Revitalization of an Urban Riparian Ecosystem

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Abstract

Bowker Creek is an eight-kilometer long urban creek. It was once a salmon bearing stream that fed the local communities. Now, however, centuries of development have taken their toll. The creek is a mere two and half kilometers above ground level, with the rest running underground through pipes and culverts. As a result, the creek's biodiversity has also greatly been reduced. The Capital Regional District (CRD) of Victoria recently announced a hundred-year restoration plan for Bowker Creek. Our project at Oak Bay High School for the upcoming conference is twofold: our first initiative is to take samples of the riparian vegetation and invertebrates living in the section of Bowker Creek next to our school. We are also taking water samples from the creek at its headwaters and near our school, to determine the water quality. We plan to use these results to determine the current, overall health of the creek ecosystem. The second part of our project is to repeat these tests after the CRD has completed their riparian habitat restoration, to determine whether or not the restoration was successful.

Keywords

restoration, riparian, water quality, invertebrates, biodiversity

1 Introduction

Bowker Creek is an urban creek, meandering through the municipalities of Saanich, Victoria, and Oak Bay. Before agricultural and urban development, fish and wildlife, including anadromous species such as coho and chum salmon, thrived and proliferated in Bowker Creek, and its tributaries. First Nations and the colonial population once used the creek to acquire food and fresh water from the stream. Nutrients transported from the watershed engendered a rich marine ecosystem and biodiversity in Bowker Creek. The water was pristine enough to nurture extensive Garry Oak Meadows and woodlands.

In 1997, the Capital Regional District Environment Committee approved a regional watershed management strategy in response to the current state of Bowker Creek. As a result, in 2004, the Bowker Creek Urban Watershed Renewal Initiative, a 100-year action plan to restore Bowker Creek, was established. It sets out watershed principles, outlines specific actions, and takes into consideration the social, economic, and environmental factors of urban watershed renewal.

The Bowker Creek Urban Renewal Initiative strives to restore the creek to its natural conditions. As part of this plan, a section of Bowker Creek flowing along the Oak Bay Secondary School property was restored in 2015 during the rebuilding of the high school. In addition to restoring the invertebrate and riparian plant diversity, the restoration also aims to provide an outdoor learning space for students, and create a community accessible green space. The municipality of Oak Bay and the Capital Regional District allocated $738,000 this project. The restoration project also involved the students at Oak Bay Secondary School in multiple aspects of the project. A group of students were involved in Creek and Careers workshops, where they had the opportunity to speak with professionals involved in the creek restoration project. In a follow-up session, students were invited to attend the design charrette to provide their input and feedback towards the final design of the creek restoration, including input on the outdoor classroom area, areas for students to gather, and the path the creek takes beside the school. Later in the restoration project, students helped plant native riparian vegetation, concluding the restoration of this urban freshwater ecosystem.

The primary objective of our team was to determine the biological health of the creek before and after the restoration. To help answer our questions, our group took samples of riparian flora, freshwater invertebrates, and creek water. The first sampling was completed during March 2015, before the restoration. In March 2016, we resampled the creek to compare the effects of the Bowker Creek restoration project on the health of this urban waterway. The focus was to determine changes in the water quality, riparian plants, and marine invertebrates, which would enable us to determine the work required in the future to continue this restoration.

2 Methodology

2.1 Water Quality Samples

Samples were collected in two locations along Bowker Creek. The samples at the headwaters of the creek helped determine the water quality prior to its exposure to an urban environment, and acted as a control. In the Spring of 2015, prior to the commencement of the restoration project, samples were collected along the creek boundary beside Oak Bay High School. Following the completion of the Bowker Creek restoration at the school, the tests were run again to measure changes in water quality.

Four types of tests were run at each site with each type needing a different type of preparation. For metals, Nitric acid (HNO_3) was added to lower the pH, forming metal salts to prevent the degradation of metal ions in the solution. For organic molecules, sulphuric acid (H_2SO_4) was added to a different sample to lower the pH, killing bacteria, stabilizing nitrogen compounds, and reacting with any oils. To detect the presence of mercury, hydrochloric acid was added, stabilizing the compound until testing occurred. To test for *E. Coli*, Sodium thiosulphate ($Na_2S_2O_3$) was added to absorb the chlorine in the sample water.

Water quality samples were analyzed by Maxxam Analytics, a local water analytics company.

