

Water Quality Observations in Natural Salmon Creeks and Hatchery Rivers in British Columbia

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ABSTRACT

This study investigated water quality in natural salmon creeks and hatchery-utilized streams in British Columbia. Salmon conservation is essential for maintaining ecological balance and economic stability. As a keystone species, salmon play a vital role in nutrient cycling, providing resources for both aquatic ecosystems and terrestrial environments, such as forests and wildlife. Water quality was assessed in both natural and hatchery creeks across the Metro Vancouver region by measuring parameters such as pH, carbon dioxide, temperature, dissolved oxygen, salinity, and ammonia. The collected data was analyzed using a multivariate analysis of variance (MANOVA) in IBM SPSS to compare abiotic variables across the sampled locations. Since this is an observational study, no specific hypothesis was tested. Comparison of abiotic variables across stream types (control, natural, and hatchery) revealed significant pairwise differences ($p < 0.05$) in pH, oxygen, and ammonia, indicating distinct water quality characteristics. Our results suggest that hatchery-managed creeks may require more careful monitoring to prevent potential negative impacts on water quality as abiotic variables such as ammonia were significantly higher than natural creeks. This will help us to further preserve thriving salmon populations, support fishing industries, recreational activities, and tourism, benefiting countless livelihoods. Without dedicated conservation efforts, the loss of salmon would have far-reaching consequences for ecosystems and economies alike.

INTRODUCTION

Across British Columbia, salmon populations are experiencing a significant decline as a result of climate change, habitat degradation, and many other factors (Kwan, 2024). As a result, this decline raises concerns about the province's biodiversity and cultural heritage, especially given salmon's importance as a staple for Indigenous communities (DFO, 2021). Consequently,

hatcheries across British Columbia have been established with the sole purpose of enhancing salmon populations by replicating the conditions of aquatic areas where reproduction and the spawning of salmon naturally take place (DFO, 2023). For this research study, water parameters in natural salmon habitats will be examined and compared against those in creeks utilized by salmon hatcheries in British Columbia. Specifically, pH, CO₂, temperature, oxygen, salinity, and ammonia levels will be measured and recorded as these abiotic variables are significant to salmon health, influencing their growth, behavior, and reproductive success (Bulbul, 2022). This research study is particularly important as understanding the differences between natural habitats and hatchery environments is essential for evaluating the effectiveness of these conservation efforts. This study is purely observational in nature by focusing on the comparison of these water parameters, this observational study aims to provide an understanding of how well-hatchery-utilized streams replicate natural habitat conditions. These insights can inform future research and guide potential improvements in hatchery practices and habitat management, ultimately contributing to the conservation efforts of salmon populations in British Columbia.

METHODS

Data Collection Method

The collection of water quality data was carried out at the following locations for both upstream and downstream sites: False Creek, Salish Creek, Hoy Creek Hatchery, Hyde Creek Hatchery, Little Campbell Hatchery and Tynehead Hatchery. This consisted of 1 control, 1 natural habitat, and 4 hatcheries that were situated next to a creek or river, respectively.

There were 6 different types of equipment used in measuring the abiotic variables of carbon dioxide, oxygen, pH, salinity, ammonia and temperature of the water at the time sampled. All measurements were replicated three times at consistent water depths for each site. In addition, all samples from each location were collected during non-rainy days except for Tynehead Hatchery and Hyde Creek, however, the rain did not have a significant impact on the outcome of their abiotic variable measurements.

A carbon dioxide titration kit was used to determine the CO₂ concentration levels in which a titration tube was filled with 20mL of water sample and then 2 drops of phenolphthalein indicator 1% was added. This was followed by the dropwise addition of carbon dioxide reagent B using the direct reading titrator (DRT). Once a very light pink color appeared in the water sample, the concentration was determined in ppm with each increment on the DRT to indicate 1 ppm.

