Comparing dissolved oxygen concentrations above and below the Capilano Fish Hatchery dam and the potential relevance to salmon

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ABSTRACT

Dissolved oxygen (DO) concentrations within aquatic habitats are crucial to the growth and development of salmon. It has been shown that bodies of water with increased turbulence have greater surface areas across which oxygen can diffuse. In this study, we investigated whether the presence of the Capilano Fish Hatchery dam altered DO concentrations through this model and explored the relevance of our findings to salmon. Measurements were collected using Vernier DO probes while simultaneously measuring pH and temperature using a pH sensor and thermometer to determine whether these factors were potentially influencing the DO measurements. The data indicates a significant difference between DO concentrations above and below the dam, with observed medians of 9.15±0.137 ppm and 9.90±0.193 ppm respectively, thus confirming our prediction of finding higher DO concentration below the dam. The null hypothesis that there is no difference in DO between sampling sites was rejected with $p = 1.45E\text{-}11 < \alpha$ (0.05). No statistical difference was found between the sampling sites for pH and temperature, nor was there any correlation found between these factors and DO, which further supports our results being due to changes in DO. The DO values at each site were found to be within the thresholds necessary for salmon survival, indicating suitable DO conditions for salmon at both sites. As hypoxic or hyperoxic conditions are detrimental to salmon health and survival, this field of research is promising for future investigations with respect to salmon welfare.

INTRODUCTION

Dissolved oxygen is a key abiotic factor critical in salmon welfare and development; inadequate concentrations of dissolved oxygen (DO) in freshwater impede the growth and survival of salmon at various life stages (Antilla et al. 1183). The embryonic and larval stages of salmon development are especially susceptible to low oxygen (hypoxic) conditions. This was observed in a study conducted by Silver et al. (327) where Chinook salmon (*Oncorhynchus tshawytscha*) held at oxygen levels less than 11 mg/L experienced significant delays in their development and hatching time. During their juvenile and adult stages, salmon require high expenditures of energy to swim and therefore depend on highly oxygenated waters (Eliason and Farrell 359). A decrease in DO can reduce the swimming performance of salmon thereby affecting their ability to forage, avoid predation and successfully perform long-distance migration. This was demonstrated in a laboratory study by Dahlberg et al. (49) which found that when DO concentrations dropped below 5-6 mg/L, the maximum sustainable swimming speeds of juvenile Coho salmon (*Oncorhynchus kisutch)* declined markedly. In a similar study, Hallock et al. (92) found that DO levels lower than 5 mg/L hindered adult Chinook salmon from successfully migrating. While sustained hypoxic conditions have proven to be lethal for salmon, so have conditions of oxygen supersaturation, which often lead to gas bubble disease. In this disease, salmon exposed to hyperoxic water conditions display oxygen embolisms in their tissues leading to complications such as: cranial swelling, blindness, and in some cases, death (Dawley and Ebel 787).

Turbulence is an important factor that determines the rate of oxygen diffusion into water. A body of water that is flowing rapidly will have increased turbulence and a greater surface area across which oxygen can diffuse (Kyung and Jain 777). Additionally, turbulence can create churning motions which increases the aeration of water and promotes further dissolving of oxygen (Hondzo 3525). Man-made hydraulic structures such as dams have been associated with increased turbulence as well as increased concentrations of dissolved oxygen directly downstream of the dam. The model for this increase in oxygen concentration is as follows: air is entrained in the water as it is falling and accumulating at the base of the dam and under hydrostatic pressure, air bubbles containing oxygen gas are forced into the water (Davis 13). This relationship between dam-driven turbulence and increased dissolved oxygen in water downstream is elucidated by the findings of a study that tested the water quality of the Bonneville Dam in the Columbia River system. Fuhrer et. al (95) found that concentrations of dissolved oxygen were above saturation levels in the lower Columbia River Basin due to spilling water at the river's dam. This oxygen supersaturation was linked to occurrences of gas bubble disease in fish as well as massive fish kills in the Columbia River.

Additional factors that may affect the rate in which oxygen is dissolved in water include temperature and pH. Minor changes in water pH can result in increased solubility of nutrients for aquatic plant as well as increased oxygen consumption and demand (Card). According to Henry's Law, as the temperature of water increases, the solubility of oxygen decreases. (Taccogna and Munro 8-9)

Our study aims to determine whether a relationship between dam-driven turbulence and dissolved oxygen levels exists at the Capilano Fish Hatchery dam. The Capilano Fish Hatchery features a small dam on the Capilano River that shoehorns salmon species returning from the Pacific Ocean, including Chinook, Coho and Steelhead salmon (Capilano Salmon Hatchery). Despite playing an important role in strengthening Capilano salmon stocks, the dam may have an effect on these species by altering DO concentrations within the water to hypoxic or hyperoxic levels. The objective of our study is to determine if there is a significant difference in dissolved oxygen concentrations above and below the dam. Our null hypothesis is that there will be no significant difference observed in DO concentrations above and below the dam, while our alternate hypothesis is that there will be a significant difference observed between these two sites.