2.2 Riparian Plant Survey

To assess changes in the biodiversity of the riparian vegetation, samples were collected at ten-meter intervals along the creek before and after the restoration. Students from Biology 11 classes at Oak Bay High School, in conjunction with a student group from Maurick College in the Netherlands, conducted the collection over a two-day process. A 30 cm by 30 cm square was used to determine the sampling area. At each 10-meter interval, a quadrat was used one and two meters away from creek's edge. Samples of all species were photographed and collected for identification. The timing of the sampling coincided with the flowering season for the plants, allowing the use of flowers, stems and leaves for more accurate species identification.

Figure 1: An example of riparian plant sampling quadrat

To help create of a plant reference library at the school, visits were arranged to the Royal British Columbia Museum (RBCM) herbarium department for detailed instructions on drying, pressing and identification. Following the pressing techniques of the RBCM, the plant presses consisted of two rectangular pieces of wood, one on top, and the other on the bottom, to create a rigid plant press frame, and alternating sheets of newspaper containing the plant samples, the identification information, blotting paper, and cardboard. The resulting package in the plant press was held securely with straps.

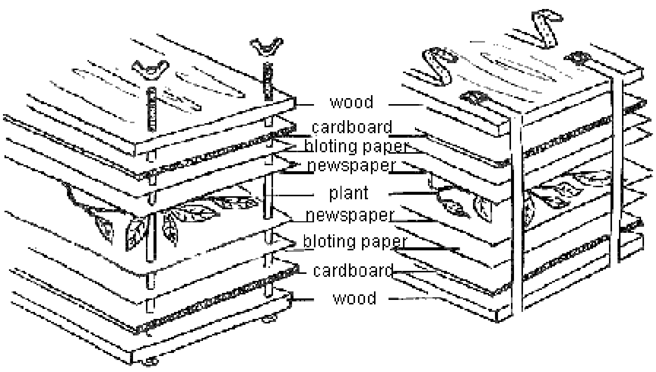


Figure 2: A diagram of the plant press.

Following the collection and plant pressing, the samples were brought to the RBCM herbarium for proper dehydration and identification of the samples. A demonstration on plant mounting to preserve the samples for a library reference collection at the school was provided. The purpose of mounting dried plant specimens on herbarium sheets is to preserve the specimens by minimizing damage from handling. Mounted specimens are safer to handle and store because brittle and fragile parts are supported.

An herbarium specimen is comprised of a pressed, dried plant fixed to a thick sheet of paper with a label bearing its collection information. To mount the sample, a specimen is placed upright with its roots near the bottom to provide a uniform appearance. Then, a transparent glue is added to fasten the specimen to the sheet. Small weights, such as lead casts, large nails, heavy washers or large nuts, hold the plant to the mount sheet while the glue is drying.

2.3 Invertebrate Survey

Sampling took place in a 30 cm by 30 cm square at 0, 50 and 100 meter intervals in the creek. The sites were selected based on their distance from the predetermined starting point. After finding a suitable location for the site and ensuring the sampling net had a flow of water coming in, the top layers of rocks within the sample site were gently washed into the net. Washing the rocks allowed the creatures on the rock to be separated and drift into the net following the flow of water. Once the rock was washed, it was then placed outside of the sampling site, so it would not be reused during the sampling procedure.

Once the top layer of rocks was removed, the smaller rocks below them were carefully sifted through to catch the invertebrates swept up by the current while preventing small rocks and pebbles from getting into the net.

Once sampling finished, the net was carefully removed and flipped inside out, before being placed over a bucket. Water was poured down the sides of the mesh so all the invertebrates from the stream on the net would be washed into the collection area.