A dissolved oxygen meter (EXTECH DO600: Waterproof ExStik® II) was carefully calibrated to a saturation of 101.7% before usage. It was then changed to the desired unit of mg/L and placed into the water sample for roughly 1 minute. This allows the reading to stabilize while gently stirring to remove air bubbles from the membrane surface at the bottom of the meter that could affect measurements.

A pH meter (Cergrey WQM-241, tri-meter pH/Temp/EC) was carefully submerged into the water sample after cleaning with distilled water and stirred gently to prevent small air bubbles from touching the electrodes. Then waited for readings to stabilize in the water sample before recording the value shown. Simultaneously, it also provided the temperature of the water being sampled.

The salinity was measured using a refractometer (Brix) by using a pipette to add 3 drops of water sample onto the prism. Then waited for roughly 30 seconds before peering through the eyepiece pointing towards a bright light source for clearer indication of where the demarcation line landed, between the blue and white background seen through the eyepiece. Recorded the aligned value in ppt which ranged from 0-100 ppt.

Umlecoa drinking water quality test kit (16 in 1) were used to quantitatively analyze the ammonia concentration by immersing the strip into a tube that is filled with a water sample for 2 seconds before removing. Then waited for 15 seconds before comparing the strip to the provided colour chart, paying close attention to the colour match and value of ammonia chloride.

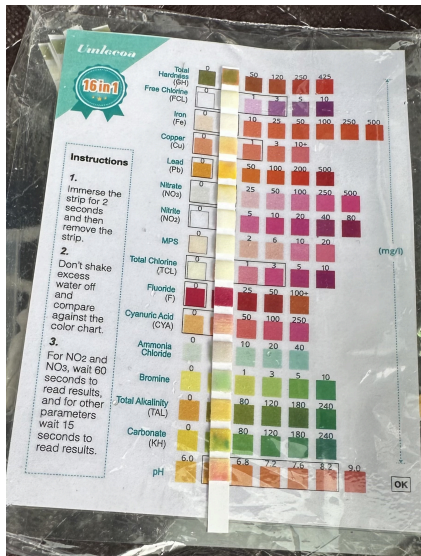


Figure 1: Photo taken from Little Campbell testing: ammonia chloride box was slightly discoloured from leaching of box above. The respective colour chart determines the concentration of ammonia chloride to be 0 mg/L.

The temperature of the air was also measured in addition to noting the day, time, and weather conditions during each collection. However, did not include them into any statistical model as they played a minimal role in the observations at the creeks and hatcheries.

On the other hand, an atmospheric river occurred a week before our water testing which may have affected our results as the natural weather event causes major flooding, sedimentation

build up, temperature changes and degradation of water quality due to storm runoffs that can carry pollutants including heavy metals, excess or depletion of nutrients, and pesticides.

Data Analysis Method

Upon data collection, a multivariate analysis of variance (MANOVA) is conducted within IBM SPSS version 30.0 to compare the abiotic variables across the different locations sampled. This statistical approach will assess variations in these parameters between control, natural habitats, and hatchery-utilized creeks, offering insights into environmental differences across sites. Within MANOVA, Tamhane's T2 Post-Hoc Test was conducted as Levene's Test displayed that the variances of the data were unequal ($p < 0.05$). The Tamhane's T2 Post-Hoc Test was then used to determine which specific group pairs were significantly different.

RESULTS

Using the raw data collected during our water quality tests at the locations of interest, the following presents the findings of the observational study in depth using MANOVA by comparing each location.