We predict that dam-driven turbulence will result in higher concentrations of dissolved oxygen in the water below the dam. Several studies have indicated that increased aeration of water below dams is a common cause of supersaturation which can result in sublethal and lethal effects for salmon (Davis 13, Fuhrer et al. 9). Our study will further investigate the role of turbulence in dissolved oxygen concentrations in water as well as the implications of this relationship for the health and survival of salmon at the Capilano Fish Hatchery Dam.

METHODS

Site Descriptions

Water sample collection was conducted at the Capilano Fish Hatchery dam in North Vancouver, British Columbia. The 3-metre tall dam is situated downstream from the larger Cleveland Dam, which feeds water into the river from the Capilano reservoir. The Capilano Fish Hatchery contains a fish ladder, the hatchery entrance for the spawning salmon, that is available for public viewing. Prior to sampling, the fish ladder was observed to determine the species that were present in the river and whether they matched the species stated to be present according to the Capilano Fish Hatchery website. This was done through the tallying of fish seen on a table created prior to the study for ease of measurement. Observation of the fish ladder confirmed the primary salmon species to be Chinook and Coho, with higher numbers of Coho observed, confirming the salmon species composition reported on the Capilano Fish Hatchery website. The species of salmon were determined through observation of their body shapes, with Chinook having a distinct hump beginning at the dorsal region of their cephalic region and Coho having a streamlined body shape. By determining that Coho and Chinook were the only salmon species present at the hatchery, insight for which species are being affected by potential changes in dissolved oxygen (DO) concentrations at that specific location was gained.

Two sampling sites were used for retrieval of the water samples: above the hatchery dam on the public observation deck and below the dam on an outcropping adjacent to the river (Fig. 1). Both sampling sites were publicly accessible. The river water at the sampling location above the dam appeared less turbulent than that below, based on the colour of the water and it's foam content. The lower sampling site contained higher quantities of foam and water of lower clarity, while the upper sampling site containing little to no foam and water that was forest green in colour (Fig. 1). The weather during sampling was clear and sunny, with no wind was present. Water levels were low, with water at the upper site moving relatively slow, making the sample collection process more difficult above the dam as the apparatus used to collect the water samples wasn't as readily filled up when compared to the lower site.

Additionally, the potential effects of confounding variables, such as changes in sunlight altering air or water temperature, were minimized through the completion of sample collection within a two-hour period which reduced the effect of diurnal changes in DO concentrations. Sampling was conducted in the late afternoon when DO concentrations were at their lowest, reflecting the minimum DO concentration the dam would demonstrate, as suggested by the Streamkeepers' Module 3 and based on the principles of water chemistry and Henry's Law where the solubility of a gas decreases as temperature increases (Taccogna and Munro 8-9).

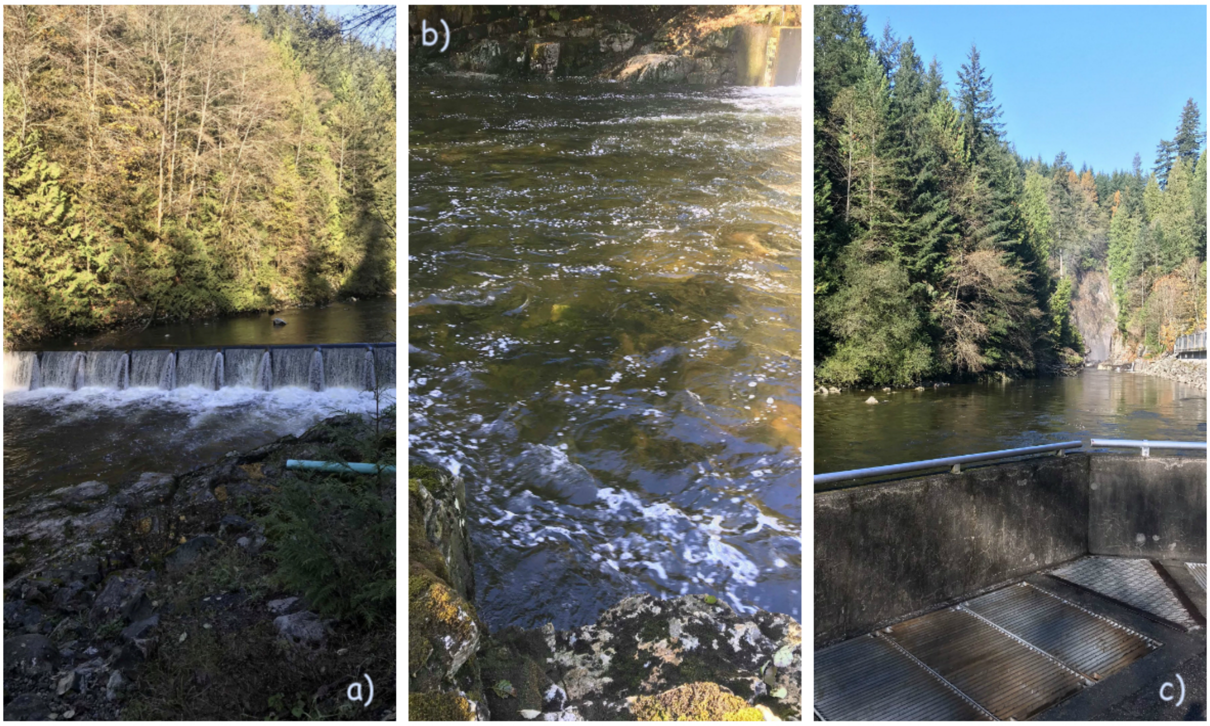

Figure 1. *Figures 1a and 1b* show the lower sampling site (below the dam) with faster moving water and a greater amount of foam present. *Figure 1c* displays the upper sampling site (above the dam) with slower moving, clear water and a lesser amount of foam present.