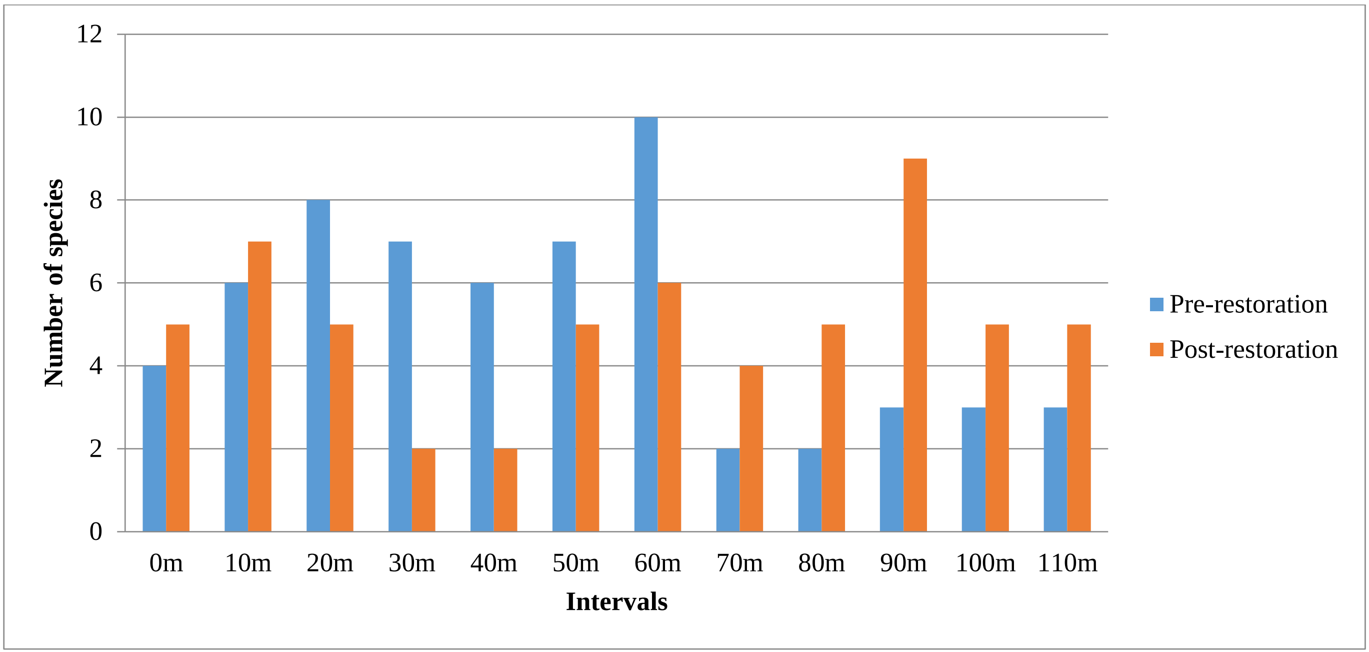
After rinsing the net, a final check for any invertebrates was made. If any were found, they were placed inside the bucket. The samples were then transferred to a separate bucket for sorting. The water from the samples was poured through a sifter to remove any large debris.

After the initial sorting, the remaining water was poured into a secondary bucket, so the smaller specimens could be sorted with pipettes to be transferred into a smaller holding tank. To identify our invertebrates, they were first sorted based on their distinctive characteristics. Traits such as the number of legs, antennae, body segments and shape were used for the first step. Dissecting Microscopes were then used get a better look at the invertebrates themselves. Appendix 1 and Appendix 2 from the Streamkeepers Module 4 booklet were then used to classify the specimens. Appendix 1 was used to visually compare the invertebrates, and Appendix 2 was used for a more detailed comparison.