	Type	Location		Mean	Std. Deviation	N	
pH	Control	Upstream	False Creek	7.4333	.00577	3	
		Downstream	False Creek	7.4633	.02887	3	
	Hatchery	Upstream	Hoy Creek	7.5233	.03215	3	
			Hyde Creek	7.4800	.03000	3	
			Little Campbell Creek	7.7467	.00577	3	
			Tynehead Creek	7.8933	.00577	3	
		Downstream	Hoy Creek	7.4100	.06557	3	
			Hyde Creek	7.5333	.04041	3	
			Little Campbell Creek	7.9533	.00577	3	
			Tynehead Creek	7.8267	.03786	3	
	Natural	Upstream	Salish Creek	7.3633	.04933	3	
		Downstream	Salish Creek	7.2233	.02082	3	
CO2 (ppm)	Control	Upstream	False Creek	4.667	1.1547	3	
		Downstream	False Creek	5.667	.5774	3	
	Hatchery	Upstream	Hoy Creek	3.333	1.5275	3	
			Hyde Creek	4.833	.2887	3	
			Little Campbell Creek	5.667	.5774	3	
			Tynehead Creek	4.167	.2887	3	
		Downstream	Hoy Creek	3.000	.0000	3	
			Hyde Creek	5.667	.2887	3	
			Little Campbell Creek	7.667	.5774	3	
			Tynehead Creek	4.000	.0000	3	
	Natural	Upstream	Salish Creek	12.000	1.7321	3	
		Downstream	Salish Creek	3.333	.5774	3	
	Temperature (C)	Control	Upstream	False Creek	11.433	.5508	3
			Downstream	False Creek	10.967	.1155	3
		Hatchery	Upstream	Hoy Creek	13.200	.4583	3
				Hyde Creek	10.533	.1155	3
				Little Campbell Creek	10.100	.0000	3
				Tynehead Creek	11.667	.1155	3
Downstream			Hoy Creek	11.200	.5196	3	
			Hyde Creek	10.333	.1155	3	
			Little Campbell Creek	10.500	.0000	3	
			Tynehead Creek	12.567	.0577	3	
Natural		Upstream	Salish Creek	12.600	.3464	3	
		Downstream	Salish Creek	11.500	.2646	3	
Oxygen (mg/L)		Control	Upstream	False Creek	8.5333	.05774	3
			Downstream	False Creek	9.0000	.00000	3
		Hatchery	Upstream	Hoy Creek	11.7400	.37987	3
				Hyde Creek	9.4100	.11533	3
				Little Campbell Creek	14.5600	.23259	3
				Tynehead Creek	11.0267	.02517	3
	Downstream		Hoy Creek	11.7167	.34962	3	
			Hyde Creek	8.6467	.22368	3	

Type	Location		Mean	Std. Deviation	N		
Salinity	Natural		Little Campbell Creek	8.6567	.04163	3	
			Tynehead Creek	10.8367	.04041	3	
	Upstream		Salish Creek	3.8333	.32146	3	
			Salish Creek	6.2033	.53201	3	
	Control	Upstream	False Creek	24.33	1.155	3	
		Downstream	False Creek	24.33	1.155	3	
	Hatchery	Upstream		Hoy Creek	.00	.000	3
				Hyde Creek	.00	.000	3
				Little Campbell Creek	.00	.000	3
				Tynehead Creek	.00	.000	3
Downstream			Hoy Creek	.00	.000	3	
			Hyde Creek	.00	.000	3	
			Little Campbell Creek	2.67	.577	3	
			Tynehead Creek	1.00	1.000	3	
Natural	Upstream	Salish Creek	.00	.000	3		
	Downstream	Salish Creek	.00	.000	3		
Ammonia Level	Control	Upstream	False Creek	.000	.0000	3	
		Downstream	False Creek	.000	.0000	3	
	Hatchery	Upstream		Hoy Creek	6.667	2.8868	3
				Hyde Creek	5.000	.0000	3
				Little Campbell Creek	.000	.0000	3
				Tynehead Creek	.000	.0000	3
		Downstream		Hoy Creek	.000	.0000	3
				Hyde Creek	5.000	.0000	3
				Little Campbell Creek	.000	.0000	3
				Tynehead Creek	3.500	.0000	3
	Natural	Upstream	Salish Creek	.000	.0000	3	
		Downstream	Salish Creek	.000	.0000	3	

Table 1. Descriptive statistics of water quality parameters (pH, CO₂, temperature, oxygen, salinity, and ammonia levels) across Control (False Creek), Natural (Salish Creek), and Hatchery (Hoy Creek, Hyde Creek, Little Campbell Creek, and Tynehead Creek) streams in British Columbia. Values represent the mean and standard deviation (SD) for each parameter, with measurements taken upstream and downstream at each site.

