effect of factories versus agriculture would be a relevant topic to inform our study design. Additionally, we did not account for weather changes between days or between cities. This is an important factor considering that precipitation can affect water acidity.

It is also important to note how we defined our independent variable. We defined level of urbanization as *urban* and *rural* based on CO_2 output from cars and buildings, a prominent feature of urban environments. Because we were looking for local differences, we had to limit the radius of our measurements to one kilometre. This may be an insufficient distance to effectively avoid the effects of urbanization.

We had limitations in our soil pH measurements in that the powder pH test was not nearly as sensitive as the pH probe. As it was based on colour change, researcher subjectivity was introduced. Gathering soil of similar composition was also a challenge as usually the river bank was composed of large boulders with little accessible soil. Small inconsistencies in substrate, such as small pebbles, may have influenced the volume of true soil placed in the test chamber.

Discussion of Results

Based on the analysis of the results, we cannot reject the null hypothesis that urbanization has an effect on the acidity of the Fraser River. We had selected three cities which serve as data points for this hypothesis, and compared the pH of two sites within those cities. Three separate statistical analyses were performed for the cities' pairs of sites. This yielded a significant difference only for Surrey, and not for Langley or Richmond.

In other words, we observed a statistically significant difference between Surrey's *rural* and *urban* locations of the Fraser River. The *urban* location had a lower pH, as we had hypothesized. This was based on the understanding that higher CO_2 levels in the air can acidify the water through diffusion of the CO_2 molecules into the water [5]. An urban site is much more likely to have higher CO_2 levels due to industrialization and subsequent pollution [6]. At the Surrey Public Wharf site, there were a number of factories in the vicinity, as well as a major bridge being not too far away. The pollution through heavy traffic and factories was expected to be significant enough to reduce the pH levels of the nearby Fraser River, to below rural sites. This is what was found. The very low pH or *urban* Surrey is startling, but It is possible that an isolated incident lowered the pH during the three days we measured, thus we suggest appropriate methods for a future study (see below).

This difference was not found for Langley and Richmond; the differences *rural* and *urban* sites were not statistically significant. In fact, in Richmond, the observed pH of the rural site was found to be lower than the urban site, completely contrary to the hypothesis. With two out of three cities not having a significant difference between rural and urban sites, thus looking at Metro Vancouver as a whole, the null hypothesis is not rejected. Richmond also had a higher standard deviation than the other two cities. This could be attributed to a greater number of possible factors which could have altered the pH on any one of the days we measured on. Anything downstream of the *urban* Surrey site could have altered the pH which was then measured in Richmond. The same could be said of Surrey which had a higher standard deviation than Langley. Upstream of Langley, there is decreased development along the Fraser lowering the number of factors which might alter the pH readings on any given day.

Despite all of this, there are still two trends that support the idea behind our hypothesis. One is the result in Surrey. If we look at this independent of Langley or Richmond's results, we can draw the conclusion that CO_2 has the potential to significantly acidify water. This is important because, as shown in previous studies, lower freshwater pH levels can harm and stunt the growth of salmon [3]. We also observe a general trend between the cities in our results. The pH levels of the Fraser River tend to generally decrease as we move from inland cities to the coast. This is possibly due to a gradual accumulation of CO_2 as the water moves through more sites where it can be polluted. Thus, with both of these trends, it is still plausible to argue that increasing CO_2 levels can acidify freshwater to a possibly detrimental degree for salmon. Based off of this small study, there is currently no significant difference to the health of salmon in industrialized or rural parts of the Fraser River, if we are solely looking at acidification levels. However, it is established that industrialization increases atmospheric CO_2 levels [(1)], which in turn lowers water pH levels in the area. Thus, it is clear that a continuation of this process can ultimately acidify Greater Vancouver's freshwater to a degree that it becomes detrimental to the health of salmon.

This effect may be accentuated by increasing temperatures of the Fraser River due to climate change. In a study by Martens et al. (2010) Sockeye Salmon migrating up the Fraser River were tagged and recaptured each year from 2002-2007. The survival rate of each subspecies dropped from 70-80% in 2002 and 2003 to about 30% in 2007. This was attributed primarily to warming temperatures. [(8)] Multiple threats to migrating salmon populations means utmost care should be taken to identify and reduce whichever threats we can.

Further studies are needed to truly understand the possible magnitude of this issue, if CO_2 levels continue to rise and make our waters increasingly unfavourable for salmon growth. We suggest future studies adopt a long-term observation method in order to account for isolated occurrences which may temporarily decrease the pH of one location. A much larger sample size would help account for the numerous factors which could contribute to acidification. In combination with an in-depth analysis of establishments surrounding measurement sites would help identify potential causes beyond speculation.

Conclusions

Only one of the three cities (Surrey) showed a difference in pH between urban and rural environments we conclude generally that urbanization has no effect on river acidity. There is a significant difference between *urban* Langley and *urban* Surrey. Results from Surrey indicate that local differences do exist along the Fraser River.

Acknowledgements

We would like to acknowledge Celeste Leander and Mindy Chow for providing guidance, ideas, being flexible to changes, and Mindy for gathering and meticulously prepping all our required equipment. Megan Fass and Jordan Hamden are also thanked for providing feedback on results presented in our poster. We would also like to thank UBC for allowing us to take this course.

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Appendix

Work Distribution

Uzair Ahmed – Data collection (Surrey), Discussion, Literature research

Andy Chang – Data Collection (Langley), Abstract, Methods (measurement)

Caleb Ritchie – Data Collection (Richmond), Introduction, Methods (data analysis), Discussion, Results, Literature Cited

pH Measurements

Langley	Urban		Rural	
	Water	Soil	Water	Soil
Day 1	5.895	6.5	5.95	6.5
	5.91		6.25	
	6.1		6.005	
Day 2	6.025	6.5	6.105	6.5
	6.027		6.027	
	5.964		6.091	
Day 3	5.983	6.5	5.963	6.5
	6.09		5.984	
	6.044		6.083	

Surrey	Urban		Rural	
	Water	Soil	Water	Soil
Day 1	5.6	5.5	6.001	5.5
	5.685		5.937	
	5.649		5.999	
Day 2	5.535	5.5	5.931	5.5
	5.552		6.055	
	5.545		5.978	
Day 3	5.647	5.5	6.029	5.5
	5.602		5.976	
	5.544		5.917	

Richmond				
	Urban		Rural	
	Water	Soil	Water	Soil
Day 1	5.774	7.5	5.907	7.5
	5.738		5.858	
	5.74		5.883	
Day 2	6.126	7.5	5.739	7.5
	5.967		5.683	
	6.201		5.65	
Day 3	5.881	7.5	5.949	7.5
	5.65		6.005	
	5.749		5.854	