3 Results

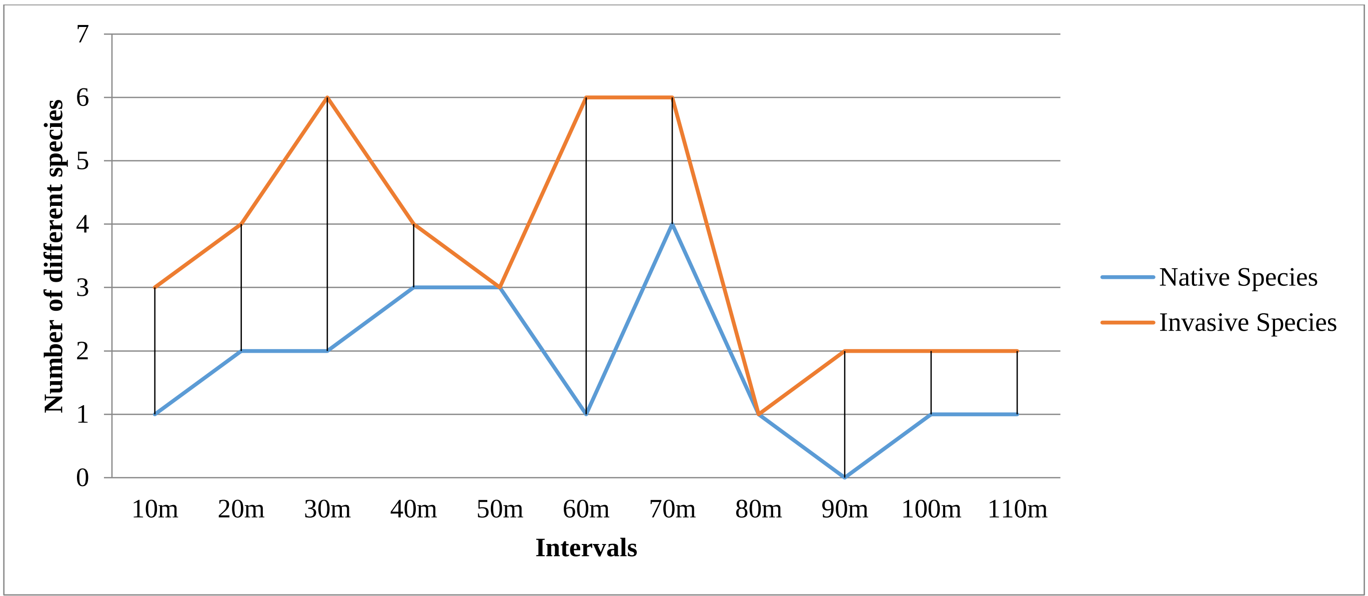
3.1 Riparian Vegetation

Table 1: Biodiversity of Pre-Restoration vs. Post-Restoration



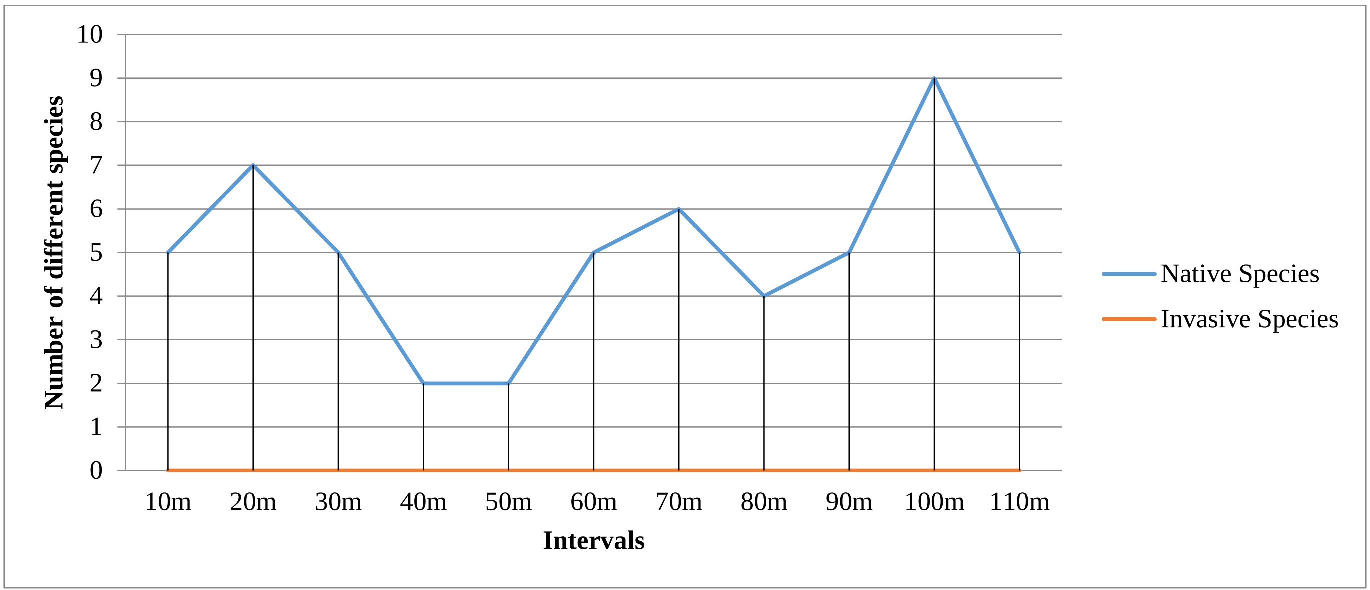
Before the restoration, the creek had relatively low and inconsistent biodiversity, and the invasive species outcompeted the native species throughout the creek banks. In total, there were 22 different types of plant species found on the creek, including 8 native plant species and 14 non-native species. Since the creek had an inconsistent biodiversity at many of the intervals, the riparian plants were divided into two different sections. From 0-70m, the creek tended to have a greater variety of plant species, with some tree cover, while from 70m onwards, invasive Himalayan blackberry and Celandine dominated the bank.