Descriptive statistics revealed significant variations in water quality parameters measured in Control (False Creek), Natural Habitat (Salish Creek), and Hatchery (Hoy Creek, Hyde Creek, Little Campbell, and Tynehead). Hatchery creeks continuously recorded the lowest CO₂ concentration (mean range = 3.00 -5.67 ppm), whereas Salish Creek had the highest CO₂ levels (mean=12.00 ppm, SD = 1.73). Salish Creek had the lowest oxygen levels (mean = 6.20 mg/L, SD = 0.53) and Little Campbell Creek had the highest oxygen levels upstream (mean = 14.56 mg/L, SD = 0.23).

The salinity was insignificant in Natural and Hatchery but constant in False Creek (Control, mean = 24.33, SD = 1.16). Only Hatchery streams had ammonia, and the highest concentrations were found upstream in Hoy Creek (mean = 6.67, SD = 2.89). It also had the highest temperature (mean = 13.20°C, SD = 0.46) while False Creek downstream had the lowest (mean = 10.97°C, SD = 0.12). These differences highlight how stream location and type of site affect water parameters.

Effect		Value	F	Sig.	Partial Eta Squared
Intercept	Wilks' Lambda	.000	289228.264	<.001	1.000
Type (Control vs Natural vs Hatchery)	Wilks' Lambda	1.000	.	.	.
Location (Upstream vs Downstream)	Wilks' Lambda	.273	8.434	<.001	.727
Name (Creeks)	Wilks' Lambda	.000	79.412	<.001	.956
Type * Location	Wilks' Lambda	1.000	.	.	.
Type * Name	Wilks' Lambda	1.000	.	.	.
Location * Name	Wilks' Lambda	.002	23.667	<.001	.872
Type * Location * Name	Wilks' Lambda	1.000	.	.	.

^a Design: Intercept + Type + Location + Name + Type * Location + Type * Name + Location * Name +

Type * Location * Name

Table 2 MANOVA results for the effects of stream type (Control, Natural, Hatchery, location (Upstream vs. Downstream), and specific creek name on water quality parameter). Significant results are highlighted by their respective *F*-values, significance levels ($p < 0.001$), and partial eta-squared values (effect size). Non-significant terms are omitted for clarity.

The multivariate analysis of variance (MANOVA) tests using Wilks' Lambda show that location (Wilks' Lambda = 0.273, $F = 8.434$, $p < 0.001$, partial $\eta^2 = 0.727$) and specific different creek/name (Wilks' Lambda = 0.000, $F = 79.412$, $p < 0.001$, partial $\eta^2 = 0.956$) showed a significant main effect. A significant ($p < 0.001$) interaction effect between creek name and location was also found (partial $\eta^2 = 0.872$, Wilks' Lambda = 0.002, $F = 23.667$, $p < 0.001$). However, in this test, we can't see a significant effect caused by stream type (Table 2).

Source	Dependent Variable	F-Value	p-Value (Sig.)	Interpretation
Type	pH	13.468	<.001	Significant effect of stream type on pH.
(Control vs. Natural vs. Hatchery)	CO2 (ppm)	3.673	.036	Moderate effect; stream type affects CO2 levels.
	Temperature (°C)	1.710	.196	No significant effect of stream type on temperature.
	Oxygen (mg/L)	29.893	<.001	Strong significant effect of stream type on oxygen levels.
	Salinity	1736.967	<.001	Very strong significant effect of stream type on salinity.
	Ammonia	4.553	.018	Significant effect of stream type on ammonia levels.