Data Collection

To obtain the water samples at each respective sampling site, a bucket was attached to a long rope and slowly lowered into the river twenty times in the same location for a total of twenty replicates at the upper and lower sampling sites. The bucket was allowed 30 seconds for acclimation and was slowly raised out of the water to prevent the creation of additional turbulence which could introduce air into the samples and artificially increase the DO concentrations. As access to the dam was limited and the water in the river flowed quickly, randomization of samples was accomplished through temporal, rather than spatial, variation. The three variables that were measured upon sample collection were DO, pH, and water temperature.

Samples were measured using a Vernier pH sensor, Vernier DO probe, and a Brown Spirit environmentally-safe thermometer (Fig. 2a). This equipment was utilized based on the accuracy of their readings; for example, the pH sensor used provided more exact readings than litmus paper for determination of sample pH. For both the pH sensor and DO probe, the measurement apparatus was removed from the storage bottle, rinsed with distilled water, and then submerged into the sample (Vernier). Here, the sensors remained until their values were stabilized on the TI-84 calculators they were connected to (Fig. 2b). The sensors were then rinsed with distilled water and placed back into the storage solution. The thermometer was submerged into the sample upon immediately sample collection and left until the pH and DO measurements were finished before being read, allowing for maximum acclimation time of the water for a more accurate reading.

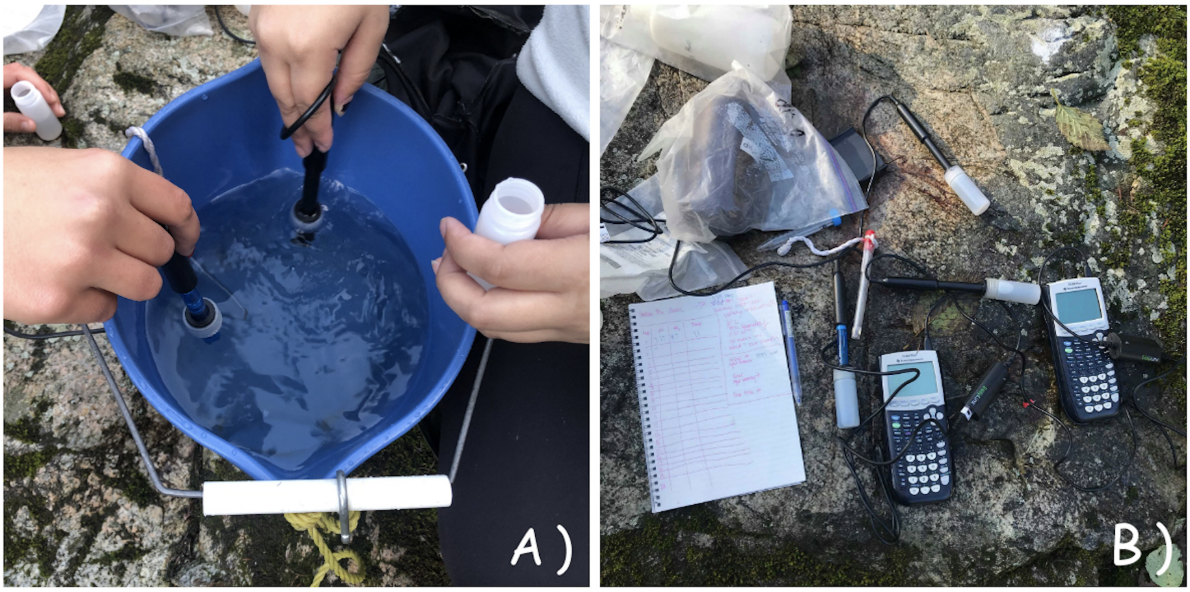

Figure 2. *2a* demonstrates the methodology for obtaining sample measurements using the Vernier pH sensor and DO probe. *2b* displays the equipment utilized during measuring, including the TI-84 calculators which contained programs necessary for DO and pH measurements.

Data Analysis

To analyse the obtained data, various statistical tests were performed using R Studio. A Shapiro-Wilk test was performed to determine whether the samples from both above and below the Capilano Fish Hatchery dam could approximate normal distributions, with the null hypothesis being that the data approximates a normal distribution and the alternate hypothesis being that no assumptions about its distribution can be made. As the data was found to be non-parametric, meaning it did not approximate a normal distribution, a permutation test was performed. The permutation test determined whether a significant difference was present in DO concentrations between the upper and lower sites, with the null hypothesis being no significant difference between the sampling sites and the alternate hypothesis being that a significant difference was present between the sites. The same aforementioned statistical approaches were applied to analyse temperature and pH. Lastly, a Pearson correlation test was performed to obtain p-values from the comparisons of temperature to pH, pH to DO, and temperature to DO to observe whether a statistically significant correlation was present between any of the two variables.