Table 2: Native vs. Invasive Plant Species at Each Interval (Pre-Restoration)



On the other hand, post-restoration biodiversity is greater in most of the intervals, and displays a more consistent trend in terms of plant variety. In contrast with pre-restoration, the restored creek is home to 31 distinct types of species, which are all categorized as native plants of the local area. Moreover, the restoration also creates an overall balance of biodiversity, as the plants are distributed throughout the entire creek. There are no significant differences between the intervals. The differences only show themselves from 20-50m.

Table 3: Native vs. Invasive Plant Species at Each Interval (Post-Restoration)



3.2 Water Quality Analysis

Table 4: Water Quality Testing Results

Substance	School location 2015	School location 2016	Headwater location	Recommended Maximum
Dissolved Nitrate	0.980 mg/L	1.62 mg/L	1.31 mg/L	400 mg/L
Dissolved Chloride	29 mg/L	31.6 mg/L	50.6 mg/L	1500 mg/L
Dissolved Sulphate	23.1 mg/L	27.3 mg/L	53.7 mg/L	1000 mg/L
Alkalinity	140 mg/L	139 mg/L	164 mg/L	n/a
Bicarbonate	170 mg/L	169 mg/L	200 mg/L	n/a
Conductivity	431 uS/L	407 uS/cm	536 uS/cm	n/a
Total Dissolved Solids	238 mg/L	228 mg/L	313 mg/L	n/a
Total Aluminum	38.4 ug/L	181 ug/L	131 ug/L	n/a
Total Arsenic	0.87 ug/L	0.59 ug/L	0.82 ug/L	50 ug/L
Total Boron	131 ug/L	90 ug/L	62 ug/L	50000 ug/L
Total Copper	3.16 ug/L	8.47 ug/L	21.9 ug/L	20 ug/L
Total Iron	151 ug/L	303 ug/L	351 ug/L	n/a
Total Manganese	12.3 ug/L	31.2 ug/L	86.9 ug/L	n/a
Total Silicon	9080 ug/L	9480 ug/L	9580 ug/L	n/a
Total Sodium	25.9 mg/L	26.5 mg/L	36.6 mg/L	n/a
E. Coli	750 CFU/100mL	1000 CFU/100mL	44 CFU/100mL	200 CFU/100mL
Biochemical Oxygen Demand	<6.0 mg/L	<5.0 mg/L	<5 mg/L	n/a
Chemical Oxygen Demand	<10 mg/L	<20 mg/L	<20mg/L	n/a

Due to the fact that there was insufficient data for the years prior to 2015, the data was directly compared between the headwaters and the school location. However, valuable data was gathered by comparing both samples. All collected samples were obtained under similar weather conditions, and were taken at around the same time of year.

3.3 Invertebrate Survey

Table 5: Pre-Restoration Invertebrate Survey

Pollution Tolerance	Invertebrates Common Name	Total	P.T Total
Intolerant	Dobsonfly	1	5
	Mayfly Nymph (EPT)	2	
	Riffle Beetle	2	
Somewhat Tolerant	Damselfly	2	57
	Scud	55	
Tolerant	Aquatic Worm	30	87
	Blackfly Larva	3	
	Midge Larva	54	
Total Number of Invertebrates		149	

Table 6: Post-Restoration Invertebrate Survey

Pollution Tolerance	Invertebrates Common Name	Total	P.T. total
Intolerant	Caddisfly Larva (EPT)		2
	Dobsonfly		
	Mayfly Nymph (EPT)		
	Riffle Beetle		
Somewhat Tolerant	Damselfly		2
	Scud		
	Sow Bug Larva	2	
Tolerant	Aquatic Worm	10	66
	Blackfly Larva		
	Leech	9	
	Midge Larva	42	
	Water Mite	5	
Total # of invertebrates		70	

Before the restoration, the total number invertebrates collected from three different sampling sites added up to 147. 87 were pollution tolerant and 57 were somewhat pollution tolerant. Only 5 invertebrates were pollution intolerant.

After the restoration the total number of invertebrates collected from the same three sampling sites decreased to 70. Sixty-six were pollution intolerant, 2 were somewhat pollution tolerant and 2 were pollution intolerant.