Table 3 Result and Interpretation Table of Between-Subjects Effects Analysis of Water Parameters Across Stream Types (Control vs. Natural vs. Hatchery). Significant effects ($p < 0.05$) were observed for pH, CO2, oxygen, salinity, and ammonia levels, Non-significant results ($p > 0.05$) were found in temperature

Significant differences were found between stream types in terms of pH ($F = 13.468$, $p < 0.001$), CO2 ($F = 3.673$, $p = 0.036$), oxygen levels ($F = 29.893$, $p < 0.001$), salinity ($F = 1736.967$, $p < 0.001$), and ammonia levels ($F = 4.553$, $p = 0.018$) according to the between-subject effect analysis (Table 3).

Parameter	(I) Type	(J) Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
pH	Tamhane	Control	Hatchery	-.2225	.04233	<.001	-.3307	-.1143
			Natural	.1550	.03569	.015	.0372	.2728
		Hatchery	Control	.2225	.04233	<.001	.1143	.3307
			Natural	.3775	.05348	<.001	.2385	.5165
		Natural	Control	-.1550	.03569	.015	-.2728	-.0372
			Hatchery	-.3775	.05348	<.001	-.5165	-.2385
CO2 (ppm)	Tamhane	Control	Hatchery	.375	.5106	.857	-1.038	1.788
			Natural	-2.500	2.0344	.611	-9.427	4.427
		Hatchery	Control	-.375	.5106	.857	-1.788	1.038
			Natural	-2.875	2.0192	.509	-9.831	4.081
		Natural	Control	2.500	2.0344	.611	-4.427	9.427
			Hatchery	2.875	2.0192	.509	-4.081	9.831
Temperature (C)	Tamhane	Control	Hatchery	-.063	.2873	.995	-.806	.681
			Natural	-.850	.3243	.083	-1.806	.106
		Hatchery	Control	.063	.2873	.995	-.681	.806
			Natural	-.787	.3517	.124	-1.751	.176
		Natural	Control	.850	.3243	.083	-.106	1.806
			Hatchery	.787	.3517	.124	-.176	1.751
Oxygen (mg/L)	Tamhane	Control	Hatchery	-2.0575	.39956	<.001	-3.0772	-1.0378
			Natural	3.7483	.56366	.003	1.8229	5.6737
		Hatchery	Control	2.0575	.39956	<.001	1.0378	3.0772
			Natural	5.8058	.67464	<.001	3.8934	7.7183
		Natural	Control	-3.7483	.56366	.003	-5.6737	-1.8229
			Hatchery	-5.8058	.67464	<.001	-7.7183	-3.8934
Salinity	Tamhane	Control	Hatchery	23.88	.466	<.001	22.44	25.31
			Natural	24.33	.422	<.001	22.85	25.82
		Hatchery	Control	-23.88	.466	<.001	-25.31	-22.44
			Natural	.46	.199	.090	-.06	.97
		Natural	Control	-24.33	.422	<.001	-25.82	-22.85
			Hatchery	-.46	.199	.090	-.97	.06
Ammonia	Tamhane	Control	Hatchery	-2.521	.5777	<.001	-4.008	-1.034
			Natural	.000	.0000	.	.000	.000
		Hatchery	Control	2.521	.5777	<.001	1.034	4.008
			Natural	2.521	.5777	<.001	1.034	4.008
		Natural	Control	.000	.0000	.	.000	.000
			Hatchery	-2.521	.5777	<.001	-4.008	-1.034

Based on observed means.

The error term is Mean Square(Error) = 5.583.

Table 4 Post Hoc Results Comparing Water Quality Parameters Across Stream Types (Control, Natural, and Hatchery) Significant pairwise differences ($p < 0.05$) were observed for pH, oxygen, and ammonia levels, indicating distinct water quality characteristics between stream types. Non-significant results ($p > 0.05$) were found for CO2 and temperature across all comparisons).