RESULTS

Dissolved oxygen

In this field study, 40 water samples were retrieved from both above and below the Capilano Fish Hatchery dam, for two datasets of 20 replicates each. For each replicate, dissolved oxygen (DO) concentrations (ppm), pH, and temperature (degrees Celsius) were measured.

To begin data analysis, histograms depicting the frequency of DO measured from our samples from both below (Fig. 3) and above (Fig. 4) the dam were made to determine whether the data was normally distributed, which at first glance, were not. To further confirm this, a Shapiro-Wilks test (n = 20) was performed on both data sets.

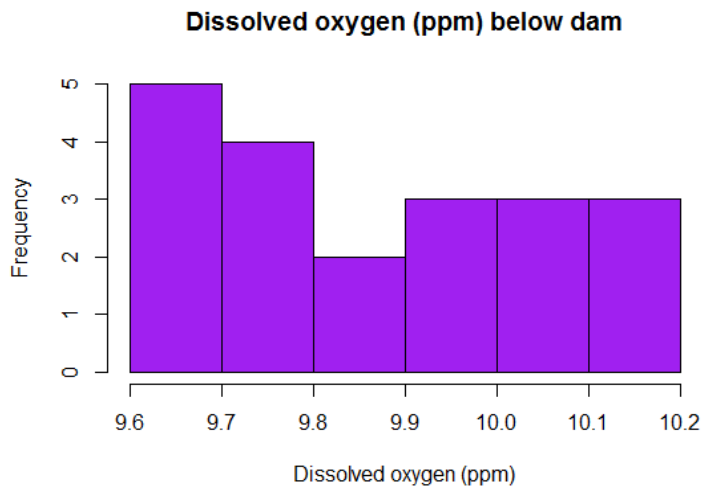

Figure 3. Histogram showing the dissolved oxygen concentration of the below-dam samples (n=20).

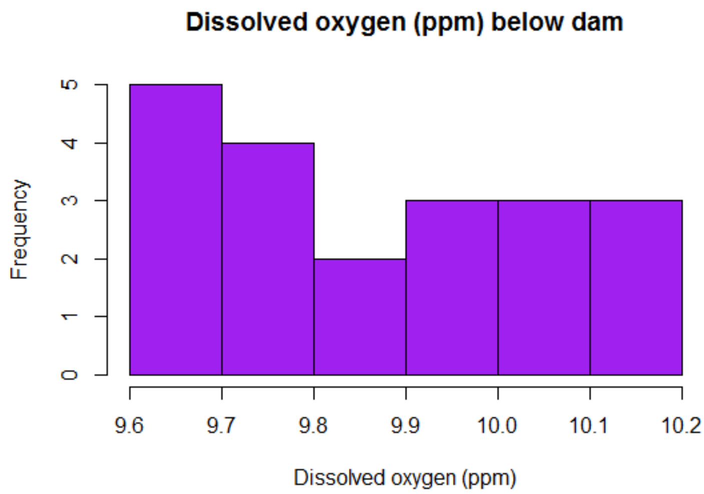

Figure 4. Histogram showing the dissolved oxygen concentration of the above-dam samples (n=20).

As aforementioned, a Shapiro-Wilks test determines whether a dataset can approximate a normal distribution. The null hypothesis of the test is that the data follows a normal distribution, while the alternative hypothesis is that it is the data is not able to approximate a normal distribution. Using a significance level of $\alpha = 0.05$, it was determined that the above-dam site does not follow a normal distribution with a $p = 0.0356$, while the below-dam site does, with $p = 0.1091$. As the above-dam site does not display a normal distribution with regards to DO, a parametric test cannot be used to compare the distributions of these two sites.

Due to the non-normally distributed nature of our data, the median was used, rather than the mode, to indicate the central tendencies. The median is a better representation of the central tendency as it states the middle value of dataset regardless of the presence of outliers, whereas the skew of non-normally distributed data would produce a mean value that is artificially higher or lower than expected.

Thus, the water samples retrieved from the above-dam site (n = 20) had a median DO concentration of 9.15 ppm with a standard deviation (SD) of 0.137 ppm (Fig. 5), while below the dam (n=20), the DO concentrations had a median of 9.9 ppm with a SD of 0.193 ppm (Fig. 5), which is an increase of 0.75 ppm (SD 0.237 ppm) from above the dam to below the dam. The 95% confidence intervals for the below-dam and above-dam sites were found to be 9.50 ppm to 10.30 ppm and 8.86 ppm to 9.44 ppm, respectively. As the two 95% confidence intervals do not overlap (Fig. 5), it is suggested that there might be a significant difference in the concentration of DO above and below the dam; however, a statistical test is necessary to confirm this.