Table 7: Comparison of Pre-Restoration and Post-Restoration Invertebrate Surveys

Restoration	Pollution Tolerant Index	Condition	ETP Index	Condition	ETP to Total Ratio	Condition
Before	16	Marginal	1	Poor	0.0067	Poor
After	9	Marginal	1	Poor	0.014	Poor

Pollution Tolerant Index: Pollution tolerance divides the invertebrates according to their tolerance for pollution

ETP Index: Ephemeroptera, Plecoptera, and Trichoptera (Mayflies, Stoneflies, Caddisflies) all require clean water and are often grouped together.

4 Conclusion

4.1 Riparian Plants

A riparian ecosystem is a transition between the aquatic ecosystem and the adjacent terrestrial ecosystem. It is identified by soil characteristics and distinctive flora. These ecosystems often consist of complex landscapes that involve interactions between the water, soil, microorganisms, plants and animals.

Based on the data, the restoration of the creek has improved the biodiversity and significantly eradicated invasive species from the riparian bank. The regional government body, the Capital Regional District, implemented the restoration process, in which all plants were removed from the original bank, and 31 native species were introduced and planted to establish a healthy and balanced ecosystem. In general, there is a greater variety of plant species in most of the intervals post-restoration. The smaller increase in biodiversity from 20-60m is a result of the immense Garry Oak Meadow that exists there.

The overall increase in biodiversity is a positive trend when it comes restoring the creek back to its healthy and stable ecosystem. Biodiversity is indicative of creek health because it signals stability and resilience. Having a variety of plant species helps protect the ecosystem when there is a drastic change in the surrounding environment and weather, or when a new disease is introduced to the area.

Before restoration, the bank was plagued with invasive species, and those plants outcompeted the local ones. Invasive species share characteristics that can make them extremely arduous to control, because they have a significantly higher rate of reproduction compared to the local species. Moreover, since they are alien to the local area, invasive species tend to have fewer natural predators and are less likely to be affected by diseases. Invasive species are generally hardy, as they are able to survive in a variety of different habitats and climate regions. Their incredible ability to prosper in various types of environments make them so successful that they outcompete the native species. The proliferation of invasive species threatens an ecosystem as it can overthrow the established balance of the area. The encroachment of invasive species can have negative environmental impacts such as limiting the overall biodiversity, which can cause extirpation and even extinction of the native plants. Removing all plants on the original bank and introducing the 31 native species are major steps in establishing a healthy, sustainable, and stable riparian ecosystem.

However, even though the restoration has successfully re-established the ecosystem, it is necessary to keep an ongoing future effort to prevent the return of the non-native species. It is crucial for the community to help prevent invasive species, detect and respond rapidly to the presence of new invaders, as well as effectively removing those that are already established in the area. In order to deem the restoration successful, the team must continue monitoring the progress of the creek in the future.

4.2 Water Quality

When looking at the health of any creek, one of the most important factors is the quality of its water. The water quality determines what animals and plants can live and survive in the creek, as well as the surrounding area. To accurately measure changes in water quality, multiple tests must be done over a time span of several years. Unfortunately, we did not have the opportunity to collect such an abundance of data. To work around this, we also took samples of water not only from the site of interest, but near the headwaters of the creek as well. This way, we could compare what the water levels were when it comes up from the aquifers to what the levels are when it reaches the school.

The E-coli level was 750 CFU/100mL (colony-forming units per milliliter), which was already a higher amount than the recommended 200 CFU/100mL. However, in the second sample, the E-coli had jumped to 1000 CFU/100mL, which is 5 times the recommended level. This is most likely due to cross connected sewers, which are a result of greater Victoria's dated sewage and storm drain system. Unfortunately, the only way to correct the current situation would be with major changes to the underground system.

When it comes to the pollutants – such as the Metals, the Chemical Oxygen Demand, Biochemical Oxygen Demand, Alkalinity, pH, and Bicarbonates – some levels increased slightly, and some had decreased.

Some of the substances, such as pH and Bicarbonate, are linked, causing an overall increase in the levels. The variation is also due to the fact that runoff water from the roads drains directly into the creek.