Post Hoc comparison (Table 4) revealed a significant pairwise variation in pH, oxygen, and ammonia levels across stream types. Oxygen levels in natural streams were significantly

higher than those in hatchery and control streams (mean difference = 5.8058, $p < 0.001$), while hatcheries' salinity (mean difference = 23.88, $p < 0.001$) and ammonia levels (mean difference = 2.521, $p < 0.001$) were significantly higher than those of control and natural stream.

Parameter	Upstream	Downstream	Mean Difference	t (df)	p-value	Cohen's d	95% CI for Difference
pH	7.573 ± 0.193	7.568 ± 0.258	0.005	0.066 (34)	0.948	0.022	[-0.149, 0.159]
CO2 (ppm)	5.778 ± 3.093	4.889 ± 1.703	0.889	1.068 (34)	0.293	0.356	[-0.802, 2.580]
Temperature (°C)	11.589 ± 1.144	11.178 ± 0.786	0.411	1.257 (34)	0.217	0.419	[-0.254, 1.076]
Oxygen (mg/L)	9.850 ± 3.399	9.177 ± 1.828	0.673	0.741 (26.074)	0.465	0.247	[-1.175, 2.543]
Salinity	4.060 ± 9.340	4.670 ± 9.120	-0.610	-0.199 (34)	0.844	-0.066	[-6.864, 5.642]
Ammonia Level	1.944 ± 3.038	1.417 ± 2.109	0.527	0.605 (34)	0.549	0.202	[-1.243, 2.300]

Table 5 Independent Samples T-Test Results Comparing Water Quality Parameters between Upstream and Downstream location. No significant differences ($p > 0.05$) were observed in all water parameters.

All water parameters did not significantly differ between upstream and downstream locations across all site types as shown by the independent samples t-test (Table 5; all $p > 0.05$). Cohen's d-effect size analysis also revealed that there is a small variation among the parameters.

DISCUSSION

The results suggest that there is a significant difference in water quality parameters across Control (False Creek), Natural (Salish Creek), and Hatchery (Hoy Creek, Hyde Creek, Little Campbell, and Tynehead) streams in British Columbia. Across all the hatcheries, there are varying species of salmon being cared for such as Chinook, Chum, and Coho which have varying life cycles and optimal conditions that need to be met to foster them properly. Our findings' implication provides an understanding of the suitability of hatcheries and natural habitats to house salmon populations and formulate guidance for conservation strategies.



Figure 2: Photos taken at Little Campbell with information about their coho rearing pond.



Figure 3: Photos taken at Tynehead Hatchery - Frozen male Chinook and Chum salmon for research on their health and other aspects of their life.

Salmon Hatchery Creeks

Hatcheries streams were recorded to have the lowest CO₂ concentration (mean = 3.00 - 5.67 ppm). This is likely due to the continuous water flow and artificial aeration that is used by most hatcheries. According to Cold and Orwicz (1991), as water flow increases, less dissolved CO₂ accumulates, which could otherwise become a limiting factor to aquatic life under low flow conditions. Ammonia was exclusively present in hatchery streams, which have the highest concentration upstream in Hoy Creek (mean = 6.67 mg/L) and Hyde Creek (mean = 5.00 mg/L). This could be explained by the accumulation of biological waste from decaying salmon carcasses, which is a known cause of high ammonia levels in aquatic environments (Marine Pollution Soucem, 2002). Moreover, inadequate waste management in some hatcheries may also

cause a spike in ammonia levels. Salmon growth and survival can be hampered by ammonia levels above critical thresholds, highlighting the necessity of efficient waste management techniques.