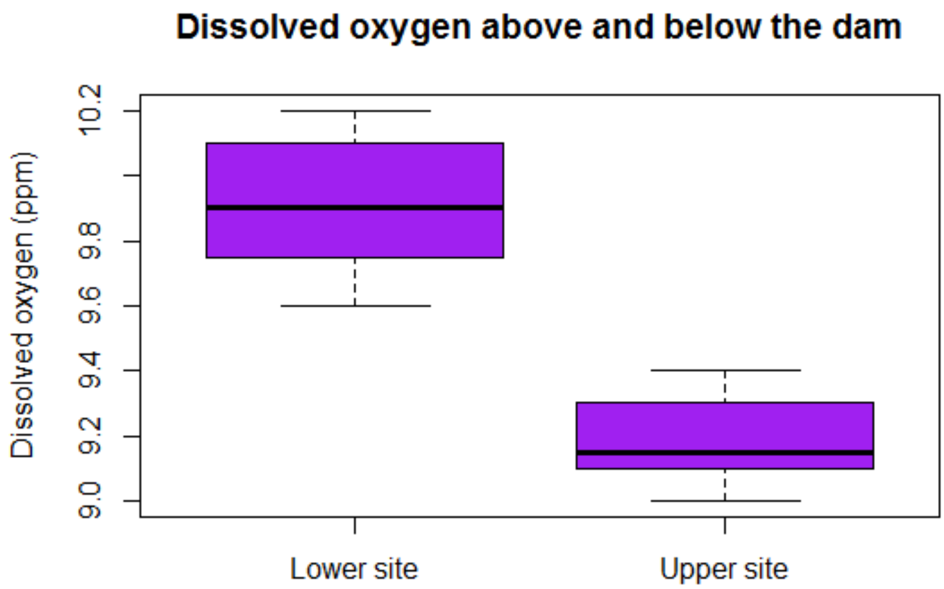

Figure 5. A box plot showing the median of dissolved oxygen concentrations below and above the dam (9.9 ppm, SD 0.193 ppm and 9.15 ppm, SD 0.137 ppm, respectively). The error bars indicate the 95% confidence intervals.

Since a parametric test cannot be used, the next most powerful test would be the Wilcoxon rank sum test; however, this test would result in an inexact p-value as there are too many ties within the data (Fig. 3 and 4). Therefore, a permutation was performed.

The permutation test (n = 40) resulted in a p-value of `1.45E-11`. This value indicates that at a 0.05 significance level, there is a significant difference between the DO concentrations above and below the Capilano Fish Hatchery dam. Thus, the null hypothesis that there is no significant difference in DO concentrations was rejected. A graphical representation of the means and 95% confidence intervals is displayed in Figure 5.

pH and Temperature

A Shapiro Wilks test to test the distributions of pH and temperature. For pH, it was found that the above-dam site had displayed an approximately normal distribution (p-value = 0.1403), whereas below the dam had a distribution that deviated from normality (p-value = 0.02951). As for temperature, it was found that the distributions of both the above-dam and below-dam sites deviated from normality (p-value = 7.387E-06 and p-value = 5.604E-06, respectively). Therefore, for both variables, a non-parametric test was used to compare the two distributions.

Median was used rather than mean to display central tendency due to the non-normal nature of the data. Above the dam, the median pH and temperature were found to be 7.075 (SD 0.0644) and 11.5 degrees Celsius (SD 0.2552) respectively, while below the dam a pH of 7.1 (SD 0.0631) and temperature of median 11.5 degrees Celsius (SD 0.2513) was observed. Therefore, from the above-dam to below-dam site, there was a change in temperature of 0.00 degrees Celsius (SD 0.358) and a change in pH of 0.025 (SD 0.0902).

The 95% confidence intervals for pH of the above-dam and below-dam sites were found to be 6.94 to 7.21 and 6.97 to 7.23 (Fig. 6) respectively. As these intervals overlap, it is suggested that these two sites are not significantly different, and a permutation test was used to confirm this. A permutation test was used because the use of a Wilcoxon rank sum test would result in too many ties and further an inexact p-value. The permutation test resulted in a p-value of 0.2271. At a significance level of $\alpha = 0.05$, this value indicates that there is no significant difference in the distributions of pH above and below the dam.

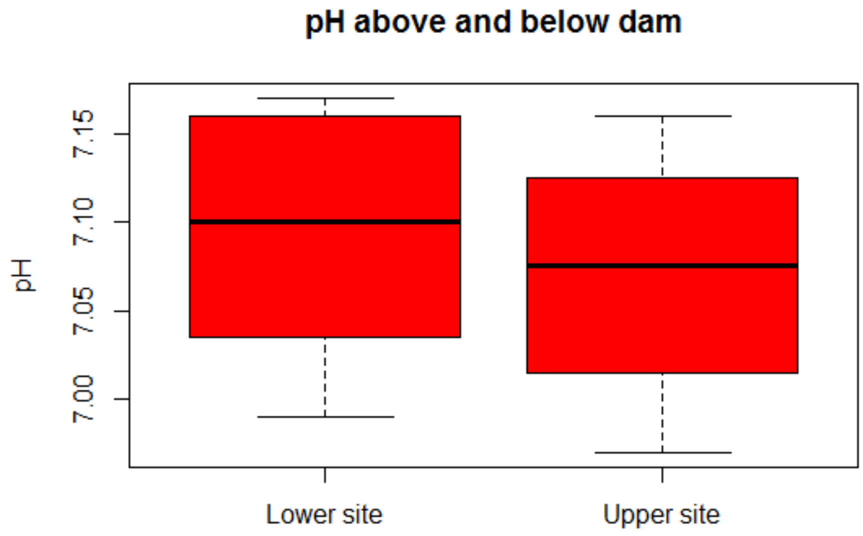

Figure 6. A box plot showing the median of pH below the dam, 7.1 (SD 0.0631), and above the dam, 7.075 (SD 0.0644). The error bars indicate the 95% confidence intervals.