Since the school is located close to the ocean, the levels of Sodium, Sulfate and Chloride are slightly different than what might be expected in a creek. The levels for all three are lower than the levels of the same substance at the headwaters. For Chloride, the head water level was at 50.6 mg/L, and lowered to 29 mg/L at the school in 2015. In 2016, it rose to 31.6 mg/L. The Sulfates followed a similar pattern, with their headwater level being 53.7 mg/L and at the school in 2015, 23.1 mg/L. In 2016, it had risen to 27.3 mg/L. Finally, Sodium started out at 36.6 mg/L in the headwaters. At the school, it had lowered to 25.9 mg/L in 2015, and 26.5 mg/L in 2016. Overall the levels were highest is at the headwaters, lower in 2015, and slightly higher in 2016.

When it comes to the Nitrates, Nitrites, Phosphorus and Total Dissolved Solids, also known as our Limiting Factors, the levels once again were varied. The Nitrate level was up from a previous level of 0.980 mg/L to 1.62 mg/L. This was partly due to the naturally occurring Nitrogen cycle in the creek, along with the addition of fertilizers for the plants surrounding it. The level of the Total Dissolved Solids was lowered from the last time the samples were collected, shifting from 238 mg/L to 228 mg/L. This is a result of a changed collection method, and the naturally occurring silt.

The levels stated are not conclusive and to form more conclusive decisions about the health of the creek, data must be collected regularly for many years, which the school has decided to take on following this project. This will hopefully bring more local interest to protect the health of Bowker Creek. Overall, the creek restoration project at Oak Bay High School represents a very positive start in the 100 Year Bowker Creek Blueprint. It is our hope that in the years to come, further projects will be created to revert Bowker Creek to a more natural state.

4.3 Invertebrates

Looking at the invertebrates can tell us many important factors concerning the water quality. These invertebrates play a significant role in the food chain since they eat algae, leaves or debris, and become food for other fish, amphibians, reptiles, birds or other insects that may live within the ecosystem. Many invertebrate species are sensitive to pollution and changes in their environment. By observing characteristics, such as diversity and pollution tolerance of the community that occupies the area, the quality of water can be determined.

The diversity of the organisms can be an indicator of the stream's health. Often, the more diverse the organisms are, the healthier the stream is. To have diversity in organisms, the habitat conditions for each have to be met. Habitat diversity leads to diversity in the benthic communities in rivers and streams.

The data collected shows the number of pollution tolerant species dominating the number of pollution intolerant species, both before and after the restoration. Pollution tolerance levels refer to the amount of pollution the organism can handle. By looking at the tolerance level of invertebrates living in the stream, it can show the stream's health. Specific species are suited for particular environments. By observing these invertebrates and their specific needs, it is easier to determine the water's health.

Before the restoration, 58% of the invertebrates were Pollution Tolerant and 38% of them were Somewhat Pollution Tolerant. Having pollution tolerant invertebrates does not necessarily mean that the water is polluted. Being pollution tolerant allows the organism to survive with or without pollution. This means that the somewhat pollution tolerant species can live in clean water and survive within a certain level of pollution. Therefore, having high numbers of both pollution tolerant species and somewhat tolerant species along with low numbers of pollution intolerant species would indicate that the pollution level of the water is fairly high.

The EPT invertebrates are a good indicator of the stream's health. All three of them fall into the pollution intolerant category. The higher the pollution level of the water is, fewer number of EPT would be present in the stream.

After the restoration, the physical layout of the stream was modified. Prior to the restoration, the creek banks consisted of a concrete wall on one side, and a very steep slope infested with invasive plant species on the other. The concrete wall is still present because it also supports the school's track field, but the creek's pathway was modified to slow down the rate of water flow. A challenge for invertebrates living in Bowker Creek is the rapid change in water flow resulting from storm water pipes that drain into the creek along its path through greater Victoria. To counter the rapid and significant rises in flow after rainfall, 'areas of refuge' were created. These areas of refuge serve to alter the stream's path of flow and provide a shallow habitat with weaker current that many invertebrates would benefit from. The data collected does not indicate a significant difference pre- and post-restoration. As with our analysis of the water quality, further sampling at regular intervals in the coming years will help determine if the 'areas of refuge' are having a significant impact on the overall numbers and biodiversity of the freshwater invertebrates. Even so, by creating the 'areas of refuge' we are hopeful that the number and variety of invertebrates will increase in the future as the area stabilizes.

5 Acknowledgments

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The Capital Regional District (CRD) initiated the Bowker Creek restoration project. They kindly put together the money that was necessary of the restoration to be started. The cooperation from the local government has helped the restoration project, and will one day provide the community we're wanting out of the restoration.

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