Figure 4: *Photos taken at Hyde Creek - Decaying salmon carcasses on the side, primarily near upstream. These salmon have already spawned beforehand.*

Natural Salmon Streams (Salish Creek)

We observed that Salish Creek has the highest CO₂ levels (mean = 12.00 ppm) in comparison to the hatcheries and control creek. As we observed the low water flow in Salish Creek upstream, this result is consistent with Feely et al. (2010) study which explains that this high CO₂ level is due to organic matter remineralization in areas with limited water flow. This creek also has the lowest oxygen concentrations (mean = 6.2 mg/L), likely caused by the dissolved oxygen being consumed by bacterial activity driven by nutrients. As explained by a previous studies with consistent results, this low oxygen level and high CO₂ may threaten salmon's health, especially during crucial life stages like spawning (Khangaonkar et al., 2018)



Figure 5: *Photos taken at Salish Creek - downstream (left) vs. upstream (right) conditions.*

Control

Due to its coastal location and tidal influence, False Creek has shown a consistently high salinity level (mean = 24.33, SD = 1.16). Moreover, there was no detectable ammonia, which suggests that this urban control site has less organic pollution than the hatchery and natural streams. Although a prior report by Cummings (2016) found localized *E. coli* contamination in False Creek due to low circulation and stormwater runoff, our results did not show any presence of ammonia level. This could be caused by its distinct water chemistry that is shaped by urban coastal dynamics, which is a helpful baseline for this study to compare with natural and hatchery streams that are more biologically influenced.

Multivariate Analysis (MANOVA)

Our Multivariate analysis exhibits significant effects of location (upstream vs. downstream; Wilks' Lambda = 0.273, $F = 8.434$, $p < 0.001$) and specific creek location (Wilks' Lambda = 0.000, $F = 79.412$, $p < 0.001$) on water quality parameters. We found an interesting result of a nonsignificant effect of the stream type on the water quality parameter in general, which indicates that the local conditions and particular creek management techniques might have a greater influence than the more general categorization of streams as Hatchery, Natural, and Control. Additional between-subjects analyses support our previous descriptive statistics by showing notable variations in pH, oxygen, salinity, and ammonia levels among stream types.

Pairwise Comparison

Although MANOVA doesn't show a significant effect of stream types on water parameters in general, we further looked into the effect of stream types on each of the specific water parameters. Significant pairwise variations in pH, oxygen, and ammonia levels were found across stream types of hatchery vs. natural streams using post hoc tests. For instance, the ammonia levels in hatchery streams were significantly higher than those in natural streams (mean difference = 2.521, $p < 0.001$). Likewise, the natural stream has significantly lower oxygen levels than the hatchery streams (mean difference = 5.8058, $p < 0.001$).

Upstream vs. Downstream

Independent samples t-test did not show any significant difference between upstream and downstream locations for any parameter. This consistency raises the possibility that site-specific procedures or more general environmental factors may have a greater influence on water quality than flow direction.

Implication

These results highlight how crucial it is for the hatcheries to improve their cleanup management and procedure to avoid the increase of ammonia level accumulation, which is shown to be detrimental to the health of salmon that will be released into the creek. Furthermore, the low oxygen levels found in the natural stream (Salish Creek) emphasize the necessity of focused restoration initiatives to reduce nutrient pollution and encourage water flow. Optimizing habitat conditions and promoting salmon conservation in British Columbia require this understanding of these abiotic factors in their habitat.

Errors

Sources of error include measurement errors, as each variable was measured using tools that required manual operation and could lead to variability or human error, such as inconsistent readings or slight delays in recording measurements. Additionally, potential systematic errors, such as fluctuations within the devices, may have impacted the accuracy of the results by causing consistent shifts in measurements. To account for this instability, averages were used when measurements were not consistent. Lastly, some locations were sampled on separate days. Although efforts were made to maintain similar weather conditions, it was not possible to ensure identical environmental factors, which may have introduced variability in the results.

CONCLUSION

The study underscores significant differences in water quality parameters across control, natural, and hatchery streams, highlighting the influence of specific management practices and environmental conditions. While hatchery streams showed elevated ammonia levels due to waste accumulation, natural streams like Salish Creek faced challenges of low oxygen and high CO₂ levels, emphasizing the need for targeted conservation and restoration efforts. These findings provide critical insights to optimize salmon habitat management, ensuring healthier ecosystems and supporting salmon populations in British Columbia.

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