The 95% confidence intervals for pH of the above-dam and below-dam sites were found to be 6.94 to 7.21 and 6.97 to 7.23 (Fig. 6) respectively. As these intervals overlap, it is suggested that these two sites are not significantly different. A permutation test was used to confirm this. A permutation test ($n = 40$) was used as the Wilcoxon rank sum test would result in too many ties and further an inexact p-value. The permutation test resulted in a p-value of 0.2271. At a significance level of $\alpha = 0.05$, this value indicates that there is no significant difference in the distributions of pH above and below the dam.

The 95% confidence intervals of the temperatures of the above-dam and below-dam sites were 10.97 to 12.03 degrees Celsius and 10.97 to 12.03 degrees Celsius respectively (Fig. 7). As these intervals overlap, it is suggested that these two sites are not significantly different. A permutation test was used to confirm this. A permutation test was used as the Wilcoxon rank sum test would result in too many ties and further an inexact p-value. The permutation test ($n = 40$) resulted in a p-value of 1. At a significance level of $\alpha = 0.05$, this value indicates that there is no significant difference in the distributions of temperature above and below the dam.

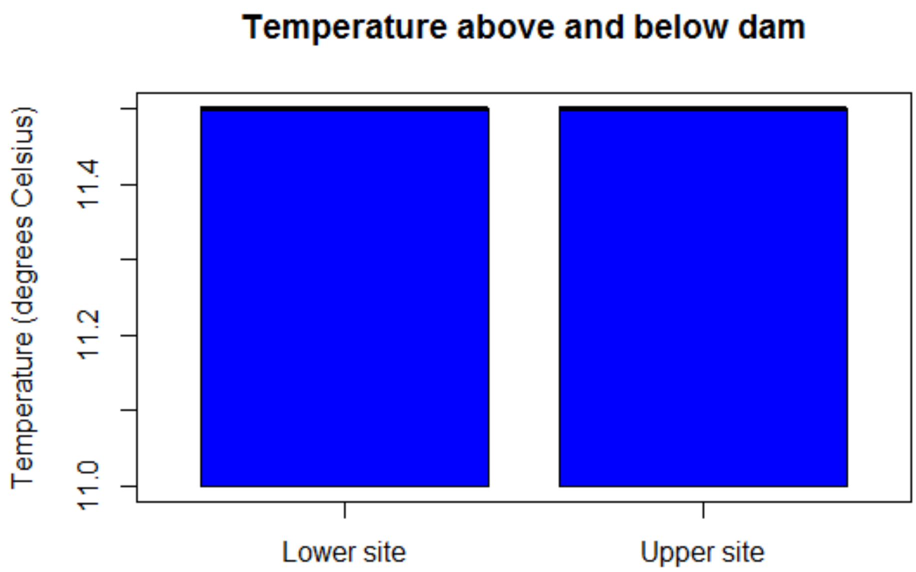

Figure 7. A box plot showing the median temperature of the below-dam site, 11.5 degrees Celsius (SD 0.2513), and the above-dam site 11.5 degrees Celsius (SD 0.2552).

Correlation between variables

To assess the correlation between each respective variable, a Pearson correlation was conducted. The Pearson correlation was used because the large number of ties within the data would result in inexact p-values having used the Kendall tau or Spearman coefficient. Every combination of two variables of the three variables tested for, temperature (degrees Celsius), pH, and DO concentration (ppm), resulted in a p-value above the significance level of $\alpha = 0.05$ (Fig. 8). The p-value of the correlation of oxygen and pH was 0.3365, that of oxygen and temperature was 0.6099, and that of pH and temperature was 0.5523. With a significance level of $\alpha = 0.05$, the null hypothesis that there is a significant correlation between any two of these three variables was rejected.

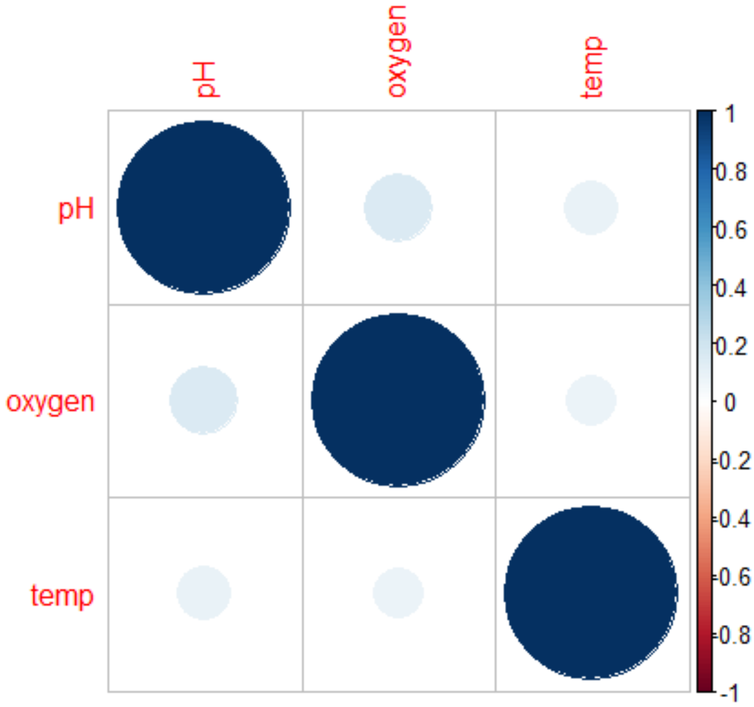

Figure 8. The correlations between the variables are all close to zero (ranging from 0.08 to 0.16). The size of the circle indicates the proportional size of the correlations and the colour indicates a positive or negative correlation.

Therefore, it can be concluded that as there is no statistical significance to the correlation between any two of the three variables measured at the Capilano Fish Hatchery dam and that the value of one variable tells us almost nothing about another (Fig. 8). There is no interaction between oxygen, temperature and pH in the sites measured.

DISCUSSION

The aim of this study was to determine whether a barrier like the Capilano Fish Hatchery Dam altered dissolved oxygen (DO) concentrations and whether a significant difference would be observed in DO concentrations above and below the dam. Following data collection, the study further aimed to relate these findings to their effects on salmon wellbeing, including impairments to their development, growth, swimming abilities, and survival amongst other potential consequences.

The null hypothesis that there would be no difference in mean DO concentrations above and below the dam was rejected, lending support to the alternate hypothesis. Figure 3 demonstrates this difference between the two sites, with a median of 9.15 ppm above the dam and 9.9 ppm below the dam, with a calculated p-value of 1.451E-11 < 0.05, indicative of statistical significance.

These results are in accordance with our prediction of a higher observed DO concentration below the dam. The turbulence resulting from water tumbling over the dam traps oxygen between waves, eventually dissolving it under high pressure (Hondzo 3525-3533), accounting for and supporting our findings. Our prediction was further confirmed as the water observed below the dam was more turbulent and visibly aerated than the slower currents observed above the dam, therefore containing more DO due to increased contact with the atmosphere due to the aerating action of the dam (Canadian Council of Ministers of the Environment 1).

Despite the difference in DO observed between the sites, both had DO concentrations well above the minimum critical concentration necessary for salmon survival at 5 ppm (Canadian Council of Ministers of the Environment 3), as well as the threshold for their optimal performance at 7 ppm (Koski 72). Neither site imposes the threat of physiological stress upon future salmon populations and embryos, nor are there drastic fluctuations in DO concentrations between the two sites which could potentially hinder their survival.

In the case of DO concentrations being well-above the threshold for optimal performance, these hyperoxic conditions bare the risk of gas bubble disease, which poses detrimental effects to salmon tissue, motility, as well as survival as a whole (Hallock et al. 151). At concentrations below the minimum threshold, metabolic processes are vastly hindered, such as growth rate, spawning ability, embryonic survival, and swimming performance (Koski 47-86). Additionally, hypoxic conditions are especially damaging to embryos, leading to premature hatching, developmental malformations, and delayed growth rates (Alderdice et al. 229-250).

Failure for an embryo to reach developmental fruition results in an overall decline in salmon populations which are crucial to ecosystems, economies, and cultures. As a keystone species, decreased survival rates and an overall reduction in their population have dire implications for their ecosystems (Kohler et al. 802-824). These effects manifest in the decline of species within higher trophic levels which depend on salmon as a key food source for survival, such as black bears and eagles (Kohler et al. 802-824). They also circulate nutrients vital for community food webs, including phosphorus and nitrogen, from the ocean and streams to creeks, that would otherwise have low productivity (Kohler et al. 802-824). This decrease in trophic productivity is further amplified as there are fewer salmon decomposing and delivering their nutrients to their surrounding habitats (Kohler et al. 802-824).

Moreover, salmon fuel a three-billion-dollar industry that serves as part of the backbone of British Columbia's economy in addition to providing countless jobs to BC residents (Schwindt et al. 73-94). The decline of salmon puts stress on the fishing industry, forcing commercial fisheries to turn to other species to support their businesses, effectively putting pressure on other fish species and in turn causing a decline in their populations (Schwindt et al. 73-94). Culturally, salmon have sacred status within indigenous communities that are considered most vulnerable to food insecurity and biodiversity loss (Nesbitt et al. 1489-1499) as their traditional food system is essential to their culture, land, and self-determination (Kuhnlein et al. 1013-1019).

Numerous precautions were taken to minimize sources of error and potential confounding variables throughout the experiment. All samples were collected within two hours of each other to reduce diurnal changes to DO concentrations. Furthermore, the samples were analysed for temperature and pH. These two abiotic factors were measured simultaneously in tandem with DO concentrations to see if these factors had any potential influence on the DO concentrations observed. No statistical difference was found between the above-dam and below-dam sites in terms of these two variables, nor was a statistically significant correlation found between DO and either variable, thus allowing lending support to the assumption that it was the dam that accounted for this statistical difference in DO observed rather than other confounding variables.

To further minimize potential sources of error, each variable sampled was taken by a single person at both sites in order to introduce the same bias across all samples and reduce systematic error and variation due to non-uniform data collection. Despite this, numerous sampling limitations existed, namely not being able to control for the effects of extraneous variables in the field on our samples, such as rainwater, salinity, water flow rate, and light intensity all factors which were found to have significant effects on DO concentrations (Fellman et al. 1-16); therefore, the dam itself may not be sufficient to make comparisons in DO concentrations.

Moreover, there was limited access to the dam, such that samples could only be collected from one side of the dam as it was not possible to extend a transect along its width, resulting in a lack of spatial variation within the samples. This could be corrected by conducting this study again at another dam with full spatial access where samples could be collected from randomly selected spots on a transect line across the width of the dam to ensure that this relationship is observed throughout.

Further studies should be conducted measuring differences in DO concentrations above and below the dam at different times of the day, different days of the year, and with varying weather conditions to ensure the replicability of this experiment and to see whether this relationship persists given these differences. Furthermore, dams of different sizes should be used to observe whether this effect is amplified with dams of larger heights and greater magnitudes. Additionally, correlational studies should be conducted to directly observe the relationships between DO concentrations and other abiotic factors, excluding pH and temperature, such as water flow rate and salinity. For example, a study conducted by Ficklin et al. (2765-2782) found DO concentrations to be inversely related to temperatures within a stream, while flow rates are found to have a directly proportional relationship with DO concentrations (Hondzo 3525-3533).

CONCLUSION

A significant difference was found between dissolved oxygen concentrations above and below the Capilano Fish Hatchery dam. Above the dam, the median of dissolved oxygen was 9.15 ± 0.137 ppm, while below the dam, the dissolved oxygen had a median of 9.9 ± 0.193 ppm. Therefore, we rejected the null hypothesis that there was no difference in dissolved oxygen concentrations above and below the dam with $p < 0.00001$, confirming our prediction that a higher dissolved oxygen concentration would be observed below the dam. Additionally, pH and temperature were found to have no statistical difference between the sampling sites and further, no statistical correlation between these factors and dissolved oxygen, thus supporting the results solely being due to changes in dissolved oxygen. Oxygen concentrations were found to be in an acceptable range for salmon productivity, indicating suitable dissolved oxygen concentrations for salmon at this site.

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APPENDIX

Table 1. Raw data collected from samples of the below-dam site of the Capilano Fish Hatchery dam of pH, dissolved oxygen, and temperature.

Below the Dam		
pH	**Dissolved Oxygen (ppm)**	**Temperature (degrees Celsius)**
7.17	9.7	11.5
7.06	9.8	11.5
7.04	10.1	11
7.03	9.9	11.5
7.17	10	11.5
7.14	10.2	11.5
7.16	9.9	11
7.17	9.6	11
7.16	10.2	11
7.14	10	11.5
7.05	9.8	11
7.02	10	11.5
7.11	9.7	11.5
7.09	9.7	11
6.99	9.8	11
7.02	10.2	11.5
7.16	10.1	11
7.06	10.1	11.5
7.01	9.8	11.5
7.12	9.7	11.5

Table 2. Raw data collected from samples of the above-dam site of the Capilano Fish Hatchery dam of pH, dissolved oxygen, and temperature.

Above the Dam		
pH	**Dissolved Oxygen (ppm)**	**Temperature (degrees Celsius)**
6.97	9.2	11.5
6.99	9.2	11
7.01	9.1	11
7.09	9	11.5
7.12	9.4	11.5
6.97	9.2	11
6.97	9.1	11.5
7.06	9.1	11
7.09	9.3	11
7.05	9.4	11.5
7.14	9	11.5
7.11	9.1	11.5
7.16	9.3	11.5
7.02	9.4	11
7.04	9.1	11
7.16	9.2	11.5
7.13	9	11
7.13	9	11
7.06	9.1	11.5
7.11	9.3	11.5

Table 3. The summary data from the Capilano fish hatchery showing the sample size, mean, median, and standard deviation of temperature, pH and oxygen above and below the dam.

Below the Dam				
	Sample Size	**Mean**	**Median**	**Standard Deviation**
Temperature (degrees Celsius)	20	11.3	11.5	0.2513
pH	20	7.0935	7.1	0.0631
Dissolved oxygen (ppm)	20	9.915	9.9	0.1927
Above the Dam				
Temperature (degrees Celsius)	20	11.275	11.5	0.2552
pH	20	7.069	7.075	0.0644
Dissolved oxygen (ppm)	20	9.175	9.15	0.1372